

ARSENIC

Arsenic is a naturally occurring trace element that is commonly associated with certain igneous (volcanic), metamorphic, and sedimentary rocks, as well as geothermal areas. Arsenic can adversely affect human health when ingested at elevated concentrations; the MCL is 10 micrograms per liter (µg/L). The arsenic distribution is shown in figure 10. The concentrations were grouped into three reporting ranges:

- low level (not detected or less than 3 µg/L, white symbols),
- elevated (5 to 10 µg/L, pink symbols), and
- MCL exceedance (greater than 10 µg/L, red symbols).

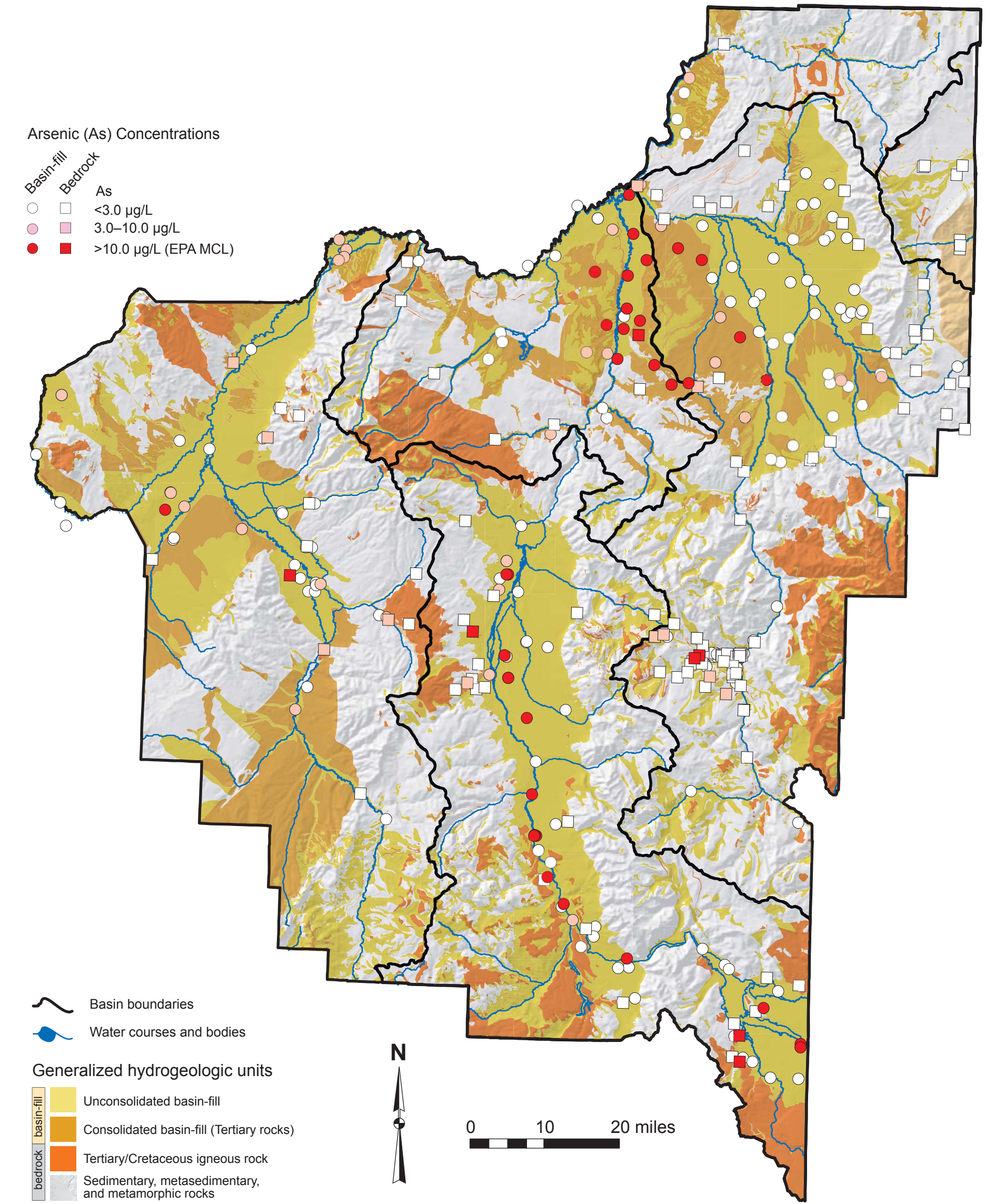


Figure 10. Most of the arsenic MCL exceedances occur in the Madison Valley. In the lower Madison Valley, along the reach of the Madison River, most wells have some detectable arsenic regardless of aquifer.

