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Reservoir Influence on Groundwater near the Cabinet Gorge Dam, Sanders County, Montana

Cabinet Gorge Dam on the Lower Clark Fork River with spillways open during peak spring runoff, June 2022. Photo by Sara Edinberg.

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INTRODUCTION

The impacts to surface-water bodies from the construction of dams and the subsequent creation of reservoirs is well studied worldwide; however, less consideration is given to the influence of dams and reservoirs on nearby groundwater. The Cabinet Gorge Dam, located on the lower Clark Fork River near the Montana–Idaho border, was completed in 1952 by the Washington Water and Power Company (now Avista Corporation) for the purpose of hydroelectric power generation. Impoundment of water behind the dam, in Cabinet Gorge Reservoir, flooded the Clark Fork River upstream as far as Noxon, Montana (about 12 river miles). The impacts to the Clark Fork River and fisheries have been well studied, but until recently, effects on groundwater levels and groundwater quality near Cabinet Gorge Reservoir have not been documented.

From 2019 to 2023, the Montana Bureau of Mines and Geology's (MBMG) Ground Water Assessment Program visited wells, springs, and surface-water sites in Lincoln and Sanders Counties to characterize the aquifers (defined as rock units that can store and transmit groundwater) and describe the area's groundwater-flow patterns and groundwater quality (fig. 1). During the course of this study, data collected from 45 wells in the Heron, MT area (fig. 2) show a clear zone where groundwater is "influenced" by the Cabinet Gorge Dam and Reservoir; i.e., where the reservoir level affects nearby groundwater levels. This pamphlet explains the general aquifer framework in the area, the extent to which these aquifers are influenced by the reservoir, and how the data collected show the connection between groundwater and the reservoir.

Figure 1. The study area (red box) is located in northwestern Sanders County, Montana, near the Idaho–Montana border, along the Clark Fork River.

STUDY AREA BACKGROUND

The landscape of Lincoln and Sanders Counties is characterized by a series of northwest-trending mountain ranges and intermontane valleys. The valleys are filled with unconsolidated sediments deposited by the Clark Fork River and tributary streams (alluvium) and sediments deposited by Glacial Lake Missoula, collectively referred to as “basin-fill” (figs. 2, 3). The surrounding mountain ranges are composed of approximately 1.4-billion-year-old sedimentary bedrock formations collectively called the “Belt Supergroup.”

The basin-fill deposits of the Lower Clark Fork River Valley near Heron can be broken into two primary aquifers:

1. A deep sand and gravel unit (>200 ft deep) deposited by Glacial Lake Missoula flooding (approximately 16,000 years old), and
2. A slightly younger and shallower alluvial sand and gravel unit (<120 ft deep) deposited by the Clark Fork River.

A layer of clay deposited by late-stage Glacial Lake Missoula is present at the surface above the deep sand and gravel aquifer. The depth and distribution of the basin-fill deposits in the subsurface are depicted in figure 3.

The bedrock of the Belt Supergroup forms a fractured-rock aquifer around the valley margins and under the basin fill. This aquifer acts as a source of deep groundwater recharge to the basin-fill aquifers; however, low yields limit its potential as an aquifer in some areas, especially along the north side of MT Hwy 200.

