Nitrate removal from shallow groundwater in Central Wisconsin: pattern and process

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Projects Funded by the Groundwater Coordinating Council’s Joint Solicitation

The lethal and sublethal effects of elevated groundwater nitrate concentrations on infaunal invertebrates in the Central Sand Plains (2008-2010)

Groundwater nitrate processing in deep stream sediments (2010-2011)

The effects of particulate organic carbon quantity and quality on denitrification of groundwater nitrate (2011-2013)

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The lethal and sublethal effects of elevated groundwater nitrate concentrations on infaunal invertebrates in the Central Sand Plains (2008-2010)

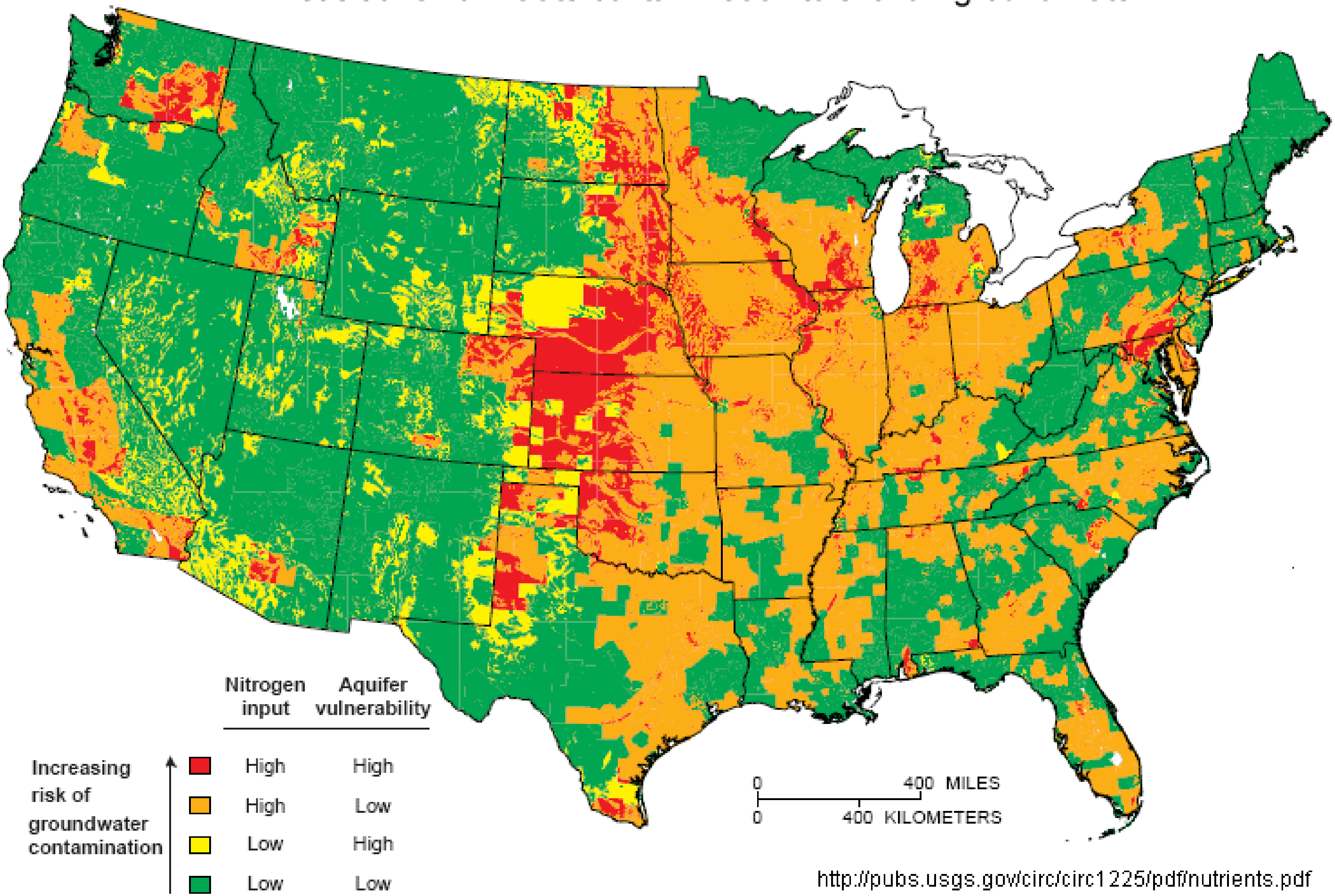
Stelzer, R.S. and B.L. Joachim*. 2010. Effects of elevated nitrate concentration on mortality, growth, and egestion rates of *Gammarus pseudolimnaeus* amphipods. *Archives of Environmental Contamination and Toxicology 58: 694-699.* DOI 10.1007/s00244-009-9384-x

Stelzer, R.S., L.A. Bartsch, W.B. Richardson, and E.A. Strauss. 2011. The dark side of the hyporheic zone: depth profiles of nitrogen and its processing in stream sediments. *Freshwater Biology*, In Press.

Groundwater nitrate processing in deep stream sediments (2010-2011)

The effects of particulate organic carbon quantity and quality on denitrification of groundwater nitrate (2011-2013)

Areas at risk of nitrate contamination to shallow ground water



http://pubs.usgs.gov/circ/circ1225/pdf/nutrients.pdf

Effects of elevated nitrate concentration in shallow groundwater

* human health problems
* localized algal blooms
* coastal eutrophication

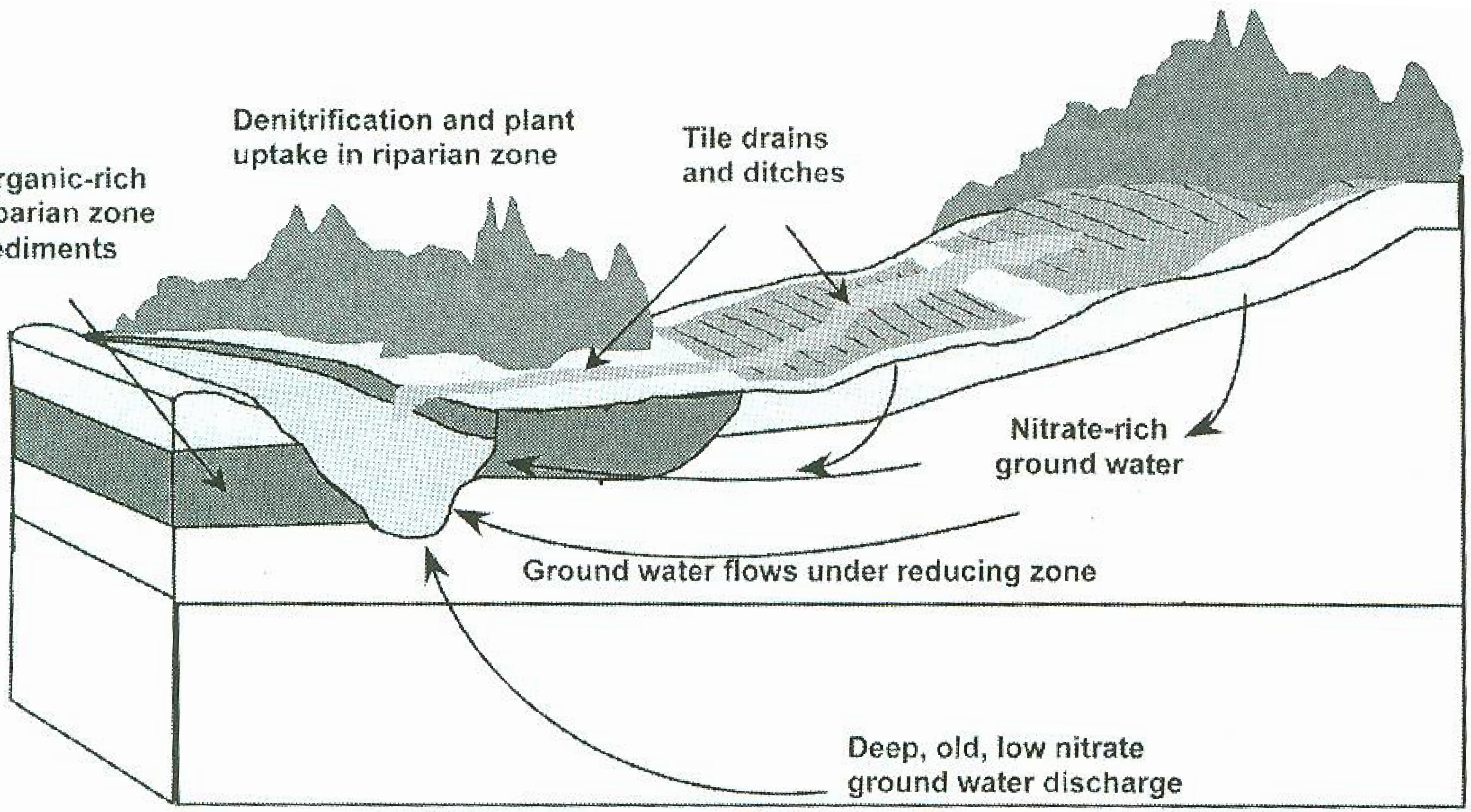


Figure 3 Several factors including the use of tile drains and ditches, and ground water flowing beneath organic-rich riparian sediments, may limit the effectiveness of riparian zones. In addition, discharge of old ground water low in nitrate may give the appearance that denitrification has occurred

