IIHR Nutrient Trading Update

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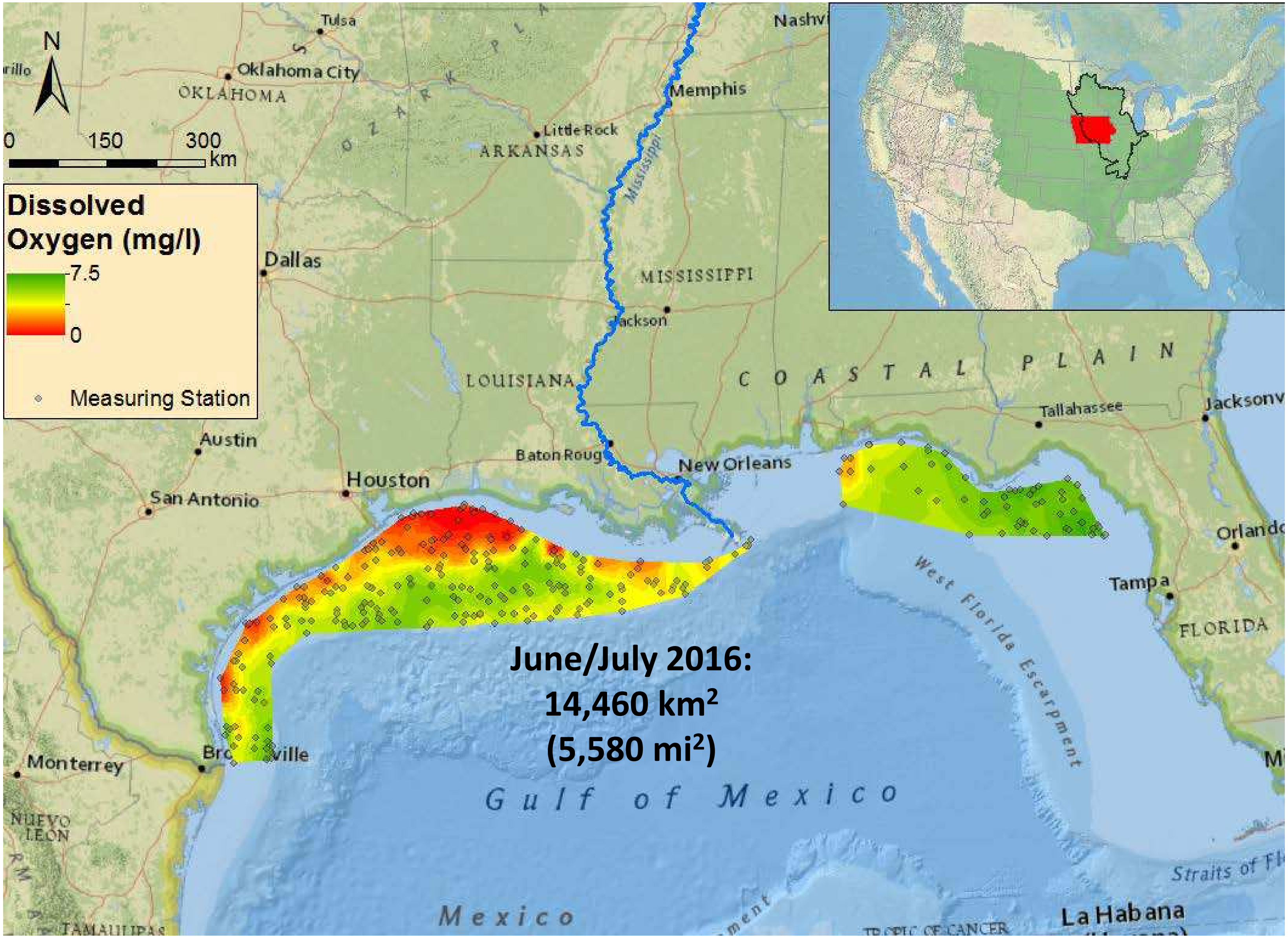
IIHR Hydroscience & Engineering

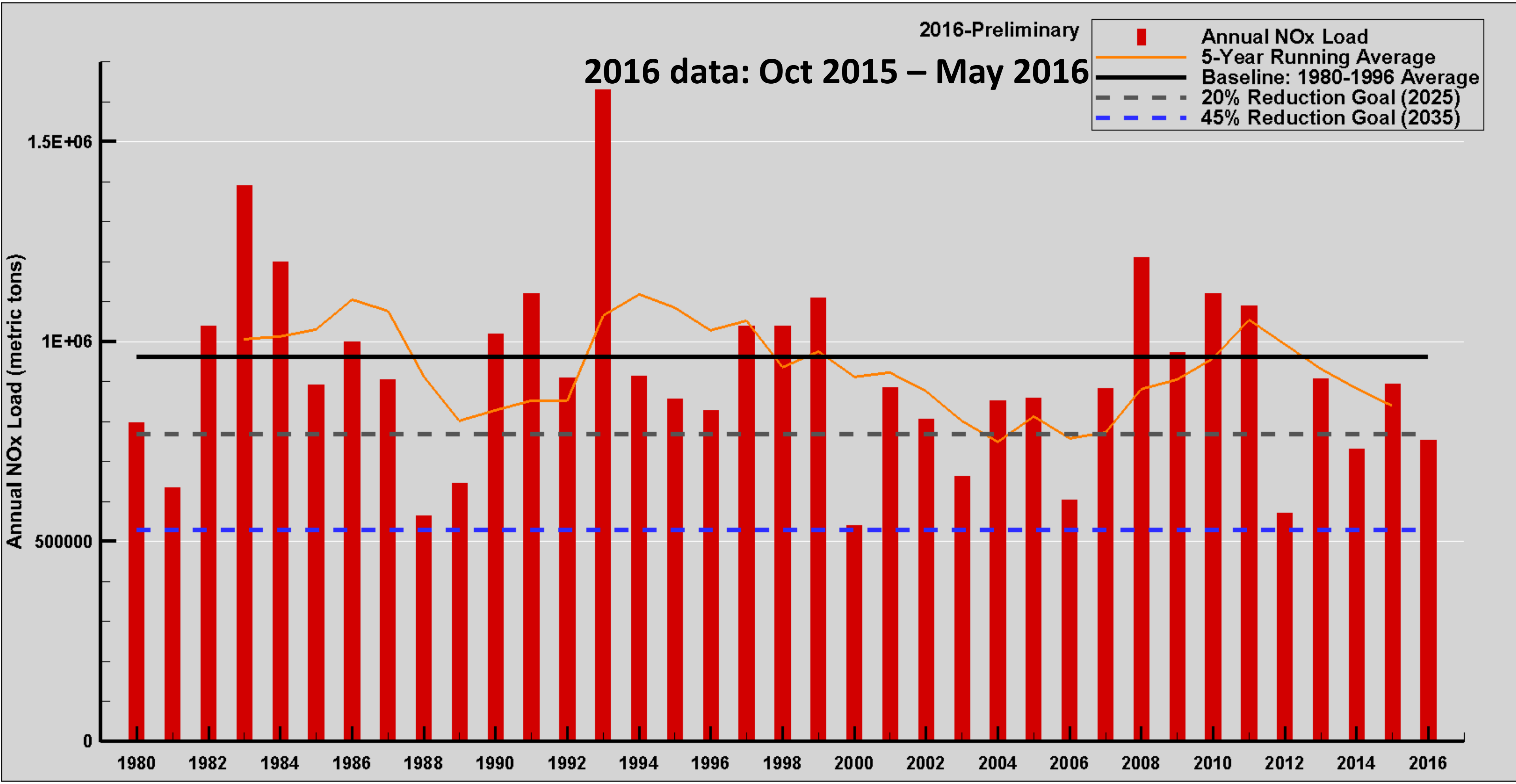
The overall goal of this research is to develop the scientific framework for a nutrient trading system in Iowa.

- Specific objectives:
  1. Develop a physically-based hydrologic and water quality watershed model of Catfish Creek to determine the coupled water quantity and quality benefits of agricultural conservation practices
  2. Develop riverine and terrestrial (crop) nitrogen process models and couple to the physically-based hydrologic model to simulate nitrogen fate and transport
  3. Use numerical simulations to evaluate the performance of individual conservation practices
  4. Perform integrated watershed modeling in Catfish Creek to quantify the nitrogen load and flow reductions possible at the watershed scale under different practice scenarios

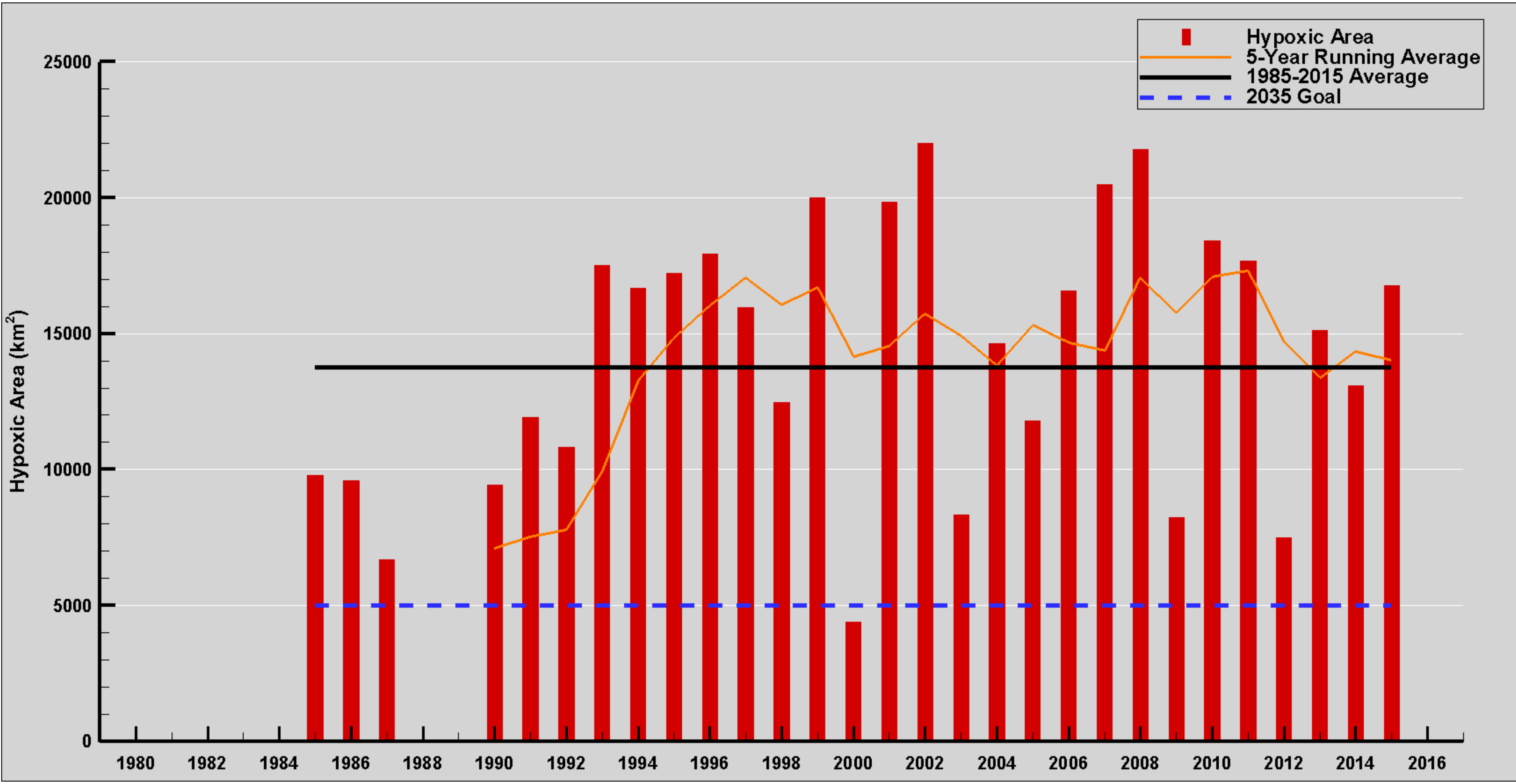
The broader motivation for this research stems from the Gulf Hypoxia.



Gulf Hypoxia Task Force Goals: Load



Gulf Hypoxia Task Force Goals: Area



The Iowa Nutrient Reduction Strategy (INRS) identifies specific nutrient reduction goals and offers nutrient trading as a water quality restoration technique.

