Sulfate reduction in the bioremediation of petroleum contaminants in groundwater

Dale Van Stempvoort,
National Water Research Institute, Environment Canada
James Armstrong
Komex International Ltd., Calgary, AB

Environment Canada Environnement Canada
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Objectives

- Investigate role of microbial sulfate reduction in natural attenuation of hydrocarbons in groundwater, Canada
- Develop techniques to enhance this process

Main Collaborators

- Environment Canada
- Komex International Ltd.
- University of Calgary

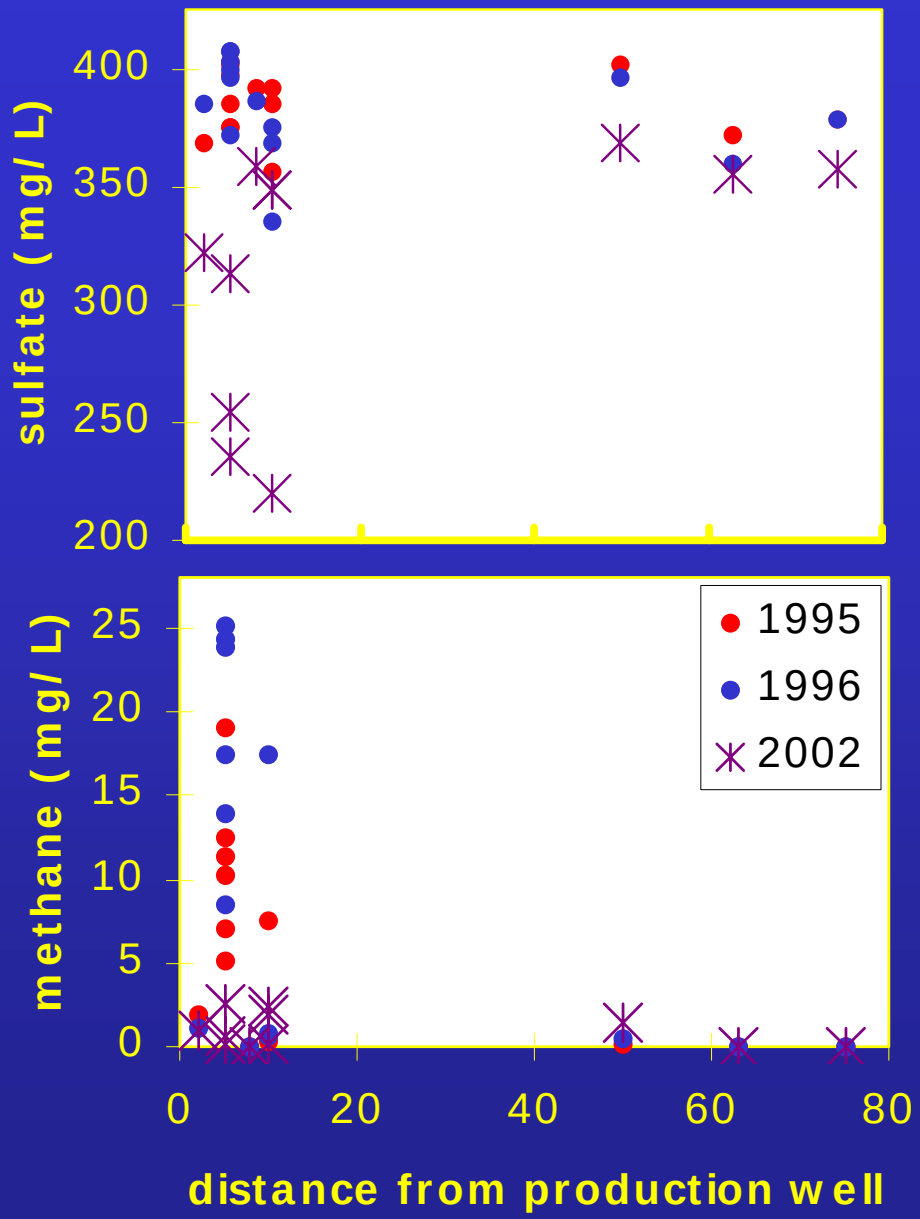
  - Coordination with CORONA (Consortium for Research on Natural Attenuation)
  - Input by Sask Research Council, Alberta Env.

