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Chasing Nitrate Through the Vadose Zone

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University of Nebraska Water Sciences Laboratory

Where is Groundwater Vulnerable?

- High irrigation density
- Crops and land use requiring high N input (corn)
- Well drained soils where denitrification potential is low
- Shallow water table

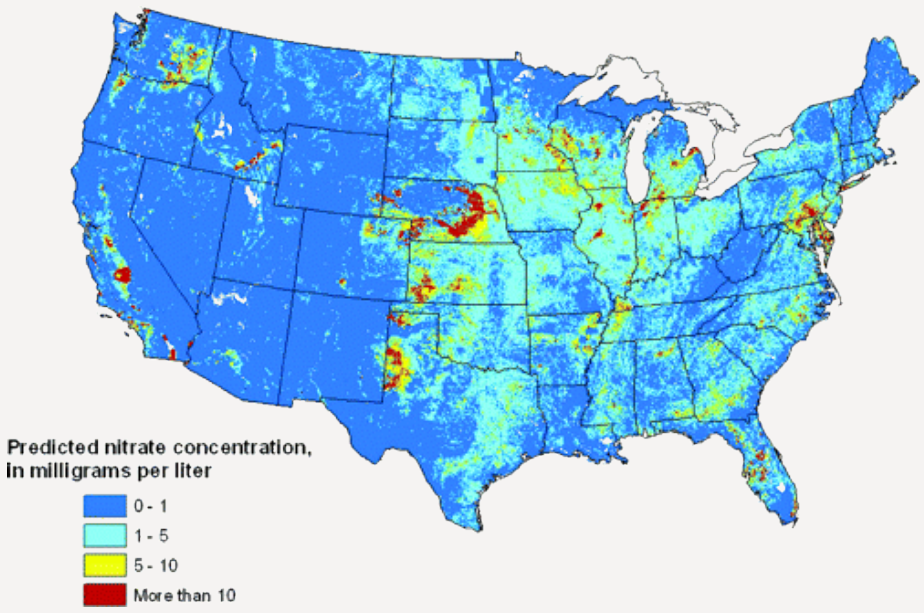

FIGURE 2. Nitrate concentration in shallow, recently recharged U.S. groundwater, as predicted by the GWAVA-S model.

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Nolan, B. T. and K. J. Hitt (2006). "Vulnerability of shallow groundwater and drinking-water wells to nitrate in the United States." Environmental Science & Technology **40(24): 7834-7840.**

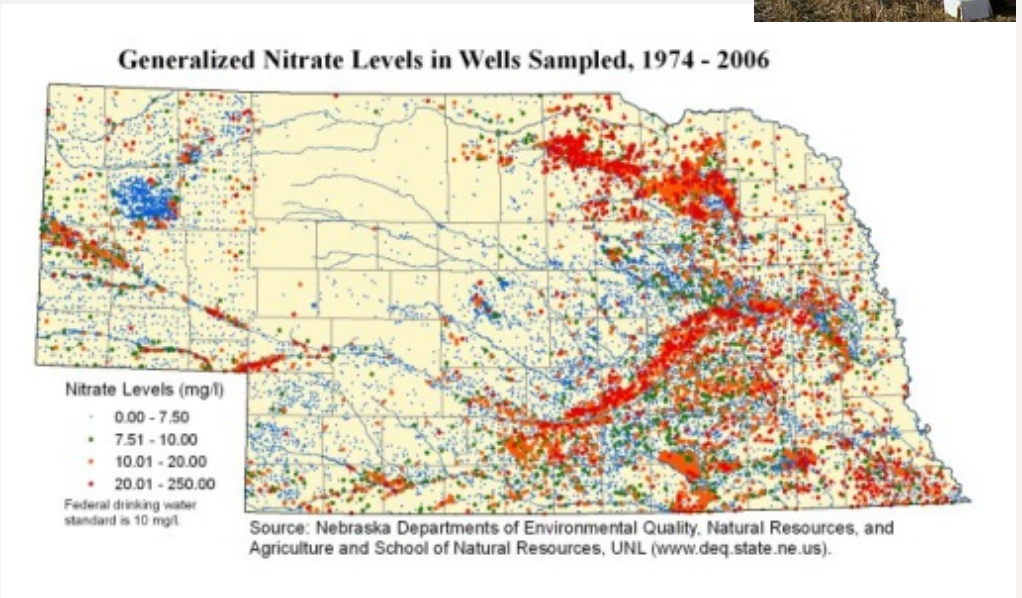
"Is Our Ground-Water Monitoring Strategy Illogical?"

- Purpose of monitoring is to prevent water contamination
- Traditional approaches rely on collecting water samples
- Like "monitoring a person's heartbeat to prevent a heart-attack"

Stephen J. Cullen, John H. Kramer, Lorne G. Everett, and Lawrence A Eccles. 1992. Is Our Ground-Water Monitoring Strategy Illogical?. Ch. 1 In: Handbook of Vadose Zone Characterization and Monitoring. Ground Water Publishing Company.

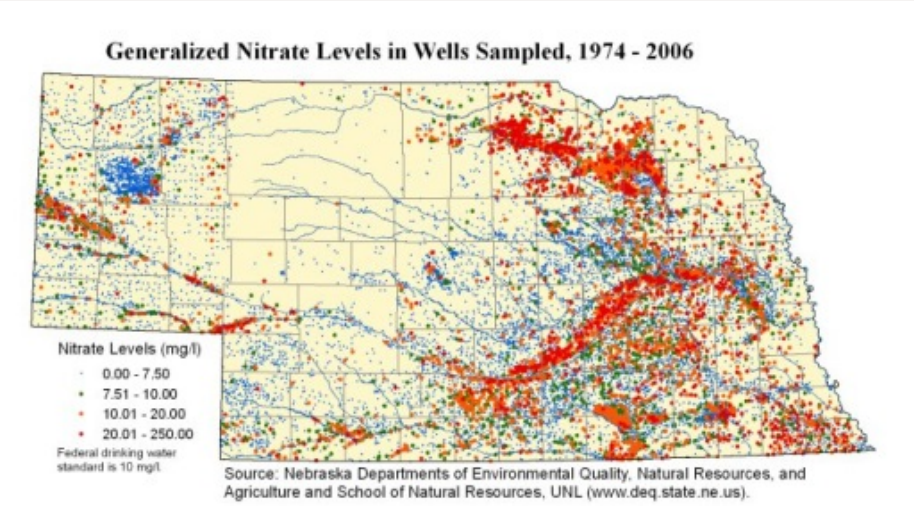
IF PREVENTION OF CONTAMINATION THE GOAL….THEN

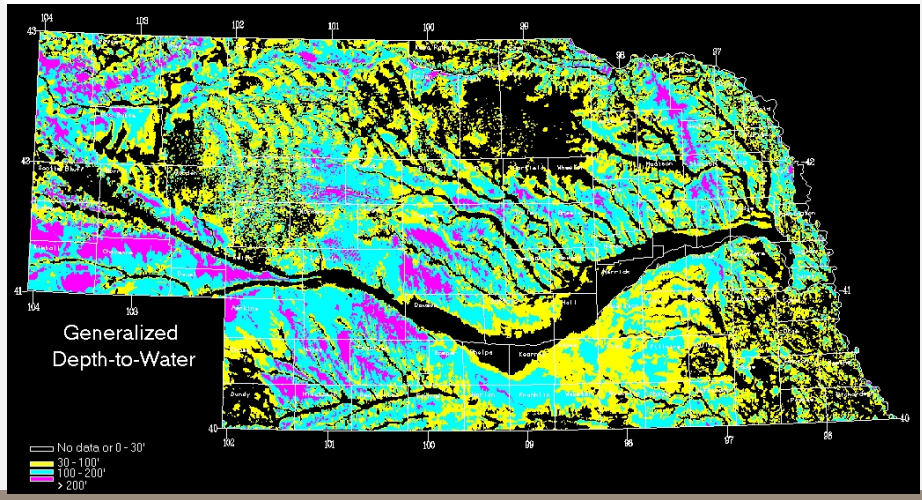
- Vadose zone monitoring could provide an “early warning” permitting early detection
- Complimented by groundwater monitoring programs used to detect, observe, regulate, and control ground water quality



Where to Look?

