

Reducing Nutrient Loads from Agriculture in the Upper Mississippi River Basin – Physical Evidence

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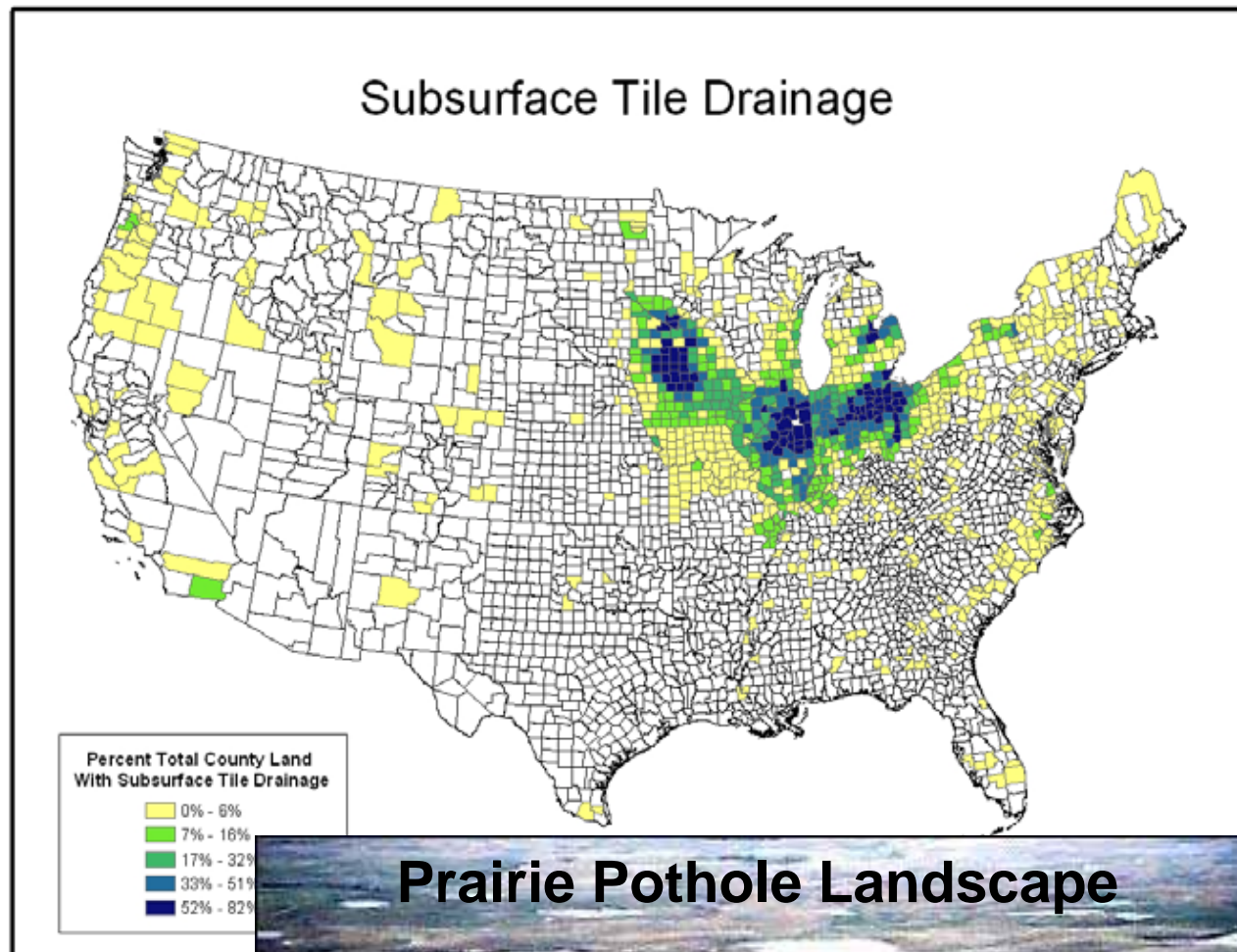
Outline

- Review key findings of recent synthesis efforts on reducing agricultural loadings – Upper Miss. River Sub-Basin Hypoxia Nutrient Committee (UMRSHNC, 2005) and EPA-Science Advisory Board Hypoxia Advisory Panel (2007).
- Integration of practices to achieve load reductions
- Critical knowledge gaps and some ideas on how to fill them

Agriculture in the upper Midwest, because of the nature of the original landscape, has remade the drainage system and altered hydrology. THE key element in improving water quality in this region is to remake the drainage system again - *“ will these replacement systems be designed to maintain the status quo or to optimize these landscapes for both environmental benefits and crop production?”*

Secretary Bill Northey, 2-10-09

We (may) now have the knowledge to do this.