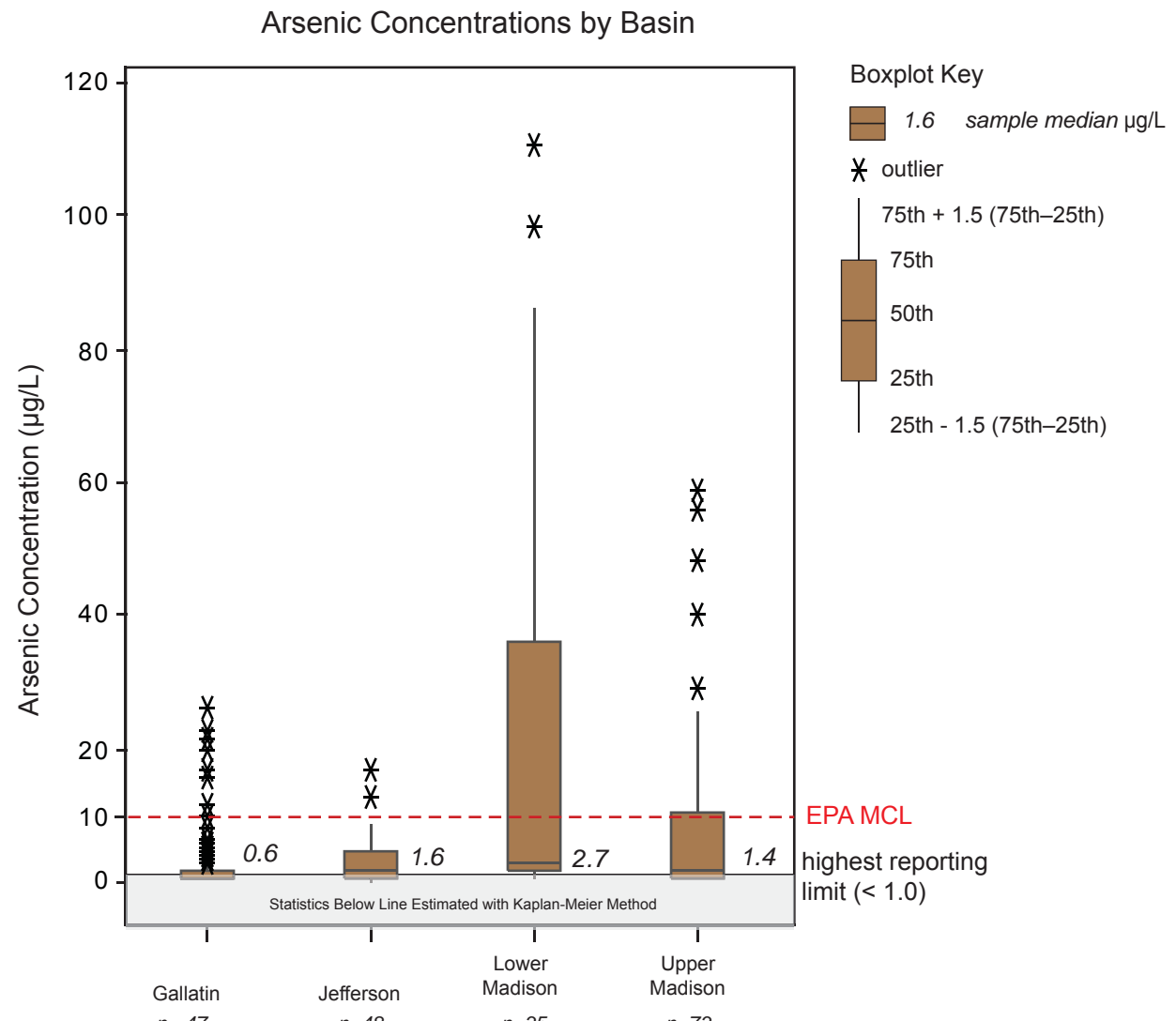


Figure 11. In the Gallatin and Jefferson Basins, arsenic concentrations are low, with few MCL exceedances. Concentrations are notably higher in the upper and lower Madison Basins. The Kaplan-Meier method (Helsel, 2012) was used to include censored data in the summary statistics.

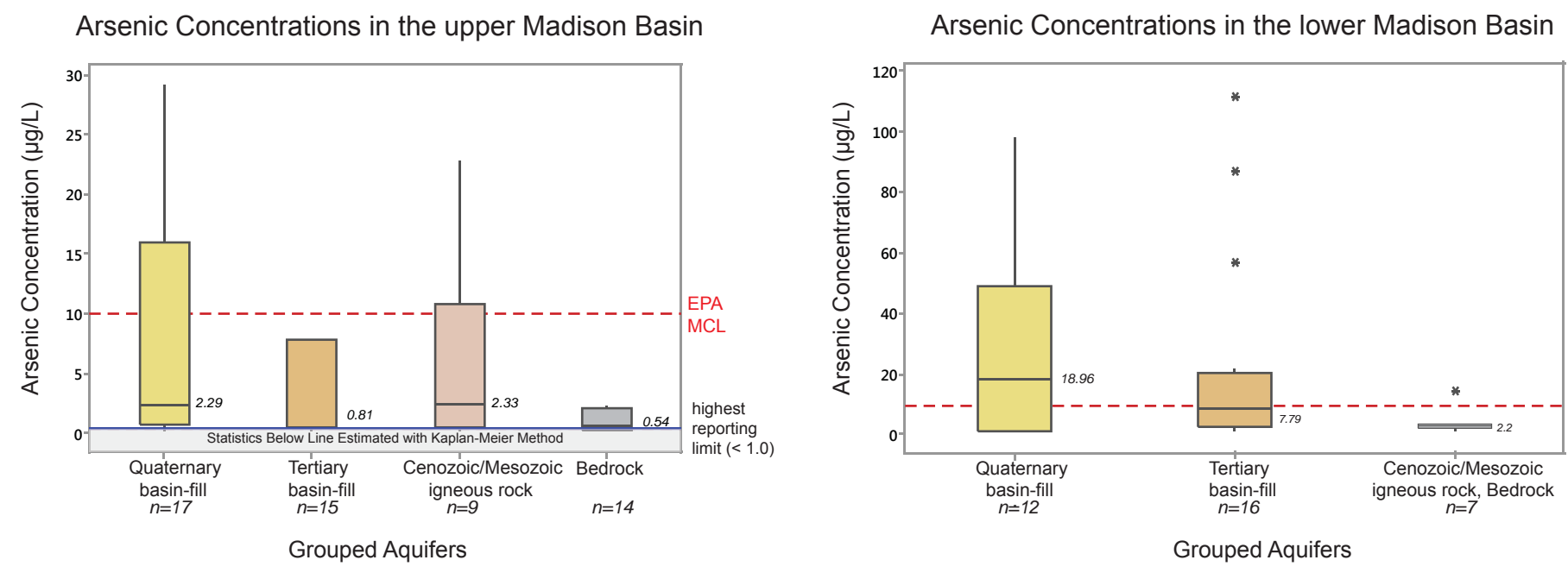


Figure 12. Although arsenic concentrations are elevated in both the upper and lower Madison Basins, there are differences between the two basins with respect to overall concentration and impacted aquifers. Note the differences in concentration scales.