Table 1 from the INRS (2014)

	Practice	Comments	% Nitrate-N Reduction[+]			% Corn Yield Change[++]		
			Min	Average (SD*)	Max	Min	Average (SD*)	Max
Nitrogen Management	Timing	Moving from Fall to Spring Pre-plant Application	-80	6 (25)	43	-16	4 (16)	71
		Spring pre-plant/sidedress 40-60 split Compared to Fall Applied	-60	5 (28)	33	2	10 (7)	25
		Sidedress - Compared to Pre-plant Application	-95	7 (37)	45	-3	0 (3)	5
		Sidedress - Soil Test Based Compared to Pre-plant	-29	4 (20)	45	-12	13 (22)**	70
	Source	Liquid Swine Manure Compared to Spring-Applied Fertilizer	-9	4 (11)	25	-17	0 (13)	35
		Poultry Manure Compared to Spring Applied Fertilizer	-32	-3 (20)	21	-33	-2 (14)	73
	Nitrogen Application Rate	Reduce to Maximum Return to Nitrogen value 149 kg N/ha (133 lb N/ac) for CS and 213 kg N/ha (190 lb N/ac) for CC	0	10‡	27	0	-1‡‡	-1
	Nitrification Inhibitor	Nitrapyrin in Fall - Compared to Fall-Applied without Nitrapyrin	-33	9 (19)	33	-4	6 (22)	104
	Cover Crops	Rye	-10	31 (29)	94	-28	-6 (7)	5
		Oat	26	28(2)***	30	-6	-5 (1)	-4
	Living Mulches	e.g. Kura clover - Nitrate-N reduction from one site	12	41 (16)	53	-86	-9 (32)	71
Land Use	Perennial	Energy Crops - Compared to Spring-Applied Fertilizer	26	72 (23)	98		-100[Y]	
		Land Retirement (CRP) -Compared to Spring- Applied Fertilizer	67	85 (9)	98		-100[Y]	
	Extended Rotations	At least 2 years of alfalfa in a 4 or 5 year rotation	24	42 (12)	62	-27	7 (7)	15
	Grazed Pastures	No pertinent information from Iowa - assume similar to CRP		85****			-100[Y]	
Edge-of-Field	Drainage Water Mgmt.	No impact on concentration	-11	33 (32)^	98			
	Shallow Drainage	No impact on concentration	5	32 (15)^	54			
	Wetlands	Targeted Water Quality	11	52†	92			
	Bioreactors		12	43 (21)	75			
	Buffers	Only for water than interacts with the active zone below the buffer. This would only be a small fraction of all water that makes it to a stream	33	91 (20)	99			

	Nitrogen Load Reduction	Phosphorus Load Reduction
Point Source	4%	16%
Non-Point Source	**41%**	29%
Total	45%	45%

Nutrient trading is a voluntary, conceptual framework to improve water quality.

Primary motivation: point source **regulation** and **cost**

CONSERVATION

Farm reduces nutrient levels
beyond requirements to gain credit

Nutrient Trading:

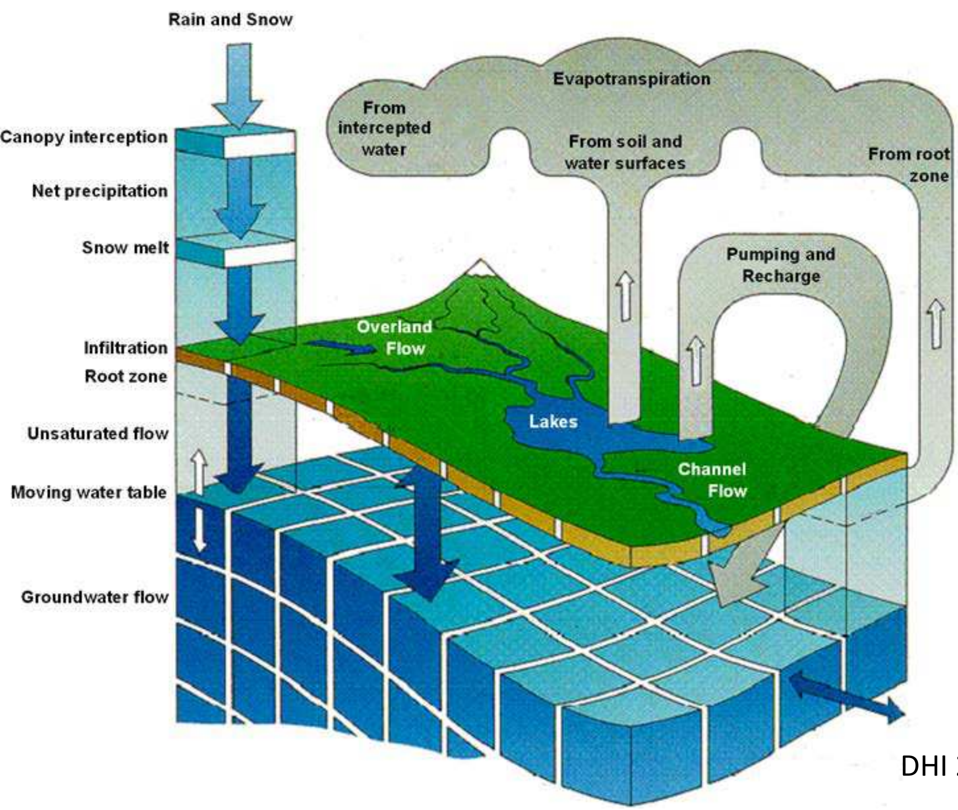
Nutrient reduction
at a lower cost

$$$

Pollution source pays farmer
for credit to meet regulations

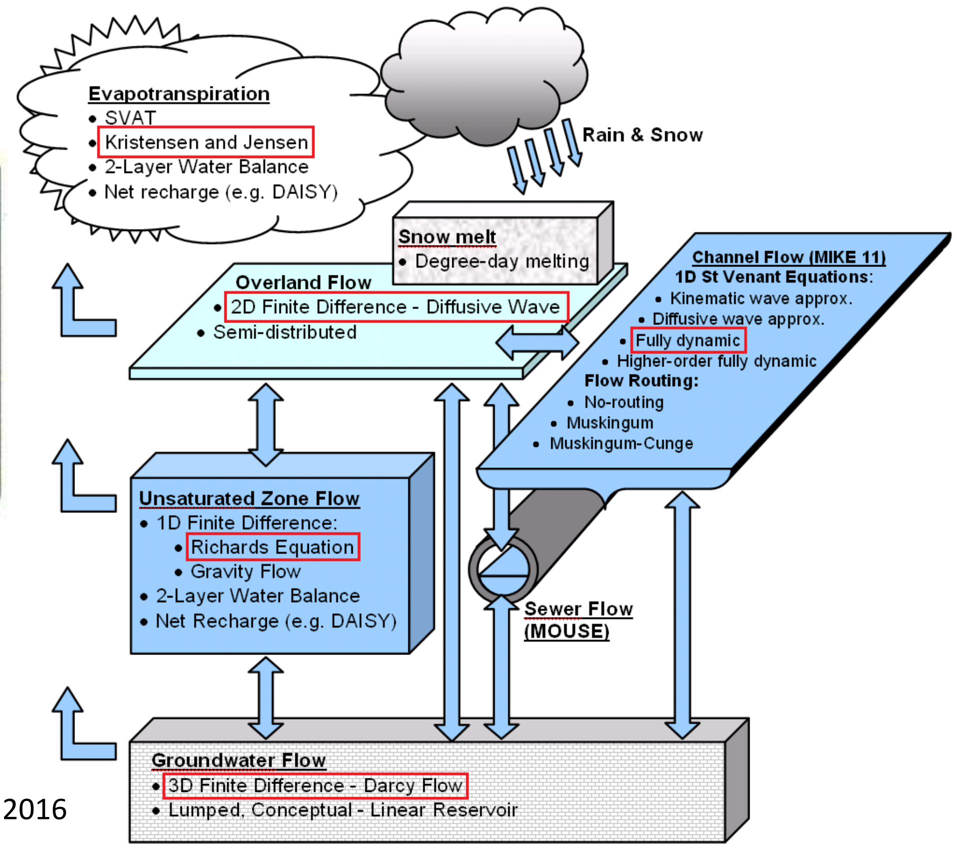
A physically-based modeling framework is being used to achieve the goals of this study.

