Bioreactors, Saturated Buffers and Controlled Drainage

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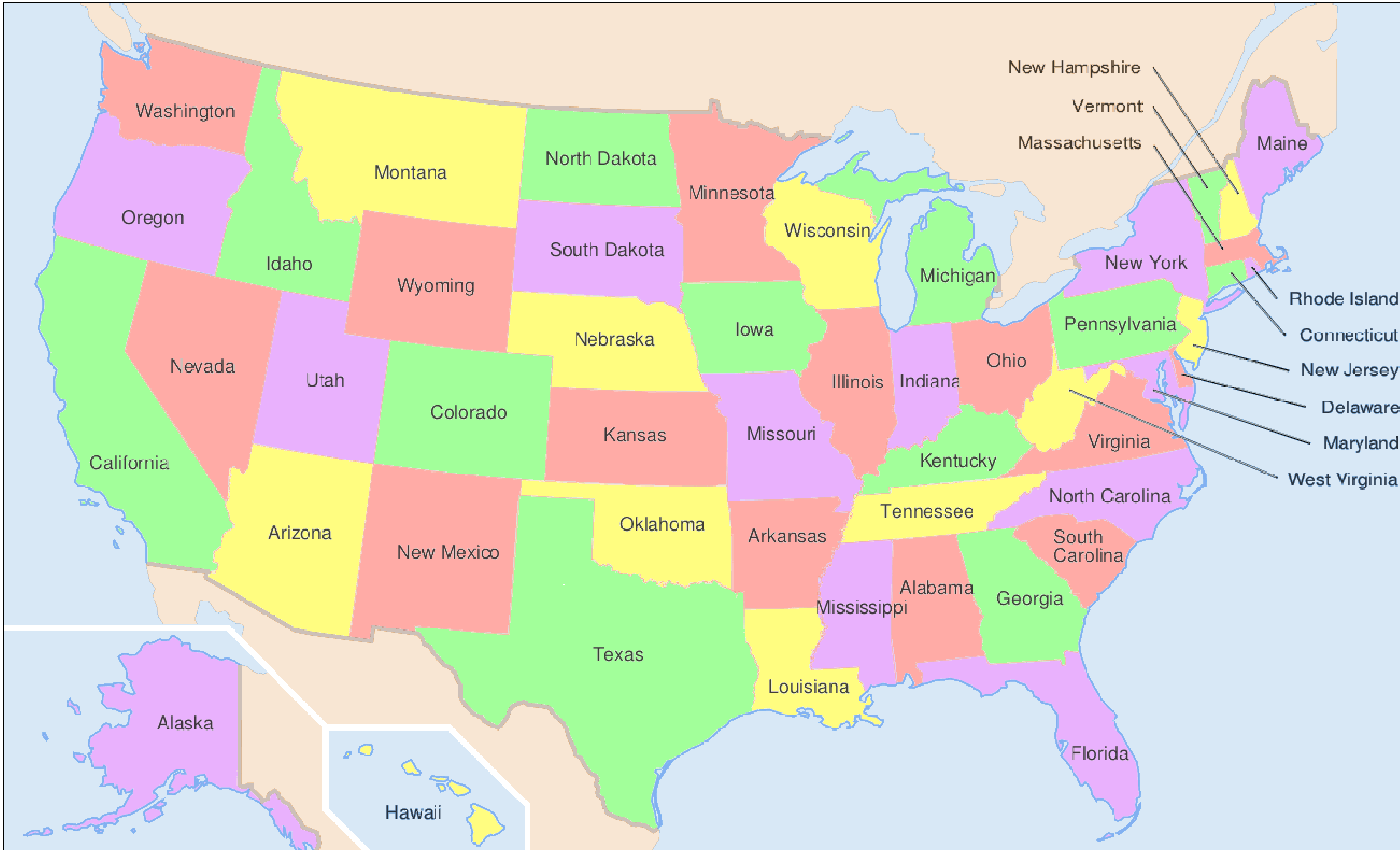

MN – DK Comparison

Minnesota

- Area: 225,170 sq km
- Water: 8.4 % of area
- Population: 5,489,000
- GDP per capita: $61,000
- Farmed area: 10,500,000 ha
- Cropland area: 8,100,000 ha
- Crop ground w subsurface drains: 2,800,000 ha

Denmark

- Area: 42,900 sq km
- Water: 1.6 % of area
- Population: 5,720,000
- GDP per capita: $53,280
- Farmed area: 2,800,000 ha
- Crop ground w subsurface drains: 1,400,000 ha (?)

Companies Headquartered in Minnesota

PENTAIR

3M

Mosaic®

Cargill®

usbank.

BEST BUY®

LAND O LAKES®

TARGET®

CHS® Farmer-owned with global connections

UnitedHealth Group

Ag production

- Top 5 corn producing states (2015): Iowa, Illinois, Nebraska, Minnesota, Indiana
- Top 5 soybean producing states (2015): Illinois, Iowa, Minnesota, Nebraska, Indiana

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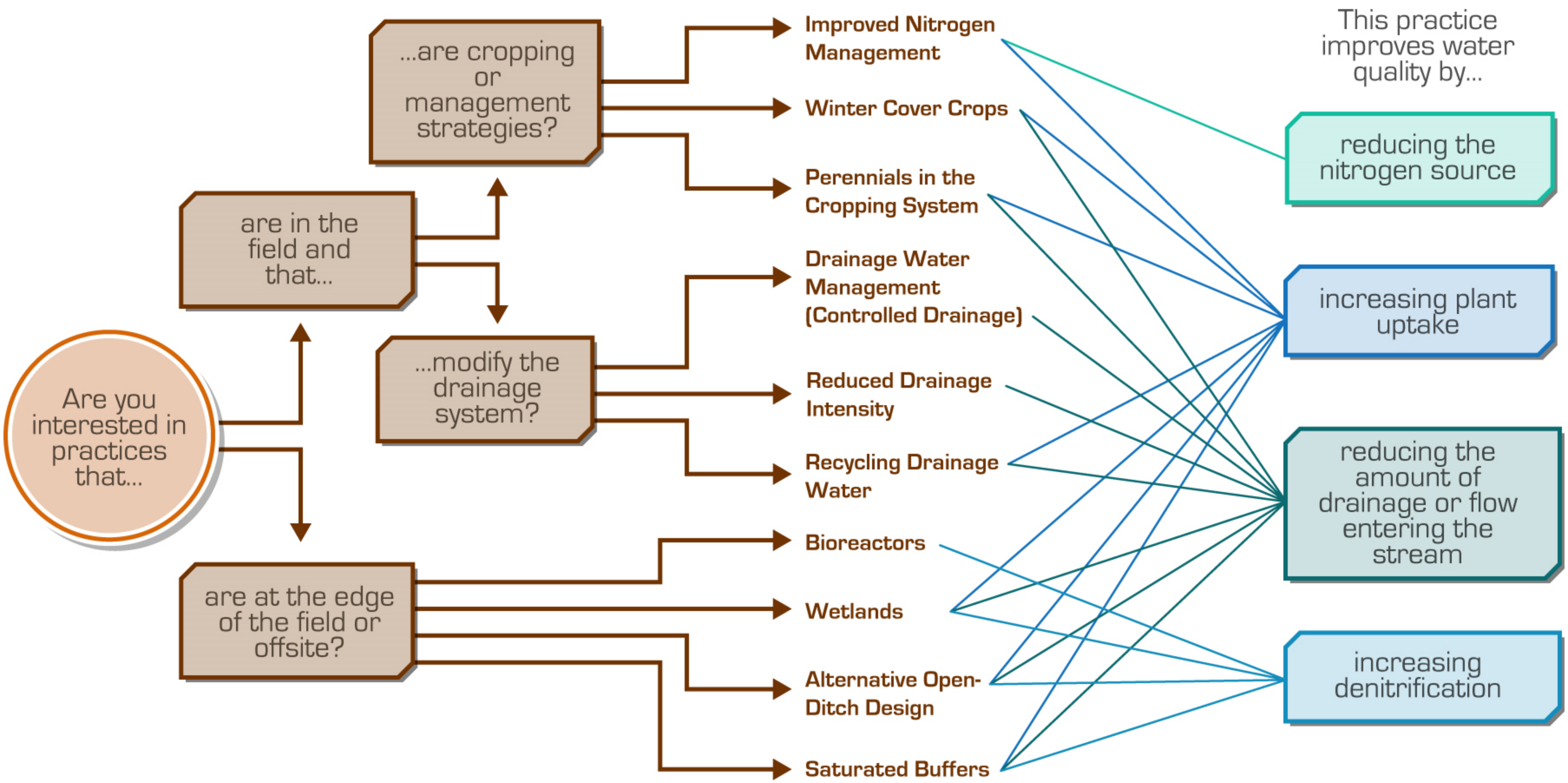
Artificial drainage is integral to crop productivity

