

Water Quality, Mixing, and Groundwater Age in an Urbanizing Agricultural Intermountain Basin, Gallatin Valley, Montana

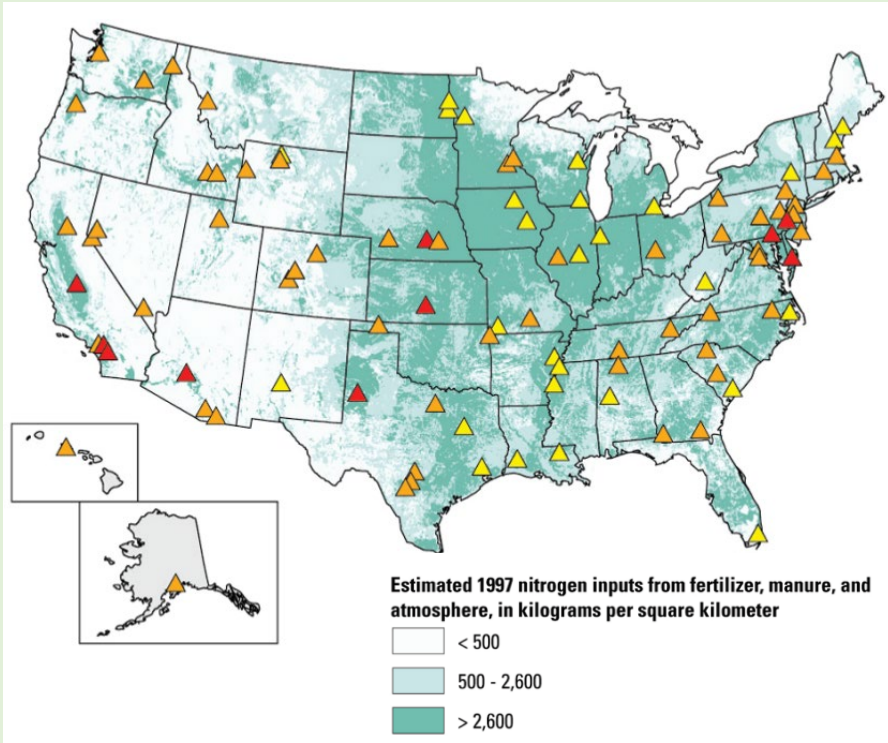
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¹Montana State University ²University of Montana, ³United States Geological Survey



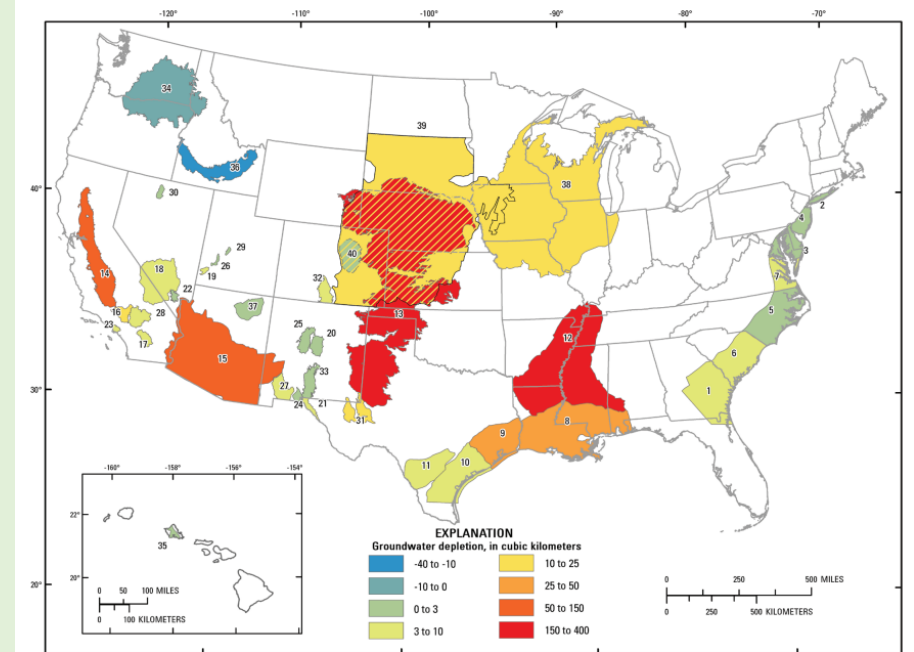
Global Motivation

Quality



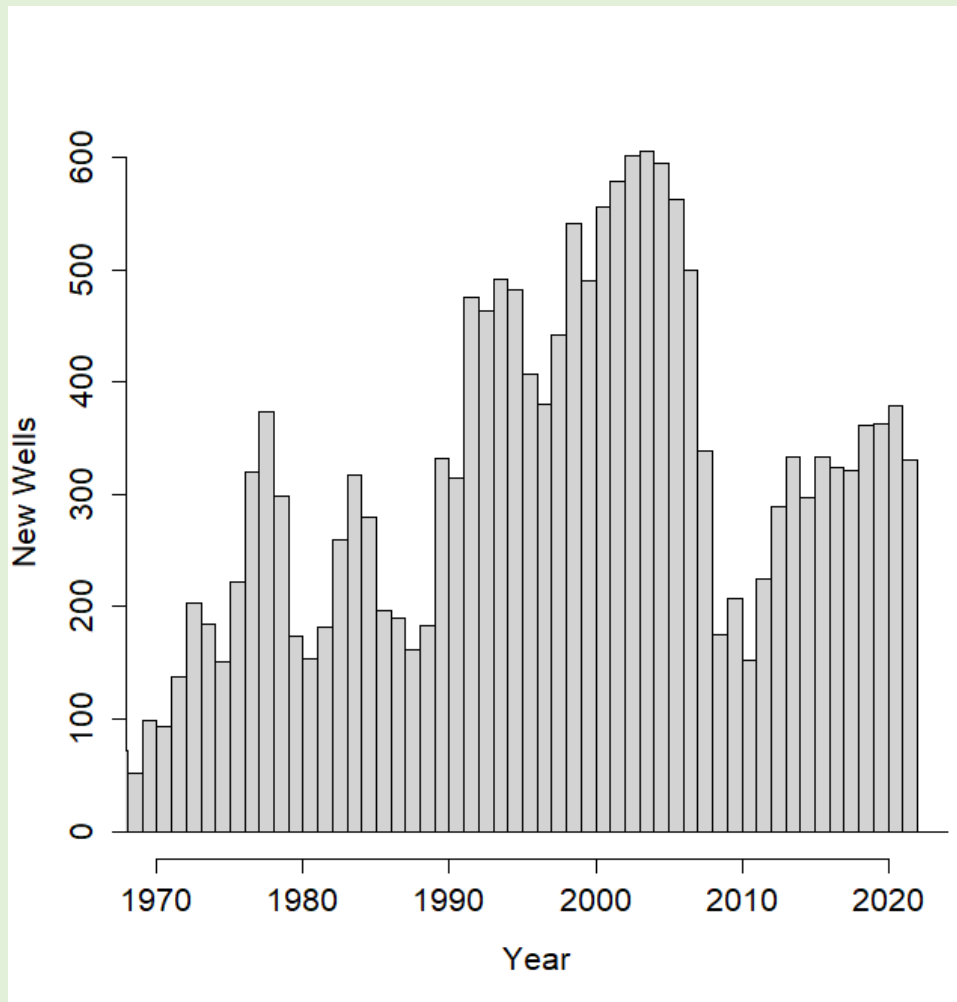
(Burow et al., 2010)