Puckett 2004

The Hyporheic Zone

A portion of the groundwater interface in streams where a mixture of surface water and groundwater can be found (Dahm et al. 2006)

Those sediments hydrologically linked to the open stream channel (Findlay 1995)

>10% but <98% channel water (Triska et al. 1989)

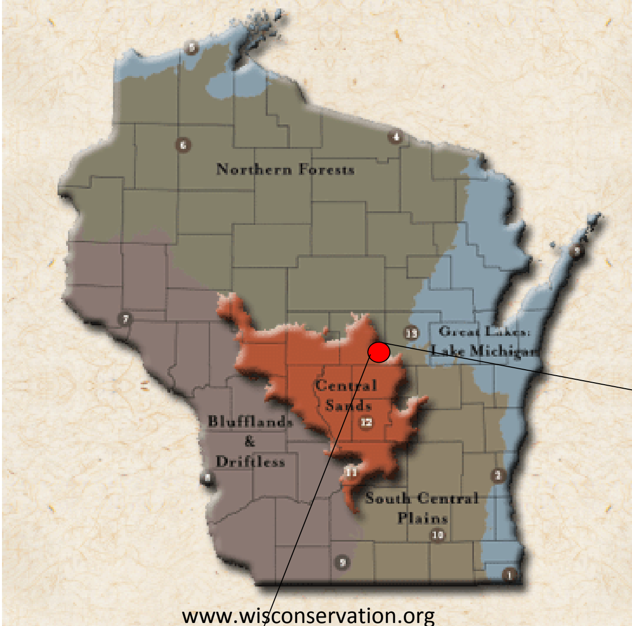
Denitrification

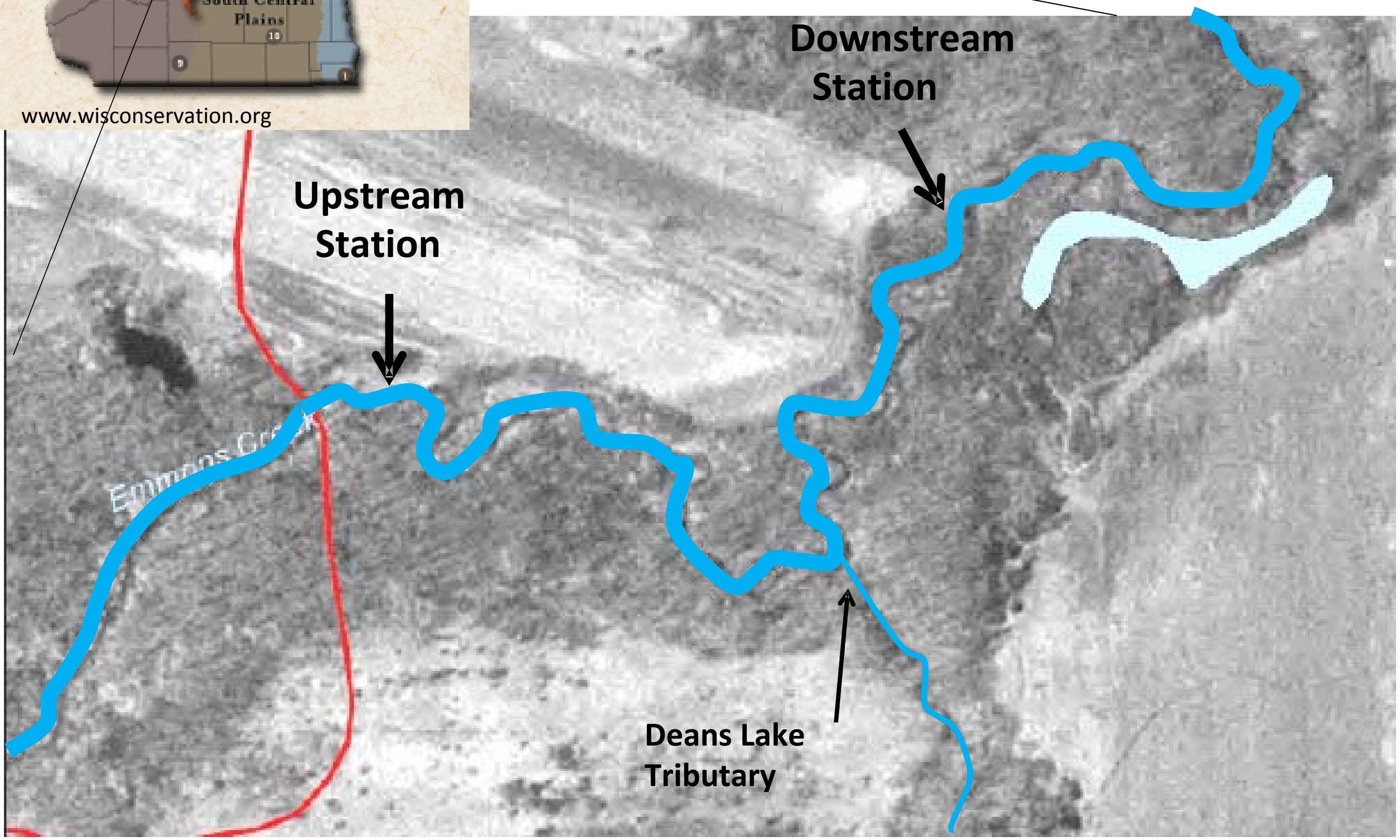
$$5CH_2O + 4H^+ + 4NO_3^- \longrightarrow 2N_2 + 5CO_2 + 7H_2O$$

