



**REGENESIS<sup>®</sup>**

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**Integrated in situ Remediation Strategies  
for Large-Scale Chlorinated Solvent  
Contamination at a Complex Site: Technical  
Approach and Outcomes**

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**REGENESIS**

March 2026

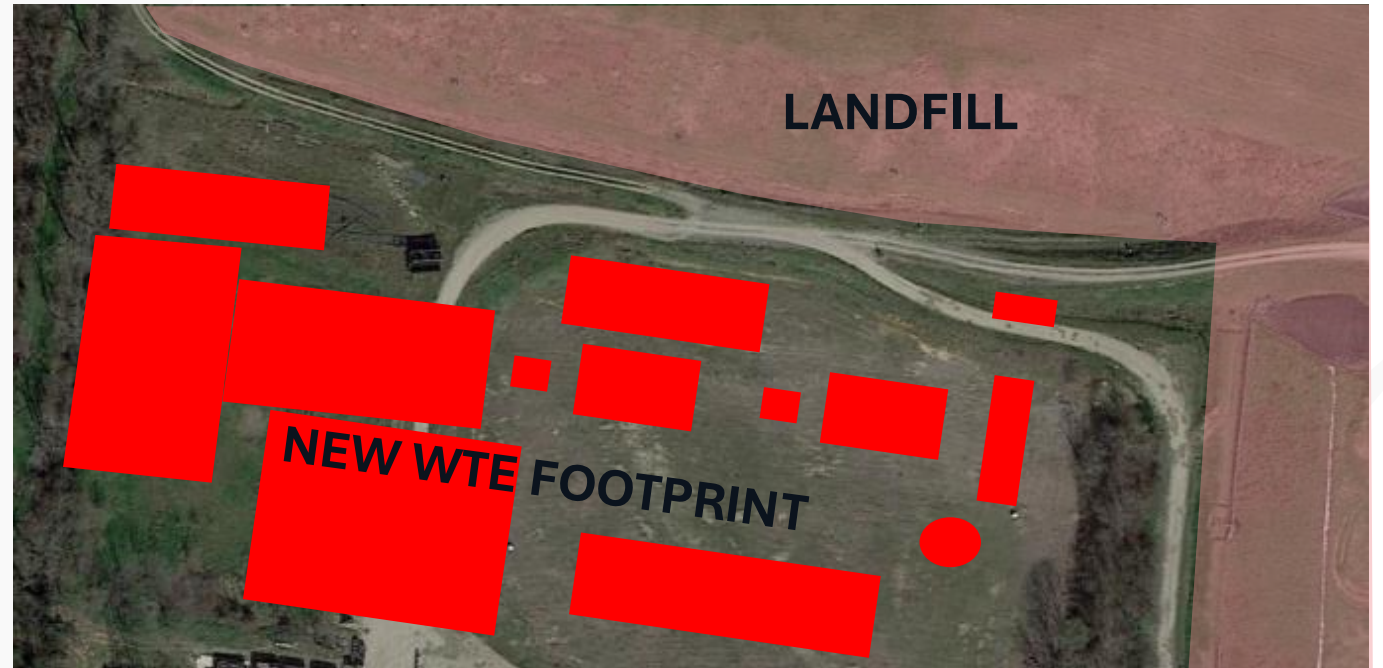
# Presentation Overview

- ❑ Site Background
- ❑ Project Introduction
- ❑ Site Investigation
- ❑ Remediation Goals
- ❑ Technology Selection Process
- ❑ Chosen Technologies
- ❑ Site Activities
- ❑ Results
- ❑ Conclusion
- ❑ Questions



# Site Background

- Current use: management of municipal wastes and some categories of industrial wastes
- A new WTE (Waste-to-Energy) plant is to be built on the site
- The site contains several landfills and waste treatment plants, and a Pump & Treat system on the boundary.
- Total area of the site is 500,000 m<sup>2</sup>
- Former land use: agricultural



# Project Introduction

- During periodic groundwater monitoring, 1,1 DCE was detected in low concentrations ( $< 1 \mu\text{g/l}$ )
- At the beginning no other contaminants found
- No chlorinated solvent waste treated at the site (plants or landfills)
- Chlorinated solvents not used at the site
- At the beginning, it was supposed that 1,1 DCE came from a diffuse pollution in the shallow groundwater or from an external source upgradient of the site



# Site Investigation

Investigation carried out to understand the source of the contamination. The characterisation process was carried out in phases:

