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

IAFSM | March 9, 2017

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UIC CIVIL AND MATERIALS ENGINEERING

THE WETLANDS INITIATIVE
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.
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
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 acts as a transport vehicle, allowing field drainage of excess water to carry nutrients with it, including nitrates.

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)

- Cover crops: 4.70–25.00
- Enhanced Nutrient Management Plans: 21.90
- Diversified crop rotation: 19.50
- Conservation tillage: 3.20
- Grassed buffers: 3.20
- Restored or constructed wetlands: 1.30–1.50
- Bioreactors: 0.95
- Drainage water management: 0.90
- Nitrogen fertilizer rate application: -0.70

"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.
Design

NRCS Criteria

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

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<thead>
<tr>
<th>POSITION</th>
<th>SIZE</th>
<th>DEPTH</th>
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<tbody>
<tr>
<td>1. Intercept tile drainage before outlet ditch or stream</td>
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<td>2. Capture high nutrient loads</td>
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<td>3. Locate in watershed headwater areas</td>
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<td>4. Marginal or unprofitable land</td>
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<td>5. Key to nutrient removal</td>
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<td>6. Allow adequate residence time</td>
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<td>7. Treatment area is 0.5-5.0% of the drainage area</td>
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<td>8. Treatment area is 12” above to 24” below permanent pool</td>
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<td>9. Marsh wetland (aka shallow “pond”)</td>
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<td>10. At least 50% of the permanent (normal) pool is 12” or less</td>
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<td>11. Anything greater than 24” in depth doesn’t count towards the ratio or treatment area</td>
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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
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 3rd-8th.
7000 Cubic Yards

Compacted Clay Liner
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
Overall, removal averaged 22% for SRP, 10.6% for nitrate and 10.3% for TIN.
Based on the measured flow rates and inlet/outlet nutrient concentrations, 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\textsubscript{3} to produce N\textsubscript{2}**

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

1. ED (simple organic compounds from OM breakdown)
2. EA (i.e. NO\textsubscript{3} from fertilizers and nitrification of NH\textsubscript{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:

Conservation Expo 2015

August 4 – 6, 2015

Questions......