

Preliminary Isotopic Investigation of Sources of Nitrate in Groundwater
Casco, Kewaunee County, Wisconsin

Presentation to
Land and Water Conservation Board, Kewaunee County

By
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Dragun Corporation

June 2022

Objectives

1. Prepare preliminary maps and figures to show the areal distribution of nitrate in local groundwater, the local subsurface geology, the local distribution of well depths, and seasonal/long-term variations in nitrate in the local groundwater.
2. Prepare preliminary maps of the areal distribution of the static groundwater levels based on the well construction logs and determine groundwater-flow direction(s) relative to Casco area.
3. Conduct limited isotopic investigation of groundwater to assist in determining the source(s) of nitrate (chemical fertilizer, animal waste/human, etc.) and the age of the nitrate (legacy or recent).

Well Records

Wisconsin Department of Natural Resources

Well Construction Information System

Search Wells

Search

Clear

WI Unique Well #:

County:

Well Completion Year:

Section:

Township:

Range:

Dir:

Well Address:

Municipality Name:

Owner Name:

Well Type:

Constructor Name:

Well Completion Date

To:

From:

Service Category:

Well Depth:

 ft ft

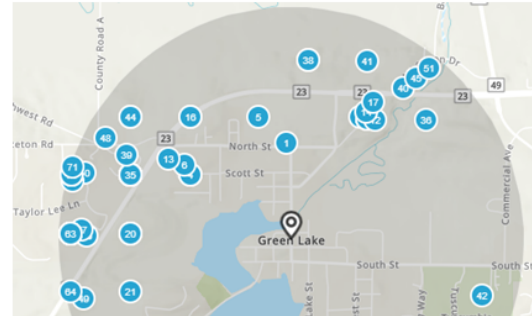
Search

Clear

SEARCH TIPS

- If your well was constructed before 1988, search only by Township, Range and Section. In the search results, you will see these reports at the bottom of the list, and most additional fields (address, owner name, year constructed) are blank. You will need to open each "Image file" PDF to see the details about each well.
- If your well was constructed 1988 or later, try searching by County and Well Address – use part of the street name, for instance if the address is 123 Main Street, try just "MAIN". However, not all well construction reports include an address. So if address does not work, try Owner Name, for example "JONES". The owner name represents the owner at the time of well construction.
- If you have any questions or corrections, please send an email to DNRWELLREPORT@wisconsin.gov

SEARCH BY MAP

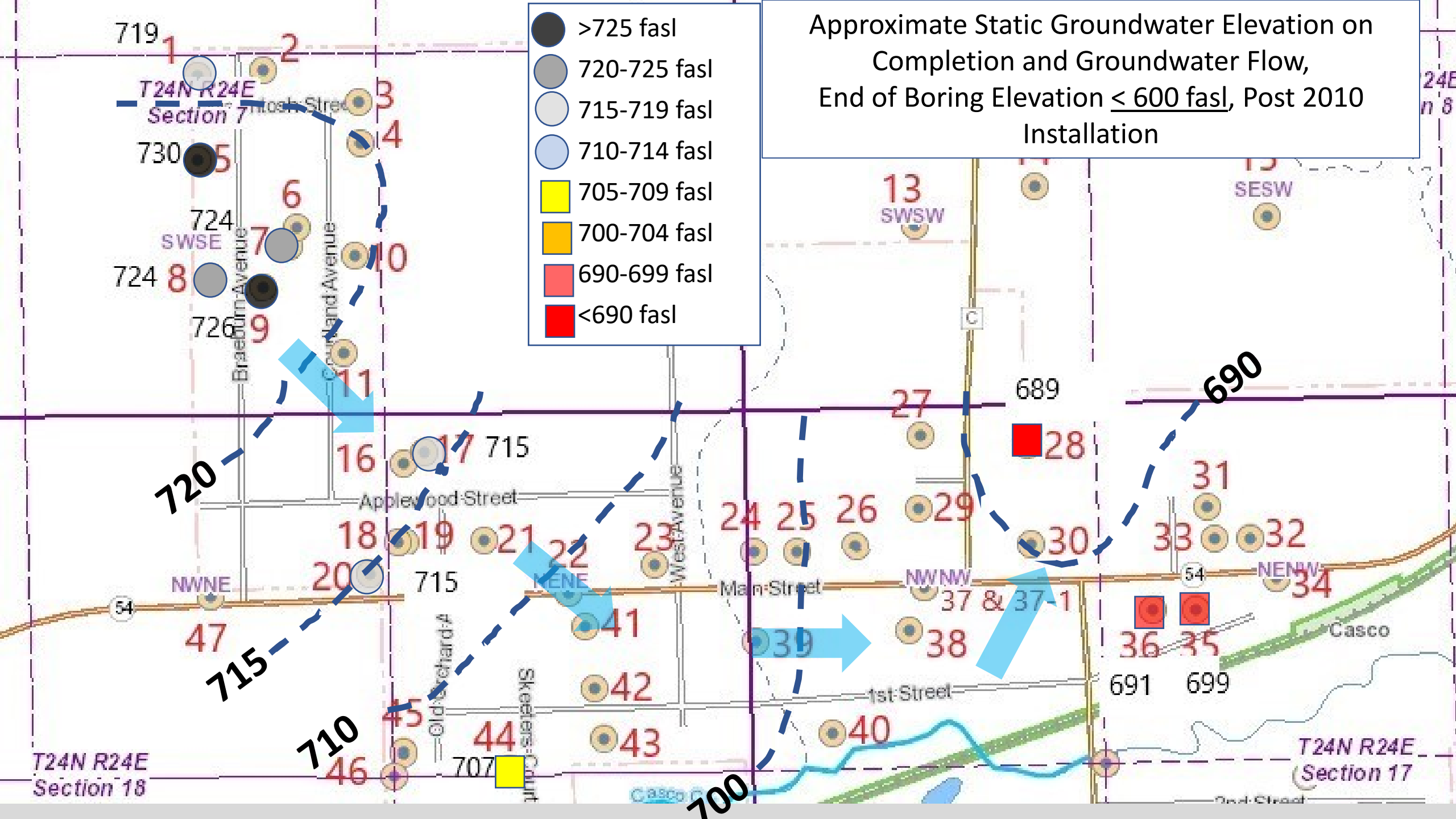


Open the map, and search for an address or place in the search box. Or click on the map in a half mile vicinity of expected well location.

Well Construction Report WISCONSIN UNIQUE WELL NUMBER				AB123		Drinking Water and Groundwater - DG/5 Department of Natural Resources, Box 7921 Madison WI 53707		Form 3300-077A	
Property Owner				Phone #		1. Well Location			
Mailing Address				City		State WI		Zip Code 54201	
County		Co. Permit #	Notification #	Completed		Subdivision Name		Lot #	Block #
Well Constructor (Business Name)				Lic. #	Facility ID # (Public Wells)		Latitude / Longitude in Decimal Degree (DD)		Method Code
RETZLAFF & GREGORICH				7267			'N	'W	GPS008
Address				Well Plan Approval #		SW	SE	Section	Township
WELL DRILLING LLC NEW FRANKEN WI 54229						or Govt Lot #	Range	2. Well Type	
Hicap Permanent Well #				Common Well #	Specific Capacity		New Well		constructed in
					0.3		Reason for replaced or reconstructed well ?		
3. Well serves				1 # of	Hicap Well ?		No		Construction Type
Private, potable					Hicap Property ?		No		Drilled
Heat Exchange				# of drillholes	Hicap Potable ?				
4. Potential Contamination Sources - ON REVERSE SIDE									
5. Drillhole Dimensions and Construction Method									
Dia. (in.)	From (ft.)	To (ft.)	Upper Enlarged Drillhole			Lower Open Bedrock			
8.75	Surface	41	Yes	Rotary - Mud Circulation		No			
6	41	163	No	Rotary - Air		Yes			
6. Casing, Liner, Screen									
Dia. (in.)	Material, Weight, Specification Manufacturer & Method of Assembly			From (ft.)	To (ft.)	9. Static Water Level			
6	XL TUBE ASTM A 53-B SCH 40 SEAMLESS PE WELDED JOINT MADE IN USA			Surface	42	24 ft. below ground surface			
Dia. (in.)	Screen type, material & slot size			From (ft.)	To (ft.)	10. Pump Test		11. Well Is	
						Pumping level 100 ft. below surface		Developed ?	
						Pumping at 20 GP M for 1 Hrs.		Disinfected ?	
						Pumping Method ?		Capped ?	
7. Grout or Other Sealing Material									
Method PRESSURE PUMPED									
Kind of Sealing Material		From (ft.)	To (ft.)	# Sacks Cement		12. Notified Owner of need to fill & seal ?			
CEMENT		Surface	41	10 S		Filled & Sealed Well(s) as needed? Yes			
13. Constructor / Supervisory Driller				Lic #	Date Signed				
KG				0					
Drill Rig Operator				Lic or Reg #	Date Signed				

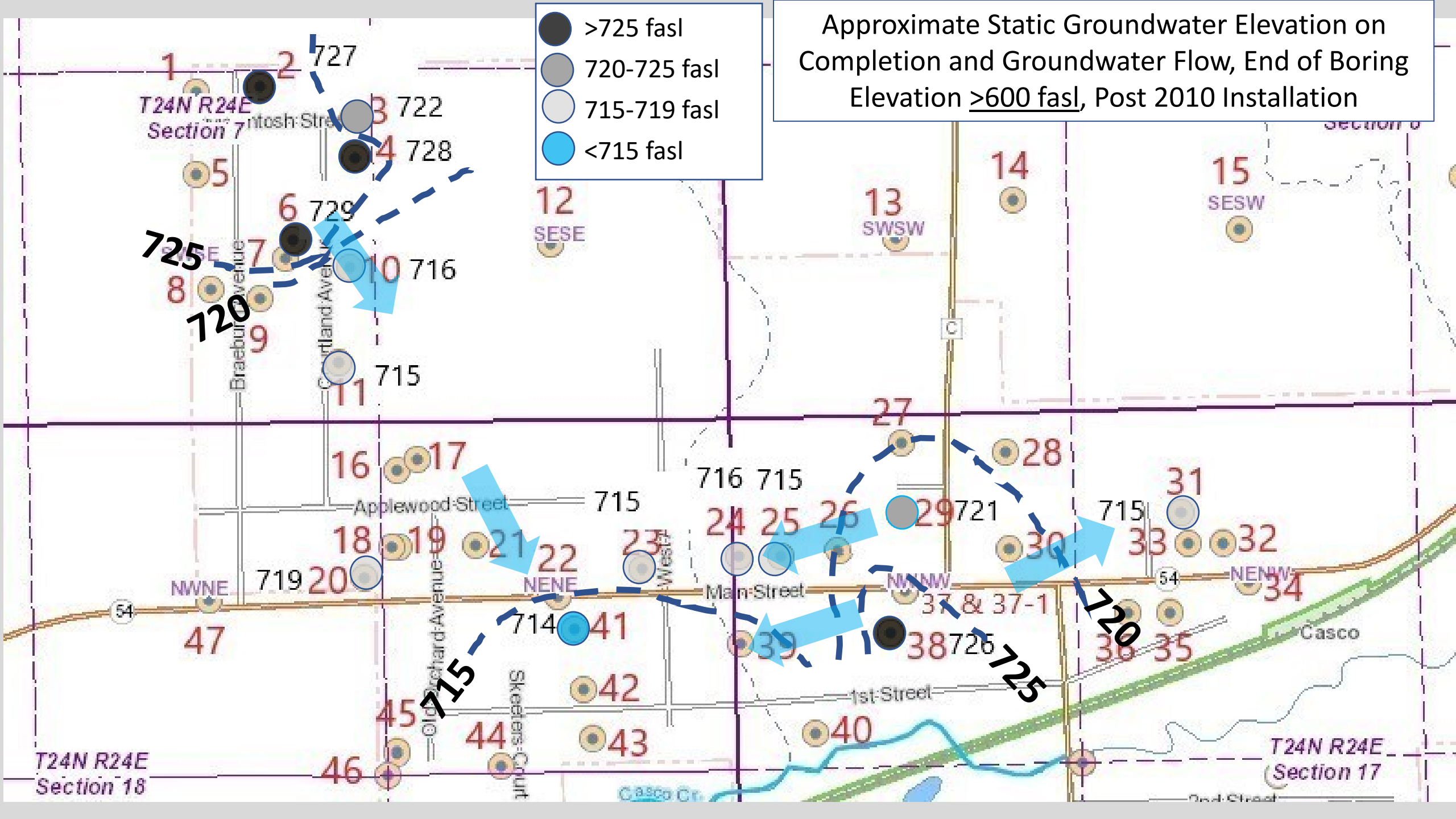
Approximate Static Groundwater Elevation on Completion and Groundwater Flow, End of Boring Elevation < 600 fasl, Post 2010 Installation

- >725 fasl
- 720-725 fasl
- 715-719 fasl
- 710-714 fasl
- 705-709 fasl
- 700-704 fasl
- 690-699 fasl
- <690 fasl



Approximate Static Groundwater Elevation on Completion and Groundwater Flow, End of Boring Elevation >600 fasl, Post 2010 Installation

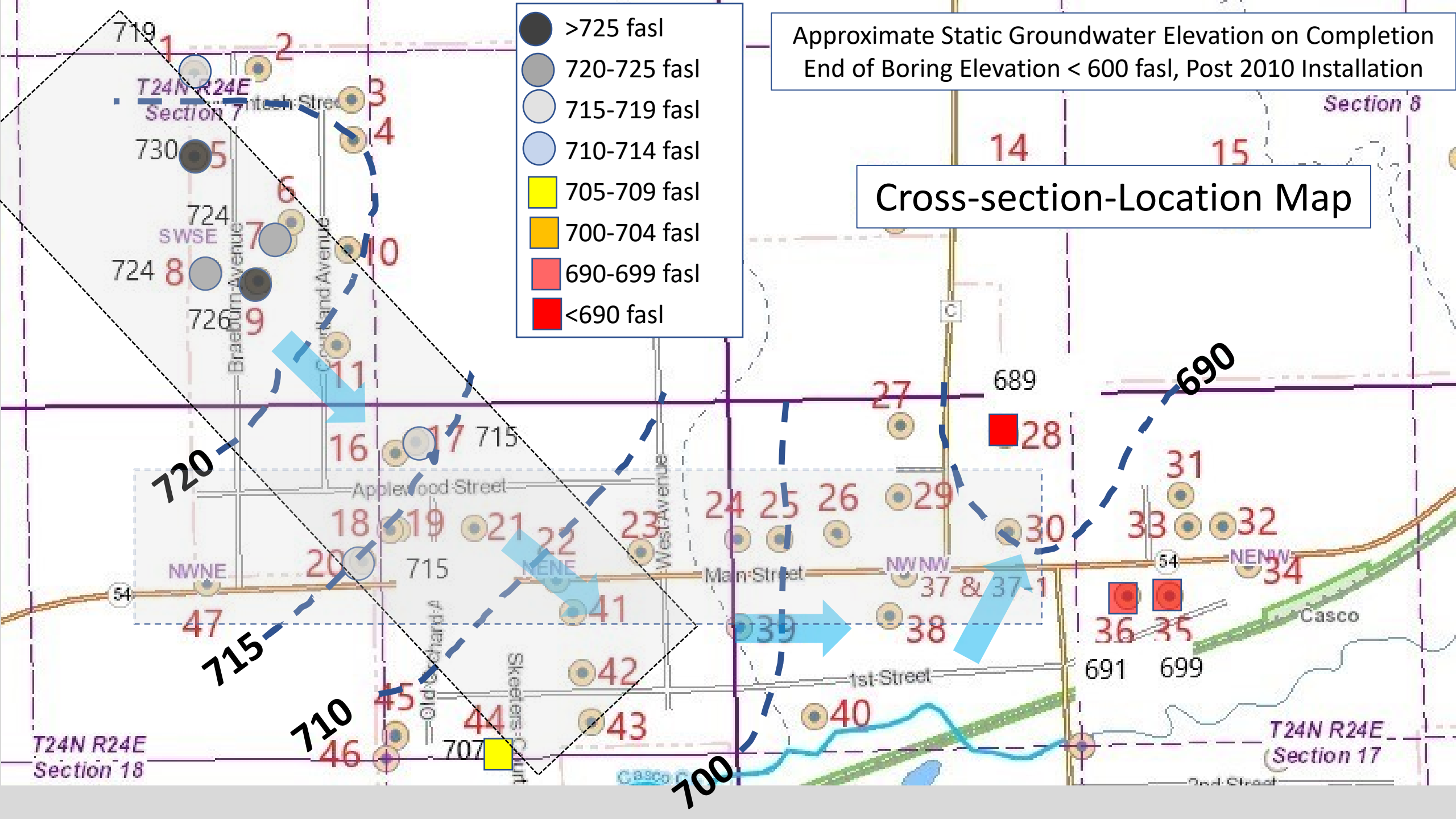
- >725 fasl
- 720-725 fasl
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- <715 fasl

