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

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science for a changing world

Outline

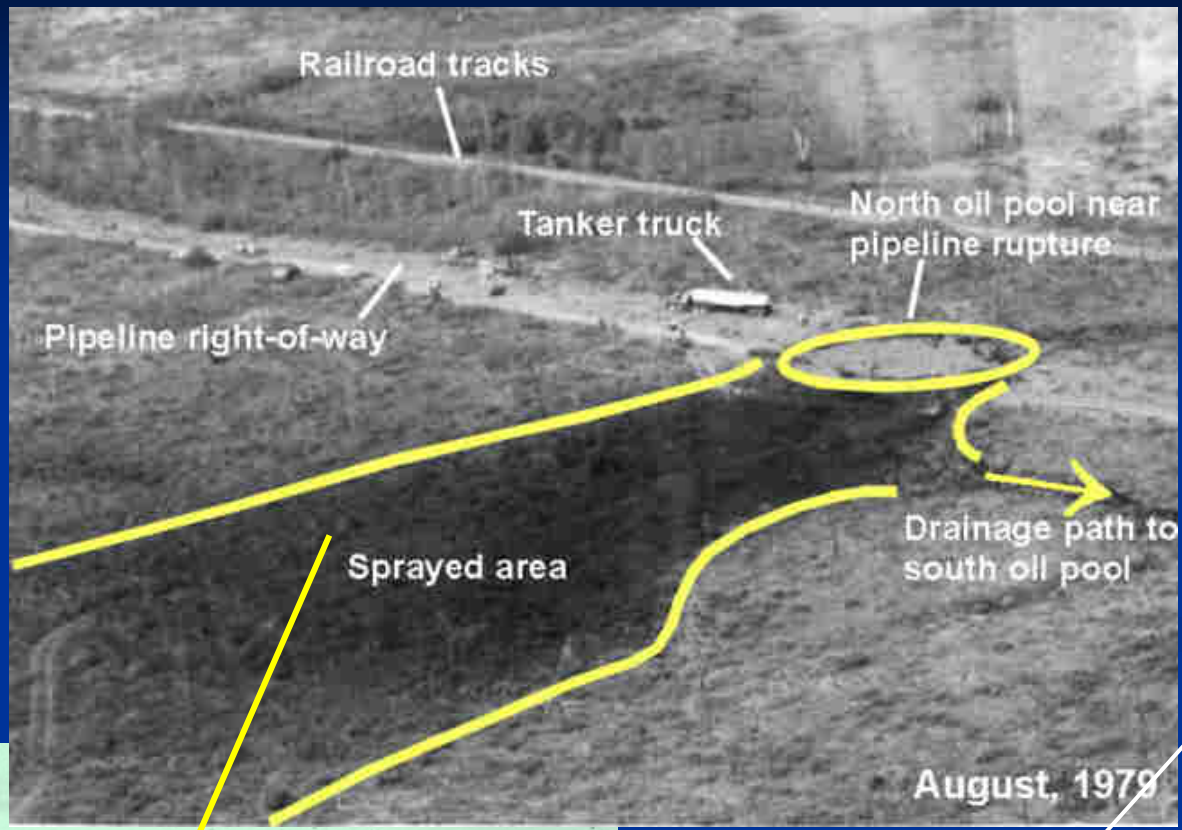
- Pipeline rupture and initial remediation (1979)

- Second phase of remediation (1998-2004)

- USGS monitoring of the remediation

- Introduction to other Bemidji presentations

Crude-oil pipeline broke in August, 1979



High pressure (3.5 MPa or ~500 psi), 86 cm (34-inch) diameter pipeline ruptured on August, 20, 1979 spilling 1,670 m^3 (10,500 barrels) of crude oil in an uninhabited area near Bemidji, Minnesota