Field Scale Approaches - Nitrate

- Reduce fertilizer application – reducing N rate from 150 to 125 reduce losses by 15% (UMRSHNC, 2005)
- Change from Fall to Spring Fertilizer Application reduce losses by 15% (UMRSHNC, 2005)
- Controlled Drainage – reduce losses by 30% (UMRSHNC, 2005)
- Winter cover crops – reduce loss up to 60% (UMRSHNC, 2005)

Issues Related to These Practices

- Yield effects of reduced fertilizer?
- Soil quality effects of reduced fertilizer?
- What proportion of land receives Fall N application?
- What proportion of drained lands are suitable for controlled drainage?
- Costs of structural changes such as controlled drainage?
- Timing of winter cover growth and survival

Reducing Fertilizer Input

-Yield Effects

- Reduce corn rate from 186 to 124, no yield effect, 27% reduction in subsurface nitrate – plot scale in CSCS sequence, spring applied UAN to corn, no N to soybeans (Jaynes et al, 2001)
- On-farm research (limited, short term) showed that reducing from 150 to 100 lb N/acre for spring applied UAN or NH₃ had minor yield reductions (167 to 164 bu/acre) Blackmer and Van De Woestyne (2002)
- Likely that a 15% reduction can be achieved through rate changes for spring applied N
- Reducing fertilizer and increasing yields have lead to changes in N balance.

	2001	2002
Inputs	----- kg N ha ⁻¹ -----	
Deposition	4	5
N Fertilizer	83	85
Soybean N Fixation	71	64
Total	158	154
Outputs	----- kg N ha ⁻¹ -----	
Maize grain N	54	51
Soybean grain N	75	86
Big Ditch total N load	21	50
In-stream denitrification	<1	1
Ground water denitrification	2	6
Field denitrification	<1	27
Total	152	221
Explicit Change in Soil Storage	----- kg N ha ⁻¹ -----	
Maize grain N derived from soil	-26	-32
Soybean grain N derived from soil	-18	-35
Total	-44	-67

Watershed scale N balances show net change in Soil N storage

Table 2. Inputs, outputs, and explicit change in soil storage for the Big Ditch, IL watershed in 2001 and 2002. Gentry et al., 2009 (In Press)

