Constructed Wetlands to Reduce Nutrients From Cropland Runoff: IMPLICATIONS FOR URBAN STORMWATER

IAFSM | March 9, 2017

Dave Buckley, PE, CFM, CPSWQ
Mahsa Izadmehr, PhD Candidate

UIC CIVIL AND MATERIALS ENGINEERING

THE WETLANDS INITIATIVE

CBB

Using the Farmable Wetland Program under the U.S. Department of Agriculture's (USDA); Conservation Reserve Program (CP-39),

The Wetlands Initiative (TWI) has successfully facilitated the design and construction of a treatment wetland located on a private farm in north central Illinois.

Two monitoring locations at the inflow and outflow allow for the measurement of nutrient concentrations throughout the growing seasons and periods of dormancy.

ILLINOIS NUTRIENT LOSS REDUCTION STRATEGY

Improving our water resources with collaboration and innovation

Nutrient pollution is a major threat to water quality in Illinois. Over the decades, state and local efforts to control nutrients have yielded positive results, but new strategies are needed to improve the effectiveness of existing water quality programs and secure the long-term health of water bodies in Illinois and throughout the Mississippi River Basin.

What is nutrient pollution?

Plants and animals need nitrogen and phosphorus to survive. But when too much of either is carried in runoff from city streets and farm fields or flows out of wastewater treatment plants, it can fuel algal blooms that decrease oxygen needed by aquatic plants and animals. In the Gulf of Mexico, nutrients washed down by the Mississippi River have created a 'dead zone' that covers thousands of square miles. Algal blooms also lower property values, hinder recreation, and threaten public health. In addition, nutrient pollution can degrade drinking water quality and require utilities to install costly treatment equipment.

What is Illinois doing to address the problem?

To help protect local streams and the Gulf, Illinois and 11 other states in the Mississippi River Basin have pledged to develop strategies to reduce the nutrient loads leaving their borders. These strategies are part of a national plan developed by the Mississippi River, Gulf of Mexico Watershed Nutrient Task Force to reduce the size of the Gulf of Mexico hypoxic zone.

The Illinois Nutrient Loss Reduction Strategy builds on existing efforts by state and local governments, as well as non-profits and industry, to protect and restore Illinois waterways.

Key Strategy Components

1. Extends ongoing regulatory and voluntary efforts
2. Identifies priority watersheds for nutrient loss reduction efforts
3. Establishes the Nutrient Monitoring Council to coordinate water quality monitoring efforts by government agencies, universities, non-profits, and industry
4. Creates the Nutrient Science Advisory Committee to develop numeric nutrient criteria for Illinois waters
5. Forms the Agricultural Water Quality Partnership Forum to oversee outreach and education efforts
6. Establishes the Urban Stormwater Working Group to coordinate and improve stormwater programs and education
7. Lays out strategies for improving collaboration among government, non-profits, and industry
8. Defines a process for regular review and revision

Why are we doing this?

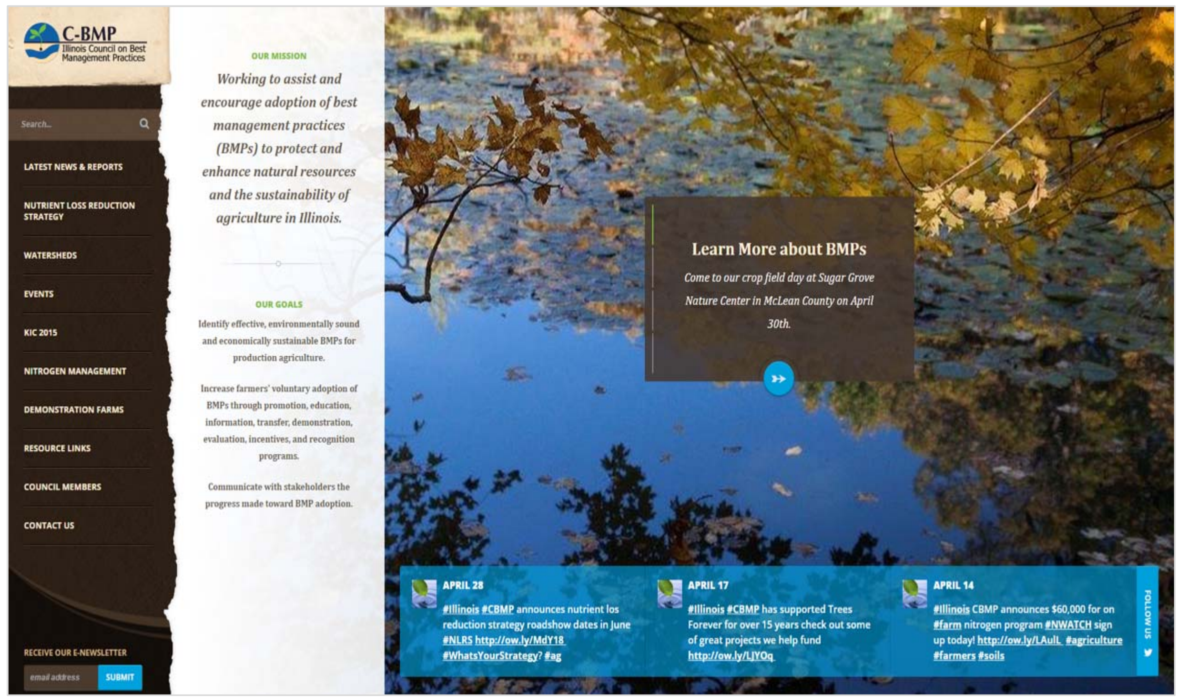
- Nutrient runoff is primarily responsible for the annual "dead zone" in the Gulf of Mexico and large algal blooms in parts of the Great Lakes.
- Row-crop agriculture is the biggest source of nutrients.
- Gulf of Mexico Hypoxia Action Plan
    - Requires all watershed states to develop a plan to reduce their nutrients.
- Illinois Nutrient Loss Reduction Strategy
    - Address point-source, urban runoff, and agricultural runoff

Illinois Nutrient Loss Reduction Strategy

- Using strategies from other states, Illinois sought input from major agricultural commodity organizations to support the strategies identified.
  - Illinois Farm Bureau,
  - Fertilizer and Chemical Association,
  - Corn Growers Association
- Illinois Council on Best Management Practices,
  - "What's your Strategy"
  - Il Council's website is the one-stop hub
- Focus on a system of practices, no single best management practice

WHAT'S YOUR STRATEGY?