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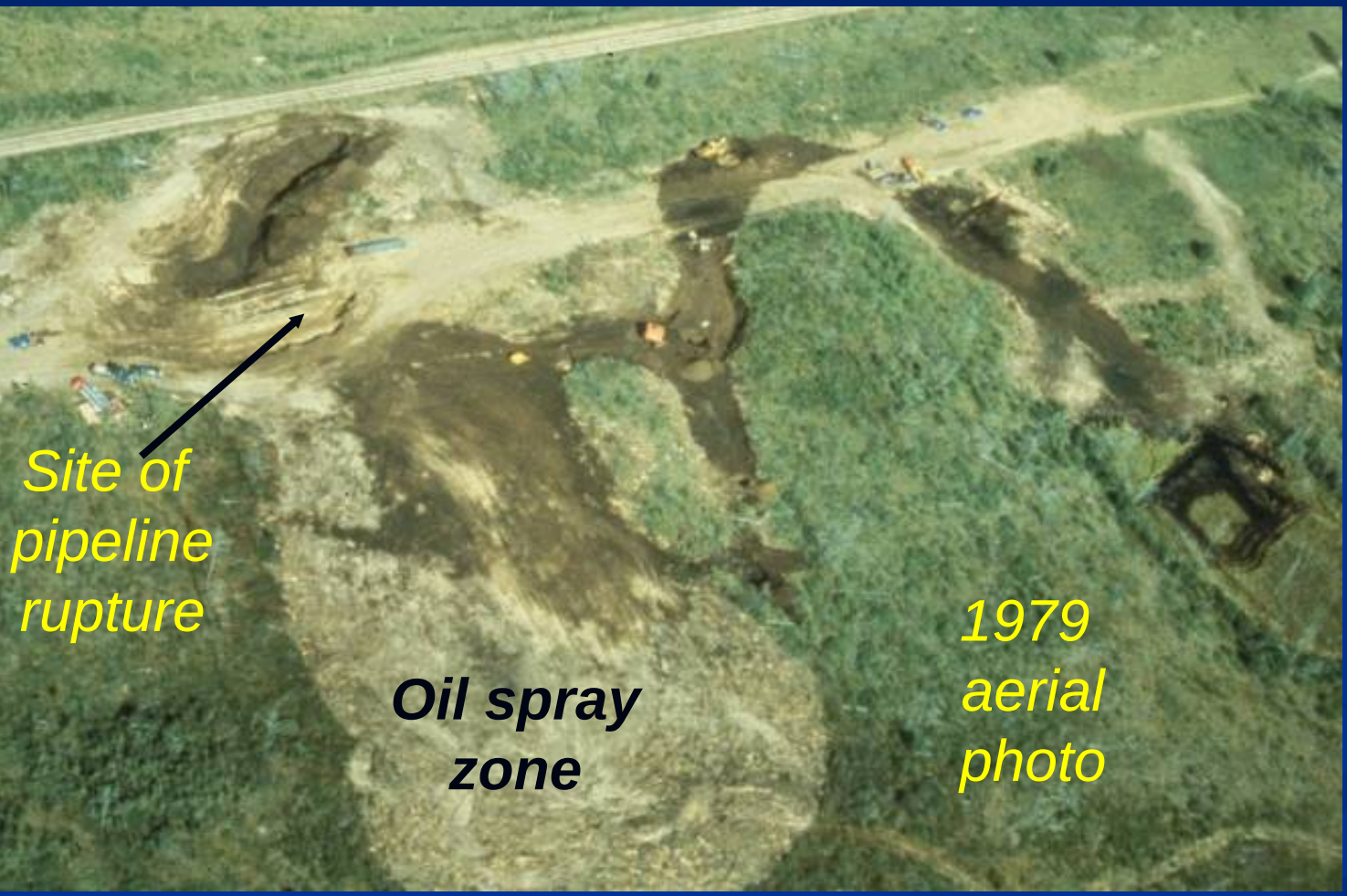
Crude oil sprayed over large area



- Oil pooled in low lying areas (≈2,000 m^2) and sprayed over area of 6,500 m^2 to the southwest of the pipeline that became known as the 'spray zone'.