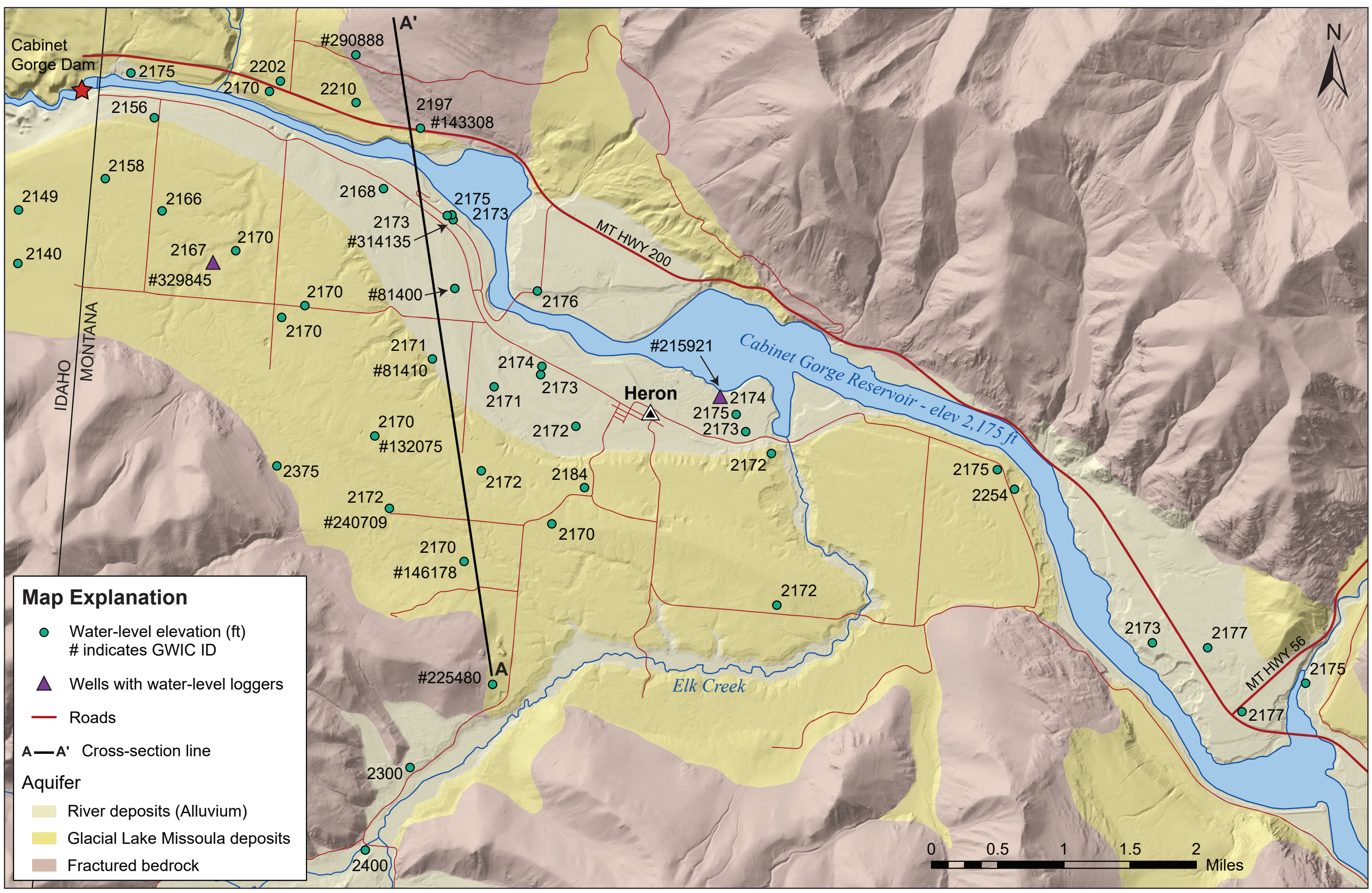

Figure 2. Groundwater elevations were measured at 45 wells in the Heron area from 2021 to 2023. Groundwater elevations are close to that of the reservoir, indicating that the reservoir has direct influence on groundwater levels in the area upstream of the dam. Geologic units that act as aquifers include young alluvium (river deposits), glacial deposits (derived from Glacial Lake Missoula), and fractured bedrock.

