

Monitored Natural Attenuation for Upstream Oil and Gas Industry

Consortium for Research
on Natural Attenuation
(CORONA)
March 2004

James Armstrong



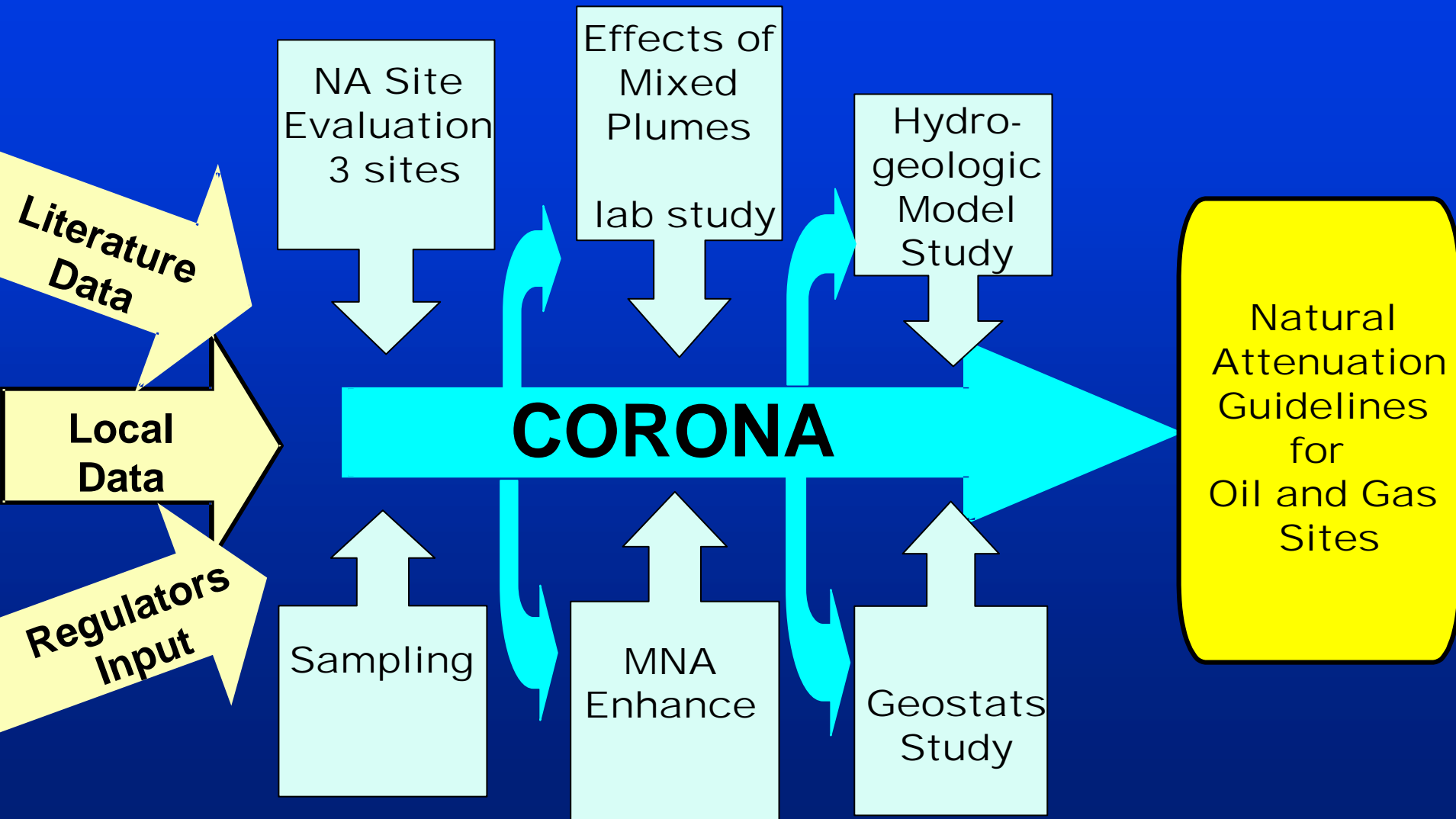
Researchers

- **University of Alberta**
 - ◆ *Dr. Kevin Biggar, Principal Investigator:*
 - Drs. Foght, Guigard, Deutsch, Mendoza
- **Technical Review**
 - ◆ *Dr. Ryan Dupont*
- **Research Partners**
 - ◆ *Kim McLeish / Dr. Cathy Ryan (U of Calgary)*
 - ◆ *Dr. Dale Van Stempvoort (NWRI)*
 - ◆ *Alexis McPherson / Dr. Ian Fleming (U Sask)*
- **Technical Support:**
 - ◆ *Komex International Ltd., Maxxam Analytics*