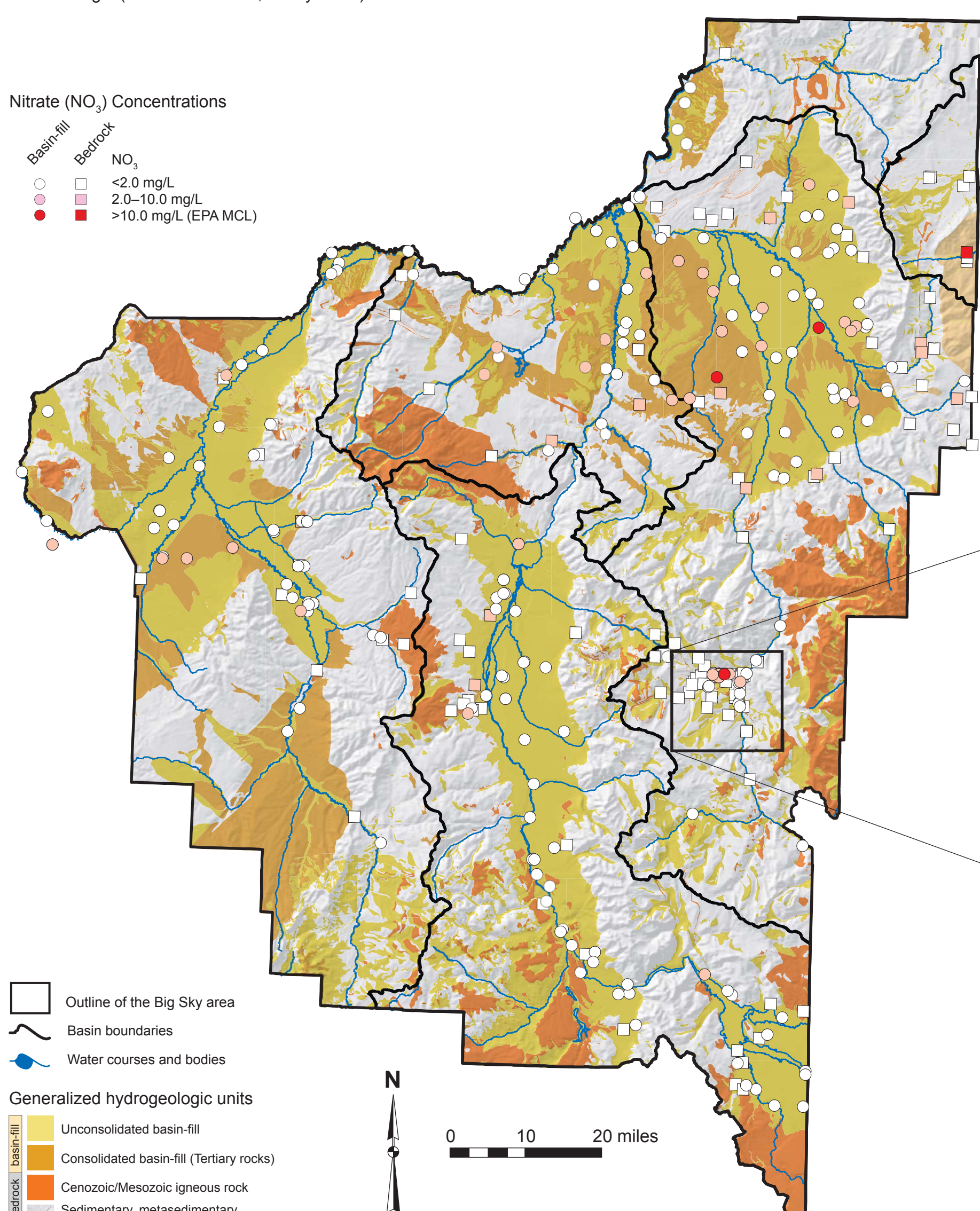


Figure 13. Groundwater nitrate concentrations in all aquifers across the study area are low, although the Gallatin Valley has many that are above background levels (> 2.0 mg/L).

NITRATE

Nitrate occurs naturally, in low concentrations, and is an essential nutrient for plant life; however, it can be harmful when present in drinking water at excessive concentrations (notably to infants). Elevated concentrations in groundwater can be an indicator of land-use impacts, such as seepage from manure, fertilizers, and septic systems.

Nitrate concentrations are shown in figure 13 (343 sites). Twenty-five sites were sampled for nitrate only, and five sites in the Big Sky area were sampled multiple times between July 2008 and March 2013 (fig. 13, Big Sky inset maps).

Naturally occurring or "background" concentrations in groundwater are less than 2.0 mg/L; concentrations greater than 2.0 mg/L may indicate effects of human activities (USGS, 1999). On the map, concentrations were grouped into three reporting ranges:

- <2.0 mg/L (natural or background, white symbols)
- 2.0–10.0 mg/L (potential land-use impacts, pink symbols)
- >10.0 mg/L (MCL exceedance, red symbols)

