Water and Nutrient Research: In-field and Offsite Strategies

Matthew J. Helmers & William G. Crumpton
Iowa State University

Water and Nutrient Research: In-field and Offsite Strategies

- **Over 25 year history of ISU and IDALS working together collaboratively on this research**
- **Resources have been leveraged to acquire funding from EPA, NIFA, FSA, INRC, NRCS, and Iowa Corn Promotion Board**

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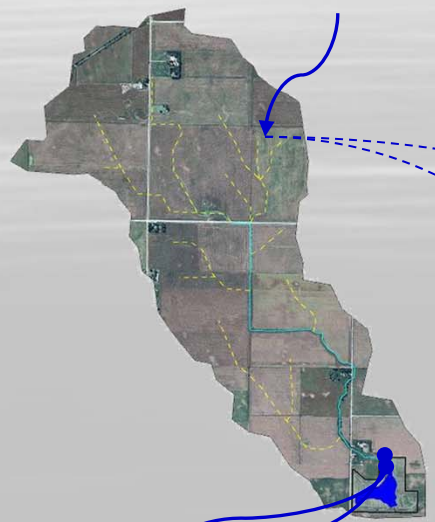
Linking Agricultural Practices to Water Quality Improvement:

- Performance of in-field practices
- CREP wetland performance
- Watershed scale outcomes
  - Monitoring N & P loads to streams
  - Modeling watershed scale outcomes

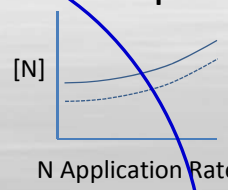
Conceptual Framework



[N] by field

N yield by field

N Response Curves



(function of practices)

Established based on experimental field studies (IDALS and USDA NIFA)

Practices by field

(also yield, for economic analyses)

Established based on GIS coverages and survey data (Iowa Corn Promotion Board and USDA)

Water Yield by field

Estimated based on observed flows, precipitation, etc. and semi-empirical models (IDALS and INRC)

Predicted load at watershed outlet ← **Estimated as** $\Sigma\ N\ yield\ across\ fields$ **(IDALS, INRC, and USDA-NRCS)**

Observed load at watershed outlet ← **Calculated based on close interval monitoring of flows and concentrations** **(IDALS and INRC)**

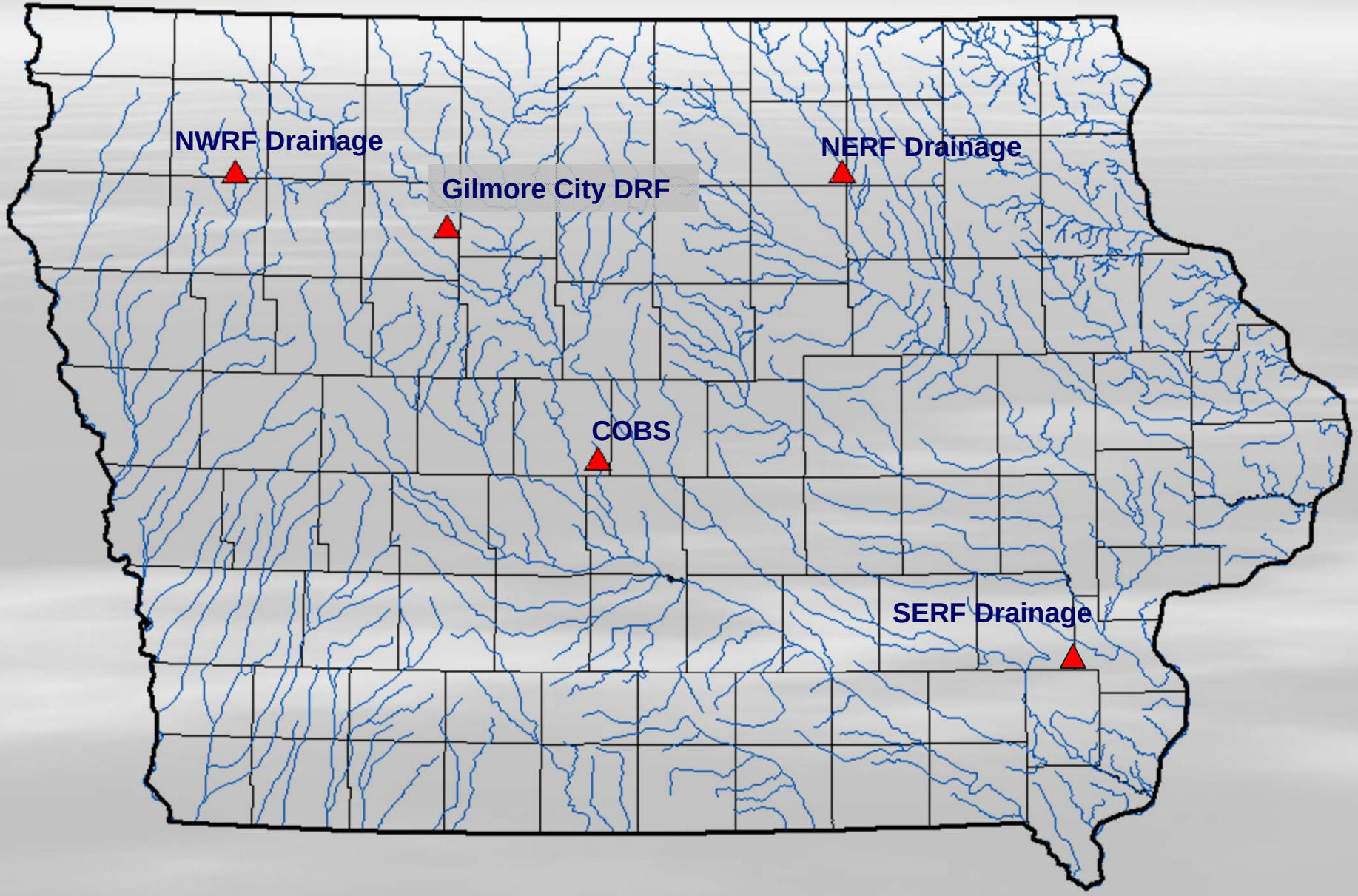
Comparison of predicted and observed load for

1) **Validation and error estimation**
2) **Iterative improvement of approach/tool**
3) **Establishing capabilities and limitations of approach/tool**

Linking Agricultural Practices to Water Quality Improvement:

- **Performance of in-field practices**
- **CREP wetland performance**
- **Watershed scale outcomes**
  - **Monitoring N & P loads to streams**
  - **Modeling watershed scale outcomes**

Replicated subsurface drainage plots to evaluate performance of various in-field management practices



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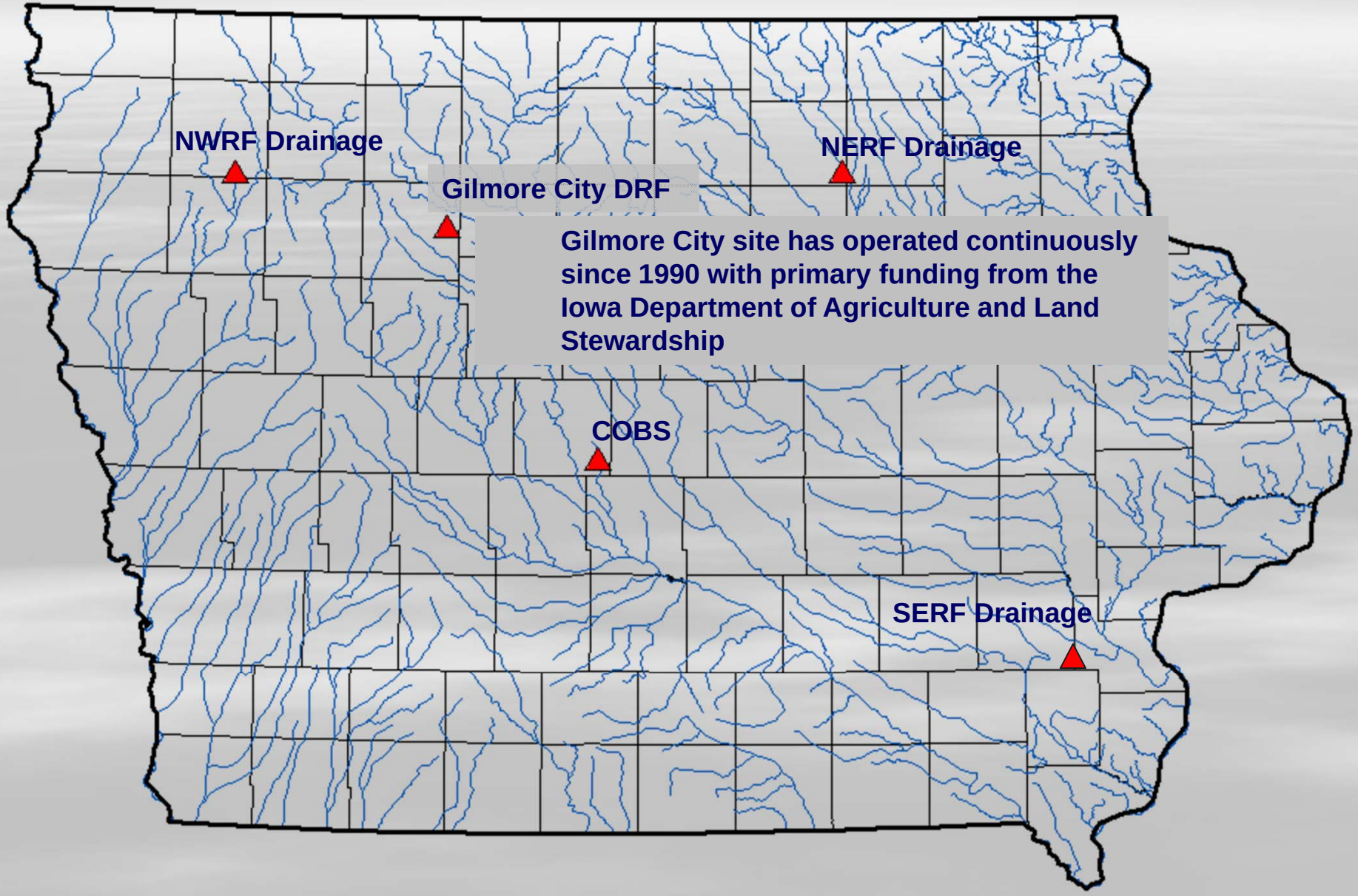
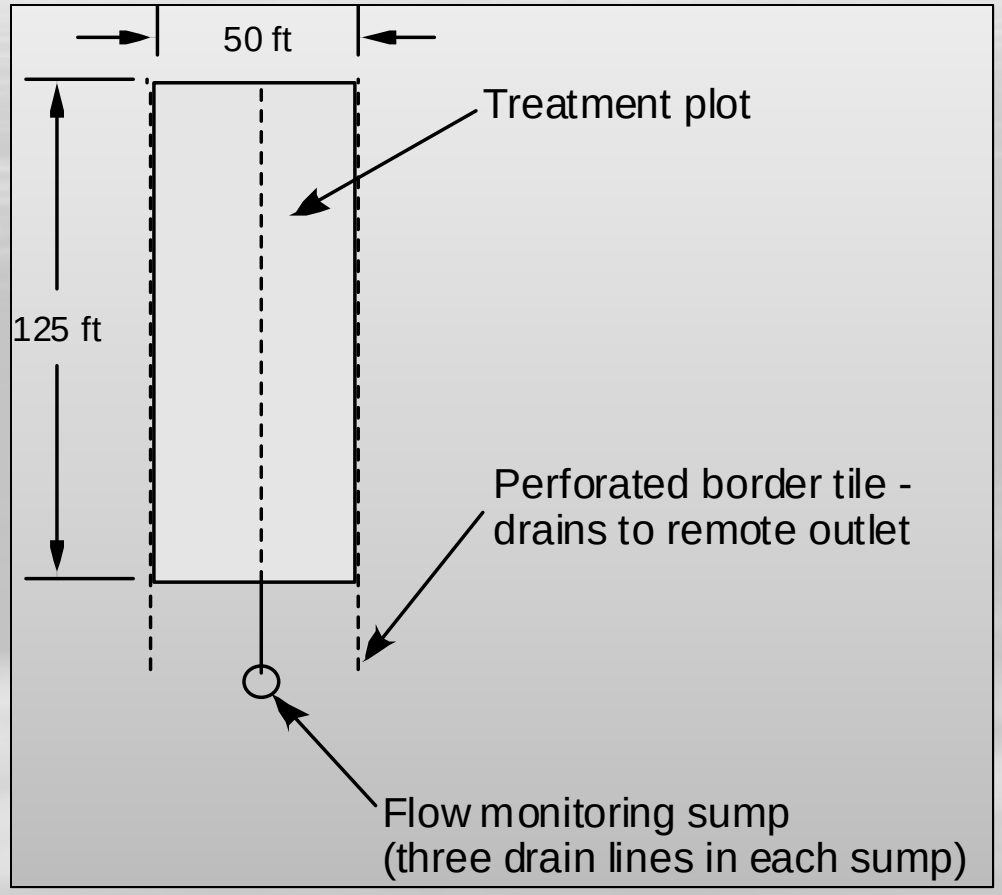
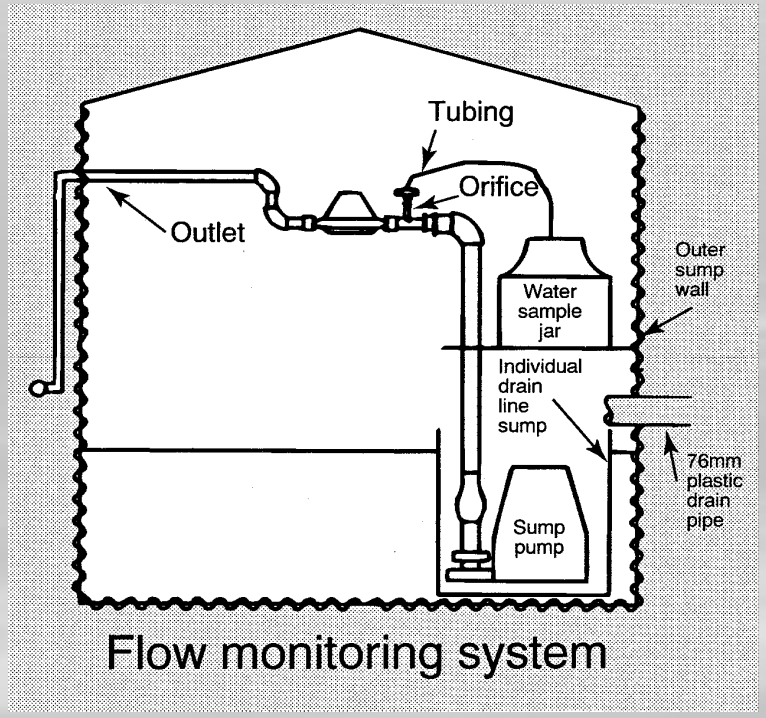


Gilmore City site has operated continuously since 1990 with primary funding from the Iowa Department of Agriculture and Land Stewardship