**Phase 1:** Installation of monitoring wells and boreholes to identify contamination plume and source

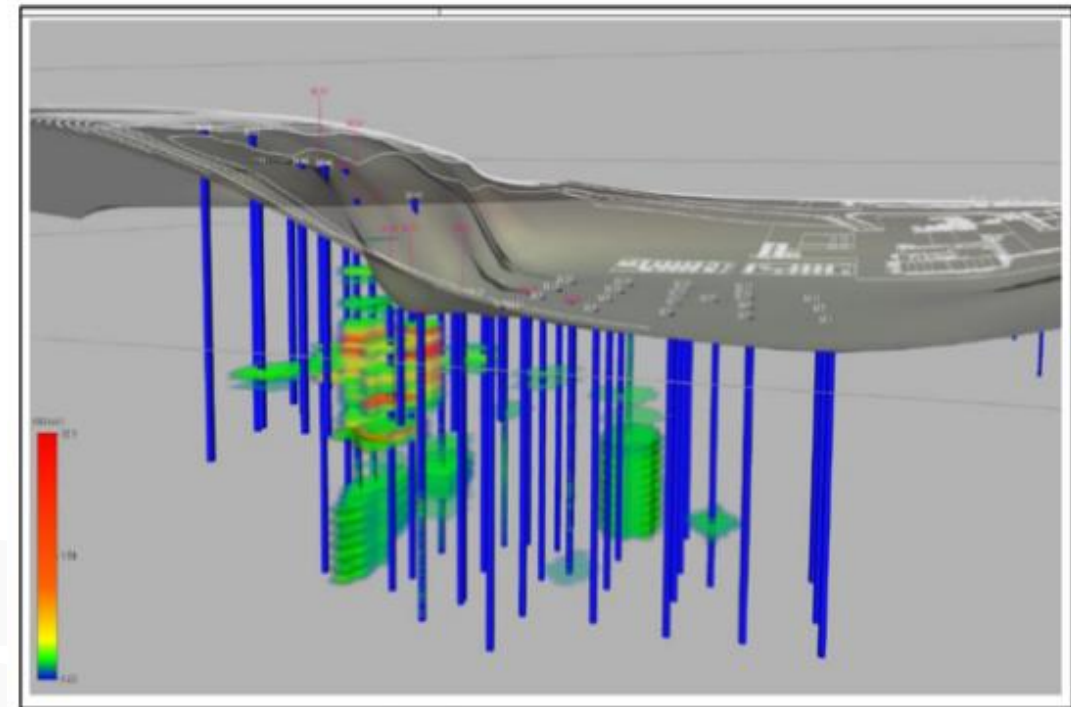
- Found higher 1,1 DCE with traces of TCM and 1,2 DCA in GW
- No contamination in unsaturated soils, and no source identified

**Phase 2:** Membrane Interface Probe (MIP) investigation on a 30x30m grid: 51 MIP points.

- Source identified in saturated soil, corresponding to a historic covered canal

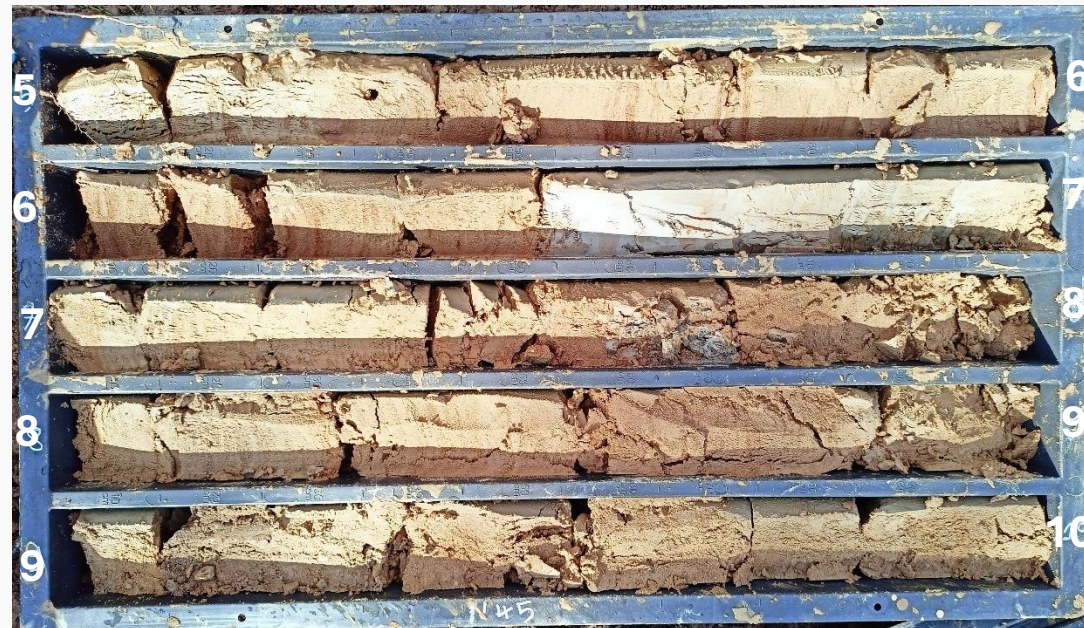
**Phase 3:** Geophysical survey

- Identified an older waste area, but excluded as source using tritium tracer of leachate
- Plume delineation completed