The US Midwest has a long history of drainage because it improves crop growth and trafficability.

http://www.nejohnston.org/wej/120%20Years%20of%20Johnston%20Farming/120%20years%20of%20Johnston%20Farming.html; http://mrbdc.mnsu.edu/sites/mrbdc.mnsu.edu/files/public/major/midminn/subshed/sevenmi/vtour/images/trench_crew_l.jpg; The Wetland Initiative



Christianson, L.E., J. Frankenberger, C. Hay, M.J. Helmers, and G. Sands, 2016. Ten Ways to Reduce Nitrogen Loads from Drained Cropland in the Midwest. Pub. C1400, University of Illinois Extension.

BIOREACTORS

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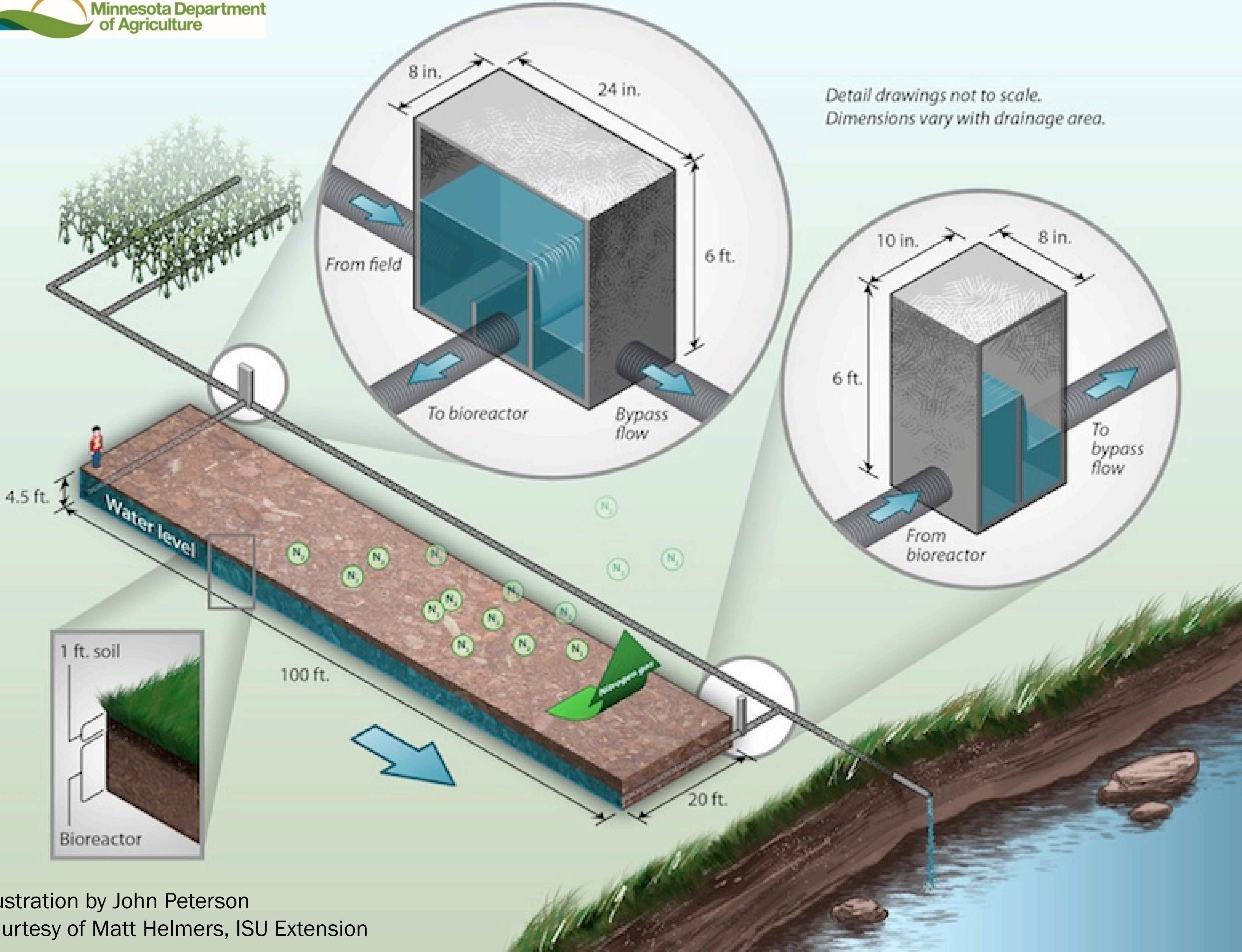
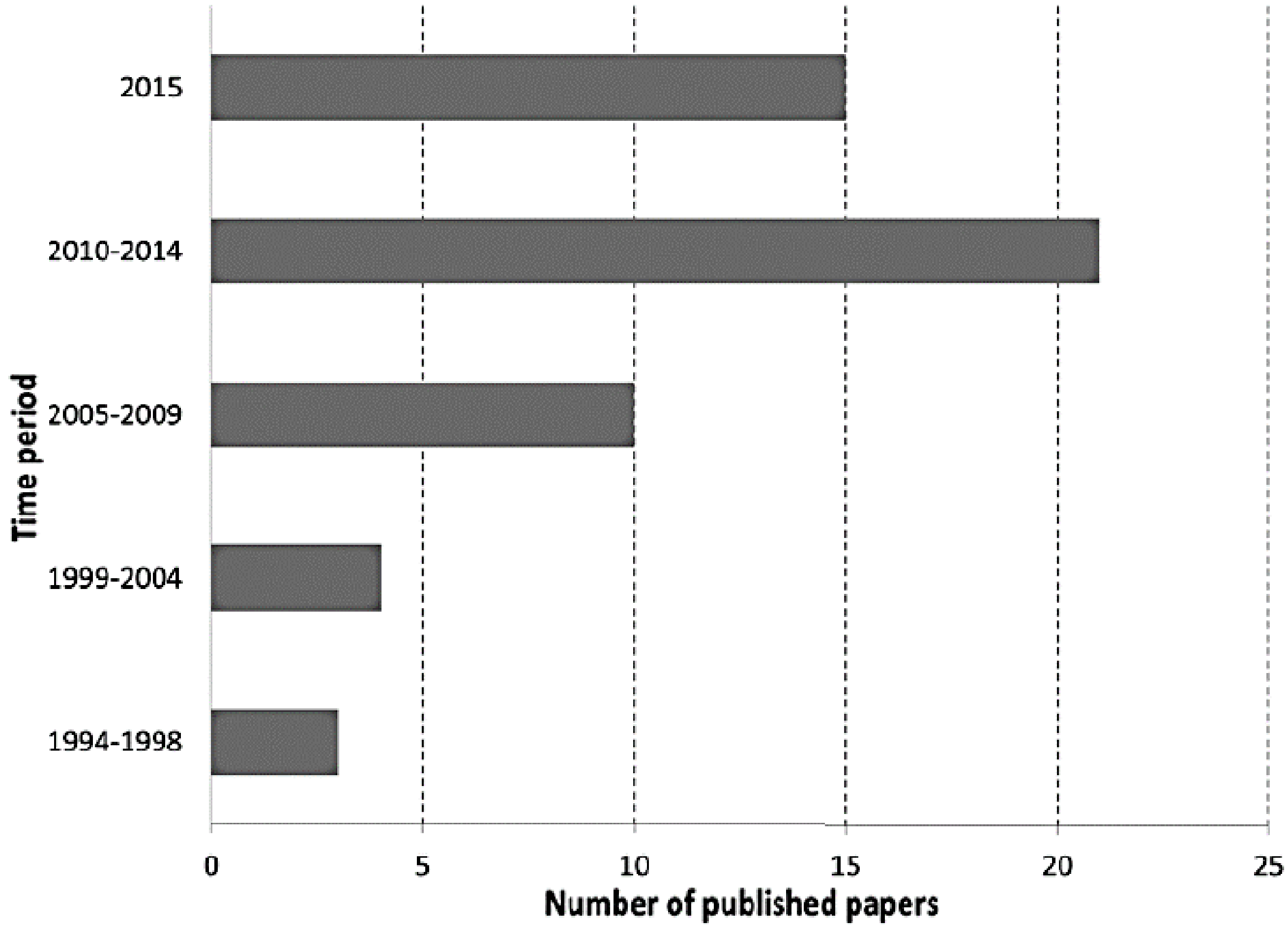


