

Woodchip bioreactors: Design modifications to “ditch” nitrogen

Laura Christianson, Ph.D.

The Conservation Fund

Re-plumbing the Chesapeake Watershed: *Improving roadside ditch
management to meet TMDL water quality goals*

The Tidewater Inn, Easton, Maryland

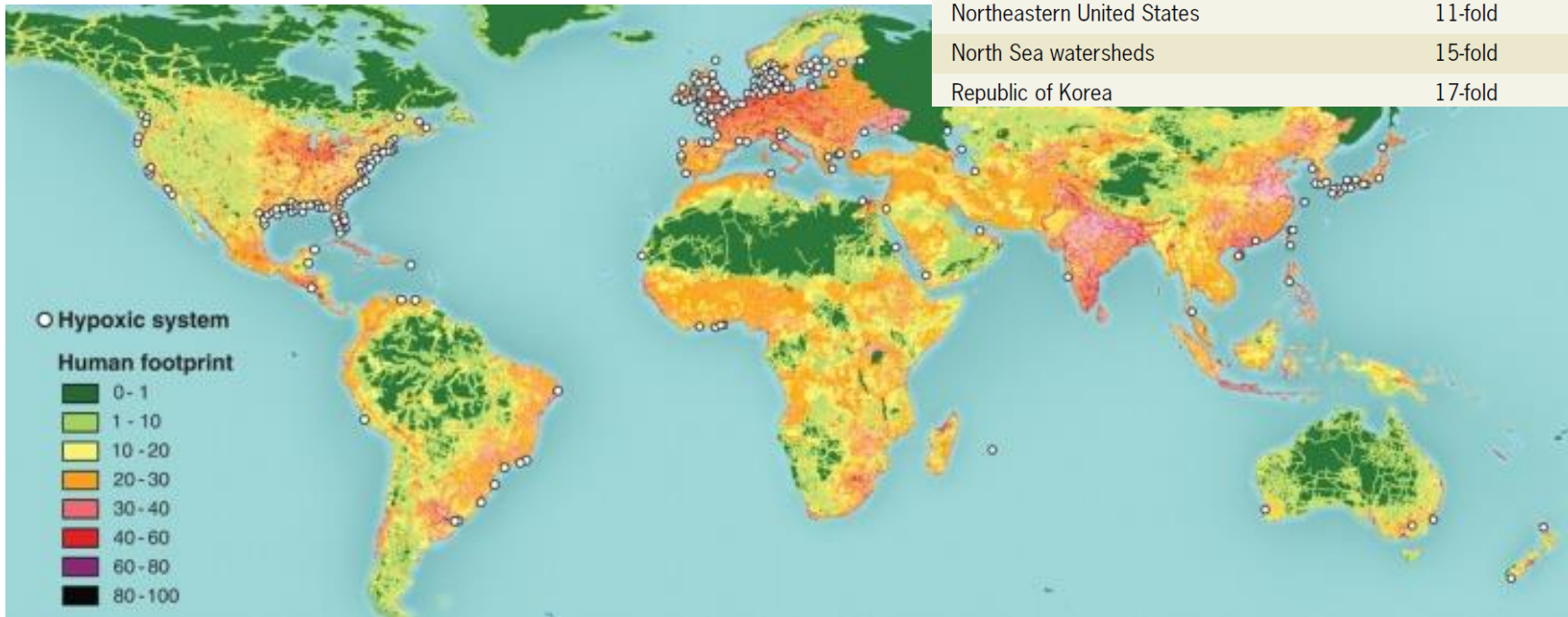
9-10 October 2014

Nitrogen: Essential for life, but WQ concern

- Need to transform reactive nitrogen to reduce the global nitrogen cascade
 - Hypoxic zones
 - Human health impacts

Table 4.1. INCREASE IN NITROGEN FLUXES IN RIVERS TO COASTAL OCEANS DUE TO HUMAN ACTIVITIES RELATIVE TO FLUXES PRIOR TO THE INDUSTRIAL AND AGRICULTURAL REVOLUTIONS (R9 Table 9.1)

Labrador and Hudson's Bay	no change
Southwestern Europe	3.7-fold
Great Lakes/St. Lawrence basin	4.1-fold
Baltic Sea watersheds	5-fold
Mississippi River basin	5.7-fold
Yellow River basin	10-fold
Northeastern United States	11-fold
North Sea watersheds	15-fold
Republic of Korea	17-fold