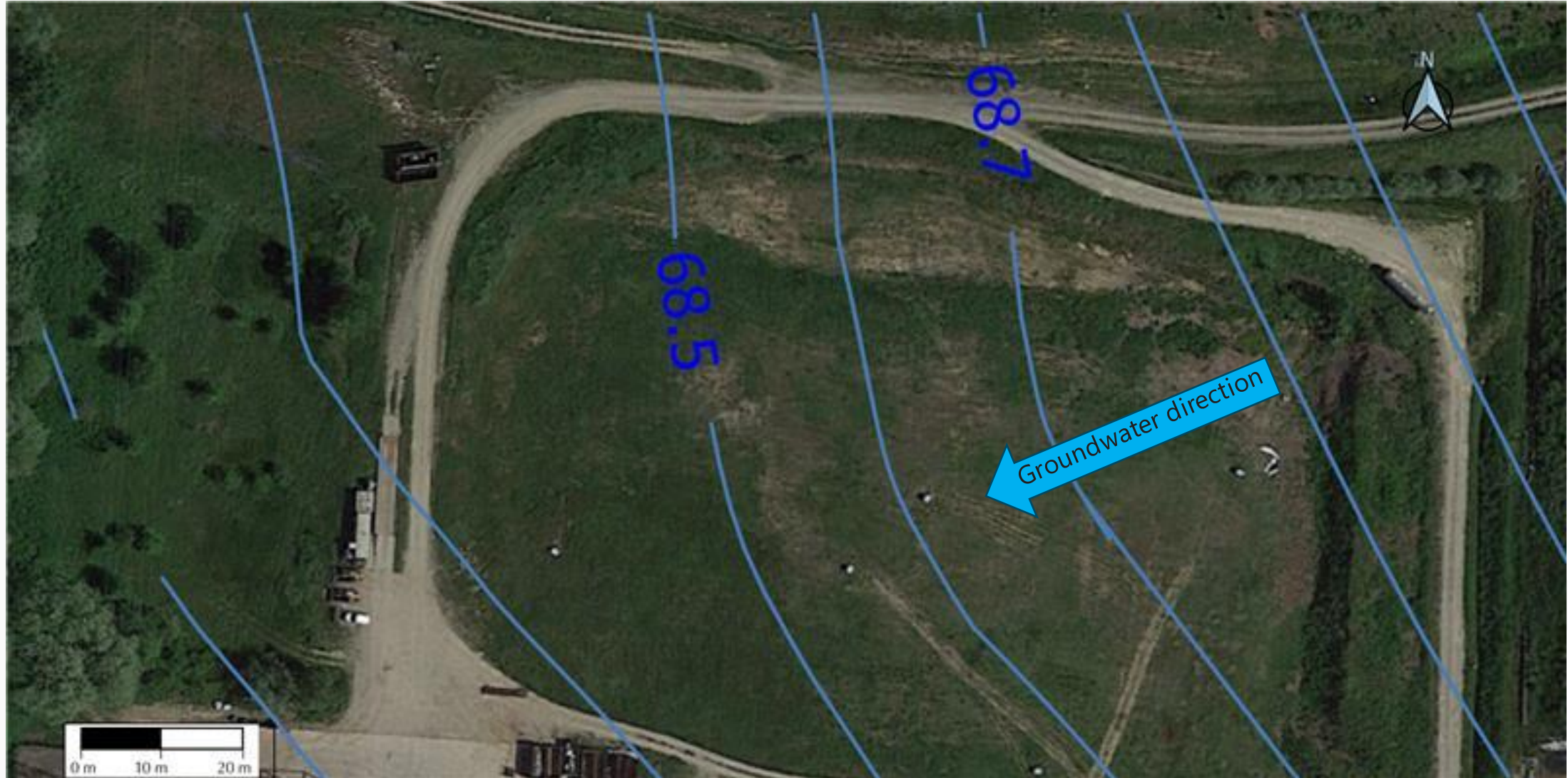


# Geological and Hydrogeological setting

- **Predominant lithology:** sand and silty sand
- **Groundwater depth of shallow aquifer:** 2 m BGL
- **Aquifer thickness:** 9 m
- **Hydraulic conductivity:**  $4.4 \cdot 10^{-4}$  m/s
- **Hydraulic gradient:** 0.3%



# Groundwater direction NE-SW



# Site Investigation Results

Contaminants of Concern: 1,1 DCE; TCM; 1,2 DCA

Maximum contamination values at the source

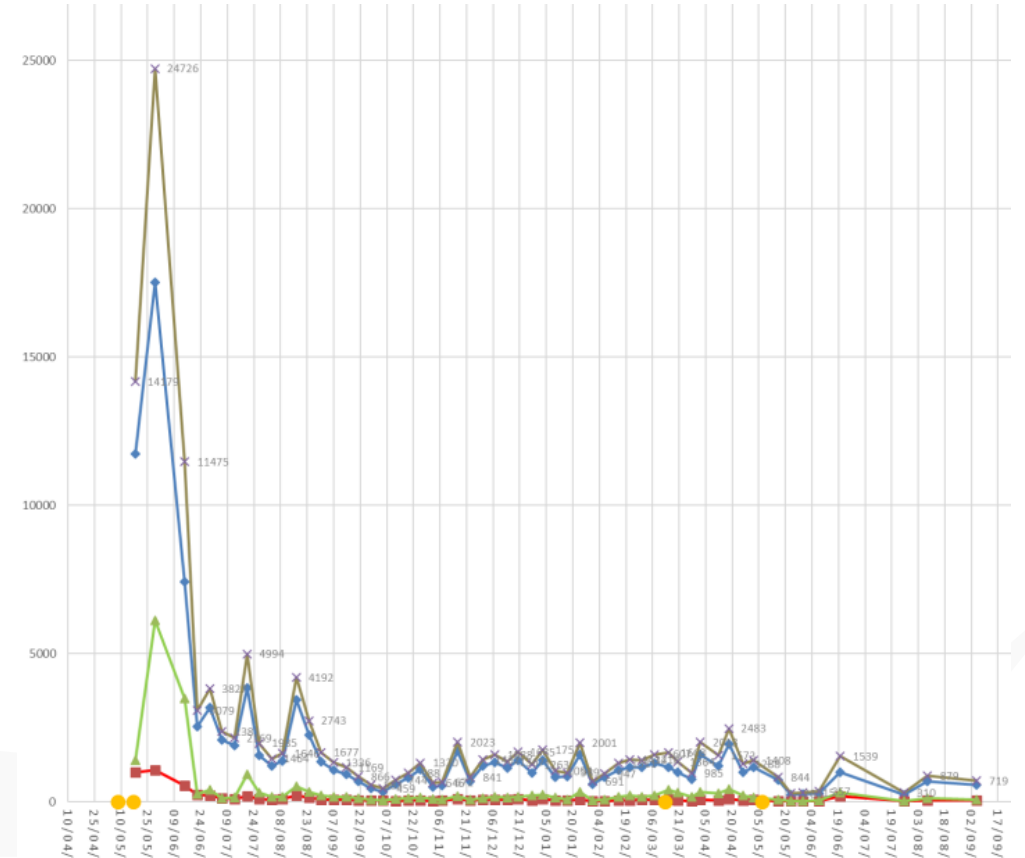
1,1 DCE 6,000 µg/l; TCM 15,000 µg/l; 1,2 DCA 1,000 µg/l