Illustration by John Peterson
Courtesy of Matt Helmers, ISU Extension

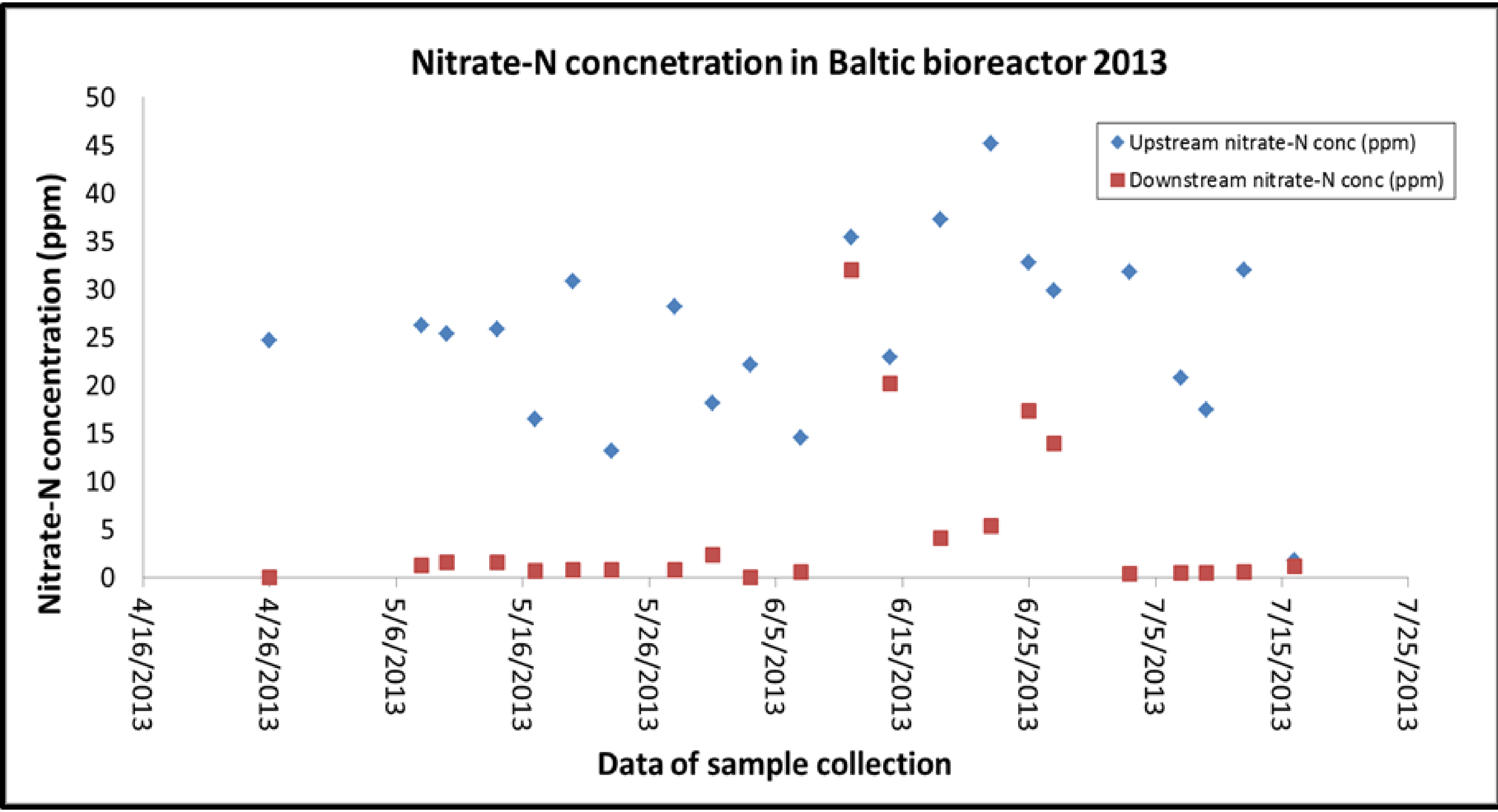
Increasing Interest in Bioreactors

(incl. lab and field-scale woodchip bioreactors and denitrification walls)



