SOURCE WATER QUALITY AND THE COST OF NITRATE TREATMENT IN THE MISSISSIPPI RIVER BASIN

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Northeast-Midwest Institute

Congressional Briefing
May 23, 2018
Nutrients and Algal Blooms

![Lake Erie Map](image1.png)

![Algal Bloom Advisory Sign](image2.png)

![Algal Bloom Sample](image3.png)
Nutrients and Drinking Water

Photo credits: Des Moines Water Works
Study Locations
### Study Locations

<table>
<thead>
<tr>
<th>Utility</th>
<th>State</th>
<th>Intake Source</th>
<th>Source Watershed</th>
<th>Watershed size (square miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Des Moines Water Works</td>
<td>IA</td>
<td>Raccoon River</td>
<td>Raccoon River</td>
<td>12,884</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Des Moines River</td>
<td>Des Moines River</td>
<td>3,625</td>
</tr>
<tr>
<td>City of Decatur</td>
<td>IL</td>
<td>Lake Decatur</td>
<td>Sangamon River</td>
<td>925</td>
</tr>
<tr>
<td>Aqua Illinois Vermilion County</td>
<td>IL</td>
<td>Lake Vermilion</td>
<td>North Fork Vermilion River</td>
<td>293</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Utility</th>
<th>State</th>
<th>Population Served</th>
<th>Capacity (MGD)</th>
<th>Average Production (MGD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Des Moines Water Works</td>
<td>IA</td>
<td>233,020</td>
<td>100</td>
<td>47</td>
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<tr>
<td>City of Decatur</td>
<td>IL</td>
<td>76,122</td>
<td>36</td>
<td>20</td>
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<tr>
<td>Aqua Illinois Vermilion County</td>
<td>IL</td>
<td>46,560</td>
<td>14</td>
<td>8</td>
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</table>
## Watershed Activities

<table>
<thead>
<tr>
<th>Watershed</th>
<th>SPARROW-Modeled Flow-Weighted Mean Concentration (mg/L)</th>
<th>10-Year Measured Mean Concentration (mg/L)</th>
<th>Total Nitrogen Load Delivered to River Outlet (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raccoon River (Des Moines, IA)</td>
<td>11.55</td>
<td>6.67</td>
<td>22,486,340</td>
</tr>
<tr>
<td>Des Moines River (Des Moines, IA)</td>
<td>9.12</td>
<td>6.02</td>
<td>30,237,999</td>
</tr>
<tr>
<td>Sangamon River (Decatur, IL)</td>
<td>6.47</td>
<td>4.52</td>
<td>3,832,495</td>
</tr>
<tr>
<td>North Fork Vermilion River</td>
<td>6.44</td>
<td>4.37</td>
<td>1,833,558</td>
</tr>
</tbody>
</table>

Vermilion County, IL
Watershed Activities

Contributions of Different Types of Nitrogen Loading to Each Influent Waterbody

Source Type: Sewerage Point Sources, Atmospheric Deposition, Manure (Confined), Farm Fertilizer, Fixation and Legume Sources, Urban Land

