

# Enhanced In Situ Bioremediation of a TCE Source Area in Deep, Fractured Basalt



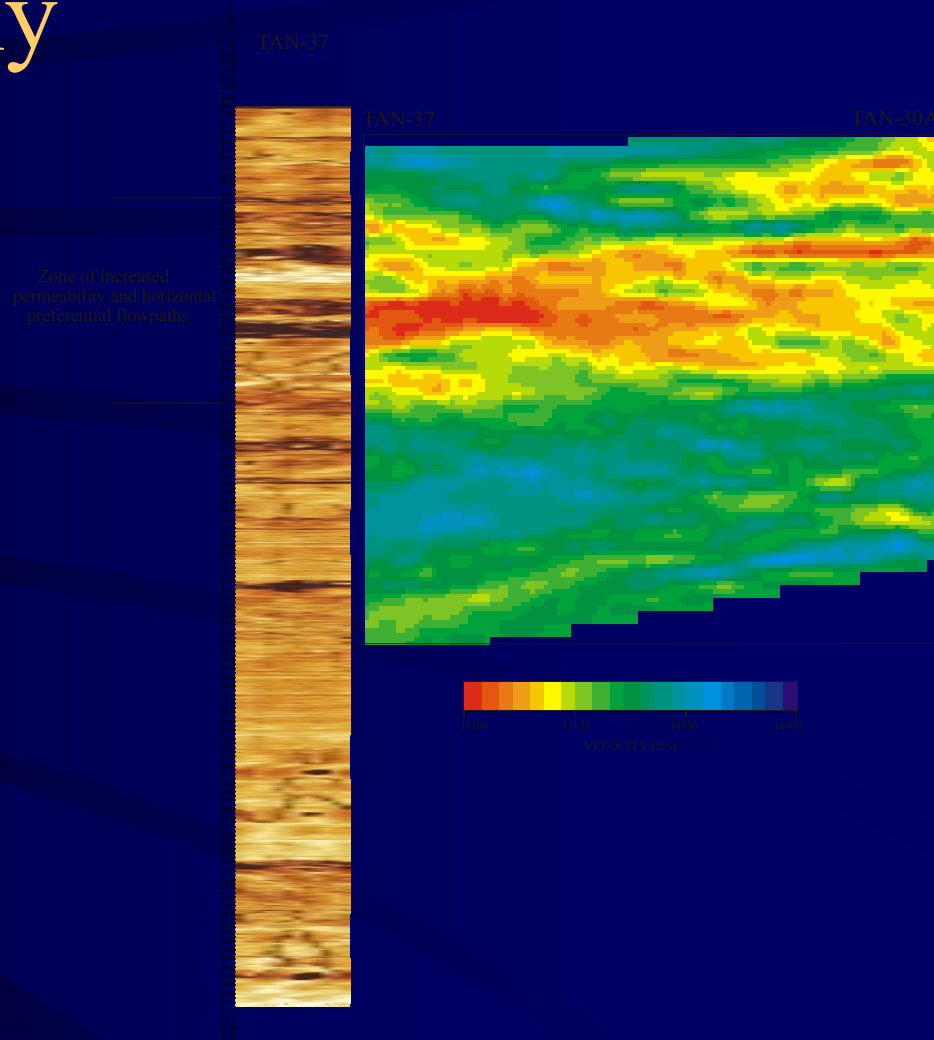
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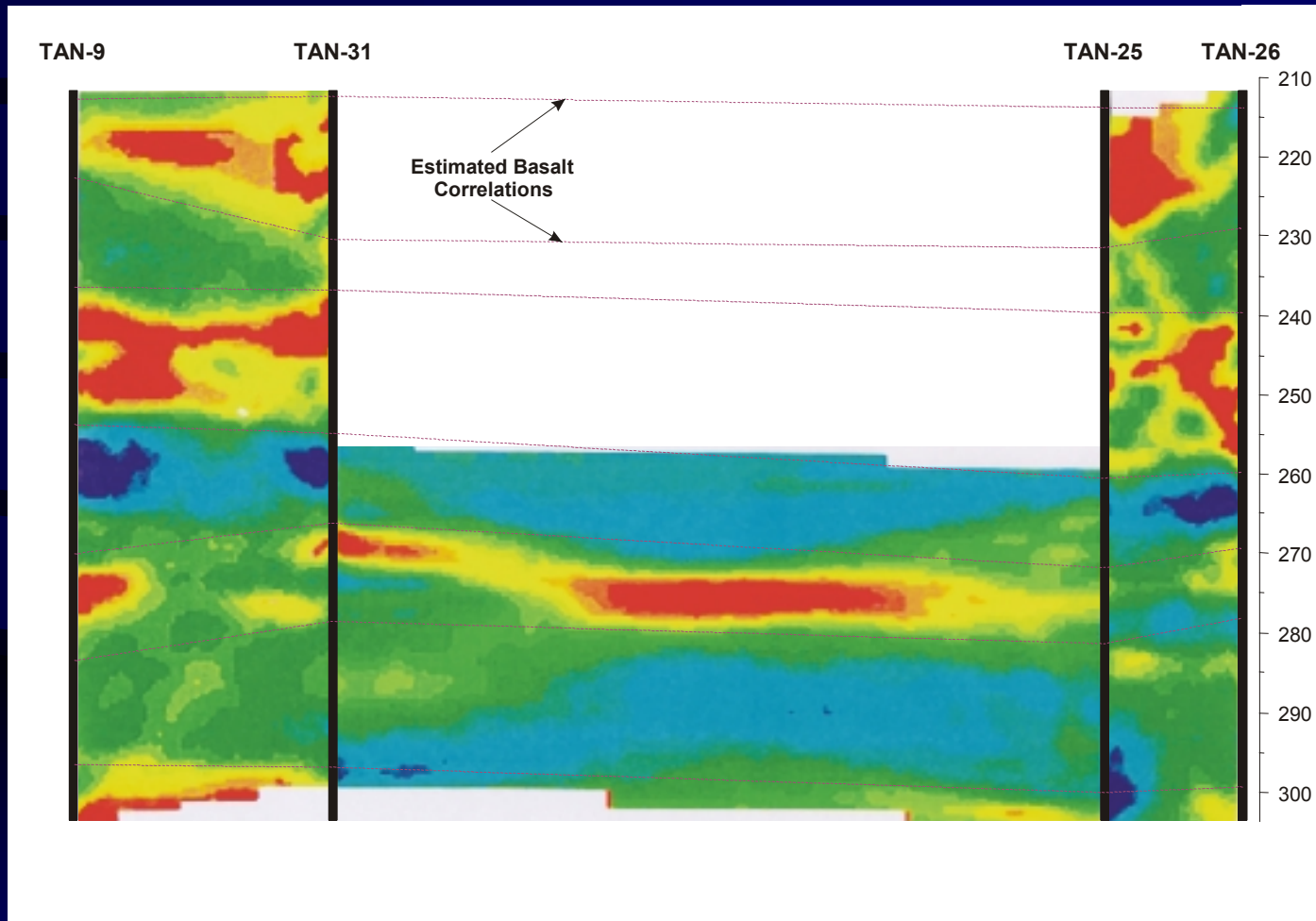


# Hydrostratigraphy

- Groundwater flow zones occur at either high porosity, rubble contacts between two basalt flows, or at fractured horizons within the dense basalt matrix
- Frequency of flow zone occurrence is greatest in shallow aquifer
- Horizontal, preferential flowpaths - discrete heterogeneities that control flow and transport at the scale of the source area

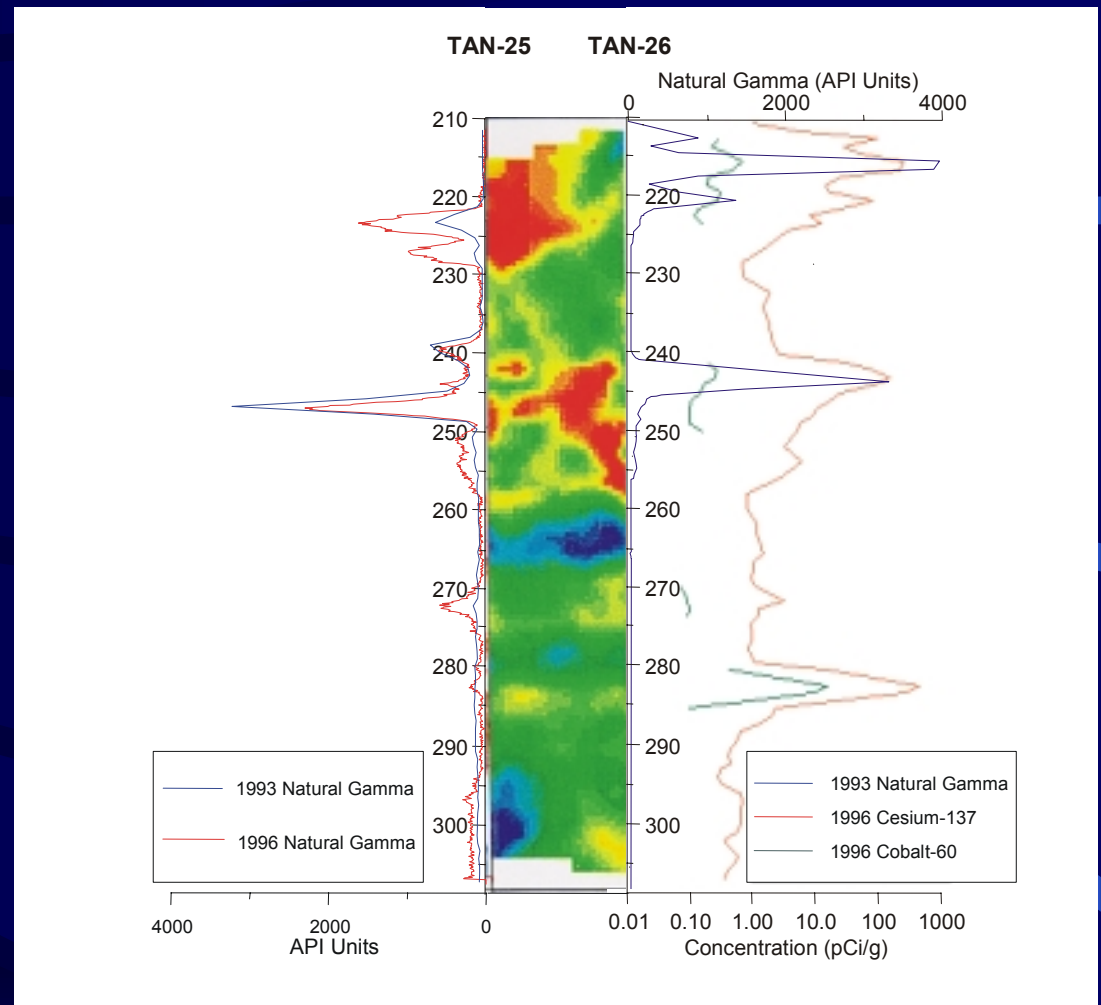


# Seismic Tomography Correlations



# Contaminant Distribution

- Sludge characterization identified the presence of radiological constituents including gamma emitters
- Gamma spectroscopy data demonstrate horizontal preferential flowpaths and indicate that the most significant component of gamma radiation is  $^{137}\text{Cs}$



# Test Area North (TAN) Background

- Industrial wastewater (including solvents), low-level radioactive wastes, and sanitary sewage were injected directly to the Snake River Plain Aquifer from the late 1950s to 1972
- TCE plume is nearly 2 miles long
- Residual source area is about 100 ft in diameter
- Contaminated aquifer is about 200-400 ft deep
- Aquifer is comprised of fractured basalt



