XX CONGRESSO BRASILEIRO
DE ÁGUAS SUBTERRÂNEAS
XXI ENCONTRO NACIONAL DE PERFURADORES DE POÇOS
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Fenágua
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FEIRA NACIONAL DA ÁGUA

Age-dating young groundwater

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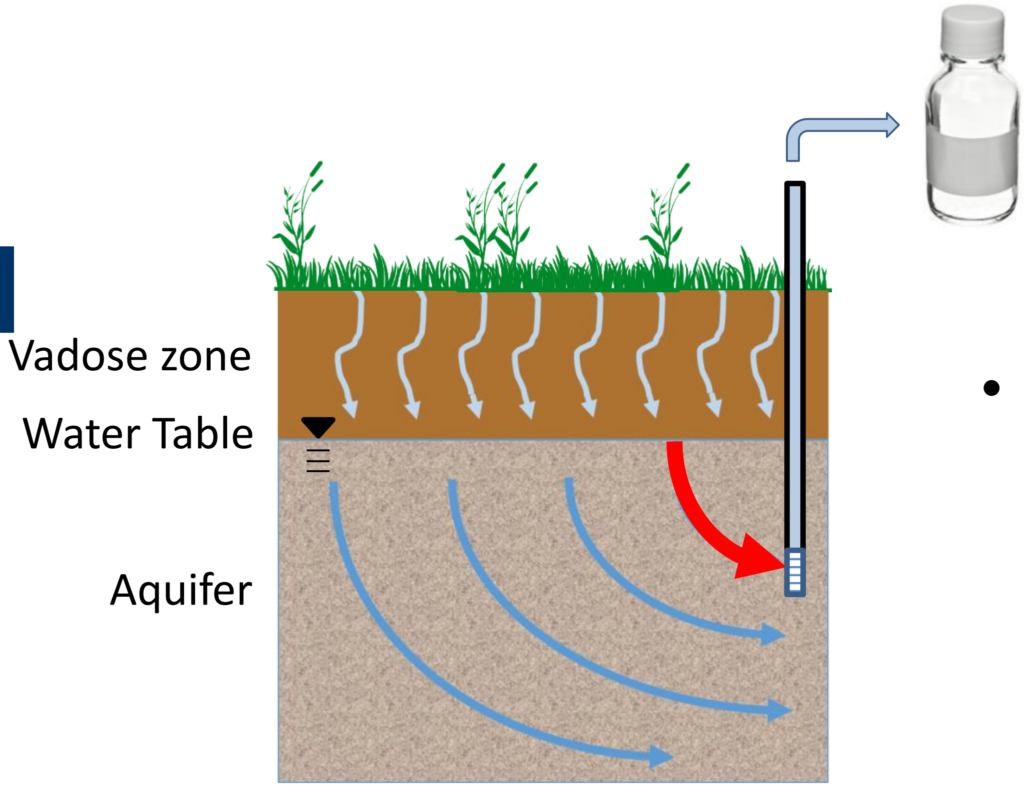
Affiliations and Funding

- **Affiliation**
  - University of Nebraska – School of Natural Resources
  - Daughtery Water for Food Global Institute

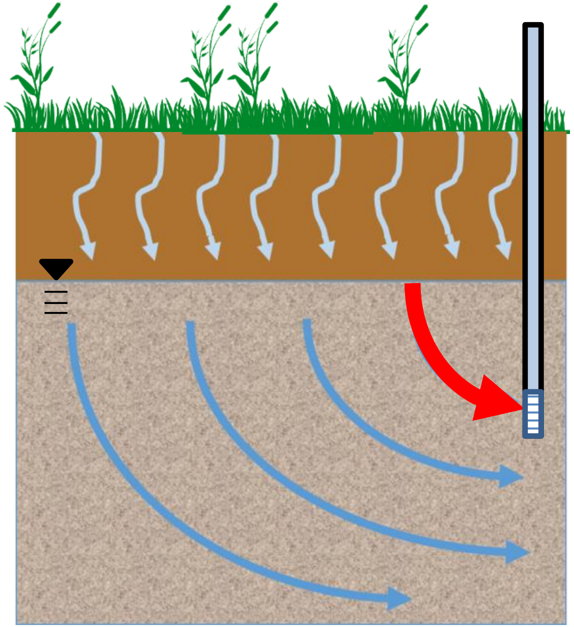
- **Travel funded jointly by the University of Nebraska and FAPESP (SPRINT)**
- **Collaboration with Prof. Didier Gastmans (UNESP – Rio Claro)**

What is groundwater age?



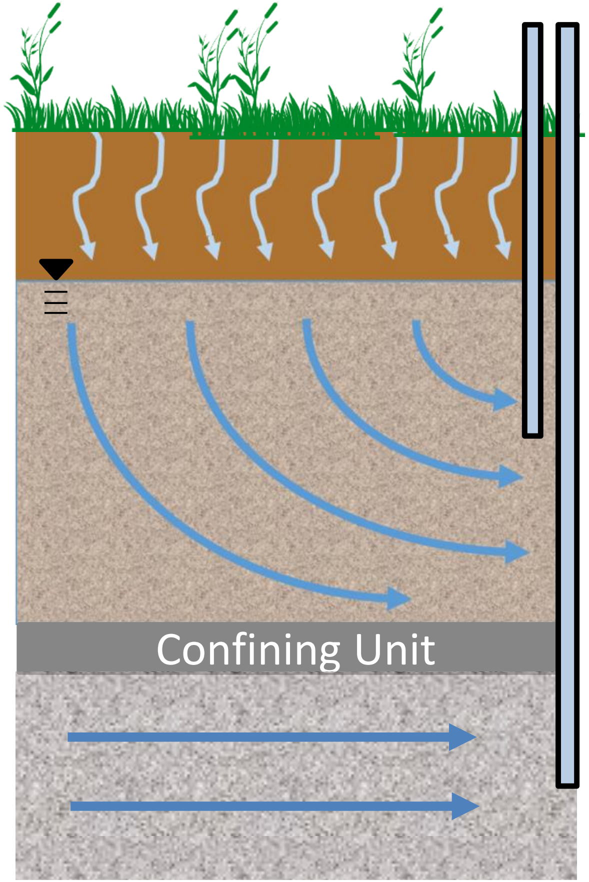
- Groundwater age is the time between groundwater recharge and the time that groundwater is sampled.

What do we learn from groundwater age?



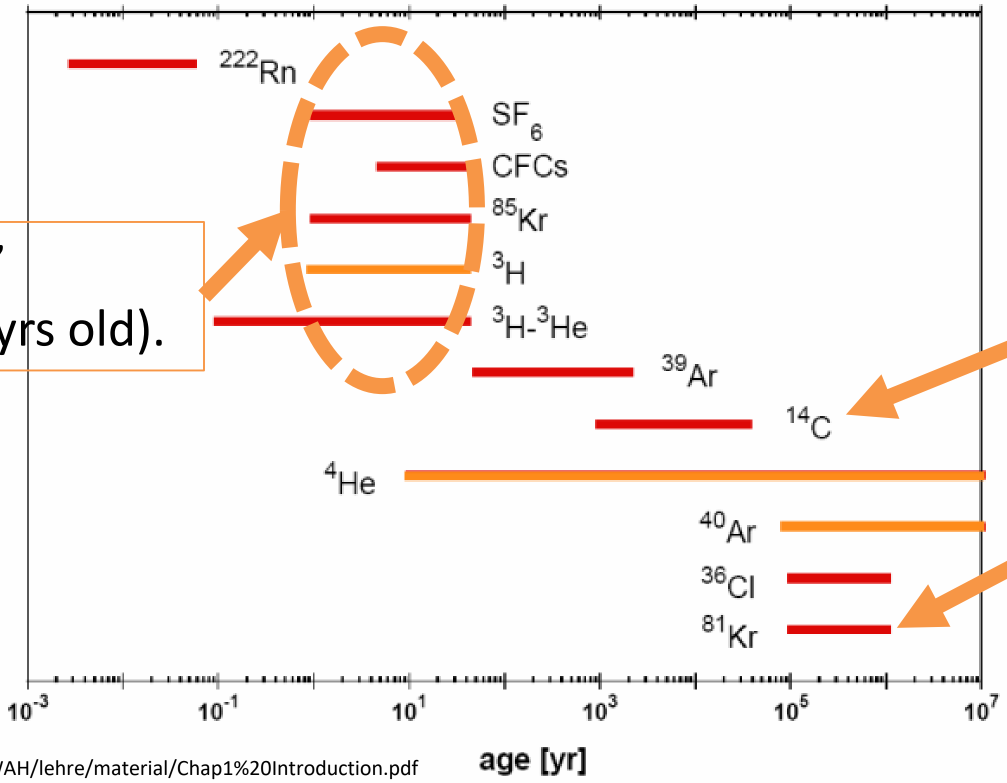
1. Recharge rates
2. History of contamination
3. Rate of groundwater movement
4. Current and future water quality issues

What do we learn from groundwater age?