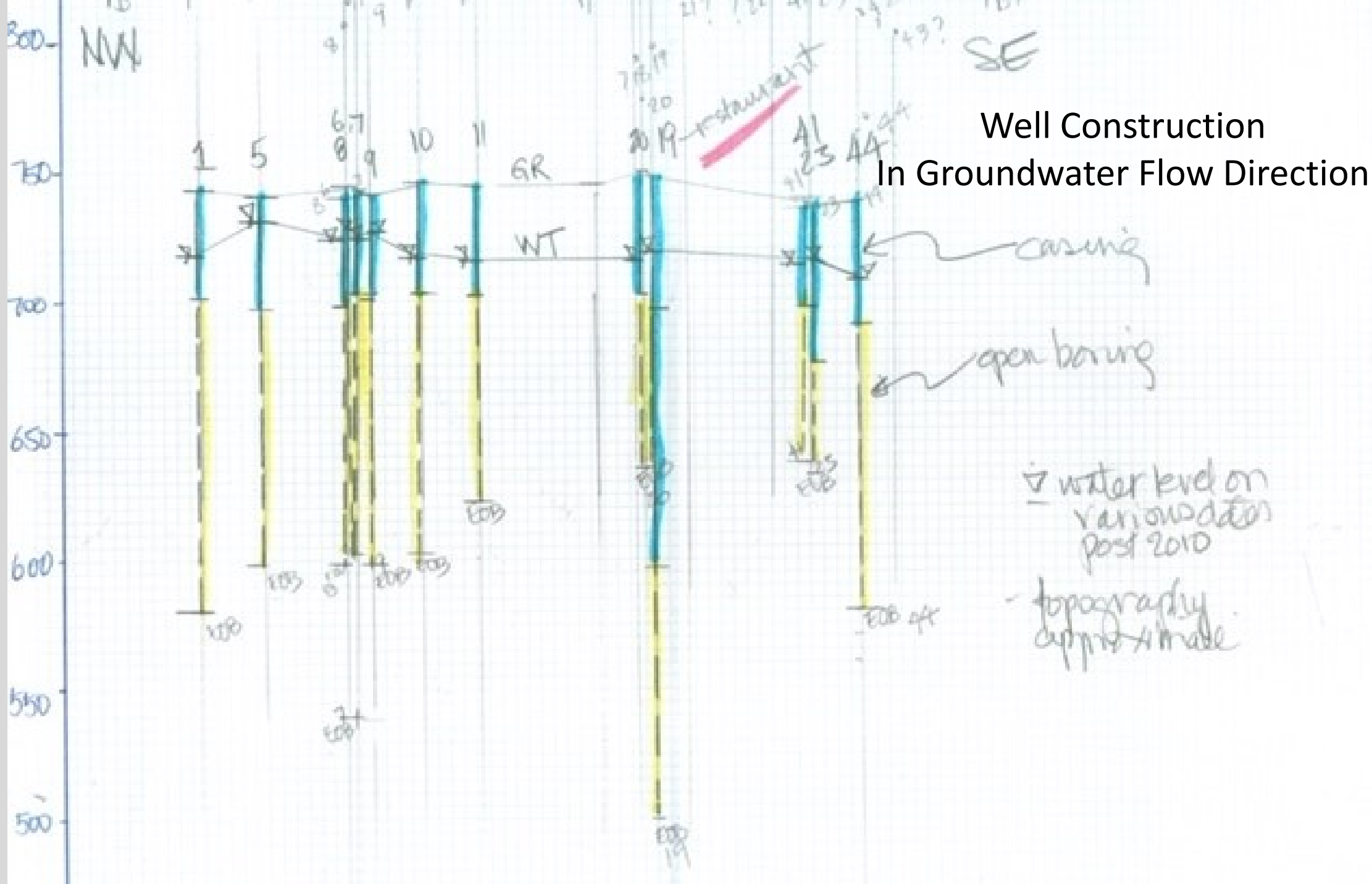


Approximate Static Groundwater Elevation on Completion
End of Boring Elevation < 600 fasl, Post 2010 Installation

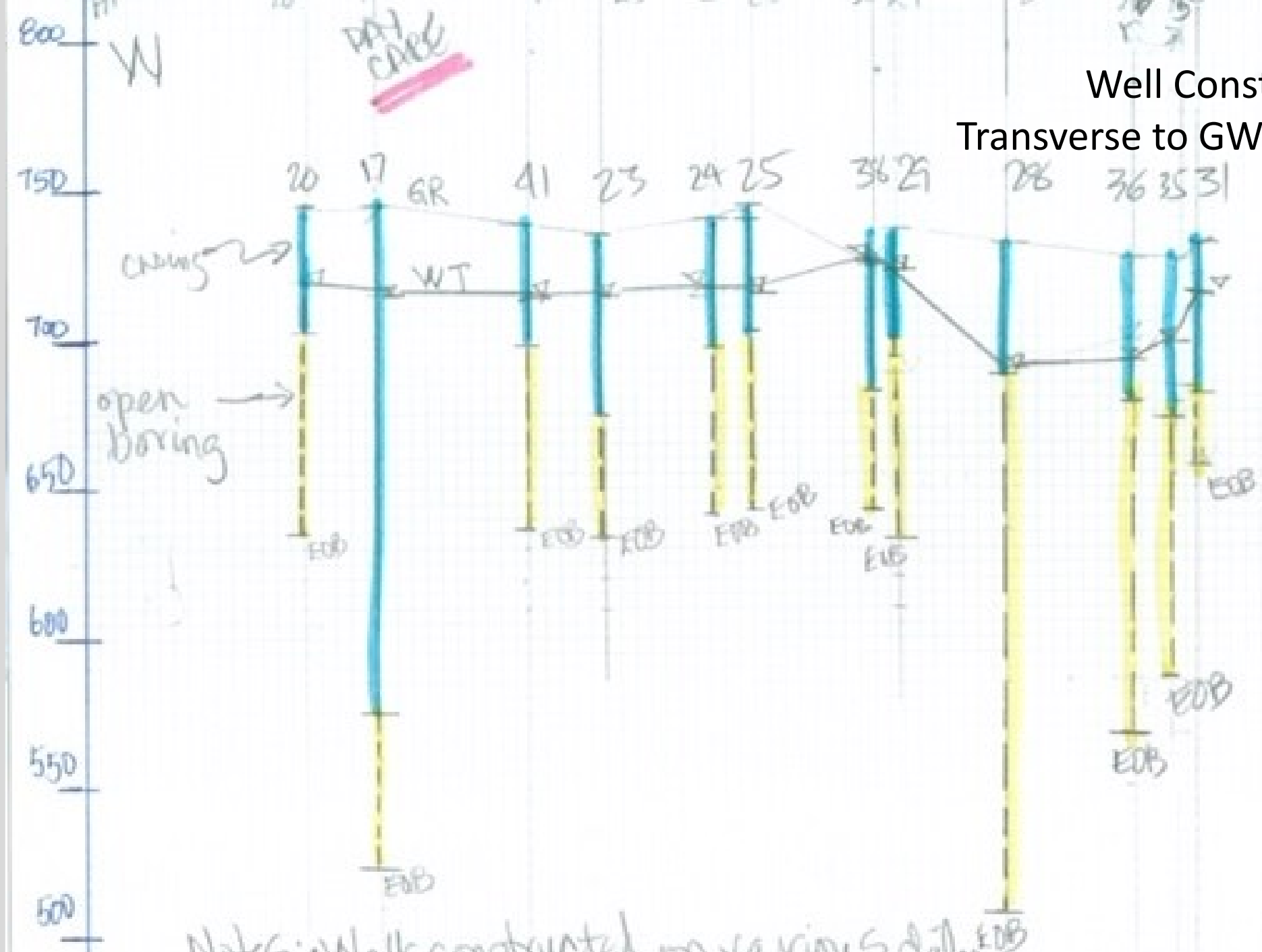
- >725 fasl
- 720-725 fasl
- 715-719 fasl
- 710-714 fasl
- 705-709 fasl
- 700-704 fasl
- 690-699 fasl
- <690 fasl

Cross-section-Location Map



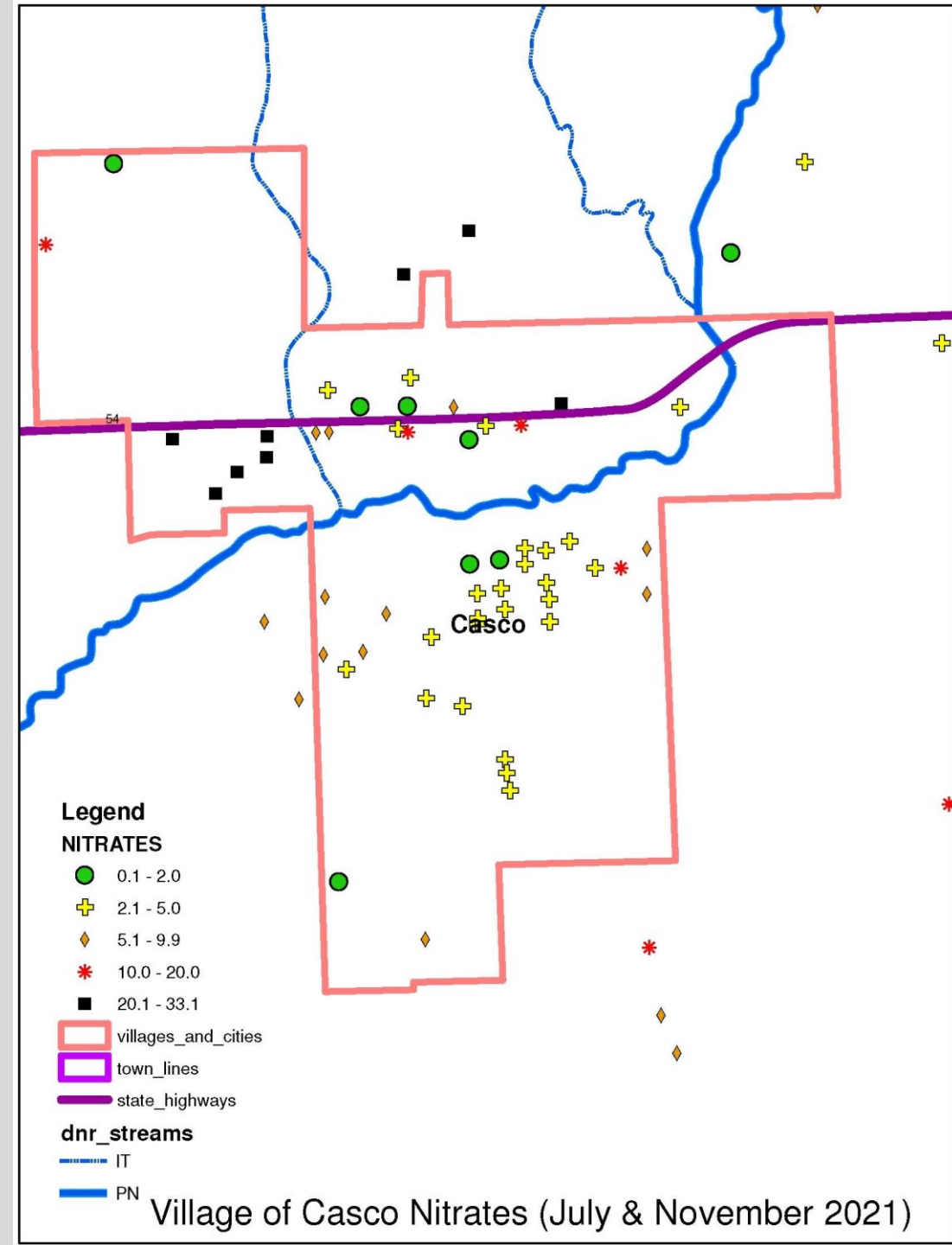


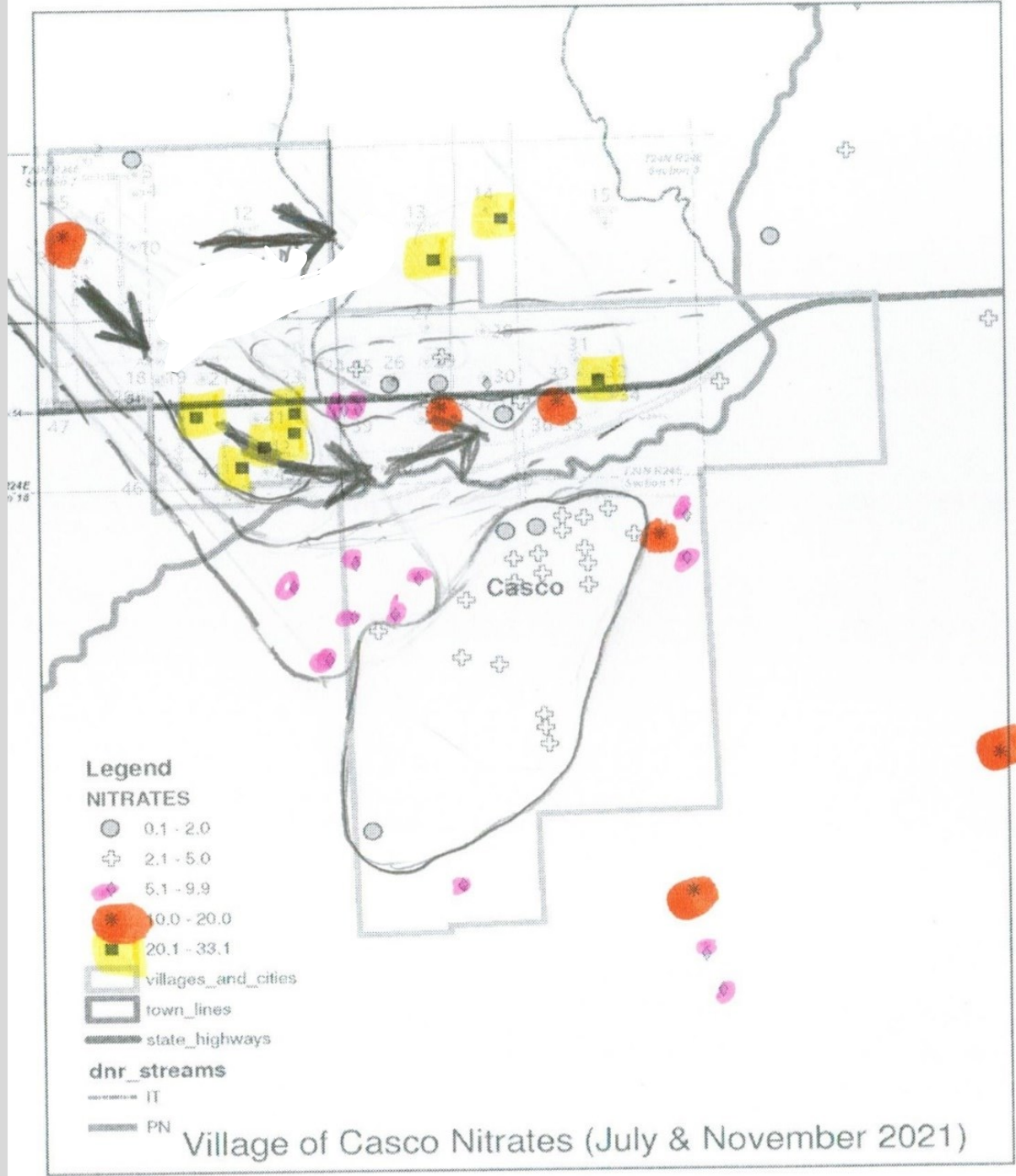
Well Construction Transverse to GW Flow Direction