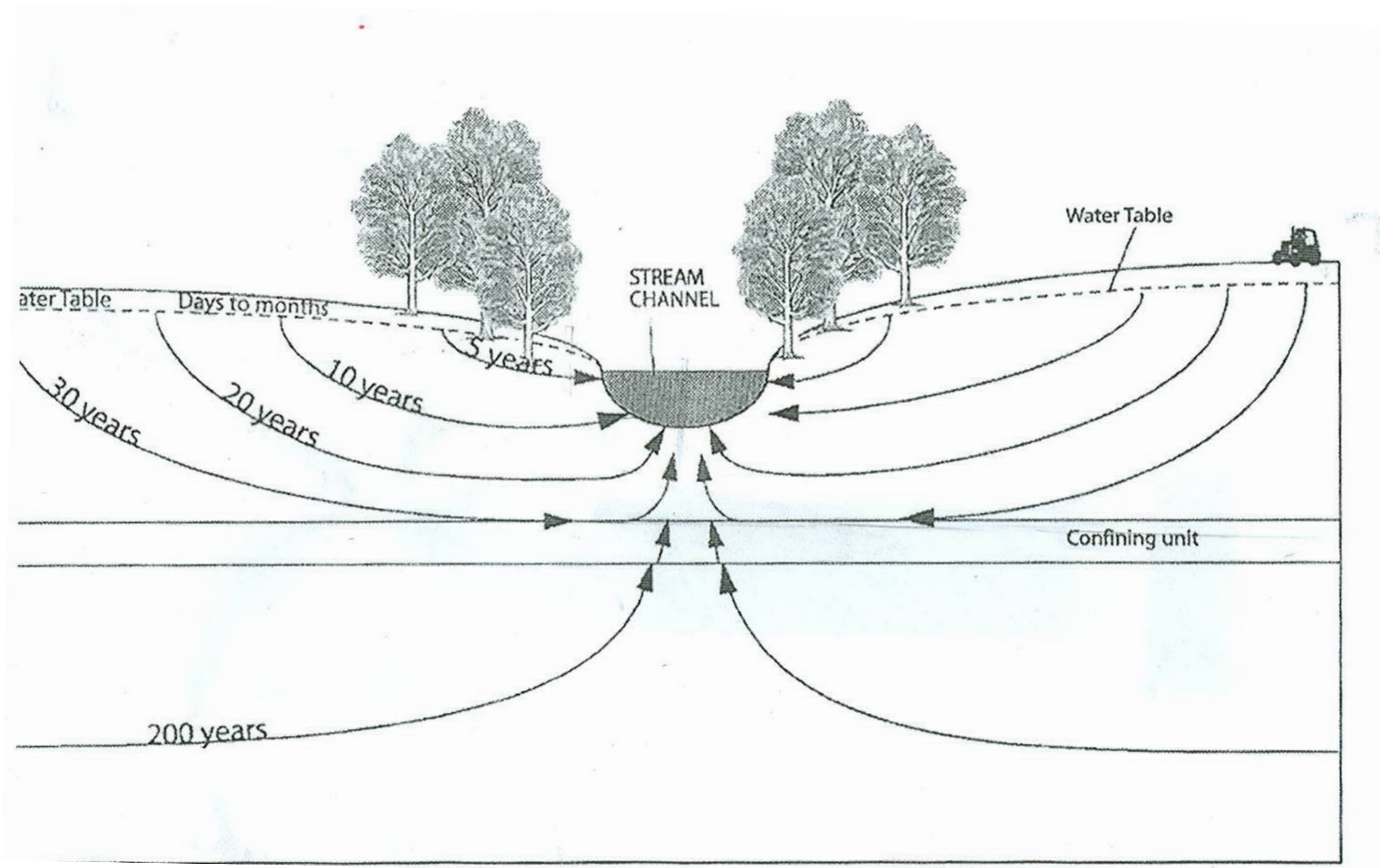
Denitrification

$$5CH_2O + 4H^+ + 4NO_3^- \longrightarrow 2N_2 + 5CO_2 + 7H_2O$$

Emmons Creek, Portage County







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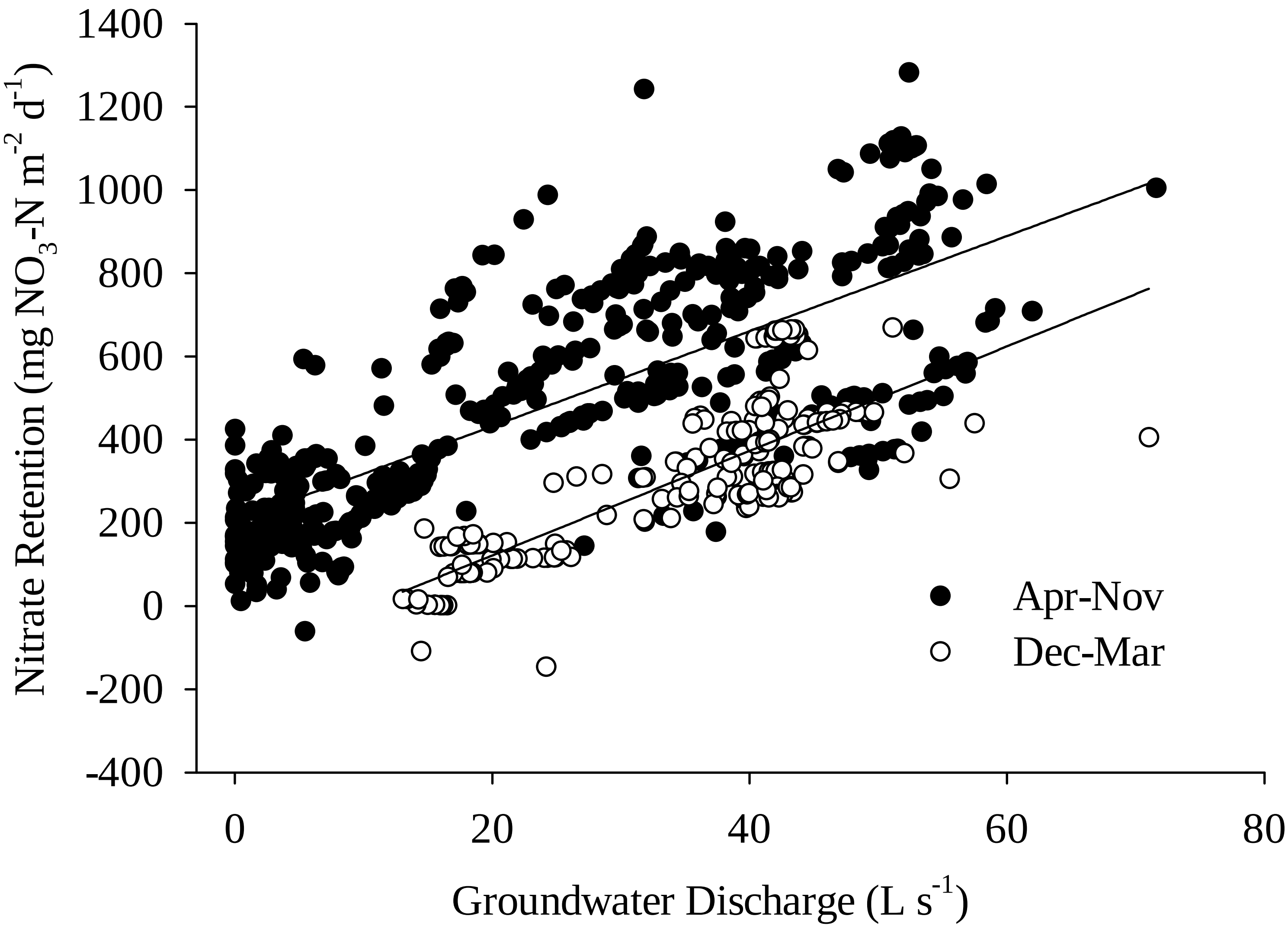
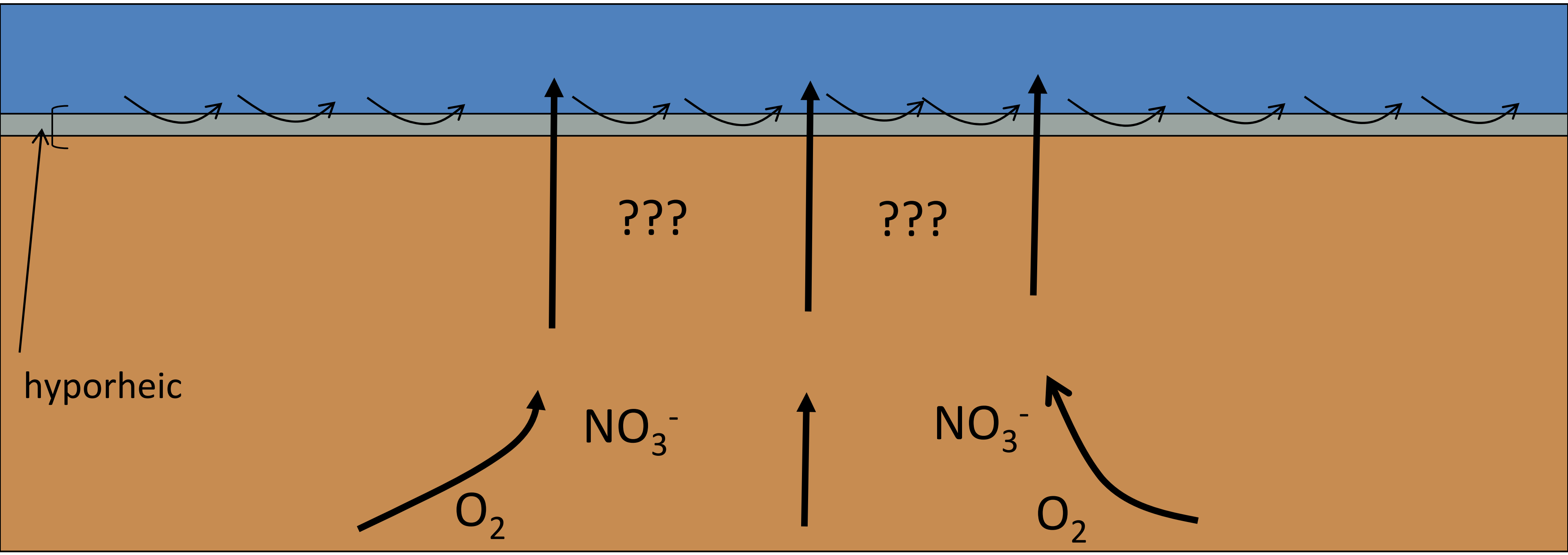


Stelzer, R.S., Drover, D.R.*, Eggert S.L. & Muldoon, M.A. 2011. Nitrate retention in a sand plains stream and the importance of groundwater discharge. *Biogeochemistry*, 103, 91-107. DOI: 10.1007/s10533-010-9449-y.

Questions

Why does nitrate retention increase with groundwater discharge?

Nitrogen Processing in Upwelling Reaches



Questions

Why does nitrate retention increase with groundwater discharge?

How do nitrate processing and profiles change with sediment depth below the hyporheic zone in Emmons Creek?

Does nitrate processing in shallow sediments follow similar patterns throughout a river network?