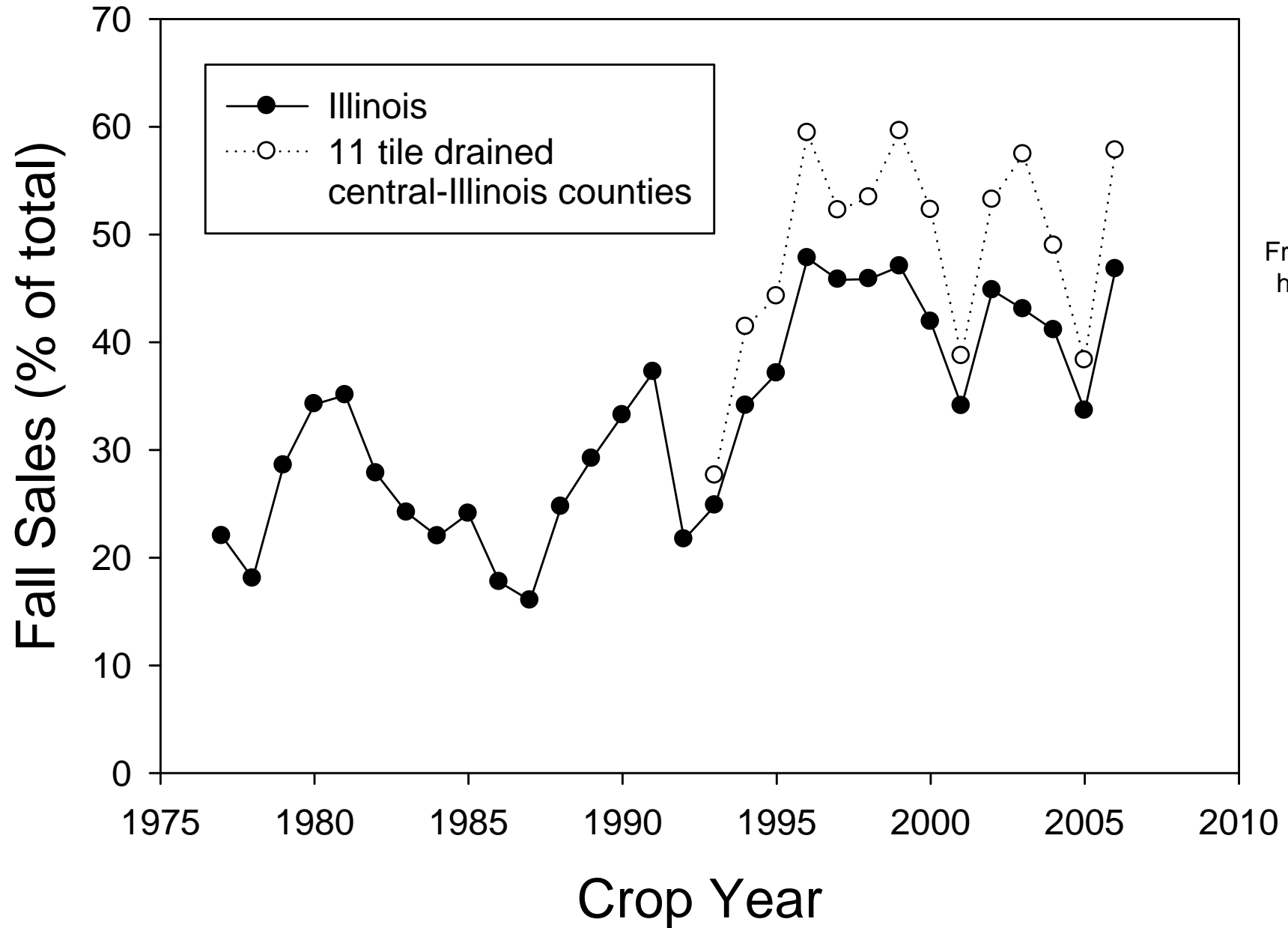
Reducing Fertilizer Input-Soil Quality

- When mass balances are negative, N has to come from someplace
- High rates, well above economic optimum, have shown increases in SOC (270 kg N/ha/yr, 23 years, Russell et al., 2002; 206 kg N/ha/yr, 15 years, Karlen et al., 1998)
- Zero N rates generally lead to SOC depletion
- Rates in the 100-180 kg N/ha/yr range generally have not shown effects on SOC
- For Illinois Mollisols, “declines in organic matter were likely completed by the 1950s with organic matter pools in a steady state under production practices in place from the late 1950s to 2002” (David et al., 2009). Khan et al. (2007) reported larger declines for similar time period under high fertilizer rates.
- Long term average soil N deficits currently in the 10 to 40 kg N/ha/yr range for corn/soybean rotations (David, personal communication)
- **Recently, as fertilizer rates have held steady, yields and N harvest have increased.**

