Impacts of Winter Road Salting on Municipal Groundwater Supplies – Evaluation Tools for Source Water Protection

Presented by:
Craig Johnston, Stantec Consulting Ltd.
Dave Rudolph, University of Waterloo
Michelle Bester, Waterloo Hydrogeologic Inc.
Jim Robinson, Region of Waterloo
Eric Hodgins, Region of Waterloo

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Introduction / Background

• Chloride concentrations have been steadily increasing since the mid-1960s at a number of key urban well fields.

• 5% of the urban supply (6 wells) were above the Ontario Drinking Water Standard (ODWS) for chloride.

• Need to understand if, and when, concentrations would exceed the ODWS.

• To develop long term management options, a technically defensible and cost effective methodology needed to be developed.
Study Area
Chloride Concentrations Trends

![Graph showing chloride concentration trends over time for different locations. The graph includes a dotted line representing the Ontario Drinking Water Objective.]
Study Approach

- Winter Road Maintenance and Road Salt Application Rates
- Road Salt Impacts to Groundwater Quality
- Determination of Chloride Loading and Distribution
- Model Development and Evaluation
- Evaluation of Management Options
Road Salt Loading Function

Road Network

• Difficulty in correlating road network lengths provided with GIS.

Road Salt Application

• Records for annual and seasonal purchases, not per season.
• Limited records on other salt uses.
• Limited historical data.
Winter Road Classification

- **Primary** - provincial, regional, main arterials.
- **Secondary** - most city streets and township roads.
- **Local** - minor city streets and gravel roadways.
Road Salt Loading Function

- Sand / Salt Applications
- Straight Salt Applications
- Salt Applications 1989-1997 Rates
- Salt Applications 1997-2002 Rates

Road Salt Application Rate (tonnes / 2-in-km)

- Primary Roads
- Secondary Roads
Road Salt Impacts to Groundwater

Field Program

- Established 12 field sites with groundwater monitoring wells.
- Completed detailed analyses of soil cores to document chloride concentrations in unsaturated zone.
- Detailed tracer tests completed at 4 locations to determine chloride migration rates and chloride loading.
- Groundwater quality monitored over a 12 month period to determine seasonal impacts.
Unsaturated Zone Profiles

Porewater Chloride (mg/L)

Depth (mBGS)

- CI - Oct-01
- CI - April-02
- Br April-02
Groundwater Chloride Concentrations

Chloride Concentration (mg/L)

Time (Months)

Primary Roads

No Salt

Secondary Roads

GB1-01  GB3-01  GB4-01  GB5-01  GB1-02  GB2-02  GB3-02
Loading to Groundwater System

- **Unsaturated Zone Data**
  - Primary Roads - Peak chloride porewater concentration 3,800 - 6,900 mg/L.
  - Secondary Roads - Peak chloride porewater concentration 1,000 - 2,300 mg/L.
  - Vertical migration rate of 3 to 4 m/yr.

- **Groundwater Data**
  - Primary Roads – Chloride concentrations 500 - 1,500 mg/L
  - Intersection – Chloride concentrations 4,000 mg/L
  - Secondary Roads – Chloride Concentrations of 50 mg/L – 4,000 mg/L
Modeling Approaches

**Mass Balance Model**
- Specify loading rate for primary and secondary roads.
- Modify percentage infiltration by soil type and recharge.
- Move chloride through system based on unsaturated and saturated travel times from previous modeling.

**3-D Solute Transport Model**
- Specify loading rate for primary and secondary roads.
- Specify percentage infiltration.
- Unsaturated and saturated transport using WATFLOW.
Greenbrook Well Field
Model Calibration - Concentration

Ontario Drinking Water Standards

- Measured Concentrations
- Mass Balance Model
- Solute Transport Model
Model Calibration - Mass

The graph shows the annual chloride mass removed (tonnes) from 1940 to 2050. The y-axis represents the annual chloride mass removed in tonnes, ranging from 0 to 1800. The x-axis represents the years from 1940 to 2050.

The graph includes three models:
- **Measured Mass Removal** (blue dots)
- **Mass Balance Model** (red line)
- **Solute Transport Model** (green line)

The measured mass removal shows a steady increase over the years, while the model lines show different trends and predictions.
Road Salt Management Options

• Do Nothing.

• 25% road salt reduction over entire capture zone.

• 100% elimination and use of alternative deicing compound (CMA) within
  • 2-Year Capture Zone.
  • 5-Year Capture Zone.
  • 10-Year Capture Zones.

• Treatment of groundwater
25% Reduction in Road Salting

Ontario Drinking Water Standard

Chloride Concentration (mg/L)

Measured Concentrations
Mass Balance Model - Calibrated
Solute Transport Model - Calibrated
Mass Balance Model - 25% Reduction
Solute Transport Model - 25% Reduction
100% Reduction in Road Salt

Ontario Drinking Water Standard

- Measured Concentrations
- Calibrated
- 25% Reduction
- 100% Elimination - 2-yr Capture Zone
- 100% Elimination - 5-yr Capture Zone
- 100% Elimination - 10-yr Capture Zone
Model Results

- Mass balance model and solute transport model provide similar results.
- Approximately 27% of the total road salt applied infiltrates to the groundwater table.
- Chloride concentrations at the Greenbrook Well Field will reach 241 mg/L by 2041. A 25% reduction in road salt application rates decreases chloride concentrations to 210 mg/L by 2041.
- Complete elimination of road salt within the 5-year and 10-year capture zones would reduce chloride concentrations to 191 mg/L and 164 mg/L by 2041.
Evaluation of Reduction Options

• Impact on Groundwater / Well Field Concentrations.
• Long Term Security.
• Environmental Impacts.
• Impact on Winter Road Maintenance Operations.
• Public Acceptance.
• Cost.
Cost Evaluation

- Do Nothing $3,060,000
- 25% Road Salt Reduction $2,800,000
- 100% Elimination in 2-Yr Capture Zone $10,500,000
- Treatment $7,800,000

Preferred Option
- 25% Reduction in Road Salt Application
- Maximum Chloride Concentration of 211 mg/L
Questions and Answers