Maximum concentration values at the site boundary (hydraulic barrier):

1,1 DCE 40 µg/l; TCM 1 µg/l; 1,2 DCA 10 µg/l

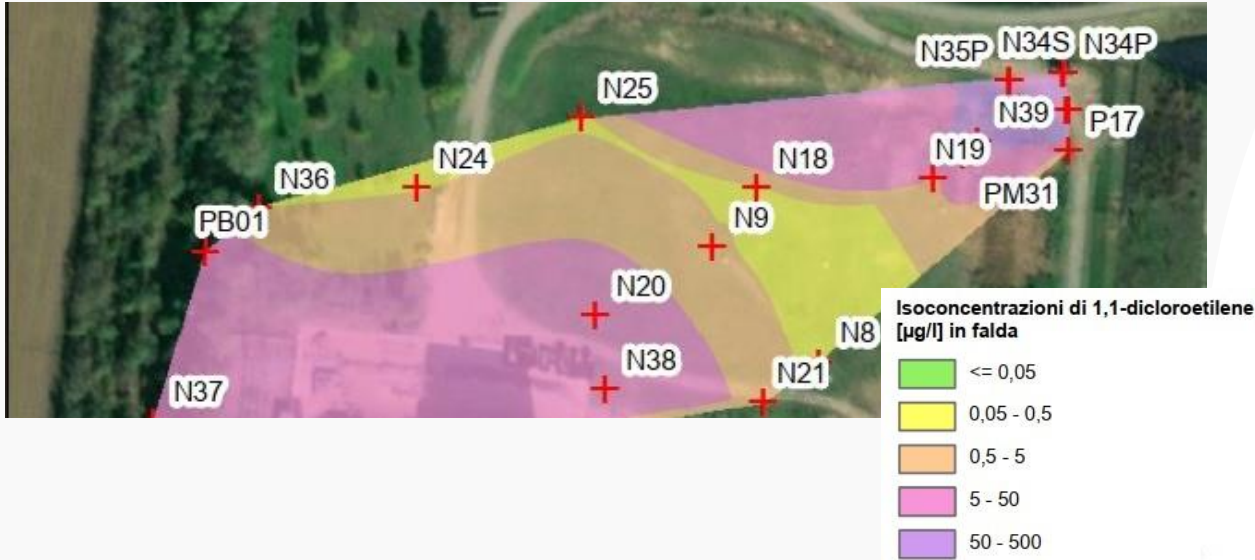
Other aquifer characteristics in the plume

- DO: 0.5-3 mg/l
- Mn 10,000 µg/l max
- Fe 6,000 µg/l max



# Concentrations in groundwater

## 1,1-DCE



## TCM



## 1,2-DCA



## VC



# Remediation Goals

**Pilot test** conducted to evaluate the remediation technology proposed by TAUW and REGENESIS (PlumeStop and HRC).

The remediation project was assigned to TAUW with the following **goals**:

In the short term

- Remediate the site while **minimizing interference with construction** of the new plant, which involves building foundations in the plume area
- **Reduce/maintain contamination** below risk threshold values from risk assessment

In the long term

- Allow the **shutdown of the hydraulic barrier** at the site boundary

# Site challenges

- Wide area to be remediated (20,000 m<sup>2</sup>)
- Wide range of chlorinated solvents present
  - Not the most common chlorinated ethenes (PCE, TCE, 1,2-DCE, VC)
  - Chloromethanes (chloroform, chloromethane)
  - Chloroethanes (1,2-DCA)
  - Chloroethenes (1,1-DCE, VC)
- Low starting concentrations
  - Treating low level diffuse concentrations is more difficult
- Very stringent targets
- Geology with clayey layers
- Shallow aquifer (risk of daylighting)
- Limited timeframe for application
- Overlapping with other remediation activities to be managed

# Treatment Goals

Table limits (CSC) on the entire site (source and plume):

