Subsurface Nutrient Processing Capacity in Agricultural Roadside Ditches

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Iowa Geological Survey

Collaborators:
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Marty St. Clair, Coe College
Justin Meissen, UNI Tallgrass Prairie Center
Why Roadside Ditches?

- Roadside ditches line more than 6.3 million km of public roads in the US – they are integral components of watershed-scale hydrologic processes.
- As linear features, they cross topographic boundaries and concentrate flow.
- Efficient conduits for NPS pollutant delivery.
- “Biogeochemical hotspots”? Do these areas provide water quality benefits?
IDOT Design Specifications

Normal width = 10 ft

Normal depth = 5 ft
Focus on roadside ditches that receive flow and nutrients from small catchments.
Roadside Ditches Project

• Funded by Iowa Nutrient Research Center in 2016
• Focusing on Lime Creek watershed for two main reasons: 1) manageable size; 2) Coe College (Dr. Marty St. Clair) monitoring in area

• Project goals:
  1. Determine how much land drains into the ditches
  2. Measure soil nutrient and heavy metal levels
  3. Quantify infiltration rates
  4. Measure groundwater nutrient concentrations
  5. Evaluate nutrient processing capacity
Lime Creek watershed

41 m² watershed in east-central Iowa
Land cover: 79% row crop, 12% grass, 2% roads
Nitrate sensor in Lime Creek
Site selection

- Utilized GIS routines developed for floodplain mapping program to determine contributing areas to ditches.
Monitored sites in Lime Creek

30% of Lime Creek watershed area drains into a roadside ditch!
Investigation Activities

- Monitoring well installation (3 per site)
- Soil sampling
- Infiltration measurements
- Roadside vegetation survey (UNI)
- Heavy metal analysis (Coe College)
- Monthly water quality sampling and analysis
Well installation

- Hand auger wells to a depth of ~12 feet in the ditch
- Installed PVC well screens and risers
Roadside Vegetation Survey

• Conducted by Justin Meissen, Tallgrass Prairie Center
• Methods:
  • Randomly selected sampling points within the ditch
  • At each point, sampled vegetation within 1 m² quadrat
  • Within quadrat, identified all species present and assessed canopy cover for each species
  • Conducted during July 13-17, 2017.
Key Findings from Vegetation Survey

**Key Findings**

- Well site ditches are variable in vegetation
- Ditches assessed are generally dominated by cool-season graminoids
- A third of ditches are dominated by native species, and another third are dominated by introduced species
- Smooth brome (*Bromus inermis*), reed canary grass (*Phalaris arundinacea*), and various native sedges (*Carex spp.*) are the most prevalent species in the assessed ditches

**Table 1.** Summary of ditch types based on canopy cover conditions. Sites meeting each condition are listed in right column.

<table>
<thead>
<tr>
<th>Condition (% cover)</th>
<th>Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native dominated (&gt;60% native)</td>
<td>1,2</td>
</tr>
<tr>
<td>Introduced dominated (&gt;60% introduced)</td>
<td>3,4</td>
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<tr>
<td>No clear native/introduced dominance</td>
<td>5,6</td>
</tr>
<tr>
<td>Grass dominated (&gt;60% grass)</td>
<td>1,3,4,5</td>
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<tr>
<td>Forb dominated (&gt;60% forb)</td>
<td>6</td>
</tr>
<tr>
<td>No clear grass/forb dominance</td>
<td>2</td>
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</table>
Soils Investigation

Soil analyzed for:
- Particle size distribution
- Bulk density
- Nutrients, CEC, OM
- TN, TC, C/N ratios
- Heavy metals