Plot Sampling Layout

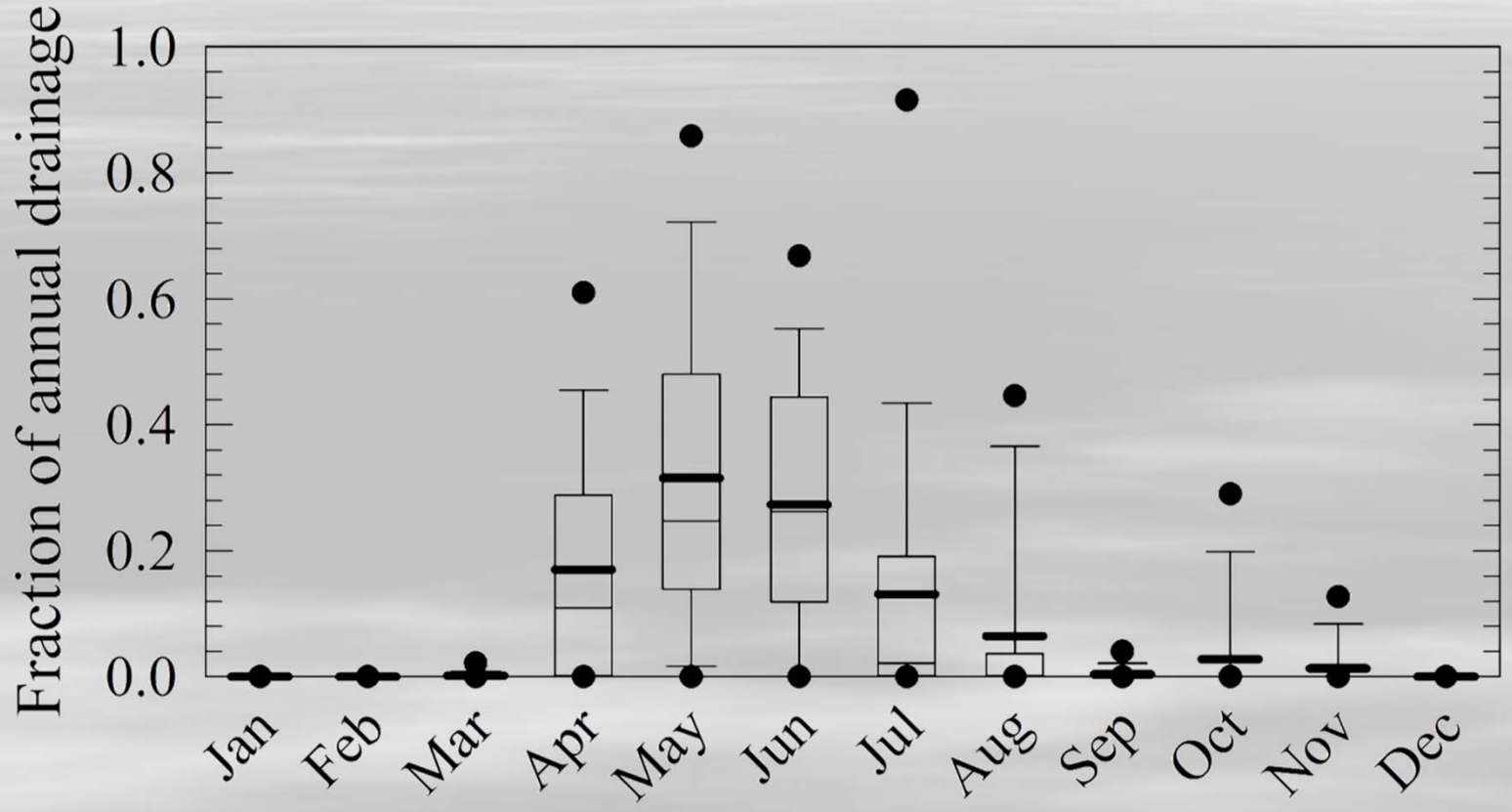




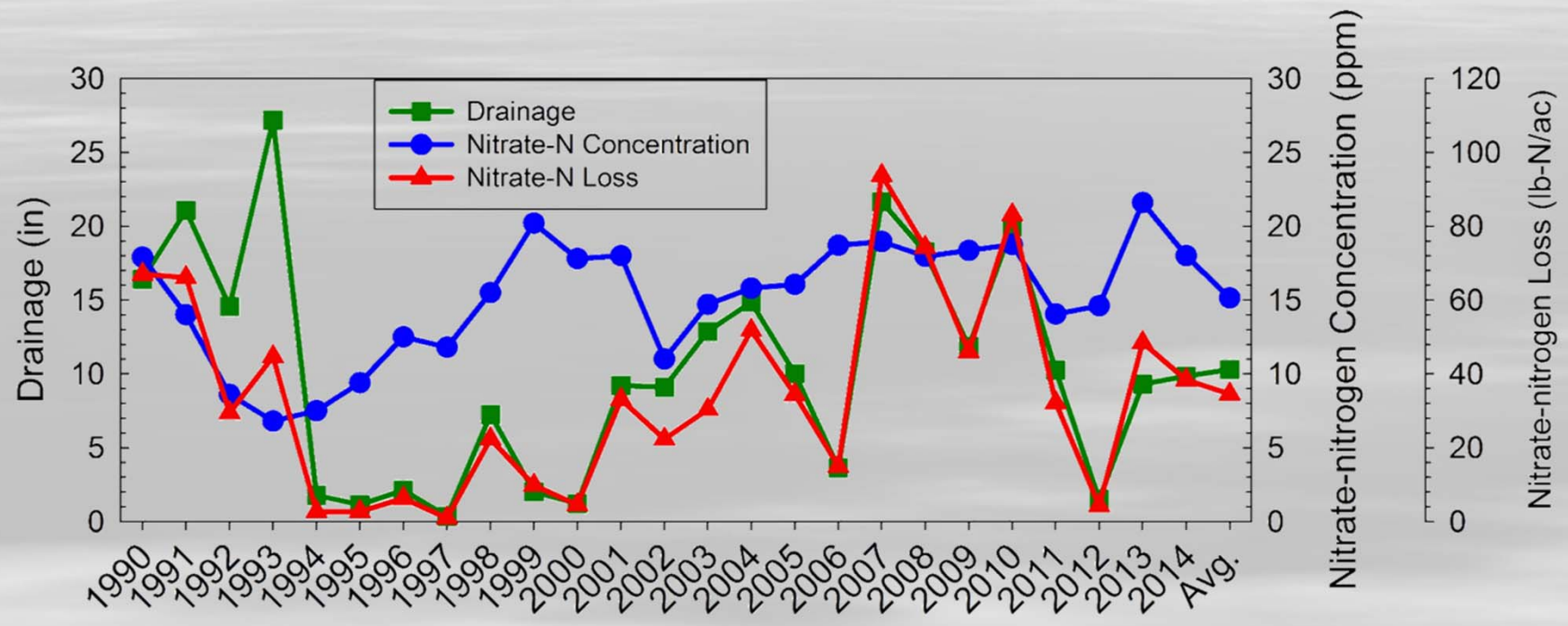
Flow monitoring system

Flow and sampling set-up at Gilmore City site

Timing of Subsurface Drainage (1990-2011)

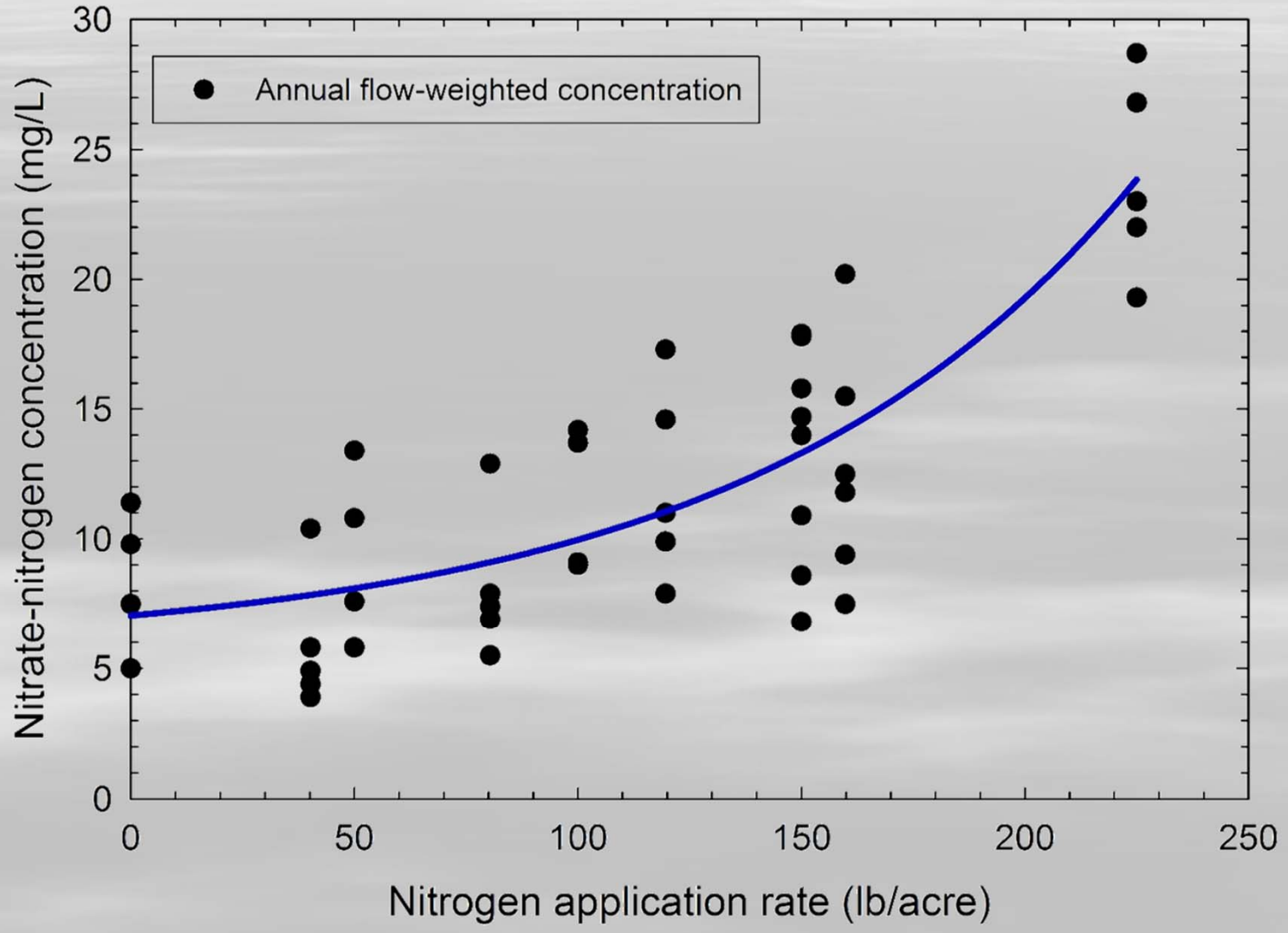


Nitrate-N Concentration Variability Even at Same N Rate

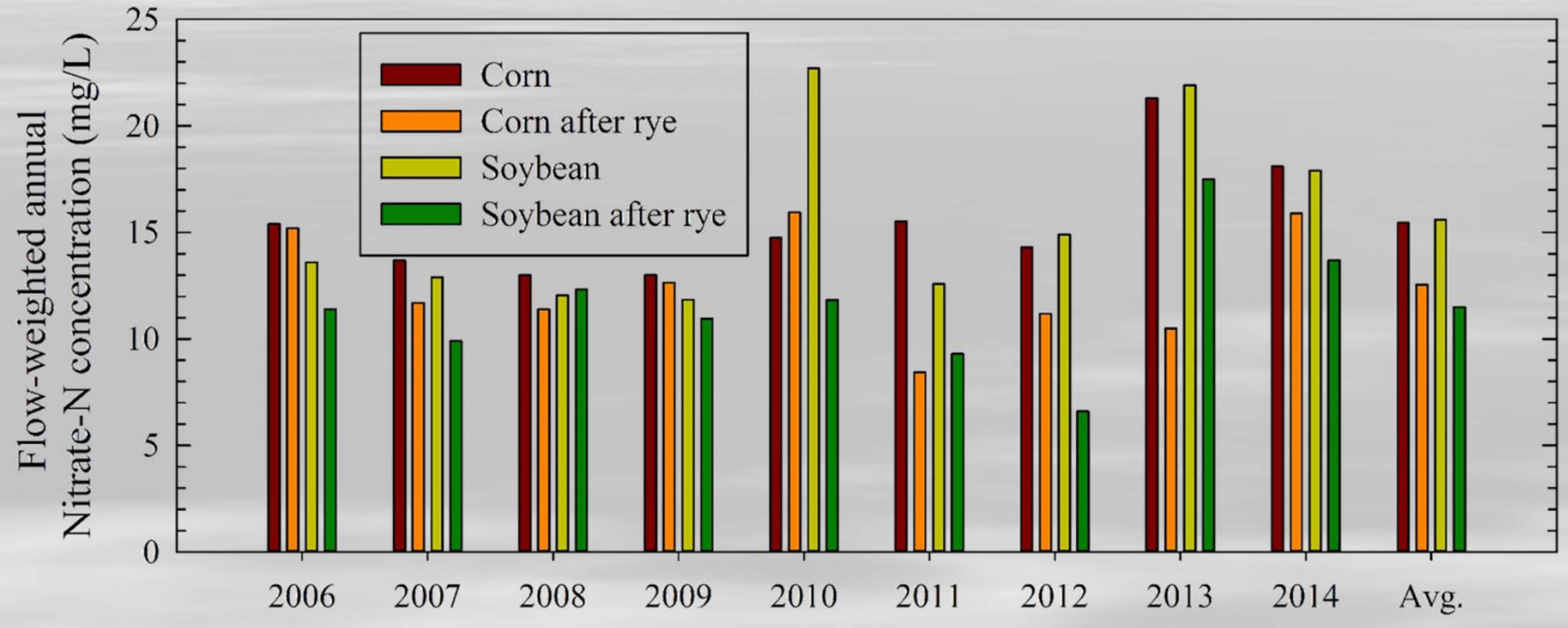


Corn-Soybean Rotation 150/160 lb-N/acre Application Rate

Nitrate-N Concentration is Influenced by N Application Rate

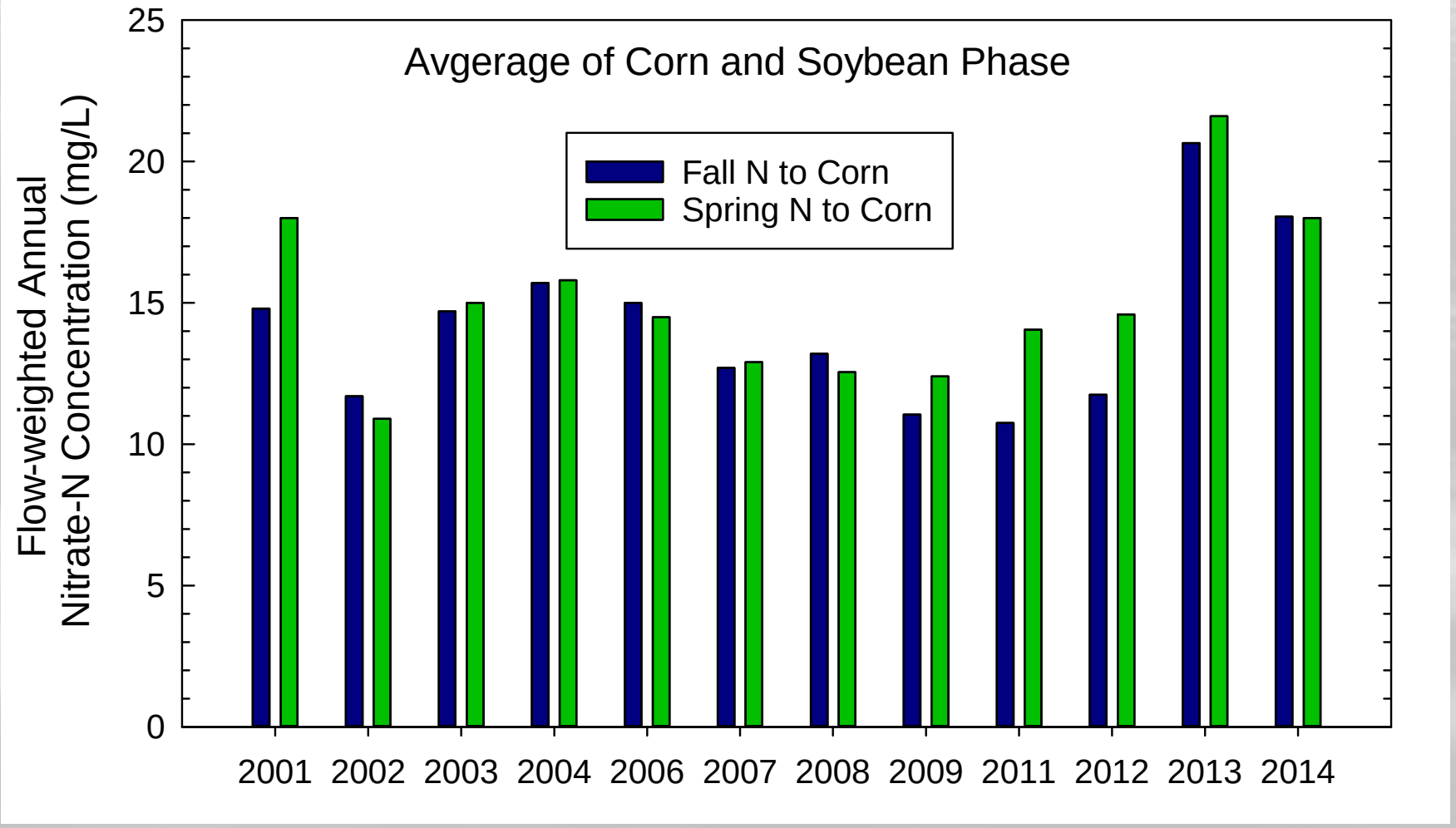


Impacts of Cover Crops on Nitrate-N Concentration in Drainage Water – Gilmore City – System with Tillage



