WATERBORNE ENVIRONMENTAL

3/14/2017

Nutrient Monitoring Council Meeting: Vermilion Headwaters, Indian Creek, and Lake Springfield Projects

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Partners and Sponsors

Lake Springfield and Indian Creek Watershed Projects

Vermilion Headwaters (MRBI)

What's Your Strategy?

C-BMP Illinois Council on Best Management Practices

City Water Light and Power Springfield, IL

American Farmland Trust

Illinois Corn Growers Association

pork Illinois Pork Producers.

FS GROWMARK

Illinois Farm Bureau

Illinois Soybean Association Checkoff Program

Keep it 4R Crop, 4R nutrient stewardship, Illinois Fertilizer & Chemical Association, IFCA

Monsanto

syngenta

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- Lake Springfield

MODELING PRIORITY WATERSHEDS

- Vermilion Headwaters
- Lake Springfield Watershed
- Indian Creek Watershed

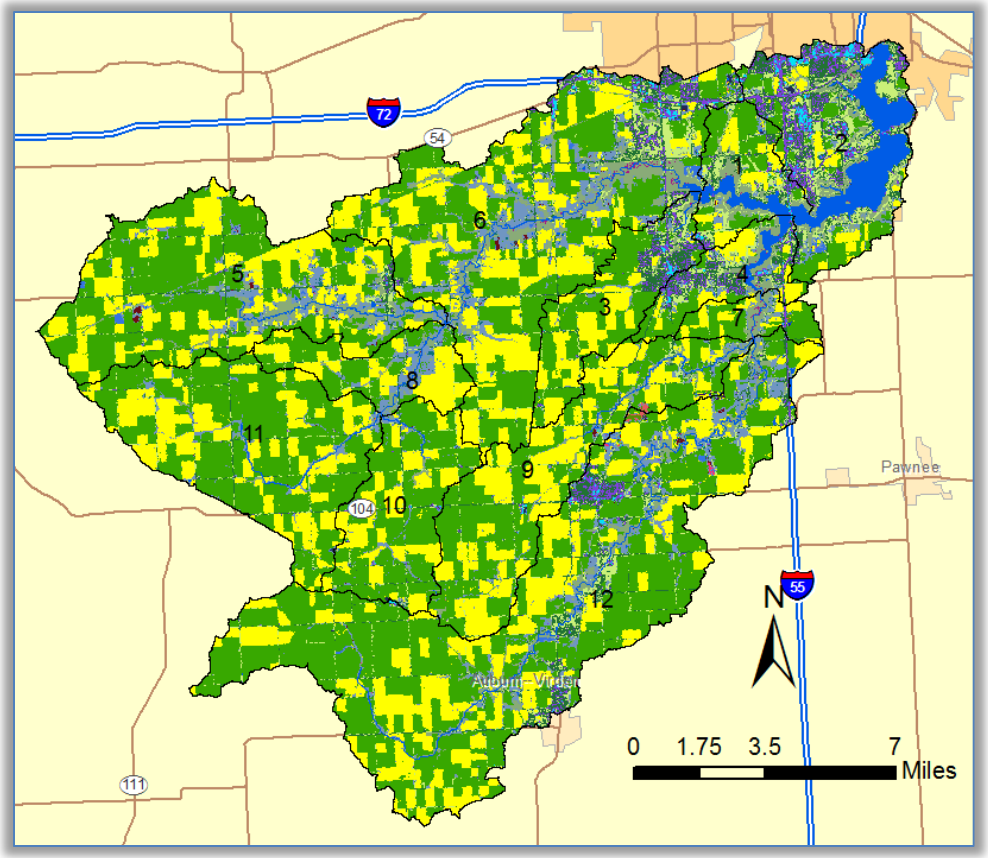

Lake Springfield Watershed Monitoring

Watershed Monitoring Background and Goals

- Lake Springfield Watershed Monitoring
  - Flow
  - Nitrate Concentration
  - Measurements collected April 2015-March 2016
- Goals
  - Determine spatial nitrate yield (lb/ac) – a form of yield
  - Understand seasonal trends

Lake Springfield Land Use

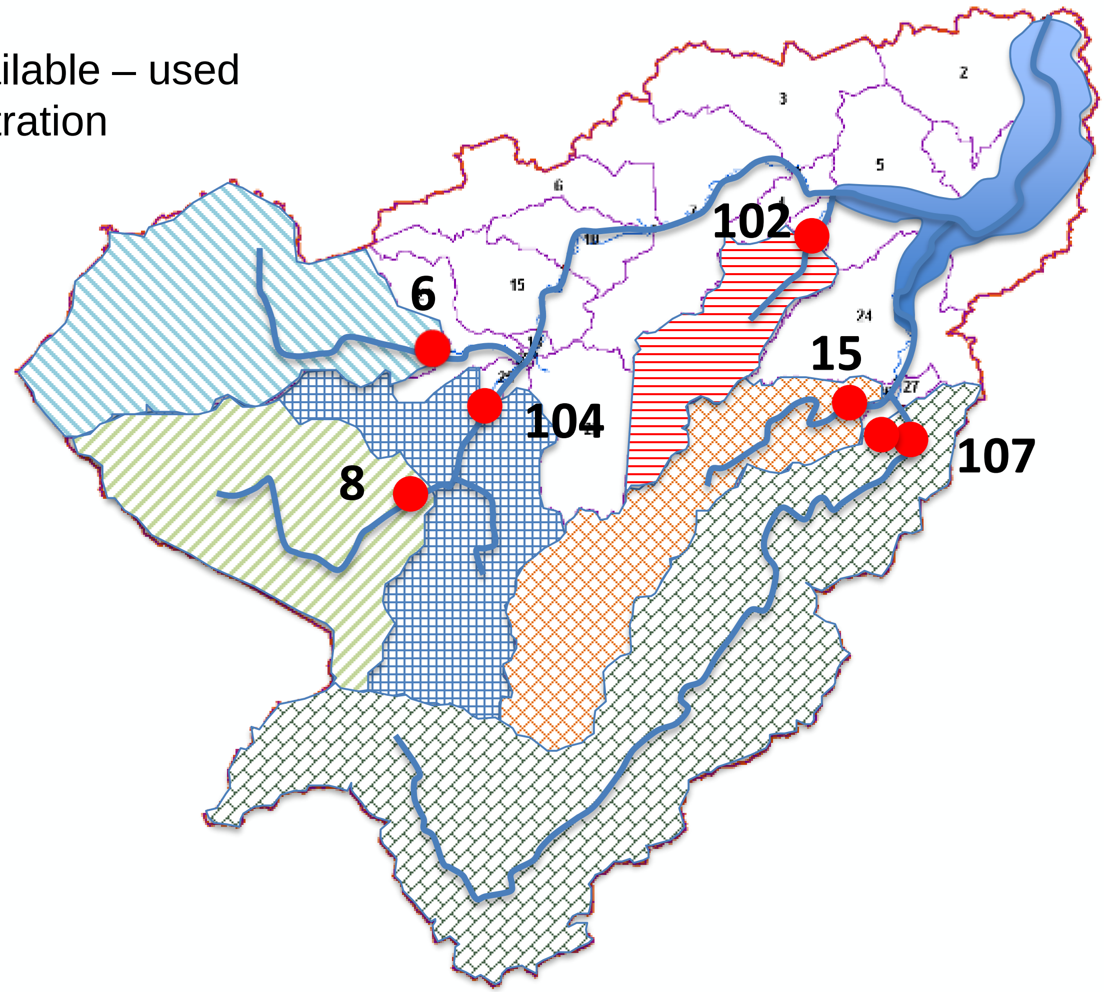
- Corn-Soy is the major land use at all the sites (>80%)
- Watershed is fairly flat with slopes < 1.5%, except near stream corridors > 5%



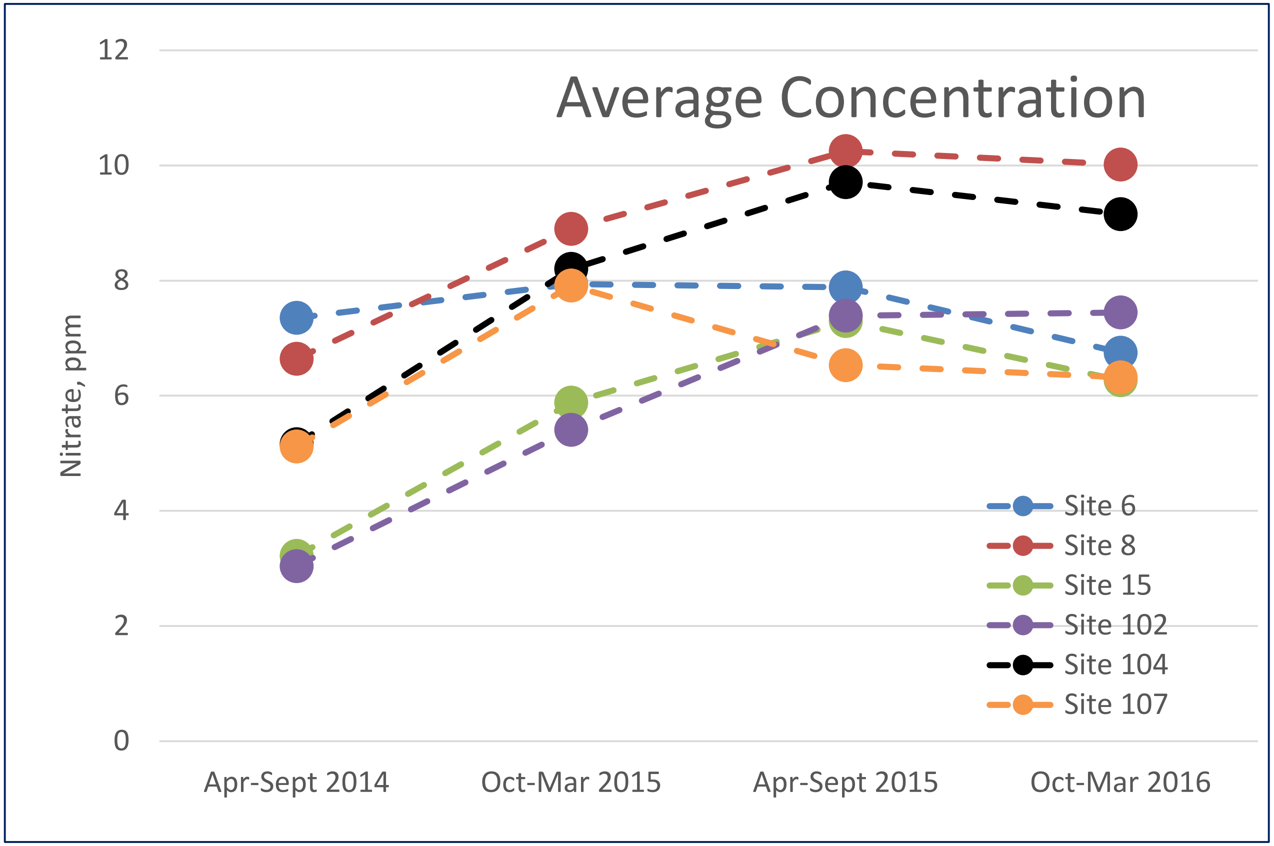
2015-2016 Monitoring Locations

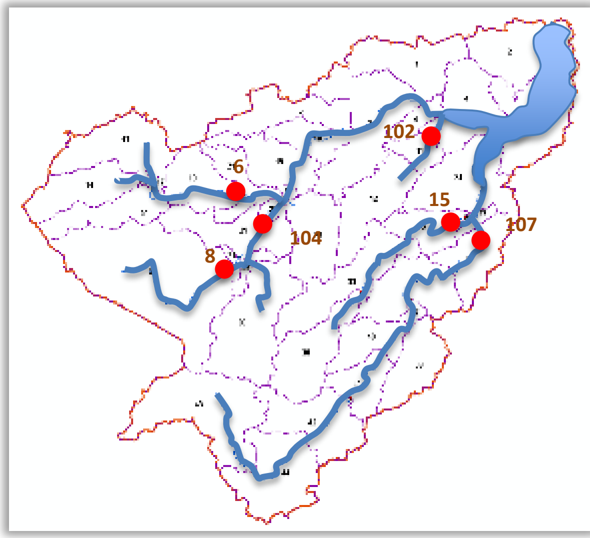
- Sites locations focus on pseudo-first order scale (single tributary)
- Some concentration data were available – used this to prioritize ***a range*** of concentration observations

Site	Square miles
6	28.3
8	25.9
15	21.9
102	10.3
104	47.4
107	64.0



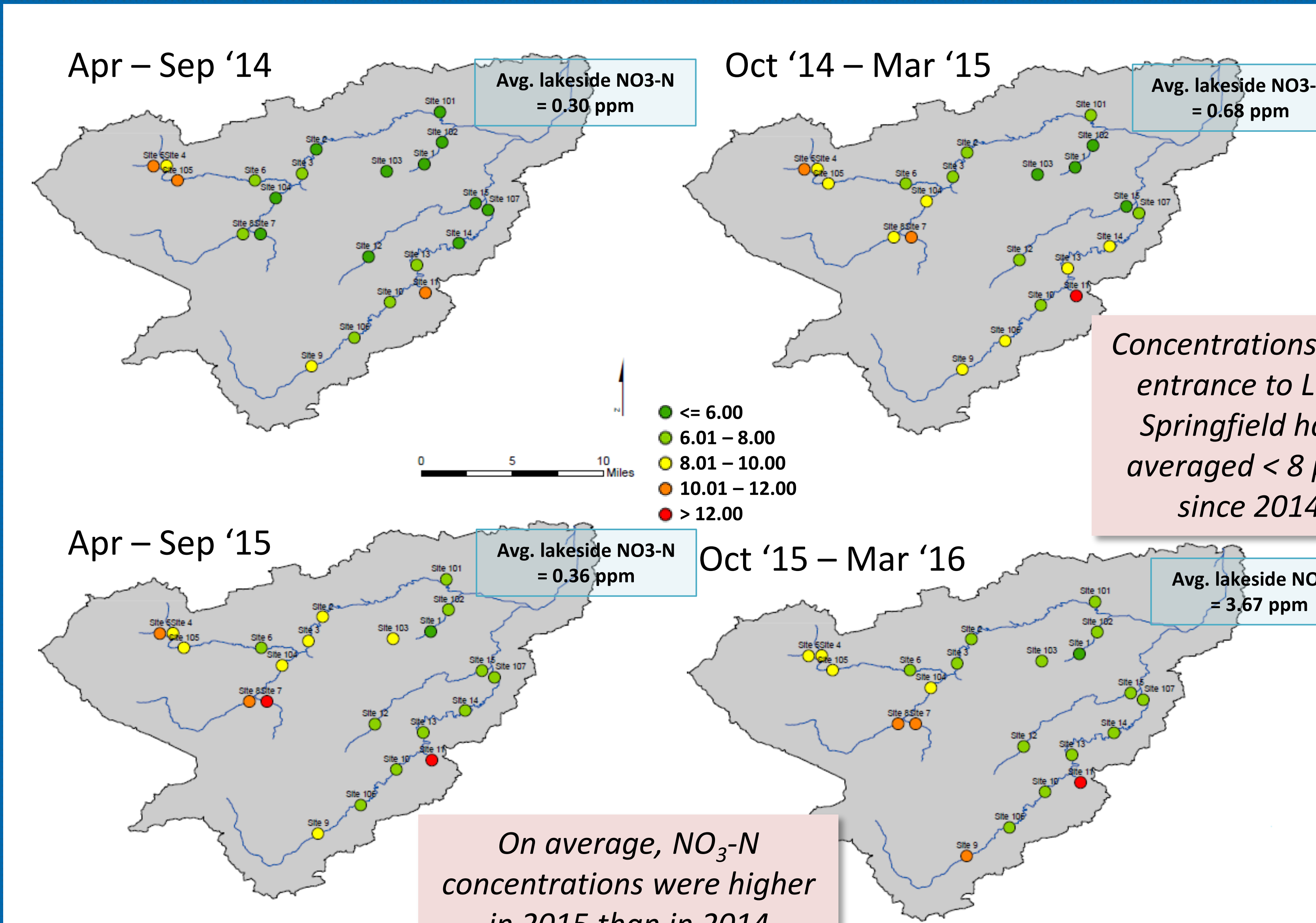
Summary of Concentration Data





Site Rank:
8>104>6>102>15>107

Average NO_3-N Detections (ppm) – By Season



Concentrations near entrance to Lake Springfield have averaged < 8 ppm since 2014

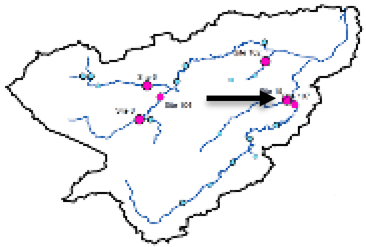
On average, NO_3-N concentrations were higher in 2015 than in 2014

