Nitrate is a drinking water contaminant that mainly affects infants and children. It is regulated under the Safe Drinking Water Act with a Maximum Contaminant Level of 10 parts per million to protect public health.

The goal of this workshop was to offer an opportunity for municipal officials, drinking water system operators and administrators to learn about our ground water-based drinking water supply sources, approaches to protect these sources from nitrate contamination, and ways to strengthen collaboration in protecting our drinking water.
## Agenda - Tuesday 10/29/2013

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Speaker/Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:30 am</td>
<td>Registration &amp; Coffee (Sponsored by Farmers Bank &amp; Trust Co. &amp; NARD)</td>
<td></td>
</tr>
<tr>
<td>9:00 am</td>
<td>Welcome and Overview</td>
<td>Cindy Kreifels, Executive Vice President, The Groundwater Foundation</td>
</tr>
<tr>
<td>9:15 am</td>
<td>The Costs of Nitrates</td>
<td>Steve McNulty, Engineering Services, Nebraska Department of Health and Human Services</td>
</tr>
<tr>
<td>9:45 am</td>
<td>Identifying Sources of Groundwater Nitrates with Isotopes</td>
<td>Daniel D. Snow, Laboratory Director and Research Associate Professor, Nebraska Water Center and Daugherty Water for Food Institute, University of Nebraska</td>
</tr>
<tr>
<td>10:15 am</td>
<td>Break</td>
<td></td>
</tr>
<tr>
<td>10:30 am</td>
<td>100 Million Looming Reasons to Experiment</td>
<td>Marty Stange, Environmental Supervisor, City of Hastings - Hastings Utilities</td>
</tr>
<tr>
<td>11:15 am</td>
<td>Salvaging Wells through Sealing the Annual Space &amp; Explosion Abandonment</td>
<td>Tom Christopherson, Program Manager, Water Well Standards, Nebraska Department of Health and Human Services</td>
</tr>
<tr>
<td>Noon</td>
<td>Lunch Break (Sponsored by NARD)</td>
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</tbody>
</table>
| 12:45 pm | Implementing On-The-Ground BMPs for Nitrates                                                      | Courtney Woodman, Water Resources Technician, Upper Big Blue Natural Resources District  
|        |                                                                                                   | Jason Moudry, Water Programs Specialist, Lower Loup Natural Resources District |
| 1:30 pm | Break                                                                                             |                                                             |
| 1:45 pm | Roundtable                                                                                       | Fred Armknecht, Water Operator, Village of Johnson  
|        |                                                                                                   | Ryan Chapman, Wellhead Protection Program, Nebraska Dept. of Environmental Quality  
|        |                                                                                                   | Dave Hunter, General Manager, City of Auburn - Board of Public Works  
|        |                                                                                                   | Rebecca Ohrtman, Source Water Protection Program, Iowa Dept. of Natural Resources |
| 2:50 pm | Closing Remarks and Adjourn                                                                     |                                                             |
Nitrates & Your Water System

Facilitator:
Cindy Kreifels
Executive Vice President
The Groundwater Foundation
Nitrates & Your Water System
Brings together agencies and organizations in Nebraska that work to support communities as they develop and adopt wellhead protection programs.
The Groundwater Foundation

MISSION
To educate people and inspire action to ensure sustainable, clean groundwater for future generations

www.groundwater.org
Nitrates

• What are nitrates?

• What are the sources of nitrates?

• What are EPA’s drinking water regulations for nitrates?

• Why should we care?
The Cost of Nitrates

Steven McNulty
Nebraska Department of Health & Human Services
Office of Drinking Water & Environmental Health
steve.mcnulty@nebraska.gov
(402) 471-1006
Who am I

- Drinking Water State Revolving Fund (DWSRF) Coordinator for DHHS
- DWSRF is a Infrastructure Funding program for Public Water Systems
- Primary Focus on Health Based projects - I.e., those that remedy Nitrate issues
- Collaborate with other Funding Programs - USDA-RD, NDED-CDBG and NDEQ-CWSRF
Figure 2. Concentrations of nitrate were greater than the U.S. Environmental Protection Agency’s Maximum Contaminant Level of 10 milligrams per liter as N in about 4 percent of the wells (DeSimone et al. 2009).
Number of POEs and Systems on Quarterly Nitrate Sampling in Nebraska

<table>
<thead>
<tr>
<th>Year</th>
<th>POEs</th>
<th>Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>196</td>
<td>139</td>
</tr>
<tr>
<td>2002</td>
<td>207</td>
<td>143</td>
</tr>
<tr>
<td>2003</td>
<td>215</td>
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<td>2004</td>
<td>248</td>
<td>180</td>
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<tr>
<td>2005</td>
<td>313</td>
<td>236</td>
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<td>2006</td>
<td>310</td>
<td>228</td>
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<tr>
<td>2007</td>
<td>392</td>
<td>284</td>
</tr>
<tr>
<td>2008</td>
<td>416</td>
<td>286</td>
</tr>
<tr>
<td>2009</td>
<td>465</td>
<td>304</td>
</tr>
<tr>
<td>2010</td>
<td>462</td>
<td>343</td>
</tr>
<tr>
<td>2011</td>
<td>477</td>
<td>305</td>
</tr>
<tr>
<td>2012</td>
<td>469</td>
<td>303</td>
</tr>
</tbody>
</table>
Problem is Tracked by the DWSRF

- Nitrates are Nebraska’s No. 1 Ranking Criteria
- Annual Needs Survey - Deadline Dec. 31st
- Current Fiscal Year Nitrate Systems - 48 Projects with just under $79M in Needs
## SFY 2002-2012 Nitrate Cost Data

<table>
<thead>
<tr>
<th>$ Spent SFY 2002-2012 on Nitrate Projects</th>
<th>$26,148,021</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFY 2012 Needs Survey involving Nitrates</td>
<td>$61,572,284</td>
</tr>
<tr>
<td>Subtotal</td>
<td>$87,720,305 − 75.8%</td>
</tr>
<tr>
<td>SFY 2002-2012 Total DWSRF/ARRA $</td>
<td>$115,675,626</td>
</tr>
</tbody>
</table>
What Does this Mean to You?