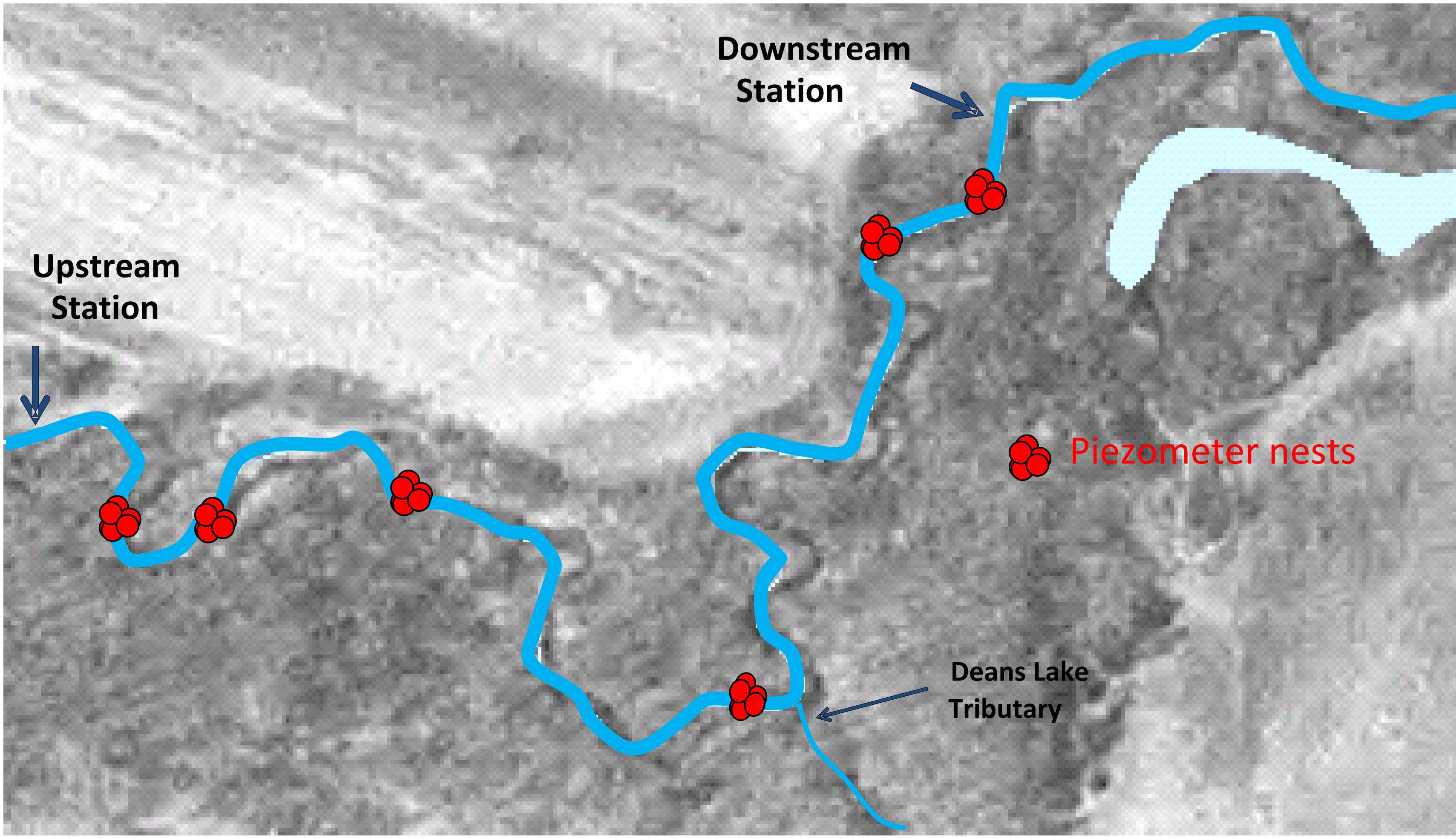
What is the role of particulate organic carbon in regulating nitrate processing in shallow groundwater?

Study Design

Sediment cores (8)
for denitrification

Peepers and well
nests (6)

Summer, Fall, Spring


Downstream
Station
Upstream
Station
Piezometer nests
Deans Lake
Tributary

Sediment core
from Radley Creek
(Fall 2010)

Photo by John Karl, Wisconsin Sea Grant

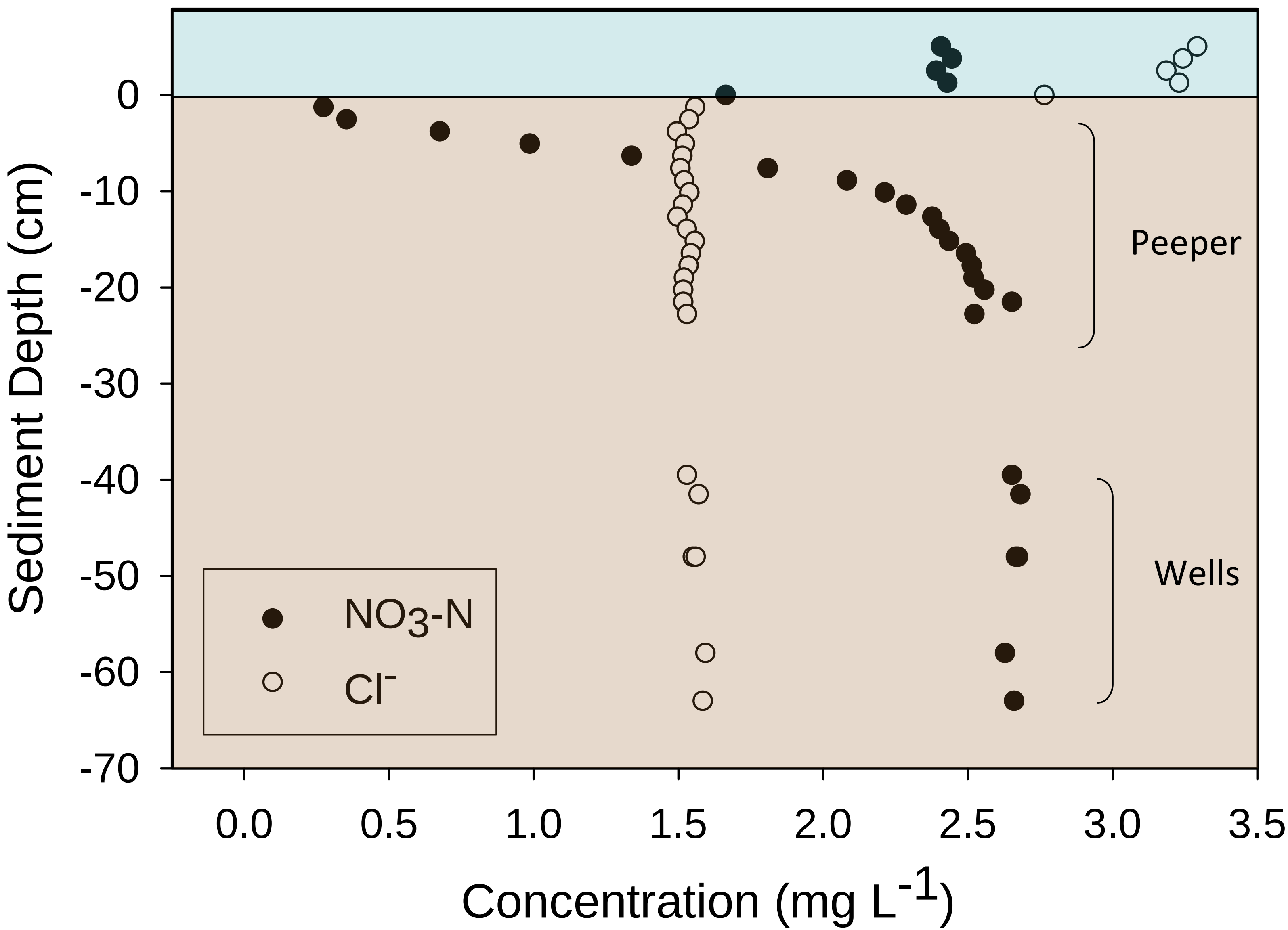
Denitrification Rates

Core Section (cm)	Denitrification Rate ($\mu g\ N_2O\text{-}N\ cm^{-2}\ hr^{-1}$)		
	Mean	SD	n
0-5	1.85	0.98	16
5-10	1.61	0.93	16
10-15	1.22	0.81	16
15-20	0.70	0.72	13
20-25	0.45	0.70	9