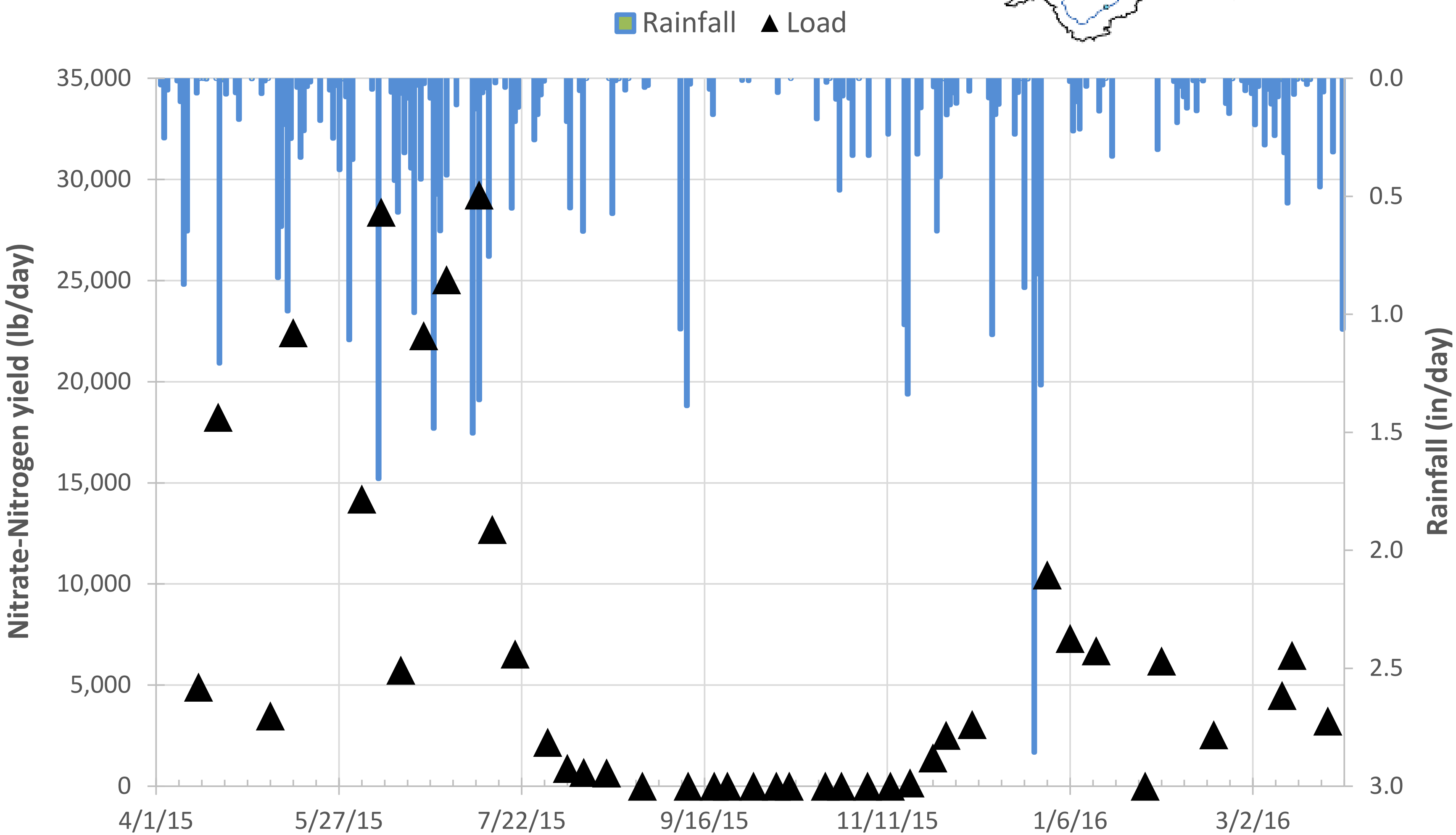
Flow Event Sampling

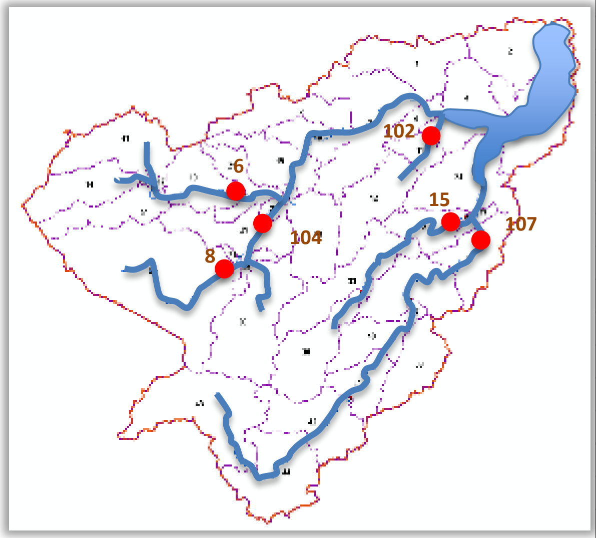
- **Similar % of flow events were sampled in each season, so yield estimates should be comparable between seasons**
  - 30 days April 2015 – March 2016 in LSW had significant rainfall events (>= 0.5” rainfall)
    - 21 days April 2015 – Sep 2015
    - 9 days Oct 2015 – March 2016
  - 13 sampling events occurred the day or two days after a significant rainfall event
    - 9 sampling events April 2015 – Sep 2015 (43%)
    - 4 sampling events Oct 2015 – March 2016 (44%)
- 43-44% of flow events were captured across the two years


Discrete Yield (lbs/ac)

EXAMPLE: Discrete load – Site 15





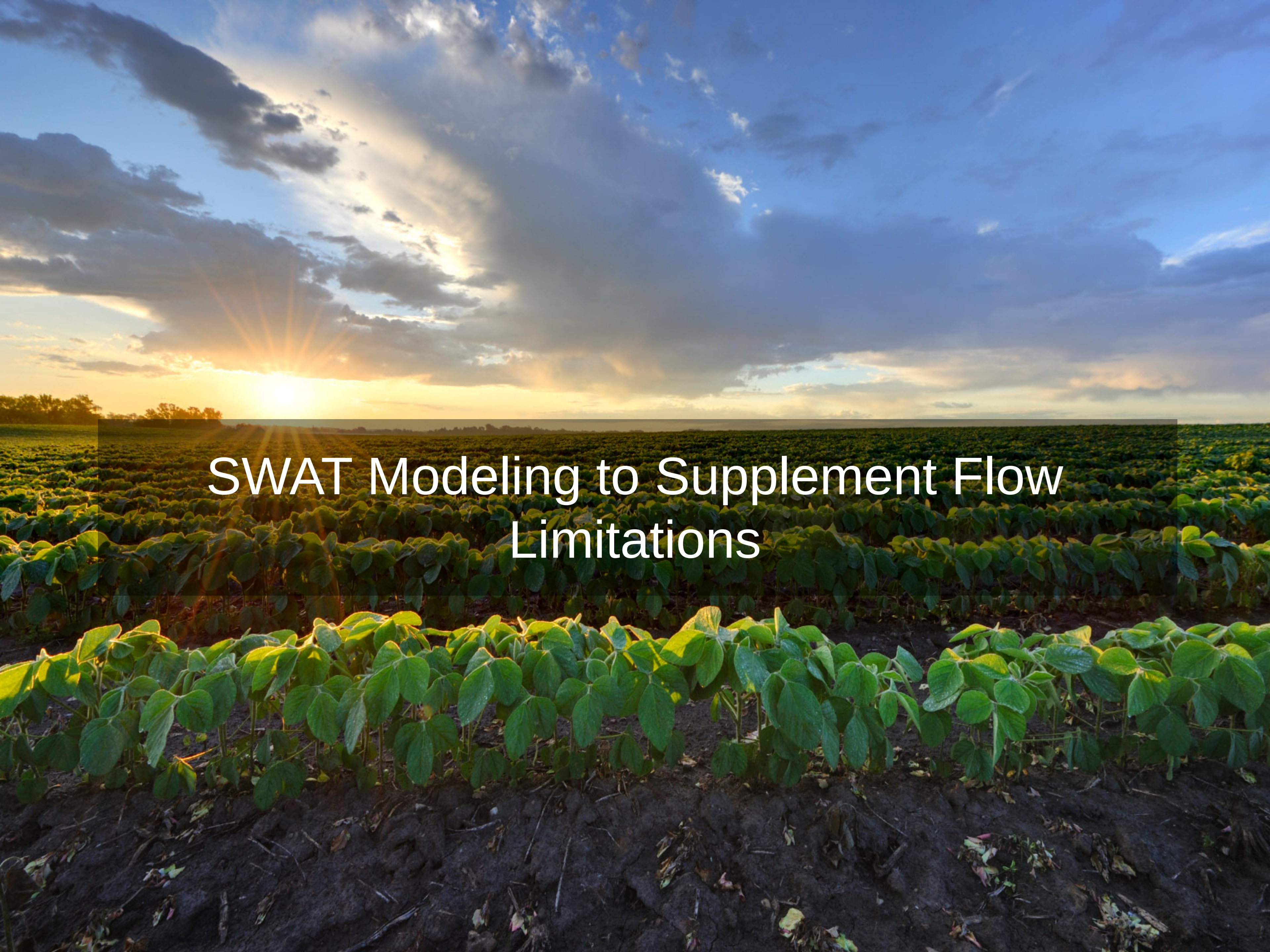


Discrete Yield (lbs/ac/day)						
	6	8	15	102	104	107
4/14/2015	0.00	0.18	0.35	0.09	0.06	0.05
4/20/2015	0.25	0.62	1.30	0.01	0.63	
5/13/2015	0.25	0.57	1.60	0.24	0.43	0.39
6/3/2015	0.15	0.33	1.01	0.70	0.03	0.18
6/9/2015	0.39	0.68	2.02		1.41	0.86
6/15/2015	0.28	0.36	0.41	0.35	0.21	0.16
6/22/2015	0.60	0.60	1.59	0.00	0.91	0.43
6/26/2015	1.40	1.33		0.00	0.71	0.51
6/29/2015	0.66	1.03	1.79	0.00	0.61	0.31
7/9/2015	0.58		2.08	0.00	0.65	0.51
7/13/2015	0.48	0.46	0.91	0.00	0.53	0.32
7/20/2015	0.19	0.23	0.47	0.00	0.19	0.07
7/30/2015	0.07		0.15	0.00	0.04	0.03
8/5/2015	0.03	0.05	0.06	0.00	0.02	0.02
8/10/2015	0.04	0.08	0.05	0.17	0.05	0.01
8/17/2015	0.02	0.02	0.05	0.93	0.01	0.01
8/28/2015	0.00	0.00	0.00	0.20	0.00	0.00
9/11/2015	0.00	0.00	0.00	0.14	0.00	0.00
9/19/2015	0.00	0.00	0.00	0.06	0.00	0.00
9/23/2015	0.00	0.00	0.00	0.43	0.00	0.00
10/1/2015	0.00	0.00	0.00	1.41	0.00	0.00
10/8/2015	0.00	0.00	0.00	0.91	0.00	0.00
10/12/2015	0.00	0.00	0.00	0.61	0.00	0.00
10/23/2015	0.00	0.00	0.00	0.53	0.00	0.00
10/28/2015	0.00	0.00	0.00	0.04	0.00	0.00
11/5/2015	0.00	0.00	0.00	0.05	0.00	0.00
11/12/2015	0.00	0.00	0.00	0.00	0.00	0.00
11/18/2015	0.01	0.49	0.01	0.00	0.09	0.01
11/25/2015	0.05	0.52	0.10	0.00	0.24	0.04
11/29/2015	0.11	0.42	0.18	0.00	0.17	0.17
12/7/2015	0.06	0.26	0.22		0.09	0.23
12/30/2015	0.95	1.05	0.74	0.00	1.61	0.87
1/6/2016	0.22		0.52	0.09	0.18	0.16
1/14/2016	0.17		0.48	0.17	0.17	0.17
1/29/2016	1.13	0.06	0.00	1.61	0.11	0.06
2/3/2016	0.14	0.29	0.44	0.17	0.30	0.07
2/19/2016	0.12		0.18		0.11	
2/26/2016	0.10	0.07			0.00	
3/11/2016	0.07	0.05	0.32		0.00	
3/14/2016	0.14	0.10	0.46	0.11	0.07	0.16
3/25/2016	0.20	0.10	0.23		0.18	0.05

Discrete yield Summary and Limitations

- Discrete flow and concentration measurements provide ***point-in-time snapshots of nitrate yield***, but difficult to precisely calculate total seasonal yield
- Sampling events are random w.r.t. flow events, so difficult to calculate flow between sampling events ***without continuous stage monitoring***
- Sites were monitored after Dec 27, 2015 event (> 2.5 in), sampling program ***missed a potential high nitrate yield***
- Nitrate ***concentrations may fluctuate*** throughout longer hydrographs

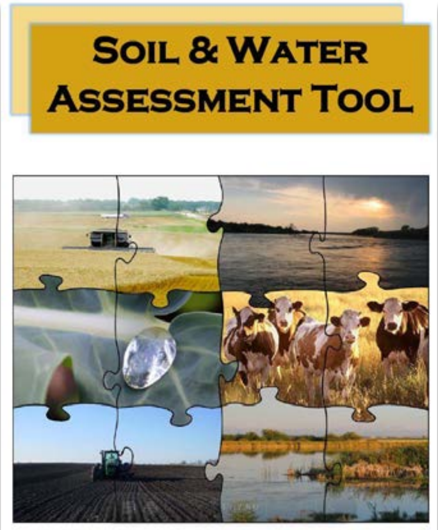
SWAT Modeling to Supplement Flow Limitations



SWAT Modeling to Supplement Monitoring

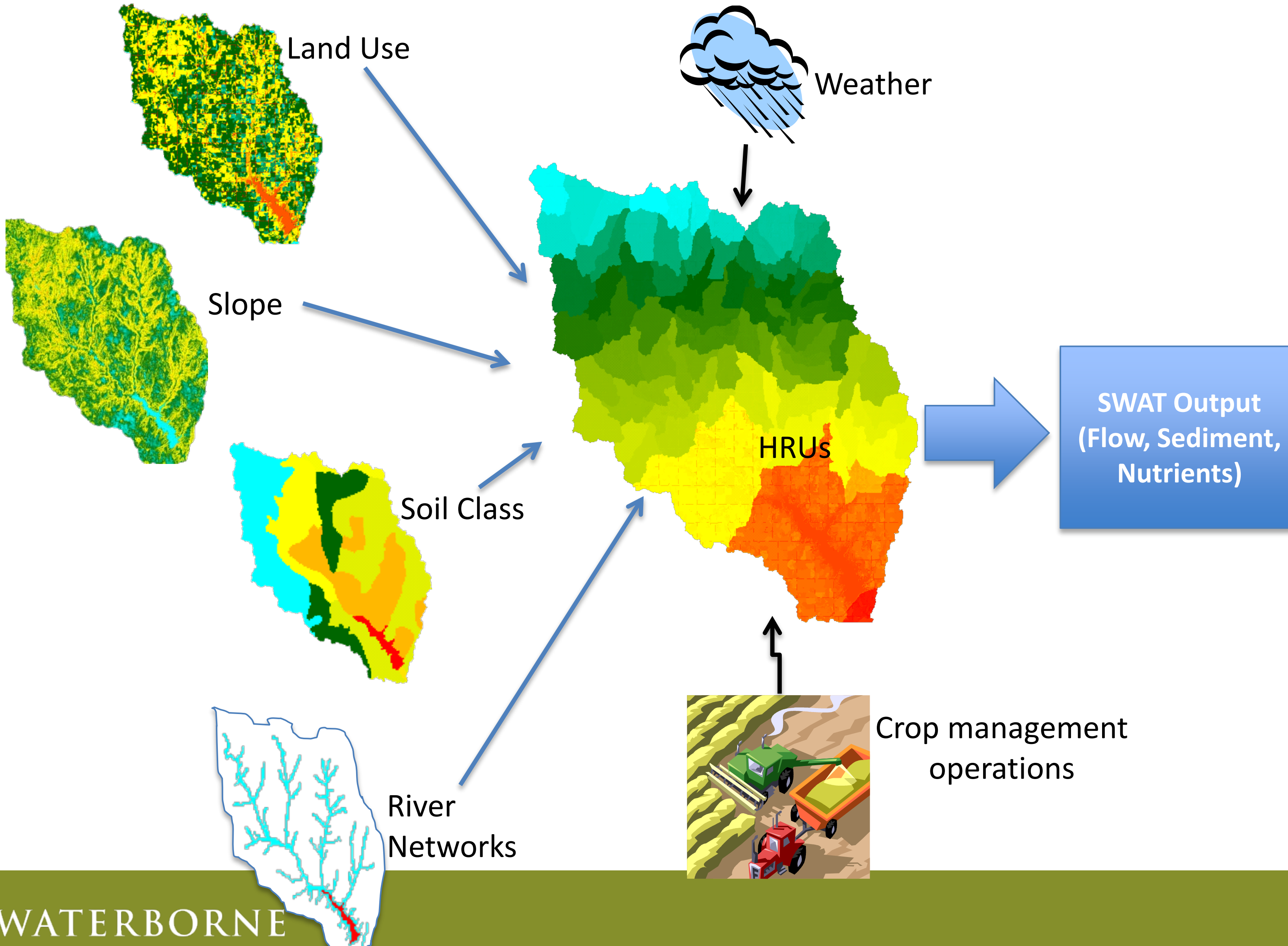
- SWAT model was used to provide daily flow estimates, based on a calibration period, to 'fill in' stream flow between measurements
- When daily flow is available, this increases accuracy of yield/yield estimates – but is still an estimate

SWAT Model



- Offers the **greatest number of management alternatives** for modeling agricultural watersheds
- Adopted as part of the USEPA Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) software package for applications including **support of TMDL analyses**
- **Used by many US federal and state agencies**, including the USDA Conservation Effects Assessment Project (CEAP), to evaluate the effects of conservation practices
- A large number of previous peer-reviewed modeling studies have used SWAT to evaluate conservation practices around the globe
- Waterborne is working closely with developers at Purdue University to actively expand capabilities of the model