- Probably Not Much
  - You will have a Specific Nitrate Problem
  - You will have a Unique Solution
- To address a Nitrate Problem
  - Hire an Engineer - $
  - Develop a Plan - $$
  - Finance the Plan - $$$
  - Construct the Project - $$$$$…
Project Financing Today

- **DWSRF**
  - 20 to 30 year Loans - 3% Rate
  - 20% to 35% Forgiveness for Nitrate Projects
- **CDBG** - $250,000 Grants with 25% Local Match
- **USDA Rural Development**
  - 40 Year Loans - 2.75% to 4.625% Rates
  - Grants Range Up to 75% of Project Amount, likely 45% or less
- **Private Market**
  - Estimated 2.6% to 4.4% for 10 to 30 Year Terms
Project Financing Tomorrow

- **DWSRF**
  - 15% to 60% Federal Program Cuts
- **USDA Rural Development**
  - Rumored Similar Cuts
- **CDBG**
  - Largest Cuts of all 3 Government Programs
- **Private Market...**
When the Federal Chairman Speaks

- Congress, 5/22/13 - Hinted at Tapering

3.11% Jump to 4.38%
Equivalent to a ~$11K Grant for every $100K in Project Cost
My Recommendations

• Questions First...
  ▫ Is your system above the Nitrate MCL?
  ▫ Do you have a Sustainable Project?

• Build the Project...Sooner than Later
  ▫ Financing will never be Markedly Better

• Your not above the MCL?
  ▫ Begin working with Everyone Else here today - Why?
San Juan Chama Summary

- Not a Nitrate but an Aquifer Project
  - They Spent $500,000,000
  - Diverted the Colorado to the Rio Grande
  - Dam, Tunnels, WTP, ~45 Miles of Pipe
- Construction Completed in 2008
- Aquifer 5 Years Later - Now Up 9 Feet
  - Down 80 to 120 Feet Historically
  - 5 Years, $500M, 1/10th Recharge
San Juan Chama Lesson for Today

- Aquifer changes take time, so Nitrate changes also take time!
- Today’s Workshop Can Help You!
  - Use it to Plan
  - Use it to Avoid Me
- If you are Working with Me on Nitrates...
  - Expect $50 a Month Water Rates
  - My Phone Number was on the 1st Slide
Identifying Sources of Groundwater Nitrates with Isotopes

Daniel D. Snow
University of Nebraska

Nitrates & Your Water System Workshop
October 29th, 2013, Nebraska City, NE
Risk of high nitrate in groundwater depends on:
Nitrogen sources, transport (vulnerability) and attenuation potential.

Nitrate in U.S. groundwater
Multiple sources and complex transformation pathways of nitrogen in agroecosystems

Significance of sources

Does the isotope composition nitrate in groundwater reflect the nitrogen source and/or transport history?

Stable isotope “fingerprint”
Many elements have more than one isotope.

Number of stable isotopes

1
H
Helium
3
Li
Lithium
4
Be
Beryllium
11
Na
Sodium
12
Mg
Magnesium
5
B
Boron
6
C
Carbon
7
N
Nitrogen
8
O
Oxygen
9
F
Fluorine
10
Ne
Neon
13
Al
Aluminium
14
Si
Silicon
15
P
Phosphorus
16
S
Sulphur
17
Cl
Chlorine
18
Ar
Argon

**Stable Isotopes**

**Quiz question:** What did the scientist say when he found 2 isotopes of helium?

**Answer:** “He He”
Isotopes in water
Isotope composition changes
Variation in multiple elements
Fractionation

Partitioning of isotopes between two substances or phases results in predictable isotopic composition

Residual water becomes enriched in heavier isotope
Evaporation changes isotope composition of remaining water
Predictable variation can be used as a tracer
Groundwater Nitrate $^{15}\text{N}$ variable

Atmospheric nitrogen $^{15}\text{N}$ constant (~0.003676)

Nitrogen Isotopes
How do we measure isotopes?
Measuring stable isotope abundance

1. Sample must be a gas
2. Molecular mass determines trajectories
Stable Isotope Standards

<table>
<thead>
<tr>
<th>Element</th>
<th>Standard</th>
<th>Material</th>
<th>Rstd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>SMOW</td>
<td>Standard Mean Ocean Water</td>
<td>D/H = 0.00015575</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>AIR</td>
<td>Atmospheric Nitrogen</td>
<td>$^{15}\text{N}/^{14}\text{N} = 0.0036765$</td>
</tr>
<tr>
<td>Oxygen</td>
<td>SMOW</td>
<td>Standard Mean Ocean Water</td>
<td>$^{18}\text{O}/^{16}\text{O} = 0.0020052$</td>
</tr>
</tbody>
</table>

$$\delta(\text{o/oo}) = \frac{R_{\text{sample}} - R_{\text{standard}}}{R_{\text{standard}}} \times 1000$$
Does the isotope composition of nitrate in groundwater reflect the nitrogen source and/or transport history?

\[ \delta(\text{o} / \text{oo}) = \frac{R_{\text{sample}} - R_{\text{standard}}}{R_{\text{standard}}} \times 1000 \]
Typical $^{15}$N range in nitrogen sources
Haber Bosch Process

\[ \delta^{15}N_{\text{air}} = 0.00 \]

\[ \frac{^{15}N}{^{14}N} = 0.0036765 \]

\[ \delta^{15}N_{\text{ammonia}} = \sim 0.00 \]
Excess nitrate leaches and accumulates below plant root zones

Exner et al 1991

Spalding and Kitchen, 1988
Commercial fertilizer applied +1 to +3 o/oo

Manure N +10 to +15 o/oo

Average =+1.5 o/oo

Average =+11 o/oo

$^{15}\text{NH}_4 \rightarrow ^{15}\text{NO}_3$ signature seems to be preserved during nitrification and leaching

Herbel and Spalding 1993

Roston et al 1996
Microbial denitrification increases $^{15}$N in residual nitrate

Bates et al 1998
Inverse trend of nitrate concentrations and $^{15}$N-NO$_3$

**Fig. 5.** Plot of $\delta^{15}$N versus NO$_3$-N for wells in Buffalo and Hall counties with NO$_3$-N $\geq$ 10 mg/l.

**Fig. 6.** Plot of $\delta^{15}$N versus depth to water for Merrick County wells with NO$_3$-N $\geq$ 10 mg/l.

Higher $^{15}$N-NO$_3$ associated with shallow groundwater.
What about the other isotope in nitrate?