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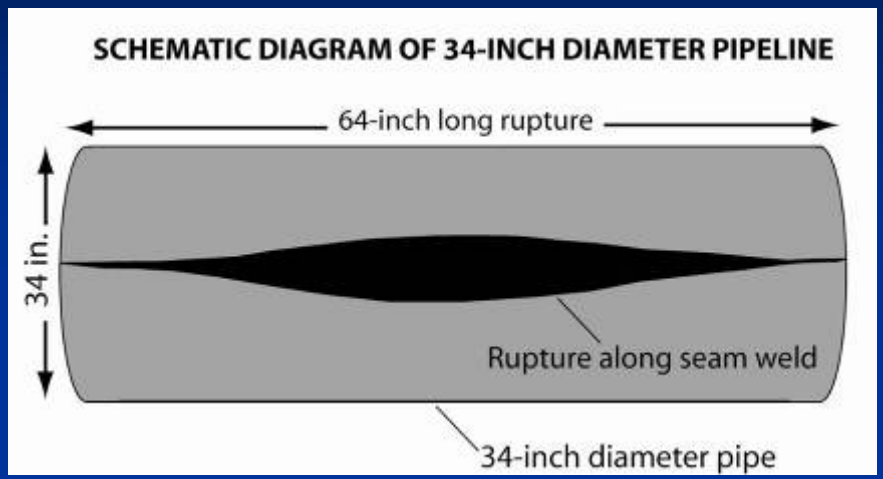
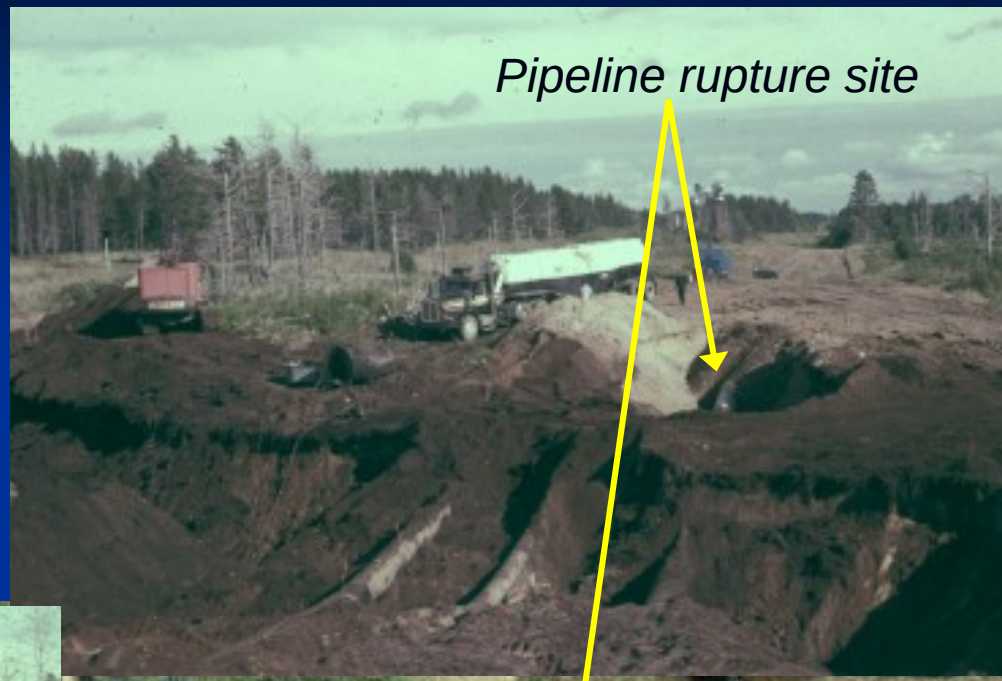
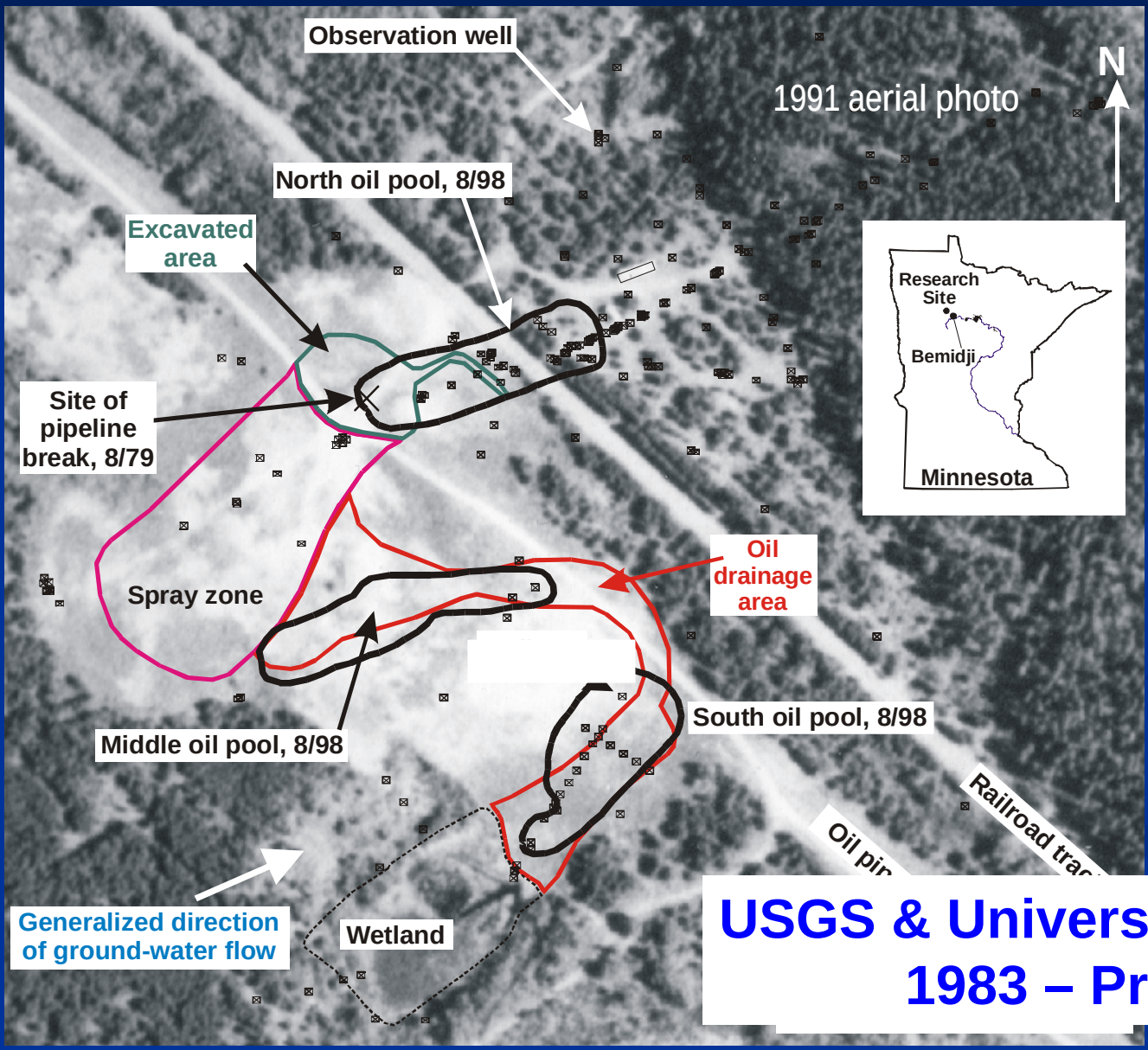
Views of Trench and Pipelines





Bemidji Crude Oil Spill Site



- Remediation efforts led to removal of ~ 75% of oil from site (about 417 m^3 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

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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**