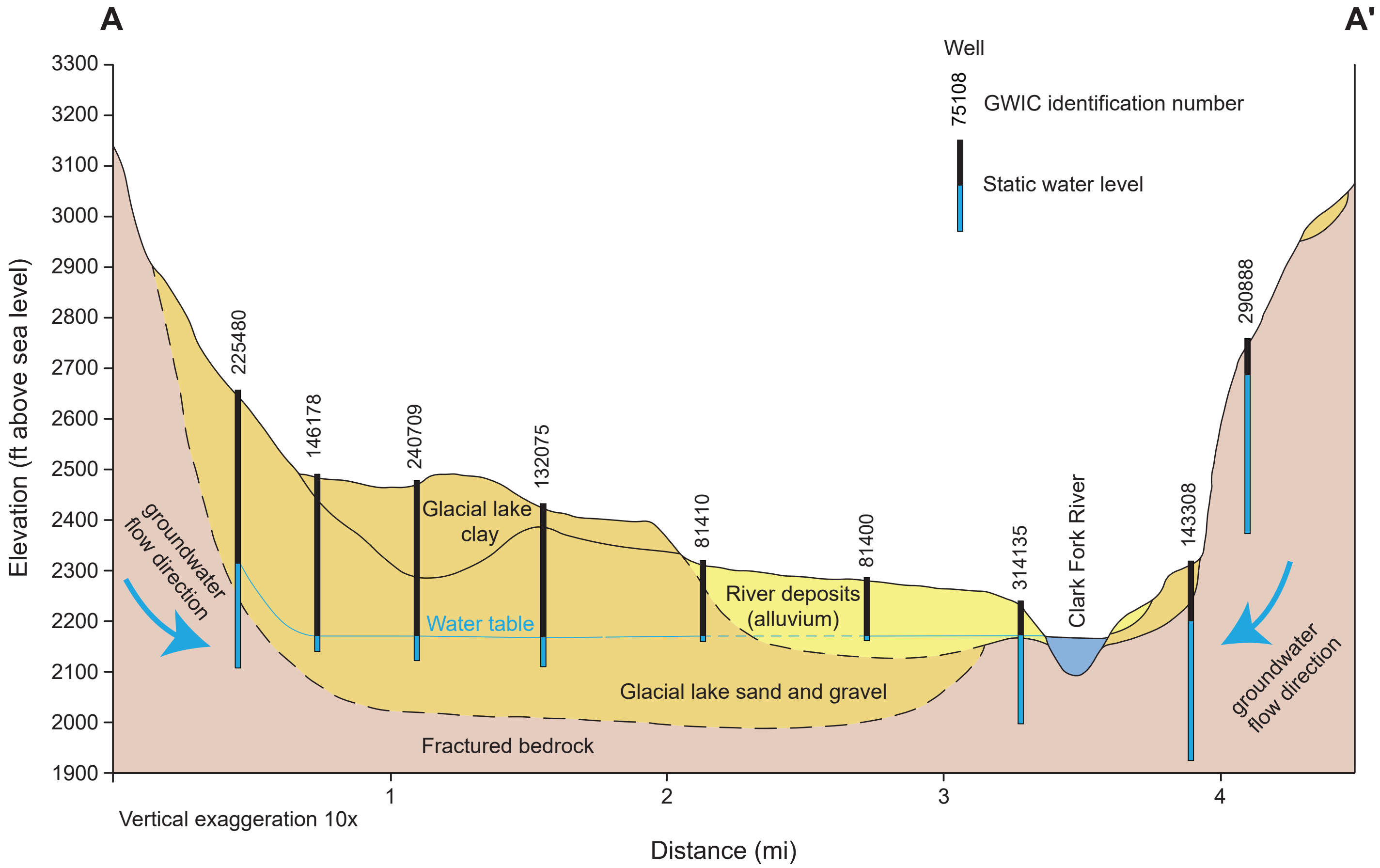

Figure 3. Cross-section represents a 2D view of the geologic deposits in the Heron area along a south–north transect that starts on upper Elk Creek and ends near Blue Creek on the north side of MT Hwy 200 (transect A–A'; shown in fig. 2).

METHODS AND DISCUSSION

Water-Level Trends

Groundwater levels were measured in 45 wells in the Heron area, including 10 wells on the north side of the reservoir along MT Hwy 200 (fig. 2). Two unused wells were instrumented with pressure transducers, which record groundwater levels on an hourly basis. One of these wells is in the alluvial aquifer less than 200 feet from the reservoir (GWIC #215921). The other well is in the deeper sand and gravel (glacial) aquifer (GWIC #329845), west of Heron and closer to the dam, but about 1 mile south of the reservoir (fig. 2).