Kendall et al 2007
Oxygen in nitrate from soil air and water

\[ \delta^{18}O - \text{NO}_3^{-} \text{(microbial)} = \frac{1}{3}(\delta^{18}O - \text{O}_2) + \frac{2}{3}(\delta^{18}O - \text{H}_2\text{O}) \]

Atmospheric \(^{18}\text{O}-\text{O}_2 = +23.5 \text{ (o/oo)}\)

Rainfall \(^{18}\text{O}-\text{H}_2\text{O} -8 \text{ to } -14 \text{ across Nebraska}\)

Predictable nitrate oxygen isotope composition

Harvey, 2011
Rainfall $^{18}$O-H$_2$O gives range for nitrate

Kendall et al 2007

Predicted $^{18}$O-NO$_3$ from nitrification of soil N
Predictable enrichment from denitrification

Kendall et al 2007
Significance of denitrification

“Dual isotope approach”

Range of $\delta^{18}$O-NO$_3$ expected from nitrification

Expected enrichment due to denitrification

Significance of denitrification
Isotopes are only one tool!
• Nitrite and nitrous oxide
• Dissolved organic carbon (DOC)
• Dissolved Oxygen
• Dissolved solids/conductivity
• pH – alkalinity
• Dissolved air

Supporting measurements for isotope “fingerprinting”
• Isotopes of nitrate can be used as a fingerprint of sources
• Predictable variation from sources and expected transformation reactions
• Best accuracy when used with other measurements to help with interpretation

Conclusions
Thank you!
City of Hastings
Well Based Nitrate and Uranium Management Plan

October 29, 2013

Marty Stange; Environmental Supervisor
Hastings Water System - Overview

- Water Supply Wells pump water from multiple locations directly into the Water Distribution System without Treatment or Storage
- Water is supplied to the Village of Trumbull, Phil Johnson Water System and the Hastings East Industrial Park / Central Community College
- Neighboring Water Systems within 2 to 5 miles include the Villages of Juniata, Glenvil, Inland, AC Schools and several rural subdivisions
Regional Groundwater Flow

GW direction near Hastings is S60° to 65°E
20 Year Time of Travel
Hastings Water Issues - Overview

- Nitrate, Uranium, Gross Alpha, Selenium, pH, Hardness and Inorganic Levels Increasing
- Atrazine Detected at low levels
- Several Wells Taken Off Line due to Nitrates
- Insufficient Capacity in 2016 Without Additional Water Supplies or Blending
Median Nitrate Capacity Trend vs Max-Day Demand

- **Typical Max-Day Demand of 20 mgd**
- Decrease in well pump capacity due to Median Trend in Nitrates
- Insufficient Capacity in 2016 without additional water supplies or blending.
HU Board: “Marching Orders”

- Implement WHP to help address long term water quality issues and continue efforts to educate the public.
- Enlist the assistance of the NRDs as they have jurisdiction outside the City of Hastings.
- Find a cost effective method to secure a potable water source – “Think outside the box”
Nitrates in Well Head Protection Area

Note: No continuous source of nitrate assumed.
Hastings Wellhead Protection Area (HWPA) - Water Sampling Effort

• **2010 Sampling**
  – 576 water samples collected for nitrates over 76 square mile area
  – 87.5% sampling of all known wells in the HWPA

• **2011 Sampling**
  – 200 water samples collected in an area exceeding 200 square miles
  – 42 samples analyzed for uranium

• **Results from 2010 and 2011**
  – 25% of samples exceeded nitrate MCL (10 mg/L)
  – Uranium levels ranged from 1.2 to 74.8 µg/L (MCL 30 µg/L)
Hastings Wellhead Protection Area (HWPA) - Water Sampling Effort

- **2012 Sampling**
  - 138 water samples collected
  - 25% of samples exceeded nitrate MCL (10 mg/L)
  - Uranium levels ranged from 1 to 345 µg/L (MCL 30 µg/L)

- **2013 Sampling**
  - 58 water samples collected (No significant change to Nitrates and Uranium contamination is better defined)

- **2014 Sampling and Beyond**
  - Minimum 40 samples each year
  - All wells in 2015 and every 5 years
Hastings Wellhead Protection Area (HWPA) - Water Sampling Effort

- 2010 Vadose Zone sampling indicates 500 to 2000 lbs. of Nitrogen is located below the Root Zone and above the Aquifer – Future Contamination Source

- Isotope sampling indicates the source of Nitrates is Commercial Fertilizer – Anhydrous Ammonia
Nitrates Source

• Nitrates are from both urban and rural use of fertilizer and excessive irrigation

• Nitrate and Water Management
  – Nitrate Management (Reduce wasting - 30%)
  – Water Conservation (Limit movement of N)

Best Management Practice must include both the proper use of Fertilizer and Irrigation. Overuse of Irrigation drives the Nitrogen below the root zone thus requiring more Fertilizer.
Uranium in Well Head Protection Area
Uranium the Unexpected Problem

• Uranium Source is Unknown
  – Naturally Occurring?
  – Phosphate Fertilizers?
  – Biological release of Uranium in the Vadose Zone?

• If naturally occurring why is it now showing up in the Municipal Wells?

• New information being developed – More to follow at end of presentation
How do we Solve the Problem?