summer, fall 2009


Cabela's
TOP 1

609 m Oct 2009



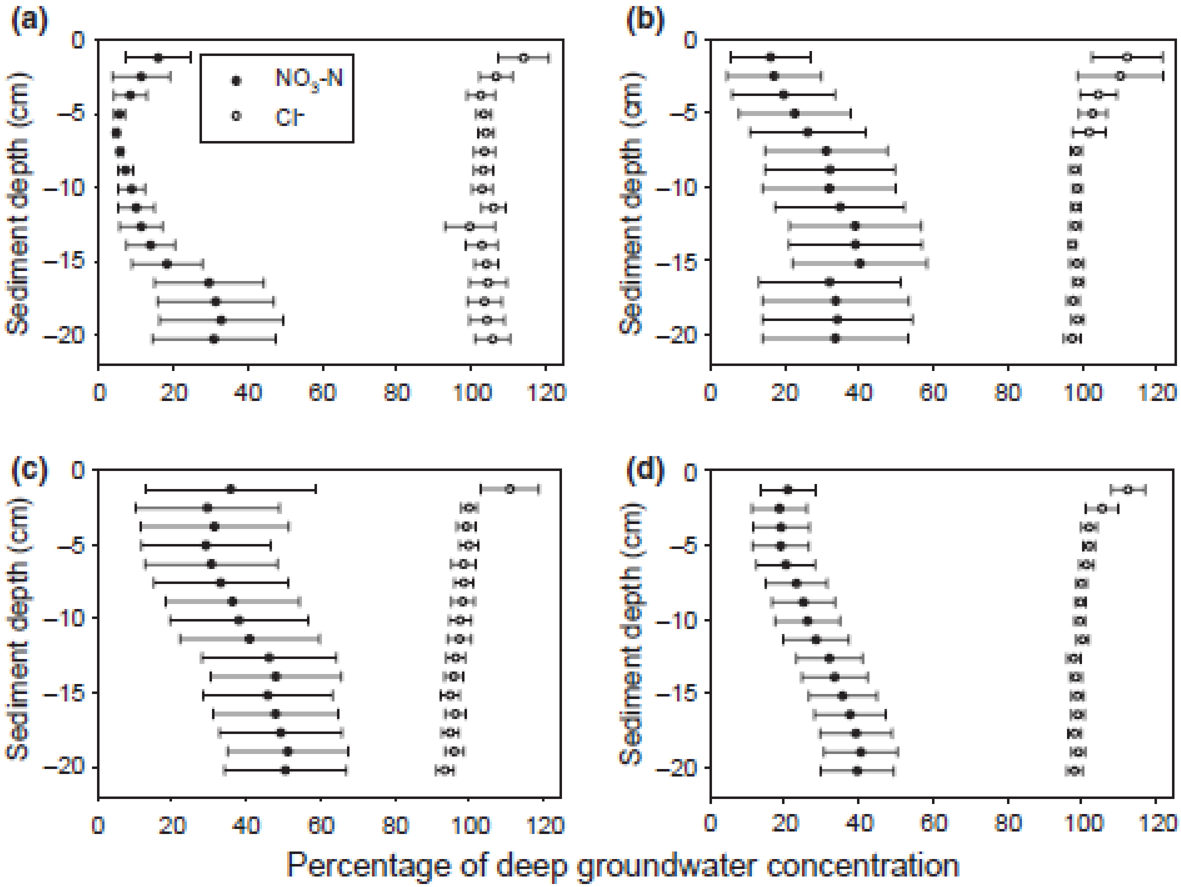
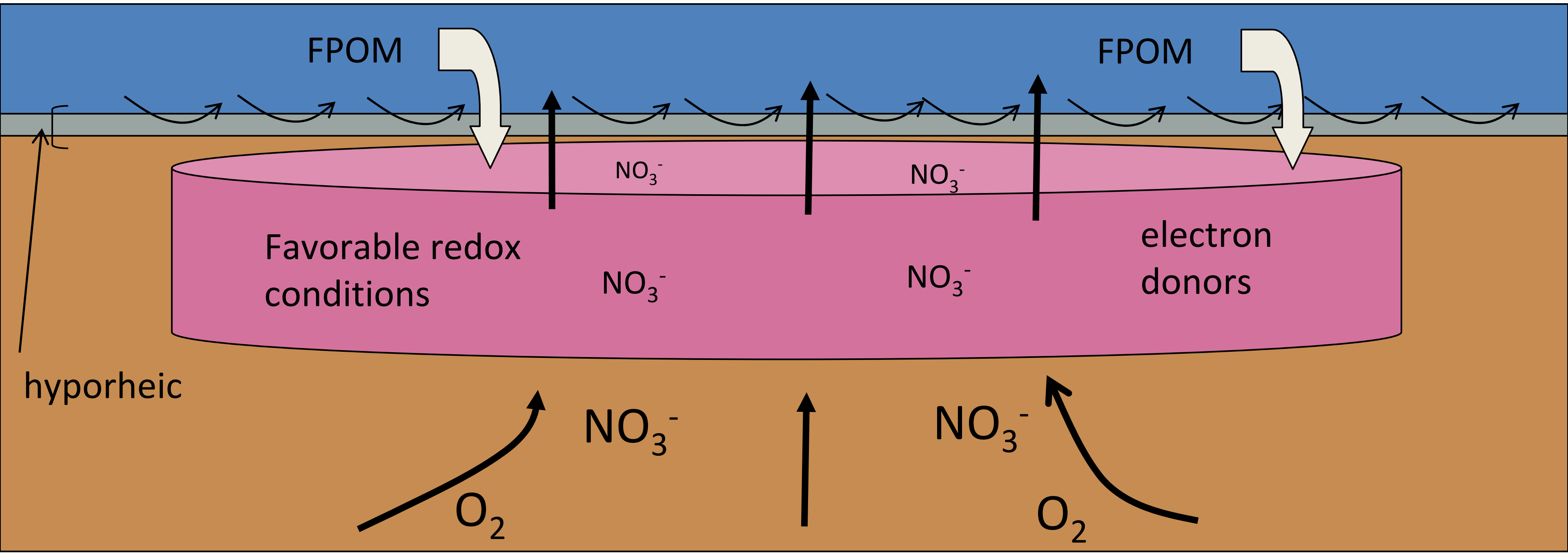


Fig. 5 Mean (+SE) nitrate and chloride concentrations in the shallow ground water of Emmons Creek (peepers) expressed as a percentage of associated deep groundwater solute concentrations (piezometers). A. July 2009, B. October 2009, C. May 2010, D. Grand means based on all three peeper deployment dates. Months indicate when peepers were sampled.

Nitrogen Processing in Upwelling Reaches



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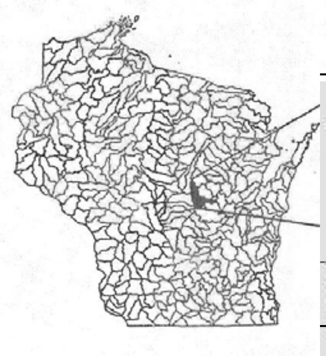
Why does nitrate retention increase with groundwater discharge?