Notes: Wells constructed on various dates

2021 Groundwater Nitrate Concentrations (mg/L)





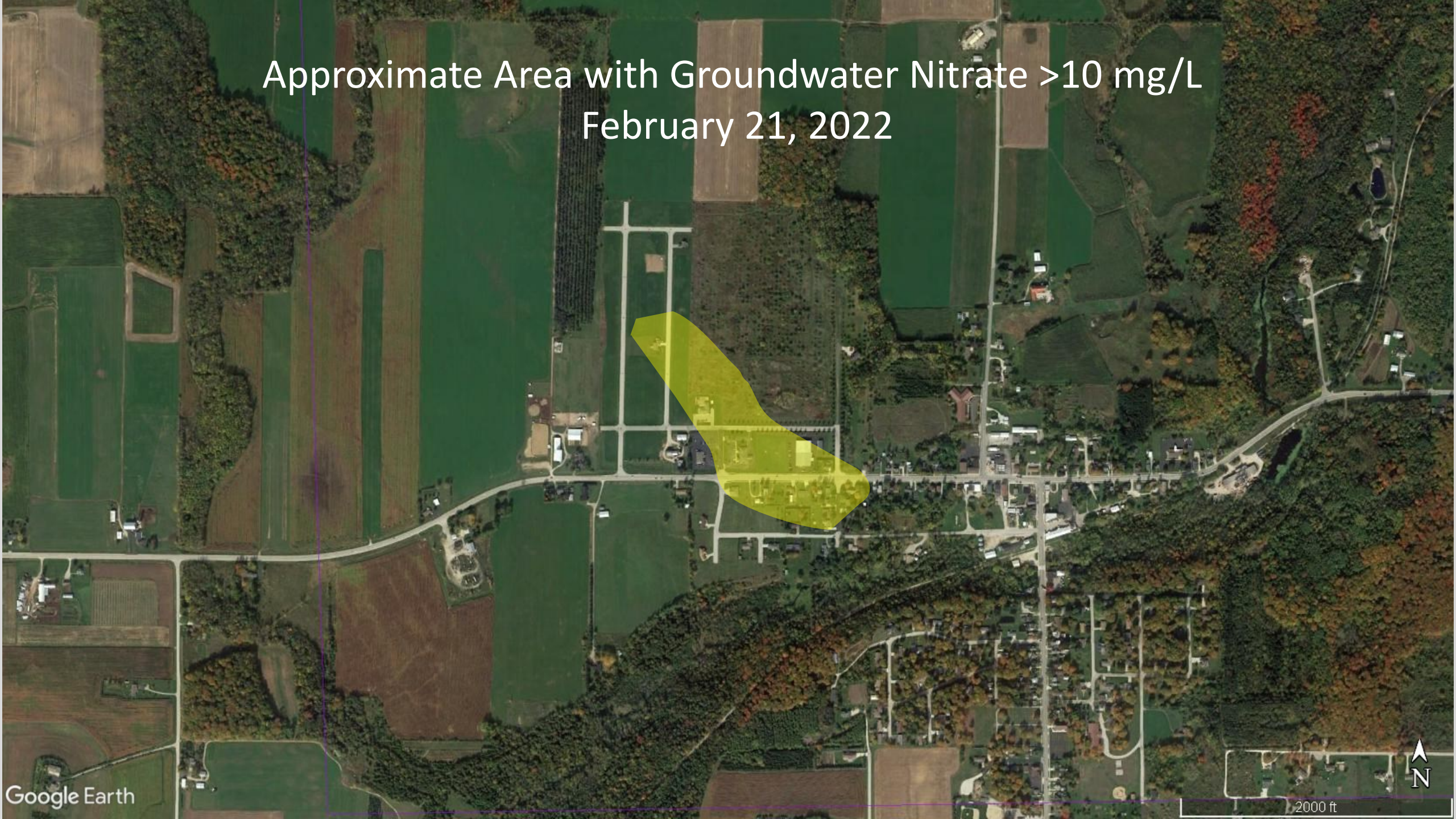
2021
 “Contoured Nitrate” and
 General Groundwater Flow Directions
 (North Side Casco Creek)

Our analysis: groundwater flowing from northwest to southeast in a narrow band had highest nitrate concentrations.

Study Area: 10 wells
February 21, 2022



Approximate Area with Groundwater Nitrate >10 mg/L
February 21, 2022



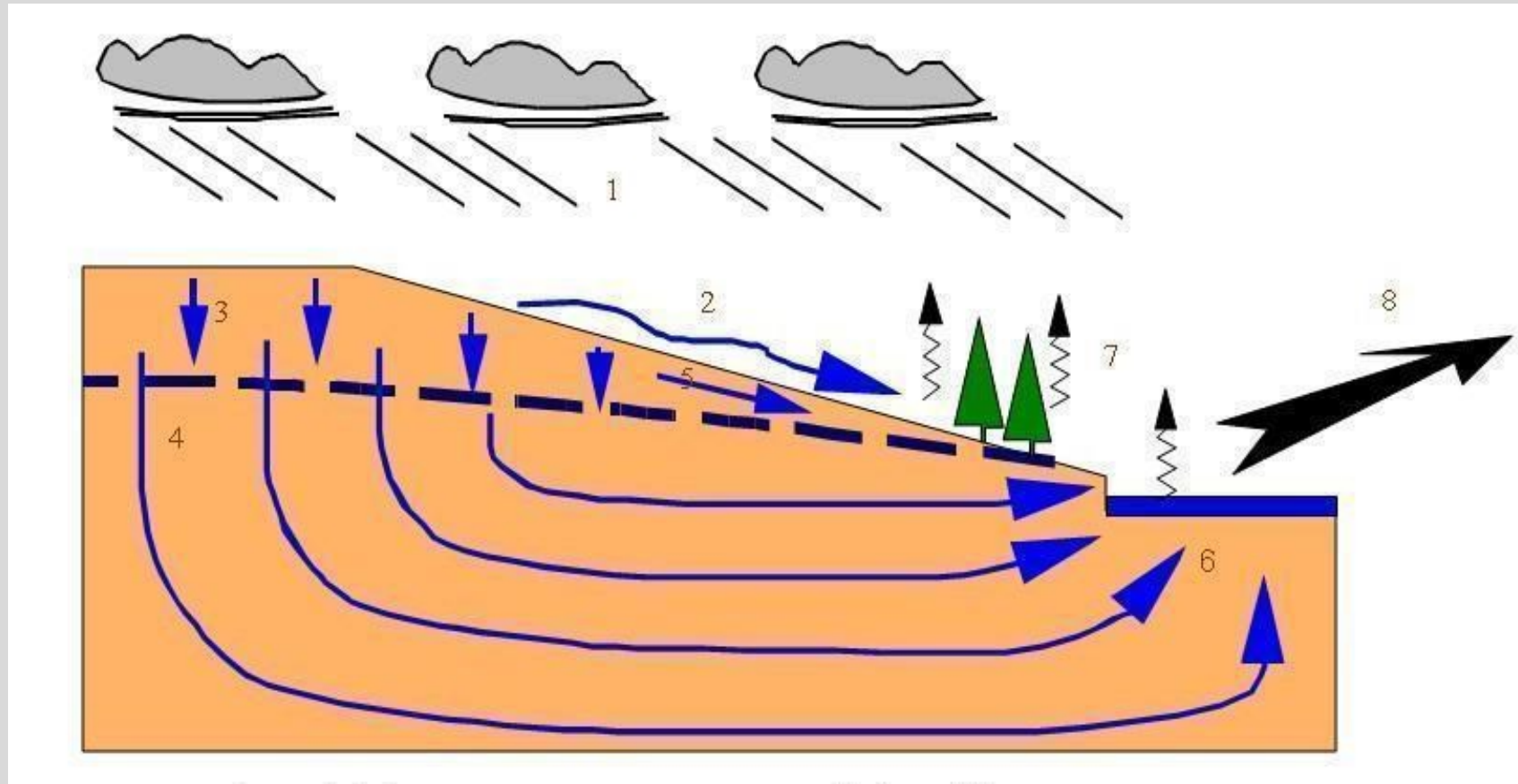
Brief Introduction to Isotope Hydrogeology



The Hydrologic Cycle:
endless transfer of water between the ocean,
atmosphere & land



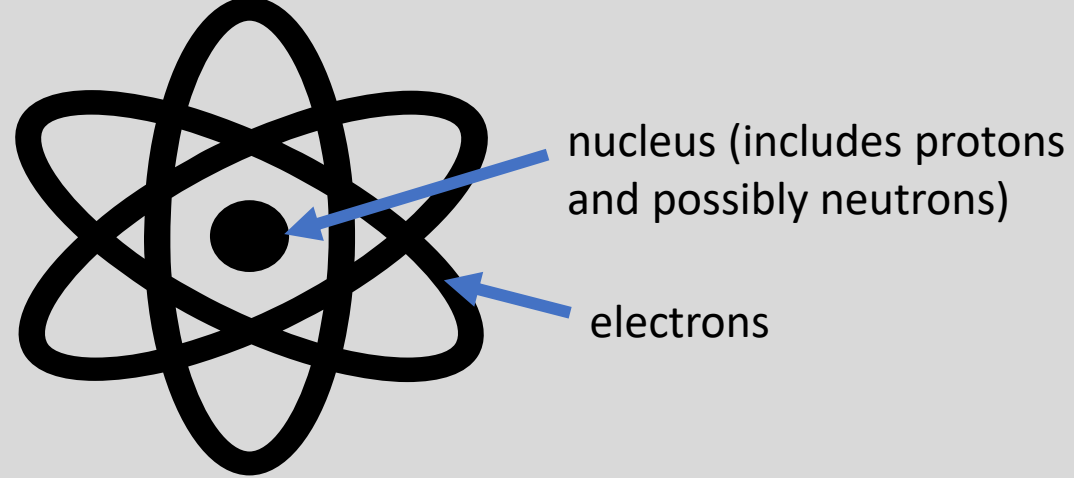
Hydrologic Cycle



1. precipitation
2. overland flow
3. infiltration
4. groundwater recharge

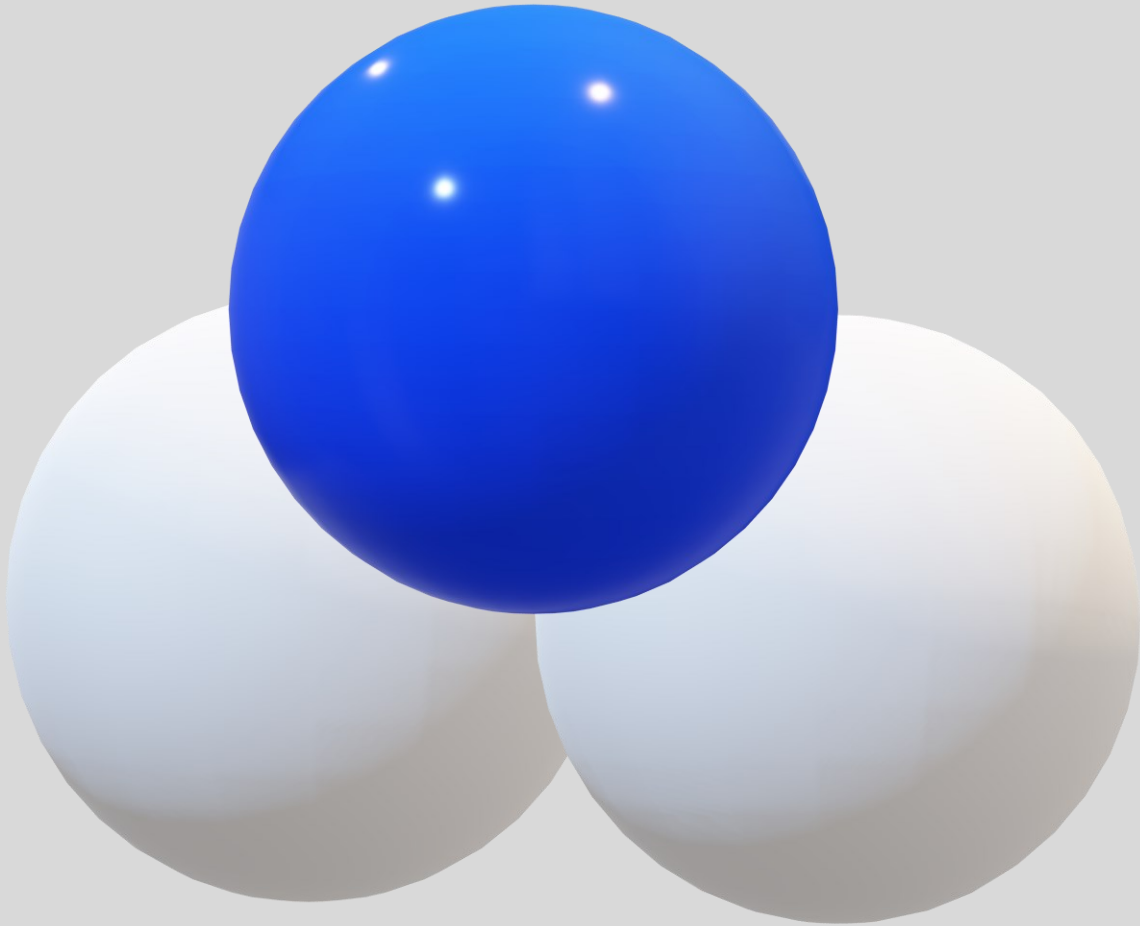
5. throughflow
6. groundwater discharge
7. evapotranspiration
8. stream flow

Environmental Isotope Hydrogeology Primer



1. “Isotopes” are versions of the atoms with different numbers of neutrons.
2. Protons and neutrons have mass, electrons do not.
3. Mass differences >> different behavior.
4. Environmental isotopes are “naturally” occurring isotopes, help solve hydrogeologic problems.
5. Environmental isotopes allow long-term “natural” tracer tests ... a different approach to groundwater investigations.
6. For Casco, we used isotopes in water molecules and in nitrate ions.

Water Isotopes



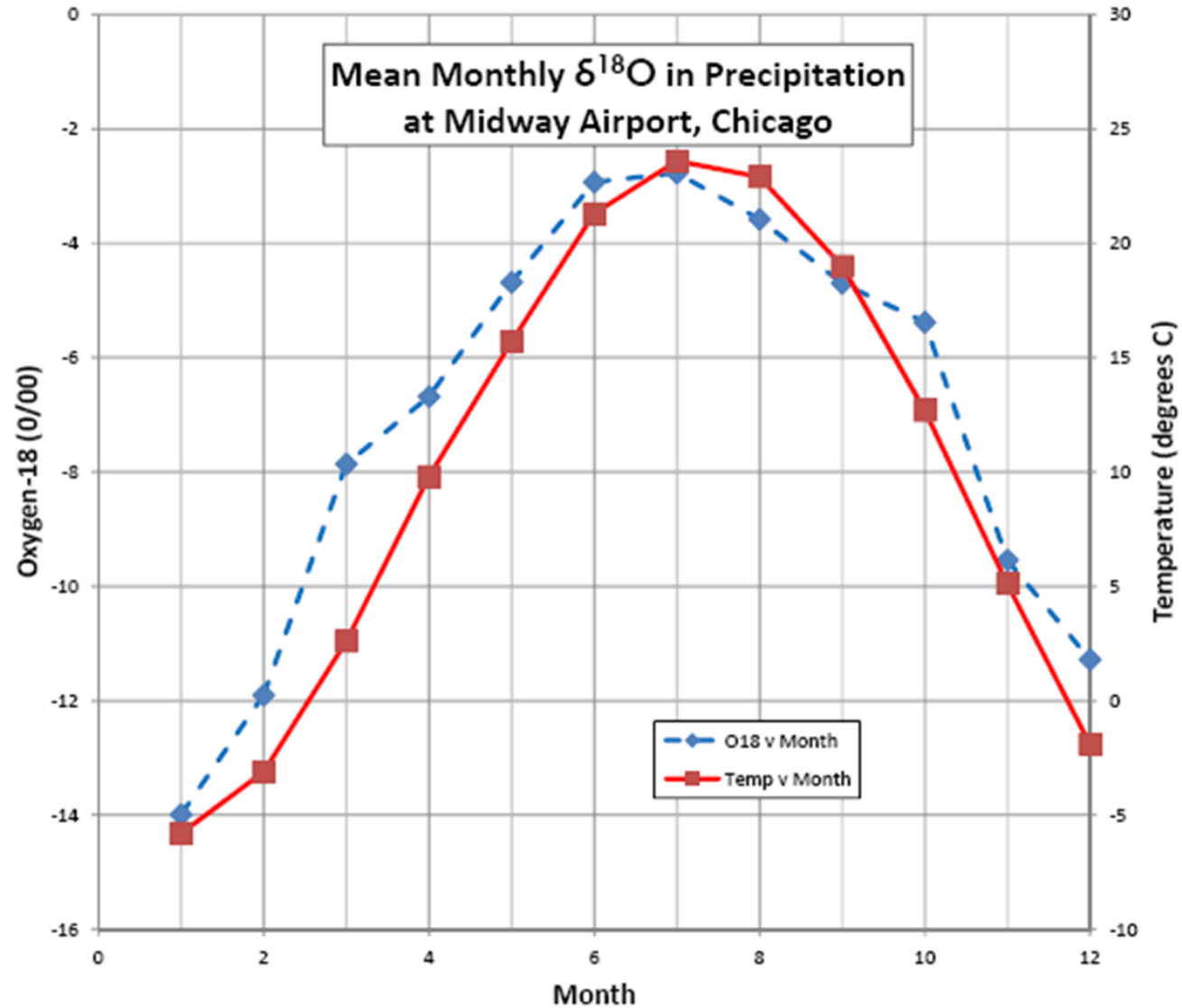
1. Chemical formula for water is H_2O .
2. Hydrogen (H) has three isotopes we use:
 - a) Protium ^1H
 - b) Deuterium ^2H
 - c) Tritium ^3H
3. Oxygen (O) has two isotopes we use:
 - a) Oxygen-16 ^{16}O
 - b) Oxygen-18 ^{18}O
4. Water molecules with heavier isotopes behave differently than water molecules with lighter isotopes.

What controls ^{18}O and ^2H concentrations in precipitation and groundwater?