Approximate Plume Boundary

Groundwater Flow  
Direction

Groundwater Flow  
Direction



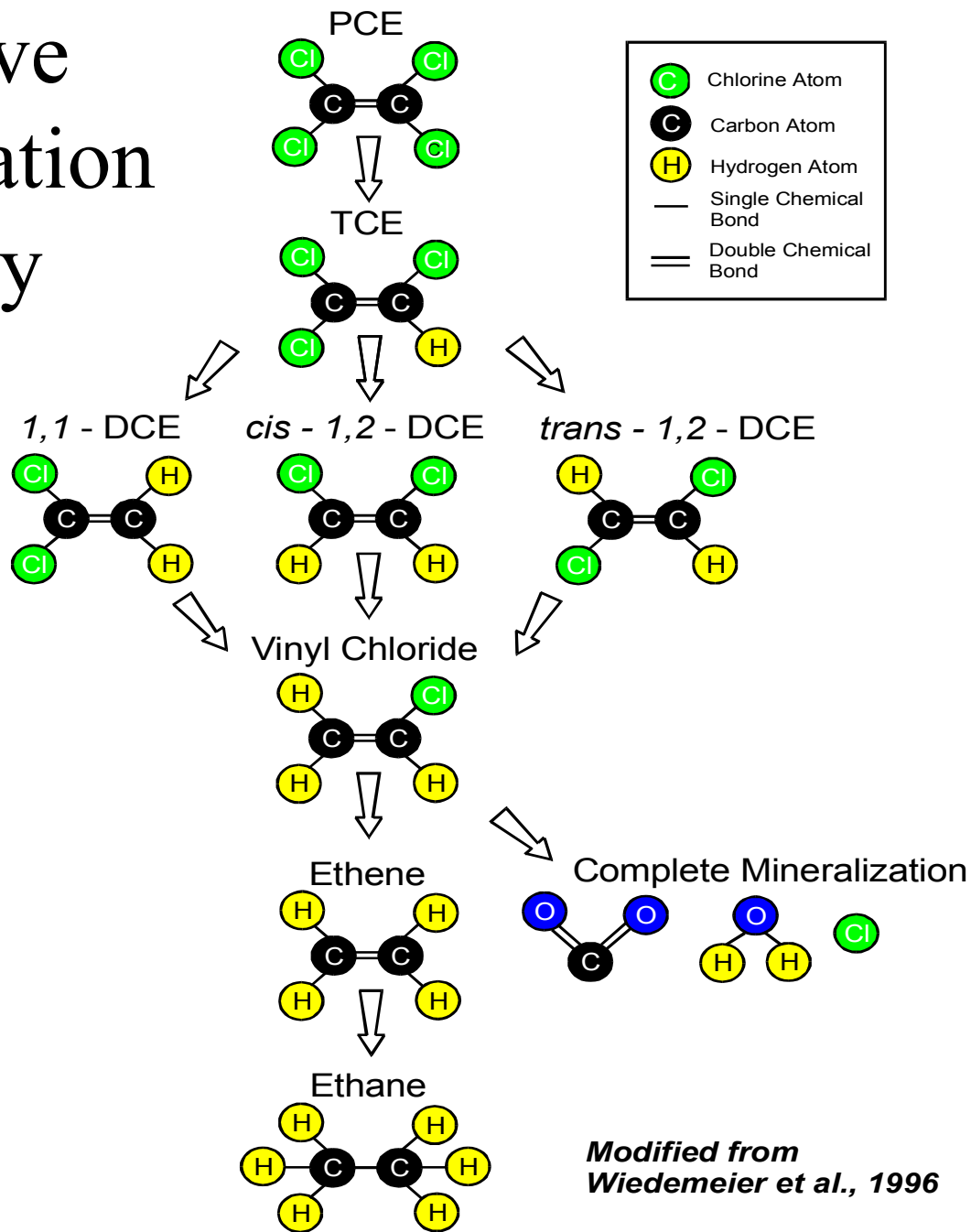
# Record of Decision (1995)

- Pump and treat selected as default remedy
- Treatability studies established for alternative technologies:
  - zero-valent iron
  - monolithic confinement
  - in situ chemical oxidation
  - in situ bioremediation
  - natural attenuation
- 100-year remedial time frame

# Reductive Dechlorination

- Microorganisms in the subsurface use chlorinated ethenes as electron acceptors (like we use oxygen)
- An appropriate electron donor (food) is needed
- “Daughter” products are generated as chlorine atoms are sequentially replaced by hydrogen atoms
- Naturally occurring inorganic electron acceptors may “compete” with the chlorinated ethenes

# Reductive Dechlorination Pathway

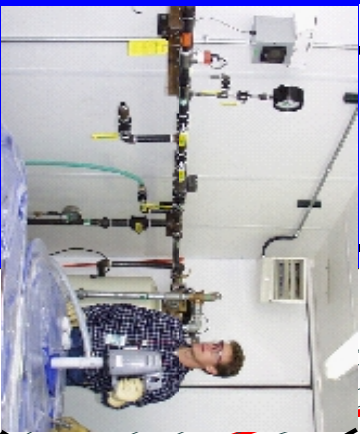


Modified from  
Wiedemeier et al., 1996

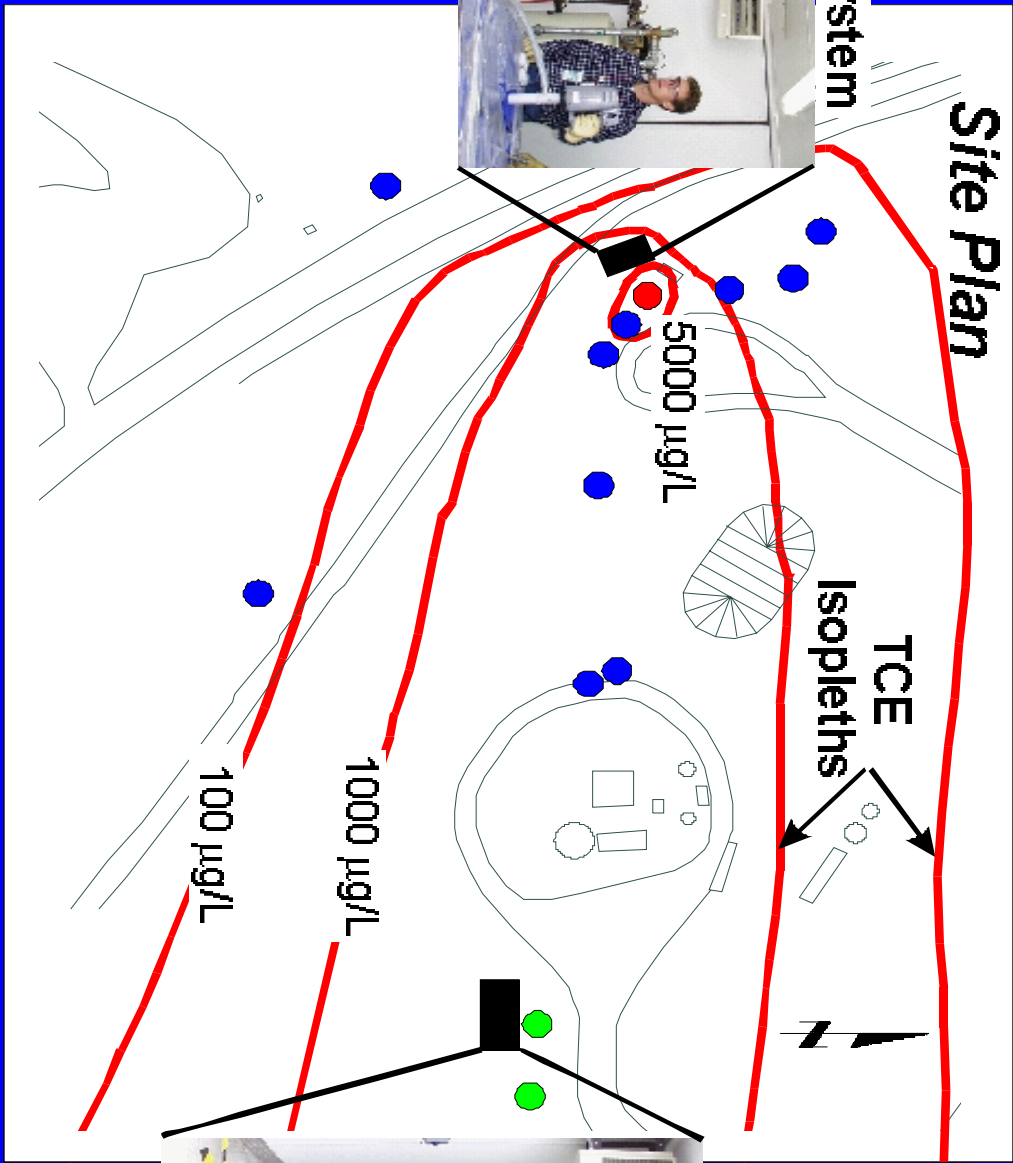
# Objectives for the 1-year In Situ Bioremediation Field Evaluation

- Primary Objective: Demonstrate that biodegradation of TCE can be significantly enhanced through electron donor addition
- Create hydraulic “treatment cell” to maintain hydraulic containment of the source area and control residence time
- Determine controls on process efficiency through extensive monitoring

**Injection System**



# Site Plan



**Air Stripper**



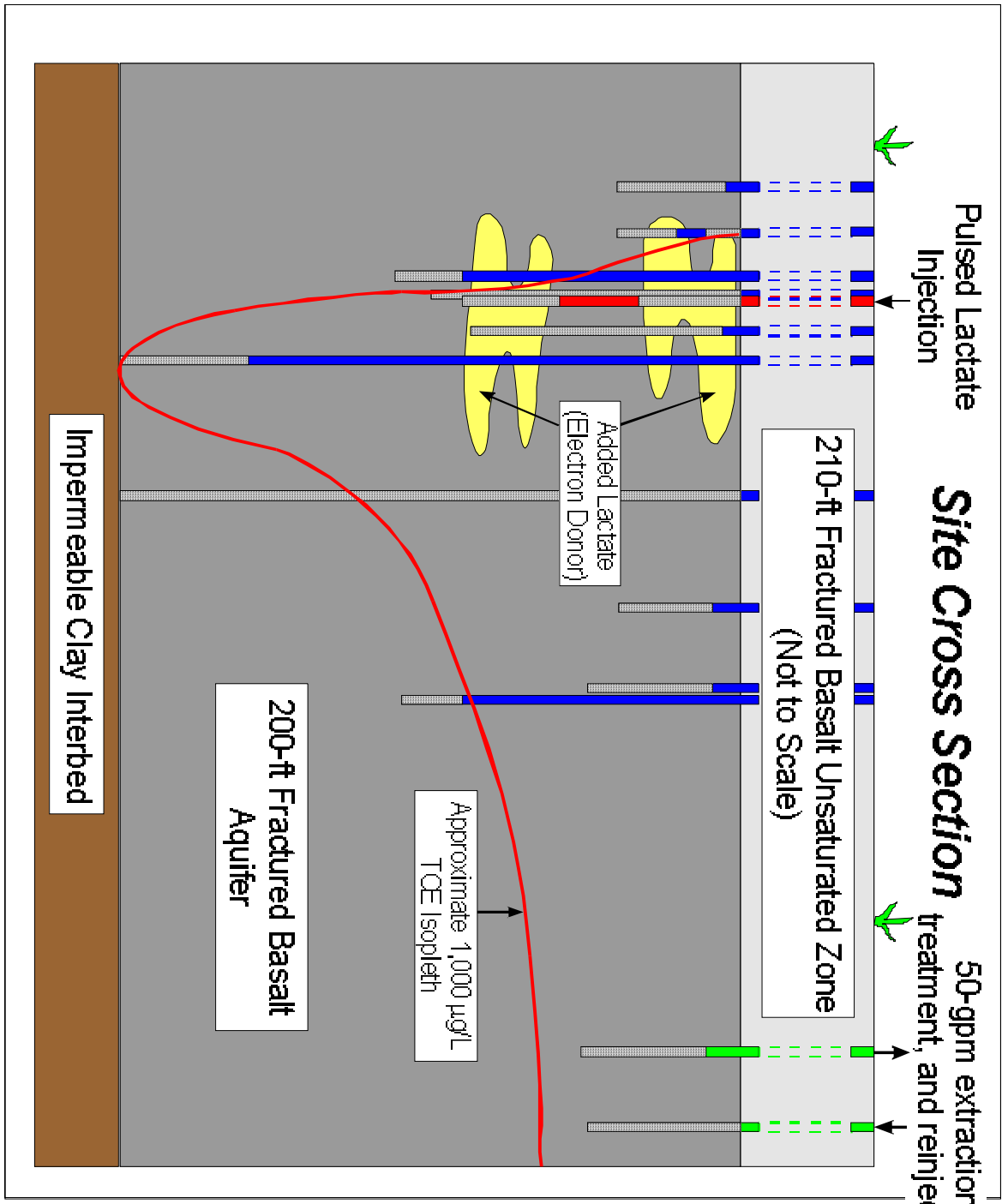
- Air Stripper Wells
- Monitoring Wells
- Injection Well

0    100    200    300  
Feet

Pulsed Lactate Injection

# Site Cross Section

50-gpm extraction, treatment, and reinjection



- Injection Well
- Air Stripper Wells
- Monitoring Wells
- ▨ Open or screened intervals



