GEOCHEMICAL INSIGHTS INTO HARNEY BASIN HYDROLOGY

Harney Science Advisory Committee

May 30, 2019

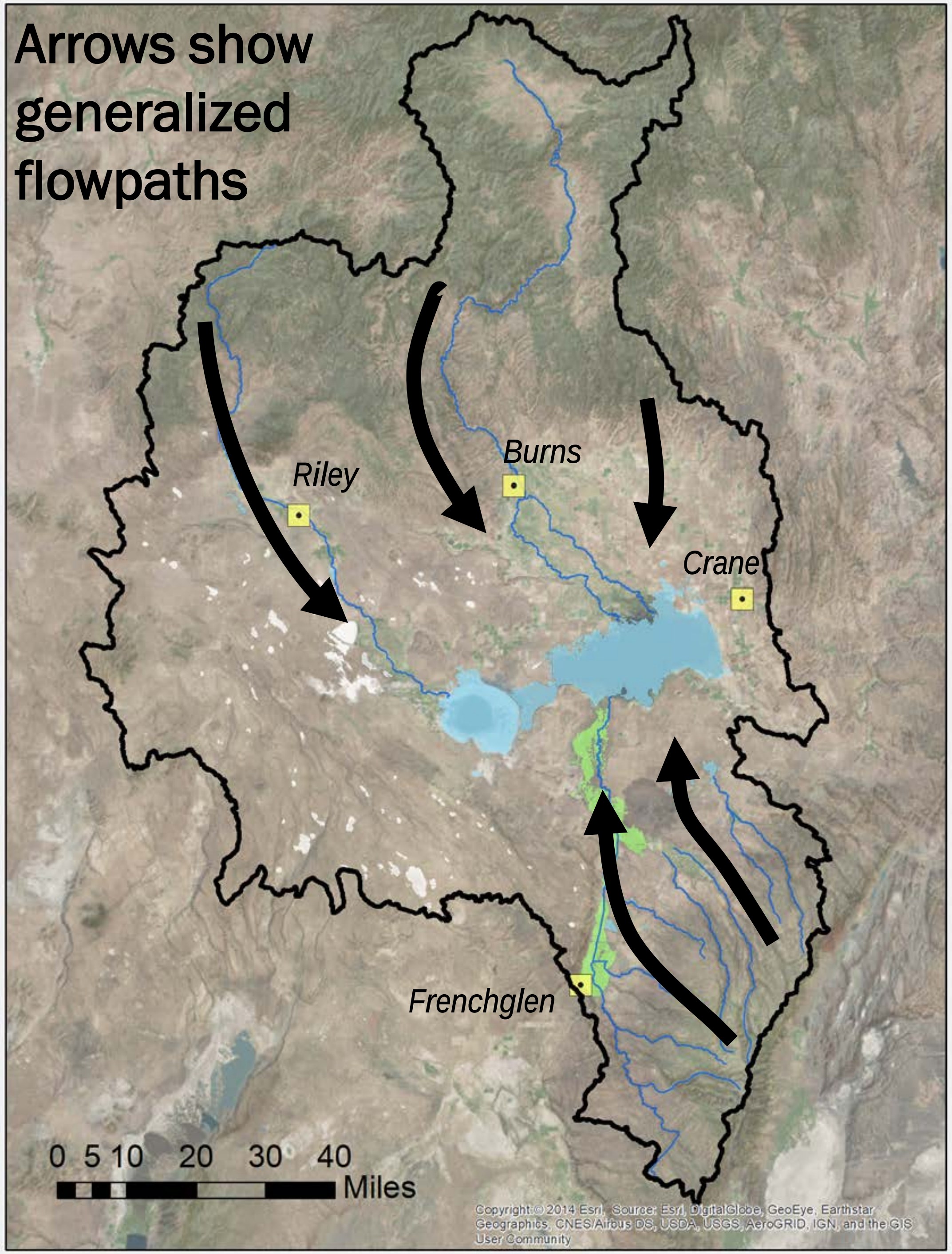
U.S. Department of the Interior
U.S. Geological Survey

Talk Overview

- Why tracers?
- Review of tracer methods
- Inventory of samples
- Isotopic signature of modern recharge
- Isotopic signature of groundwater
  - Relation to recharge
  - Relation to geology

Use natural chemistry of the groundwater to:

- Clarify flowpaths
- Estimate travel times
- Identify mixing
- Calibrate numerical models



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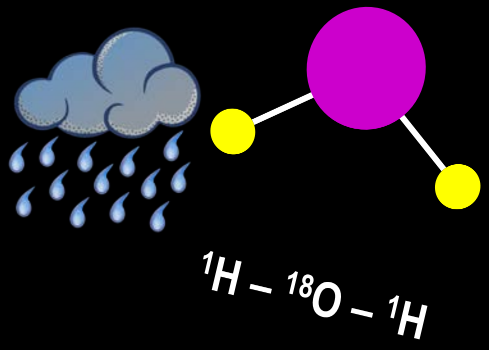
Recharging precipitation carries trace amounts of chemicals that can be used to determine the age of groundwater

Stable isotopes of water



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Isotopes

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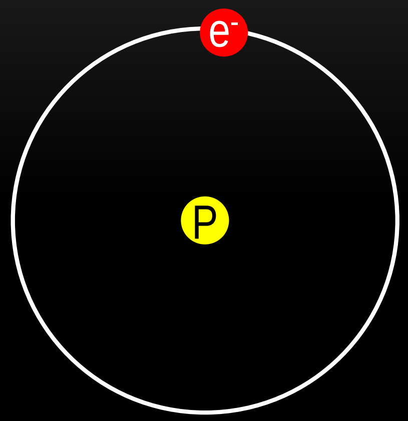
Isotopes of Hydrogen

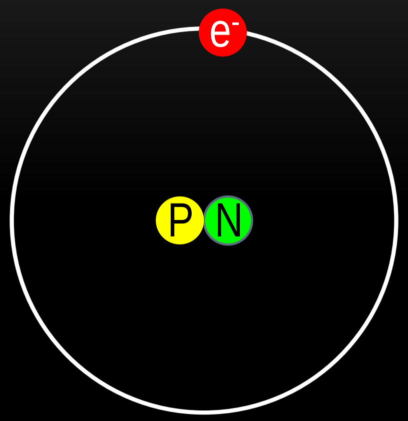


Common Hydrogen

Stable

^{1}H

99.9885%

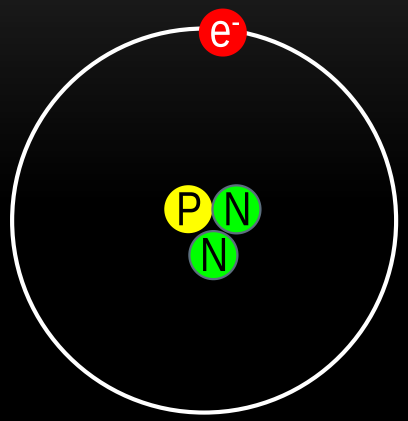


Deuterium

Stable

^{2}H

0.0115%



Tritium

Radioactive

^{3}H

Trace

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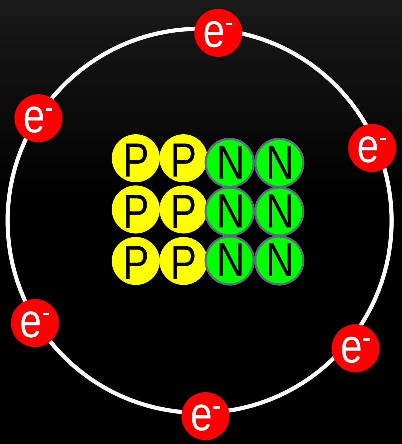
Isotopes of Carbon

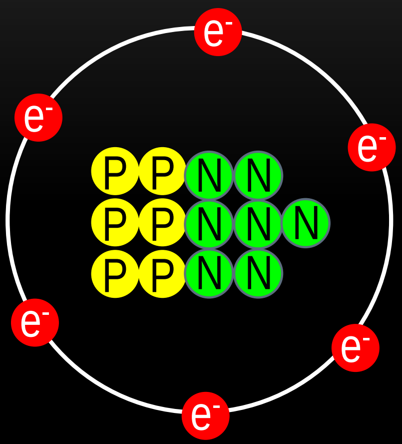


Carbon-12

Stable

^{12}C

98.93%

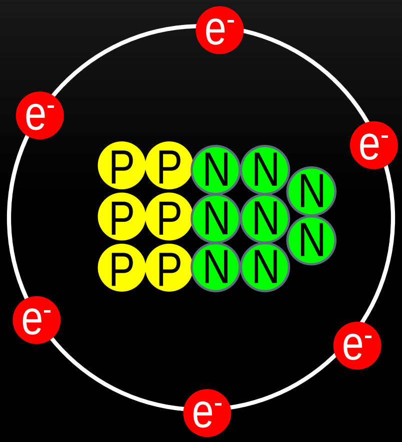


Carbon-13

Stable

^{13}C

1.07%



Carbon-14

Radioactive

^{14}C

Trace

Carbon-14

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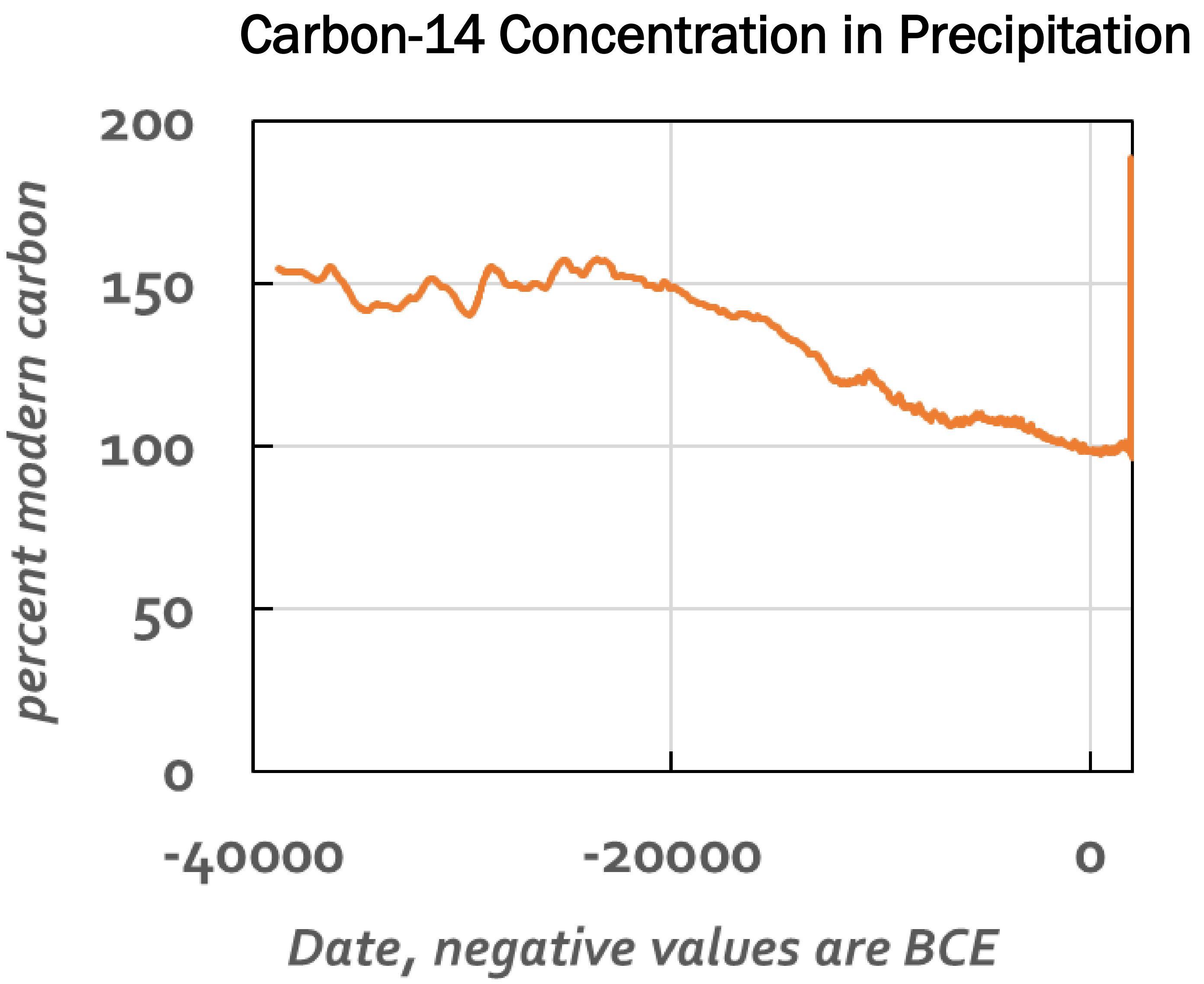

Radioactive isotope of hydrogen with a half life of 5,730 years

Occurs naturally in atmosphere at trace concentrations

Useful for dating water > 500 years old

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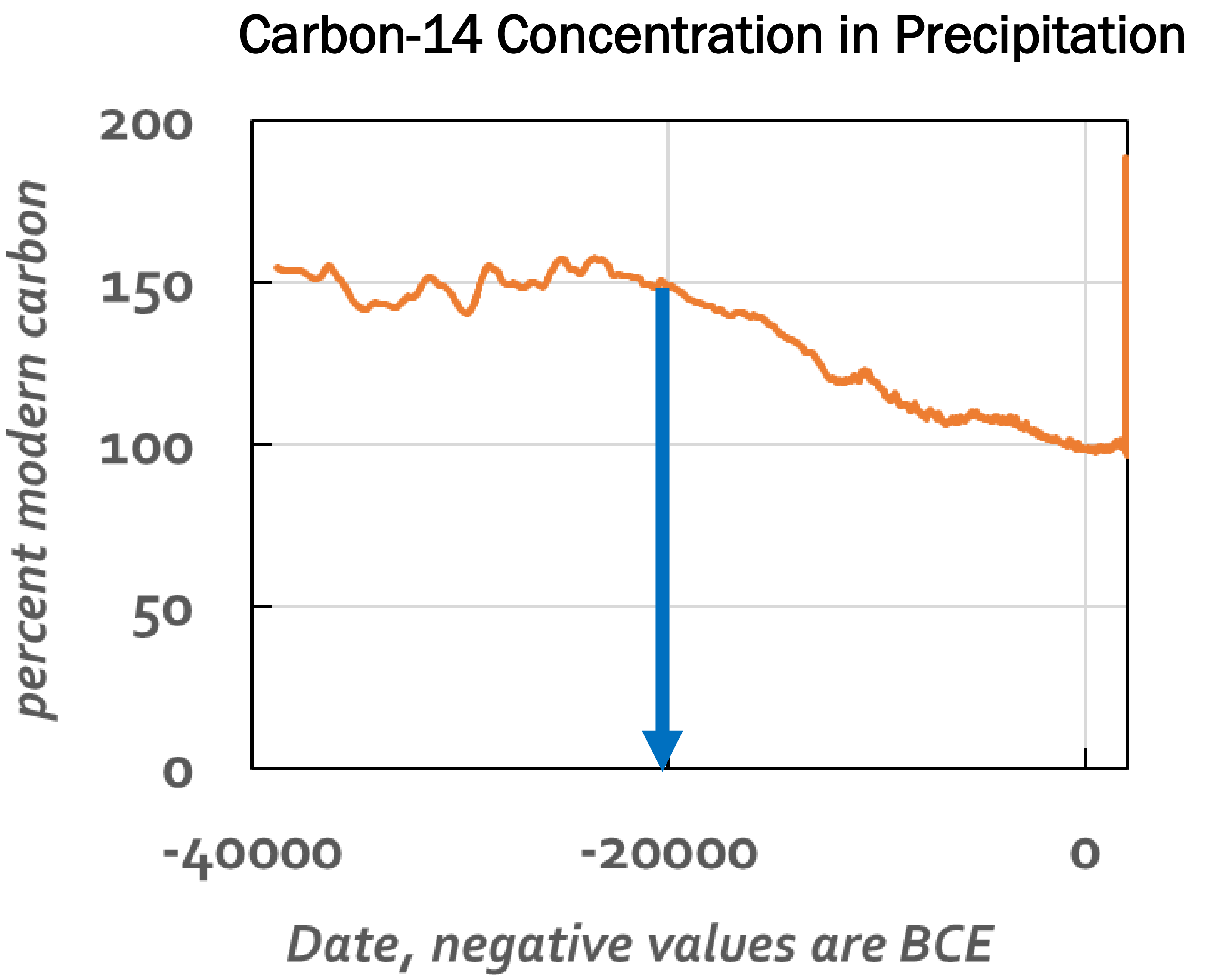
Carbon-14 concentrations from Jurgens et al., 2012



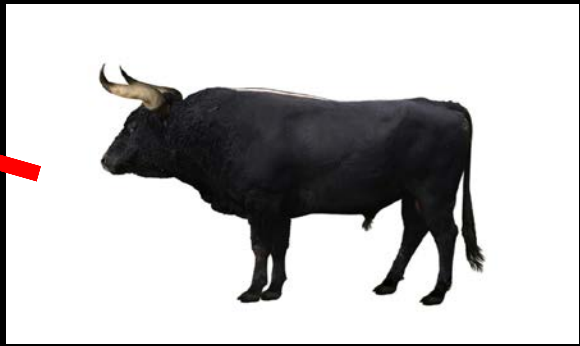
Carbon-14 concentrations from Jurgens et al., 2012

https://commons.wikimedia.org/wiki/File:Clovis_Point.jpg

https://commons.wikimedia.org/wiki/File:Woolly_Mammoth-RBC.jpg

Half Life	Year	Concentration
0	20,000 BCE	150 pmC
1	14,270 BCE	75 pmC
2	8,540 BCE	38 pmC
3	2,810 BCE	19 pmC
4	2,920	9 pmC

Today



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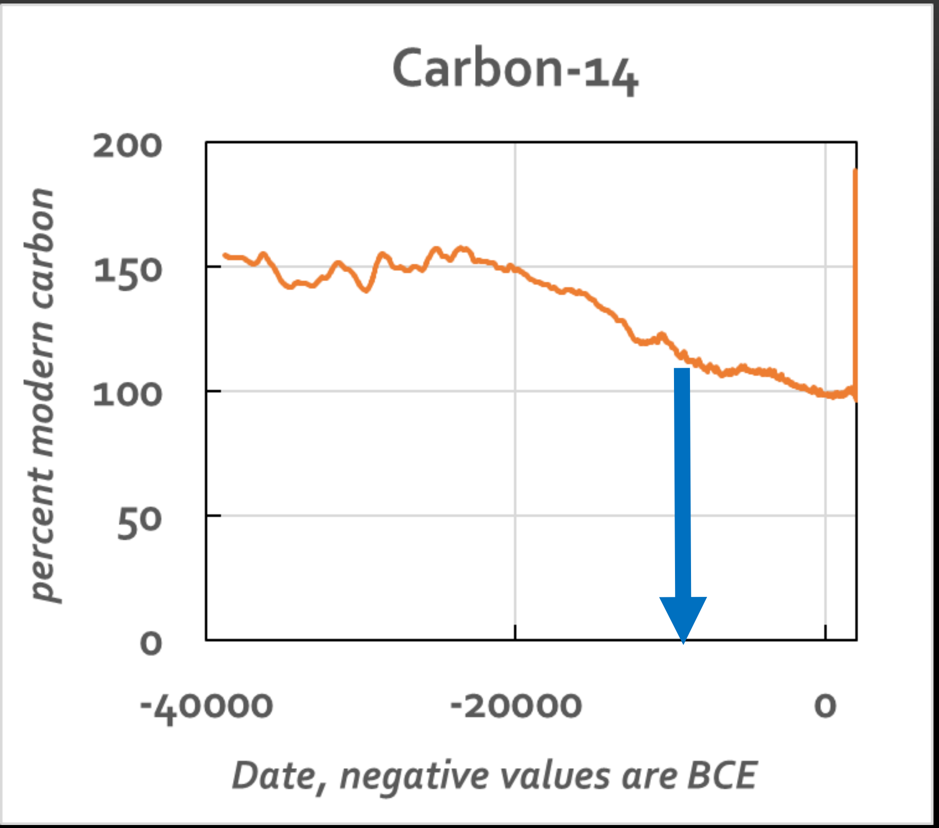

Half Life	Year	Concentration
0	10,000 BCE	110 pmC
1	4,270 BCE	75 pmC
2	1460	38 pmC
3	7190	19 pmC

Today

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Carbon-14 concentrations from Jurgens et al., 2012

Tritium (^3H)