MIKE SHE Hydrologic Processes



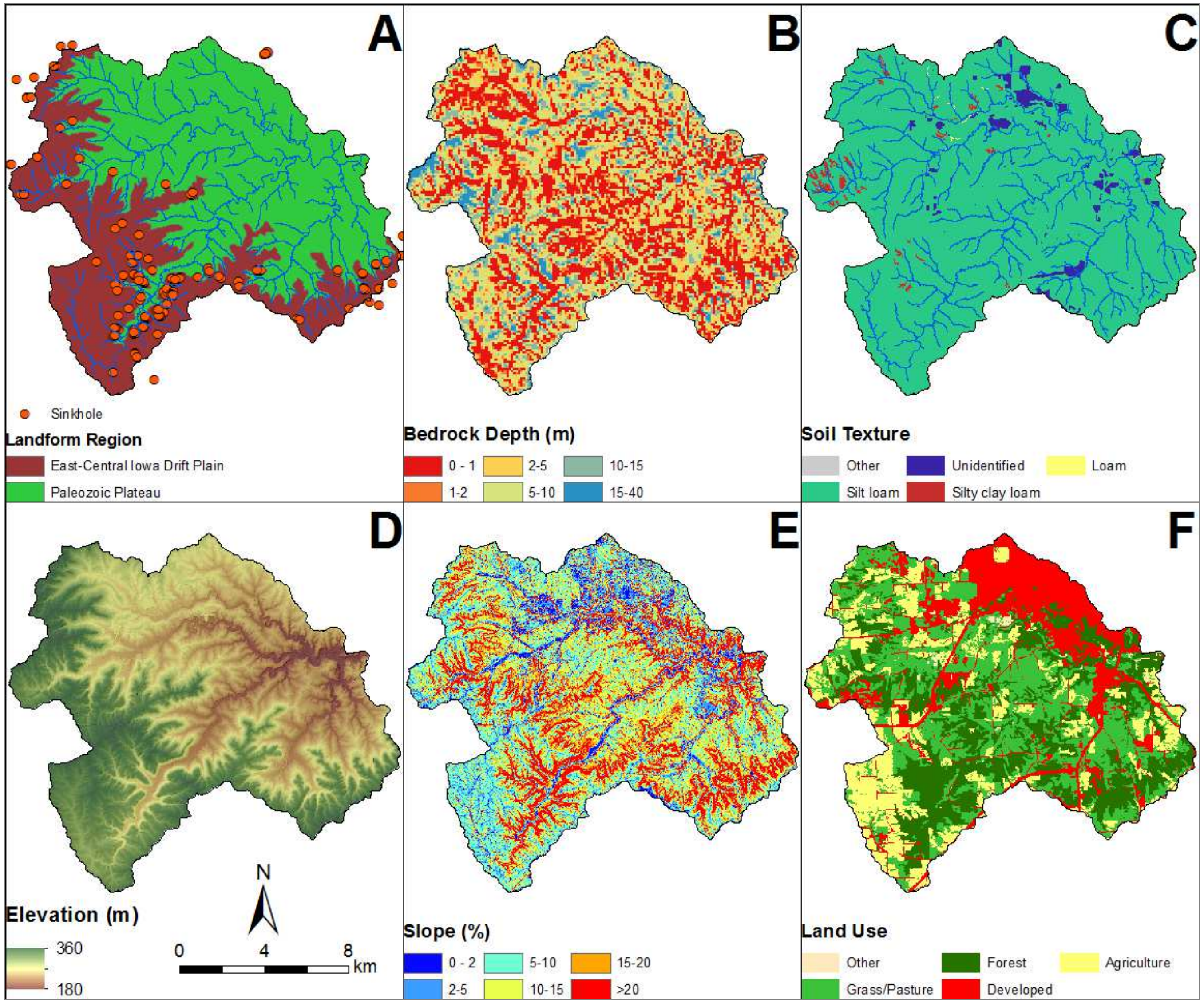
DHI 2016

Mathematical/Numerical Description



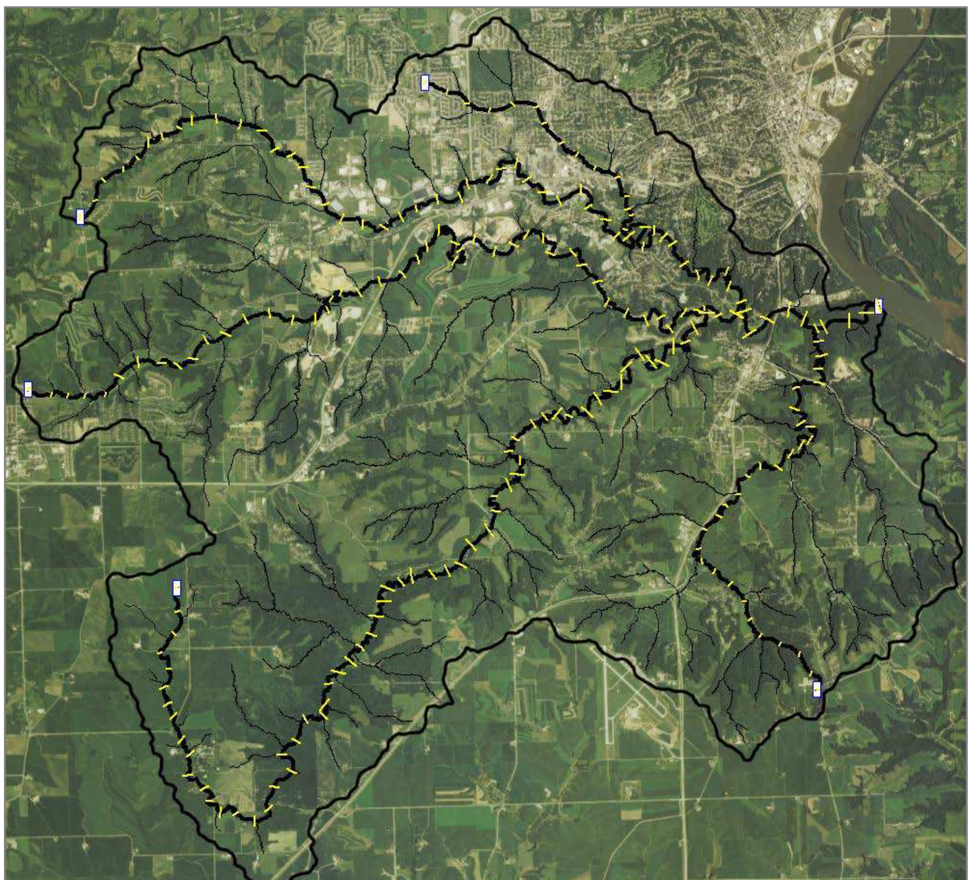
Catfish Creek

The Catfish Creek MIKE SHE hydrologic model was built using publically available datasets and model parameters derived from literature.

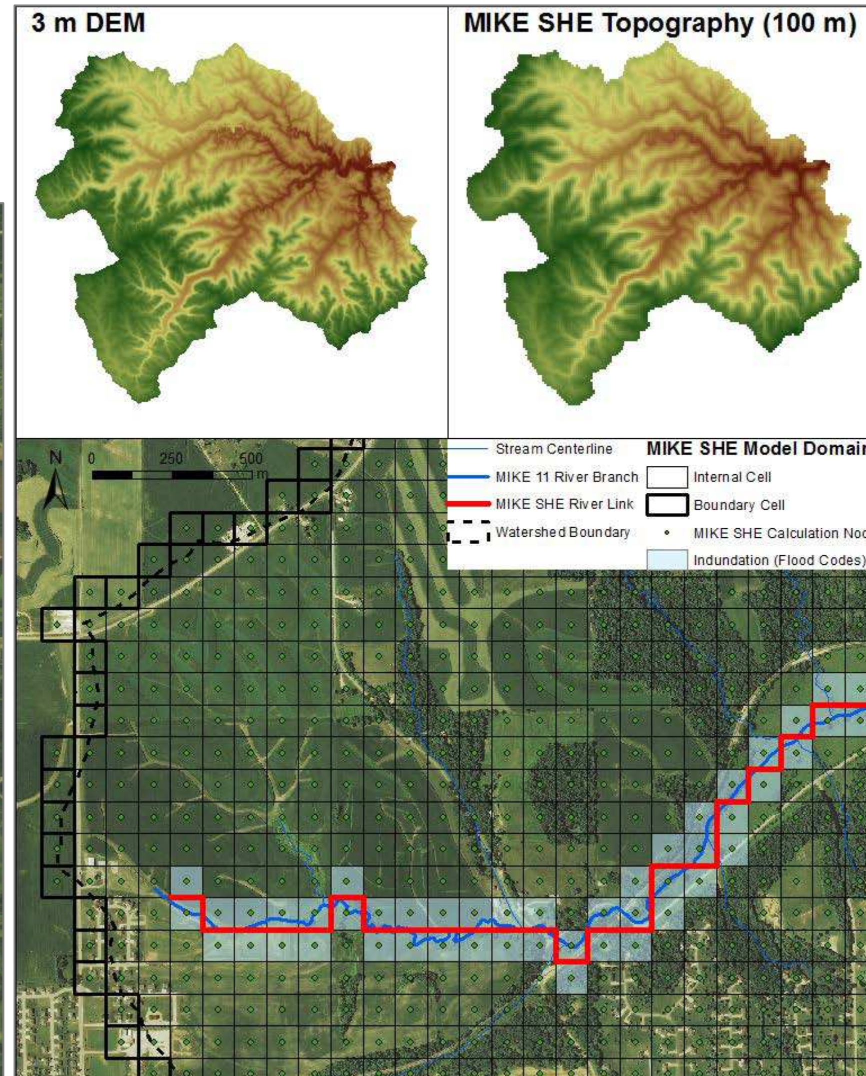


MIKE SHE is coupled to MIKE 11 to simulate river discharges and water levels.

Catfish Creek MIKE 11 Network



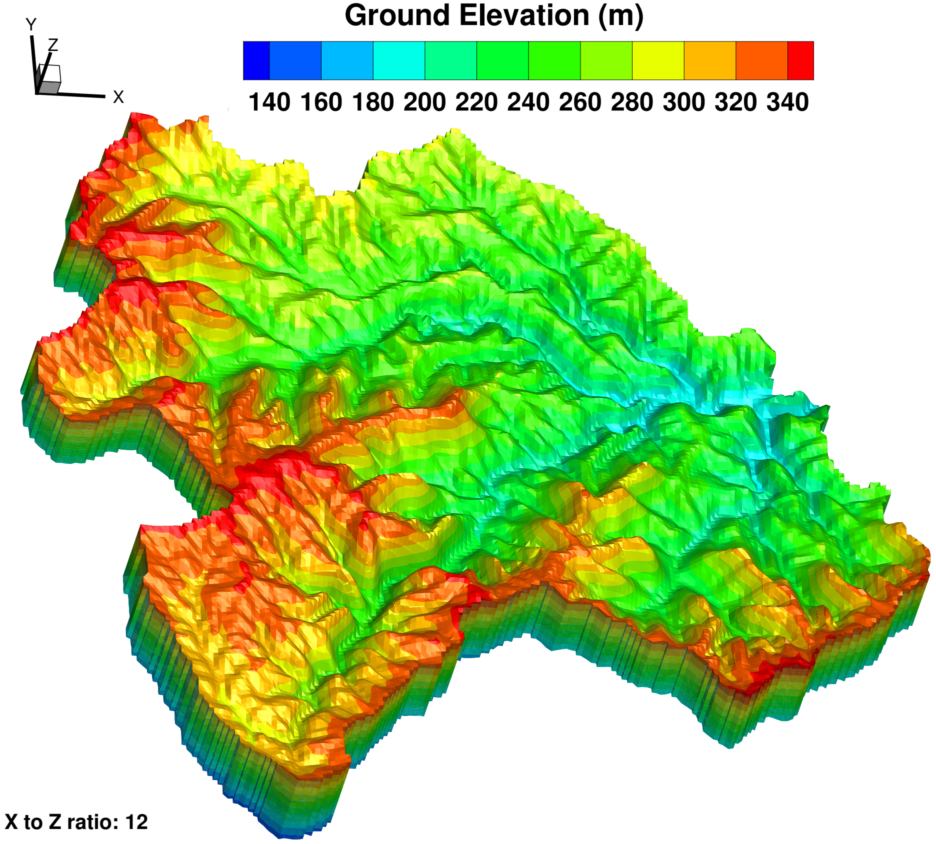
MIKE SHE Mesh and Coupling to MIKE 11

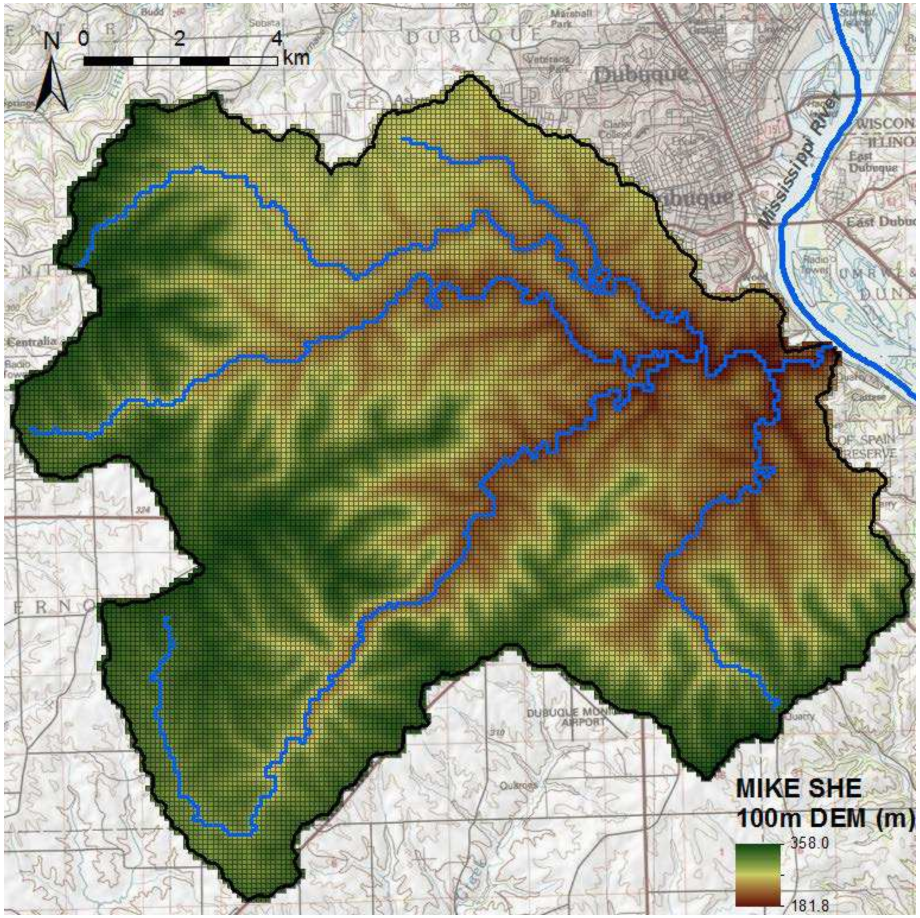


Catfish Creek MIKE SHE Model Development

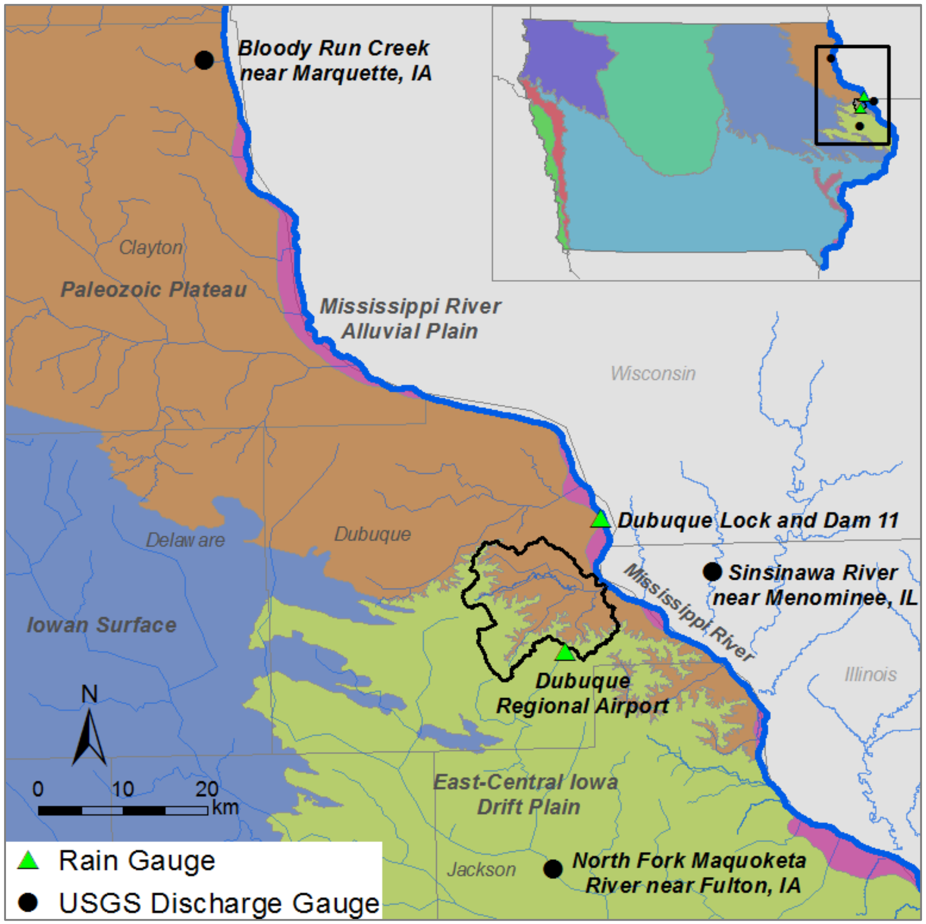
100 m cells (18,655 surface nodes)
139 nodes per UZ column
2 SZ layers (50 m vertical extent)