• New Source?
  – No alternative aquifers are available
  – Nitrate sampling indicates contamination in principal aquifer cannot be avoided

• Conventional Water Treatment?
  – No existing treatment facility
  – No centralized collection point

• Wellhead Management?
  – Won’t solve the problem alone (Long Term Issue)
Management Plan Objectives

• Continue to Provide Safe and Reliable Supply of Water
  – Nitrates and Uranium are a 50 year problem (or more)

• Minimize Financial Impact to Utility and Customers

• Protect Long Term Viability of Aquifer

• Extend Useful Life of Existing Wells and Delay/Minimize Treatment
## 20-Year Facility Implementation Plan Phase 1
### Water Treatment Costs (2010 Dollars)

<table>
<thead>
<tr>
<th>Phase</th>
<th>Date</th>
<th>Project</th>
<th>Description</th>
<th>RO Only Treatment</th>
<th>IX Only Treatment</th>
<th>Annual O&amp;M Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2011</td>
<td>1a</td>
<td>Westbrook Water Treatment Plant Phase 1</td>
<td>$3,700,000</td>
<td>$3,700,000</td>
<td>$280,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1b</td>
<td>Westbrook Water Treatment Plant Phase 2</td>
<td>$1,700,000</td>
<td>$1,700,000</td>
<td>$280,000</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2011-2014</td>
<td>2</td>
<td>Storage and Pump Station(^2) at Future North Baltimore WTP Site</td>
<td>$14,300,000</td>
<td>$14,300,000</td>
<td>$230,000</td>
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<tr>
<td></td>
<td></td>
<td>3</td>
<td>Chemical Treatment Building(^3)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>4</td>
<td>Piping Network Phase 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2013-2018</td>
<td>5</td>
<td>Piping Network Phase 2 and 3</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>6</td>
<td>North Baltimore Water Treatment Plant Phase 1 Treatment Facility(^1)</td>
<td>$31,800,000</td>
<td>$23,800,000</td>
<td>$650,000</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Evaporation Pond (2 Cells)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pipe to WPCC</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2019-2025</td>
<td>7</td>
<td>North Baltimore Water Treatment Plant Phase 2 Treatment Facility(^1)</td>
<td>$18,300,000</td>
<td>$10,600,000</td>
<td>$650,000</td>
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<tr>
<td></td>
<td></td>
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<td>Evaporation Pond (2 Cells)</td>
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<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pipe for Agricultural/Irrigation Blending</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>2026-2030</td>
<td>8</td>
<td>Elevated Storage Tank at South Location</td>
<td>$2,500,000</td>
<td>$2,500,000</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Estimated Total:** $72,300,000 $56,600,000

\(^1\) North Baltimore Water Treatment Plant Phase 1
\(^2\) Future North Baltimore WTP Site
\(^3\) Chemical Treatment Building

$100,000,000 could be spent over the next 20 years for Capital and Operating Expenses
Well Based Nitrate and Uranium Management Approach – Preliminary Design

- Dual Pumping
- Aquifer Storage and Restoration
- Focused Water Treatment
- Irrigation Management
- Blending and Storage

Combination of all approaches potential to substantially reduce capital investments in infrastructure and operating costs.
Nitrate Skimming (Dual Pump)

- Goal – Extend useful life of existing Wells and delay/minimize treatment
- Nitrates appear to be highest at the top of the aquifer
- Dual Pumping is an idea where two wells located in close proximity simultaneously withdraw water from the top of and bottom of the aquifer thus separating these two water layers
Submersible Pump (Sub)

Pumping level

Water Surface

Static water level

Draw Down

Top of Screen

Bottom of Screen

Shallow Pump Setting
Deep Pump Setting

Water Surface

Top of Screen

Pumping level

Bottom of Screen

Vertical Turbine (Main)

Draw Down

Static water level

Deep Pump Setting
Submersible Pump (Sub)

Pumping level

Vertical Turbine (Main)

Draw Down

Top of Screen

Bottom of Screen

Dual Pump Configuration

Water Surface

Static water level
Static water level

Dual Pump Configuration

Top of Screen

Bottom of Screen

Water Surface

Static water level
Implementation of a Dual Pump System

• Low Volume/High Concentration Raw Water can be Intercepted by a Second Pump Installed in a Municipal Well

• Concept Can be Applied in the Design of Future Wells or by Modifying Existing Wells

• Dual Pump is a Viable Alternative
  – Reduce Volume of Water Requiring Treatment
  – Reduce Capital Improvement and O&M Costs
Aquifer Storage and Restoration - Concept

• Protect Long Term Viability of Aquifer

• Key – Intercepting Contamination Up Gradient of City Well Field

• Treat with Reverse Osmosis and Returned to the aquifer
  – Recover using existing down gradient wells

• Blending and Storage within the Aquifer thus Delaying Storage

• Retains use of Existing Wells
Overall ASR System Approach

Nitrate Treatment

Uranium and Nitrate Treatment
Westbrook System
Conceptual Site Plan
Treatment and Residuals Disposal

• Modular Approach to Treatment – Add on as Needed
• Uranium Treatment
  – Uranium adsorptive media with disposal in licensed facility
• Nitrate Treatment
  – Reverse osmosis
• RO Residuals
  – 325 gpm to Sewer (25% of PCF Treatment Capacity)
  – Remainder to Evaporation and Irrigation
    • Approximately 40 acres required at North Baltimore Site
    • Pump up to 1,500 gpm for agricultural reuse during summer months
Irrigation Reuse and Management

• Protects Stored ASR Water for Potable Use
• Beneficially disposes of Nitrates by Agricultural Production
Water Treatment - Blending

- Blending of Several Wells to lower the Nitrate level in the Potable Water prior to delivery into the Water Distribution System - Water Storage Reservoirs
## Overall Plan Costs

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
<th>Base Estimated Construction Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot</td>
<td>ASR and Dual Pumping System Pilots</td>
<td>$2,132,000</td>
</tr>
<tr>
<td>I</td>
<td>North Baltimore ASR System</td>
<td>$20,636,000</td>
</tr>
<tr>
<td>II</td>
<td>Westbrook ASR System</td>
<td>$16,415,000</td>
</tr>
<tr>
<td>III</td>
<td>Storage and Blending at North Baltimore Site</td>
<td>$6,728,000</td>
</tr>
<tr>
<td></td>
<td><strong>Total Estimated Construction Cost</strong></td>
<td><strong>$45,911,000</strong></td>
</tr>
</tbody>
</table>

This plan carries some risk. It is a new concept. The projects will be staged such that if full water treatment is required it can be installed with limited duplication of costs. Does not include lost treatment capacity at Wastewater Treatment Plant.
HU Board Concerns

• Future Potable Water Supply is threatened by activities outside the City of Hastings’ control
• The proposed cost of water treatment is too high and threatens the City of Hastings’ and the surrounding communities’ economic viability
Regional Concerns

- Nitrates is a regional issue impacting other water system such as the Village of Juniata, Prosser, Kenesaw, Glenvil, Trumbull, Inland, Adam Central Schools and the Hastings Regional Center

- The Hastings Water System may be needed to develop a Adams County Rural Water System
Policy Questions

- Based upon the recent 130 years of water system operation, the Citizens of Hastings have come to expect access to potable water. Is the right to use groundwater only a quantity issue or does it imply a reasonable expectation for potable quality?

