Golder Associates Inc.
1951 Old Cuthbert Road, Suite 301
Cherry Hill, New Jersey 08034
Tel: 856 616 8166
www.golder.com

In-Situ Treatments using Nano-Scale Zero-Valent Iron Implemented in North America and Europe

Florin Gheorghiu, Mace Christian, Ramesh Venkatakrishnan, (Golder Associates Inc.),

Wei-xian Zhang (Lehigh University)

October 20, 2005 Washington DC

Golder Associates

Presentation Outline

- Overview of ZVI technology
- NZVI treatment implementation steps
- Results
- Conclusions

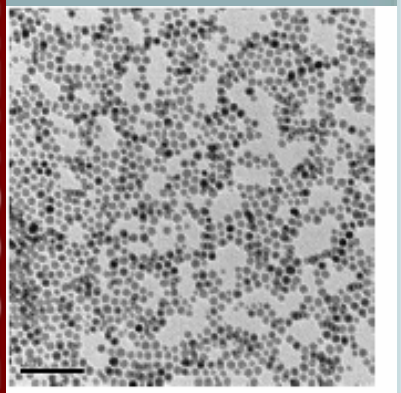
Golder Associates

Iron Filings

- Cost Considerations
- Specific surface ~500 m^2/kg
- Typical quantities needed - Several metric tones

Golder Associates

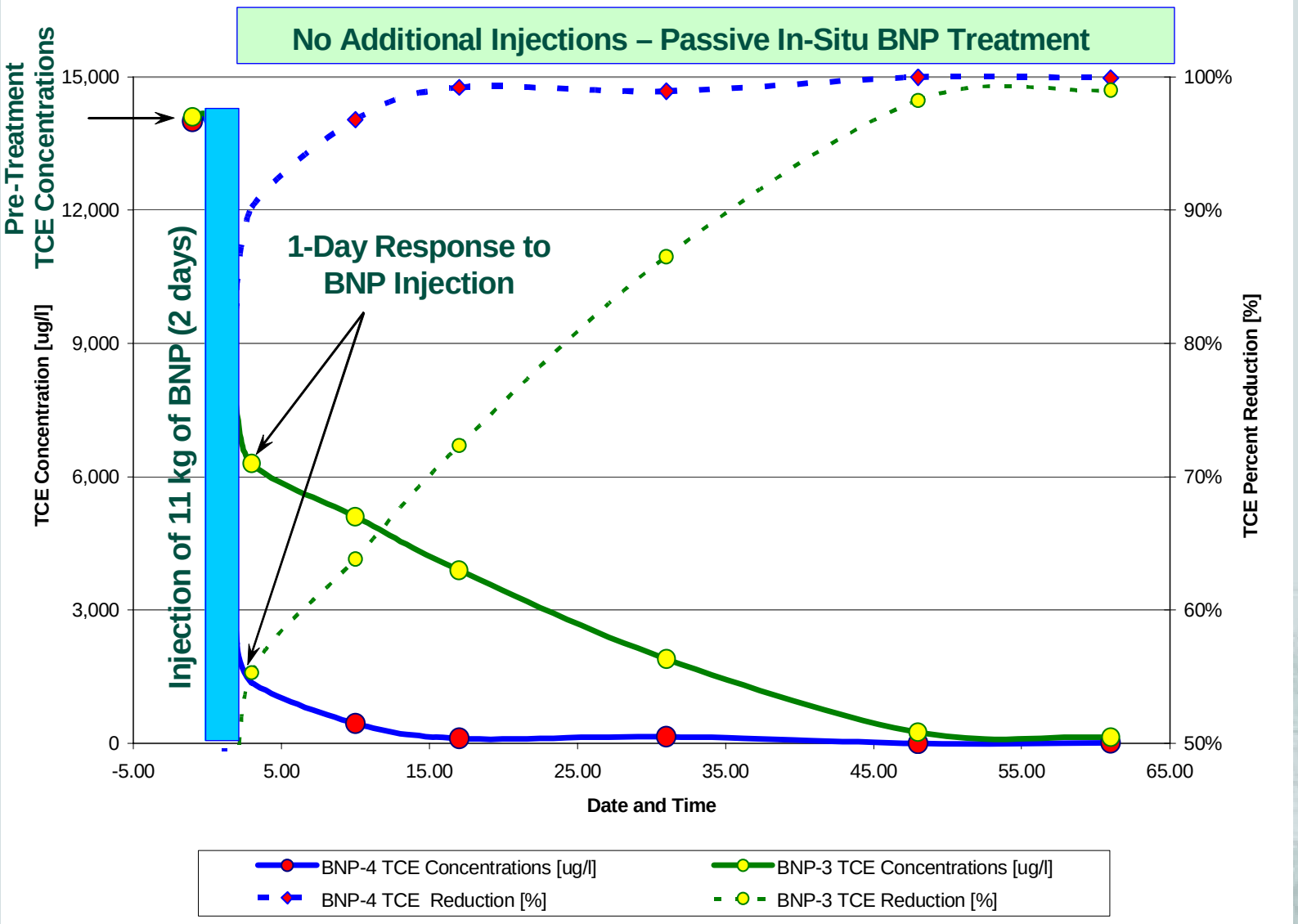
Nanoscale Zero-Valent Iron Particles



- Lehigh University
- Iron particles with palladium coatings (BNP)
- Nanoscale zero-valent Iron (NZVI)
- Specific surface for 50-60 nm ~ 25,000 m^2/kg
- Specific surface for 2-5 nm ~ 142,000 m^2/kg
- Treatment of:
  - Chlorinated solvents
  - Cr^{6+}, etc.

Golder Associates

TCE Reduction, BNP-4 and BNP-3



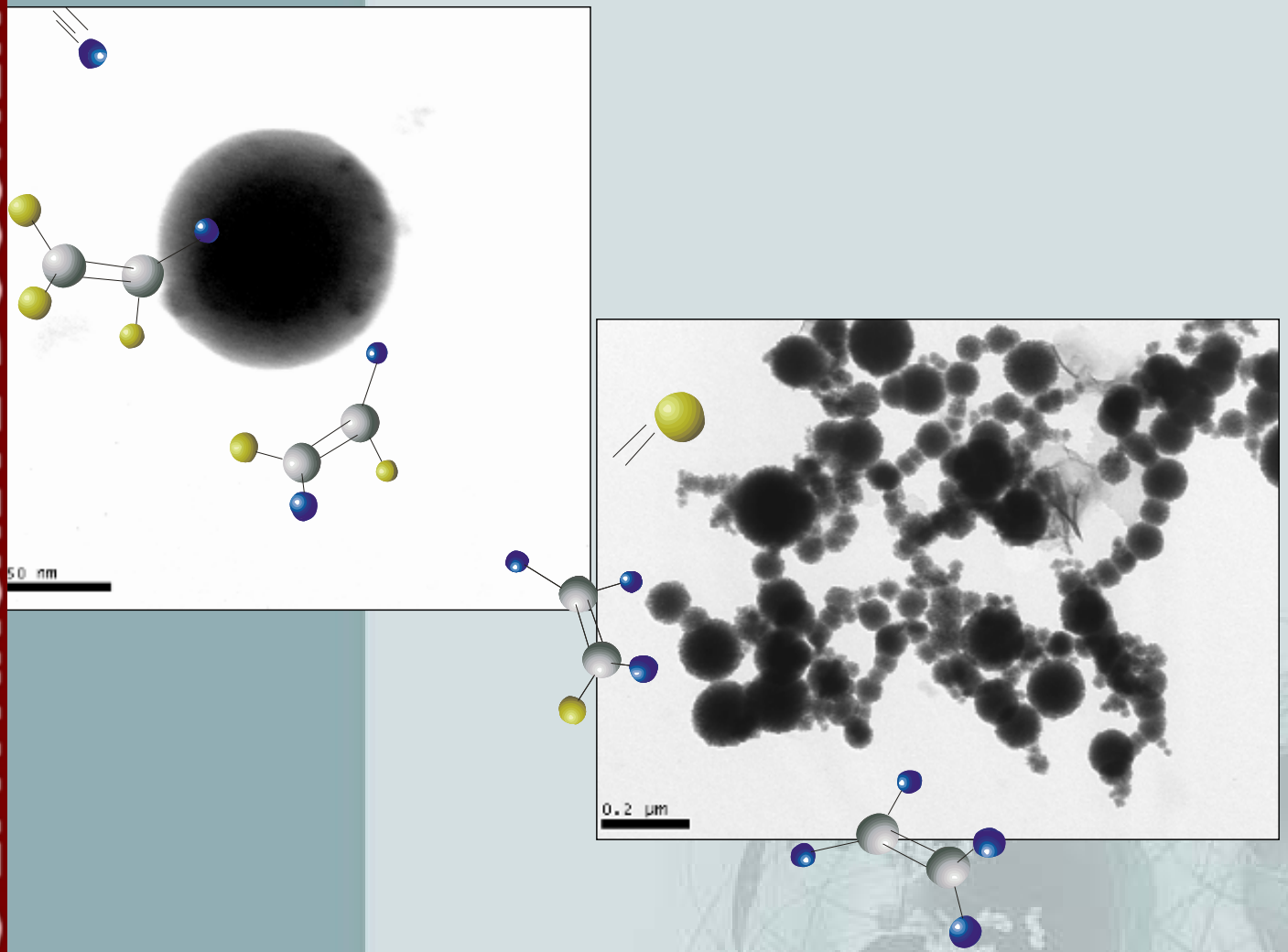
Golder Associates

Nanoscale Zero-Valent Iron Particles

- NZVI water slurry (no additives)
- Subsurface placement by gravity feed
- No special well construction needed
- Fast reaction time – real time monitoring and reactant dosage
- Minimum design requirements / permit level design
- Does not eliminate anaerobic bacteria activity
- Flexible remedial system that can be modified with time