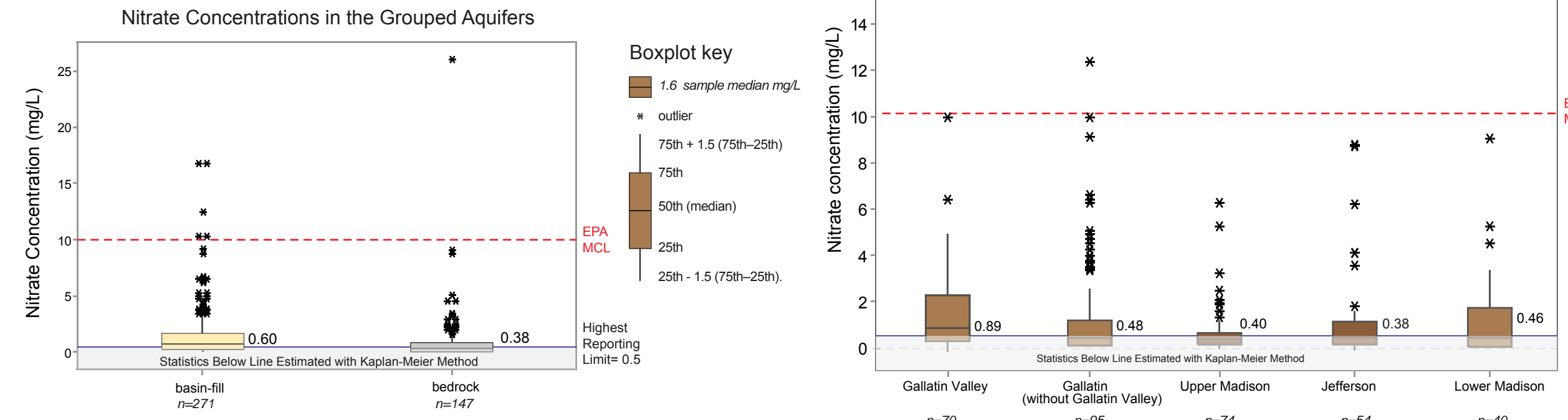


Figure 14. Nitrate values are low, only four samples exceed the EPA's MCL of 10 mg/L.

Figure 15. All basins have low nitrate concentrations.

Big Sky nitrate

Elevated nitrate concentrations were detected in the alluvial aquifer associated with the West Fork of the Gallatin River in the Big Sky Meadow Village. The area is characterized by residential development around a golf course where wastewater is used as irrigation water. Five sites were selected for repeated sampling between July 2008 and March 2013. Concentrations in all the wells generally ranged between 2 and 6 mg/L; well 155052 had a concentration spike of 12.38 mg/L in 2009 (fig. 16). The persistent elevated levels and the observed fluctuations suggest that the nitrate is from land-use impacts and moves relatively rapidly through the aquifer.

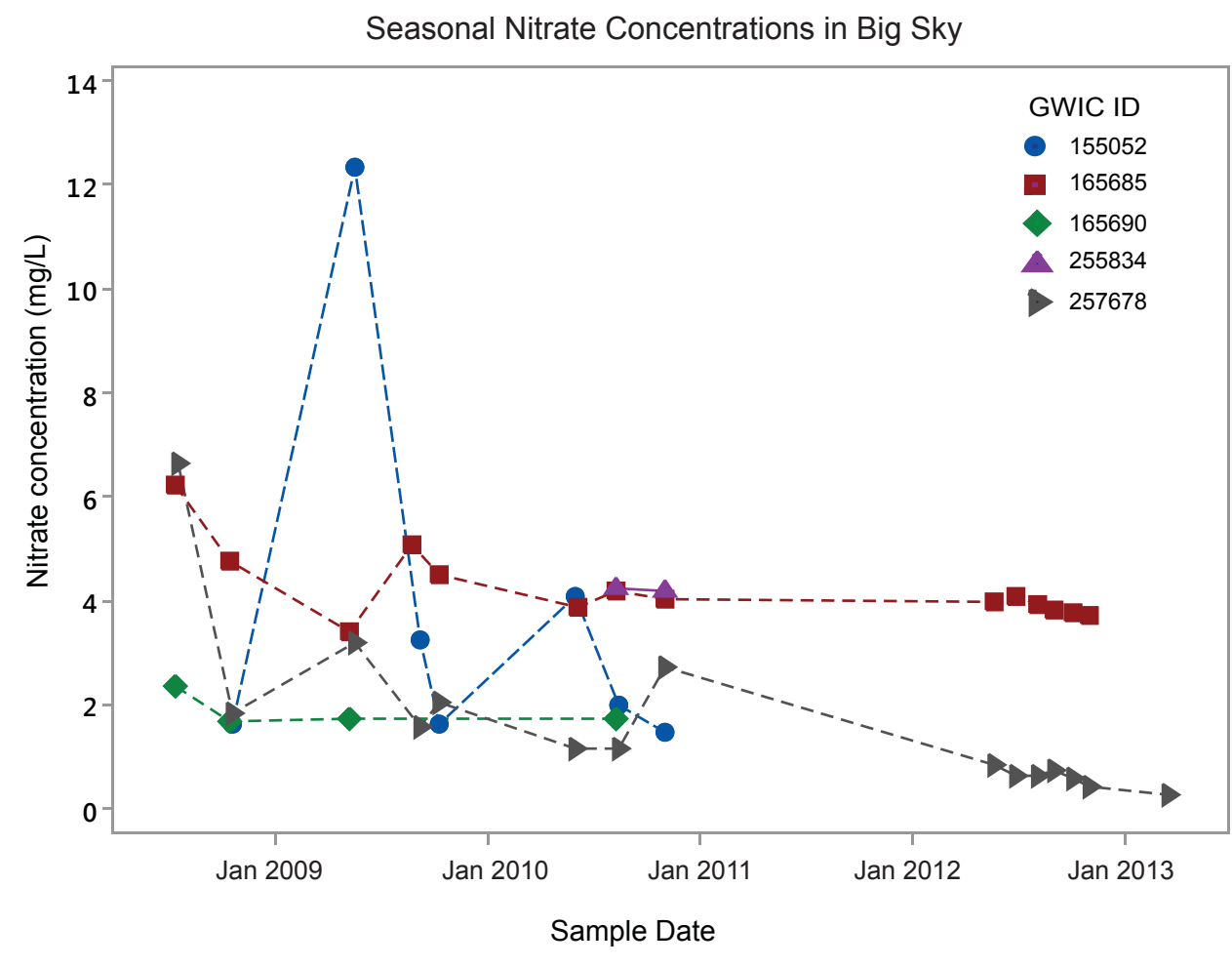


Figure 16. Nitrate samples were collected at five sites from July 2008 to March 2013. These sites, associated with the Meadow Village alluvial aquifer, show some annual and year to year variability. Only one sample exceeded the EPA MCL (this site had a landscaping nursery located beside it during this time). Although sample concentrations do not exceed the EPA MCL they are consistently above "background" concentrations associated with non-impacted aquifer conditions.