# Field Evaluation Monitoring

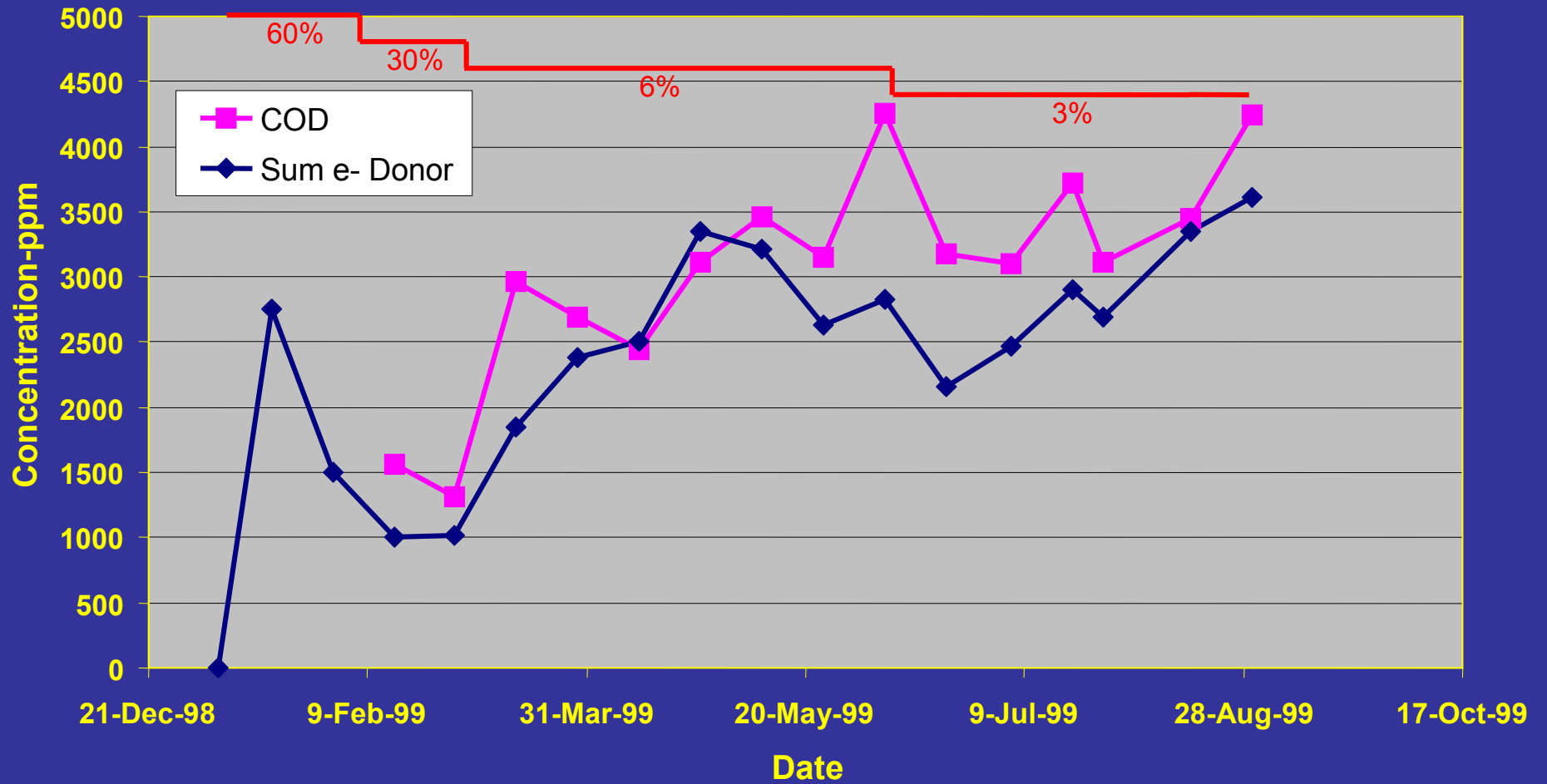
- Biweekly sampling at 8 to 11 locations
- 19 Analyses per sample
  - Electron Donors/Nutrients: 5
  - Competing Electron Acceptors: 4
  - Biological Activity Indicators: 2
  - Contaminants and Daughter Products: 3
  - Water Quality: 4
  - Internal Tracer: 1
- Two major areas of cost savings:
  - Integration of field and in situ analyses with fixed lab analyses (only 5 fixed lab analyses)
  - Use of modified micropurging method for sampling

# Electron Donor Addition

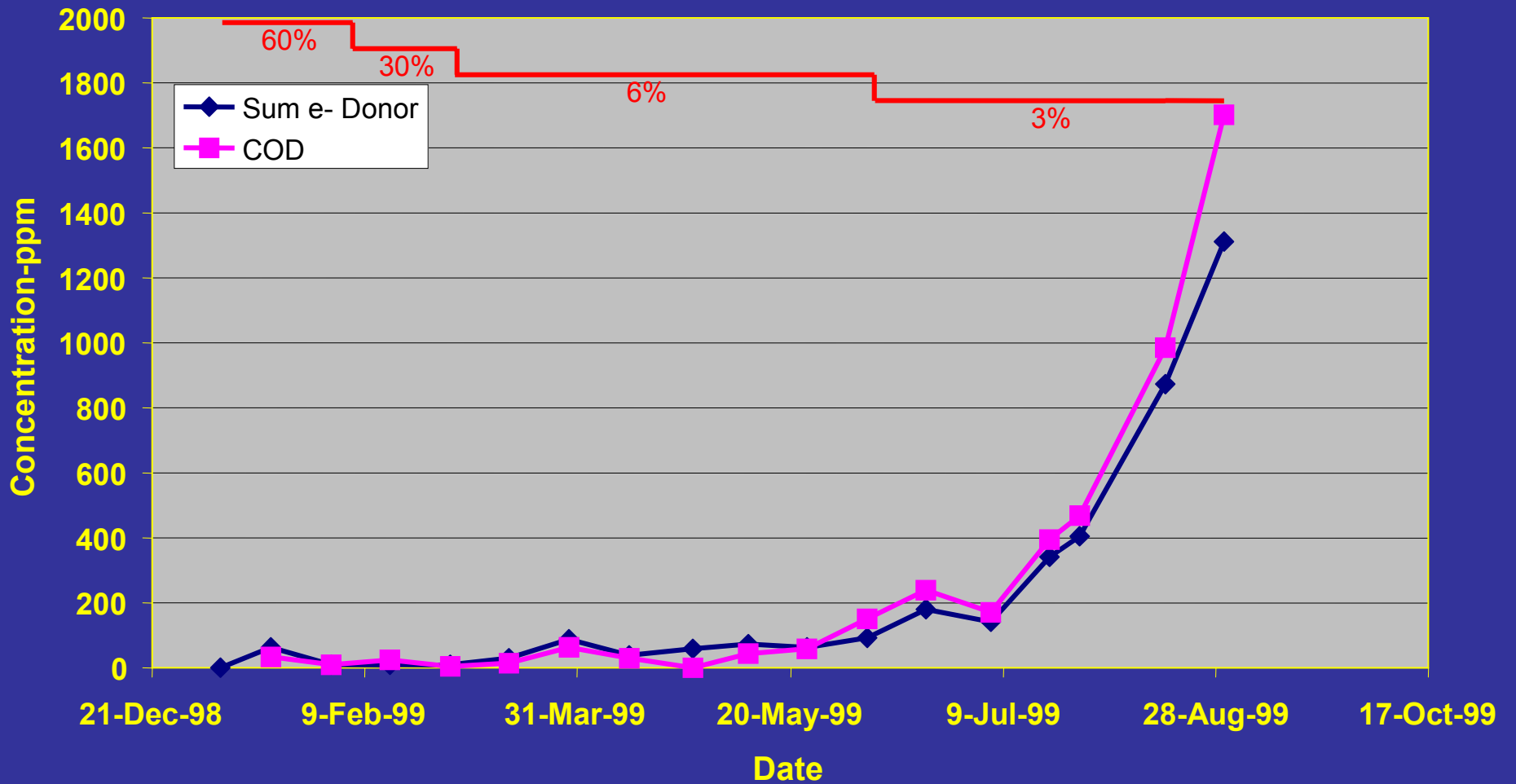
- Initial strategy: weekly injection of 300 gal of 60% sodium lactate solution into Well TSF-05 (January 1999)
- Potable water injected for 1 hour at 20 gpm to “flush” the injection well
- Subject to change based on monitoring
  - Feb. 2 - changed to 30%
  - Mar. 2 - changed to 6%
  - June 9 - changed to 3%
- No lactate addition after September 8, 1999



