CHASING VADOSE ZONE NITRATE: CASE STUDIES IN NEBRASKA

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• Vadose zone monitoring provides an "early warning" and early detection
• Complimented by groundwater monitoring programs used to detect, observe, regulate, and control ground water quality
OK – JUST WHERE IS THIS VADOSE ZONE?
What questions need to be answered?

- Variation of nitrate-N concentrations with depth?
- Changes in vadose nitrate over time?
- Estimated transport rates?
- Relationship to nutrient-water management?
- Effect of sediment lithology?
- Potential for nitrate transformation?

- Sediment composition (hydraulic and mineral properties)
- Moisture, pH, ammonia-N, carbon
Geologic Profile Beneath the MSEA Site

- Water Table
- Vadose nitrate-N
- Ground water nitrate-N

Graph showing depth (ft) vs. nitrate-N (mg/L)
Look at each parameter individually and then put everything together.
Gravimetric Water Content (g/g)
Vadose Zone NH4-N (µg/g)
Dry Weight NO3-N (µg/g)
Pore Water NO3N (mg/L)

~150 lbs/acre
HASTINGS WELLHEAD PROTECTION AREA
Figure 3 shows the 2005 land use throughout the LBNRD. The source is the UNL-CSID database.
The image shows a map of the Little Blue Natural Resources District with a focus on groundwater recharge values. The map uses color gradients to indicate different recharge rates, with high rates in orange and yellow and low rates in green. The legend on the left provides a basis for understanding the color coding, with symbols for principal aquifers, 10/50 areas, recharge contours, and base data legends. The map is used to illustrate the estimated mean annual total recharge rates as a percentage of precipitation in Nebraska. The sources include information from the Nebraska Department of Natural Resources (NE DNR) and other relevant datasets. The note at the bottom of the map refers to additional information on data sources and methods used to create the map. The figure is labeled as Figure 30.1 and is credited to Joseph Szlagy, Associate professor, Conservation and Survey Division, School of Natural Resources, Lincoln, Nebraska.
This map shows geologic cross sections locations "A" through "E" developed for the LBNRD. The lines incorporate data from LBNRD monitoring wells that had corresponding geologic logs from the Nebraska DNR in addition to UNL- CSD test holes. See individual cross section sketches for a profile corresponding to each identified line. Note that this map (and Map 16) also shows the estimated glacial boundary limit found in the Little Blue NRD.
A cross section diagram from A-A' through the center of Adams and Webster Counties, north to south. (See Figure 7 for cross section location.)
Figure 11. Most recent recorded Nitrate-N concentrations of 20,306 wells from 1994-2014.  
(Source: Quality-Assessed Agrichemical Database for Nebraska Groundwater, 2015) 

Empty areas indicate no data reported, not the absence of nitrate in groundwater.
COMPARISON OF 20-YEAR MODELED TIME OF TRAVEL TO EXTENT OF GROUNDWATER NITRATE
2011 Coring Locations Compared to Extent of Groundwater Nitrate
LAND USE IRRIGATION PRACTICES
Thirty-six 60 foot long cores collected using direct-push technology.

Sites selected based on availability, land use, and cropping history.

Provided an initial baseline of vadose zone in wellhead protection area to evaluate whether improved water and nutrient management effectively control nitrate leaching.

2011 SURVEY OF VADOSE ZONE NITRATE
- Crops: estimated pore water nitrate-N ranged between 5-50 mg/L, or 250-2500 lbs/acre
- Residential/abandon livestock areas generally lower, 10-25 mg/L, or 100-400 lb/acre except for 1 yard
- Assumed average 2.5 foot/year transport rate to predict approximate time of loading/leaching event

![Graph showing pore water nitrate-N concentration](image)

**2011 OBSERVATIONS**
Residential Area

HC-3A - 2011

Total NO₃-N 290 lbs/acre

Bulk Density assumed=1.33 g/cm³

HC-3A - 2016

Total NO₃-N 600 lbs/acre

Average Bulk Density=1.57 g/cm³
Gravity Irrigated Corn Site

HC-11E - 2011

HC-11E - 2016

Total NO$_3$-N 524 lbs/acre

Bulk Density assumed=1.33 g/cm$^3$

Top 60’ = 230 lbs/acre

Total NO$_3$-N 410 lbs/acre

Average Bulk Density=1.35 g/cm$^3$
Pivot Irrigated Corn Site

HC-13 - 2011

HC-13 - 2016

Total NO₃-N 315 lbs/acre

Bulk Density assumed = 1.33 g/cm³

Top 45' NO₃-N 560 lbs/acre

Total NO₃-N 830 lbs/acre

Average Bulk Density = 1.41 g/cm³
Figure 11. Most recent recorded Nitrate Levels.
(Source: Quality-Assessed Data)

Empty areas indicate no data reported, not the absence of nitrate in groundwater.

1996 NO$_3$-N 680 lbs/acre
2016 NO$_3$-N 200 lbs/acre
DH-47 Pivot Irrigated, Corn/Soybean Rotation

DH-47 NO₃-N

2016 Average = 1.7

DH-47 Pore Water NO₃-N

2016 Average = 28.8

DH-47 Gravimetric Water Content

2016 Average = 0.15

DH-47 NH₄-N

2016 Average = 0.33

2016 NO₃⁻N 445 lbs/acre
DH-49 NO₃-N

0 20 40 60 80 100 120
Feet Below Surface

DH-49 NO₃-N (ug/g)

Feet Below Surface

2016 Average = 2.38

DH-49 Pore Water NO₃-N

0 20 40 60 80 100
Pore Water NO₃-N (mg/L)

Feet Below Surface

2016 Average = 31.6

DH-49 Gravimetric Water Content

0.00 0.05 0.10 0.15 0.20 0.25 0.30
Feet Below Surface

DH-49 Gravimetric Water Content

2016 Average = 0.15

DH-49 NH₄-N

0 2 4 6 8
Feet Below Surface

2016 Average = 1.41

2016 NO₃-N 612 lbs/acre
Comparison of Average Vadose N

- Residential
- Gravity Irrigated Corn
- Pivot Irrigated Corn
- Pivot Irrigated Corn/Soybeans
- Pivot Irrigated Corn/Soybeans
- Gravity Irrigated Corn/Soybeans

- NO₃ N Average (µg/g)
- Porewater Average (mg/L)
- NH₄ N Average (µg/g)
Possible relation between sediment NO$_3$N and porewater NO$_3$N
DH-32 NO3-N

Feet Below Surface

-100
-80
-60
-40
-20
0
20
40
60
80
100

NO3-N (ug/g)

NO3-N Concentration

Bulk Density

µg NO3-N | g soil | g NO3-N | 1 lbs NO3-N | 1,233,481,855 cm³ soil
---------|--------|---------|-------------|-----------------
  g soil  | cm³ soil | 1,000,000 µg NO3-N | 454 g NO3-N | 1 acre-ft soil

Is this conversion helpful?
2016 Vadose Total N (lbs/acre) (Excluding DH19)
Nitrate fate and transport occurs in a geologic framework
Long term evaluation of changing N, H₂O and land use practices
Total N Loading = lost nitrogen + moisture + lithology +?
Collecting and presenting measurements across time and space
Conclusion

Ammonium Nitrate is taken-up directly by plants while urea first needs to be converted. Ammonium Nitrate therefore offers a higher nitrogen use efficiency than urea. Ammonium Nitrate thus reduces losses and environmental impact.