Quantity

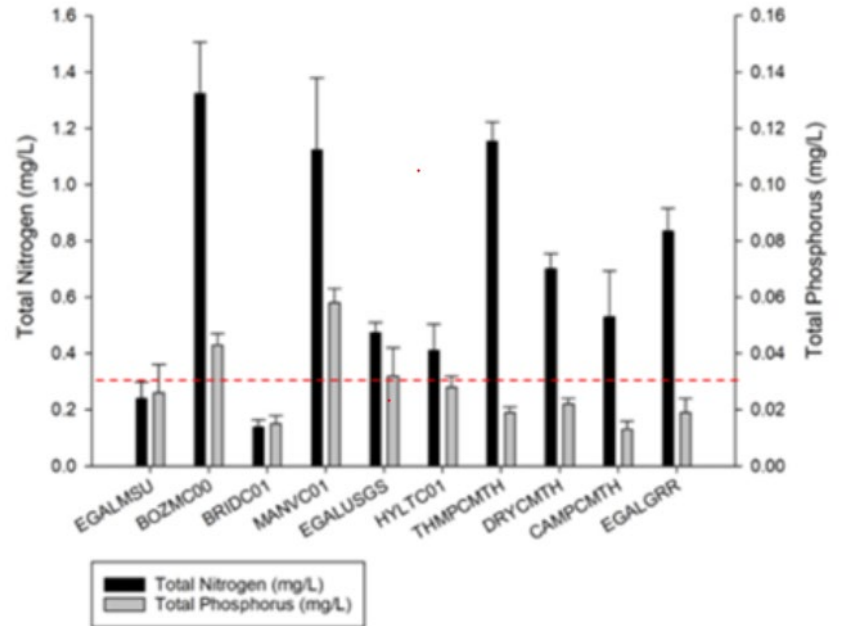


(Konikow, 2013)

Local Motivation

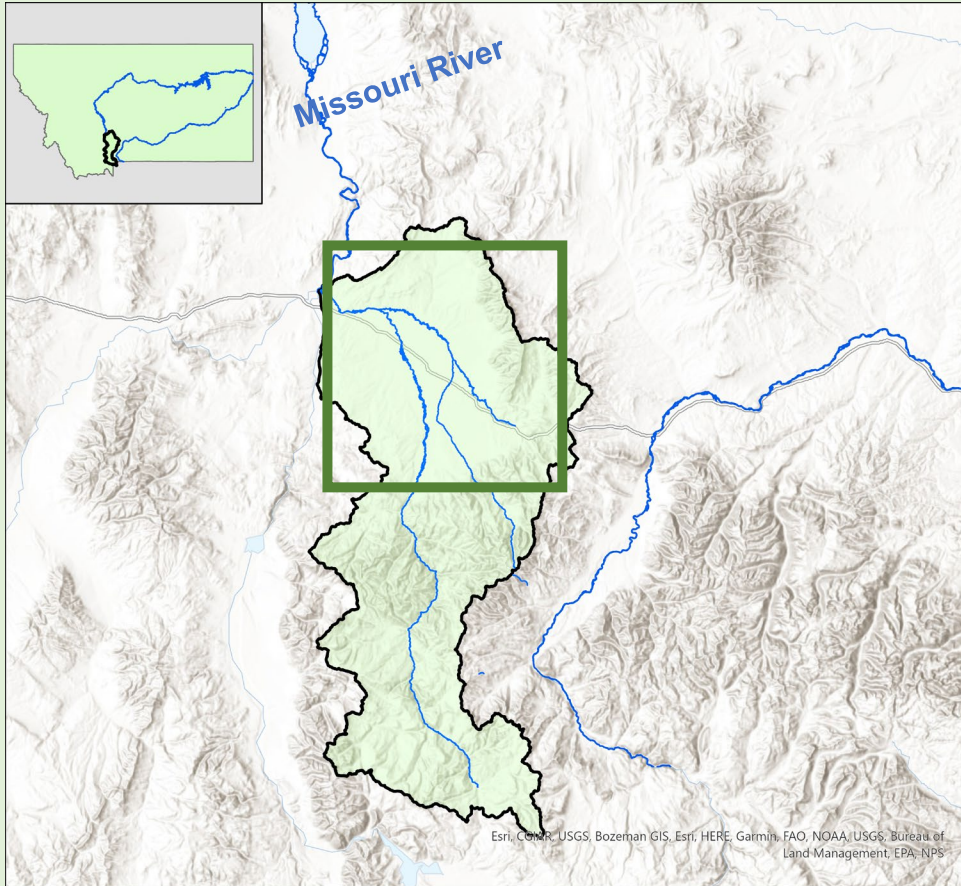


2022 TN & TP Surface Water Concentrations (mg/L)



*Red dash line indicates the DEQ designated impairment concentration for both Total Nitrogen and Total Phosphorus.
 0.3 mg/L - Total Nitrogen
 0.03 mg/L - Total Phosphorus

Gallatin Valley, Montana



- **Representative intermountain basin**
- **Irrigated and dryland agriculture, urbanization**
- **Population of 120,000 (doubled since 1998)**

0 25 50 100 Kilometers



Research Objectives

How does Gallatin Valley hydrogeologic system exacerbate or attenuate nutrient contamination?

- 1. Further understanding of contaminant introduction and transport**
- 2. Characterize groundwater and surface water geochemical evolution within Gallatin Valley hydrologic system**
- 3. Locate and quantify inputs from Archaean and Tertiary bedrock aquifers**

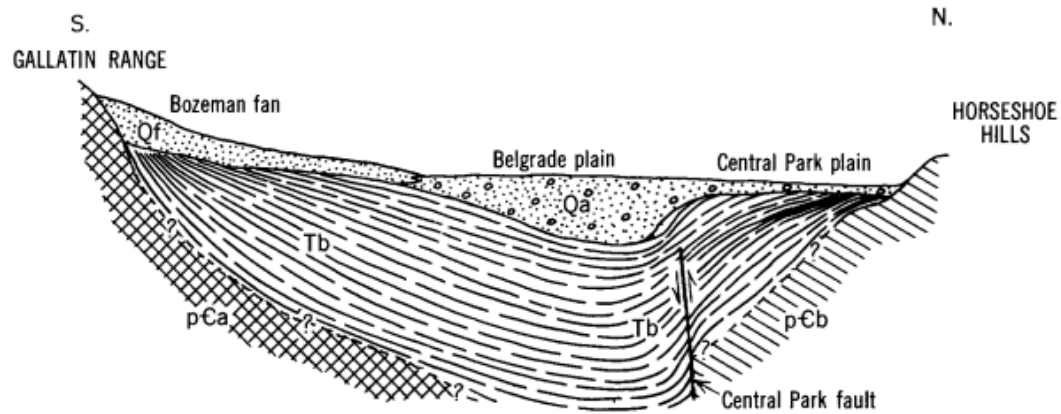


- Mountains comprised of volcanic, sedimentary, and metamorphic rocks
- Valley-fill sediments, Quaternary/Holocene (unconsolidated), and Tertiary (semi-consolidated to consolidated)