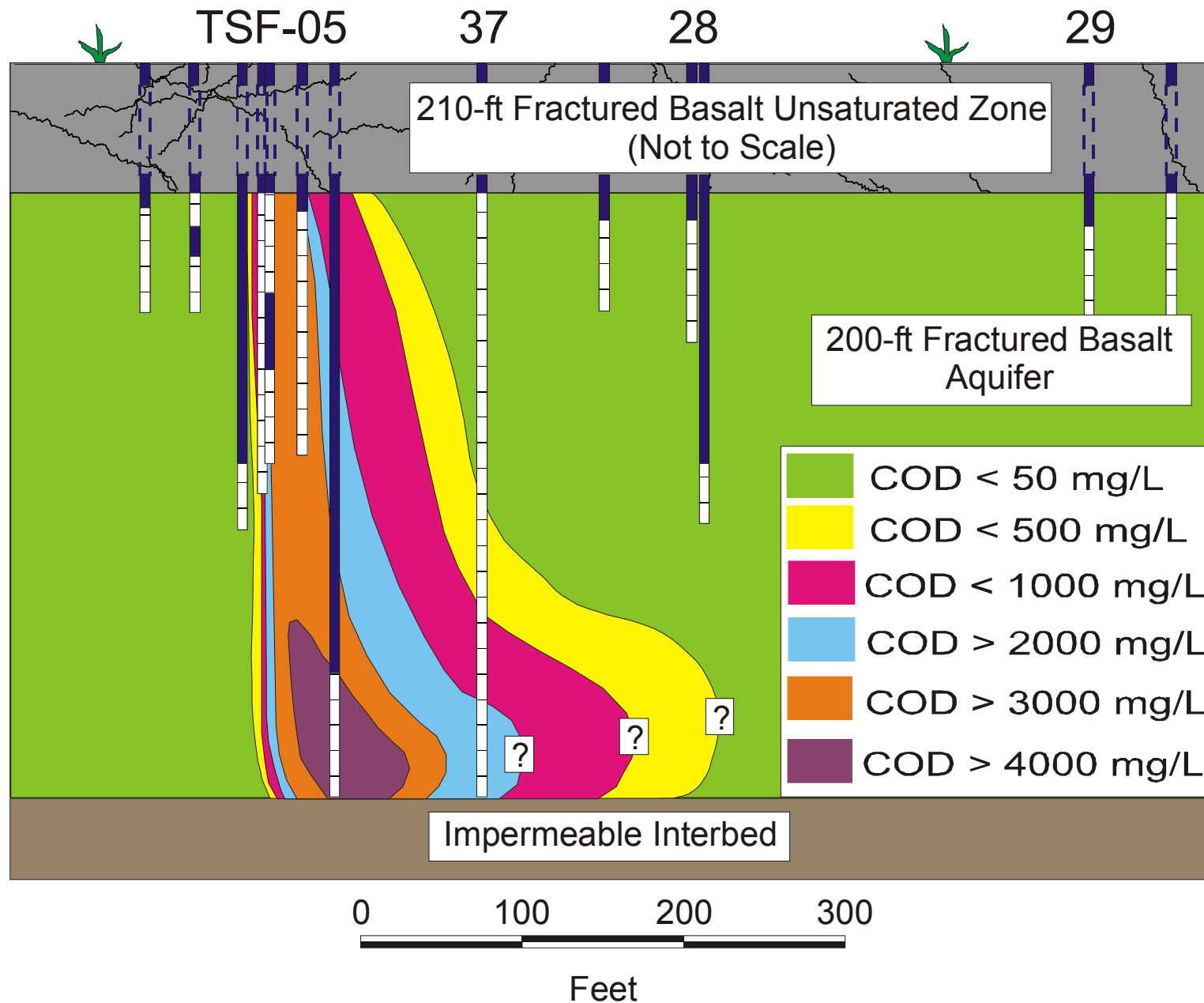
## Electron Donor In TAN-25



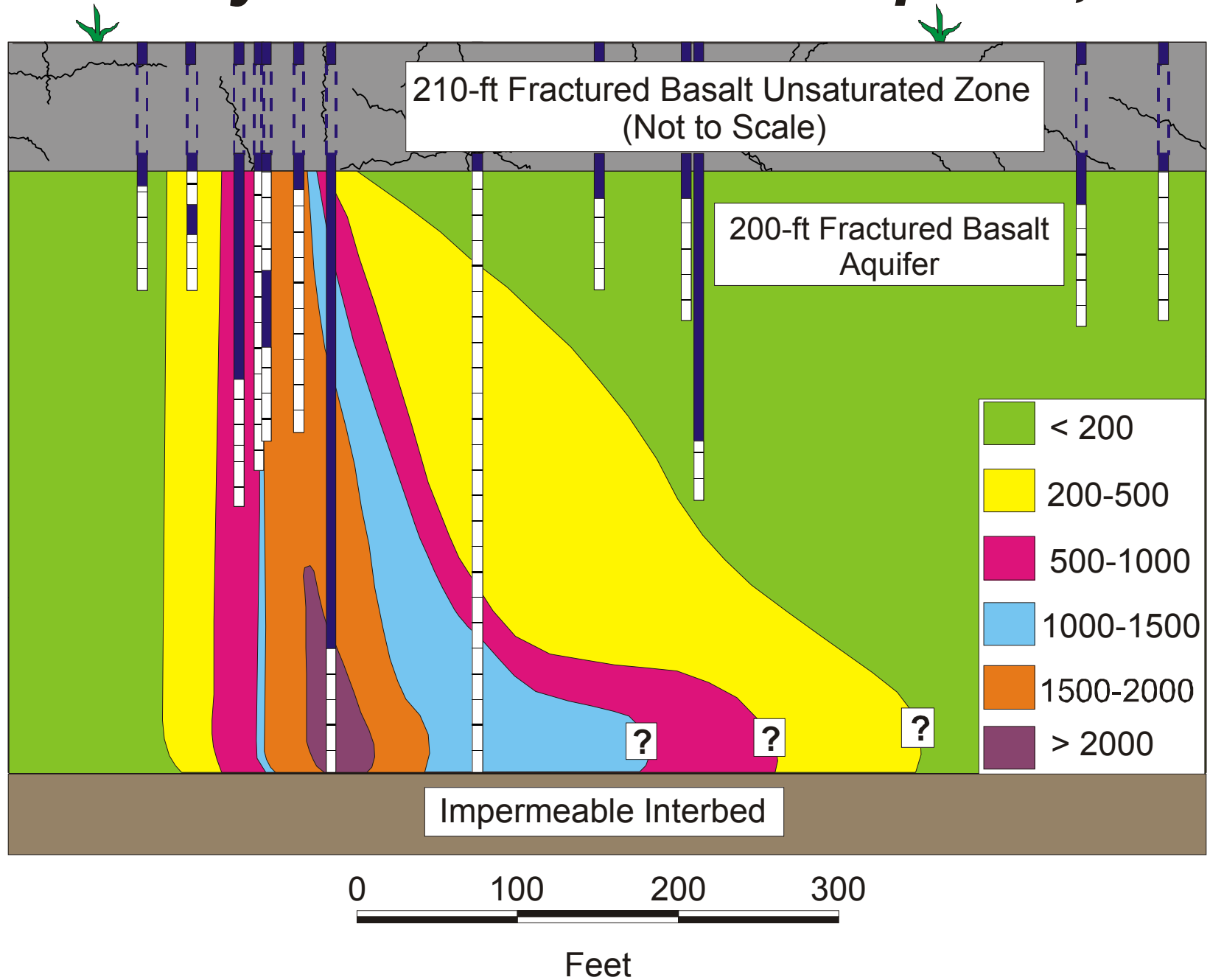
## Electron Donor in TAN-31



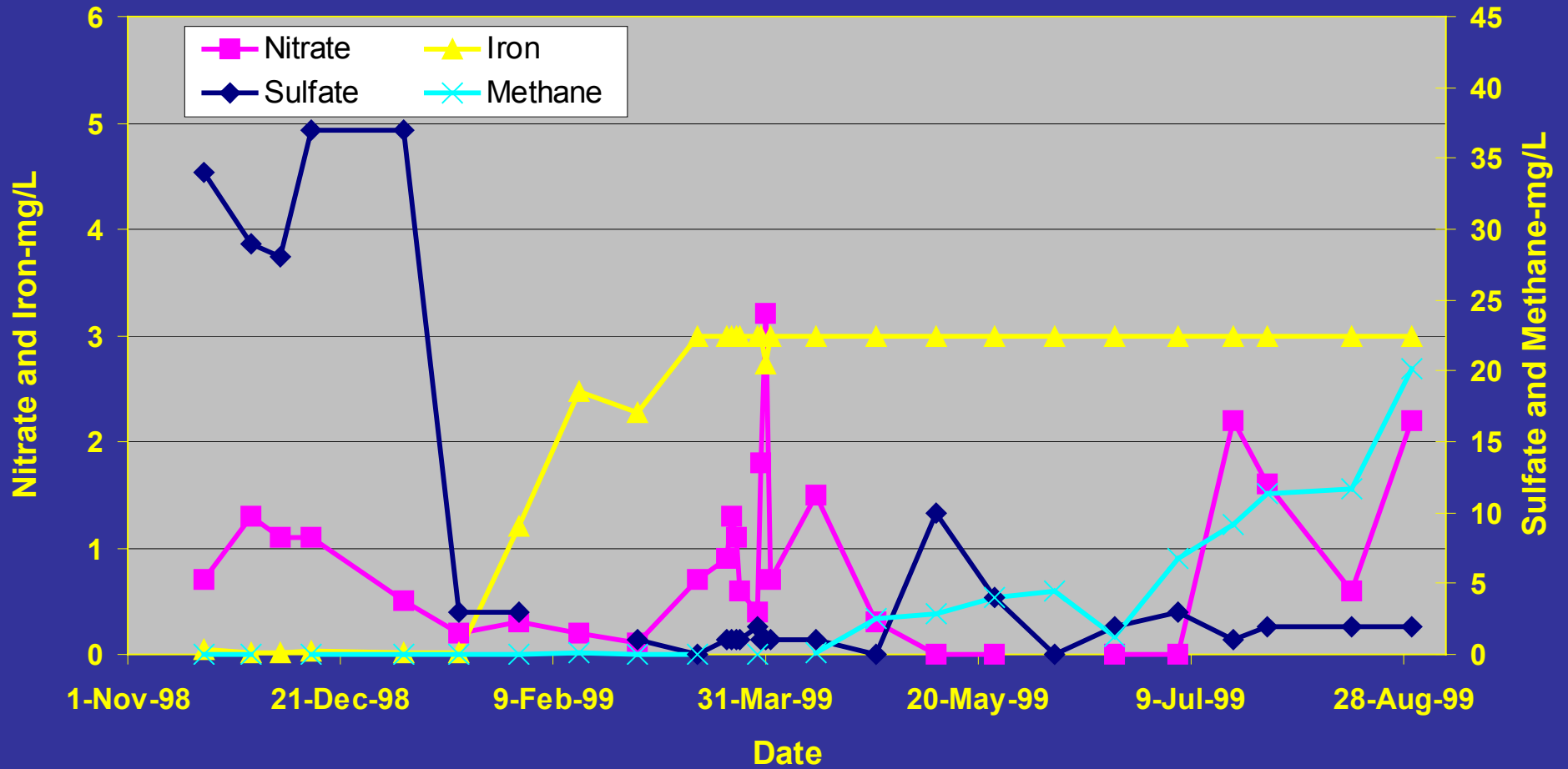
# Chemical Oxygen Demand Sept. 13, 1999



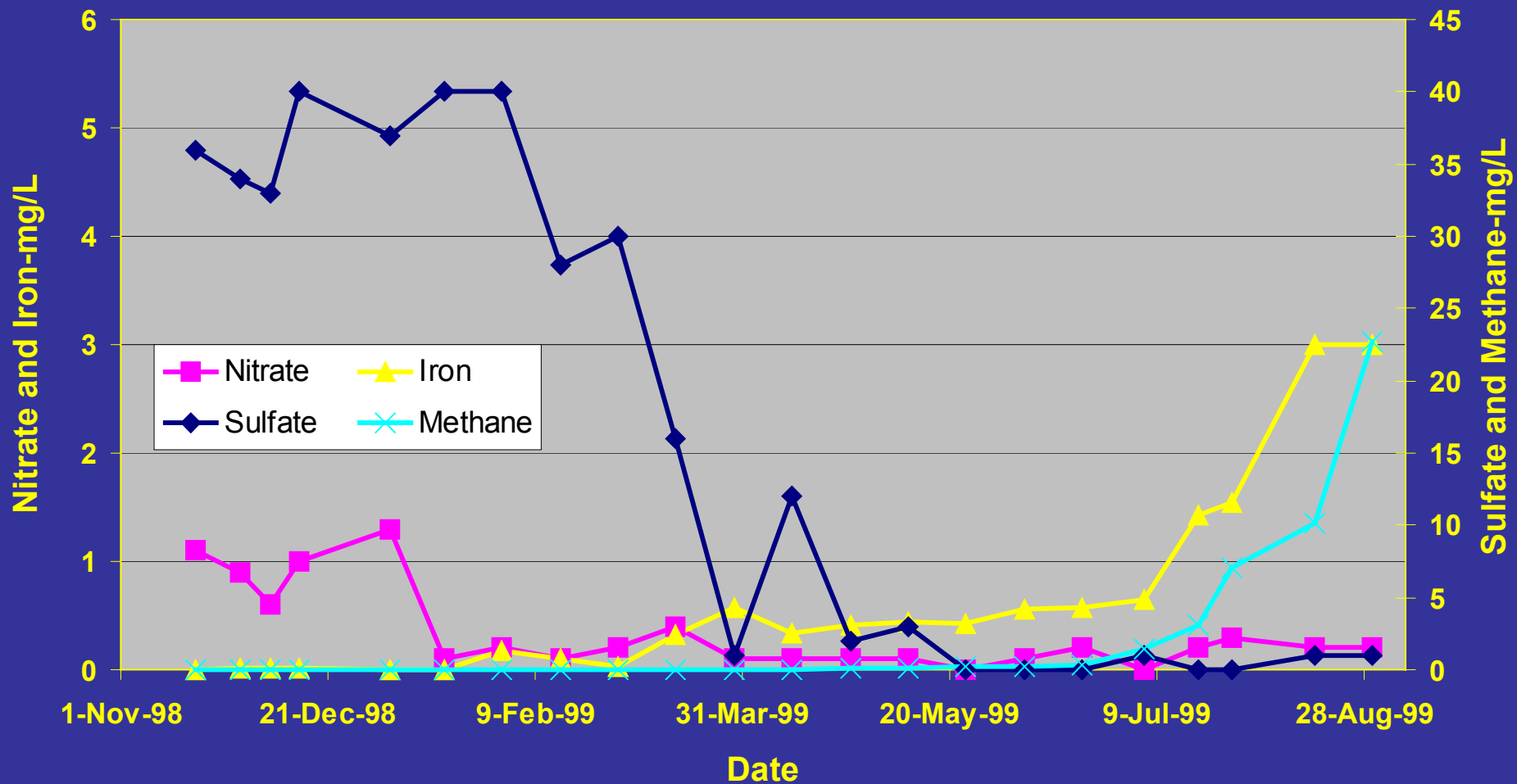
# Alkalinity Concentrations Sept. 13, 1999