Golder Associates

Nanoscale Particles



Golder Associates

NZVI Injection Equipment

Golder Associates

NZVI Injection Equipment

Golder Associates

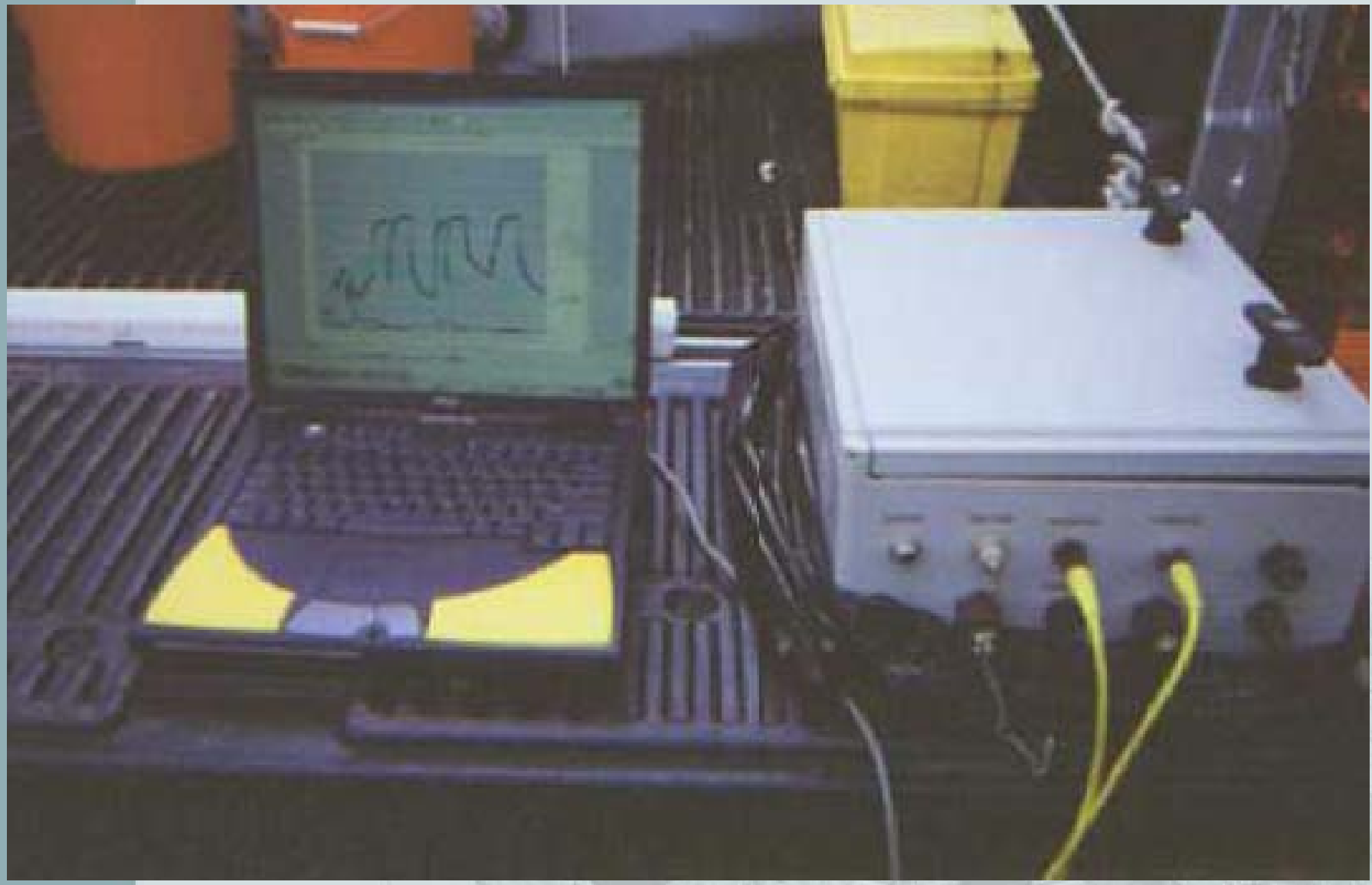
NZVI Injection Equipment

Golder Associates

NZVI Injection Equipment

Golder Associates

Field Monitoring Equipment



Golder Associates

Field Monitoring Equipment

Parametric sensors

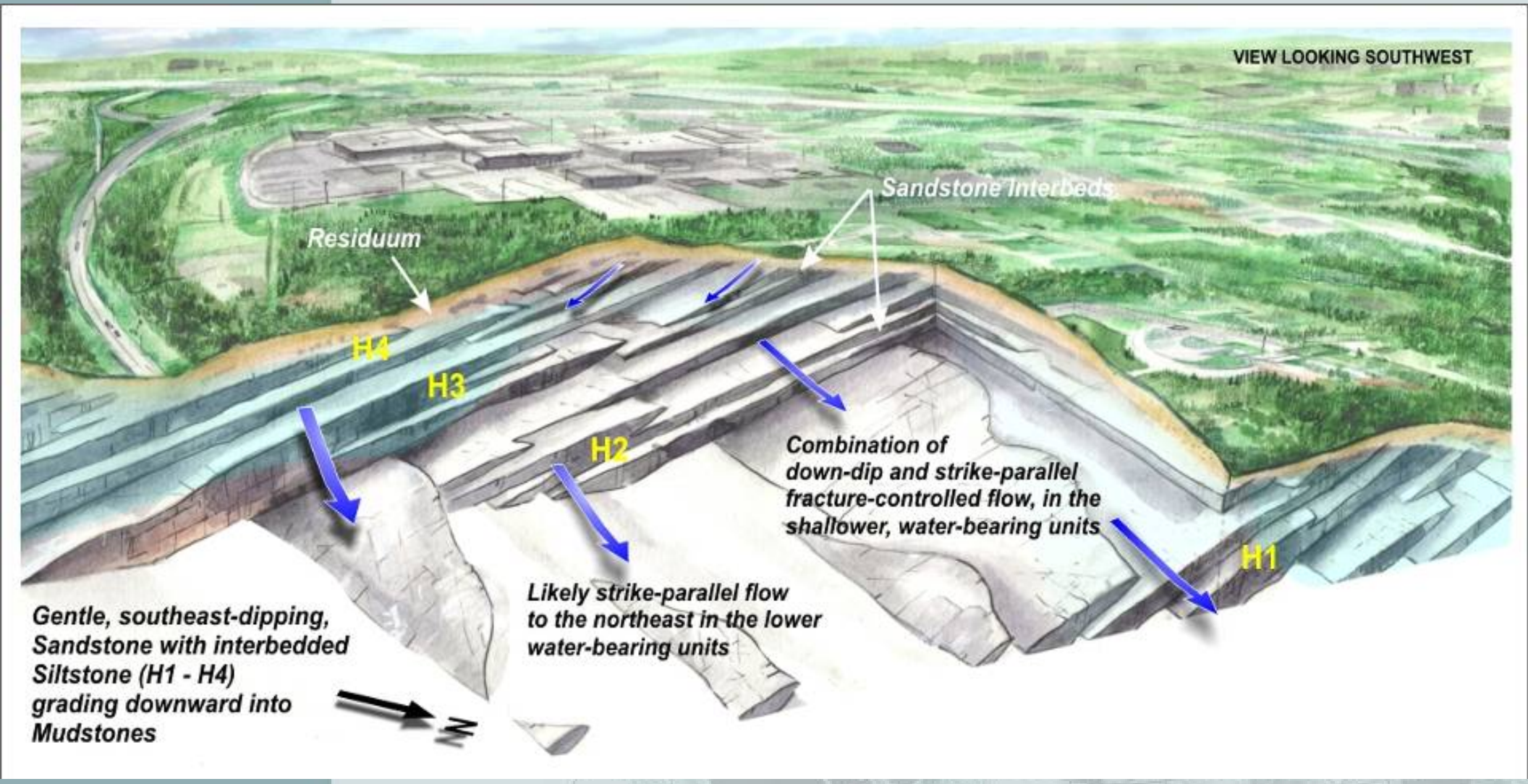
Data logger

Trench for cables

Injection System

Golder Associates

Conceptual Geologic and Hydrogeologic Model



Golder Associates

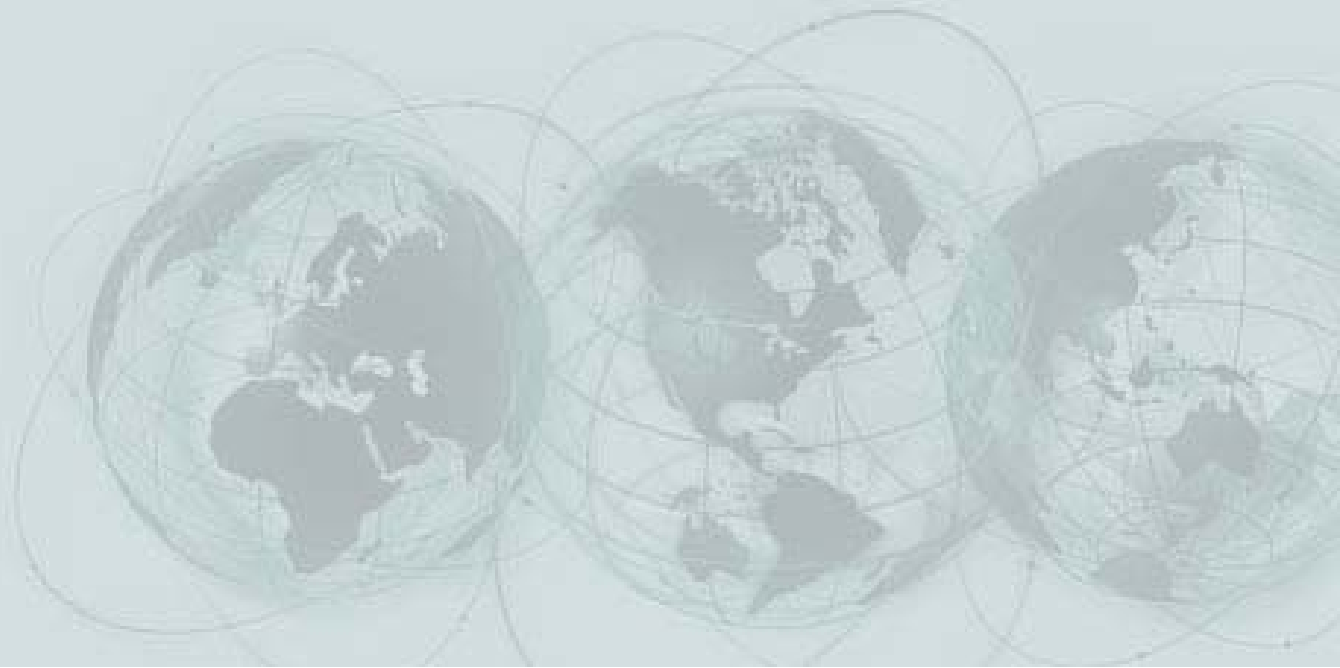
Project Team

- USA
  - Florin Gheorghiu
  - Christian Mace
  - Dr. Ramesh Venkatakrishnan
  - Allen Kane
  - Steve Finn
  - Randy White
  - Dr. Todd Rees
  - Bob Glazier
  - Bob Stetkar
  - Dr. Bill Diesing
  - Peter Swinick
  - Dr. Wei-xian Zhang (Lehigh University)
- Australia
  - Dave Thomas
- Canada
  - Steve Desrocher
  - Tom Grimminck
- Europe
  - Michael Pupeza
  - Dr. Graham Norris
  - Dr: Miroslav Cernik (Aquatest Czech Republic)