~25% Reduction in Nitrate-N Concentration
With Annual Rye Cover Crop

Impact of Application Timing: 2001-14



Linking Agricultural Practices to Water Quality Improvement:

- Performance of in-field practices
- CREP wetland performance
- Watershed scale outcomes
  - Monitoring N & P loads to streams
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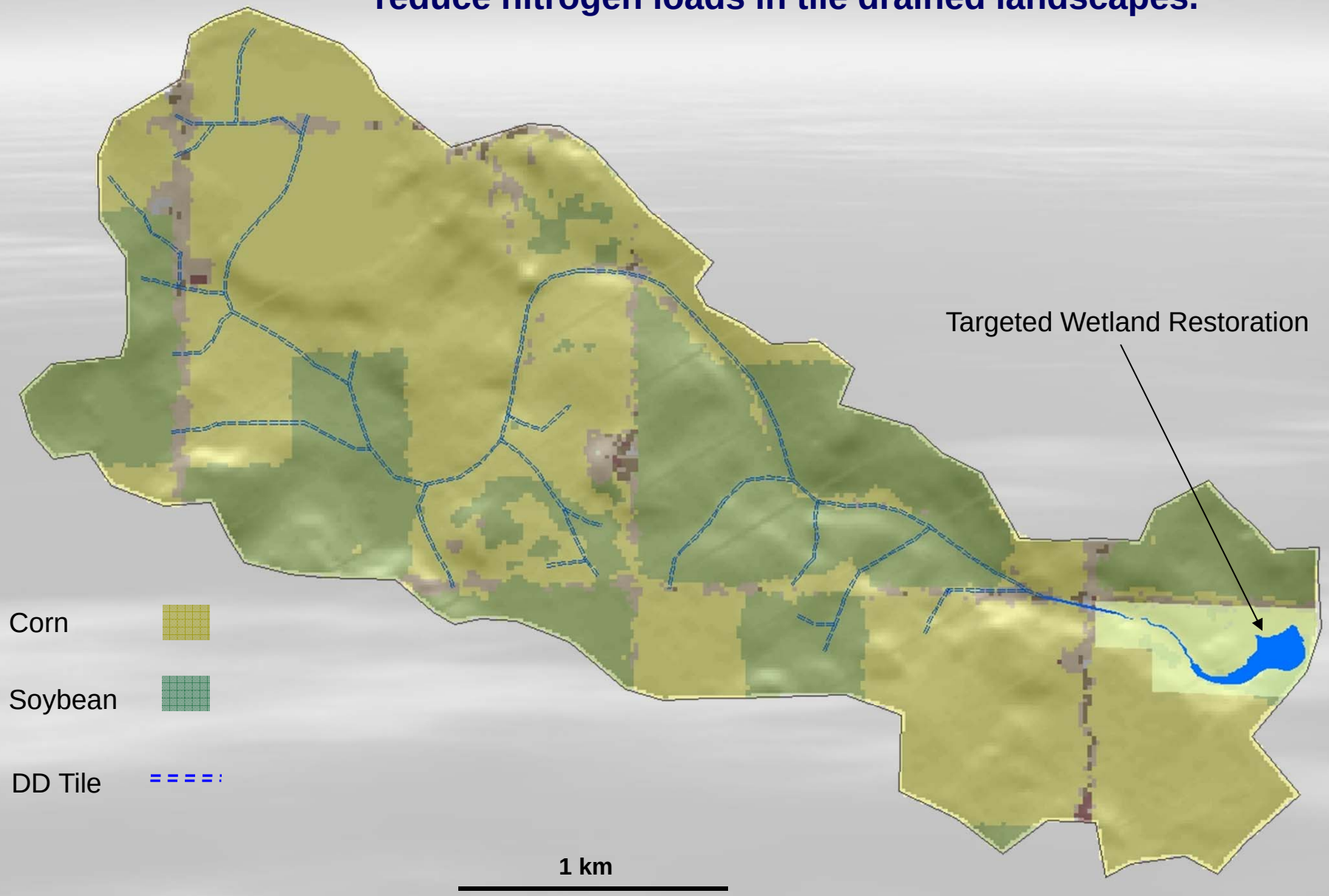
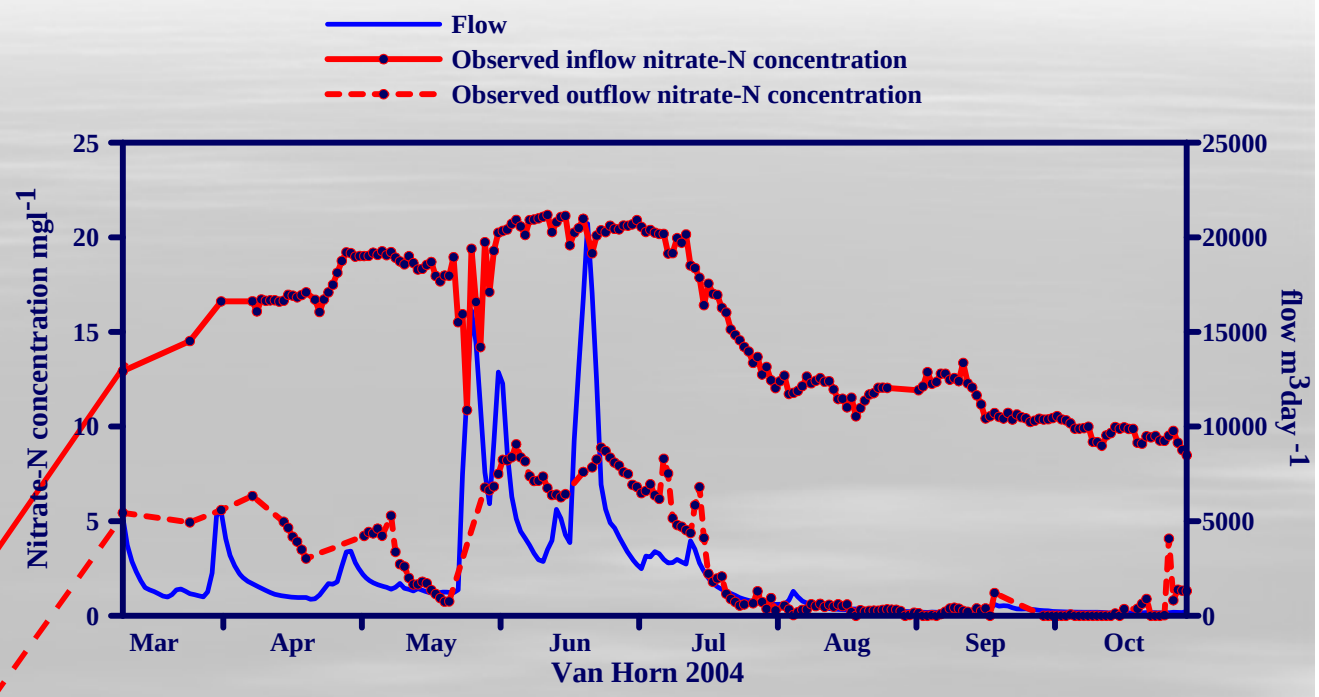
There is considerable interest in using wetlands to intercept and reduce nitrogen loads in tile drained landscapes.



Monitoring of Wetland Performance

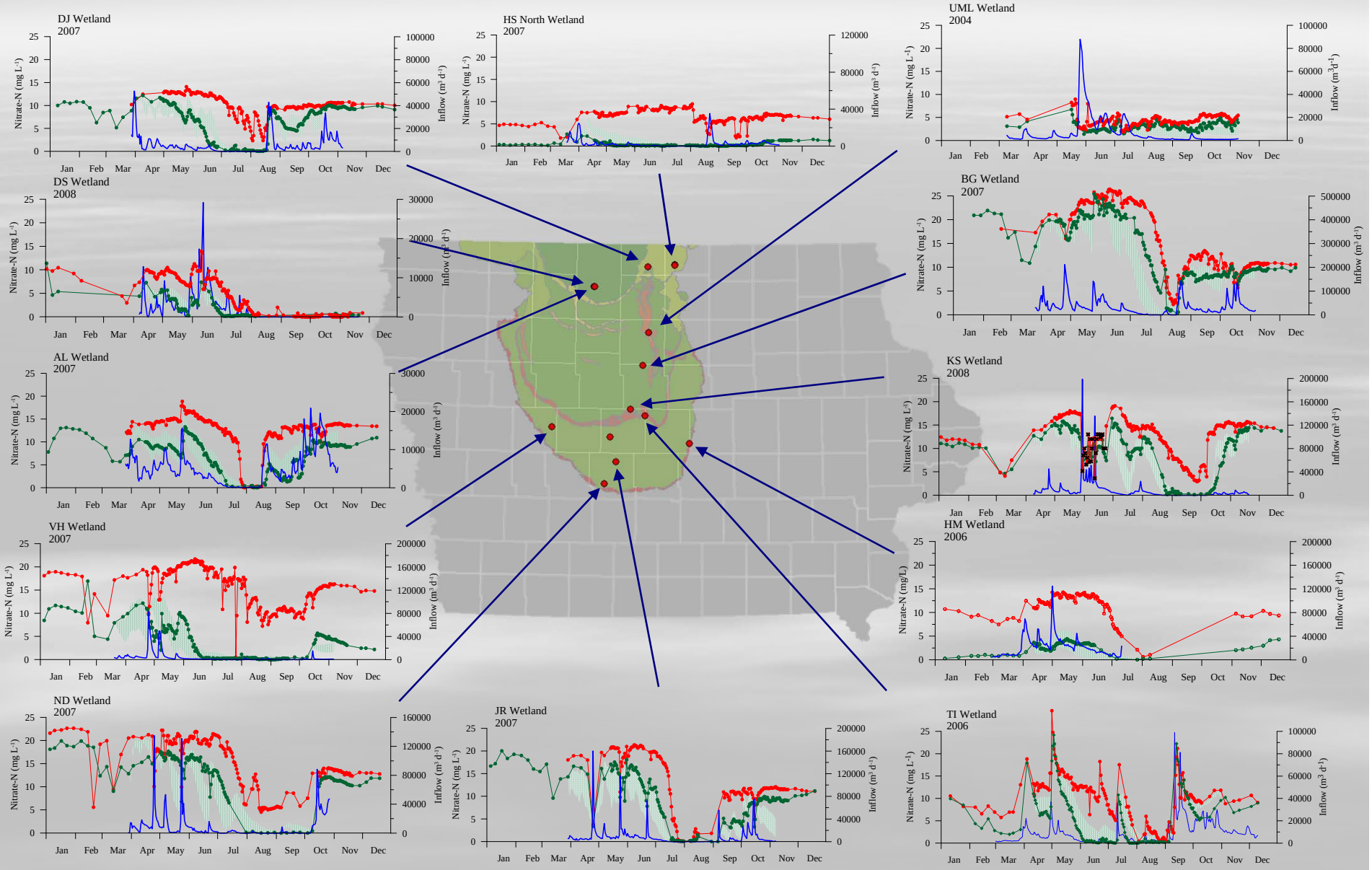
Field sites instrumented for automated sampling and flow measurement