Basics of the SWAT model

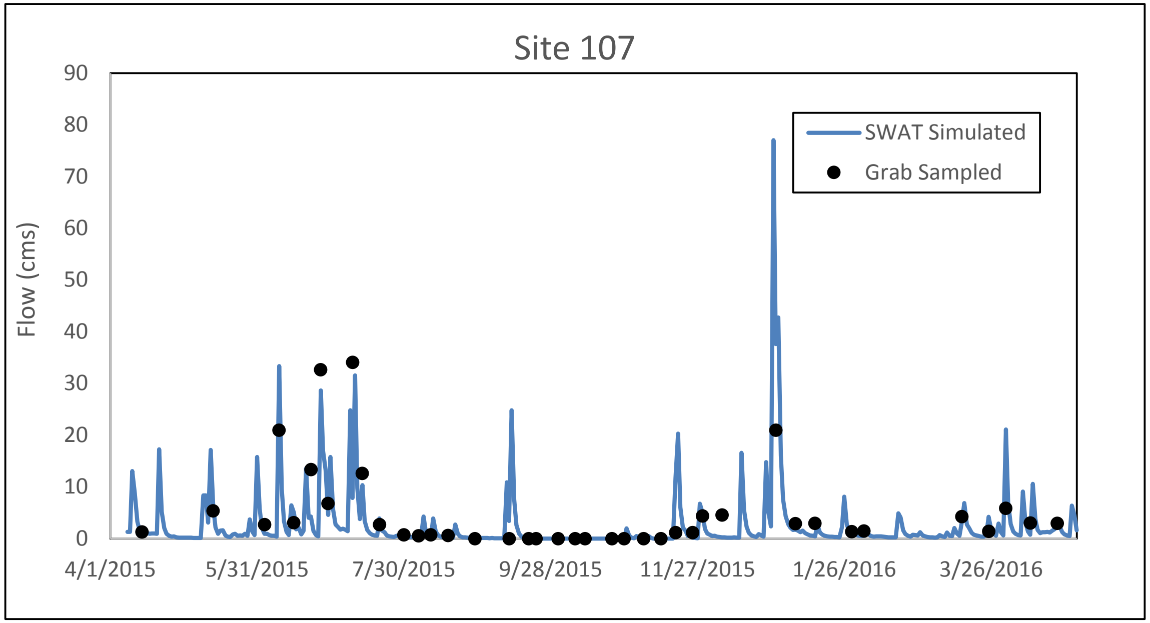


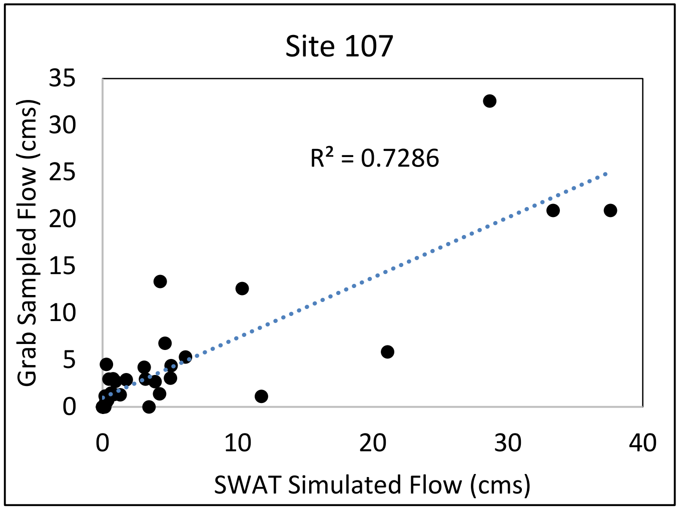
SWAT Model Calibration

- SWAT calibration parameters such as runoff (CN), tile flow (tile depth, distance between tiles, drainage coefficient), and tillage
- SWAT was calibrated spatially at 6 sites using discrete flow measurements
- Lake Springfield watershed was delineated in to 44 sub-basins
- Sub-basin weighted NEXRAD rainfall data (2005 – April 2016)
- Continuous corn-soybean rotations are assumed in the watershed; NASS (2013) was used to setup land use
- SSURGO soils
- Subsurface tiles were assumed in all corn and soybean land use

EXAMPLE: Daily Average Flow vs Snapshot Flow

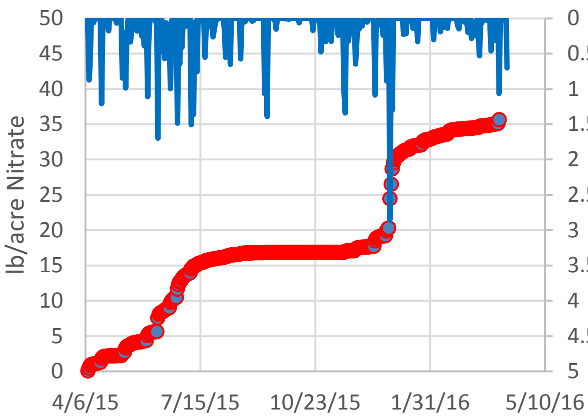
- SWAT simulated daily average flow matched well with measured flow (timing)
- SWAT underestimated flow during July 7, 2015 event
- Magnitude of flow varies with timing of the sample collected



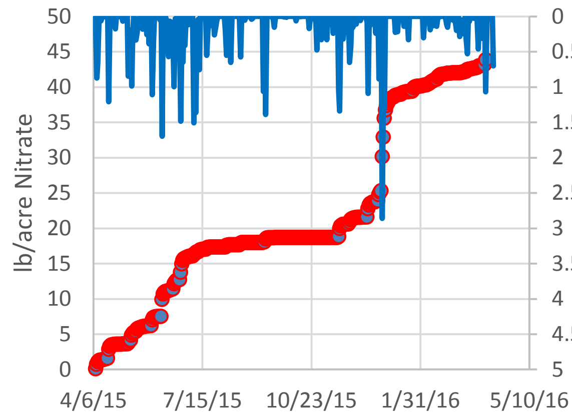


Estimated Cumulative NO_3-N Yield Summary

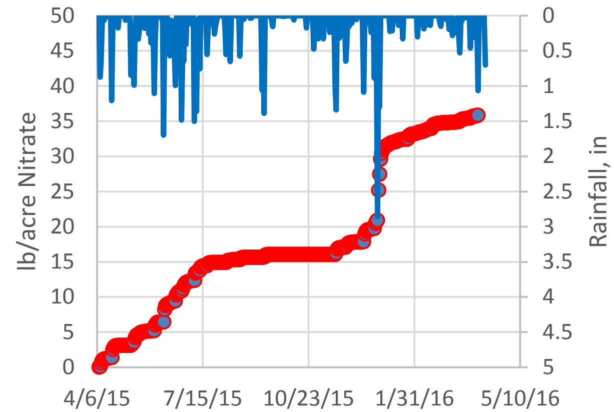
Site 6



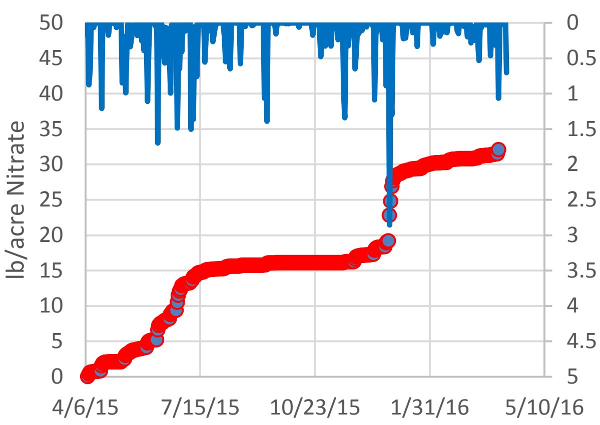
Site 8



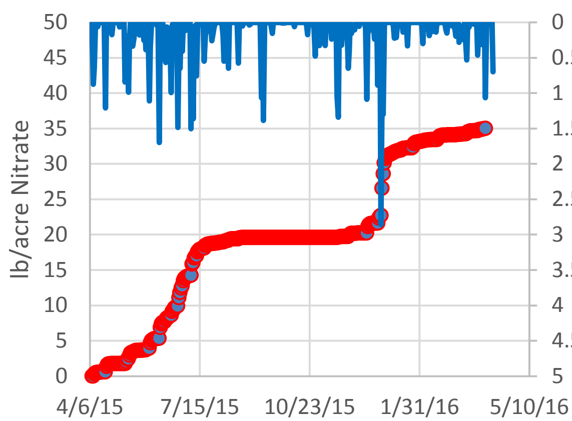
Site 104



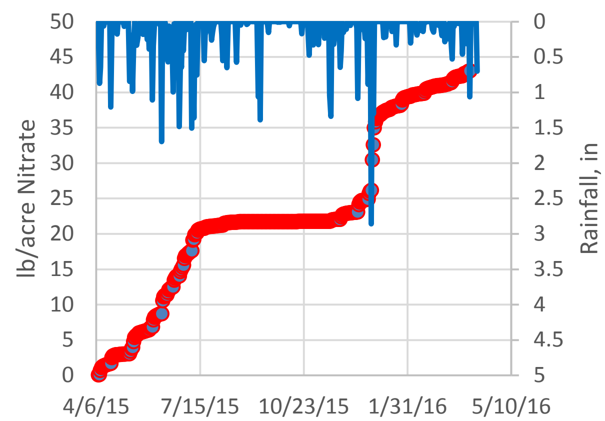
Site 102



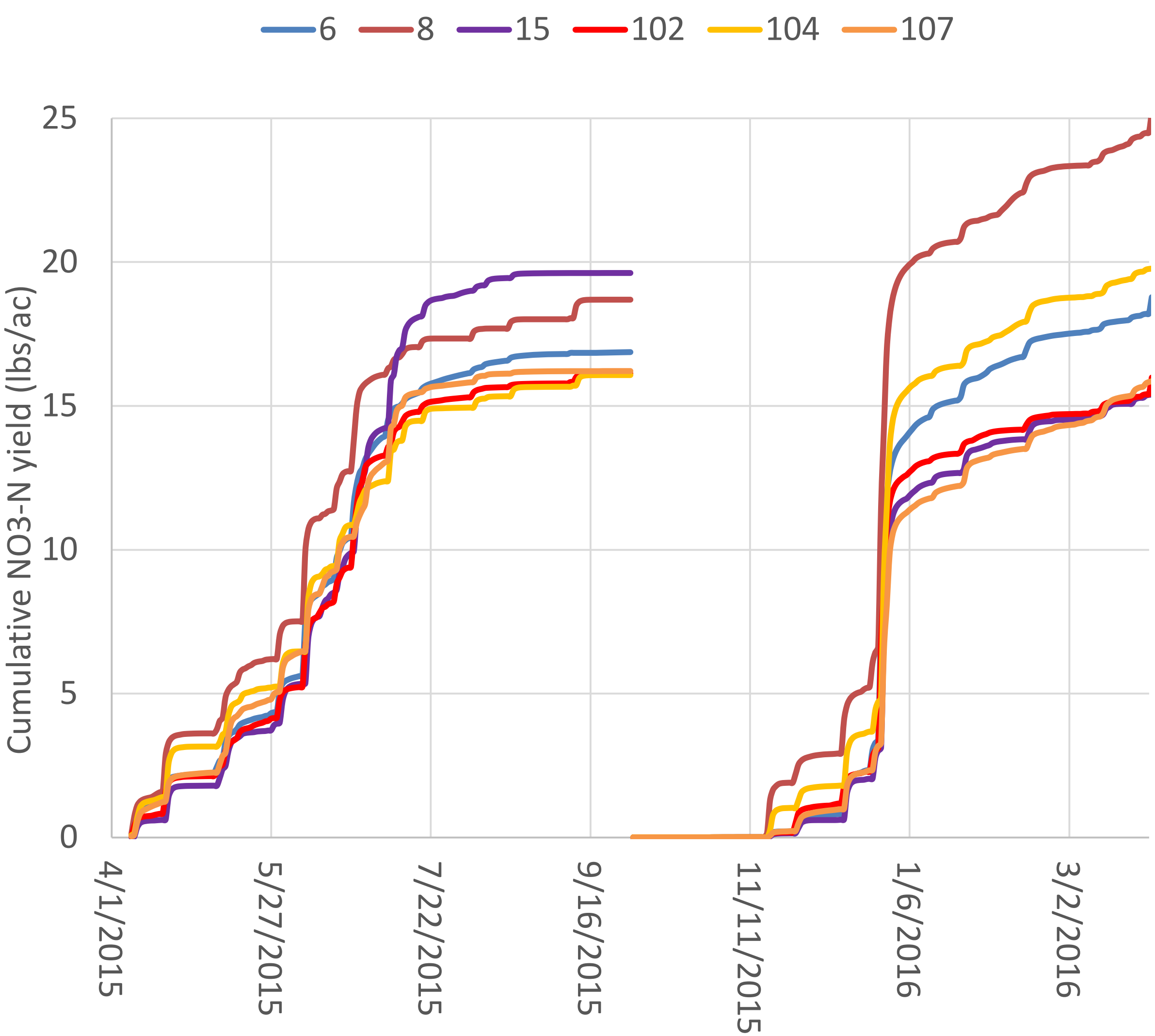
Site 15

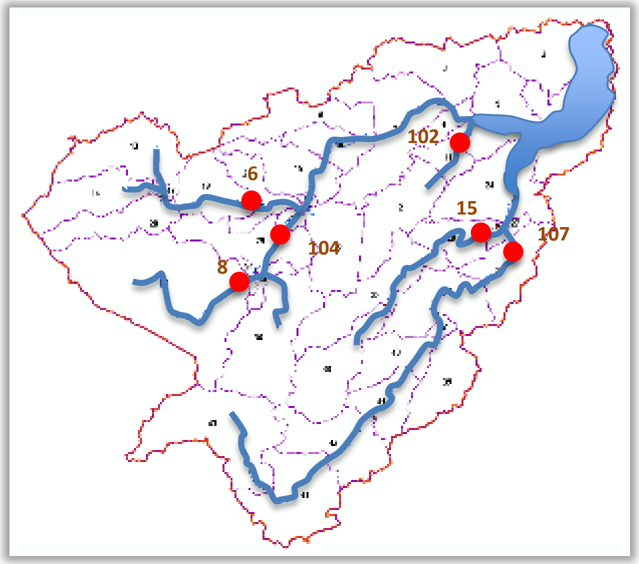


Site 107



Cumulative NO_3-N yield – lb/acre

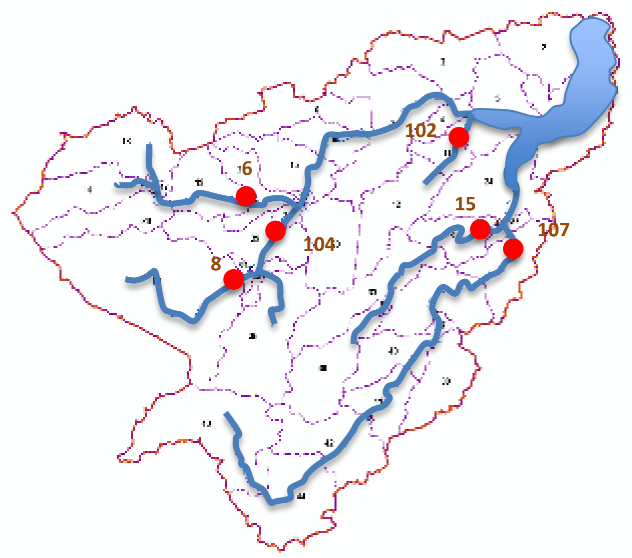




Cumulative NO_3-N yield

- Cumulative nitrate yield (lbs/ac)

Site #	Apr-Sep 2015	Oct 2015-Mar 2016
6	16.8	18.7
8	18.6	25.1
15	19.5	15.3
102	16.1	15.9
104	16.0	19.7
107	16.1	15.8

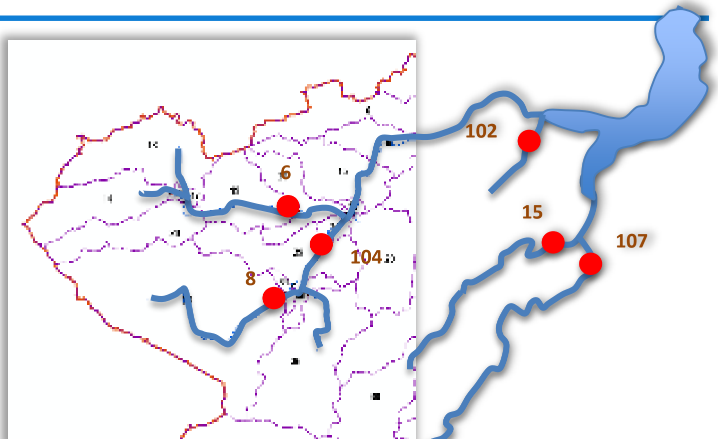


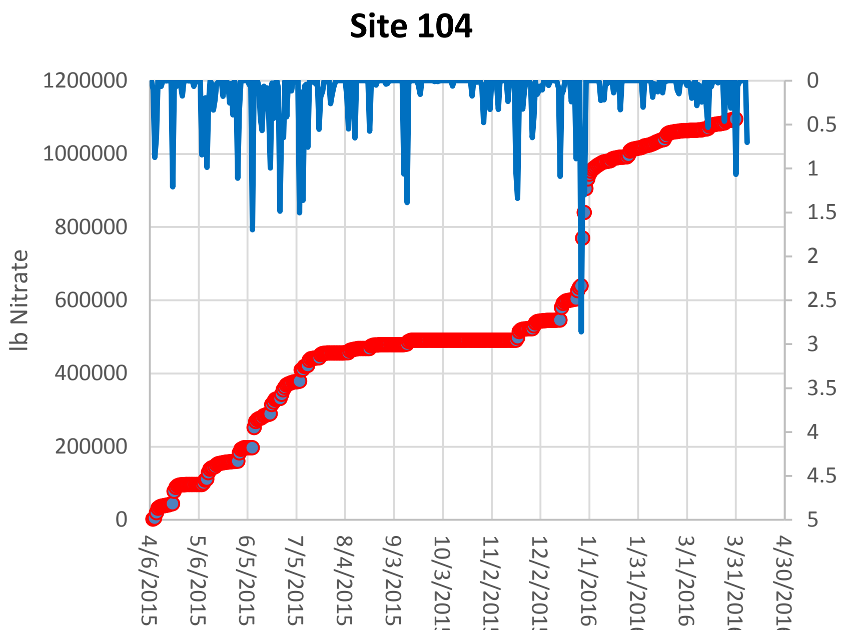
- Site 8 had higher nitrate yields on per acre basis when compared to other sites (both 2015 and 2016)
- Site 104 had higher nitrate yields in 2016
- Site 104 is downstream of Site 8 ***and*** had lower yields per acre in both 2015 and 2016
  - Site 8 subbasin is contributing more than the rest of the Site 104 sub-basin