- lighter isotopes tend to be more energetic
- lighter isotopes preferentially leave the liquid phase
- liquid phase becomes enriched in heavier isotope

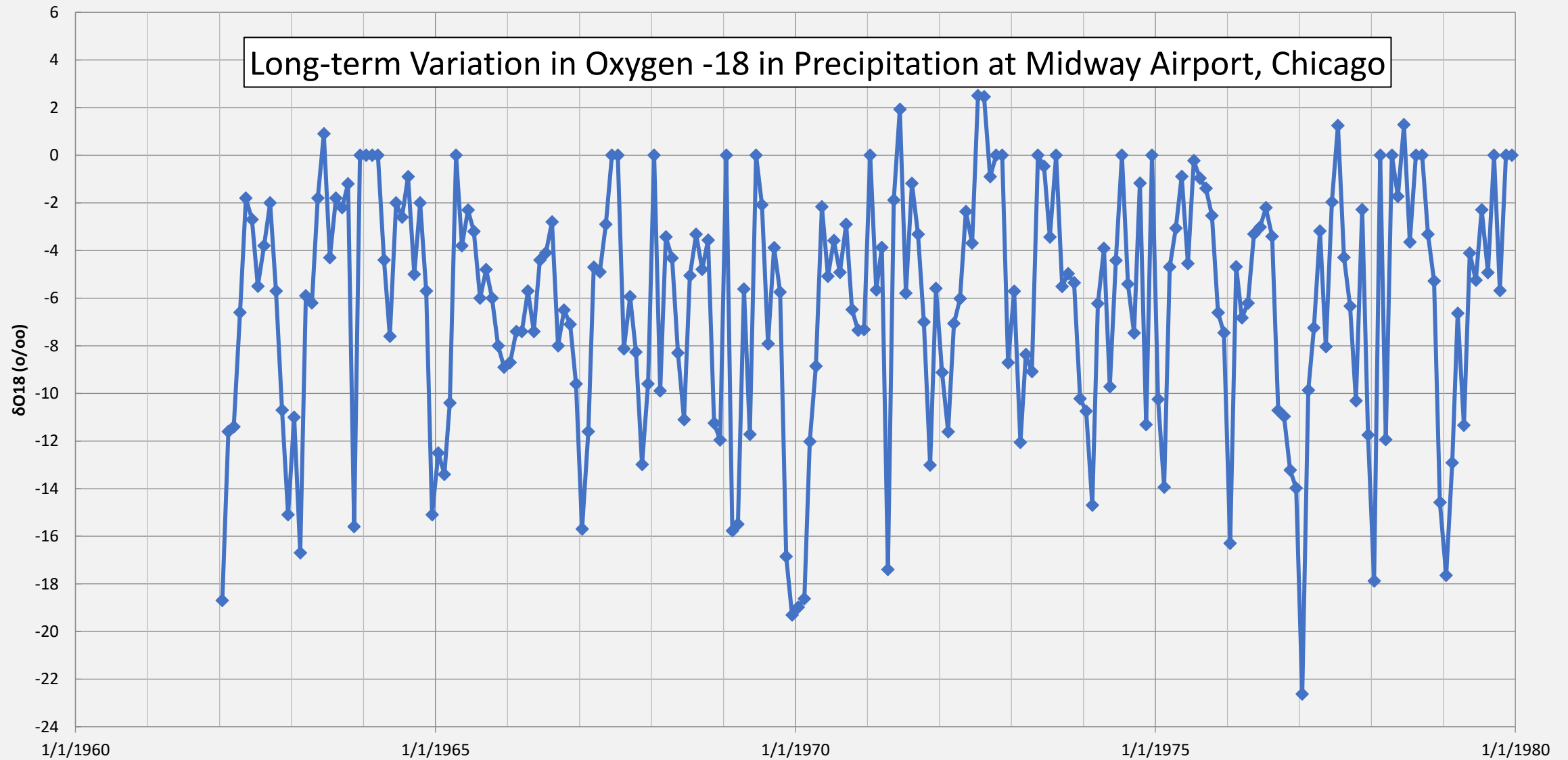


^{18}O concentrations in precipitation depend on temperature (values are more negative in winter, less negative in summer)

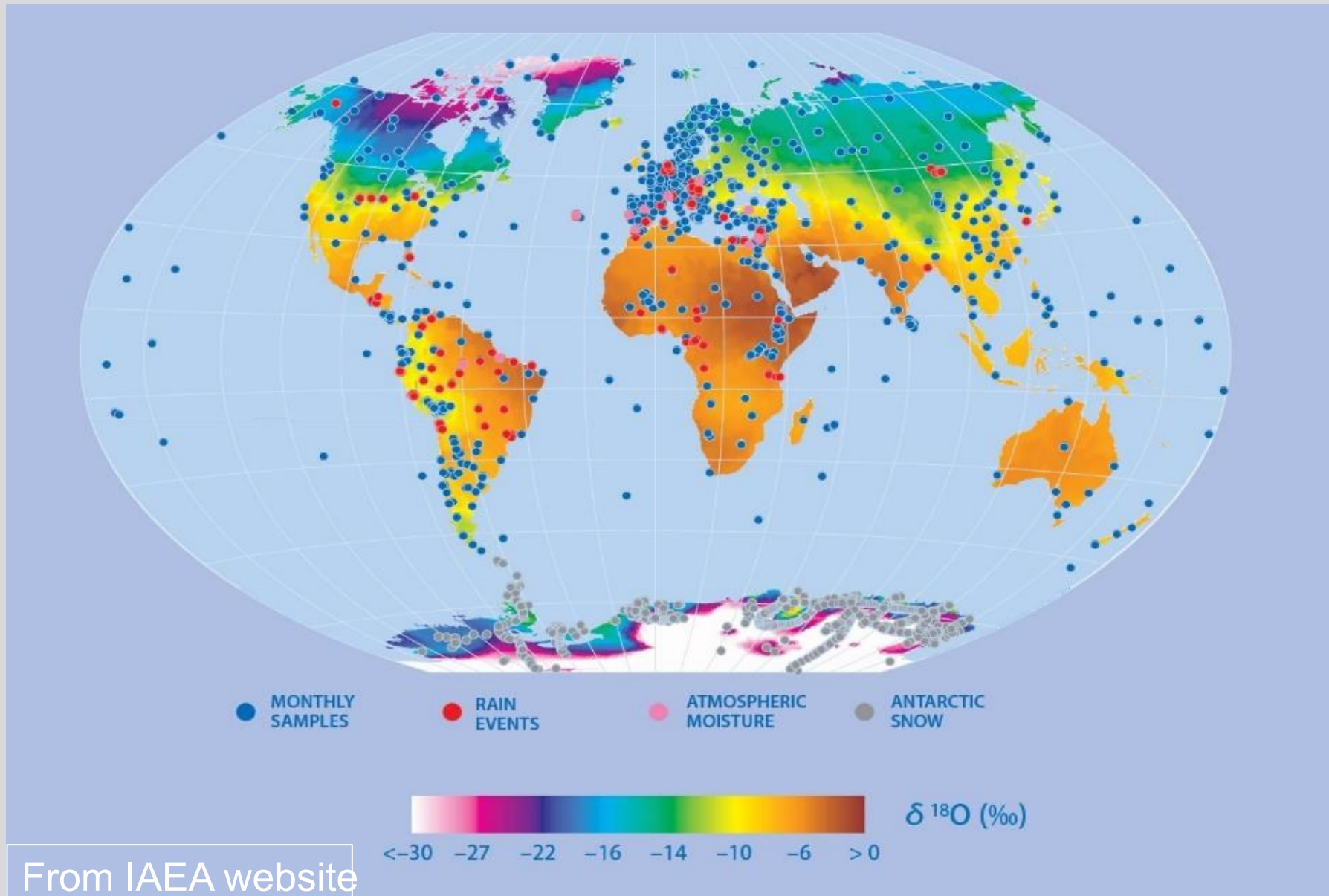


^{18}O concentrations in precipitation depend on temperature

(values are more negative in winter, less negative in summer)



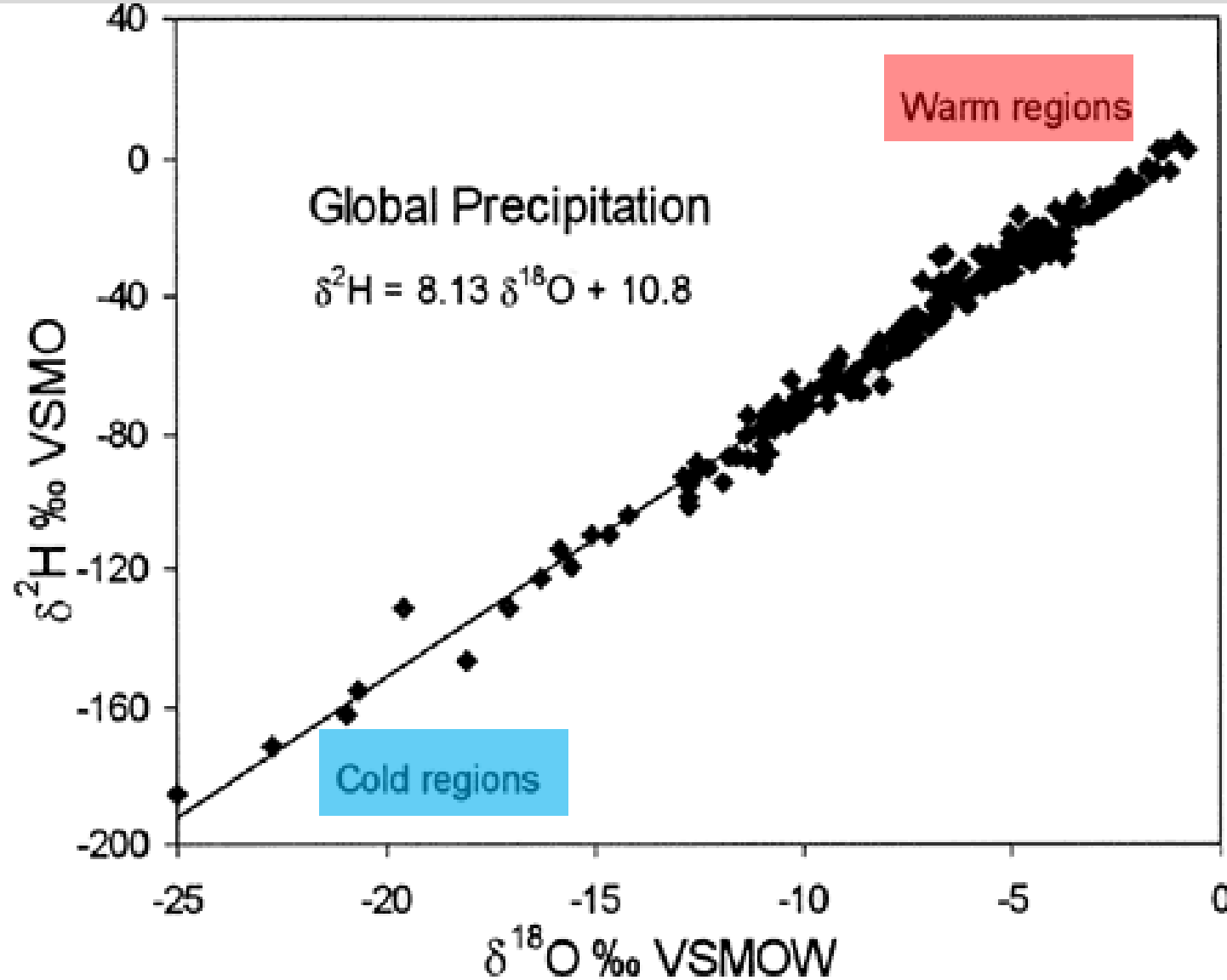
^{18}O concentrations in precipitation depend on location/temperature
(values are colder areas are more negative, less negative in warmer areas)



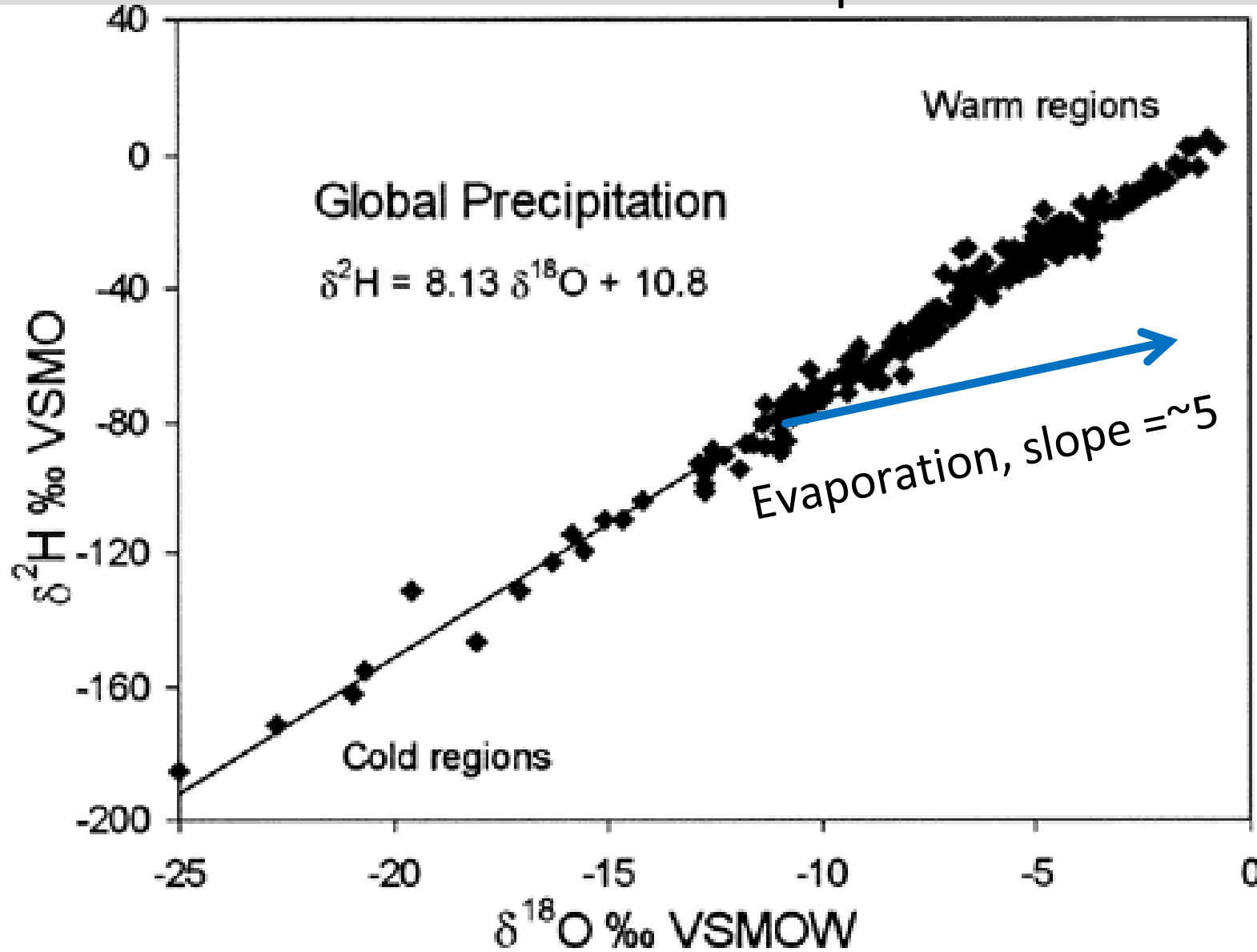
From IAEA website

^{18}O and ^2H concentrations in precipitation are linearly related

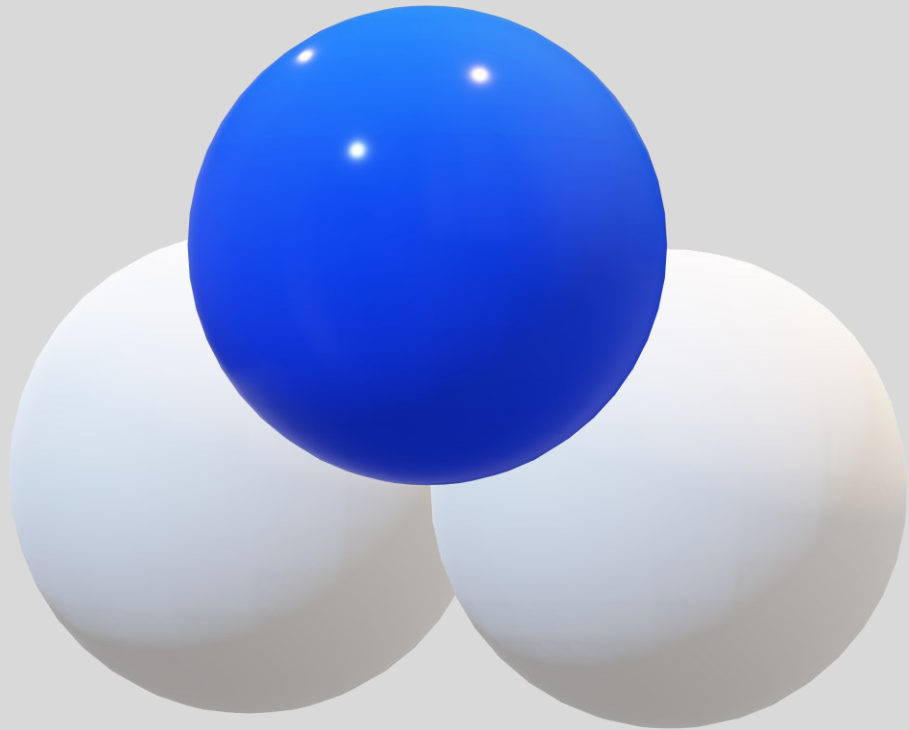
(“global meteoric water line” summarizes values across the globe, each area on the globe has a slightly different meteoric water line)