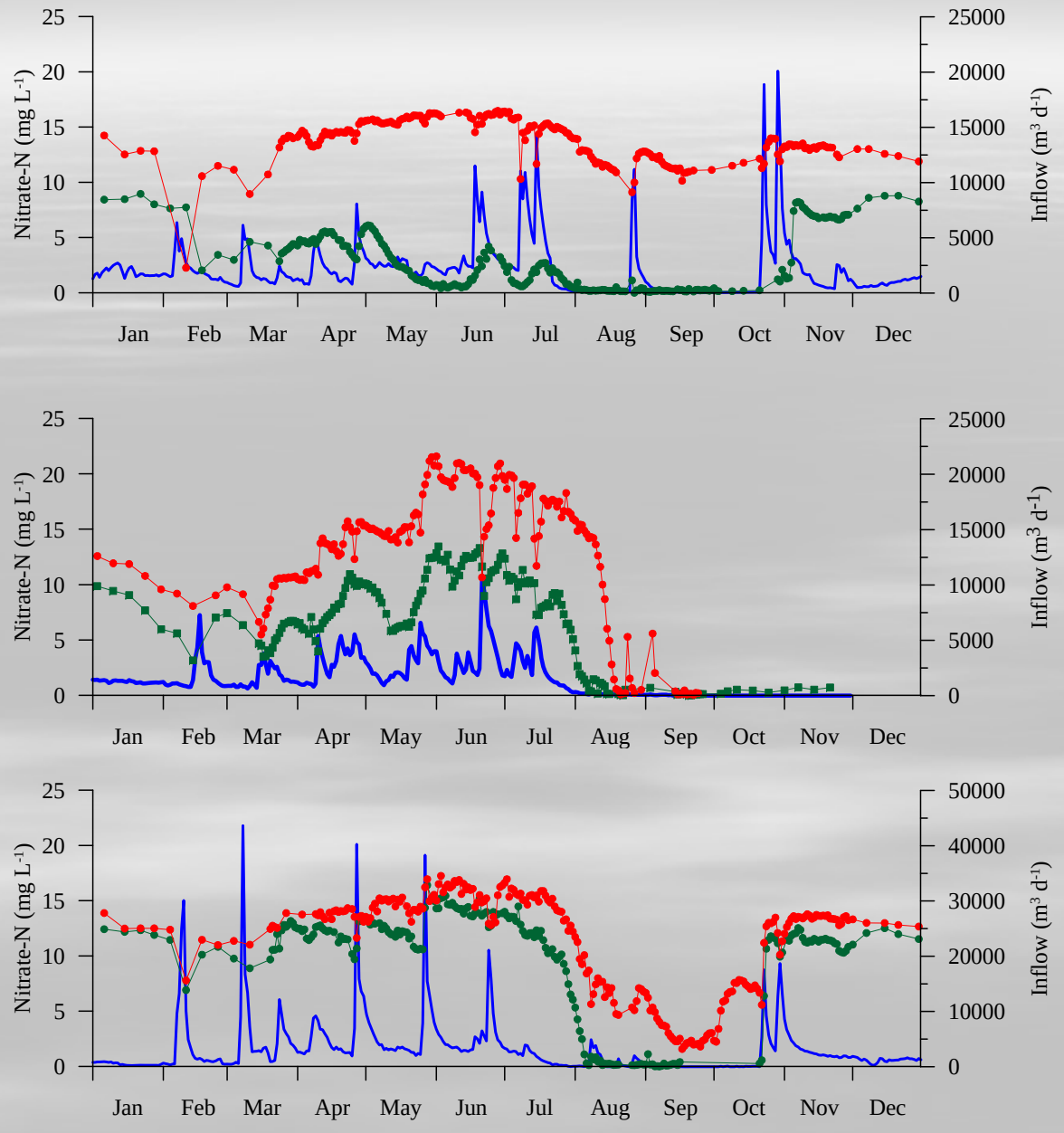
Monitoring of Wetland Performance

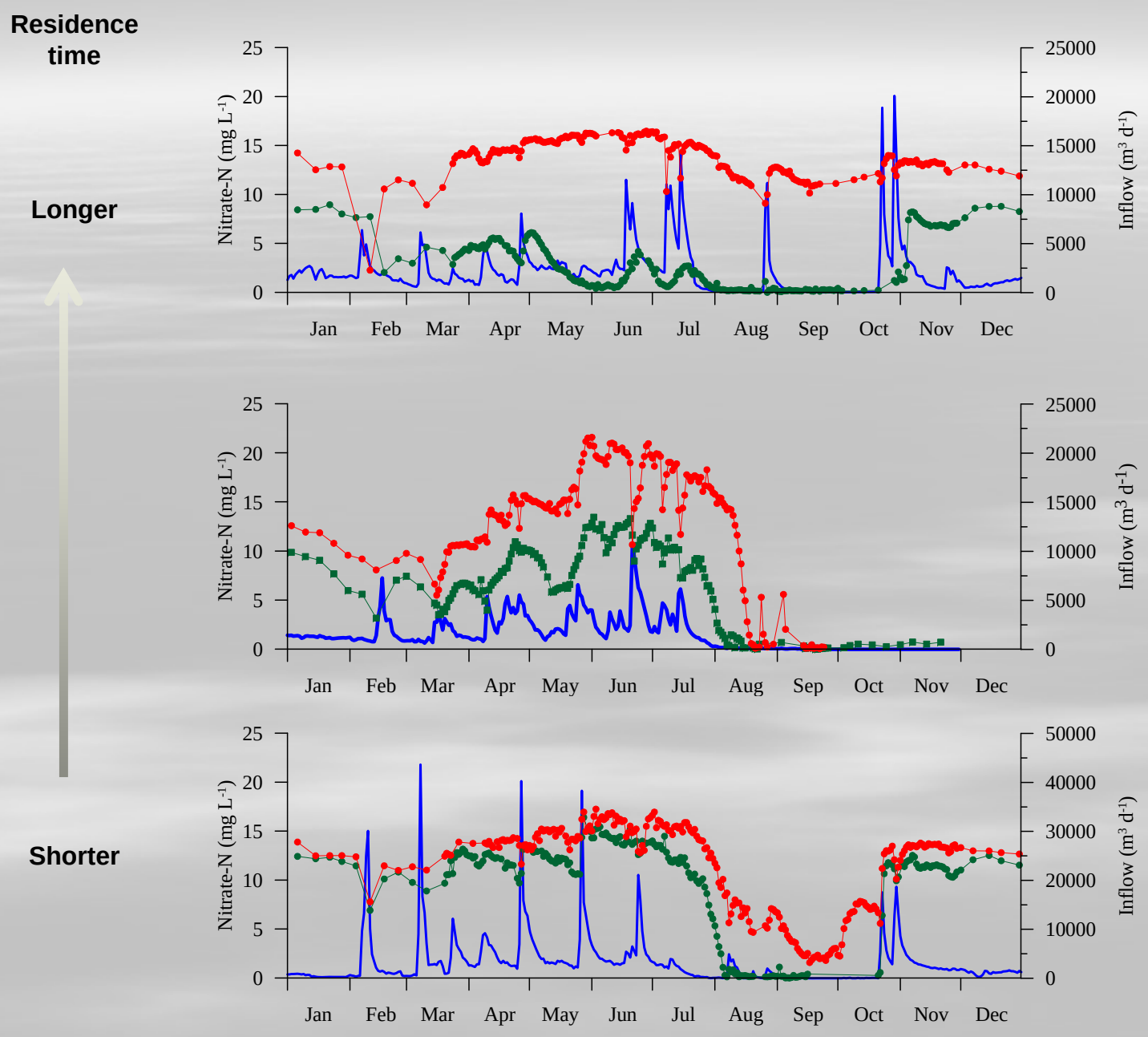


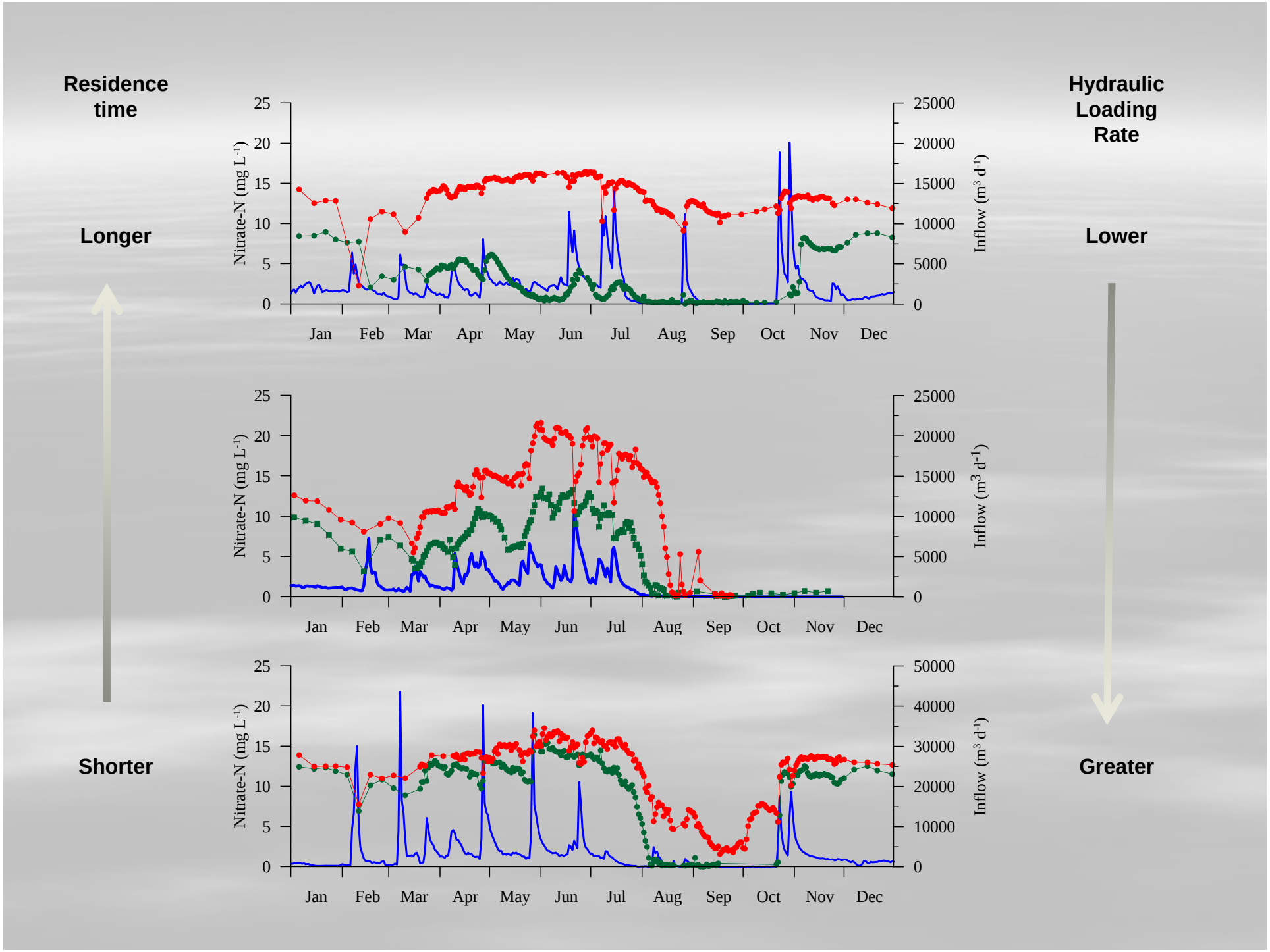
Observed Nitrate concentrations and flow rates for Van Horn Wetland in 2004

Examples from annual monitoring

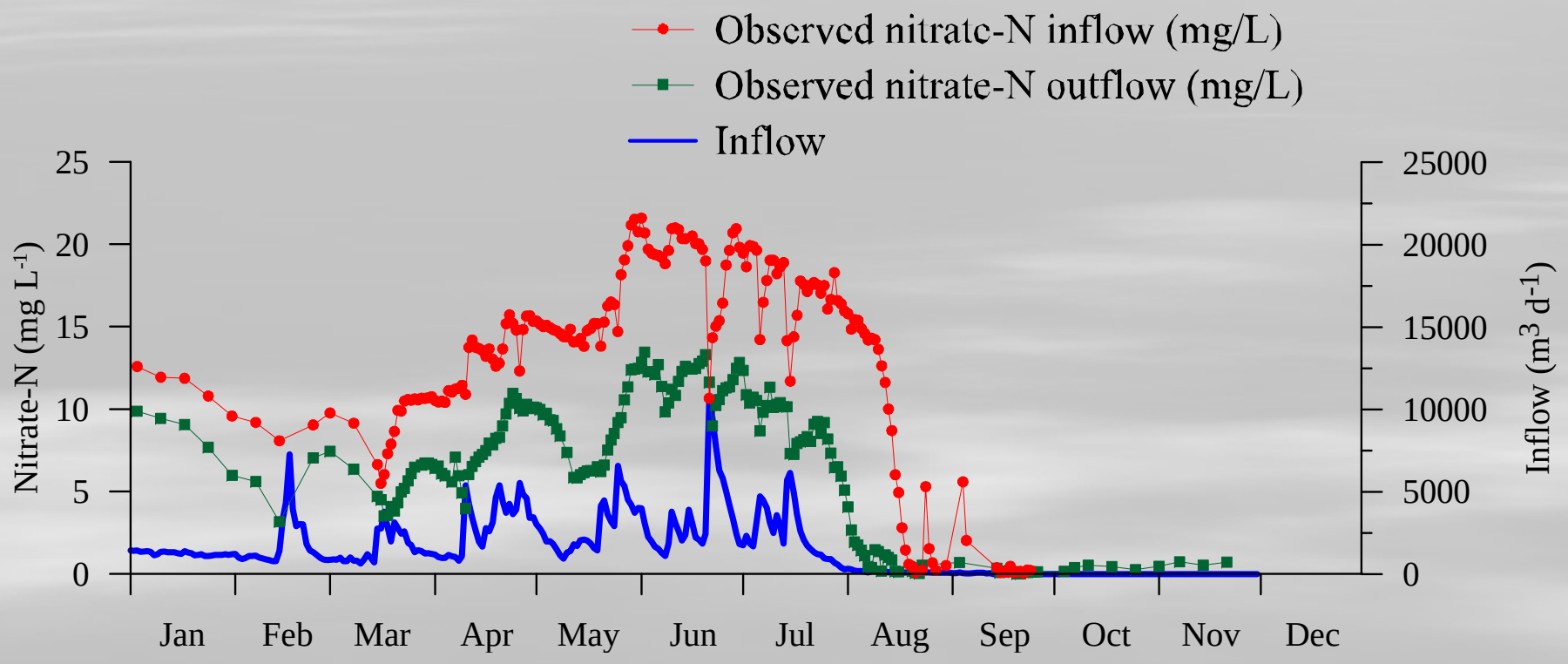



Nitrate-N (mg L-1)
Inflow (m3 d-1)
25
20
15
10
5
0
25000
20000
15000
10000
5000
0
50000
40000
30000
20000
10000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

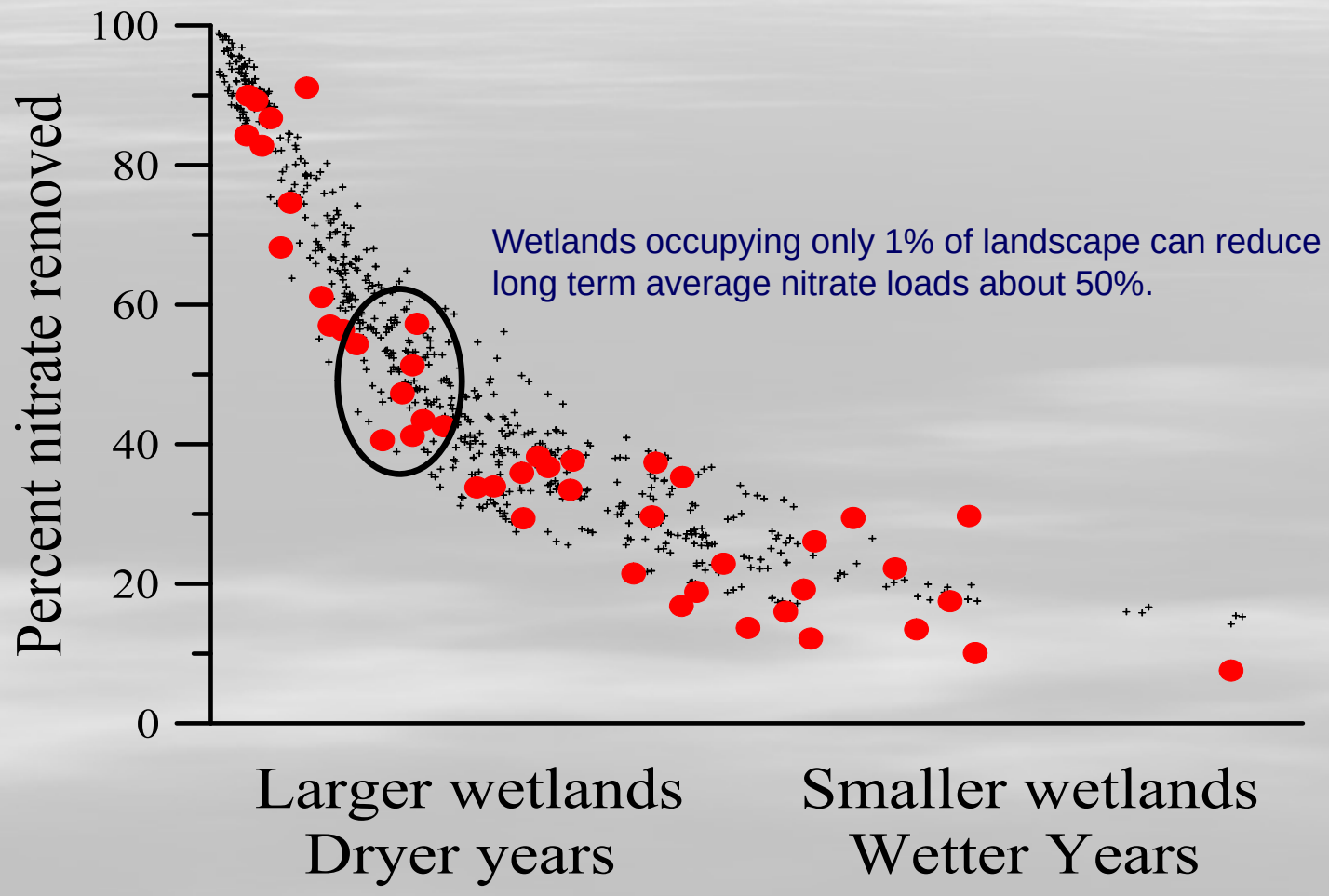

Residence time
Longer
Shorter
Nitrate-N (mg L-1)
Inflow (m3 d-1)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Residence time
Longer
Shorter
Hydraulic Loading Rate
Lower
Greater
Nitrate-N (mg L-1)
Inflow (m3 d-1)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Wetlands targeted to intercept nitrate loads at the point of delivery to streams can be extremely effective in reducing nitrate loads.



Hydrologic and nutrient loading rates are major drivers of wetland performance.