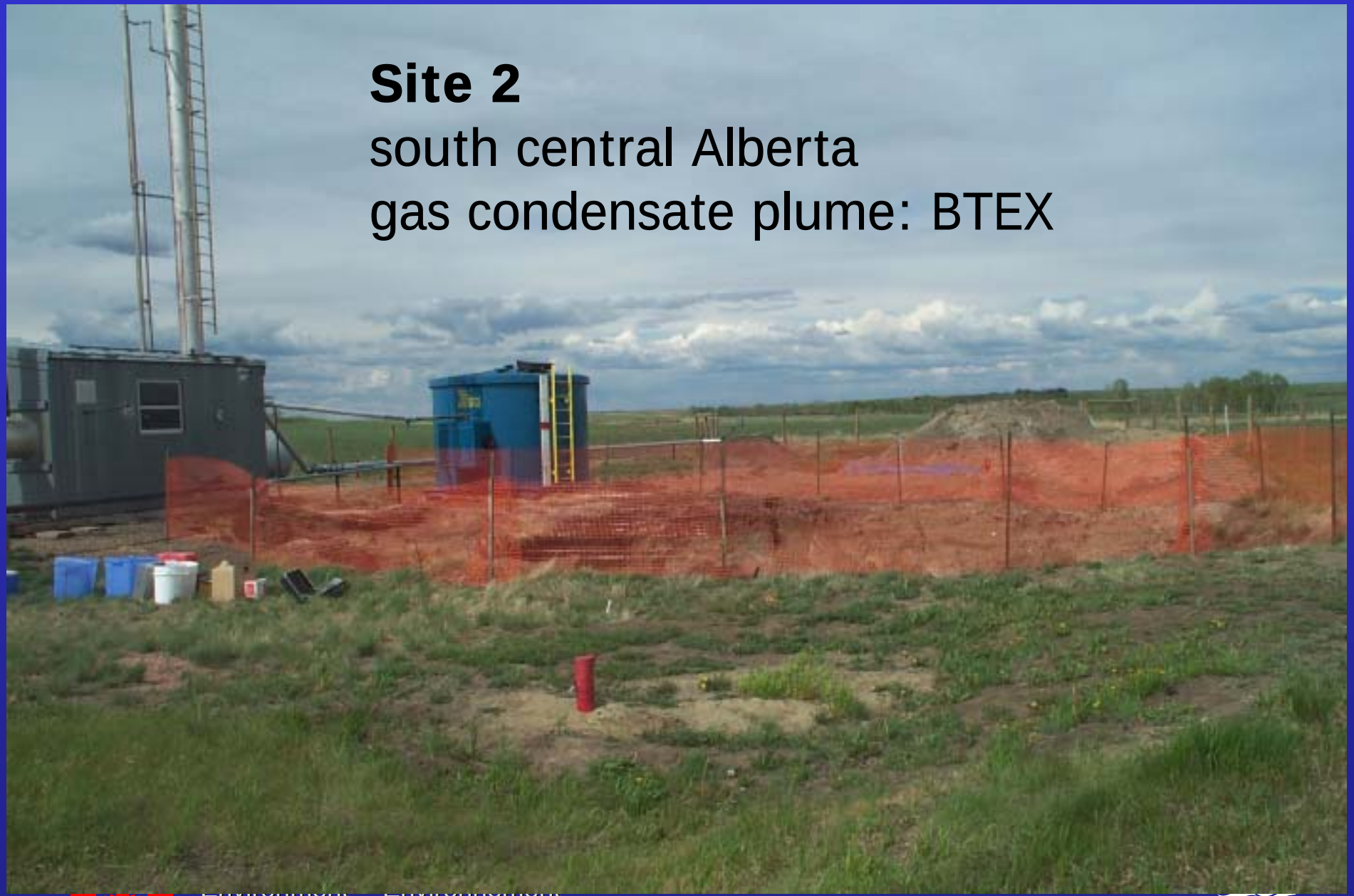
Methods

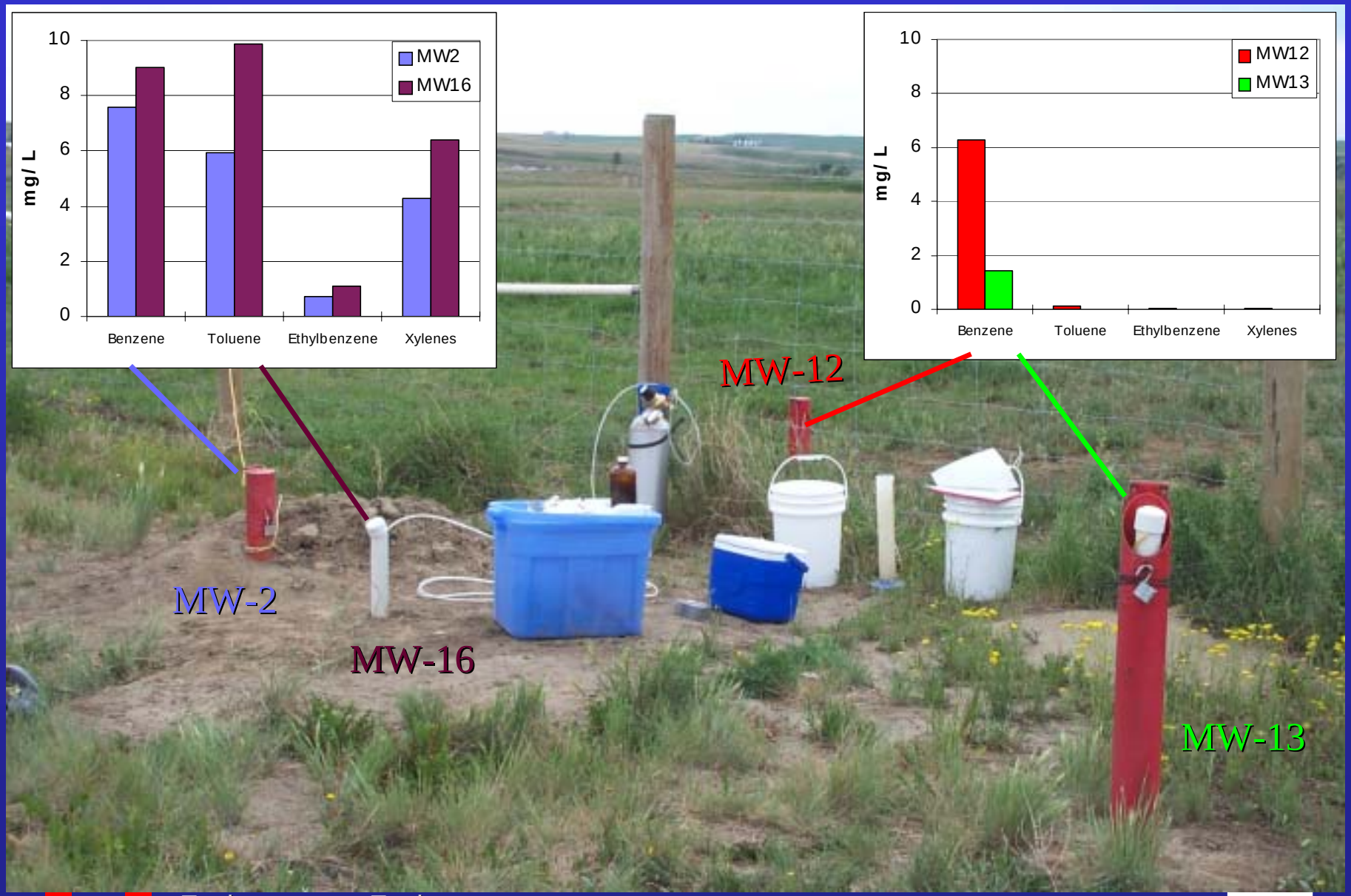
- Field investigations at 3 sites in Alberta
  - biodegradation of petroleum hydrocarbons under anaerobic, high-sulfate conditions.
  - Sulfate injection tests

- Parallel laboratory batch tests using aquifer and groundwater samples
  - anaerobic, vary sulfate concentrations
  - effects of other parameters (sulfide, chloride, Fe)
  - molecular analyses of microbial pop (PCR/DGGE)

Site 1:
NW of Lloydminster, Alberta
- leakage of natural gas from an old production well to an aquifer