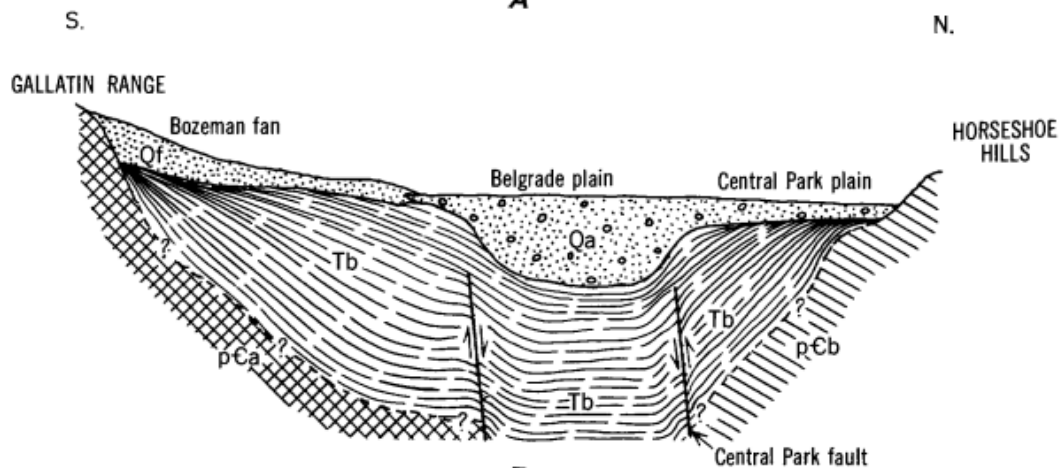
N



0 2.5 5 10 15 20 Kilometers



A

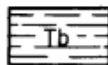


B

EXPLANATION



Alluvium of Quaternary age



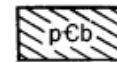
Deposits of Tertiary age



Precambrian metamorphic rocks



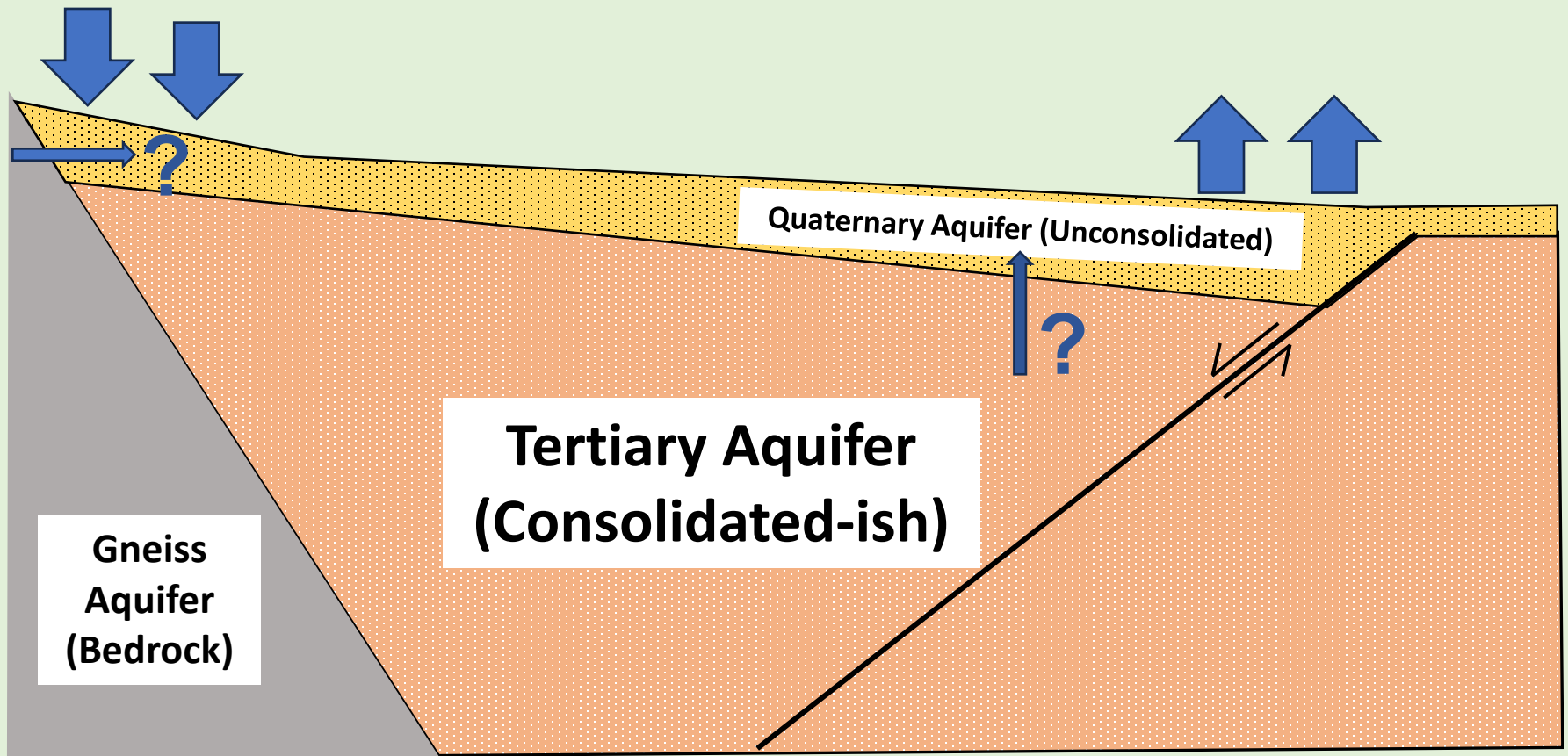
Alluvial-fan deposits of Quaternary age



Belt series (Precambrian)

FIGURE 13.—Diagram showing alternative hypotheses for the formation of the Belgrade trough. **A.** By downwarping of the Tertiary strata northward toward the Central Park fault. **B.** By down dropping of block between the Central Park fault and a fault south of Belgrade.

- Focused recharge along mountain front from losing streams
- Large groundwater discharge zone in lower valley