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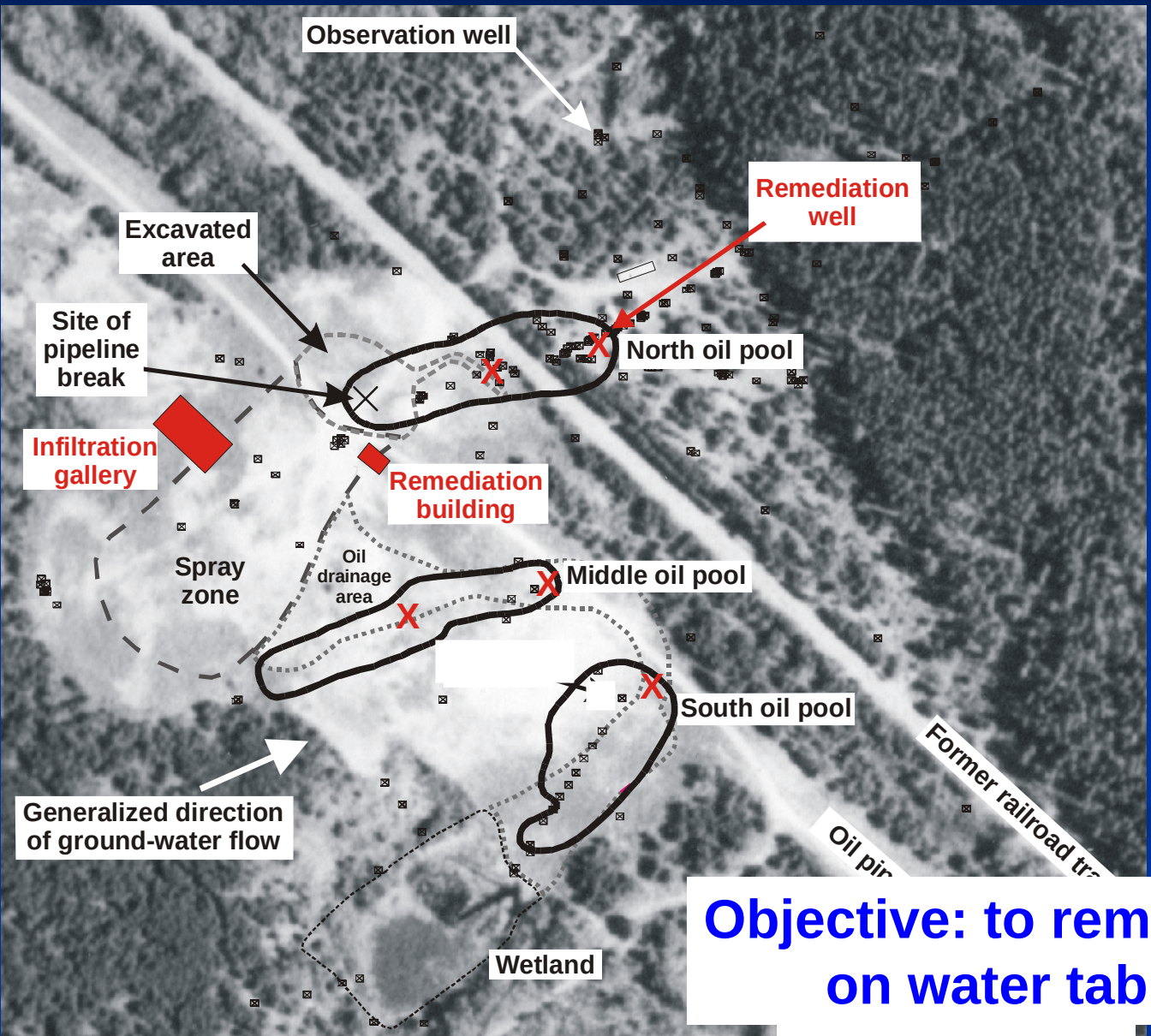
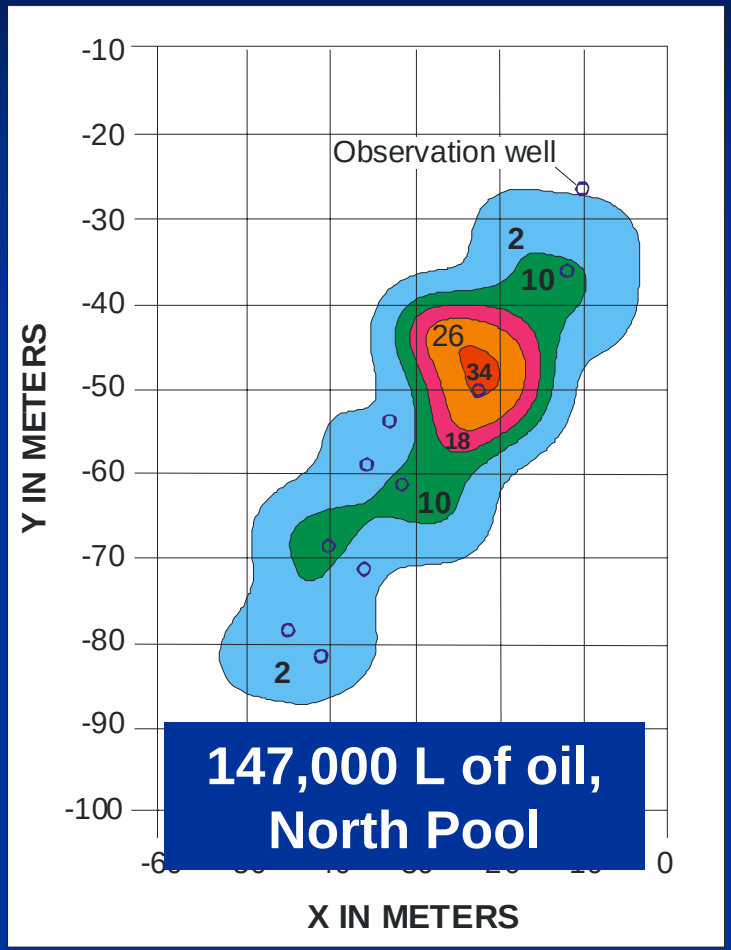
Renewed Remediation – 1998