Millennium
Ecosystem
Assessment,
2005

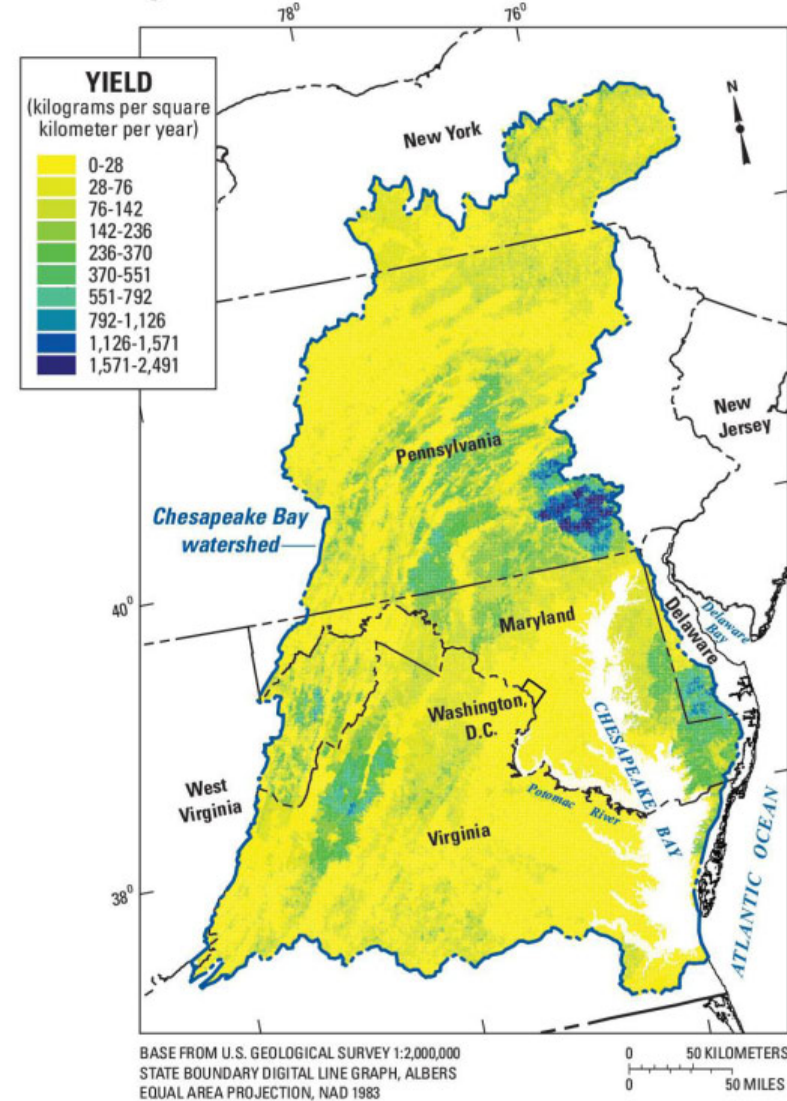
Diaz and
Rosenburg,
2008

Nitrogen: Essential for life, but WQ concern

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- Food production requires N

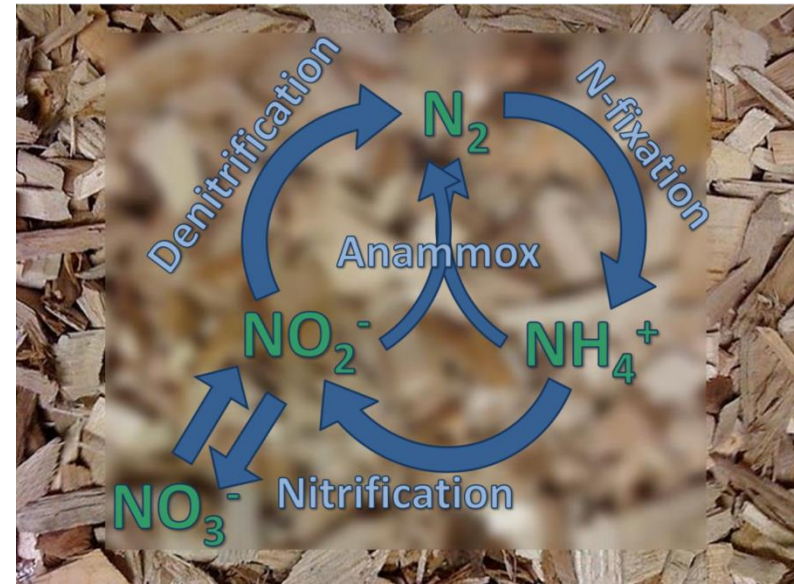


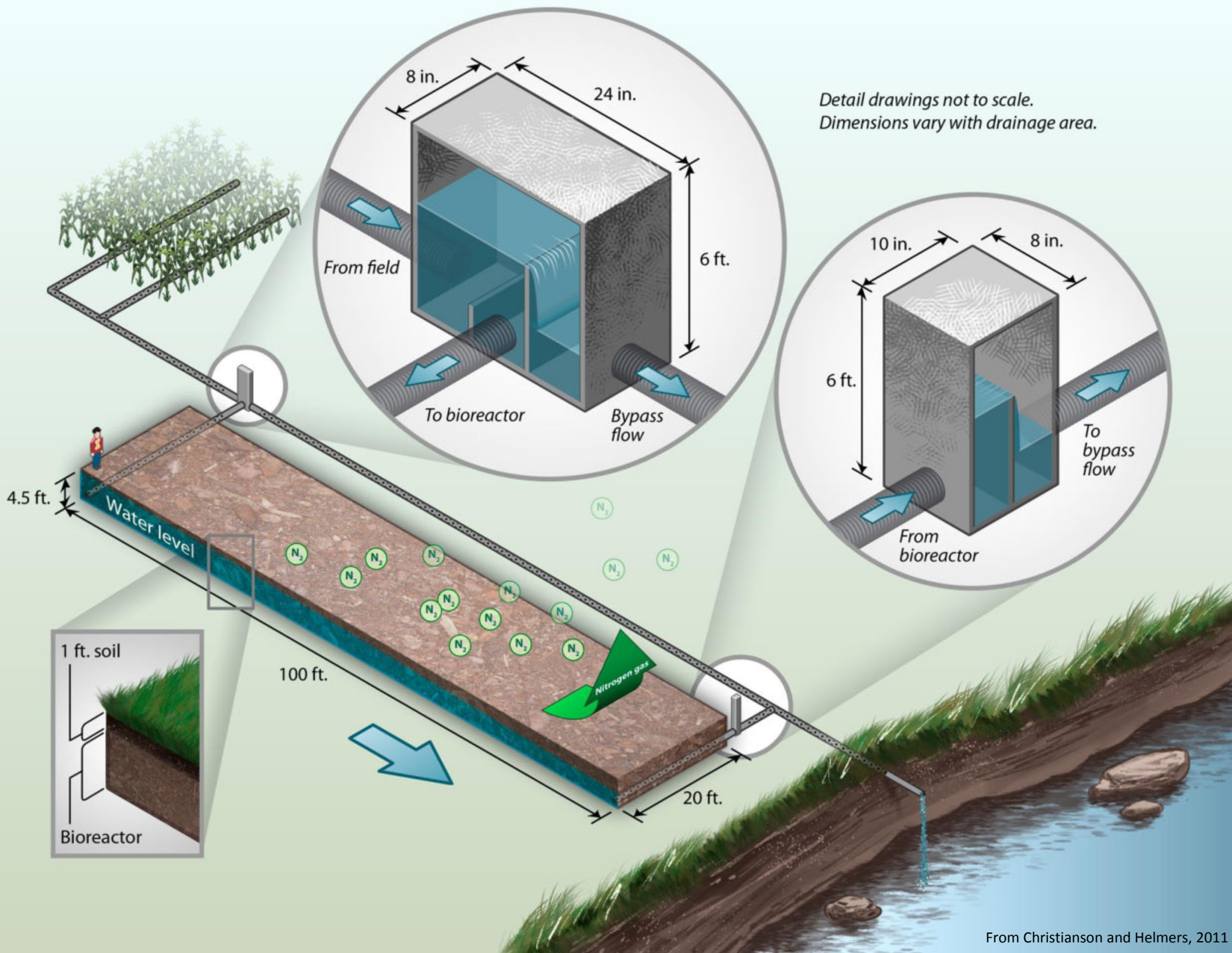
B. Total nitrogen attributable to manure