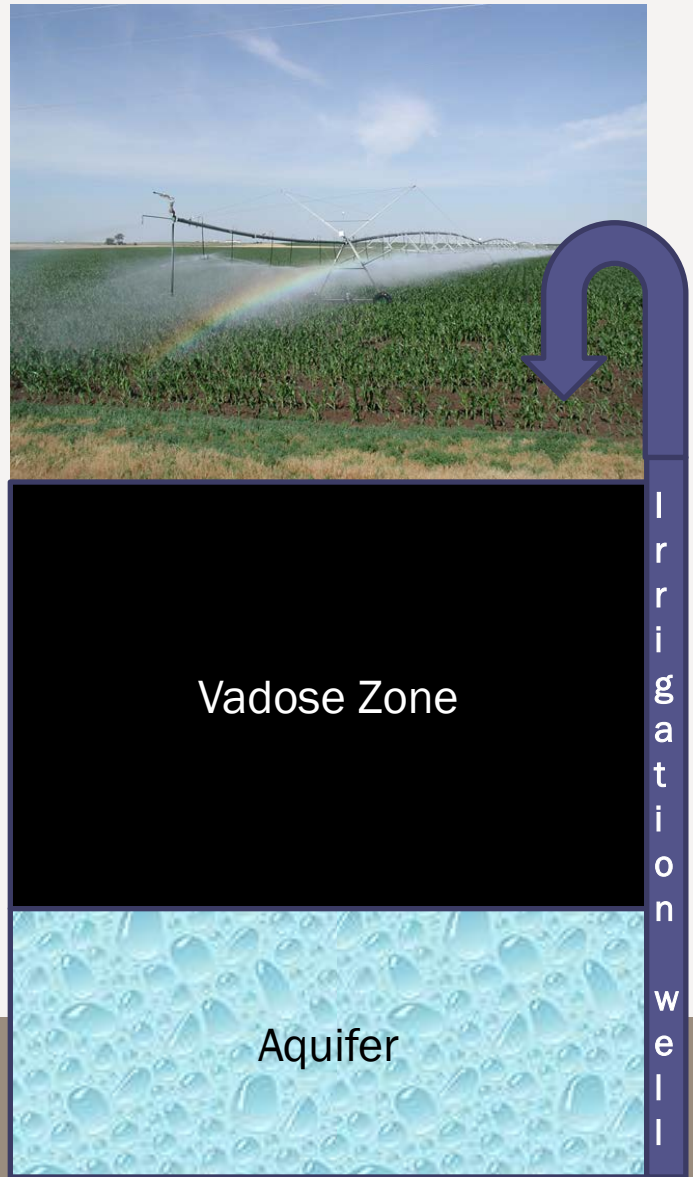
- Pick areas impacting present or future drinking water sources
- Relatively permeable vadose zone
- Intermediate depth to water table (50-150’)





What is the Vadose Zone?

- Earth between the land surface and the top of the phreatic **zone** i.e. the position at which the groundwater (the water in the soil's pores) is at *atmospheric pressure*
- **Vadose** is from the Latin for "shallow")
- Does not include capillary fringe but does affect water table



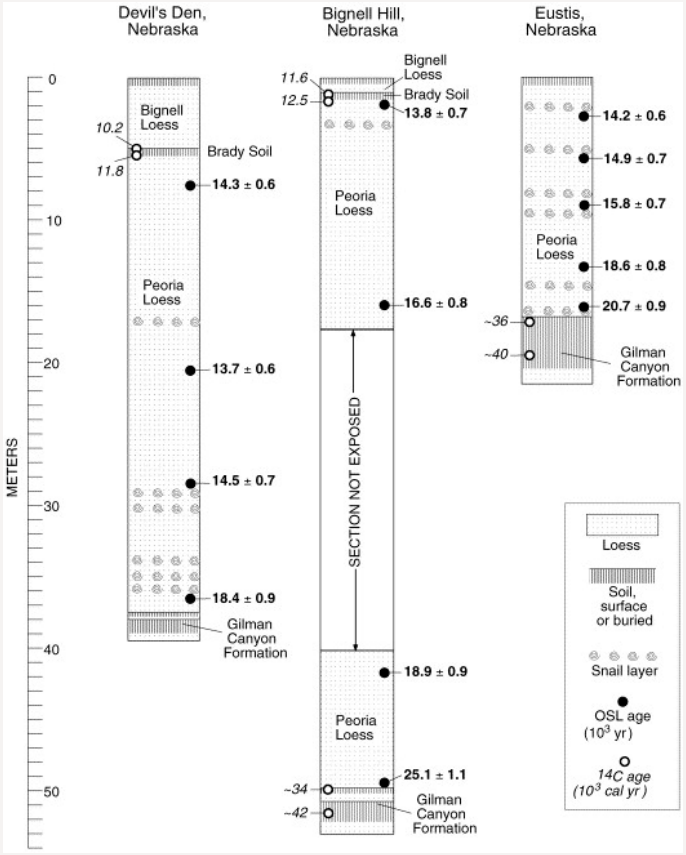
Vadose Zone

- Geologic profile below the surface and above the first principal aquifer
- Highly variable water flow rates
- Saturated flow in response to precipitation and hydrologic events

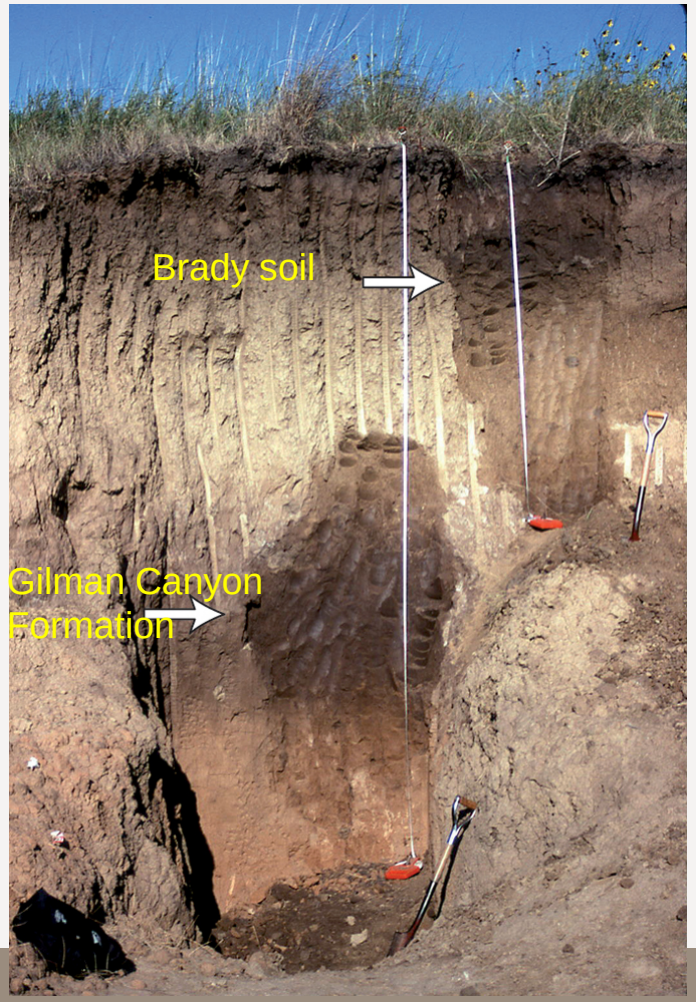
Road cut along US 281, just north of the North Loup River

Stephen J. Cullen, John H. Kramer, Lorne G. Everett, and Lawrence A Eccles. 1992. Is Our Ground-Water Monitoring Strategy Illogical?. Ch. 1 In: Handbook of Vadose Zone Characterization and Monitoring. Ground Water Publishing Company.

COMPOSITION HIGHLY VARIABLE



Roberts, H. M., D. R. Muhs, A. G. Wintle, G. A. T. Duller and E. A. Bettis Iii (2003). "Unprecedented last-glacial mass accumulation rates determined by luminescence dating of loess from western Nebraska." Quaternary Research **59(3): 411-419.**



Johnson, W. C. (2014). "Carbon cycle: Sequestration in buried soils." Nature Geosci **7(6): 398-399.**

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STANDARDIZE DATA COLLECTION THE VADOSE ZONE

The Federal Remediation Technologies Roundtable (FRTR) works to build a collaborative atmosphere among federal agencies involved in hazardous waste site cleanup.

https://frtr.gov/default.htm

FIELD SAMPLING AND ANALYSIS MATRIX: FIELD SAMPLING AND COLLECTION TECHNIQUES

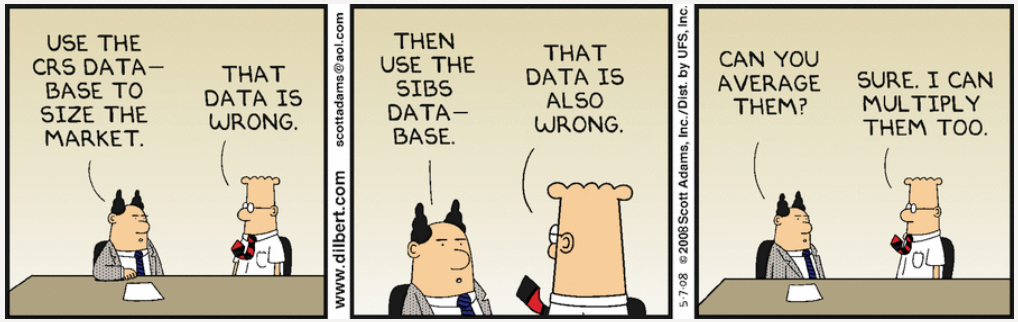
https://frtr.gov/site/samplegif.html

Handling, storage and Data Collection

- Soils and sediments biologically active
- Grain size versus chemical analysis?
- Use handling methods that preserve parameters to be measured
- Sampling Interval?
- Textural description?