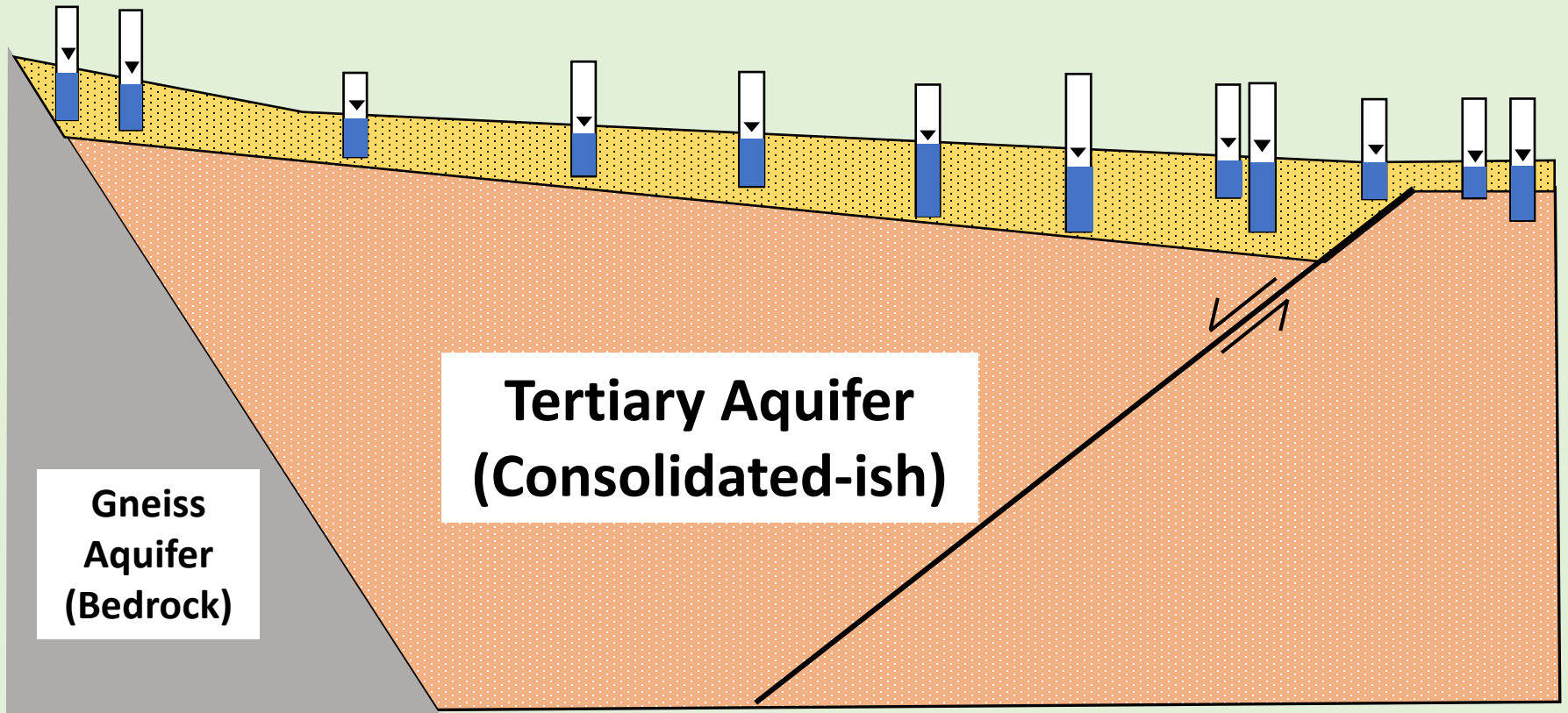







Surface Water Oct. 2021

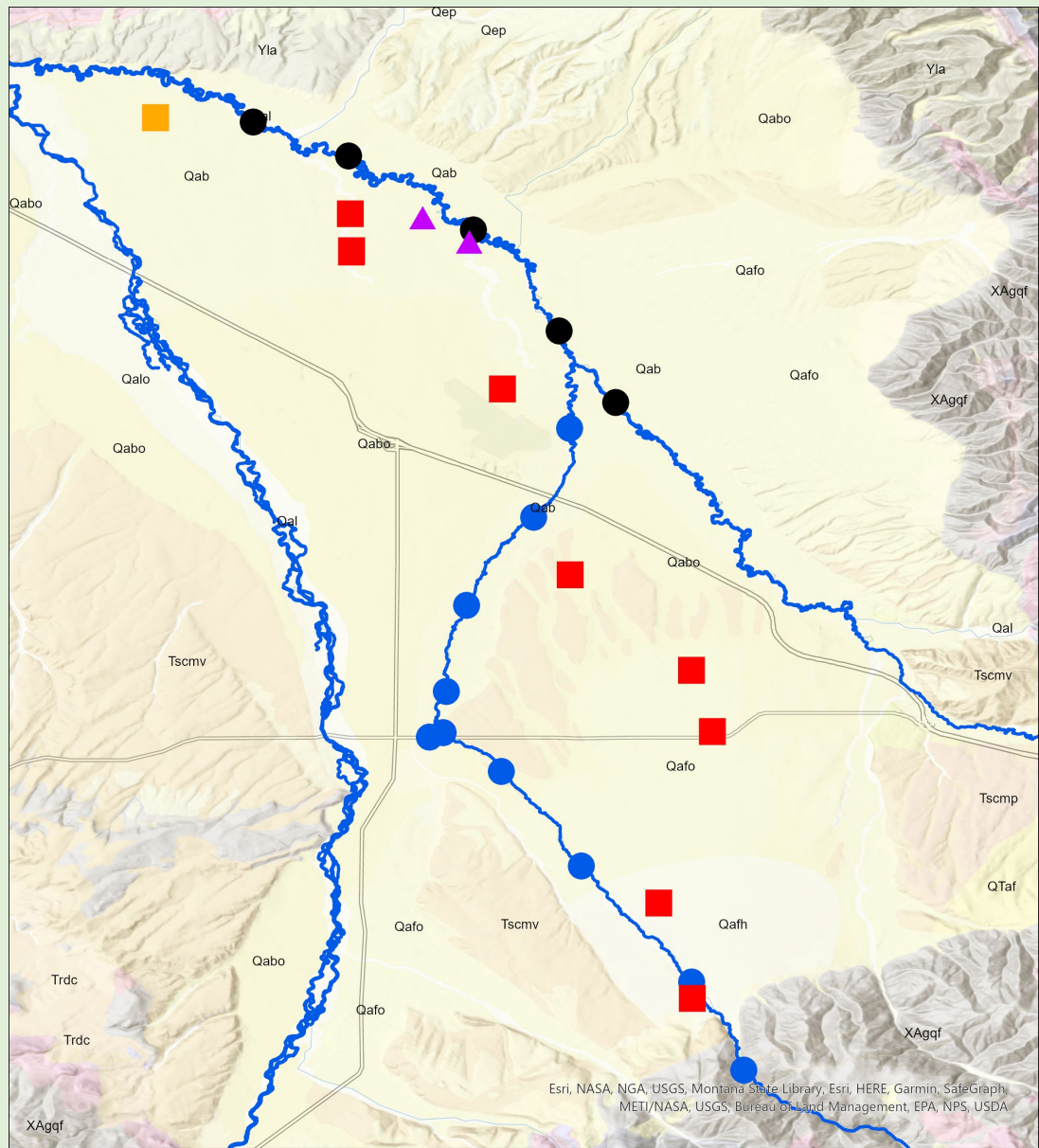
- 9 Hyalite
- 5 E. Gallatin
- ▲ 2 Spring Creeks

Groundwater May 2023

- 9 Quaternary Wells
- 2 Tertiary Wells

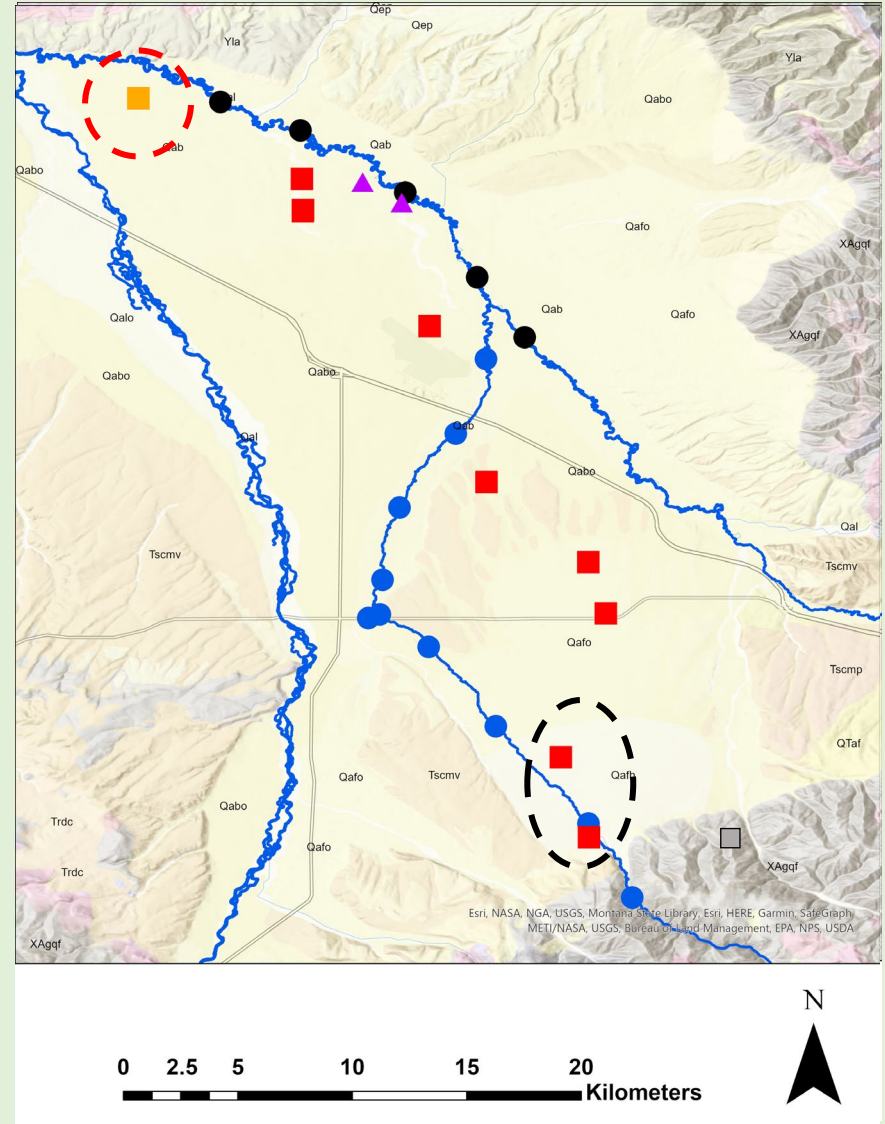
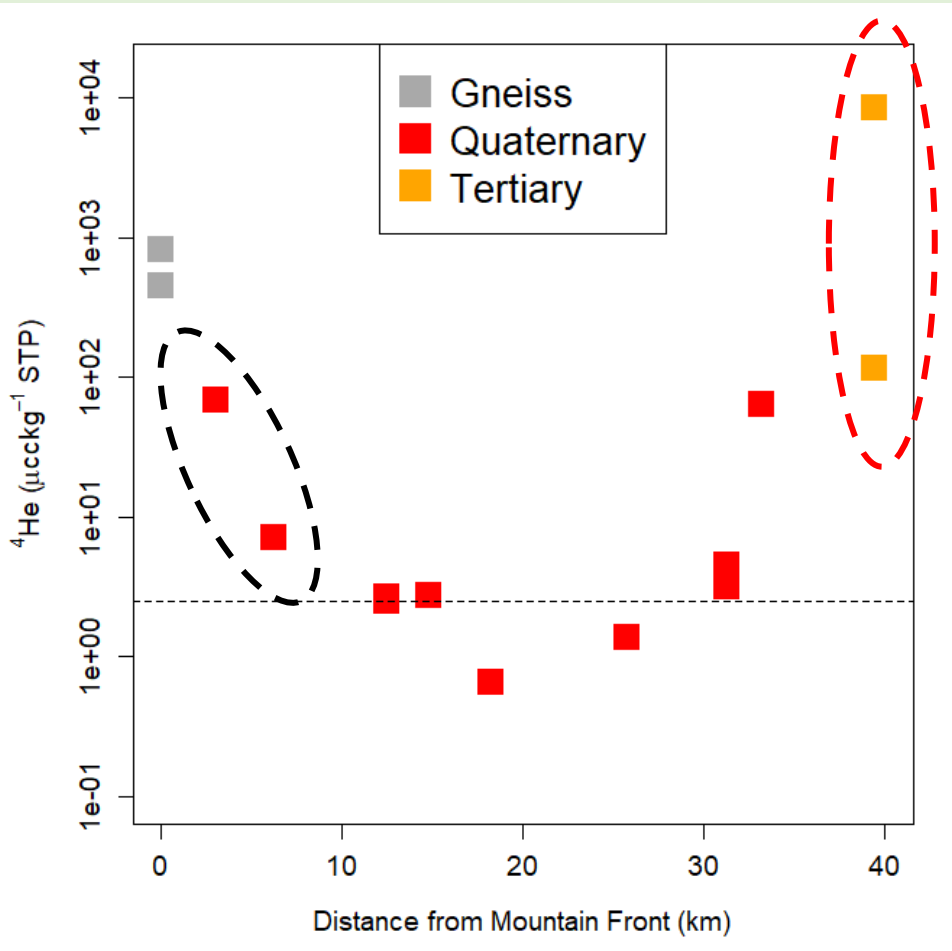