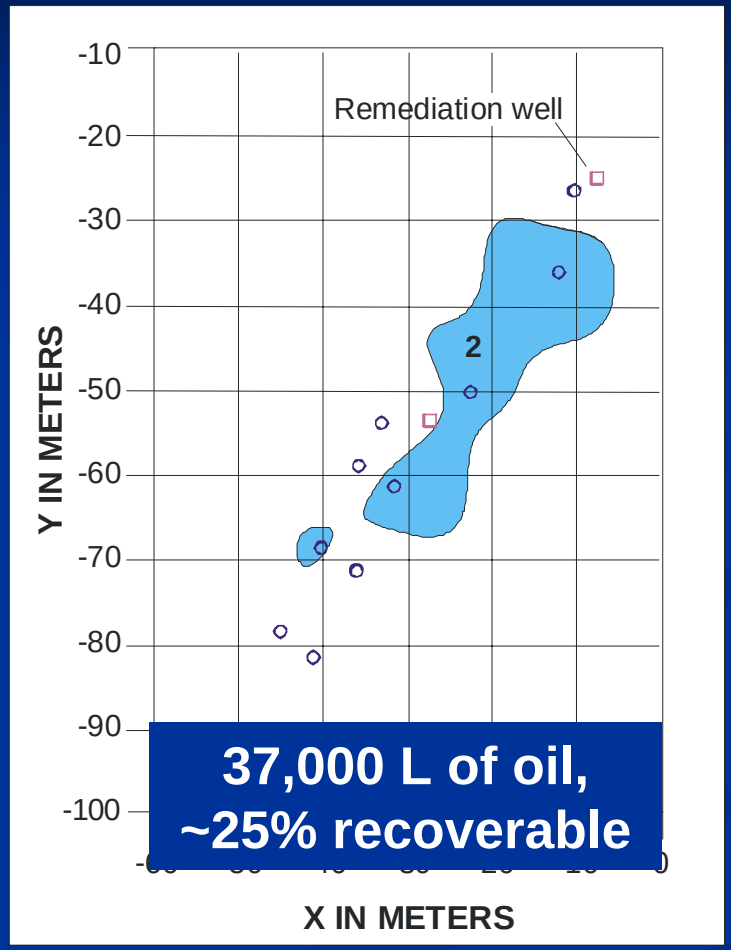
Second phase of remediation began in December 1998

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



Likely amount that can be recovered, cm

Herkelrath, 1999

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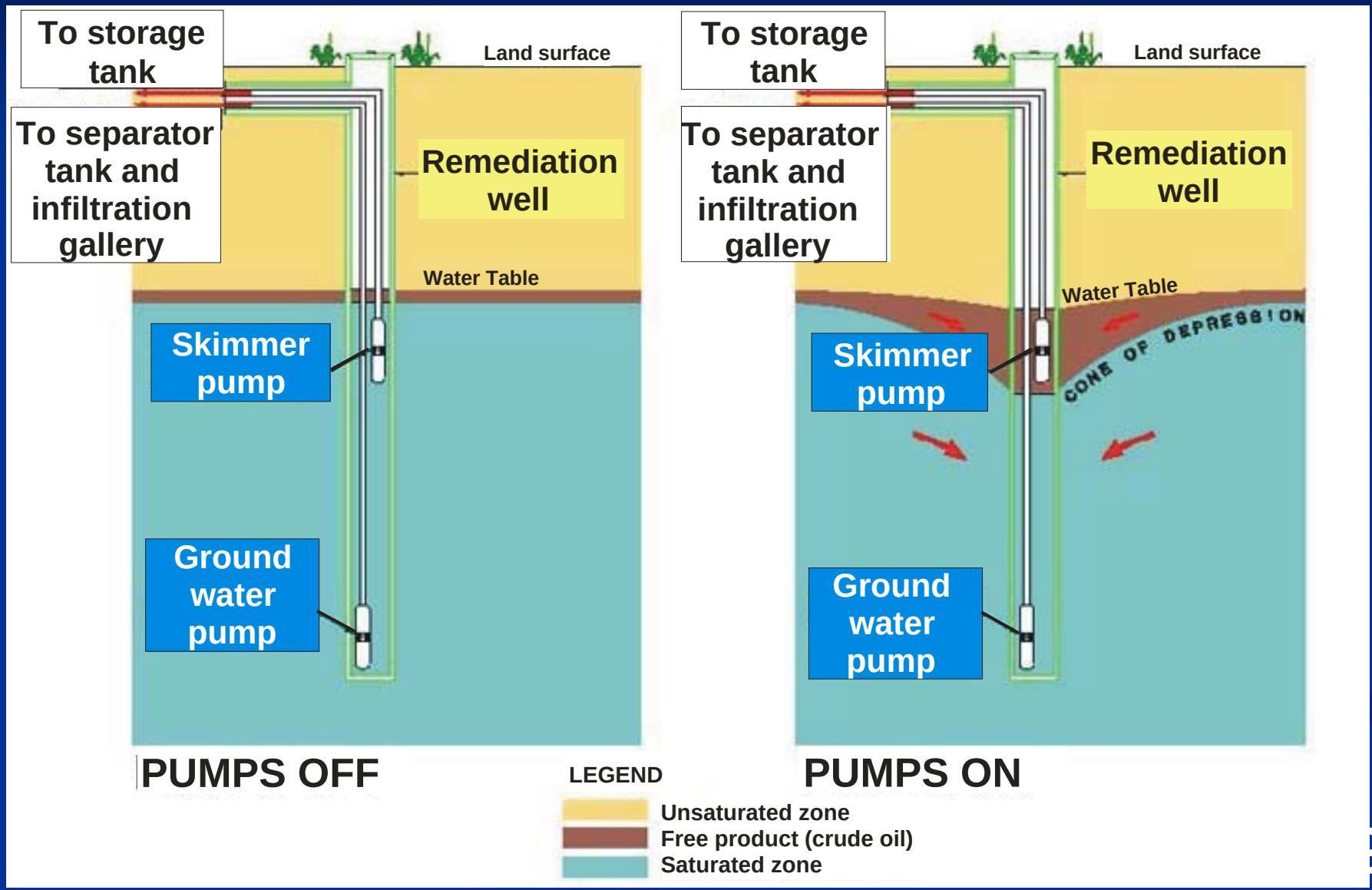
Remediation Well
S, looking NW