Timing of N Fertilizer Application



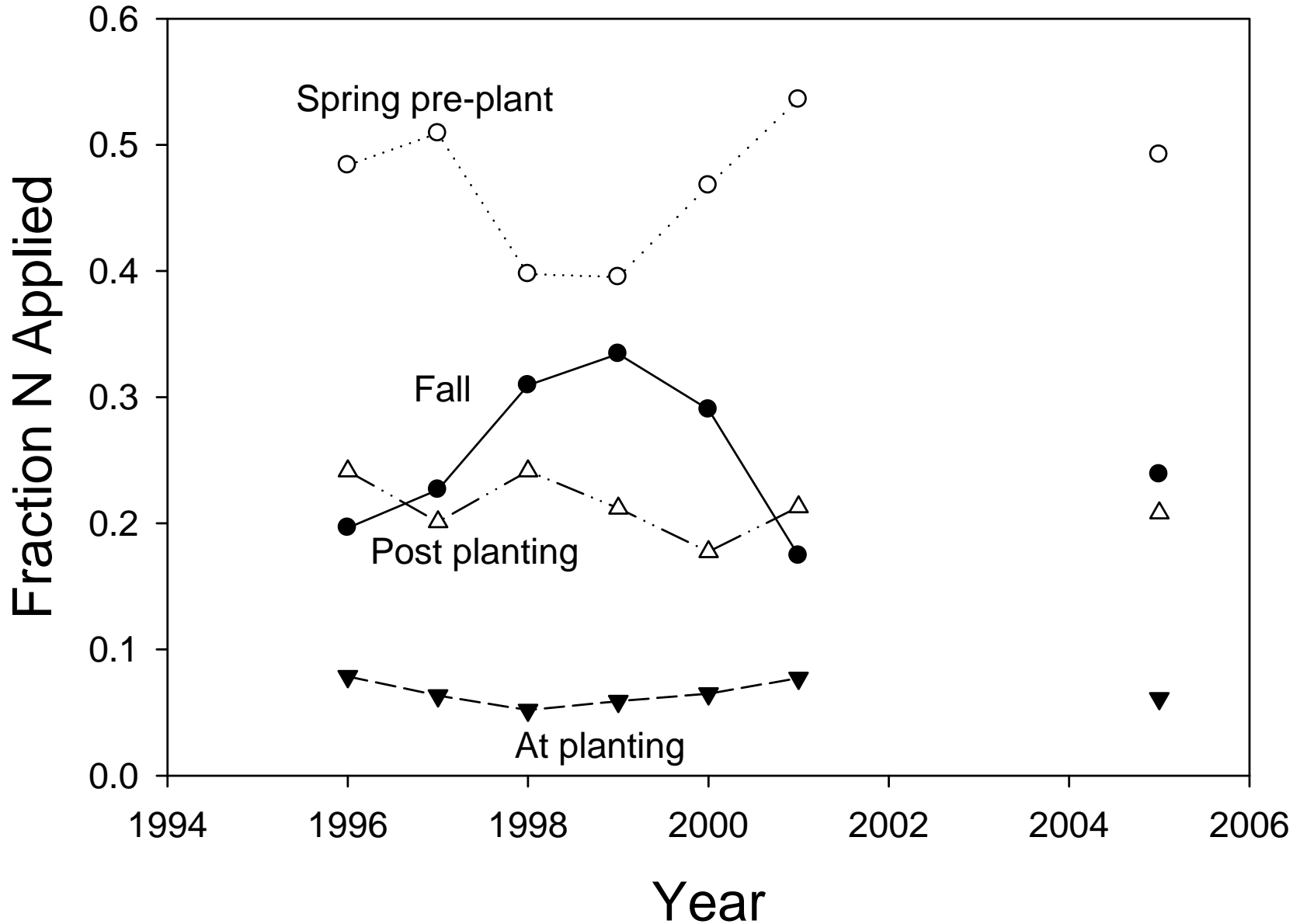
Fall Sales of Fertilizer - Illinois



From EPA-SAB
hypoxia report

ARMS data for the corn belt states (IA, IL, IN, OH, and MO)

15% reduction
x
30% Fall
applied =
4.5% overall
load reduction



From EPA-SAB
hypoxia report

Winter Cover Crops (Catch Crops)

- From UMRSHNC, 2005 (Kaspar et al.):
- Rye or ryegrass winter cover % reduction in nitrate leaching: Kladivko et al., 2004 (IN) – 61% (with fertilizer reduction); Jaynes et al., 2004 (IA) - 62%; Stroock et al., 2004 – 13%; Feyereisen et al, 2003 (MN , modeling) – 25-36%

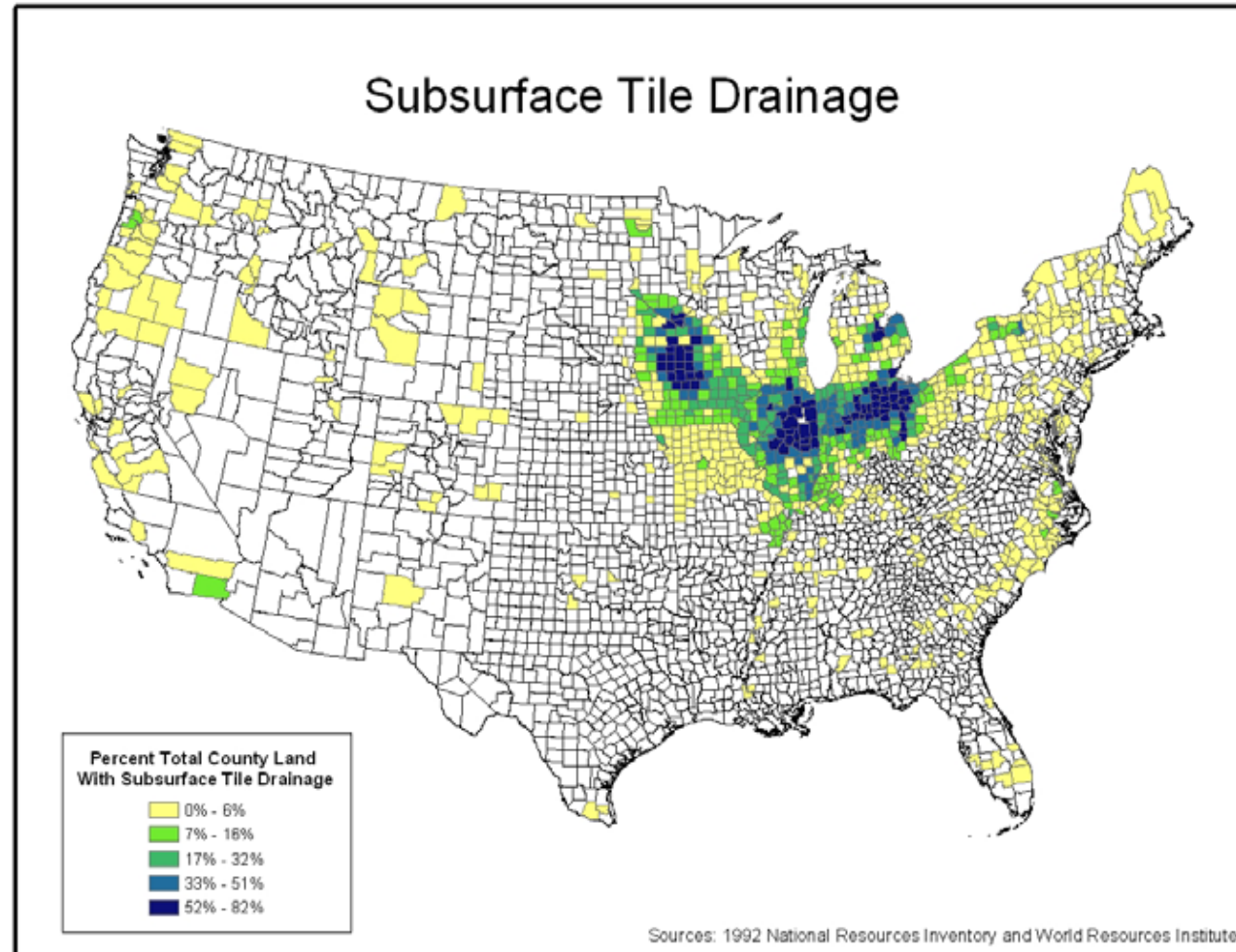
Winter Cover Crops (Catch Crops)