Contributions (%):
- Raccoon River
- Des Moines River
- Sangamon River
- North Fork Vermillion River
<table>
<thead>
<tr>
<th>Source Reduction Percentage</th>
<th>On/Off (100%)</th>
<th>Nutrient Reduction Scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20%</td>
<td>45%</td>
</tr>
<tr>
<td><strong>Individual Sources</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sewerage Point Sources</td>
<td>99</td>
<td>100</td>
</tr>
<tr>
<td>Atmospheric Deposition</td>
<td>85</td>
<td>97</td>
</tr>
<tr>
<td>Confined Manure</td>
<td>64</td>
<td>97</td>
</tr>
<tr>
<td>Farm Fertilizer</td>
<td>49</td>
<td>97</td>
</tr>
<tr>
<td>Fixation and Legume Sources</td>
<td>96</td>
<td>99</td>
</tr>
<tr>
<td>Urban Land Runoff</td>
<td>96</td>
<td>99</td>
</tr>
<tr>
<td><strong>Source Combinations</strong></td>
<td></td>
<td></td>
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<tr>
<td>Point Sources</td>
<td>84</td>
<td>97</td>
</tr>
<tr>
<td>Runoff Loads</td>
<td>45</td>
<td>89</td>
</tr>
<tr>
<td>Urban Sources</td>
<td>96</td>
<td>99</td>
</tr>
<tr>
<td>Farm Field Loads</td>
<td>35</td>
<td>87</td>
</tr>
<tr>
<td>Background Sources</td>
<td>71</td>
<td>94</td>
</tr>
<tr>
<td>Farm Fertilizer + Background Sources</td>
<td>20</td>
<td>84</td>
</tr>
</tbody>
</table>

Cells colored in shades of red indicate lower rates of nitrogen loading reduction, with the darkest cell representing the lowest reduction; cells colored in shades of green indicate a greater nitrogen loading reduction, with the darkest cell representing the greatest reduction; and cells colored in shades of yellow indicate intermediate reductions.
Watershed Activities – Raccoon River

Total Nitrogen Load by SPARROW Catchments in the Raccoon River Watershed to the Des Moines Intake (Primary 1)

Legend
- PWS Intake
- Raccoon River Watershed
- Catchment N Load as Percent of Watershed N Load (Quantities)
  - Lowest
  - 2nd
  - 3rd
  - Highest

Total Nitrogen Yield by SPARROW Catchments in the Raccoon River Watershed to the Des Moines Intake (Primary 1)

Legend
- PWS Intake
- Raccoon River Watershed
- Total N Yield (Quantiles)
  - Lowest
  - 2nd
  - 3rd
  - Highest
Influent Nitrate Concentrations – Des Moines – Raccoon River Intake

Des Moines, IA Daily Raccoon River Influent Nitrate Concentration

MCL

Date


Daily Influent Nitrate Concentration (mg/L)

0.00 5.00 10.00 15.00 20.00 25.00
Nitrate MCL Exceedances

Daily Exceedances of the Nitrate MCL at Intake

Year


Daily Exceedances of the Nitrate MCL at intake

- Des Moines, IA - Raccoon River
- Des Moines, IA - Des Moines River
- Decatur, IL
- Vermillion County, IL
# Nitrate MCL Exceedances

<table>
<thead>
<tr>
<th>Utility</th>
<th>Annual Influent Concentration Exceedances (in Days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10 mg/L</td>
</tr>
<tr>
<td>Des Moines, IA (Raccoon River)</td>
<td>80</td>
</tr>
<tr>
<td>Des Moines, IA (Des Moines River)</td>
<td>56</td>
</tr>
<tr>
<td>Decatur, IL</td>
<td>21</td>
</tr>
<tr>
<td>Vermilion County, IL</td>
<td>15</td>
</tr>
</tbody>
</table>
Nitrate MCL Exceedances

Number of Exceedances by Nitrogen Reduction Scenarios

- **Decatur - Sangamon River**
- **Vermilion County - North Fork Vermilion River**
- **Des Moines - Raccoon River**
- **Des Moines - Des Moines River**

Exceedances Over USEPA MCL (Days)

Number of exceedances by nitrogen reduction scenarios:
- Recorded Data
- 10% Reduction
- 20% Reduction
- 45% Reduction
# Nitrate Treatment Costs