Golder Associates

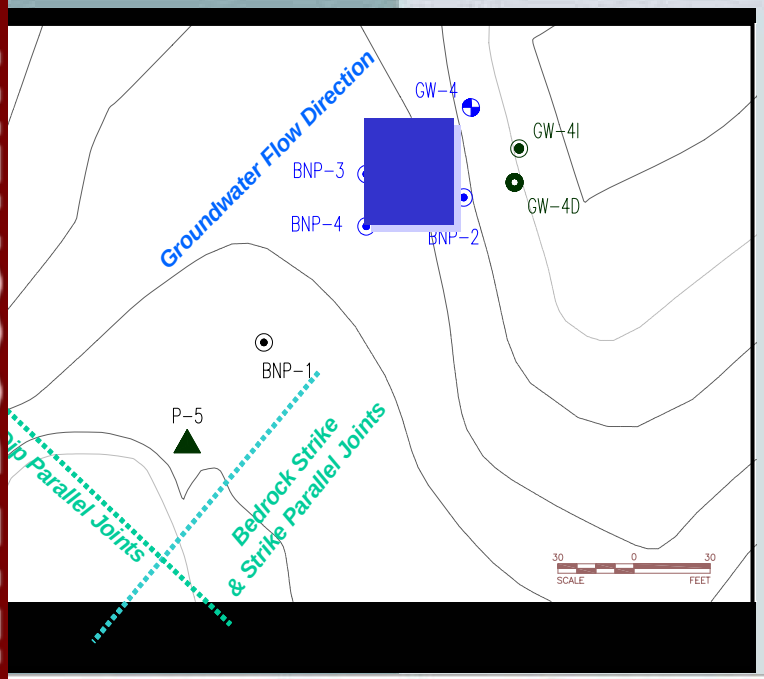
Clients

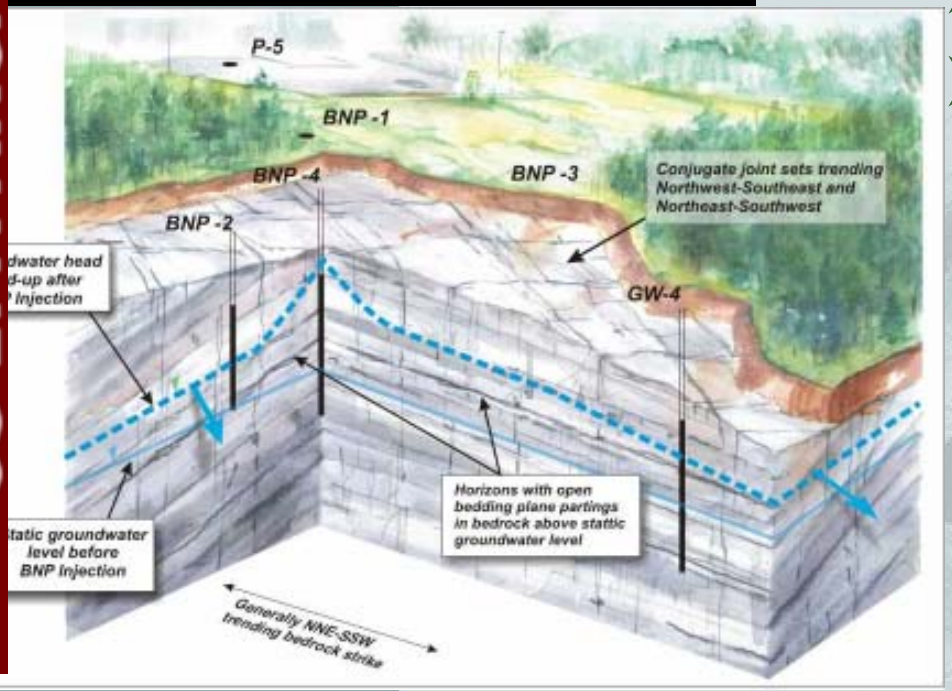
- Dr. Rainer Domalski
  - Ruetgers Organics Corporation (Salem, Ohio Site)
- Other Confidential Clients……



Golder Associates

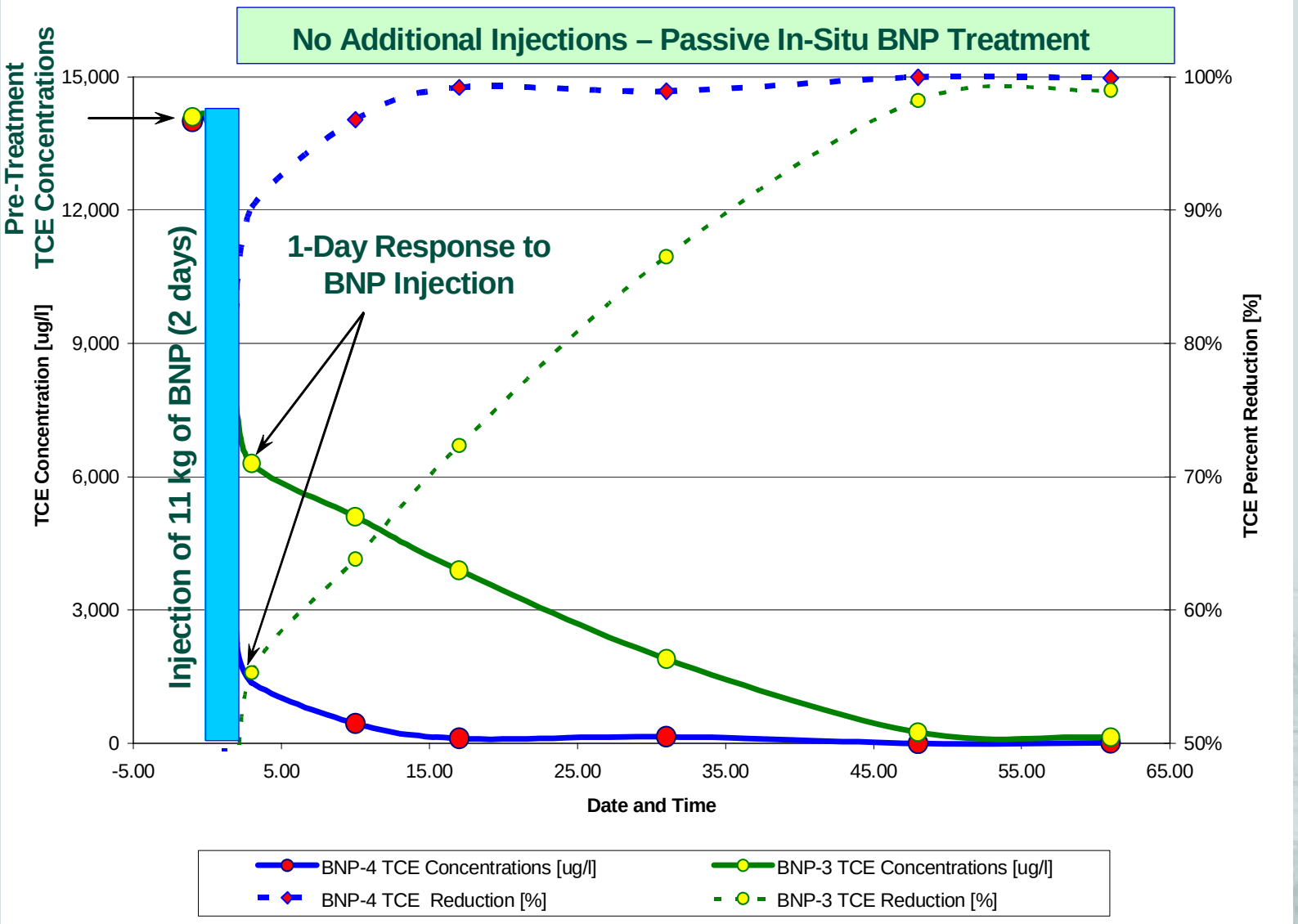
Test Design





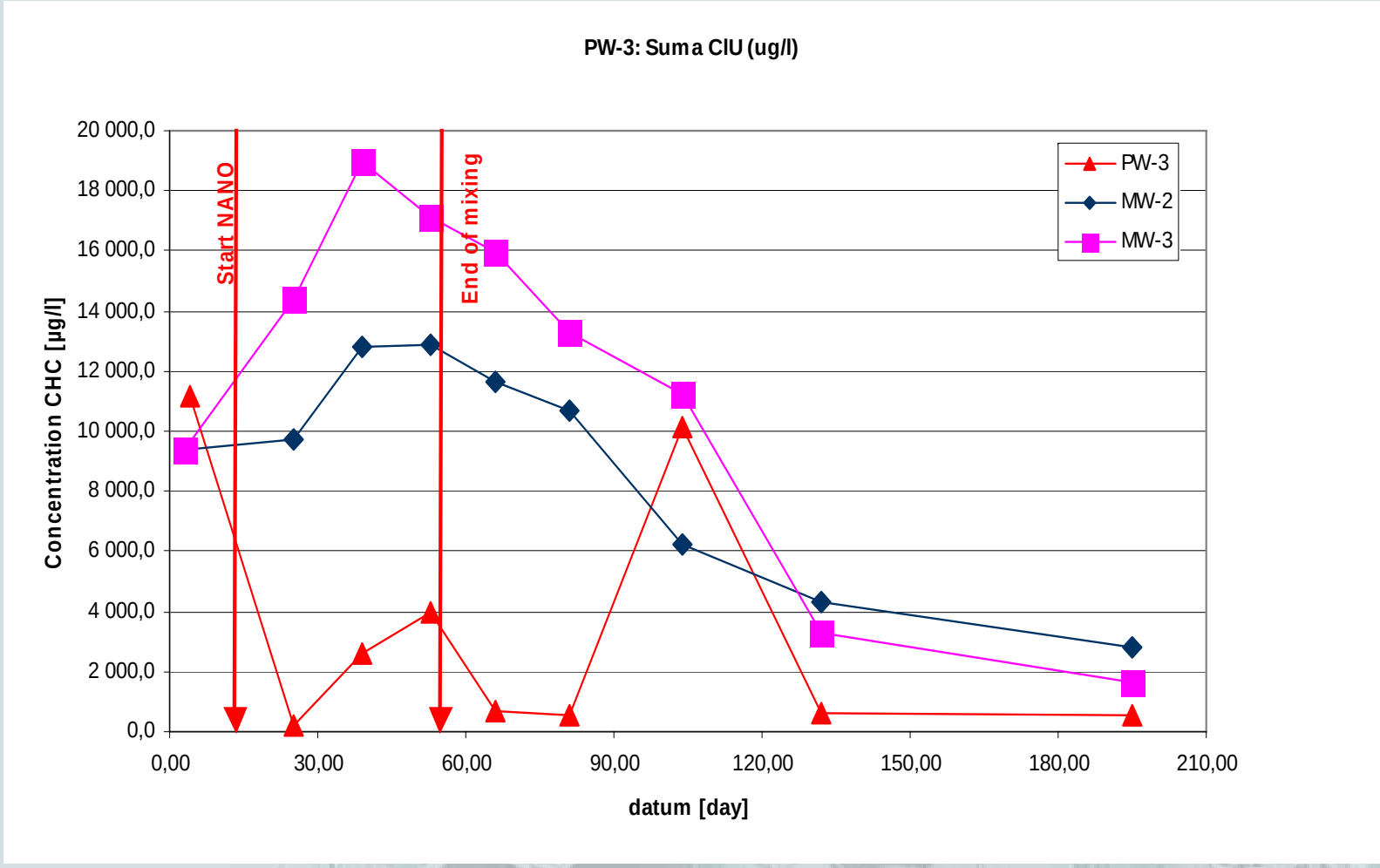
- Geology: fractured interbeds of sandstone / siltstone
- Total BNP slurry volume = 6,050 l
- BNP mass injected: 11.2 kg
- Injection Well BNP-4
- Monitoring Wells
  - BNP-3: 6.5 m north of BNP-4
  - BNP-2: 13 m northeast of BNP-4
  - GW-4: 21 m north-northeast of BNP-4