Addy et al. (2016). JEQ 45:873-881

Influent Nitrogen Concentration



Partheeban and Kjaersgaard, 2014

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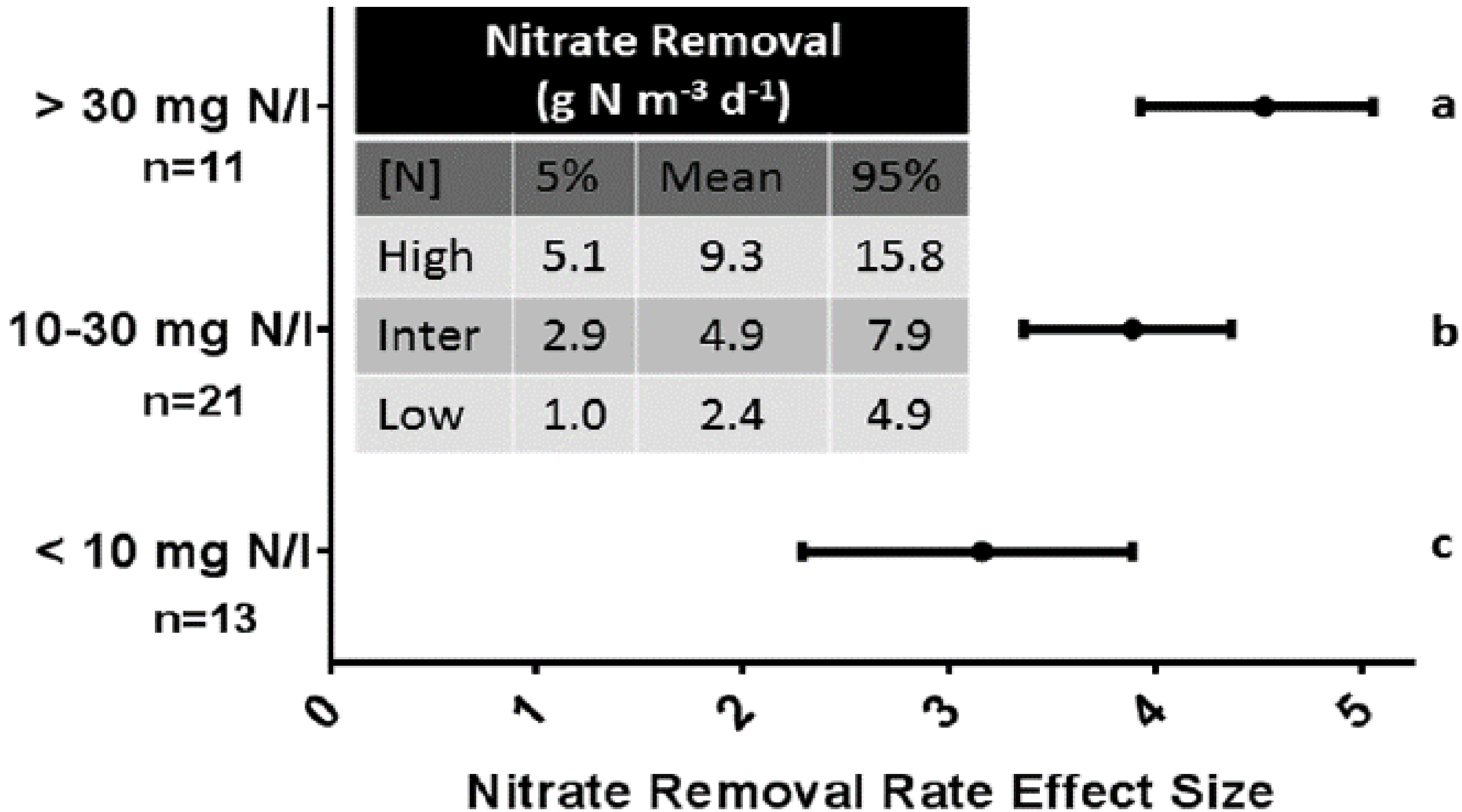
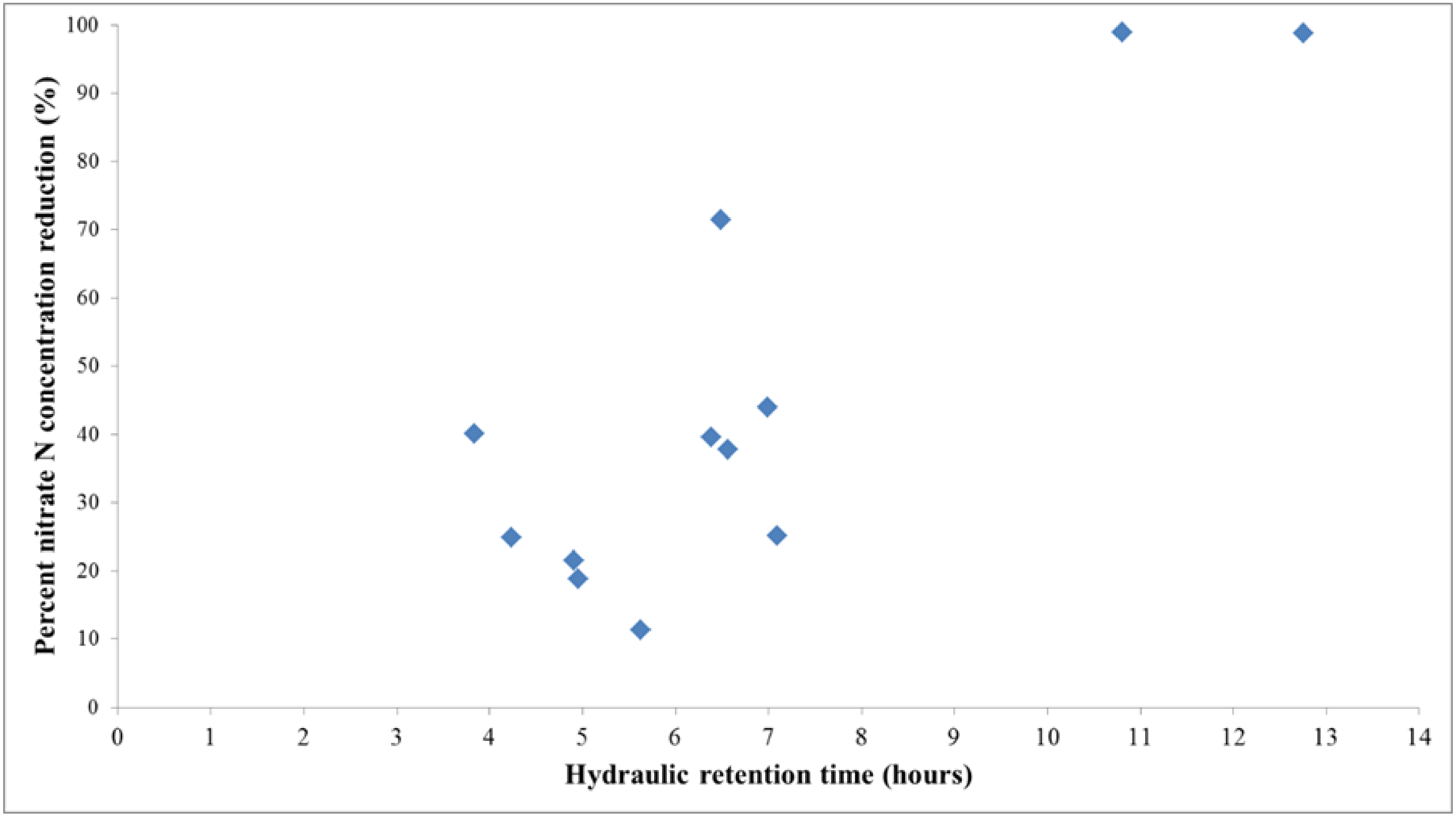
Influent Nitrogen Concentration