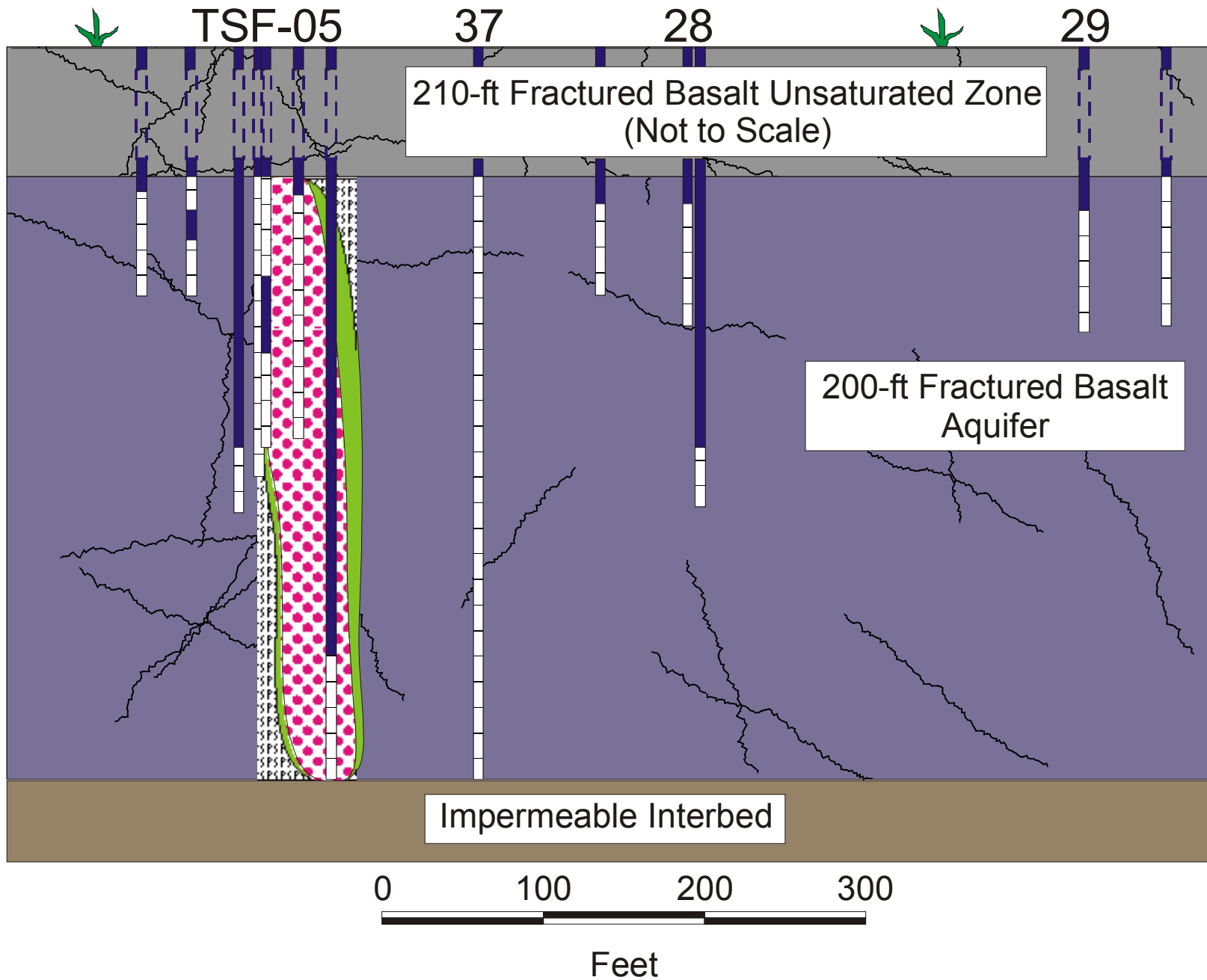
## Redox Indicators in TAN-25



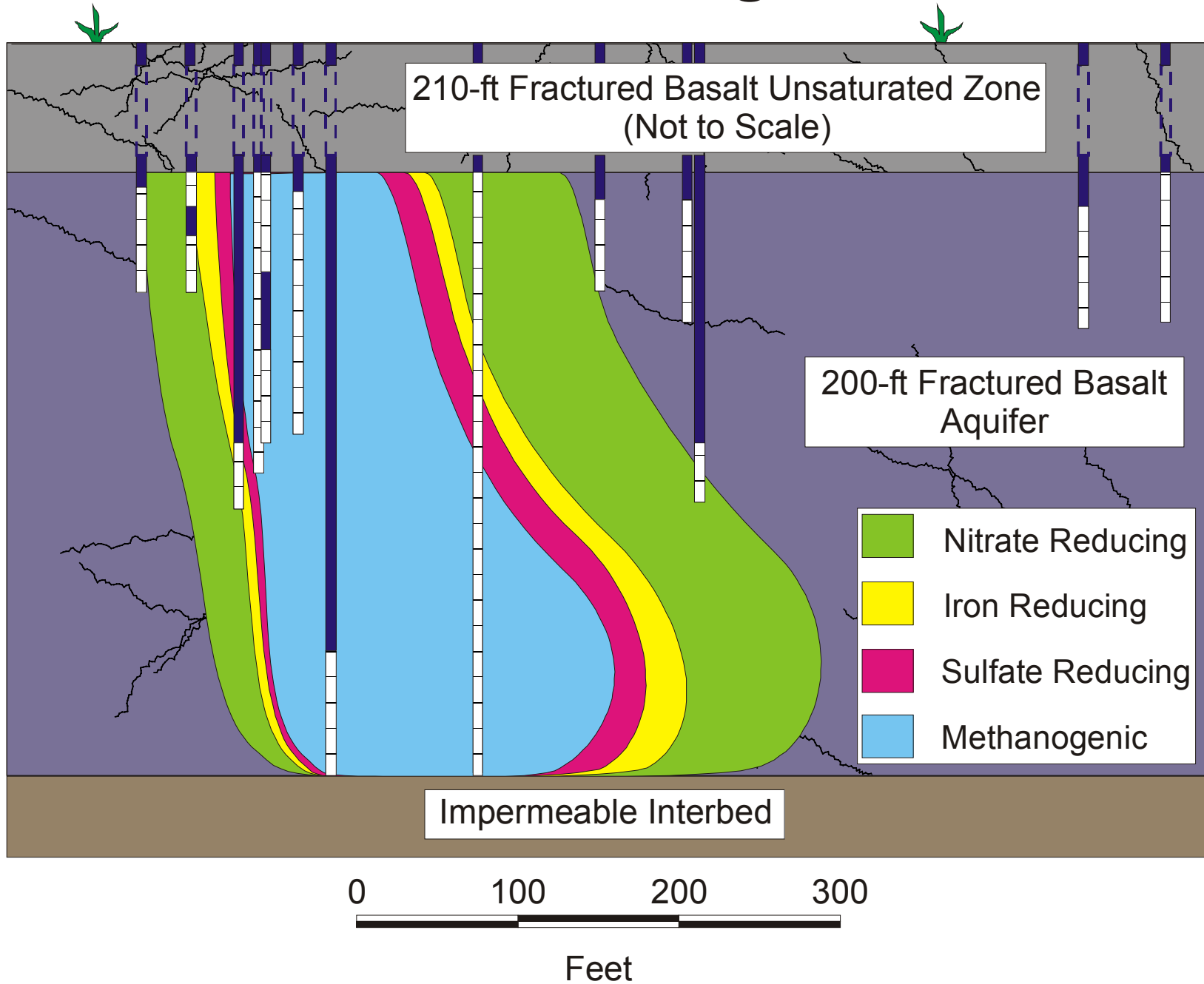
## Redox Indicators in TAN-31



# *Initial Redox Conditions*

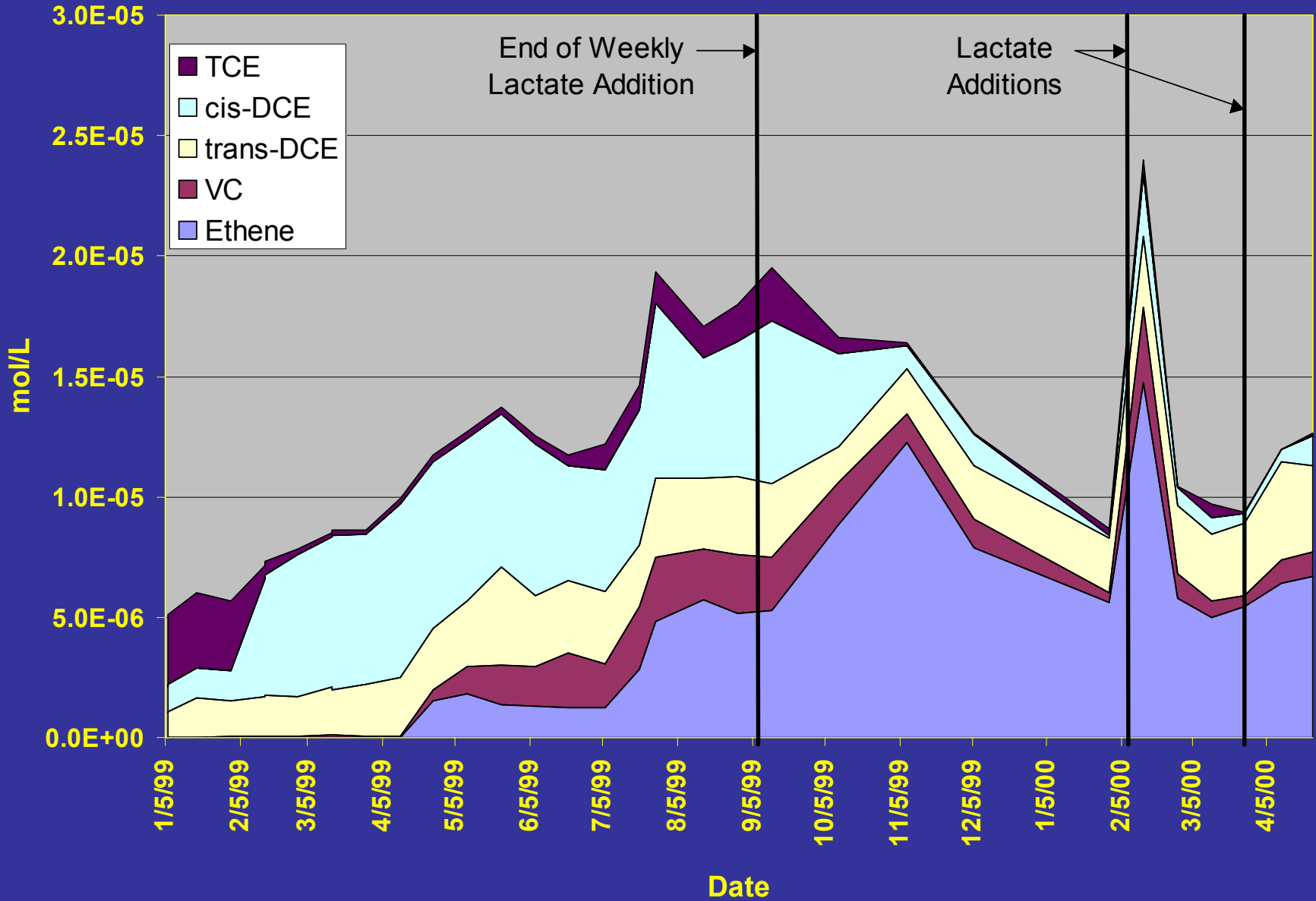


# Redox Conditions August 30, 1999

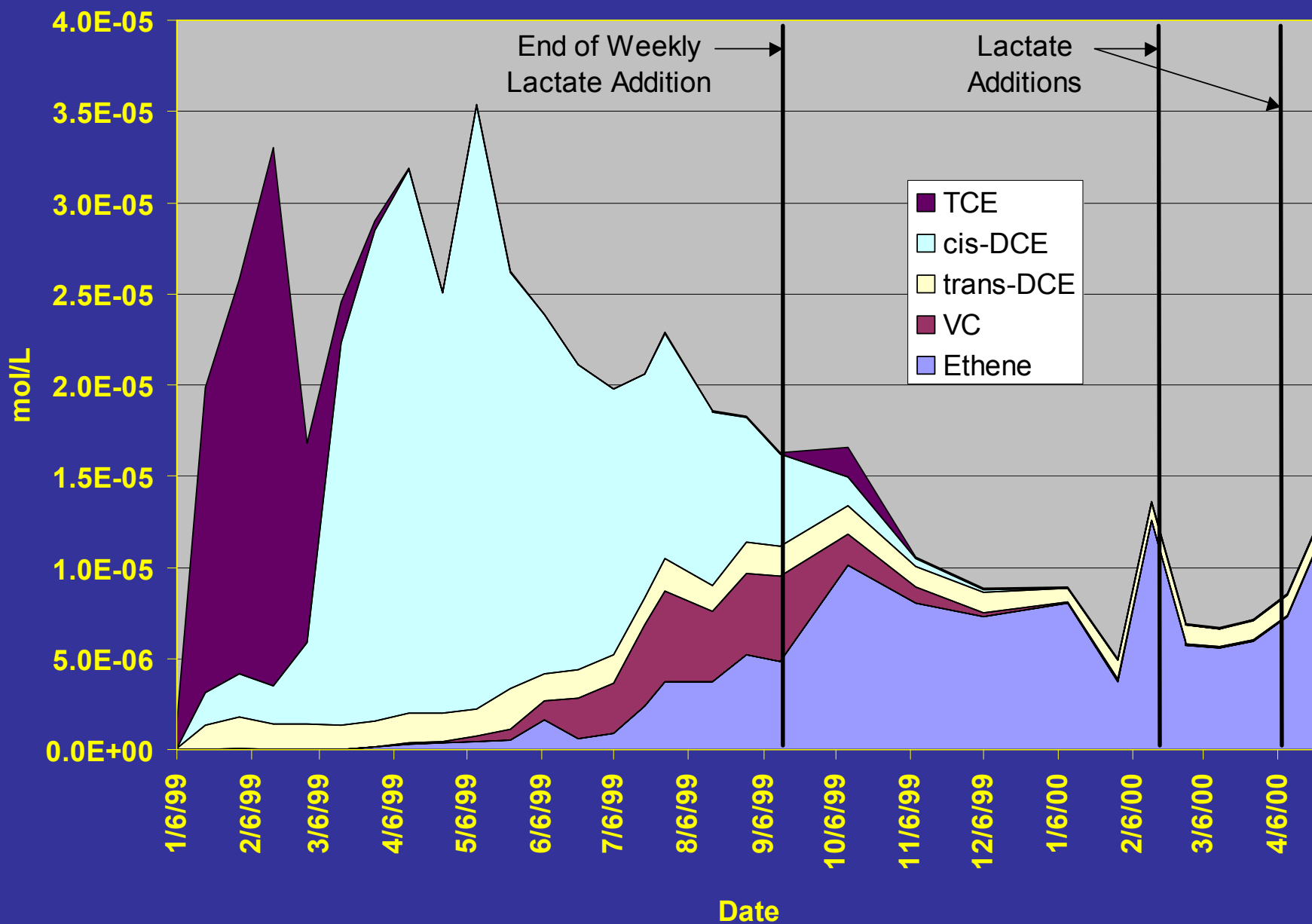




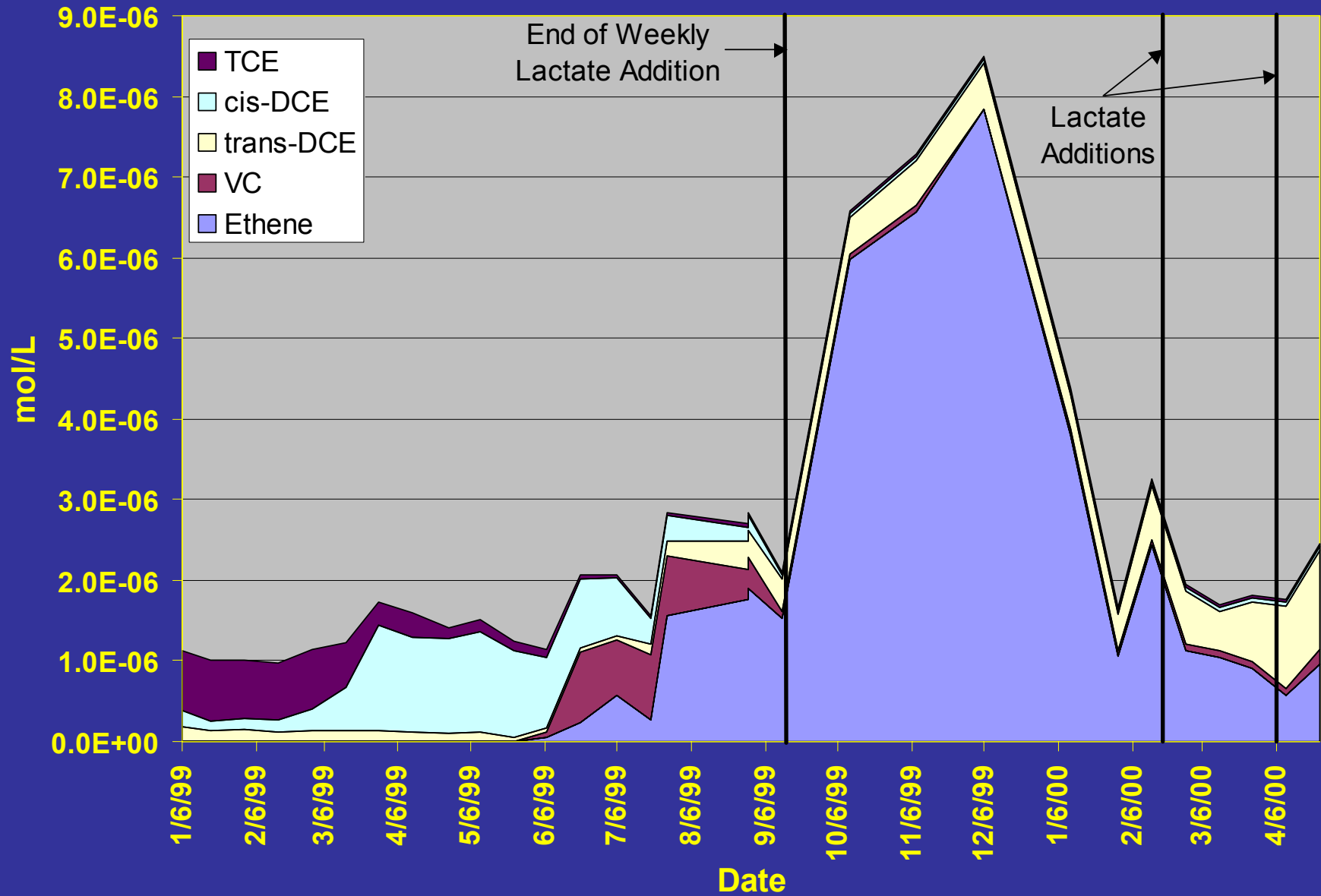
## Reductive Dechlorination Indicators in TAN-25