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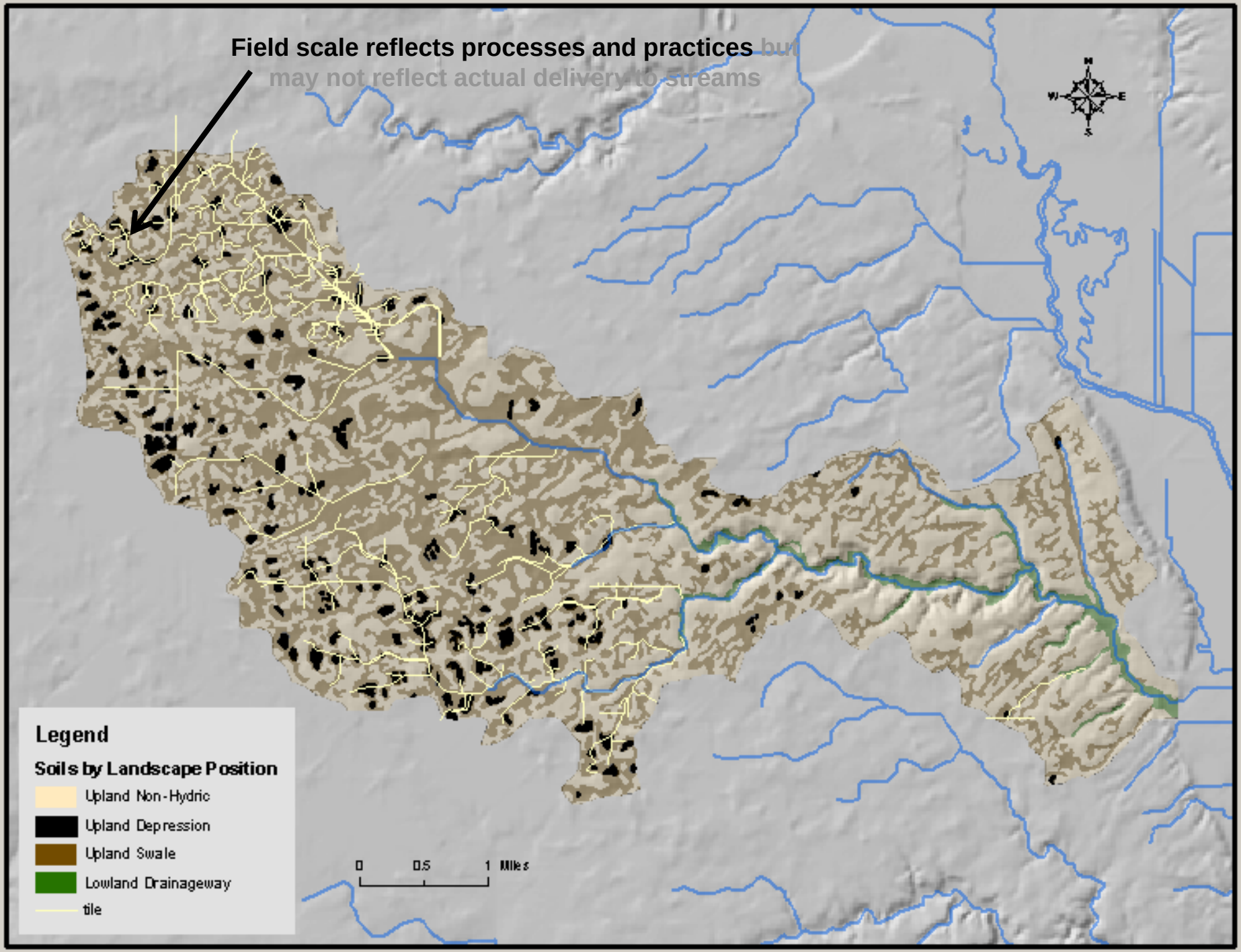
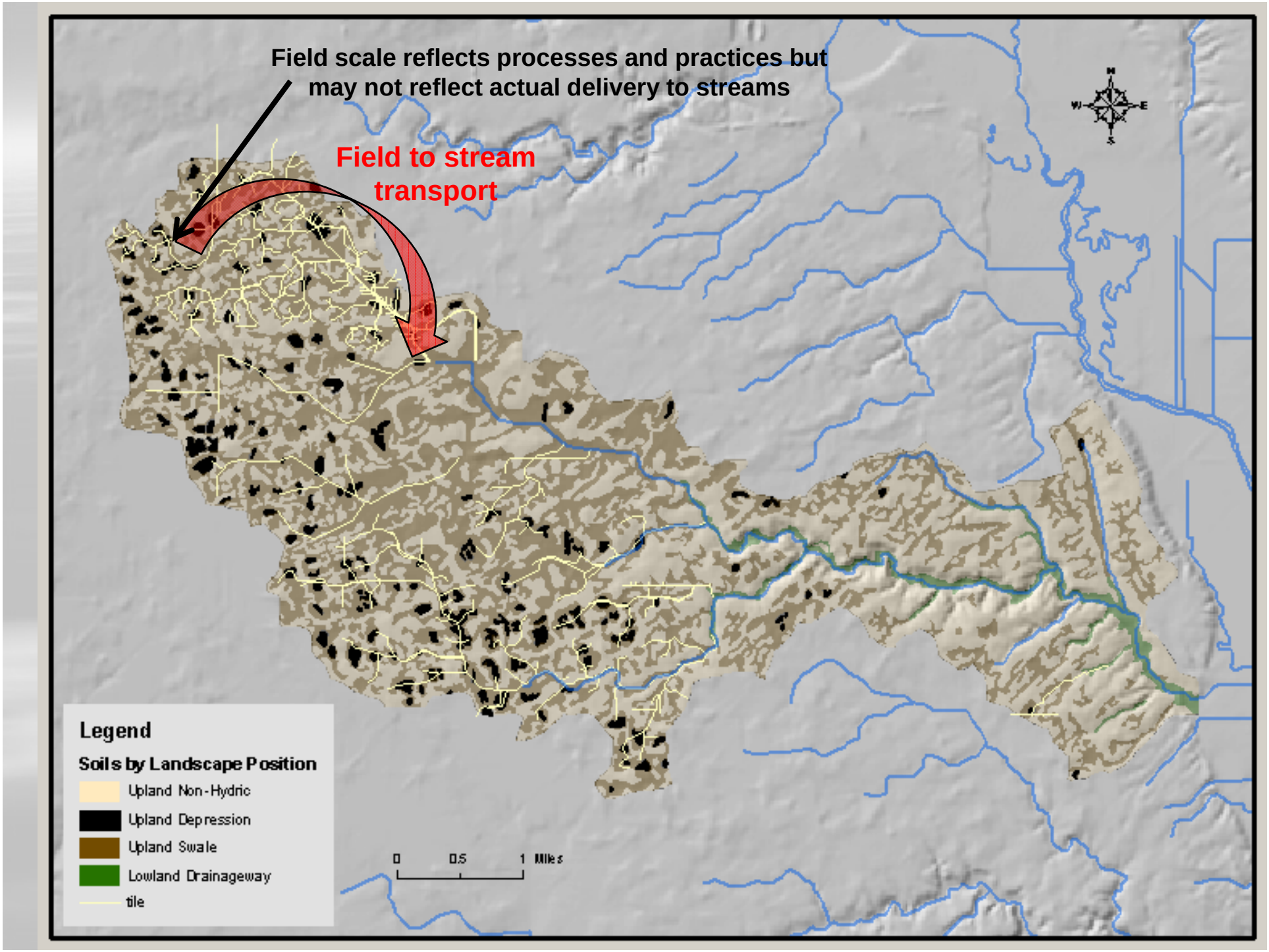

Field scale reflects processes and practices but
may not reflect actual delivery to streams
Legend
Soils by Landscape Position
Upland Non-Hydric
Upland Depression
Upland Swale
Lowland Drainageway
tile
0
0.5
1 Miles


Field scale reflects processes and practices but may not reflect actual delivery to streams
Field to stream transport
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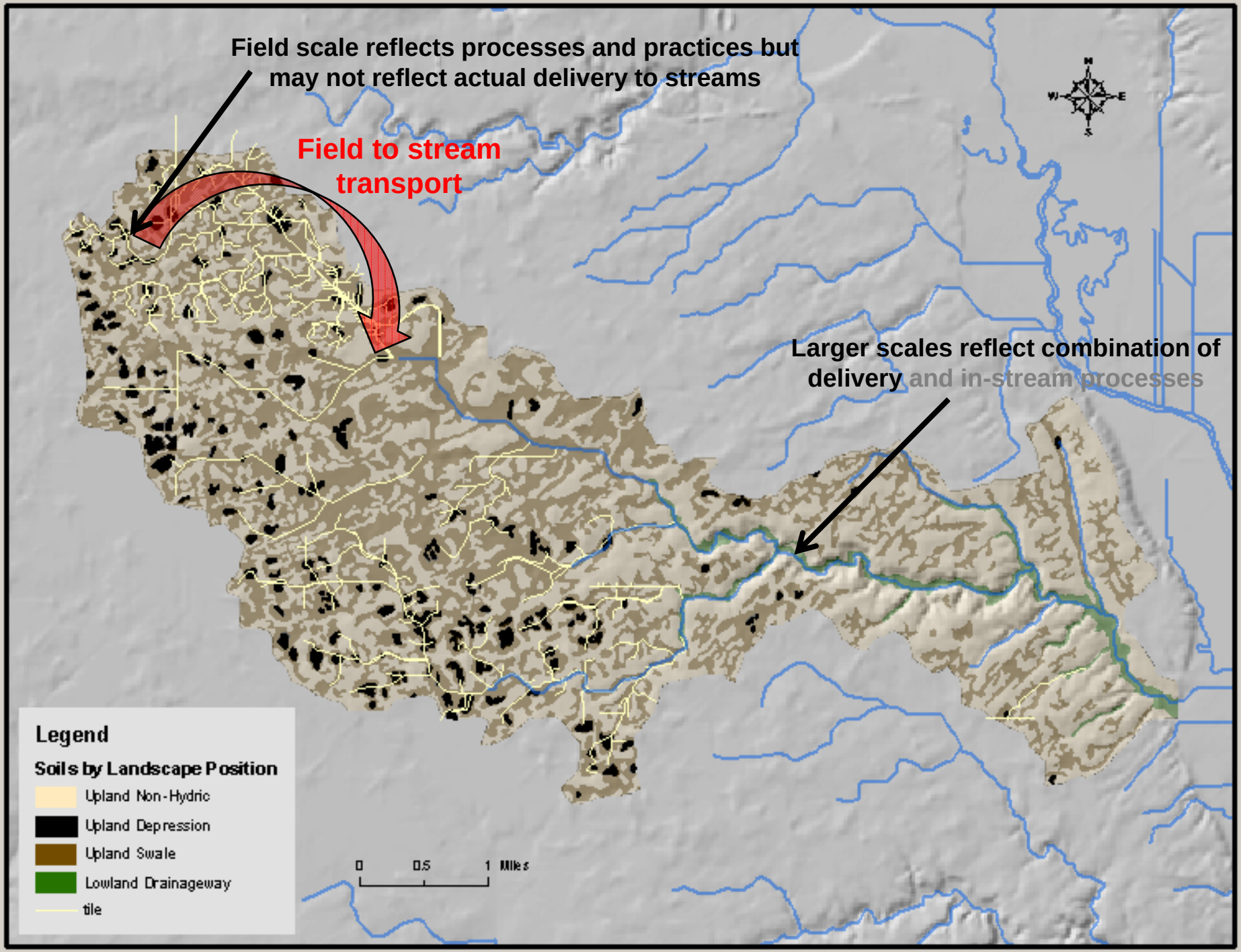
Field scale reflects processes and practices but may not reflect actual delivery to streams
Field to stream transport
Larger scales reflect combination of delivery and in-stream processes
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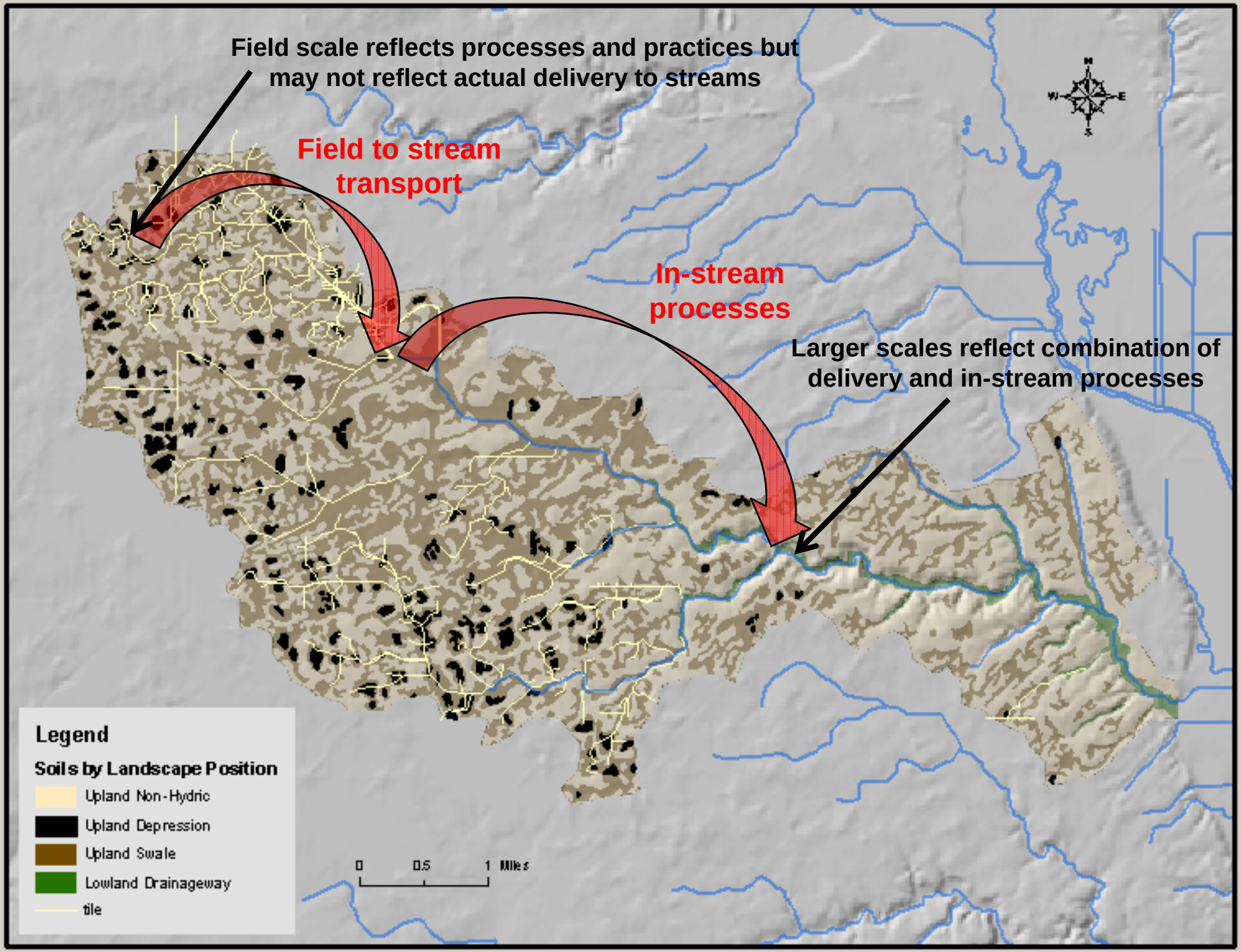
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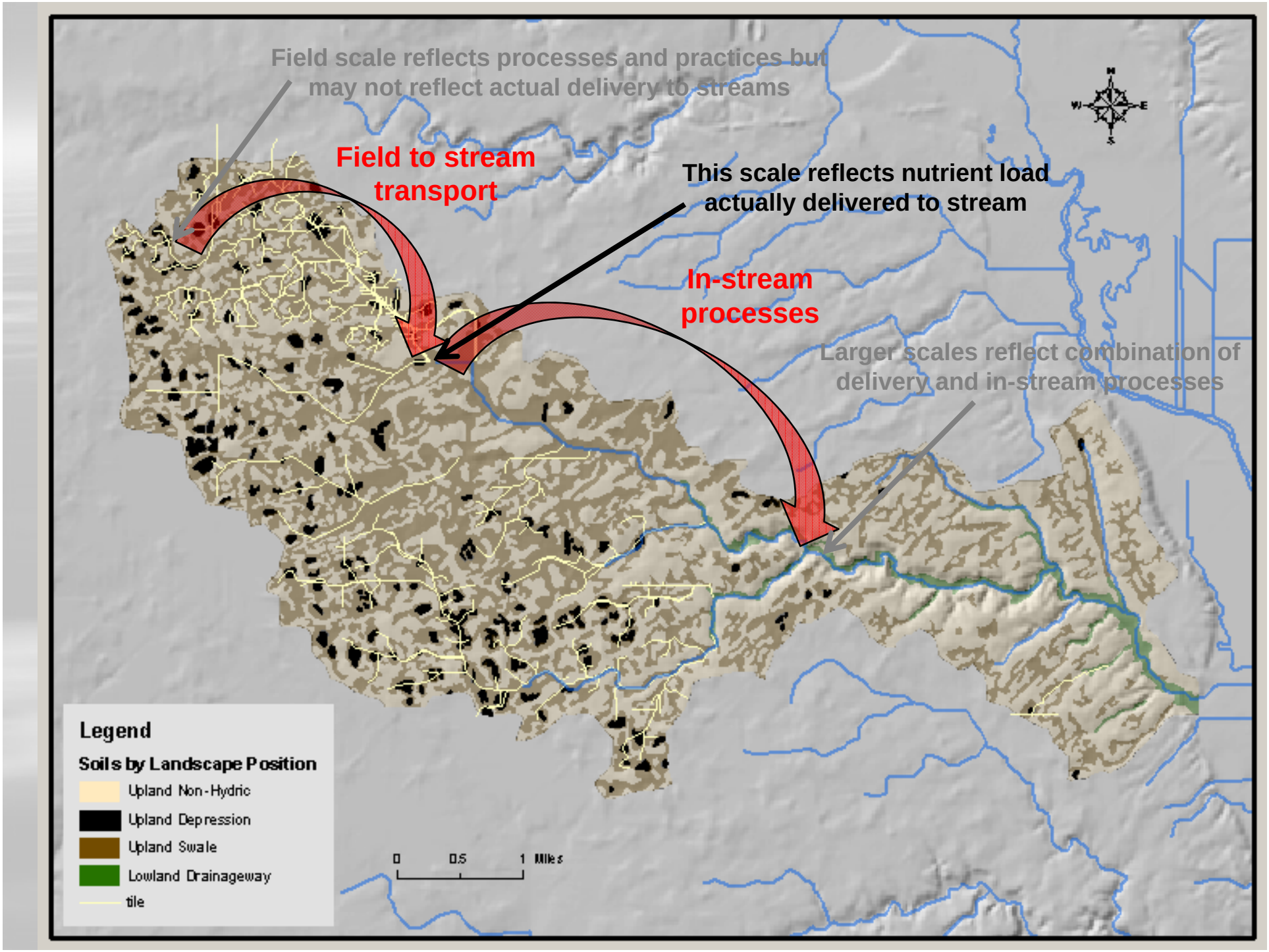
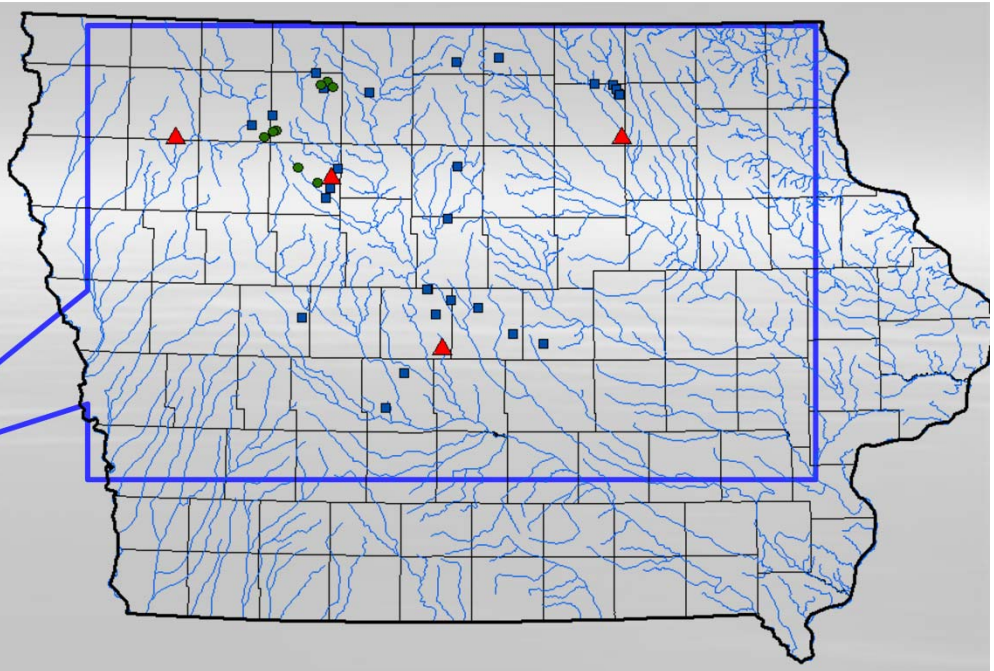
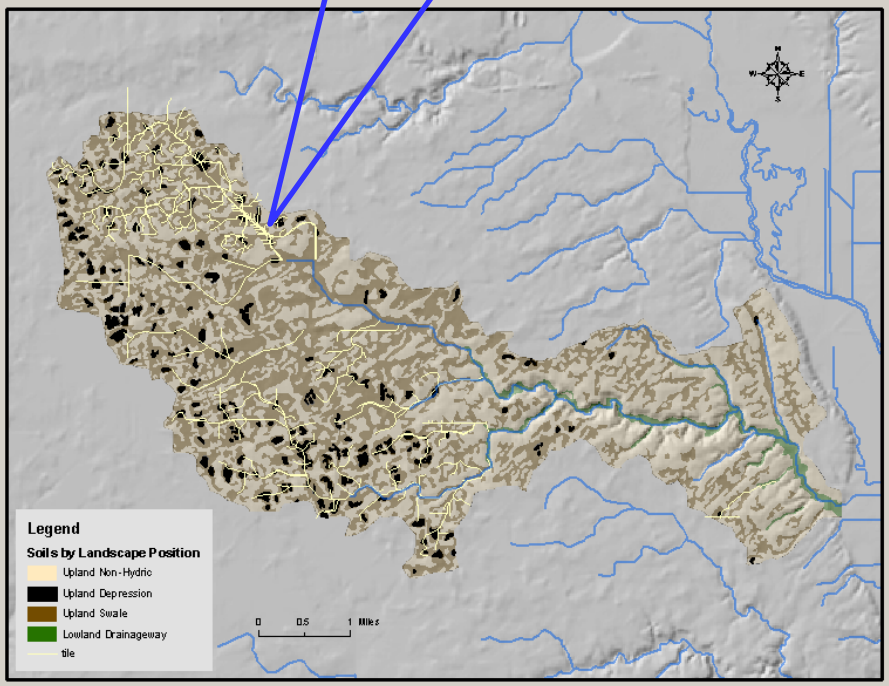