Nitrate Removal ($g\ N\ m^{-3}\ d^{-1}$)			
[N]	5%	Mean	95%
High	5.1	9.3	15.8
Inter	2.9	4.9	7.9
Low	1.0	2.4	4.9

Addy et al. (2016). JEQ 45:873-881

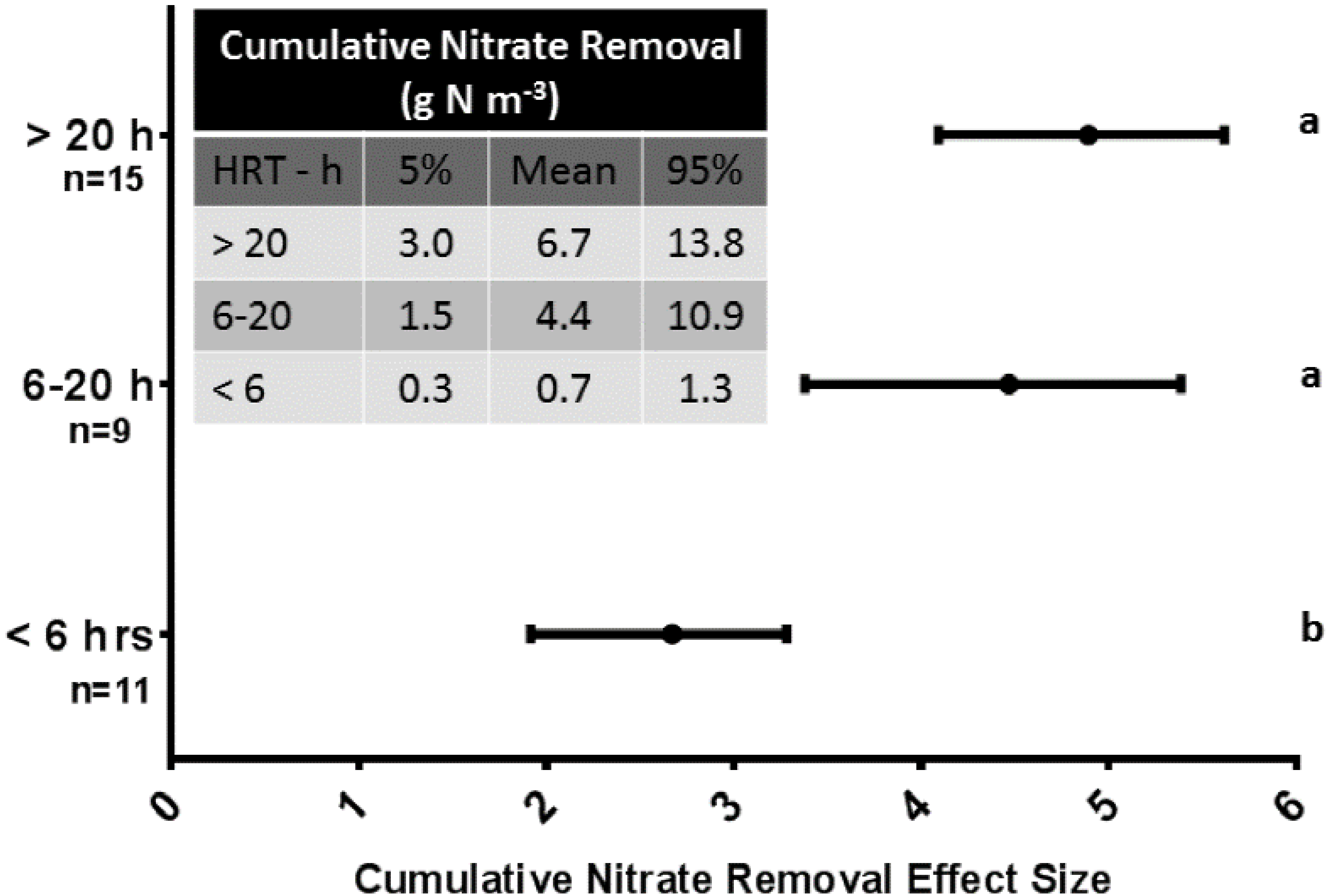
Hydraulic Retention Time



Partheeban and Kjaersgaard, 2014

Hydraulic Retention Time

Cumulative Nitrate Removal ($g\ N\ m^{-3}$)			
HRT - h	5%	Mean	95%
> 20	3.0	6.7	13.8
6-20	1.5	4.4	10.9
< 6	0.3	0.7	1.3



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Installation cost (Bioreactor near Baltic, SD)

Cost Category	Descript.	US$	DKK (7:1)	EUR (0.95:1)
Excavation and backfilling	2.5 days	1900	13300	1805
Wood chips	190 m3	3925	27475	3729
Control structures	Qty=2	1675	11725	1591
Plastic liner		500	3500	475
Pipe, elbows, fittings		300	2100	285
Misc. supplies		200	1400	190
Labor	2 students	500	3500	475
Total installation cost		**9000**	**63000**	**8550**