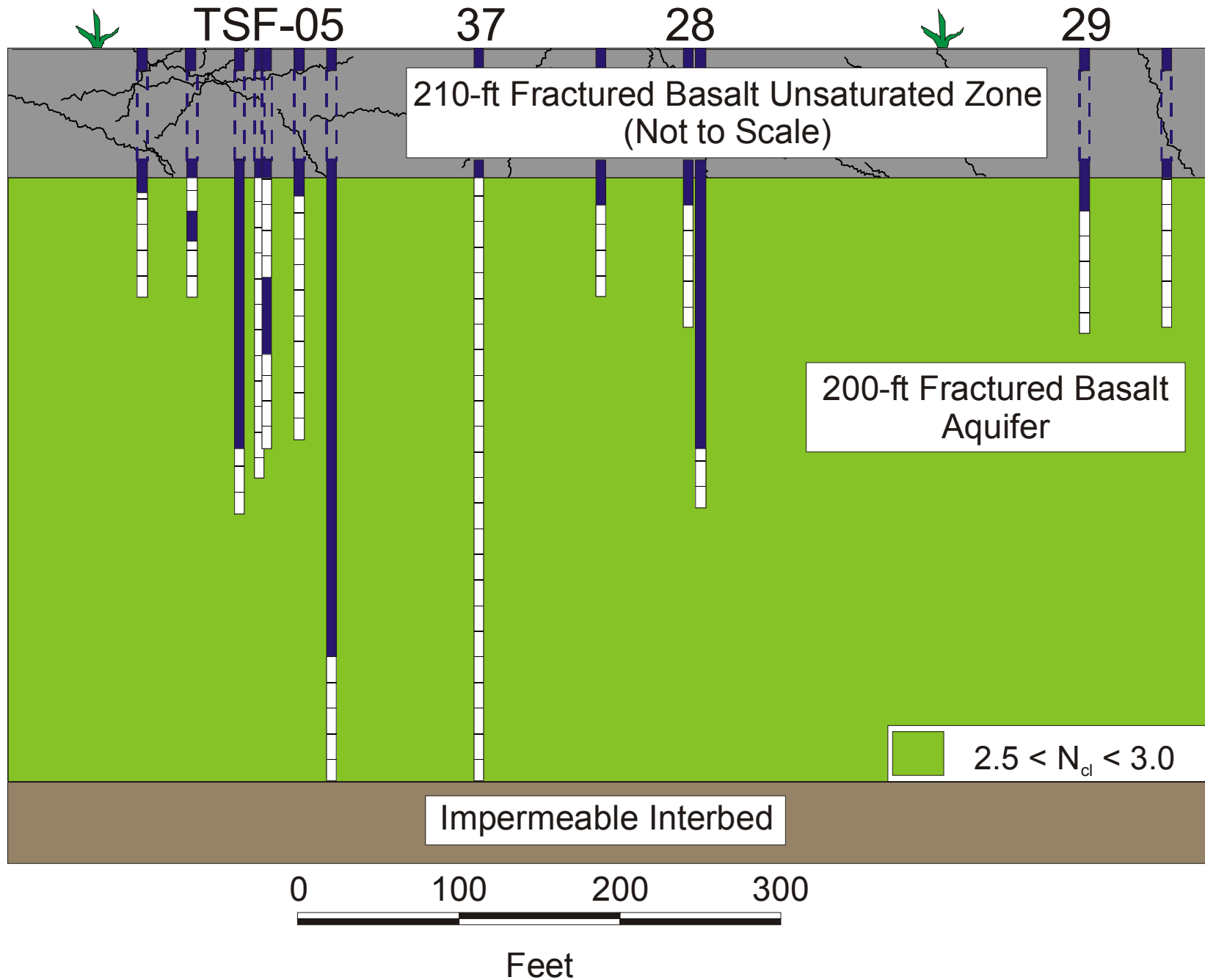
## Reductive Dechlorination Indicators in TAN-26



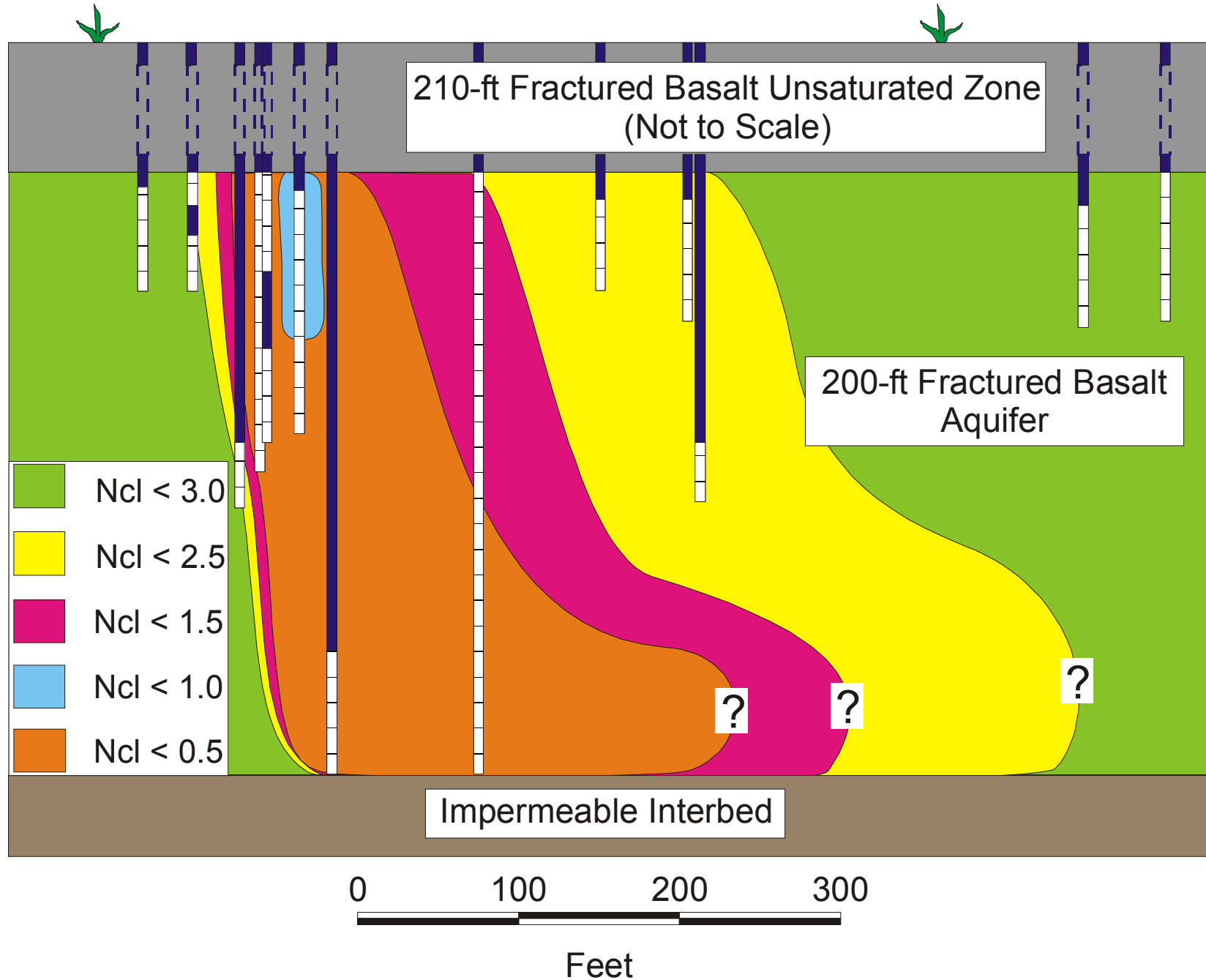
## Reductive Dechlorination Indicators in TAN-31