Nitrogen: Essential for life, but WQ concern

- Need to transform reactive nitrogen to reduce the global nitrogen cascade
 - Hypoxic zones
 - Human health impacts
- Food production requires N
- To enhance denitrification in the landscape, we need:
 - A carbon source
 - Anoxic conditions
 - Nitrate
- Novel wood-based denitrification technologies in the 1990's





Detail drawings not to scale.
 Dimensions vary with drainage area.

Three tile drainage bioreactors in Iowa

Bioreactor	Location	Installed	Drainage Area (ha)	Design Flow Rate (gpm)	L x W x D (m)	Vol. (m ³)	L:W
Greene Co.	Central Iowa	Aug. 2008	19.0 (47 ac)	90-130 gpm	15.2 x 7.6 x 1.1	127	2.0
Hamilton Co.	Central Iowa	June 2009	20.2 (50 ac)	40-90 gpm	30.5 x 3.7 x 0.9	102	8.3
Research Farm	Northeast Iowa	April 2009	14.2 (35 ac)	20-70 gpm	36.6 x 2.4 (bottom) x 1.0	128	15.3



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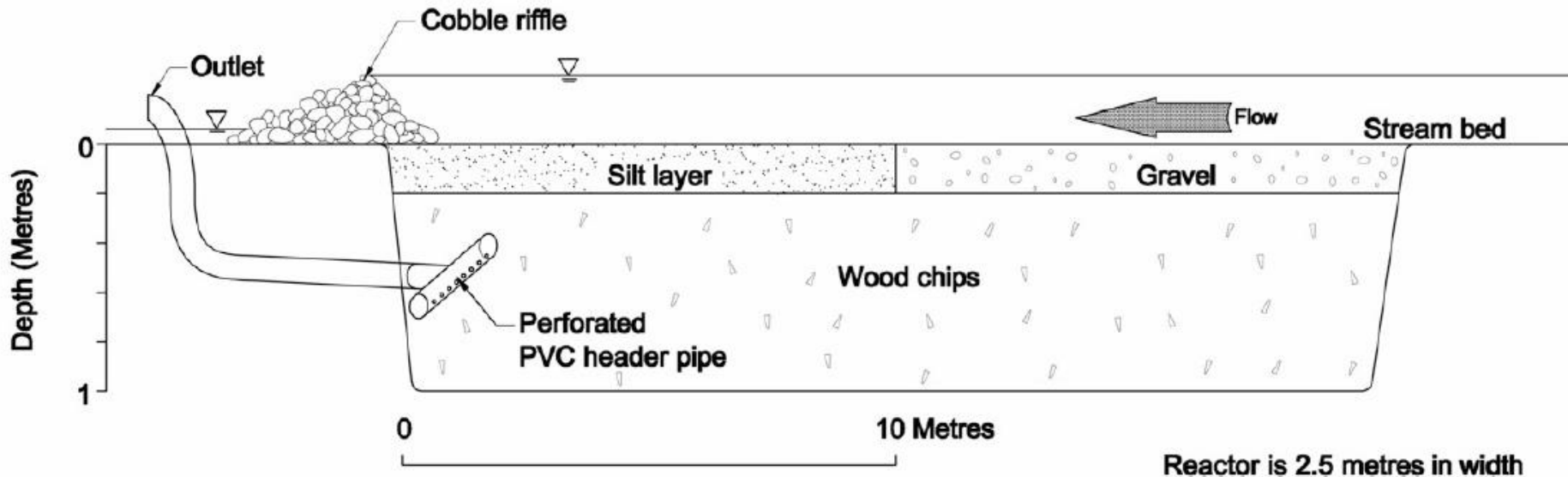
Denitrification bioreactors: Ditch drainage

In-Stream Bioreactor for Agricultural Nitrate Treatment

W. D. Robertson* University of Waterloo

L. C. Merkley Upper Thames River Conservation Authority

Published in J. Environ. Qual. 38:230–237 (2009).