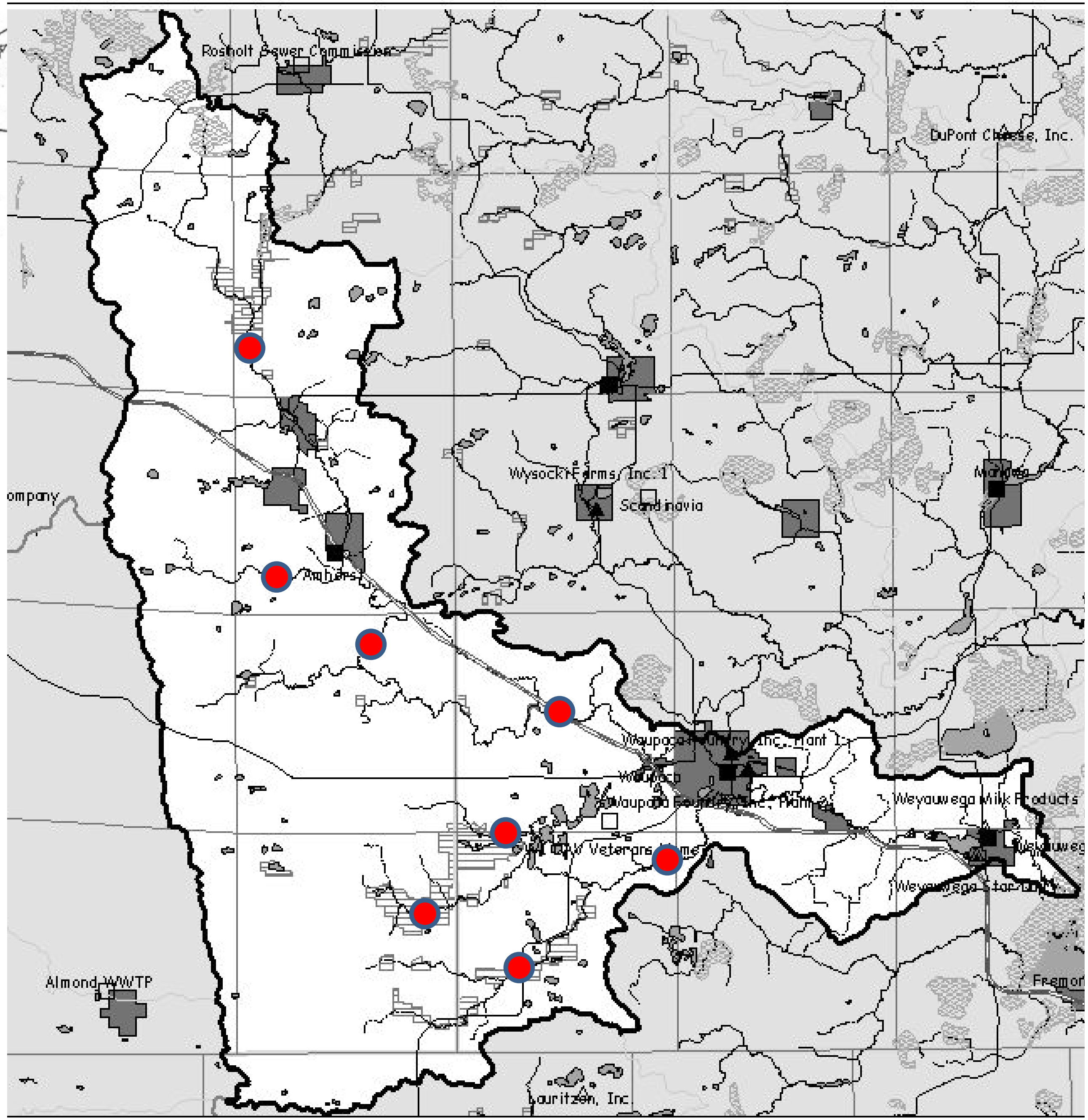
How do nitrate processing and profiles change with sediment depth below the hyporheic zone in Emmons Creek?

Is our conceptual model of groundwater nitrogen processing in shallow sediments applicable to a river network?

What is the role of particulate organic carbon in regulating nitrate processing in shallow groundwater?

Waupaca River Watershed





WDNR

Site	mg NO_3-N/L	VHG
Hartman Cr.	0.01	0.006
Waupaca R.	0.01	0.031
Crystal R.	0.95	0.000
Tomorrow R. @ River Rd	1.25	0.068
Emmons Cr.	1.31	0.076
Bear Cr.	6.81	0.034
Radley Cr.	10.36	0.199
Tomorrow R. @ Hwy T	10.49	0.072

Study Design

8 study sites

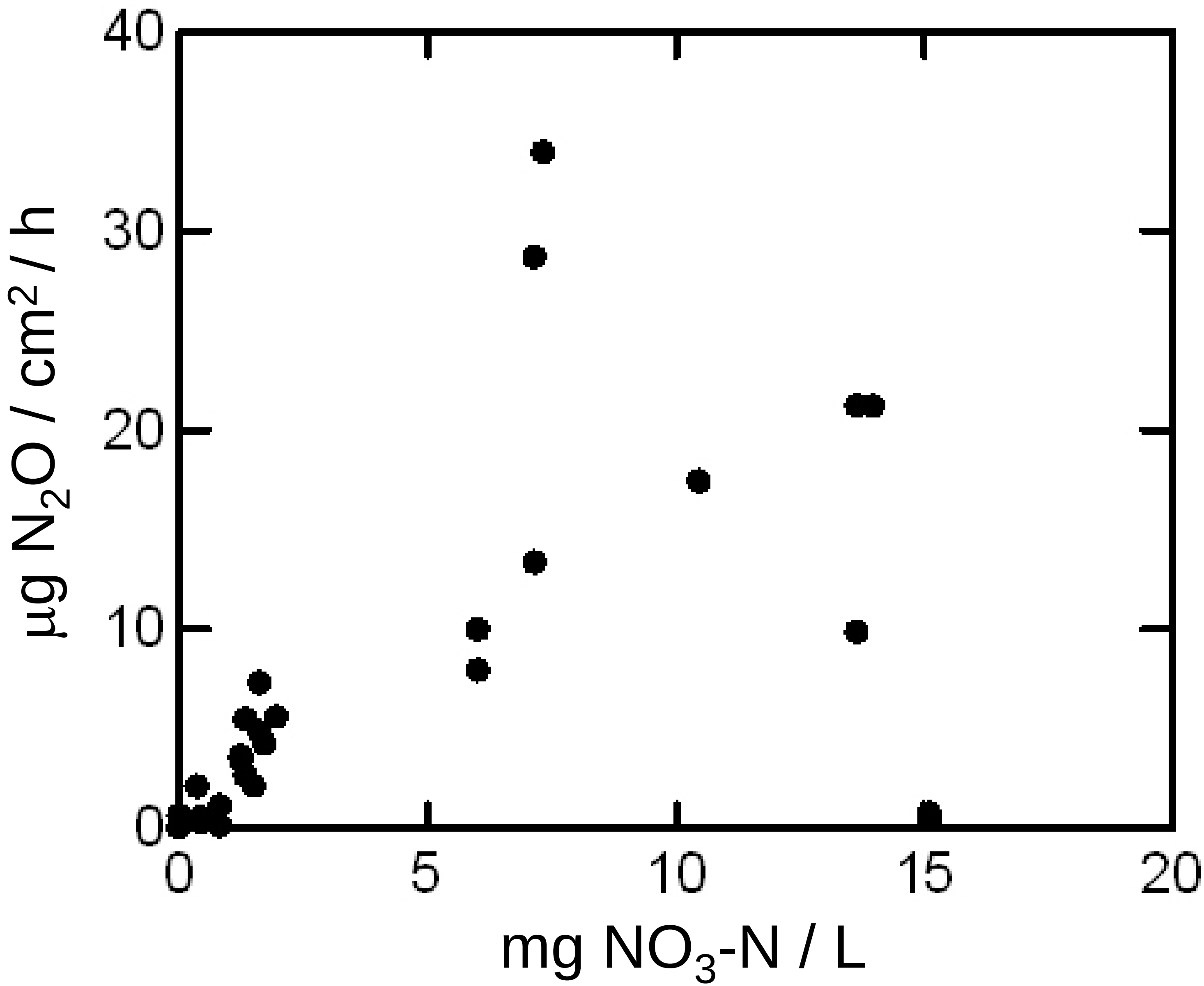
Sediment cores (4 to 5) for denitrification