1. Recharge rates
2. History of contamination
3. Rate of groundwater movement
4. Current and future water quality issues
5. Conceptual models (e.g., confined vs unconfined aquifer)
6. “Young” versus “old” groundwater

Anthropogenic and/or isotope tracers in groundwater used to age-date groundwater



Typical for "young" groundwater (<60 yrs old).

Most common tracer for "old" groundwater

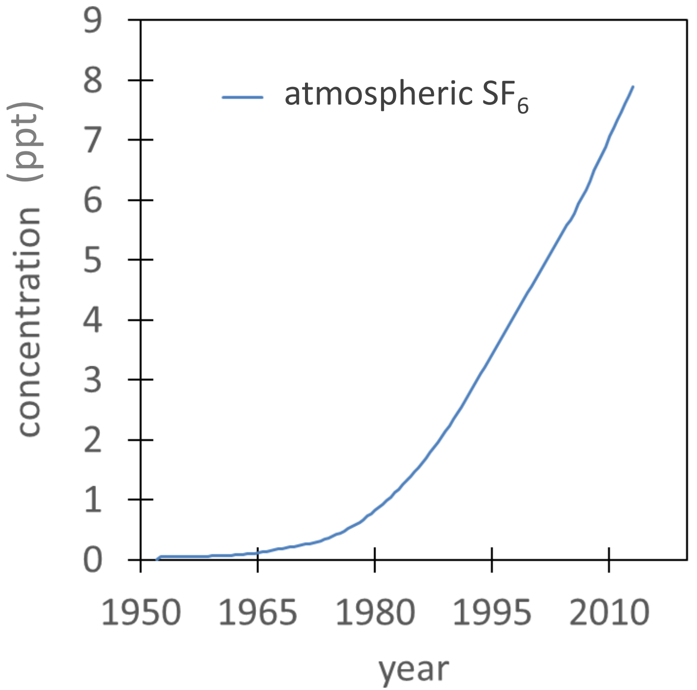
Guarani Aquifer ~500,000 years

http://www.iup.uni-heidelberg.de/institut/forschung/groups/aquasys/WAH/lehre/material/Chap1%20Introduction.pdf

Application of anthropogenic and isotope tracers in groundwater

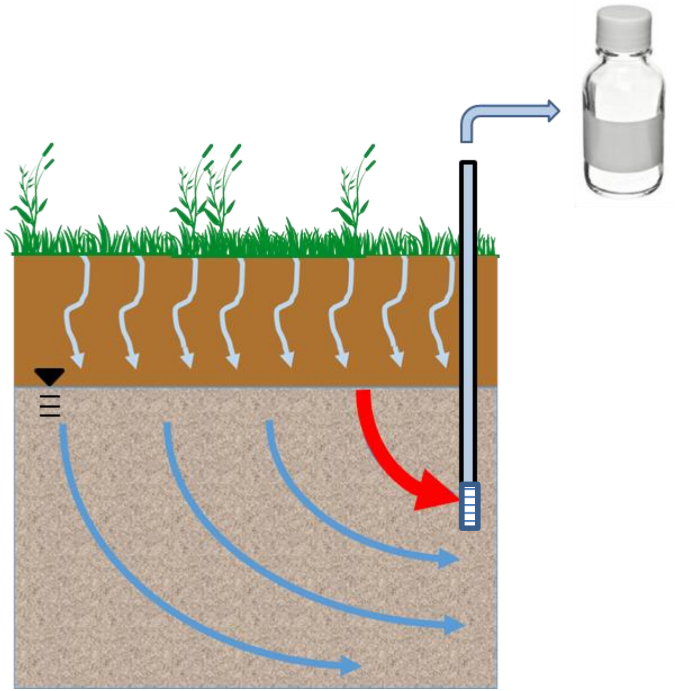
1. Using known history of tracer concentration
2. Using known decay or production rates of tracers

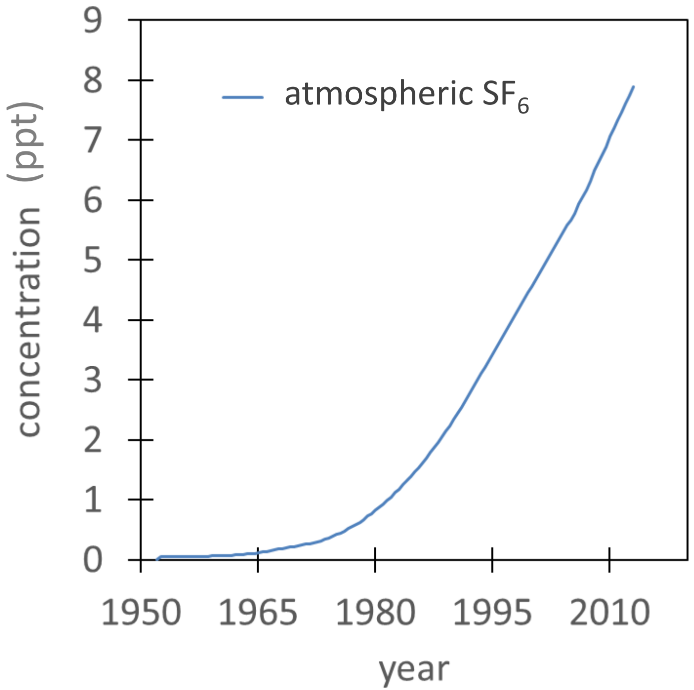
1. Using known history of tracer concentration



Busenberg and Plummer, 2007 (air curve revised 2011)

1. Using known history of tracer concentration





Busenberg and Plummer, 2007 (air curve revised 2011)

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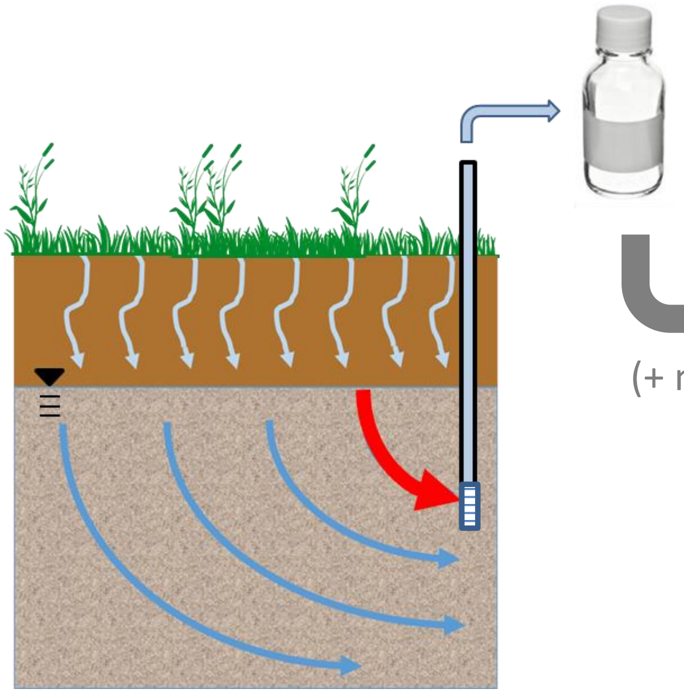
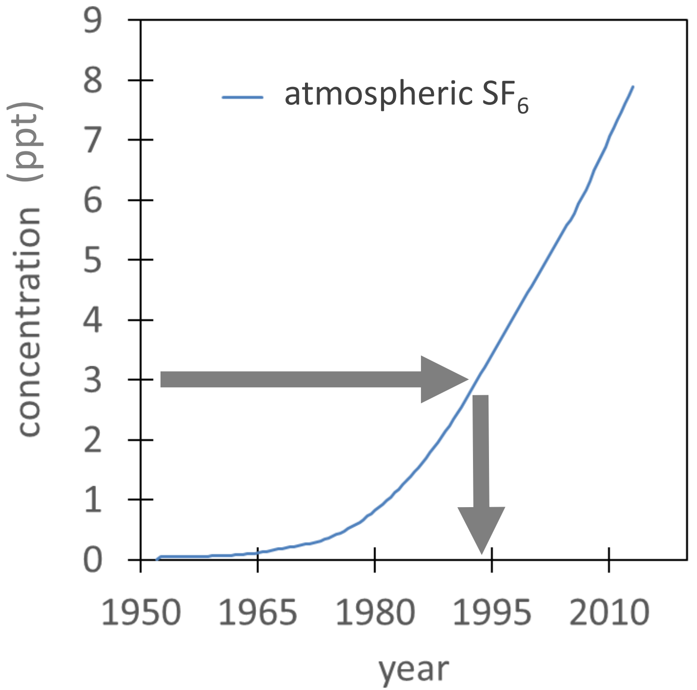
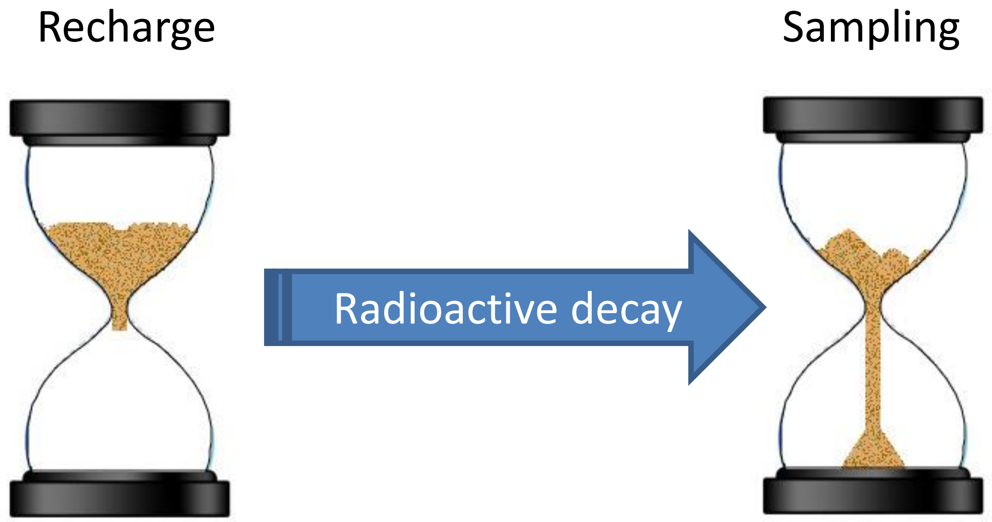