RADON

Radon (radon-222) is a naturally occurring radioactive gas that is soluble in water. It has a half-life of 3.8 days and is derived from the radioactive decay of uranium-238. Rocks that contain uranium include intrusive igneous rocks (e.g., granite) and extrusive (mostly felsic to intermediate volcanic rocks), some sedimentary rocks, and metamorphic rocks derived from the above.

Exposure by inhalation to radon gas is a health risk. Radon gas can enter homes through soil and bedrock that is in contact with the house. It also can be released into the air when radon-bearing water is used for showering or other in-home uses; however, this is considered to be a minor source to indoor air (EPA, 2015). For public water systems, the EPA has set an action level of 4,000 pCi/L (picocuries per liter), but recommends concentrations be less than 300 pCi/L.

Samples for radon analyses were collected from 22 bedrock and 43 basin-fill sites. In cases of multiple samples from the same site, the greater value was used to characterize the site. The concentrations were grouped using the EPA's recommended levels (fig. 17).

Radon is widespread in the groundwater of Gallatin and Madison Counties; but overall, only 6 of the 65 samples had concentrations below 300 pCi/L. One bedrock sample was above the 4,000 pCi/L level (red square in West Yellowstone area), and 13 were above the 300 pCi/L level. There were 41 basin-fill aquifer samples that exceeded 300 pCi/L and two that exceeded 4,000 pCi/L (see red symbols with concentration values on map).

The median for basin-fill samples (762 pCi/L) was twice that of the bedrock samples (387 pCi/L), but the bedrock samples displayed a greater range of concentrations (fig. 18). Radon above 300 pCi/L was detected in all the major basins; however, the highest concentrations were detected in the upper Madison Basin.

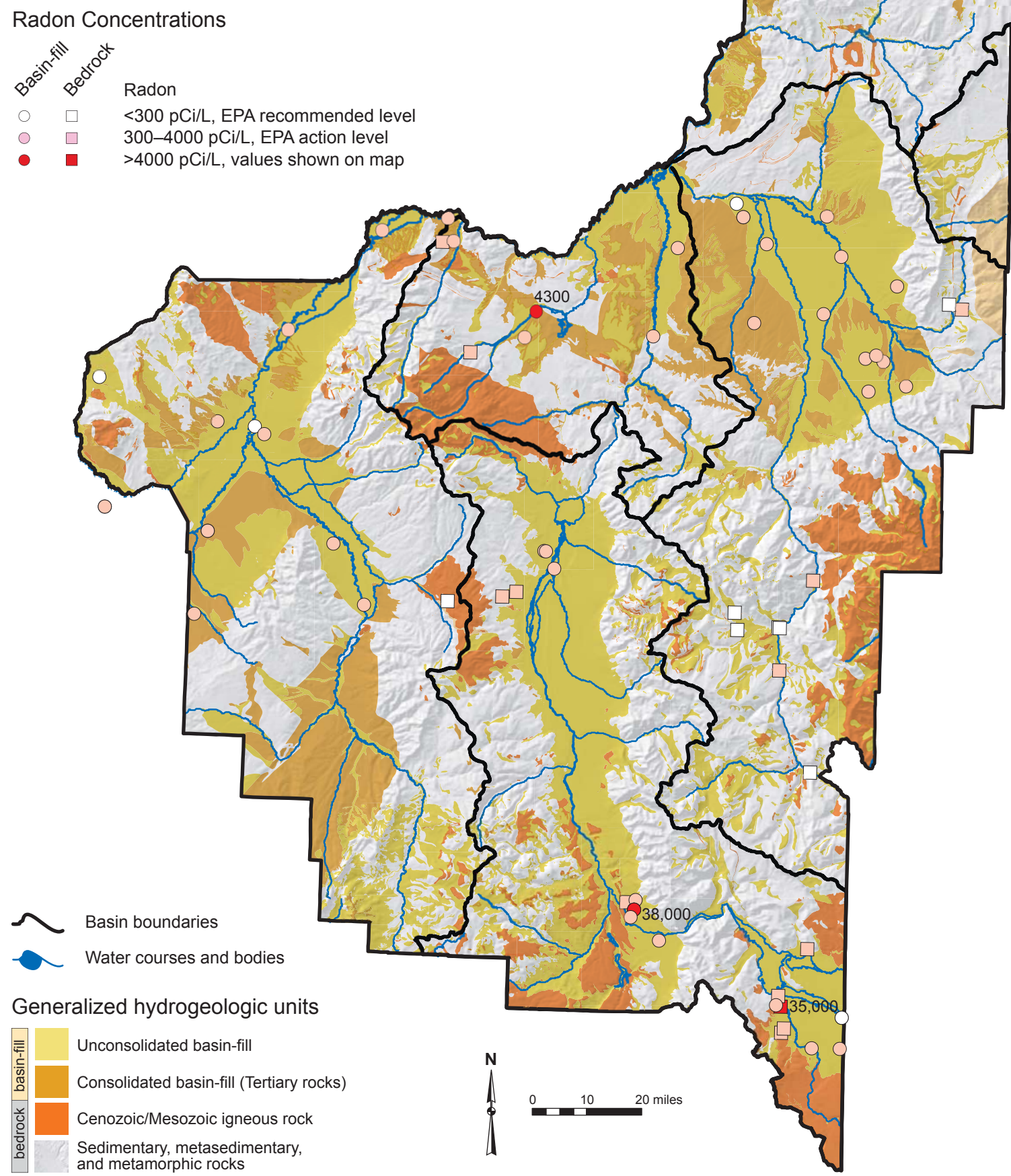


Figure 17. From 65 sample sites, most (82%) were above 300 pCi/L and three had concentrations above 4,000 pCi/L.