Assuming: 20 yr. life span, 4% interest, 16 ha treated - $36/ha/year

Partheeban and Kjaersgaard, 2014

SATURATED BUFFERS

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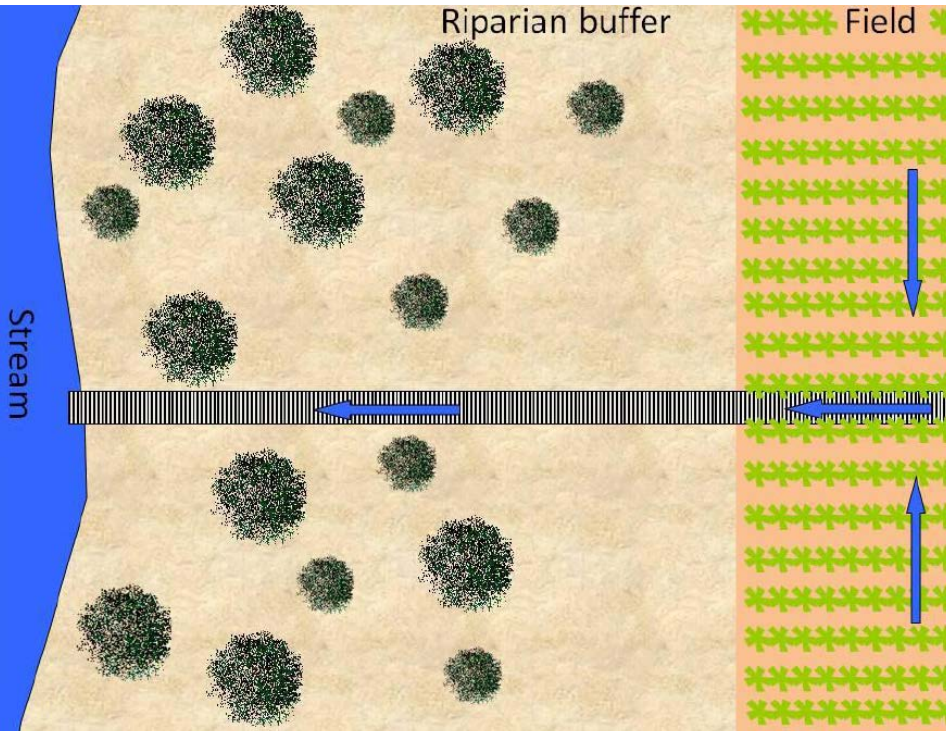
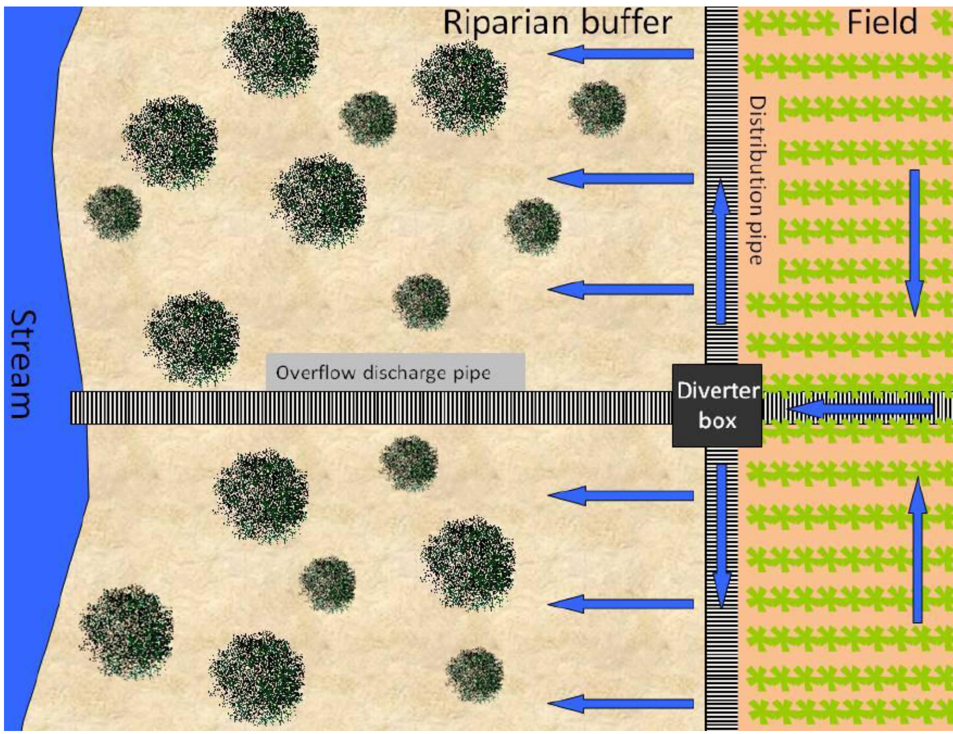
Saturated buffer





Graphics: Dan Jaynes USDA ARS

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Saturated Buffer Pilot Study