Based on the hourly water-level records, groundwater levels generally mimic water levels in the reservoir. Groundwater levels respond quickly to changes in reservoir water levels. However, groundwater levels fluctuate to a lesser degree than the reservoir (fig. 4). For example, between January 1 and January 4, 2024, reservoir water levels dropped 2.2 ft; groundwater levels accordingly dropped 0.9 ft in GWIC #329845 and 0.6 ft in GWIC #215921 during that same time period (fig. 4). This also shows that reservoir influence on groundwater decreases with increased distance upstream of the dam. The relationship between groundwater and surface water results in a "flat" water table in the area; i.e., groundwater elevations change minimally over a given distance (fig. 2). The flat gradient doesn't mean that groundwater isn't moving—rather, groundwater is flowing in response to changes in reservoir elevation, and may change direction (to a very small degree) depending on whether the reservoir is filling or draining. Although it is evident that the reservoir influences groundwater levels, more data are necessary to determine the timing and extent to which the reservoir flows into the groundwater, or vice versa.

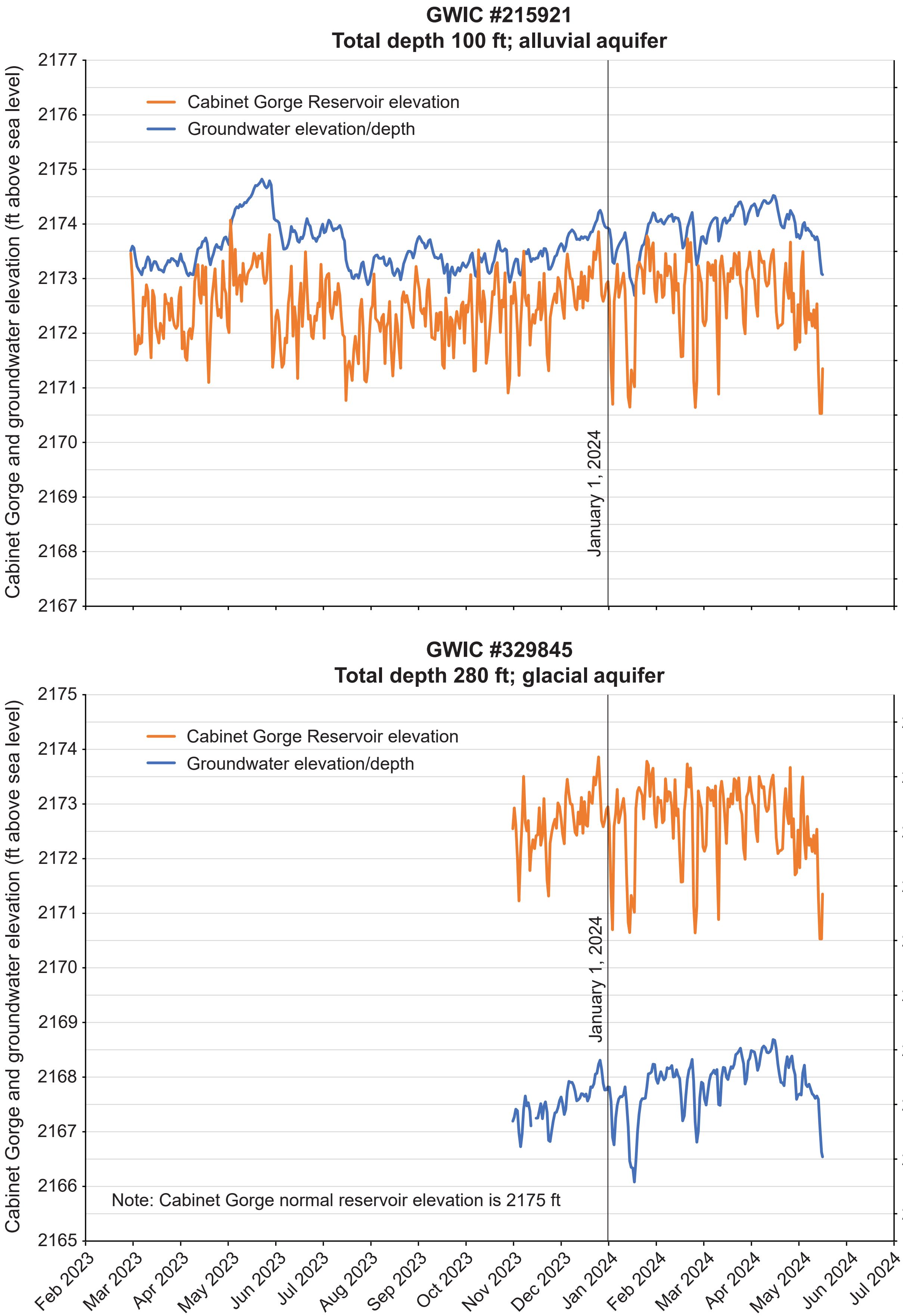

Figure 4. These graphs show changes in groundwater levels over time from two wells in the Heron area. Changes are shown as elevation above sea level on the right axis, and as depth below the top of the well casing on the left axis. Cabinet Gorge levels are shown as elevation above sea level (right axis). Well locations are shown in figure 2.