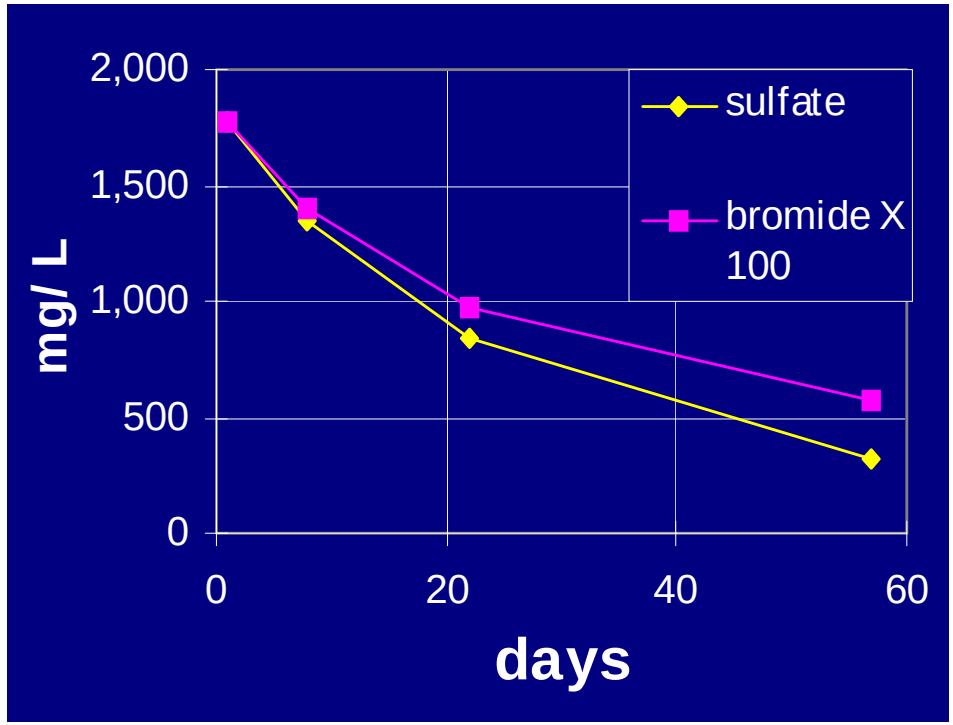



Site 2
south central Alberta
gas condensate plume: BTEX


10
8
6
4
2
0
mg/ L
MW2
MW16
Benzene
Toluene
Ethylbenzene
Xylenes
MW12
MW13
MW-12
MW-2
MW-16
MW-13

Site 2

Test injection (June 02)