5 MIKE 11 branches
63.2 stream miles



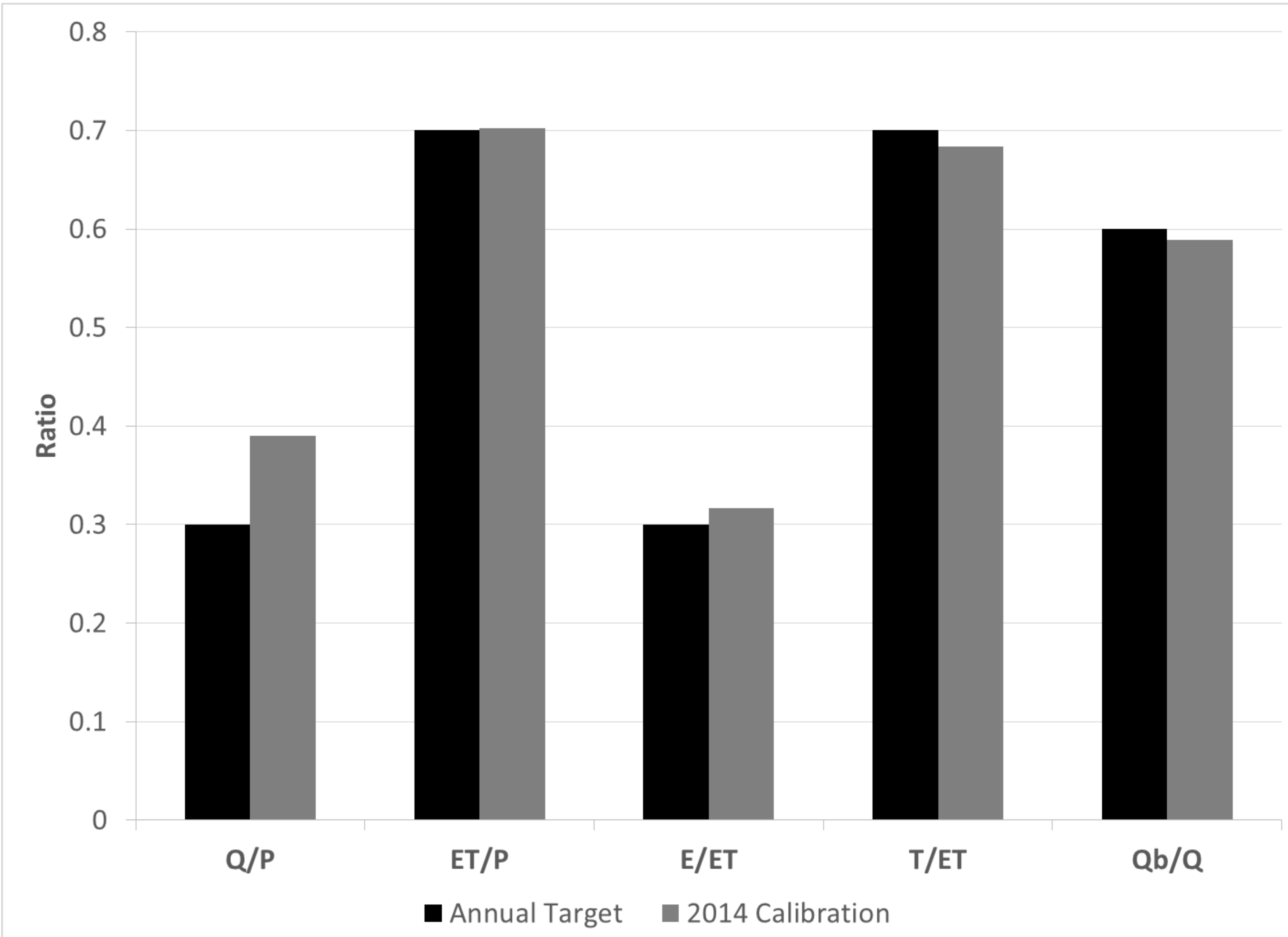


A water balance approach is being used to calibrate the Catfish Creek hydrologic model to 2014.

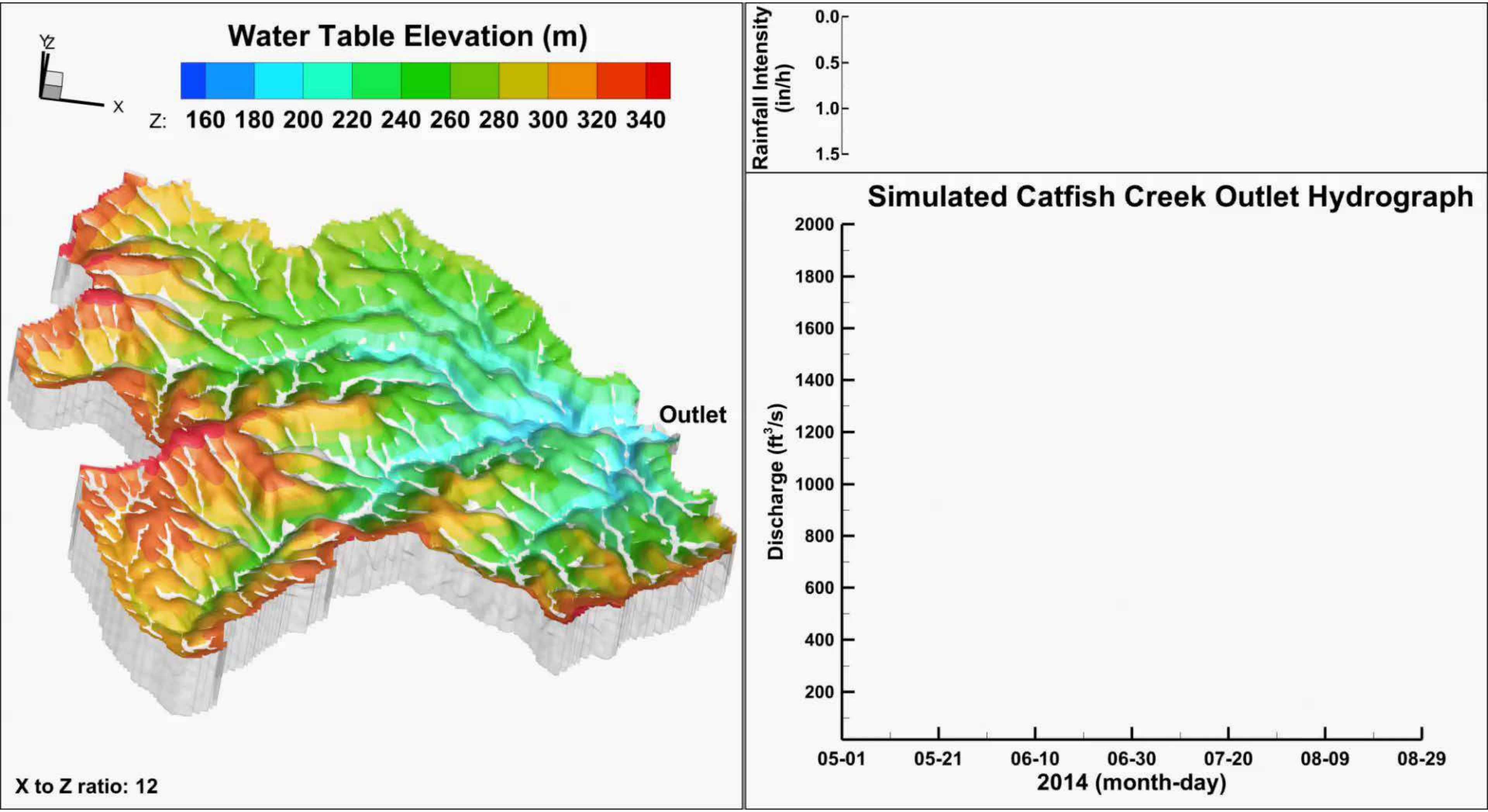


Ratio	Target	Literature/Study Values	References
Q/P	**0.3**	0.28	Schilling & Libra 2003
		0.26-0.33	Schilling & Wolter 2005
		0.31	Bradley 2014
		0.26-0.35	Drake 2016
ET/P	**0.7**	0.73-0.80	McDonald 1961
		0.65	Sanford and Selnick 2013
		0.69	Bradley 2014
		0.65-0.74	Drake 2016
E/ET	**0.3**	0.26, 0.33	Kang et al. 2003
T/ET	**0.7**	0.67, 0.74	Kang et al. 2003
		0.61±0.15	Schlesinger & Jasechko 2014
		0.6	Berkelhammer et al. 2016
Q_b/Q	**0.6**	0.56, 0.62	Schilling & Libra 2004
		0.63, 0.67	Schilling & Wolter 2005
		0.71	Bradley 2014
		0.61	StreamStats 4.0 2016
		0.70-0.75	Drake 2016

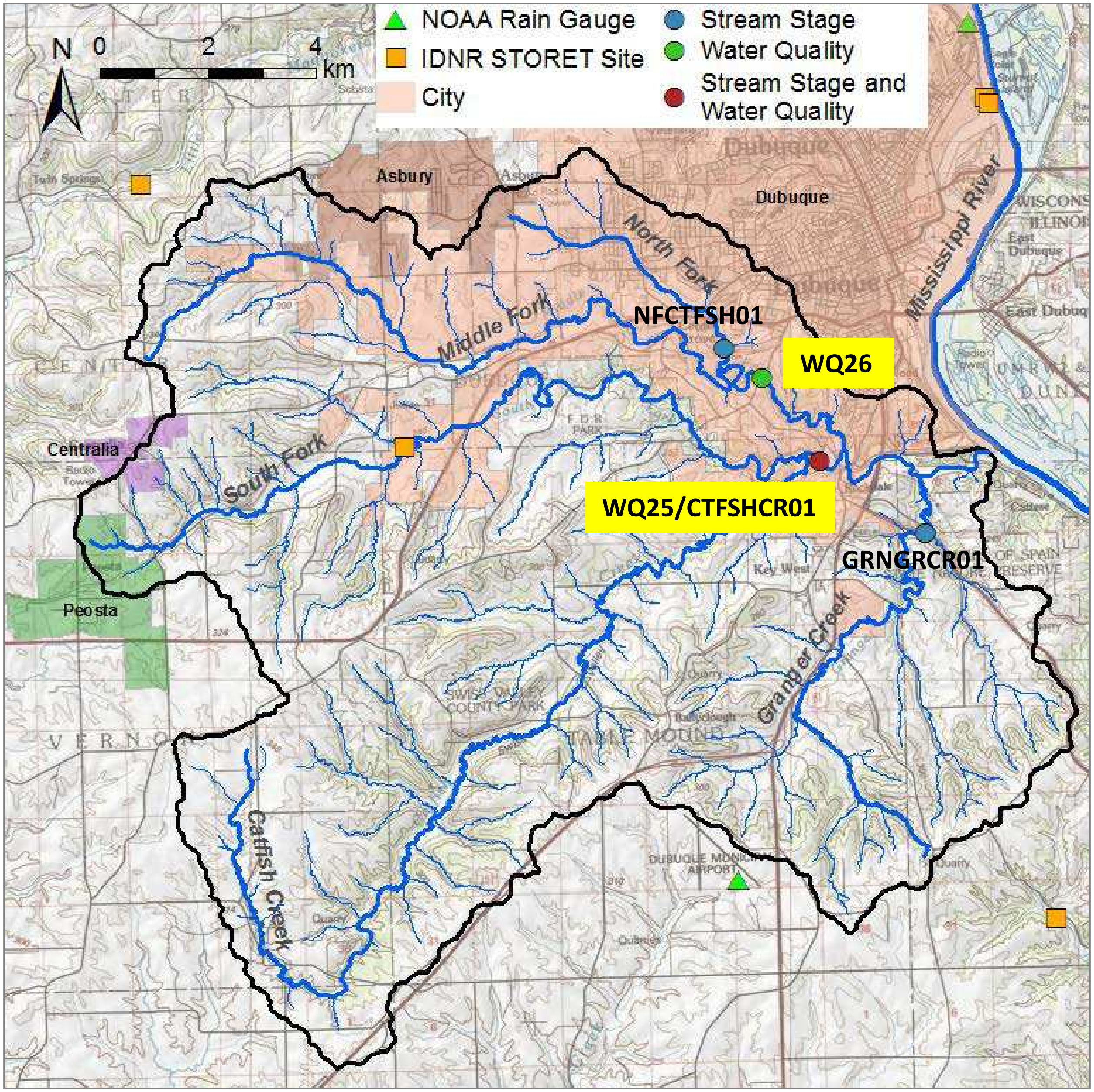
The simulated annual water balance for Catfish Creek is reasonable.