Isotopes and Reservoir Influence

Stable-water isotopes are commonly used to identify groundwater recharge sources and trace groundwater flow pathways. Isotopes are variations in the number of neutrons in atoms of the same element; that is, isotopes have the same number of protons (positive charge) and electrons (negative charge), but the difference in the number of neutrons changes the total mass of the element. For example, most oxygen atoms have 16 neutrons, but sometimes oxygen forms as a stable (not radioactive) isotope with 18 neutrons. Oxygen-18 has more neutrons and is therefore heavier than oxygen-16. Stable-water isotope samples measure the ratio (δ) of "heavy" versus "light" water molecules in units of per-mil (parts per thousand).

To help determine which wells are influenced by the reservoir, stable-water isotope samples were collected from surface water in Cabinet Gorge Reservoir, and from 40 groundwater wells and springs, representing a range of distances from the reservoir (fig. 5). Samples are plotted on a graph (fig. 6) and categorized into four groups based on their isotopic "signature":

a. Those collected from the reservoir ("reservoir sample"),
b. Those similar to the reservoir ("reservoir influenced"),
c. Those different from the reservoir ("mountain recharge"), and
d. Those with a mixed signature ("mixed").

Reservoir water isotopes are "lighter" than water recharged from mountain snowpack (mountain recharge). When these groundwater sample locations are plotted on a map, it is clear that the reservoir influences groundwater as far as 1.5 miles south of the reservoir shoreline (fig. 5).