TCE Reduction, BNP-4 and BNP-3



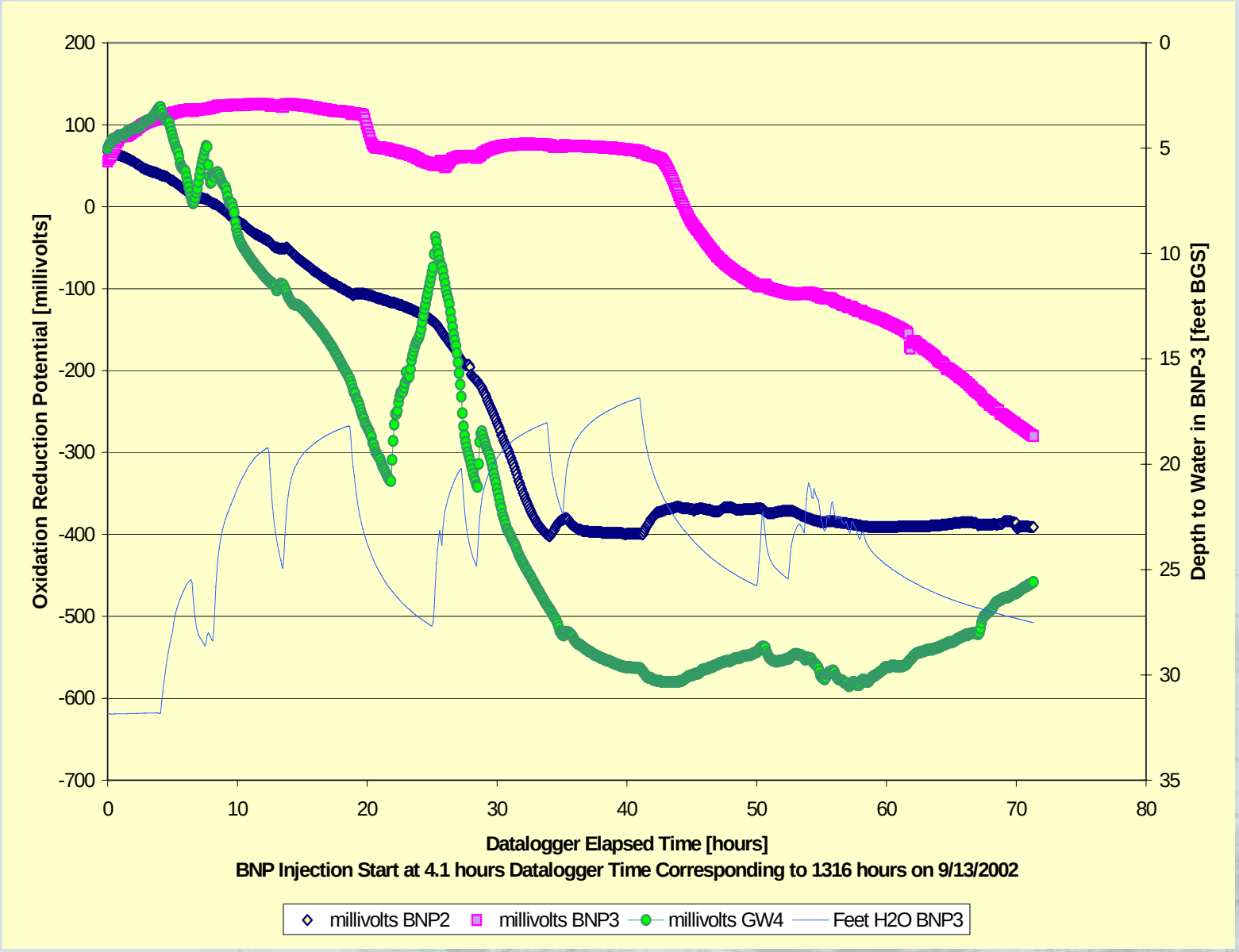
Golder Associates

Test Results Czech Republic



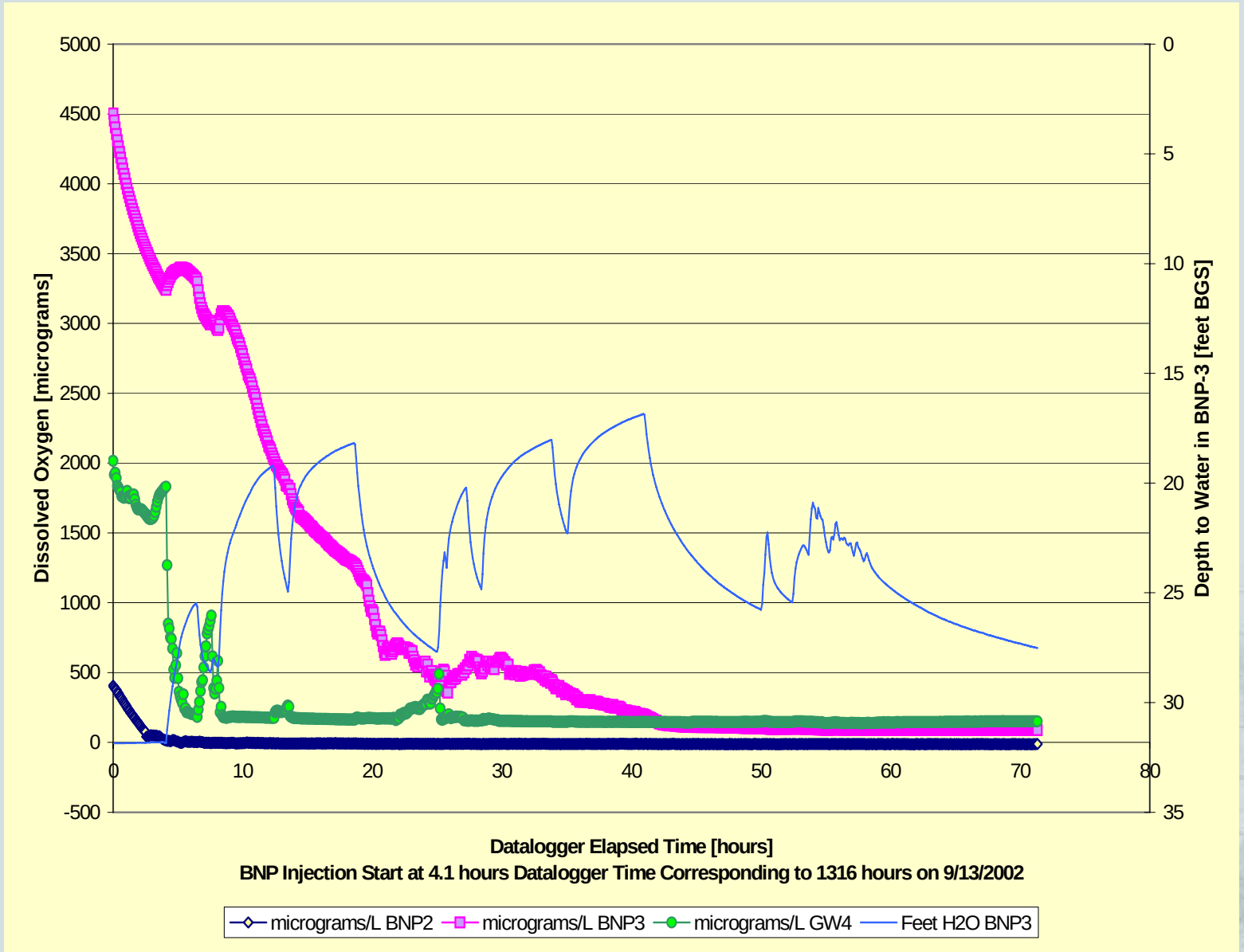
Golder Associates

ORP vs. Time