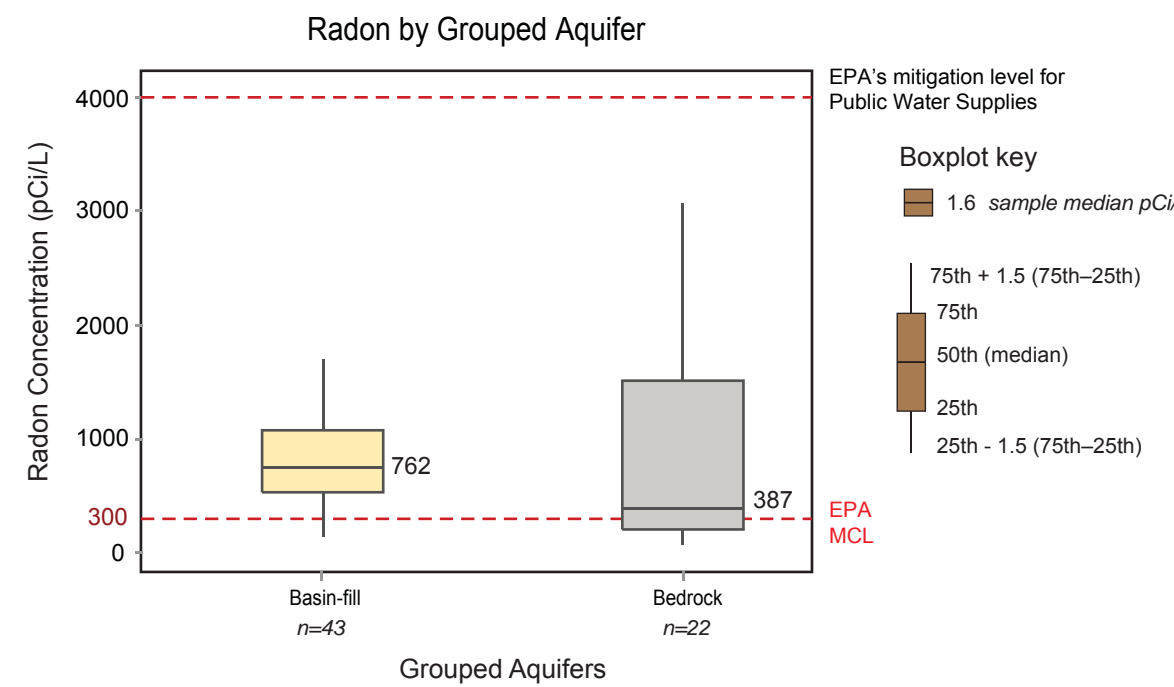


Figure 18. Although only a few samples exceed the EPA's action level of 4,000 pCi/L, most are above the recommended 300 pCi/L (outliers are not shown).

WATER ISOTOPES

Tritium

Tritium (³H) is a naturally occurring radioactive isotope of hydrogen that has a half-life of 12.32 years (Lucas and Unterwieser, 2000). It is naturally produced in the upper atmosphere, where it is incorporated into water molecules and therefore present in precipitation that becomes groundwater recharge. Tritium values in groundwater are usually reported in tritium units (TU); one tritium unit equals one tritium atom in 10¹⁸ hydrogen atoms.

Levels of tritium in precipitation spiked following above-ground nuclear testing during the 1950s and 1960s. In the northern latitudes precipitation values went from a background level of 5–10 TU to greater than 1,000 TU. The relative short half-life and the "bomb"-produced tritium make it a valuable marker of groundwater that has been recharged within the past 60 years. Detectable tritium indicates water recharged since above-ground nuclear testing.

Tritium was measured in samples from 98 sites (fig. 19). For sites sampled more than once, the sample with the most complete information or the most recent sample was used to represent the site. Tritium values were divided into three categories: "sub-modern," "sub-modern to modern," and "modern" with some "bomb" tritium (fig. 19).

The samples were split fairly evenly between bedrock (46) and basin-fill aquifers (52). Nine bedrock and 11 basin-fill samples did not have detectable tritium (<0.8 TU), indicating old water (recharged pre-bomb). The samples were all from deep wells (190–815 feet). One of the samples was from a spring that comes to the surface through basin-fill but probably is bedrock sourced. Five samples with tritium values (TUs) between 15.5–19.5, suggesting recharge during bomb testing (or mixed old and young water), were from basin-fill aquifers (well depth 100–425 feet). Samples from bedrock aquifers ranged in concentration from non-detect to 10.2 TUs. However, most samples (74 percent) with TU values between 0.8 and 15 indicate recharge within the past 60 years.