IL COUNCIL ON BMPs
www.illinoiscbmp.org



The drain tile acts as a transport vehicle, allowing field drainage of excess water to carry nutrients with it, including nitrates.

We need fertilizer and drainage for productive farming.

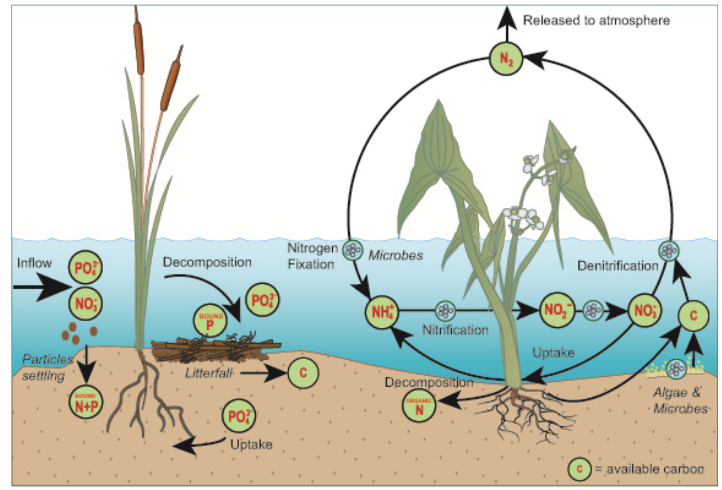
One of the least expensive ways to address nutrient runoff is through the rate and timing of fertilizer applications.

However even the most careful farmer can't avoid some nutrient loss. This is largely due to the drain tile system.

The drain tile has been a critical aspect to farming since the mid-19th century responsible for making planting and harvesting more consistent and reliable from year to year.

Cropland Treatment Practices – BMPs

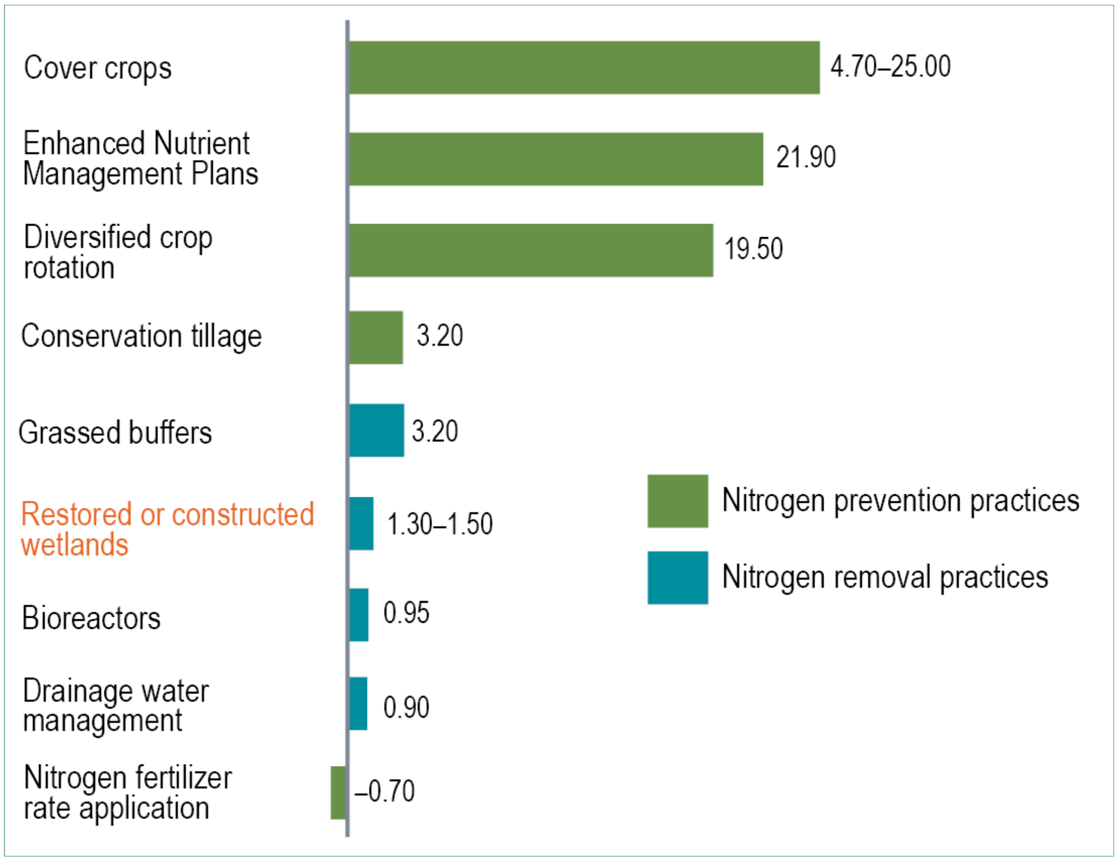
- Achieve significant nitrate reduction by treating nutrients leaving the field through drain tiles
  - Vegetated Buffers
  - Bioreactors
  - Constructed Wetlands



- Constructed Wetlands
  - Specifically located and designed for a particular drainage area for the purpose of intercepting drain tile drainage to reduce nutrients before reaching a receiving waterway.
  - Optimize the natural process to remove nutrients.