<table>
<thead>
<tr>
<th>Utility</th>
<th>Year of construction</th>
<th>Production (MGD)</th>
<th>Inflation-adjusted capital cost ($ million)</th>
<th>Amortized annual capital cost ($)</th>
<th>Average annual O&amp;M cost ($)</th>
<th>Average annual cost per unit volume ($/kgal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Des Moines</td>
<td>1991</td>
<td>47</td>
<td>10.3</td>
<td>207,429</td>
<td>513,286</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.04</td>
</tr>
<tr>
<td>Decatur</td>
<td>2002</td>
<td>20</td>
<td>14.6</td>
<td>384,503</td>
<td>67,598</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.06</td>
</tr>
<tr>
<td>Vermillion County</td>
<td>2001</td>
<td>8</td>
<td>12.3</td>
<td>318,733</td>
<td>25,193</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.12</td>
</tr>
</tbody>
</table>
Nitrate Treatment Costs

Annual Capital Cost for Nitrate Treatment

\[ R^2 = 0.8403 \]
Nitrate Treatment Costs

![Graph showing the relationship between average daily water production and annual O&M cost per unit volume.](image)

Annual O&M Cost for Nitrate Treatment ($/kgal)

- Average daily water production (MGD)
- Annual O&M cost per unit volume ($/kgal)

**R² = 0.0517**
Key Findings

- Farm fertilizer was the largest contributor of nitrogen loading.
- Nitrogen reduction scenarios suggested that cross-sector reductions would be most effective in reducing nitrogen loads in the source waters.
- Nitrate concentrations generally increased over the 10-year study period, resulting in an increase in the daily exceedances of the nitrate MCL.
- Daily exceedances were significantly higher during the second half of the study period. A 45 percent reduction in the intake nitrate concentrations would virtually eliminate exceedances, but even a modest 10 percent reduction would bring down exceedances by 20-33 percent.
- Capital expense is a significant component of the overall cost of nitrate treatment at the three utilities.
- Amortized capital cost of the treatment unit outweighed annual O&M costs, except in Des Moines.
- In years when influent nitrate levels were the highest, utilities spent 4-9 percent of their overall operating budget on nitrate treatment.
- Smaller utilities face an undue burden of nitrate pollution in drinking water sources.
- Conservation programs have the potential to limit some of these costs to utilities, although the extent of their impact will depend on a variety of factors specific to the watershed.
Open questions

- Comprehensive assessment of nitrate treatment costs
- Measure the impact of conservation on water quality
- Identification of data gaps
Recommendations

- Capital support to small communities
- Facilitate reporting of nitrate treatment costs
- Consider regulation of ag discharges as point sources
- Encourage nutrient trading
- Technical assistance programs and research
Thank You

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Research on Nutrients and Nitrate
Water Research Foundation

Advancing the science of water to improve the quality of life
The integrated organization represents the evolution of water research issues, the overlap between water and wastewater, and efficiencies to be gained through a consolidated research program.

Learn more at www.waterrf.org and www.werf.org
Outline

• Research on Source Water Protection
  - Focus on Nutrient Control

• Research on Nitrate Control Technologies

• Future Research
Source Water Protection Research Planning Workshop - 4091

• 25 attendees representing DW, WW, regulators, academics, NGOs, and consultants

• 16 projects in three goal areas $\rightarrow$ $5.5M
Developing a Roadmap and Vision for Source Water Protection for U.S. Drinking Water Utilities - 4176

- Vision/Roadmap
- Strategy
- Framework
- Decision-Making: Process and Tools

Watersheds of the Upper Scioto River and the Upper Big Walnut Creek
Barriers to Source Water Protection Programs

• Lack of authority to do anything to protect the source water

• Restricted resources that are directed toward other higher-priority utility functions

• Belief that some other entity is responsible for source water protection

• Government agencies (other than the municipalities) controlling the lakes/reservoirs used
Nitrate Technology Options

- Conventional Ion Exchange (IX)
  - Standard resin
  - Nitrate selective resin (10-20% more expensive)
- Biological Nitrate Treatment
  - Microvi Biological Nitrate Removal System
  - BKT Biofiltration
  - Biottta
- Brine Reuse with Electrochemical Denitrification
Biological and Ion Exchange Nitrate Removal Evaluation - 4131