Peepers and piezometer nests (3) placed in upwelling zones

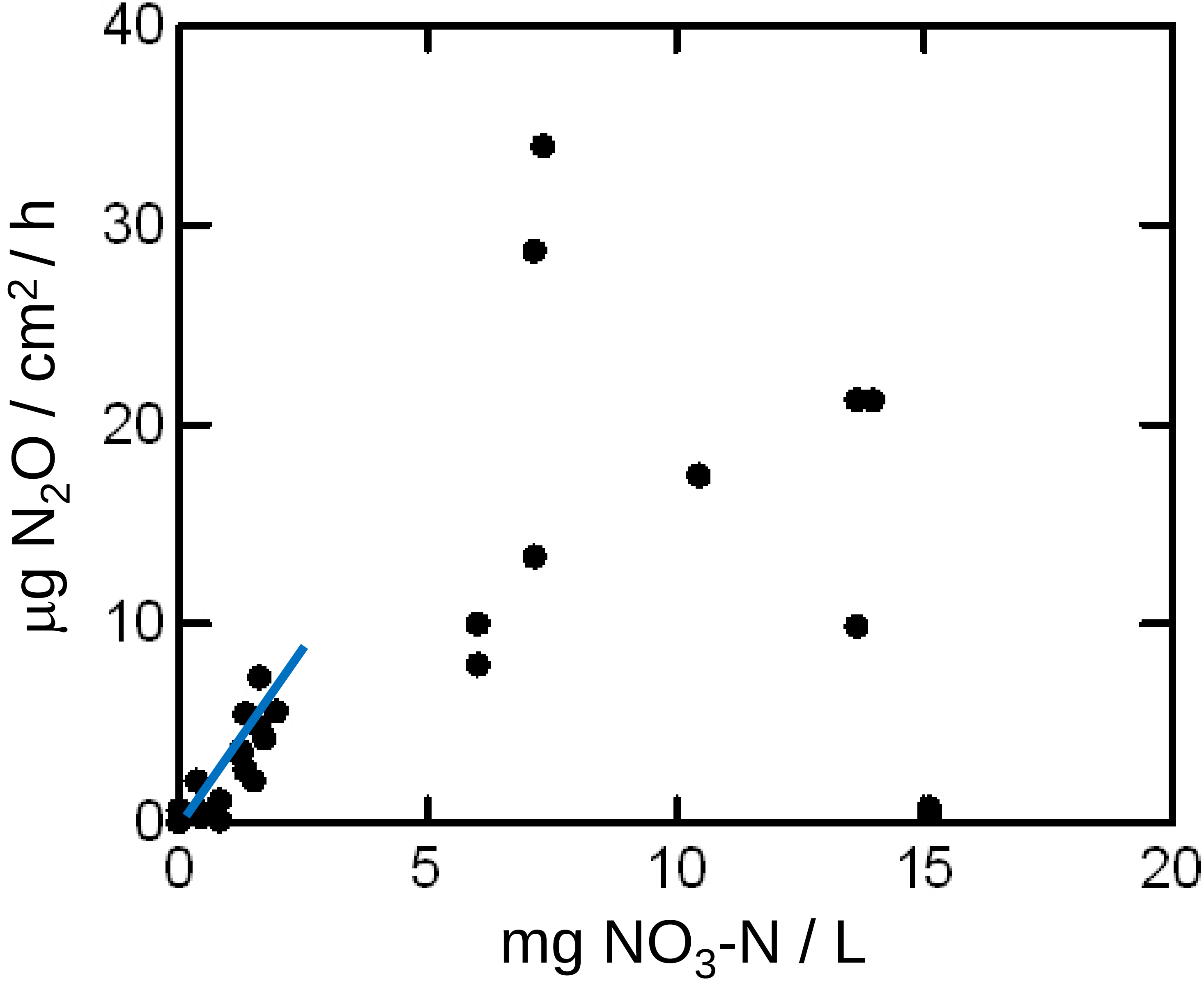
June – September 2010

Denitrification Rates in the Waupaca River Network

Core Section (cm)	Mean (μg N_2O-N/cm^2/h)	SD	N
0-5	2.04	2.78	33
5-10	1.98	3.68	33
10-15	0.94	1.81	33
15-20	0.68	1.39	33
20-25	0.71	2.08	30
25-30	0.80	1.97	17



40
30
20
10
0
0
5
10
15
20
μg N_2O / cm^2 / h
mg NO_3-N / L



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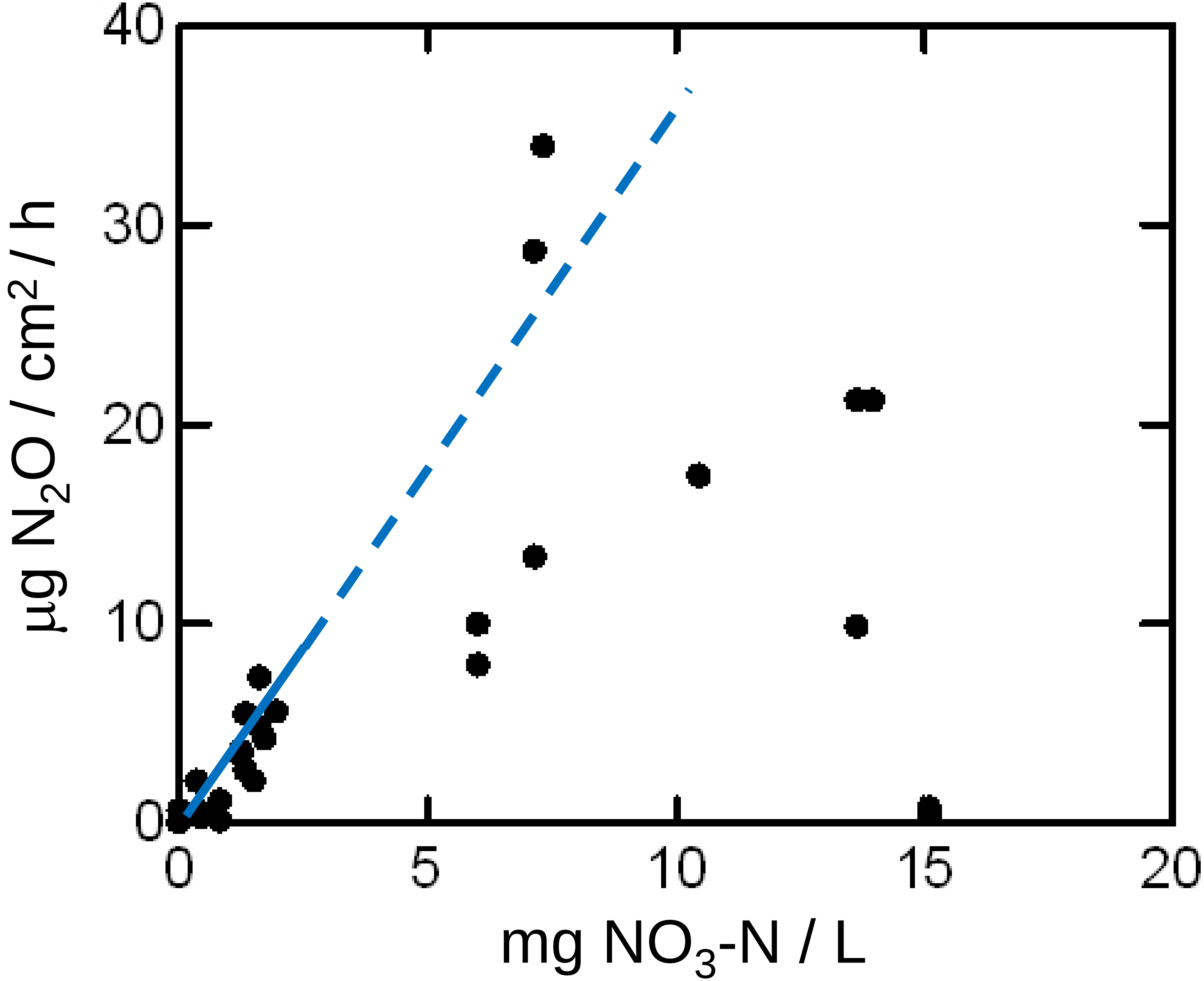

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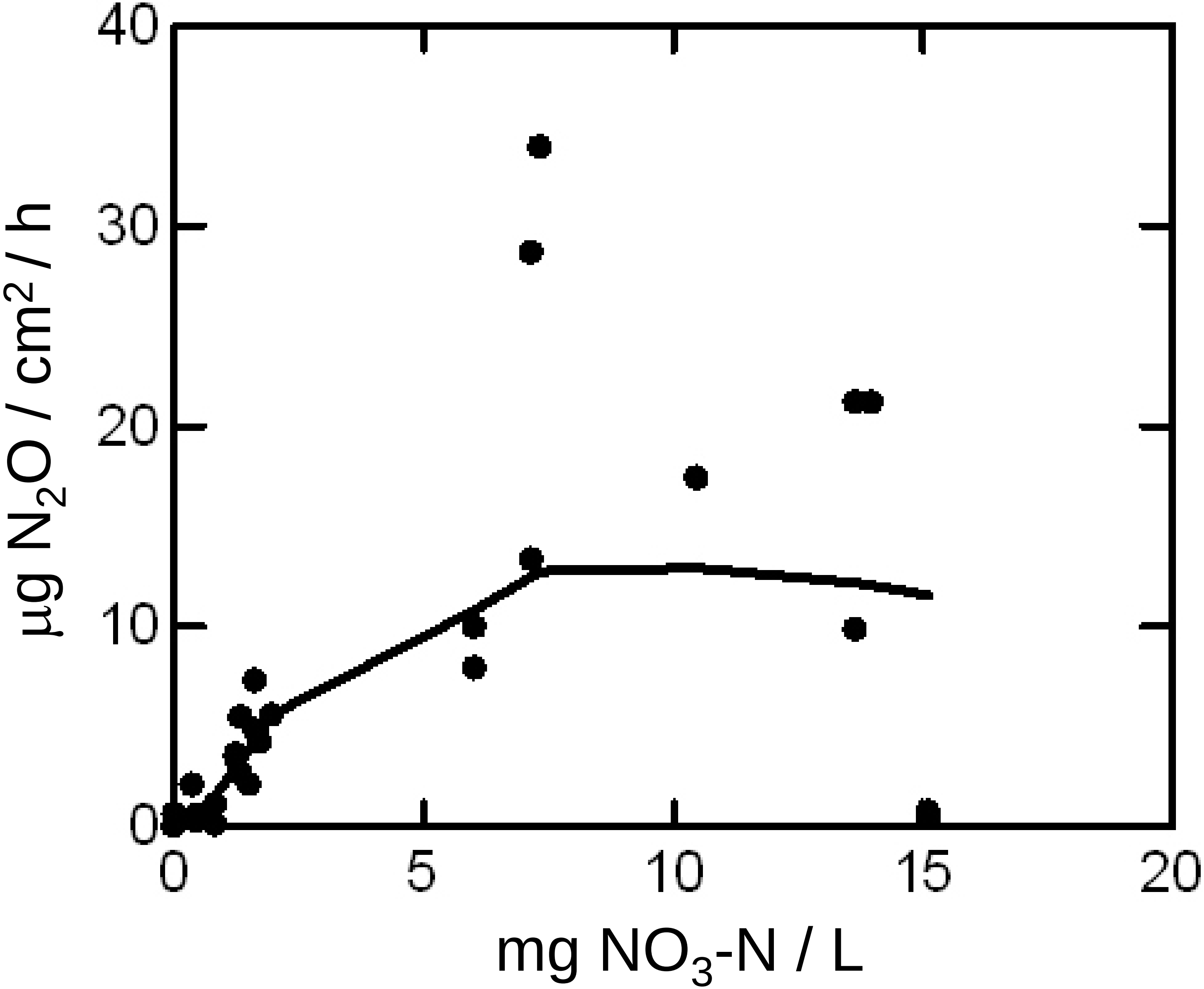