Comparison of nitrogen removal cost-effectiveness for select agricultural practices

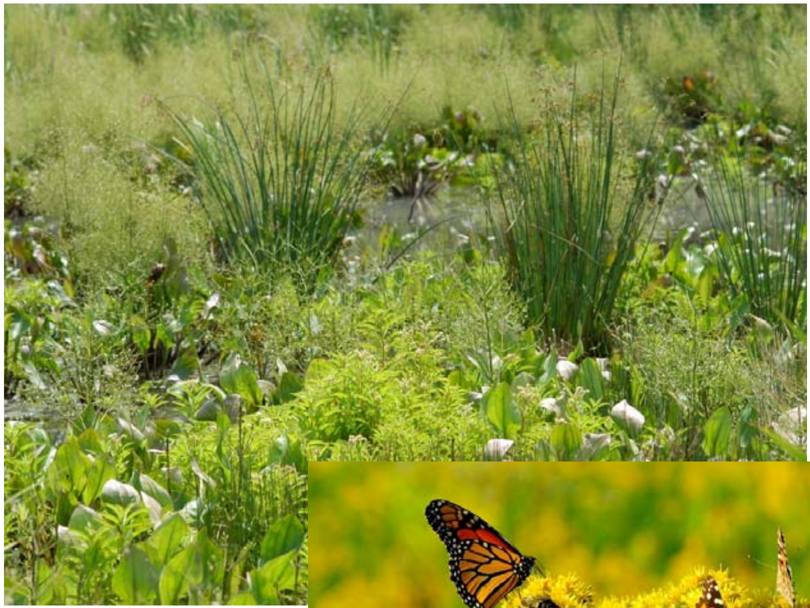
(estimated average annual cost in $/pound of nitrogen removed)



World Resources Institute, 2/1010; Christianson et al., 2013)

"Working wetlands" are one of the most promising practices for reducing nutrient loss.

Constructed Wetland



- Densely vegetative marsh versus open water
- Vegetation is critical to slow water down while providing substrate for working microbes
- 50 year functionality with very low maintenance
- Provides environmental benefits
  - Pollinator habitat
  - Wildlife habitat
  - Carbon sequestration

Buy-In and Cost Share

- The Wetlands Initiative works with farmers (1 on 1) to promote interest.
  - TWI is a non-profit organization dedicated to restoring the wetland resources of the Midwest.
  - Land owner confidence that the practice will work.
    - Local buy-in, trusted farm leaders.
    - Minimizing impacts to farming operations.
    - Implemented in often low producing areas of the farm.
- Not simply building a few wetlands and assume other farmers will copy and take action.
  - TWI is spreading the practice within the real-life economics of the working Farm Belt.
  - TWI wants to prove this type of on-the-ground conservation is not some little boutique thing but a normal part of the working farm-belt landscape just like nutrient management, grassed waterways or drainage ditches.
- Federal cost share programs → Farm Service Agency
  - Offset the cost for this practice while reducing investment in less-profitable land.
    - EQIP – Environmental Quality Incentives Program
    - CRP – Conservation Reserve Program
      - Is the project eligible
  - NRCS – must approve the design.

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Design

NRCS Criteria

1 POSITION

- Intercept tile drainage before outlet ditch or stream
- Capture high nutrient loads
- Locate in watershed headwater areas
- Marginal or unprofitable land

2 SIZE

- Key to nutrient removal
- Allow adequate residence time
- Treatment area is 0.5-5.0% of the drainage area
- Treatment area is 12” above to 24” below permanent pool

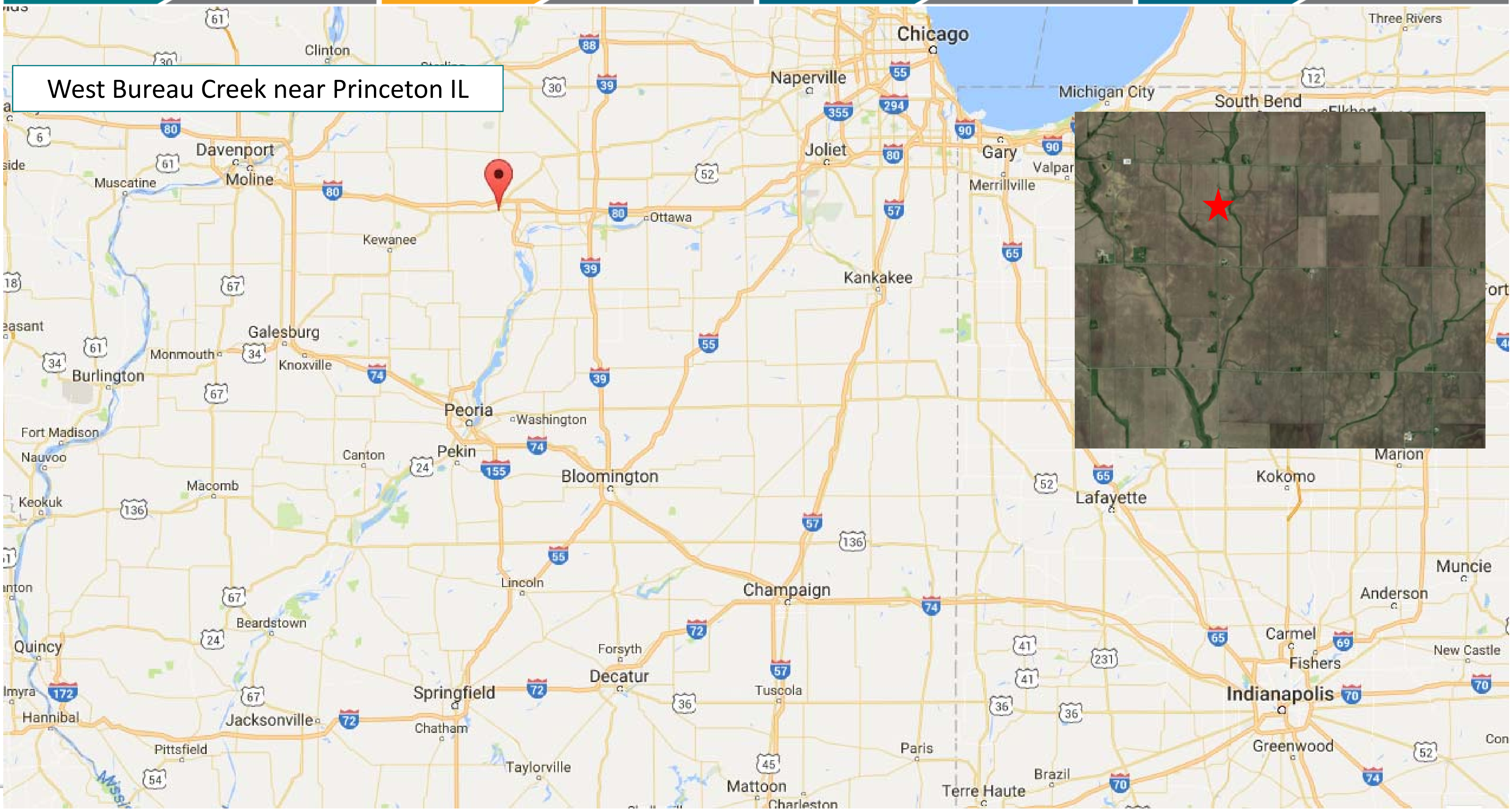
3 DEPTH

- Marsh wetland (aka shallow “pond”)
- At least 50% of the permanent (normal) pool is 12” or less
- Anything greater than 24” in depth doesn’t count towards the ratio or treatment area