- Limitations – effects of winter conditions
- Interactions with other practices that reduce nitrate in the profile
- Timing – do periods of active growth and uptake coincide with periods of water movement through the profile



Controlled Drainage

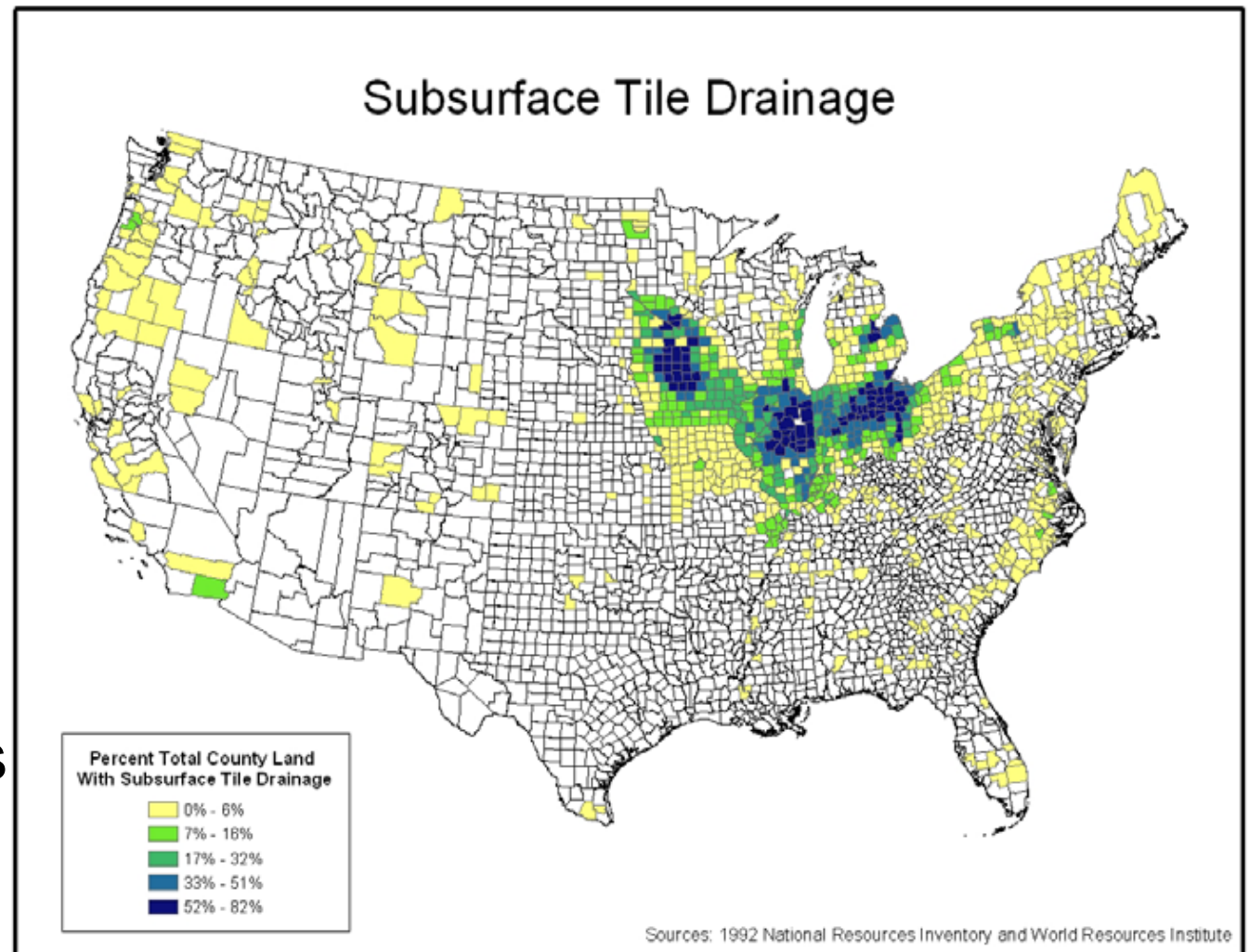
- 30% Nitrate Load reduction but no data on the extent of tile drainage where it is applicable (e.g. 30% reduction x 20% of land treated = 6% load reduction)
- Most applicable and economical on land with less than 1% slope



Controlled Drainage

- Possible trade-offs between subsurface flow and surface runoff. Increased surface runoff will require other treatment practices

- Cost will be an issue - \$50 to \$220 per hectare. Range is for retrofitting flatter land versus new system on steeper land. Steeper land requires more control structures



An aerial photograph of a rural landscape. A stream flows through the center, with a pond on the right. A house and farm buildings are visible in the bottom left. The fields are a mix of green and yellow, with dark green buffer strips along the stream and pond. A bird is flying in the sky.

