Combining Risk Management and Targeted In-Situ Remediation to Facilitate Brownfield Redevelopment

Stephanie Drake and Marc Bowles
October 18, 2013
Outline

► Overview
► Site Setting and History
► Brownfield Redevelopment
  • Risk Management Plan
  • Targeted In-Situ Remediation
► Challenges
Environmental Management

- **WorleyParsons involvement**
  - Approval renewal
  - Regulatory water monitoring
  - Remediation system operation and optimization

- **Previous phases of work**
  - Several other consulting companies
  - University of Calgary
Site Setting

► 180 ha Brownfield site in South Calgary
  • Shopping centre and natural area
► Located on Bow River flood plain
► Overlies gravel domestic use aquifer
► Preferential groundwater flow paths
► Dynamic hydrology
Site History

Fertilizer manufacturing plant
- Operations began in 1942, shut down completed in 1992
- 35 ha plant area

Production
- Ammonia
- Gas and steam
- Nitric acid
- Ammonium nitrate
- Urea

Site History

- 40 areas of potential environmental concern identified
- Multi-year, multi-phase characterization program
- Source elimination and soil remediation
  - Excavation and off-site disposal
  - Landspreading
  - Soil blending
  - Seeding

Soils generally remediated to 1991 CCME Commercial/Industrial Criteria

Soils generally remediated to Alberta Tier 1 Criteria
Site History

- 1994: Remediation initiated
  - Three extensive programs followed by geotechnical characterization

- 2003: Obtained Reclamation Certificate for two areas
  - Residential development
  - Commercial development
Groundwater flow

- Residual impacts remain below water table
- Groundwater flow velocity
  H 600 m/year
- 210 ha plume extends to the east and southeast
  - Copper
  - Ammonia-N
  - Nitrate-N
  - Nitrite-N

Legend

- Groundwater monitoring well
- Surface water sampling location
Nitrogen Cycle

Atmospheric Nitrogen ($N_2$)

Assimilation

Denitrifying Bacteria

Nitrate ($NO_3^-$)

Nitrates

Nitrifying bacteria

Nitrites ($NO_2^-$)

Nitrifying bacteria

Ammonium ($NH_4^+$)

Ammonification

Nitrogen-fixing soil bacteria

Relative Concentration

$\text{NH}_4^+$

$\triangle \text{NH}_3$

pH

0

0.2

0.4

0.6

0.8

1

2

4

6

8

10

12

Photo Source: Wikimedia Commons
Monitoring Locations

- **Surface water**
  - 10 locations
  - 3 times per year

- **Groundwater**
  - 28 monitoring wells
  - 2 times per year

- **Analytical Schedule**
  - Routine potability
  - Nitrogen parameters
  - Dissolved and total metals
Guidelines

- Alberta Tier 1
- Site-specific surface water guidelines
  - Based on background water quality
  - Calculated from pH, hardness, and temperature

Contingency plan based on trigger values
Copper

2012 Exceedances

- Total Copper
- Dissolved Copper

Year:
- 1997
- 2002
- 2007
- 2012

mg/L:
- 0
- 0.2
- 0.4
- 0.6
- 0.8
Ammonia-N

▶ 2012 Exceedances

Total Ammonia as N

mg/L

0 50 100 150

1997 2001 2006 2011

Year
Ammonia-N

2012 Exceedances

Total Ammonia as N

mg/L


Year
Nitrate-N

2012 Exceedances

Nitrate as N

mg/L

Year

Nitrate-N

2012 Exceedances

Nitrate as N

mg/L


Year
Nitrogen Plume

- Plume migration
  - Source material mostly removed or attenuated
  - Evidence suggests repeating cycles of adsorption and dissolution of nitrogen species

- Nitrogen species transformation

- \( \text{NH}_4^+ \rightarrow \text{N}_2 \)
  - Natural Attenuation
  - Active Remediation
Brownfield Redevelopment Strategy

- Risk Management Plan
- Targeted In-Situ Remediation
Risk Management Plan

- Developed in 2001 by Bel•MK

- Land use restrictions
  - Reflect remediation guidelines and residual impacts
  - West of Deerfoot Trail
    - Commercial and light industrial
  - East of Deerfoot Trail
    - Partial commercial and light industrial
    - Natural park area
  - Receptor Protection
    - Signage

Photo Source: Google Earth
Management controls

- Use of groundwater for potable purposes not permitted
- Agricultural-based activities not permitted
- Construction activity restrictions
  - Landscaping
  - Utility and foundation construction
  - Worker protection
  - Reporting requirements
Brownfield Redevelopment Strategy

Risk Management Plan
+
Targeted In-Situ Remediation
In-Situ Remediation

- Custom designed in-situ nitrification and denitrification system
- Collaborative design between consultants and University of Calgary
- Topic of several university studies
- On-going study and optimization
In-Situ Remediation

- Nitrification

\[ \text{NH}_4^+ + \text{O}_2 \xrightarrow{\text{Nitrosomonas Bacteria}} \text{NO}_2^- \]

\[ \text{NO}_2^- + \text{O}_2 \xrightarrow{\text{Nitrobacter Bacteria}} \text{NO}_3^- \]

Maximum delivery rate H 55 mg/L
Denitrification
- Bacterially mediated

$$\text{NO}_3^- + \text{Carbon Source} \rightarrow \text{NO}_2^- \rightarrow \text{N}_2$$

No practical limit to carbon addition
In-Situ Remediation
Groundwater flow
Evidence of Anammox

**ANaerobic AMMonium OXidation**

\[ \text{NH}_4^+ + \text{NO}_2^- \rightarrow \text{H}_2\text{O} + \text{N}_2 \]

- Ammonia and nitrite transformed to water and nitrogen
- Only occurs over a narrow range of dissolved oxygen concentrations (H 1 to 2 ppm)
- Only occurs over a narrow pH range (H 6.5 to 8.5)
Challenges
Challenges

- Frequent sampling requirements
- Guidelines
  - Total vs. dissolved
- Biomass buildup around injection wells
Challenges

- Preferential flow through buried channels
- Investigation and interpretation
  - Follow up mapping
  - Geophysics
  - Groundwater modelling

Photo Source: Google Earth
Challenges

- Data reproducibility and trend analysis affected by dynamic flow conditions
  - Groundwater/surface water interaction
Challenges

- Other anthropogenic nitrogen sources
  - Industrial areas
  - Golf courses and driving ranges
  - Dog park

- Chloride from street salting used to differentiate between surficial nitrogen and groundwater plume
Challenges

- Background surface water nitrogen loading
  - Treatment plant approximately 4 km upstream
    - May be adding 1.1 mg/L nitrogen to the river (2012)
  - Groundwater flux contributions to the river
    - 0.7% of total ammonia
    - 0.1% of total nitrate
Challenges

- Background surface water nitrogen loading
  - Assessed through triad study
    - Sediment sampling
    - Surface water sampling
    - Benthic invertebrate assessment
  - Additional assessments
    - Microtox and Chironomid survival testing
    - Hyporheic zone porewater sampling
Successful Brownfield Redevelopment
Thank you. Questions?