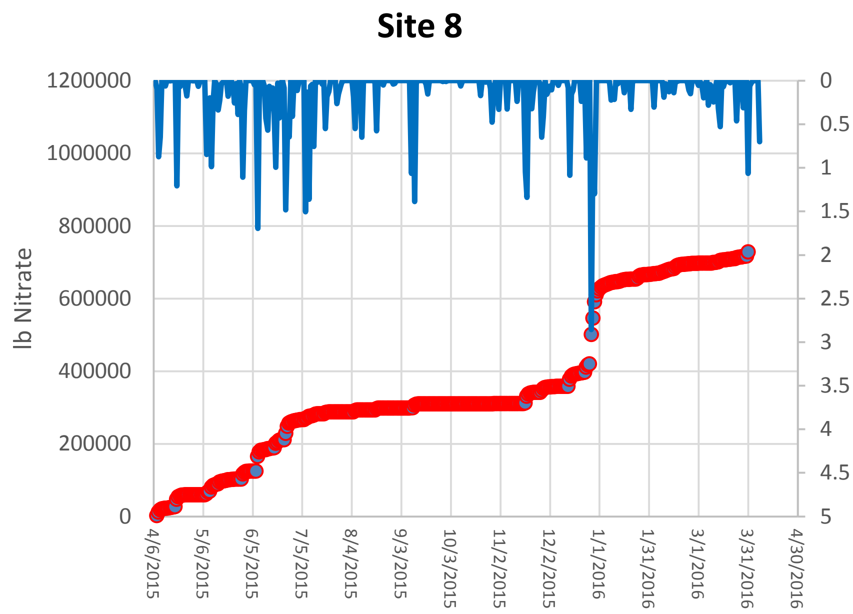
Recall: Concentration Site Rank:
8>104>6>102>15>107

Mass of Nitrate at 104 (downstream) and 8

- Site 104 carries more mass (pounds) in the stream because it is downstream of 8





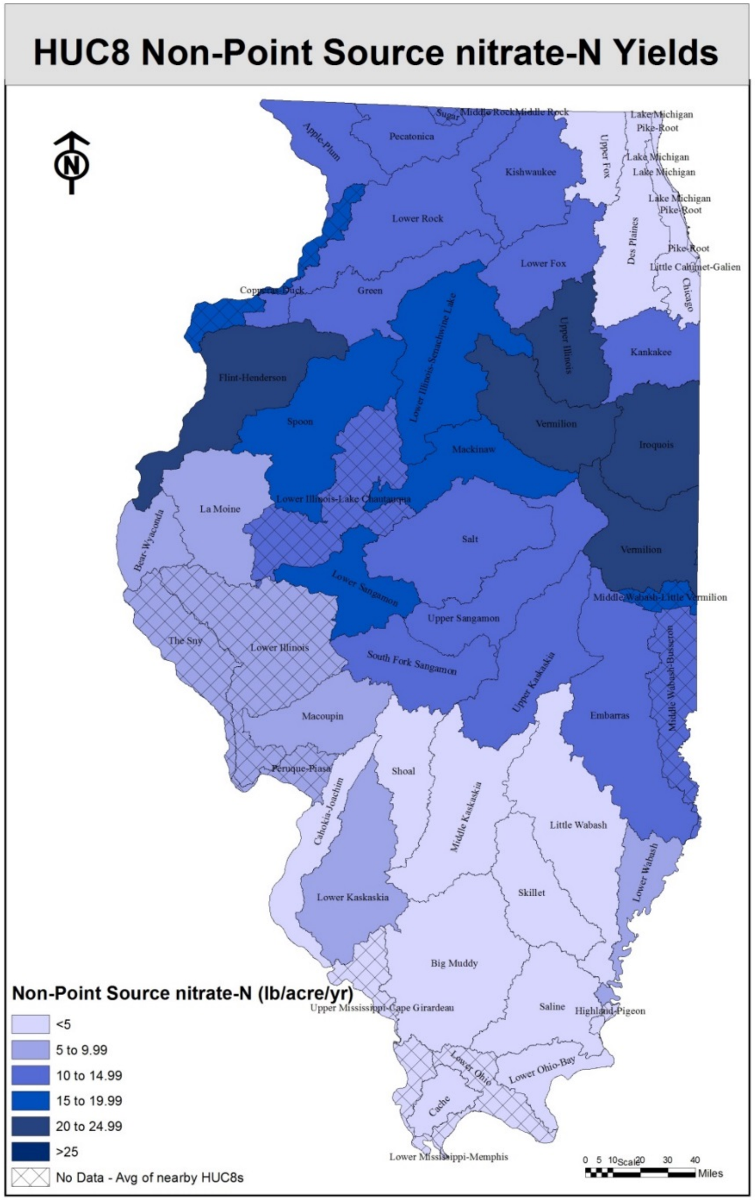


IL NRLS

- Illinois Nutrient Loss Reduction Strategy Science Assessment: South Fork Sangamon – nitrate yield = **10-14.99 lbs/acre/year**

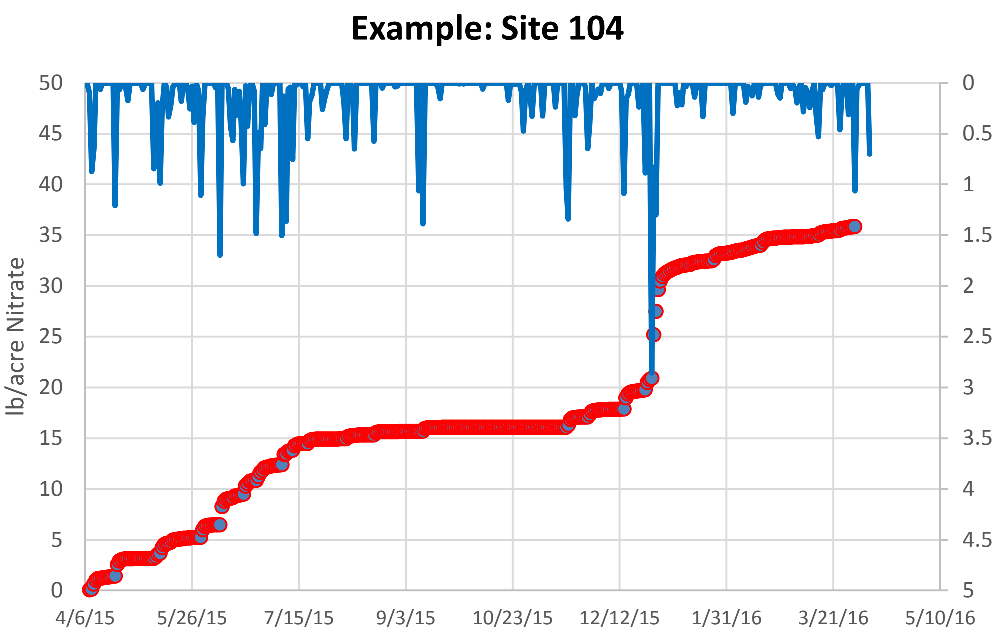
Estimated from measurements

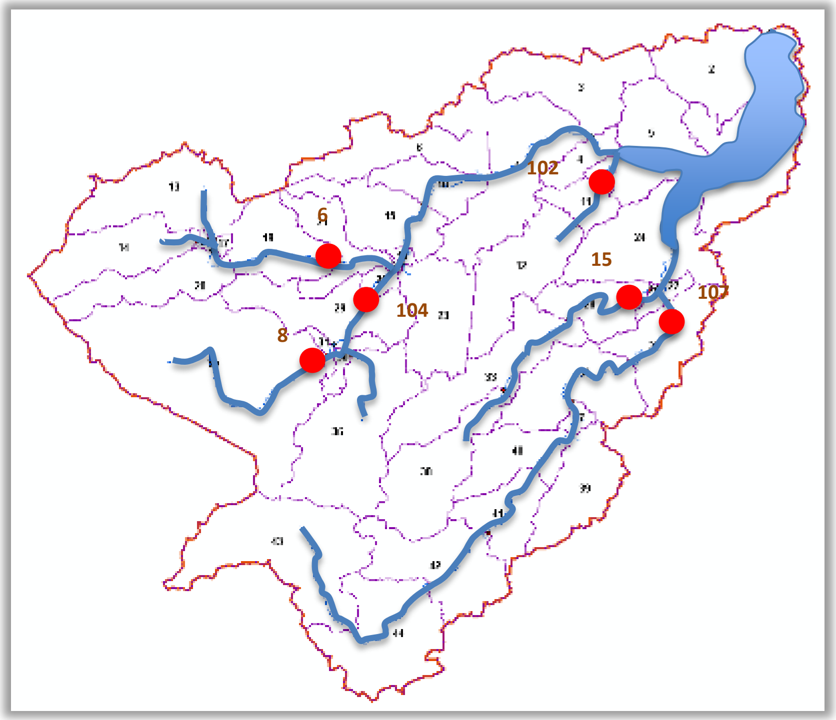
- 2015 yield estimates (watershed average was **17.1 lbs/acre/year**
- 2016 yield estimates (watershed average was **18.4 lbs/acre/year**



Cumulative NO_3-N Yield Summary

- Warm winter in 2016 led to high nitrate concentrations (> 10 ppm) and runoff events at all the sampling sites
- 3-in rainfall event on Dec 27 2015 led to spiked flow and yields at all sites (no crop growing to take up the rainfall)





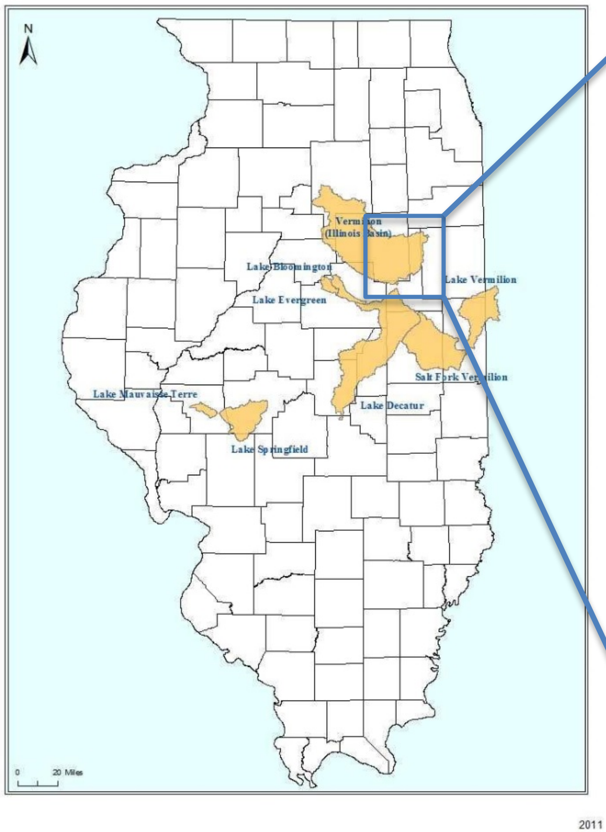
Overall Summary

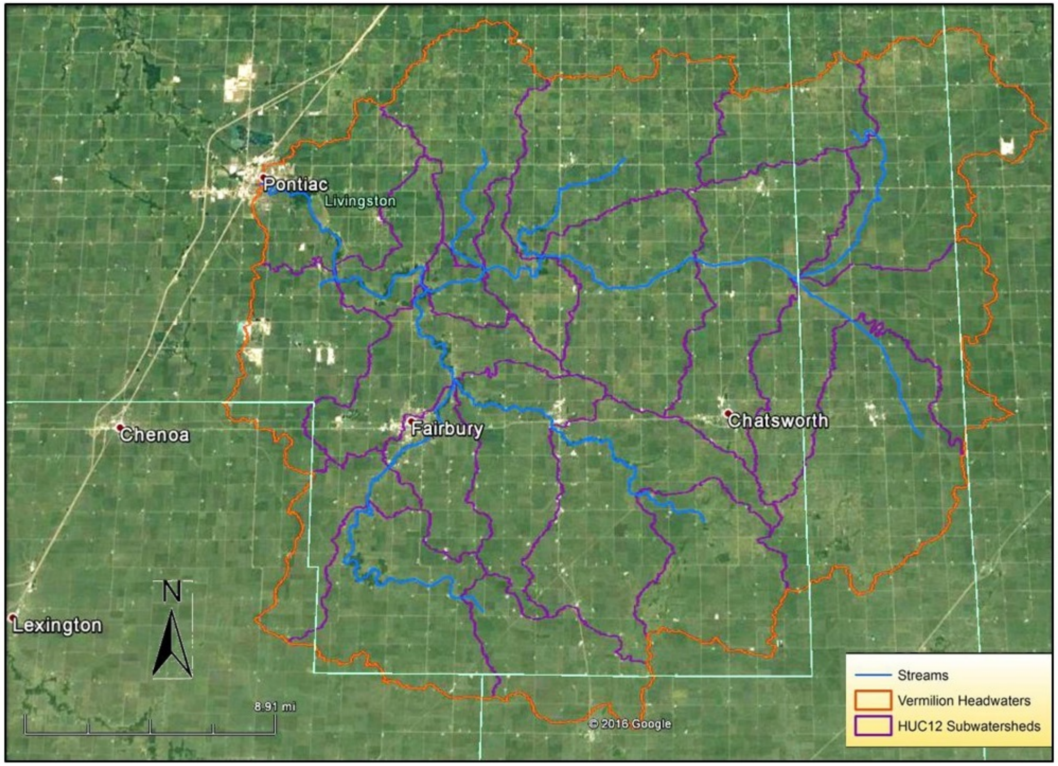
- Estimated yield from watershed-averaged calculations (based on monitoring data) were slightly higher than NLRS estimates
  - IL NLRS was estimated at HUC 8, where Lake Springfield watershed is smaller – could be a factor
- Average watershed average yield increased in 2016
- Spatial monitoring data allowed for sub-basin estimation of yield
- High concentrations do not always equal high yield
  - Concentration at site 6 was the highest, on average, but exhibited an average yield (per acre)
- Some upstream (headwater sub-basins) may exhibit relatively high yield – on a per acre basis – e.g. Site 8
  - Land use practices may matter locally
  - When USGS data is available at the lake entrance, comparison of local yield to lake yield can be done


Potential Site Selection Using Modeling:
MRBI Vermilion Headwaters Watershed
Priority Watershed

Vermilion River Headwaters Watershed – American Farmland Trust

- Characterize N yield potential as a function of BMP adoption rate
- Identify relevant, representative water quality sampling locations for a paired watershed approach

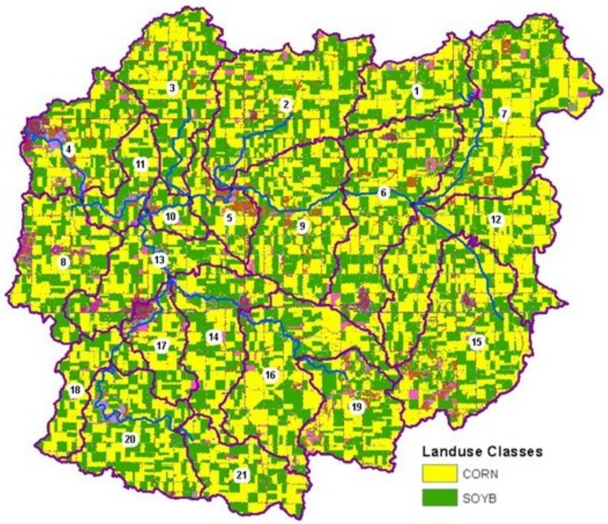




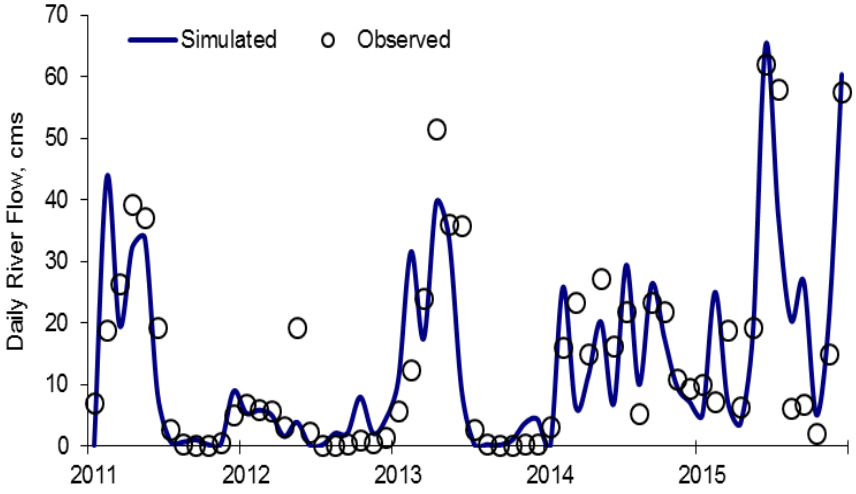
SWAT Model: Baseline Scenario Approach

- Simulate 15 years of N yield at a sub-watershed scale using ‘Baseline’ conditions
- Apply BMPs in the sub-basins and re-model over 15 year period
- Characterize differences between BMP scenario and ‘Baseline’ scenario
  - Focus on practices and adoption rate in paired watersheds to eventually characterize differences using field observations