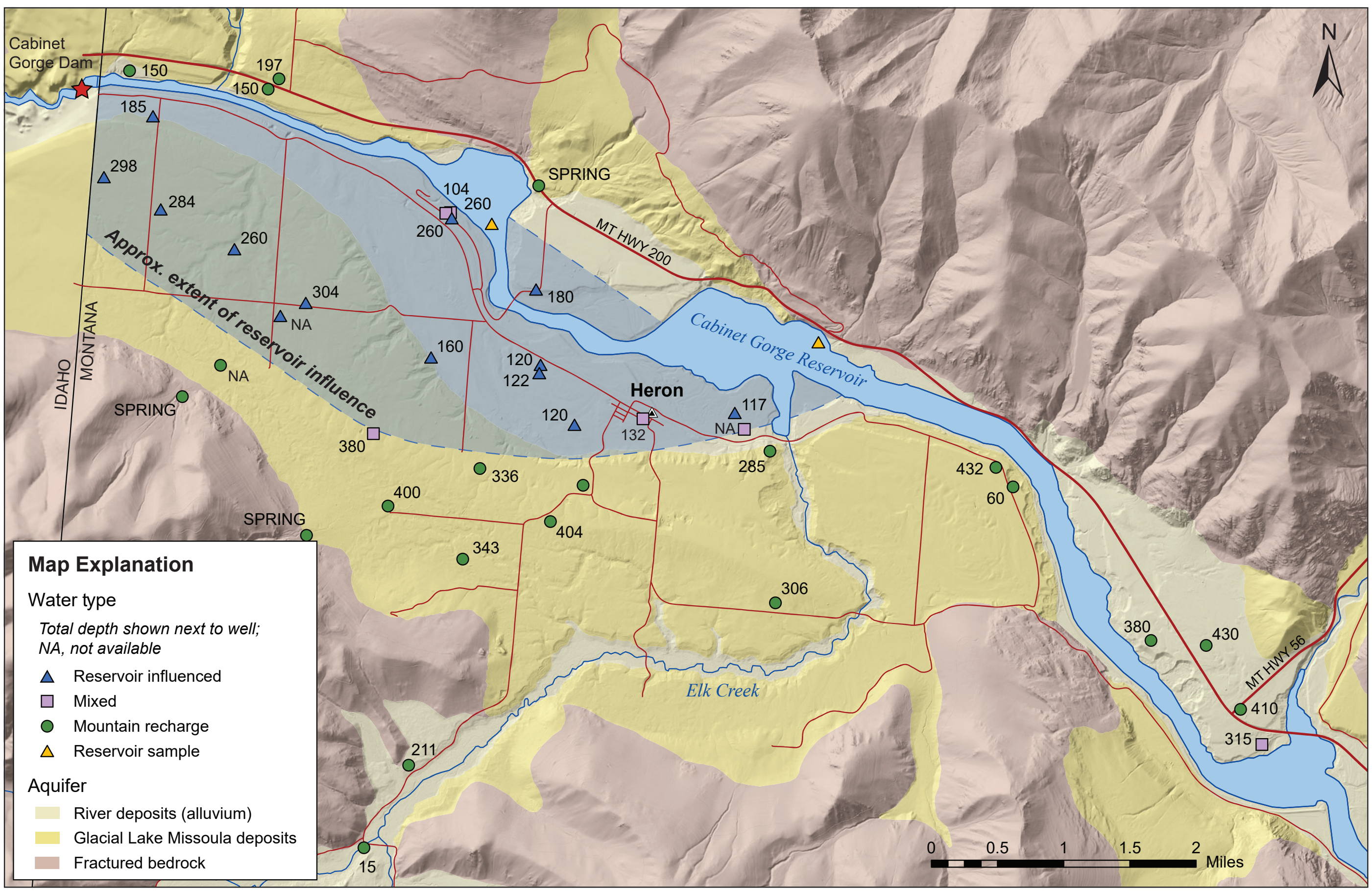

Figure 5. When isotope signature results are plotted on a map, it is clear that the Cabinet Gorge Dam and Reservoir influence groundwater elevations as much as 1.5 miles inland. The extent of influence appears to dissipate with increased distance from the dam. The approximate area of influence is shown on the map, shaded in blue. Total well depth in feet below ground surface.