^{18}O and ^2H concentrations in evaporated water (like in a lake) take on a different slope



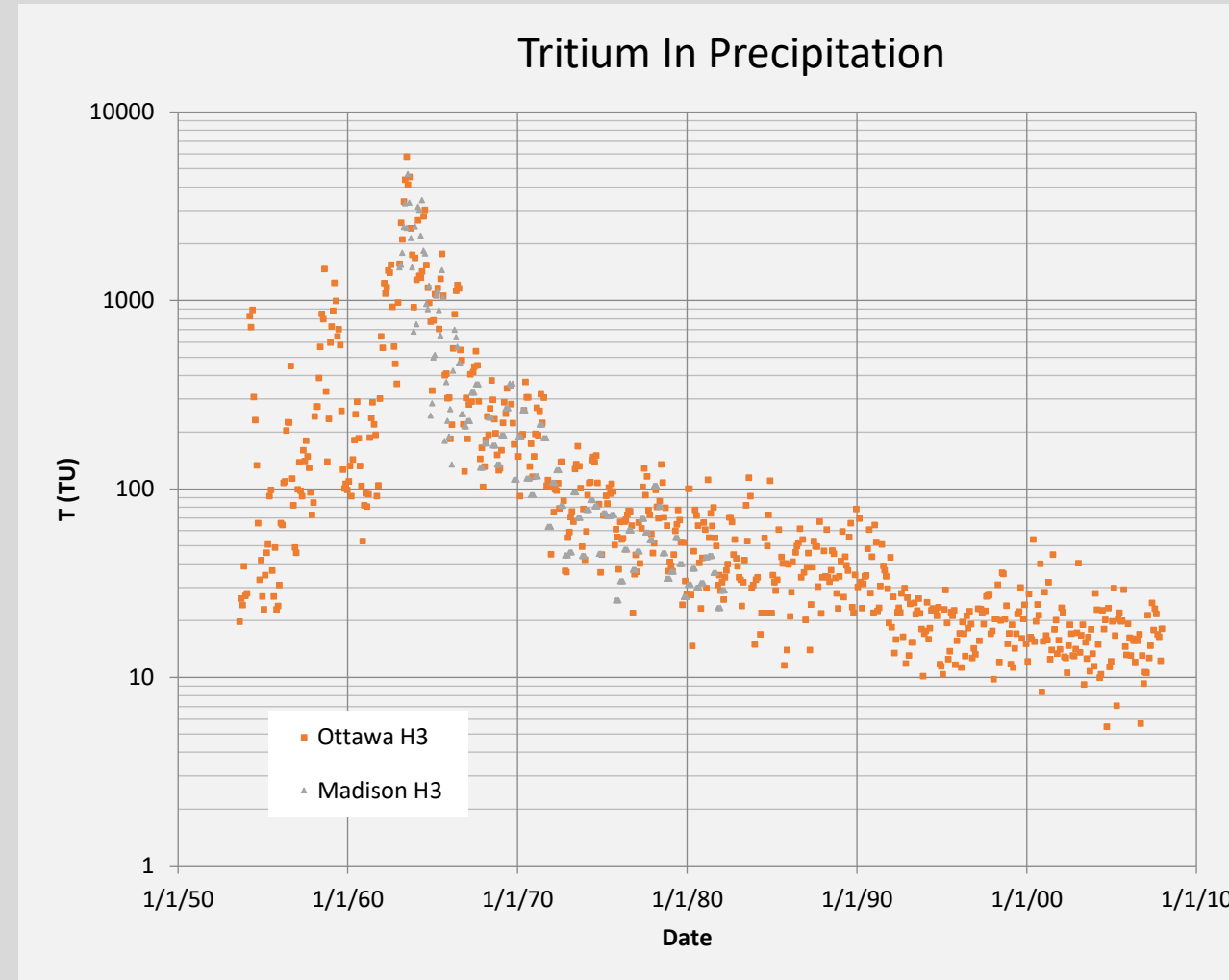
Typical Uses of ^{18}O and ^2H Isotopes



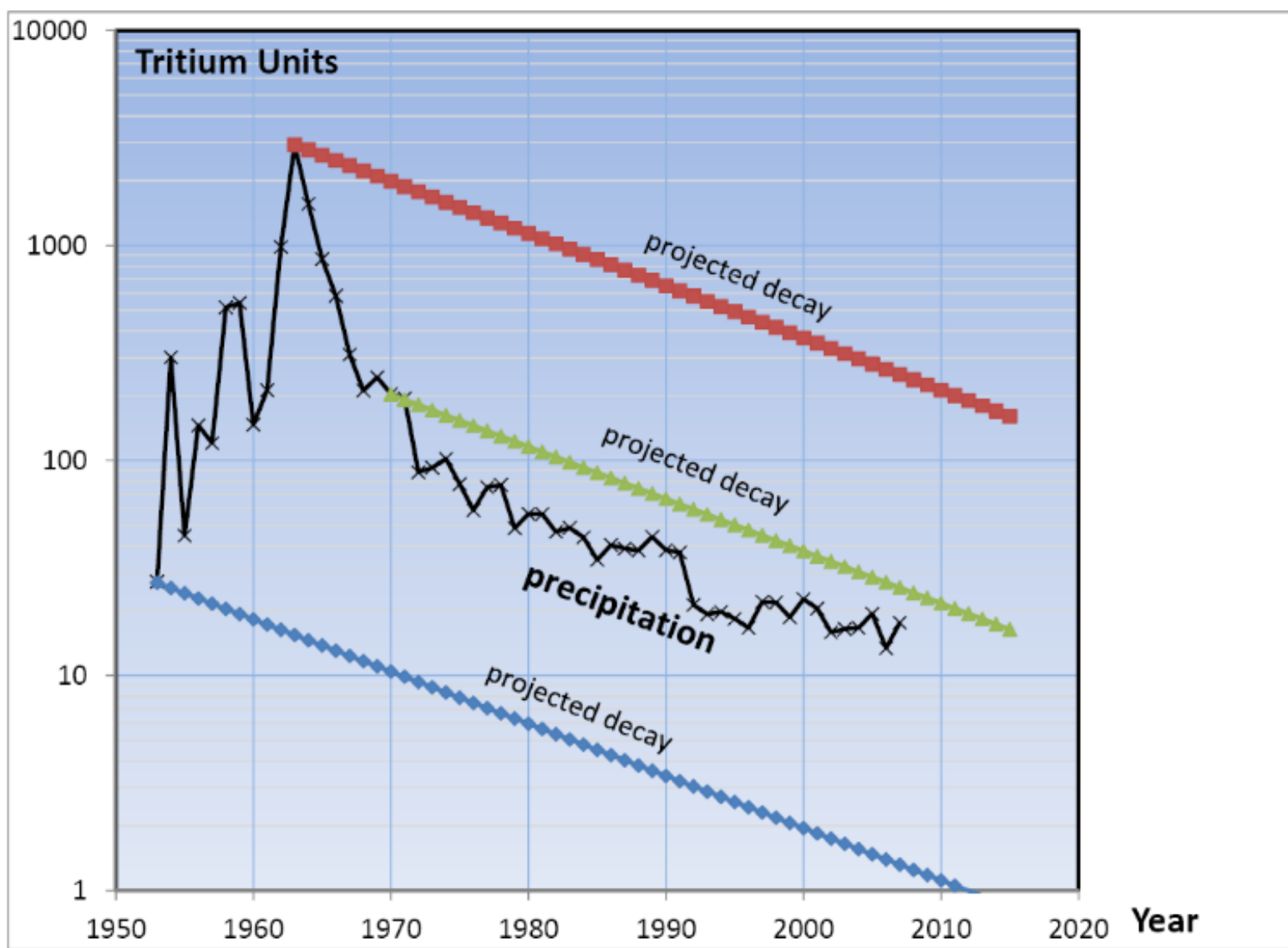
1. Distinguish between glacial age groundwater (1000s of years old) and recent recharge.
2. Identify groundwater that has been evaporated (flow-through lakes).
3. Determine amount of groundwater in storm runoff in streams.
4. Evaluate extent of landfill leachate plumes.

What controls tritium (H^3) concentrations in precipitation and groundwater?

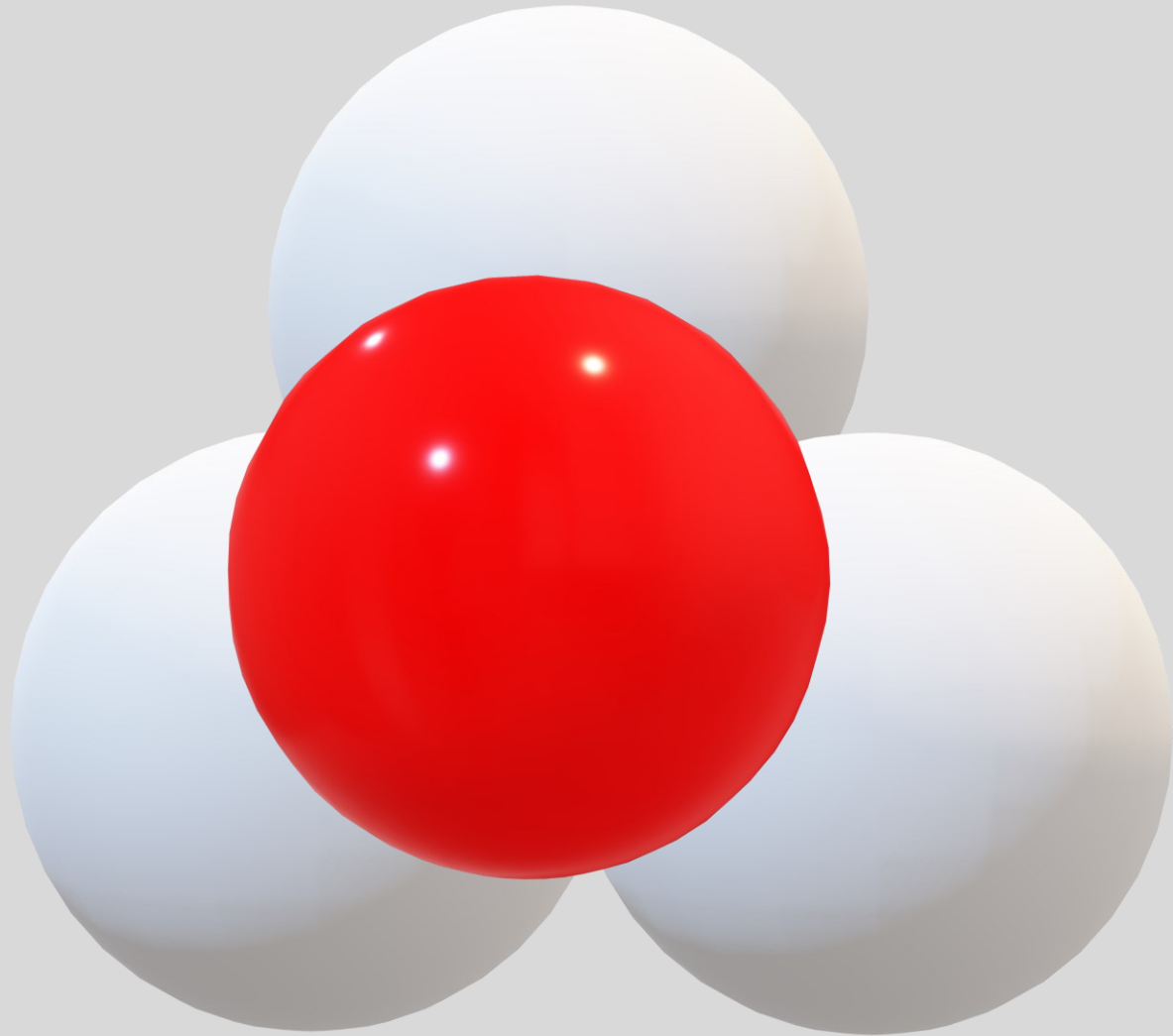
- concentration in “tritium units” (TU)
 - 1TU = 1 tritium in 10^{18} protiums
- natural tritium < 25 TU
- atmospheric testing of nuclear bombs started in 1950s
- peak values in 1000's of TU in ~1963
- atmospheric test ban treaty 1963
- radiogenic with half-life of ~12.3 years



Typical Use of ^3H – Determining Age of Groundwater by Aging Tritium in Precipitation



Nitrate Isotopes



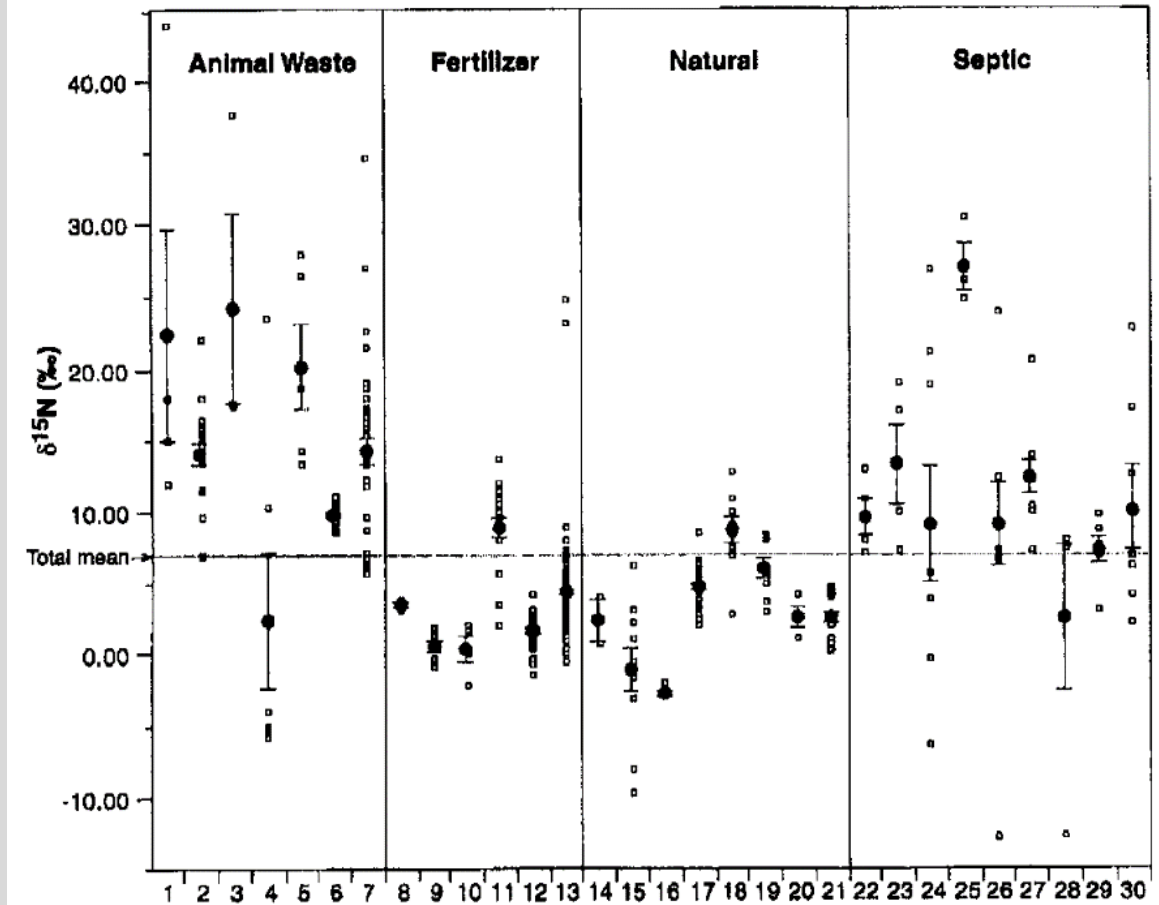
1. Chemical formula for nitrate is NO_3^- .
2. Nitrogen (N) has two isotopes we use:
 - a) ^{14}N
 - b) ^{15}N
3. Oxygen (O) has two isotopes we use:
 - a) Oxygen-16 ^{16}O
 - b) Oxygen-18 ^{18}O
4. Heavier versus lighter isotopes in nitrate depends on origin of nitrate (mineral, animal/human waste, water source, biological processes, etc.)