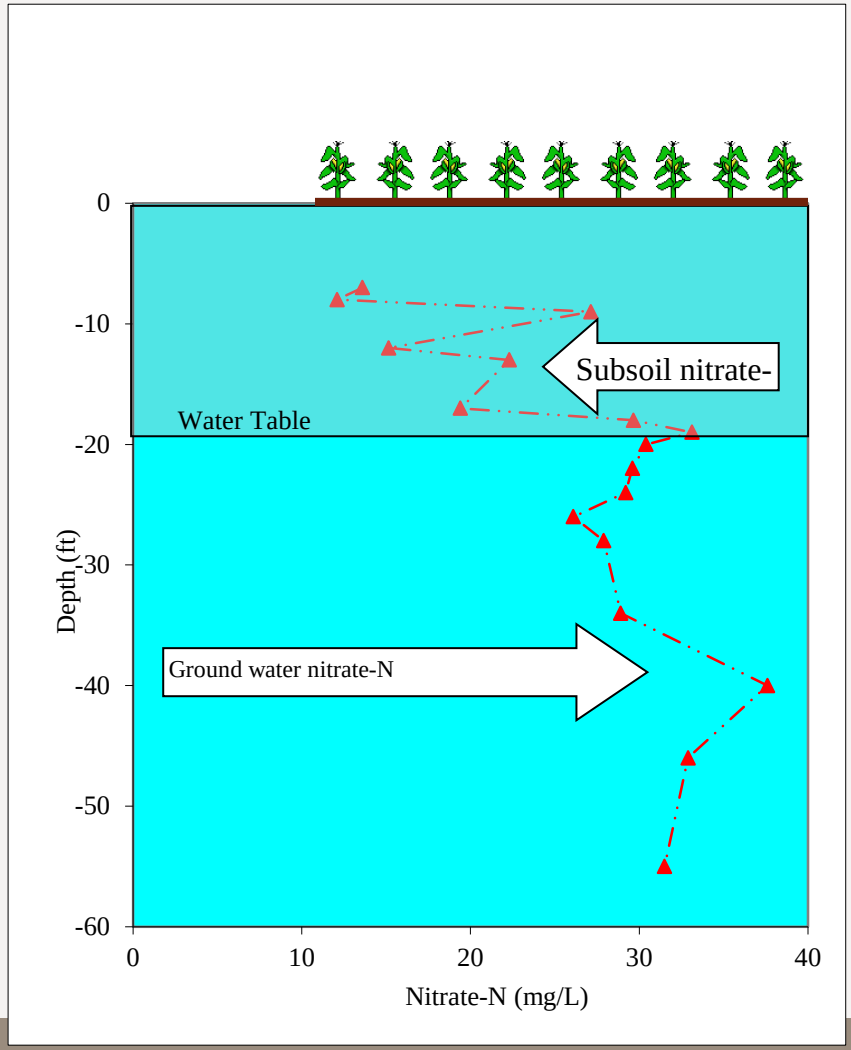
Why standardize/classify Data Collection?

- Easier for comparing trends over time and between locations
- Other measurements made at the time of collection can be used to help interpret changes over time



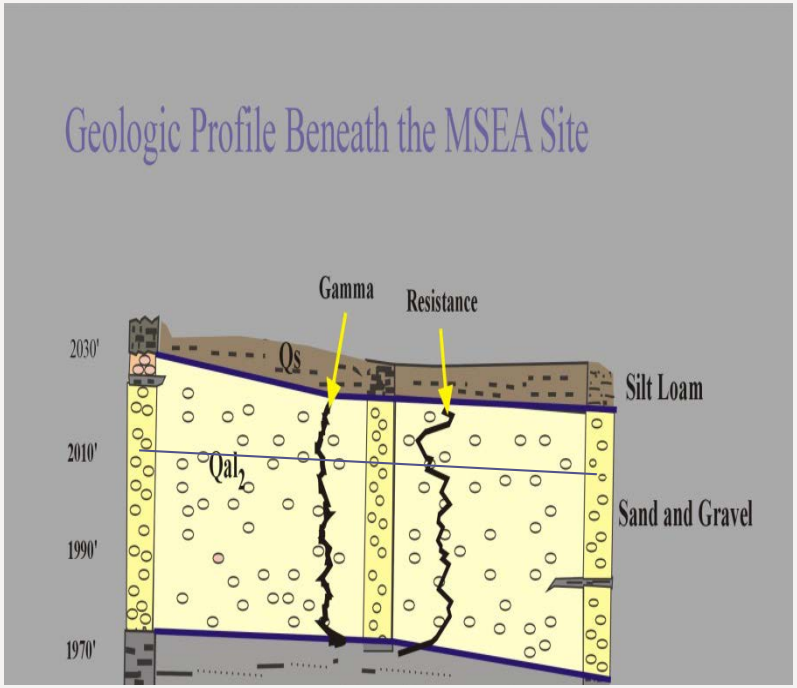
Vadose Zone Measurements

- What questions need to be answered?
- Variation of nitrate-N concentrations with depth
- Sediment composition (hydraulic and mineral properties)
- Moisture, pH, ammonia-N, carbon



PREDICT POTENTIAL FOR NITRATE LEACHING

Depth	Bulk Density	Grav. Water Content	pH	Soil NH4-N	Soil NO3-N	Pore Water NO3-N	Soil NO3-N
(ft)	(g/cc)			(ug/g)	(ug/g)	(mg/L)	(lbs/acre)
-7	1.24	0.20	6.8	4.39	2.68	13.6	9.0
-8	1.41	0.21	6.7	1.78	2.49	12.1	9.5
-9	2.03	0.08	6.8	1.59	2.20	27.1	12.2
-12	1.65	0.08	6.9	1.32	1.27	15.2	5.7
-13	2.24	0.06	7.0	1.23	1.32	22.3	8.0
-17	1.80	0.13	6.8	0.91	2.54	19.4	12.4
-18	2.10	0.16	7.0	1.55	4.64	29.7	26.4
-19	1.88	0.14	7.0	1.18	4.73	33.1	24.1



WHAT DATA IS MOST USEFUL?

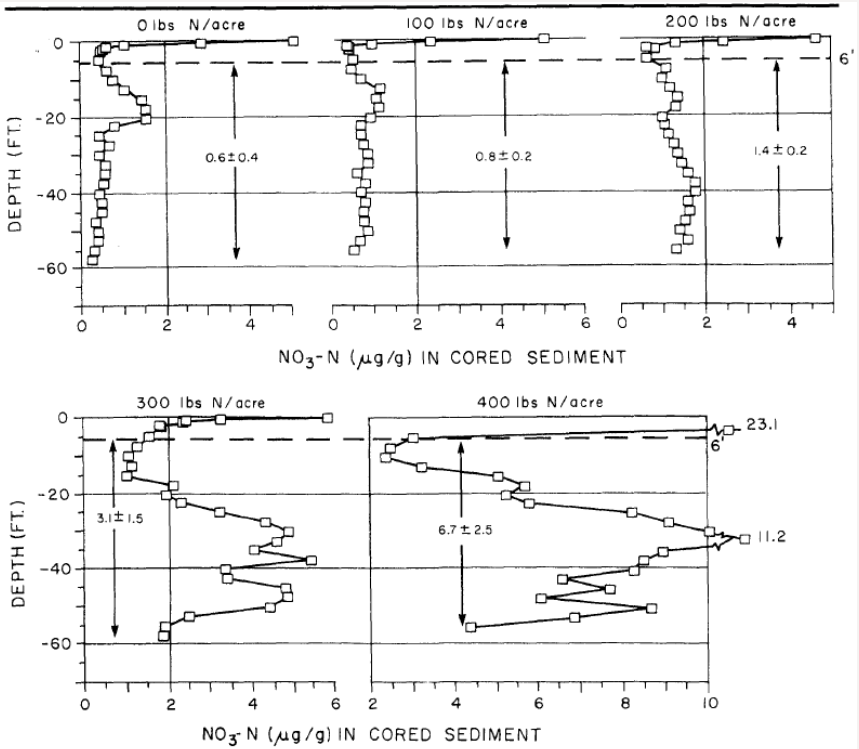


Figure 2. Average vertical nitrate-N profiles on a dry weight basis (μg/g) from fertility plots at SCREC. Number between arrows is the average NO_3-N concentration and standard deviation for the IVZ.