(+ noble gas data)

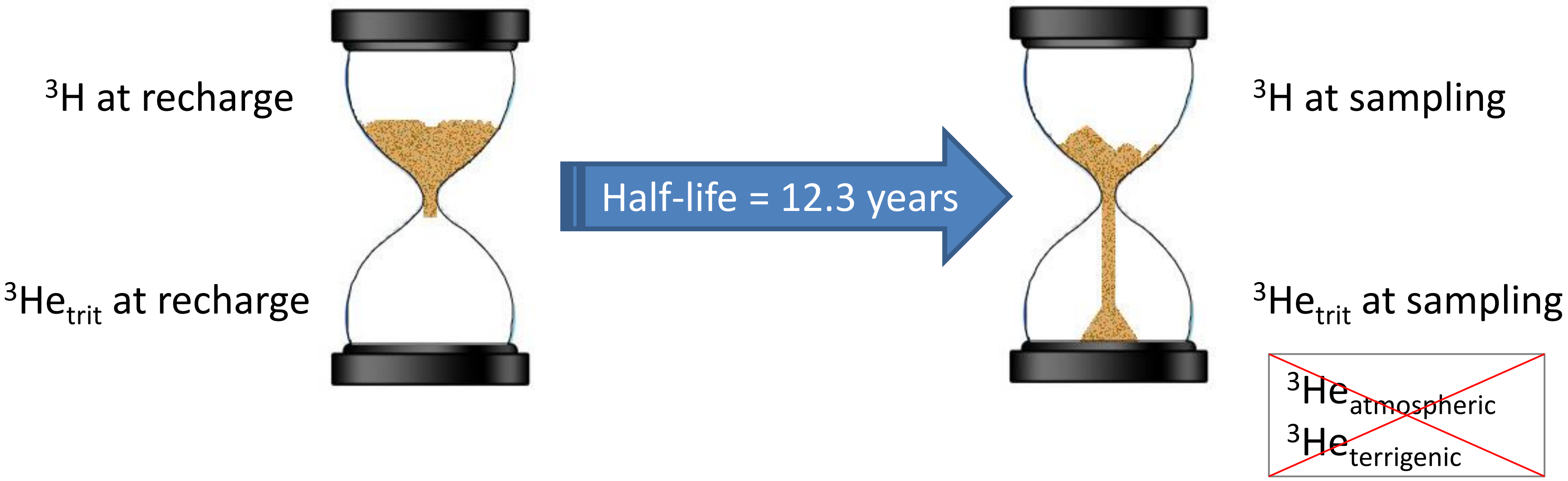


Busenberg and Plummer, 2007 (air curve revised 2011)

2. Using known decay rate of tracer



2. Using known decay rate of tritium (^3H) to tritiogenic helium ($^3He_{trit}$)



2. Using known decay rate of tritium (^3H) to tritiogenic helium ($^3He_{trit}$)

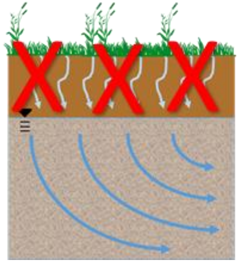
^3H at sampling

$^3He_{trit}$ at sampling

$$\tau = \lambda^{-1} \ln\left(1 + \frac{^3He_{trit}}{^3H}\right)$$

Important considerations

1. Groundwater age does not include travel time through the vadose zone, above the water table



2. Groundwater ages are "apparent ages", or <u>approximations</u>

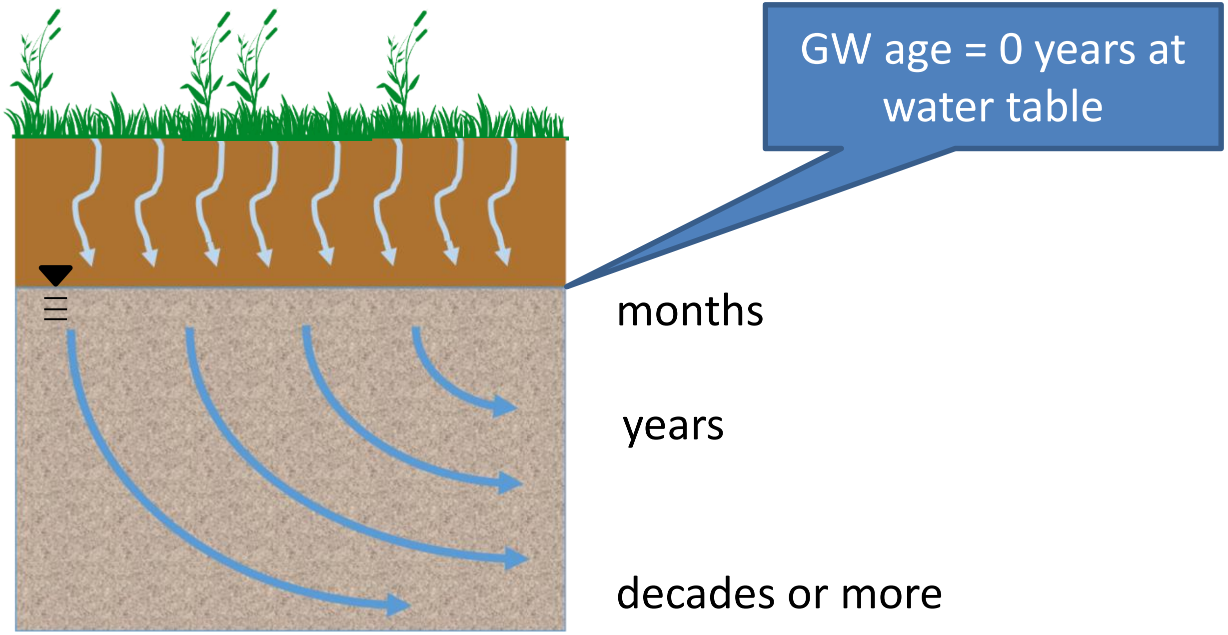
3. Groundwater samples are mixtures – using more than one tracer is preferable to ensure apparent ages are a reasonable representation of actual travel time

Example Field Applications

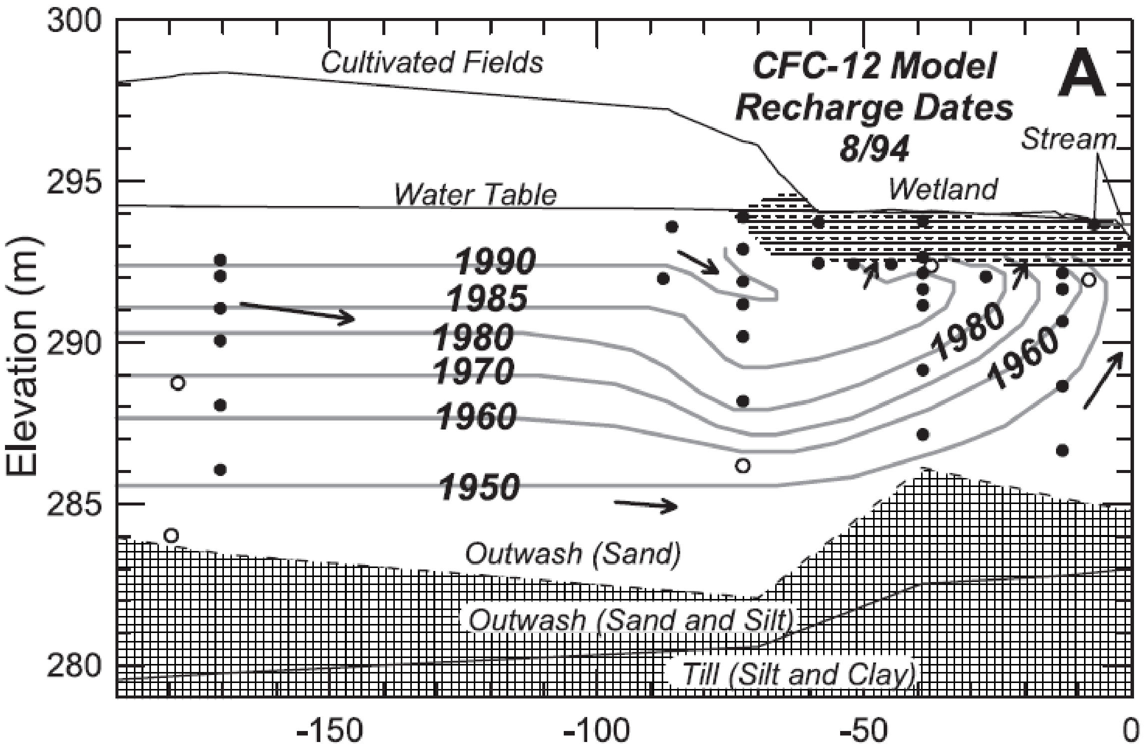
1. Groundwater recharge rate and nitrate (NO_3^-) in unconfined aquifer
2. Implications for stream water quality