Spatial Variation in Nitrogen Isotope Values Beneath Nitrate Contamination Sources

by Graham E. Fogg^{a,b,c}, D.E. Rolston^{a,b}, D.L. Decker^{a,d}, D.T. Louie^a, and M.E. Grismer^{a,b}

Observed ranges of ^{15}N isotope composition by activity determined from existing plots used exclusively for animals, chemical fertilizer, septic systems, or natural.

Fogg et al. (1998)



^aDept. of Land, Air and Water Resources, University of California, Davis, CA 95616.

^bHydrologic Sciences, University of California, Davis, CA 95616.

^cDept. of Geology, University of California, Davis, CA 95616.

^dNow at Hydrogeology Program, University of Nevada, Reno.

Received August 1996, accepted September 1997.

tifying NO_3 sources with greater certainty.

According to literature sources (Figure 1), average $\delta^{15}\text{N}$ values of soil water NO_3 (excluding ground water samples) from sites beneath animal waste, fertilizer, soil organic nitrogen ("natural"), and sewer septic sources typically range from +10 to +25, 0 to +5, -3 to +5, and +7 to +15‰, respectively. Variability of val-

Ranges of ^{15}N and ^{18}O in nitrate
Spalding et al. (2019)

Note:

Animal waste includes human waste,
such as septic system effluent.

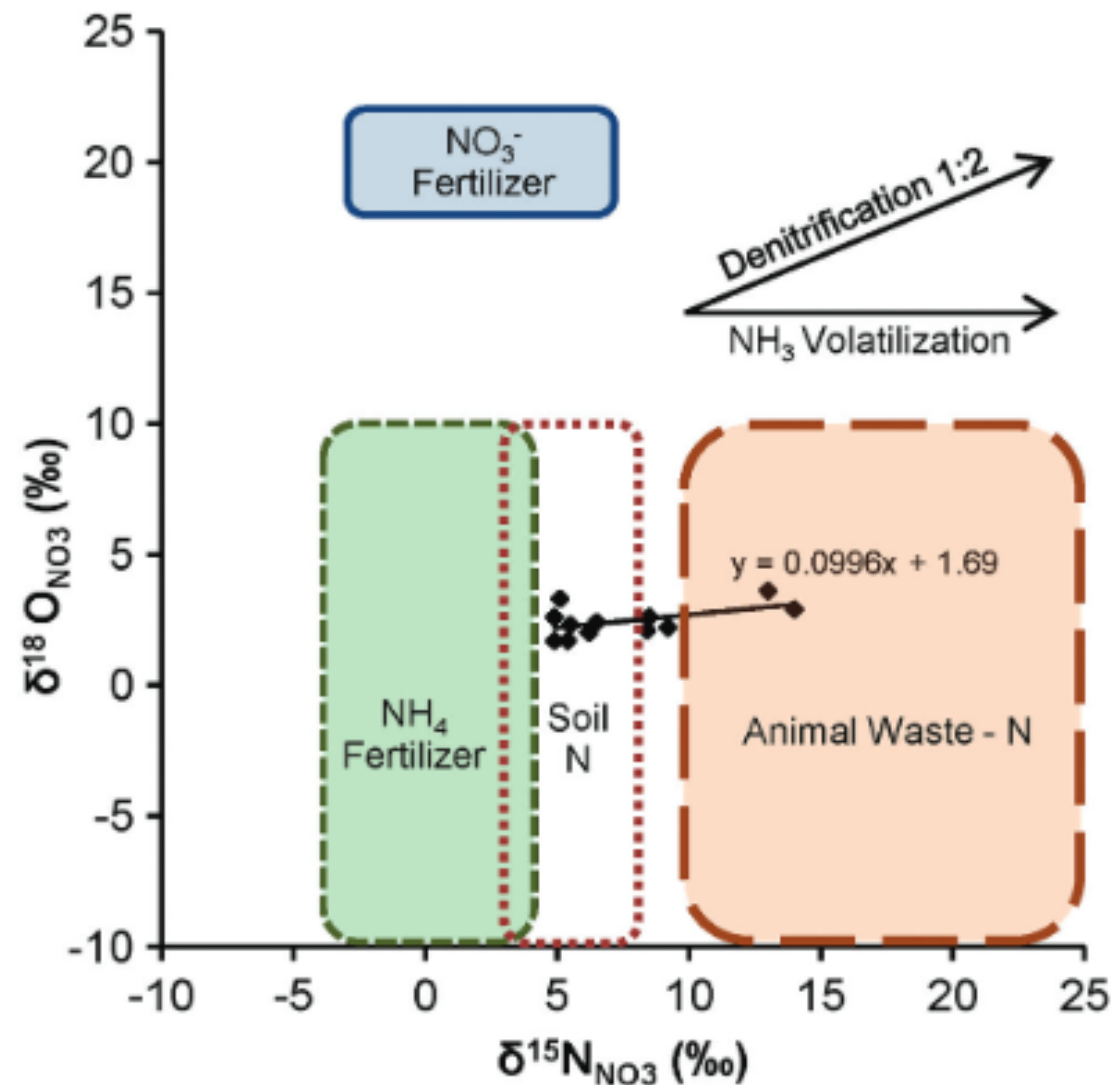
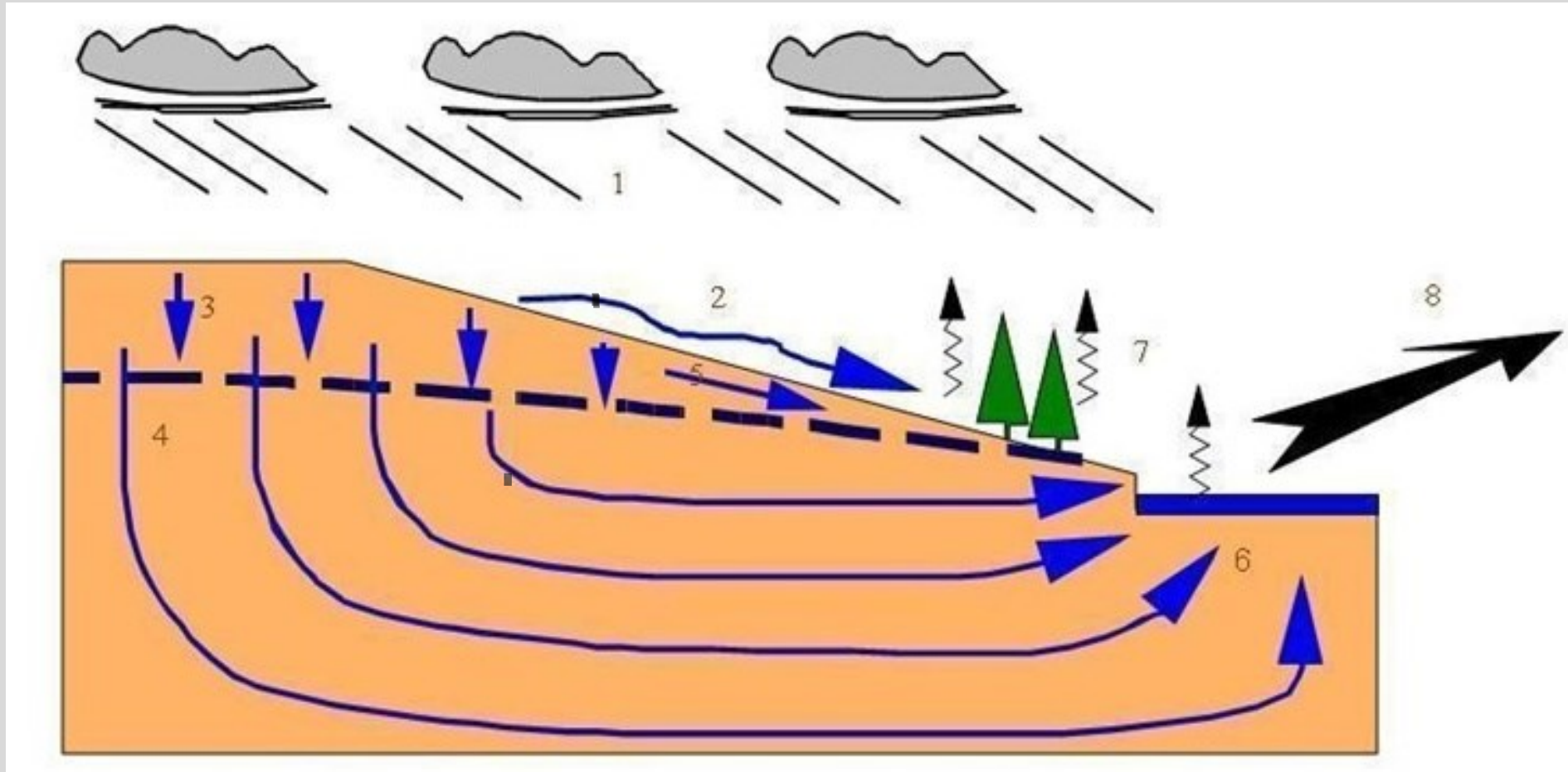


Figure 3. Dual isotope N-source envelopes and high-capacity well DIM results.

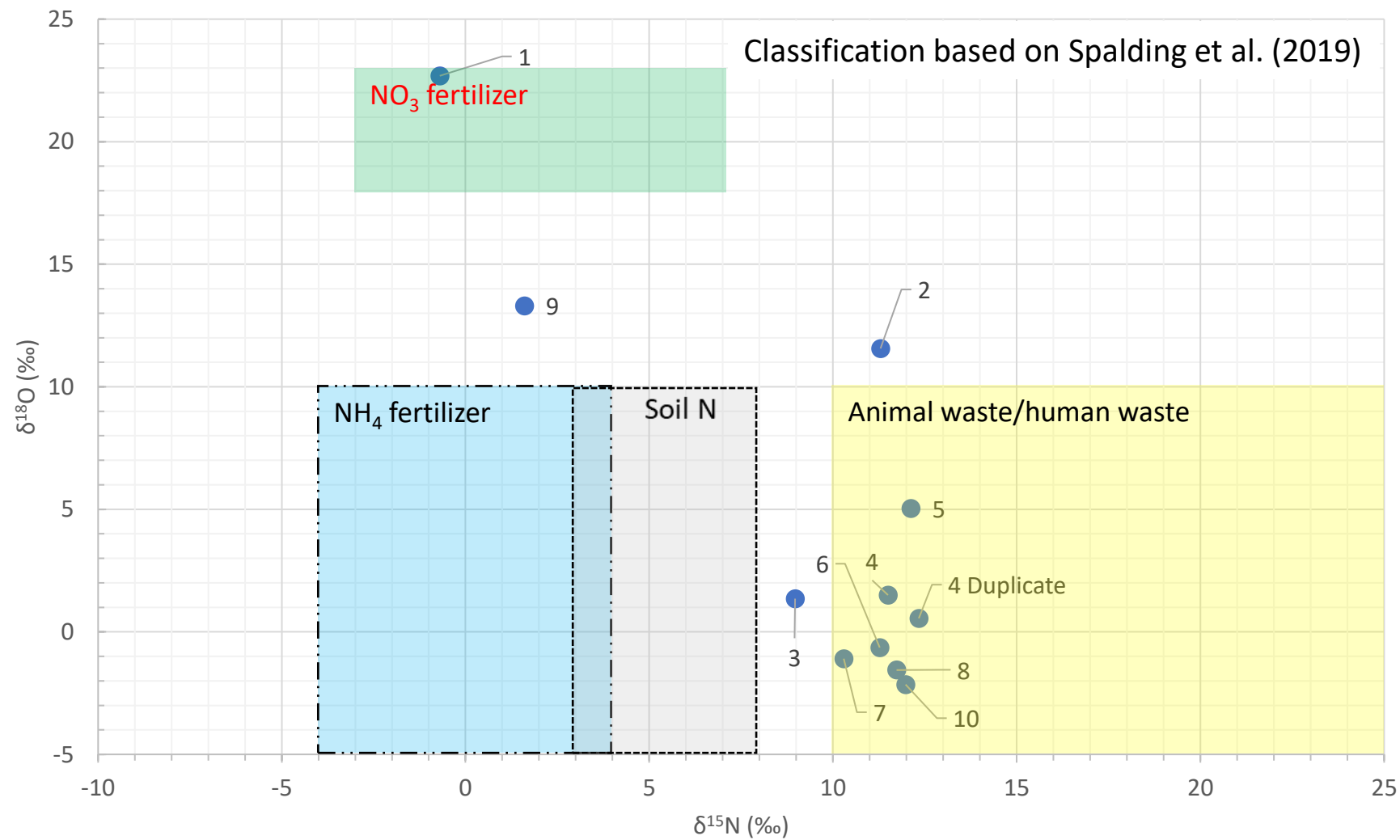
Assumptions we use: Limited Mixing in Groundwater Flow Systems



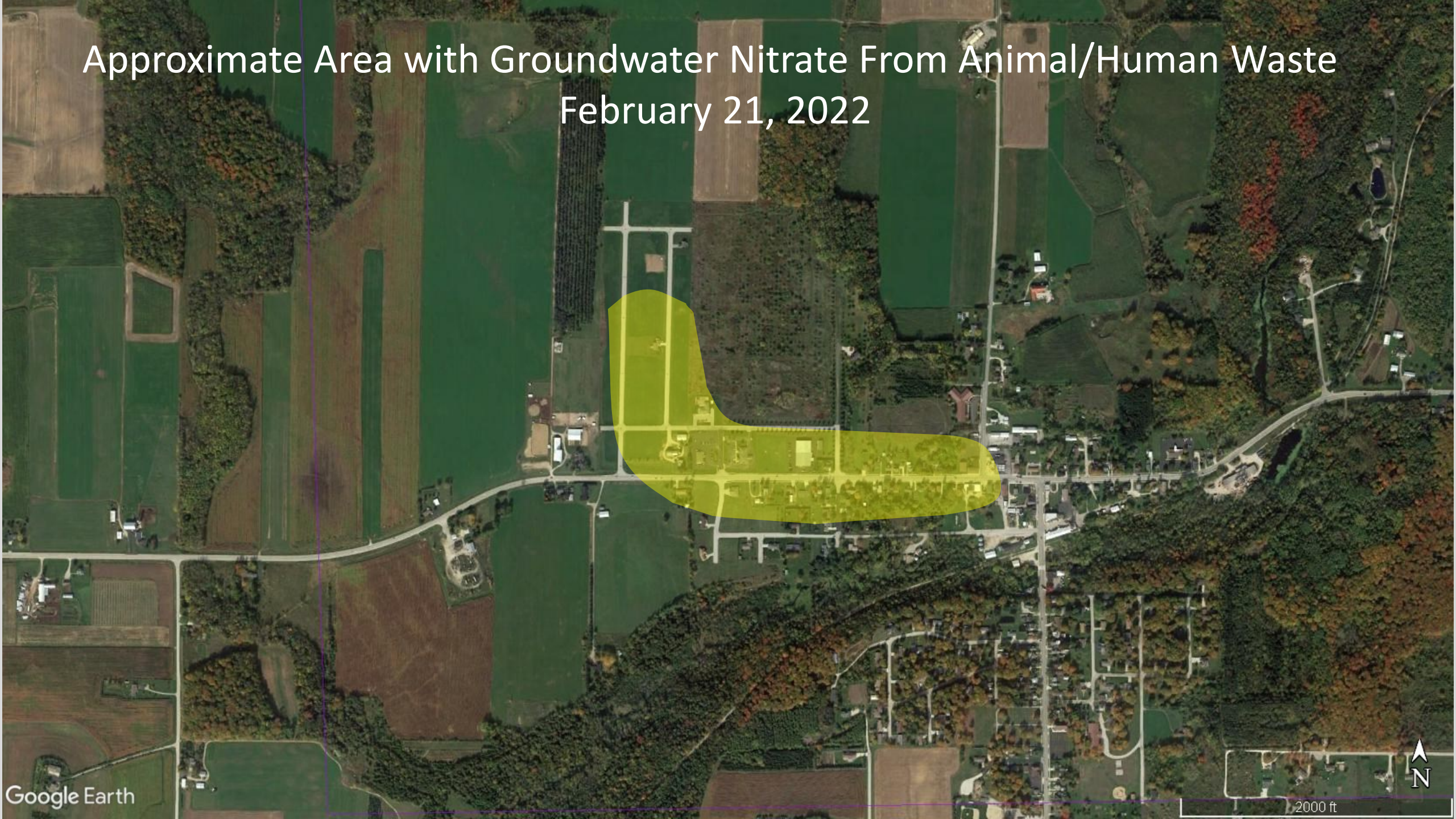
Isotope Hydrogeology Results – February 2022 Data