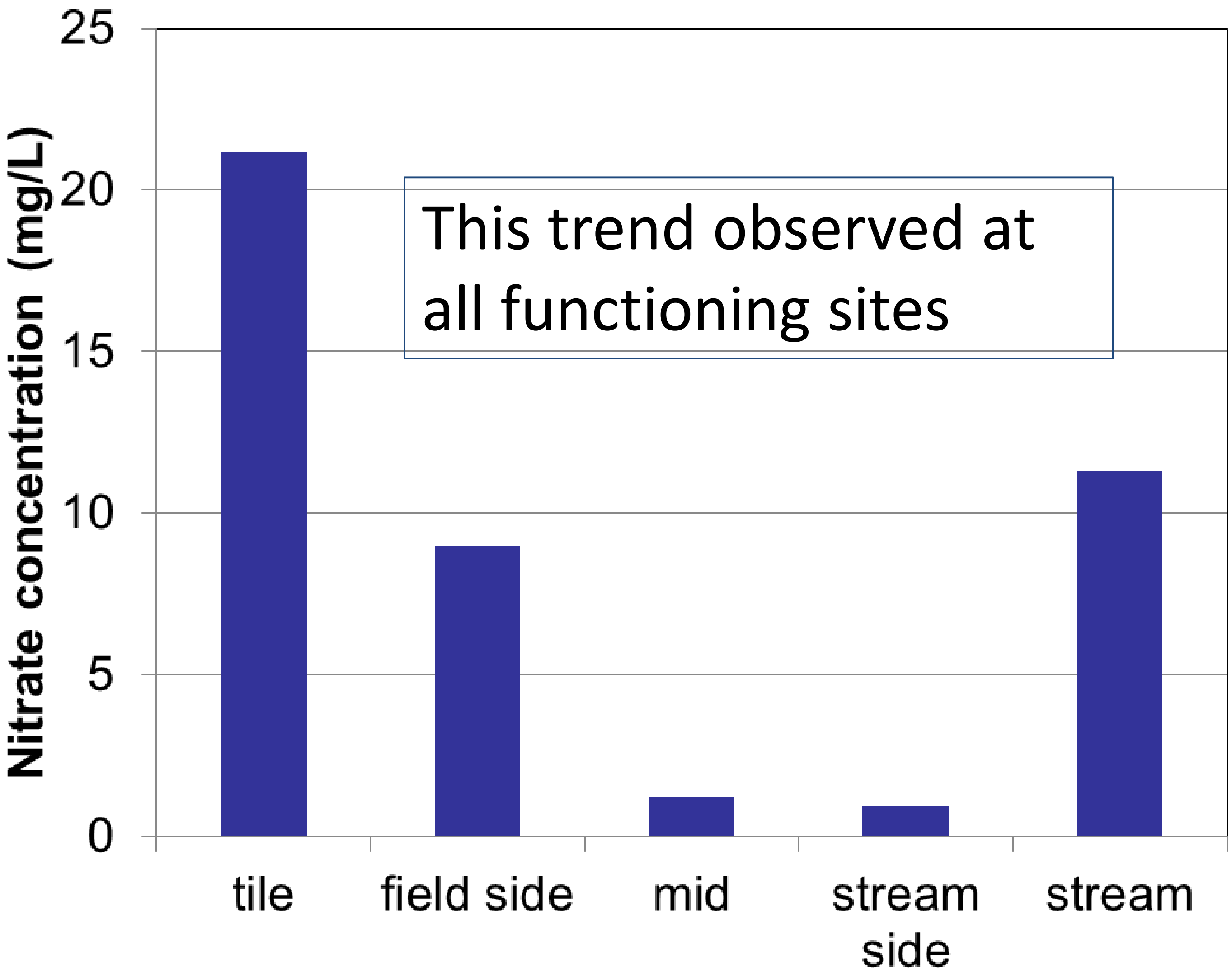
Pilot site

15 site regional project

- Flow rates
- Nitrate and phosphorus
- Soil information
- Overall performance

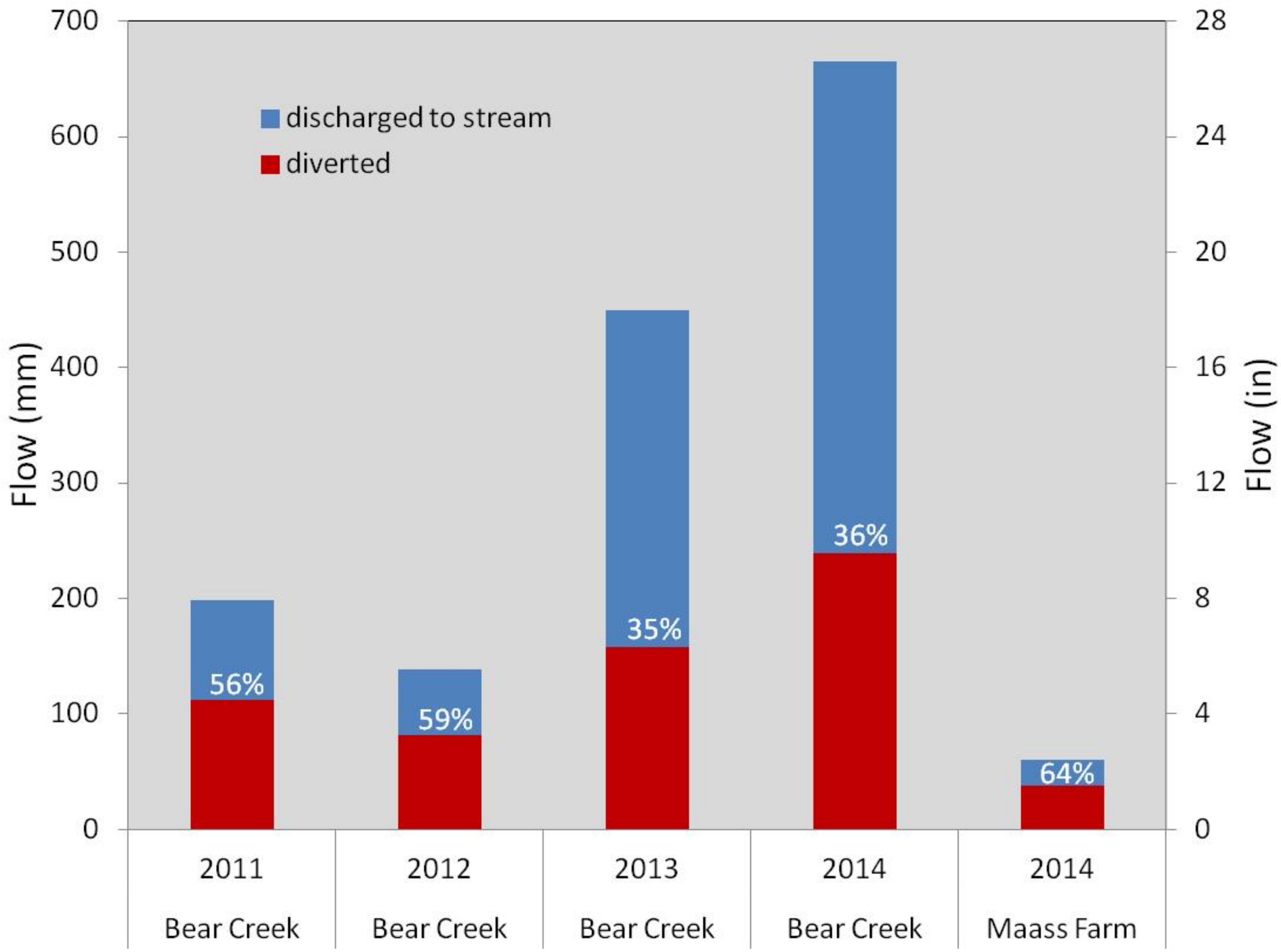
Image courtesy of Nathan Utt, University of Minnesota

Saturated Buffer Pilot Study



Graphic courtesy of Nathan Utt, University of Minnesota

Saturated buffer



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Saturated Buffer Pilot Study

Site	2014 kg Nitrate removed	2014 %flow diverted	2014 %NO3 removed	2015 kg Nitrate removed	2015 %flow diverted	2015 %NO3 removed	Saturated buffer performance		
							performing	promising	not performing
IA-1	42.6	64	**64**	48.5	91	**77**	+		
IA-2	0.0	0	0	0.0	0	0			+
IA-3	n.d.	n.d.	n.d.	83.9	30	29	+		
IL-1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.			+
IL-2	132.9	64	15	n.d.	n.d.	n.d.		+	
IL-3	1.4	19	19	30.8	33	28	+		
IL-4	38.1	91	83	2.9	13	4		+	
IL-5	5.9	91	28	73.0	26	11	+		
IN-1	0.0	81	0	1.6	6	5			+
IN-2	0.7	99	85	1.0	4	3			+
IN-3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.			+
MN-1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.			+
MN-2	0.0	0	0	11.8	22	16			+
MN-3	2.3	40	32	0.0	0	0		+	
MN-4	5.0	58	18	1.5	4	2			+

Table courtesy of Nathan Utt, University of Minnesota

Saturated Buffer Pilot Study

Success

- Adequate soil carbon
- Ability to maintain elevated water table
- Sufficient drainage flow diverted into buffer
- Adequate monitoring of system performance

Failure

- Highly permeable soils
- Lack of available carbon
- Inadequate drainage flow
- Topographic/management constraints
- Poor installation
- Lack of sufficient data due to flooding or sensor malfunction

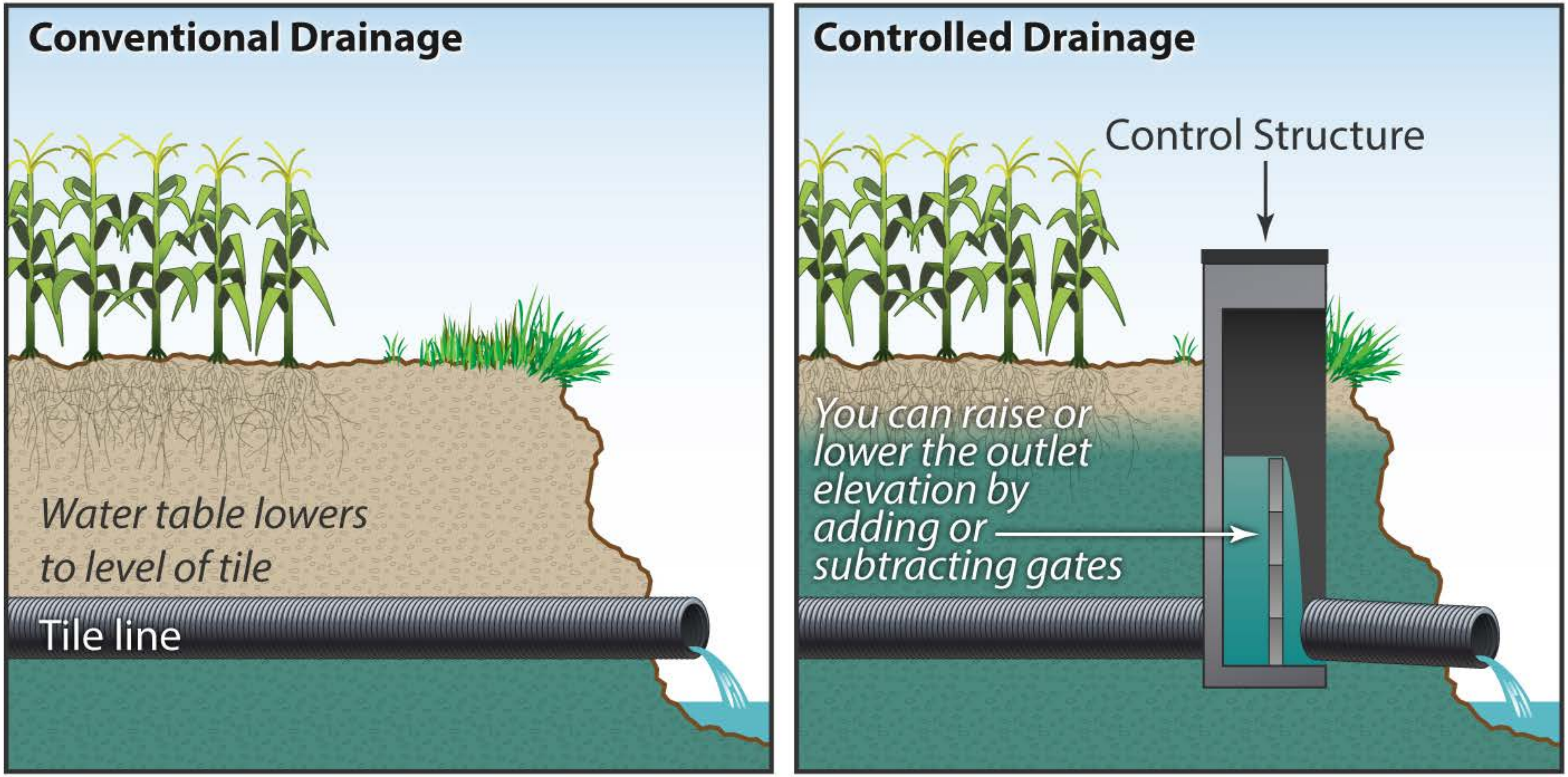
Data from Nathan Utt, University of Minnesota