-  Hyalite Cr.
-  E. Gallatin R.
-  Spring Creek
-  Quaternary All.
-  Tertiary

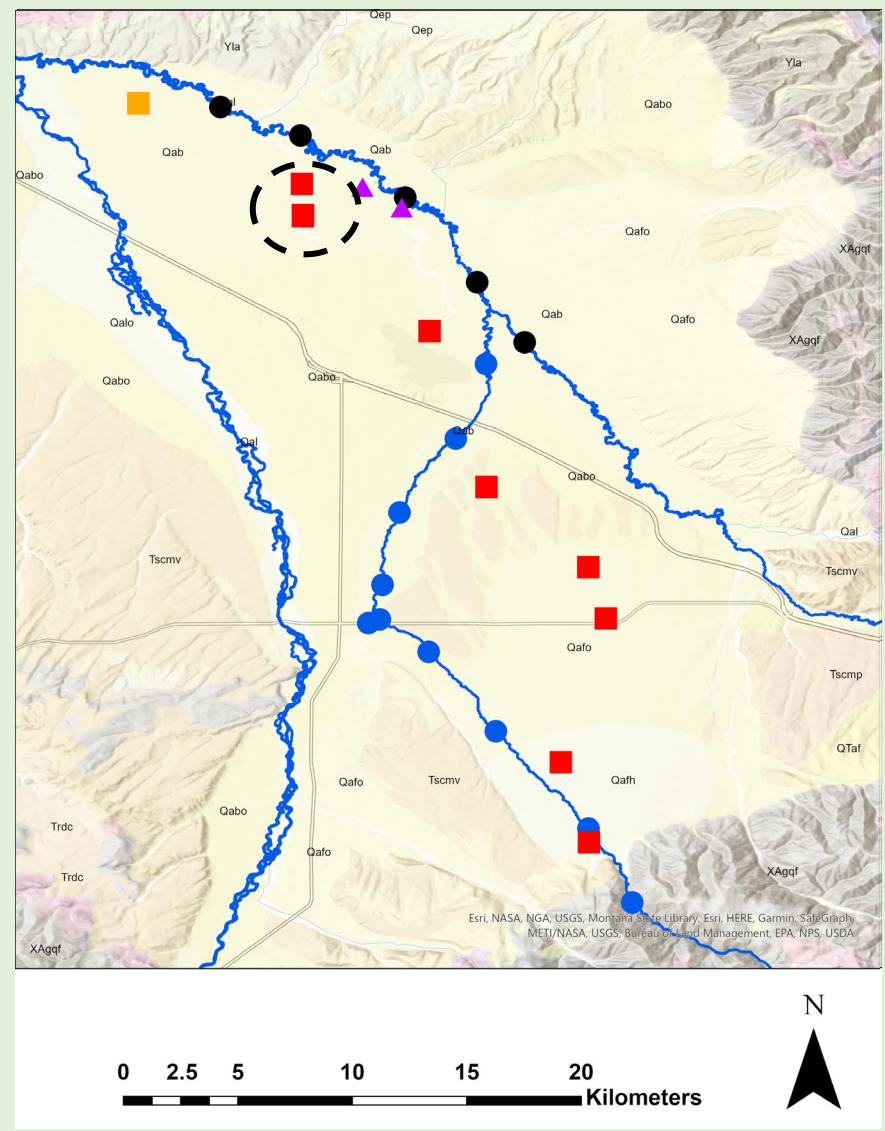
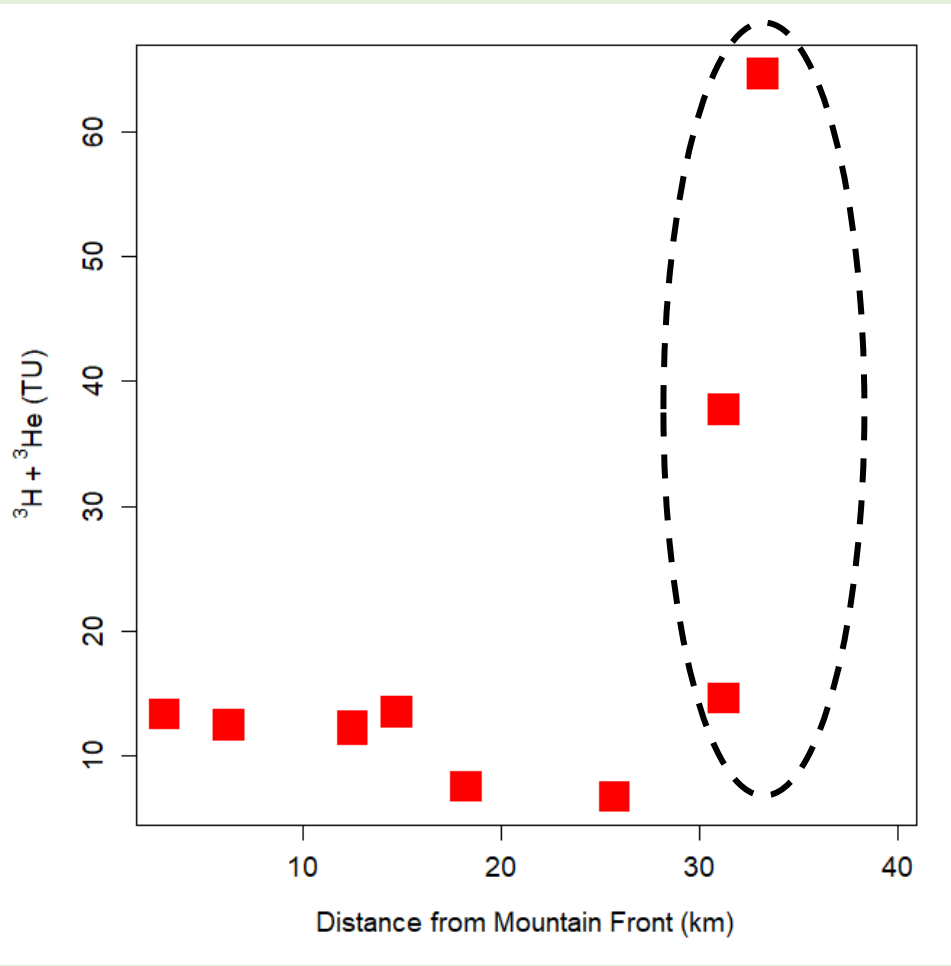