Pipeline rupture site

South pool

10 20'98

Dual-Pump Remediation System



North Pool Remediation Wells

Total pumping rate of water from all wells ~113 L/min (~30 gpm)

Remediation Building, May 1999

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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

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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

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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.***

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Oil Thickness Measurements

Using an oil-interface meter

Field Parameter Sampling

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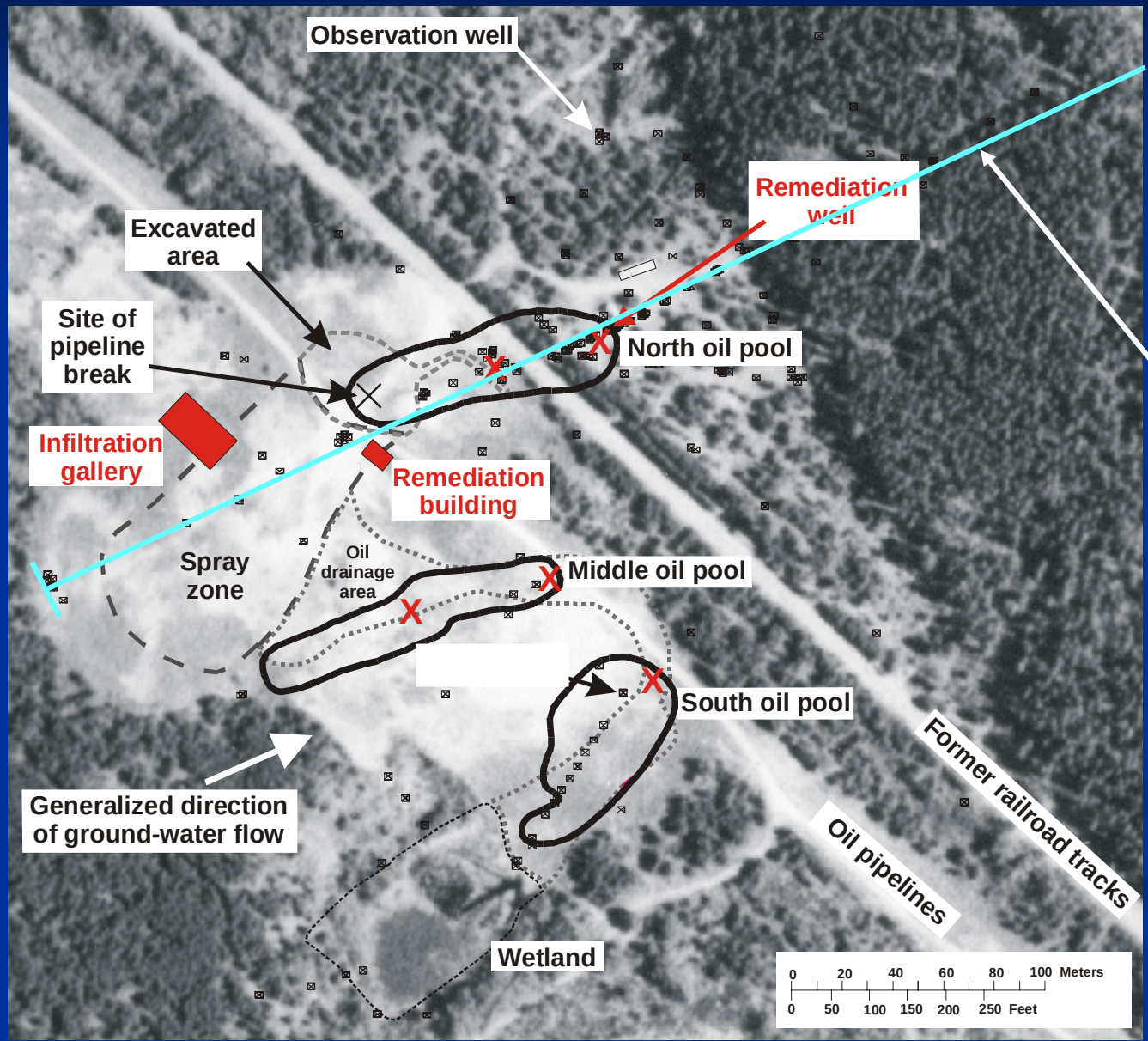
North Pool Transect of Wells



To "Unnamed lake"