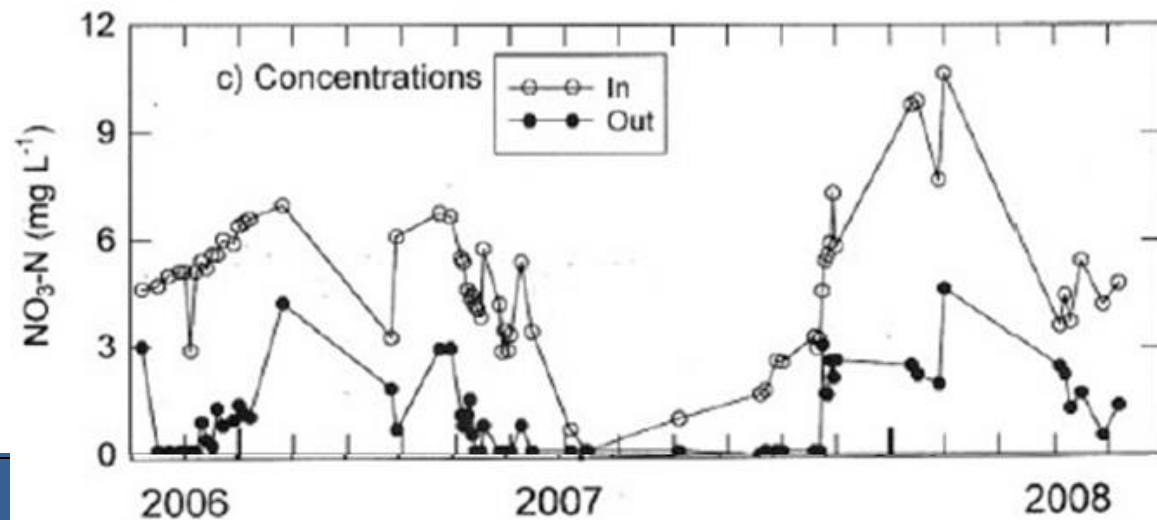
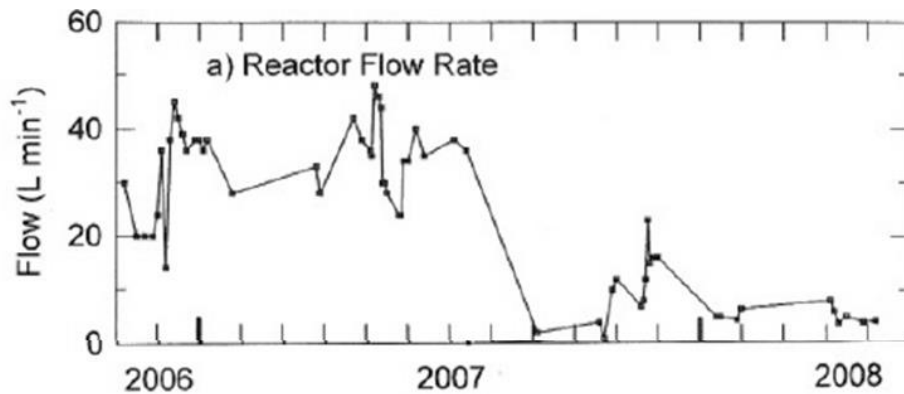
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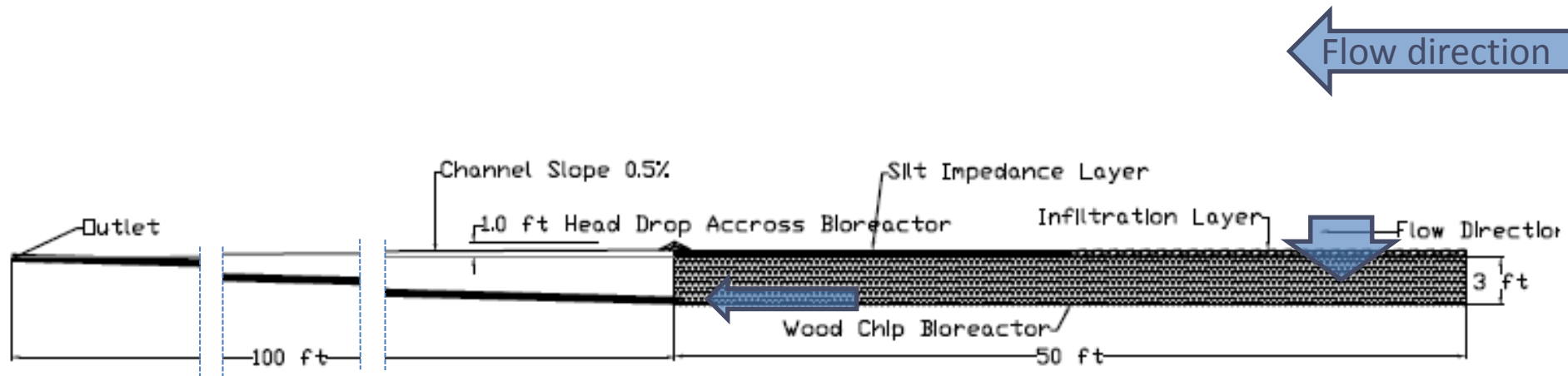
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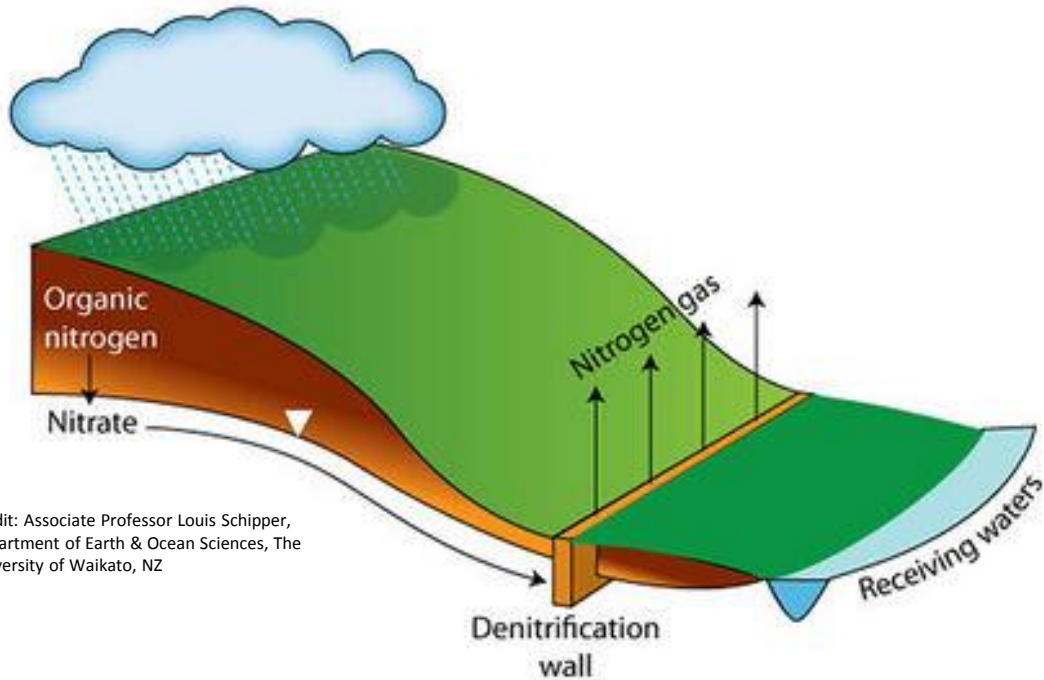
Denitrification bioreactors: Ditch drainage