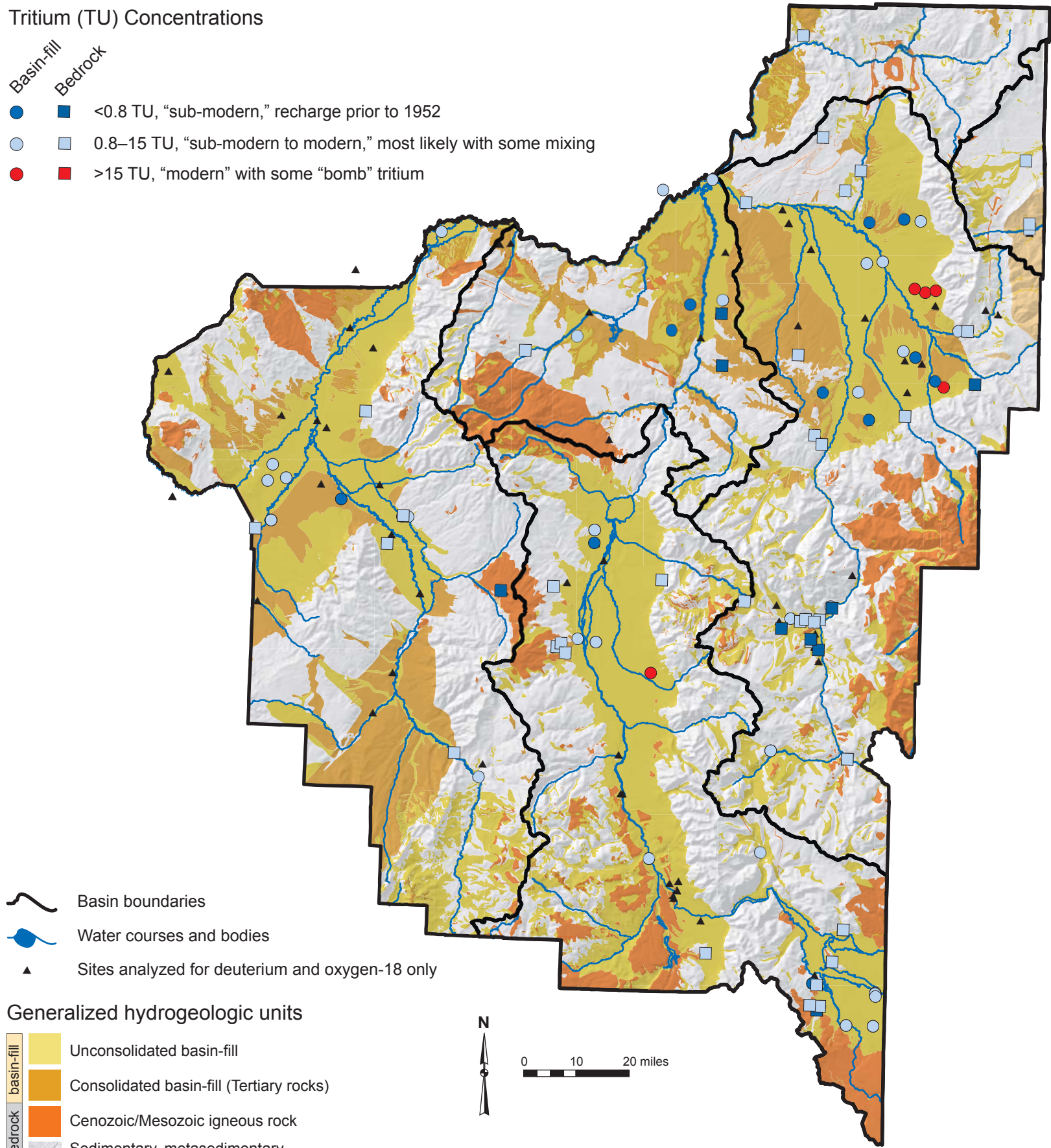


Figure 19. Ninety-eight tritium samples indicate that most water is of a "modern" age (light blue). Ninety of these sites were also analyzed for deuterium and oxygen-18. Twenty-five additional sites were sampled for just deuterium and oxygen-18. These sites were sampled more than once for a total of 157 samples. All values are displayed in Figs. 20 and 21.

Oxygen-18 and hydrogen-2 (deuterium)

Groundwater from 117 sites (157 total samples) was analyzed for ratios of the stable isotope of oxygen (¹⁸O/¹⁶O) and hydrogen (²H/¹H). The isotopic ratio is expressed as the difference between the measured ratios of the samples and the reference water, divided by the ratio of the reference water. Vienna Standard Mean Ocean Water (VSMOW) is the standard reference for oxygen-18 and deuterium (hydrogen-2) isotopes. The ratio is known as delta (δ) and is expressed in units of parts per thousand, or per mille (‰).

The δ²H and δ¹⁸O values plot slightly below the global meteoric water line (GMWL; Craig, 1961), indicating a meteoric origin of water in all the sampled aquifers (fig. 20). There was no discernible difference in the values among the basins (fig. 21), and the values were similar between the bedrock and basin-fill aquifers (fig. 20).