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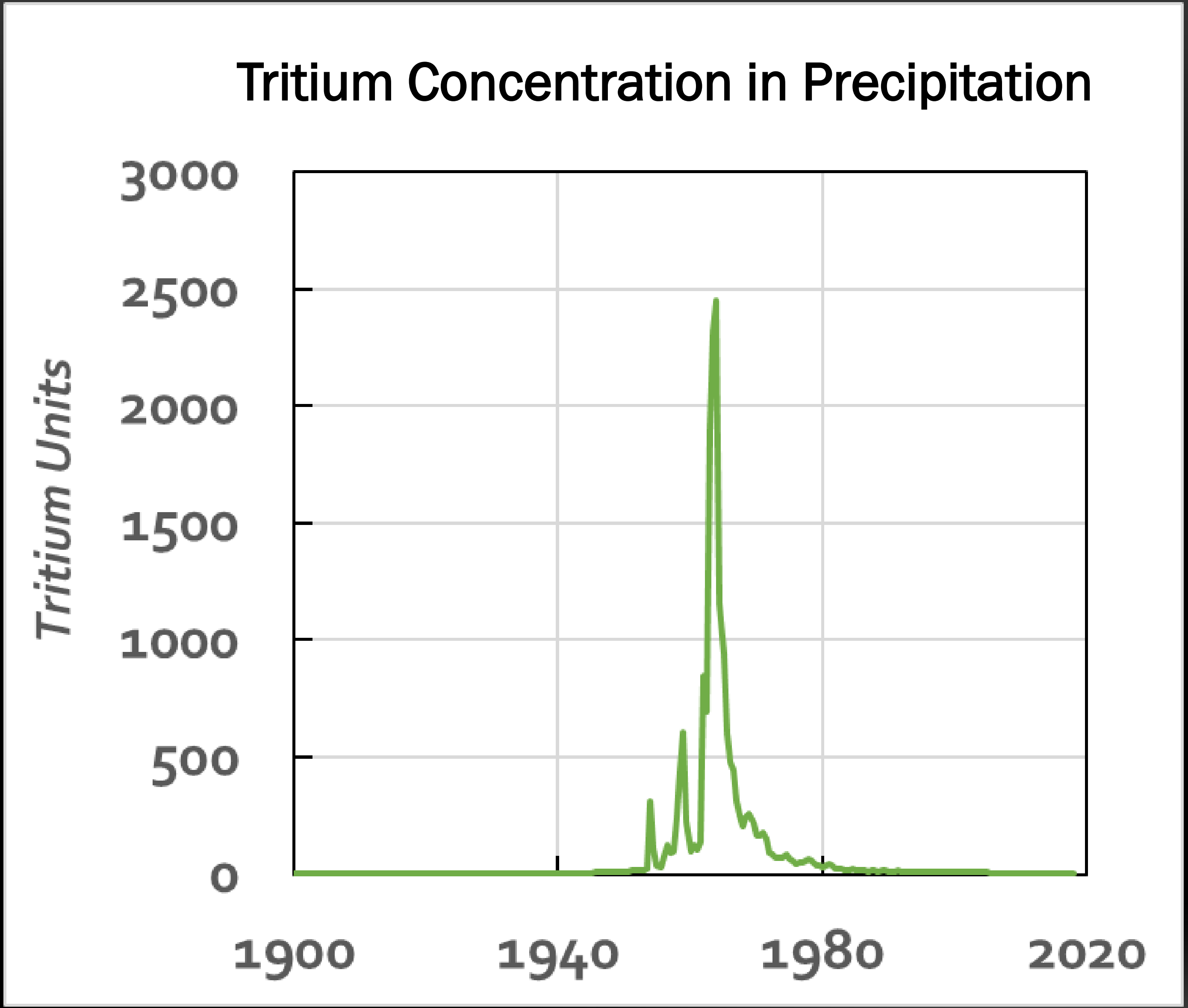

Radioactive isotope of hydrogen with a half life of 12.32 years

Occurs naturally in atmosphere at trace concentrations

Above-ground nuclear weapons testing generated large amounts of tritium

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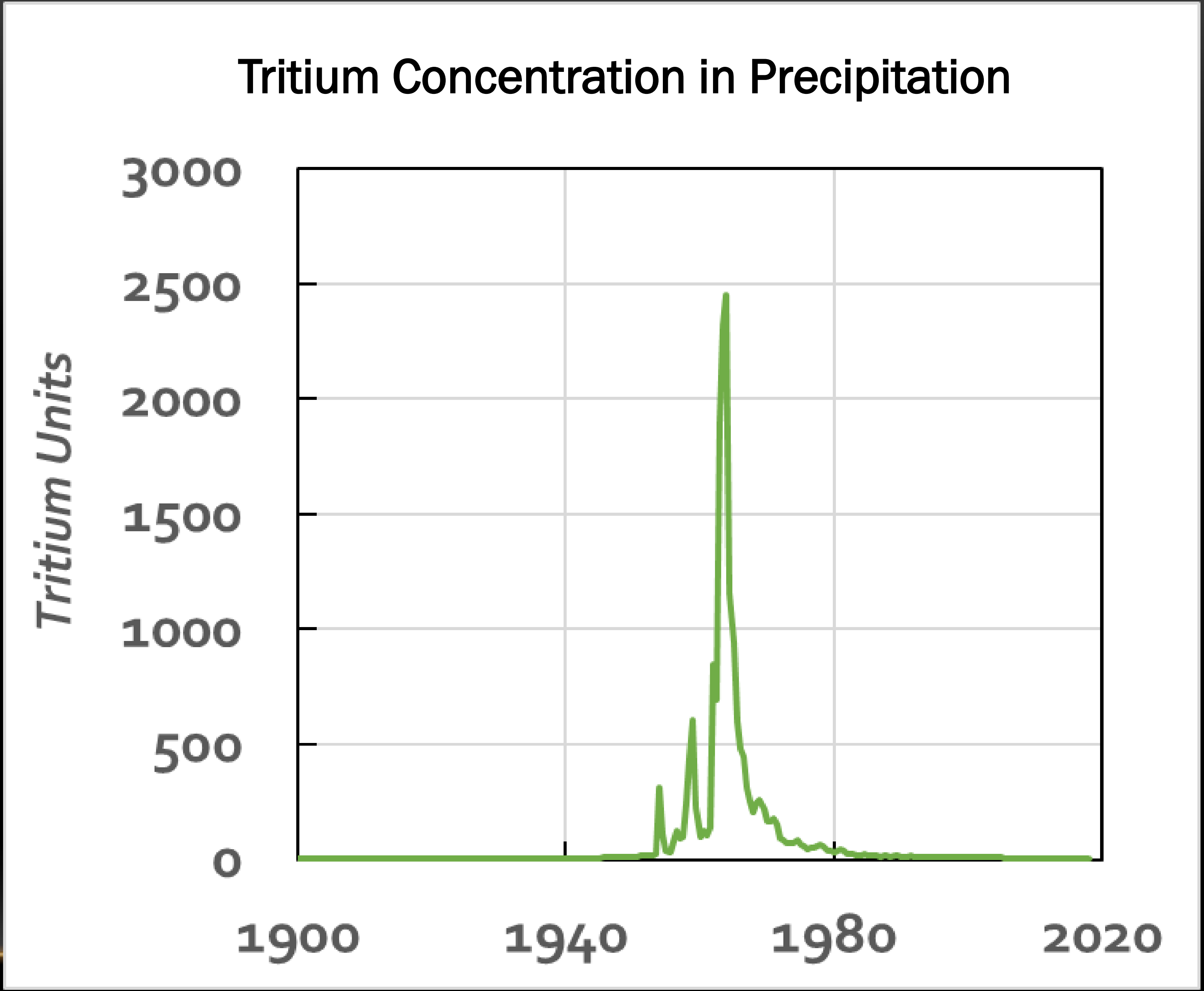
Tritium concentrations from Jurgens et al., 2012

Pre-1945, ^3H concentration in atmosphere were about 3-7 TU

1945 – 1963, ^3H concentration in atmosphere increased – "bomb pulse"

1964 – early 2000s, decay of ^3H from bomb pulse

Mid 2000s to present, ^3H at pre-bomb concentrations (3-7 TU)



Tritium concentrations from Jurgens et al., 2012

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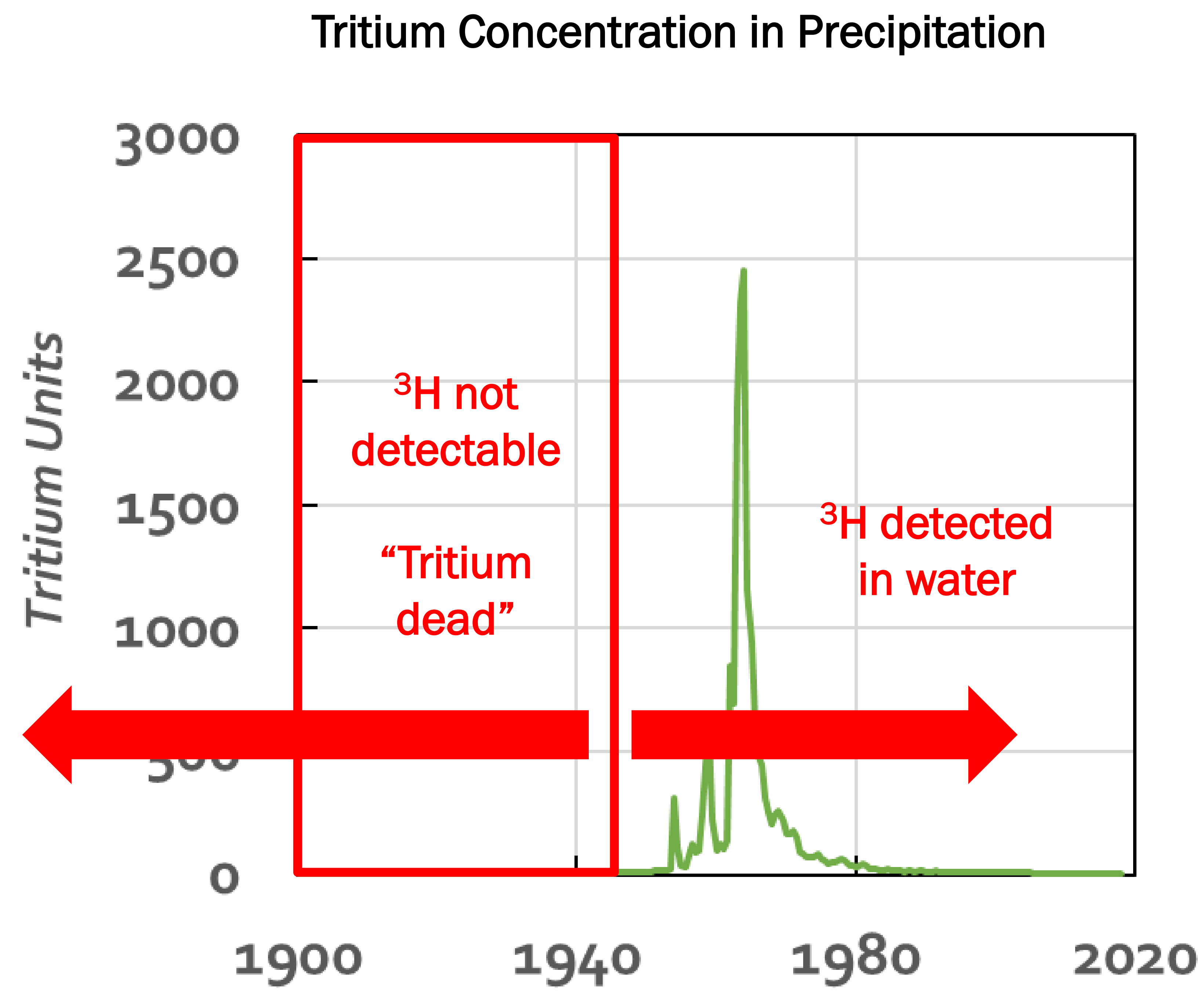
Half Life	Year	Concentration
0	1945	7 TU
1	1957	3.5 TU
2	1970	1.75 TU
3	1982	0.88 TU
4	1994	0.44 TU
5	2006	0.22 TU
6	2019	0.11 TU

Below Detection Limit of Lab



Tritium concentrations from Jurgens et al., 2012

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Stable Isotopes of Water

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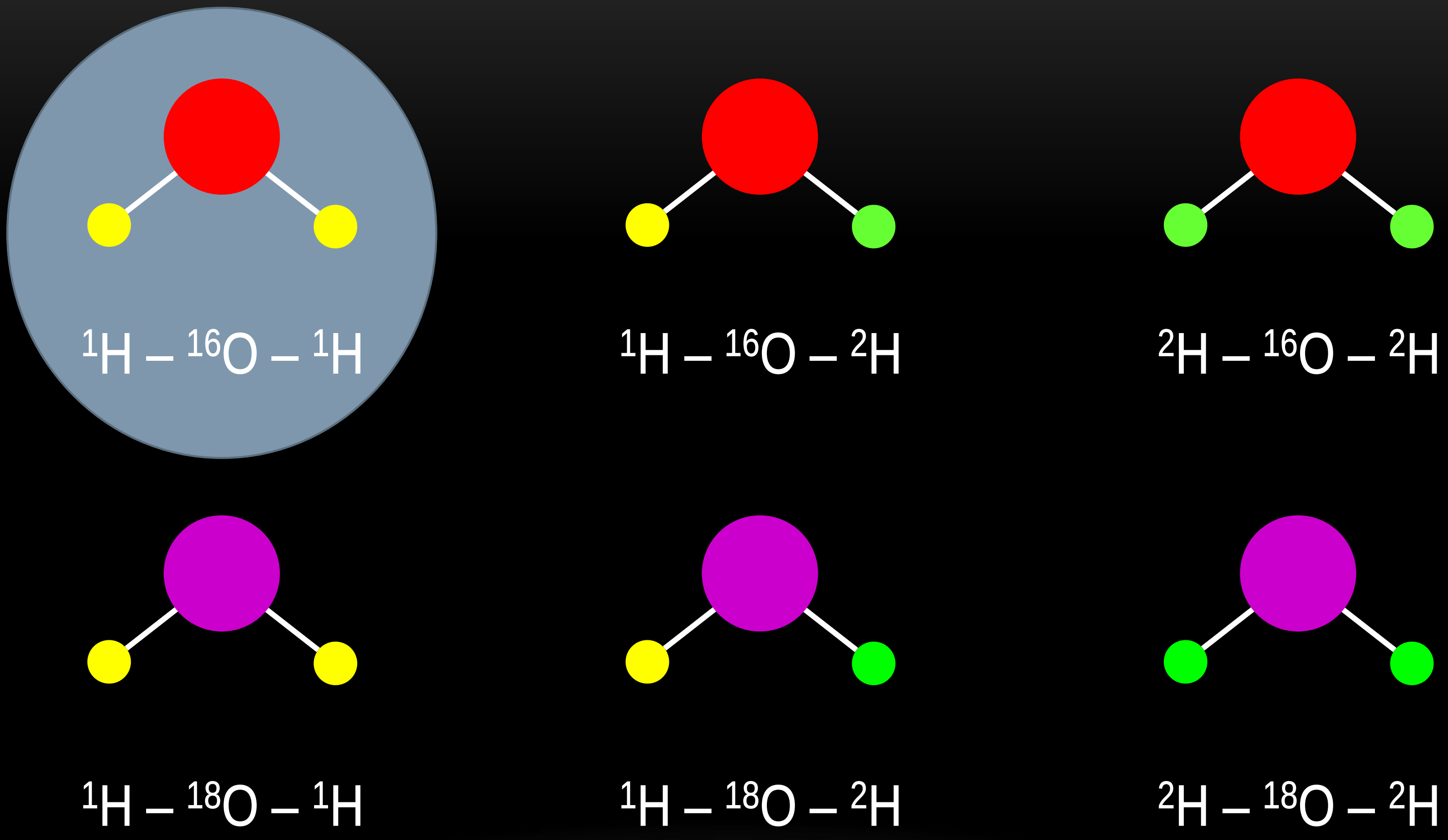

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H_2O – Isotopic Variations

Evaporation and

precipitation patterns

determine the relative abundance

of the isotopic variations

of water in a sample

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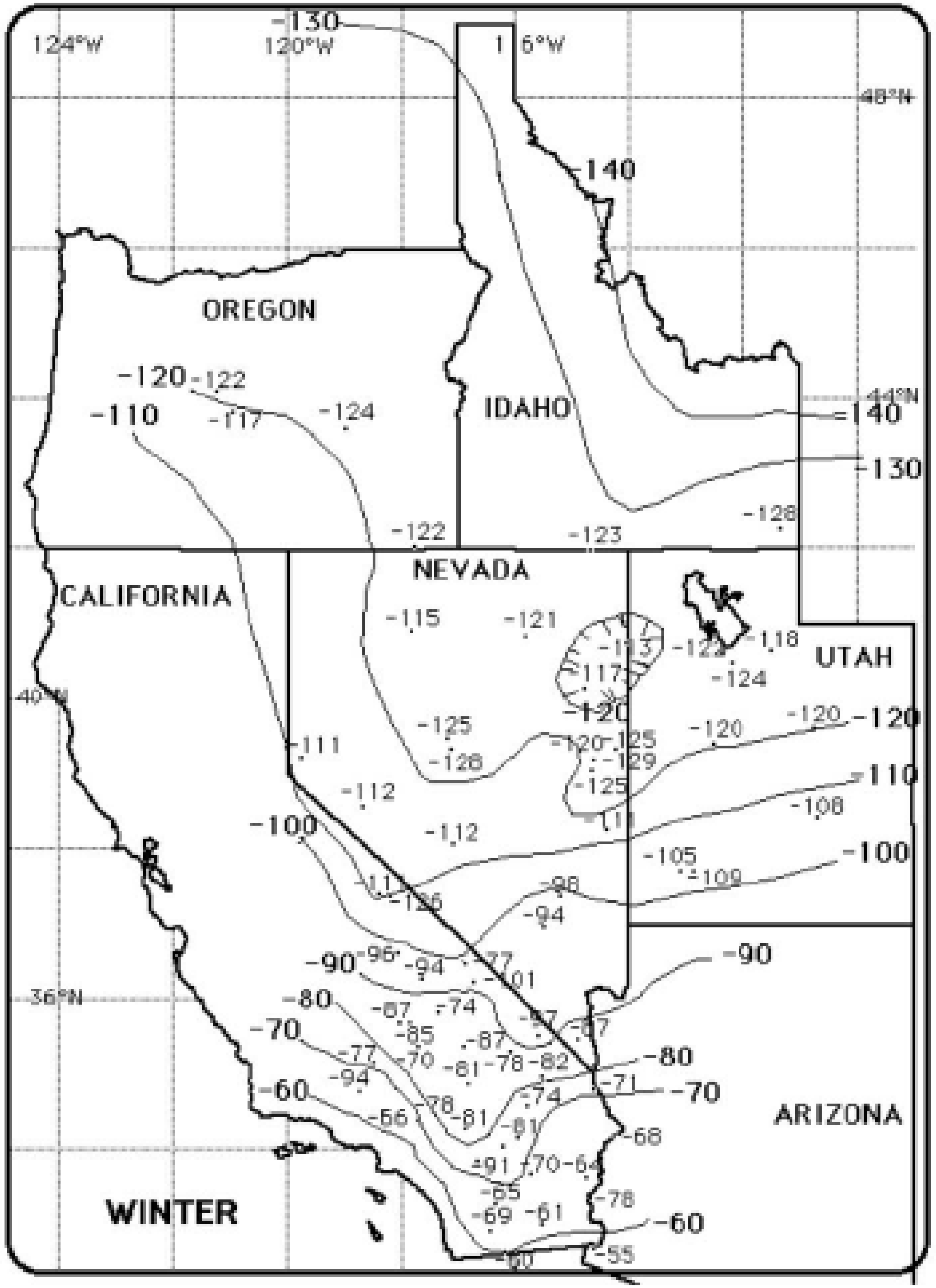
Deuterium (^2H) in winter precipitation

(Friedman et al., 2002)



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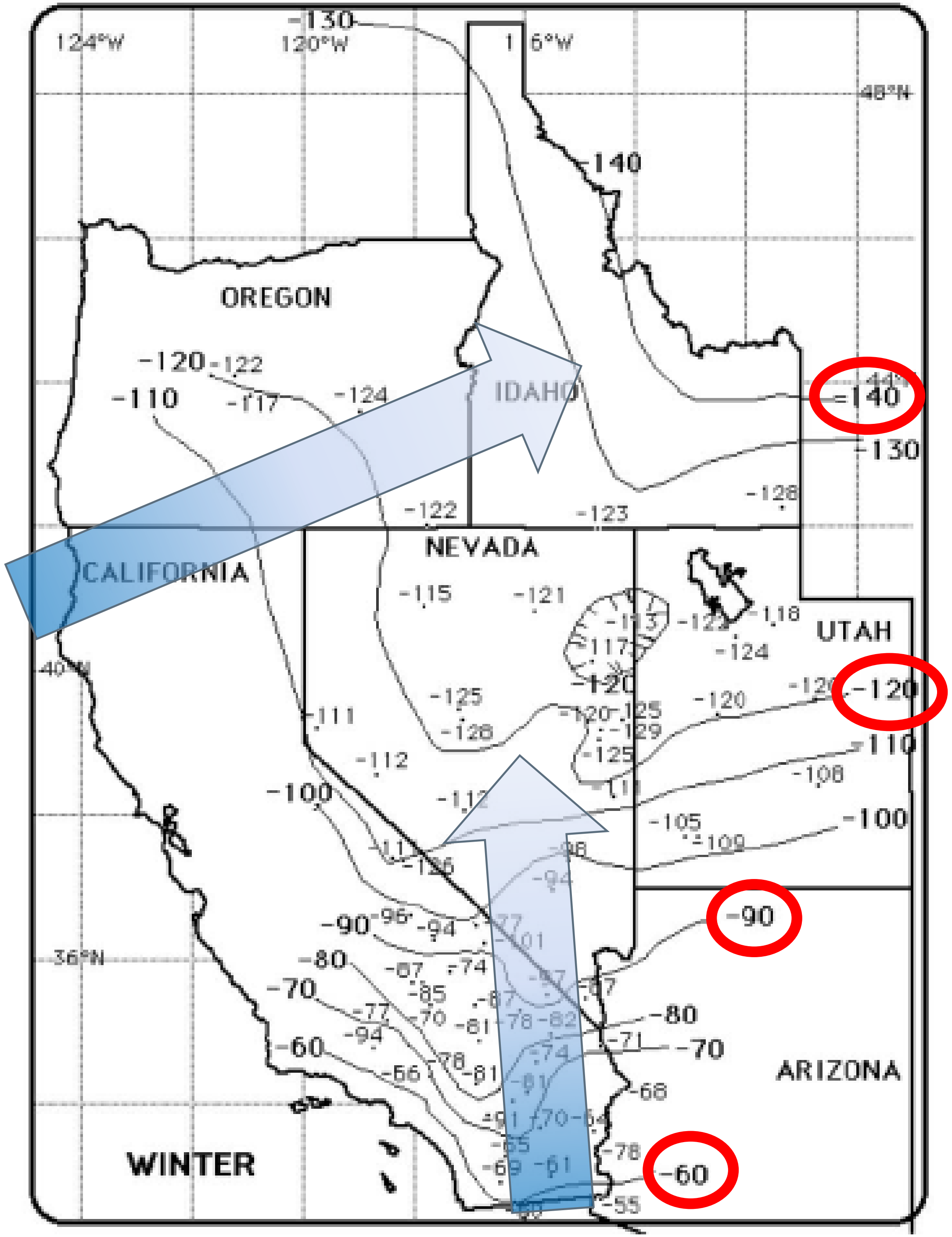
Deuterium (^{2}H) in winter precipitation