- Limited head drop in most ditches and ditches may be very shallow
 - Design limitation: Don't back water up in fields or overtop roads
- For design parameters consider:
 - Contributing area
 - Baseflow
 - Nitrate concentrations
- Potential infiltration layer sedimentation

Concept Design:
R. Christianson (Center for
Watershed Protection) and L.
Christianson (The Conservation Fund)

Denitrification bioreactors: Groundwater Walls



Credit: Associate Professor Louis Schipper,
Department of Earth & Ocean Sciences, The
University of Waikato, NZ



Photo credit: http://www.watercorporation.com.au/_files/BEI1_Denitrification_Trench_Pamphlet.pdf

Denitrification bioreactors: Groundwater Walls



Contents lists available at SciVerse ScienceDirect

Ecological Engineering

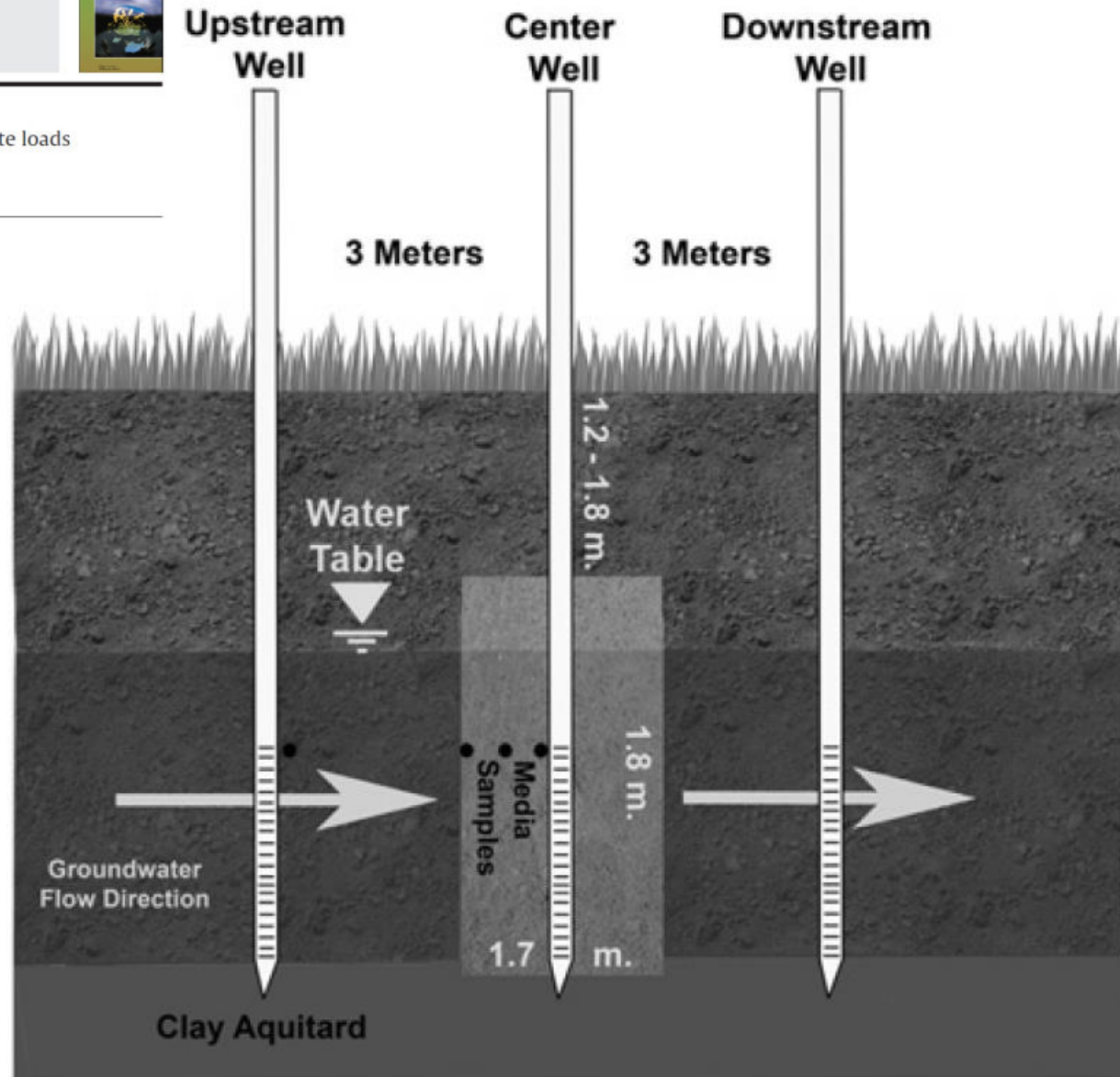
journal homepage: www.elsevier.com/locate/ecoleng



Efficacy of a denitrification wall to treat continuously high nitrate loads

Casey A. Schmidt*, Mark W. Clark

Department of Soil and Water Science, University of Florida, 106 Newell Hall, Gainesville, FL, USA