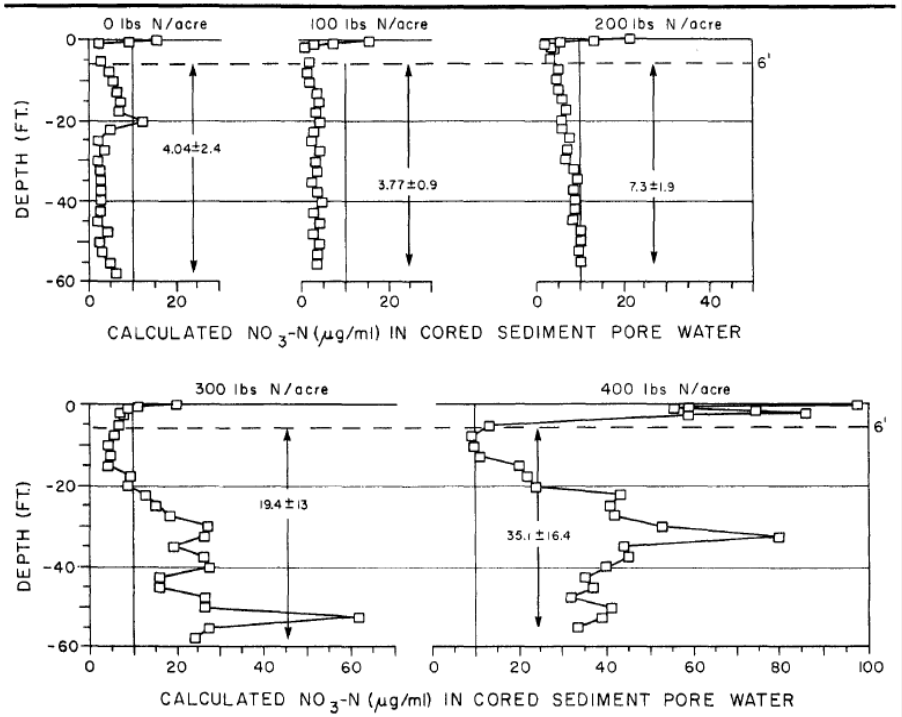


Figure 3. Calculated average vertical nitrate-N profiles in pore water (μg/mL) from fertility plots at SCREC. Number between arrows is the calculated average NO_3-N concentration and standard deviation for the IVZ.

Spalding, R. F. and L. A. Kitchen (1988). "Nitrate in the intermediate vadose zone beneath irrigated cropland." Ground Water Monitoring & Remediation **8(2): 89-95.**

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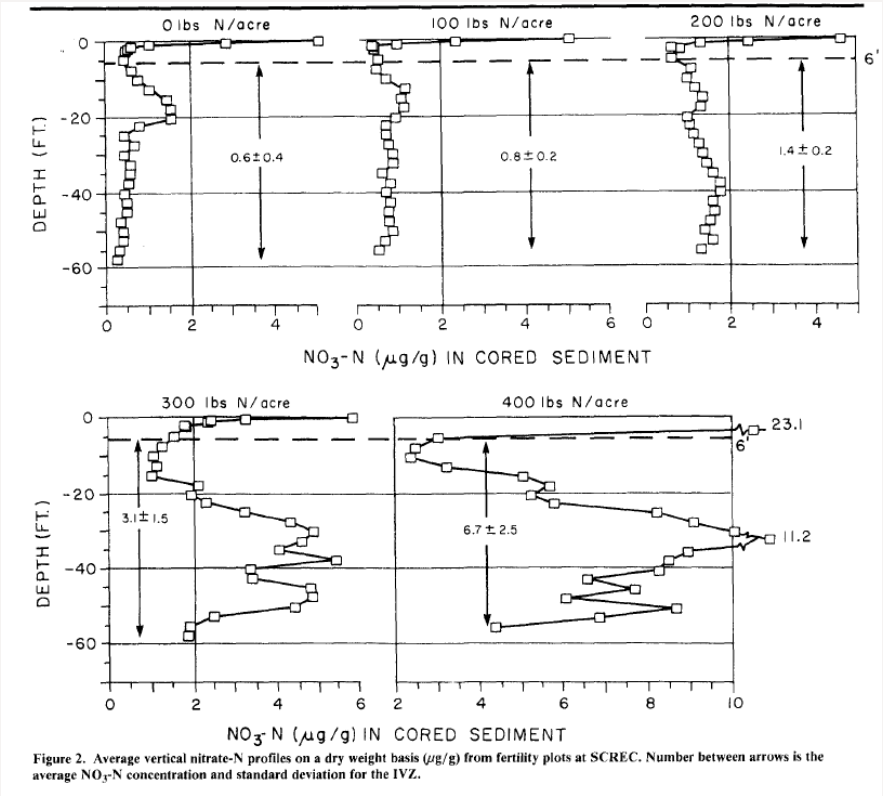

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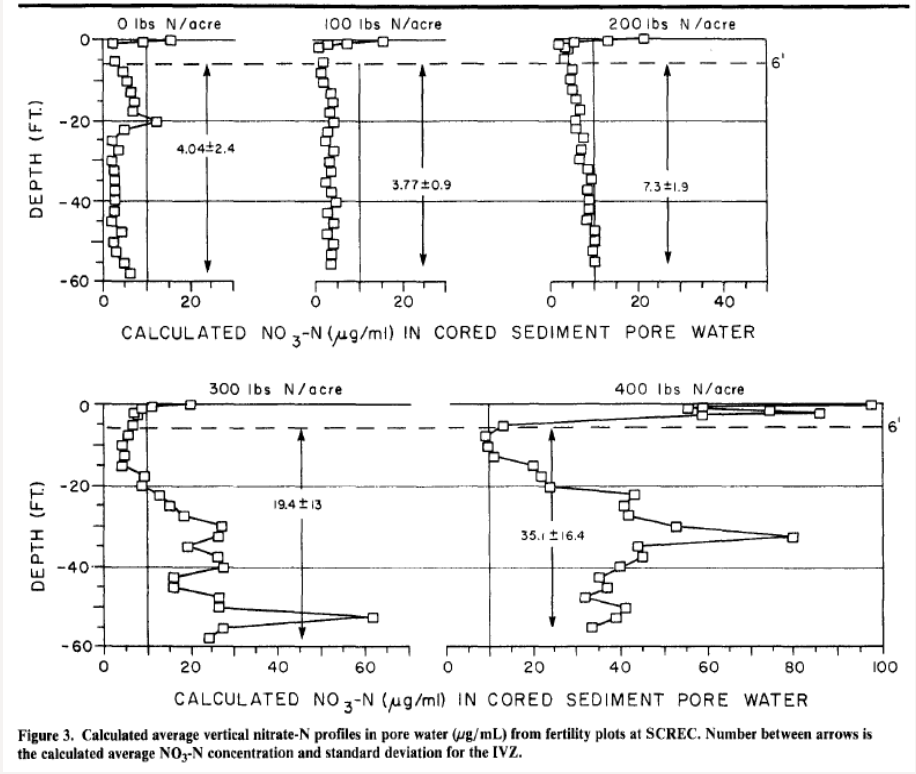

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Water Table = 99'

- Ave particle size: 30% clay:56% silt:14% sand (n=44)
- Paleosol @ 17-20', Sandy zones @ 25-28' & 45-48'
- Thick sand layer at 60 feet

Spalding, R. F. and L. A. Kitchen (1988). "Nitrate in the intermediate vadose zone beneath irrigated cropland." Groun
Water Monitoring & Remediation **8(2): 89-95.**

WHAT DATA IS MOST USEFUL?