Example 1: Minnesota, USA

Groundwater age varies with depth in an unconfined aquifer



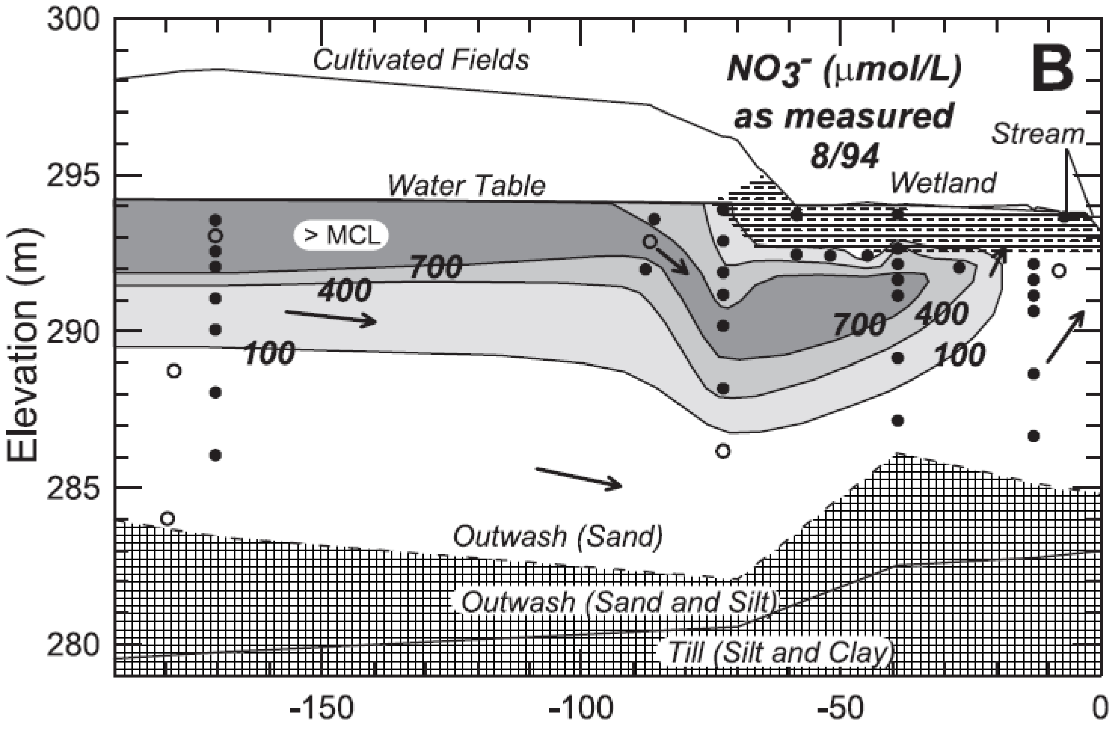
Example of groundwater age gradient



- **Agricultural watershed in Minnesota, USA**
- **Samples collected 1994 (•) and 1993 (◦)**
- **Age gradient indicated average recharge rate of ~150 mm/yr**

Böhlke et al. (2002), *Water Resources Research* 38(7): 1105, DOI 10.1029/2001WR000663

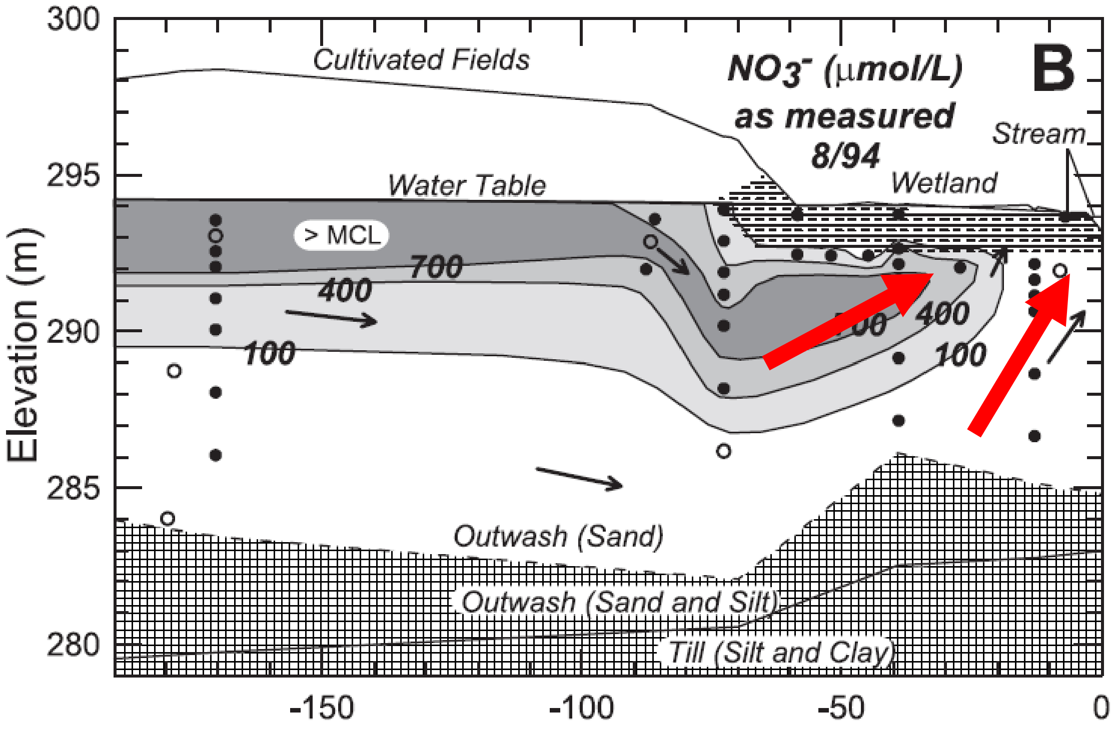
Age gradient influences groundwater quality



- **Younger, shallower groundwater more contaminated with nitrate**
- **Denitrification also affects water quality**
- **Important consideration for drinking water wells**

Böhlke et al. (2002), *Water Resources Research* 38(7): 1105, DOI 10.1029/2001WR000663

Age gradient influences surface water quality



- **Many streams receive groundwater discharge**
- **Wide range (distribution) of ages for groundwater discharging to streams**

Böhlke et al. (2002), *Water Resources Research* 38(7): 1105, DOI 10.1029/2001WR000663

Example 2: North Carolina, USA

NC STATE UNIVERSITY

David Genereux
Helena Mitasova

THE UNIVERSITY OF UTAH

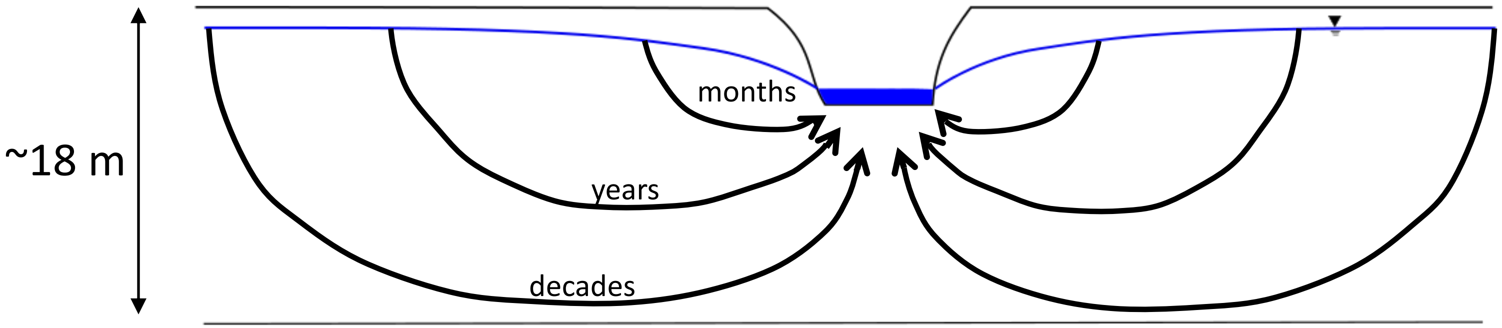
D. Kip Solomon
John Solder (now USGS)