Inputs

Activities

Outcome



Input

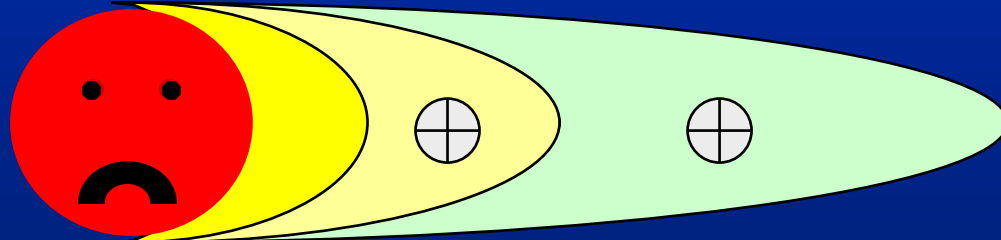
- Do monitoring data support MNA?
 - ◆ *decreasing hydrocarbon concentrations*
 - ◆ *characteristic geochemical patterns*

Background

Well



Source



Plume

Wells



Lower oxygen, nitrate, sulfate
higher iron, manganese, methane

Past Findings

Database review (250 plumes at 125 sites)

- ▣ *Good evidence of natural attenuation*
- ▣ *Sulfate reduction is dominant process*
- ▣ *Most common co-contaminant is salt*

Site Evaluation

Characterize and monitor:

- ☐ *UVIF-CPT evaluated*

 - works well when significant aromatic content
 - requires ground truthing

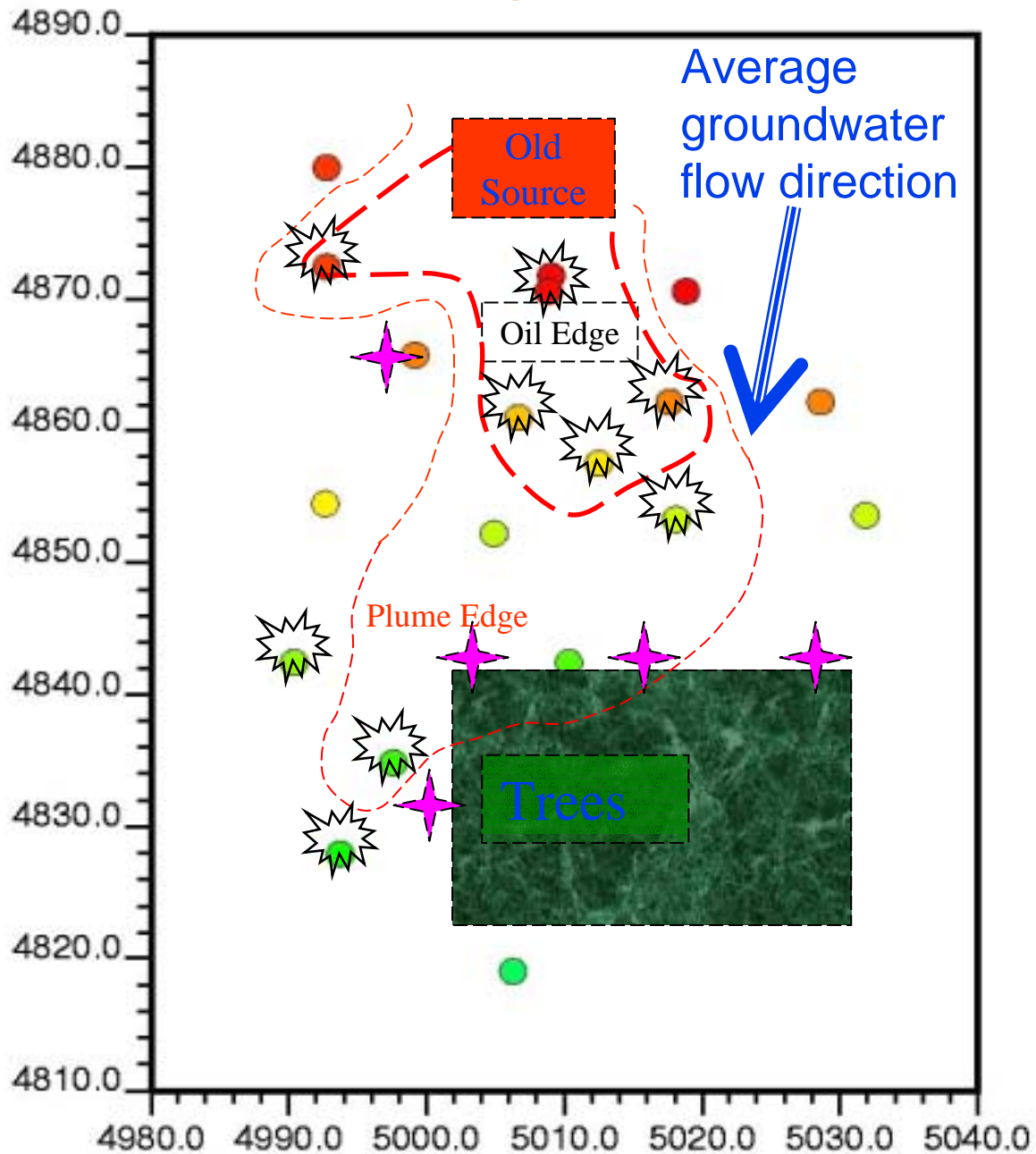
- ☐ *Require seasonal monitoring*

 - seasonal effects necessitate quarterly sampling

- ☐ *Trends: contaminants and indicators*

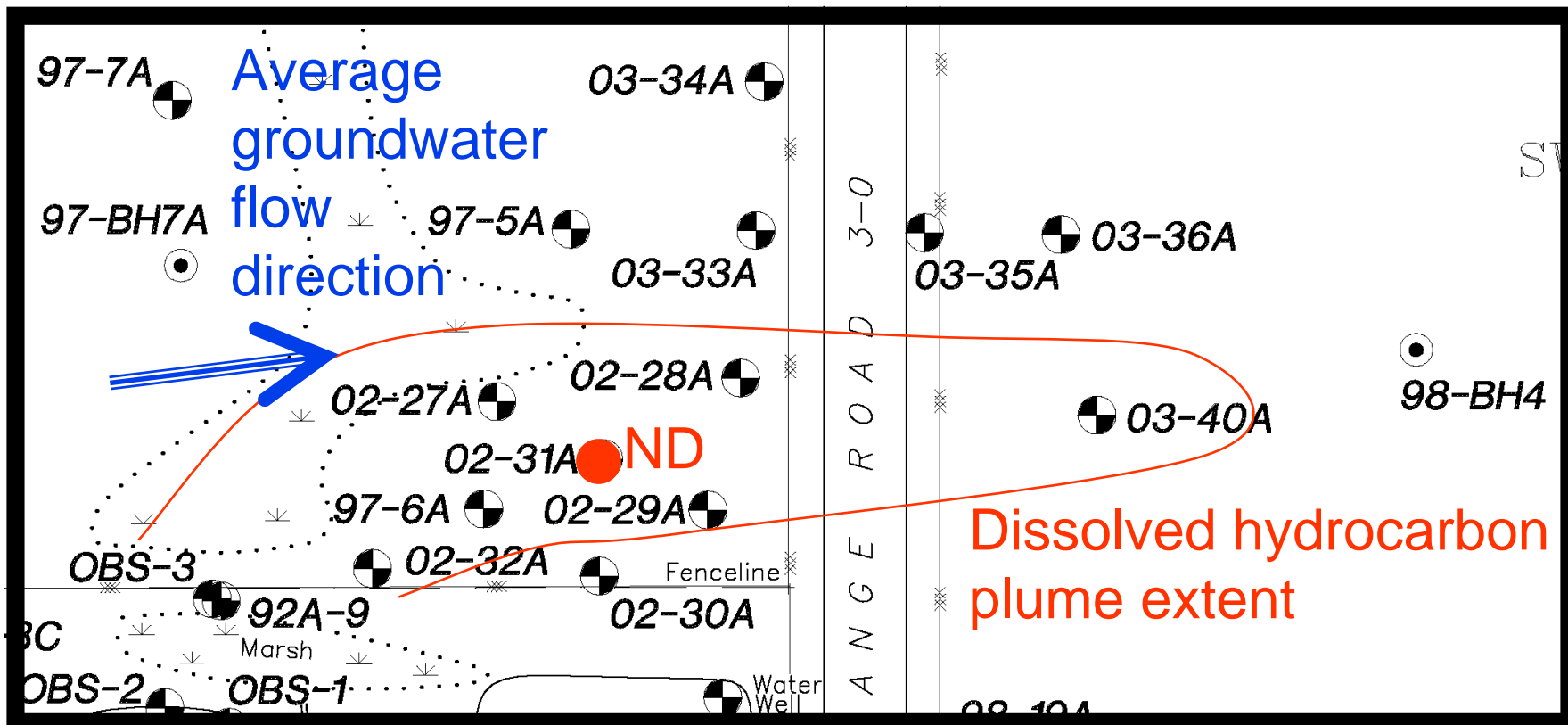
 - minimum 2 years of data (variability?)