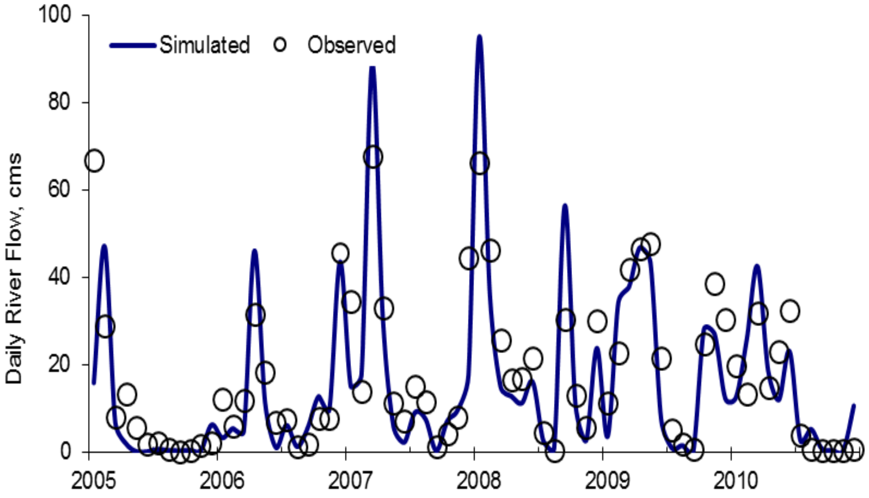
Crop in rotation	Agronomic practice	Assumed date
All corn and soybean acres are assumed to be tile drained		
Corn	Tillage: Field cultivated	April 1
	Fertilizer application (anhydrous N = 107.5 lb/ac N)	April 10
	Planting	April 20
	Harvest	October 10
	Tillage: Chisel plow	October 15
	Fertilizer application (DAP, 45 lb/ac N)	November 1
Soybean	Tillage: Field cultivated	April 25
	Planting	May 1
	Harvest	October 10
	Tillage: Chisel plow	October 20
	Fertilizer application (anhydrous N = 107.5 lb/ac N)	November 1



SWAT Model Calibration



5-year Calibration – R^2 = 0.7



5-year Validation – R^2 = 0.6

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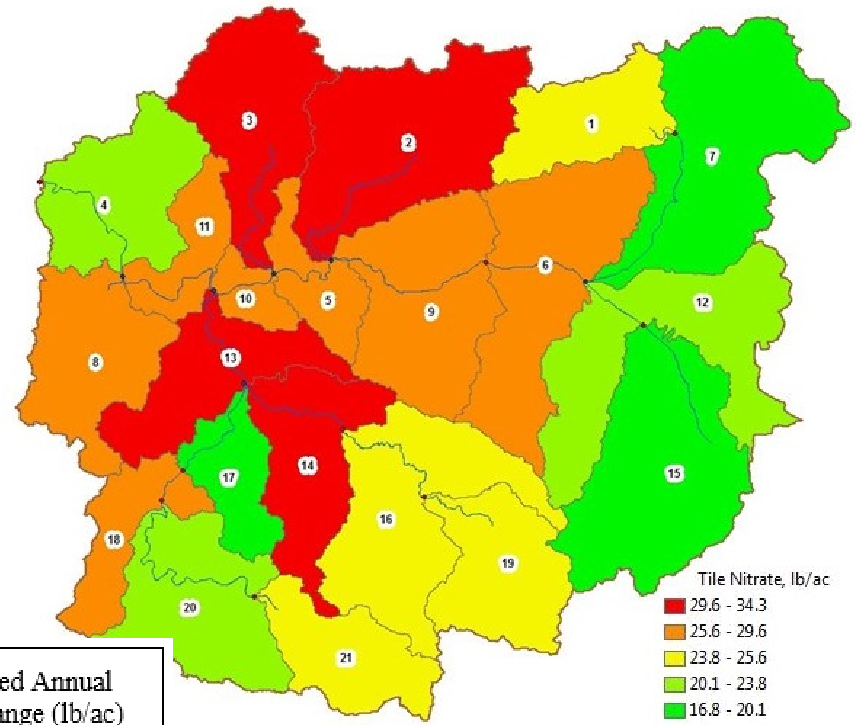
SWAT Model Results Toward Paired Watershed Site Selection

- Spatially-distributed results allowed for watershed ranking, based on N yield
- Provides a framework to evaluate BMPs



Sub-watershed Numbers Included in Relative Ranking	Relative Ranking	SWAT-estimated Annual Average Load range (lb/ac)
2, 3, 13, and 14	High Load Potential (red color)	29.6 – 34.3
5, 6, 8, 9, 10, 11, and 18	Medium-High Load Potential (orange color)	25.6 – 29.6
1, 16, 19, and 21	Medium Load Potential (Yellow)	23.8 – 25.6
4, 12, and 20	Medium-Low Load Potential (Light green)	20.1 – 23.8
7, 15, and 17	Low Load Potential (dark green)	16.8 – 20.1

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Evaluated 5 BMPs and Monitoring Recommendation

- MRTN rate
- Spring anhydrous application only
- 50% cereal rye cover crop
- 35% drainage to constructed wetlands
- Edge-of-field filter strips (not modeled)

- Evaluation criteria:
  - 1) Average annual reduction over 15 years (compared to baseline)
  - 2) How many years out of 15 (modeled years) would you expect an N yield reduction of 5%?
- 10%? Up to 20%.
- Recommended 2 paired watersheds for monitoring

MRTN BMP – reduction potential by SWAT sub-basin

Sub-watershed number	5% reduction	Sub-watershed number	10% reduction	Sub-watershed number	15% reduction	Sub-watershed number	20% reduction
1	100%	1	80%	7	33%	12	20%
2	100%	2	80%	12	33%	7	13%
3	100%	3	80%	15	27%	15	13%
4	100%	4	80%	21	20%	1	7%
5	100%	5	80%	4	13%	2	7%
6	100%	6	80%	16	13%	3	7%
7	100%	7	80%	19	13%	4	7%
8	100%	8	80%	20	13%	5	7%
9	100%	9	80%	1	7%	6	7%
10	100%	11	80%	2	7%	8	7%
11	100%	12	80%	3	7%	9	7%
12	100%	15	80%	5	7%	10	7%
13	100%	16	80%	6	7%	11	7%
14	100%	19	80%	8	7%	13	7%
15	100%	20	80%	9	7%	14	7%
16	100%	21	80%	10	7%	16	7%
17	100%	10	73%	11	7%	17	7%
18	100%	13	73%	13	7%	18	7%
19	100%	14	73%	14	7%	19	7%
20	100%	18	73%	17	7%	20	7%
21	100%	17	60%	18	7%	21	7%

Spring-applied N – reduction potential by SWAT sub-basin

Sub-watershed number	5% reduction	Sub-watershed number	10% reduction	Sub-watershed number	15% reduction	Sub-watershed number	20% reduction
5	80%	14	67%	20	47%	4	33%
10	80%	2	60%	2	40%	12	33%
11	80%	3	60%	4	40%	20	33%
1	73%	4	60%	6	40%	21	33%
2	73%	6	60%	7	40%	1	27%
3	73%	8	60%	8	40%	5	27%
13	73%	9	60%	9	40%	6	27%
4	67%	10	60%	10	40%	7	27%
8	67%	11	60%	11	40%	10	27%
14	67%	13	60%	13	40%	11	27%
16	67%	16	60%	15	40%	15	27%
17	67%	18	60%	19	40%	16	27%
6	60%	19	60%	3	33%	17	27%
9	60%	20	60%	12	33%	18	27%
12	60%	21	60%	16	33%	19	27%
15	60%	1	53%	21	33%	2	20%
18	60%	5	53%	1	27%	3	20%
19	60%	7	53%	5	27%	8	20%
20	60%	12	53%	14	27%	13	20%
21	60%	15	53%	17	27%	14	20%
7	53%	17	40%	18	27%	9	13%

WATERBORNE ENVIRONMENTAL

Cover crops (cereal rye) – reduction potential by SWAT sub-basin

Sub-watershed number	5% reduction	Sub-watershed number	10% reduction	Sub-watershed number	15% reduction	Sub-watershed number	20% reduction
7	93%	17	73%	1	27%	2	13%
15	93%	21	60%	3	20%	4	13%
16	93%	1	53%	5	20%	8	13%
18	93%	4	53%	7	20%	9	13%
21	93%	13	53%	14	20%	10	13%
1	87%	14	53%	17	20%	11	13%
3	87%	18	53%	21	20%	13	13%
4	87%	19	53%	2	13%	17	13%
5	87%	2	47%	4	13%	19	13%
12	87%	3	47%	6	13%	20	13%
14	87%	5	47%	8	13%	1	7%
17	87%	8	47%	9	13%	5	7%
2	80%	10	47%	10	13%	6	7%
6	80%	16	47%	11	13%	7	7%
8	80%	6	40%	12	13%	12	7%
9	80%	7	40%	13	13%	15	7%
10	80%	11	40%	15	13%	16	7%
11	80%	12	40%	16	13%	18	7%
13	80%	20	40%	18	13%	21	7%
19	80%	9	33%	19	13%	3	0%
20	80%	15	33%	20	13%	14	0%

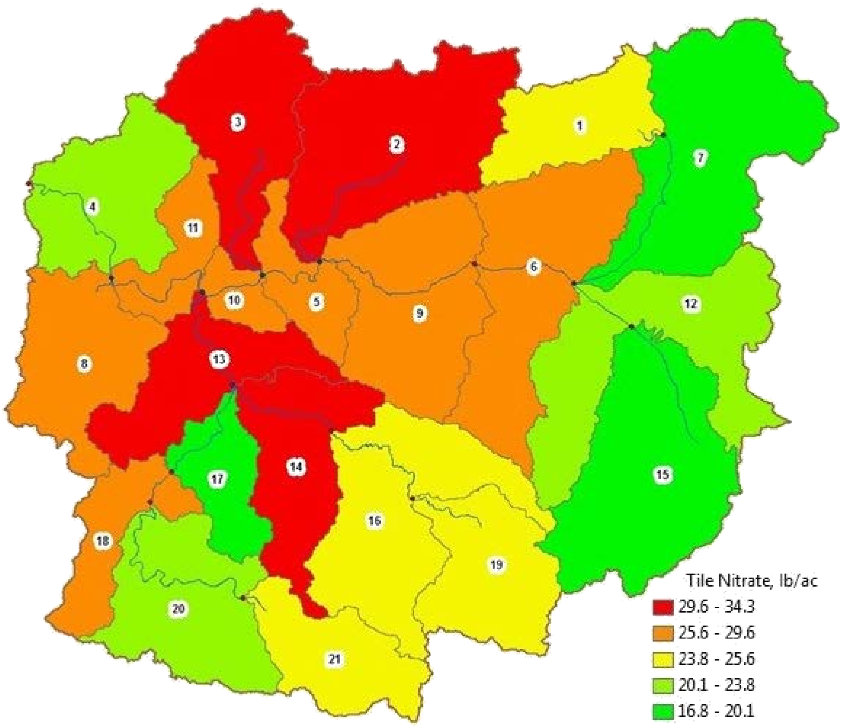
WATERBORNE ENVIRONMENTAL

Edge-of-field Constructed Wetland – reduction potential by SWAT sub-basin

Sub-watershed number	10% reduction	Sub-watershed number	15% reduction	Sub-watershed number	20% reduction	Sub-watershed number	25% reduction
1	100%	1	100%	7	47%	1	20%
2	100%	2	100%	12	47%	2	20%
3	100%	3	100%	15	47%	6	20%
4	100%	4	100%	16	47%	7	20%
5	100%	5	100%	1	40%	9	20%
6	100%	6	100%	4	40%	12	20%
7	100%	7	100%	6	40%	15	20%
8	100%	8	100%	17	40%	16	20%
9	100%	9	100%	19	40%	17	20%
10	100%	10	100%	20	40%	19	20%
11	100%	11	100%	21	40%	4	13%
12	100%	12	100%	2	33%	5	13%
13	100%	13	100%	5	33%	8	13%
14	100%	14	100%	8	33%	10	13%
15	100%	15	100%	9	33%	11	13%
16	100%	16	100%	10	33%	13	13%
17	100%	17	100%	11	33%	14	13%
18	100%	18	100%	13	33%	18	13%
19	100%	19	100%	14	33%	20	13%
20	100%	20	100%	18	33%	21	13%
21	100%	21	100%	3	27%	3	7%

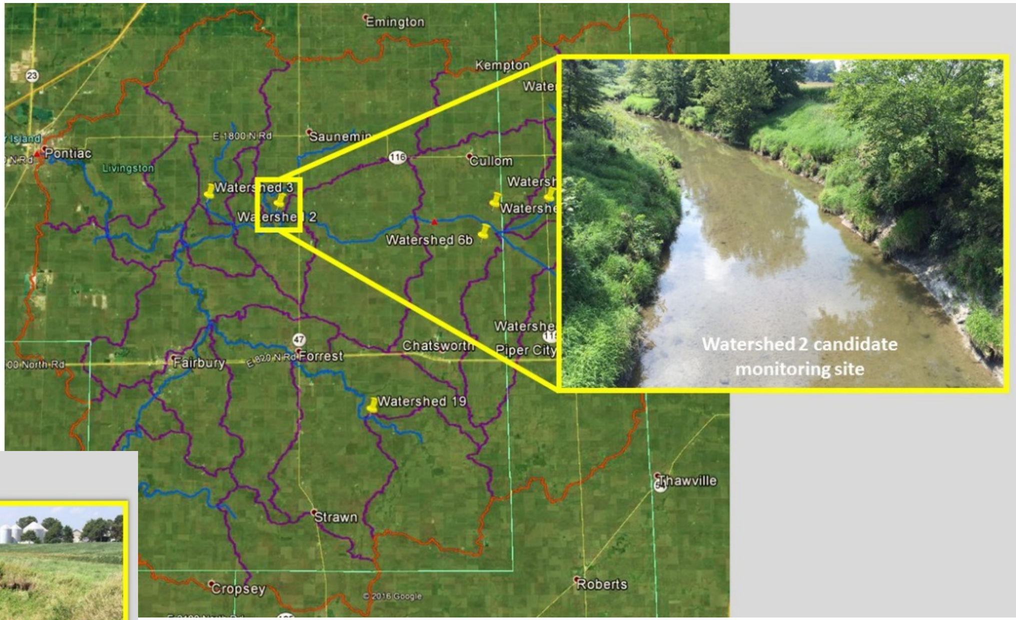
Water Quality Monitoring Considerations

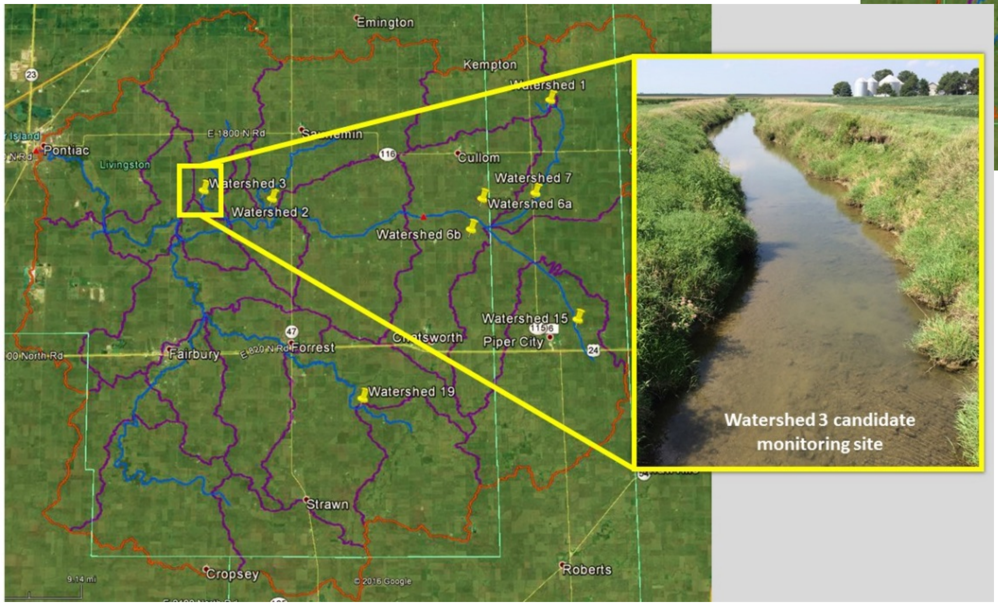
- Proximity to rights of ways, bridges, and other access points
- Consent from land owners to access private property
- Security of equipment to avoid theft, vandalism, and damage from natural phenomenon (e.g. flooding, wind, etc.)
- Paired watersheds were selected so that each pair would represent the same N yield class
- BMP impact within paired watersheds should be probably (according to the modeling) so differences may be observed within a reasonable amount of monitoring time



Two Paired Watersheds Recommended: Watersheds 2 and 3

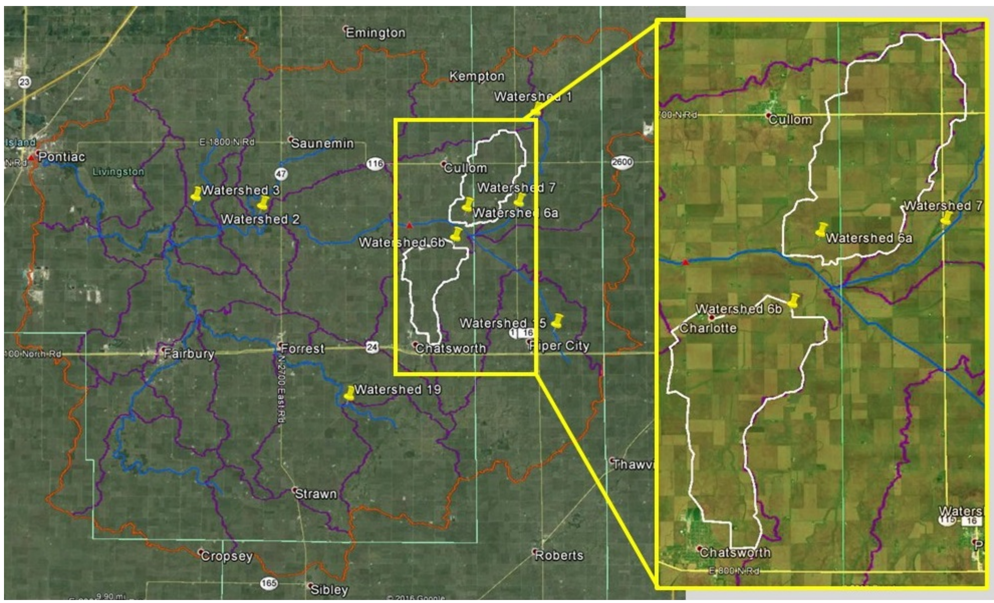
Watersheds 2 and 3	Expected BMP frequency of reaching 10% nitrate loss reduction
MRTN	8 out of 10 years
Spring application	6 out of 10 years
Cover crops	~5 out of 10 years
Wetlands	Every year
Filter strips	Unknown