Fisher Fountain was dedicated as a sign of Hope during the Dust Bowl years.
Uranium Saga Continues

• Initial discussion with UNL Professor Dr. Karrie Weber has indicated that Nitrates are increasing aquifer biological activity and thus mobilizing Uranium from the soils

• Source of uranium is naturally occurring as uraninite is found in our geological formation (clay soils)
Uranium Saga Continues

• We know we have uranium in our aquifer as we use Gamma logging of wells to detect the radioactive decay found in these clay soils

• Nitrates, Carbonates, Iron, increasing pH, increasing water velocity all contribute to increased biological activity in the aquifer
Uranium Saga Continues

The aquifer is a natural and thriving biota

Tardigrade – Water Bear
Uranium Saga Continues

• We have seen a rise in pH from 7.0 to 7.5 pH 15-years ago to 8.0 to 8.5 pH today

• Increased water velocity in the aquifer due to increased pumping for irrigation
Uranium Saga Continues

- Increased nitrate and phosphorous loading
Uranium Saga Continues

• Hardness increasing due to velocity changes (CO2 being released) and recycling of irrigation water – Evaporation concentrating hardness and mineral salts

• Surface soils are becoming more acidic yet groundwater is becoming more alkaline
Uranium, Nitrate and Iron Zones
Uranium Saga Continues

• Stay tuned for more activities in the future – UNL?
Recommended Action Items

• Plot your historical data it will give you indication of the future trends – Nitrates, etc.

• Get the NDOH 1960’s water quality study

• Sample your wellhead protection area for more than just nitrates – minimum of 2 to 3 wells per section (both domestic and irrigation wells)
Recommend Action Items

• Groundwater modeling is necessary to actually know where your water is coming from – determine how your aquifer is being recharged.

• Suggest regional groundwater modeling if smaller communities can not afford it – NRD assistance?
Questions?
Annular Space Research Task Force

State of Nebraska Dept. of Health and Human Services, Dept. of Environmental Quality, University of NE., Water Well Contractors and Licensing Board.
Mission of the Task Force

To address the issue of inadequate ground water protection in water wells constructed prior to the adoption of standards October 1, 1988.

Mission Statement;

“The goal of the Nebraska Annular Seal Task Force is to study methods that can be utilized to introduce an annular seal in existing water wells in order to protect our groundwater resources by inhibiting preferential movement of fluids through the annular space of wells”.
Ground water use - Nebraska

Irrigation - 92% - 7.5 b-gpd
Domestic - 5% - 382 m-gpd
Livestock - 1.6% - 110 m-gpd
Industry - 0.1% - 11 m-gpd

Ground Water pollution concerns:
• Chemicals
• Bacteria - pathogens
Active Irrigation Wells

1900-1930 ---150
1930-1956---9239
1956-1976---34,491 * Pre-Plastic Pipe
1976-1989---22,204 * Pre-Construction Stds.
1989-2013---27,021 * After Standards

• Total active irrigation wells---93,105
• Total before standards--------66,084---70%
• Total before PVC------------------43,880---47%
Irrigation well construction prior to 1970’s

Predominately concrete tile or cement asbestos “transite” casing

Concrete tile normally;
- 30” in length strung on a cable or pop riveted straps for connection
- 24” OD
- 2.5” wall thickness
- Gravel packed from TD to surface
- Clay pack or concrete surface pad

Cement asbestos “Transite” casing
- 13’ in length banded to together with a notch and groove design
- ¾” wall thickness
- 18” OD
- Gravel Pack from TD to surface
- Clay pack or concrete surface pad
Impacts on Public Health

The concentrations of contaminants is on the rise in Nebraska. To combat this situation;

- One purpose of the Water Well Standard and Contactors Practice Act is to protect the health and the welfare of the citizens of Nebraska;
- By helping to maintain the economic viable use of the States natural resources
- Another purpose is to protect the ground water from potential pollution;
  - Through the development of well construction standards (grout study)
  - Development of decommissioning standards (annular seals study)
Gravel-packed Cased Well

- The bore hole is normally 8-12 inches for domestic use and 18-36” for municipal/irrigation wells.
- Casing sizes for domestic use is 4-6 inches and 8-16 inches for municipal/irrigation.
- Before standards the bore hole was gravel-packed from the surface to the bottom.
- The only seal of the bore hole was earth around the pitless adapter or concrete pad.
Gravel-packed Decommissioned Well

- Even a fully decommissioned well casing is subject to being a potential source for contamination

- Nothing can enter the well with a bentonite cap

- But the borehole can leach contaminants into the aquifer thru the gravel pack in the borehole
Cement Asbestos Transite
Brushing and Airlift development

Before Brushing

After brushing
Full diameter brush
Well before brushing
After brushing
### Water Quality before and after cleaning

#### Before cleaning

**Date Collected:** 5/23/2013 13:16  
**Sample ID:** 237378  
**Lab ID:** 237378  
**Sample Location:** TIM SHANAHAN WELL PR

