1. Establish regional field facility for long-term monitoring of BMP impacts.
2. Develop monitoring strategy to quantify BMP performance in a timely fashion.
3. Employ predictive tools (models) to assess potential magnitude and timing of impacts on municipal wells.

Socio-economic Challenges

Thornton Well Field, Woodstock, Ontario
- Primary water supply for Woodstock
- 5 production wells in sand and gravel aquifer.
- Average well depth 30 m
- Adjacent to active farm land where fertilizers applied for decades.
- Typical setting for municipal groundwater supply in Ontario

Regional Nutrient Impacts
- Legacy fertilizer use has resulted in elevated nitrate levels in some municipal wells.
- Nutrient reductions in well head protection areas are being implemented as BMPs.
  - Paucity of field-based data available on the performance of these BMPs.
  - Long response times result in monitoring challenges and discourage municipal authorities.

Nitrate Concentrations in Municipal Wells}

- Drinking water limit
- Year
- Nitrate concentration (mg/L, N)
Nutrient Management Strategy

2. Release tender for managing the land under reduced nutrient use (BMP).
4. Implement monitoring protocol to assess effectiveness of the BMPs.

Land Purchase
- Complex glacial moraine environment
- Subsurface sediments
  - Silty-sandy loams
  - Outwash sands and gravels
- Thick unsaturated zone 3 - 30 m (~ 10 m avg)

Changes in Nutrient Application

<table>
<thead>
<tr>
<th></th>
<th>Historical Practice</th>
<th>Modified Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crops</td>
<td>Cattle/Hog production;</td>
<td>Soy-wheat-corn rotation;</td>
</tr>
<tr>
<td></td>
<td>primarily corn cropping,</td>
<td>some fields in permanent</td>
</tr>
<tr>
<td></td>
<td>some wheat and soy</td>
<td>grass</td>
</tr>
<tr>
<td>Applied Nutrients</td>
<td>Synthetic Fertilizer</td>
<td>Synthetic fertilizer</td>
</tr>
<tr>
<td>Average N application</td>
<td>100 lb/ac</td>
<td>54 lb/ac</td>
</tr>
<tr>
<td>N - Balance</td>
<td>(+) 23 lb/ac</td>
<td>(-) 25 lb/ac</td>
</tr>
</tbody>
</table>

Stored Nitrate Mass in Vadose Zone

1. Repeat coring of the vadose zone at a series of locations across site.
2. Analysis of soil samples (NO₃, Br & moisture content).
**Stored Nitrate Mass in Unsaturated Zone**


- BMPs begin
- Core 1
- Core 2
- Core 3

**Example Soil Core Data**

- Nitrate Mass Load to Water Table
  a. Quantify groundwater recharge rates
    - MET data
    - bromide tracer
    - transient soil moisture profiles
    - 1-D modeling tools
  b. Estimate vertical nitrate mass flux
    - combine nitrate concentration and recharge rate

**Network of Nitrate Mass Flux Stations**
Cumulative mass vs Depth at Station 4

Extrapolated Nitrate Mass Flux to Groundwater (post BMP)

Key Observations

1. Highly variable nitrate mass loading
   - Averages out as scale increases

2. Loading correlates with:
   - Topography
   - Permeability of near-surface materials
   - Nutrient management

3. Avg. conc. beneath root zone decreased from ~17 mg/L to ~7 mg/L

4. Total nitrate mass loading decreased from 5.6 to 2.1 tonnes/year (from 2006 to 2008)
   * 60% reduction *

3. Predict magnitude and timing of impacts on municipal wells
   a. Regional scale groundwater flow model (FeFlow)
   b. Local variably saturated flow and transport model
   c. Simulate Scenarios
      * Pre-BMP conditions
      * Post BMP condition

Regional Scale Modeling

Haslauer, 2007

Pre-BMP Scenario
Simulate using unsaturated zone concentrations = 17 mg/L

Resulting Municipal Well Concentrations

[Graphs and maps illustrating data and observations]
Implications and Conclusions

1. Regional nutrient management BMPs can effectively improve municipal groundwater quality.
   - Full impact may require years to decades
   - Local area may be sufficient

2. Source water protection polices can consider these BMPs in recommended guidelines.

3. Combined vadose zone monitoring with upscaling and regional modeling can be useful in predicting BMP performance.

Researchers
Joanna Passmore
Don King (SRG)
Greg Wall (SRG)

Technicians
Paul Johnson
Bob Ingleton
Jeff Melchin

Students*
Loren Bekker
Jamie Koch
Marcelo Sousa
Claus Hastauer

Partners
Ont. Ministry of Environment
Ont. Ministry of Agriculture, Food and Rural Affairs

Oxford County
Ontario Pork
Canadian Water Network
NSERC
David Start (Farm Operator)