USGS science for a changing world

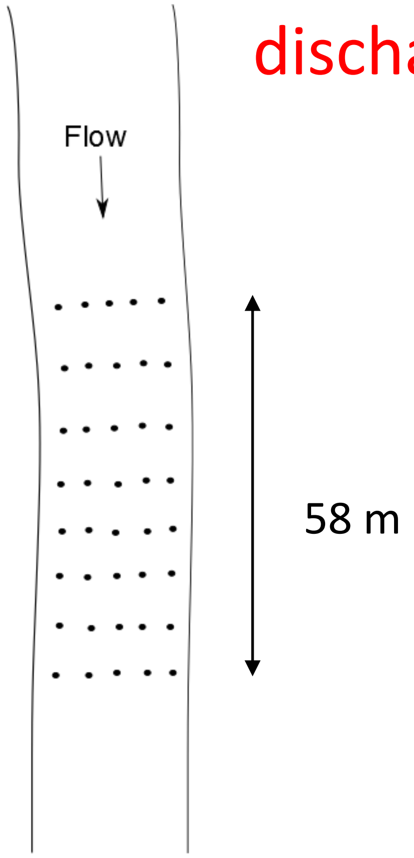
Briant Kimball
(Salt Lake City, UT)
Niel Plummer
(Reston, VA)