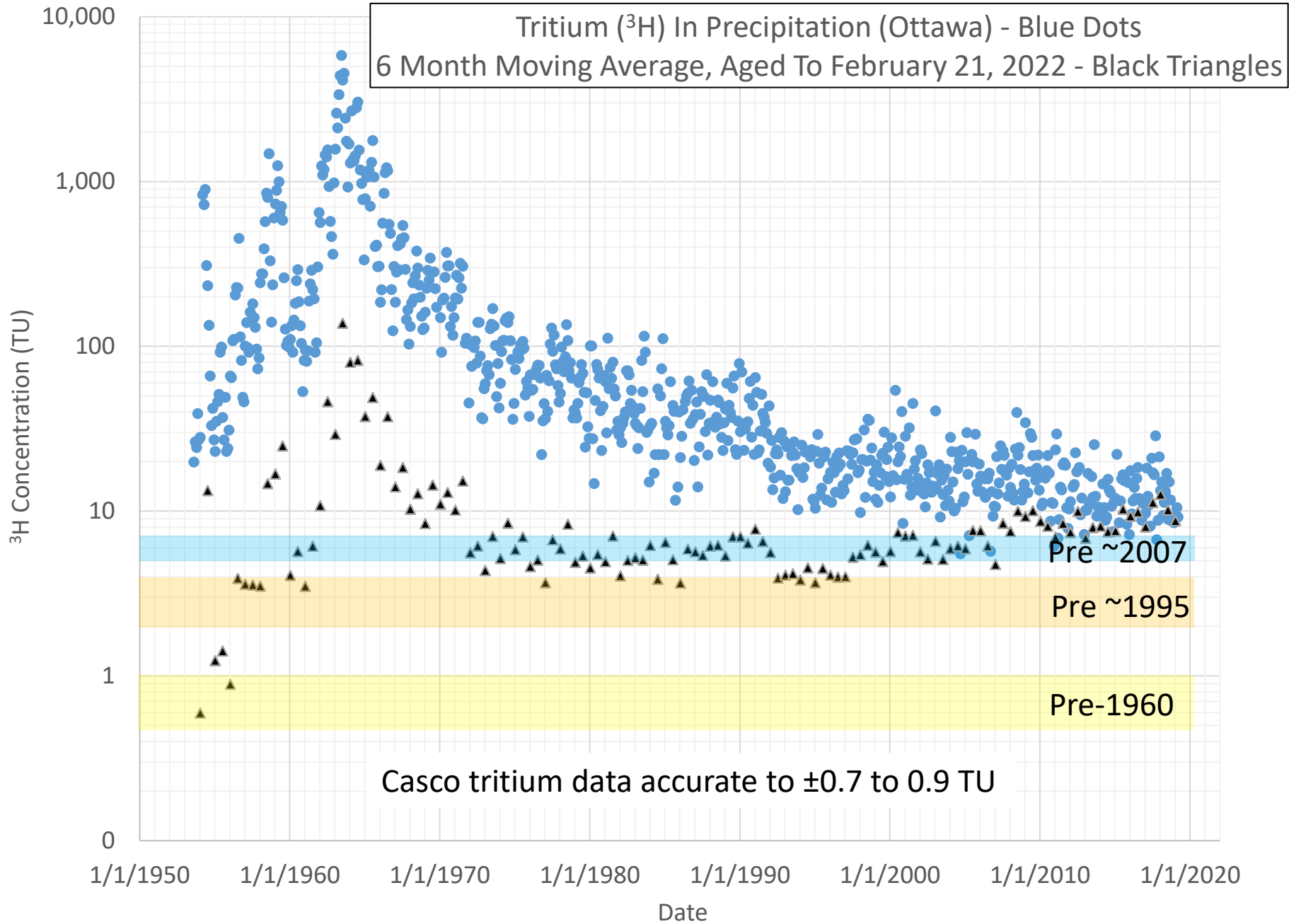


Casco, WI: $\delta^{15}\text{N}$ versus $\delta^{18}\text{O}$ in Nitrate, February 2022



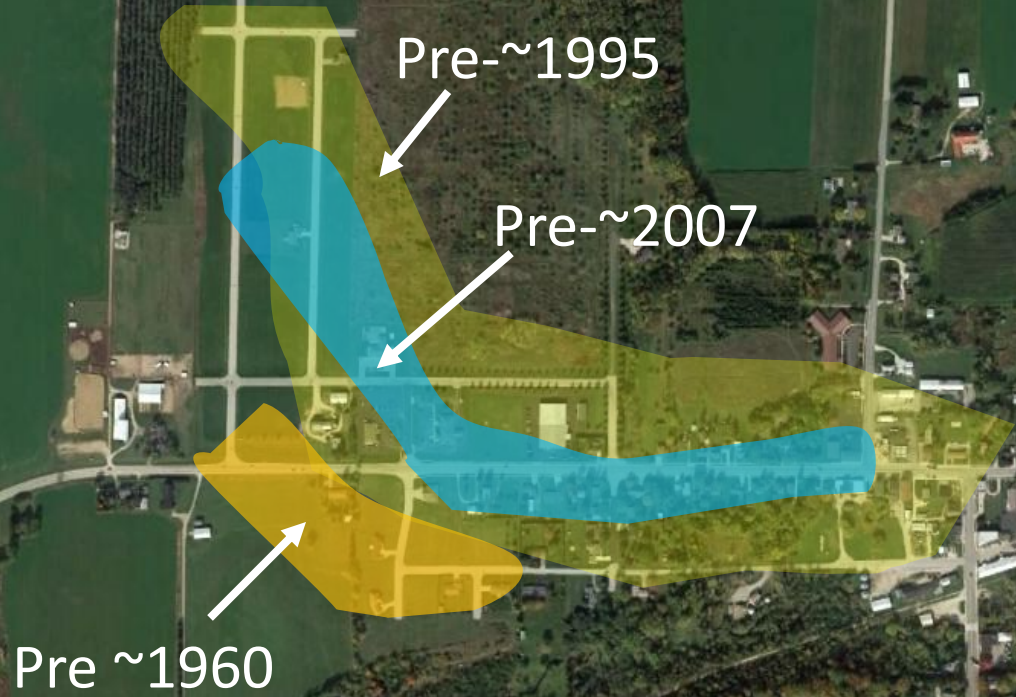
Approximate Area with Groundwater Nitrate From Animal/Human Waste February 21, 2022



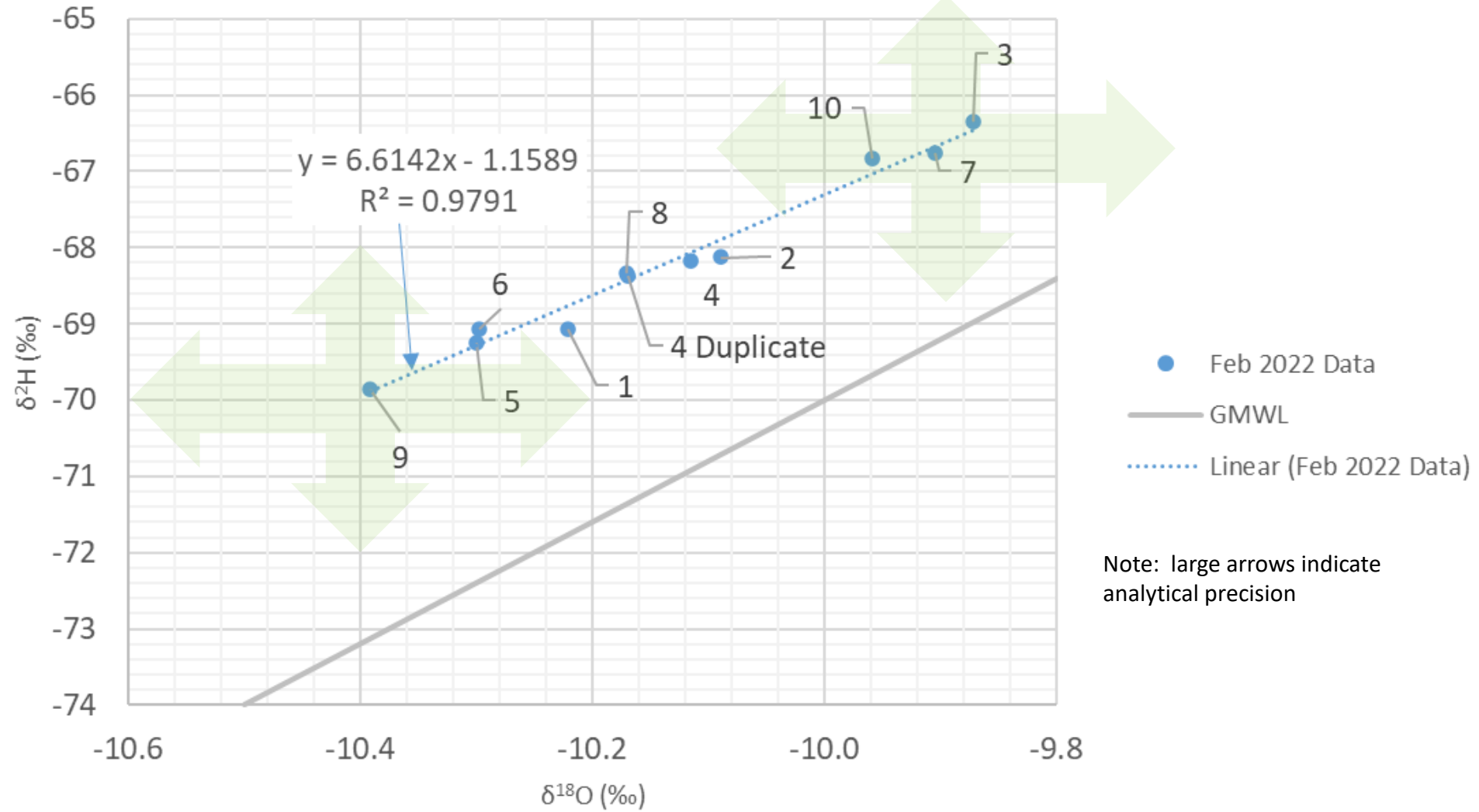


Casco	
Sample #	^3H (TU)
1	3.1
2	3.5
3	5.8
4	2.4
5	<0.8
6	2.8
7	6.7
8	5.5
9	0.9
10	5.2

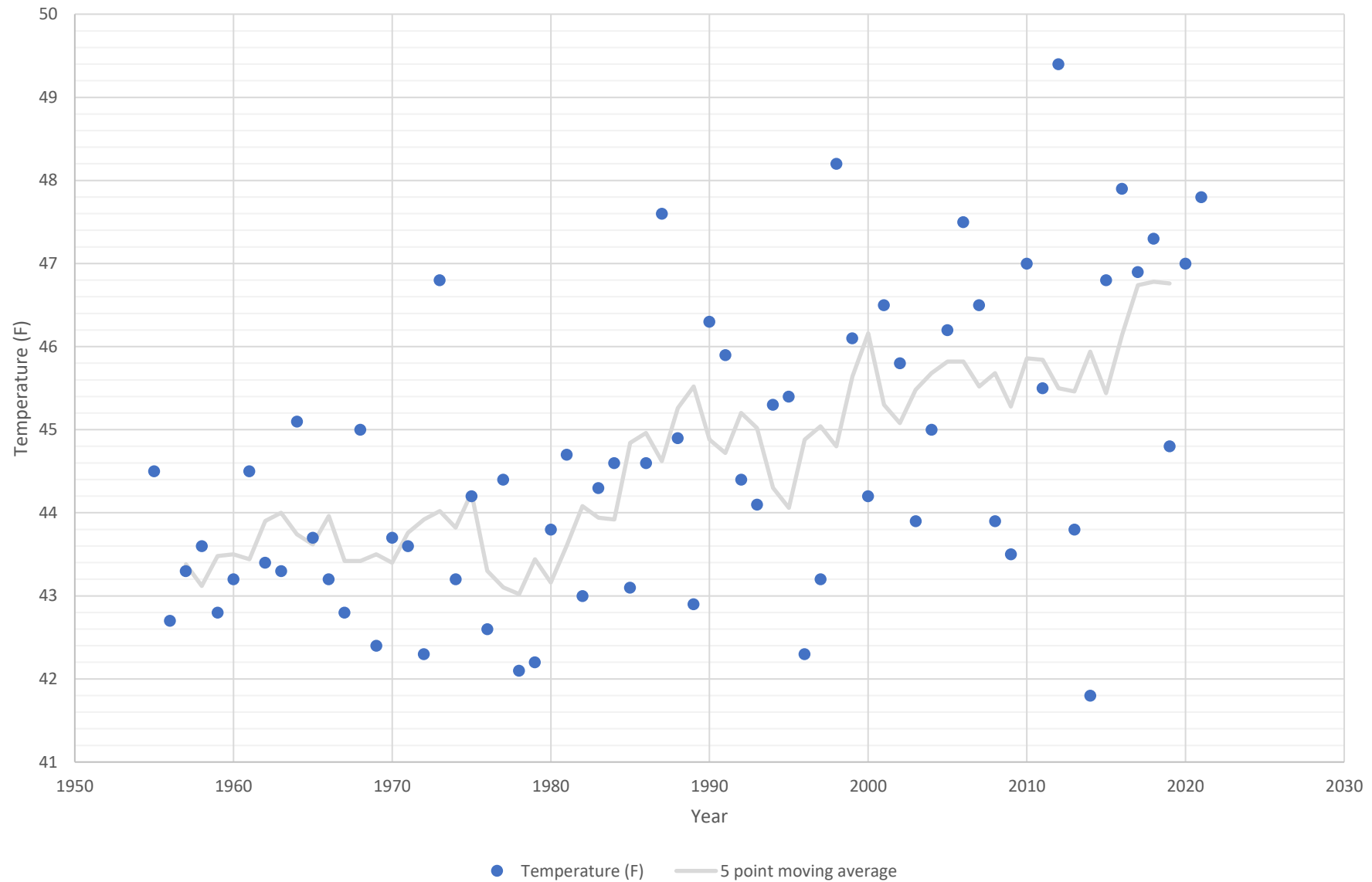
Groundwater Age, Approximate February 21, 2022



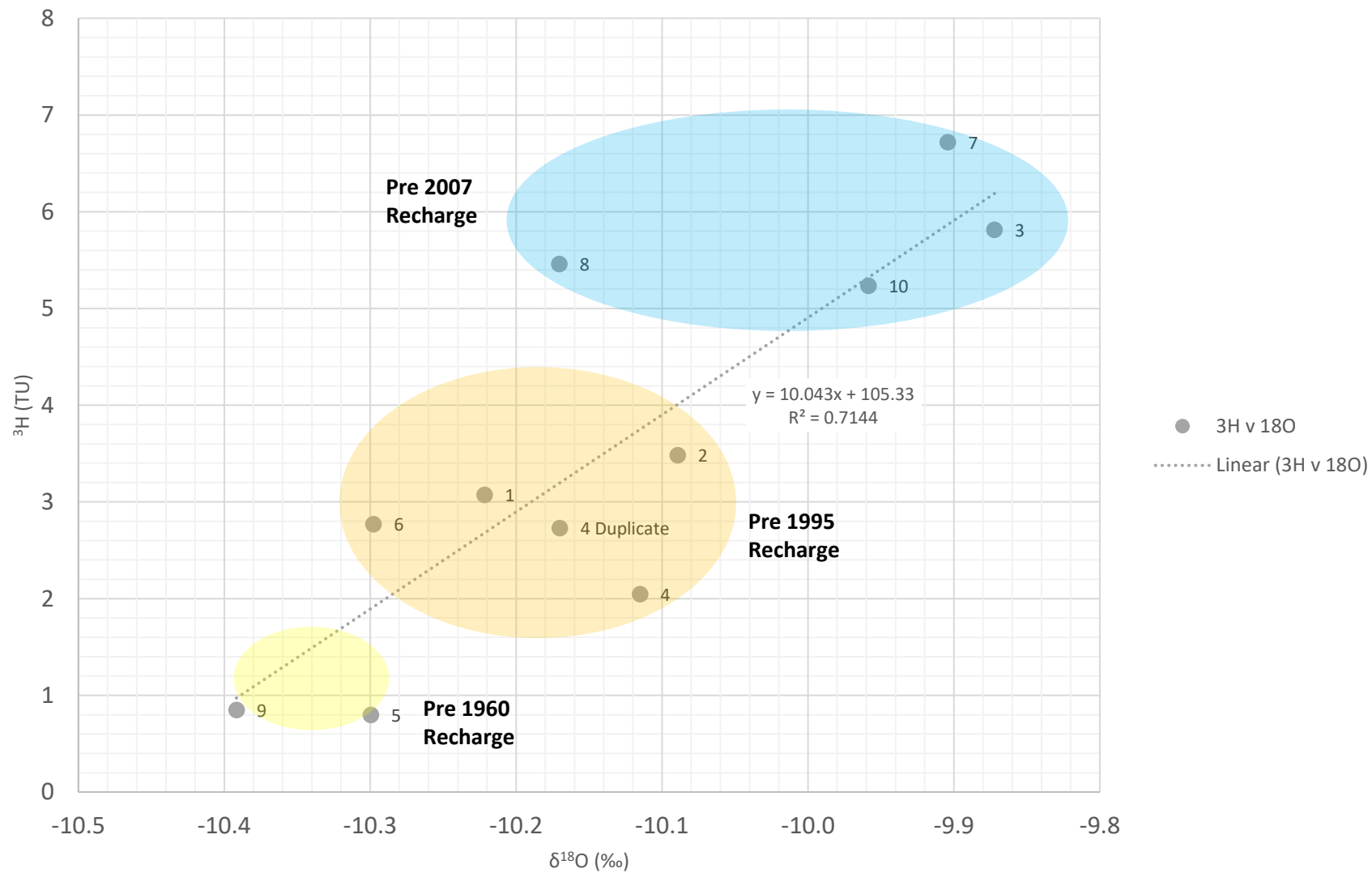
Casco, WI: $\delta^2\text{H}$ versus $\delta^{18}\text{O}$ in Water, February 2022