(Friedman et al., 2002)

Deuterium ratio becomes more negative as vapor masses move inland

Condensation of cloud vapor into rain or snow preferentially removes water molecules containing the heavier isotopes, ^{2}H and ^{18}O



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Harney Basin Tracer Inventory

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Stable isotopes of water

- 284 samples collected for study or related on-going projects (October 2016-present)

- 31 historic samples in USGS database (1982-2015)

• 85	Streams/rivers
• 202	Wells/springs
• 22	Plant tissue
• 6	Soil water

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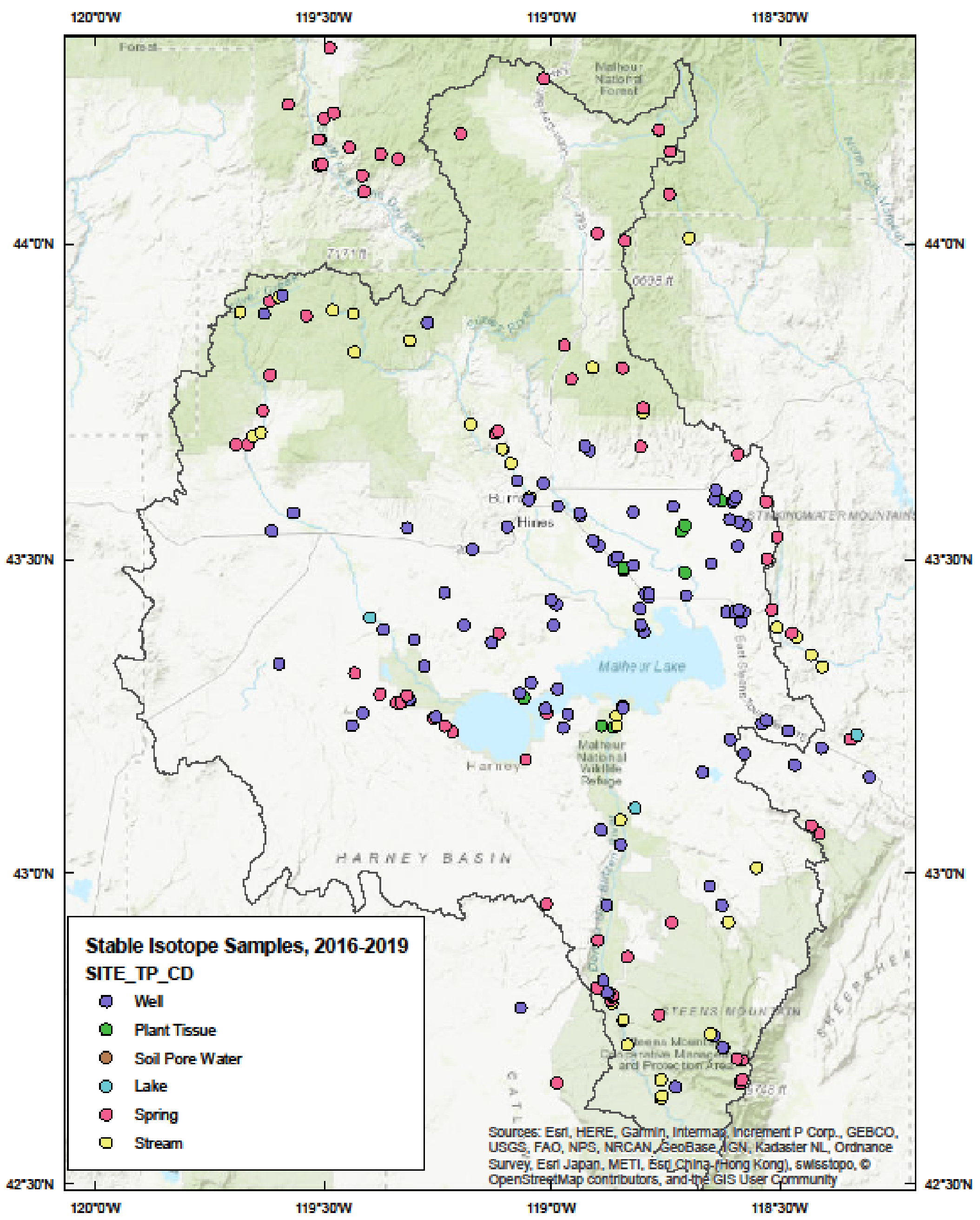

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Stable isotopes of water

- 37 sites with at least 2 measurements (max = 9)

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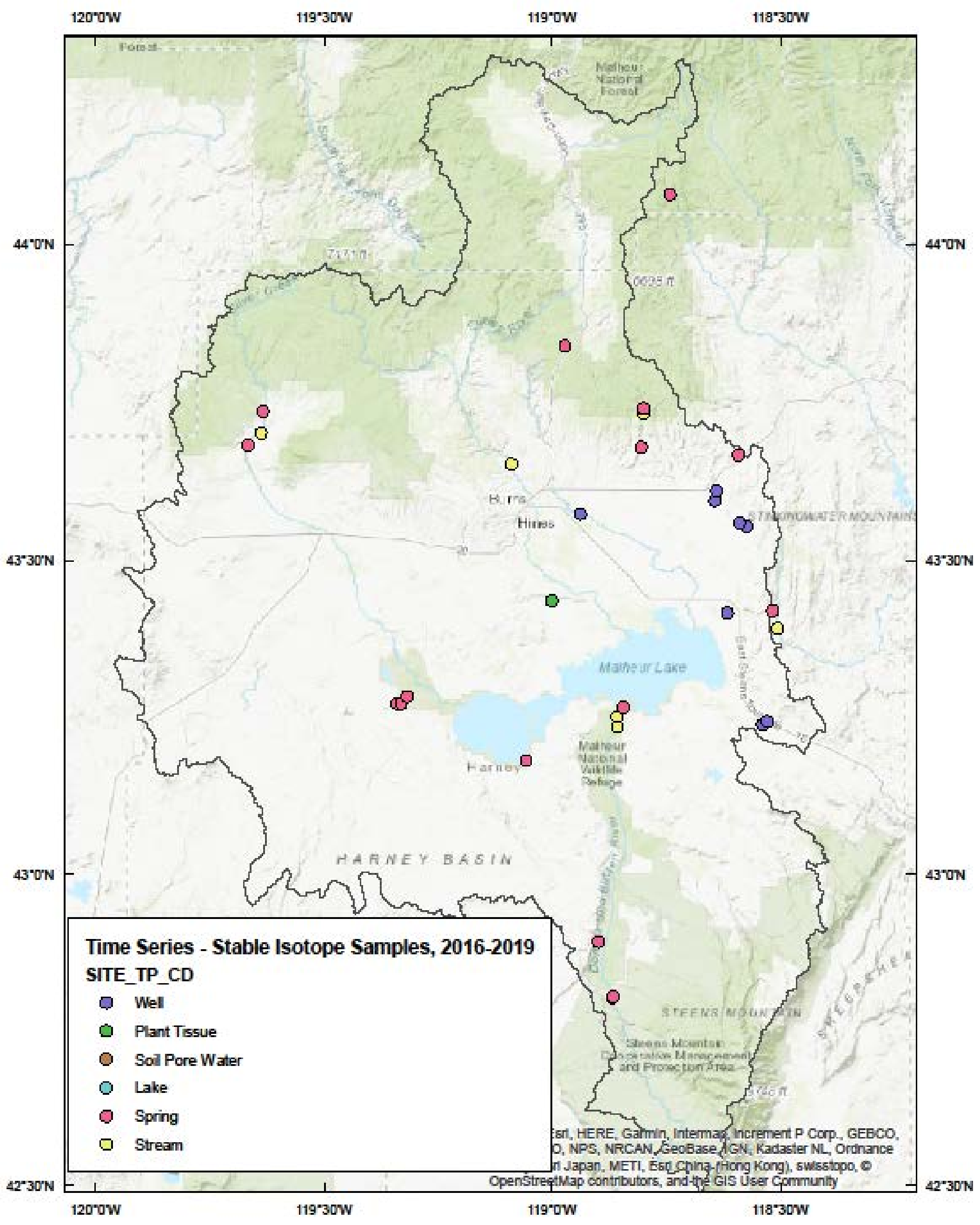
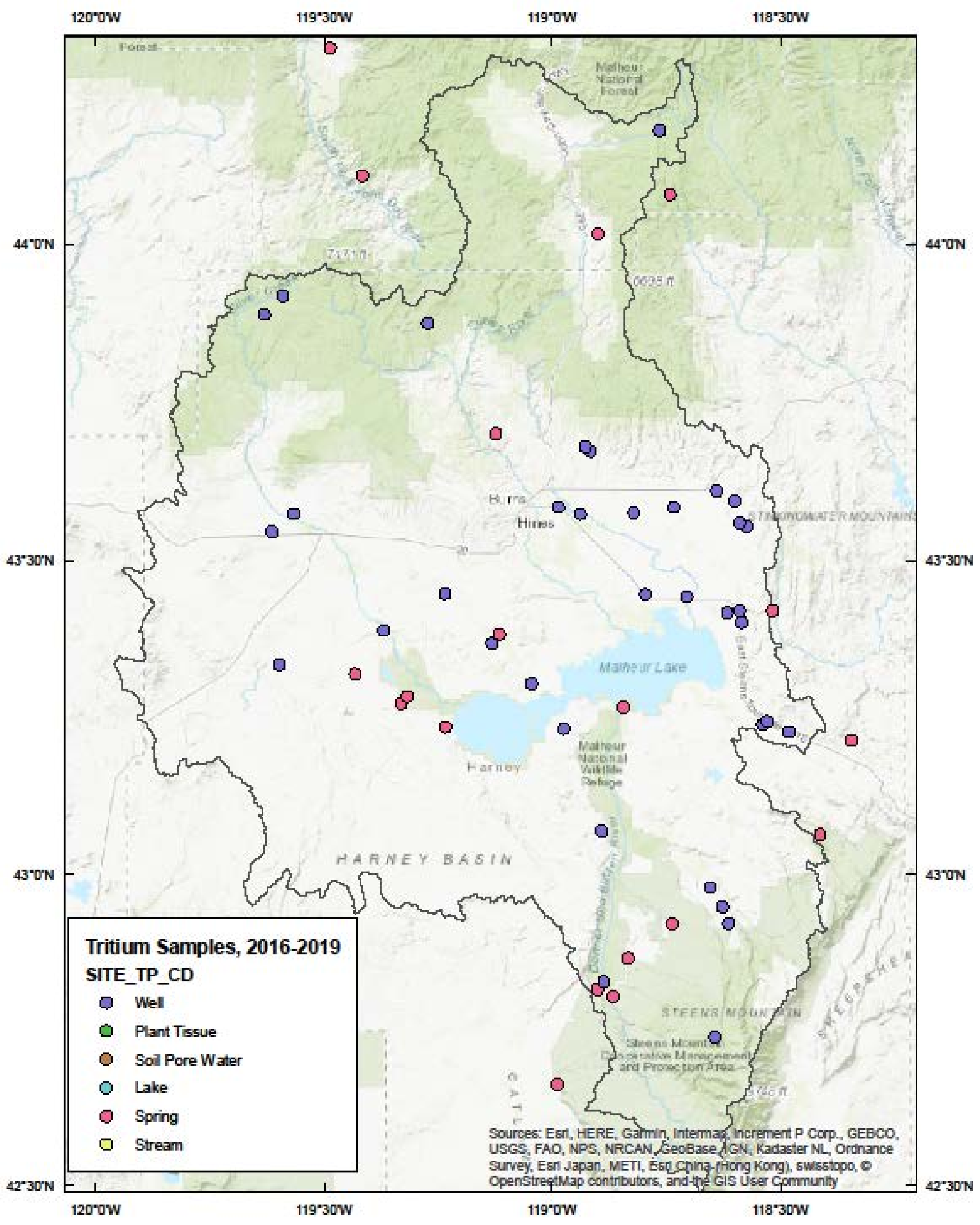


Sample Inventory

Tritium

- 102 samples collected for study or related on-going projects (October 2016-present)
  - 17 analyses completed
  - 42 analyses pending (incl. 1 replicate)
  - 43 samples archived (incl. 3 replicates)
- No historic samples in USGS database

Analyzed + Pending



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Carbon-14

- 23 samples collected for study or related on-going projects (October 2016-present)

    - 15 analyses completed
    - 4 analyses pending
    - 4 samples archived

- No historic samples in USGS database

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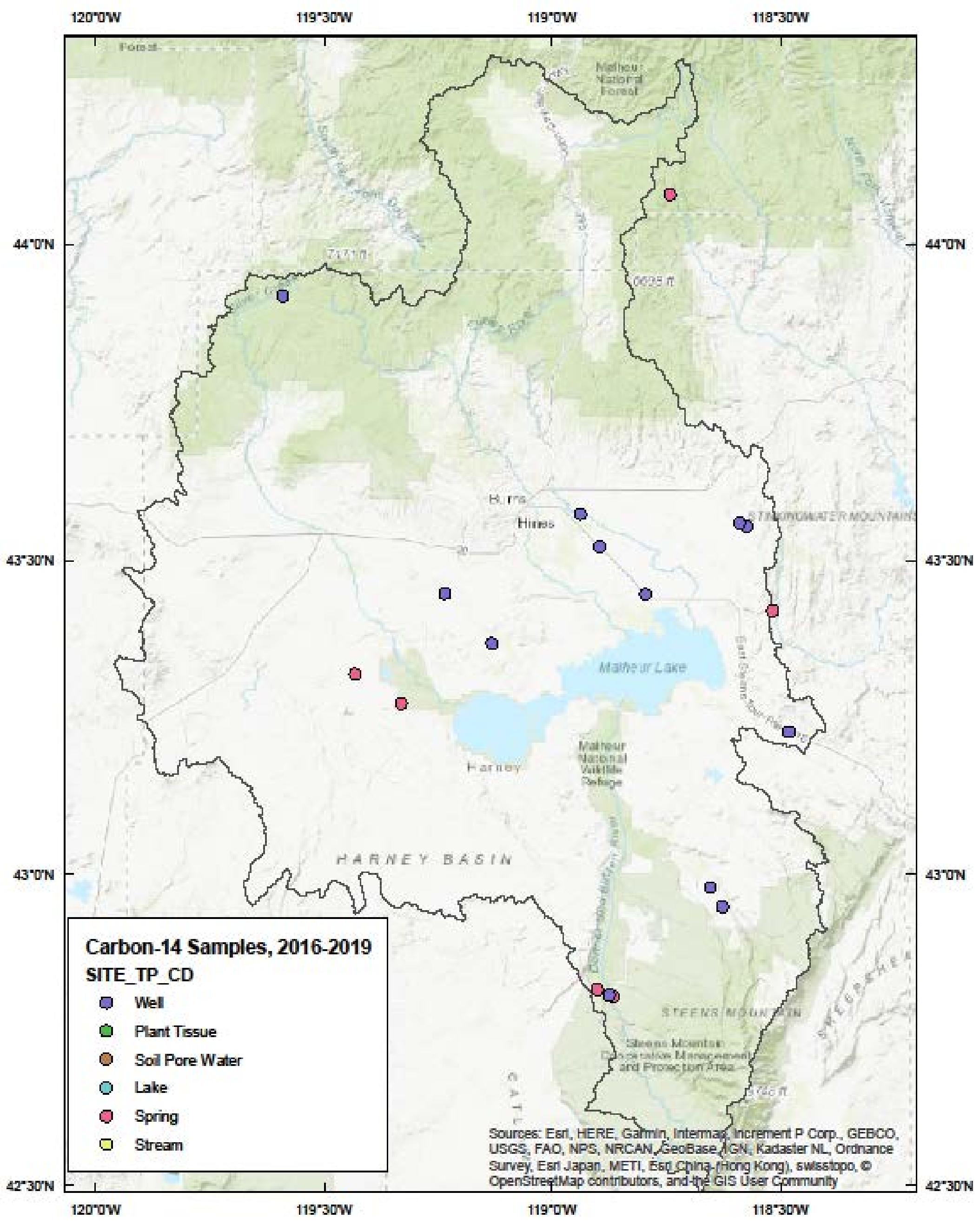
Analyzed + Pending



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Sulfur Hexafluoride (SF_6)

- 4 samples collected for study or related on-going projects (October 2016-present)
  - 2 analyses completed
  - 2 analyses pending
  - 0 samples archived
- No historic samples in USGS database

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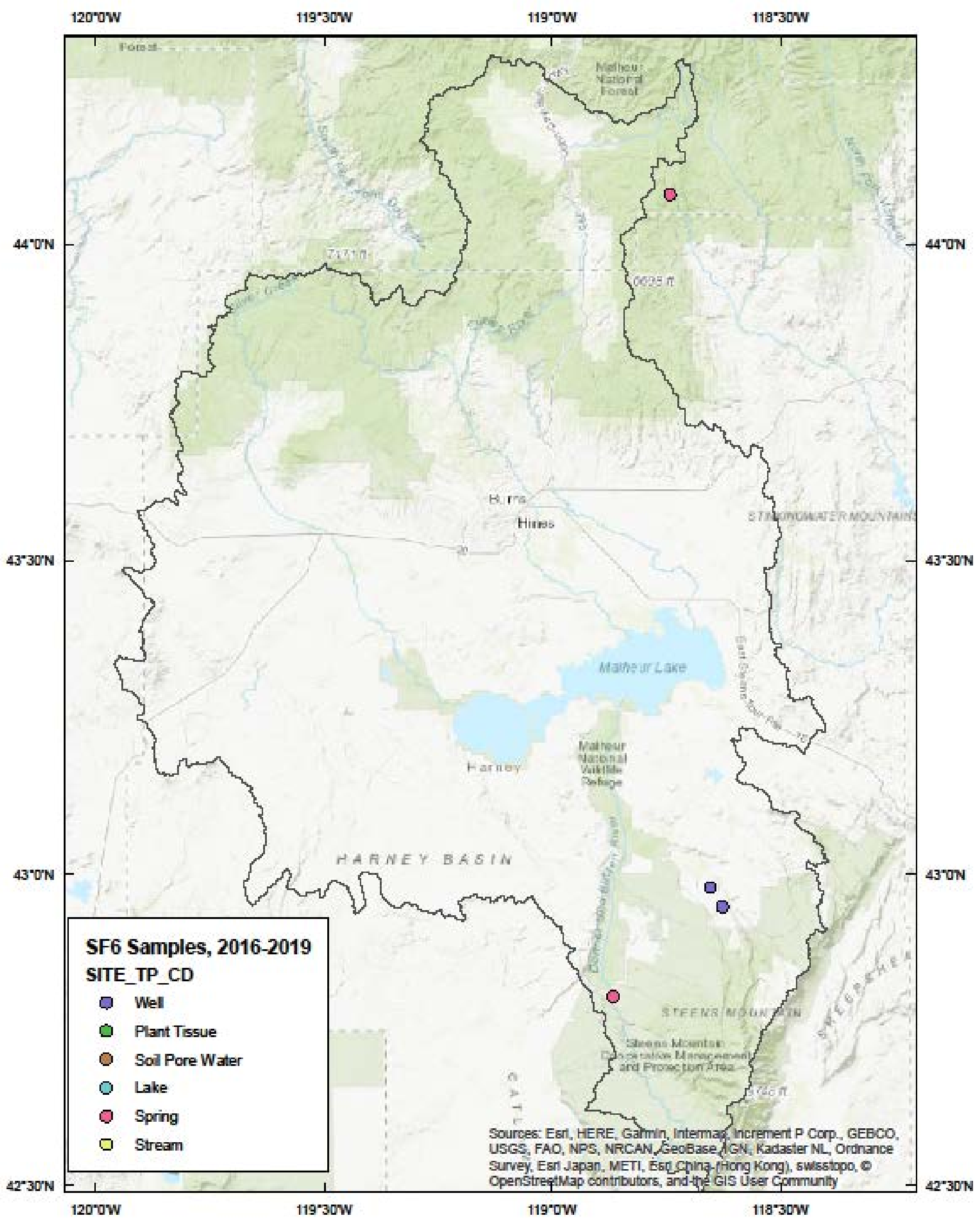
Analyzed + Pending



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Deuterium (d2H) Ratios of Modern Water in Harney Basin