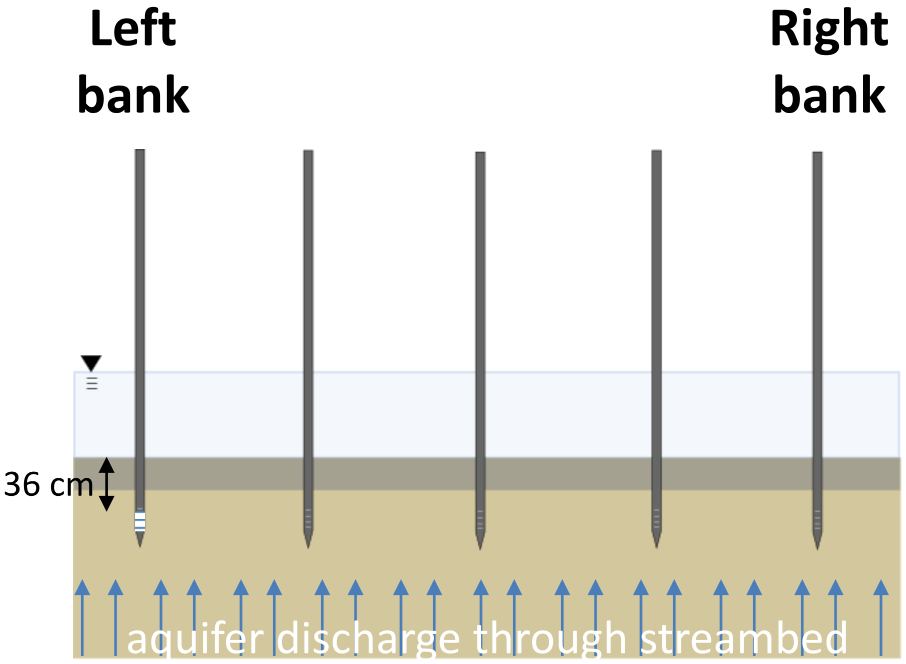
NSF

Groundwater with a range of ages discharges to a stream

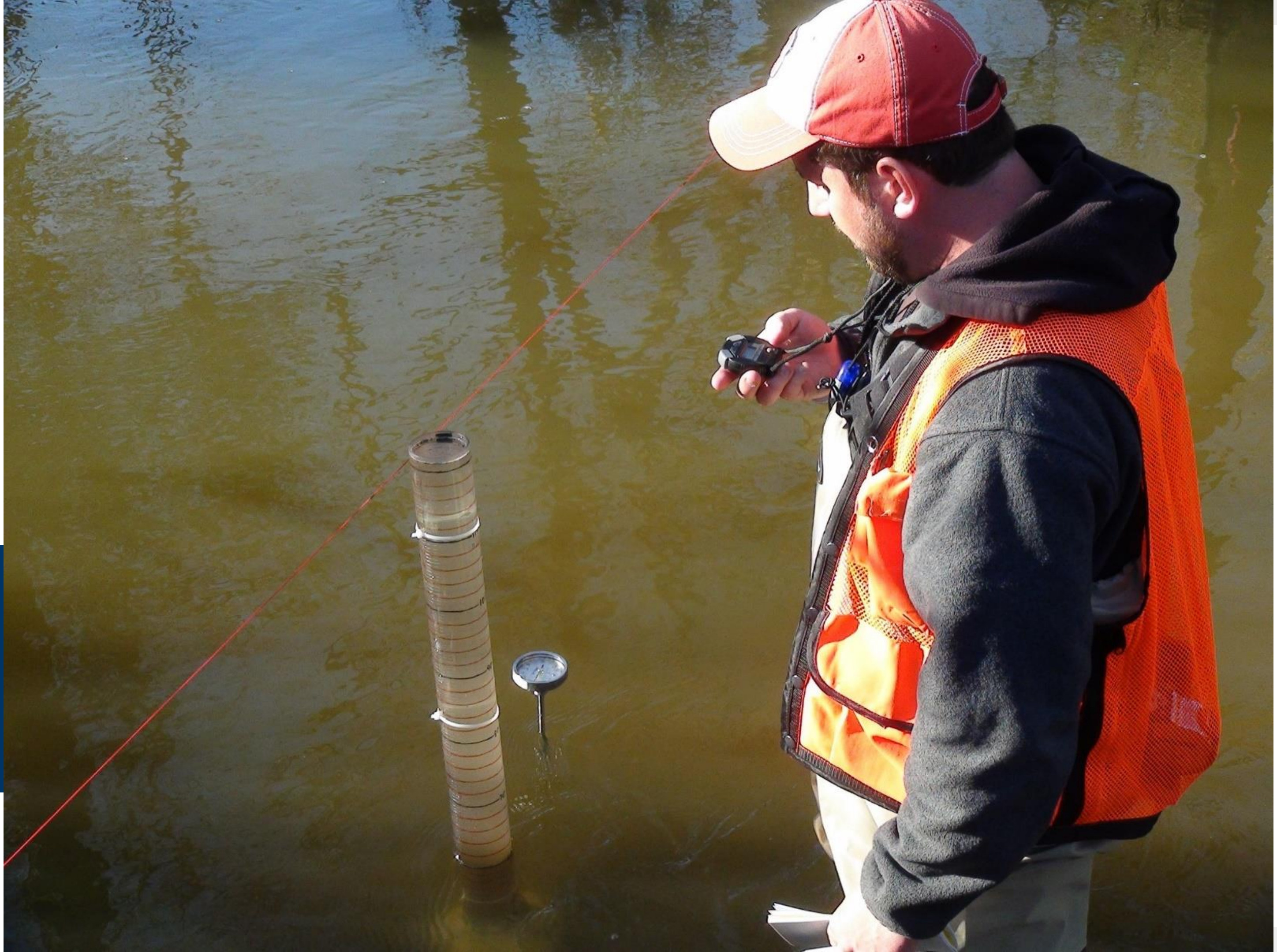


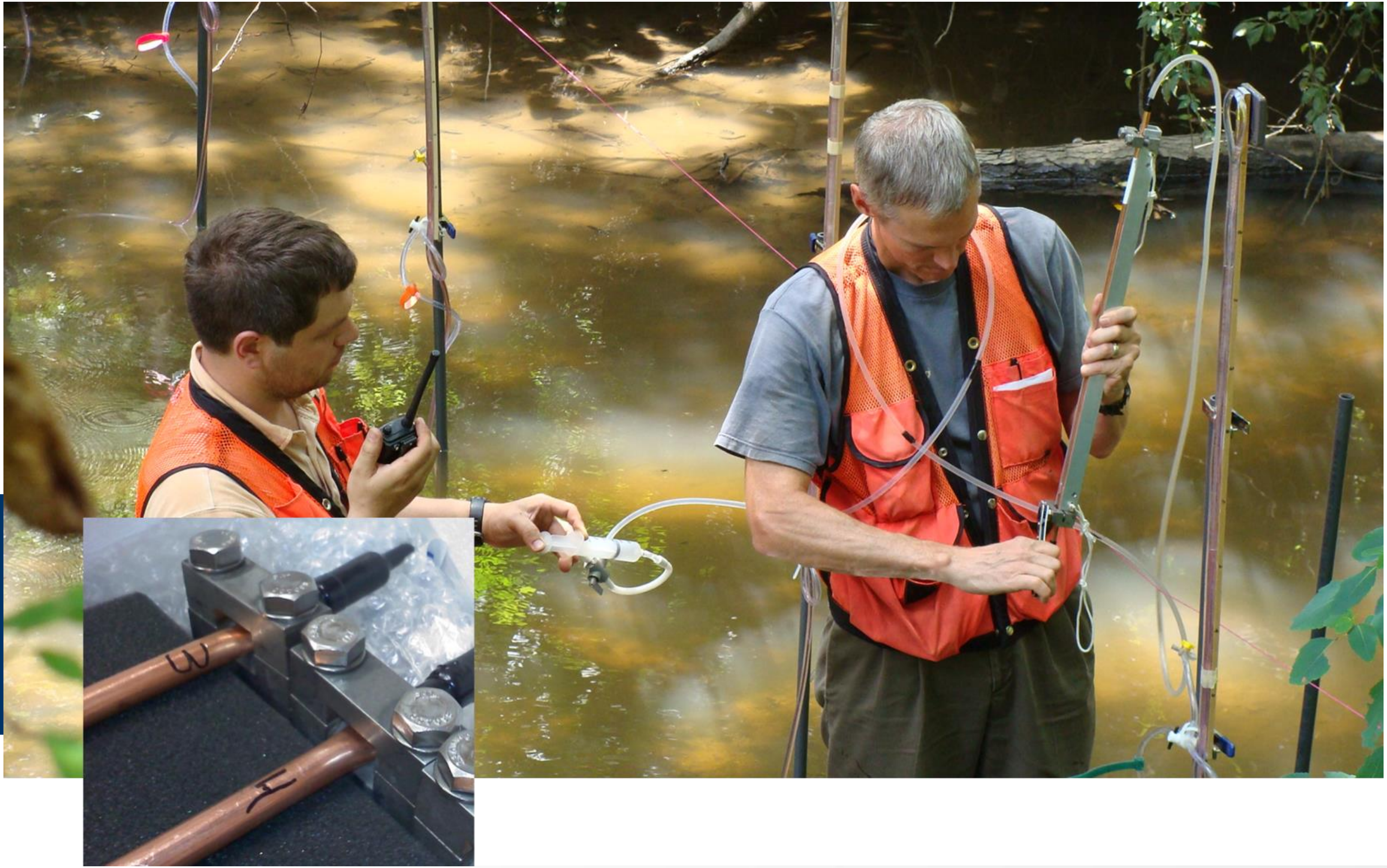
Data collection: collect sample and measure GW discharge at points in streambed



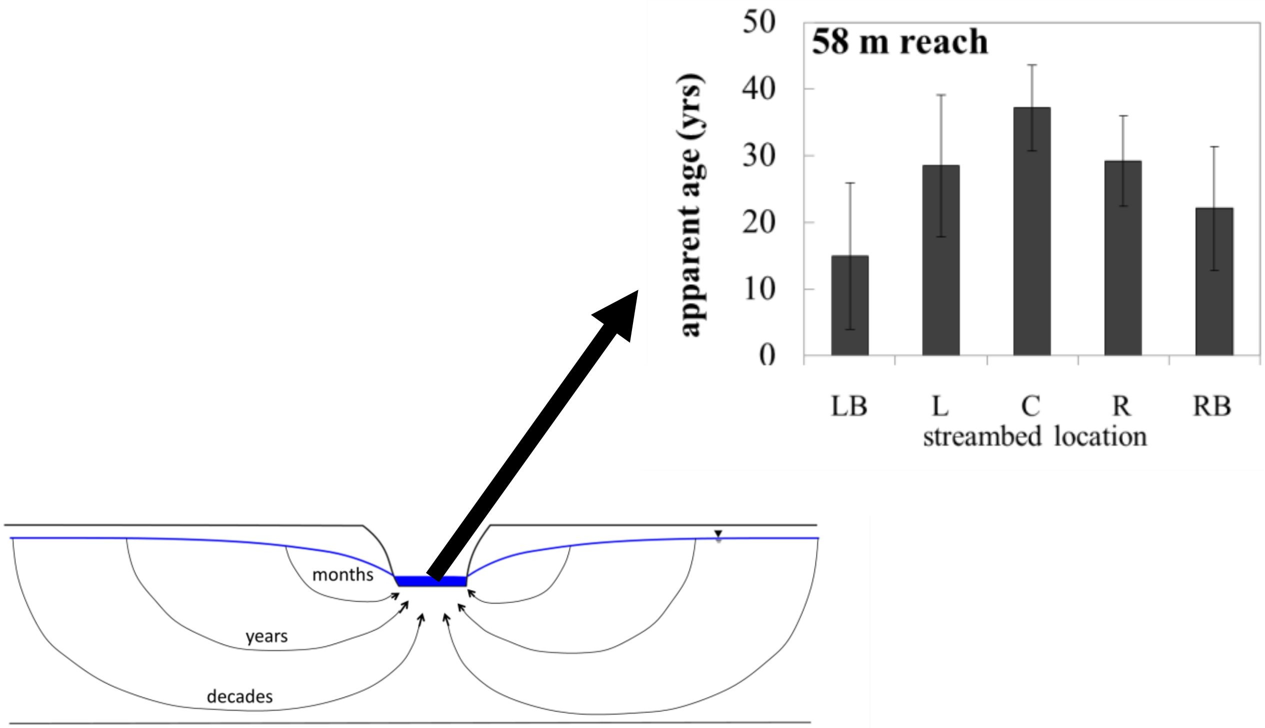


Kennedy et al. 2007, 2009; Genereux et al. 2008; Gilmore et al. 2016

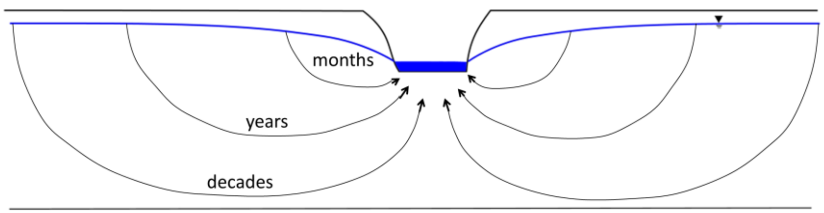


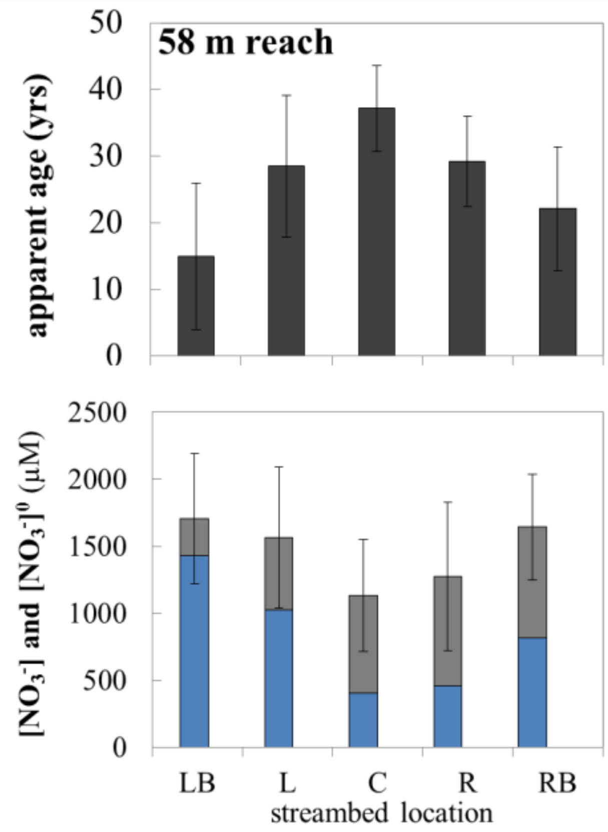


Results: Horizontal GW age gradient in streambed

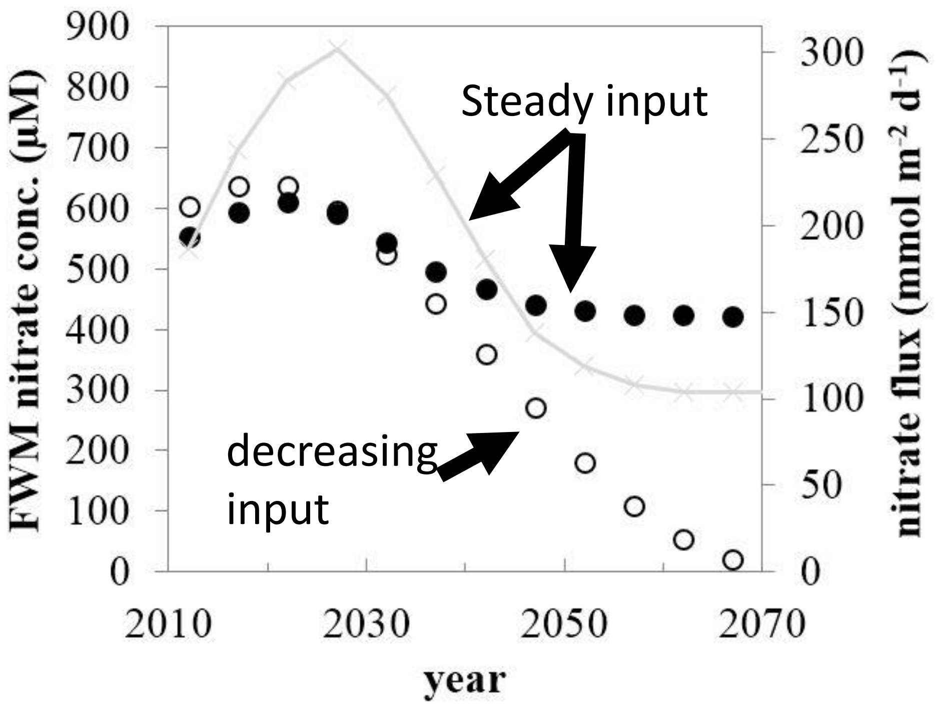


Nitrate discharge to stream is consistent with age gradient





FUTURE nitrate concentration in aquifer discharge, based on GW age, NO_3^-, and GW discharge estimates