Saturated Buffer Cost

Source	Diverter Box			Distribution line		
	USD	DKK	EUR	USD	DKK	EUR
Lewandowski et al. 2005	4000	28000	3800	11/ft	253/m	34/m
Jaynes 2014	1000	7000	950	0.33/ft	8/m	1/m
Kjaersgaard 2014	1000	7000	950	1/ft	23/m	3/m
Utt et al. 2015	Total cost: USD$ 3000-5000 / DKK 21000-35000 / EUR 2850-4750					

CONTROLLED DRAINAGE

Controlled Drainage



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Controlled Drainage

	2006	2007	2008 (controlled)	2008 (conv.)
Precipitation (inches)	24	24	20	20
Drainage (inches)	5.8	2.0	1.5	4.5
TN (lbs/ac)	41	3.8	4.4	16.9
NO_3-N (lbs/ac)	43	3.6	4.3	16.7
NO_3-N FWMC (mg/L)	10.6	9.96	12.7	10.8

Courtesy of Gary Sands, University of Minnesota

Cost Comparison

Table 1. Cost/benefit analysis of nitrogen removal by DWM in comparison to other approaches for reducing nitrogen.

Practice	Cost ($ kg^{-1} N)	Reference
Drainage Water Management	2.71	This paper
Constructed Wetlands	3.26	Hyberg, 2007
Fall Cover Crop	11.06	Saleh et al., 2007
Bioreactor	2.39 – 15.17	Schipper et al., in press

Source: Jaynes et al. (2010)

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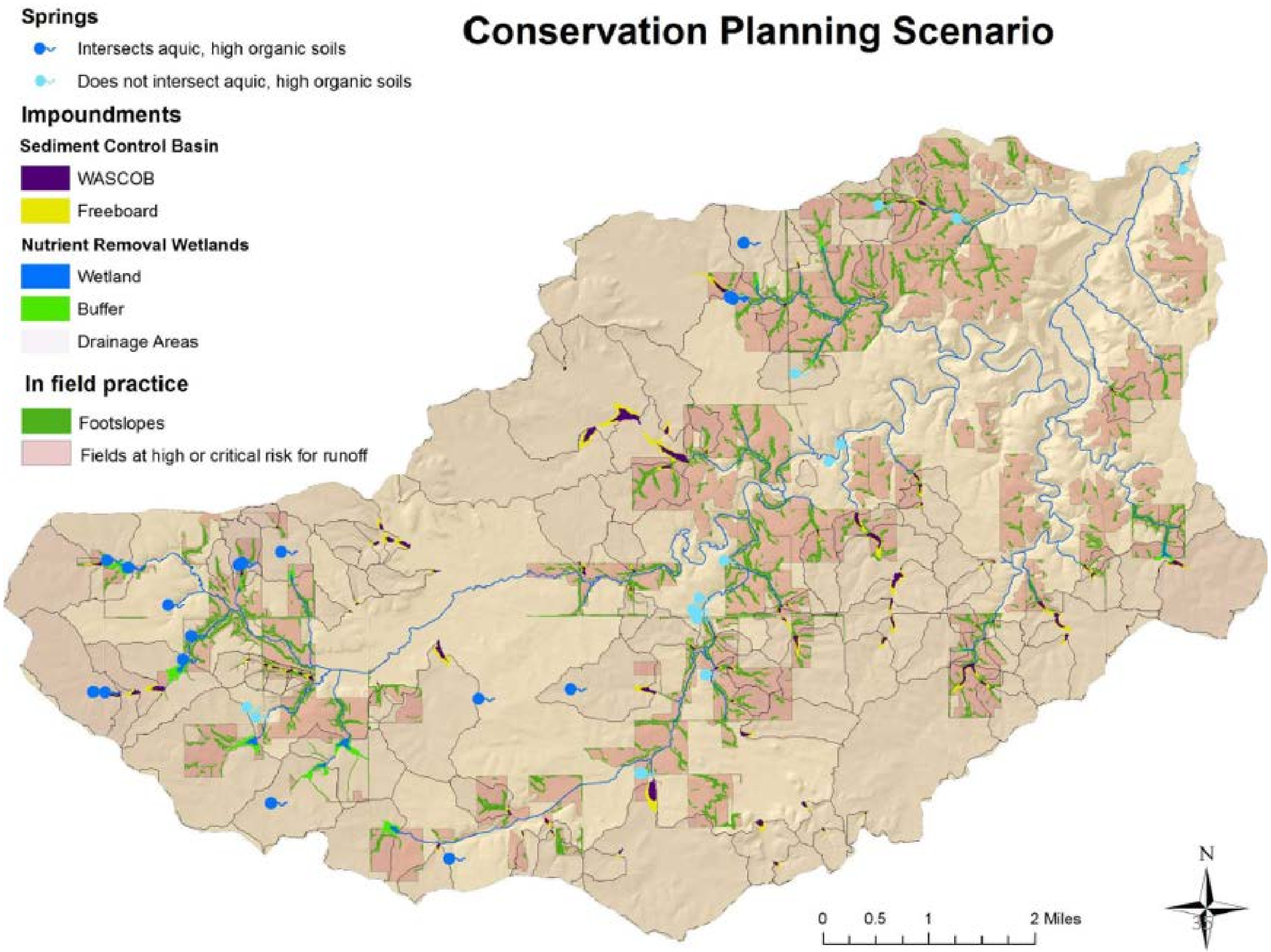
Watershed Planning Tools



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