Average transport rate = 76cm/yr

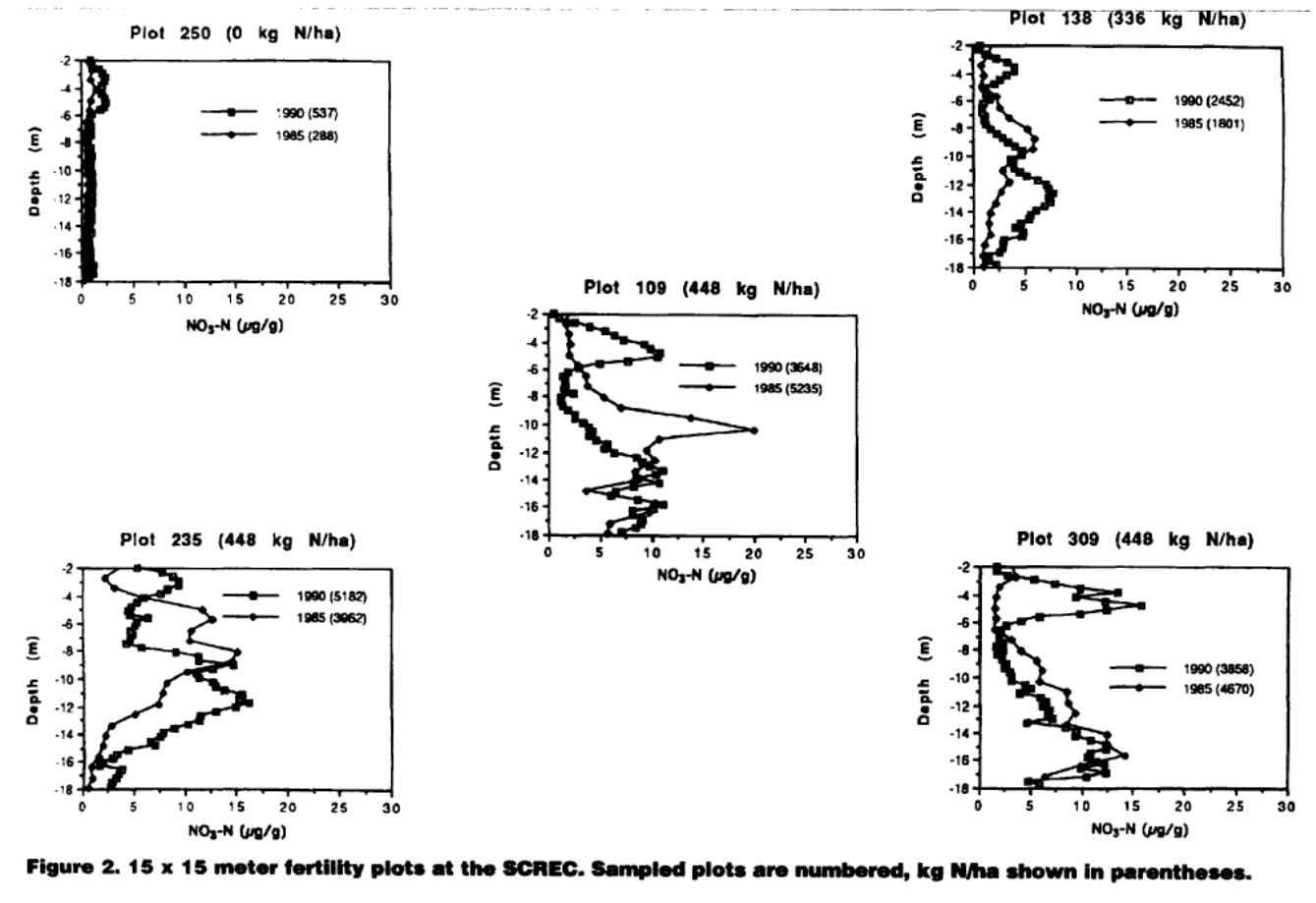
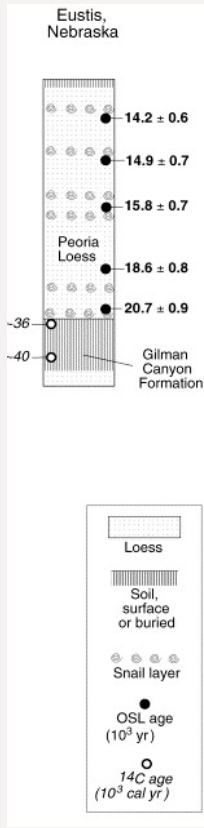


Figure 2. 15 x 15 meter fertility plots at the SCREC. Sampled plots are numbered, kg N/ha shown in parentheses.



120 miles west

Bobier, M. W., K. D. Frank and R. F. Spalding (1993). "Nitrate-N movement in a fine-textured vadose zone." Journal of Soil and Water Conservation **48(4): 350-354.**

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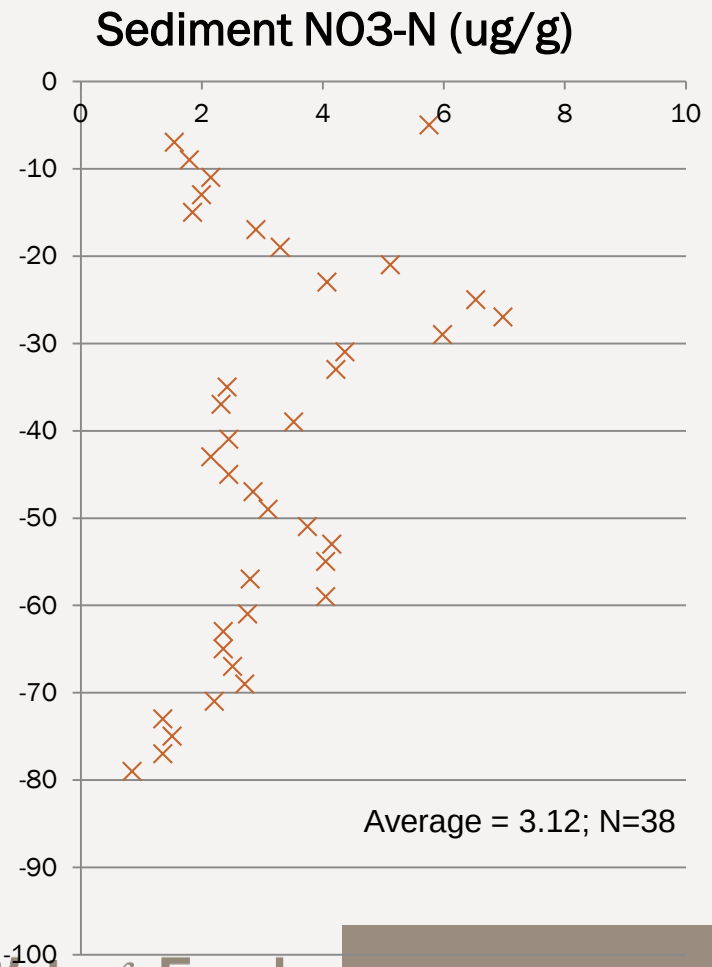
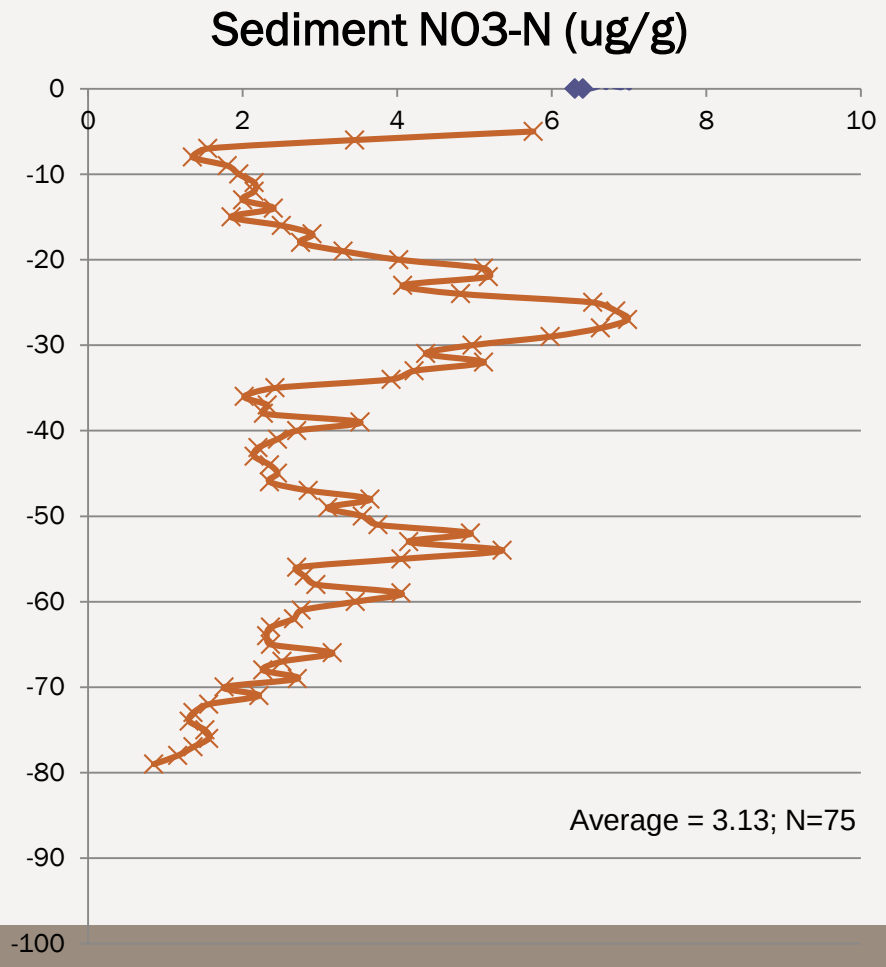
Data Collection Strategy – How many depths?