Site 1

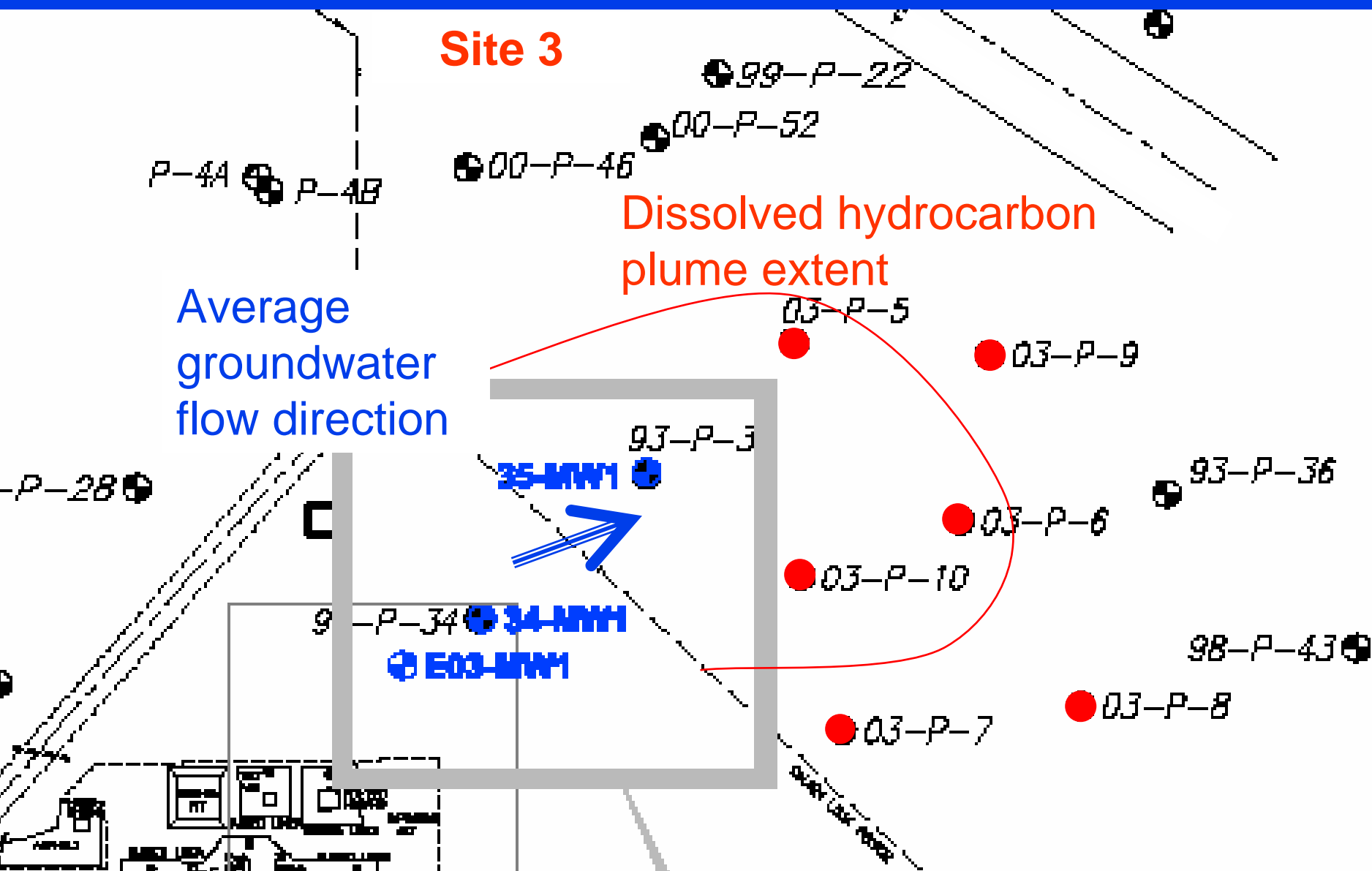


- Monitoring Well
- CPT-UVIF Hole
- CPT-UVIF Well

Site 2



Site 3



Average groundwater flow direction

Dissolved hydrocarbon plume extent







Sampling (outcome)