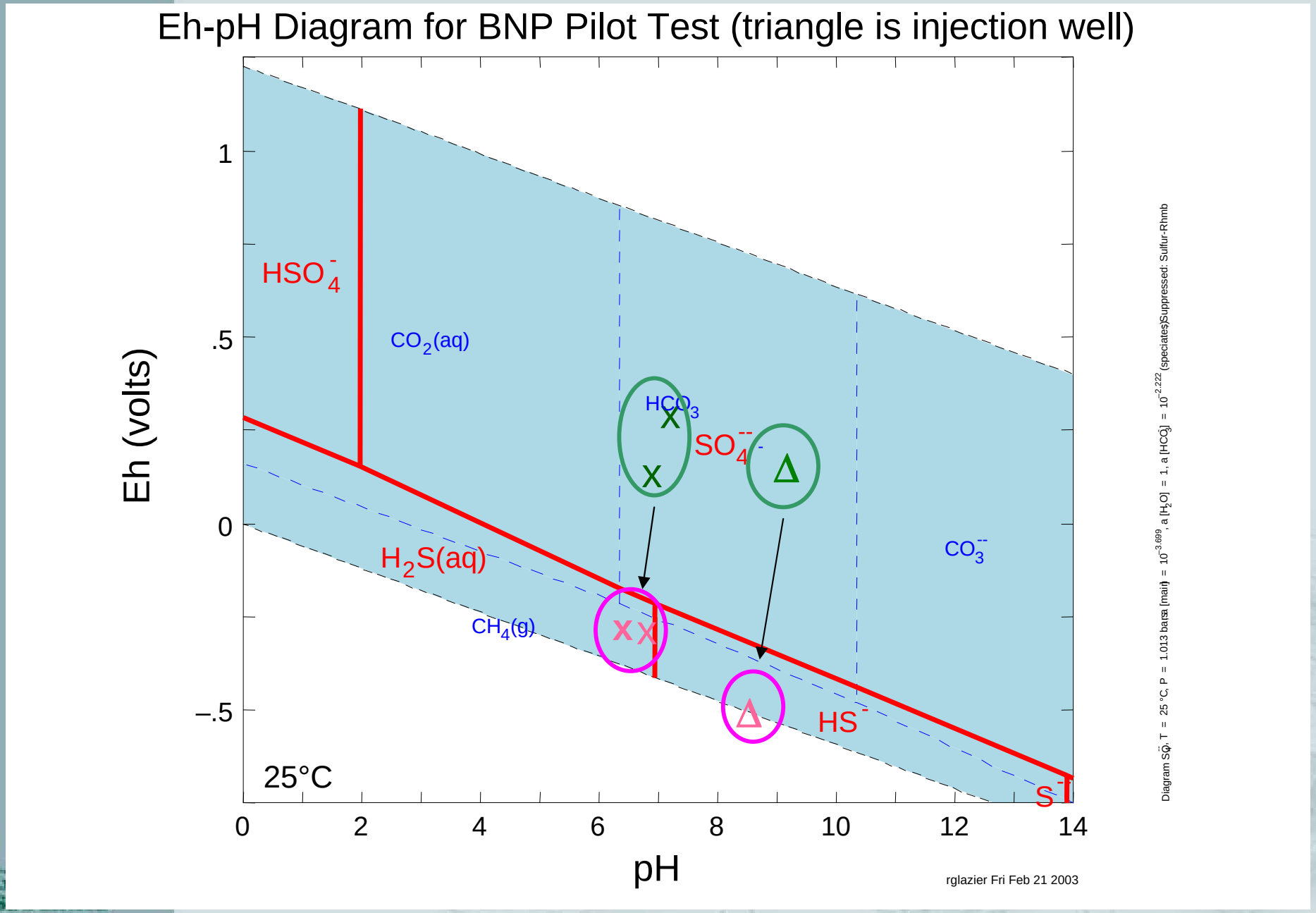
Golder Associates

DO vs. Time

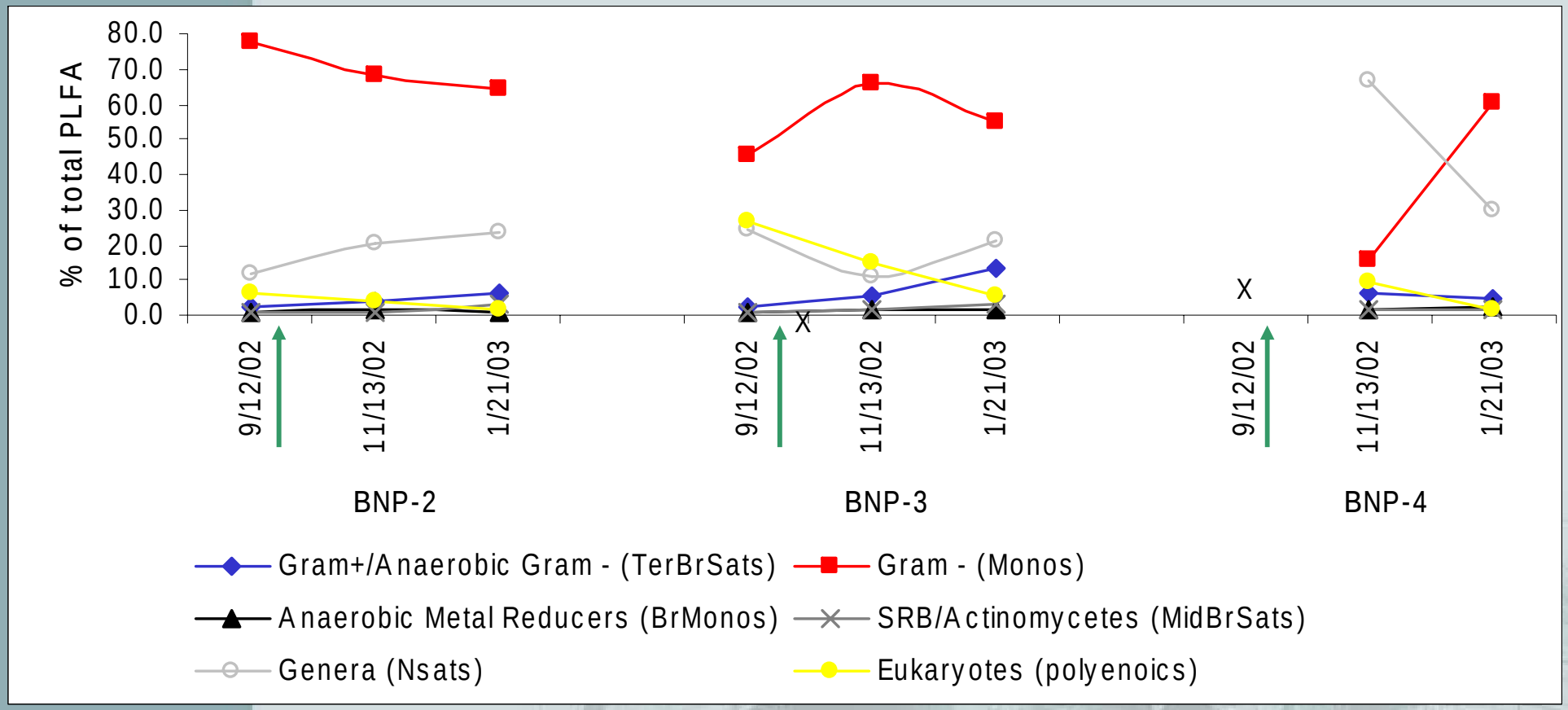


Golder Associates

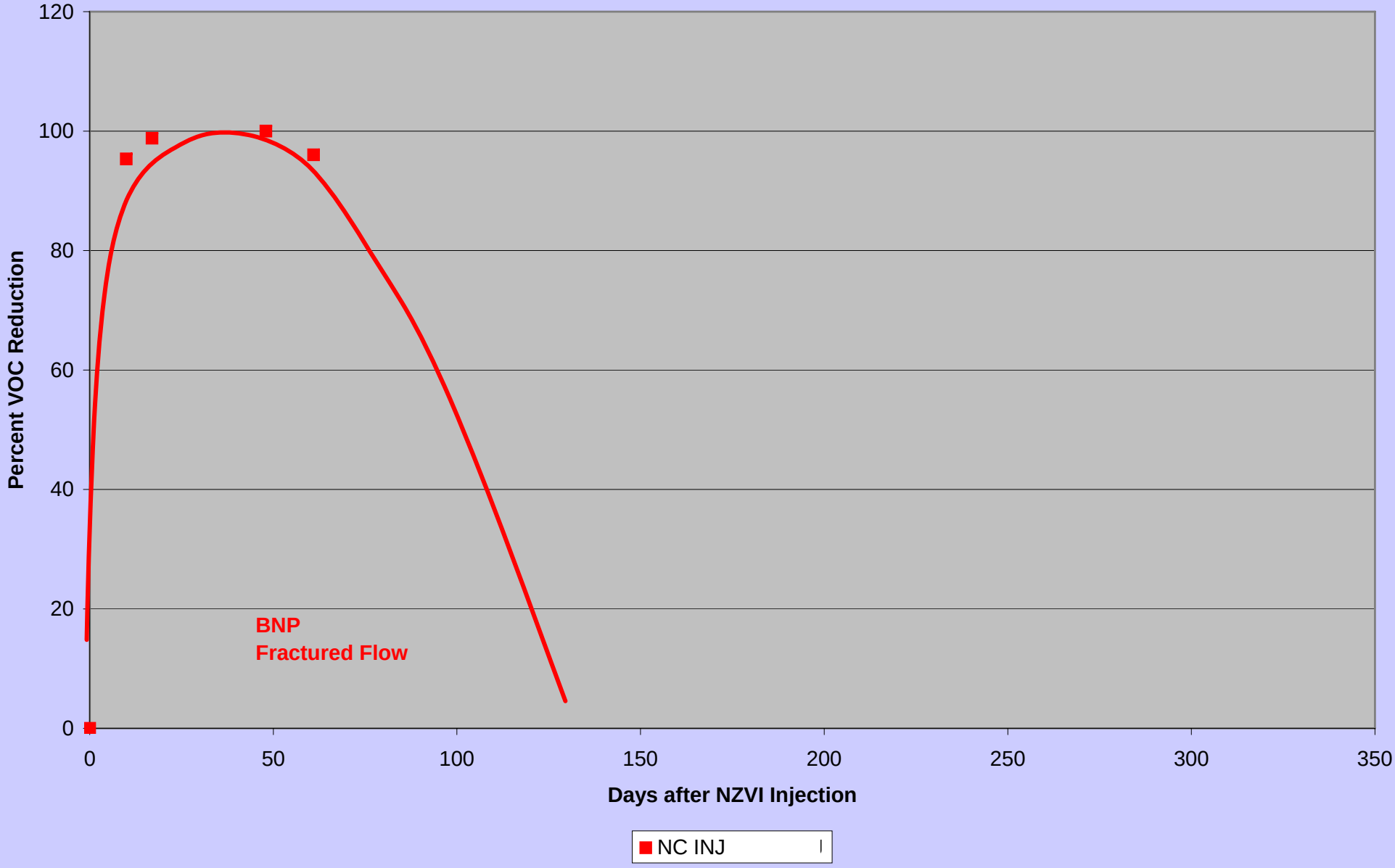
Pre- and Post-Injection Eh – pH Conditions