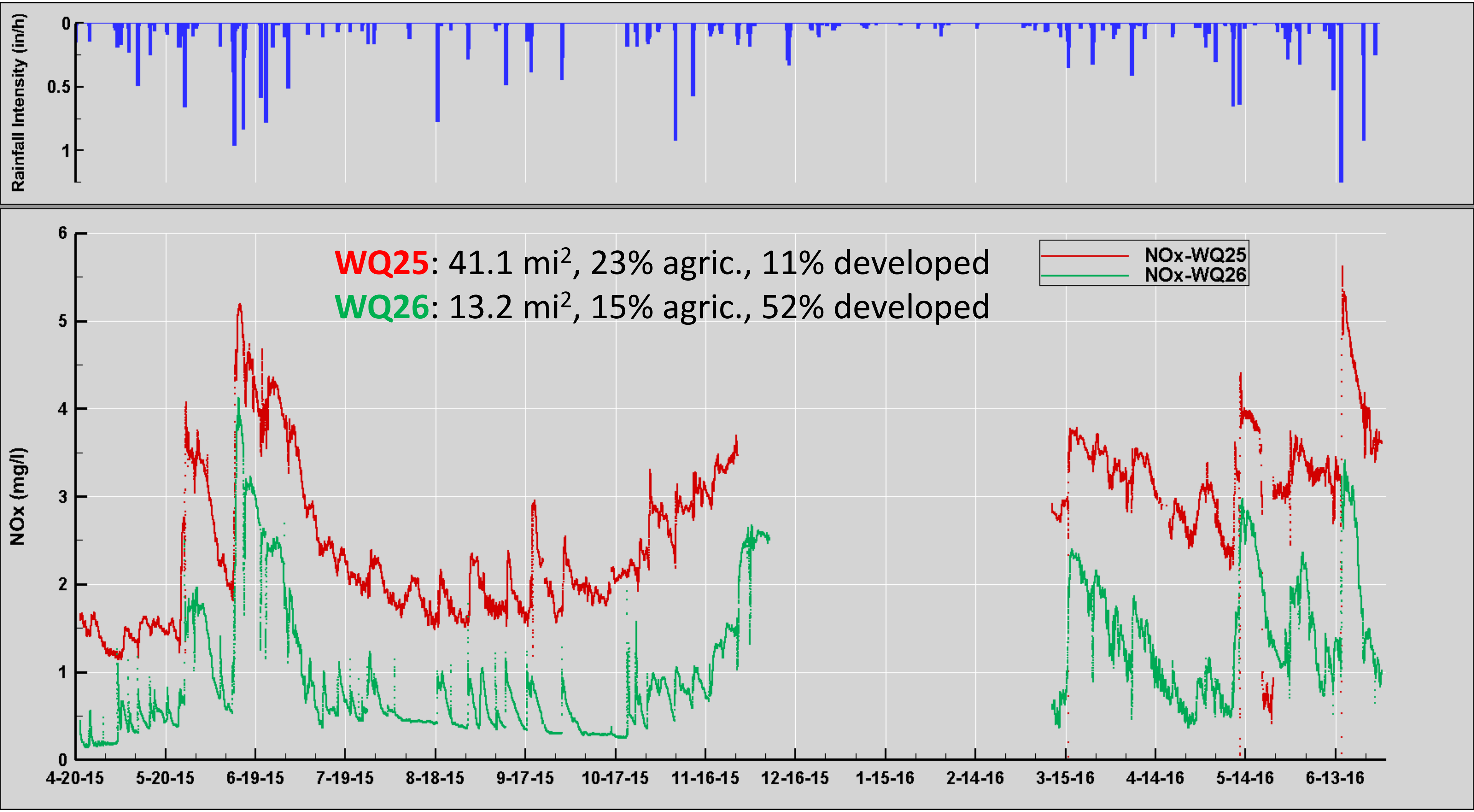
Visualization



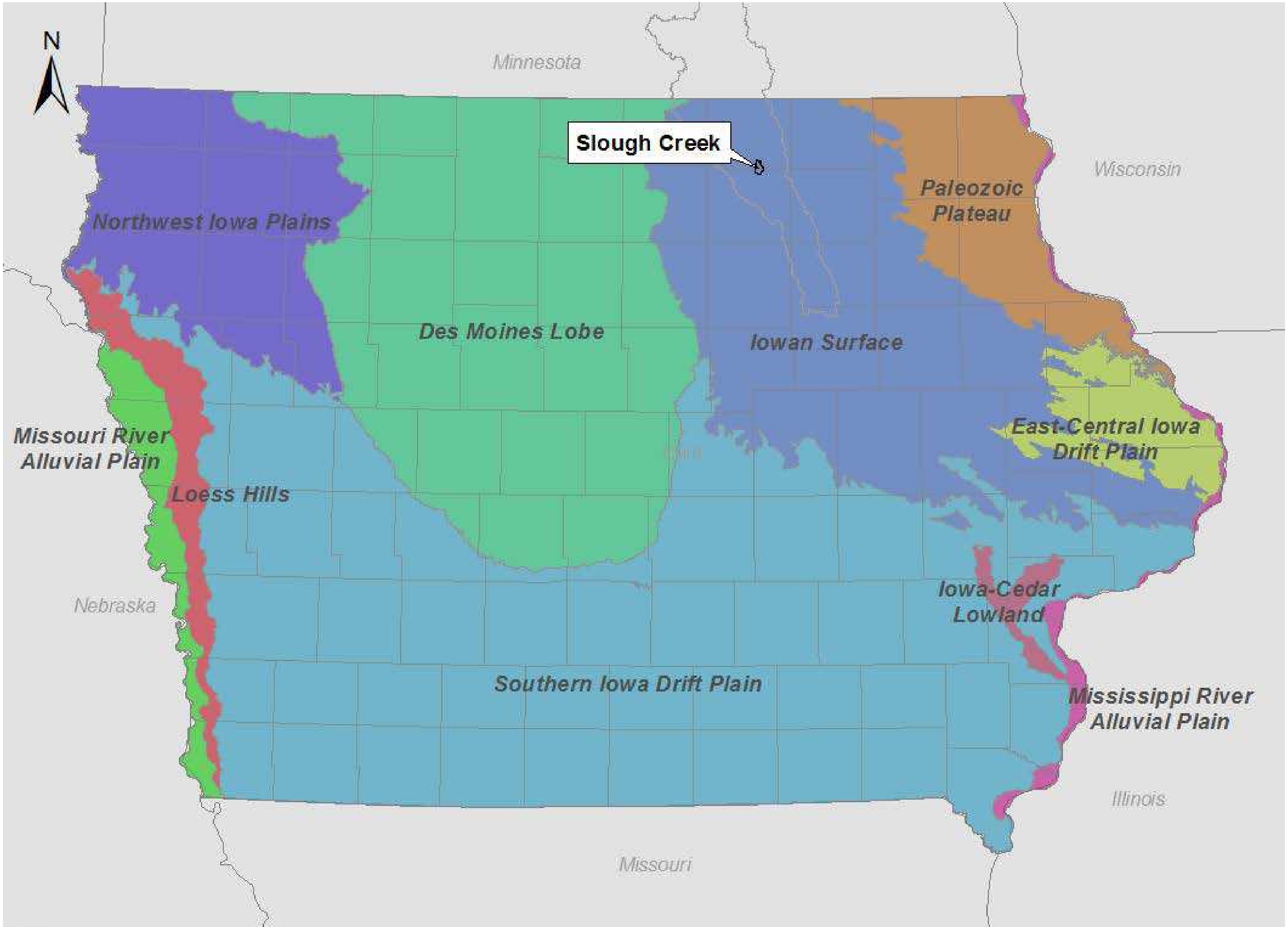
Catfish Creek Instrumentation



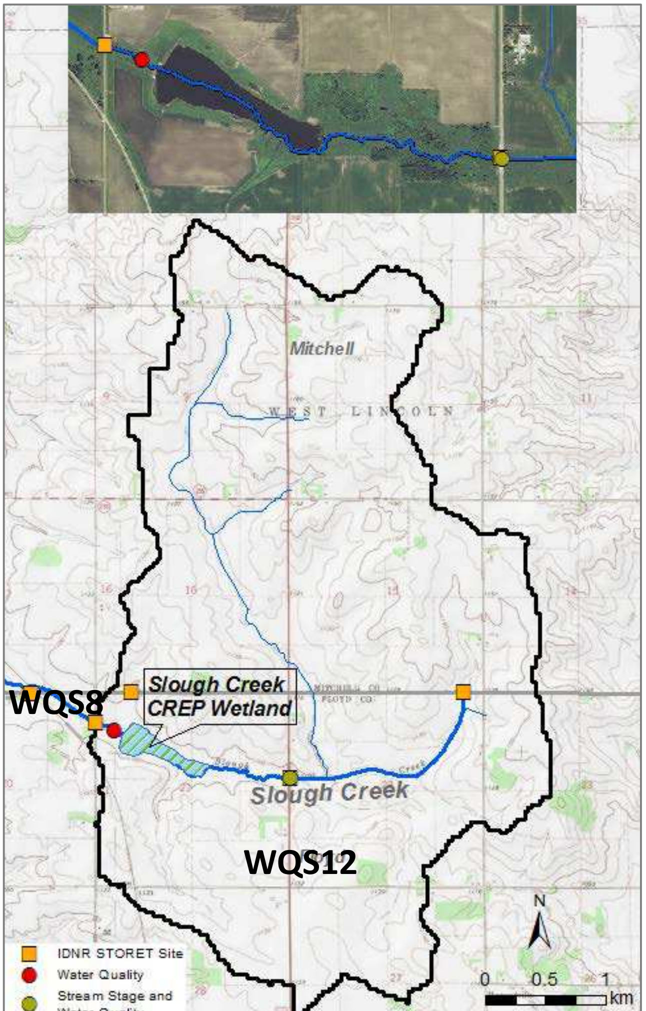
Catfish Creek Water Quality

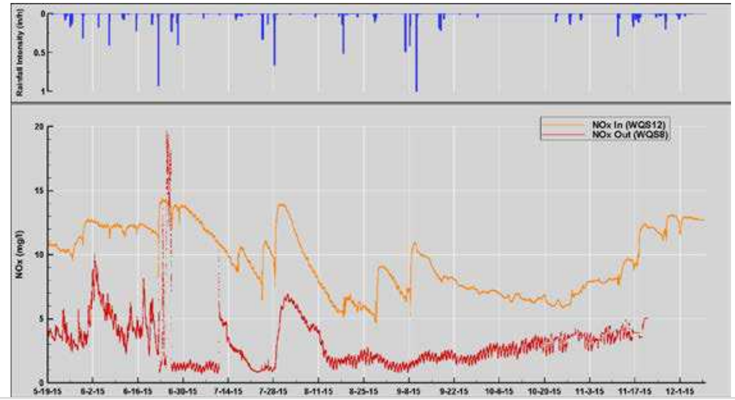


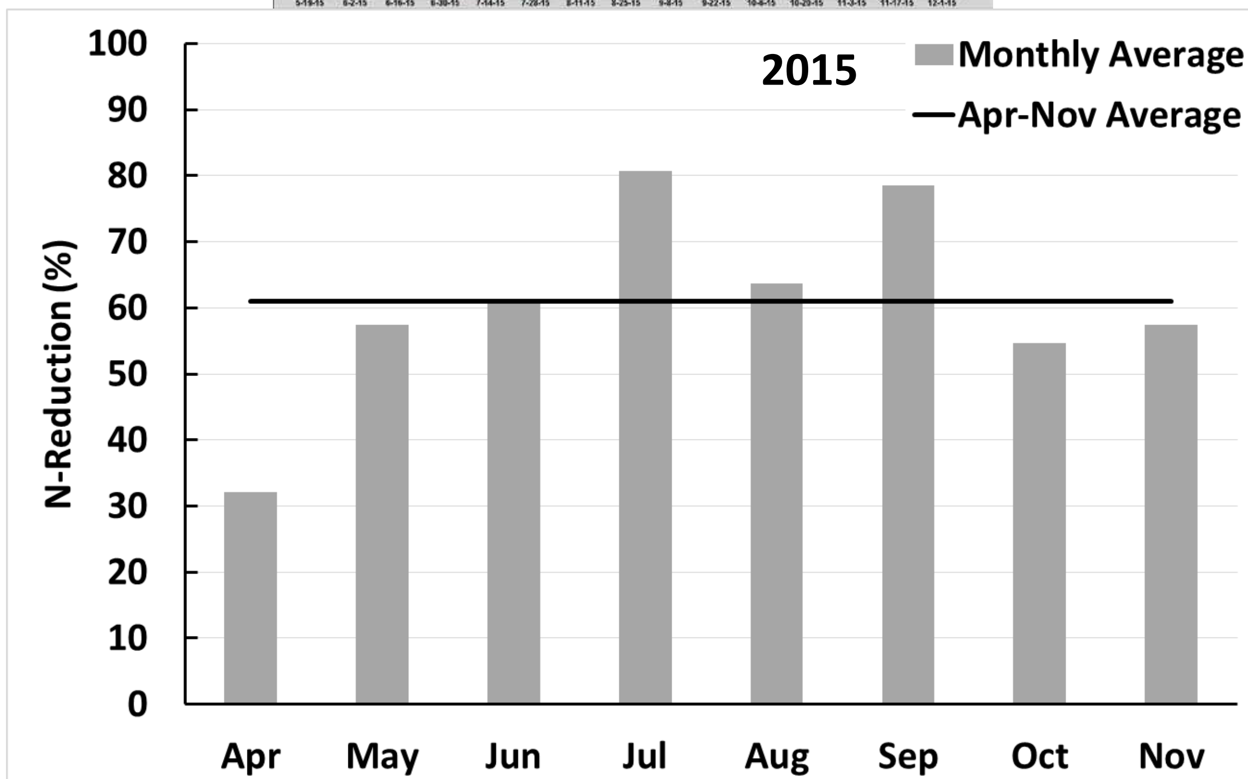
Wetland Evaluation



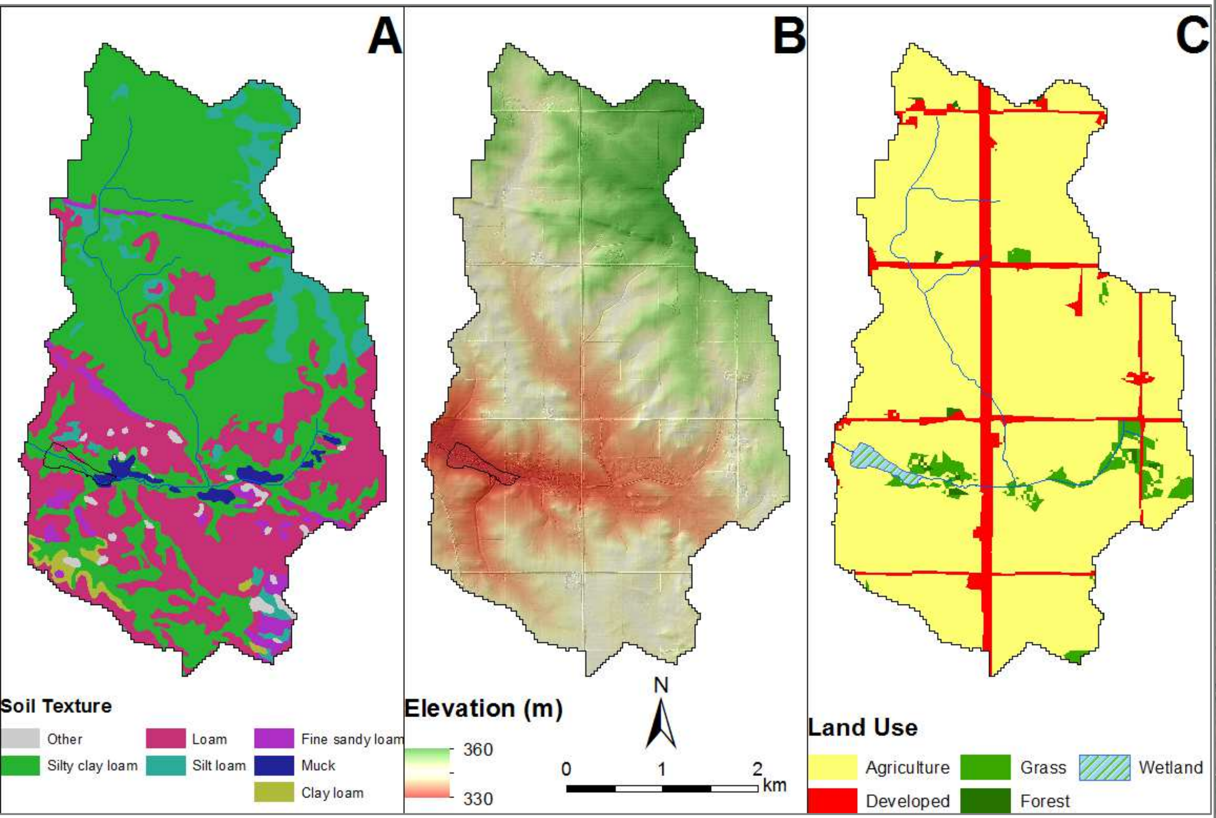