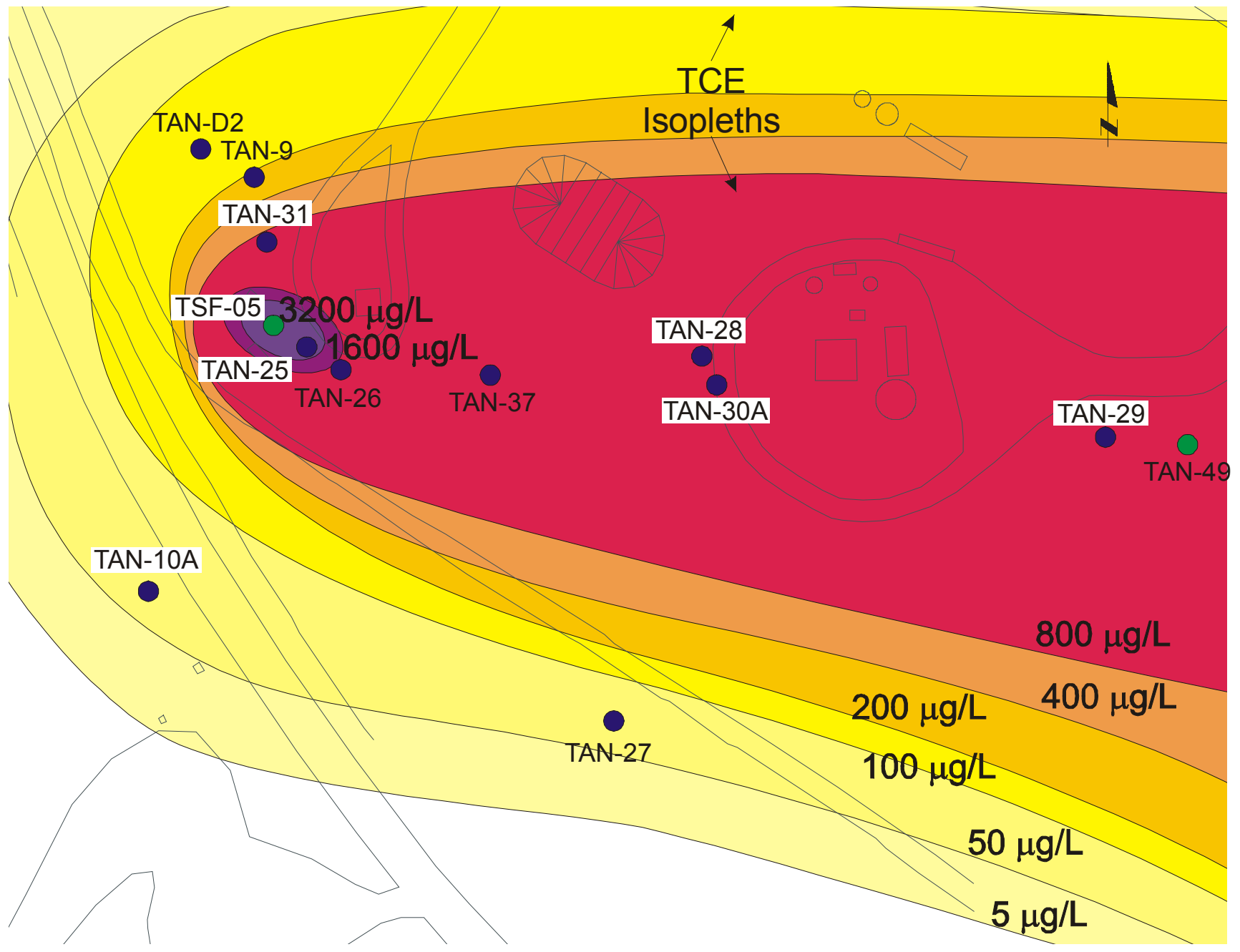
# Initial Chlorine Numbers



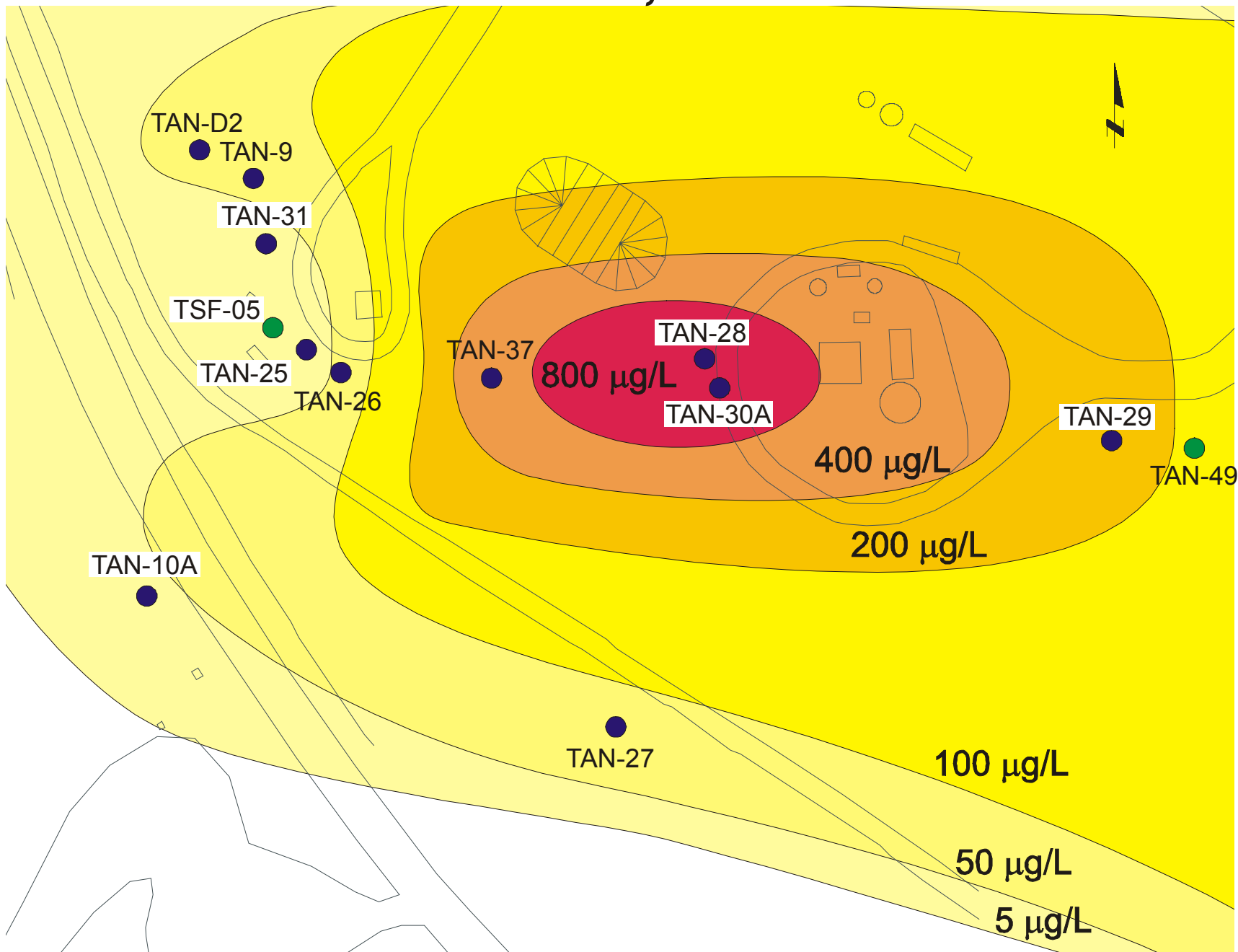
# Chlorine Numbers January 10, 1999



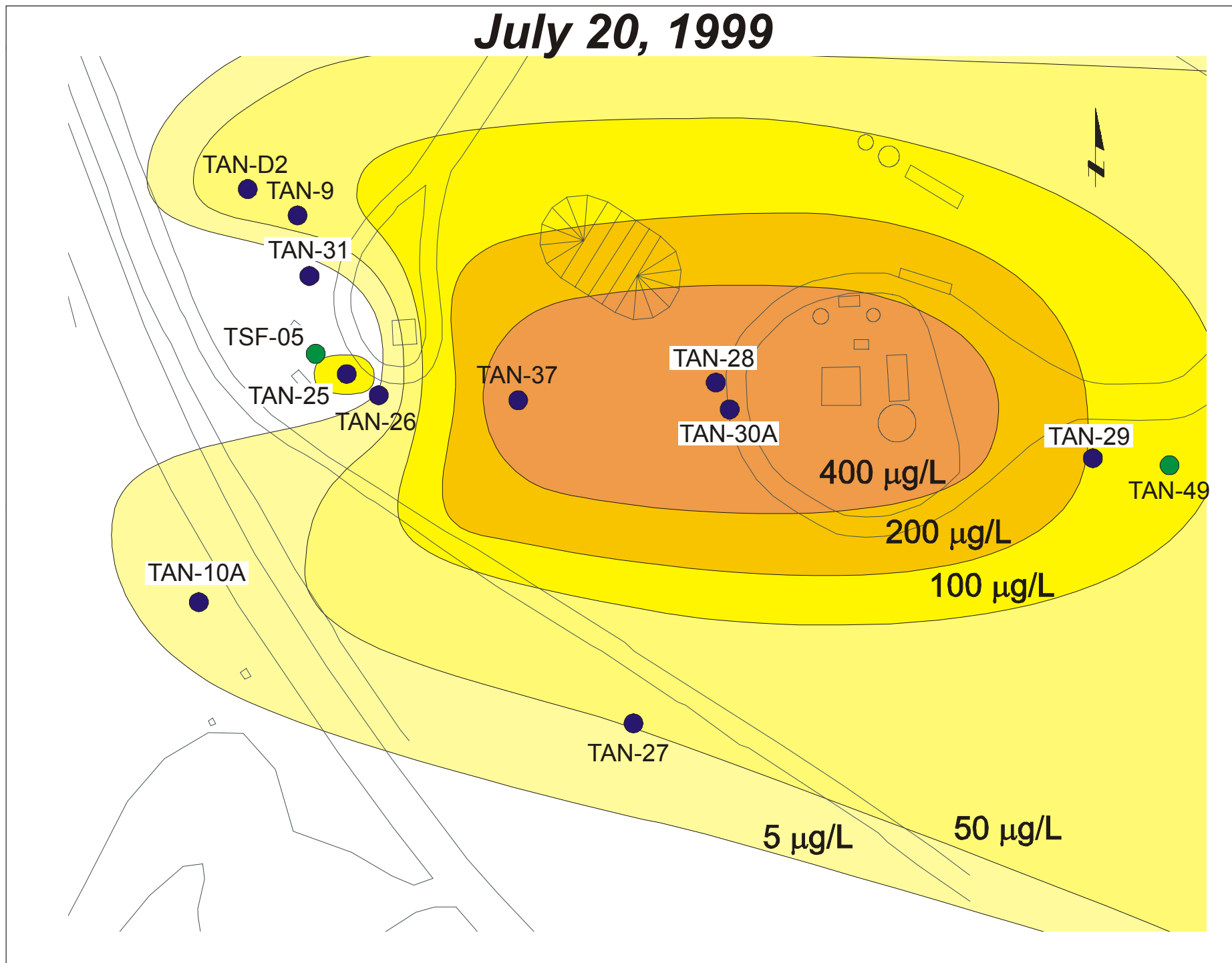
# Pre-Lactate



# March 29, 1999

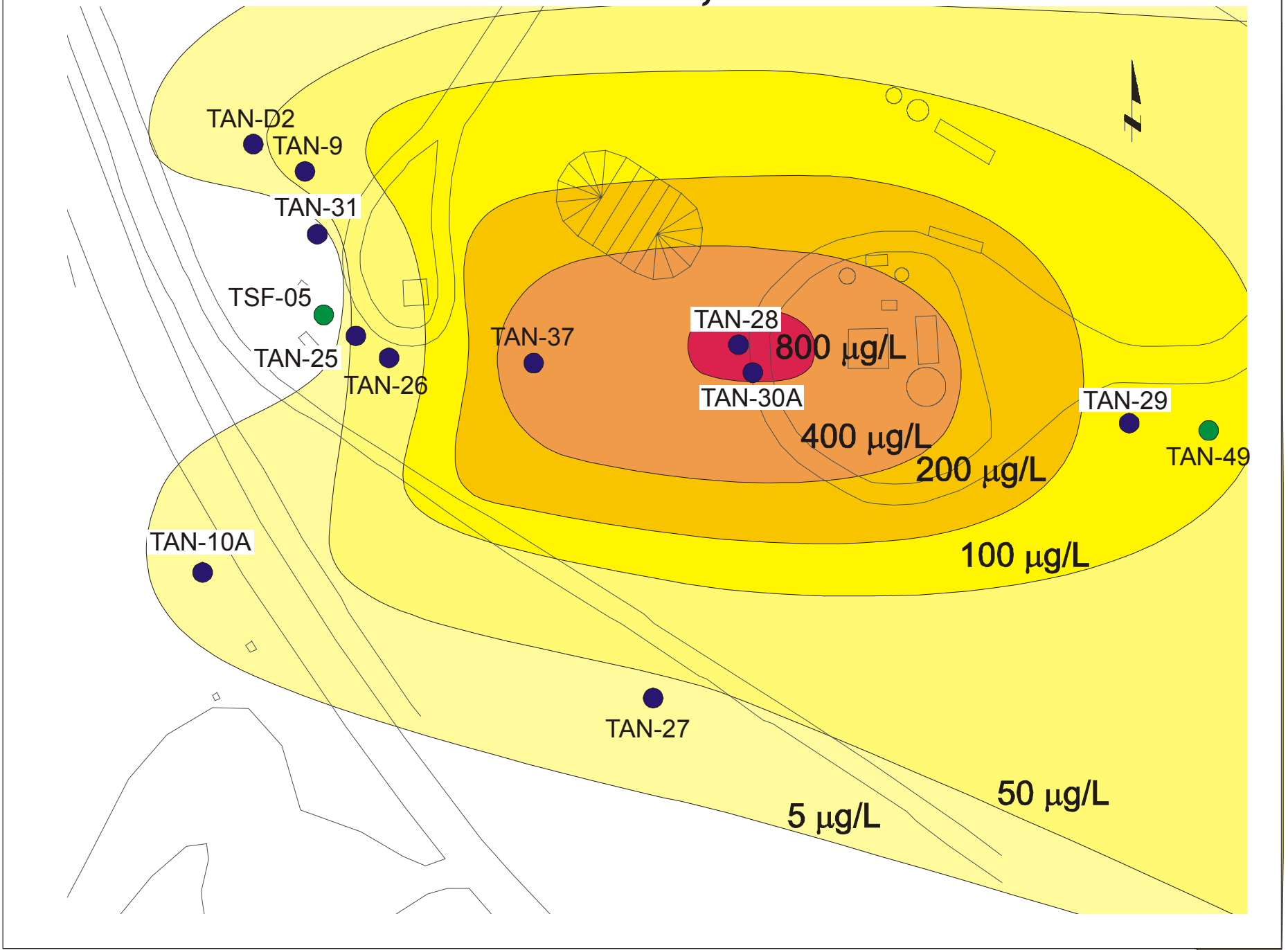


**July 20, 1999**

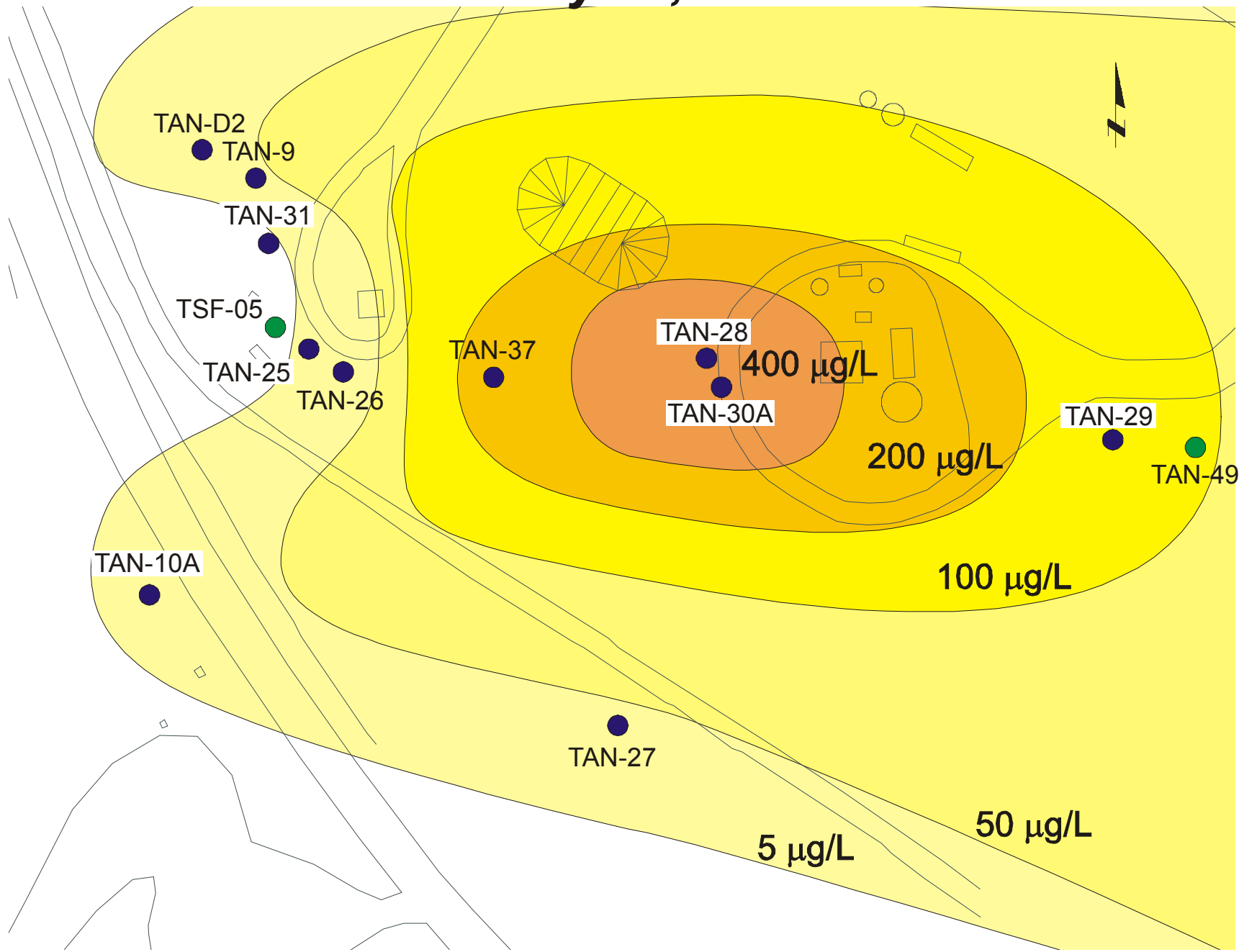




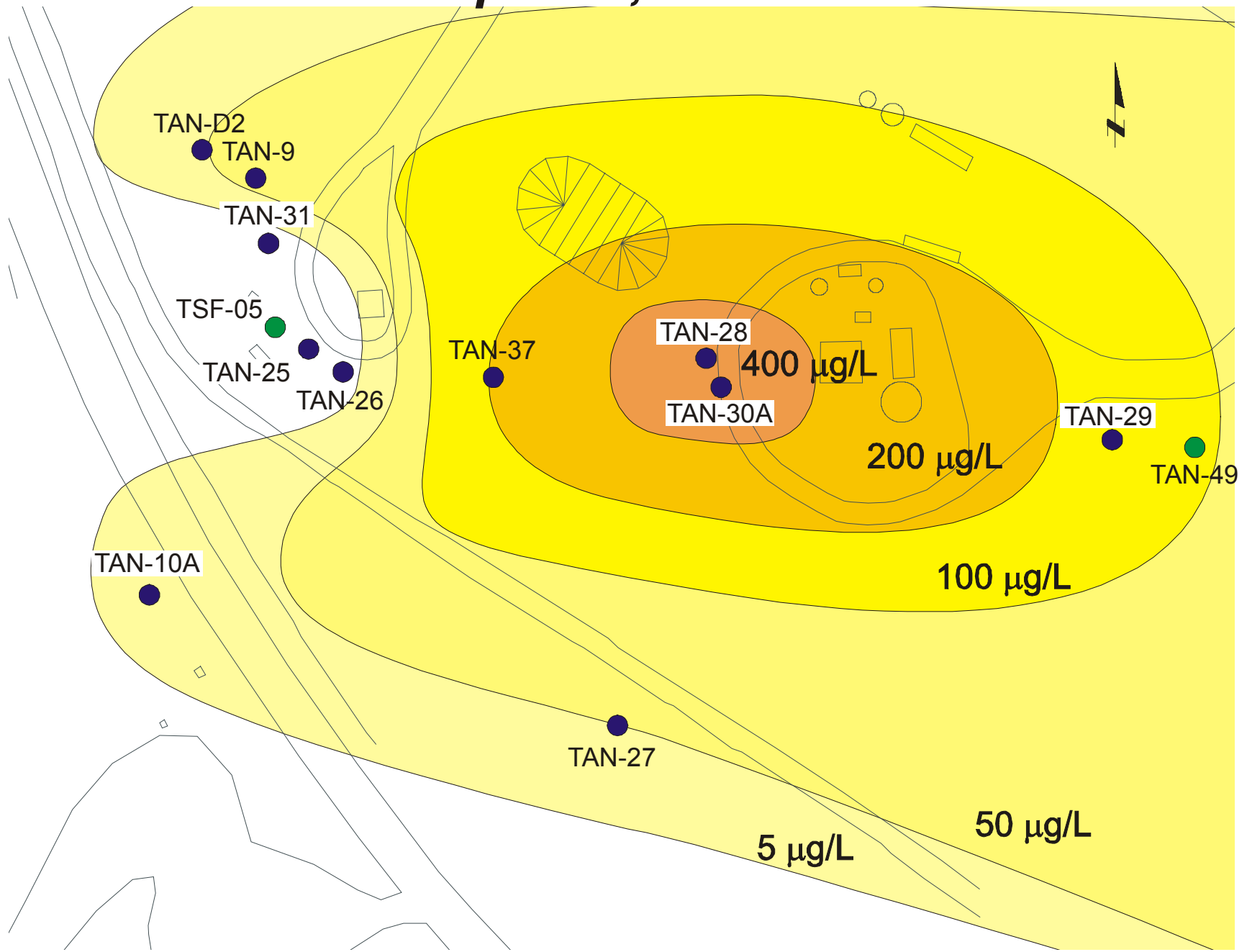
# October 11, 1999



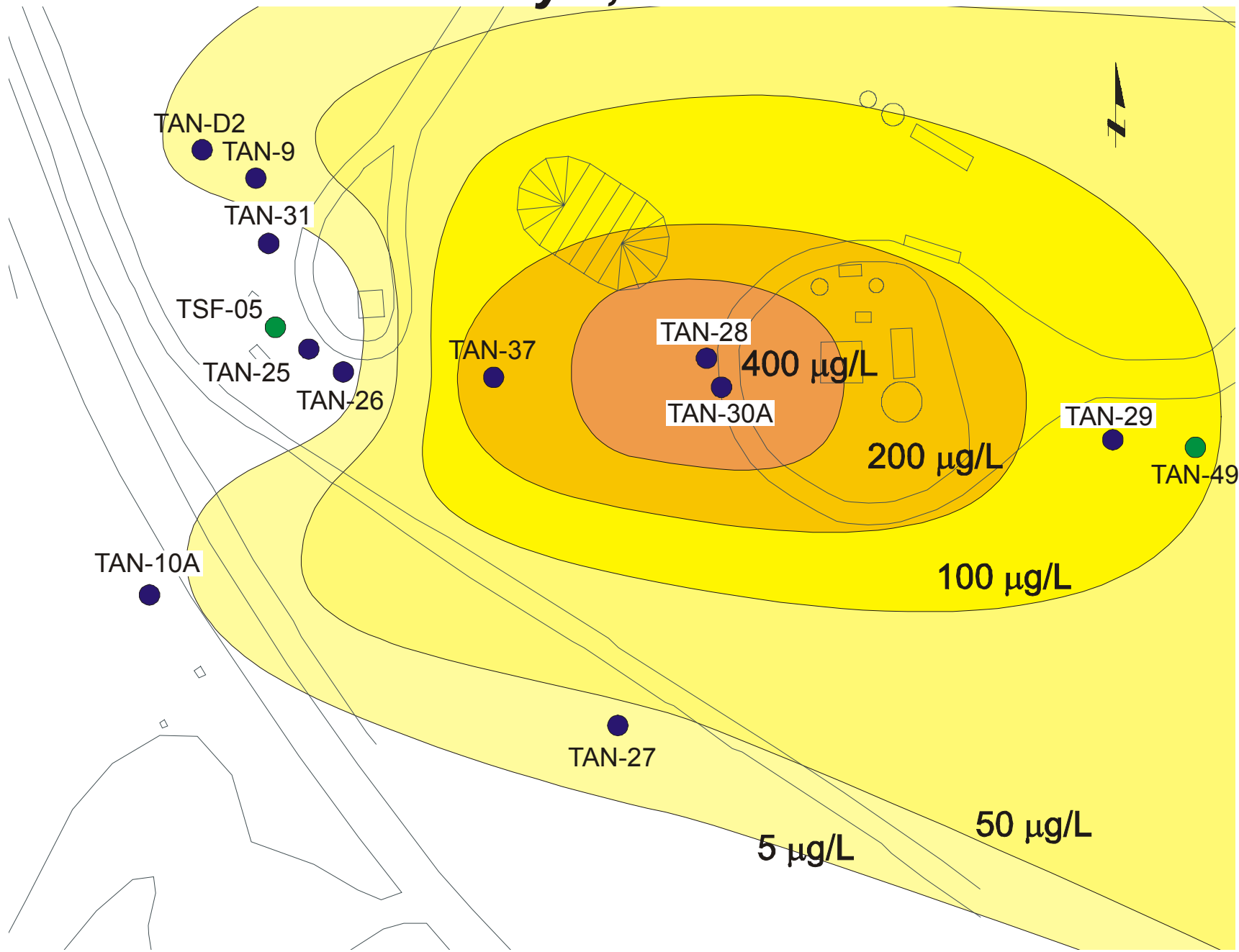
# January 10, 2000



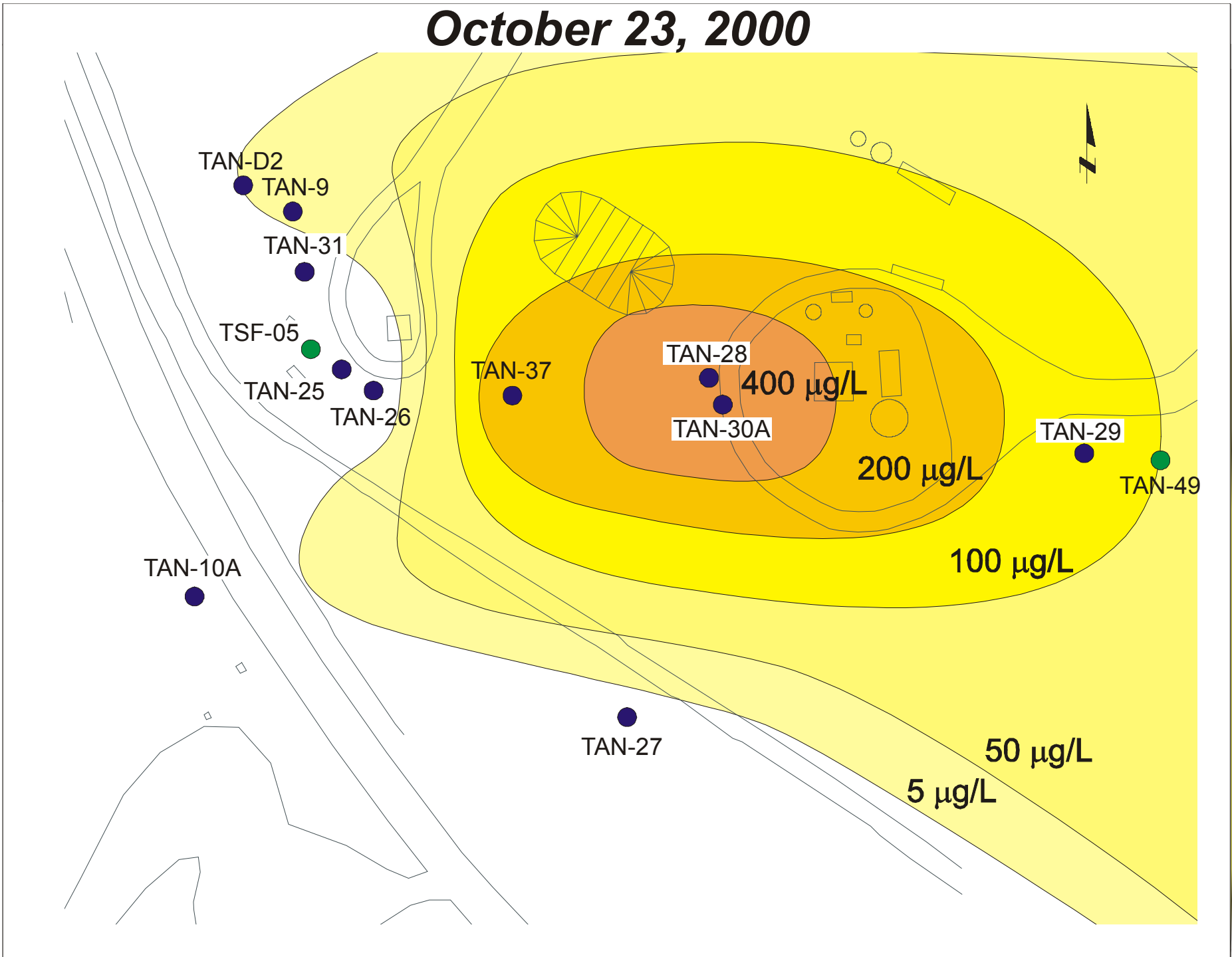
**April 10, 2000**



**July 5, 2000**



# October 23, 2000



# Lessons for Field Application of In Situ Bioremediation

- Dechlorination can be successful in complex settings and is strongly dependent on 2 things:
  - Redox conditions (competing electron acceptors)
  - Electron donor distribution and type

## Lessons (cont.)

- Dechlorination efficiency may be affected by competition among microbial populations, the impact of which can be minimized with an appropriate addition strategy
- Field test kits are very cost-effective and provide near real-time data

# Status of Enhanced In Situ Bioremediation at TAN

- Formal regulatory approval to implement bioremediation at the TAN source area as a replacement for the default remedy has been granted. A proposed plan is going out for public review and will be followed by a ROD amendment.
- Pre-design activities have begun.



# Acknowledgments



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