<table>
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<th>Parameters</th>
<th>Units</th>
<th>Qual</th>
<th>Report Limit</th>
<th>MCL</th>
<th>Analyzed By</th>
</tr>
</thead>
</table>
| **Analytical Method:** EPA 383.2-Nitrate/Nitrite  
Nitrate = N, 
Nitrite = N  
N = 16.5 | mg/L | 0.05 | 0 | 10 | 5/7/2013 | KUM |
| **Analytical Method:** SM 3111B - Minerals by AA  
Calciuim, Total | mg/L | 0.15 | 5 | 0 | 5/19/2013 | AMU |
| Iron, Total | mg/L | 0.15 | 5 | 0 | 5/19/2013 | AMU |
| Sodium, Total | mg/L | 27.8 | 5 | 0 | 5/19/2013 | AMU |
| **Analytical Method:** SM 4506 SO4-E, Sulfate | mg/L | 10 | 0 | 0 | 5/19/2013 | TWI |
| **Analytical Method:** SM 9223B - Coliform Quantities | MPN/100mL | 0 | 0 | 0 | 6/4/2013 | TWI |
| **Analytical Method:** ALK, SM2320B  
Alkalinity (Total) As CaCO3 | mg/L | 20 | 0 | 0 | 6/7/2013 | SKH |
| **Analytical Method:** TDS, SM 2540C  
Total Dissolved Solids | mg/L | 302 | 0 | 0 | 6/7/2013 | SKH |
| **Analytical Method:** EPA 209.8, ICP-MS  
Manganese, Total | mg/L | 5 | 0 | 0 | 5/29/2013 | AMU |
| **Analytical Method:** SM 4506-F, Fluoride  
Fluoride | mg/L | 0.50 | 0 | 0 | 5/7/2013 | KUM |
| **Analytical Method:** EPA 150.1, pH  
P, Laboratory | pH unit | 7.14 | 0 | 0 | 5/5/2013 | SKH |
| **Analytical Method:** EPA 355.2-Chloride  
Chloride | mg/L | 7.51 | 0 | 0 | 5/5/2013 | KUM |
| **Analytical Method:** SM 2340C, Total Hardness  
Total Hardness | mg/L | 41.4 | 0 | 0 | 5/7/2013 | SKH |

#### After cleaning

**Date Collected:** 6/28/2013 14:00  
**Sample ID:** 242616  
**Lab ID:** 242616  
**Sample Location:** SHANAHAN IRRG WELL

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<th>Report Limit</th>
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<th>Analyzed By</th>
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</table>
| **Analytical Method:** EPA 383.2-Nitrate/Nitrite  
Nitrate = N, 
Nitrite = N  
N = 0.354 | mg/L | 0.04 | 0 | 10 | 7/22/2013 | SKH |
| **Analytical Method:** SM 3111B - Minerals by AA  
Calciuim, Total | mg/L | 0.15 | 0 | 0 | 0 | 7/22/2013 | AMU |
| Iron, Total | mg/L | 0.15 | 0 | 0 | 0 | 7/22/2013 | AMU |
| Sodium, Total | mg/L | 153 | 0 | 0 | 0 | 7/22/2013 | AMU |
| **Analytical Method:** SM 4506 SO4-E, Sulfate | mg/L | 10 | 0 | 0 | 7/22/2013 | TSW |
| **Analytical Method:** SM 9223B - Coliform Quantities | MPN/100mL | 0 | 0 | 0 | 6/9/2013 | SKH |
| **Analytical Method:** ALK, SM2320B  
Alkalinity (Total) As CaCO3 | mg/L | 20 | 0 | 0 | 7/1/2013 | SKH |
| **Analytical Method:** TDS, SM 2540C  
Total Dissolved Solids | mg/L | 350 | 0 | 0 | 7/1/2013 | SKH |
| **Analytical Method:** EPA 209.8, ICP-MS  
Manganese, Total | mg/L | 7.8 | 0 | 0 | 7/9/2013 | TMS |
| **Analytical Method:** SM 4506-F, Fluoride  
Fluoride | mg/L | 0.2 | 0 | 0 | 7/2/2013 | KUM |
| **Analytical Method:** EPA 150.1, pH  
P, Laboratory | pH unit | 7.97 | 0 | 0 | 7/1/2013 | SKH |
| **Analytical Method:** EPA 355.2-Chloride  
Chloride | mg/L | 1 | 0 | 0 | 7/2/2013 | AMU |
| **Analytical Method:** SM 2340C, Total Hardness  
Total Hardness | mg/L | 200 V | 0 | 0 | 7/1/2013 | SKH |

**Remarks:** See reverse side of report for description of acronyms and data qualifiers. For inquiries on result interpretation call: (402) 471-6435.
Retrofit Design

The Challenge;
Install a sufficient volume of grout material without destroying the well to;

• to provide groundwater protection by;
• preventing the comingling of waters through the annular space gravel pack and;
• retain the functional use of the well.

The Answer;
Utilize the properties of micro fine cement

• By pressure grouting from the inside of the casing through a joint out to the borehole wall or;
• install grouting pipe in the annular space and pressure grout on the outside of the casing forcing the cement into the gravel pack to the borehole wall.
Borehole Schematic

Figure 1a Configuration of Annular Space Installations, Plan View
Side View Schematic

- Sight Glasses (80-ft Max Depth)
- Dye Injection Tubes (15-16-ft deep and 5-10 ft above TBD Joint)
- Annular Space Clay Fill
- Grout Injection Tubes (22-ft Max Depth)
- Proposed Annular Seals (Minimum 5-foot thickness)
- Transite Casing 13-foot lengths

TBD = To Be Determined
Microfine Cement

COLOR
Concrete gray

USES
- Stabilizing weak soils
- Sealing seepage in mines, dams and tunnels
- Low permeability grout curtaining
- Hazardous waste containment
- Oil well squeeze-cementing
Cutting Transite Casing
Mixing Micro-FineCement
Inflatable Straddle Packer
Sight Glass inspection

2013:08:08 20:46:55

001 cnt per ft
0280.0 ft

CAL Reel Clear
Grout and Gravel pack-Existing Well
Cemented
Cleaning the packer
Dye Testing
Discoveries

- Transite casing can be slotted without damaging the well
- Brushing and cleaning imperative
- Greater transmissivity through gravel pack than previously thought
  - Minutes verses days or weeks
- Grouting through the joints inhibits placement of grout-unsatisfactory
  - Joints can be sealed
Cement set times dependent on GW temperature and water in the annulus
  - Temperature can double initial gel set
  - Water and temperature can triple initial gel set
Other cases studies

• Methods of Rehabilitation- retro-fitting grout cleaning and brushing
  • Needs to studied on a wide scale
  • DHHS- Grant from NE Environmental Trust
    • 2 years-750K
    • 6 NRDs
      • LENRD
      • LPNNRD
      • LPSNRD
      • UBBNRD
      • LBBNRD
      • LBNRD
  Minimum of 2 wells to rehab in or close to well head protection area -PWS
Well Decommissioning

- Methods of Decommissioning - retro-fitting grout cleaning and Shot detonator - used in California since 2006
- Needs to be studied on a wide scale
  - DHHS - Grant from NE Environmental Trust
    - 2 years - 750K
    - 6 NRDs
      - LENRD
      - LPNNRD
      - LPSNRD
      - UBBNRD
      - LBBNRD
      - LBNRD
- Minimum of 2 wells to decom in or close to well head protection area - PWS
The village constructed a new water well to replace an older well (1929)

Challenge – decommission the old steel well by detonation leaving the well house intact.