Field Edge Practices

Buffer Strips: Common Sense Conservation

Sub-Basin	Contour Buffer Strips (acre)	Field Border (acre)	Filter Strip (acre)	Grassed Waterway (acre)	Riparian Forest Buffer (acre)	Stream bank Protect (miles)	Windbreaks and Shelterbelts (acres)	Conservation Buffers Applied (acres)
Ohio	8308	13446	125073	52745	80299	469	1962	283745
Tennessee	483	4730	26499	2019	26568	260	4	64307
Upper Miss.	54899	18178	394376	107291	185667	448	20874	784339
Lower Mississippi	407	18633	25387	1632	138636	313	966	186525
Missouri	18220	40556	288497	76764	77815	292	97300	634279
Arkansas White-Red	4652	38624	196831	20254	73500	178	5370	359007
Sum	86969	134168	1056662	260705	582485	1961	126476	2312201
Acres treated (ratio)	1:1	1:1	3:1	3:1	3:1	NA	3:1	
Acres treated	86969	134168	3169986	782115	1747455	NA	379428	5596221

Table 11. Acres of conservation buffers installed in the six sub-basins of the MARB. Miles shown for streambank protection. Areas treated based on ratio shown. From NRCS-PRS, <http://ias.sc.egov.usda.gov/prshome>.

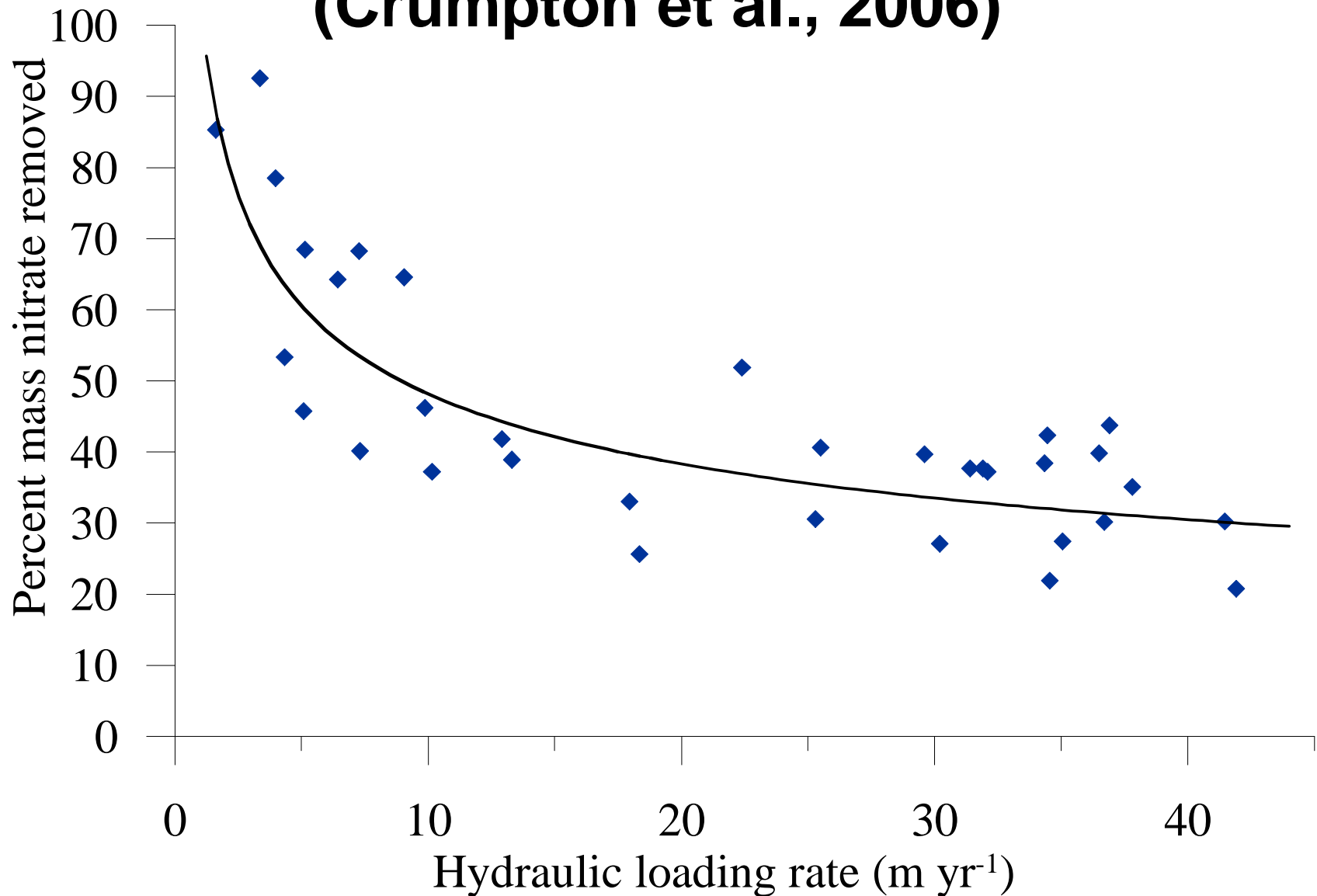
Iowa Conservation Reserve Enhancement Program