- 1,1-DCE: 0.05 µg/L
- VC: 0.5 µg/L
- 1,2-DCA: 3.0 µg/L
- TCM: 0.15 µg/L

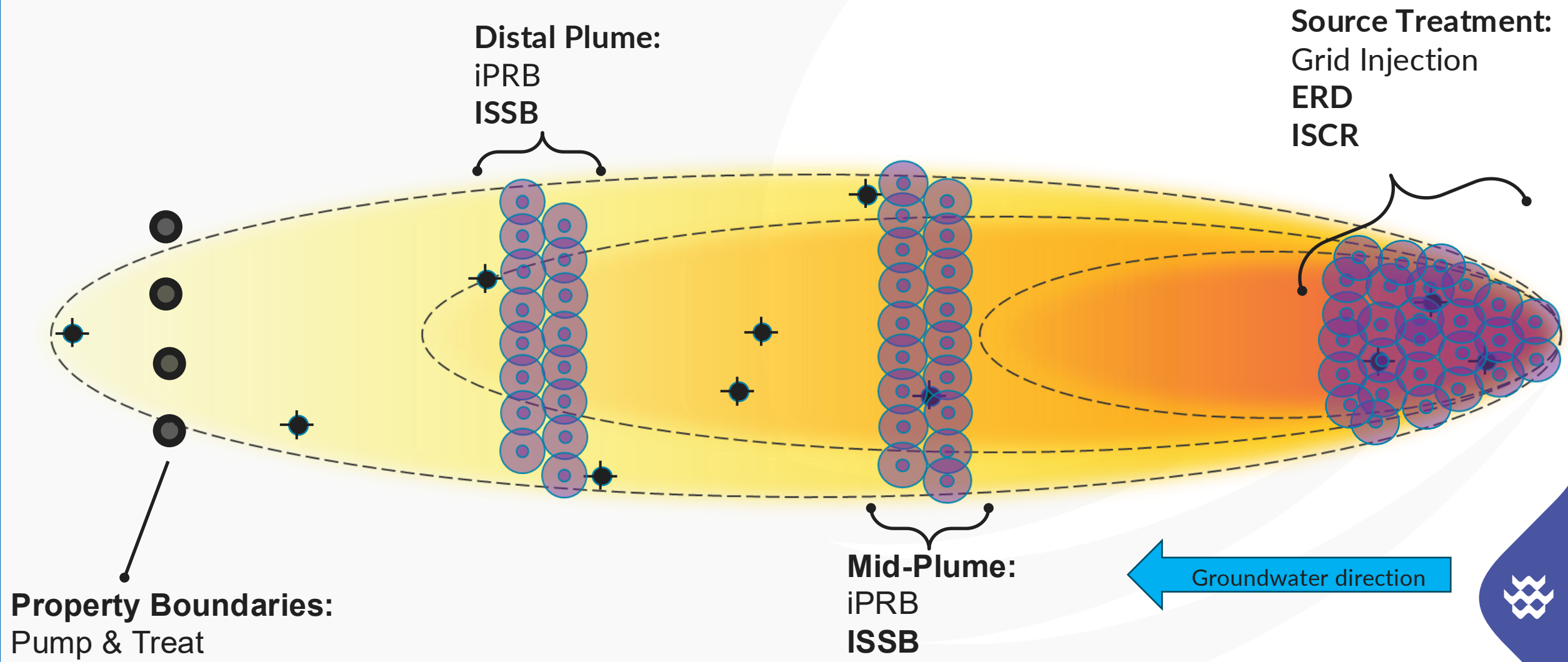
P&T needs to remain active until complete remediation is achieved