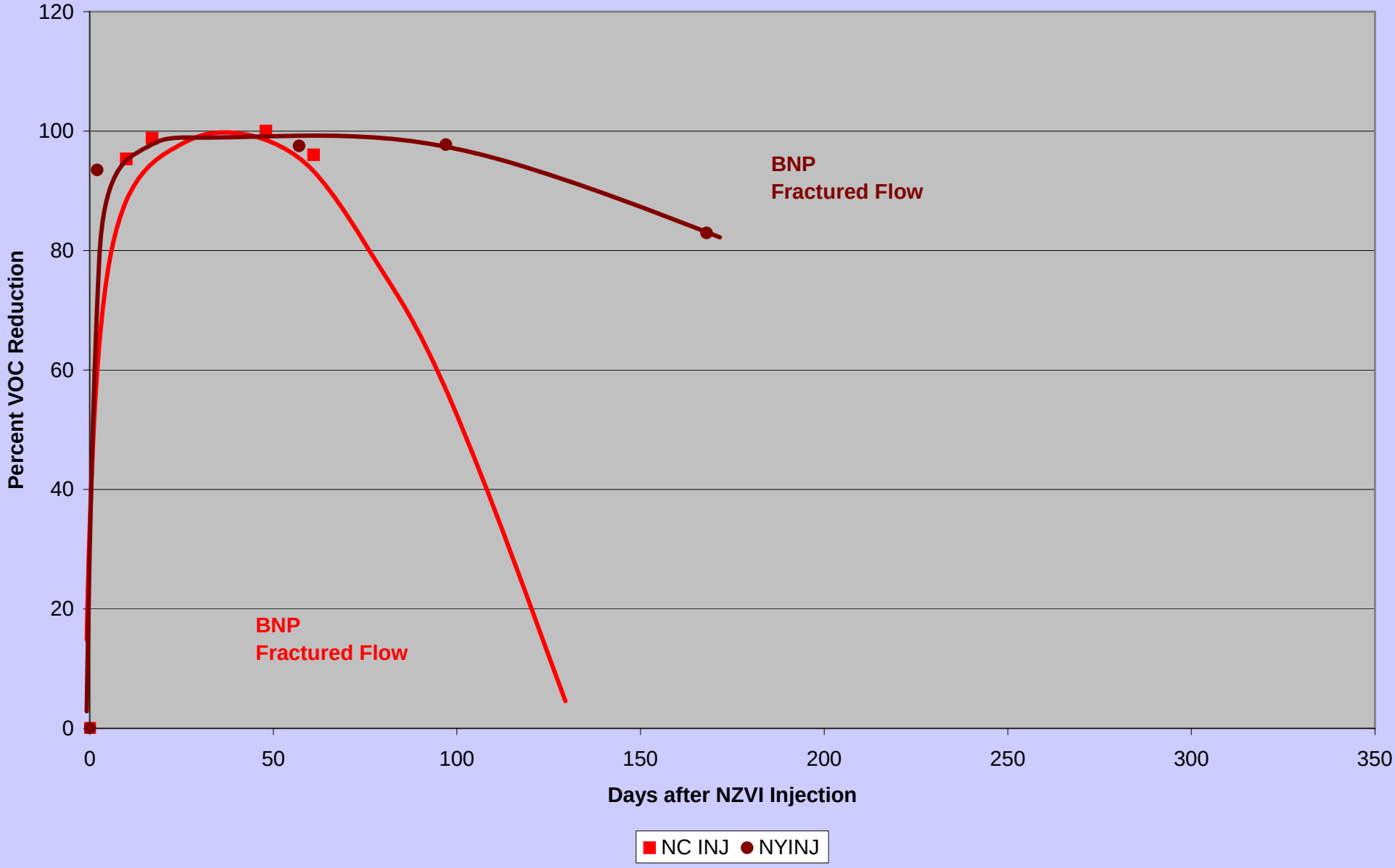
Microbial Community Structure



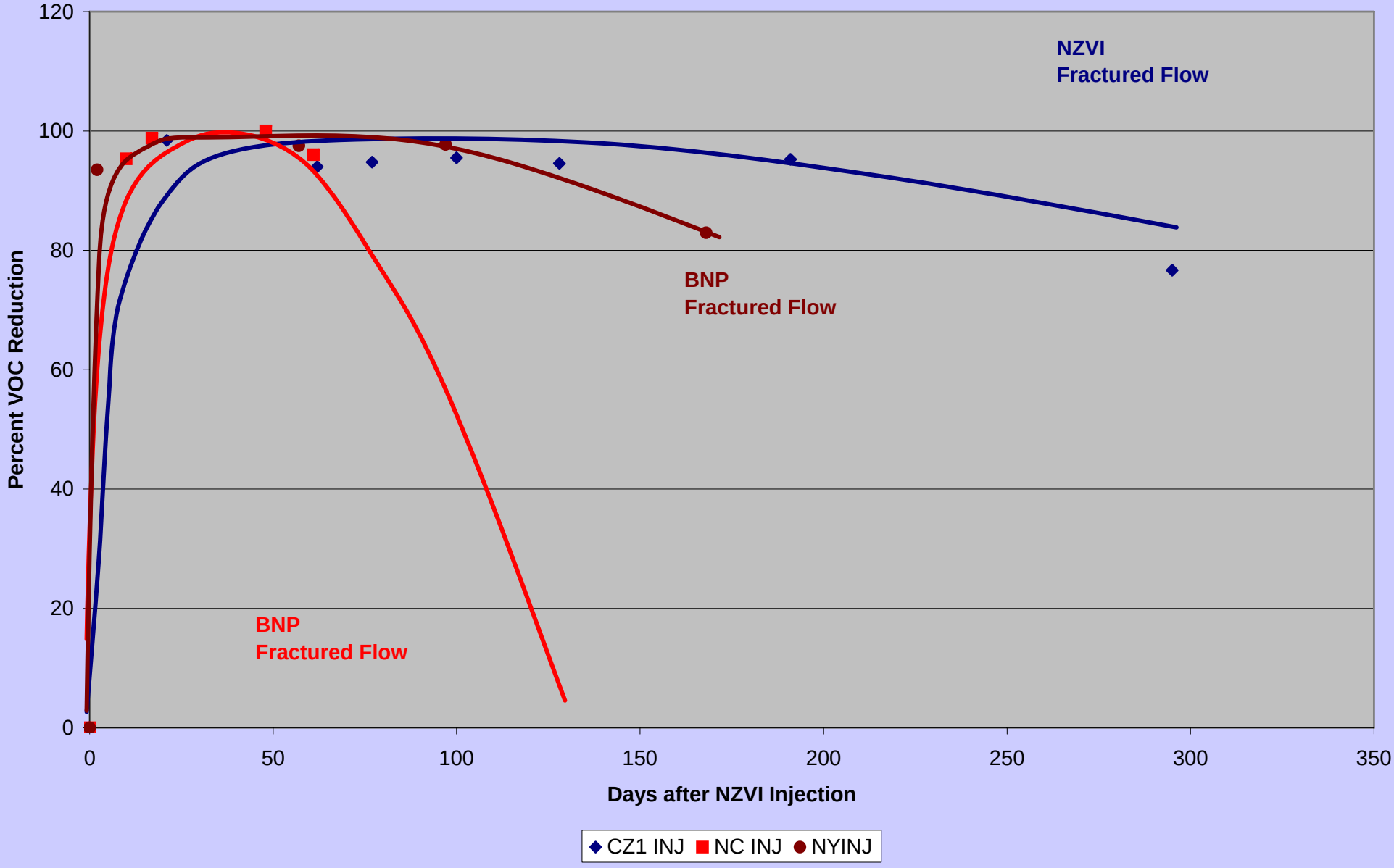
Golder Associates

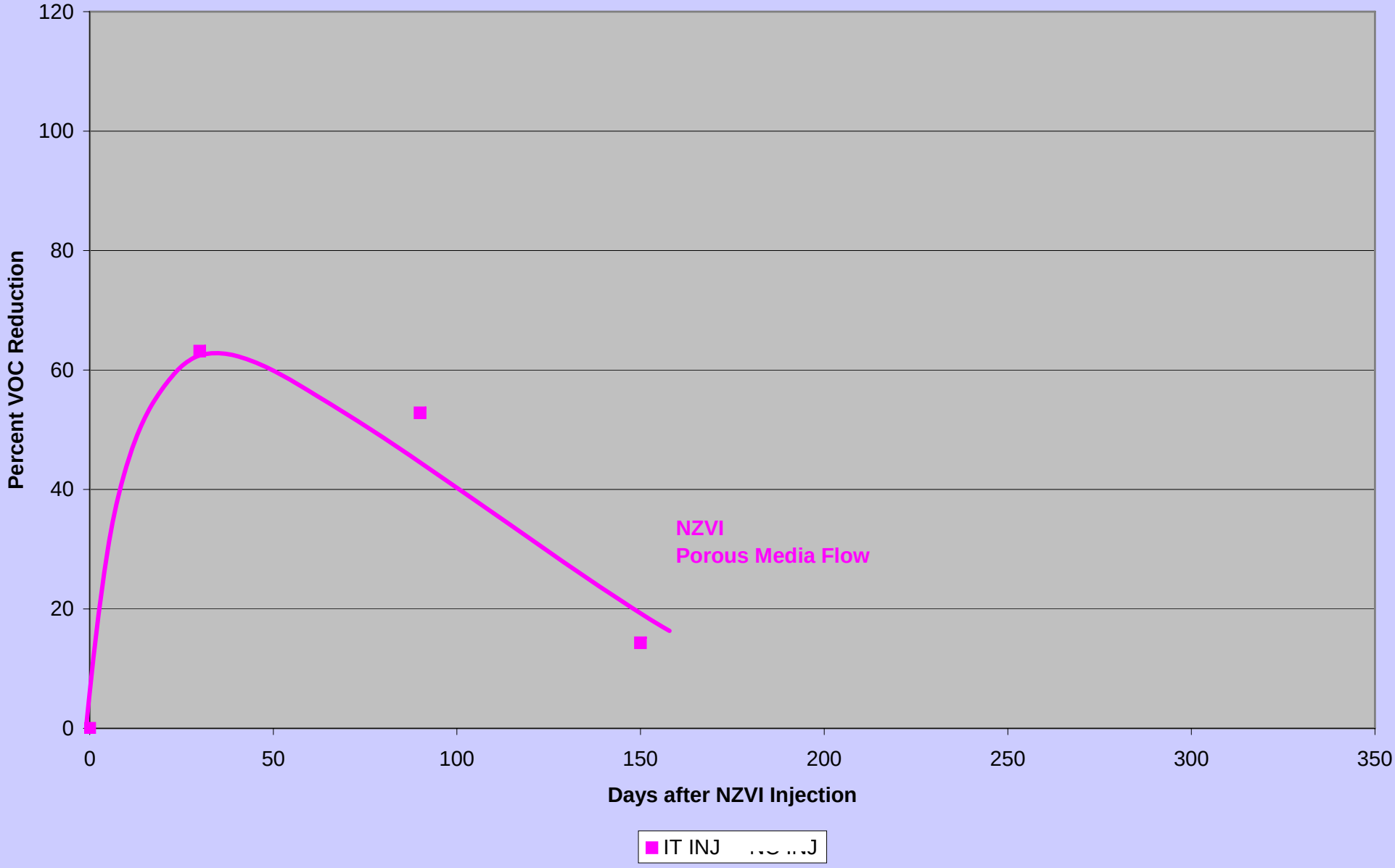


Golder Associates

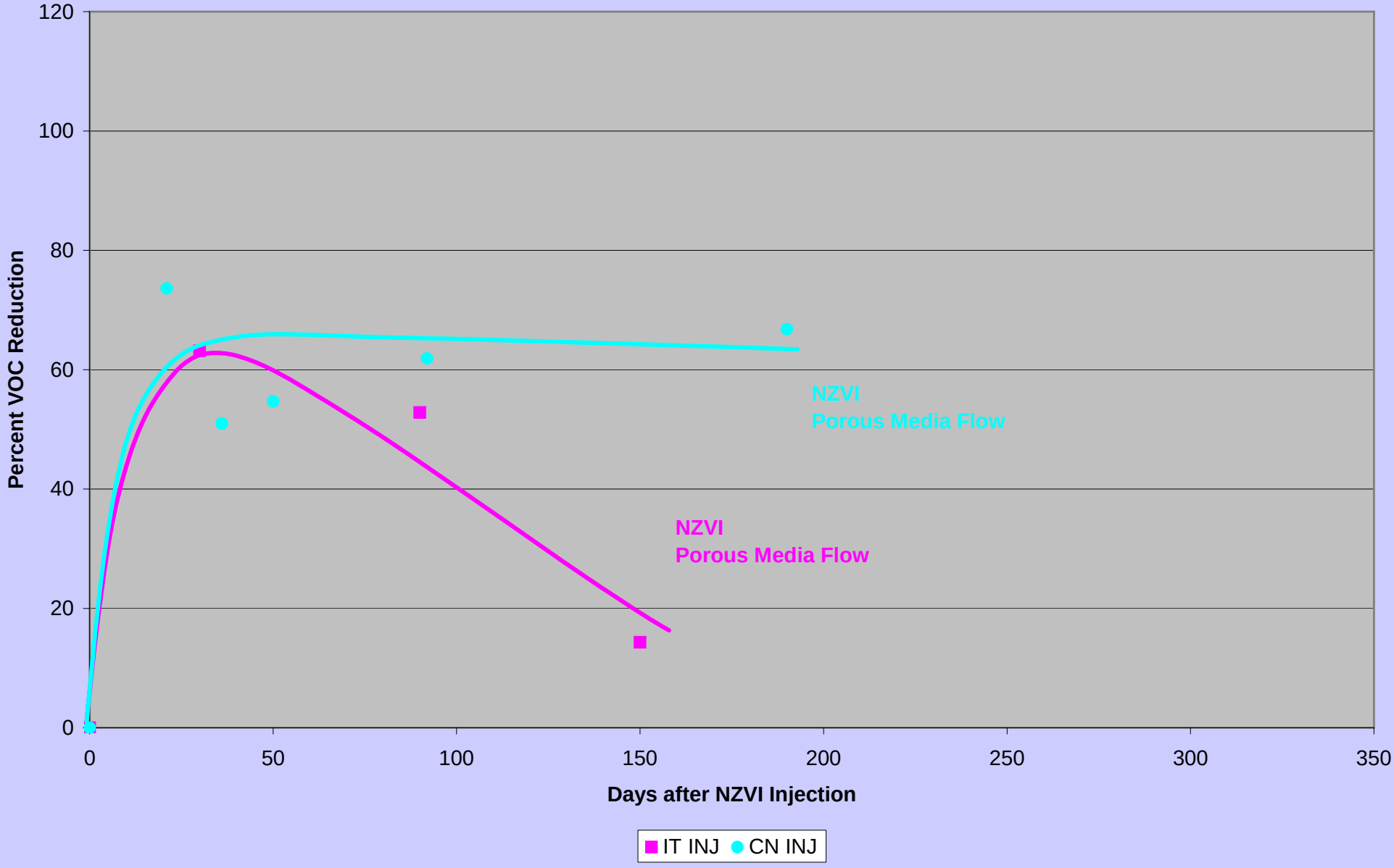


Golder Associates

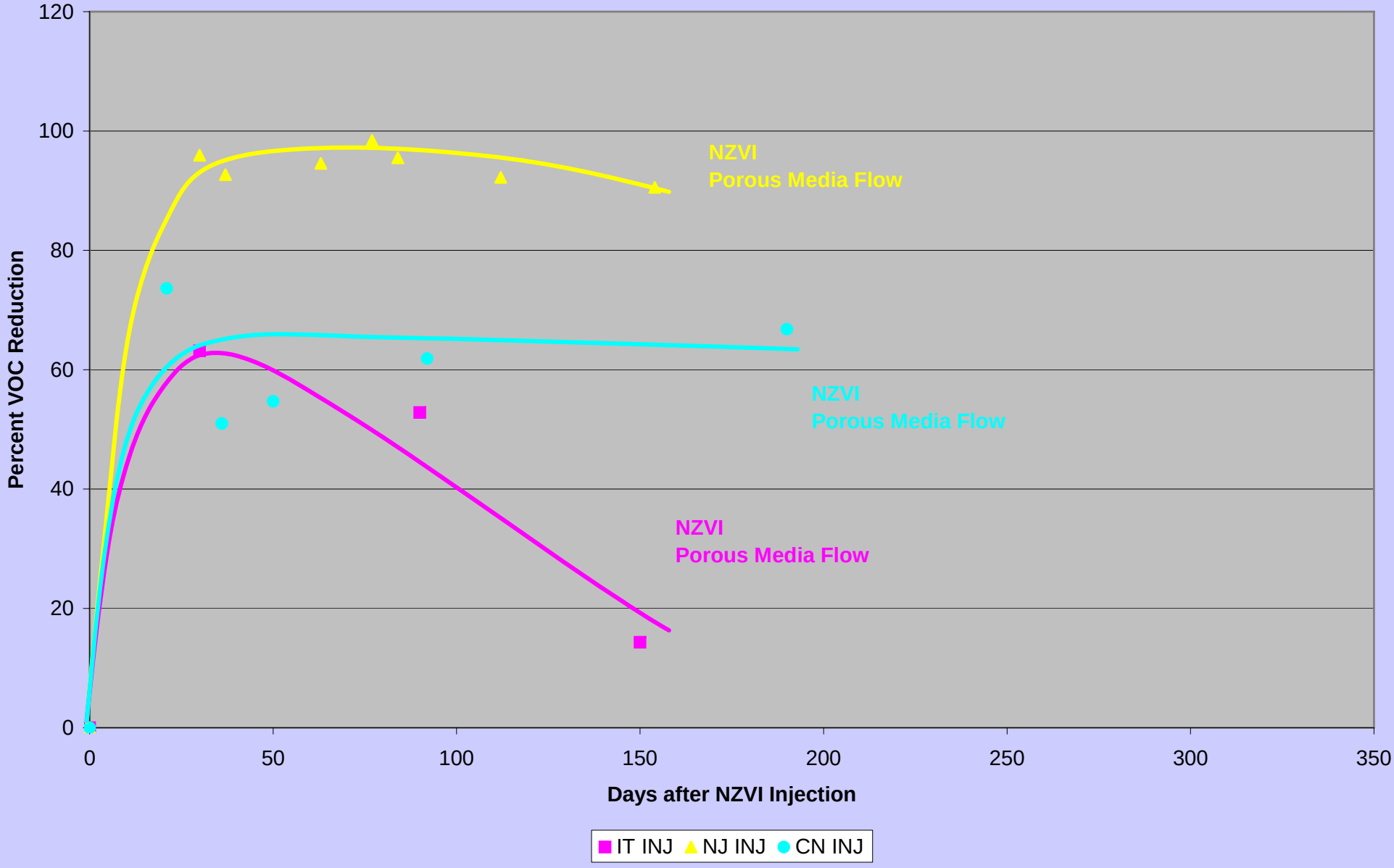




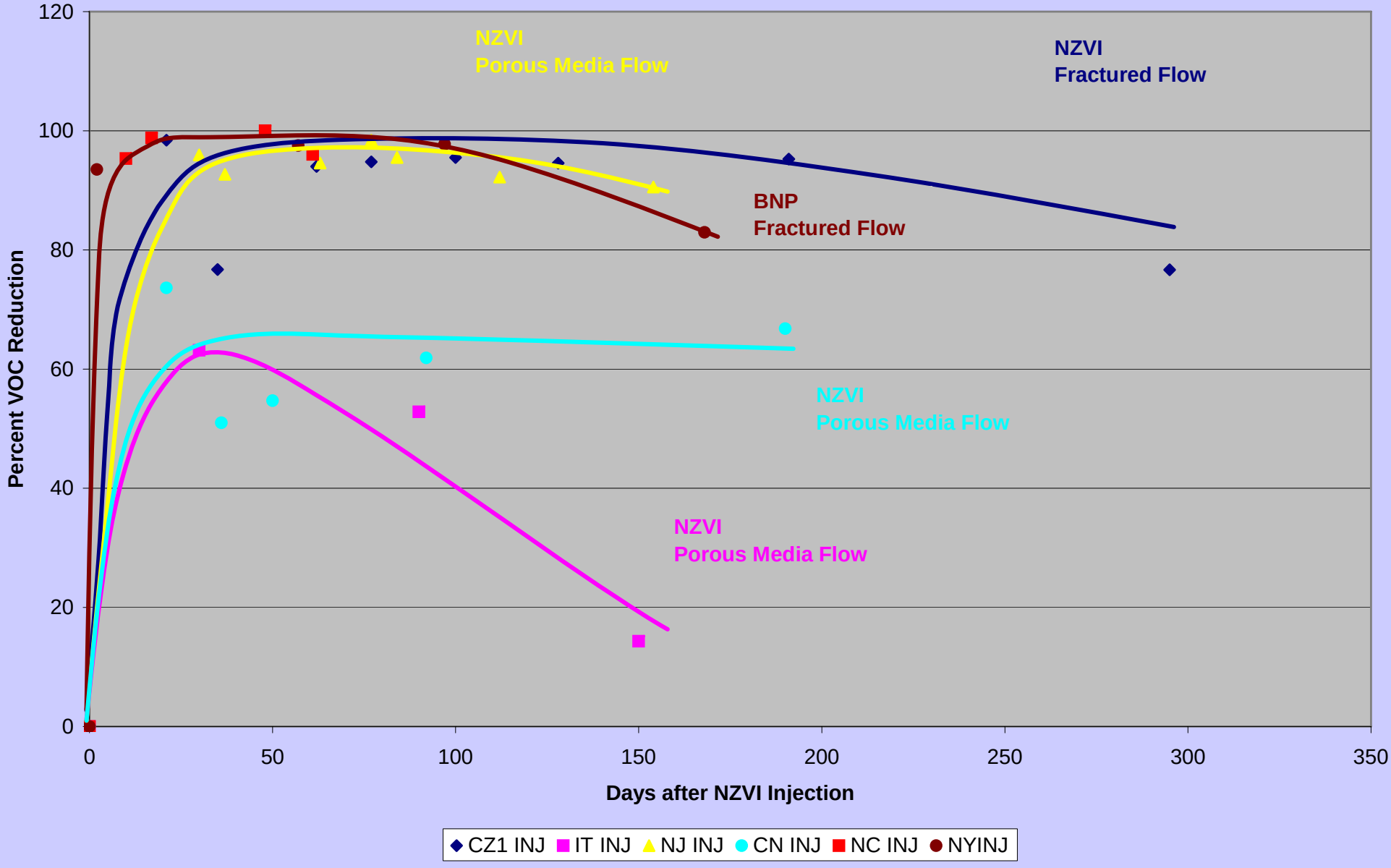
Golder Associates

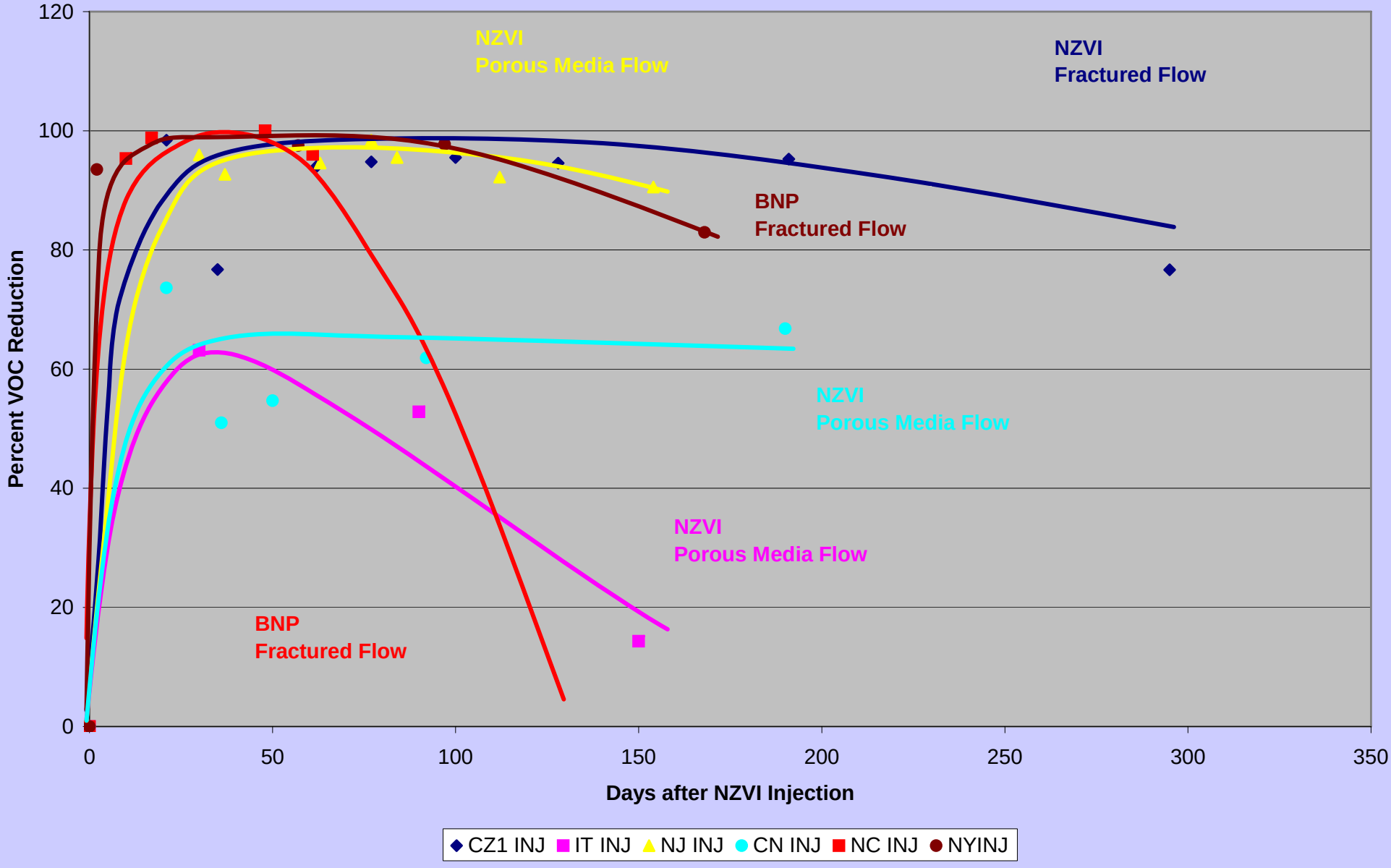