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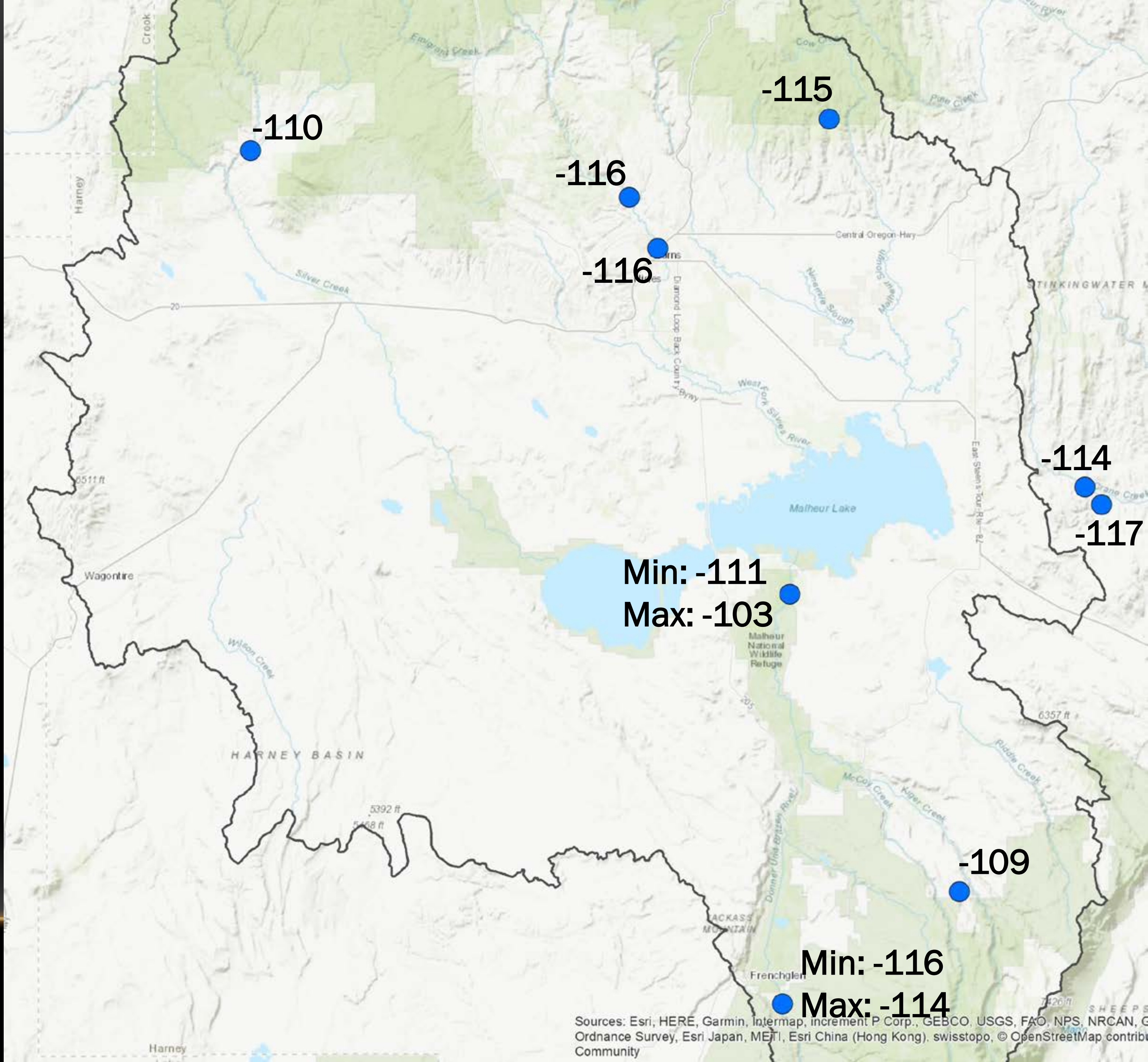
d2H ratios in streams during freshet period, 2017-2018



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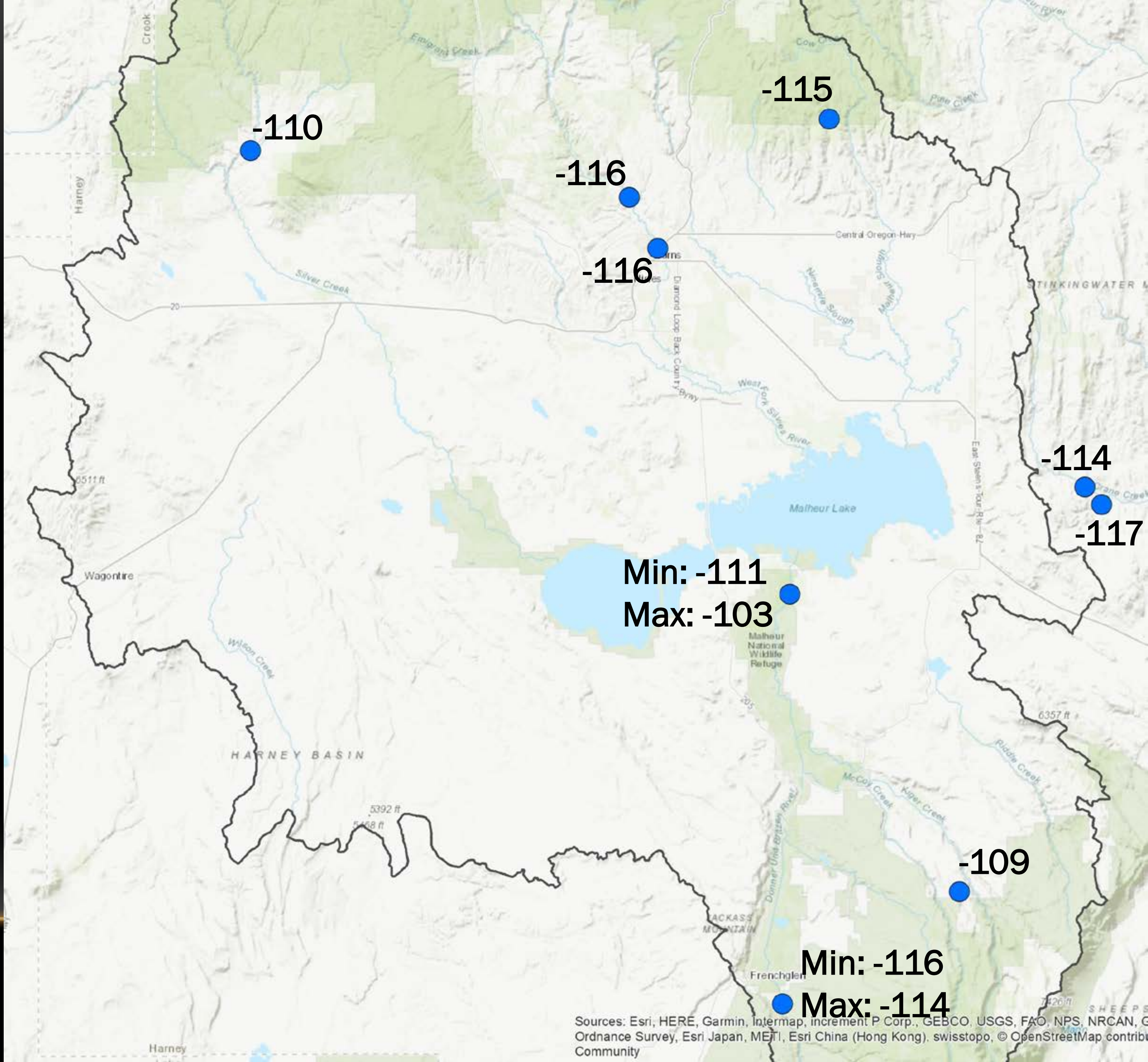
d2H ratios in streams during freshet period, 2017-2018

- Min: -117
- Max: -103



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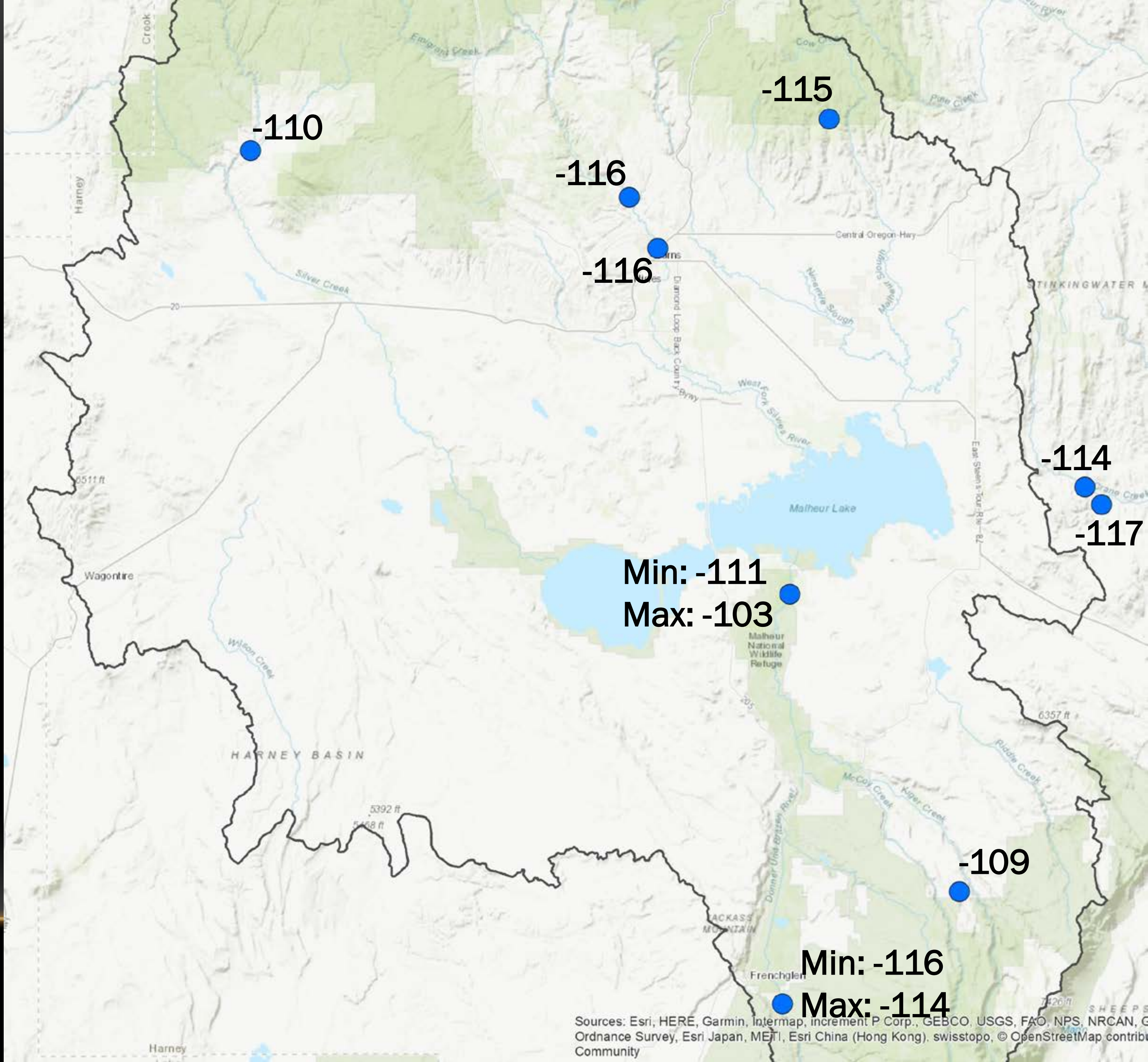
d2H ratios in streams during freshet period, 2017-2018

- Min: -117
- Max: -103

This range provides an estimate of d2H in modern freshet recharge. It is an imperfect estimate due to highly variable isotopic ratios of freshet water.



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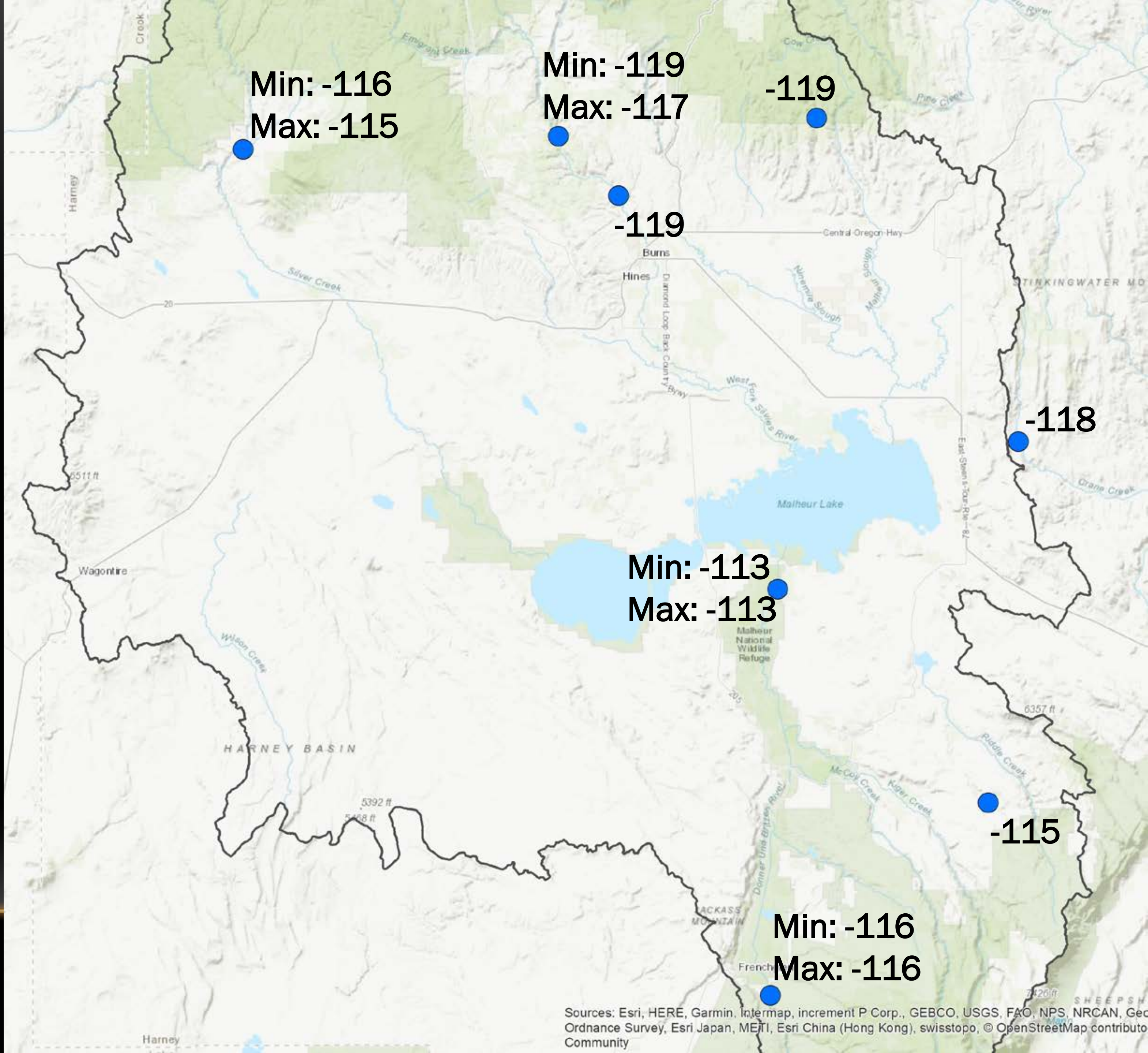
d2H ratios in streams during baseflow, 2016-2018



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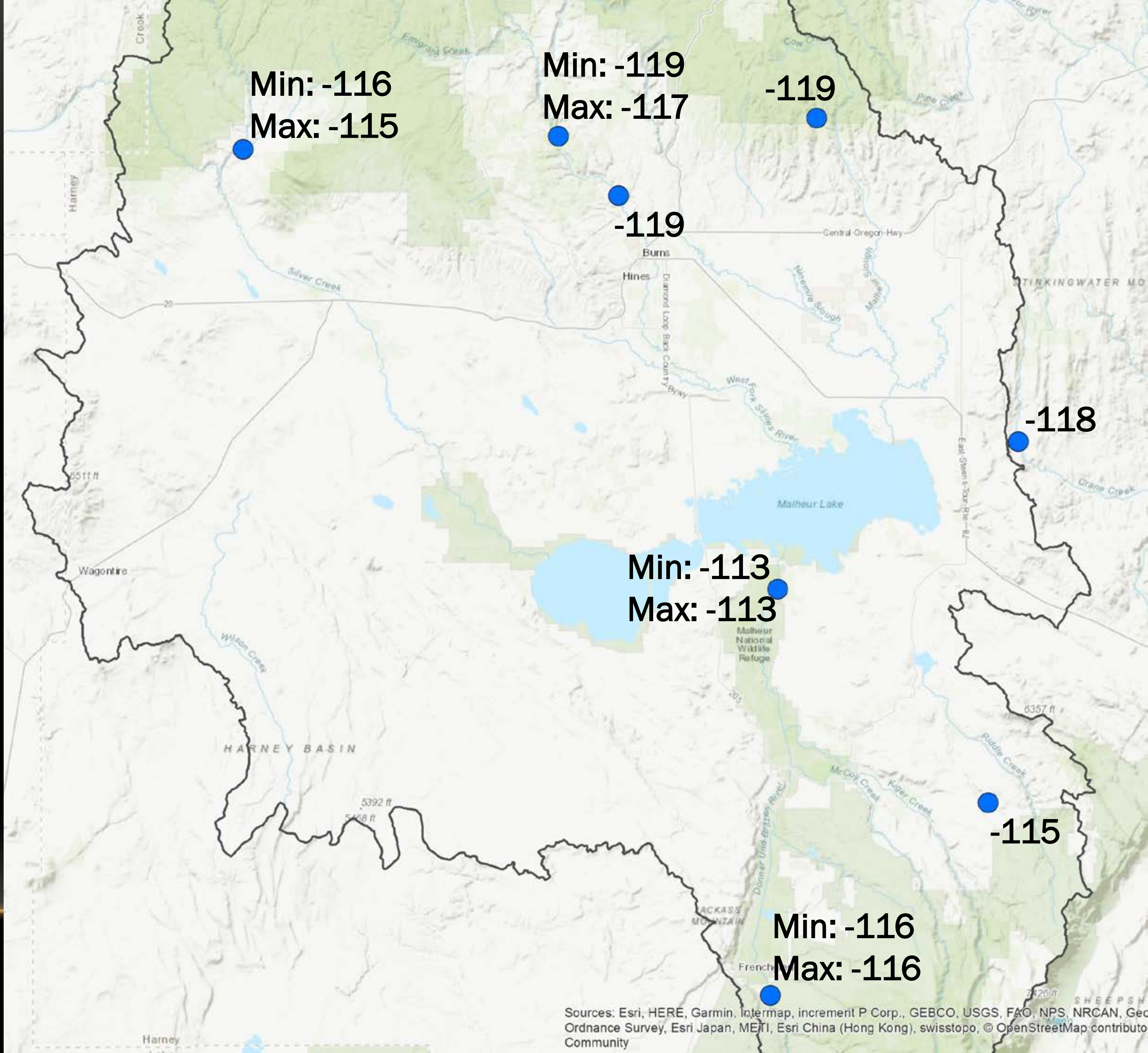
d2H ratios in streams during baseflow, 2016-2018

- Min: -119
- Max: -113



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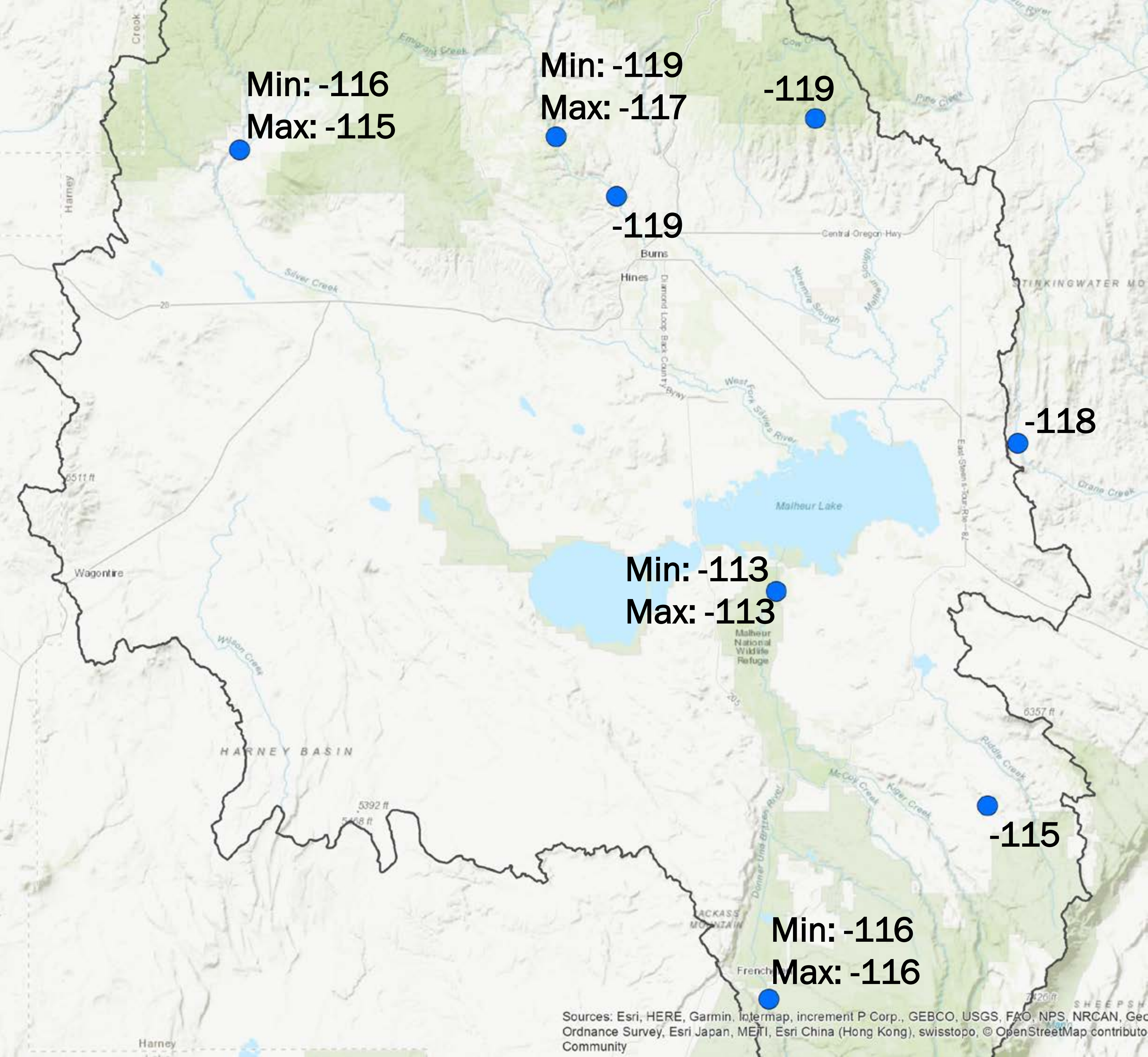
d2H ratios in streams during baseflow, 2016-2018

- Min: -119
- Max: -113

This range provides a reasonable estimate of d2H in modern recharge from streamflow seepage loss



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KEY POINTS

Range of d2H ratios in freshet samples:

- -117 to -103

Range of d2H ratios in baseflow samples:

- -119 to -113

Range of d2H ratios in composite precipitation samples from Burns, McDermitt, and Lakeview (1991-1997; Friedman, 2002):