Esri, NASA, NGA, USGS, Montana State Library, Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA





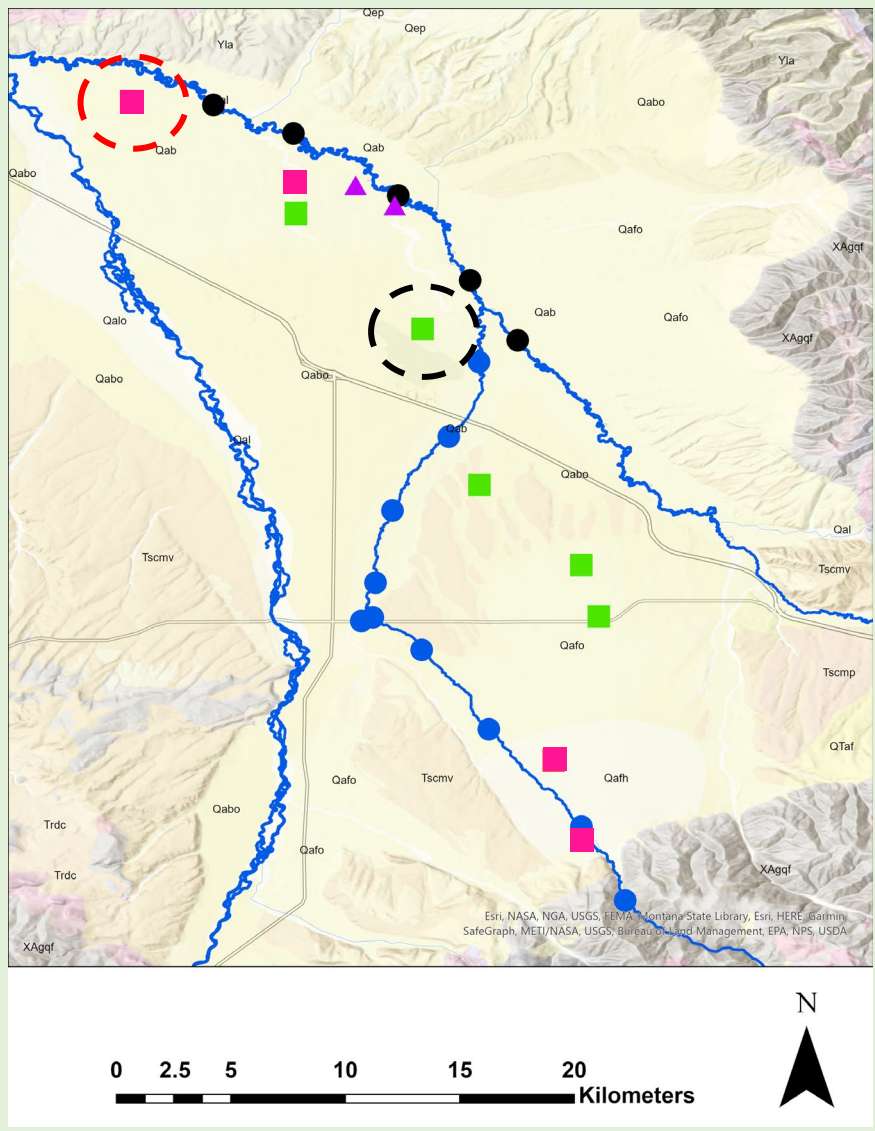
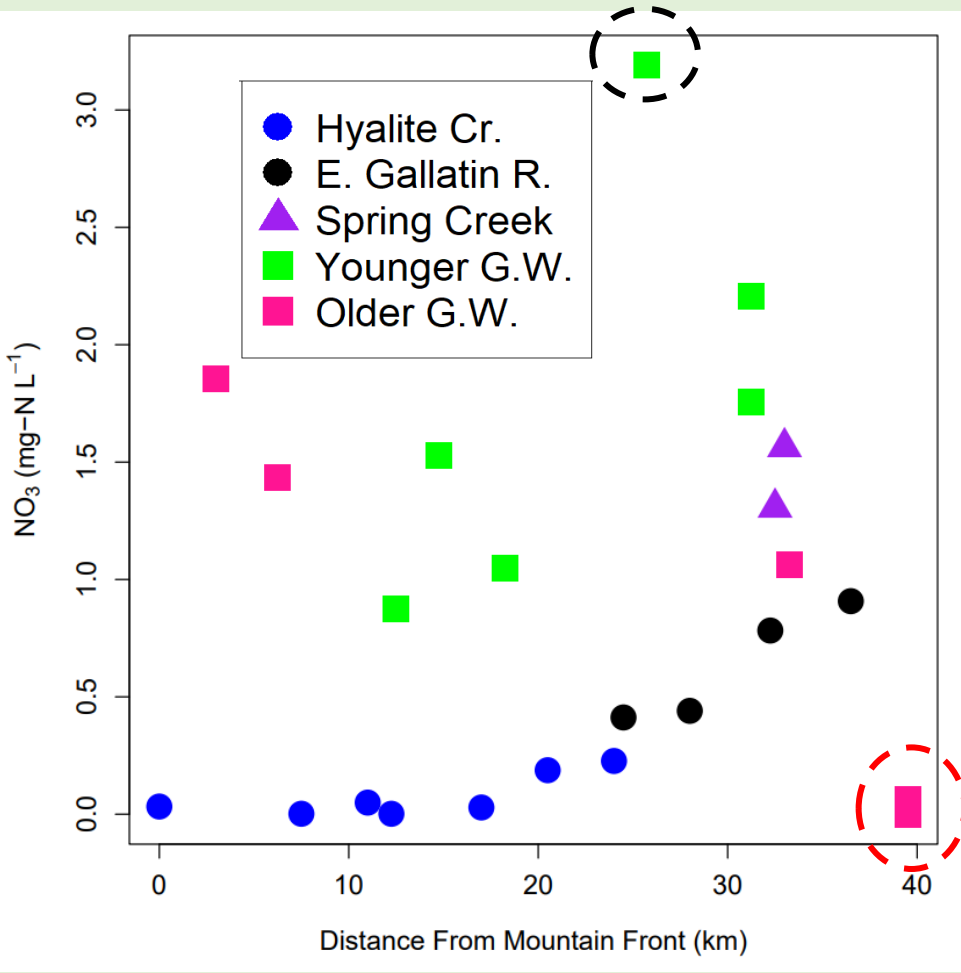
- Elevated ⁴He at mountain front and in G.W. discharge zone
- Mountain-block recharge and upwelling of older and bedrock influenced waters



- **Seemingly ancient bedrock well contains modern tritium**
- **Tritium increases and decreases downgradient**