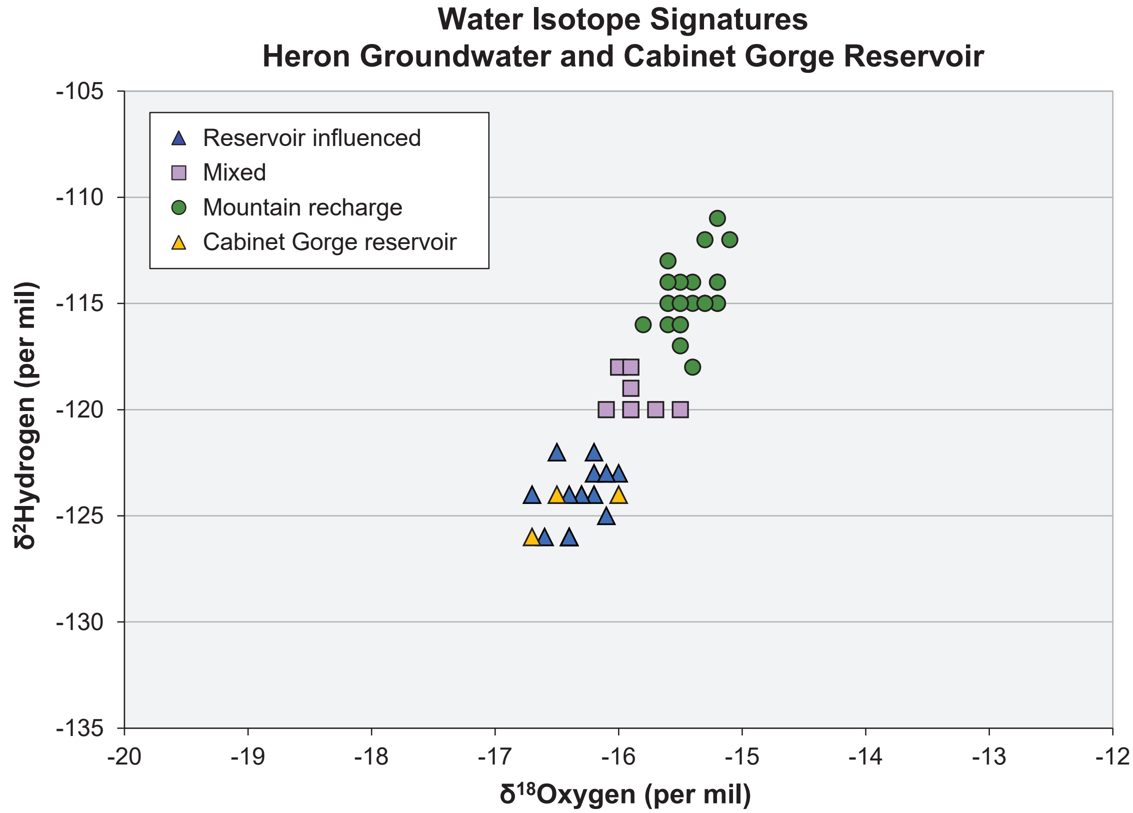

Figure 6. This graph shows the water isotope signatures for groundwater (wells) and surface-water (Cabinet Gorge Reservoir) sites in the Heron area. Cabinet Gorge Reservoir samples are denoted with a yellow triangle. Wells that had an isotope signature similar to the reservoir are symbolized with a blue triangle; these wells are inferred to be influenced by the reservoir. Wells not influenced by the reservoir (mountain recharge) are symbolized with a green circle, and wells with a mixed signature (combination of mountain recharge and reservoir water) are symbolized with a purple square.

Water Quality

The connection between the reservoir and groundwater raises questions about potential impacts to water quality in the aquifers. Water-quality samples collected from 21 wells in the Heron area show that most wells have low concentrations of total dissolved solids (<200 parts per million, which is well below the Environmental Protection Agency's recommended level of <500 parts per million for drinking water), and do not exceed any Federal or State water-quality standards. The U.S. Geological Survey monitors the Clark Fork River downstream of the dam, and samples indicate that the river water meets drinking water standards for inorganic constituents (ex., iron, lead, copper, etc.). Wells that are influenced by the reservoir do not show any significant differences in water quality from those that are not influenced by the reservoir. This is most likely because the water chemistry of the reservoir is very similar to that of groundwater. Additional water-quality data would be helpful to determine the full extent of reservoir influence on nearby groundwater.

CONCLUSIONS AND FUTURE WORK

Reservoir influence on groundwater near the Cabinet Gorge Dam and Reservoir appears to extend a maximum of about 1.5 miles south of the shore of the reservoir; the magnitude of influence decreases with distance upstream of the dam. Reservoir influence is demonstrated by: (1) groundwater levels that fluctuate in accordance with changes in the reservoir elevation; and (2) similar stable-water isotope signatures of the reservoir and nearby groundwater. Groundwater quality does not appear to be affected by the reservoir, most likely because the water chemistry of the reservoir and of groundwater are very similar.

This pamphlet is meant to provide a broad overview of groundwater in Heron, MT, with a focus on the reservoir influence. Additional reports by MBMG are in progress; these reports will provide a more detailed look at water quality and groundwater flow paths for the aquifers throughout Lincoln and Sanders Counties.

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https://www.mbmg.mtech.edu/mbmgcat/catMain.asp

All data collected by the MBMG are available on our Ground Water Information Center website:
https://mbmggwic.mtech.edu/

Reservoir elevation data are measured by Avista Corporation and made available online by the Army Corps of Engineers:
https://www.nwd-wc.usace.army.mil/dd/common/projects/www/cab.html

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