- -119 to -108

Deuterium Ratios of Groundwater in Harney Basin

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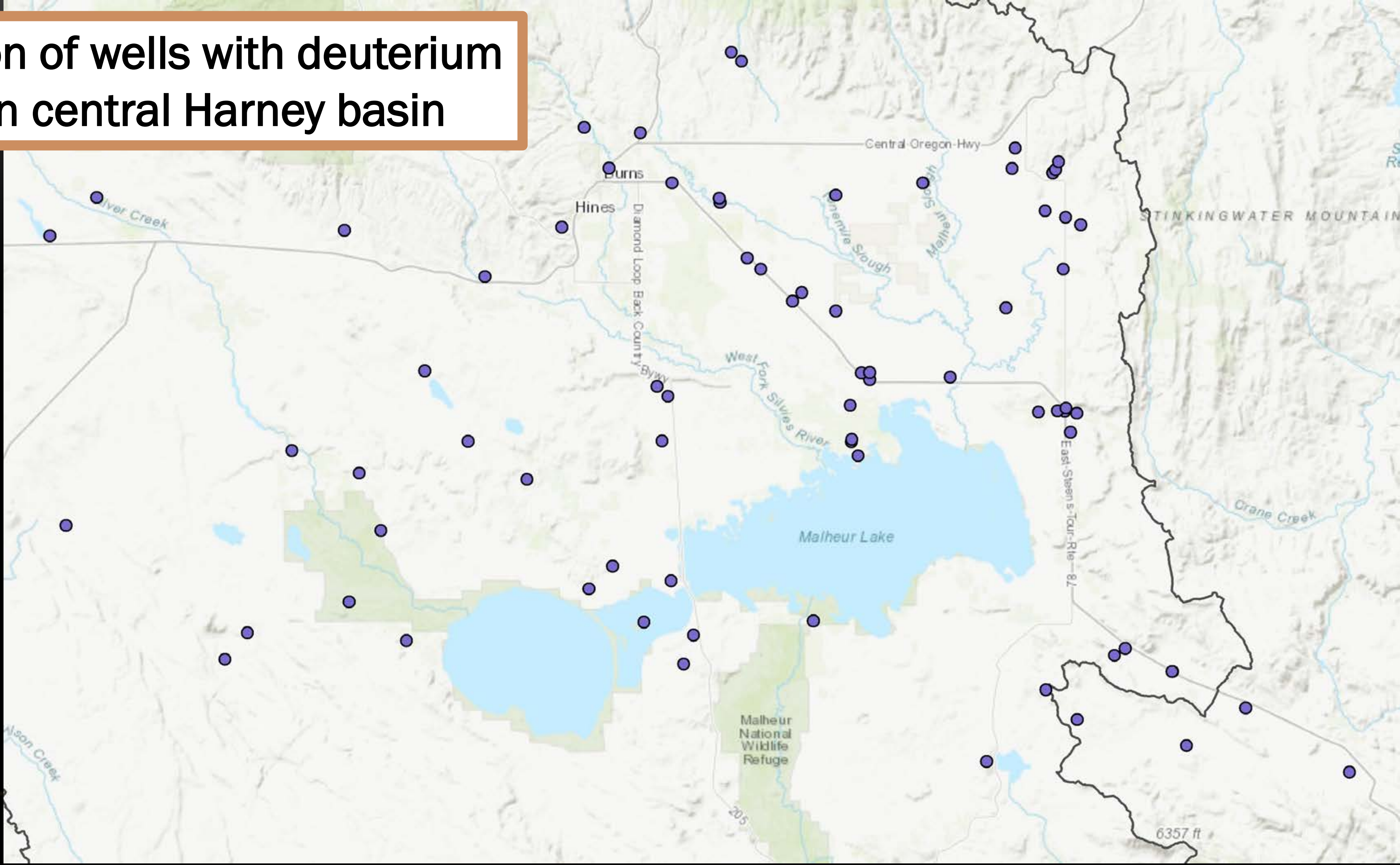
Distribution of wells with deuterium analyses in central Harney basin



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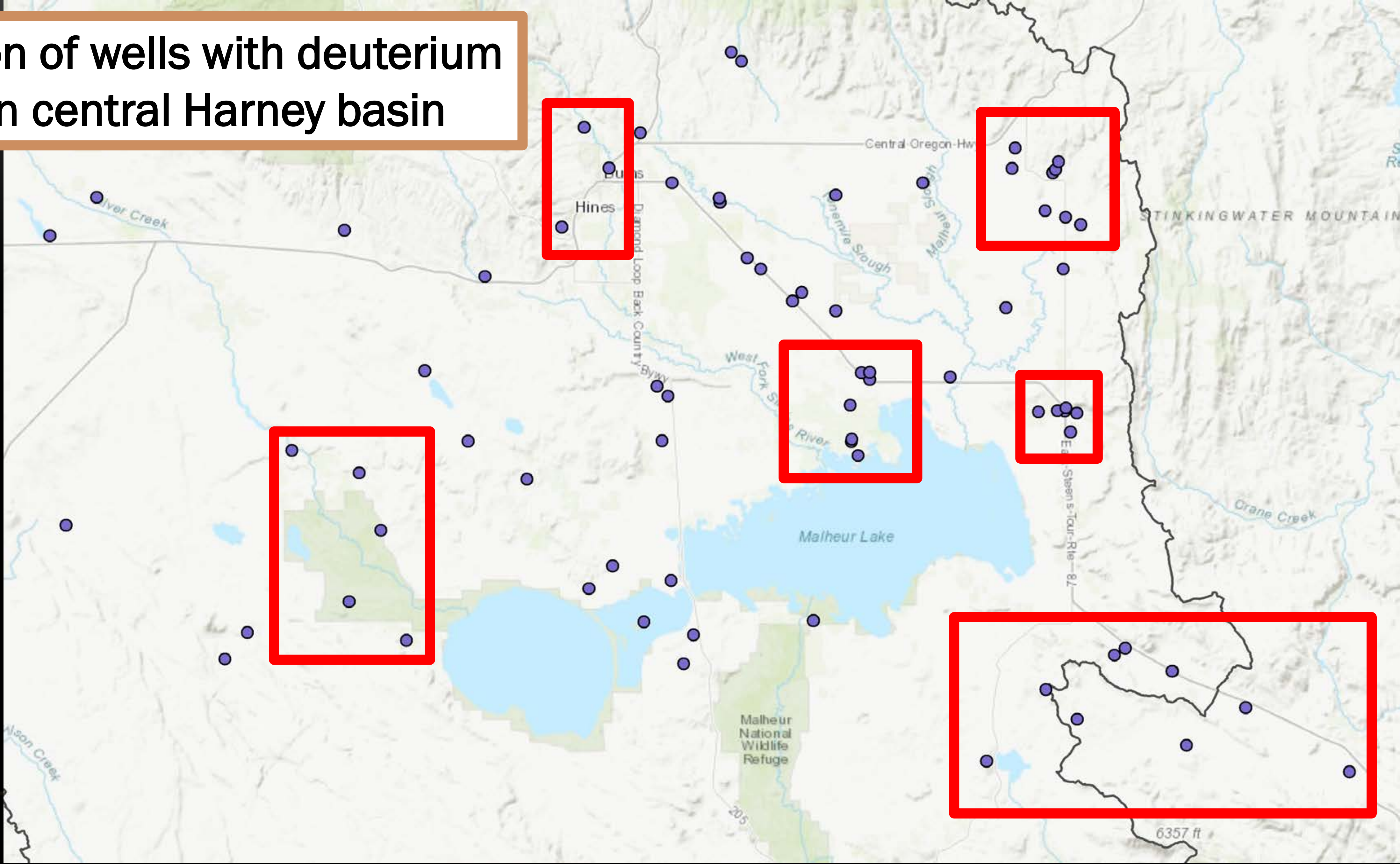
Distribution of wells with deuterium analyses in central Harney basin



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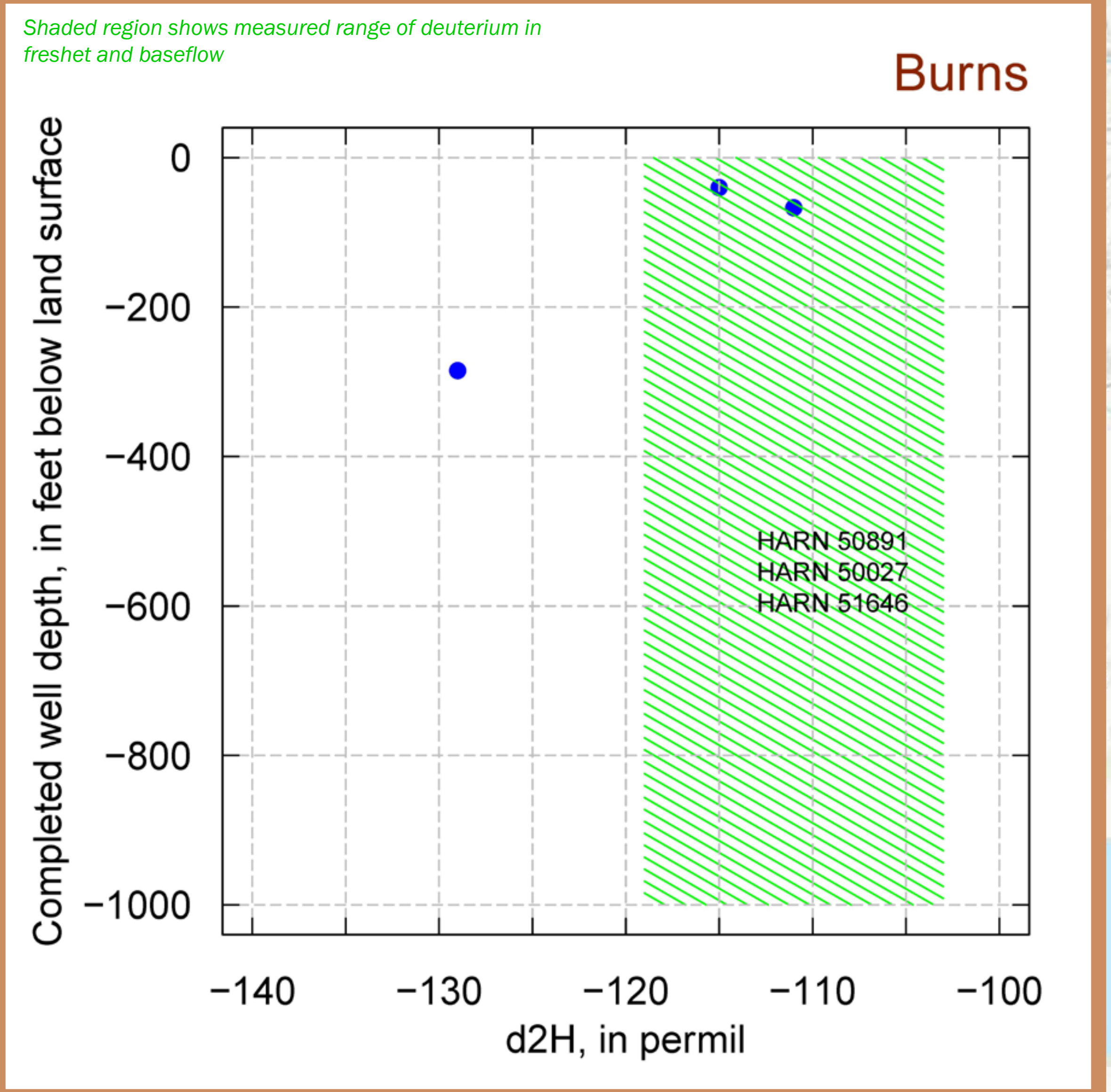

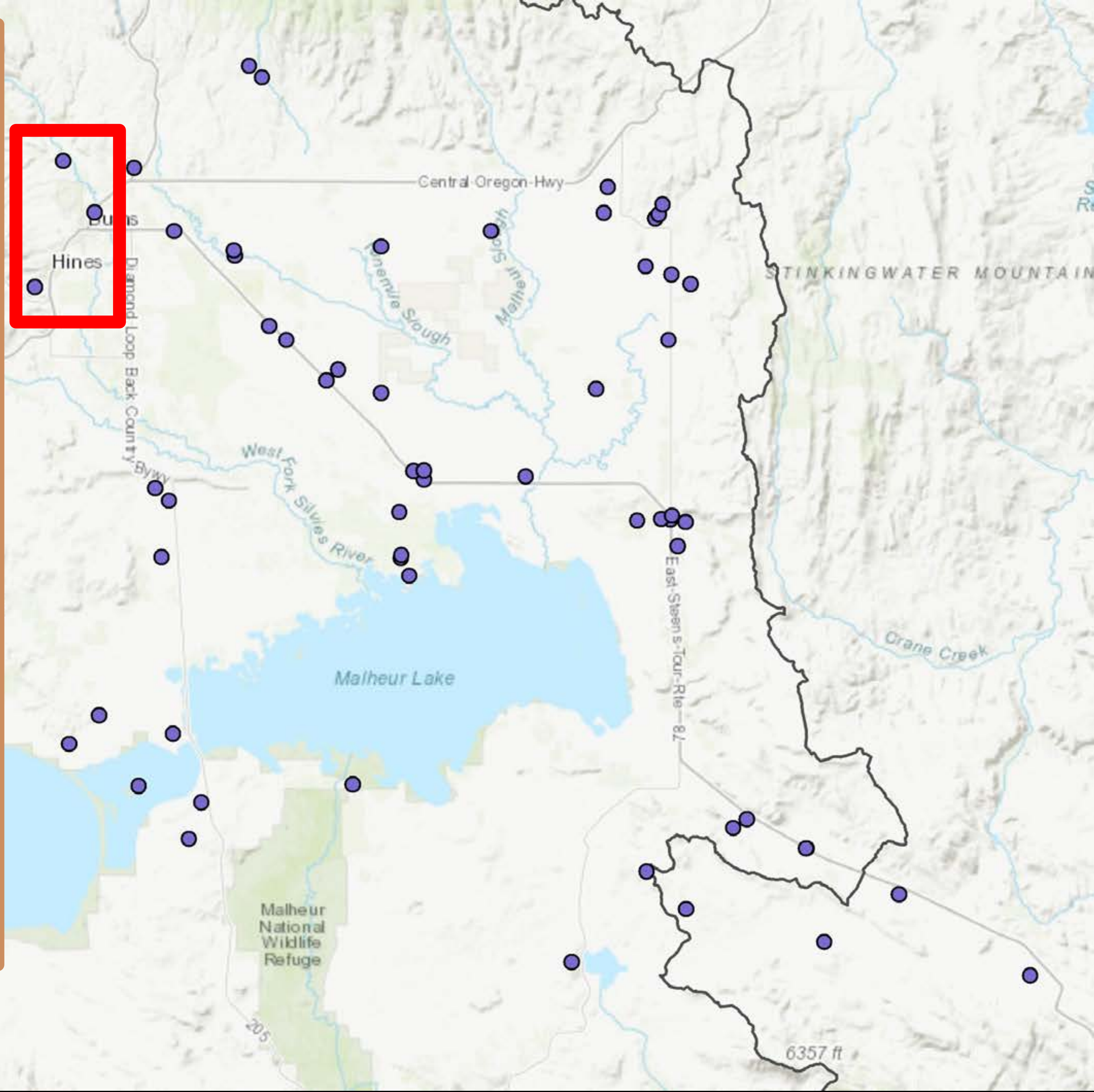

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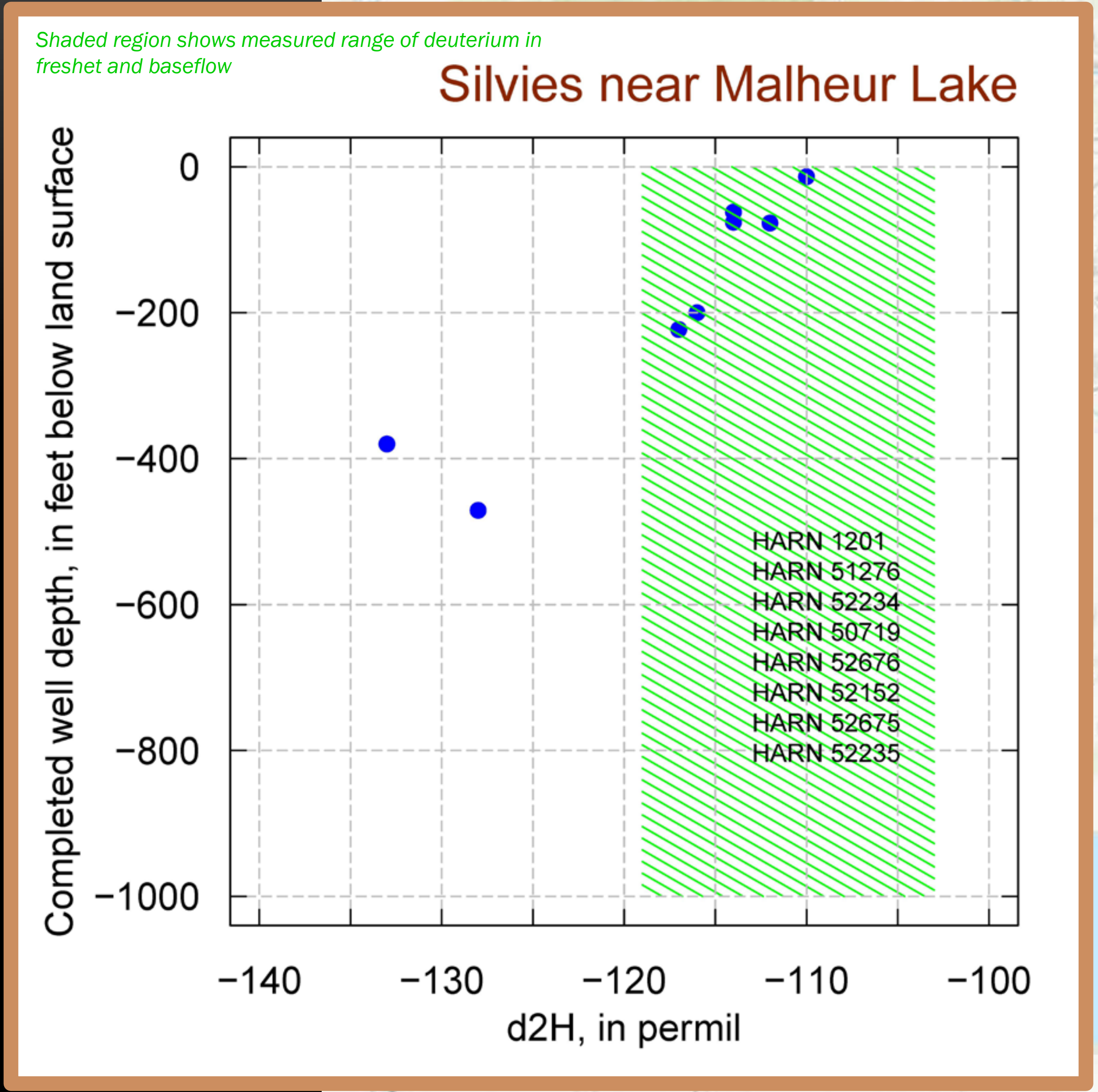