Slough Creek provides an opportunity to evaluate nitrogen removal processes in a relatively well monitored CREP wetland.

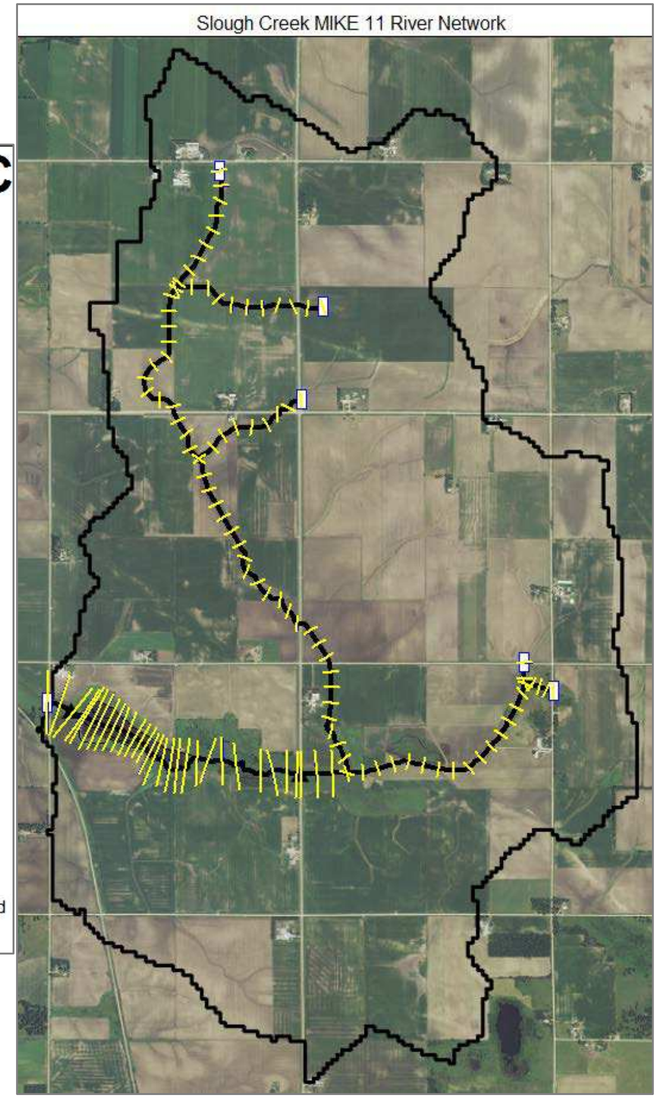






Following the same methodology used for Catfish Creek, a MIKE SHE hydrologic model was developed for Slough Creek that was calibrated to annual water balance ratios.