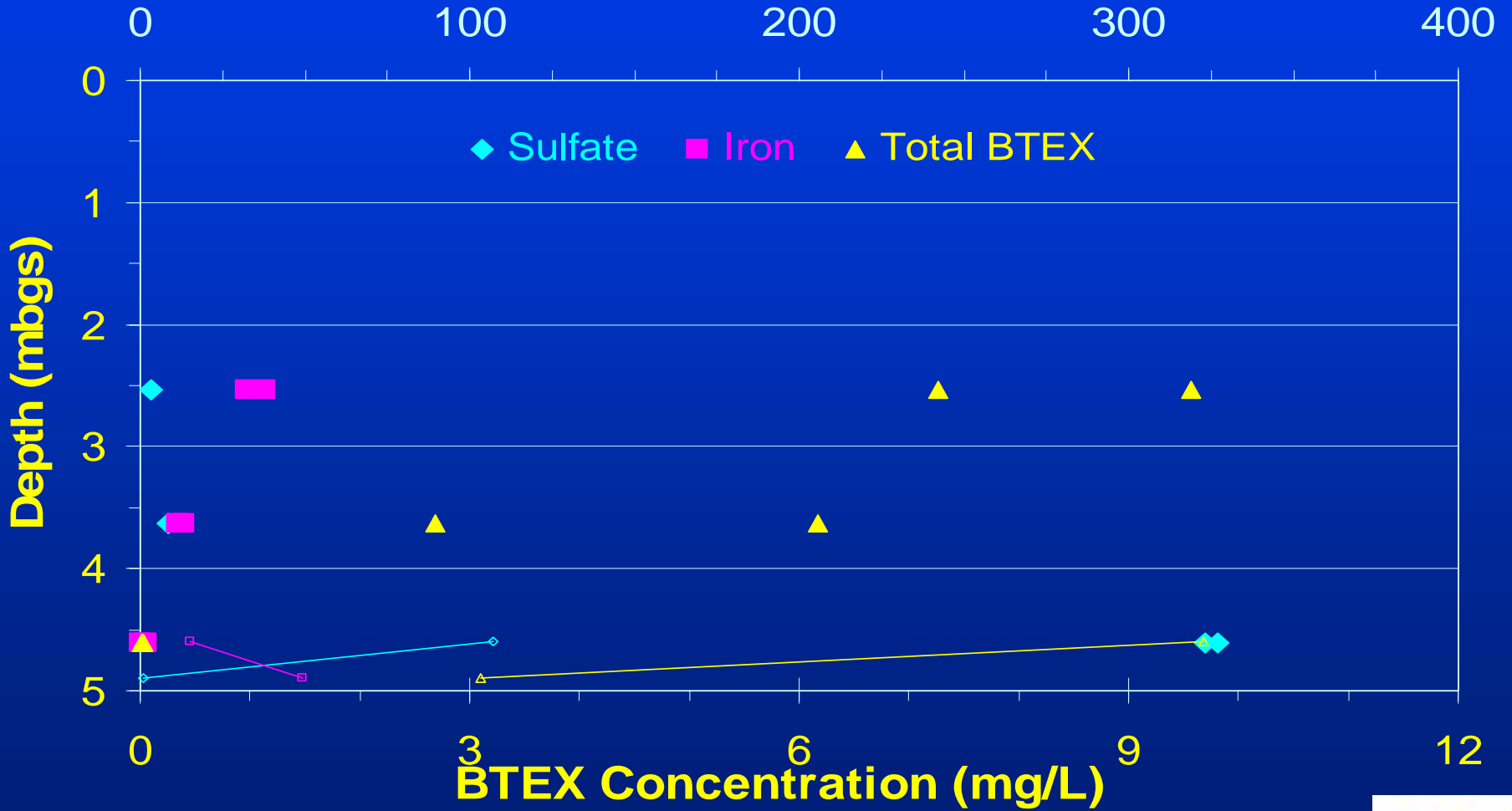
Multiple sampling techniques evaluated:

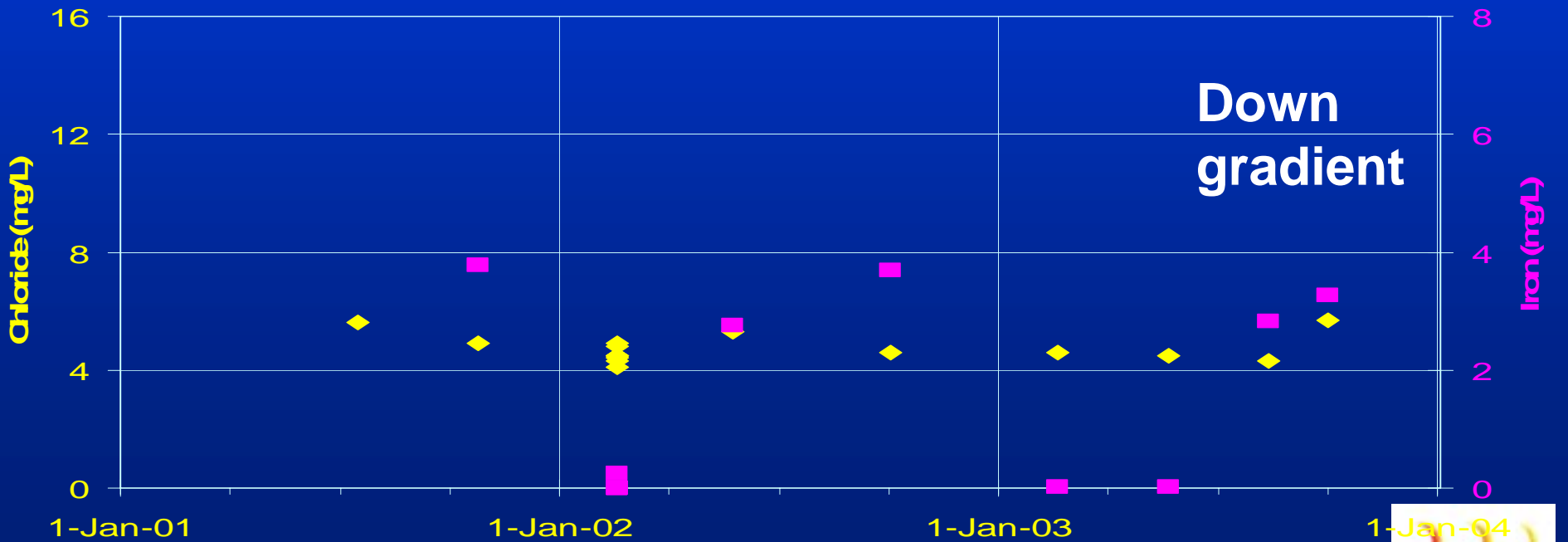
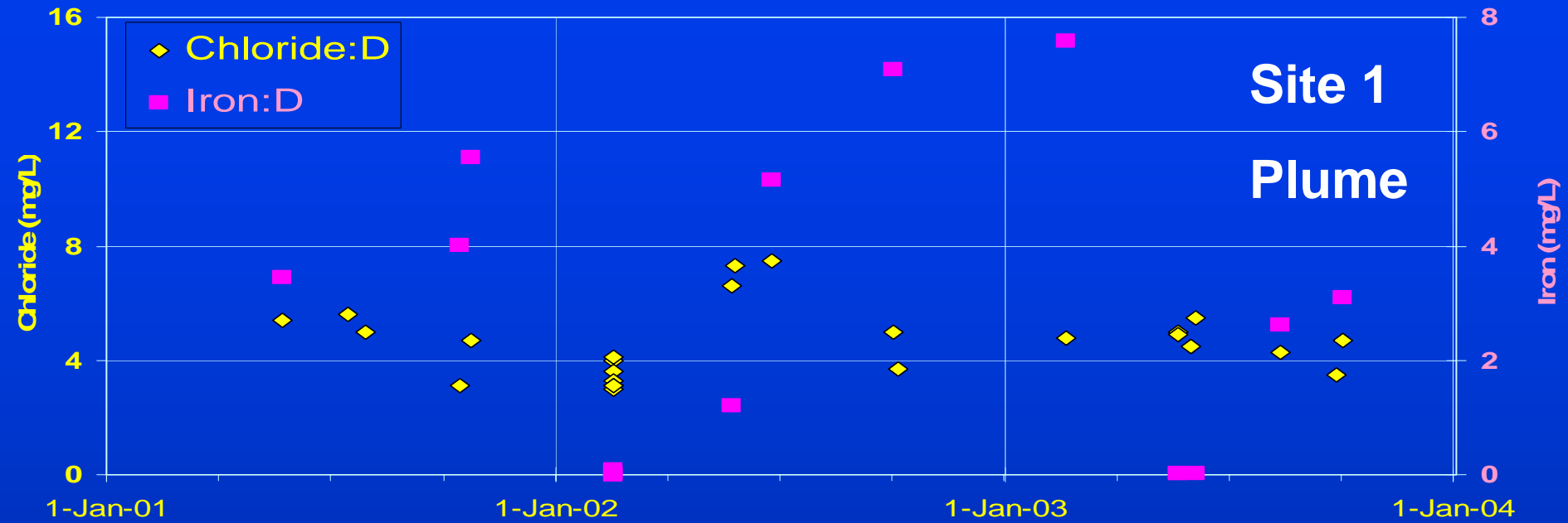
- ▣ *Purging not needed; can be misleading:*
don't draw water surface into screen
- ▣ *Spatial variability can dominate*
big local changes (lateral &/or vertical)
- ▣ *Dialysis sampling system*
works well, assessing relative merit



Site 3 Direct Push Wells

Sulfate, Iron Concentration (mg/L)





Lab Study in progress

Mixed Plume Effects

Enhancement approaches:

- ▣ *Design and set up mesocosms*
- ▣ *Establish metabolite analyses to:*
 - confirm biodegradation
 - identify co-contaminant effects
 - identify enhancement effects
 - help verify monitoring data

Metabolite (Dr. Foght)

- Intermediary biodegradation compounds
- Provide direct evidence of biodegradation
- Method being developed

Enumeration (Dr. Foght)

- MPN's tested at start, 6 months, 12 months

Sulfate reducing Bacteria (Fedorak medium)	Iron reducing Bacteria	Aerobic Hydrocarbon Degraders
Sulfate reducing Bacteria (API medium)	Methanogens	Aerobic colony forming units
Ammonia producers	Nitrate reducing Bacteria	

Mesocosms

(Dr. Guigard)

- Examine addition of amendments to enhance natural attenuation
- Duplicate Tests

Nitrate only	Nitrate+nutrients	Unamended
Sulfate only	Sulfate+nutrients	Sterile control
Nutrients only		



Corona
Extra

Corona
Extra

BKC
Quality Sample Bag
4



MNA Enhancement

Laboratory study started in fall 2003

- ▣ *Mesocosms started, data showed oxygen leak*
- ▣ *Re-fitted to avoid oxygen leakage*
- ▣ *Second round planned with co-contaminants*
- ▣ *Metabolite testing to be incorporated*

MNA Modelling

Geostatistical approach started in 2004

☰ *Effects of parameters:*

☰ uncertainty

☰ sensitivity

☰ *Value of additional data*

☰ *Value of effort to reduce uncertainty*

MNA Modelling

Deterministic approach to start in 2004

- ▣ *Utility of existing models*
- ▣ *Use geostatistical results for uncertainty*
- ▣ *Identify data needs: site characterization*