Field scale reflects processes and practices but may not reflect actual delivery to streams
Field to stream transport
This scale reflects nutrient load actually delivered to stream
In-stream processes
Larger scales reflect combination of delivery and in-stream processes
Legend
Soils by Landscape Position
Upland Non-Hydric
Upland Depression
Upland Swale
Lowland Drainageway
tile
0
0.5
1 Miles





Monitoring sites instrumented for close interval sampling and flow measurement

Watershed Scale Findings

- **Phosphorus**
  - Tile drainage delivers much higher P loads to streams than previously thought based on plot scale research and surface runoff contributes only about half of the total P load in tile drained landscapes. This is important since practices that target surface runoff will have less effect on P loads than expected.
- **Nitrogen**
  - Regardless of the extent or capacity of tile drainage, row cropped lands export significant nitrate loads to streams.
  - Wetlands sited to intercept NPS nutrient loads could contribute significantly to meeting statewide N reduction goals.

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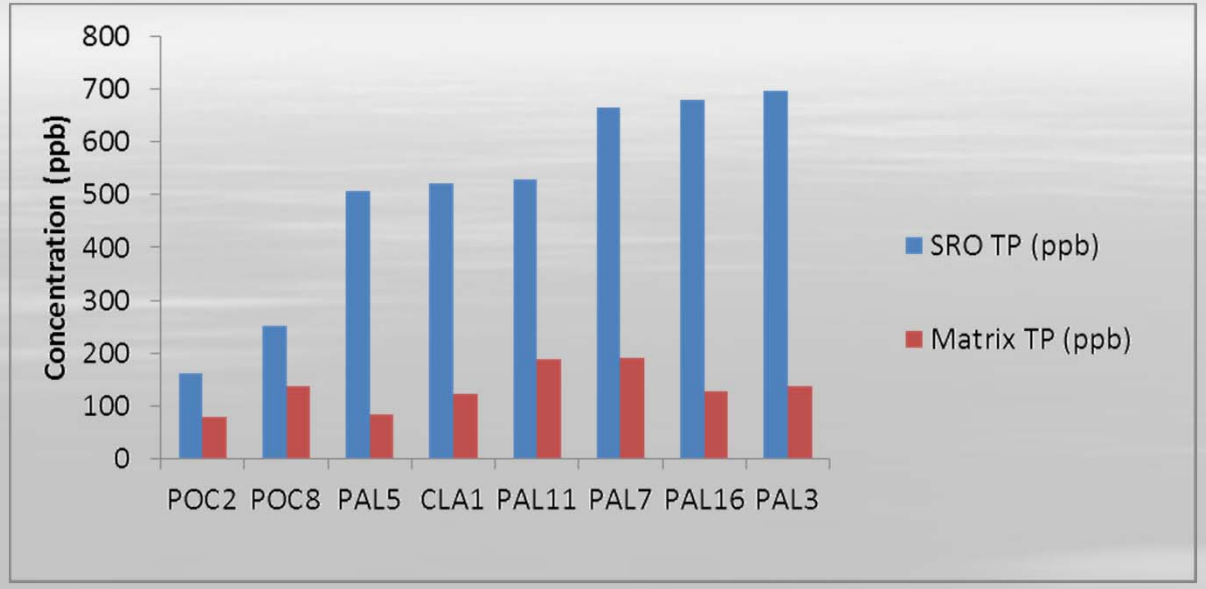
TP concentration and yields in surface runoff and “matrix” flow



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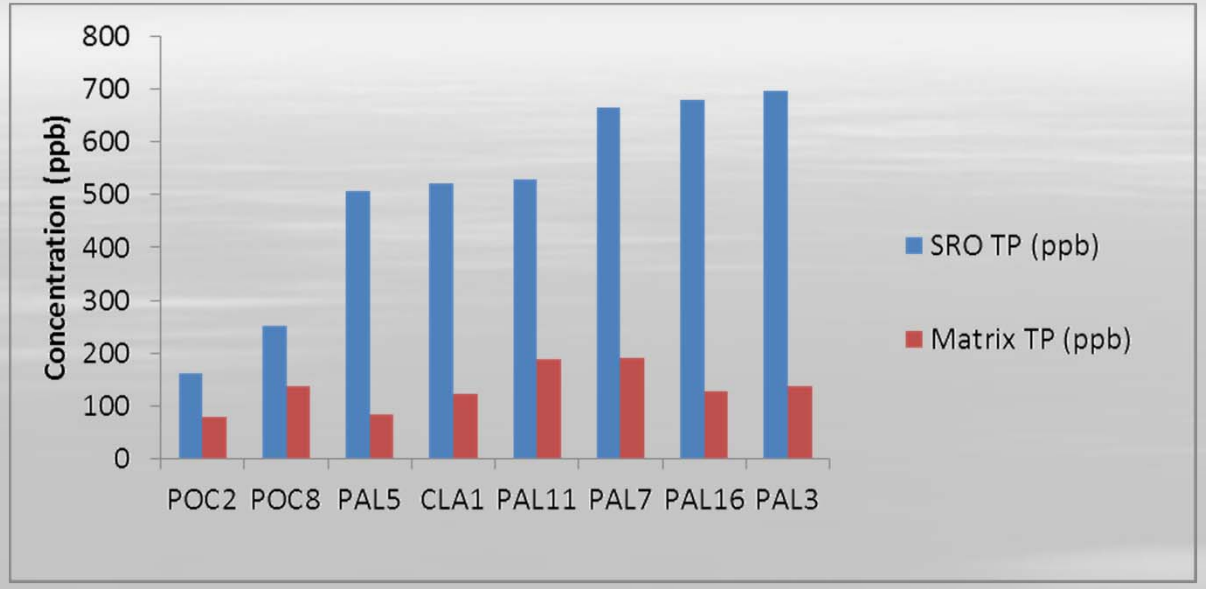
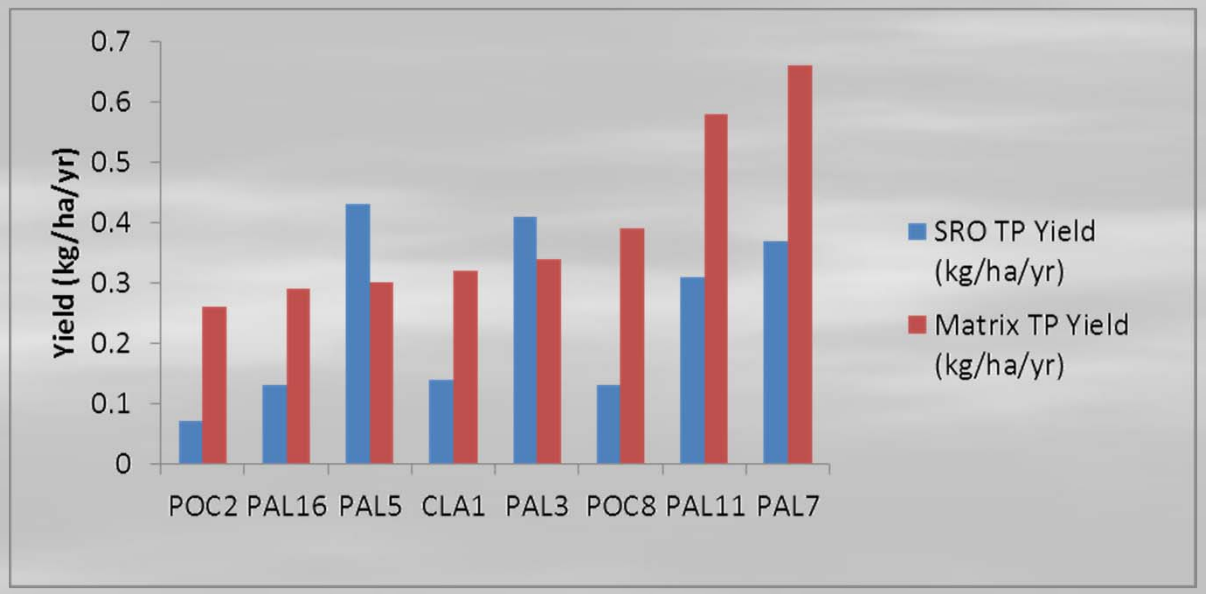
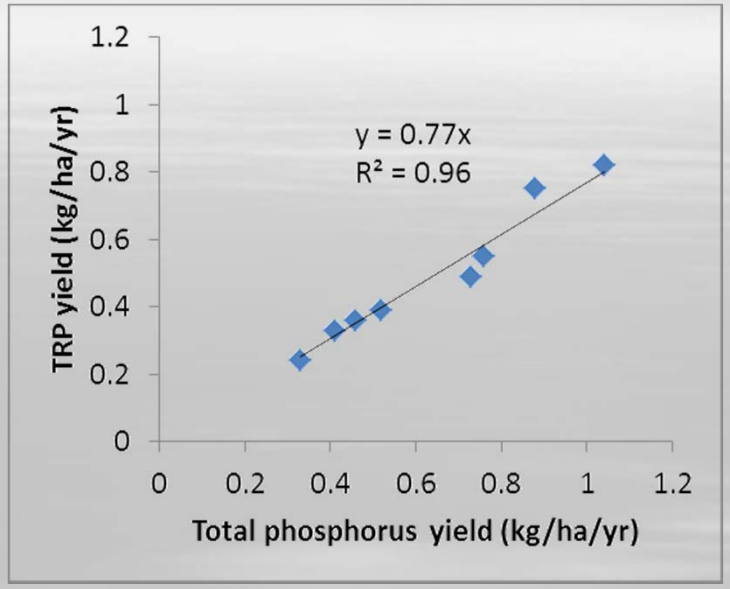
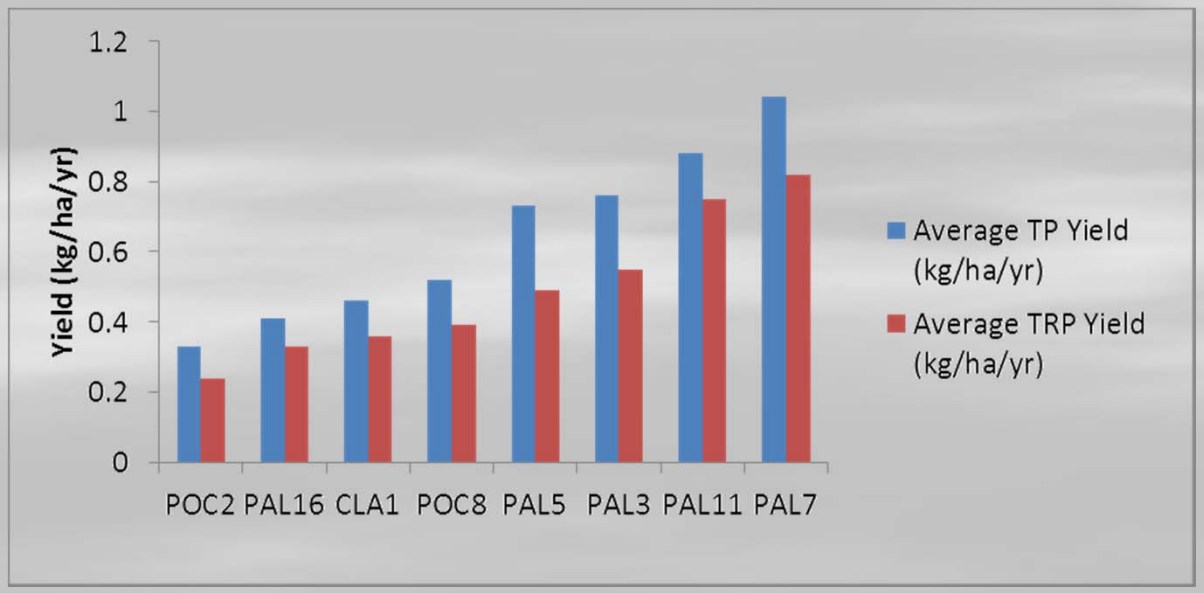




Average yields: Total phosphorus and total reactive phosphorus

	Average TP Yield (kg/ha/yr)	Average TRP Yield (kg/ha/yr)	TRP percent of TP
CLA1	0.46	0.36	78
PAL3	0.76	0.55	72
PAL5	0.73	0.49	67
PAL7	1.04	0.82	79
PAL11	0.88	0.75	85
PAL16	0.41	0.33	80
POC2	0.33	0.24	73
POC8	0.52	0.39	75