<table>
<thead>
<tr>
<th>Transect</th>
<th>sand%</th>
<th>silt%</th>
<th>clay%</th>
<th>TN%</th>
<th>TC%</th>
<th>C/N</th>
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<tbody>
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<td>29</td>
<td>24</td>
<td>0.087</td>
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<td>27</td>
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<td>24</td>
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</table>
• Most ditch soils identified as highly altered with evidence of extensive sedimentation
• Since ditches were created, surface horizons (A horizons) had developed to varying depths ranging from 10 – 53 cm with a mean depth of 22 cm and were most often underlain by either Bw or Bg horizons.
• Boundaries between the A and B horizons were predominately abrupt.
• These A horizons are formed almost entirely in depositional sediments.
• A horizons were significantly higher in silt content (39%) compared to B (25%) and C (24%) horizons whereas B and C horizons were significantly higher in clay (27% and 22%, respectively) compared to A horizons (12%) (p<0.0001).
• Silt is an important indicator of soil sedimentation (sand particles do not move as far from their source in the field and clay particles will stay in suspension and are carried to streams and rivers).
- Total nitrogen was 10X higher in A horizons (0.2% compared to 0.02%) and NO$_3$-N averaged 3.6% in the A horizons compared to 1.6% and 1.5% in B and C horizons, respectively.
Organic matter and total carbon contents were significantly higher (p<0.0001) in A horizons compared to B and C horizons (3% compared to 0.5% and 0.5%, respectively for each).
900 lbs of deposited soil sediments per every 5 ft of road ditch
Sedimentation depths ranged from 11-37 cm with a mean of 27 +/-10 cm at the upper and 10-47 cm with a mean of 31 +/-16 at the lower locations
Metals with portable XRF unit

• Soil samples analyzed with Thermo Scientific XRF Analyzer

• Surface soils collected near road, ditch bottom and field edge

• Goal: Assess spatial variations related to road type and use
Metals with portable XRF unit

<table>
<thead>
<tr>
<th>Analyte</th>
<th>field</th>
<th>Ditch</th>
<th>Road</th>
<th>Road Type</th>
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<td></td>
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<td>6.4</td>
<td>5.2</td>
<td>4.8</td>
<td>5.7</td>
</tr>
</tbody>
</table>

Higher Ca near road
Overall, not many trends
Higher Sc near road
Slightly higher Pb near road
## Infiltration and bulk density measurements

<table>
<thead>
<tr>
<th>Ditch</th>
<th>ditch average mm/min</th>
<th>ditch average g/cm³</th>
<th>Road type</th>
</tr>
</thead>
<tbody>
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<td>0.34</td>
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<td>Highway</td>
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<td>3</td>
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<tr>
<td>5</td>
<td>0.24</td>
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<tr>
<td>11</td>
<td>0.30</td>
<td>1.55</td>
<td>Gravel</td>
</tr>
</tbody>
</table>

Assuming an average infiltration rate of 0.3 mm/min and ditch length of 500 ft and width of 10 ft, approximately 54,000 gal/day of water can be infiltrated through the roadside ditches.

Infiltration and bulk density measurements were made at all the roadside ditch well locations.
Groundwater sampling

- Water samples collected monthly from 17 monitoring wells
- Surface water sampled when available
- Nutrients
- Field parameters
Groundwater level monitoring

Ditches dry out in the summer

Ditch fed by tile drainage discharge
Groundwater summary – NO$_3$-N concentration patterns

4 of 6 sites showed evidence for groundwater NO$_3$-N reductions

2 of 6 sites had no detectable NO$_3$-N

Average decrease from 10.6 mg/l to 4.3 mg/l (60% reduction)
Groundwater Quality

Road salt impacts

Surface water in ditch

Shallow bedrock
Phosphorus concentrations

DRP concentrations typical for Iowa shallow groundwater

No trends in upgradient-downgradient relations
Potential N processing capacity

• Considering four sites with N reductions
• Average (4 sites) from 10.6 mg/l to 4.3 mg/l (60% reduction)
• Assuming infiltration rate of 0.3 mm/min
• Surface runoff NO3-N concentrations 1-2 mg/l
• Approximate N reduction rate of 0.2 to 0.4 g m²/day
• Similar or slightly higher retention rates compared to restored oxbows and wetlands
Summary and conclusions

1. Variable vegetation in ditches but tends to be dominated by cool season grasses
2. Evidence for sedimentation in ditches, NO$_3$ deposition, but few heavy metals found
3. Similar texture and infiltration rates observed across ditches
4. Evidence for groundwater nitrate processing in ditches, Are ditches “linear wetlands”?
What’s next?

• Study results published in Science of the Total Environment
• Seek additional funds to expand investigation to other sites
• IDOT programs? County programs?

Are there opportunities to modify ditches to encourage more nutrient processing? Two-stage ditches? Retention times? Critical source areas?
More thoughts on future work

- Catchment areas draining directly to ditches is not often considered
- Larger catchment area = more flow, greater risk of sedimentation, ditch filling with sediment, potential erosion
- Sedimentation leads to poor performance, less drainage capacity
- If erosion, ditch instability
- Quantify ditch catchment areas in watersheds, counties? Examine catchment area land use, conservation practices to reduce flow and sediment?
Questions?