- Need to evaluate possible interference between P&T and injections

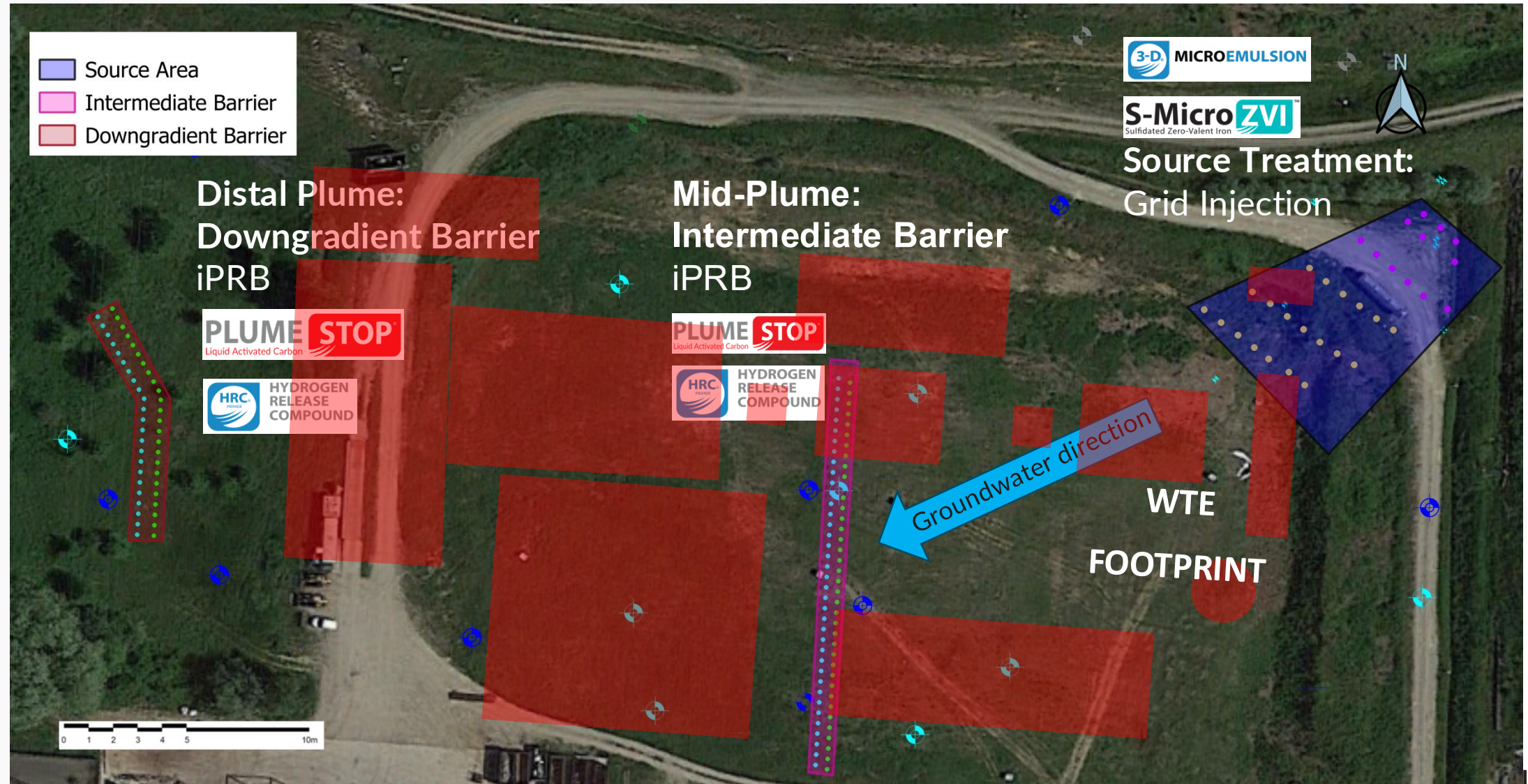
# Technology Selection

- Needed fast treatment
  - Minimize interference on site
    - Allow for WTE construction while remediation is ongoing
    - No treatment plants
  - High efficiency with low concentrations and extremely stringent targets
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- In situ injections – one shot
  - Highly engineered substrates – long lasting reagents
  - Combination of technologies
    - ERD – Enhanced Reductive Dechlorination
    - ISCR – In Situ Chemical Reduction
    - ISSB – In Situ Sorption and Biodegradation

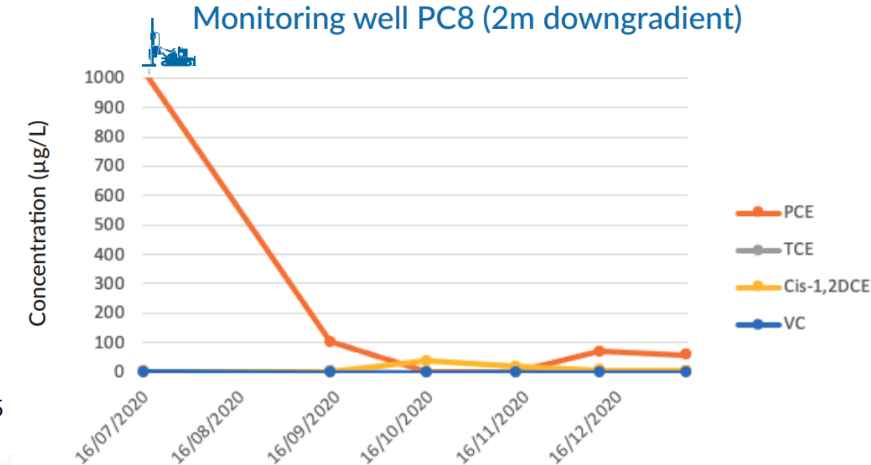
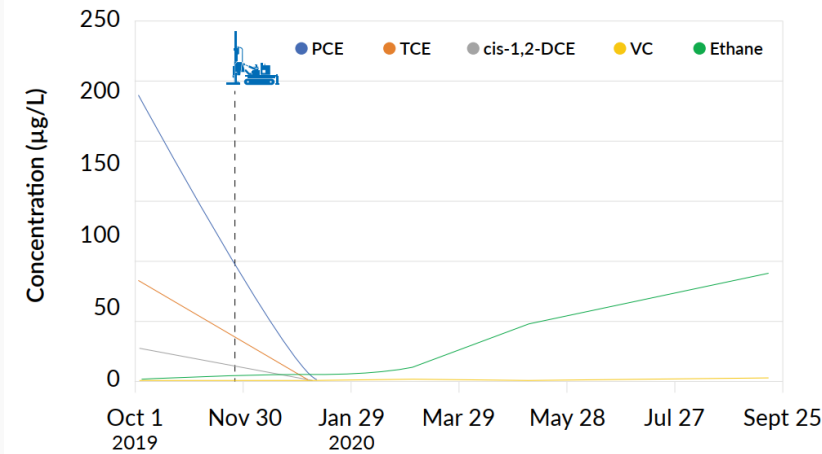
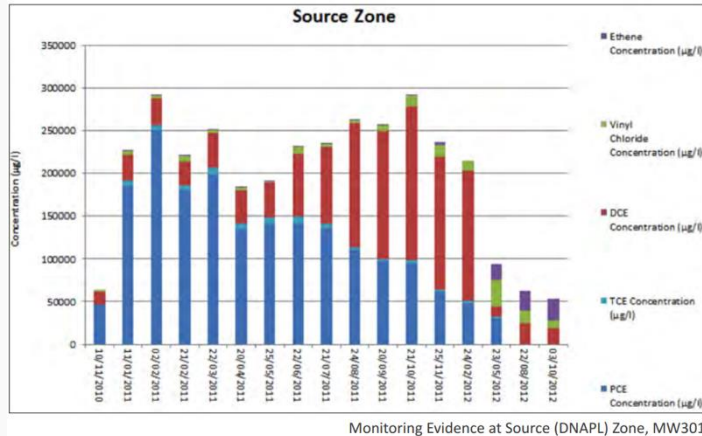
# Groundwater Remediation Concept