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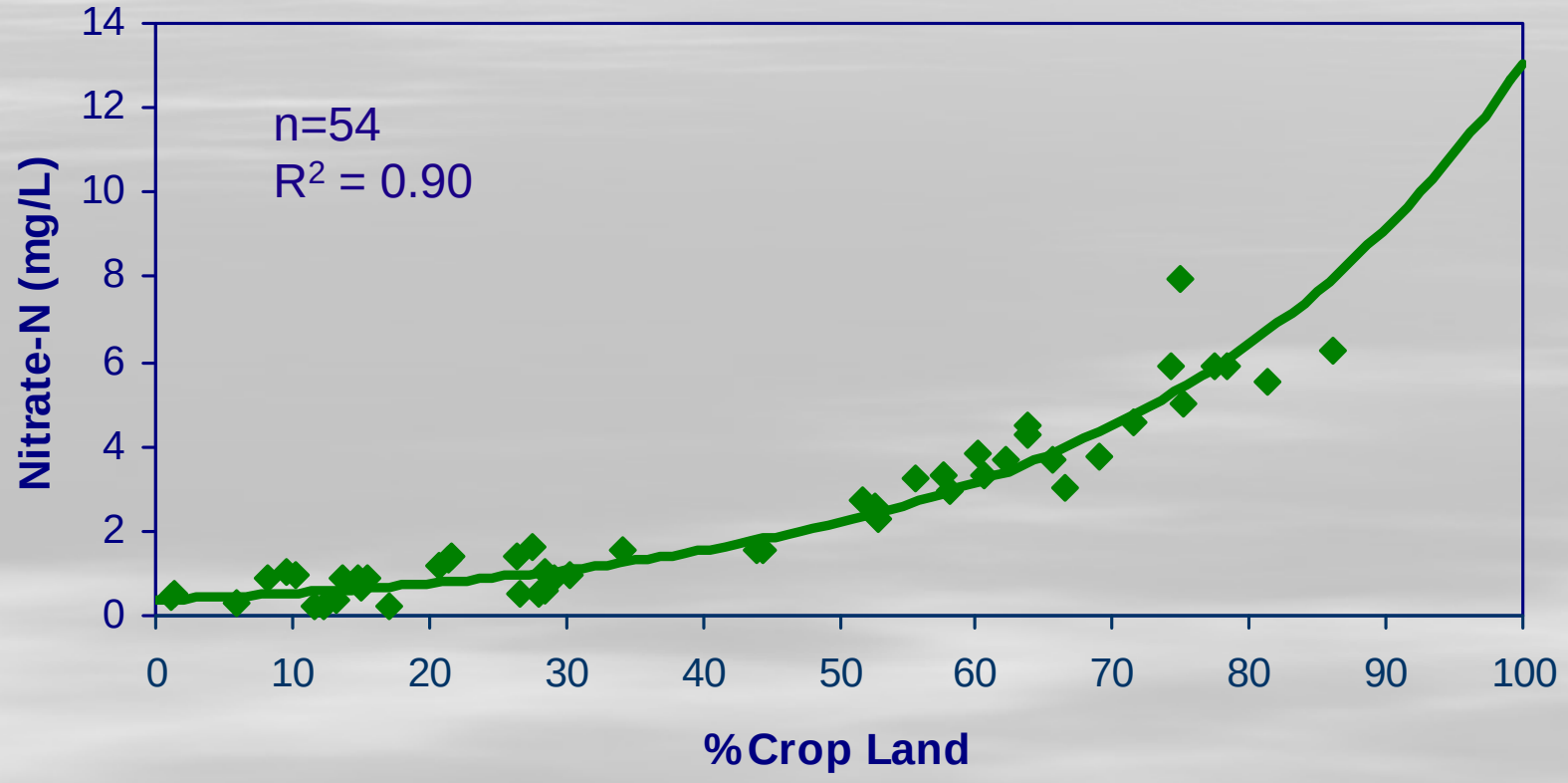
Nitrate concentration versus cropland.

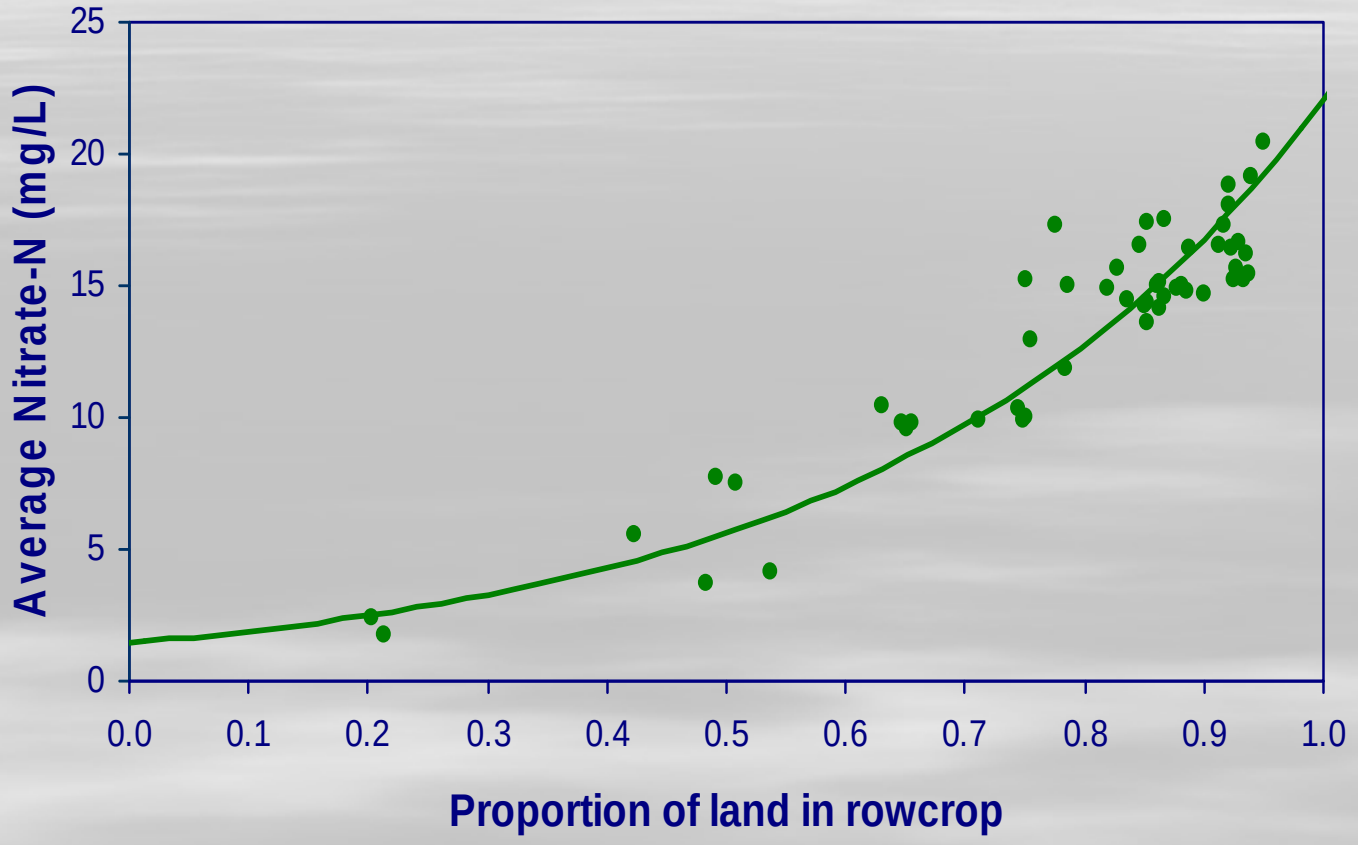
Mississippi River Basin NASQAN sites



◆ 1980 to 1993 Average — Expon. (1980 to 1993 Average)

Nitrate concentration versus cropland.

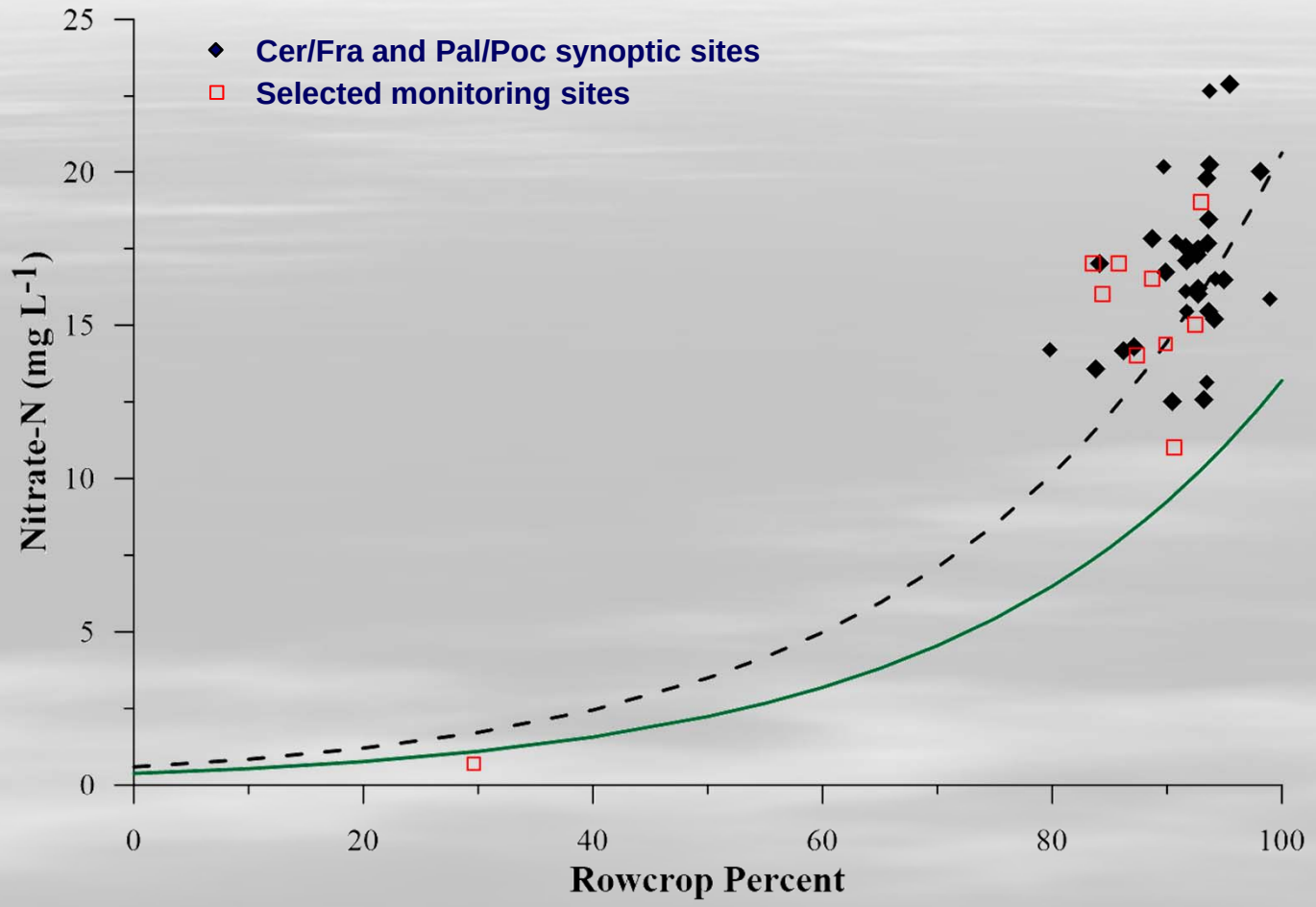
Raccoon River Watershed



(Estimated based on AMJ concentrations for sites in Raccoon River Watershed 2001, 2002, 2003)

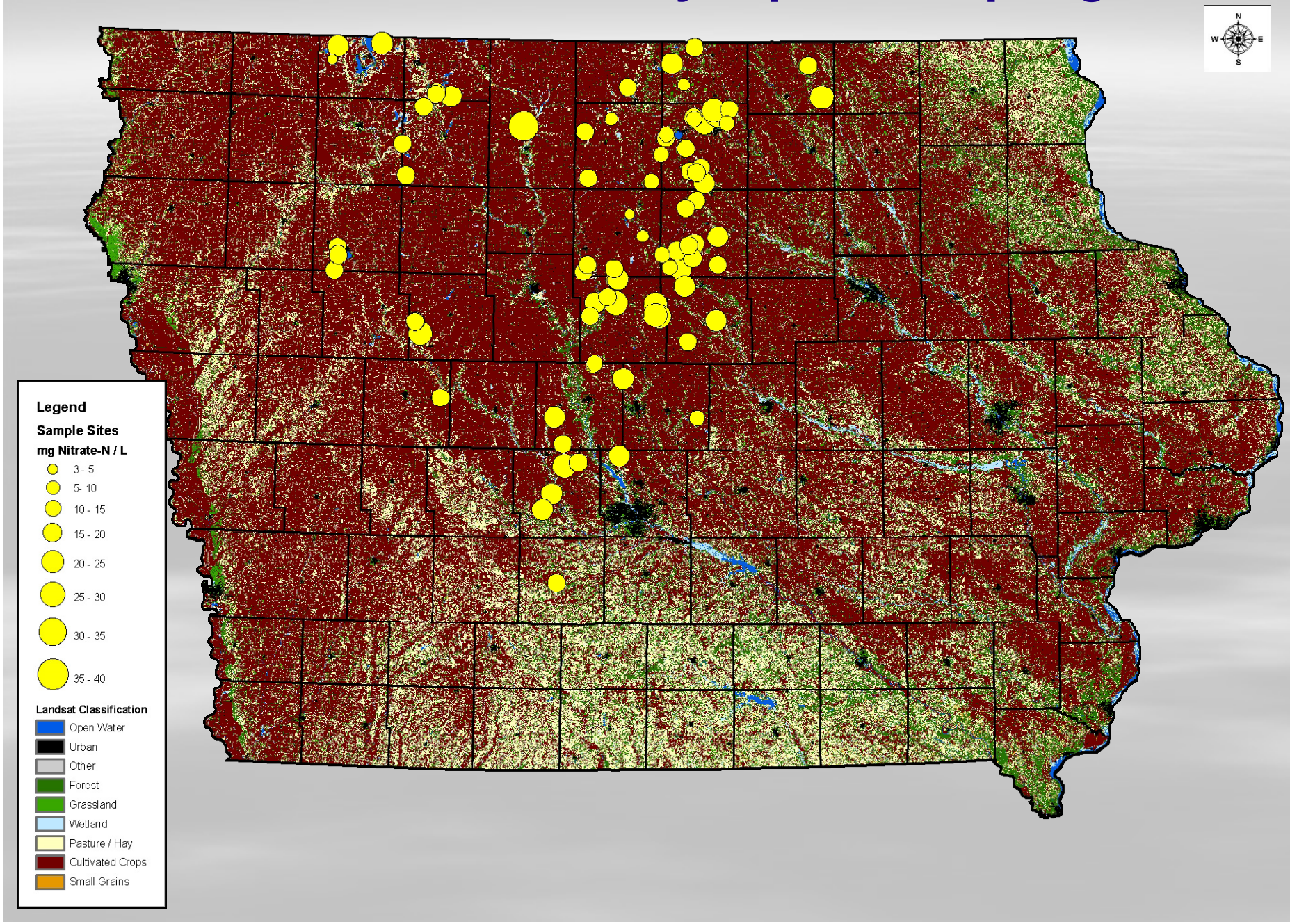
Nitrate concentration versus cropland.