Sargent Irrigation - contractor

Well 189 feet deep

Clay unit from 0-120’ below grade

Goal is 10 foot grout seal from 110-120’ below grade
Pumping cement
Detonation
Previously abandoned well
More potential projects

The list of Municipalities interested in the research to save existing wells;

1. Edgar- irrigation wells in well head protection area
2. Hastings- existing municipal wells-nitrate and uranium
3. Glenvil- nitrates
4. Laurel- Selenium
5. Aurora- nitrates
6. York-nitrates
7. Elgin- nitrate
8. Wauneta- nitrates
Towns interested in decommissioning

Mead- waste water lagoon
Ithica- Salt water intrusion
Brainers- Selenium
Closed loop rehab

NE Games and Parks

- Lake McConaughy visitors center
- Well drillers Assoc. installed 16 loops in 2000 for the HVAC system
- Loop failures begin in 2001
- NGTF installs study wells in 2003
  - Discovers grout vanished in the borehole
  - July 2013 Program studies if sand grout can be re-installed in study loop
- 1300 lbs of sand installed in 3 loop wells
- Immediate improvement in heat transfer
End Game

The end results will provide answers to NRD’s, PWS, GW Irrigation users, water well contractors with information for:

- Providing protection for public health
- Prevent further degradation of the Ground Water
- Developing Best Management Practices (BMP) for areas susceptible to GW pollution
- Restoring the natural protection provided by sealing of the annular space
Brighter future for Nebraska GW users
IMPLEMENTING ON-THE-GROUND BMPS FOR NITRATES: CITY OF HASTINGS

Courtney Woodman
Upper Big Blue NRD
Water Resources Technician
JOIN ALL INTERESTED PARTIES

- Join all interested parties
- Key: Communication and Cooperation

- Adams County
- Department of Health
- UNL Extension
- City of Hastings
- Rural Residents
- Urban Residents
- Hastings Utilities
- LB and UBB NRDs
AN EVOLUTION OF BMPS THROUGH FOCUS GROUPS

- Everyone has an idea, opinion, or different perspective - utilize it all
- Each focus group has a function designed to meet a goal

Goals:
- Open the lines of communication between all interested parties
- Research and develop baseline data
- Prioritize and manage issues that arise from data analysis
Goal: Open the lines of communication between all interested parties

Cast of Characters:
- UNL Extension
- Urban and rural residents
- City of Hastings
- Hastings Utilities
- Adams County
- Little Blue and Upper Big Blue NRD staff
DISCUSSING THE ISSUES: HASTINGS WELLHEAD PROTECTION COMMITTEE

A “public” working group

Topics Discussed:
- What is the problem?
- How did this escalate?
- Brainstorming to resolve the problem

Conclusion: We need data
Goal: Research and develop baseline data

- Cast of Characters:
  - UNL Extension
  - Dept of Health and Human Services
  - Rural Residents
  - Hastings Utilities
  - Little Blue and Upper Big Blue NRDs
Primary group responsible for data collection and analysis

Provide support to the Hastings Wellhead Protection Committee
- Data and resources: maps, reports
2010 - 586 samples
2011 - 292 samples
2012 - 138 samples
2013 - ~80 samples

2010-2012 All samples were analyzed for farm chemicals, heavy metals, gross alpha, uranium, and nitrate

2013 All samples analyzed for heavy metals, gross alpha, uranium and nitrate
Goals:
- Prioritize and manage issues that arise from data analysis
- Create a Nitrate Management Plan

Cast of Characters:
- Hastings Utilities Board members
- Little Blue NRD Board members
- Upper Big Blue NRD Board members
- Local farmers
THE DECISION MAKERS: WATER EXECUTIVE COMMITTEE

- Incorporate new and existing technologies
  - Irrigation management
  - Soil nutrient analysis
  - Fertilizer application rates
  - Training course

- Incorporate urban regulations as well
  - Training course
  - Reporting
Each respective board review drafts throughout the process

Responsibilities were divided
- Little Blue NRD - training
- Upper Big Blue NRD - reporting
- Hastings Utilities - urban requirements

The Technical Committee remained active throughout the process to provide support - data and resources
Packet: FAQ’s, detailed rules and regulations, contact information, cost-share programs available.
FAQ’s provided to the public
Hastings Wellhead Protection Groundwater Management Area
Action Plan Fact Sheet: Farming Activities

MANAGEMENT ACTIVITIES:

- **Nitrogen Application**
  - Anhydrous ammonia may not be applied before to November 1st.
    - A nitrification inhibitor must be used with all anhydrous ammonia applied between November 1st and March 1st, per manufacturer's recommendations.
  - Pre-plant nitrogen applied on or after March 1st greater than 100 pounds of actual nitrogen per acre must be applied using a nitrification inhibitor, per manufacturer's recommendations.
  - Liquid and dry nitrogen fertilizers may not be applied between September 1st and March 1st.

- **Fertilizer Application Exceptions**
  - Nitrogen fertilizer for any purpose other than fertilization for spring planted crops.
  - Nitrogen fertilizer for spring planted small grains (example: barley, oats, and rye).
  - Nitrogen fertilizer on pastures.
  - Application of fertilizer that is not considered a "nitrogen fertilizer" as defined.
    - **Nitrogen fertilizer**: means a chemical compound in which the percentage of nitrogen is greater than the percentage of any other nutrient in the compound or, when applied, results in an average application rate of more than twenty-five (25) pounds of nitrogen per acre over the field onto which it is being applied.
  - Spreading of manure, sewage and other by-products conducted in compliance with state

Description of Proposed Rules and Regulations
1. Be United
   - Overseeing boards and data behind you

2. Information and Education tools are necessary
   - Use available media outlets

3. Put your ducks in a row
   - Present concepts before the hearing
QUESTIONS

Courtney Woodman
Upper Big Blue NRD
Water Resources Technician
Lower Loup NRD
Utilizing Best Management Practices

Jason Moudry
Water Programs Specialist
Lower Loup NRD
Phase III Management Area

Area 28

Subject to additional requirements for Nitrogen Management that the rest of the Areas are not.