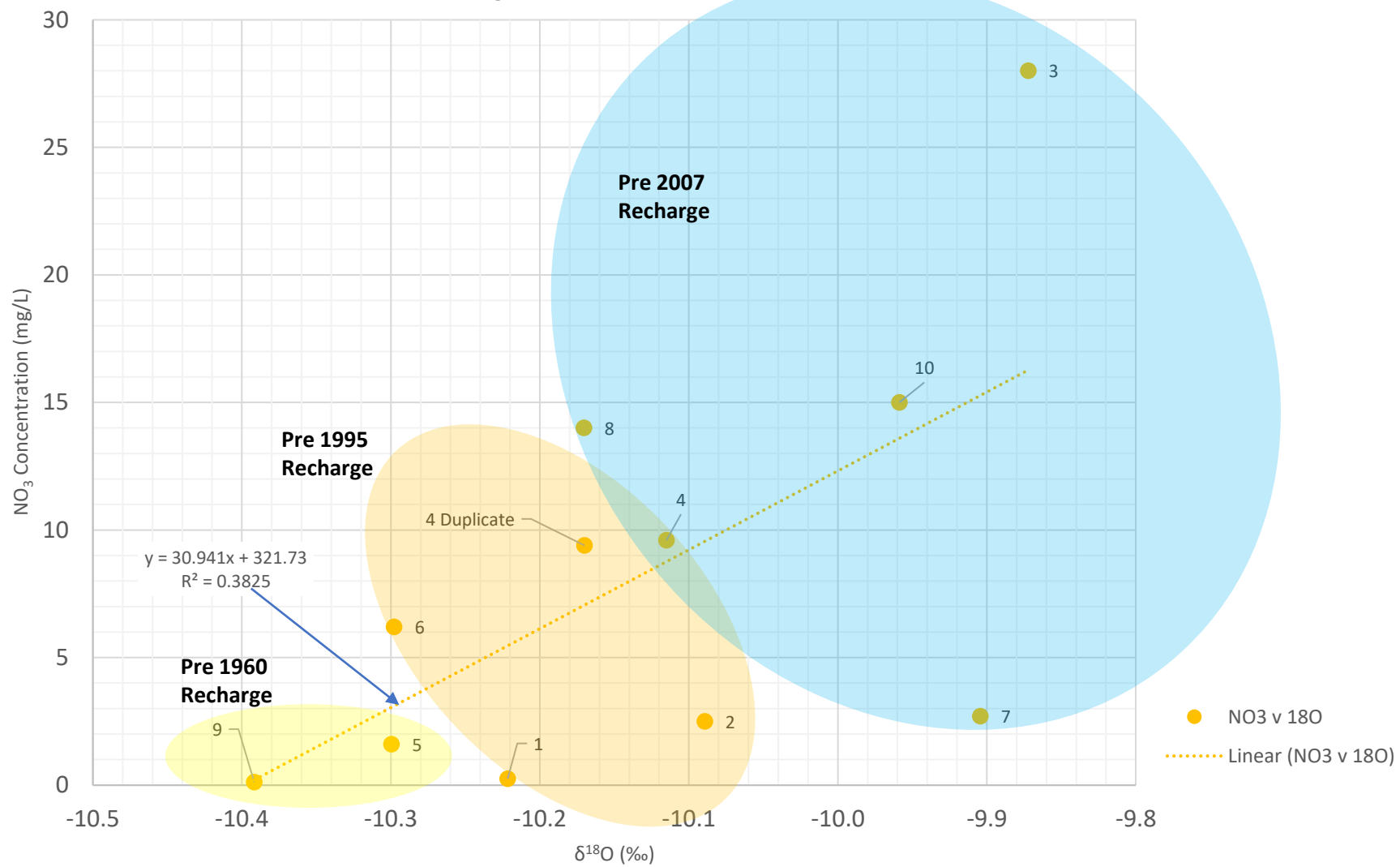
Average Annual Temperature Trends at Green Bay, WI



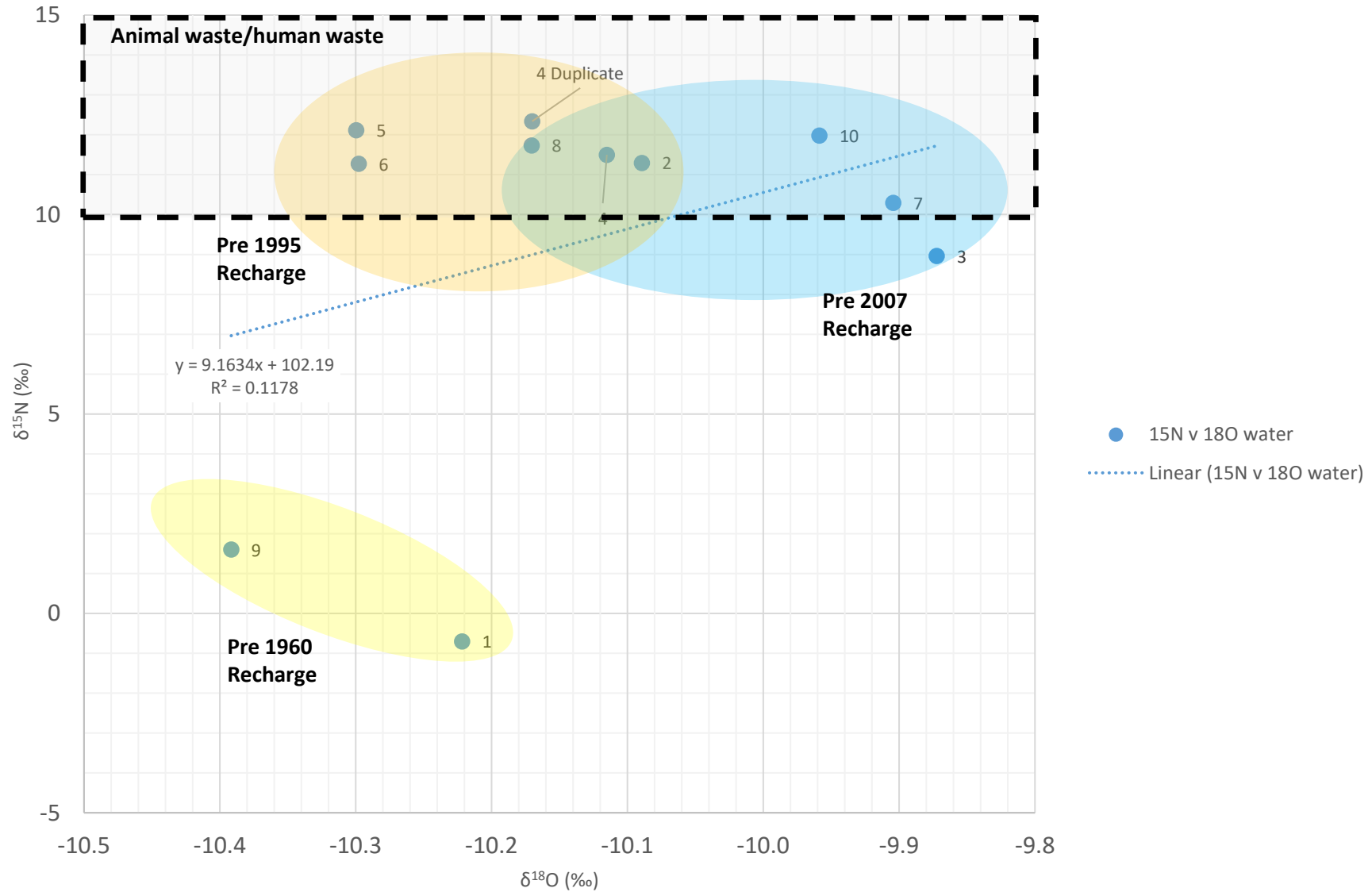
Casco, WI: ^3H versus $\delta^{18}\text{O}$ in Water, February 2022



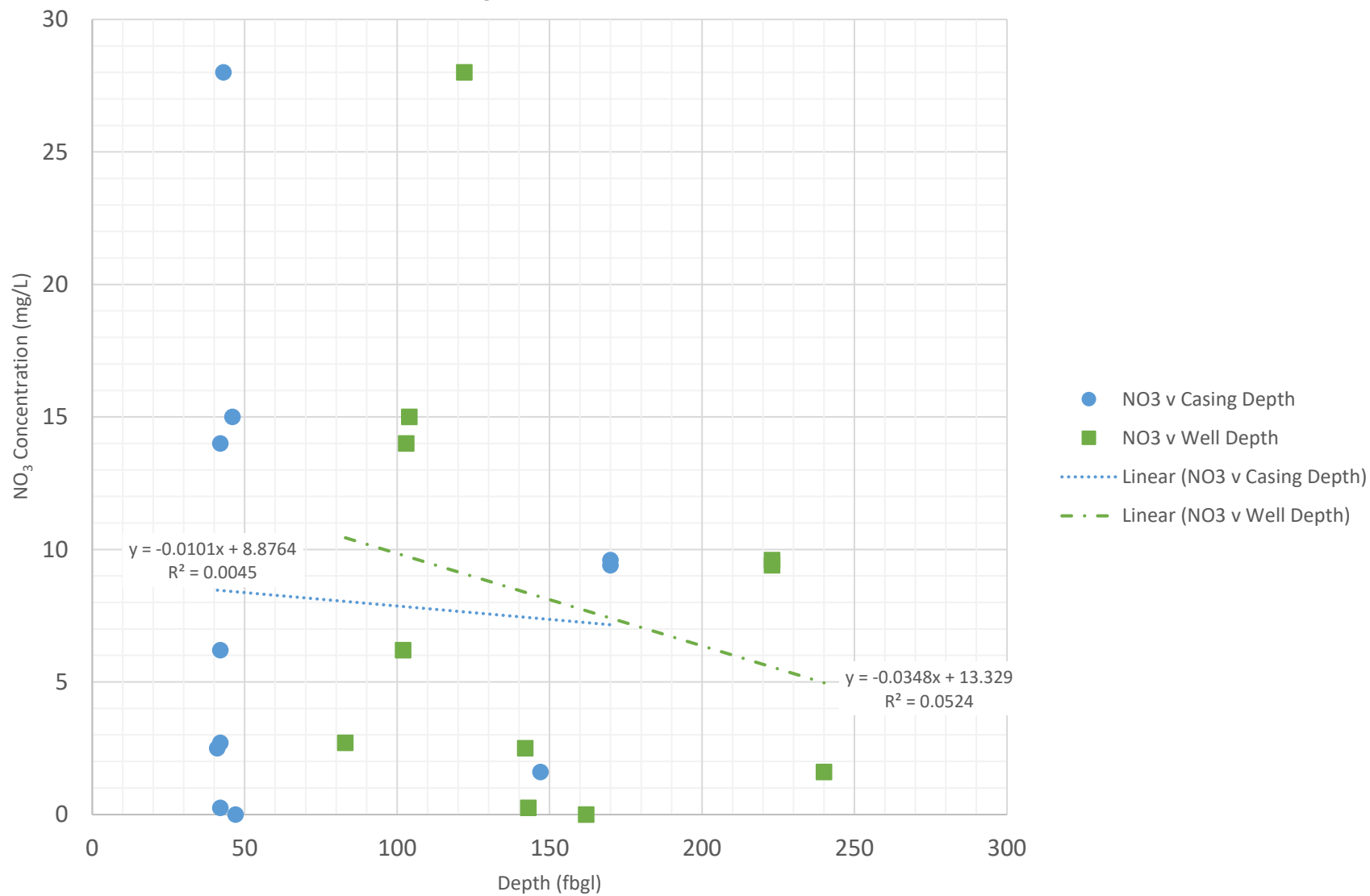
Casco, WI: NO₃ versus δ¹⁸O in Water, February 2022



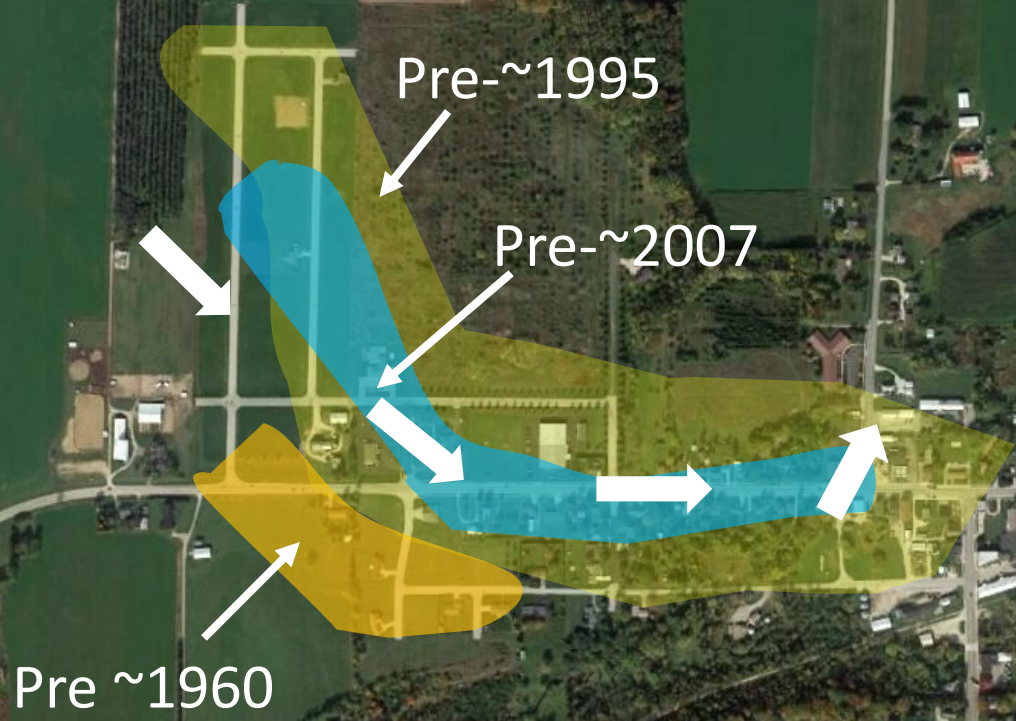
Casco, WI: ^{15}N versus $\delta^{18}\text{O}$ in Water, February 2022



Casco, WI: NO₃ versus Casing and Well Depth, February 2022



Groundwater Age (Approximate) and Groundwater Flow (Approximate) February 21, 2022



Findings Related to Water Well Records

Based on the wells we tested in February 2022:

1. Bedrock subcrop occurs at about 28-47 fbgl.
2. Most are open bedrock wells cased to below the bedrock subcrop.
3. Most of the wells are open boreholes between about 100 and 160 fbgl.
4. Two of the wells are cased deeper (147 and 170 fbgl) and extend deeper (240 and 233 fbgl, respectively.)
5. Groundwater elevations based on well logs from wells installed after 2010 indicate groundwater flow is from northwest to southeast towards the center of Casco.

Findings Related to Nitrate and Nitrate Isotopes

We were not provided with any long-term nitrate data sets for Casco.

Based on the wells we tested in February 2022:

1. Nitrate exceeds drinking water criteria in a narrow band along the groundwater flow direction in the central part of the study area.
2. Nitrate isotopes indicate that most of the nitrate originated from animal/human waste.

Findings Related to Nitrate, Water Isotopes, and Nitrate Isotopes

Based on the wells we tested in February 2022:

1. Tritium (^3H) data indicate a range of groundwater ages in three groupings: pre-1960, pre ~1995, and pre ~2007. None of the groundwater is ~post-2007. Groundwater nitrate is “legacy” to various degrees.
2. The highest nitrate concentrations appear to be in pre-2007 groundwater that runs in a narrow band in the groundwater flow direction through Casco.
3. Nitrate concentrations are loosely related to age.
4. Regardless of age, groundwater nitrate is from animal/human waste except for the very old groundwater (pre-1960).

Other Findings and Thoughts

Based on the wells we tested in February 2022:

1. The depths of the well casing and the well are not factors in the nitrate concentration.
2. Oxygen-18 (^{18}O) and deuterium (^2H) can also be used to approximate groundwater age because they are temperature-sensitive and temperatures have progressively increased since the 1960s. Using ^{18}O and ^2H instead of ^3H would make further investigation of legacy nitrate less expensive.
3. Since the highest nitrate concentrations in Casco groundwater align in a narrow band in the groundwater flow direction, source is likely a “point” source rather than a regional source.
4. High groundwater near Main and “C”.

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Casco, Kewaunee County, Wisconsin

Presentation to
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June 2022