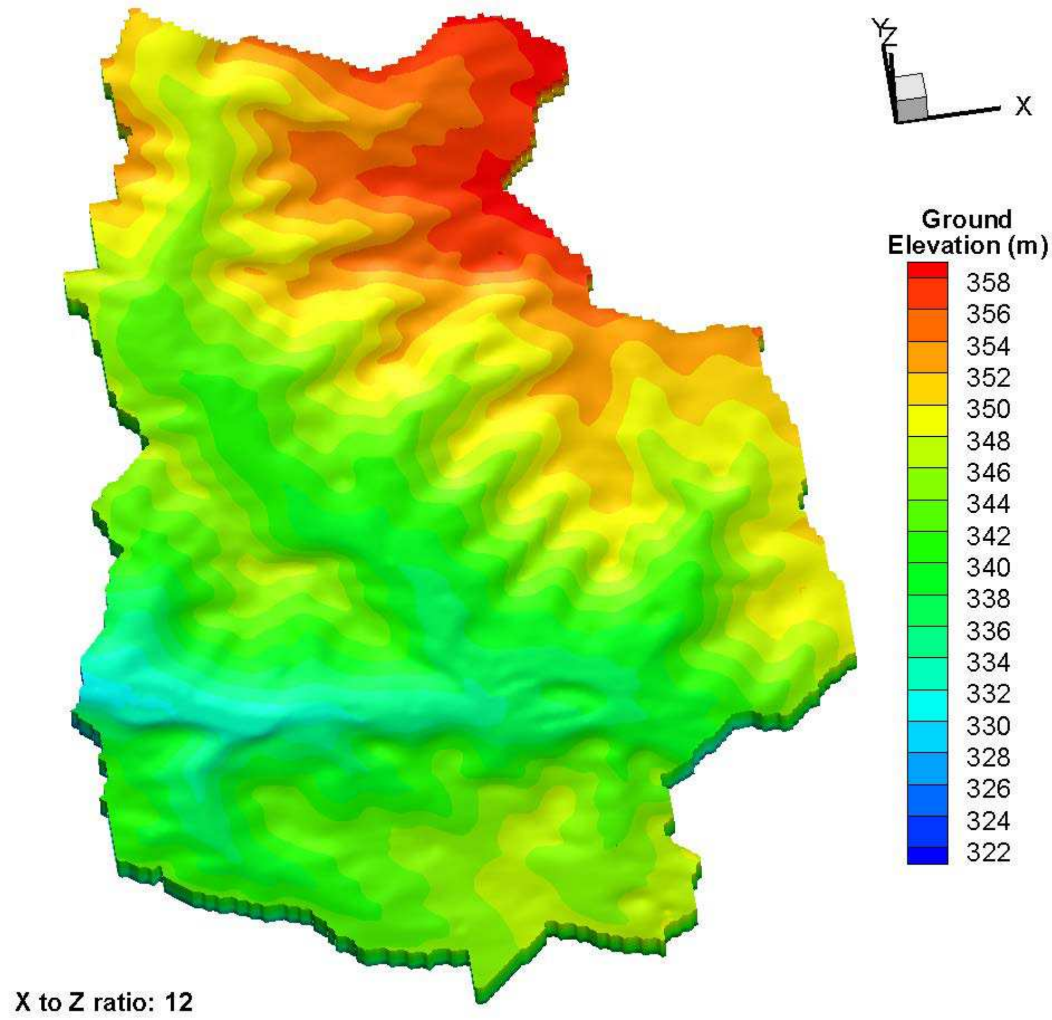


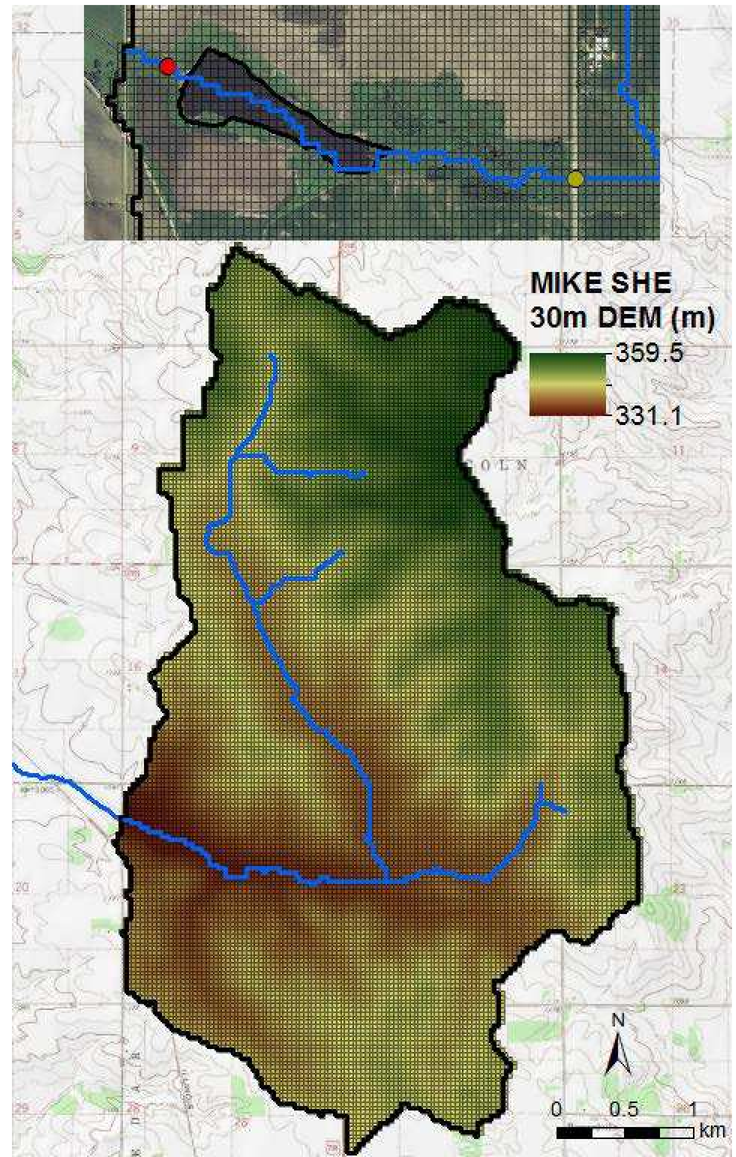


Slough Creek MIKE SHE Model Development

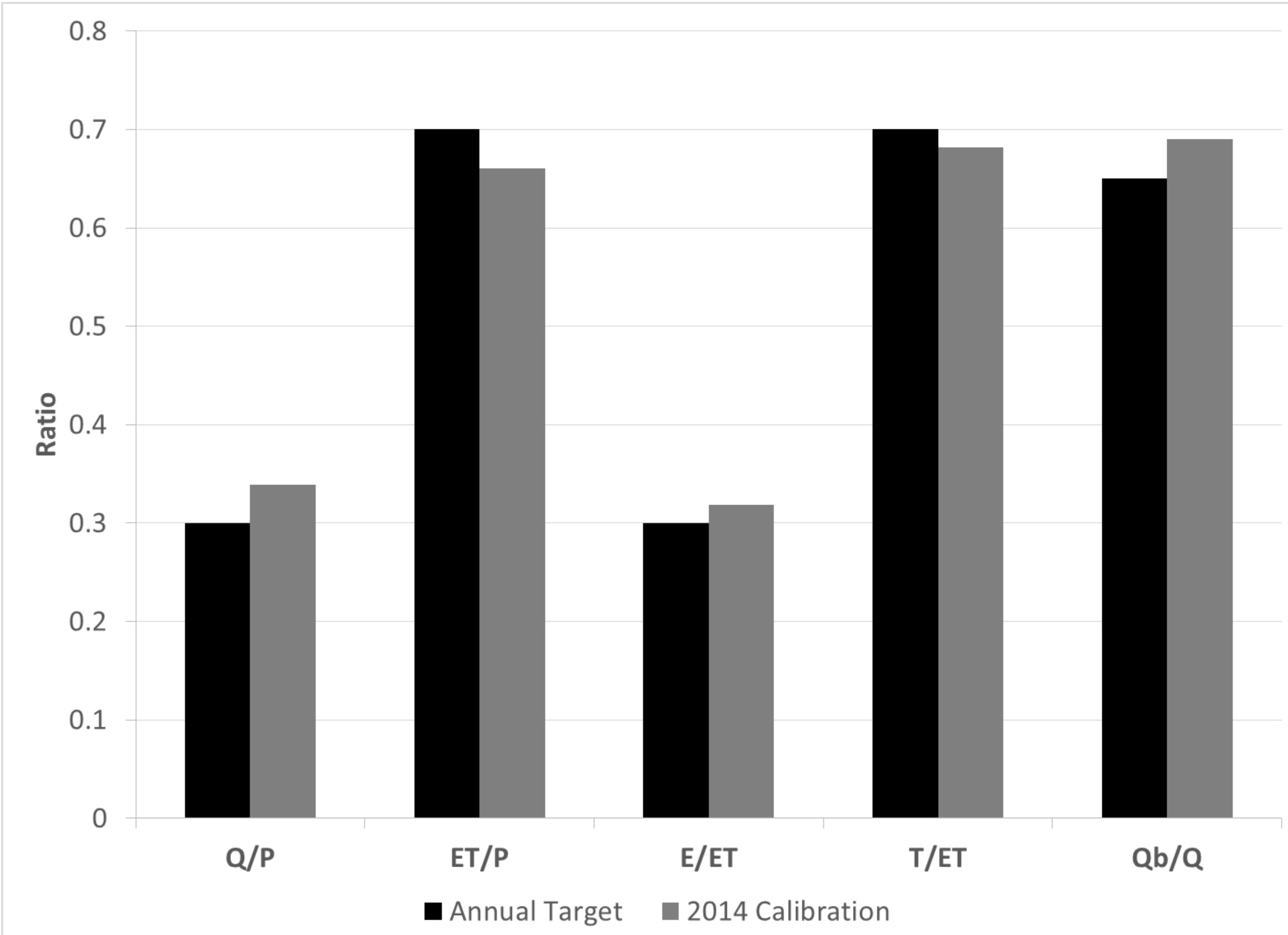
30 m cells (18,440 surface nodes)
79 nodes per UZ column
2 SZ layers (10 m vertical extent)

5 MIKE 11 branches
6.5 stream miles

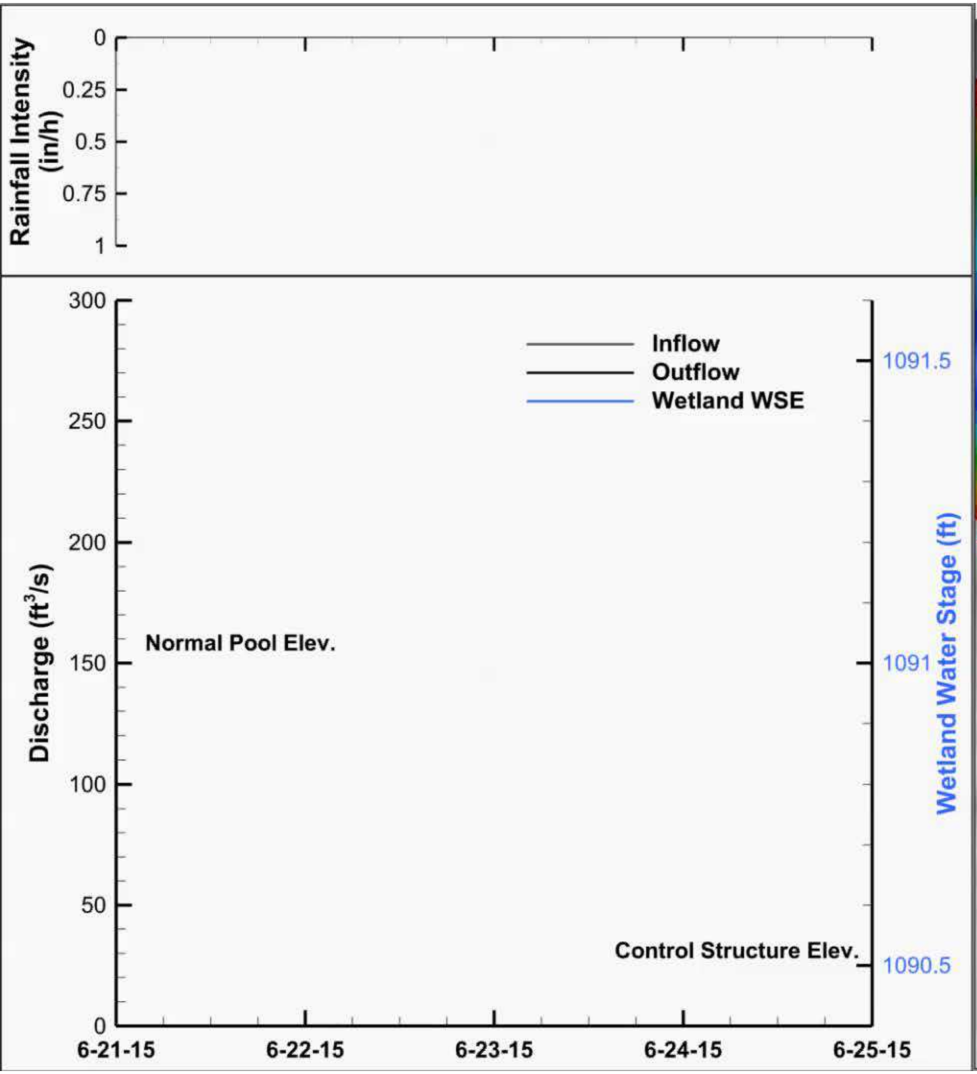


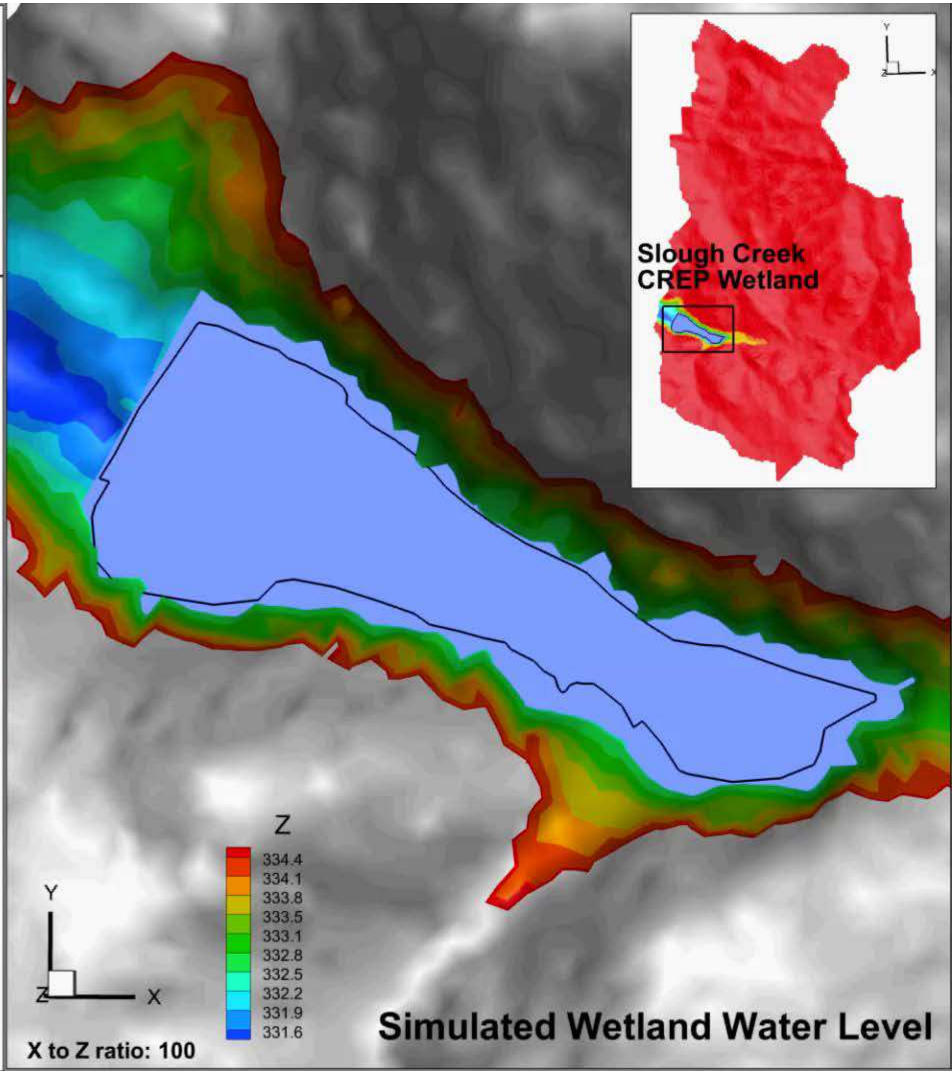


The simulated annual water balance for Slough Creek is reasonable.