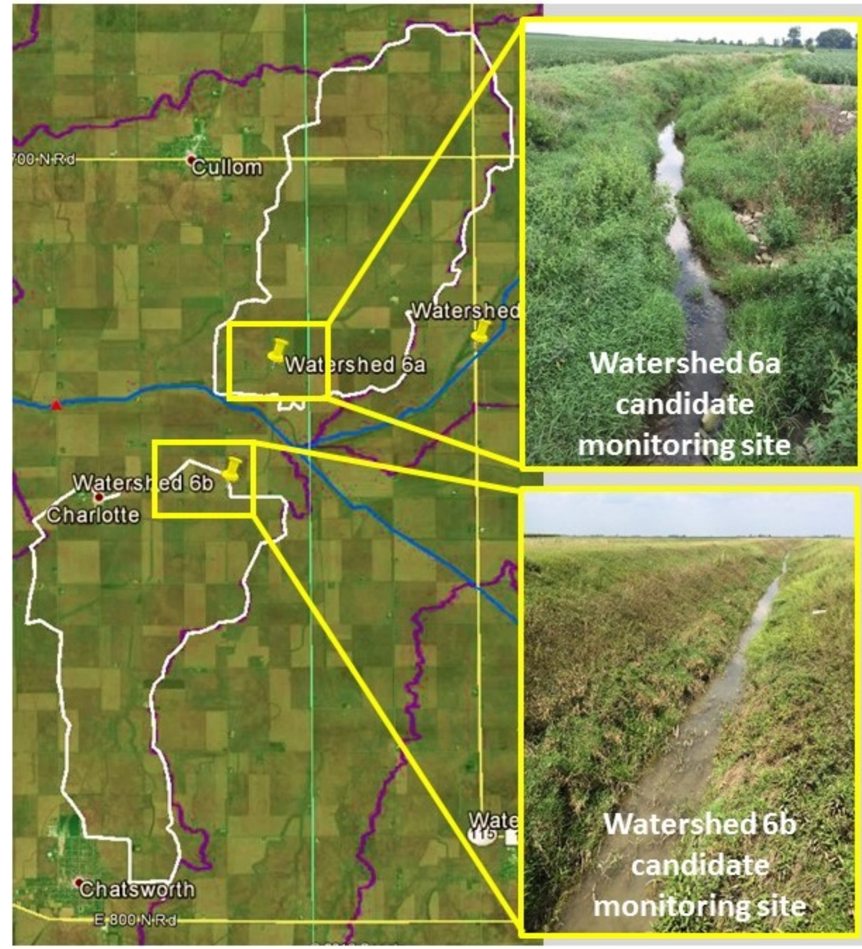




Two Paired Watersheds Recommended: 6a and 6b

Watersheds 6a and 6b	Expected BMP frequency of reaching 10% nitrate loss reduction
MRTN	8 out of 10 years
Spring application	6 out of 10 years
Cover crops	4 out of 10 years
Wetlands	Every year
Filter strips	Unknown






Modeling Priority Watersheds: SWAT Model

Scope of Projects: Priority Watersheds

- **Lake Springfield SWAT modeling** – Lake Springfield Watershed
  - Evaluation of rate, timing, and type
  - Calibration using distributed stream flow data (Waterborne-lead)
  - Presented to city officials (Springfield City Water and Light) and commodity group leadership (Council on Best Management Practices)

- **Indian Creek SWAT modeling** – Vermilion River Headwaters
  - Evaluation of Rate, Timing, and Type
  - Evaluation of impact of cover crops – Presented at Gulf of Mexico Hypoxia Public Meeting (2016)
  - Calibration using USGS gaging station at outlet
  - Presented to city officials and commodity group leadership (Council on Best Management Practices)

Lake Springfield SWAT Modeling

4R modeling: Comparison to a 'baseline'

Objectives:

1) Explore the potential, long-term nutrient loss impact as it relates to Nitrogen source, rate, and timing in two Illinois watersheds
    a. What happens to nutrient loss if we change N source, rate, and timing?
2) Estimate the long-term relationship between nutrient management and potential impact to corn yield
    a. What happens to yield when we change N source, rate, and timing?
3) Use a 'scenario' approach

Baseline Scenarios:

- Lake Springfield – 85% Fall anhydrous, 5% Spring anhydrous, 10% Fall ammonium sulfate (AMS)

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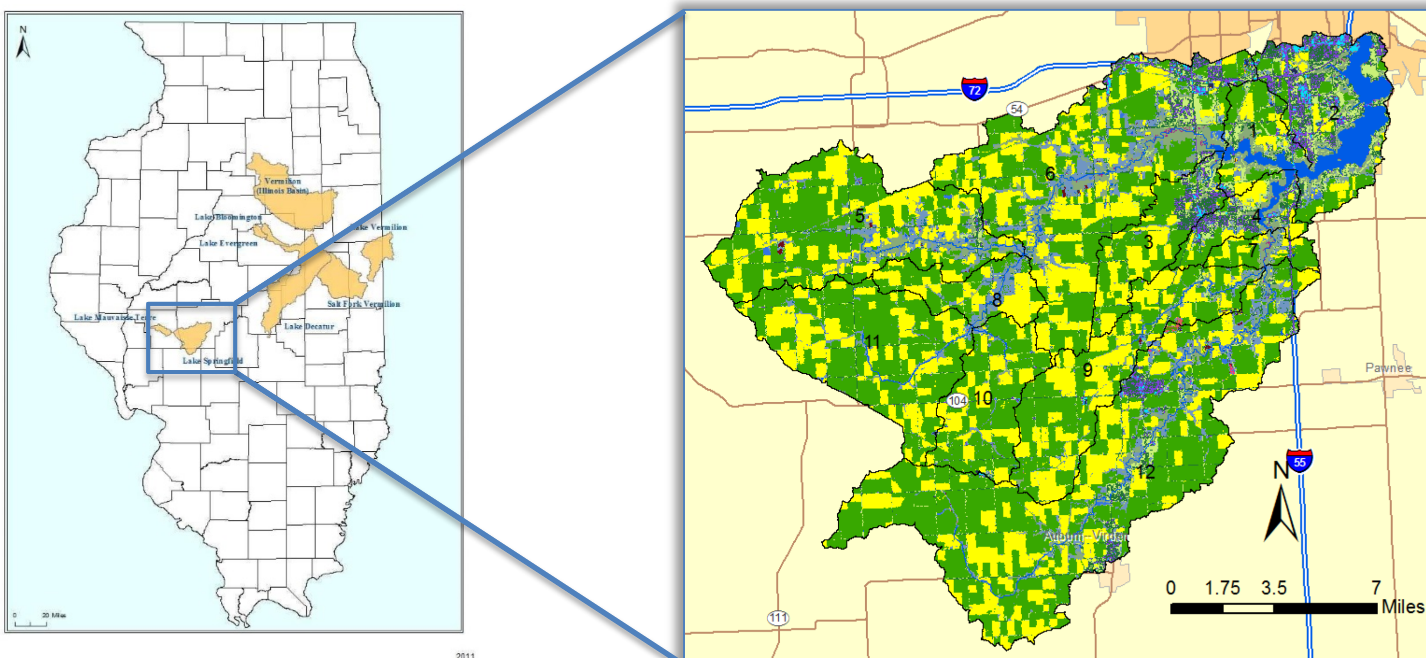
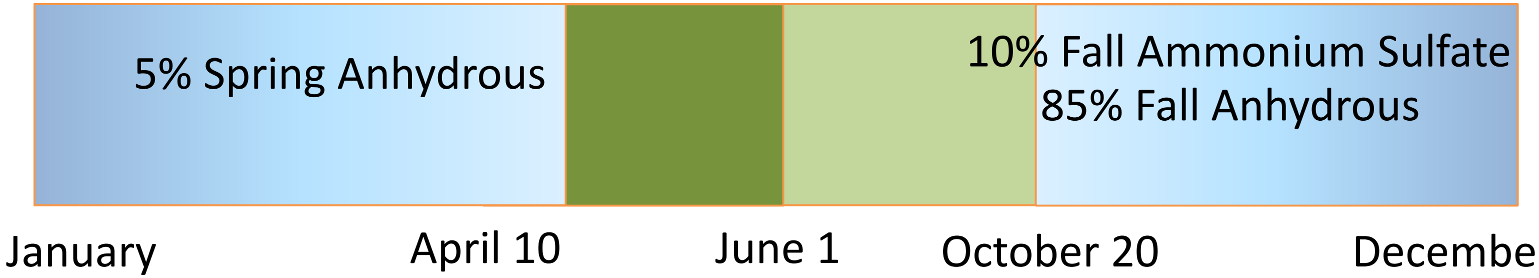
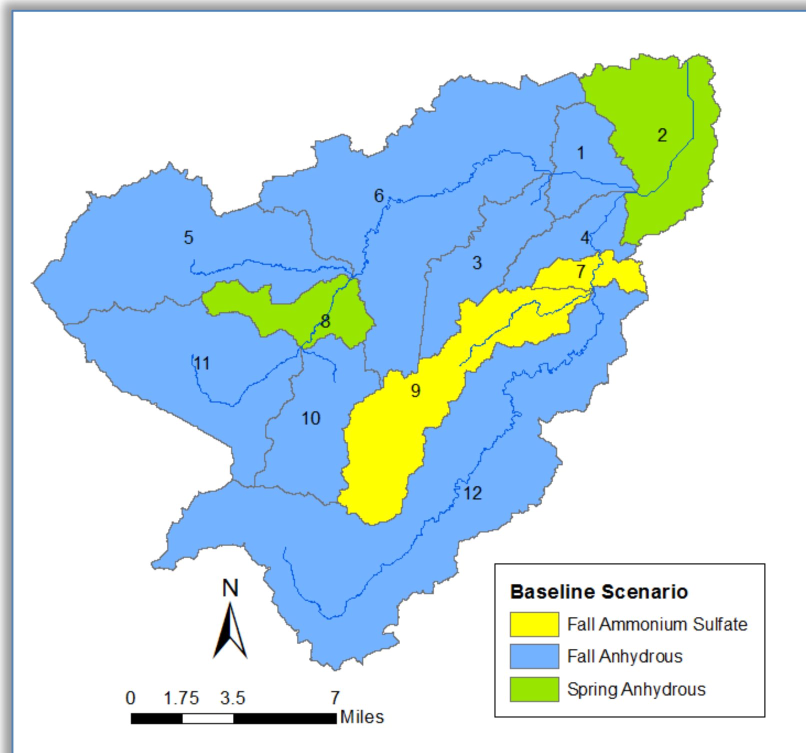
Lake Springfield Location and Characteristics

- Area – 263 sq. mi (located in Sangamon County)
- Corn and beans – 72.6%
- Majority of the watershed slope is < 1.5%
- Silt loam – silty clay loam soils (Ipava, Virden, Osco soils)
- Two tributaries draining to Lake Springfield
- Public water supply for Springfield, IL



‘Baseline Scenario’ Application





Details of 4R Scenarios Evaluated in SWAT: Carried 4 forward for rate assessment

ID	Scenario	Nitrogen (lbs)
Baseline	Fall Anhydrous + Spring Anhydrous + Spring UAN	50%+30%+20%=167
1	Fall Anhydrous (82% N)	167
2	Spring Anhydrous (82% N)	167
3	Spring UAN (28% N)	167
4	Fall UAN	167
5	Spring DAP	167
6	Fall DAP	167
7	Fall DAP + Spring Anhydrous	(30% + 70%) = 167
8	Spring Anhydrous + Spring Sidedress UAN	(70% + 30) = 167
9	Fall Anhydrous + Spring UAN	(50% + 50%) = 167
10	Fall Anhydrous + Spring Anhydrous	(50% + 50%) = 167

Lake Springfield Scenarios – N Rate

- Nitrogen rate was varied over 3 scenarios to simulate the effects of nitrate load and corn yields

Scenario	Nitrogen (lb)	Fall AH (lb)	Spring AH (lb)	Fall DAP + Spring AH (lb)	Spring AH + Sidedress UAN (lb)
Rate 1	167	167	167	167 (30% + 70%)	167 (70% + 30%)
Rate 2	180	180	180	180 (30% + 70%)	180 (70% + 30%)
Rate 3	197	197	197	197 (30% + 70%)	197 (70% + 30%)

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Lake Springfield Scenarios – N Rate Results

- When Fall-only or Fall+Spring applications occurred, Nitrate yield increased by ~5-10% for any rate
- Fall-only application resulted a yield decrease of 3-5%
- Similar trend was observed across 3 rates

Nitrate Yield

Nitrogen (lb/ac)	Fall Anhydrous	Spring Anhydrous	Fall DAP + Spring Anhydrous	Spring Anhydrous + Side-dress UAN
167	35	25	30	26
180	38	27	33	28
197	41	29	37	29

Corn Yield (bu/ac)

Nitrogen (lbs)	Fall Anhydrous	Spring Anhydrous	Fall DAP + Spring Anhydrous	Spring Anhydrous + Side-dress UAN
167	157	161	160	162
180	159	163	162	163
197	160	164	163	164

N Loss Reduction Comparison to Scenarios

- Baseline results: The 25-year average nitrate yield with baseline scenario was 38 lbs/ac

- **Fall-only** applications caused a 3% average increase in nitrate yield, while the **Spring-only** and Combined increased nitrate yield reduction by 24-43%

Nitrate (lbs/ac)	Fall	Spring	Combined	Baseline
Average	40	27	31	38
Change from Baseline	+3%	-43%	-24%	--

Fall Anhydrous(85%) + Fall AMS (10%) + Spring Anhydrous (5%)

Scenario (all at 167 lb)
Fall Anhydrous
Fall UAN
Fall DAP
Spring Anhydrous
Spring UAN
Spring DAP
Spring Anhydrous + Sidedress UAN
Fall DAP + Spring Anhydrous
Fall Anhydrous + Spring UAN
Fall Anhydrous + Spring Anhydrous

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Yield Comparison to Scenarios

- Baseline results: Corn yields were 156 bu/ac +/- 40%
- 25-year Average results: Corn yields essentially the same as applications while **Spring** and Combined had ~3-5% increas to baseline

Scenario (all at 167 lb)
Fall Anhydrous
Fall UAN
Fall DAP
Spring Anhydrous
Spring UAN
Spring DAP
Spring Anhydrous + Sidedress UAN
Fall DAP + Spring Anhydrous
Fall Anhydrous + Spring UAN
Fall Anhydrous + Spring Anhydrous

Corn Yield (bu/ac)	Fall	Spring	Combined	Baseline
Average	155	161	159	156
Change from Baseline	~0	+5	+3	--

WATERBORNE ENVIRONMENTAL

4R Scenario Ranking for N Loss

- Spring months produced high nitrate yields regardless of timing of application
- Fall N application have high nitrate yields (Avg Annual yield = 40 lbs/ac) compared to Spring and Combined N applications produced ~ 27 lbs/ac

ID	Scenario	Nitrogen (lb)	High to low loss
1	Fall Anhydrous	167	Highest loss (~40%)
9	Fall Anhydrous + Spring UAN	(50% + 50%) = 167	
10	Fall Anhydrous + Spring Anhydrous	(50% + 50%) = 167	
7	Fall DAP + Spring Anhydrous	(30% + 70%) = 167	
8	Spring Anhydrous + Spring Sidedress UAN	(70% + 30) = 167	
2	Spring Anhydrous	167	Lowest loss (~27%)

WATERBORNE ENVIRONMENTAL

4R Scenario Comparison to Baseline

Year	Fall AH	Spring AH	Fall DAP + Spring AH	Spring AH + Sidedress UAN	Fall AH + Spring UAN	Fall AH + Spring AH
1990	8	45	31	42	21	26
1991	7	28	13	28	15	17
1992	8	35	20	35	9	21
1993	1	41	30	41	16	21
1994	6	28	16	22	-5	[illegible]
1995	-4	16	-1	14	3	[illegible]
1996	7	27	14	22	14	[illegible]
1997	-3	17	-14	16	4	7
1998	10	20	8	20	13	15
1999	3	20	17	17	10	12
2000	5	26	20	25	14	16
2001	-1	23	15	21	9	11
2002	15	31	24	30	23	23
2003	26	32	16	31	30	29
2004	3	44	30	43	16	23
2005	13	25	20	23	17	19
2006	12	37	29	40	18	24
2007	2	32	20	31	13	17
2008	19	44	36	45	19	32
2009	6	36	10	37	12	21
2010	1	51	36	52	18	26
2011	25	31	31	32	26	29
2012	14	30	24	27	20	22
2013	19	27	22	27	18	22
2014	9	25	12	21	-4	17