MBfR + Ozone + Biologically Active Carbon Filtration

Fixed Bed Bioreactor with Plastic Media + Ozone + Biologically Active Carbon Filtration

Fixed Bed Ion Exchange + Evaporation Ponds/Landfill
## Cost Estimates

### Cost summary for nitrate treatment alternatives

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Project construction cost* ($     )</th>
<th>Annual O&amp;M cost* ($/year)</th>
<th>Net present worth* ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alt. 1—MBfR + Ozone + BAC</td>
<td>$23,844,600</td>
<td>$3,429,100</td>
<td>$66,593,700</td>
</tr>
<tr>
<td>Alt. 2—Fixed Bed Bioreactor with Plastic Media + Ozone + BAC</td>
<td>$19,652,400</td>
<td>$2,712,200</td>
<td>$53,450,100</td>
</tr>
<tr>
<td>Alt. 3—Ion Exchange + Evaporation Ponds</td>
<td>$16,446,000</td>
<td>$3,175,200</td>
<td>$56,014,900</td>
</tr>
</tbody>
</table>

* Rounded up to the nearest hundred dollars.
Pilot Testing Nitrate Treatment Processes with Minimal Brine Waste - 4578

- A proprietary biological denitrification system (MB-N2)

- Standard IX resin without brine reuse

- Nitrate selective IX resin with electrochemical denitrification (ECD) system
## Cost Estimates

<table>
<thead>
<tr>
<th>Treatment alternatives</th>
<th>Capital cost</th>
<th>Annual O&amp;M cost</th>
<th>20-year present worth cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative 1 - 1,600 gpm MB-N2 system</td>
<td>$6,293,000</td>
<td>$234,300</td>
<td>$9,212,000</td>
</tr>
<tr>
<td>Alternative 2 - 1,930 gpm conventional IX system</td>
<td>$5,317,000</td>
<td>$763,400</td>
<td>$14,829,000</td>
</tr>
<tr>
<td>Alternative 3 - 1,600 gpm IX-ECD system</td>
<td>$10,945,060</td>
<td>$331,700</td>
<td>$15,078,000</td>
</tr>
<tr>
<td>Parameters</td>
<td>Alternative 1 - 1,600 gpm MB-N2 system</td>
<td>Alternative 2 - 1,930 gpm conventional IX system</td>
<td>Alternative 3 - 1,600 gpm IX-ECD system</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
<td>----------------------------------------</td>
<td>-------------------------------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>Operational complexity</td>
<td>High (1)</td>
<td>Low (3)</td>
<td>High (1)</td>
</tr>
<tr>
<td>Waste disposal and environmental sustainability</td>
<td>High (3)</td>
<td>Low (1)</td>
<td>Moderate (2)</td>
</tr>
<tr>
<td>Overall safety (dealing with hazardous chemicals, toxic gas release, etc.)</td>
<td>Moderate (2)</td>
<td>High (3)</td>
<td>Low (1)</td>
</tr>
<tr>
<td>Process reliability</td>
<td>Moderate (2)</td>
<td>High (3)</td>
<td>Moderate (2)</td>
</tr>
<tr>
<td>Footprint</td>
<td>High (1)</td>
<td>Low (3)</td>
<td>Moderate (2)</td>
</tr>
<tr>
<td>Source water variability</td>
<td>Moderate (2)</td>
<td>High (3)</td>
<td>High (3)</td>
</tr>
<tr>
<td>Technology / treatment history</td>
<td>Moderate (2)</td>
<td>High (3)</td>
<td>Low (1)</td>
</tr>
</tbody>
</table>

**Total scores =**

- Alternative 1: 13
- Alternative 2: 19
- Alternative 3: 12
Treatment Conclusions

• Biological treatment processes are showing promises
  - No brine disposal
  - Enhanced Nitrate removal

• Ion Exchange
  - Increased efficiency with new advancements
  - Also results in less brine

• Cost alone should not drive decisions
Future Research on Nutrient Control

Remote Sensing: Areal and Satellite Data

Evidence of runoff identified in the aerial data but no accessible to ground team.
Thank you!!