At point of delivery to stream for selected Iowa sites



-2007 estimated FWA based on AMJ average for Cer/Fra County synoptic sites
-2007 measured FWA at selected watershed scale intensive monitoring sites

Small Watershed Synoptic Sampling



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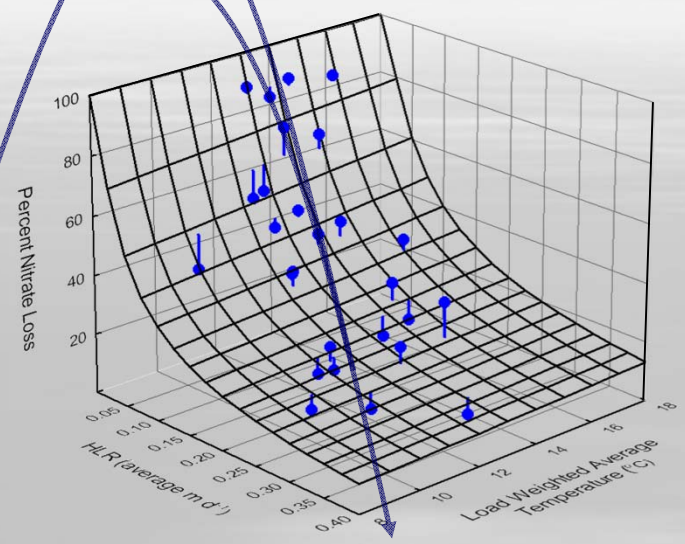
  - **Wetlands sited to intercept NPS nutrient loads could contribute significantly to meeting statewide N reduction goals.**

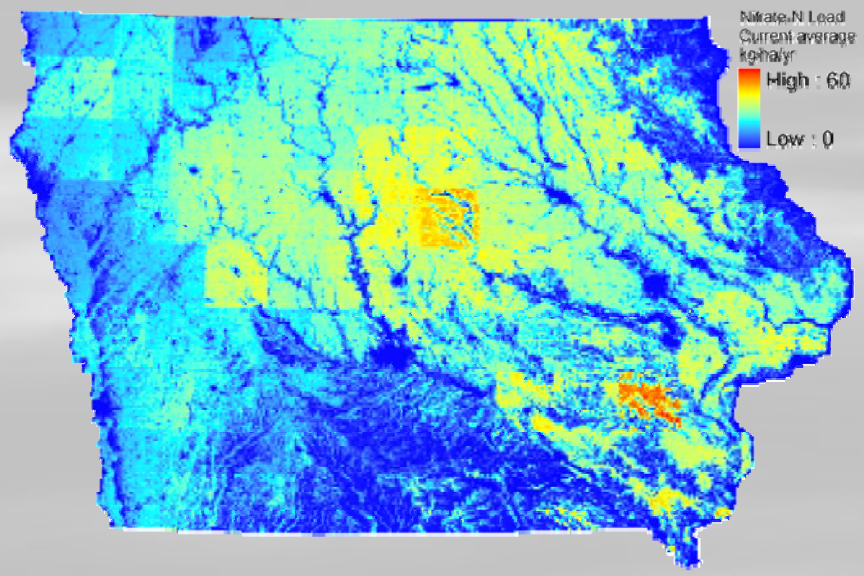
Estimating Potential Nitrate Loss in Wetlands

Water yield grid

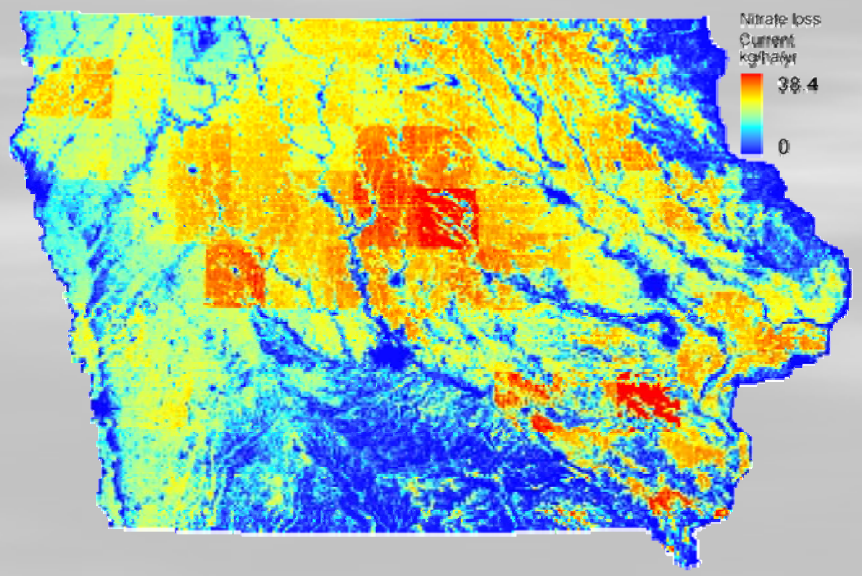
and loss function



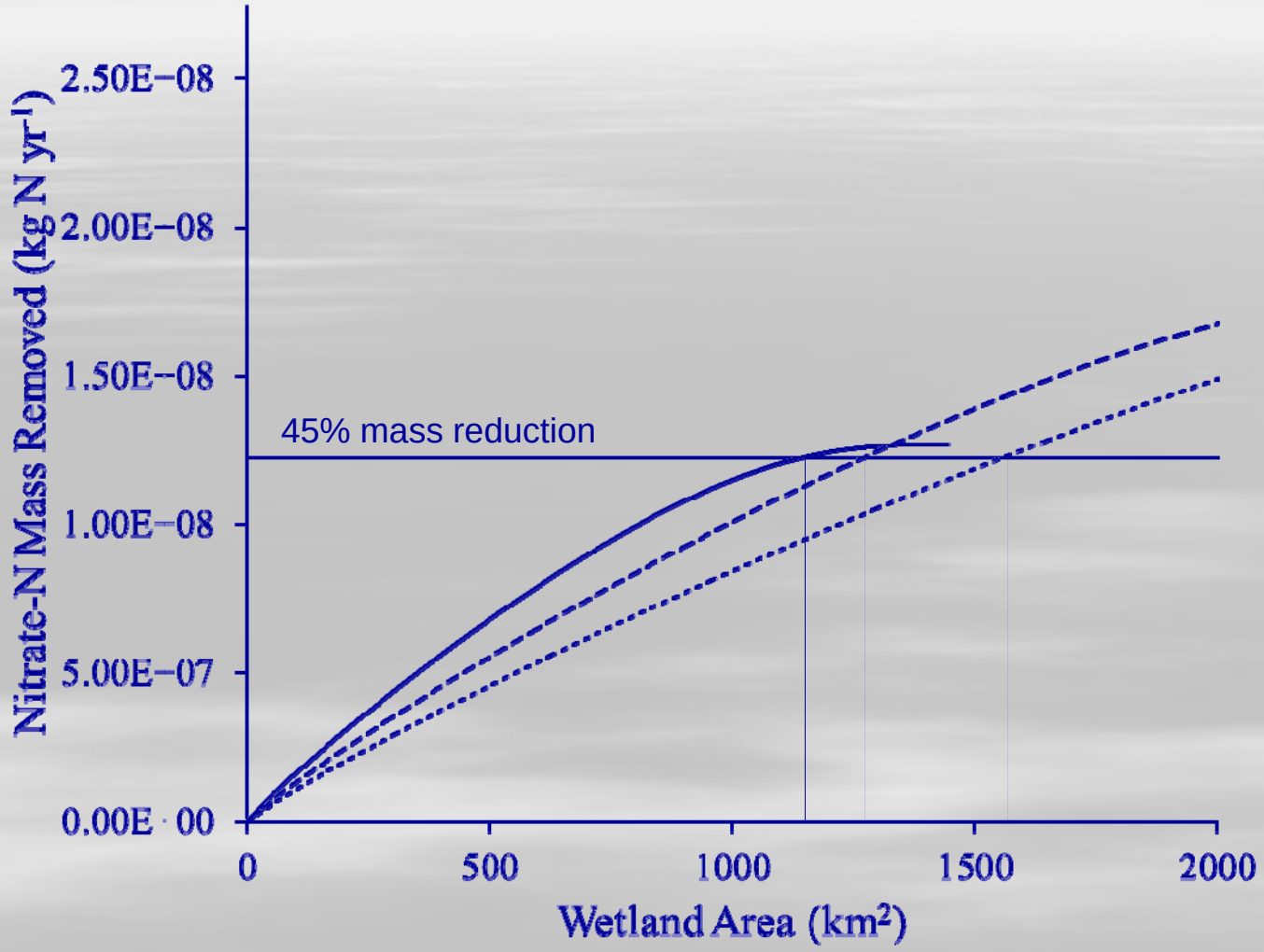
Nitrate yield grid



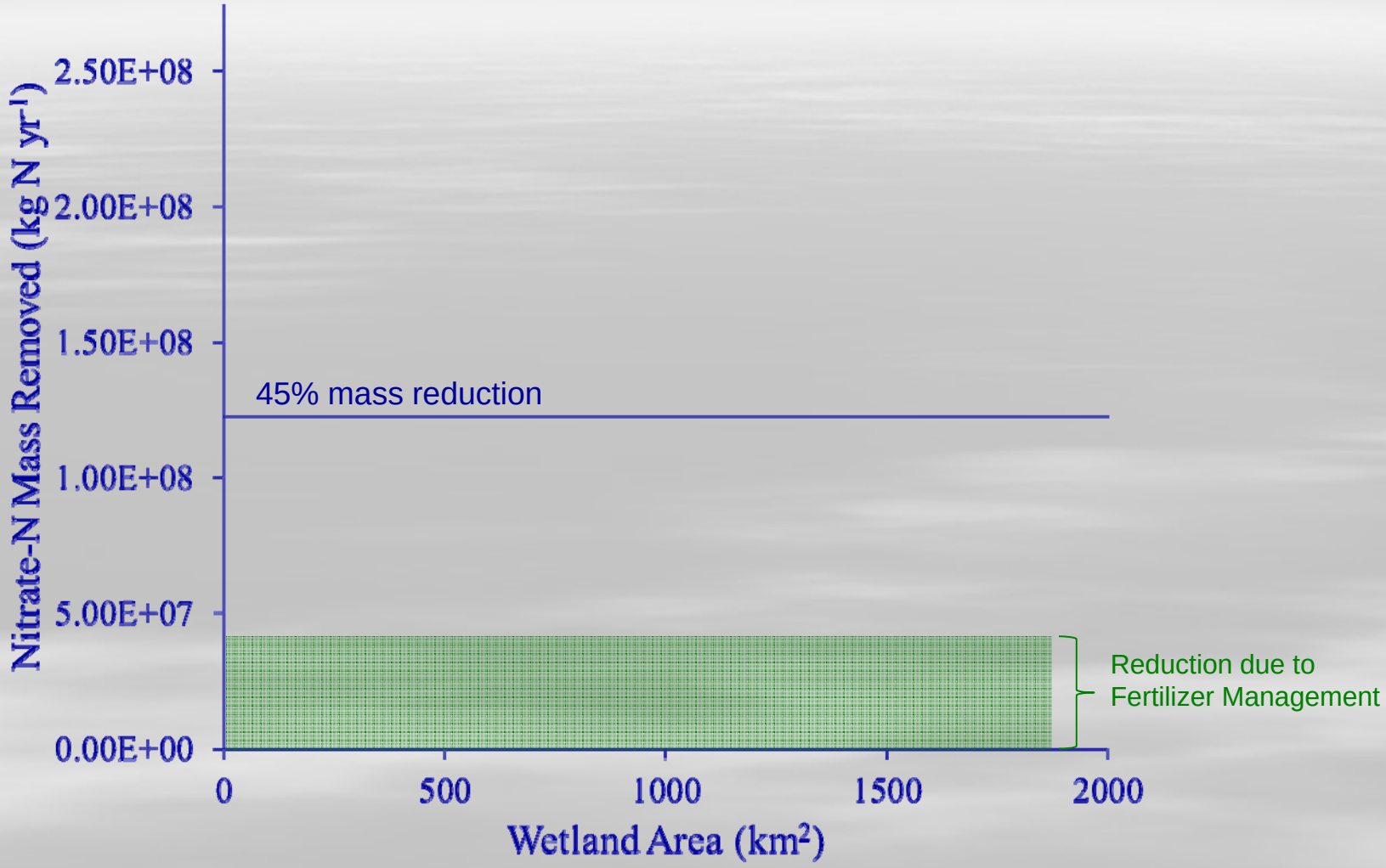
generate Nitrate loss grid



Potential N Reduction in Wetlands with Existing N Management



Potential N Reduction in Wetlands with MRTN based N Management



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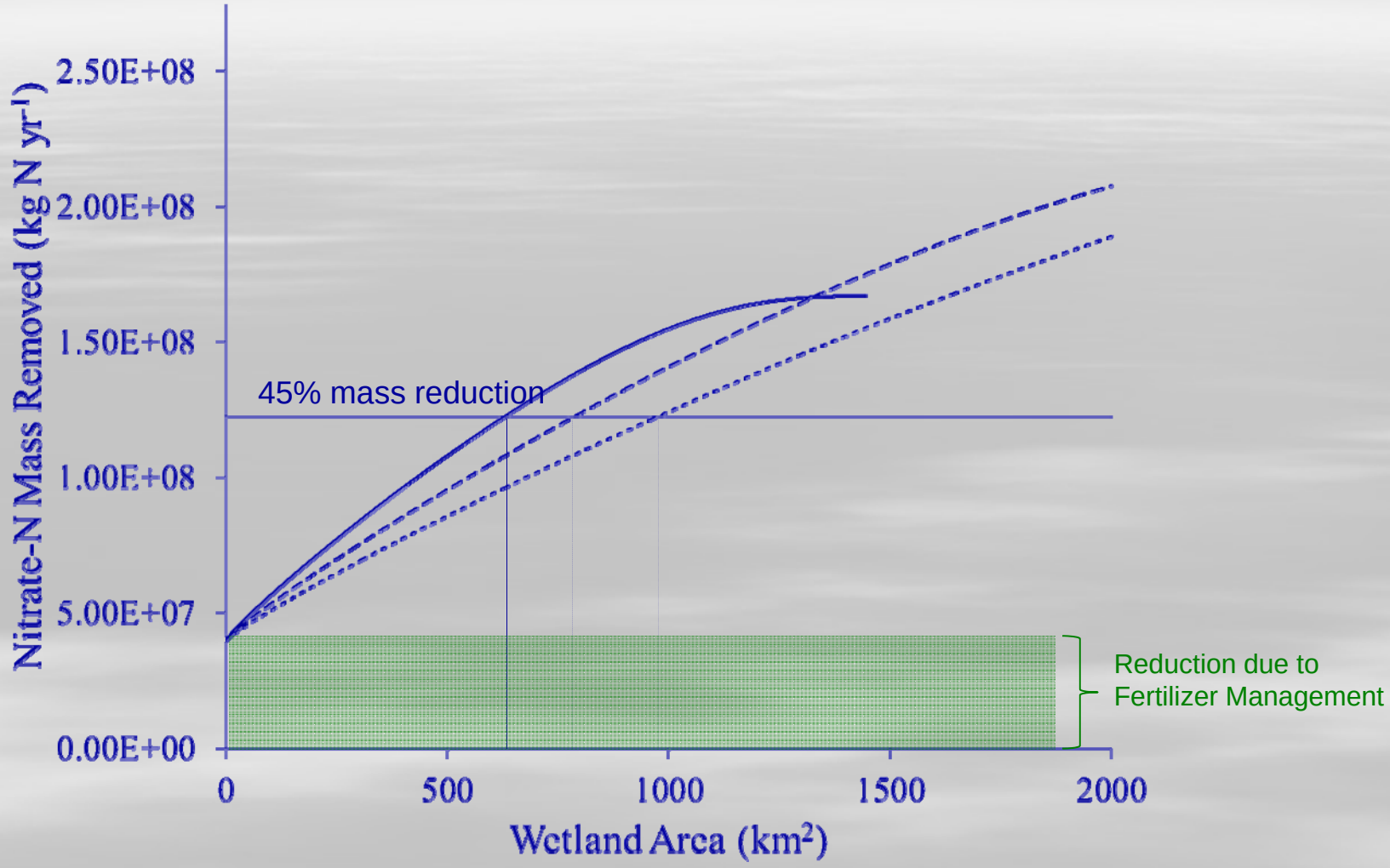
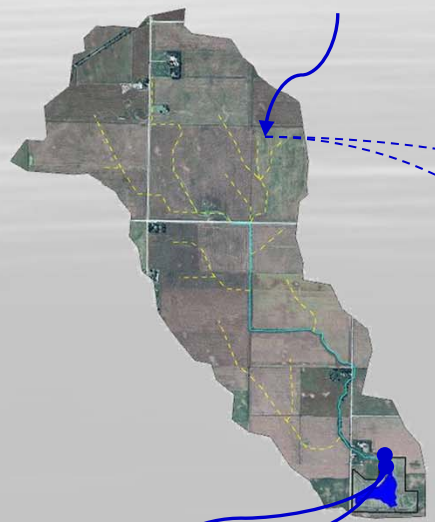


Conceptual Framework



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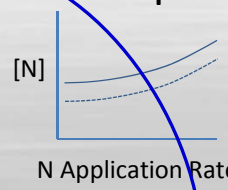
N yield by field

N Response Curves



(function of practices)

Established based on experimental field studies (IDALS and USDA NIFA)

Practices by field

(also yield, for economic analyses)

Established based on GIS coverages and survey data (Iowa Corn Promotion Board and USDA)

Water Yield by field

Estimated based on observed flows, precipitation, etc. and semi-empirical models (IDALS and INRC)

Predicted load at watershed outlet ← **Estimated as** $\Sigma\ N\ yield\ across\ fields$ **(IDALS, INRC, and USDA-NRCS)**

Observed load at watershed outlet ← **Calculated based on close interval monitoring of flows and concentrations** **(IDALS and INRC)**

Comparison of predicted and observed load for

1) **Validation and error estimation**
2) **Iterative improvement of approach/tool**
3) **Establishing capabilities and limitations of approach/tool**