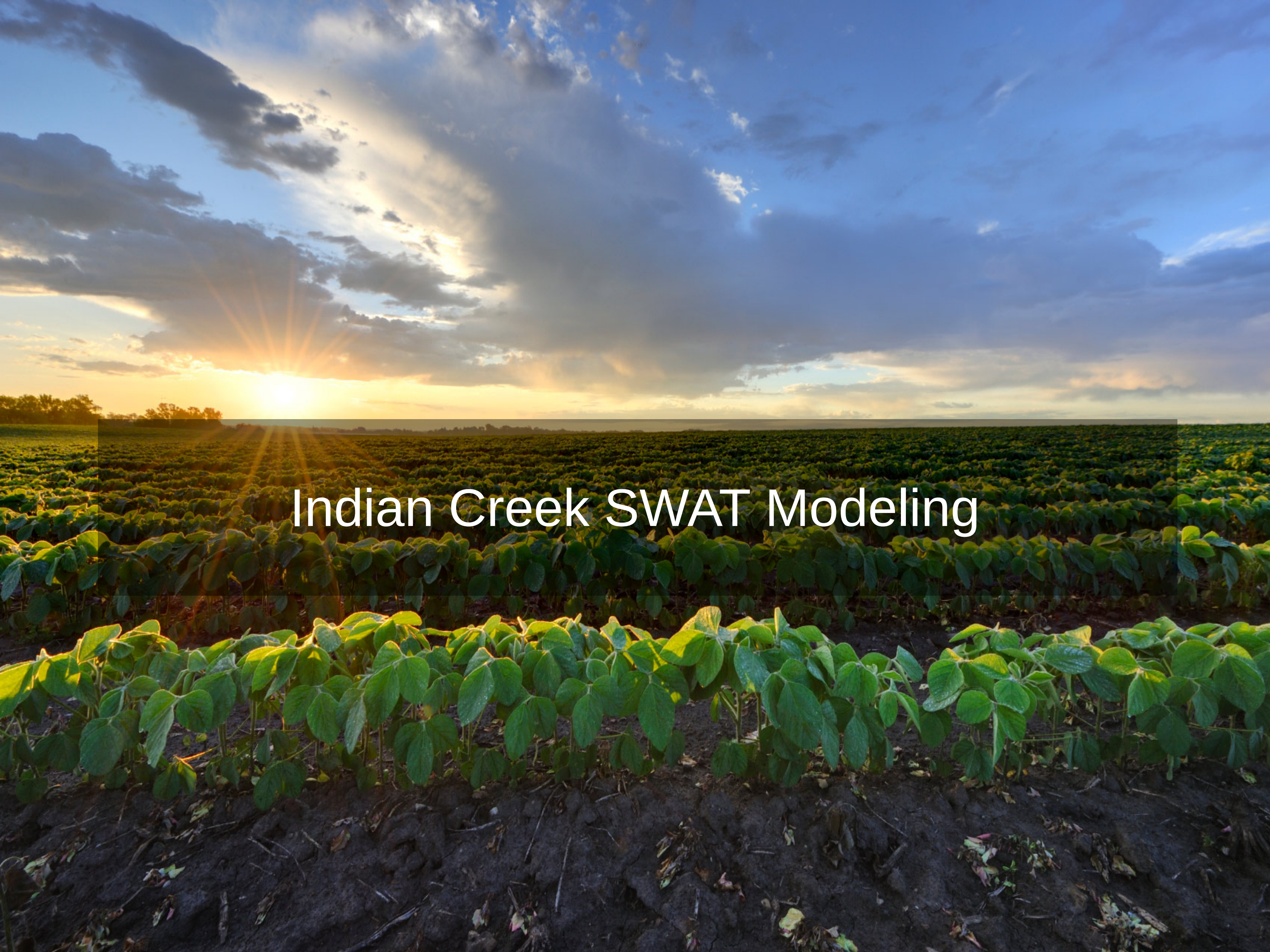
Scenario (167 lb)
Fall Anhydrous
Spring Anhydrous
Fall DAP + Spring Anhydrous
Spring Anhydrous + Sidedress UAN
Fall Anhydrous+ Spring UAN (50/50% split)
Fall Anhydrous + Spring Anhydrous

Nitrate yield

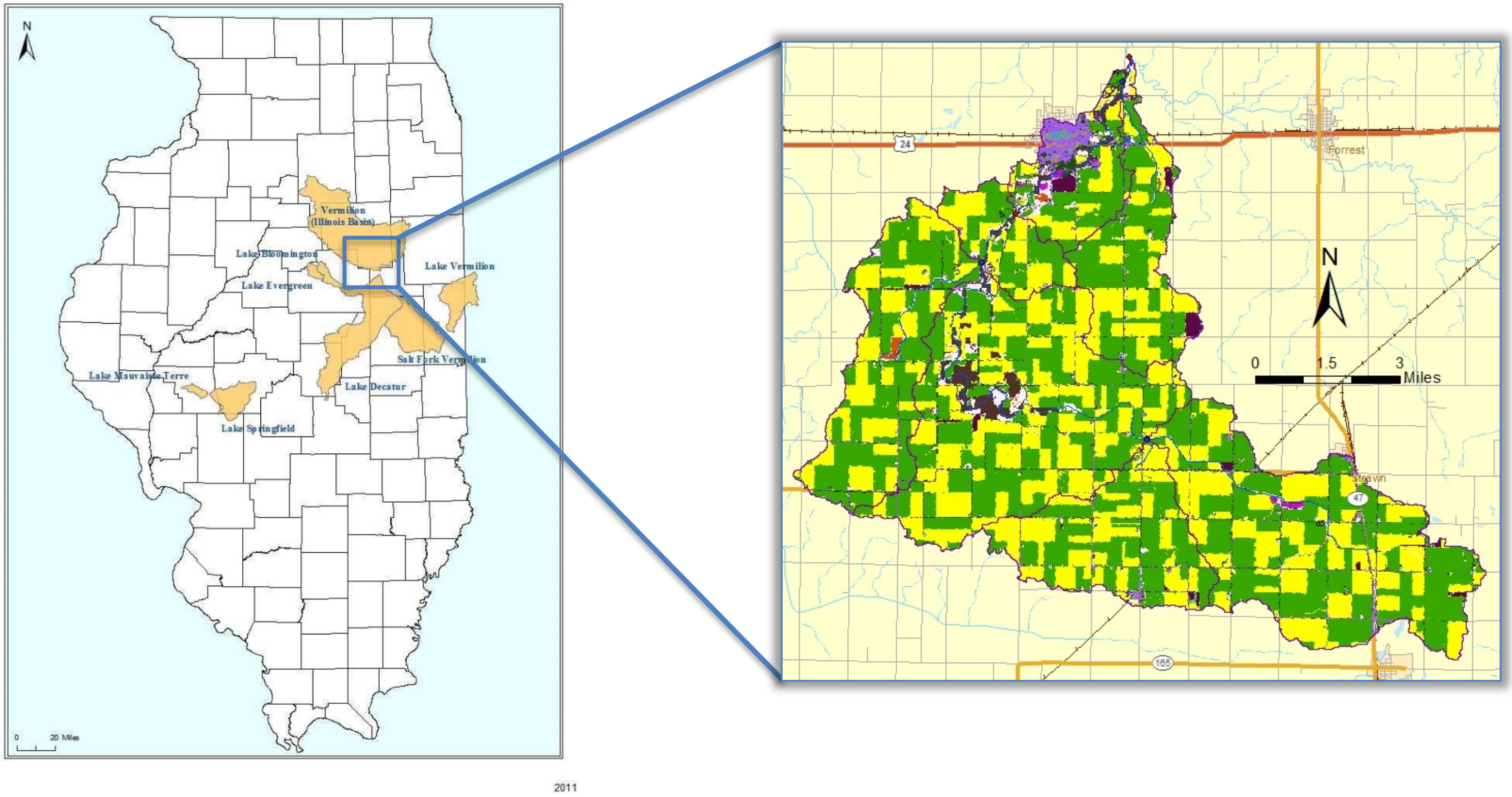
10% improvement in N loss: Best case: 19/25 years (76% of the time)

Lake Springfield Summary

- Explored 10 scenarios – compared to a baseline practice
- Spring-only and Combined Fall+Spring applications resulted in lower nitrate yields (24-43% reduction) compared to baseline (95% fall)
- Yield increase using split applications was marginal (3-5%) but positive
- Switching to 50/50% Fall/Spring split e.g. Anhydrous/UAN resulted in greater than 10% improvement in nitrate loss 76% of the time

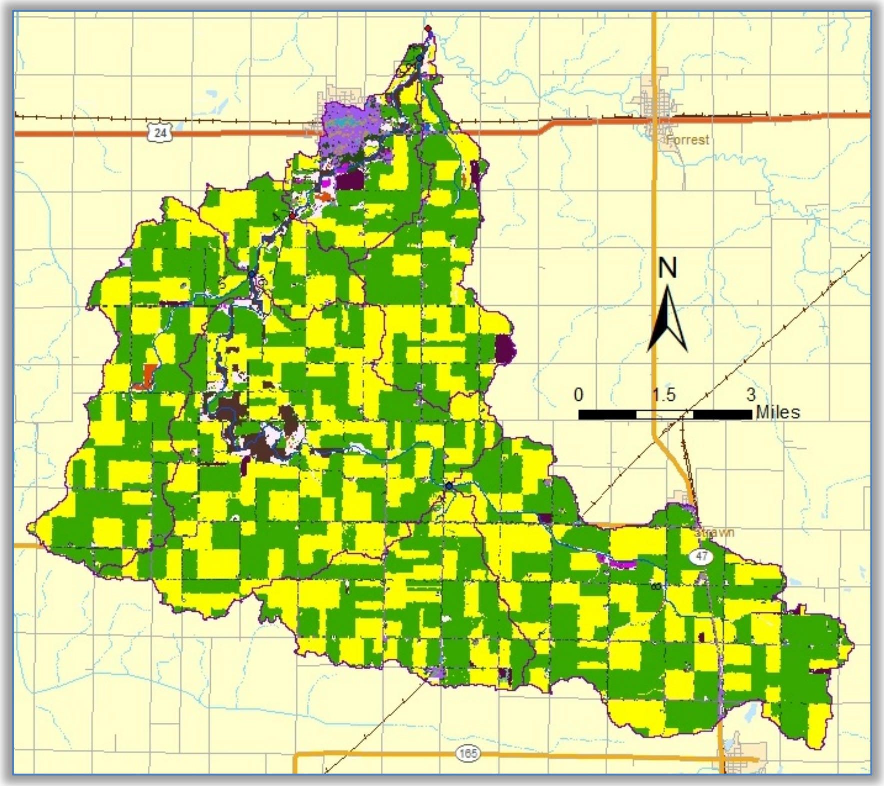

Indian Creek SWAT Modeling

Indian Creek Location



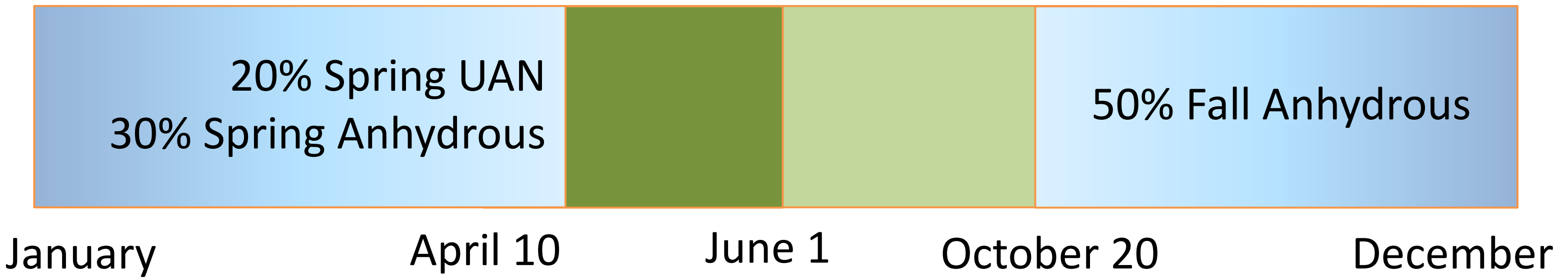
Indian Creek Watershed Characteristics

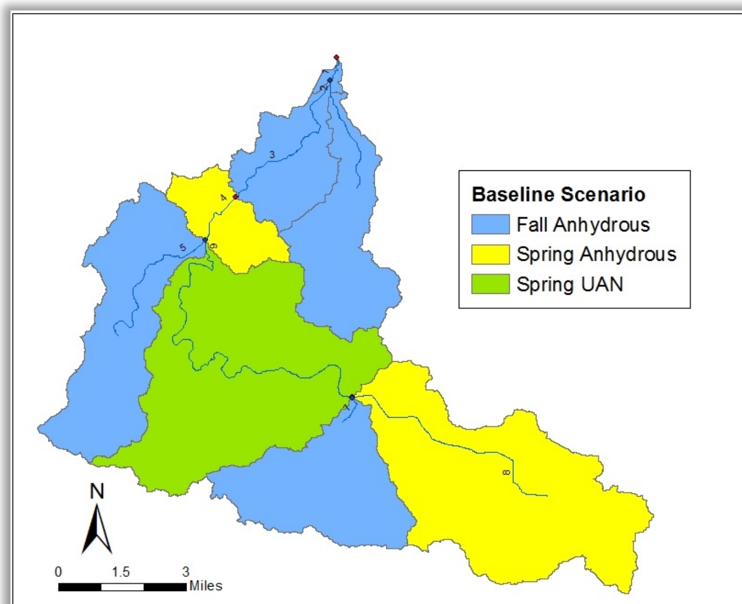
- Area – 77 sq. mi (Drains to Vermillion River Watershed)
- Corn and beans – 88%
- Urban – 5.9%
- Majority of watershed slope is < 2%
- Silty loam – Silty clay- Loamy soils (Drummer, Reddick, Elliott etc)



4R modeling: Comparison to a ‘baseline scenario’

- Indian Creek – 50 % Fall anhydrous, 30% Spring anhydrous, 20% Spring Urea-applied-N (UAN)





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Baseline Crop Management Scheme

Year	Date	Operation	Crop
1	April 1	Tillage – Field Cultivator	Corn
	April 20	Planting	
	October 10	Harvest	
	October 20	Tillage – Chisel Plow	
2	April 1	Tillage – Field Cultivator	Soybean
	April 15	Planting	
	October 10	Harvest	
	October 20	Tillage – Chisel Plow	

Years 1 and 2 are repeated for 25 years

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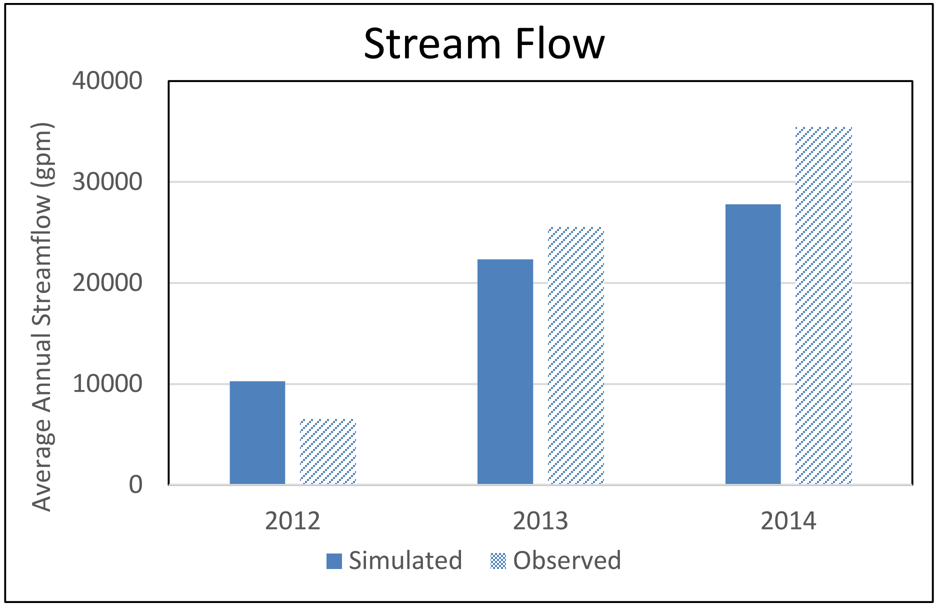
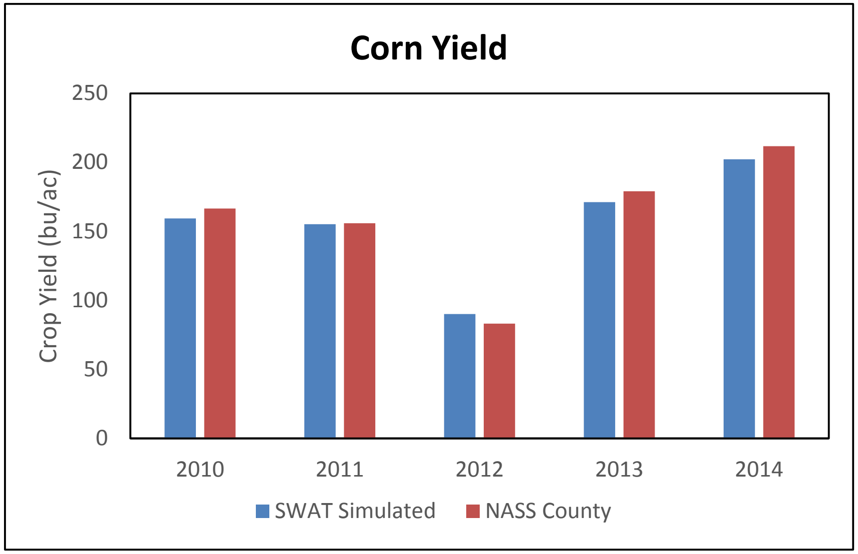
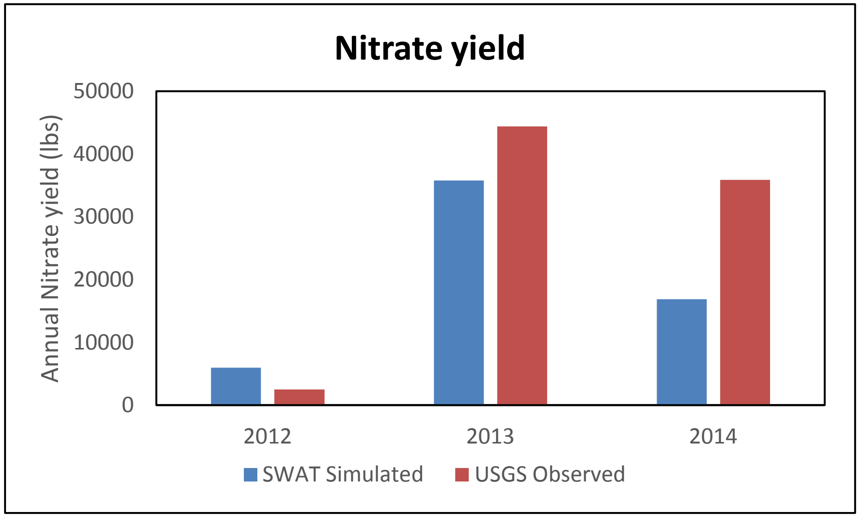
Model Calibration Results







* USGS measured stream nitrate concentrations in June, July 2014 were between 18-25 mg/L. SWAT under-predicted during those times.