John Albert
Chief Research Officer
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303.734.3413
@JohnAlbertWRF
NRCS Field Office Locations, 2017

Legend
- NRCS - 2,429
- Federal land

Note: Includes field office locations where technical assistance is provided directly to producers and landowners, including co-located offices. Other USDA facilities not included.
Conservation Technical Assistance

• 70% of Landownership is Private

• NRCS provide voluntary, science-based technical and financial assistance to landowners to address resource concerns (e.g. soil erosion, water quality, wildlife habitat, etc.)
CPTAD – Conservation Planning

Conservation Planning Certification

- Apprentice Planner
  - Support Certified Conservation Planners in Planning Process
- Certified Conservation Planner
  - Serve as Responsible Federal Official (RFO)
- Master Conservation Planner
  - Watershed Planning
  - Quality Assurance Responsibilities
NRCS manages nearly 50,000 miles of boundaries – if added together they would stretch around the earth twice!

<table>
<thead>
<tr>
<th>NUMBER OF EASEMENTS</th>
<th>ACRES</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL</td>
<td>21,481</td>
</tr>
<tr>
<td></td>
<td>5,214,333</td>
</tr>
</tbody>
</table>
FAPD – EQIP

Program Purpose

Primary Goals:

1. Financial Assistance to address resource concern(s)

2. Almost 200 conservation practices available

354,000 + conservation practices per year
FAPD – EQIP

Locally Led Conservation

State Technical Committee

47 Resource Concerns => WQ competition

State Conservationist

Examples

- Conservation Practices
- Payment Limits
- Payment Rates
- Prioritization
- Resource Concerns

47 Resource Concerns => WQ competition
## Top Practices – 2014 Farm Bill

<table>
<thead>
<tr>
<th>Practice Name</th>
<th>Number</th>
<th>Dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover Crop</td>
<td>57,791</td>
<td>$295,608,194</td>
</tr>
<tr>
<td>Fence</td>
<td>54,996</td>
<td>$231,639,820</td>
</tr>
<tr>
<td>Brush Management</td>
<td>34,529</td>
<td>$206,389,345</td>
</tr>
<tr>
<td>Irrigation System, Sprinkler</td>
<td>6,571</td>
<td>$204,645,533</td>
</tr>
<tr>
<td>Waste Storage Facility</td>
<td>4,847</td>
<td>$202,370,766</td>
</tr>
<tr>
<td>Irrigation Pipeline</td>
<td>11,549</td>
<td>$166,364,188</td>
</tr>
<tr>
<td>Irrigation System, Micro</td>
<td>5,446</td>
<td>$134,572,460</td>
</tr>
<tr>
<td>Pipeline</td>
<td>33,829</td>
<td>$121,853,865</td>
</tr>
<tr>
<td>Waste Facility Cover</td>
<td>4,529</td>
<td>$116,092,229</td>
</tr>
<tr>
<td>Pasture &amp; Hayland Planting</td>
<td>22,390</td>
<td>$105,841,936</td>
</tr>
<tr>
<td>Heavy Use Area Protection</td>
<td>31,446</td>
<td>$99,466,305</td>
</tr>
<tr>
<td>Forest Stand Improvement</td>
<td>16,753</td>
<td>$94,695,469</td>
</tr>
<tr>
<td>Pumping Plant for Water Control</td>
<td>16,367</td>
<td>$86,999,642</td>
</tr>
<tr>
<td>Trough or Tank</td>
<td>40,891</td>
<td>$83,977,626</td>
</tr>
<tr>
<td>Combustion System Improvement</td>
<td>2,128</td>
<td>$73,828,447</td>
</tr>
</tbody>
</table>

Original obligations which do not reflect downward adjustments. Fiscal year 2017 obligations are preliminary pending final approval.
Conservation Stewardship Program (CSP)
Active Contracts as of 2017