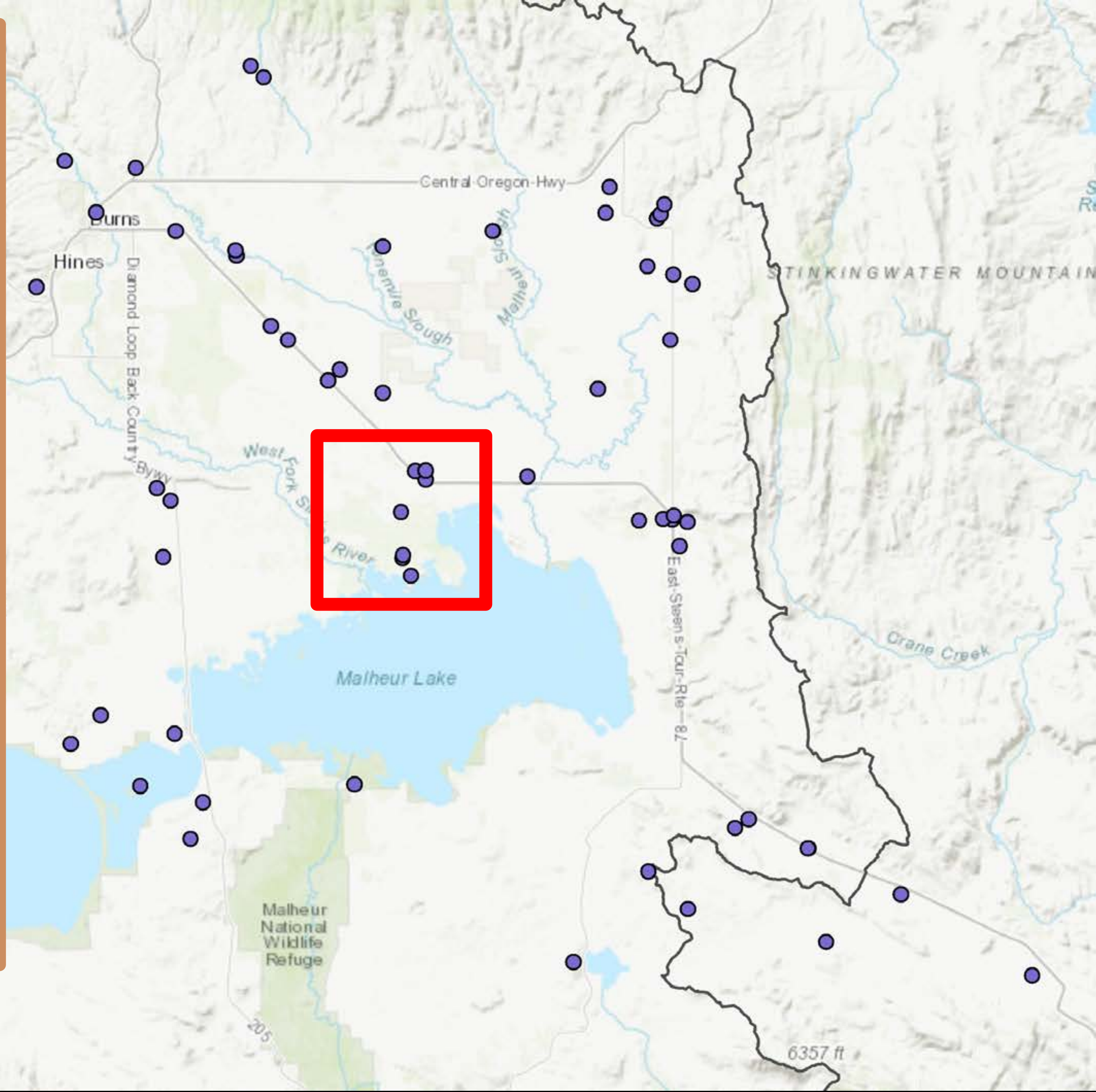

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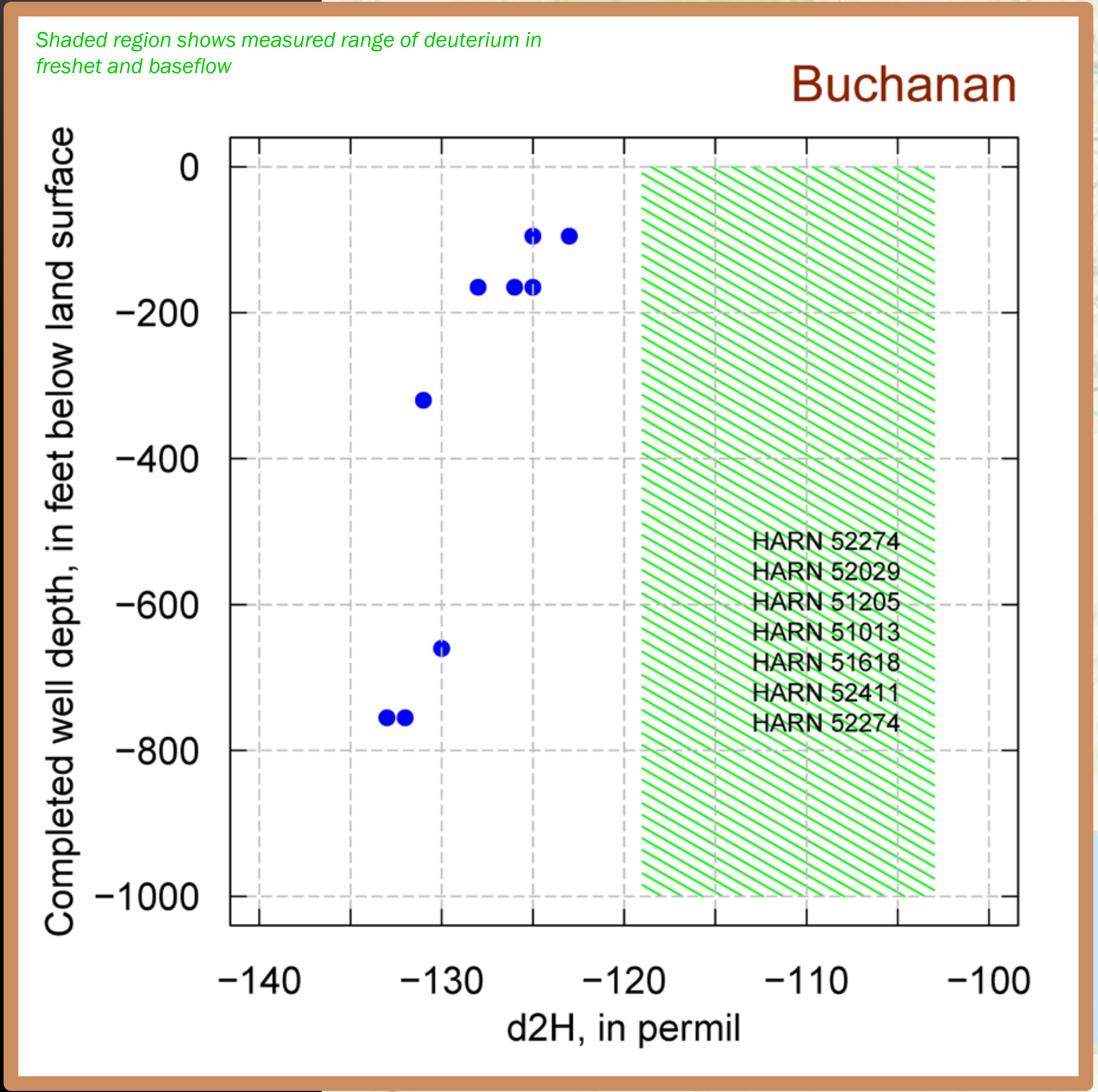

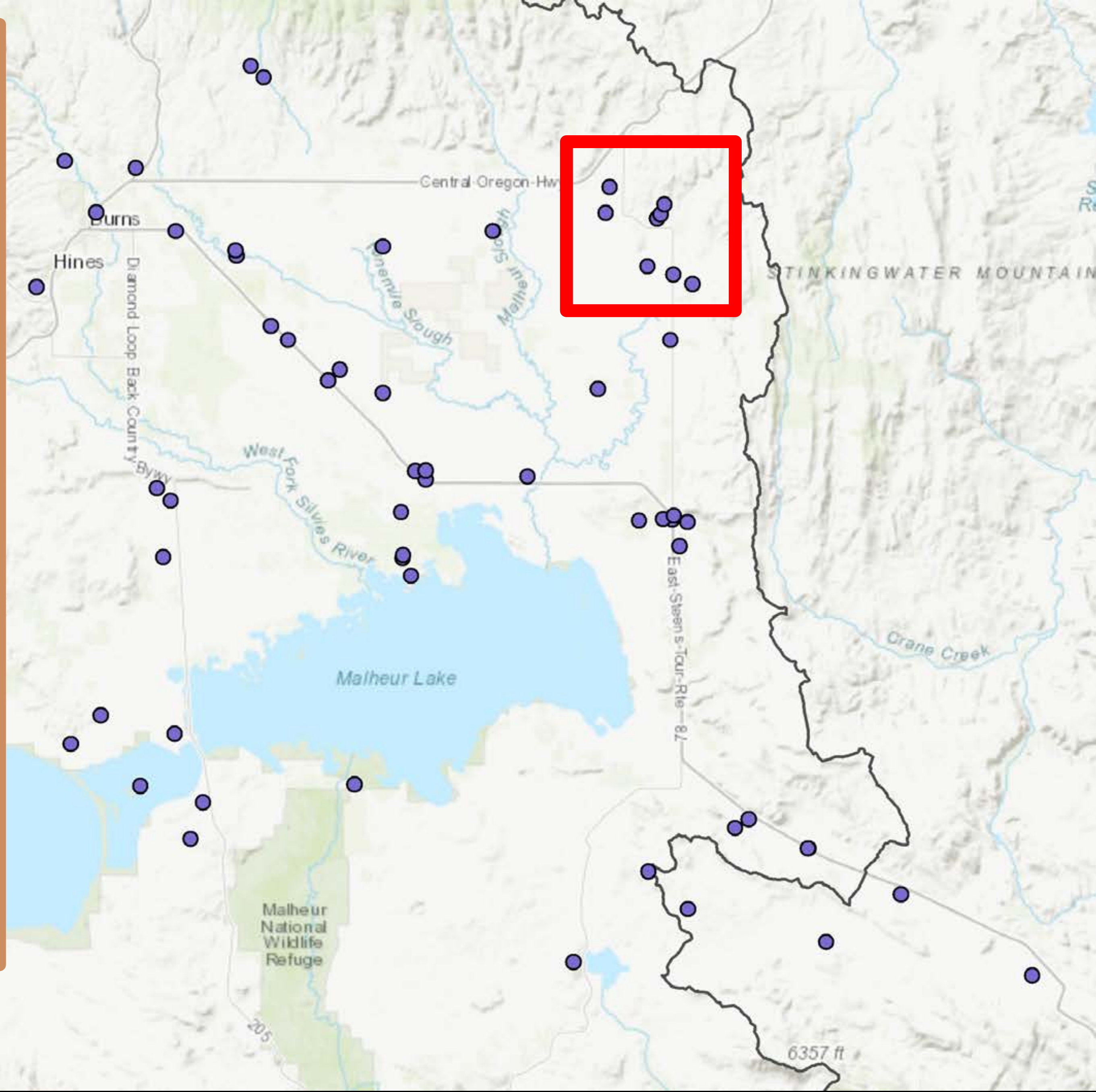

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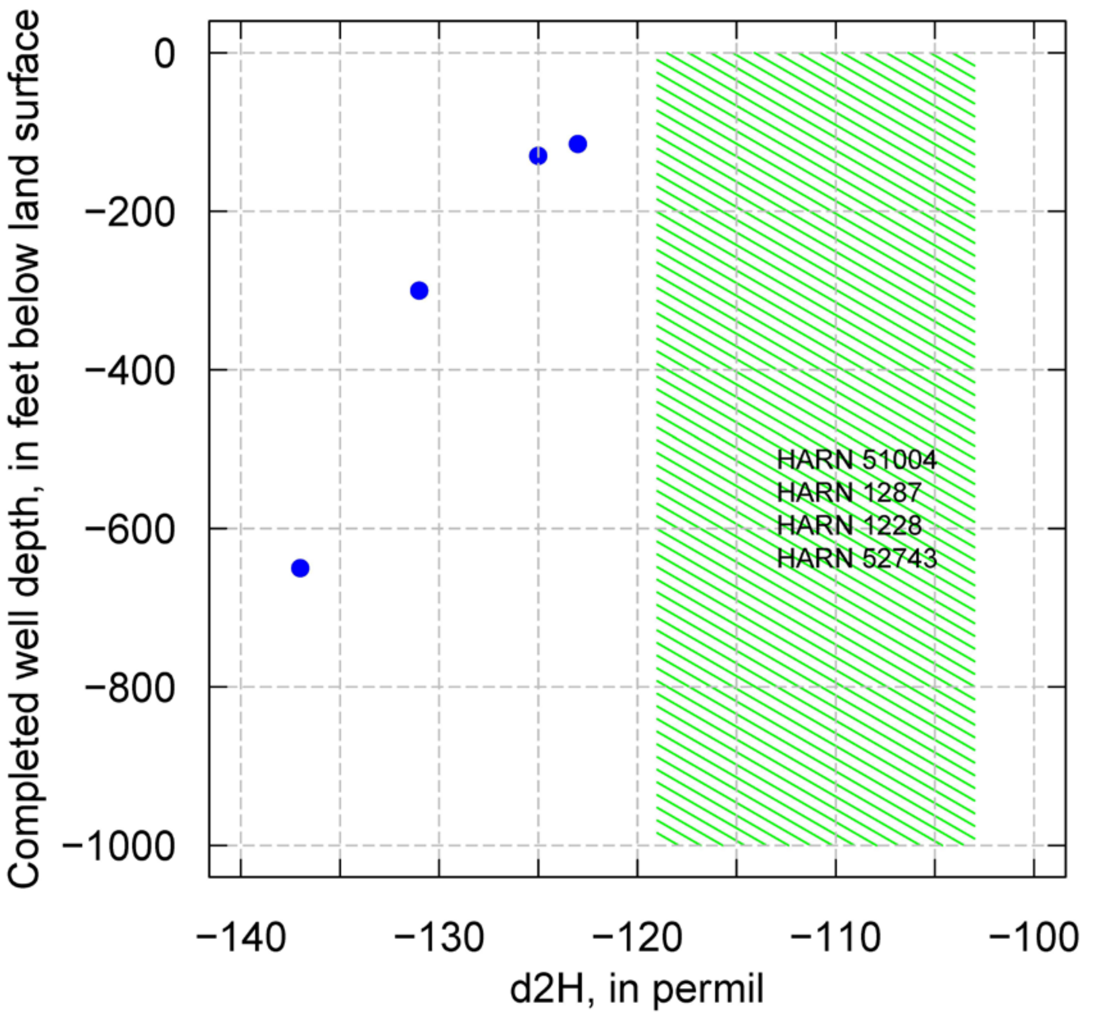
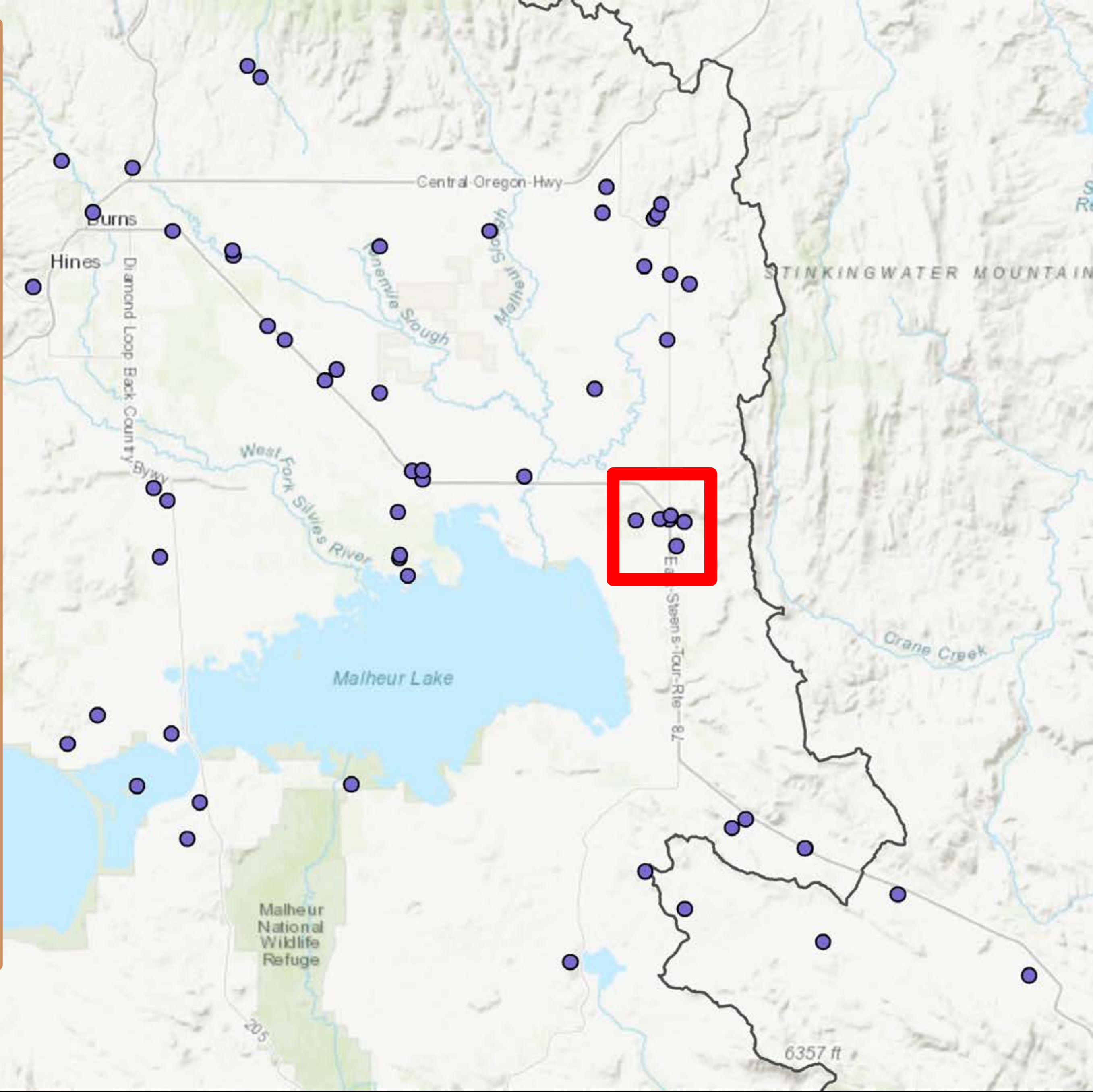
Crane

Shaded region shows measured range of deuterium in freshet and baseflow





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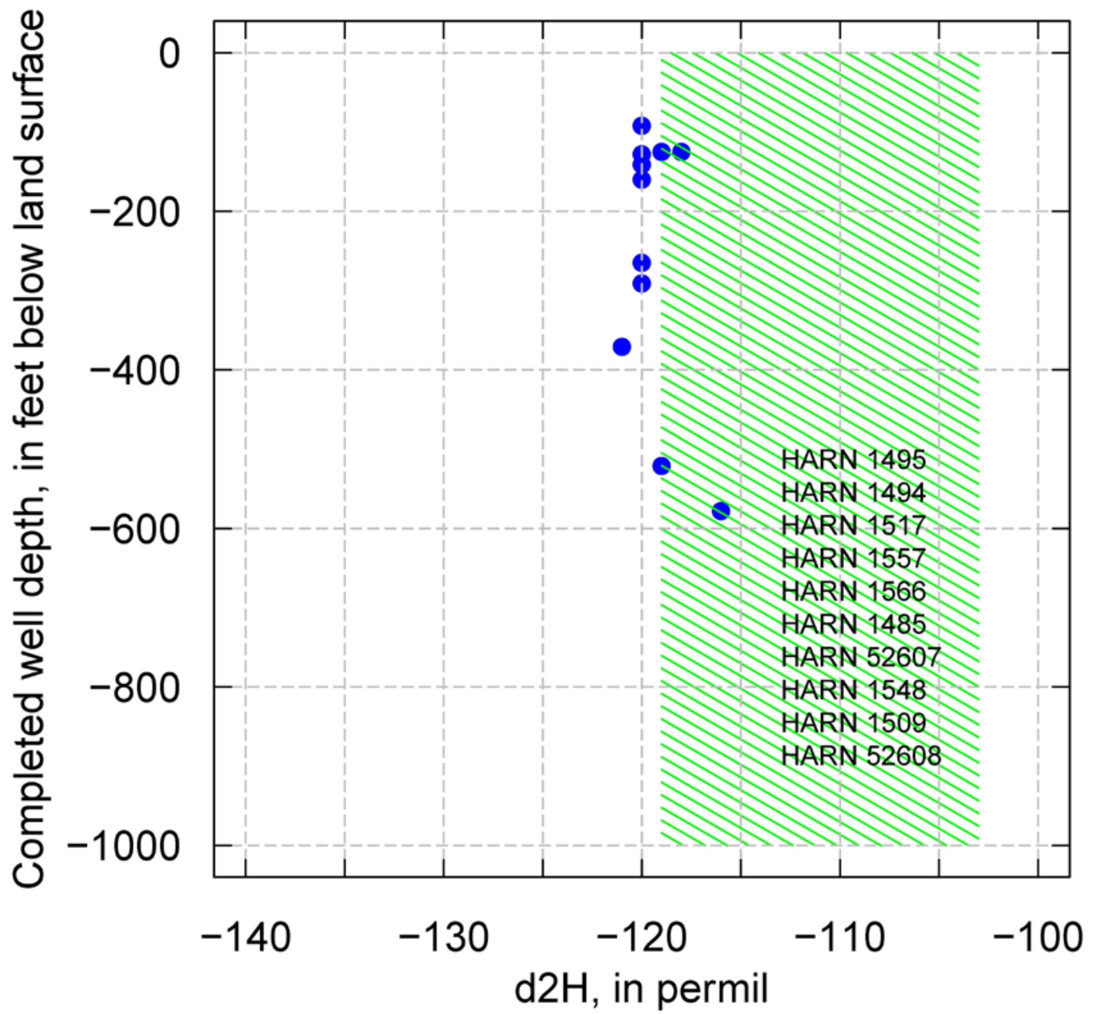
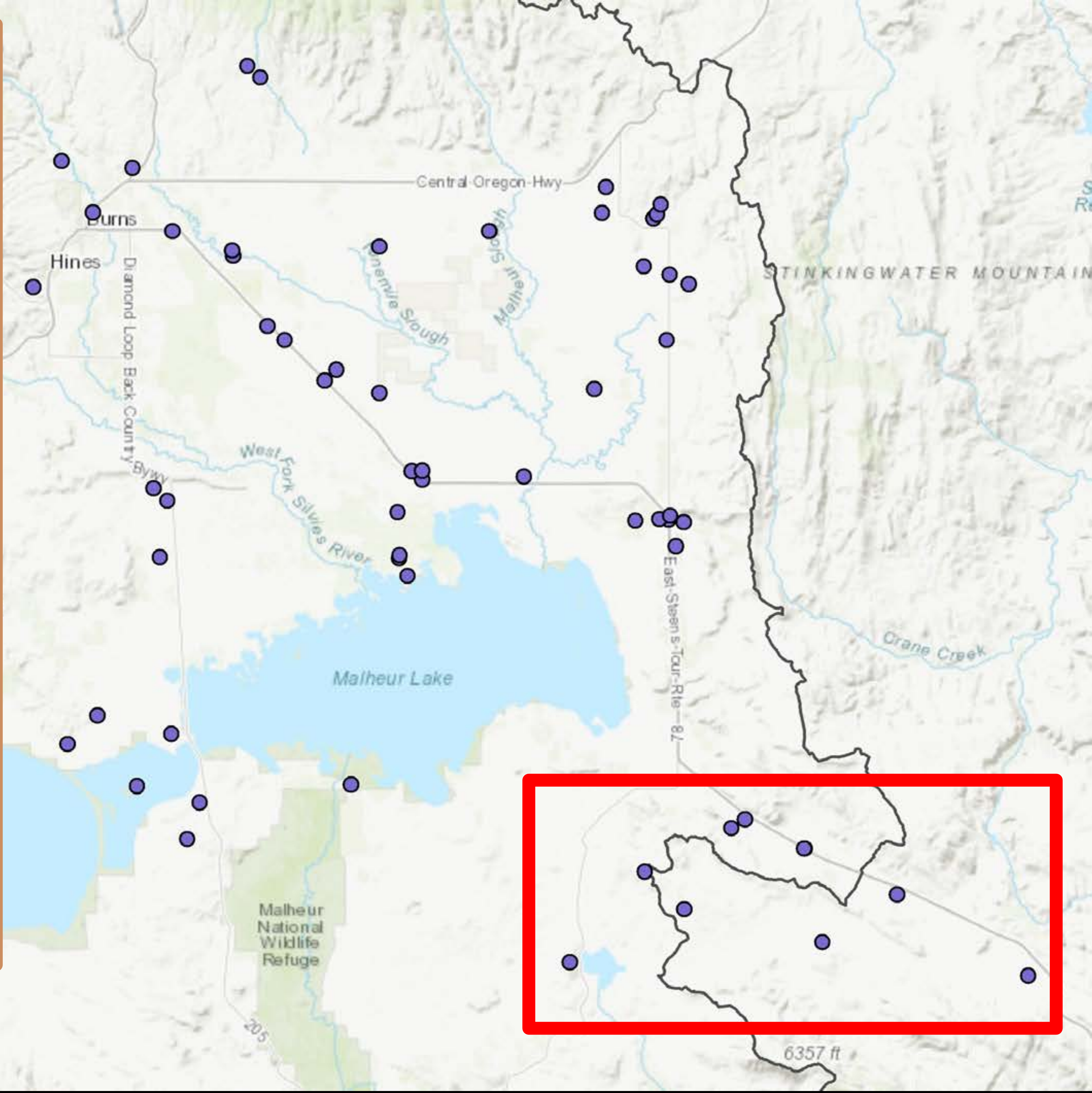
Shaded region shows measured range of deuterium in freshet and baseflow