Inferred sulfate reduction rate:
2 to 3 mg/L per day

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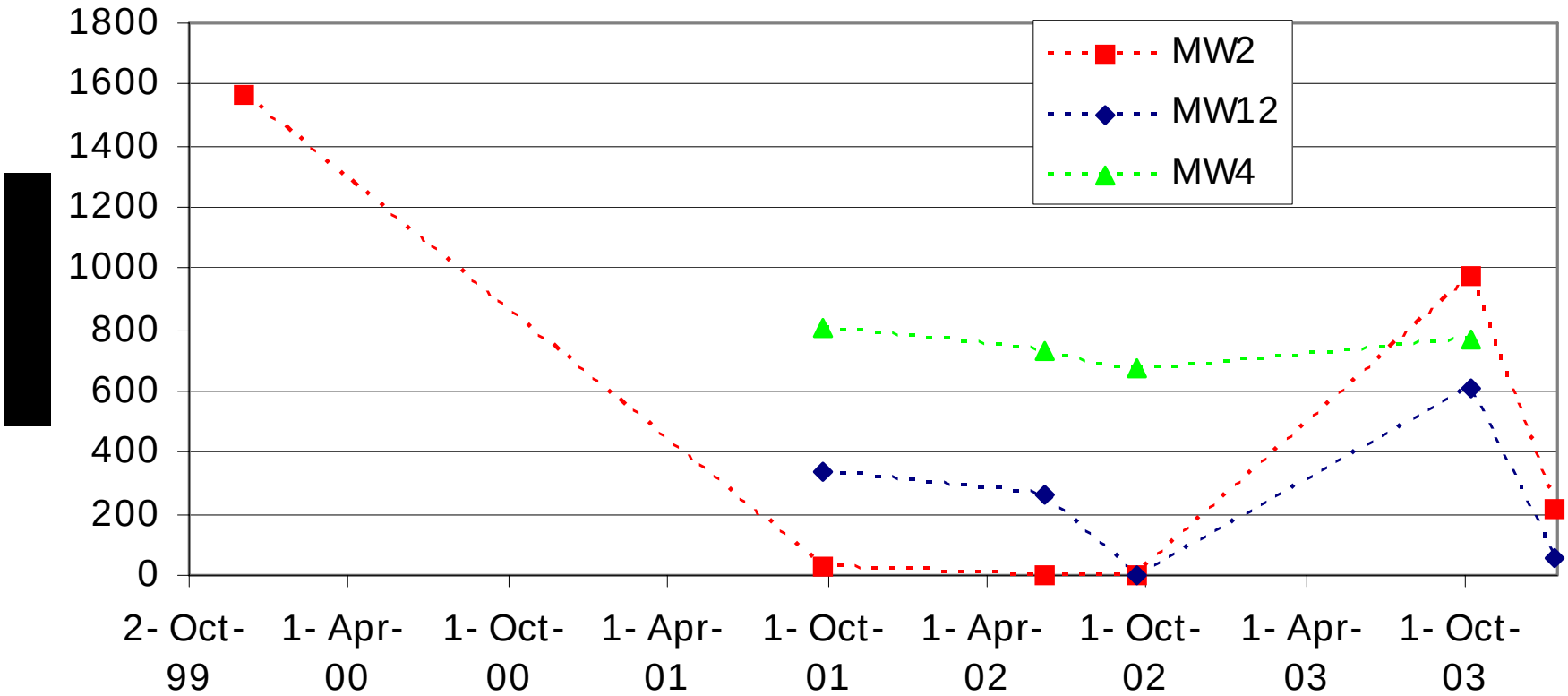
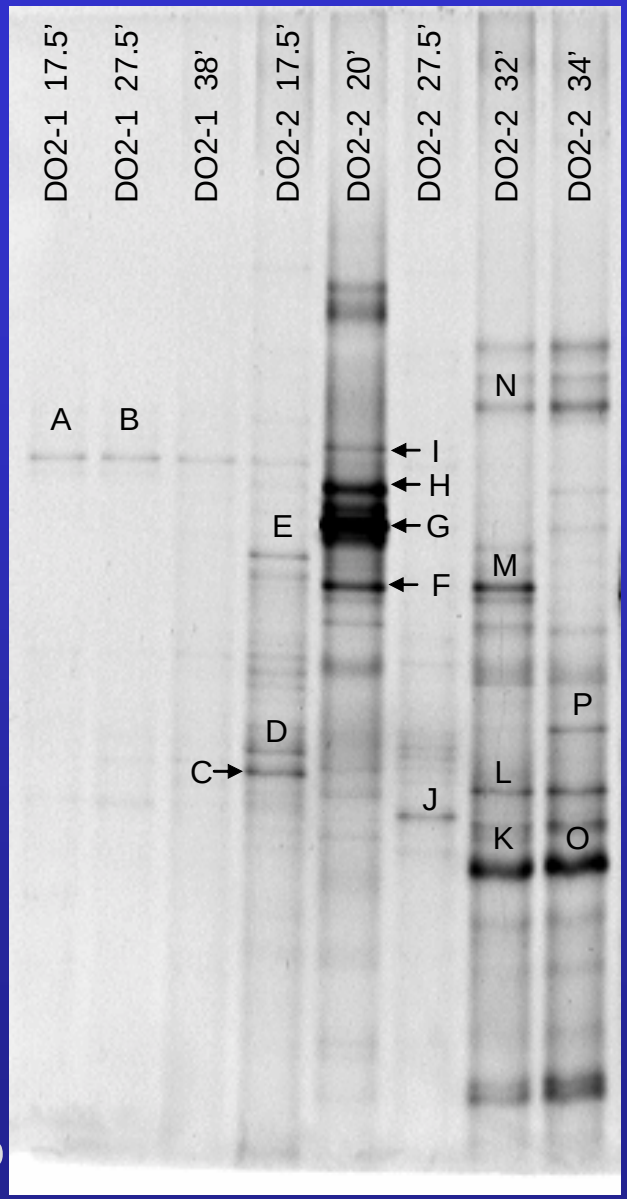
Unintended “artificial” recharge apparently plays key role



- Declines in sulfate in plume indicate reduction
- "Rebound" in 2003 apparently related to recharge
- Inferred sulfate reduction rates in 2003-04: 6-8 mg/L per day