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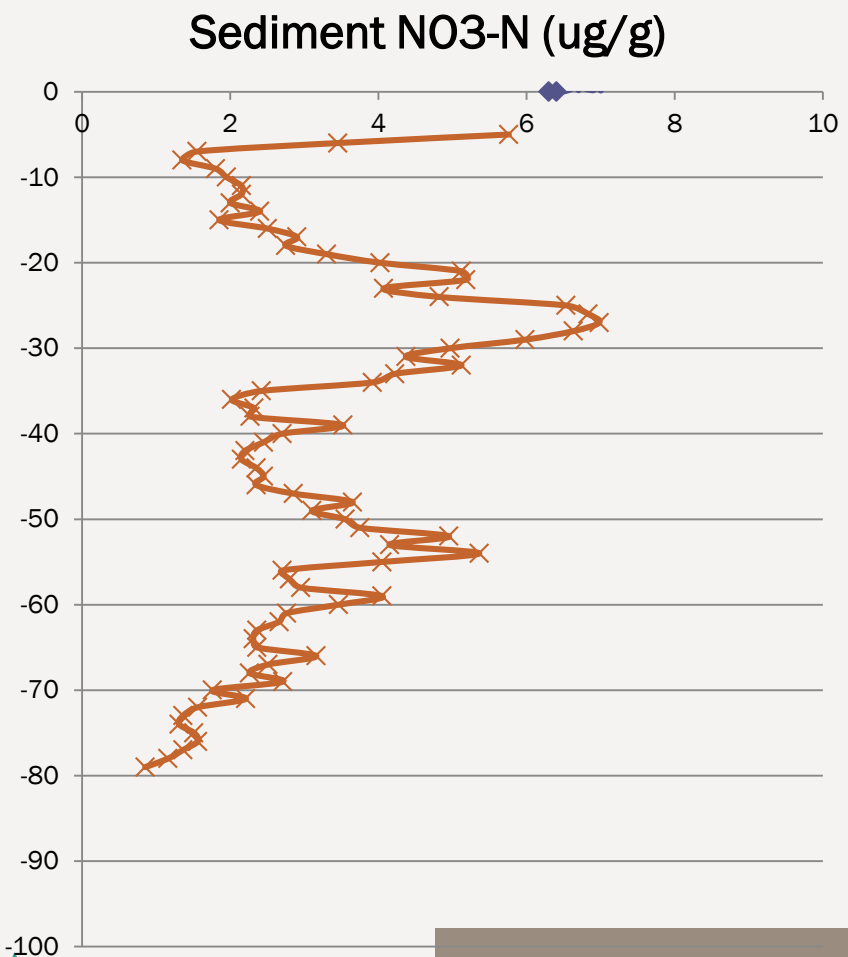
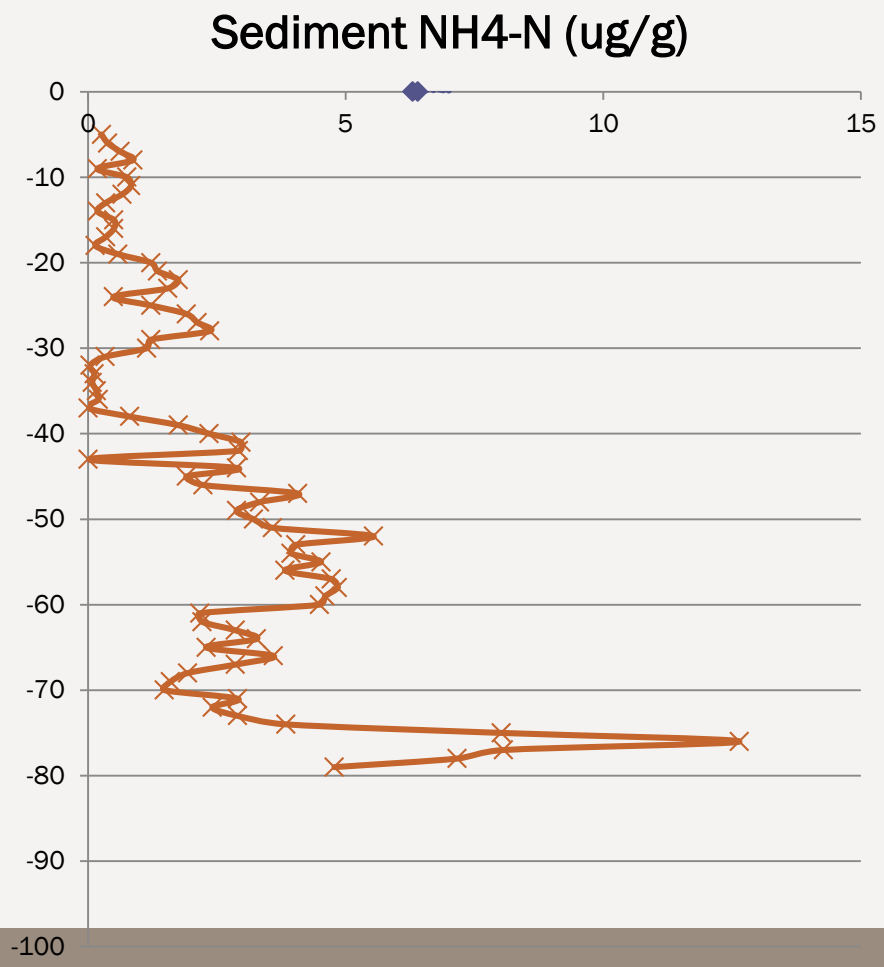
Data Collection – Other forms of nitrogen?