Virginia Valley





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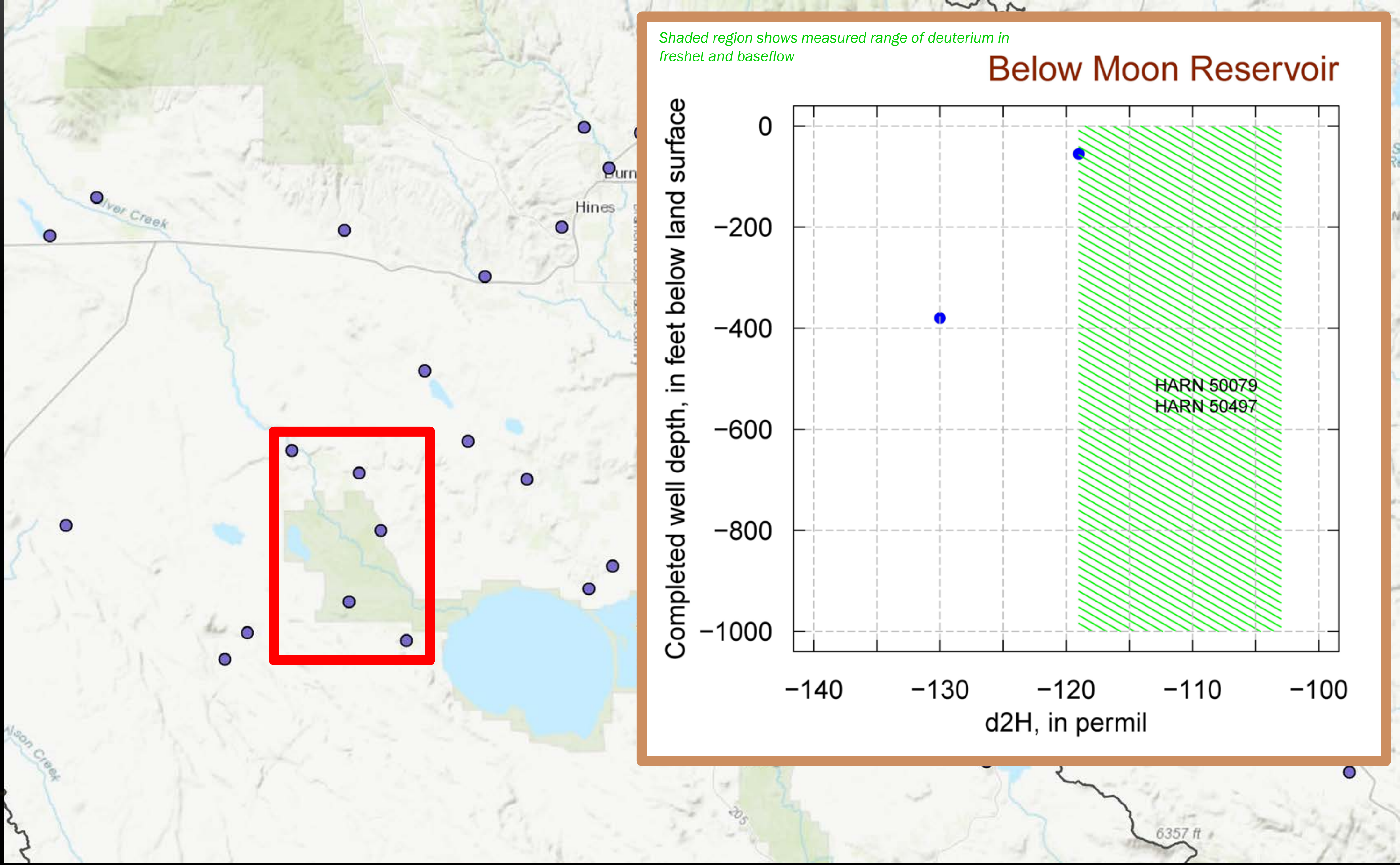

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KEY POINTS

- d2H in samples from wells generally are more negative than modern recharge sources

- d2H in samples from wells similar to modern recharge are generally less than 100 ft deep

Relating Deuterium to Groundwater Age

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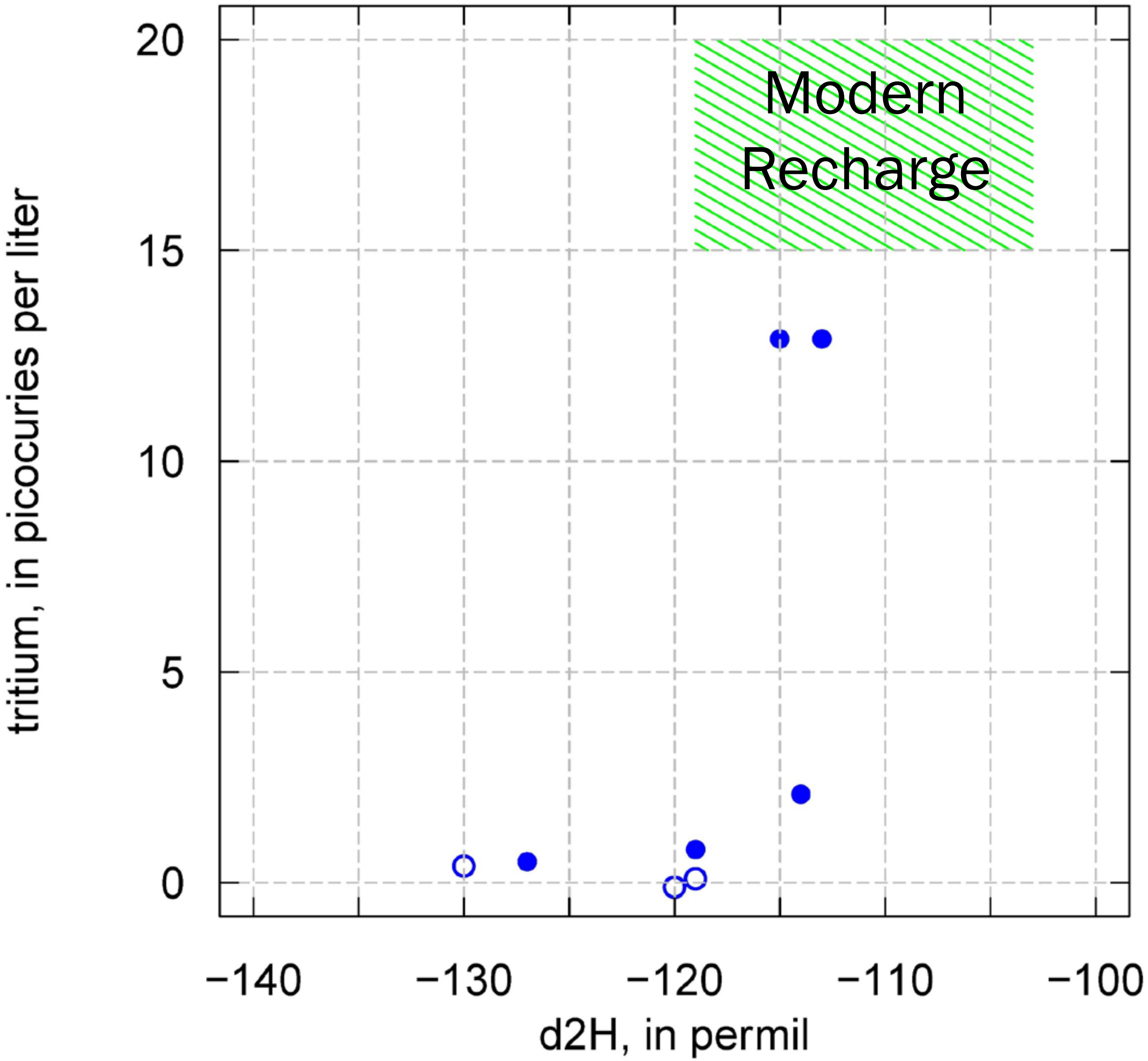
Tritium-dead water associated with deuterium ratios < -119

Tritium-dead = recharge prior to 1945

Mixing is evident



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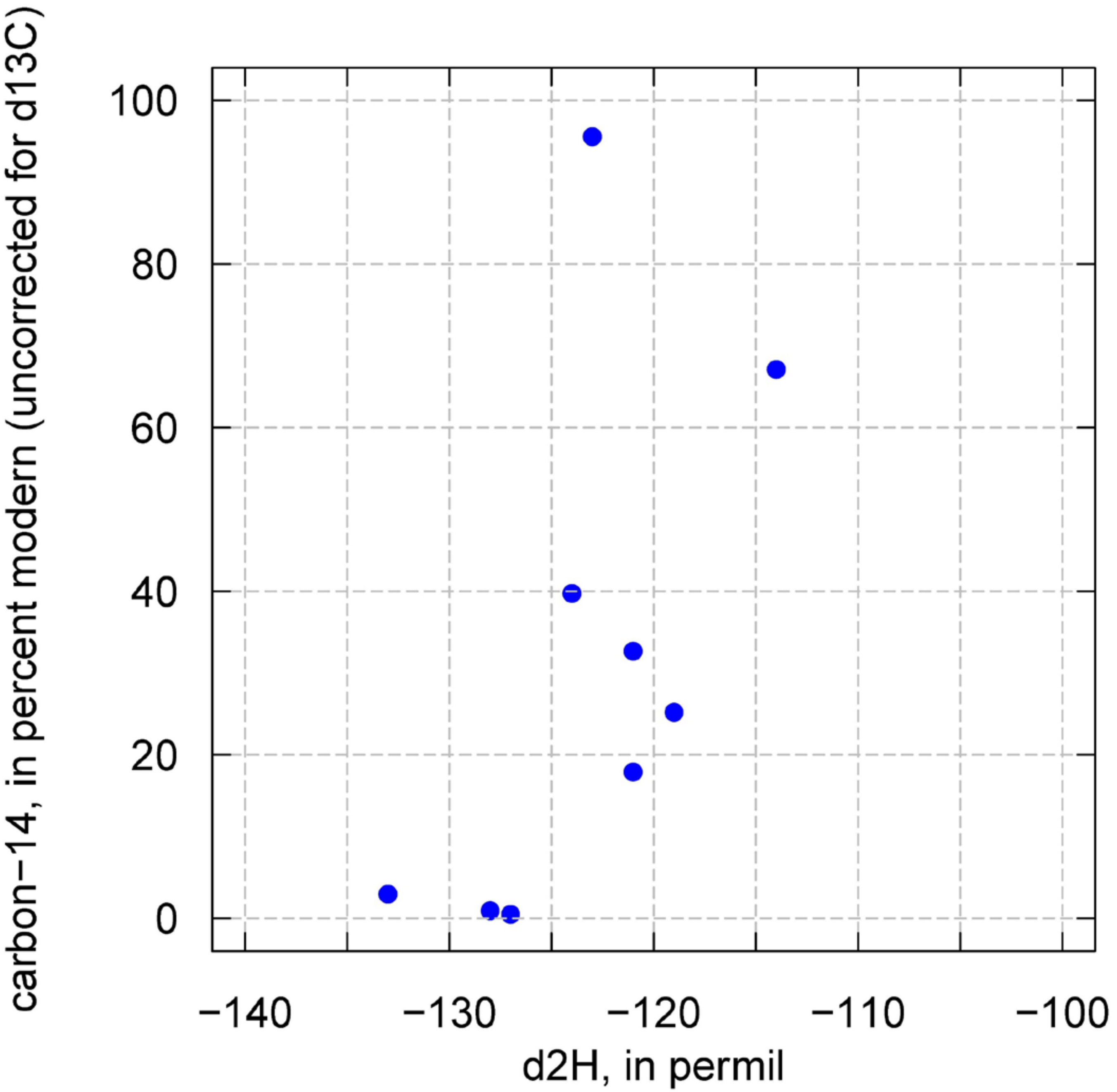
Carbon-14 content decreases as deuterium ratios becomes more negative

Mixing is evident



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KEY POINTS

- Deuterium ratios less than -119 associated with old water
- The more negative the deuterium ratio, the older the water

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Putting It All Together

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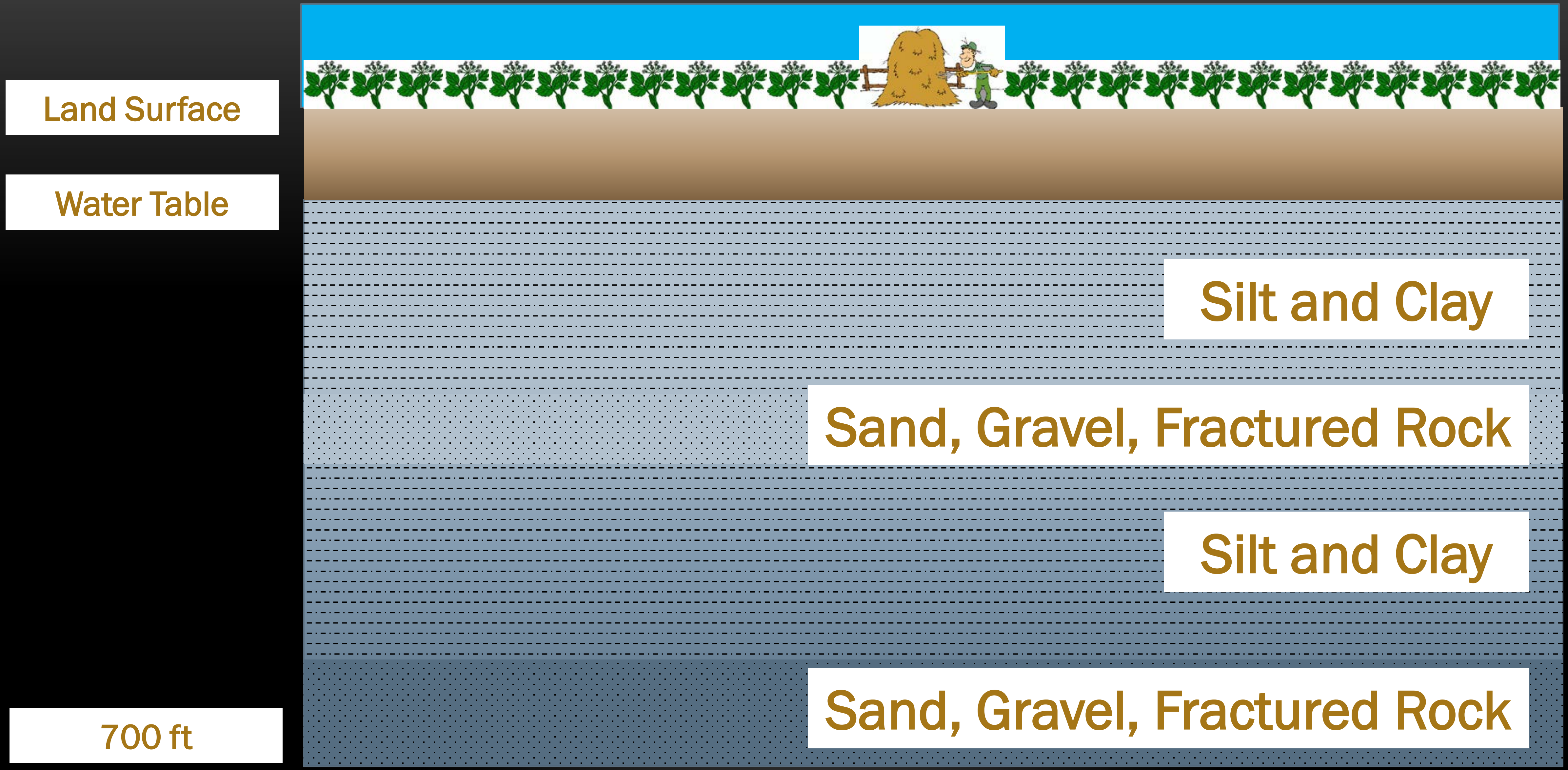
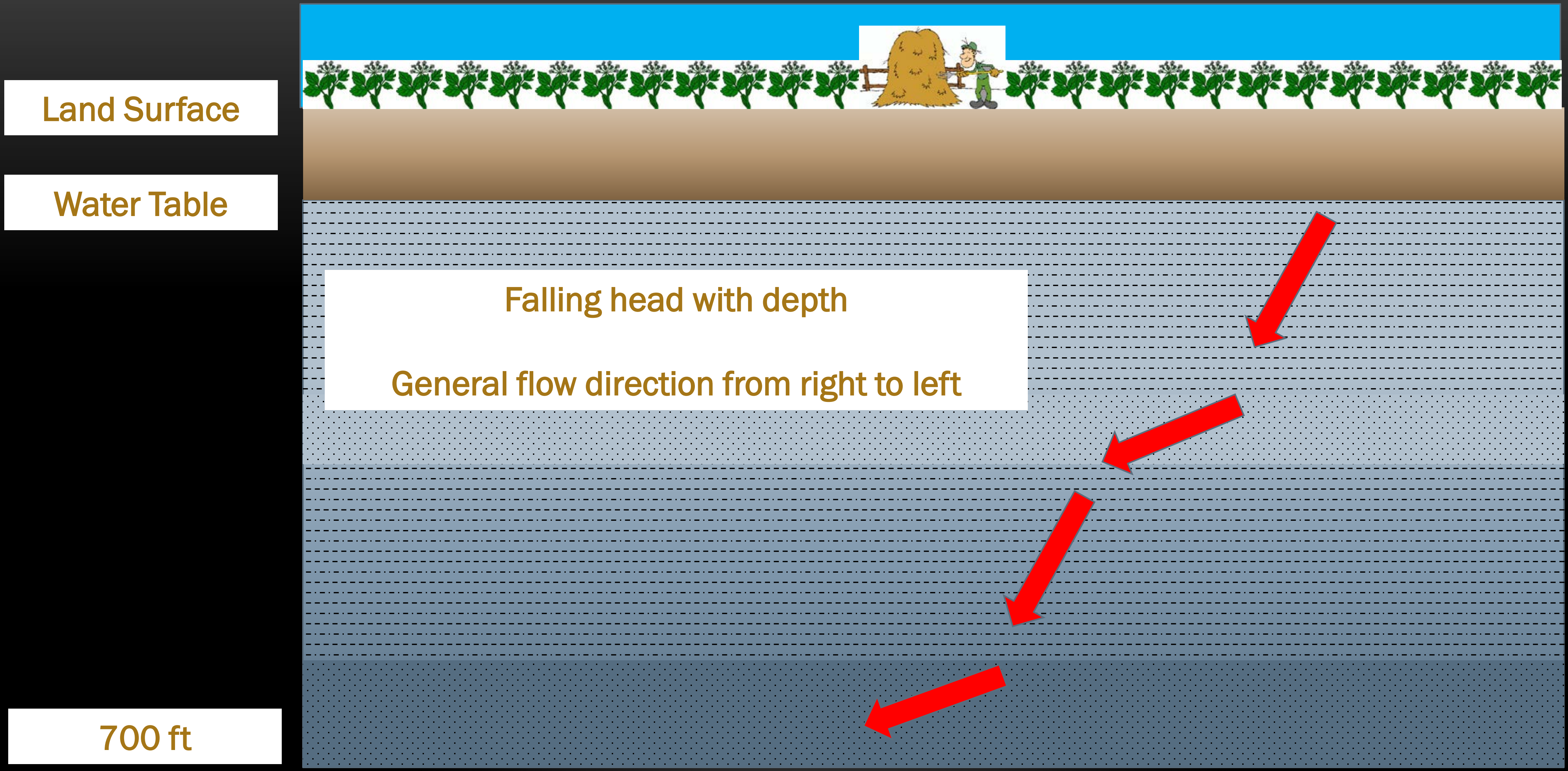

Land Surface
Water Table
Silt and Clay
Sand, Gravel, Fractured Rock
Silt and Clay
Sand, Gravel, Fractured Rock
700 ft