(adjusted for denitrification)

Conclusions

- Groundwater age is the time between groundwater recharge and the time that groundwater is sampled.
- Groundwater age gives valuable information about:
  - Recent GW recharge and rate of GW movement
  - Contaminant history and water quality
  - Present and future water quality in aquifers and streams

Obrigado!

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Wells, M. J., **Gilmore, T. E.**, Mittelstet, A. R., Snow, D., & Sibray, S. S. (2018). *Water*, 10(8), 1047. https://doi.org/10.3390/w10081047

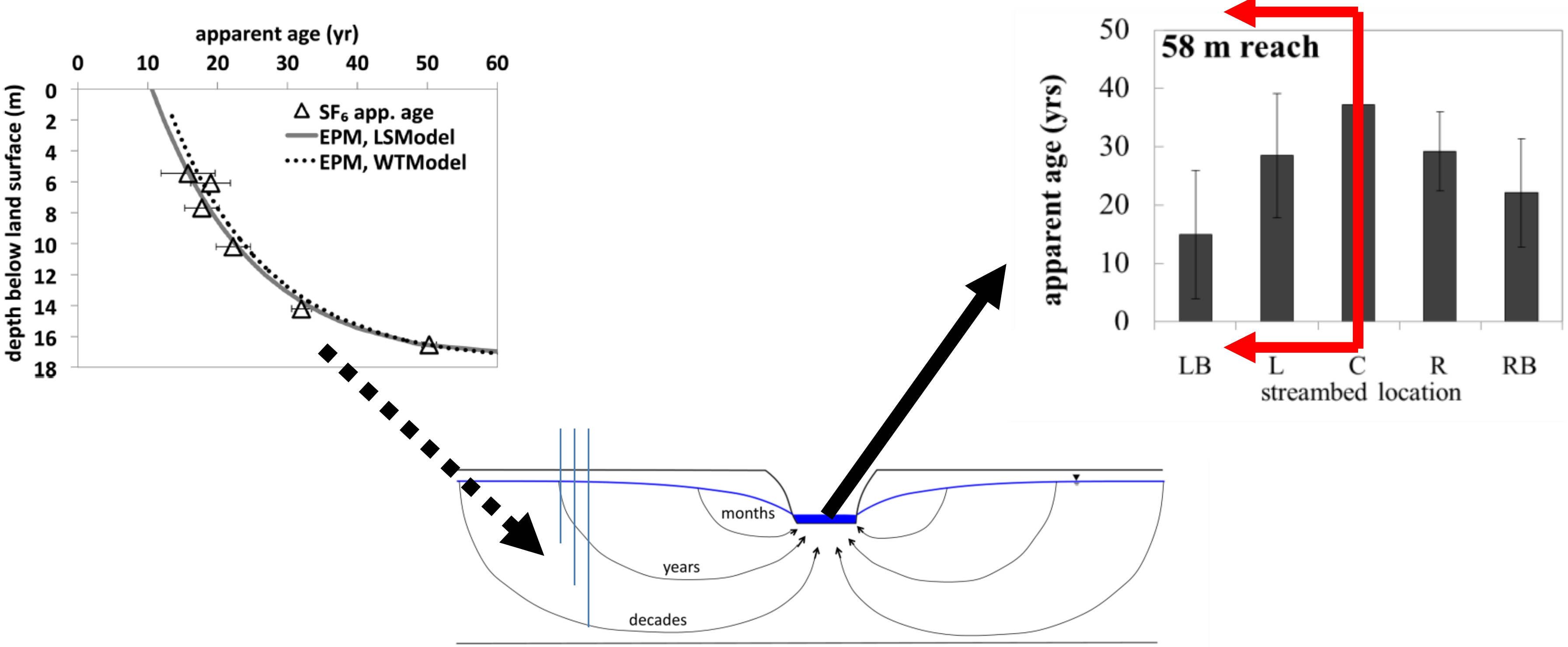
Gilmore, T. E., Genereux, D. P., Solomon, D. K., & Solder, J. E. (2016). *Water Resources Research*, 52(3), https://doi.org/10.1002/2015WR017600

Gilmore, T. E., Genereux, D. P., Solomon, D. K., Farrell, K. M., & Mitasova, H. (2016). *Water Resources Research*, 52(11), https://doi.org/10.1002/2016WR018976

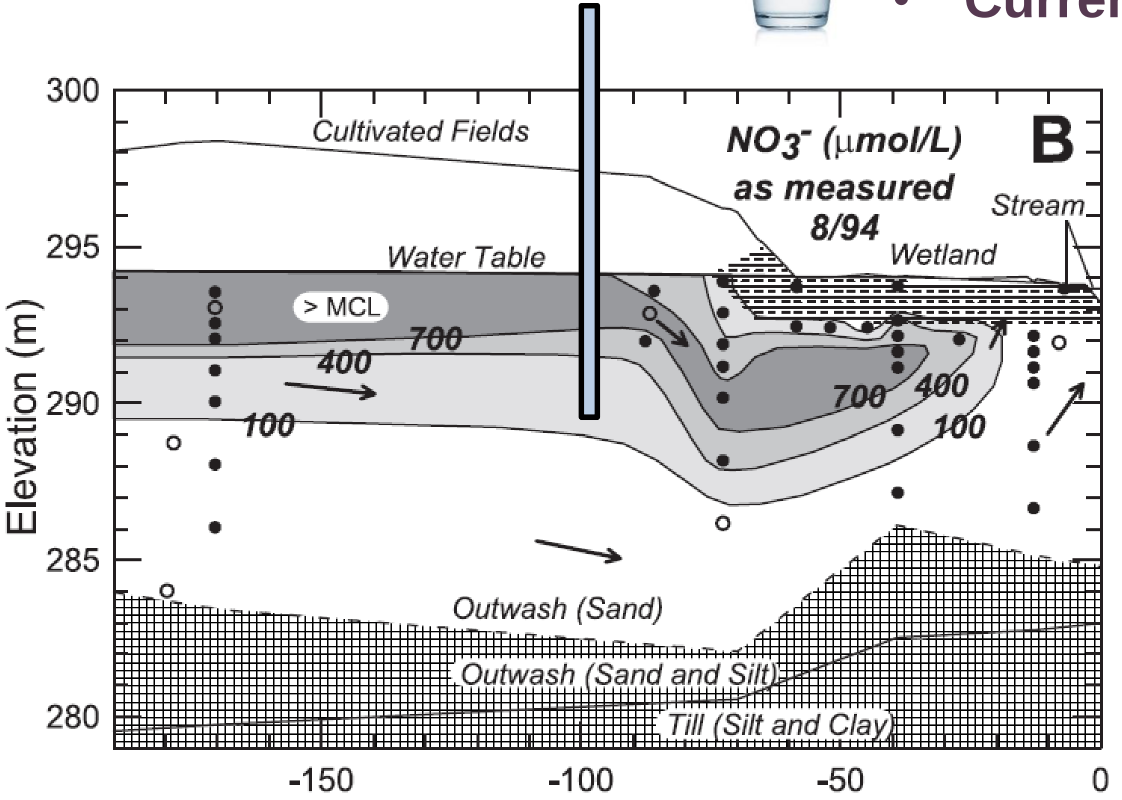
Gilmore, T. E., Genereux, D. P., Solomon, D. K., Solder, J. E., Kimball, B. A., Mitasova, H., & Birgand, F. (2016). *Water Resources Research*, 52(3), https://doi.org/10.1002/2015WR017599

Solomon, D. K., **Gilmore, T. E.**, Solder, J. E., Kimball, B., & Genereux, D. P. (2015). *Water Resources Research*, 51(11), 8883–8899. https://doi.org/10.1002/2015WR017602

Results: Horizontal GW age gradient in streambed is consistent with vertical age gradient in aquifer