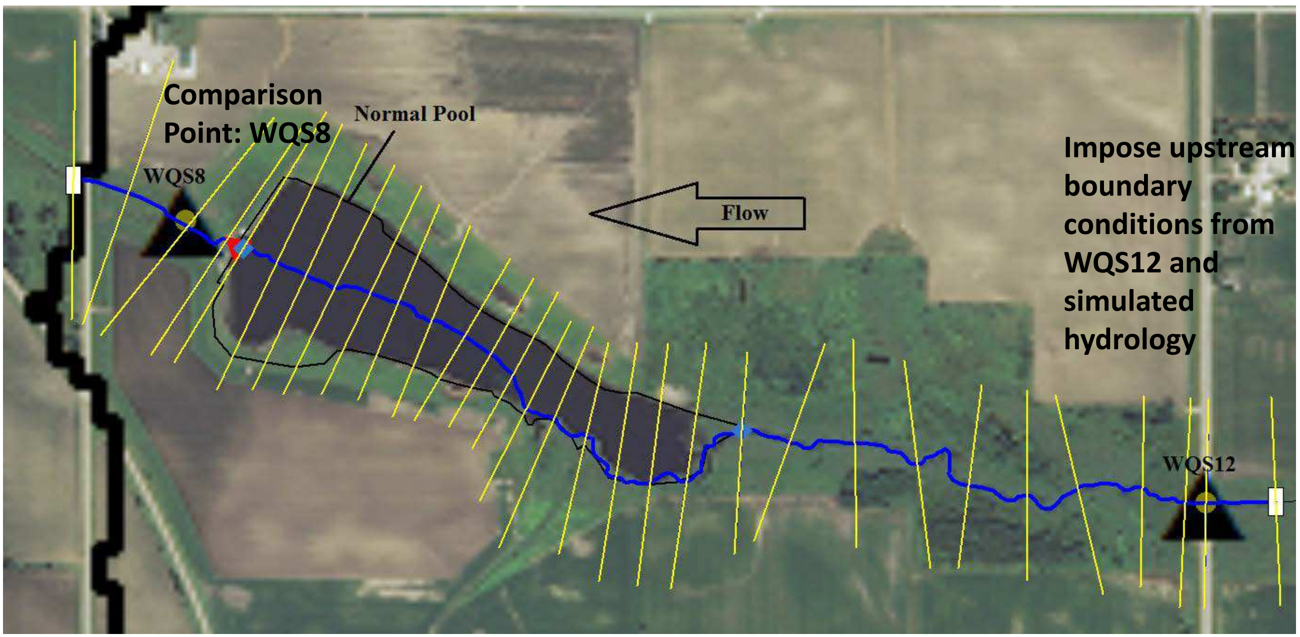
Visualization

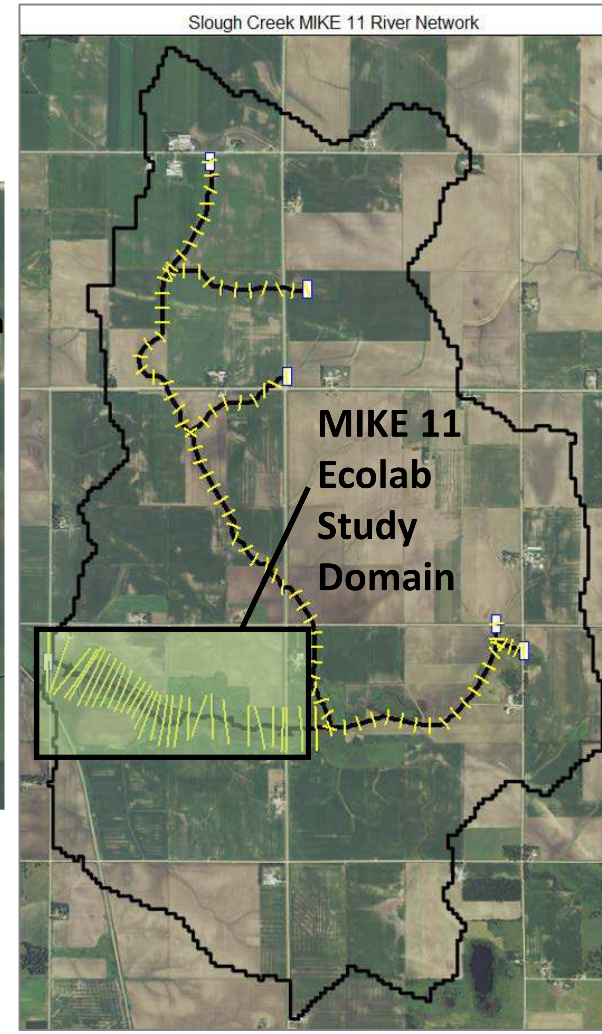




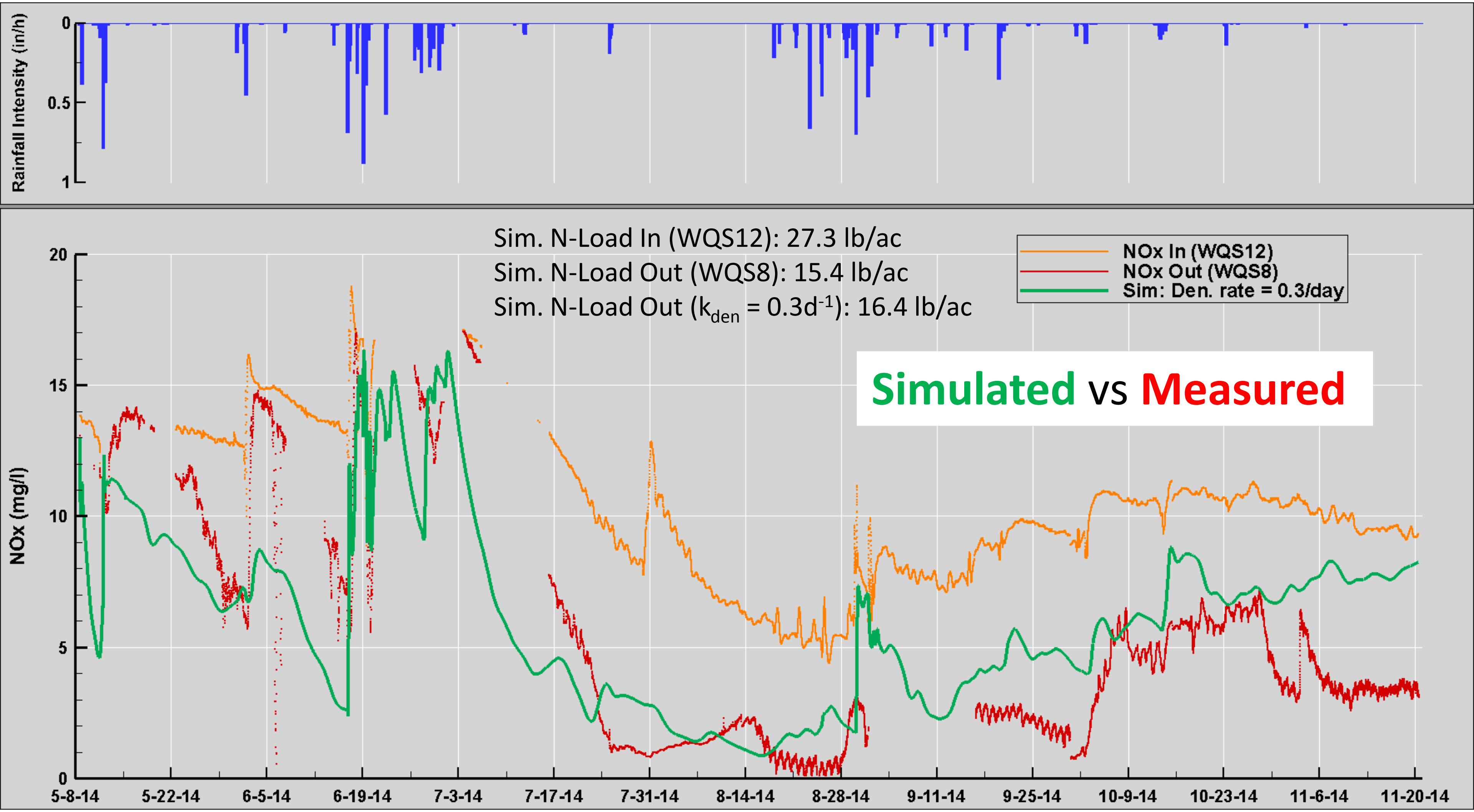
Water quality simulations in MIKE 11 were performed to assess nitrate removal dynamics in the Slough Creek wetland.

MIKE 11 Ecolab Study Domain: WQS12 → WQS8

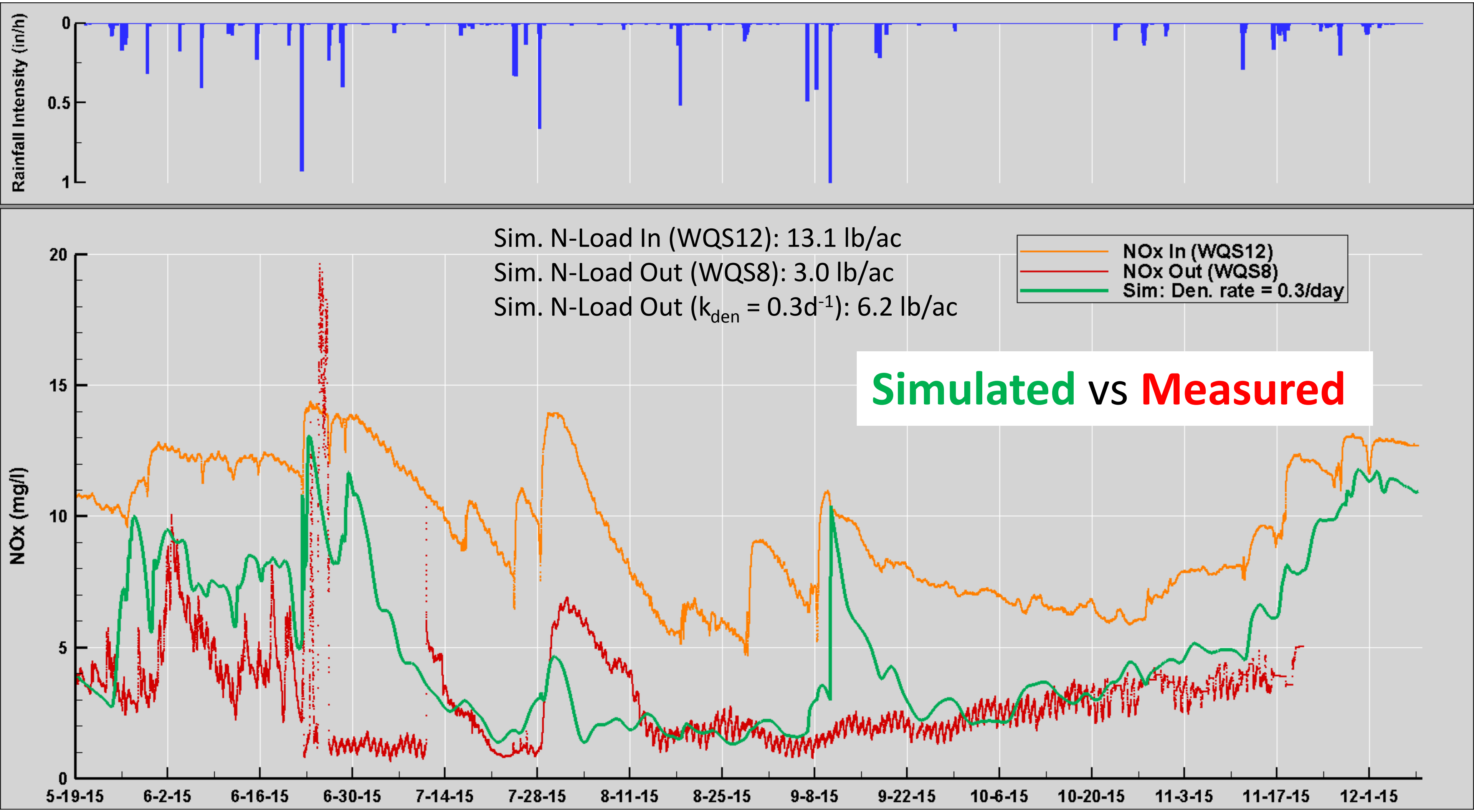




“Best” Simulated Nitrate Concentration: 2014



“Best” Simulated Nitrate Concentration: 2015



Future work centers on simulating nitrogen fate and transport for other conservation practices.

Chronological Order	Future Work Topic	Description/Comments	Related Objective
1	Improve simulated hydrology at seasonal and monthly time scales	Use radar rainfall, implement snowmelt, expand MIKE 11 network, review ET and subsurface characterizations	1
2	Develop riverine and terrestrial nitrogen process models in Ecolab	Necessary for evaluating nutrient reduction benefits of selected practices	2
3	Select agricultural conservation practices to evaluate	Wetlands Proposed: farm ponds, cover crops, bioreactors, saturated buffers	3
4	Use numerical simulations to evaluate each practice	Perform a sensitivity analysis to model parameters	3
5	Quantify watershed scale benefits of different practice scenarios in Catfish Creek	Targeted placement of practices, evaluate variable agricultural management decisions and climate change projections	4