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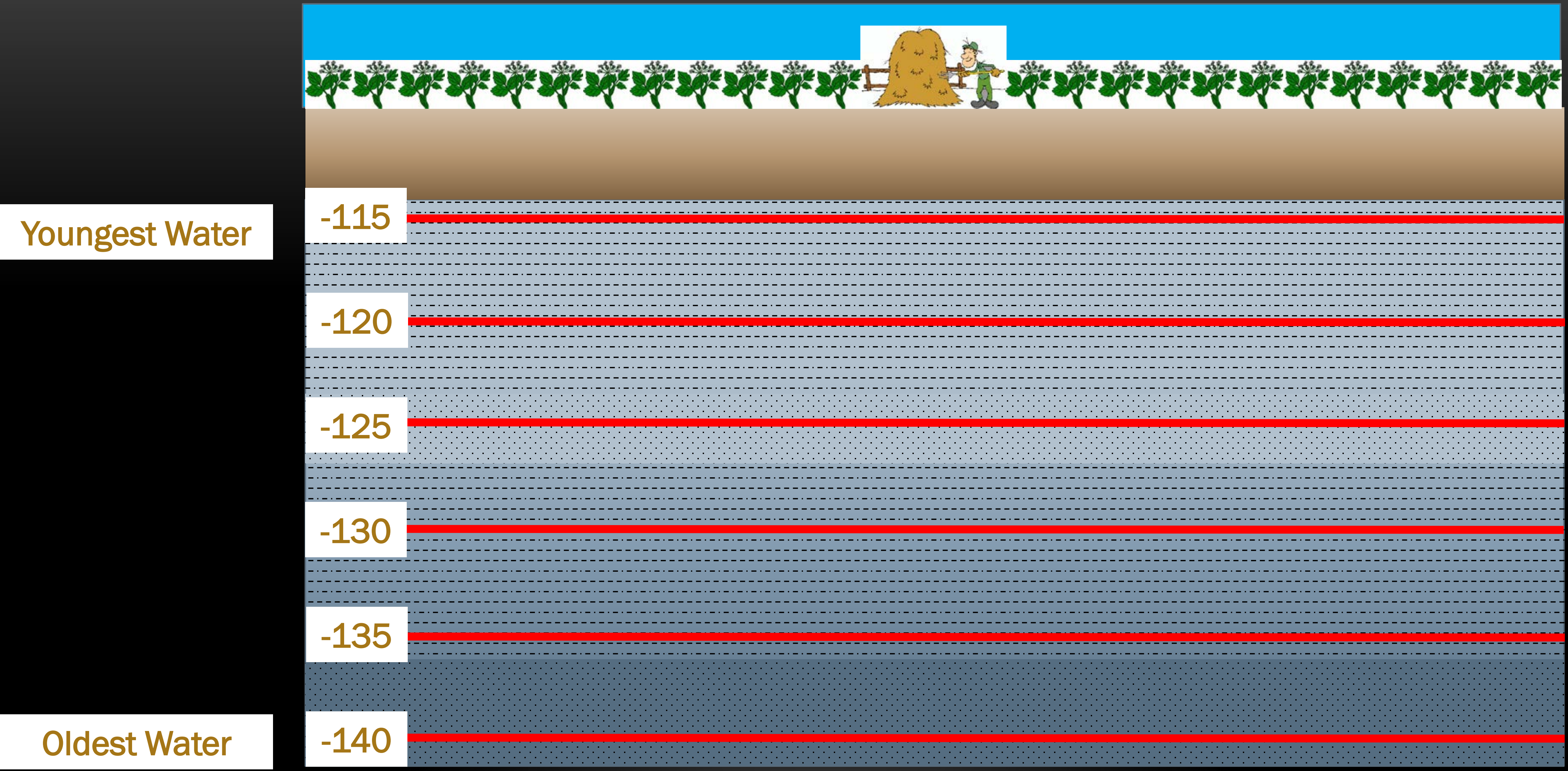

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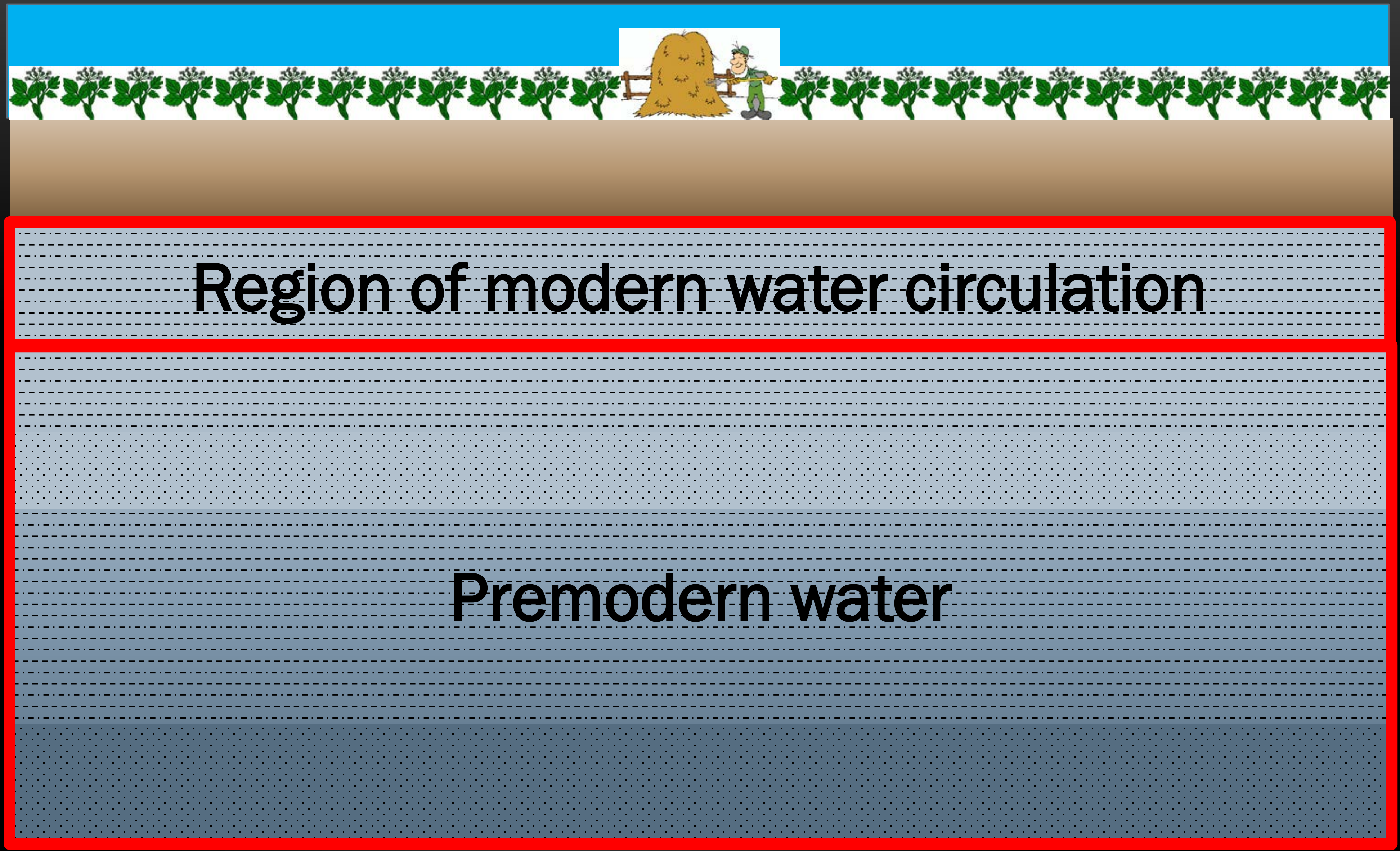
More negative deuterium ratios occur as depth increases



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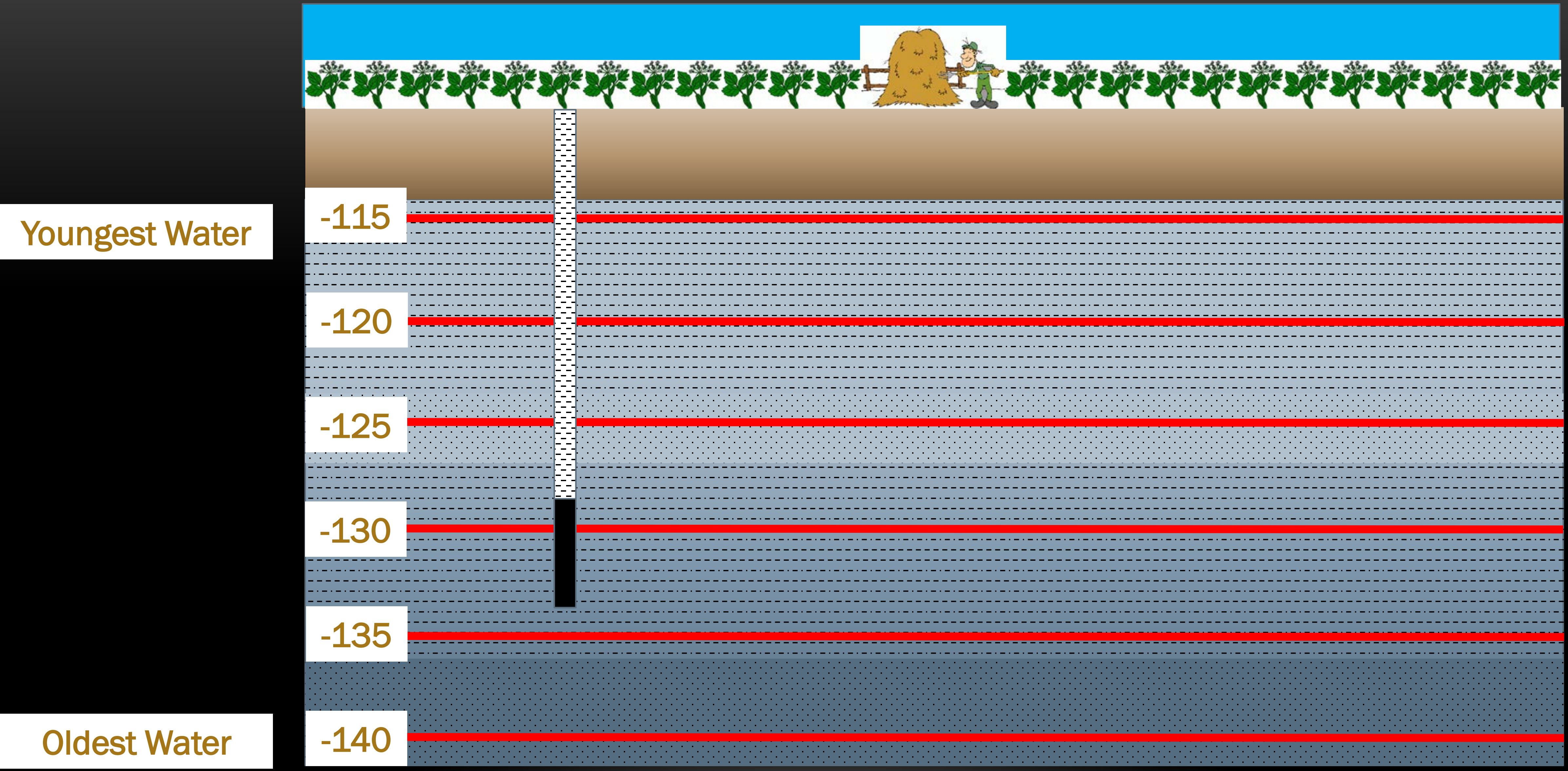
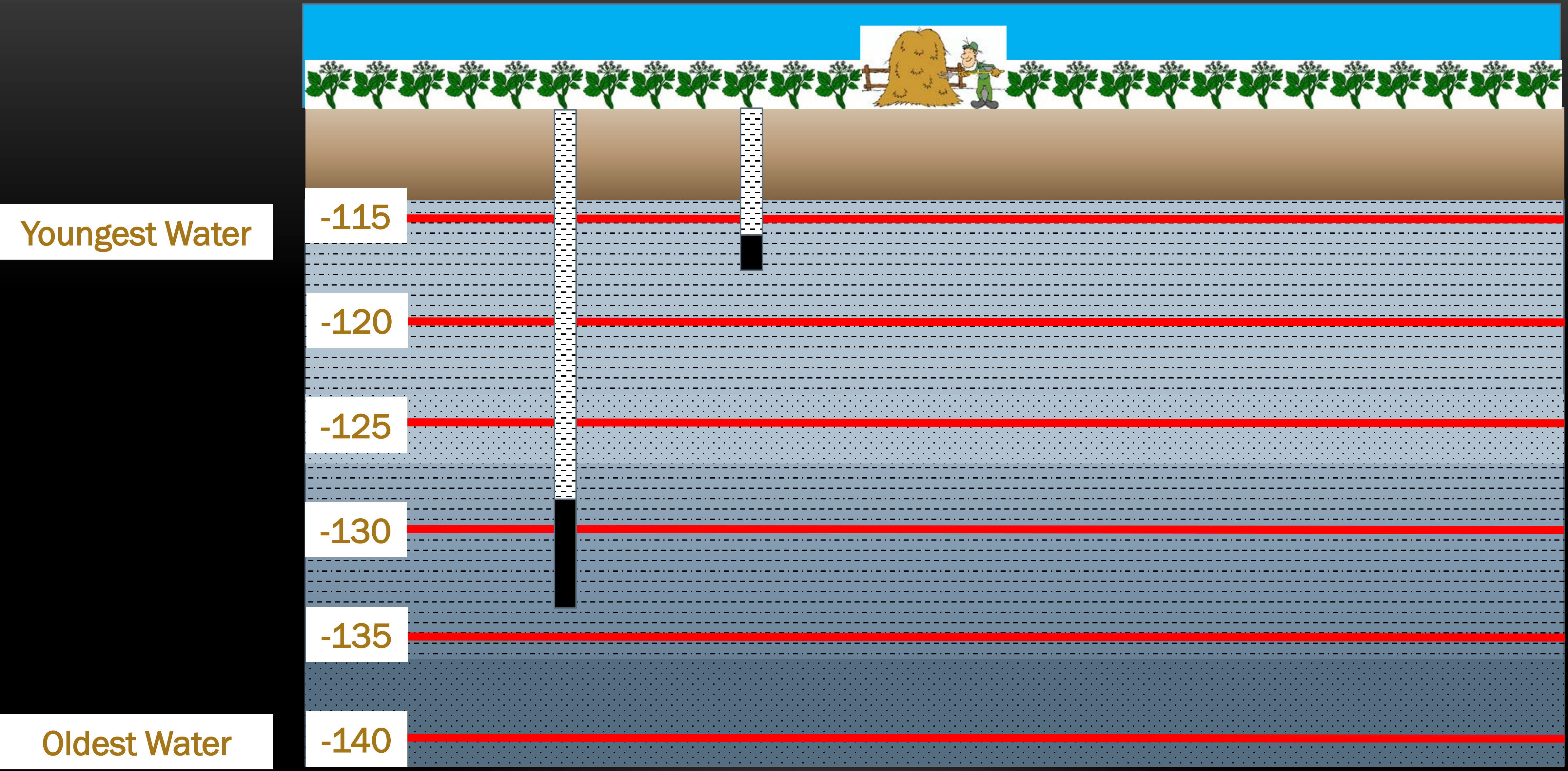


More negative deuterium ratios occur as depth increases



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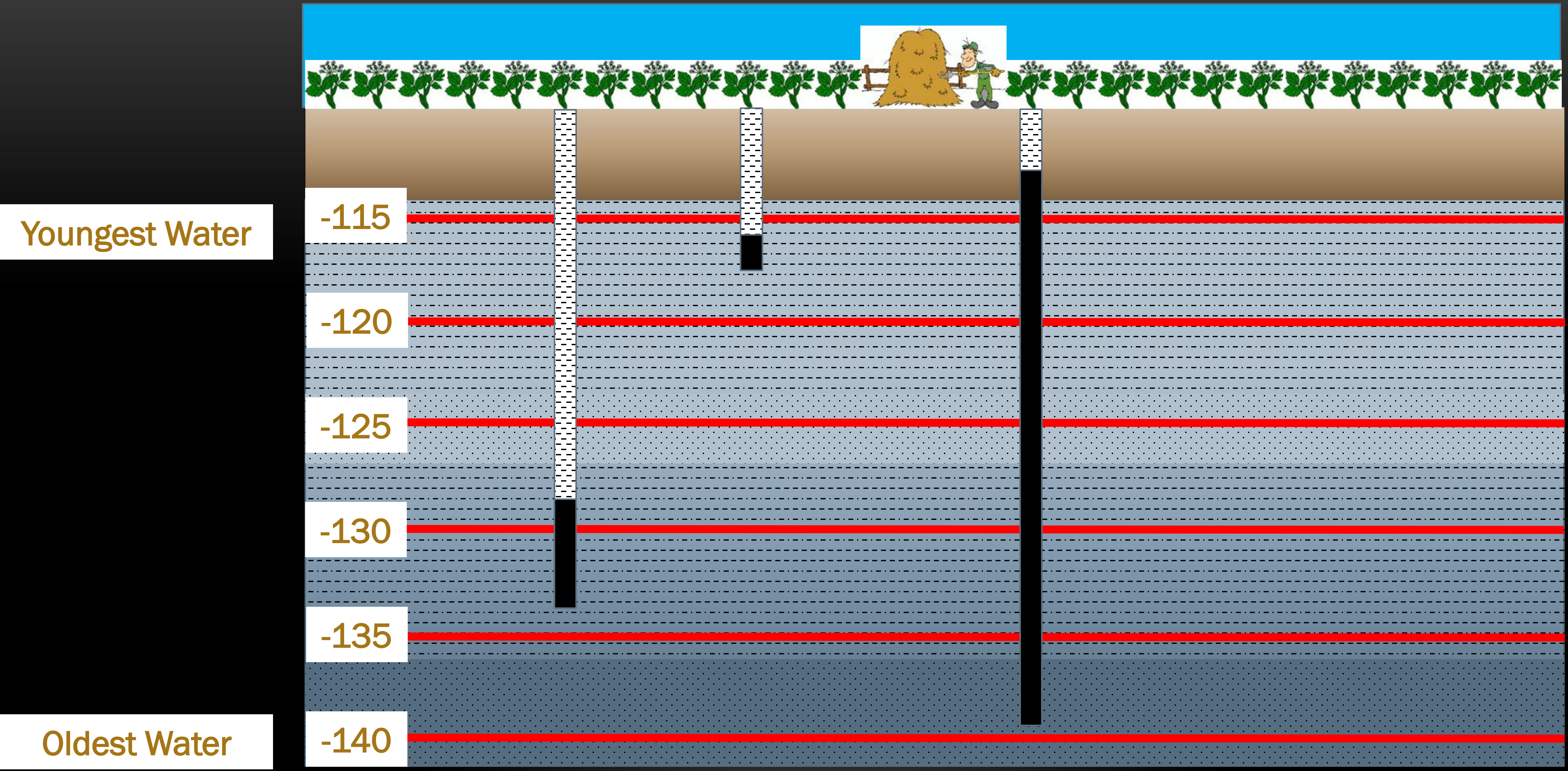
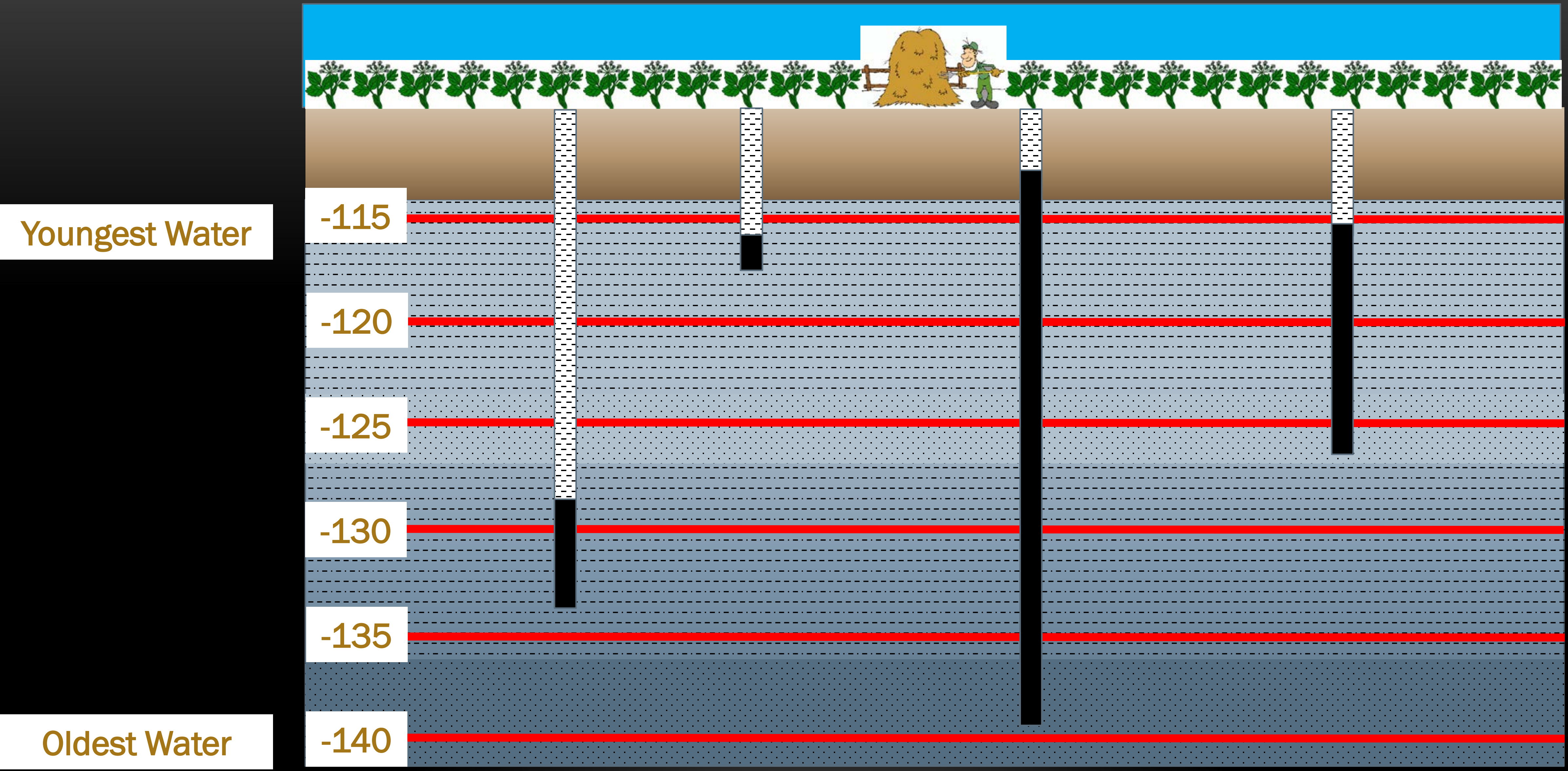


More negative deuterium ratios occur as depth increases



More negative deuterium ratios occur as depth increases

LAST THOUGHT...

Old water in basin fill is consistent with:

- Subsurface geology and productivity described on driller's logs
- Measured and estimated rates of recharge
- Observed distribution of water levels and head gradients
- Geologic history of the basin – closed basin, pluvial lakes

References

Friedman, I., Smith, G.I., Johnson, C.A., and Moscati, R.J., 2002, Stable isotope compositions of waters in the Great Basin, United States 2. Modern precipitation: Journal of Geophysical Research: Atmospheres, v. 107, no. D19, p. ACL 15-11-ACL 15-22.

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End of Presentation