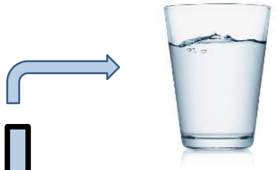


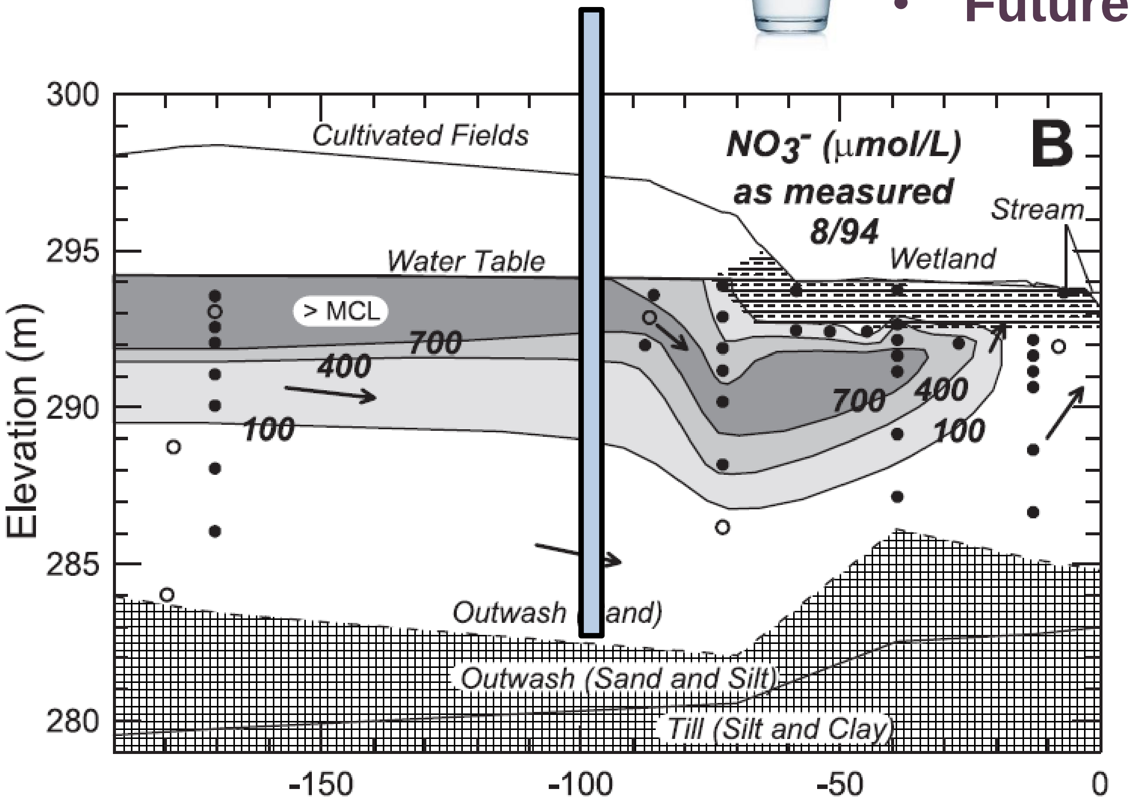
- **Shallow domestic well**
- **High nitrate from shallow GW**
- **Current and future health concerns**



Böhlke et al. (2002), *Water Resources Research* 38(7): 1105, DOI 10.1029/2001WR000663

- **Municipal well with long screen**
- **Mixture of shallow and deep GW**
- **Future health concerns**





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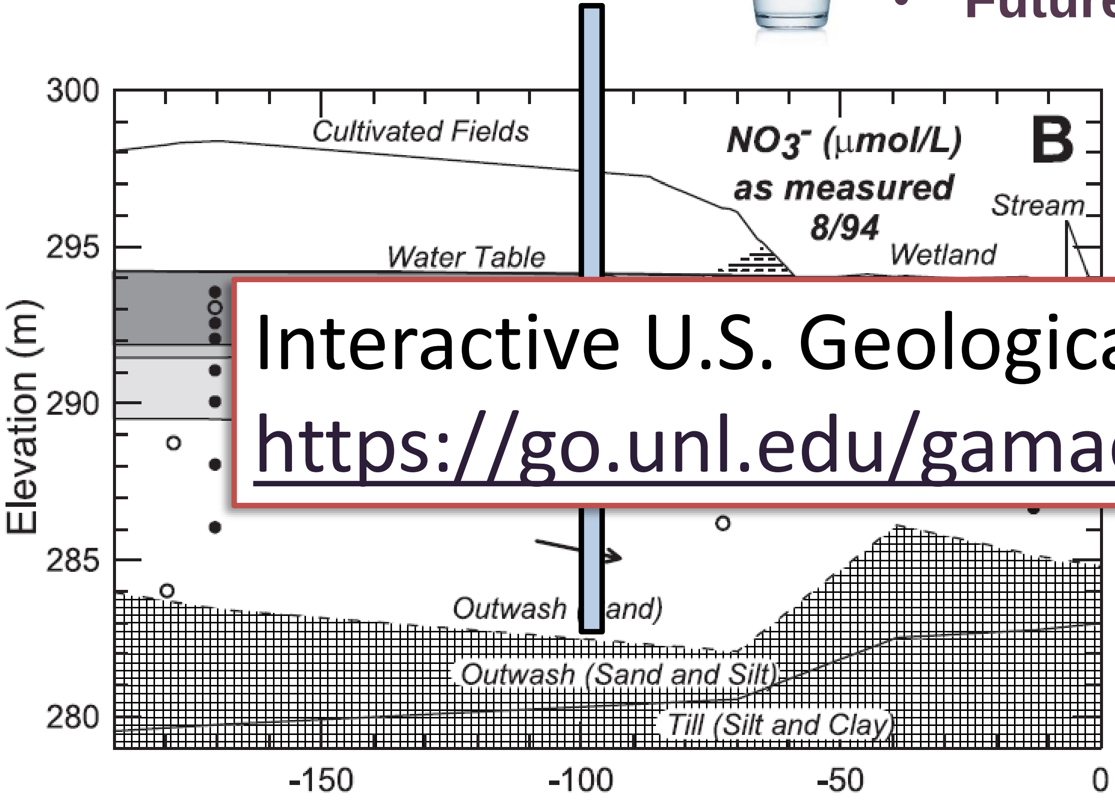

Interactive U.S. Geological Survey model:

https://go.unl.edu/gamactt

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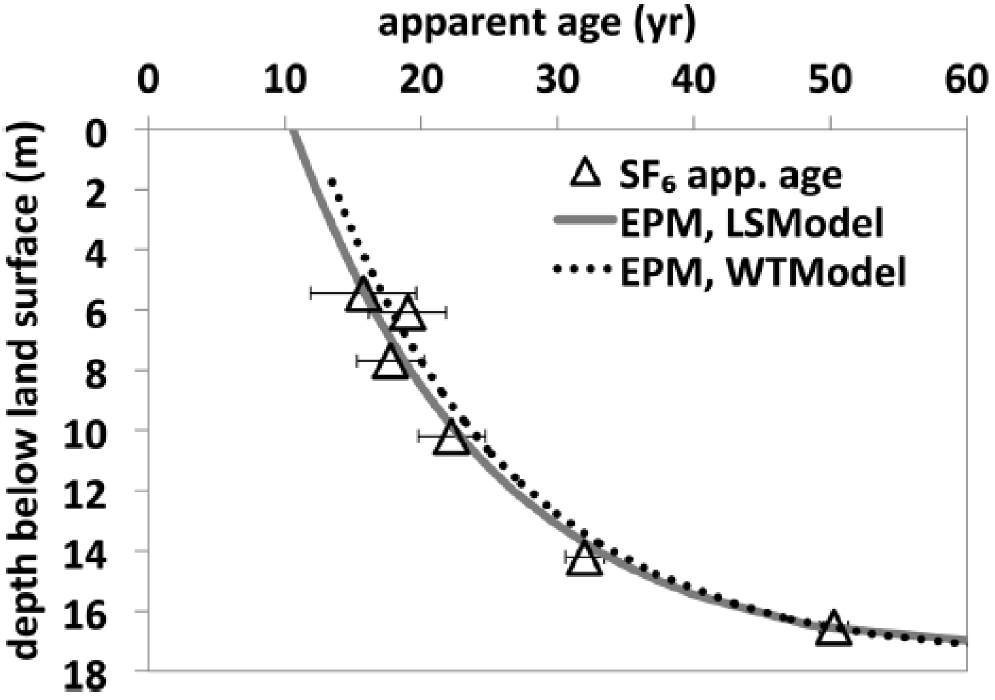
Age gradient indicates recharge rate



- **Agricultural watershed in North Carolina, USA**
- **Samples collected 2013**
- **Based on simple model, aquifer geometry, porosity, and age gradient, Recharge = 200 to 250 mm/yr**

Solomon, D. K., Gilmore, T. E., Solder, J. E., Kimball, B., & Genereux, D. P. (2015). Evaluating an unconfined aquifer by analysis of age-dating tracers in stream water. *Water Resources Research*, *51*(11), 8883–8899. https://doi.org/10.1002/2015WR017602