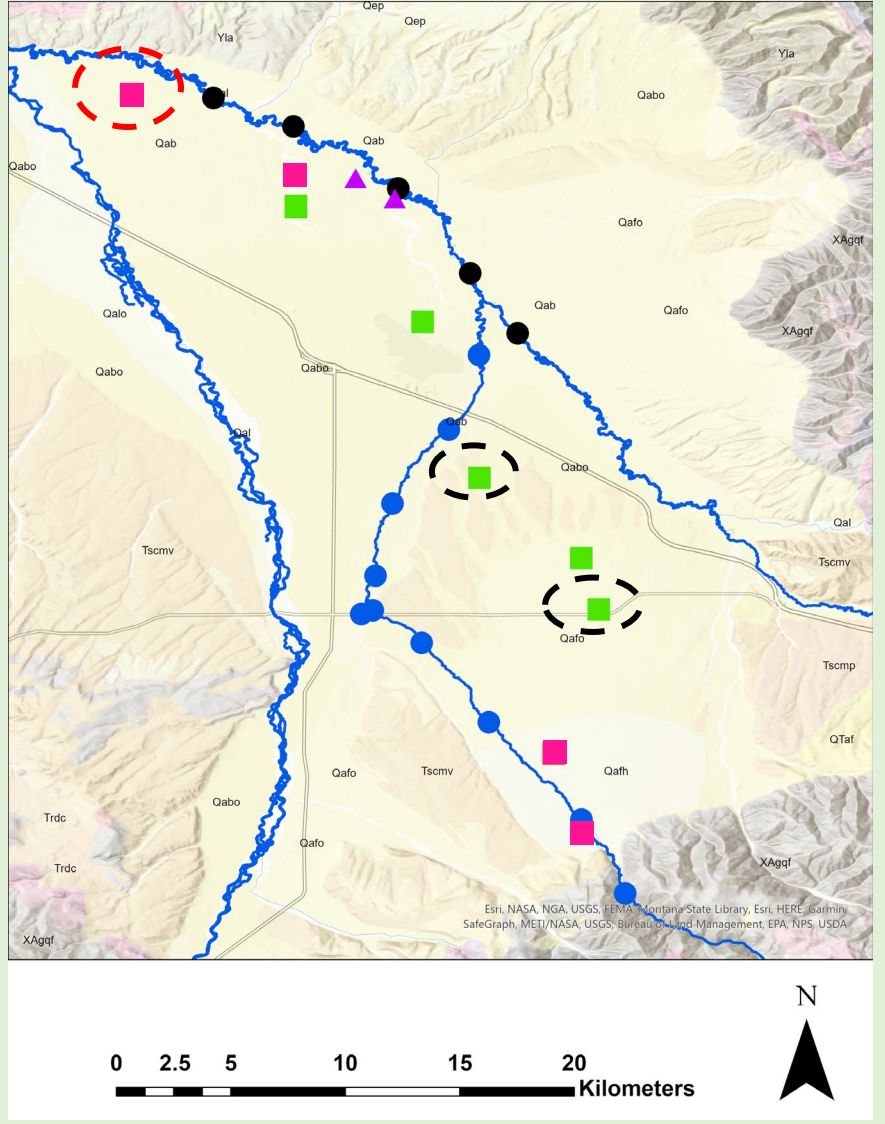
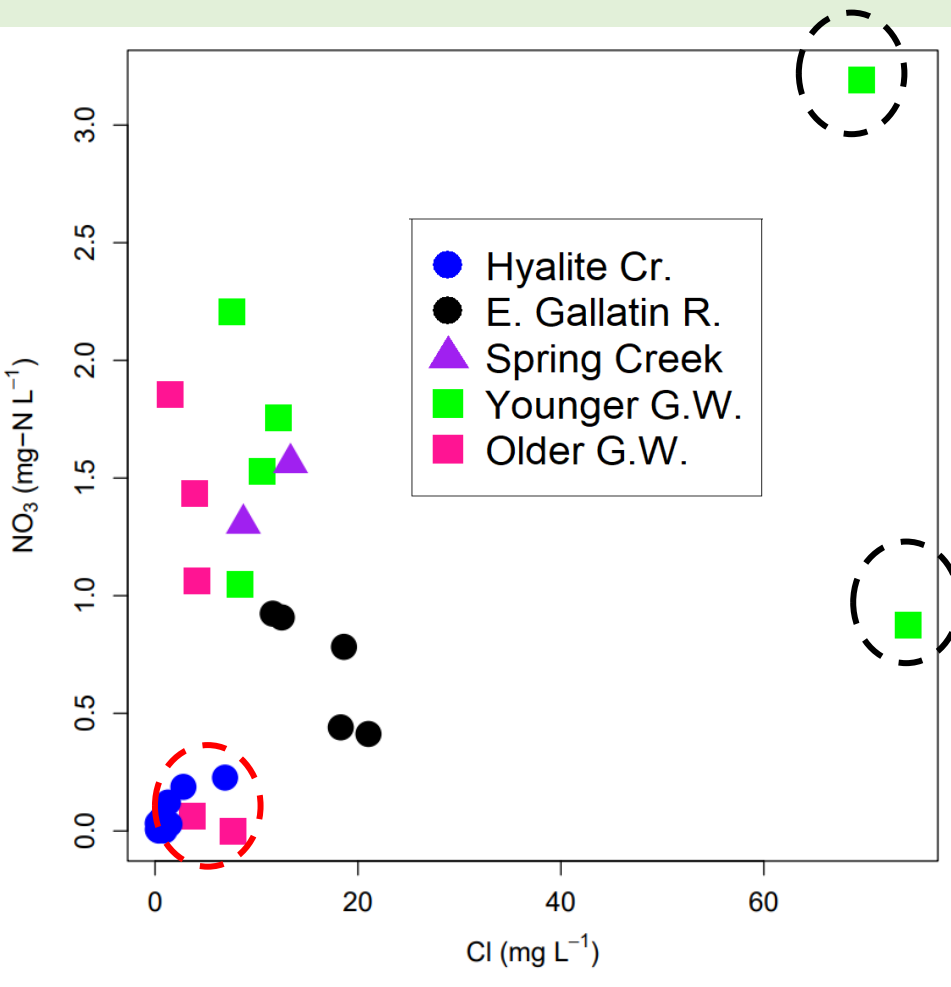
Water Isotopes and Noble Gases

- **Older water present at mountain front and in groundwater discharge zone**
- **Older waters in groundwater discharge zone have distinct recharge conditions**
- **Do these variable ages and recharge conditions have any bearing on nutrients or major ion composition?**



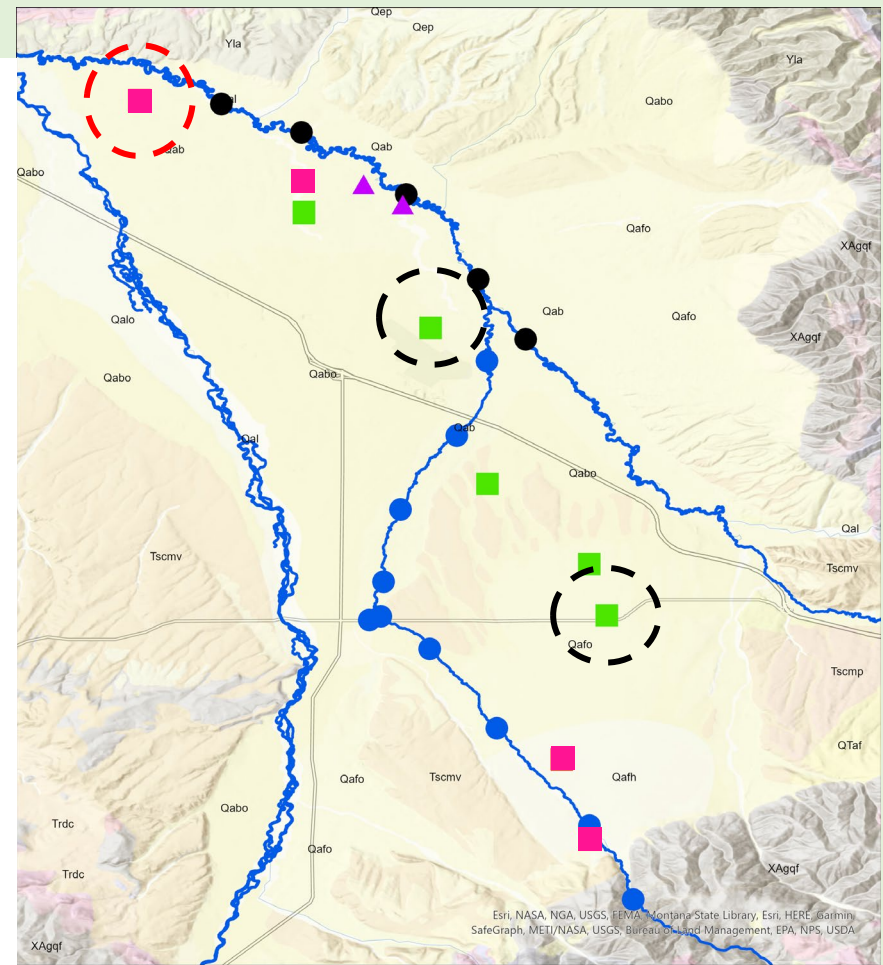
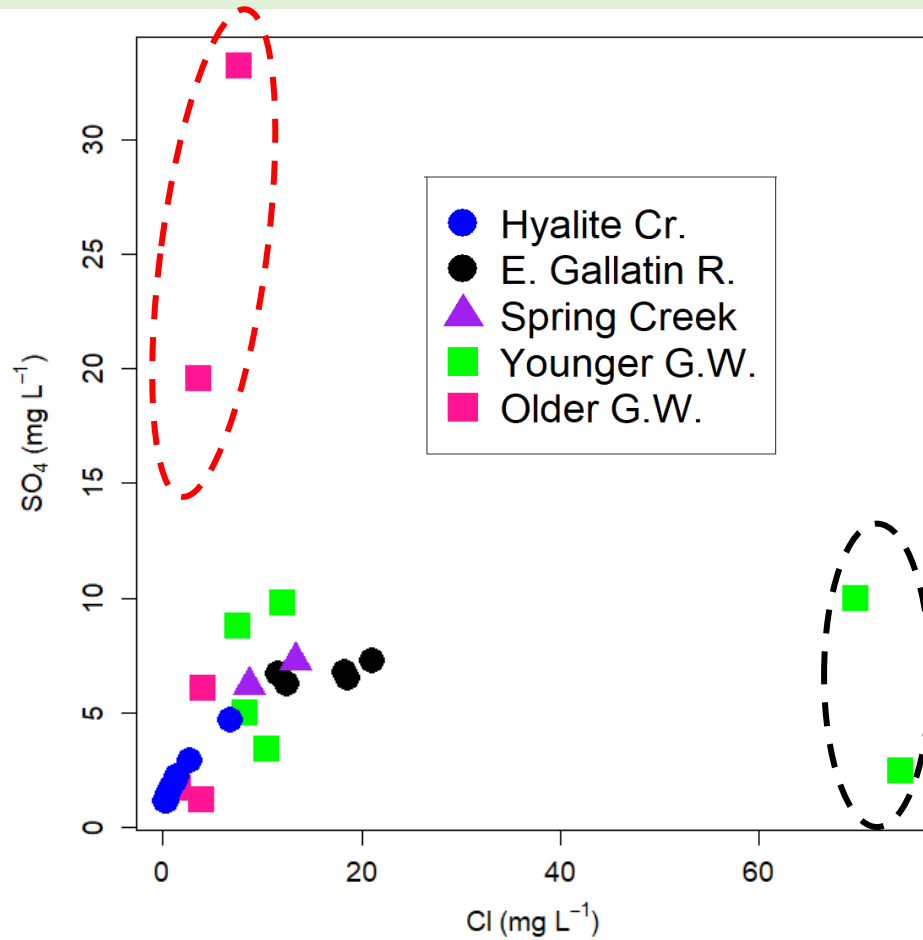
- Groundwater concentrations are high
- Surface water increases downgradient