Guidelines

- **Steering Committee started development**
- **Draft in preparation for internal review**

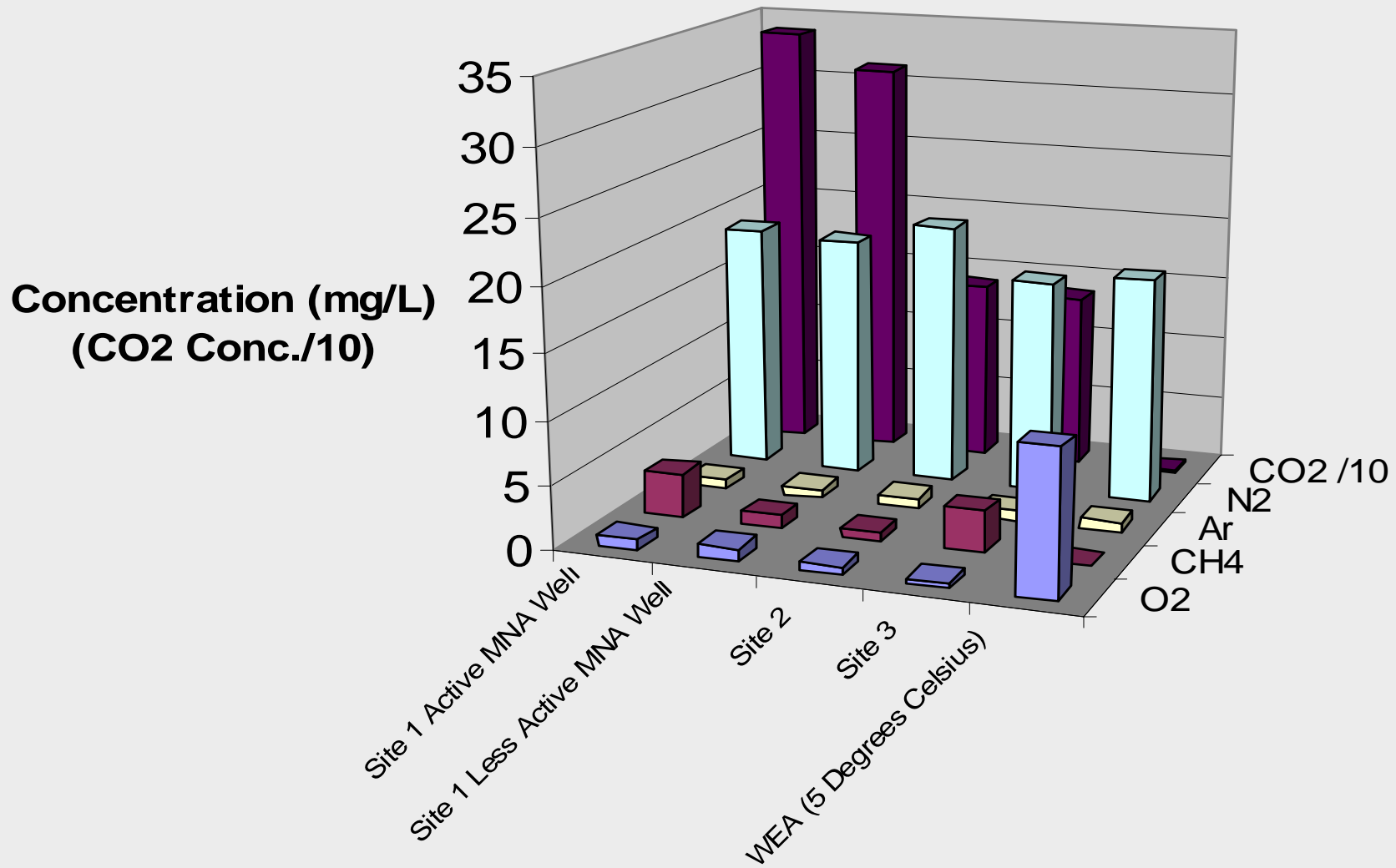
Partner Programs

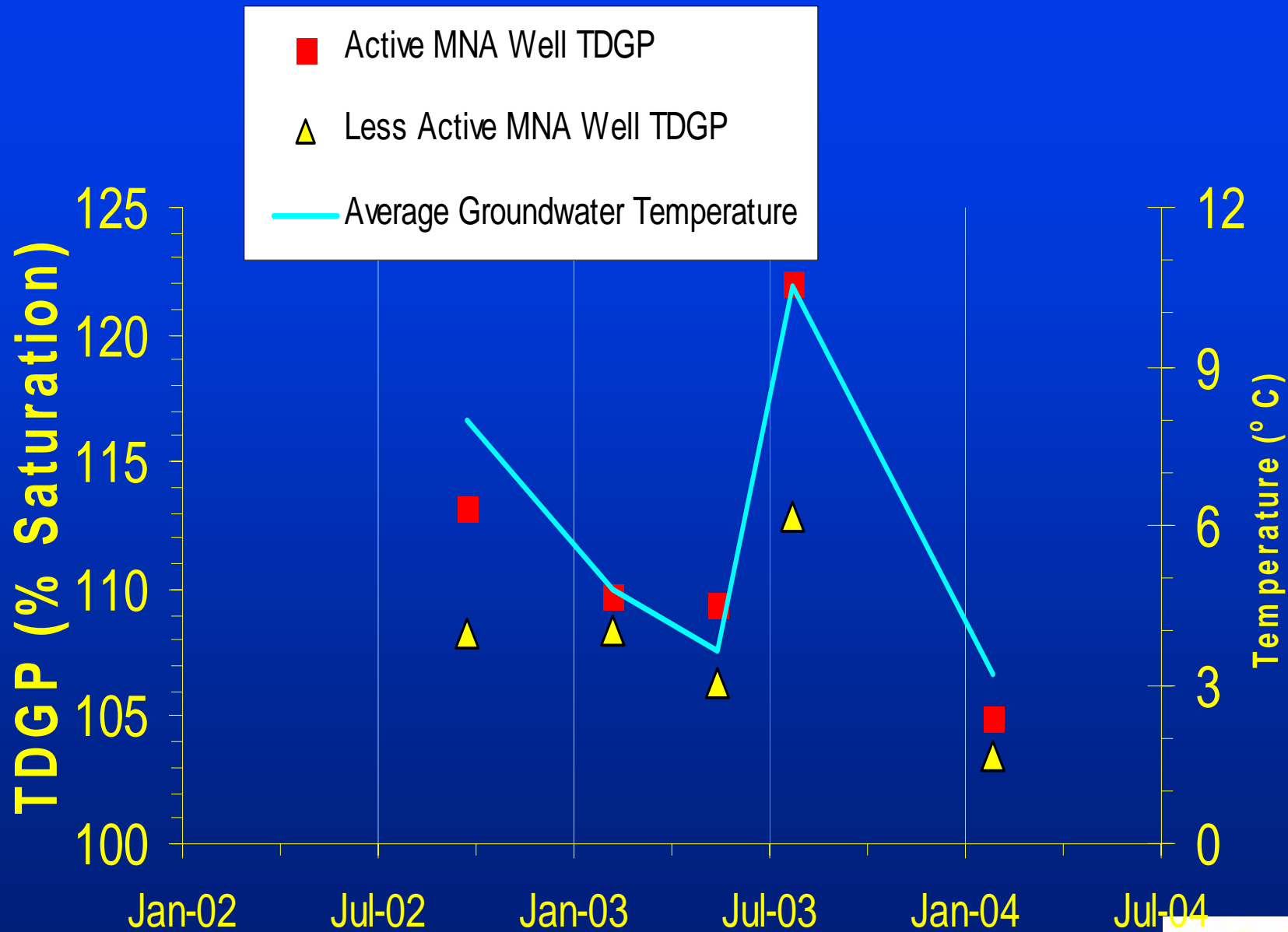
- **NWRI: Enhanced biodegradation through sulfate injection (Dale Van Stempvoort presenting)**
- **U of C: dissolved gas testing**
- **U of S: microbiological activity testing**

Dissolved Gas

- **U of C: Kim McLeish, Ph.D. student**
 - *Field sampler developed*
 - *Analytical method developed*
 - *Applied at CORONA test sites*

Comparison of Dissolved Gas Concentrations at Monitored Natural Attenuation Sites in Alberta (February 2003)





Implications

- **Site characterization is key for MNA**
- **Sampling:**
 - ◆ *no need to purge*
 - ◆ *dialysis method shows promise (accuracy)*
 - ◆ *dissolved gas shows seasonal influence*
- **Microcosms and metabolites:**
 - ◆ *hard to do*

Partnerships

- Continue working with NWRI, U of C
- UBC: geochemical modelling for long-term assessment
- UFZ: diffusion-based toxicity/chemical testing

Funding Summary

■ Industry \$524K

- ◆ *ConocoPhillips, Devon Canada*
- ◆ *Canadian Association of Petroleum Producers*
- ◆ *Komex International, Maxxam Analytics*

■ Government \$629K

- ◆ *Environment Canada – PERD*
- ◆ *NSERC*
- ◆ *Coordination of University Research for Synergy and Effectiveness (COURSE) – Gov't of Alberta*

Budget Summary

- **Spent \$500K (capital cost, analyses, stipends):**
 - ◆ *Detailed site drilling*
 - ◆ *Initial site sampling*
 - ◆ *Started lab and microcosm studies*
- **Remaining \$600K (analyses and stipends):**
 - ◆ *Ongoing site sampling*
 - ◆ *Laboratory work*
 - ◆ *Modelling*