HMS Hydrologic Modeling

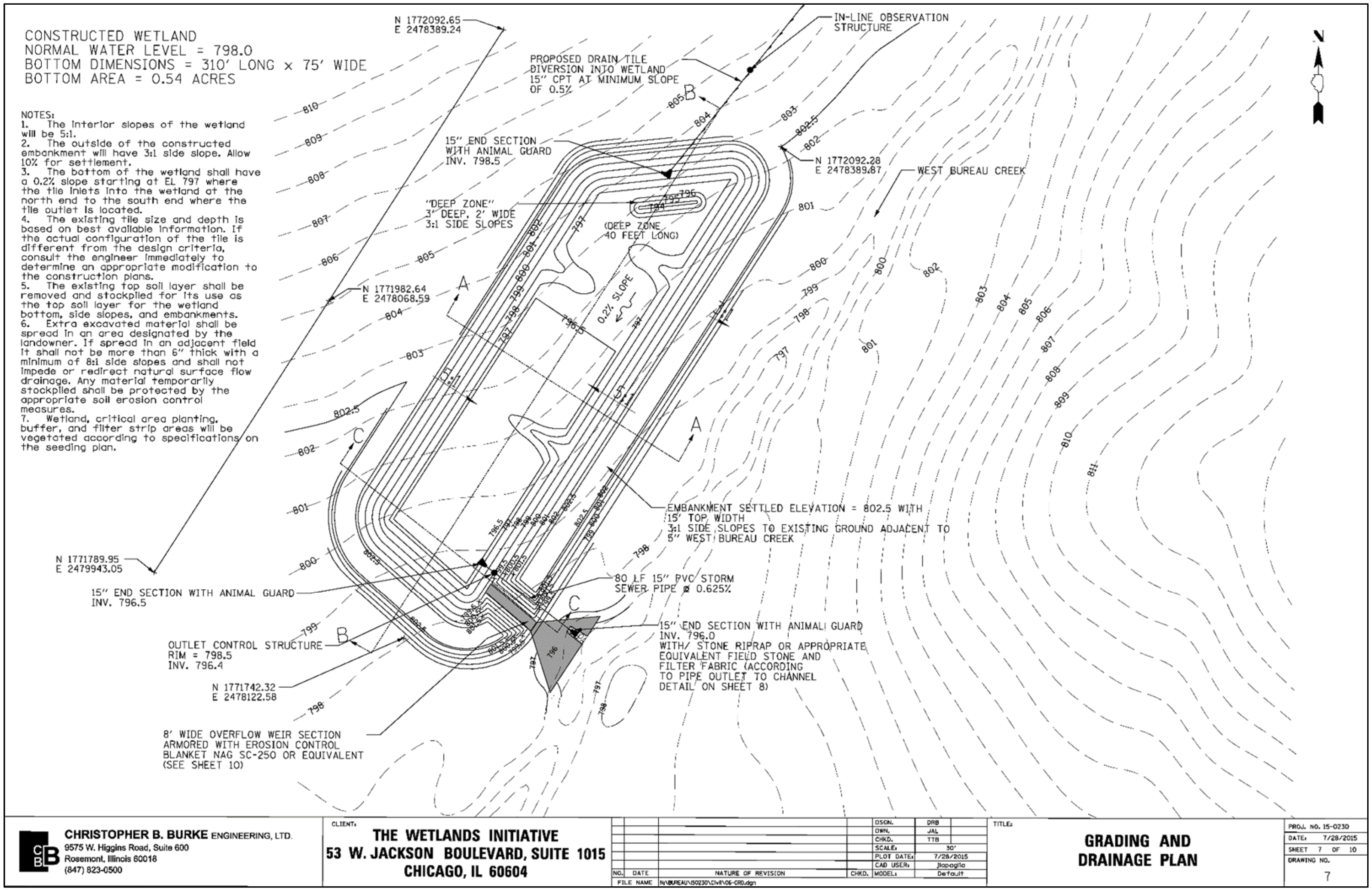
- SCS Methodology
- 25-yr, 24-hr
- Max velocity = 1.5 ft/sec
- 72-hr draw down; 10yr, 24-hr storm