- Spring creeks are highest nitrate surface waters
- Two bedrock wells contain low, but detectable nitrate



- High chloride groundwaters found in urban and septic sites
- No discernable relationship between groundwater nitrate and chloride

- Surface waters generally increase downgradient



- Distinct geochemical signals from bedrock and human-influenced aquifers
- SO₄ and Cl increase downgradient in S.W.

Major Ions & Nutrients

- **Inflows of older waters to alluvial aquifer do not meaningfully attenuate nitrate or alter major ions**
- **Chloride concentrations associated with younger waters**
- **Groundwater discharge zone increases S.W. nitrate concentrations**
- **Surface water geochemical evolution towards chloride, anthropogenic or geogenic?**

Acknowledgements and Thanks

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Collaborators

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Tom Michalek

Field Assistance

Jack Poole

Madison Weber

Rachel Anderson

Laboratory Analysis

MSU Environmental Analytical Lab

USGS Noble Gas Laboratory – Denver

USGS Denver Radiogenic Isotope Lab

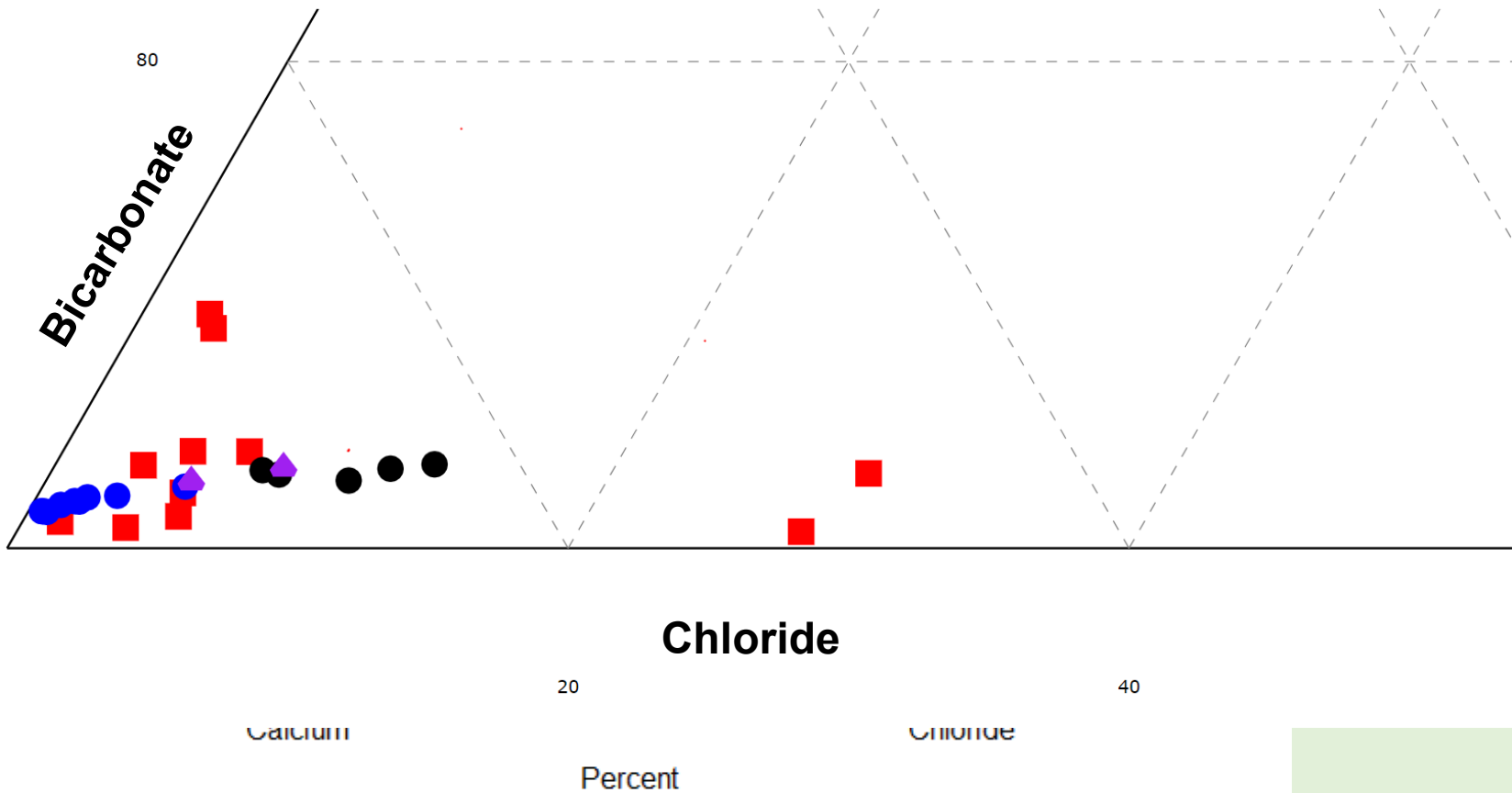
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A person wearing a plaid shirt and dark pants stands in a field, holding a long vertical pole. The field is filled with tall, dry grasses. In the background, there are mountains with patches of snow under a cloudy sky. A metal guardrail is visible on the left side of the image. The word "Questions?" is written in large, bold, black letters across the center of the image, with a horizontal line underneath it.

Questions?

- Hyalite Cr.
- E. Gallatin R.
- ▲ Spring Creeks
- Groundwater



- Hyalite Cr.
- E. Gallatin R.
- ▲ Spring Creek
- Younger G.W.
- Older G.W.