- Install Treatment Wetlands and Buffers to Control Nitrogen (and P) Transport
- Current progress 715 acres of wetland treating 86,100 acres (Wetland is 0.83% of source)



Too much water can be bad for a treatment wetland

(Crumpton et al., 2006)



Treatment Wetlands - Illinois

Wetland	Retention time (days)*	Nitrate Removal (%)	Phosphate Removal (%)
small	11	34	7
large	21	41	32

- Mean for April-June. All values are mean of 3 years. Wetland was 3-7% of source.
- From Kovacic et al., 2001

Wetlands and Buffers – Bear Creek, IA – Schultz, Isenhardt et al.



Wetlands and Buffers– Bear Creek

	Total N	Nitrate N	Total P	DMRP
	-----Per Cent Retention-----			
Low intensity (2.5 cm/hr) , SG	64	61	72	44
Low intensity (2.5 cm/hr) SG-W	80	92	93	85
High intensity (6.9 cm/hr) SG	50	41	46	28
High intensity (6.9 cm/hr) SG-W	73	68	81	35

SG = switchgrass, w = woody

Lee, et al., 2000, 2003

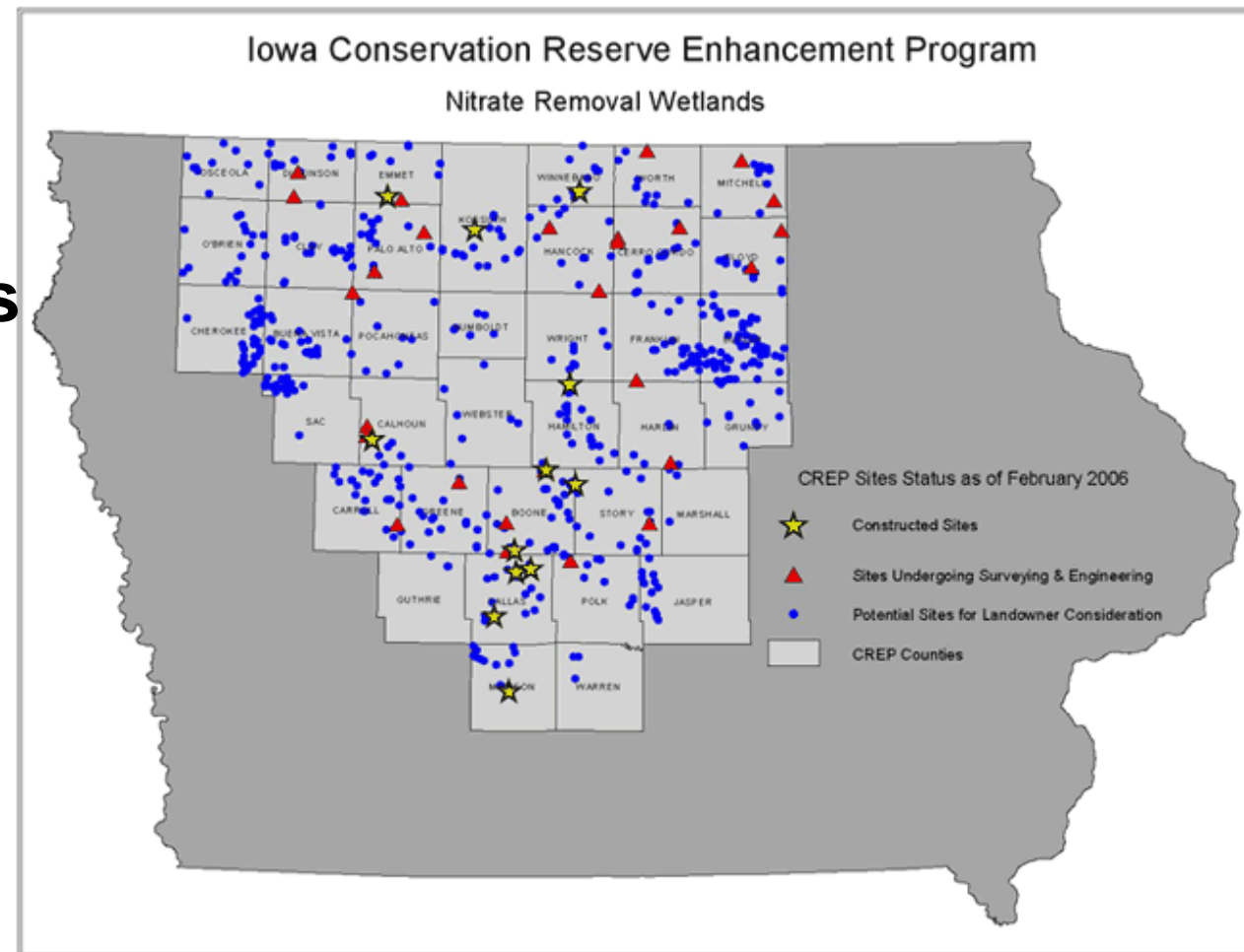
•30% removal for nitrate is a minimum for well-designed treatment wetlands.