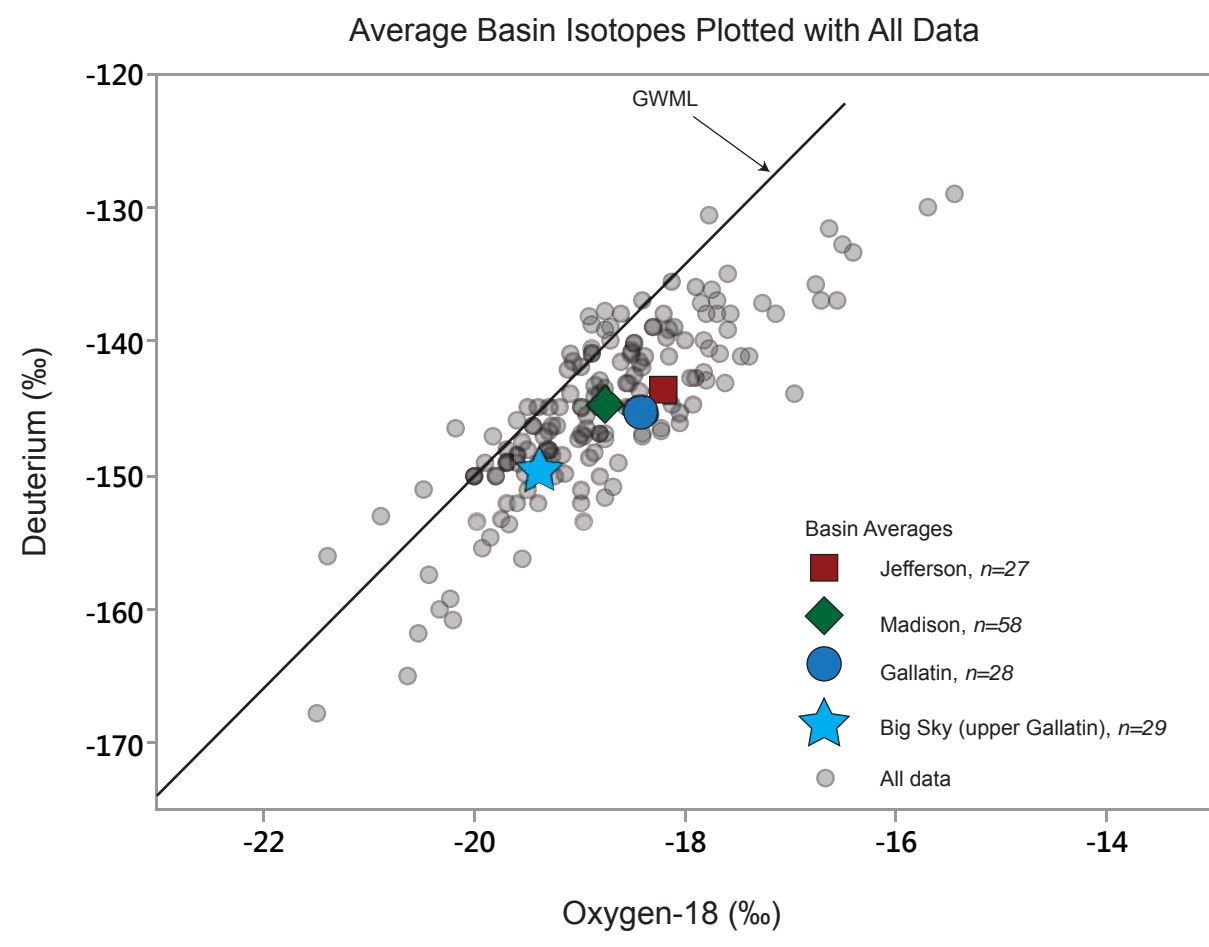


Figure 20. The averages for each basin plot closely; data from Big Sky are slightly more negative (blue star on graph). Major basin samples represent 90 percent of samples collected in the study area.

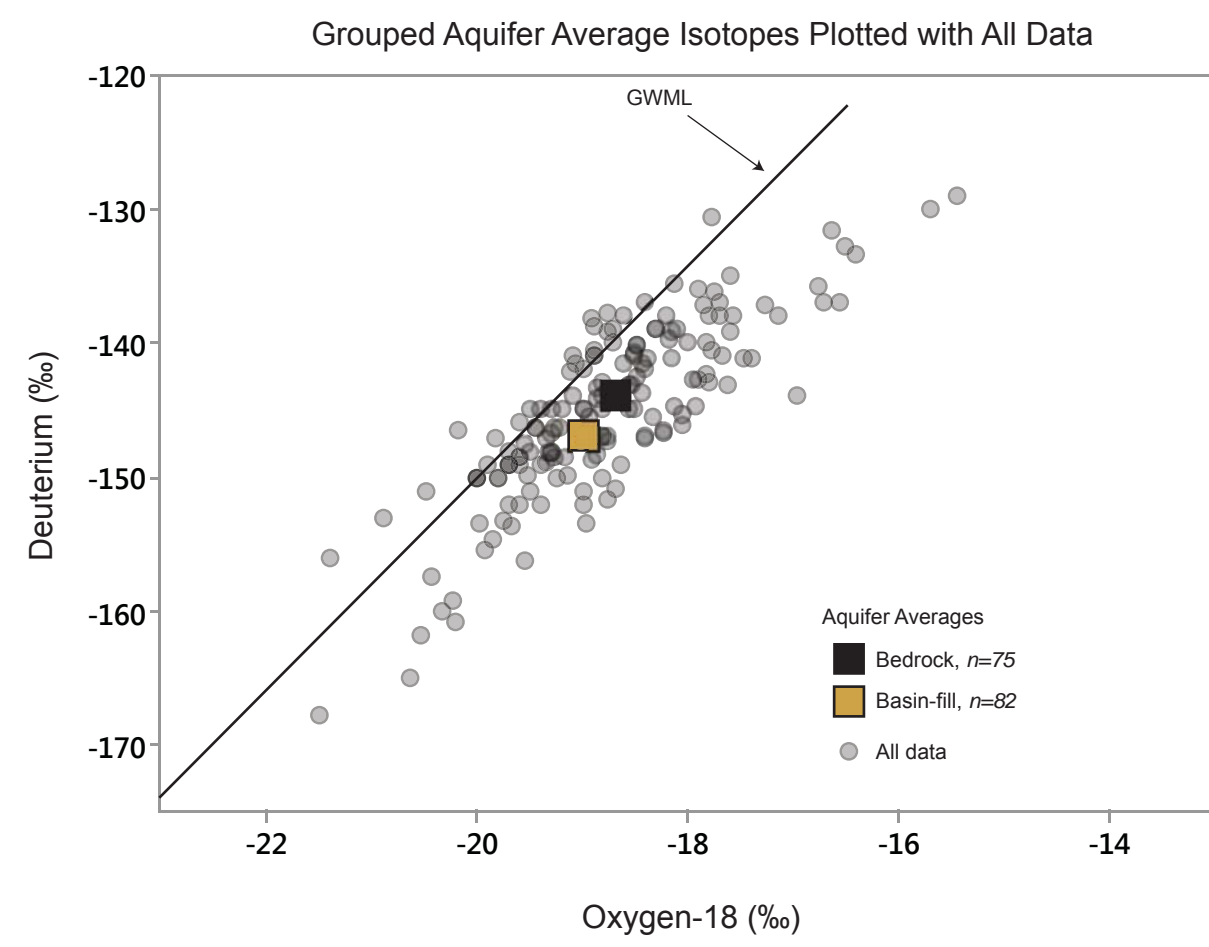


Figure 21. Averages for the basin-fill and bedrock aquifers plot very close to one another.



Montana Ground Water Assessment Atlas 8, Map 3, Sheet 2 of 2

Groundwater Quality of the Intermontane Basins, Gallatin and Madison Counties, Southwest Montana

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Author's Note: This map (sheet 1 and 2) is part of the Montana Bureau of Mines and Geology (MBMG) Ground Water Assessment Atlas for the Gallatin–Madison Groundwater Characterization Study Area. It is intended to stand alone and describe a single hydrogeologic aspect of the area, although many of the area's hydrogeologic features are interrelated. For an integrated view of the hydrogeology of the Gallatin–Madison Study Area, the reader is referred to other maps of the Montana Ground Water Assessment Atlas 8.

Maps may be obtained from:
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