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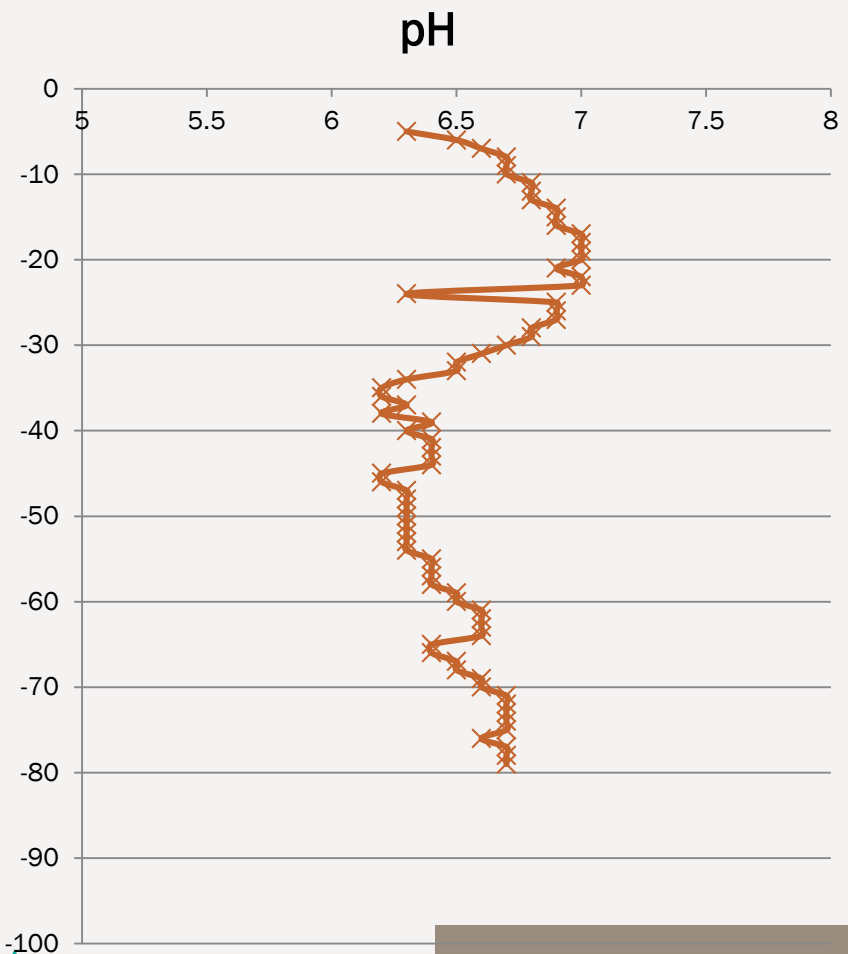
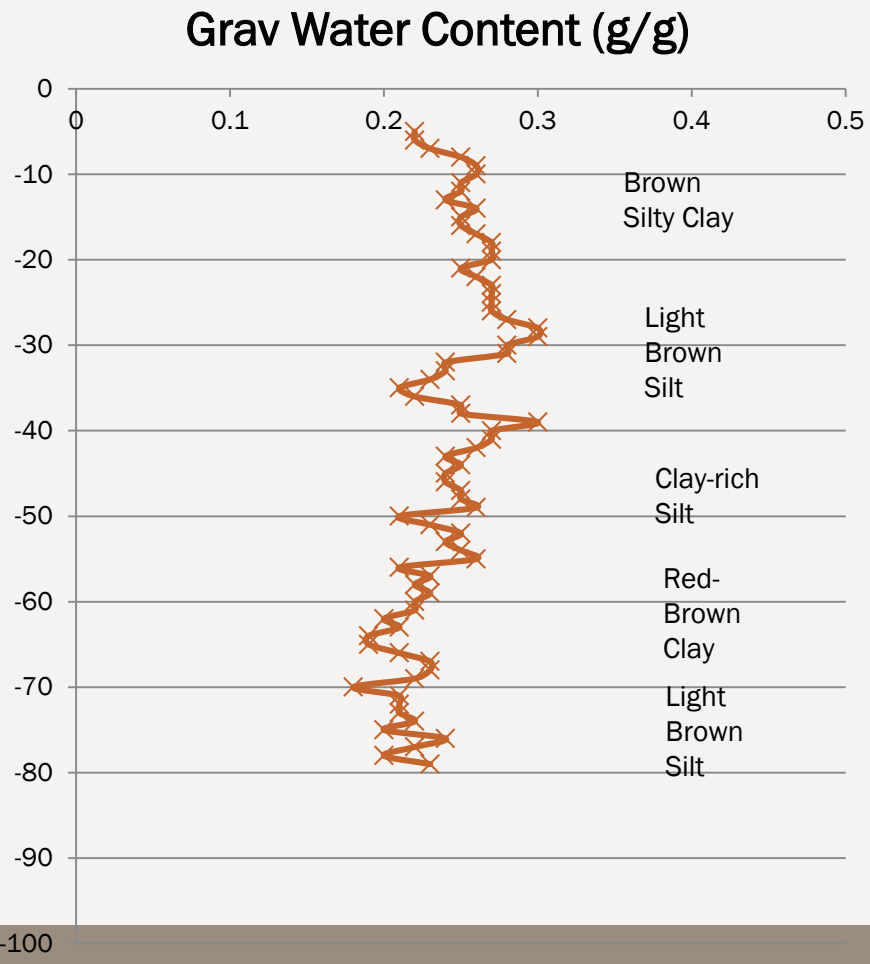
Data Collection Physical/Chemical?





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Other Data to characterize sources, related contaminants, and transport rates

- $^{15}N\text{-}NO_3$, $^{18}O\text{-}NO_3$
- Total and soluble organic carbon
- Iron, Manganese
- Uranium, Arsenic, Selenium
- Pesticides
- Tracers: Chloride, $^{2}H\text{-}H_2O$, $^{18}O\text{-}H_2O$

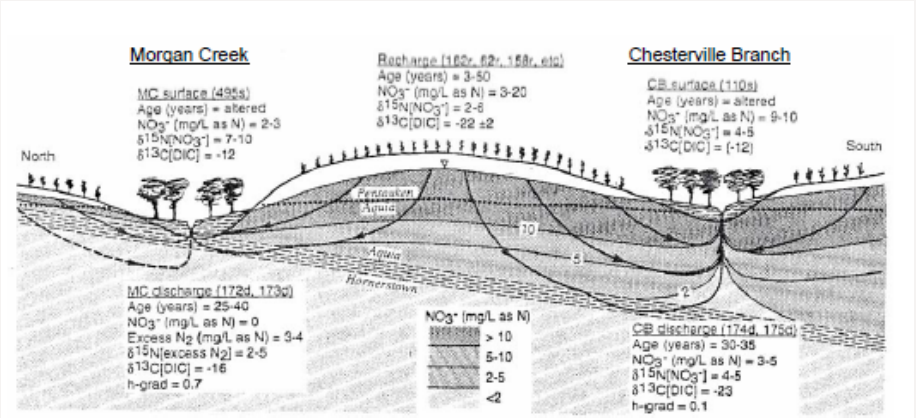

Figure 5.4. Schematic cross section through two shallow catchments in Maryland (after Böhlke and Drever (1995).

How can we use previous vadose zone Nitrate data?

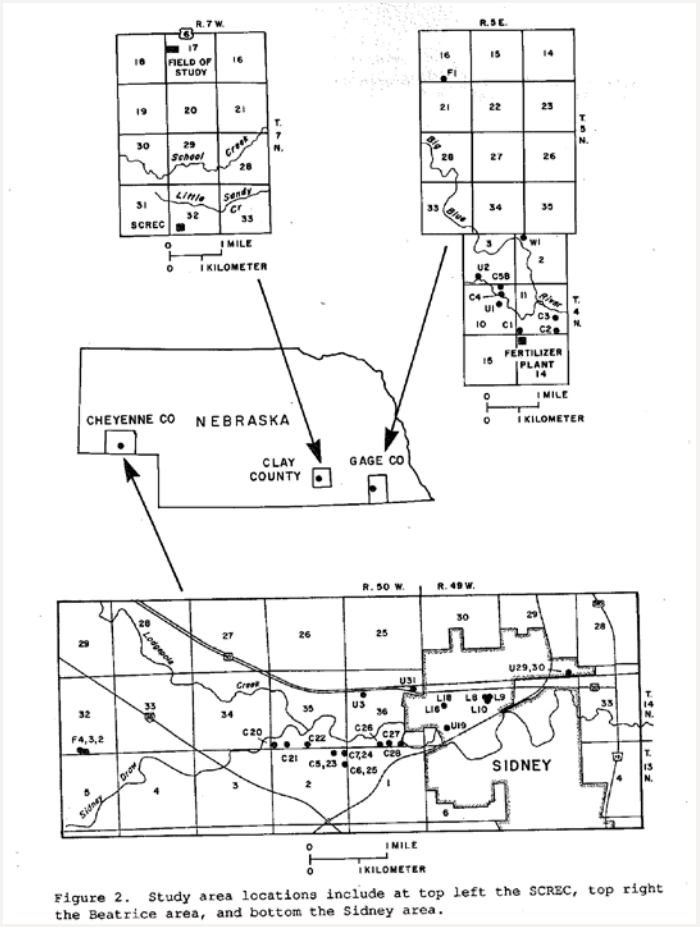

Figure 2. Study area locations include at top left the SCREC, top right the Beatrice area, and bottom the Sidney area.

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Spalding, Bryda and Kitchen. 1988. Intermediate Vadose Zone Nitrate. In: Agricultural Impacts on Ground water - A Conference. National Groundwater Association. March 21-23, 1988, Des Moines, Iowa.

What are the best practices for comparing Historical to modern Vadose zone nitrate profiles?

- Coring and subsample collection methods?
- Are textural descriptions available?
- Were additional measurements made?
- What data has been collected during the time lapse?