•Nitrate removal should be very long lasting function

•P removal also depends on retention time but is likely to be much more variable than nitrate.

•Enhanced long-term P removal in wetlands where substrate is rich in Ca and Mg

Wetlands and Buffers



Wetlands and Buffers

- 30% removal for N and P in surface runoff is very achievable with switchgrass and woody buffers.

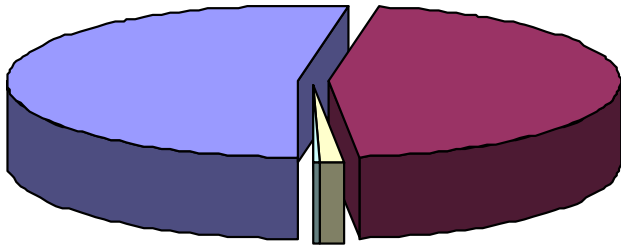
- Edge of field and edge of stream buffers will be especially important on undrained land and if drainage management changes take place leading to greater saturation excess surface runoff



Phosphorus and Manure Management

Phosphorus Inputs
240,418 tons

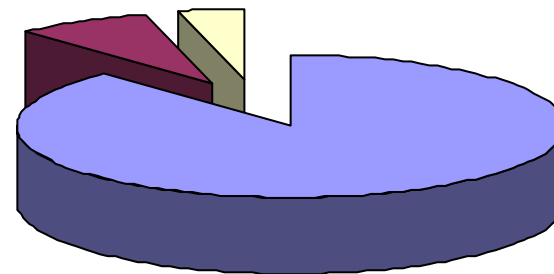
- Fertilizer - 54%
- Manure - 45%
- Human - 1%
- Industry - 1%



In contrast, manure N is 13% of total inputs

Phosphorus Outputs
276,586 tons

- Harvest - 88%
- Grazing - 8%
- Streams - 4%



Phosphorus and Manure - Issues

- For many watersheds, much bigger proportion of P input is in manure compared to N input
- Movement of feedlots to proximity of corn ethanol plants to use DDGs
- Are we using proper thresholds for implementing P based applications in CNMPs?
- Are proper P (and N) credits being given for nutrients in manure?

Future Needs and a Few Questions (of Many)

- Basic information to allow precision conservation – the watersheds with the greatest loads are generally known. We need to know details of both farm operations and drainage within those watersheds
- Creative approaches with conservation programs to allow the use of existing funds. CREP is a great start. There needs to be a better way to focus conservation programs in the tile drained regions on nitrate transport without losing ground on P.

Future Needs and a Few Questions (of Many)

- Adaptive management approach – requires enhanced monitoring on appropriate levels – 8 to 12 digit HUCs and the ability to map and model where practices are being applied
- Major question – Can we continue the 2001 to 2005 trajectory of decreasing N loads? Have we changed something in N management that is increasing P?

Future Needs and a Few Questions (of Many)

- What are the actual effects of changes in crop selection to provide grain feedstocks for ethanol?
- Will a switch to cellulosic feedstocks help or hurt water quality and sustainability?
- How much can impoundments help and can they be designed and retrofitted with wetland components ?

Thank you

	1980 to 1996	2001 to 2005	change	45% N target	40% P target
	million m ³ or million metric tons		%	million metric tons	
Annual					
Water	692500	652500	-5.8		
Nitrate-N	0.96	0.81	-15.4	0.53	
TKN	0.61	0.43	-30.0	0.34	
Total N	1.58	1.24	-21.1	0.87	
Total P	0.137	0.154	+12.2		0.082
Spring					
Water	236800	210600	-11.0		
Nitrate-N	0.38	0.33	-12.4	0.21	
TKN	0.21	0.14	-31.5	0.12	
Total N	0.59	0.48	-19.2	0.32	
Total P	0.046	0.050	+9.5		0.027

Table 4.2.1. Annual and spring (sum of April, May, June) average flow and N and P fluxes for the MARB for the 1980 to 1996 reference period compared to the most recent five year period (2001 to 2005). Load reductions in mass of N or P also shown.

From EPA-SAB hypoxia report