West Bureau Creek near Princeton IL



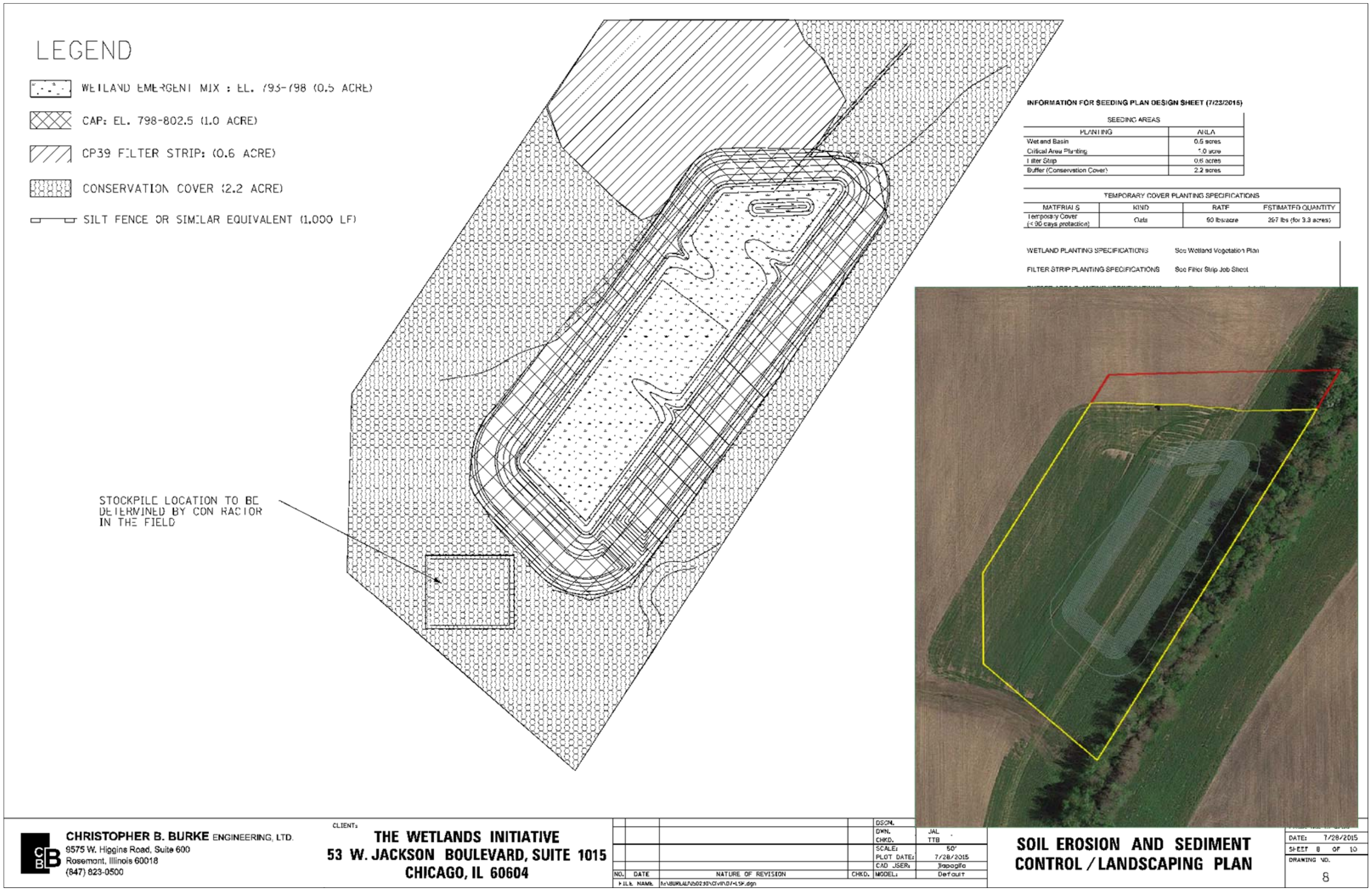
Design

- Located adjacent to creek
- Inlet and outlet structures
- 40 acres of tributary area
- Treatment area is 0.5 acres
- Small berms to increase flow path



Planting Plan

- Total footprint is 4.3 acres
- Wetland area
- Different seed mixes each zone



Construction

Conservation Expo 2015

August 4 – 6, 2015

ILLINOIS CHAPTER
Land Improvement Contractors of America
LICA
DEDICATED TO PROFESSIONAL CONSERVATION OF SOIL & WATER

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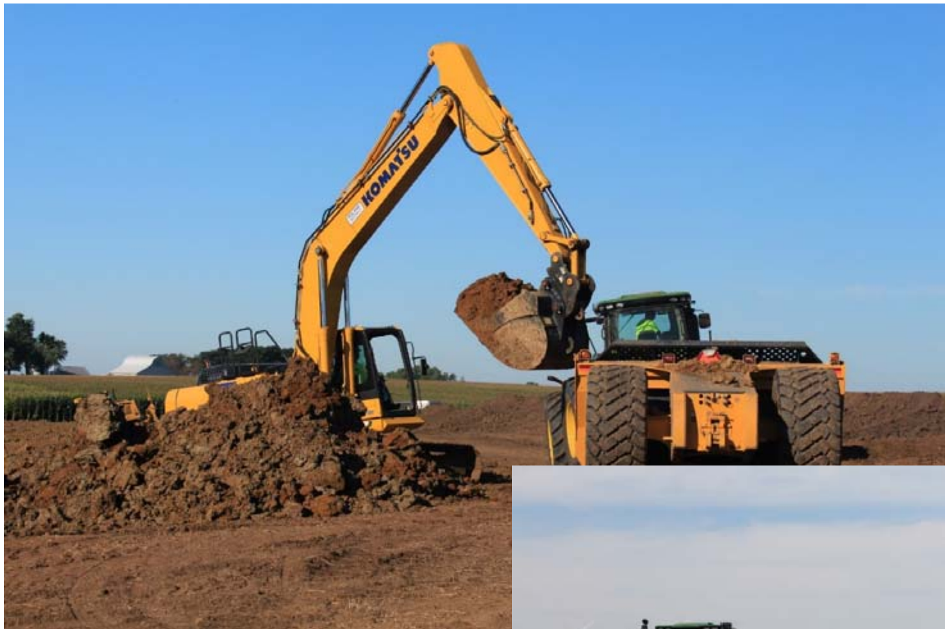
In an effort to increase public awareness and education, TWI partnered with the IL chapter of the Land Improvement Contractors of America.

The wetland was built as part of ILICA's conservation expo that was held Aug 4-6th. The construction was between the 3nd- 8th.