Extraction / Analysis of DNA from Sediment Samples

- DGGE profiles of eubacterial 16S rDNA fragments
- Indicated sulfate reducing bacteria (*Desulfosporosinus spp.*) and other anaerobes (e.g. *Geobacter*)

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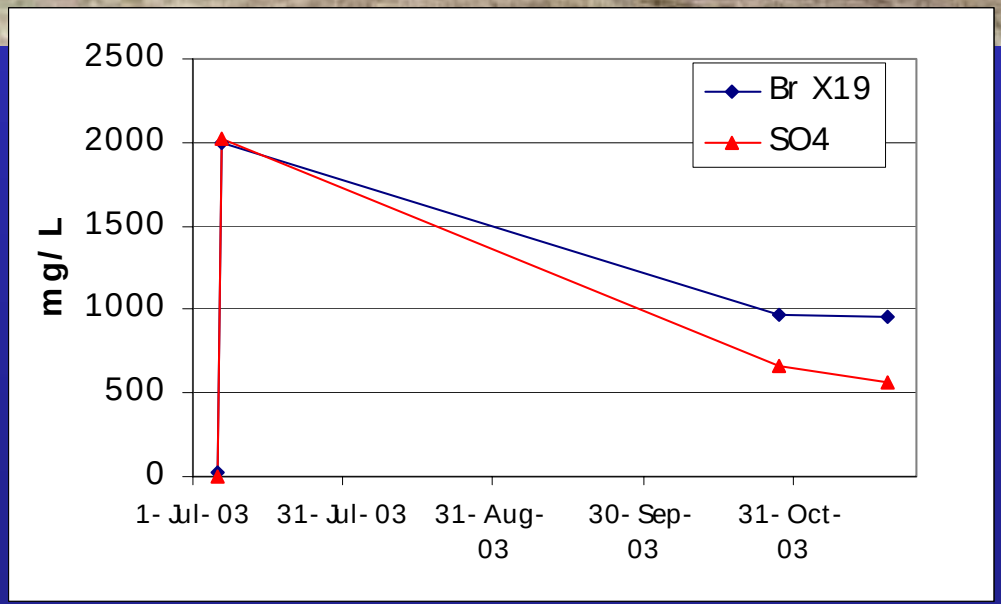
Site 3

gas processing plant in southeast Alberta

Site 3

Injection test July-November, 2003



inferred sulfate reduction rate: 0-3 mg/L per day (Jul-Oct), 5-11 mg/L (Oct-Nov)

Results to date: 3 Sites

- sulfate reduction important at ~ 5˚C
- 2 injection tests: 2 to 5+ mg/L per day (same order as US tests)
- SO_4 recharge can be important (Site 2)

Implications

- Sulfate reduction → equivalent to degradation of ~ 30 to 150 mg/kg of hydrocarbons in aquifer per year
- Injection of sulfate → increase in hydrocarbon degradation rate
- BTEX plume potentially degraded a few m from source

Output 1

- Improved/validated input data for existing models or new predictive models characterizing the fate and behaviour of hydrocarbons in anaerobic environments:
  - Field measured sulfate reduction rates with inferred link to hydrocarbon degradation

Output 2

- Potentially a new technique to enhance remediation of hydrocarbons in groundwater via sulfate reduction.
  - Injection of sulfate solution into source zone, plume
  - Artificial recharge of sulfate-rich water
  - Collaboration with industry

Publications to date

Van Stempvoort, D., Maathuis, H., Jaworski, E., Mayer, B. and Rich, K. 2004. Submitted to Ground Water

Van Stempvoort, D.R., Armstrong, J. and Mayer, B. 2002. Proceedings, 2002 Petroleum Hydrocarbons and Organic Chemicals in Ground Water Conference (NGWA/API), November 6-8, 2002, Atlanta

Van Stempvoort, D.R., Armstrong, J. and Biggar, K. 2002. Proceedings, 55th Canadian Geotechnical and 3rd Joint IAH-CNC /CGS Conference, October 21-23, 2002, Niagara Falls, Ontario

Focus in 2004-05

- Probe link between iron and sulfide → FeS as sink for reduced sulfur
- DNA-based molecular analyses
- Probe link between sulfate reduction and degradation of BTEX (microcosms)
- Numerical model of processes (Site #2)