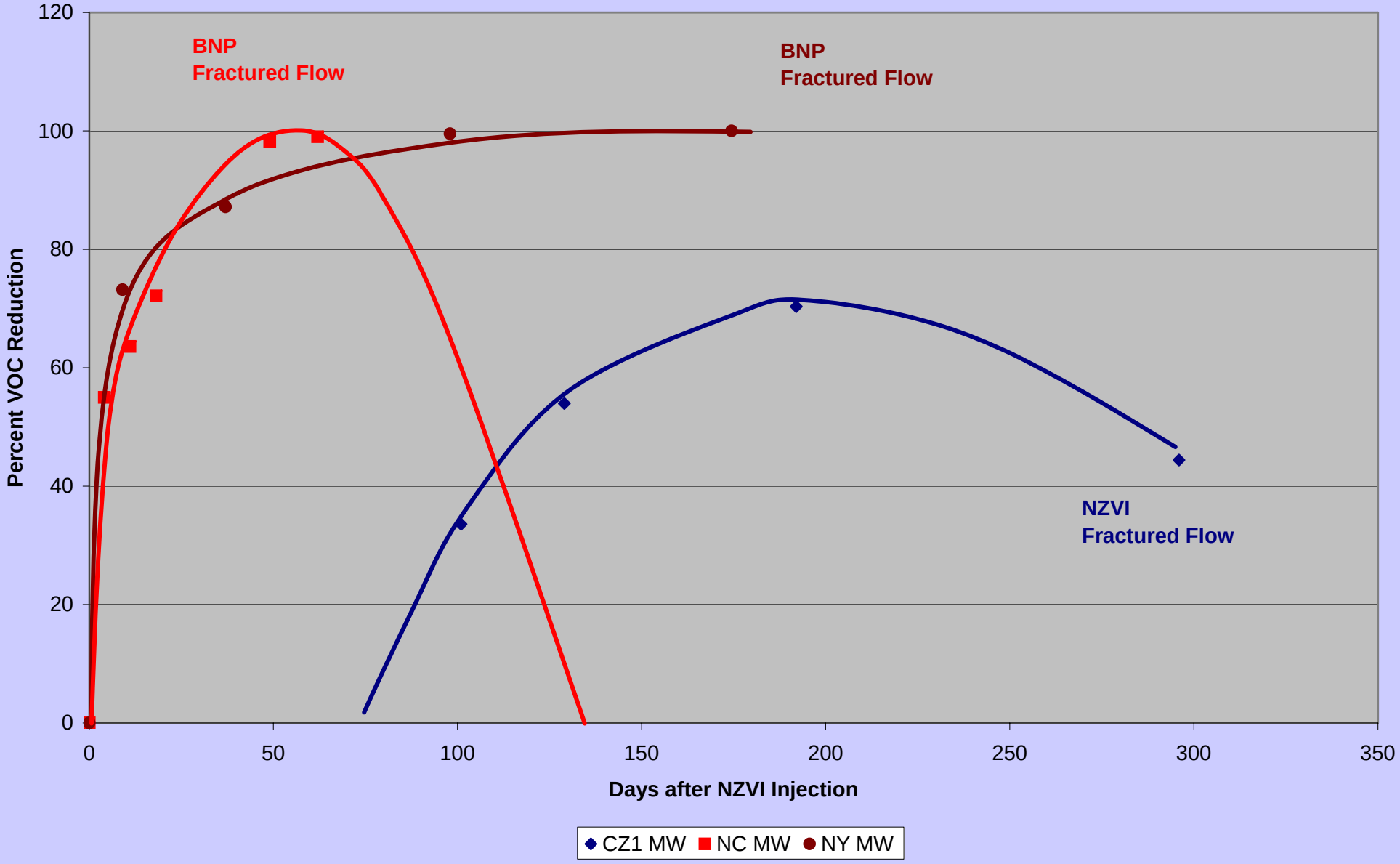
Golder Associates



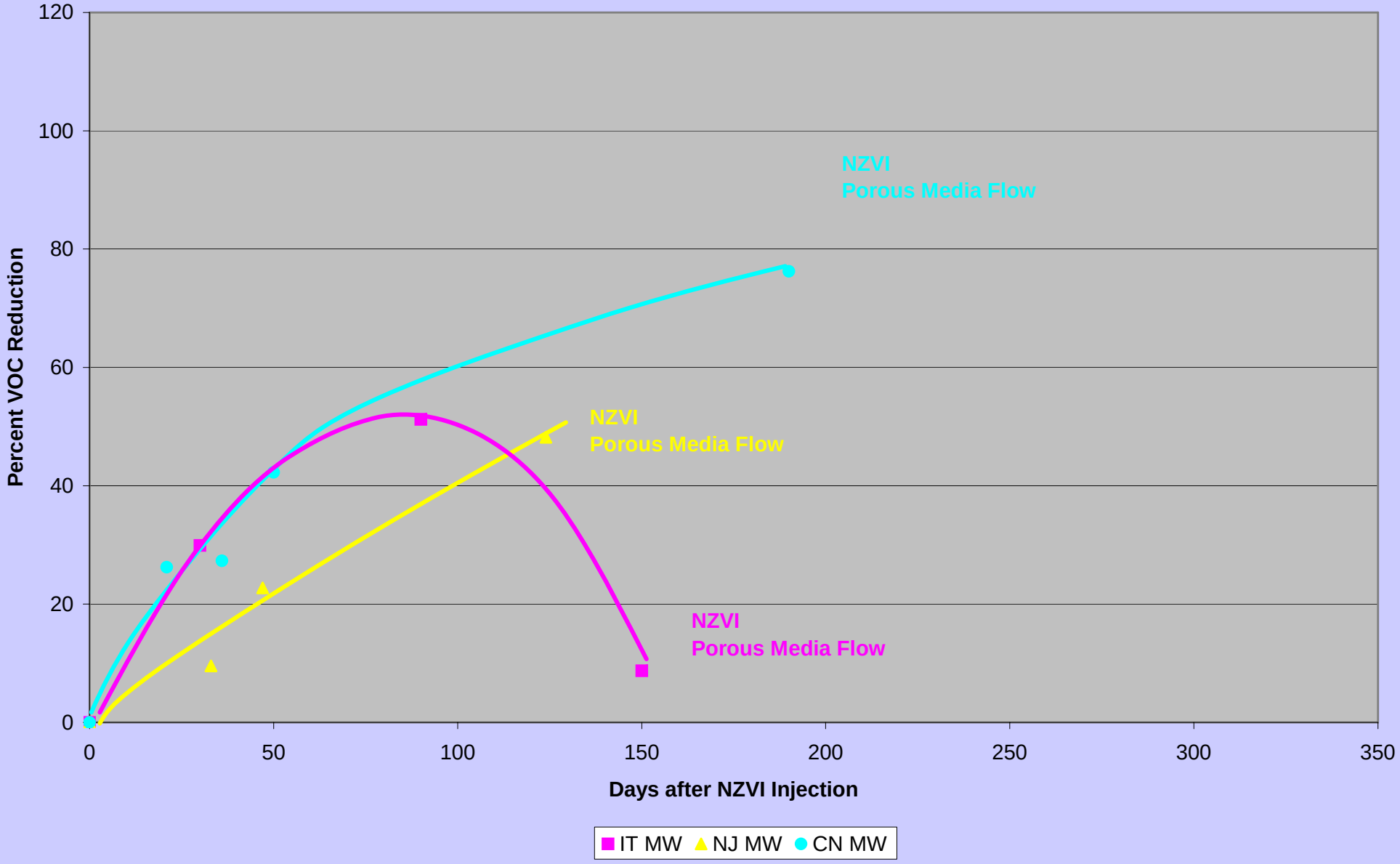
Golder Associates



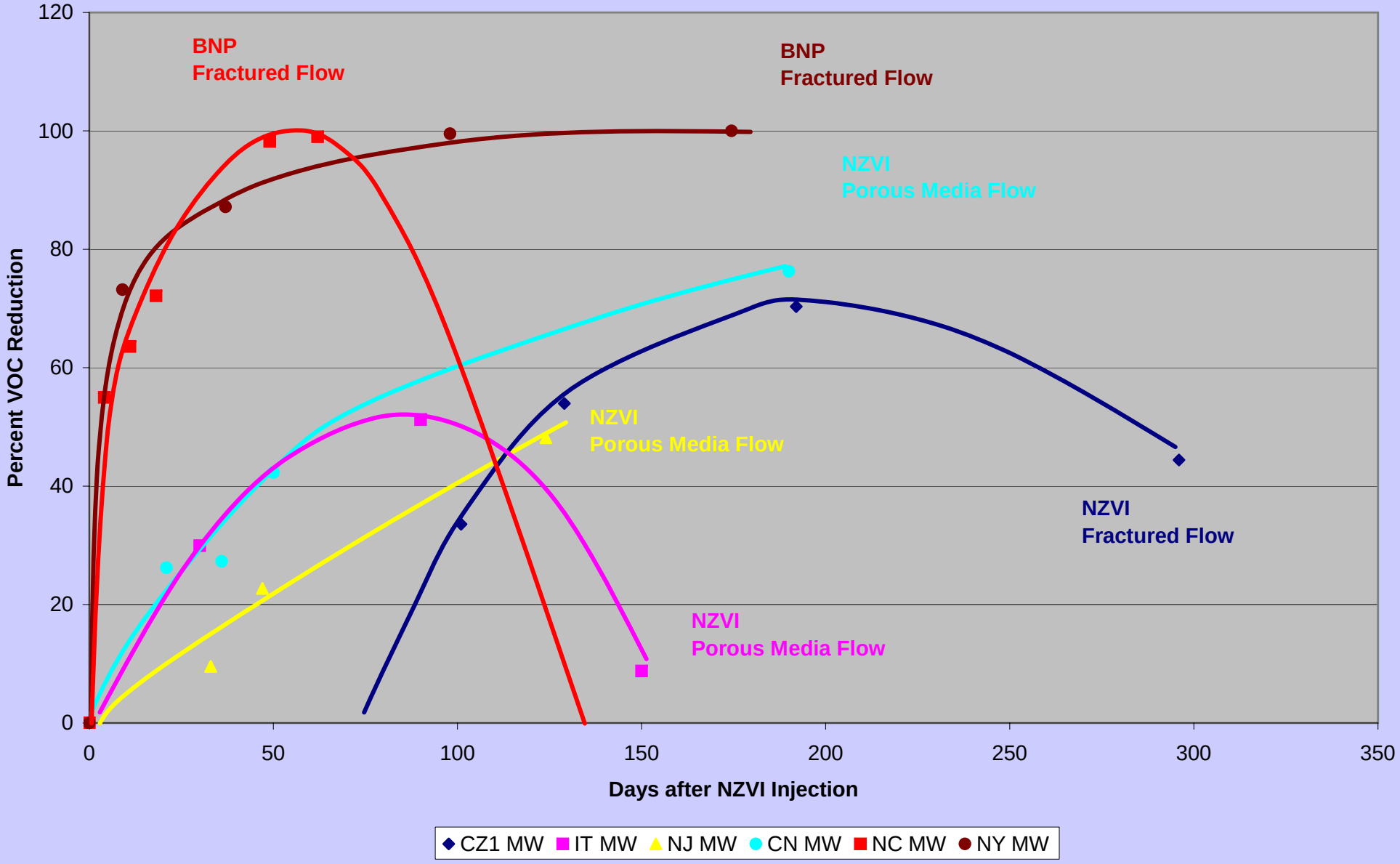




Golder Associates



Golder Associates



Golder Associates

Implementability

Golder Associates

Implementability

Conclusions

- Dramatic decrease of VOC concentrations over short time in fractured bedrock aquifers
- Slower but steady decrease of VOC concentrations in primary porosity aquifers
- Iron particles travel with groundwater, quicker in fractured media, slower in unconsolidated sediments
- Persistence of VOC treatment over a long period of time (BNP react quicker but are spent more rapid, NZVI react slower but have longer effect)
- Does not eliminate anaerobic bacterial activity

Golder Associates