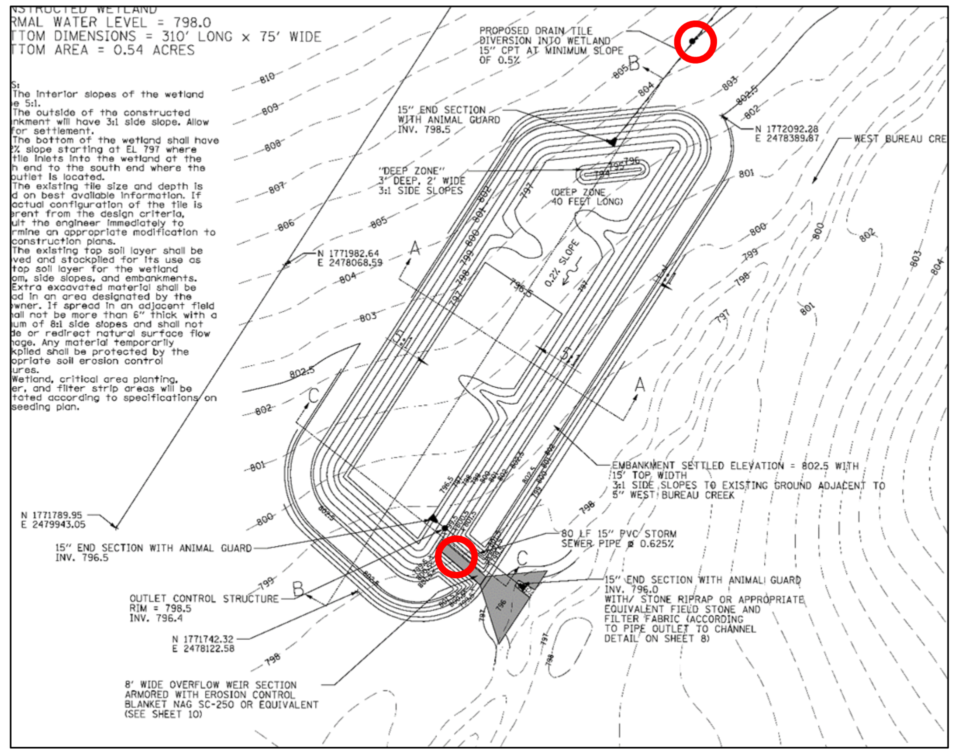
7000 Cubic Yards

Compacted Clay Liner

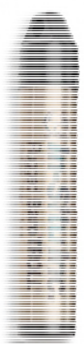

CASE

Performance Monitoring by UIC Dept. of Civil and Materials Engineering

Sampling at Inflow and Outflow

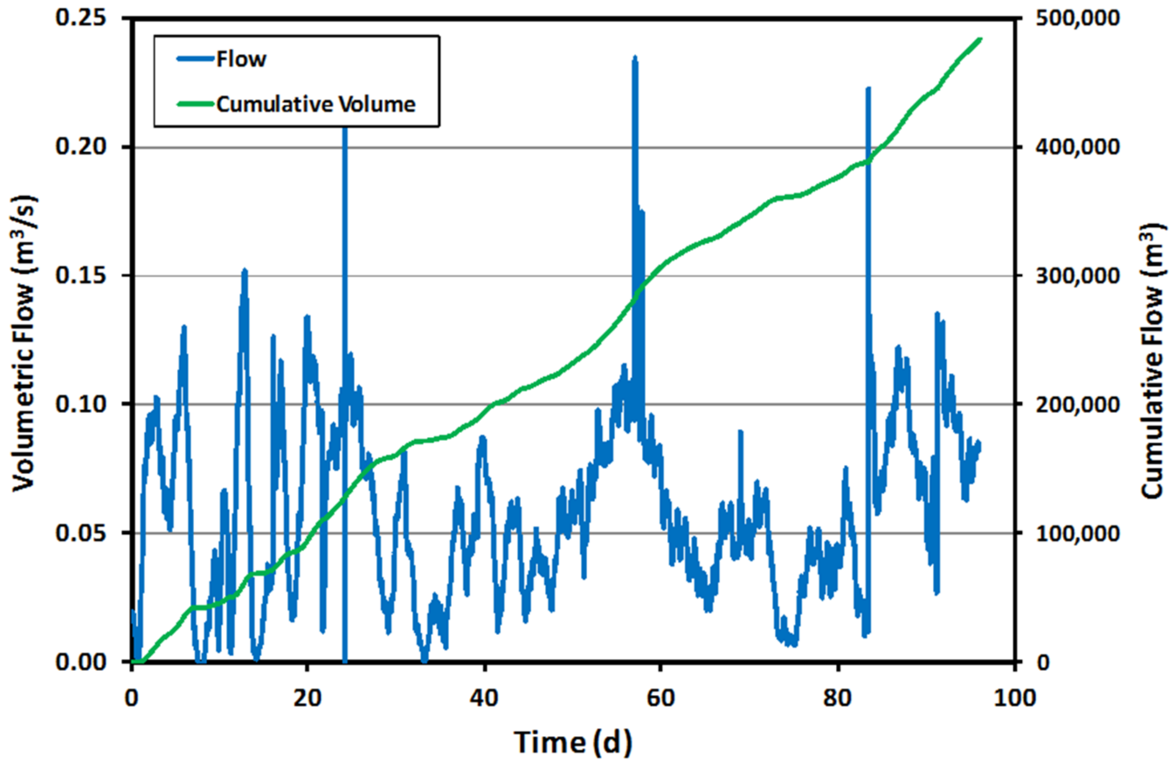


Wetland water level controlled by outlet weir



Flow calculated from known geometry and measured stage using the Francis weir equation

