Effects of Remediation at the Bemidji, Minnesota Crude-Oil Spill Site

Geoffrey Delin and William Herkelrath
U.S. Geological Survey

Scott Lounsbury
Enbridge Pipeline Company

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Outline

- Pipeline rupture and initial remediation (1979)
- USGS monitoring of the remediation
- Introduction to other Bemidji presentations
High pressure (3.5 MPa or ~500 psi), 86 cm (34-inch) diameter pipeline ruptured on August, 20, 1979 spilling 1,670 m³ (10,500 barrels) of crude oil in an uninhabited area near Bemidji, Minnesota.
Crude oil sprayed over large area

- Oil pooled in low lying areas (∼2,000 m²) and sprayed over area of 6,500 m² to the southwest of the pipeline that became known as the ‘spray zone’.
Views of Trench and Pipelines

SCHEMATIC DIAGRAM OF 34-INCH DIAMETER PIPELINE

- 64-inch long rupture
- Rupture along seam weld
- 34-inch diameter pipe

Pipelines are ~3 m below land surface

Pipeline rupture site
Remediation efforts led to removal of ~75% of oil from site (about 417 m³ or 2,600 barrels of oil remained)

USGS & University Research 1983 – Present
Many Research Groups Have Been Involved at Bemidji Site

Numerous USGS research teams
University of British Columbia
University of Colorado
University of Kansas
University of Massachusetts
University of Minnesota
Stanford University
University of Texas
University of Virginia
University of Waterloo
Bemidji State University
Indiana University
Enbridge Pipeline Company
Minnesota Pollution Control Agency
Significant Research Highlights

- Bemidji site one of first field sites where **natural attenuation** demonstrated
- **Results and technologies transferred to numerous other sites**
- **Oil degradation is greater in areas of increased recharge**
- **Redox processes change over small vertical intervals**
- **Succession from iron-reducing to methanogenic microbial communities = slight growth of the plume**
Renewed Remediation – 1998

Second phase of remediation began in December 1998

Objective: to remove oil to a sheen on water table in the wells
Predicted Remediation Effects

- **Total volume of oil per unit area prior to remediation, cm**
  - 147,000 L of oil, North Pool
  - 37,000 L of oil, ~25% recoverable

- **Likely amount that can be recovered, cm**

_Herkelrath, 1999_
Installing Remediation Well

South pool

Hydrophobic soil in spray zone

Pipeline rupture site
Dual-Pump Remediation System

LEGEND

- Unsaturated zone
- Free product (crude oil)
- Saturated zone

PUMPS OFF

To storage tank

To separator tank and infiltration gallery

Remediation well

Ground water pump

Skimmer pump

PUMPS ON

To storage tank

To separator tank and infiltration gallery

Remediation well

Ground water pump

Skimmer pump

Water Table

Land surface
North Pool Remediation Wells

Total pumping rate of water from all wells ~113 L/min (~30 gpm)
Pipeline rupture site
(looking NE)

Remediation Building,
May 1999
Collaborative Agreement

- **Established in 2008**
  20-year duration

- **Partners:**
  1. Scientists at the USGS and academic institutions,
  2. Enbridge pipeline company,
  3. Beltrami County, and
  4. Minnesota Pollution Control Agency

- **Primary Purpose:** To promote research and educational opportunities

- **Secondary Purpose:** To test the effects of in-situ alternative remediation strategies at the site
LNAPL Remediation

Problems:
- LNAPL recovery, although common, is expensive ($100,000’s / year)
- BTEX analyses to evaluate contaminant migration and effects of remediation are also expensive

Opportunities:
- Simple, less-expensive methods are needed to evaluate remediation effects
- Few of these remediation studies are documented in the literature
USGS Research Objective: Evaluate effects of the oil-recovery scheme using simple methods

Hypothesis: The renewed remediation would have an insignificant effect on oil distribution, rates of volatilization, and rates of biodegradation.
Oil Thickness Measurements

Using an oil-interface meter
North Pool Transect of Wells

- Observation well
- Excavated area
- Site of pipeline break
- Infiltration gallery
- Remediation building
- North oil pool
- Middle oil pool
- South oil pool
- Oil drainage area
- Sprayed zone
- Generalized direction of groundwater flow
- Remediation well
- To "Unnamed lake"

North pool transect

Oil pipelines

Former railroad tracks

Oil drainages

Wetland

0 80 50 100 150 200 250 Feet

0 20 40 60 100 Meters

USGS
Vapor Transport Monitoring

- Observation well
- Excavated area
- Site of pipeline break
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- Remediation building
- North oil pool
- Middle oil pool
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- Oil drainage area
- Generalized direction of ground-water flow
- Remediation well
- Transect of vapor wells
- Wetland
- Former railroad tracks
- Oil pipelines
- Periodic to annual sampling
- Vapor samples analyzed in field using GC

Vapor well

Generalized direction of ground-water flow

Periodic to annual sampling

Vapor samples analyzed in field using GC
1985 Methane Vapor, % of Atmospheric

Floating oil
Upcoming Bemidji-Related Presentations

**ORALS**
- Technology transfer to Mandan, ND diesel spill site
- Long term fate of intractable LNAPLs
- Bemidji science drives model development
- Technology transfer to Cass Lake, MN crude-oil spill site

**POSTERS**
- Iron-reducing, in-situ microcosm
- Temperature as an indicator of microbial degradation
- Predicted effects of renewed remediation
- Effects of renewed remediation
- Methanogenic biodegradation of hydrocarbons
- Push-probe reconnaissance (new tools)
- Reactive gas transport modeling
- Loss of volatile hydrocarbons in the oil: 1985 to 2008

Questions?