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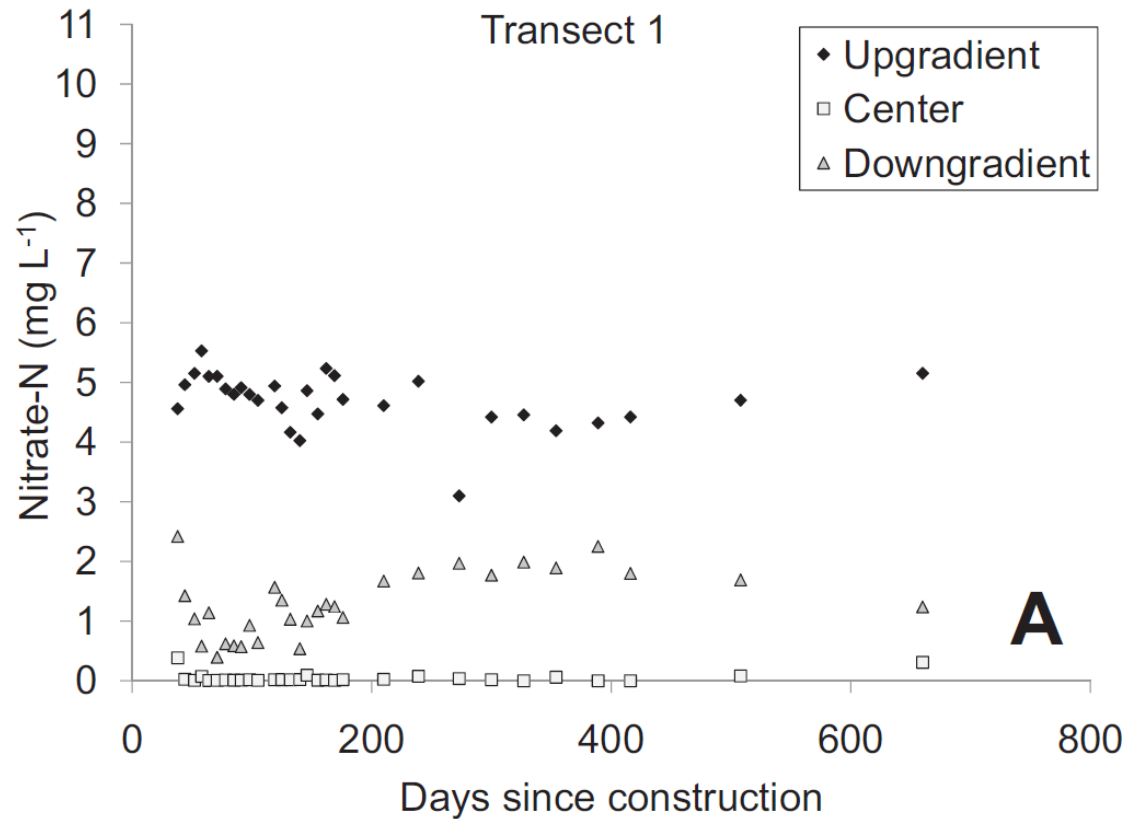
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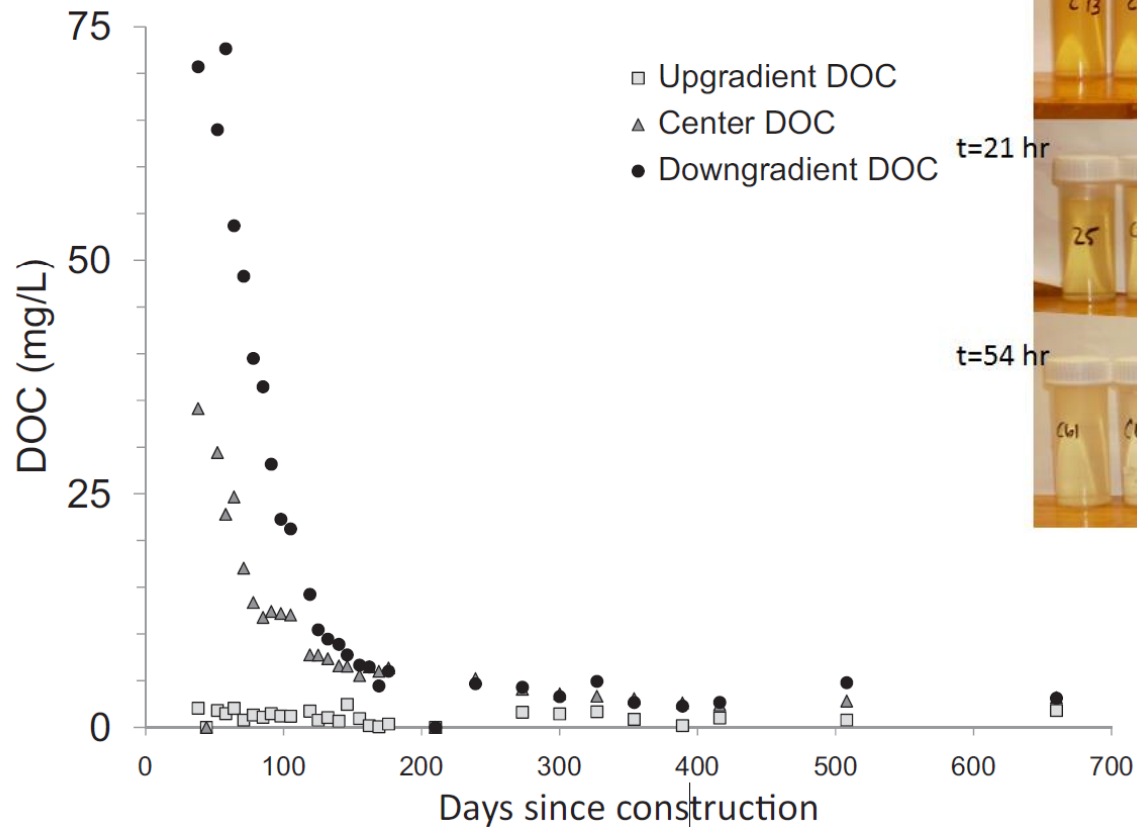
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t=7 hr



t=14 hr



t=21 hr



t=54 hr



Christianson, Unpublished

Where have wood-based enhanced-denitrification technologies been used?