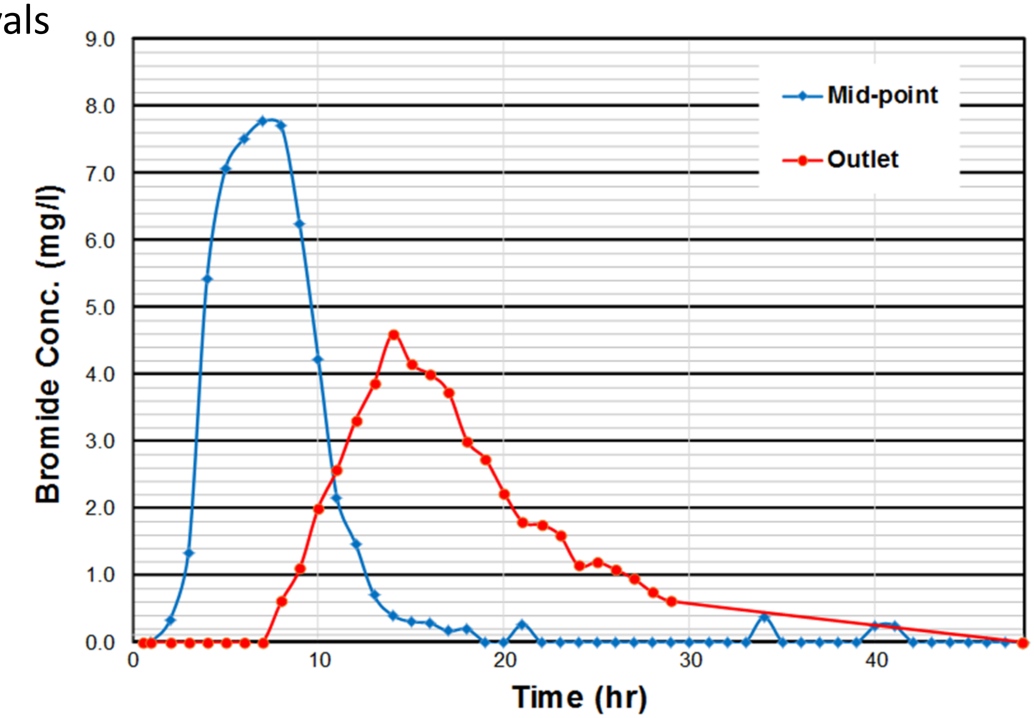
$$Q = 1.838LH^{3/2}$$



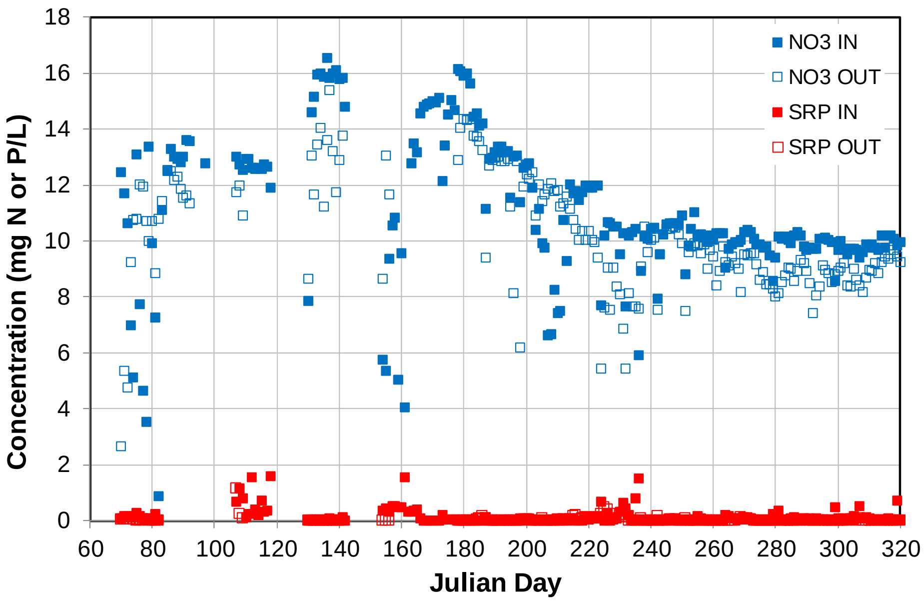
Wetland Hydraulics: Tracer Study

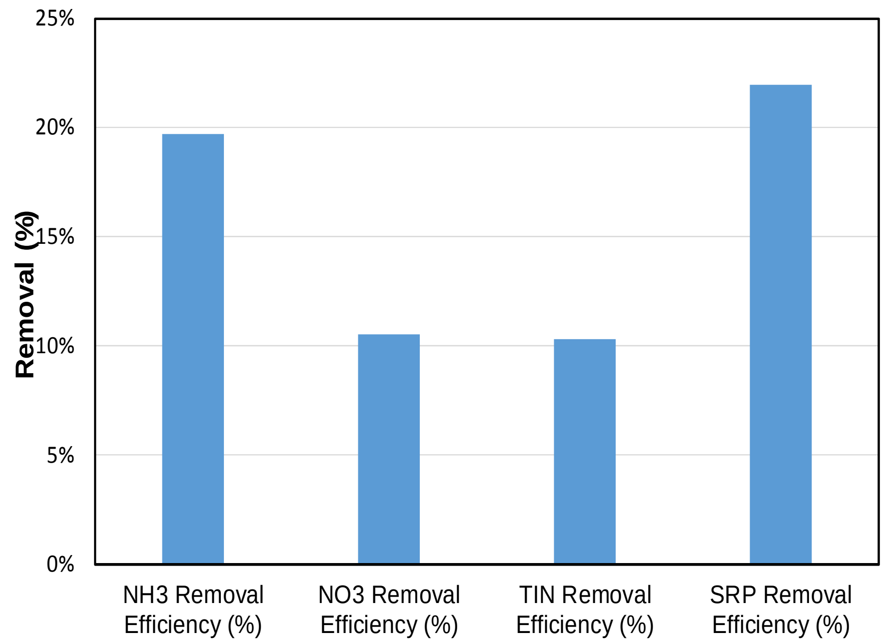
- Bromide (Br^-) tracer injected for 6 hrs at inlet
  - Sampling at wetland cell mid-point and the outlet control structure
  - Conductivity at 5 min intervals, Br^- at 1 hr intervals
  - Overall recovery was ~90%

- 1D Transport with Inflow and Storage (OTIS) model
  - No substantial short-circuiting
  - Substantial dispersion
  - Clear peak tailing in the outlet tracer
  - HRT = 17.5 ± 6.7 hr