# Injection Layout



# Selected *in situ* technologies

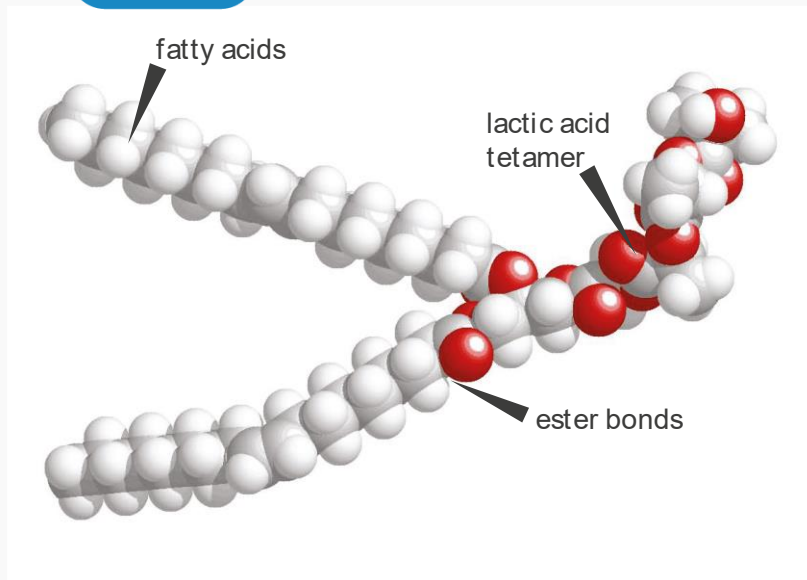


Self-distributing 5 years staged released, electron donor for complete reductive dechlorination