North pool transect

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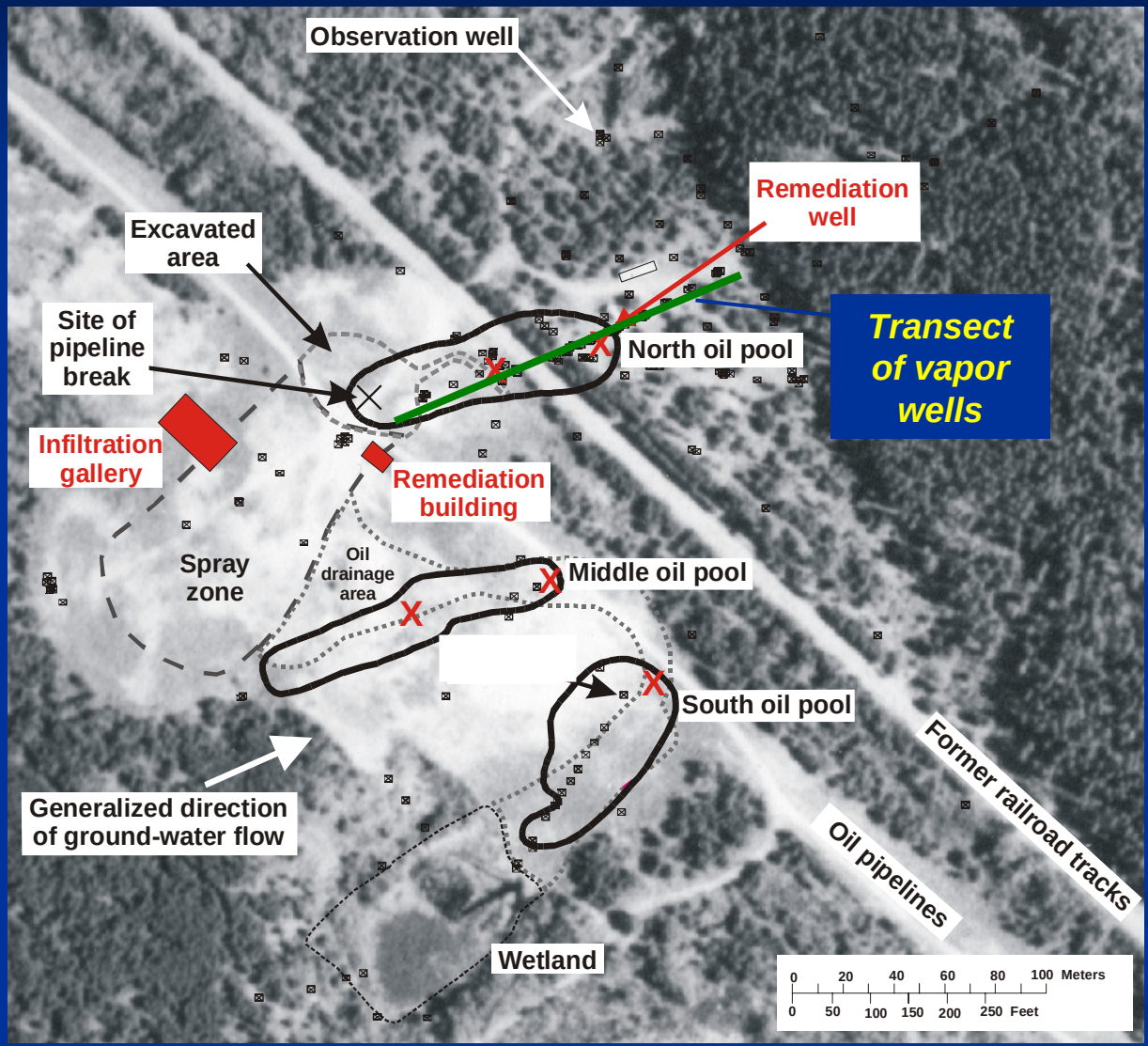
Vapor Transport Monitoring



Vapor well

Periodic to annual sampling

Vapor samples analyzed in field using GC

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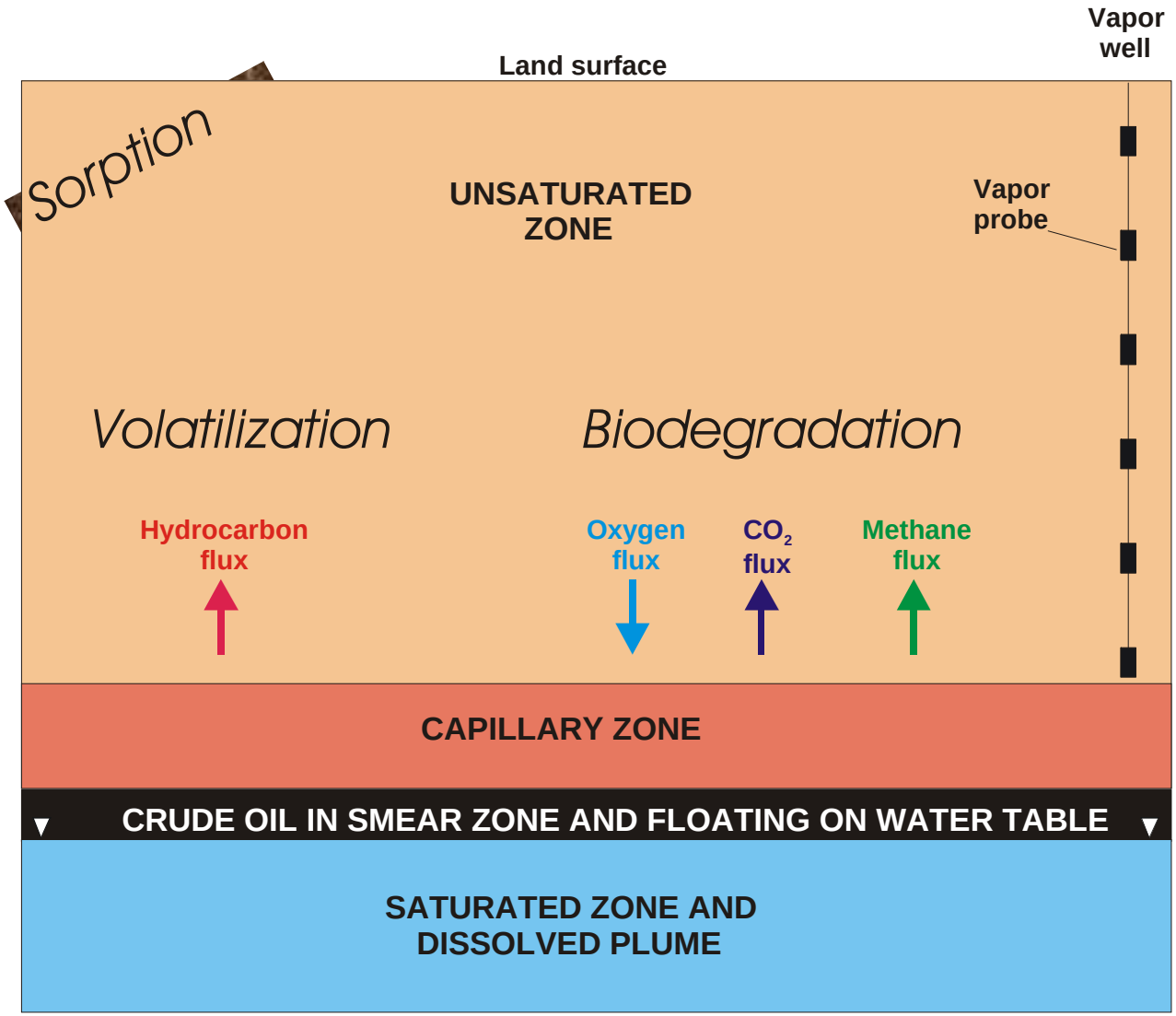
Conceptual Vapor Model