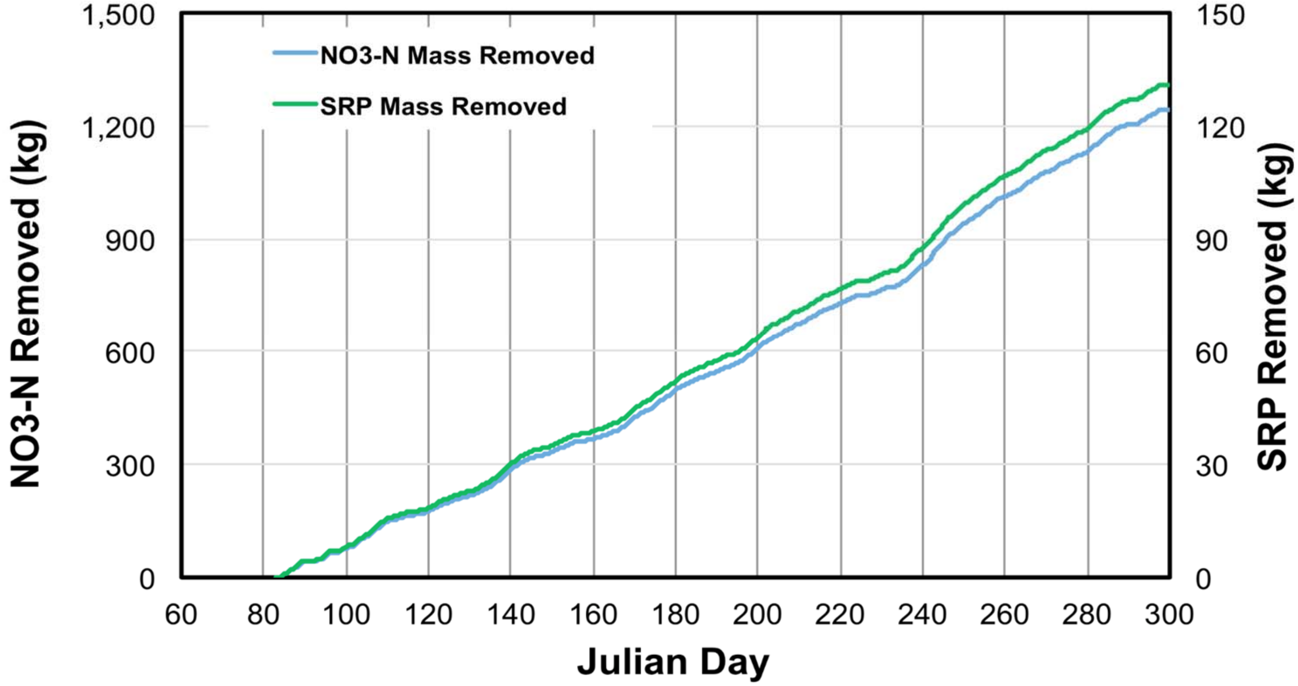
P removal > N removal (on a % basis)





Overall, removal averaged 22% for SRP, 10.6% for nitrate and 10.3% for TIN

Cumulative N and P mass removal by the system



Based on the measured flowrates and inlet/outlet nutrient concetrations, the cumulative N and P removal was determined using a mass balance approach.

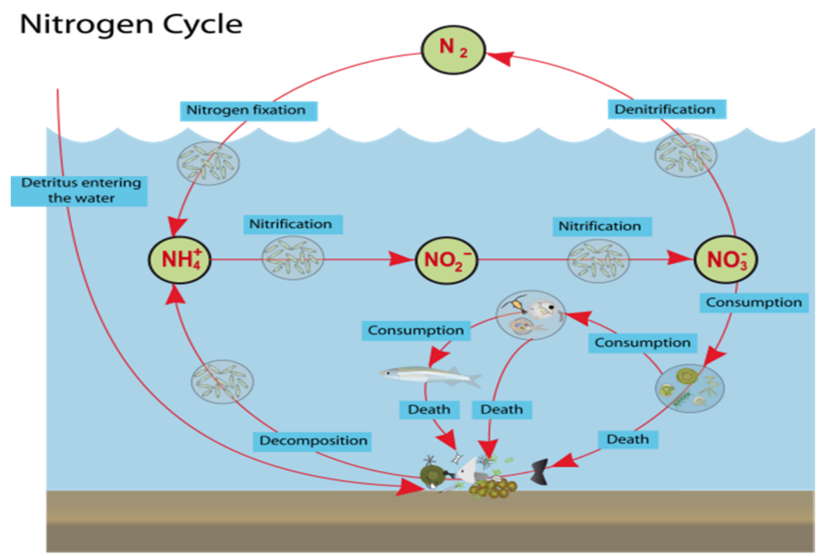
Approximately 120 kg of SRP and 1200 kg (1.3 tons) of NO3-N

Why was N removal efficiency low?

N removal is primarily through **denitrification of NO_3 to produce N_2**

Denitrification requires the presence of three (3) components simultaneously:

1. ED (simple organic compounds from OM breakdown)
2. EA (i.e. NO_3 from fertilizers and nitrification of NH_3) **NOT** AN ISSUE HERE!
3. Competent microbes to carry out the process (i.e. denitrifying bacteria)



Thus, possible reasons for lack of/low N removal include:

1. Lack of ED
2. No/low levels of denitrifying bacteria present
3. Hydraulic overloading (EA overwhelms available ED)

Why was N removal low?

Investigating these one by one:

1. Lack of ED (plenty of EA!)
   - Although the sediment is **~4% OM**, this OM may not be highly biodegradable and thus may not produce sufficient amounts of ED to match the EA load
   - Further monitoring of OM levels will help determine whether they increase from wetland growth and development

2. Lack of competent microbial community structure
   - It is likely that denitrifying bacteria need time to adapt to the wetland conditions with abundant NO_3 levels
   - Further monitoring of N removal and microbial community structure analysis via 16S RNA sequencing is ongoing

3. Overloading (EA overwhelms available ED)
   - It is possible that the higher flowrates resulted in NO_3 overloading
   - 17.5 hr HRT in the tracer study was lower than we expected, resulting in less time for denitrification to occur
   - We expect possibly longer HRT now that the weir depth is fixed and wetland plants established

Wetland development: From planting to operation

Increased incorporation of new labile OM into sediments from wetland plant growth

This will result in increased N removal efficiency (more denitrification) from our constructed “kidney”

Lessons learned

- Initial establishment of the wetland plants will require manipulation of water depths
    - Now that the system is established, water **depth adjustment is no longer needed**

- **Short-circuiting was not an issue** prior to plant establishment
    - The **conditions will only improve** now that plants are established

- Nutrient removal efficiency was variable during the wetland establishment period, but **substantial N and P removal has occurred**

- The wetland plants rapidly grow in the first summer
    - Created a **high-value wetland habitat** for wildlife

Construction photos and thanks to all involved:

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Questions…….