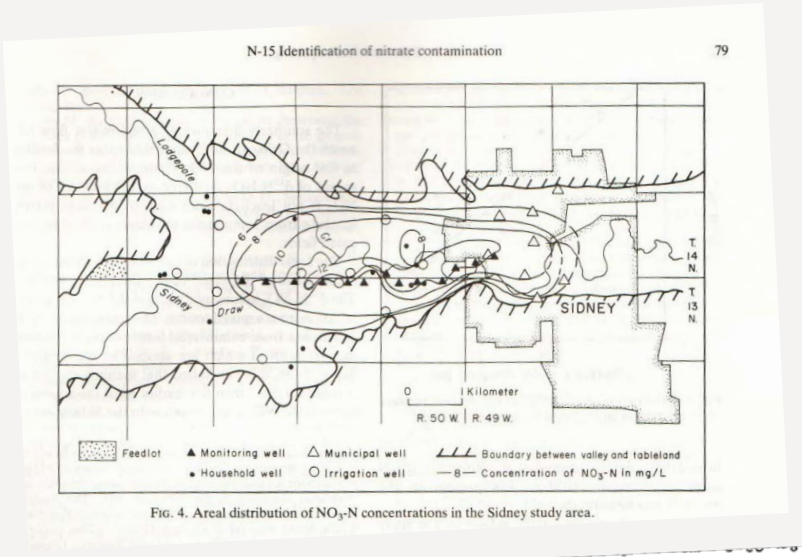


FIG. 4. Areal distribution of NO_3-N concentrations in the Sidney study area.

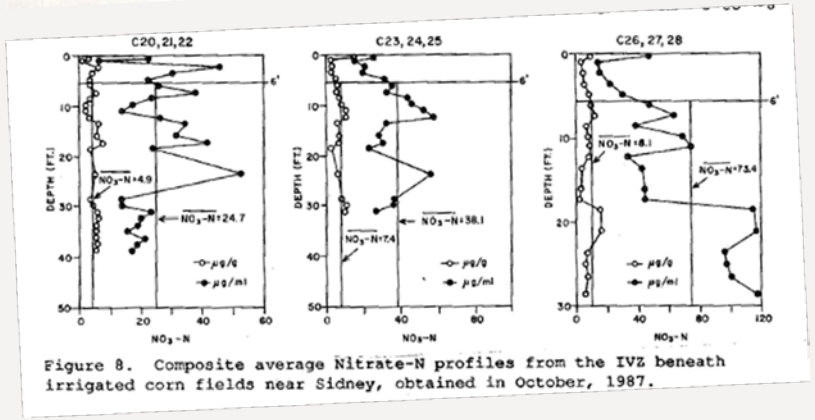
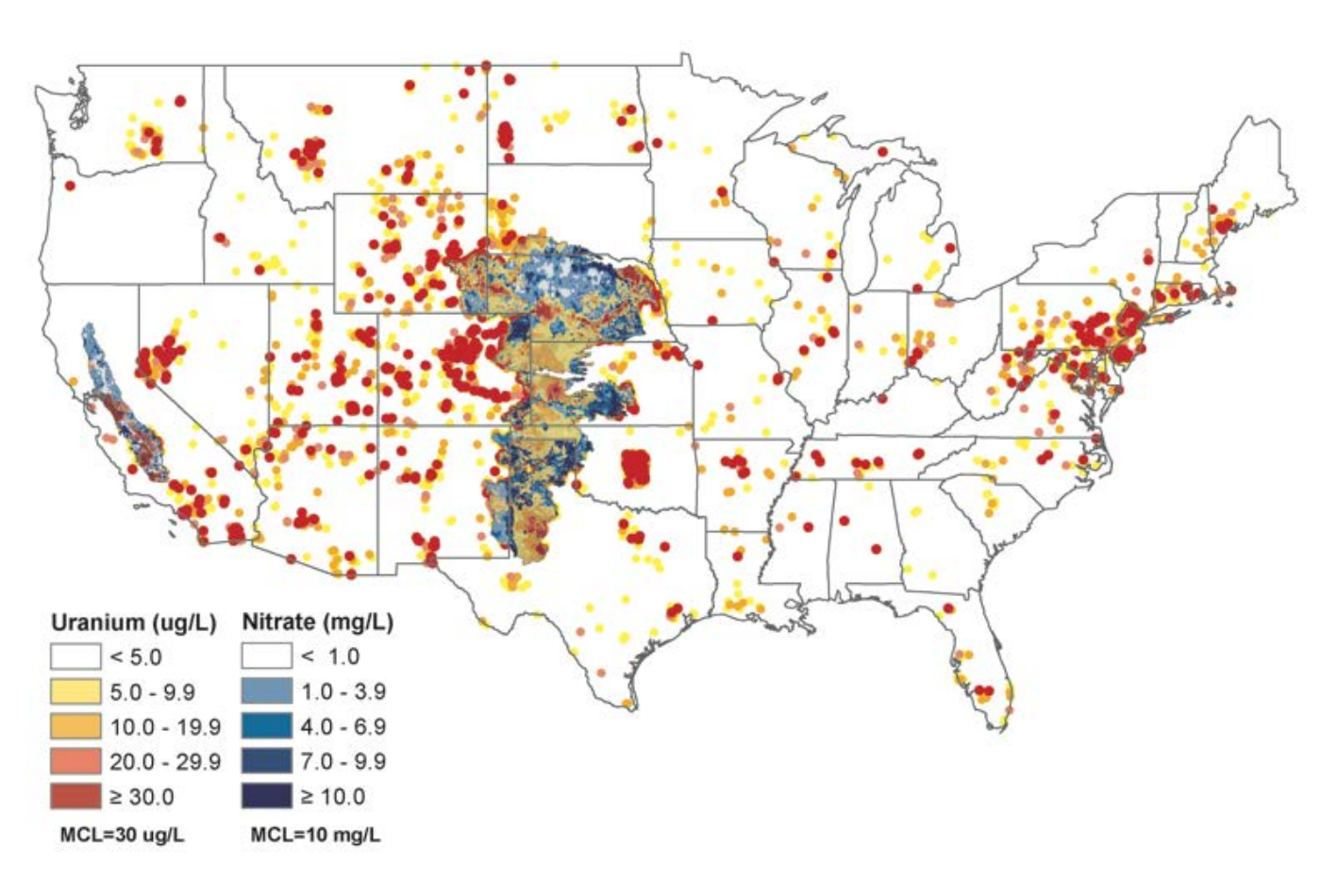


Figure 8. Composite average Nitrate-N profiles from the IVZ beneath irrigated corn fields near Sidney, obtained in October, 1987.

Exner, M. E. and R. F. Spalding (1994). "N-15 identification of nonpoint sources of nitrate contamination beneath cropland in the Nebraska Panhandle: two case studies." Applied Geochemistry **9: 73-81.**

IT'S NOT JUST ABOUT NITRATE



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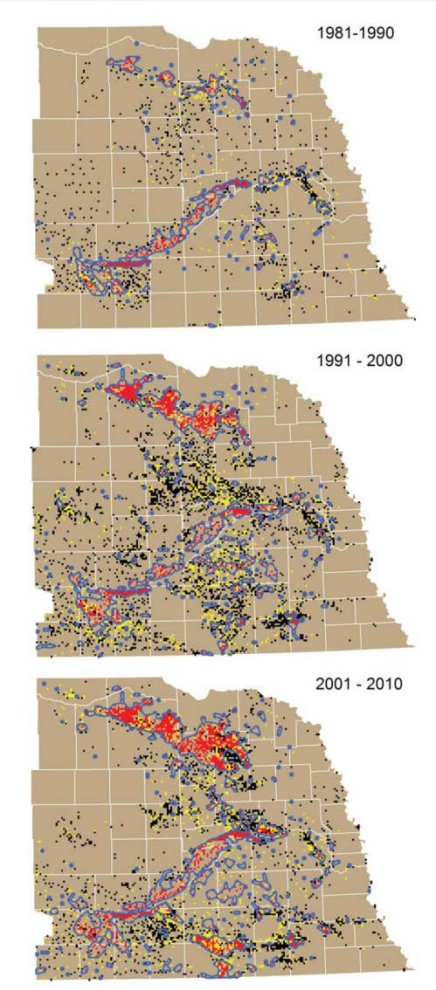
Nolan, J., & Weber, K. A. (2015). Natural uranium contamination in major US aquifers linked to nitrate. *Environmental Science & Technology Letters*, *2*(8), 215-220.

Chasing Nitrate in the Vadose Zone

- Nitrate is a moving target
- Occurrence and movement in the vadose zone not well understood
- Vadose zone difficult to sample, but critical for informed monitoring



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Exner, M. E., A. J. Hirsh and R. F. Spalding (2014). "Nebraska's groundwater legacy: Nitrate contamination beneath irrigated cropland." Water Resources Research **50(5): 4474-4489.**

Questions?

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