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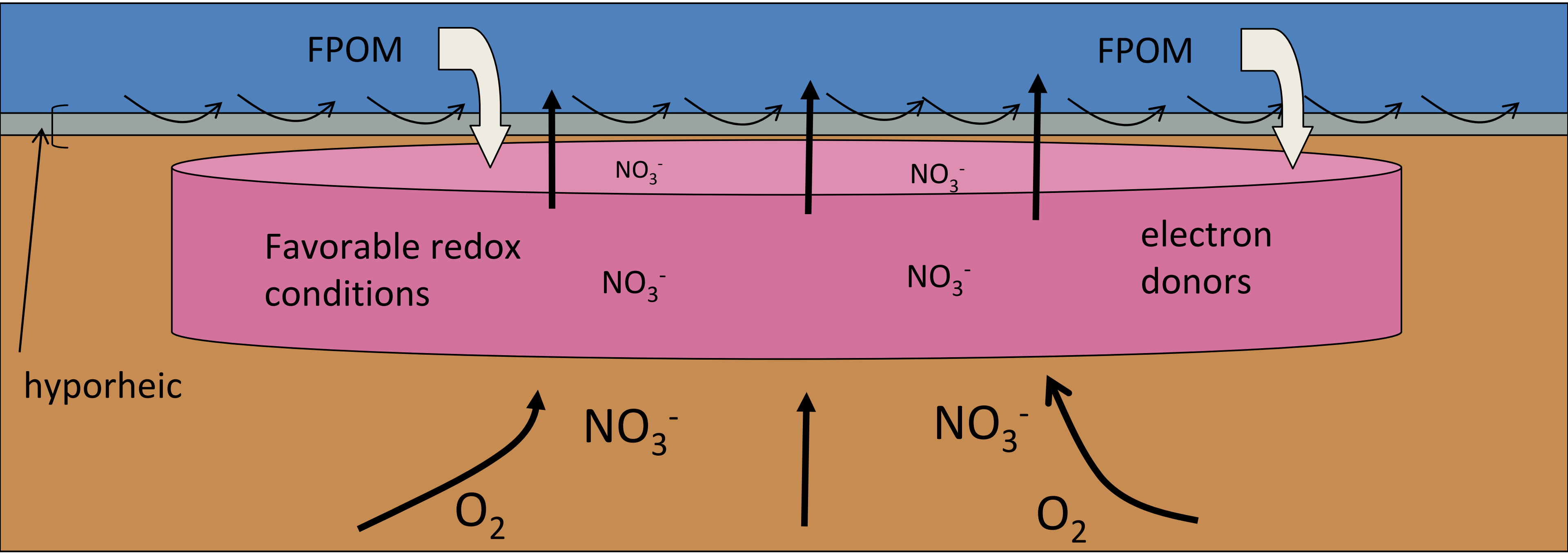
Nitrogen Processing in Upwelling Reaches



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Is our conceptual model of groundwater nitrogen processing in shallow sediments applicable to a river network?

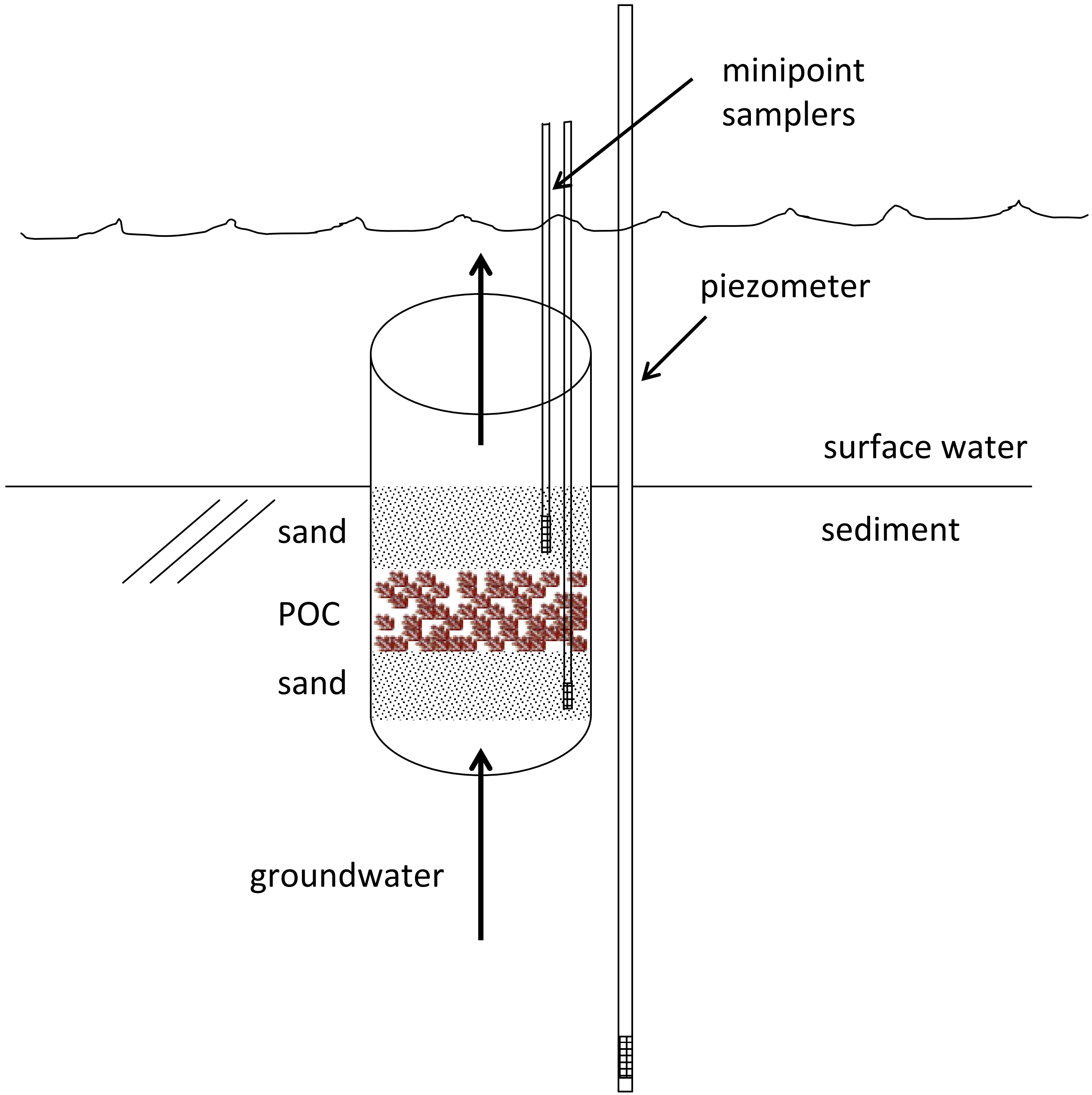
What is the role of particulate organic carbon in regulating nitrate processing in shallow groundwater?

Year 1 - How does particulate organic carbon quantity affect the removal of groundwater nitrate?

Year 2 - How does particulate organic carbon quality affect the removal of groundwater nitrate?

POC Quantity Experimental Design

Treatment	Replicates
Ambient	10
Control	10
Low POC	10
High POC	10


minipoint
samplers
piezometer
surface water
sediment
sand
POC
sand
groundwater

Conclusions and Recommendations for Ecosystem Management

- Our results suggest that shallow groundwater systems associated with rivers can remove nitrate but that this capacity can be overwhelmed at high nitrate concentrations

- Maintaining natural stream channels and sediments is important for promoting nitrate removal

- Our preliminary results suggest that riparian vegetation promotes denitrification in sediments by providing a carbon source

Acknowledgements

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