Groundwater nitrate dynamics at the Flickner Innovation Farm

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Groundwater nitrate contamination

Widespread changes in groundwater quality across the High Plains Aquifer over the past several decades

Groundwater nitrate concentrations have increased significantly (Lane et al. 2019)

Efforts to address nitrate contamination and understand its underlying causes have been stymied by high local variability

Lane et al. 2019
Project goals

1) Quantify nitrate concentrations in wells on the Flickner Innovation Farm.
   • Determine any spatial and temporal/seasonal variation

2) Identify source of groundwater nitrate

3) Explore potential drivers of nitrate patterns
   • Vertical lithologic controls
   • Well characteristics
   • Irrigation strategies
Location of Flickner Innovation Farm within the Equus Beds Aquifer, a portion of the High Plains Aquifer
## Flickner Innovation Farm wells

<table>
<thead>
<tr>
<th>Well name</th>
<th>Well depth (ft)</th>
<th>Screen Interval (ft)</th>
<th>Well Age</th>
<th>Irrigation</th>
<th>Num. Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home South</td>
<td>N.D.</td>
<td>N.D.</td>
<td>1955</td>
<td>SDI</td>
<td>7</td>
</tr>
<tr>
<td>Home Yard</td>
<td>141</td>
<td>106-139</td>
<td>1977</td>
<td>SDI</td>
<td>10</td>
</tr>
<tr>
<td>Jonas Yard</td>
<td>101</td>
<td>61-100</td>
<td>1980</td>
<td>SDI</td>
<td>6</td>
</tr>
<tr>
<td>Gringoe</td>
<td>138</td>
<td>99-138</td>
<td>1984</td>
<td>SDI</td>
<td>7</td>
</tr>
<tr>
<td>Dave G</td>
<td>136</td>
<td>96-136</td>
<td>1993</td>
<td>Center Pivot</td>
<td>6</td>
</tr>
<tr>
<td>Jones West</td>
<td>112</td>
<td>72-112</td>
<td>1995</td>
<td>SDI</td>
<td>9</td>
</tr>
<tr>
<td>Goering</td>
<td>131</td>
<td>91-131</td>
<td>2011</td>
<td>SDI</td>
<td>6</td>
</tr>
<tr>
<td>Kirby</td>
<td>87-95</td>
<td>70-95</td>
<td>2017</td>
<td>Flood</td>
<td>8</td>
</tr>
<tr>
<td>Home Domestic</td>
<td>N.D.</td>
<td>N.D.</td>
<td>N.D.</td>
<td>N.A.</td>
<td>5</td>
</tr>
</tbody>
</table>
## 2022 sampling dates

### 2022 Water Level Data: Harvey County Index Well

<table>
<thead>
<tr>
<th>Sampling date</th>
<th>Time point</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/27-29</td>
<td>Pre-planting</td>
</tr>
<tr>
<td>6/10</td>
<td>Post-planting/pre-fertilizer</td>
</tr>
<tr>
<td>7/13</td>
<td>Mid-season</td>
</tr>
<tr>
<td>8/10</td>
<td>Mature crop</td>
</tr>
<tr>
<td>9/27</td>
<td>End of season</td>
</tr>
</tbody>
</table>
Nitrate concentrations vary across wells

1. Large variation in concentration in nearby wells (Gringoe and Goering - quarter mile apart)

2. Wells with highest concentrations were also the most variable
Nitrate concentrations are highest in spring

1. Greatest variability in concentrations occurs in spring (April)
2. Mean concentrations level off during pumping season
2022 seasonal patterns vary by well
Isotopic fingerprinting

Analyzing dual isotopes of oxygen and nitrogen in nitrate in water samples can be used to trace the source of nitrate in groundwater.

Figure adapted from Kendall et al. 2000
Isotopes indicate mixed fertilizer/manure source

No systematic change in nitrate source between June and July

Figure adapted from Kendall et al. 2000
Potential drivers of nitrate concentrations?

Nitrate concentrations vary among wells, even in close proximity.

Concentrations tend to be highest in spring, but the source is relatively consistent.

What factors might explain this heterogeneity?
- Subsurface structure
- Well characteristics
Electrical conductivity (EC) logging provides lithologic information about soil conductivity and resistivity.

Soil conductivity is a function of both parent mineralogy as well as conductivity of pore fluids, and can be used to classify soils.

- Silts and clays exhibit higher electrical conductivity.
- Sands and gravels (water bearing units) exhibit lower conductivity.
Benefits and Limitations of HPT

Benefits of Direct Push:
- Minimally invasive + small footprint
- Relatively quick (~2 hours per 100 ft profile)
- Can be paired with hydraulic profiling tool to provide information on hydraulic conductivity

Limitations:
- Depth limited – max depths ~100ft.
- Can’t be used in areas with very hard substrate (caliche or dense clay)
EC profiles across N gradient

**High conductivity = lower permeability zones**

- Avg. NO3 conc = 2.8 mg/L
- Avg. NO3 conc = 10 mg/L
- Avg. NO3 conc = 13.5 mg/L
Driller logs corroborate EC profiles

Avg. NO3 conc = 2.8 mg/L
Well age is a strong predictor of avg. nitrate concentration

Well age was best single predictor of average nitrate concentration

No apparent relationships with screen interval/depth, etc.

$R^2 = 0.59$
Clay lenses above screened intervals

Diffuse transport of nitrate to GW (slow)

Confining layers + intact well casings slow down vertical transport of nitrate
Adapted from Townsend 2000

- Diffuse transport of nitrate to GW (slow)
- Rapid movement of nitrate down well annulus
- Accumulation of nitrate at depth over non-pumping season
- Flushing of local zone of contamination in spring

Water table
Next steps and discussion

Well construction methods are important.

Water conservation measures might also be important for reducing vertical transport of nitrate.

Source of nitrate is linked to fertilizer – precision methods will help over time.

Direct push can be useful “rapid” screening tool to identify sites with shallow confining layers.

Next step: Can we use broader sampling campaign combined with the WWC5 database (well age and presence/depth of confining layers) to predict which wells may have higher nitrate concentrations?
Questions?

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• the Kansas Water Office for funding this research!
• Jim Butler, Steve Knobbe, Brook Armijo, and Masi Veisi