WATERBORNE ENVIRONMENTAL

N Rate Evaluation

- When Fall-only or Fall+Spring applications occurred, Nitrate yield increased by ~5-8% for any rate
- Fall-only application resulted a yield decrease of 4-6%
- Similar trend was observed across 3 rates

Nitrate yield (lb)

Nitrogen (lb)	Fall Anhydrous	Spring Anhydrous	Fall DAP + Spring Anhydrous	Spring Anhydrous + Side-dress UAN
167	30	22	27	22
180	32	24	29	24
197	36	27	32	26

Corn Yield (bu/ac)

Nitrogen (lbs)	Fall Anhydrous	Spring Anhydrous	Fall DAP + Spring Anhydrous	Spring Anhydrous + Side-dress UAN
167	156	162	160	162
180	158	164	162	164
197	160	165	164	165

4R Scenario Ranking for N Loss

- Same order as Lake Springfield
- Spring months produced high nitrate yields regardless of timing of application
- Fall N application have high nitrate yields (Avg Annual yield = 30 lbs/ac) compared to Spring and Combined N applications produced ~ 24 lbs/ac

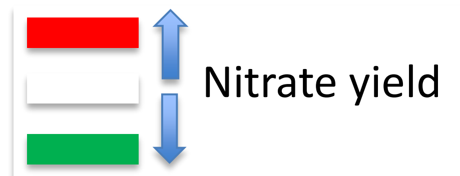
ID	Scenario	Nitrogen (lb)	High to low loss
1	Fall Anhydrous	167	Highest loss (~30%)
9	Fall Anhydrous + Spring UAN	(50% + 50%) = 167	
10	Fall Anhydrous + Spring Anhydrous	(50% + 50%) = 167	
7	Fall DAP + Spring Anhydrous	(30% + 70%) = 167	
8	Spring Anhydrous + Spring Sidedress UAN	(70% + 30) = 167	
2	Spring Anhydrous	167	Lowest loss (~24%)

WATERBORNE ENVIRONMENTAL

N Timing Compared to Baseline Scenario

Year	Fall AH	Spring AH	Fall DAP + Spring AH	Spring AH + Sidedress UAN	Fall AH + Spring UAN	Fall AH + Spring AH
1990	-36	17	-6	14	-20	-12
1991	-26	6	-13	9	-18	-13
1992	-29	-1	-18	-3	-23	-14
1993	-48	17	-7	18	-26	-16
1994	-18	7	-23	7	[illegible]	-13
1995	-23	-10	-42	-10	[illegible]	-42
1996	-23	11	-16	9	[illegible]	-11
1997	-19	5	-17	5	[illegible]	-9
1998	-8	1	-8	1	-3	-2
1999	-10	1	-4	-3	-7	-6
2000	-11	5	-2	2	-5	-6
2001	-42	1	-17	1	-27	[illegible]
2002	-19	-16	-16	-16	-11	[illegible]
2003	-16	0	-24	-1	-10	[illegible]
2004	-33	22	3	22	-14	[illegible]
2005	-12	3	-3	2	-8	-4
2006	-27	11	-3	14	-16	-9
2007	-29	14	-4	12	-13	-7
2008	-25	17	0	20	-19	-5
2009	-33	12	-18	14	-23	-10
2010	-46	21	1	20	-25	-18
2011	-13	6	0	10	-7	-3
2012	-6	2	1	3	3	1
2013	-19	-12	-19	-8	-19	-16
2014	-7	11	1	13	-11	3

Scenario (167 lb)
Fall Anhydrous
Spring Anhydrous
Fall DAP + Spring Anhydrous
Spring Anhydrous + Sidedress UAN
Fall Anhydrous+ Spring UAN
Fall Anhydrous + Spring Anhydrous



10% improvement in N loss:
Best case: 10/25 years (40%)

N Loss Reduction comparison to Baseline Scenario

- Baseline results: The 25-year average nitrate yield with baseline scenario was 23 lbs/ac (with annual loss of up to 26%)

- **Fall-only** applications caused a 30% increase in nitrate yields, while the **Spring-only** and Combined attributed to 2 and 12 % of nitrate yield reduction

Scenario (all at 167 lb)
Fall Anhydrous
Fall UAN
Fall DAP
Spring Anhydrous
Spring UAN
Spring DAP
Spring Anhydrous + Sidedress UAN
Fall DAP + Spring Anhydrous
Fall Anhydrous + Spring UAN
Fall Anhydrous + Spring Anhydrous

Nitrate (lbs/ac)	Fall	Spring	Combined	Baseline
Average	30	24	26	23
Change from Baseline	+23%	+2%	+12%	--

Yield Comparison to Baseline Scenario

- Baseline results: Corn yields were 151 bu/ac +/- 36%
- 25-year Average results: Corn yields essentially the same as baseline for **Fall-only** applications while **Spring** and Combined had ~ 5% increase in yield, compared to baseline

Scenario (all at 167 lb)
Fall Anhydrous
Fall UAN
Fall DAP
Spring Anhydrous
Spring UAN
Spring DAP
Spring Anhydrous + Sidedress UAN
Fall DAP + Spring Anhydrous
Fall Anhydrous + Spring UAN
Fall Anhydrous + Spring Anhydrous

Corn Yield (bu/ac)	Fall	Spring	Combined	Baseline
Average	152	162	158	153
Change from Baseline	~0%	+6%	+4%	--

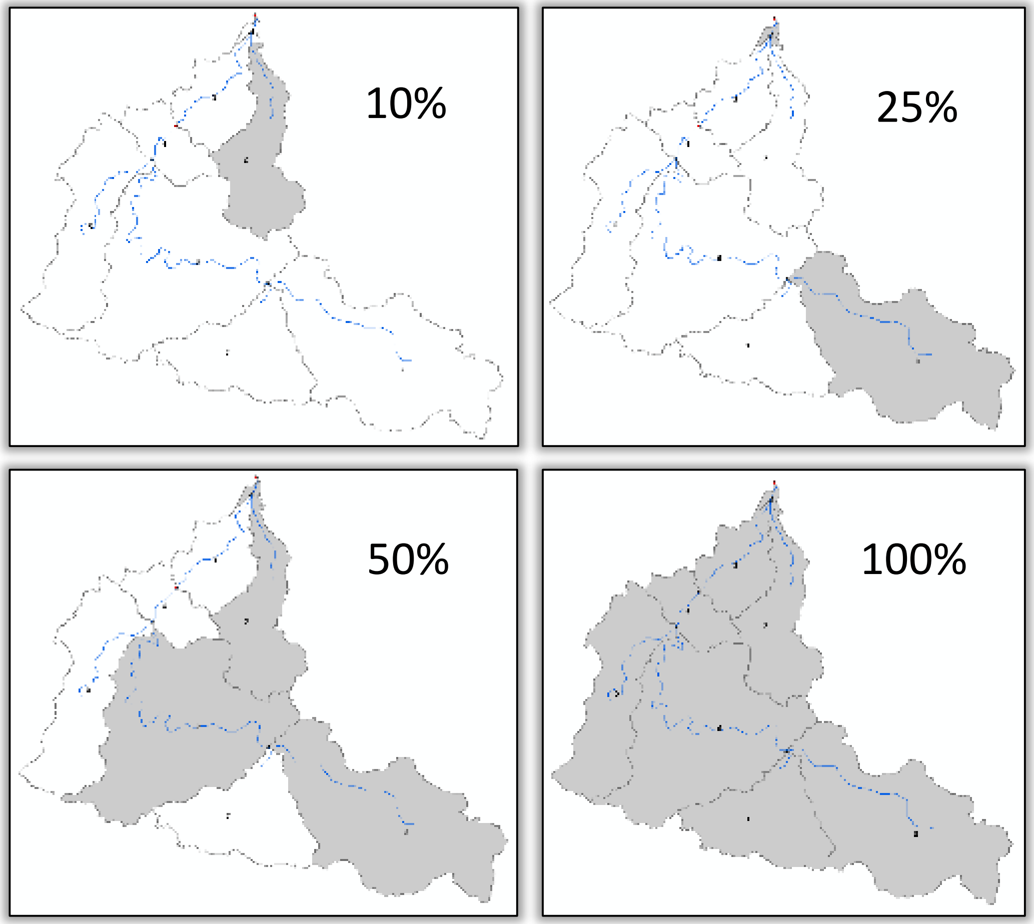
WATERBORNE ENVIRONMENTAL

Summary of Indian Creek Watershed

- Explored 10 scenarios – compared to a baseline practice
- Fall + Spring application did not appear to have significant long-term benefits in yield and resulted in higher nitrate loss (12-23% increase from baseline)
- Even the best scenarios of N application timing (**Spring AH** and **Spring AH + Spring Side dress**) resulted in a ~40% chance of improving N loss, compared to the baseline practice

Assessing Potential Impact of Cover Crops Adoption on Nitrate Reduction

- One primary purpose of cover crops is to improve soil quality
- Reduce soil erosion, improve porosity, organic matter
- The goal of this project is to understand the impacts of cover crops on water quality and crop yield
    - At 10%, 25%, 50%, 100% coverage of the watershed



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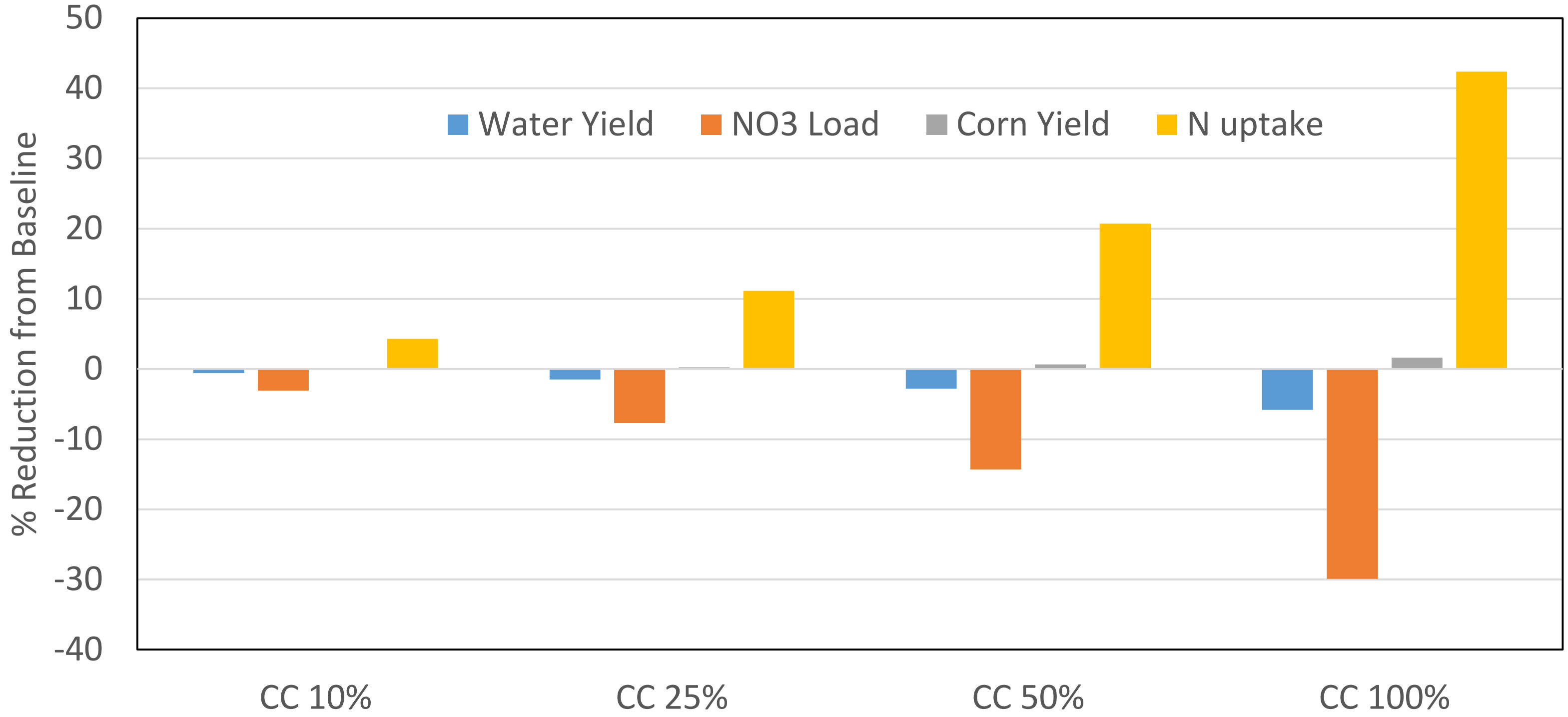
Indian Creek Cover Crop Results



	10% Cover Crop	25% Cover Crop	50% Cover Crop	100% Cover Crop
Water Yield	- 0.6	- 1.5	- 2.8	- 5.8
NO3 Load	- 3.1	- 7.7	- 14.3	- 29.9
Corn Yield	0.1	0.2	0.6	1.6
N uptake	4.3	11.1	20.7	42.4

Potential Future Work

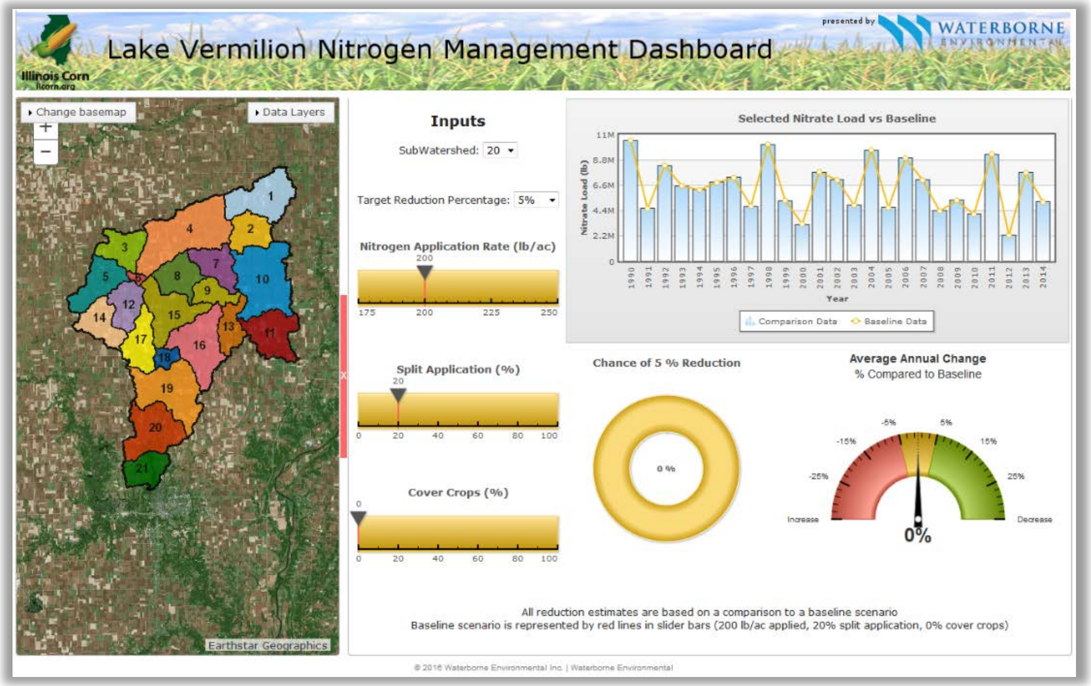
- **Temporary flooding impacts on crop yield**
  - An innovative approach to identify in-field ponding areas using LiDAR DEM and NRCS soils data
  - DRAINMOD will be used to identify flooded areas and crop damage
  - SWAT will be used to assess cover crop impacts in crop damage areas and N losses

- **Model nitrogen stabilizers**
  - DRAINMOD-N model is capable of simulating N dynamics in poorly drained soils
  - SWAT N routines will be updated with DRAINMOD-N routines to assess N stabilizers impacts on N loss
- **Nutrient Yield Web-based Dashboards**
  - Beta versions exist for Lake Vermilion watershed
  - Allow users to understand combinations of 4R practices and other BMPs
  - Can be linked to stewardship and yield in cost-benefit framework


Modeling Priority Watersheds:
Concentration and Load Dashboards

N yield Web-Based Dashboard – Beta

- Allows user to evaluate management practices at watershed scale
- 9000+ combinations of SWAT runs (beta)
- Focus on yield (loss of efficiency)
- Accessible, engaging, and simple for the user
- Allow users to dynamically change important parameters
- Provide output that is useful
- Provide transparency



WATERBORNE
ENVIRONMENTAL

Concentration Web-based Dashboard – Beta

- Converts the statistical model into a predictive tool
- Allows user to interact with the statistical model to increase engagement
- Future potential
  - Rely on real-time information (currently looks historical)
  - Add uncertainty bounds
  - Add tillage (recently discovered dataset)
  - Add more years of calibration
  - Increase application to other watersheds