Examples:
- No Fall Fertilizer
- Soil and Water Sampling Reporting
- (NEW) Recommended for Next year: Water Meters for the management of water application for water quality purposes
- Calculate application of nitrogen already in the water
- Help to prevent over irrigation to avoid leaching
NDEQ – 319 Funding Source

Water Quality Analysis & Outreach for WHPAs

- Project Goals and Objectives
  - Collect Vadose Zone Nitrate Information
  - Investigate the Groundwater Aquifers
  - Information and Education
  - Wellhead Protection Management Plans
Vadose Zone Sampling
Giddings Probe
Investigate the Groundwater Aquifers

Sampling

- Water for Nitrates - hydrolab
  - Includes irrigation, domestic, and livestock wells
- Isotope testing
- Age dating
Lower Loup NRD, Area 28 Nitrate Study
Nitrate Isotope Evaluation

Nitrate from Fertilizer
Nitrate from Animal Waste / Sewage
Soil Nitrate

Analysis completed at Water Sciences Lab at University of Nebraska-Lincoln
Investigate the Groundwater Aquifers
Age Dating

Sample I.D. | Age using EA Method (yrs) | Age Error +/- (using EA) | Screen Interval (Feet bgs) | Midscreen (feet bgs) | Depth to Water (Feet below TOC)
--- | --- | --- | --- | --- | ---
A1-Shallow | -1.8 | 0.8 | 5-10 | 7.5 | 6.44
A1-Deep | 48.8 | 0.6 | 53-58 | 55.5 | 8.16
B1-Shallow | -7.0 | 1.3 | 4-9 | 6.5 | 7.2
B1-Deep | 32.9 | 10.3 | 29-34 | 31.5 | 6.9
C1-Shallow | 0.1 | 0.7 | 32-37 | 34.5 | 37.72
C1-Deep | 9.2 | 3.0 | 49-54 | 51.5 | 38.11
D1-Shallow | 21.2 | 0.5 | 7-12 | 9.5 | 6.86
D1-Medium | 27.7 | 0.5 | 18-23 | 20.5 | 6.54
D1-Deep | 55.8 | 23.1 | 49-54 | 51.5 | 6.64
E1-Shallow | 0.6 | 0.5 | 70-75 | 72.5 | 73.57
E1-Medium | 29.3 | 2.8 | 95-100 | 97.5 | 73.03
E1-Deep | 29.8 | 2.8 | 120-125 | 122.5 | 73.51

Notes:
- Cross section lithology symbols described in Figure 4
- Pink boxes indicate confined conditions
- bgs = below ground surface
- EA = Excess Air Method
- TOC = top of casing
- TBD = To Be Determined – analysis pending at the time of report publication

Results and relative age interpretations from the University of Utah, Dissolved and Noble Gas Laboratory
Information and Education

- Public Water Supply Meetings
  - NE Rural Water Association
  - Individual Area Results
  - Newsletters and Radio Spots

St. Paul Rotary Meeting
Wellhead Protection Management Plans

- No New Irrigated Acres Inside WHPA
  - Includes transfers
Wellhead Protection Management Plans

Best Management Practices

Well Abandonment
Best Management Practices
Agricultural Side

Crop Nitrogen Recommendation Rates

- Use the new UNL Nitrogen Calculator
- Require the producer to follow the UNL Calculator
  - Accounts for Soil Texture
  - Accounts for Soil Organic Matter
  - Accounts for Manure Application and gives additional Nitrogen Credit for the next three years
  - Accounts for Timing
Best Management Practices
Agricultural Side

- Evaluate Expected Yield Accuracy
  - 5 year Average plus 5%

- Conversion from Flood to Sprinkler

- Crop Rotations and Cover Crops
  - Utilize Excess Nitrogen in the Soil
  - Can also serve as Nitrogen Sink
Best Management Practices
Agricultural Side

Nitrogen Timing
- After March 1\textsuperscript{st} of the planting year
- Split Applications
- Fertigation

New Technologies
- Precision Agriculture and Variable Rate Technologies
- Nitrogen Inhibitors – Controlled Release fertilizers
Best Management Practices
Agricultural Side

- Irrigation Scheduling
  - golf courses also

- Manure Management
  - Must be applied to NRD Certified Irrigated ground
  - Any changes to application method must be noted
Lower Loup NRD
Depth to Water and 2011 Nitrates
Best Management Practices

Area 28

- Use of Flowmeters for Water Quality
  - By December 31\textsuperscript{st} of 2016
  - Includes all high capacity wells > 50 gpm
Best Management Practices
Area 28 - Recharge Monitoring

- Lysimeters
  - Approximately 20’ from edge of field
  - 6’ below ground service
Best Management Practices
Area 28 Recommendations Summary

- NRD recommended N rates
- Fertigation
- Conversion from flood irrigation
- Cover crops
- Irrigation scheduling
Any Questions?

Jason Moudry
Lower Loup NRD
jasonm@llnrdrd.org
3D Hydrogeology of Area 28
3D Hydrogeology of Area 28
3D Hydrogeology of Area 28
3D Hydrogeology of Area 28
3D Hydrogeology of Area 28
Nitrates & Your Water System

Round Table
Panelists

Fred Armknect, Water Operator, Village of Johnson

Ryan Chapman, Wellhead Protection Coordinator, Nebraska Department of Environmental Quality

Dave Hunter, General Manager, City of Auburn Board of Public Works

Rebecca Ohrtman, Source Water Protection Program Coordinator, Iowa Department of Natural Resources
What are the biggest barriers you have run into when trying to address nitrate issues?
What are your ideas or things you have tried to get around these barriers?
What can we do together as a group of water professionals to be better prepared or help break down barriers?
Do decision makers realize the potential financial consequences of nitrates?
Questions?
Nitrates & Your Water System
Nitrates & Your Water System

Thank You!