<http://www.artificialinsinks.org/>

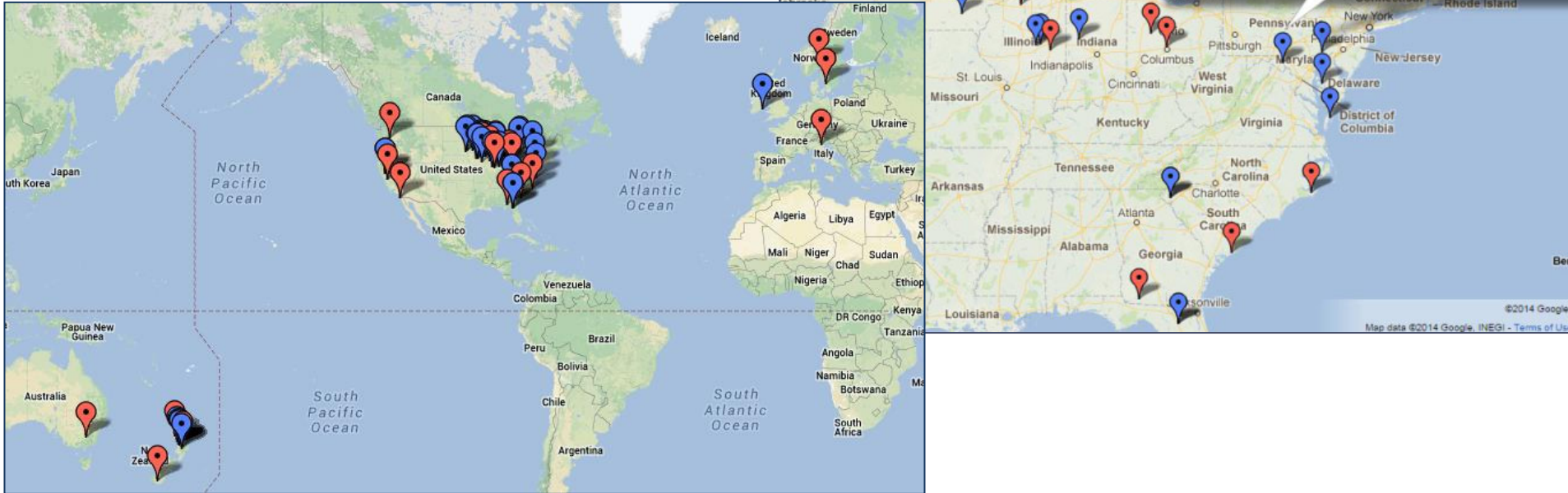
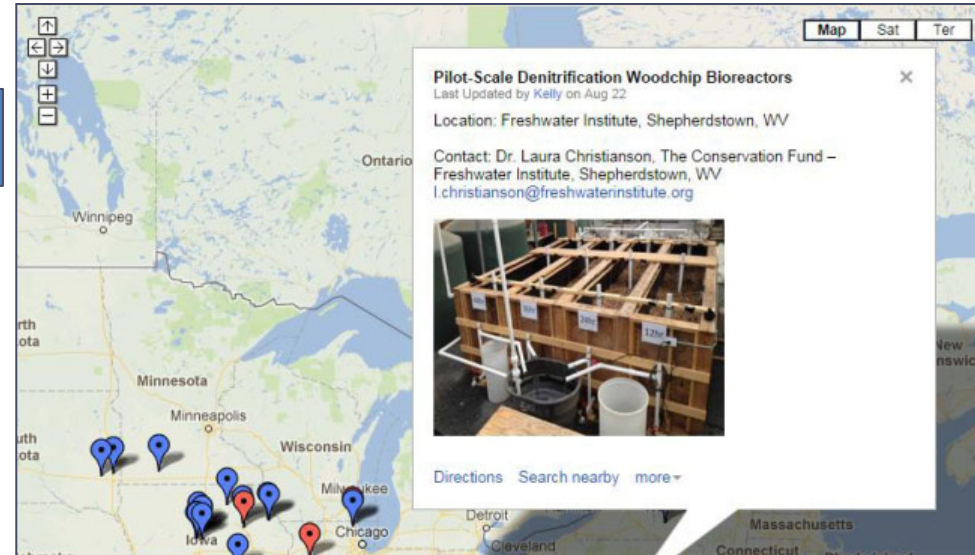
Legend:



Constructed wetlands



Denitrifying Bioreactors



Woodchip bioreactors being trialed in the CB



Midshore
Riverkeepers
Conservancy

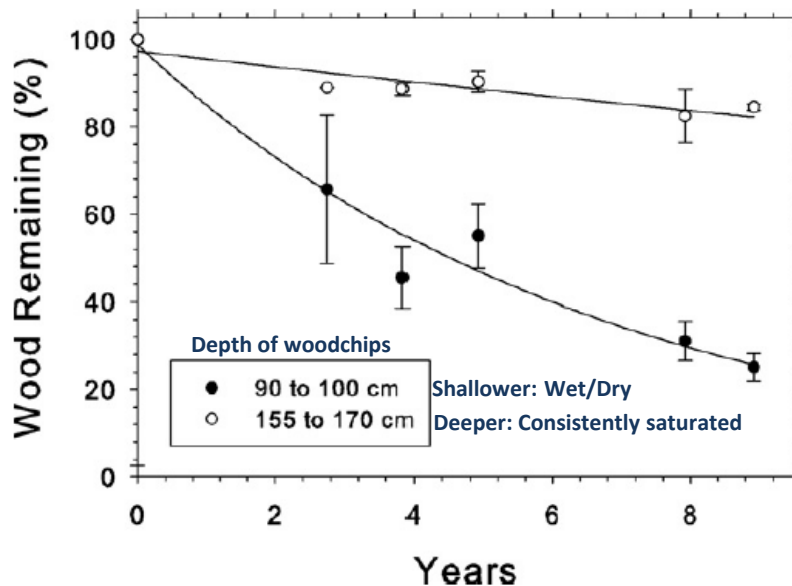


Wood-based Denitrification Performance

Source	Site	Influent NO ₃ ⁻ -N Conc.	Percent Reduction	Nitrate-N Removal Rate
van Driel et al., 2006	Ontario, Canada	11.8 mg/L	--	2.5 g N/m ² /d
Jaynes et al., 2008	Central Iowa	19.1 to 25.3 mg/L	40% - 65%	0.62 g N/m ³ /d
Woli et al., 2010	East-Central Illinois	2.8 to 18.9 mg/L	23% - 50%	6.4 g N/m ³ /d
Christianson et al., 2012	Central Iowa	1.2 to 8.5 mg/L	22% - 74%	0.4-3.8 g N/m ³ /d
Christianson et al., 2012	Northeast Iowa	9.9 to 13.2 mg/L	12% - 14%	0.9-1.6 g N/m ³ /d
Christianson et al., 2012	Central Iowa	7.7 to 15.2 mg/L	27% - 33%	0.4-7.8 g N/m ³ /d
Christianson et al., 2012	Central Iowa	7.7 to 9.6 mg/L	49% - 57%	0.4-5.0 g N/m ³ /d

What is the life?

- Life estimated at **10 to 15 years**
- Stoichiometric estimates: 20 to >50 yrs
- Empirical evidence:
 - Robertson et al., 2008: 15 yr septic treatment wall
 - Long et al., 2011: 14 yr sawdust groundwater wall
 - Moorman et al., 2010: 9 yr woodchip drainage wall



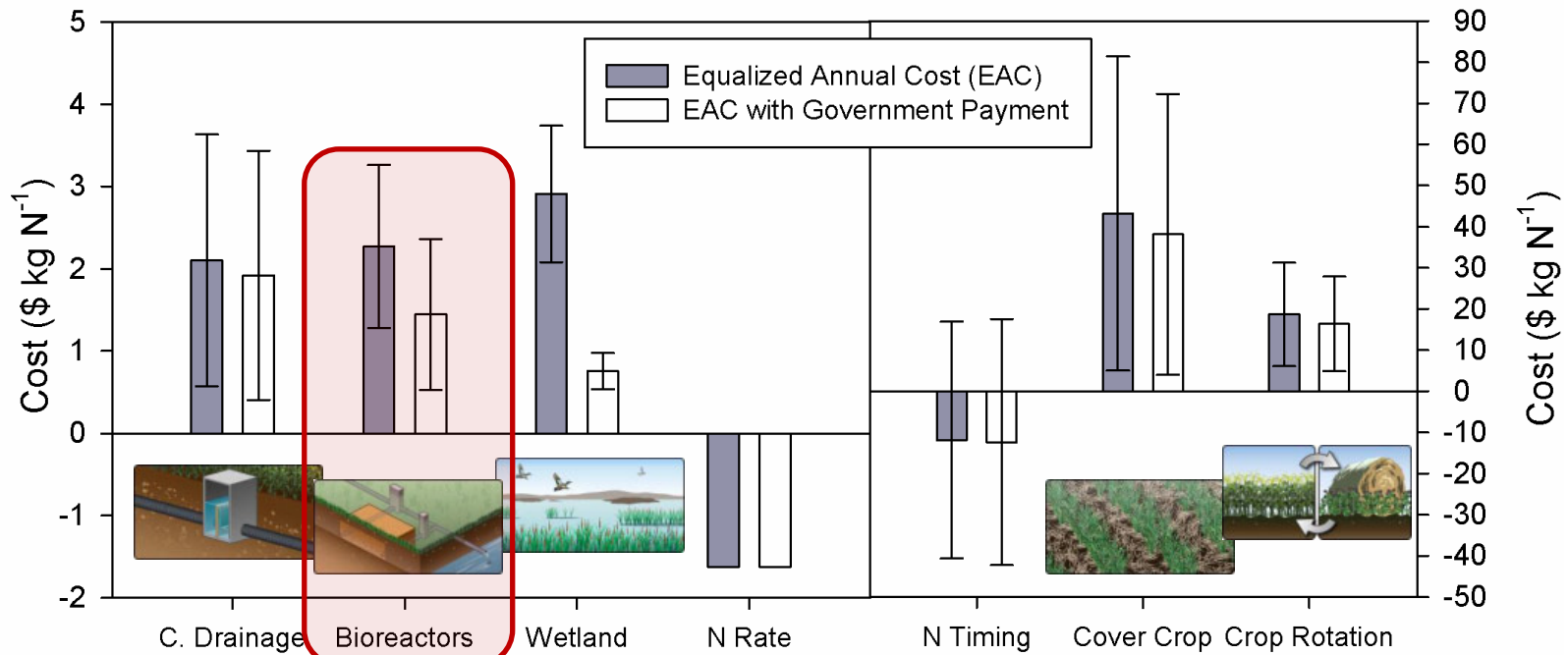
What do bioreactors cost?

	Structure	Contractor	Woodchips	Supplies	Total
Greene Co.	\$2,750.00	\$5,250.00	\$1,245.00	\$500.00	\$9,745.00
Hamilton Co.	\$1,640.00	NA†	\$2,400.00	\$350.00	\$4,390.00
Iowa 1	\$1,970.00	\$1,800.00	\$3,350.00	\$560.00	\$7,680.00
Iowa 2	\$1,270.00	\$1,890.00	\$3,000.00	\$780.00	\$6,940.00
Iowa 3	\$1,640.00	\$5,030.00	\$4,650.00	\$500.00	\$11,820.00
Iowa 4	\$1,480.00	\$2,710.00	\$2,520.00	\$400.00	\$7,110.00

Maryland MRC:
 ≈ \$20,000
 bioreactor
 < \$5,000 walls

†contractor time donated

Average: \$152.07/ac



Acknowledgements

- Cooperative agreement with the USDA ARS (No. 1930-31320-001-00D)
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- Keegan Kult and Todd Sutphin at the Iowa Soybean Association
 - Agriculture's Clean Water Alliance
 - The Sand County Foundation
- Coldwater Palmer Watershed Association



More information

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