Map ID: m14242
Data Source:
ProTracts Program Contracts System December 2017
U.S. Department of Agriculture, Natural Resources Conservation Service

Map Source:
U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS)
Soil Survey and Resource Assessment (SSRA)
Resource Assessment Division (RAD) Beltsville, MD December 2017

National Total: 95,258
Data is as of the end of FY 2017.
<table>
<thead>
<tr>
<th>Practice Code</th>
<th>Practice Name</th>
<th>Frequency Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>E595116X</td>
<td>Reduce risk of pesticides in surface water by utilizing precision pesticide application techniques</td>
<td>931</td>
</tr>
<tr>
<td>E595116Z</td>
<td>Reduce risk of pesticides in surface water by utilizing IPM PAMS techniques</td>
<td>691</td>
</tr>
<tr>
<td>E340107Z</td>
<td>Cover crop to minimize soil compaction</td>
<td>544</td>
</tr>
<tr>
<td>E340106Z2</td>
<td>Use of multi-species cover crops to improve soil health and increase soil organic matter</td>
<td>516</td>
</tr>
<tr>
<td>E328136Z</td>
<td>Leave standing grain crops unharvested to benefit wildlife food sources</td>
<td>497</td>
</tr>
<tr>
<td>E528140Z1</td>
<td>Maintaining quantity and quality of forage for animal health and productivity</td>
<td>442</td>
</tr>
<tr>
<td>E340106Z1</td>
<td>Intensive cover cropping to increase soil health and soil organic matter content</td>
<td>428</td>
</tr>
<tr>
<td>E590118Z</td>
<td>Improving nutrient uptake efficiency and reducing risk of nutrient losses to surface water</td>
<td>148</td>
</tr>
<tr>
<td>E511137Z1</td>
<td>Harvest of crops (hay or small grains) using measures that allow desired species to flush or escape</td>
<td>132</td>
</tr>
<tr>
<td>E666137Z1</td>
<td>Snags, den trees, and coarse woody debris for wildlife habitat</td>
<td>123</td>
</tr>
</tbody>
</table>
### Science Based Evaluations

**Conservation Effects Assessment Project (CEAP)**

<table>
<thead>
<tr>
<th>Region</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mississippi River Basin</td>
<td>20+%</td>
</tr>
<tr>
<td>Western Lake Erie</td>
<td>36%</td>
</tr>
<tr>
<td>Great Lakes</td>
<td>43%</td>
</tr>
<tr>
<td>Chesapeake Bay</td>
<td>38+%</td>
</tr>
</tbody>
</table>

- NRI Data Points, Aerial Photos
- NRCS Delivery System, Landowner Surveys
Science Based Outcomes

Mature Science

• Resource Concerns unequal
  • sheet/rill vs. streambank and legacy sediments
  • surface water vs groundwater

Less Mature Science

> 7 Million Fields
CPTAD – Precision Conservation

Precision Agriculture

DRIVERS
- Consistency
- Heritage Foundation
- President’s Budgets
- Farm Bill
  - Hiring Limits
  - Funding Carryover
- NRCS Standards
- NRCS Agreements

CAP 132
Questions?
Policy Implications
I. Immediate Policy Implications (Do No Harm)

A. The Farm Bill
B. The Clean Water Rule
C. U.S. – China Trade Relations
II. General Policy Implications (Nitrate Removal Is Expensive)

- Regulatory changes can increase treatment costs
- These costs generally hit smaller, rural communities hardest
- Certain Conservation Programs Can Lower These Cost
- We Need Better Data
III. Legislative Solutions
(How to Fix It)
III. Legislative Solutions
(How to Fix It)

- Provide capital support to small communities
- Facilitate nitrate removal cost reporting
- Explore the possibility of regulating agricultural discharges as point source
- Nutrient trading
- Technical assistance
- Mindful appropriations
Thank You

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