FICK'S LAW

$$J_{k\bar{k}\bar{k}} = -D \frac{dG}{dz}$$

Sand and gravel aquifer

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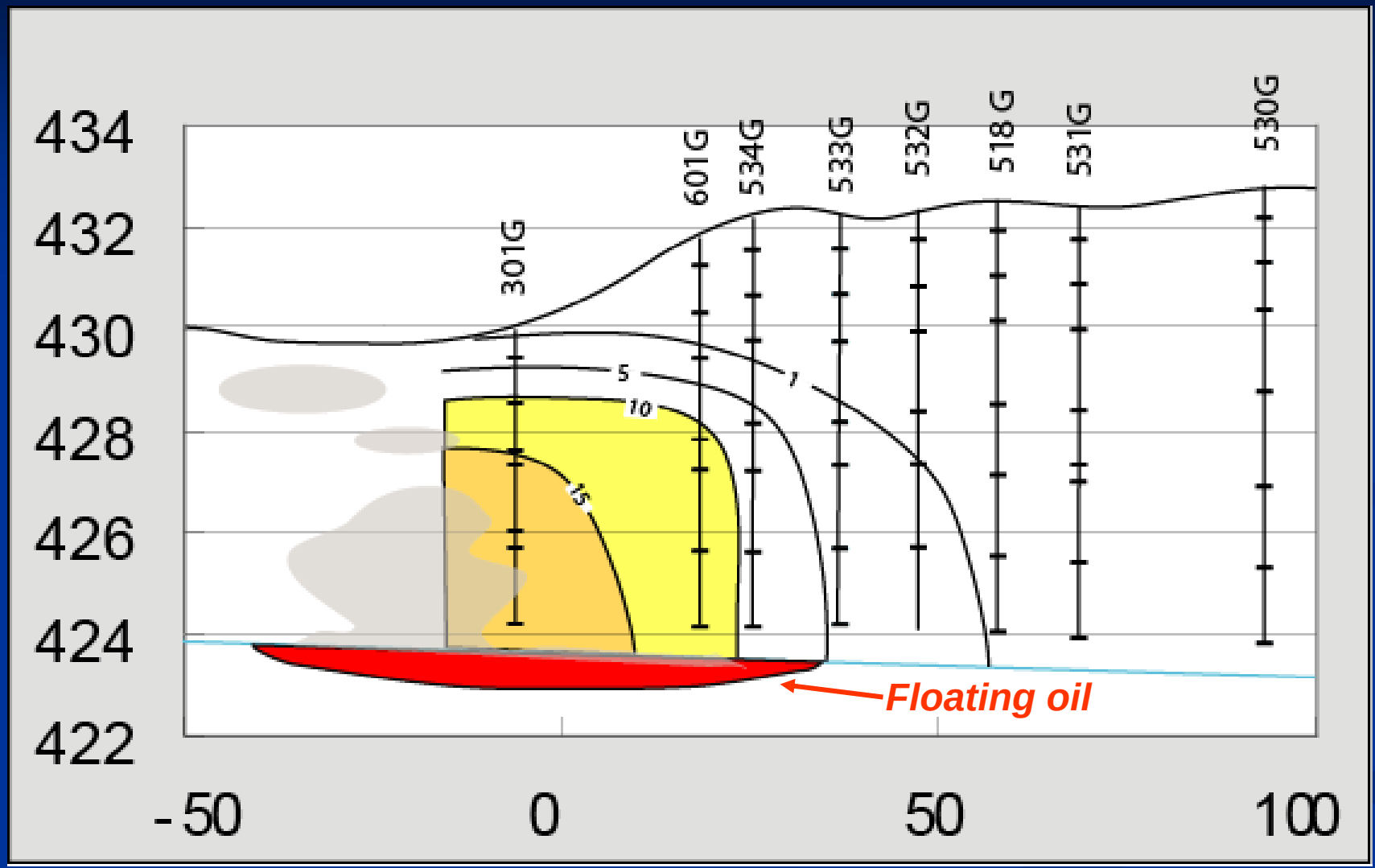
1985 Methane Vapor, % of Atmospheric



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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?

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