Rapid and permeant contaminant mass reduction

Fast parent compound destruction with minimal daughter product formation

# Enhanced Reductive Dechlorination

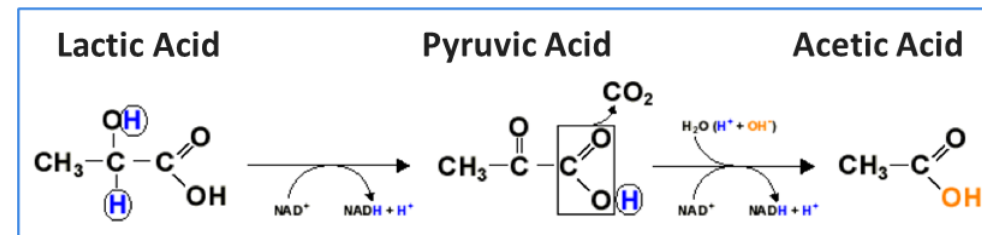


The molecular structure of 3-D Microemulsion®

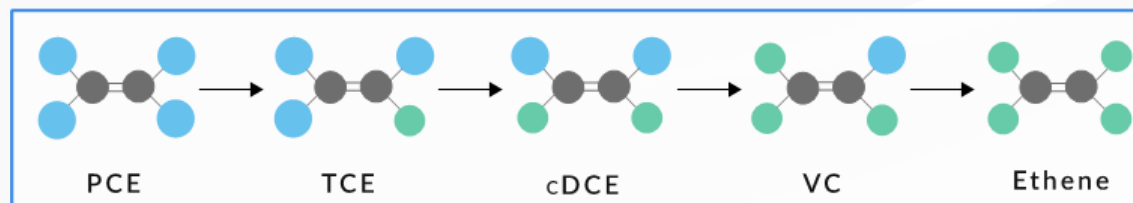


Dissolution

Fermentation



Enhanced Reductive Dechlorination



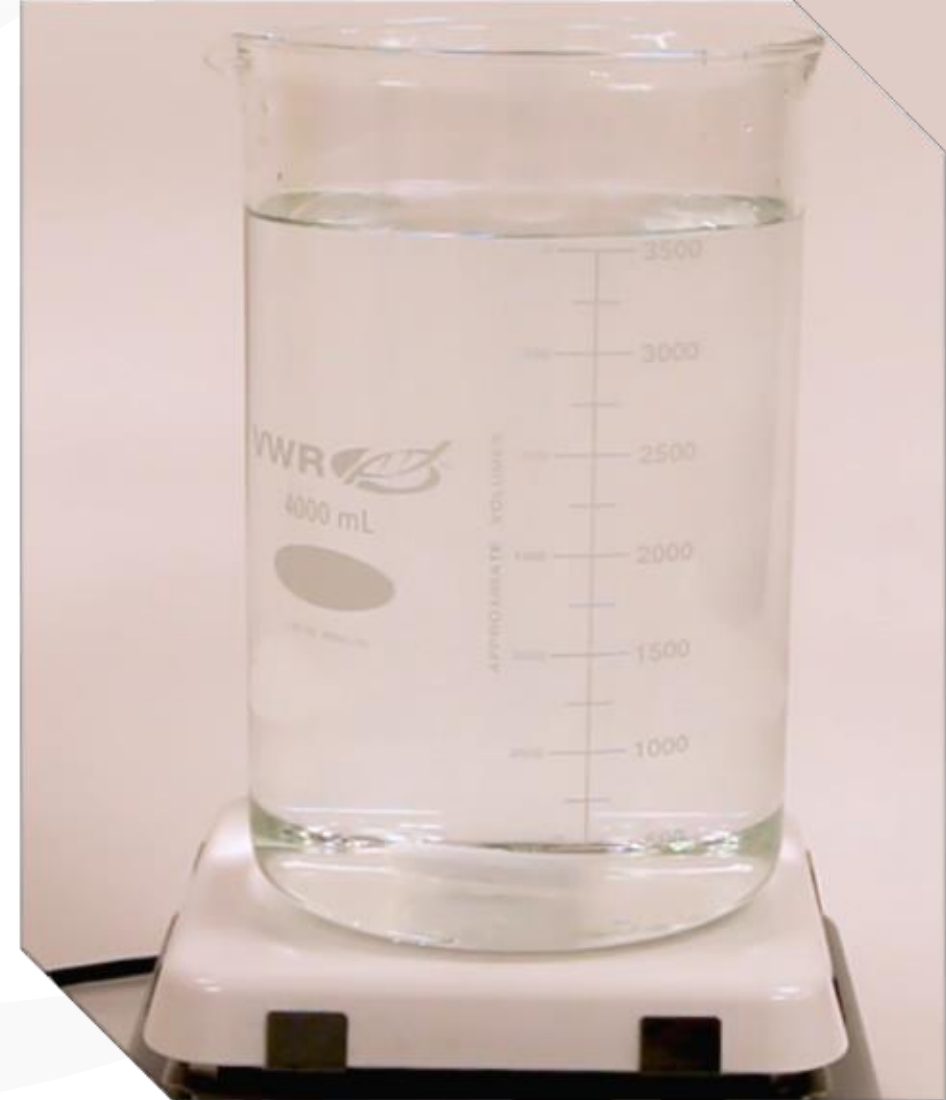


# Colloidal Activated Carbon

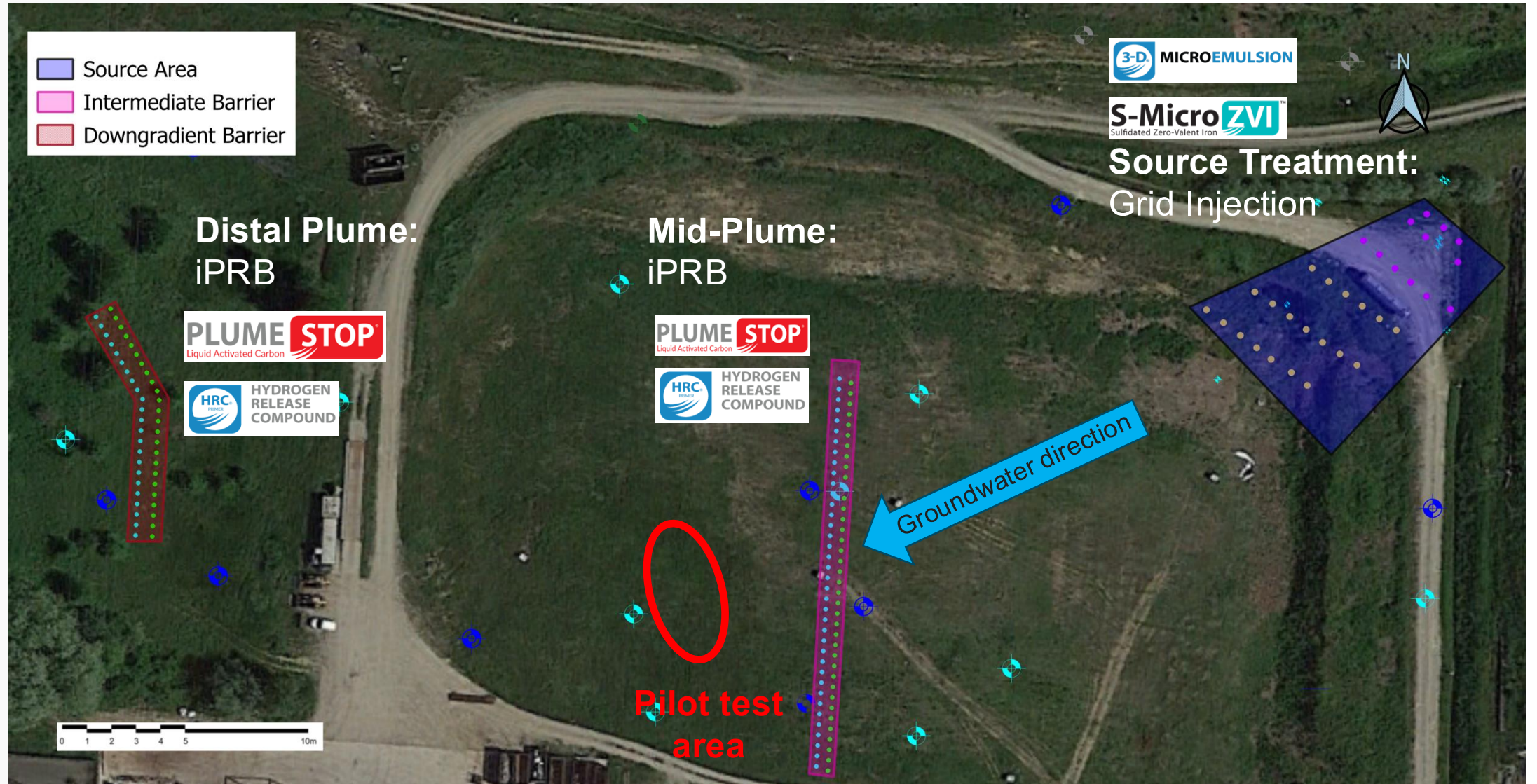
## What is it?



- Liquid activated carbon
- Particle sizes 1 – 2  $\mu\text{m}$
- Suspended as a colloid in a polymer solution
- Distributes widely under low pressure
- Provides extremely fast sorption sites
- Converts underlying geology into purifying filter
- Granular Activated Carbon (GAC)
  - 1-2 mm
  - Only ex situ
- Powder Activated Carbon (PAC)
  - 20-200 micron
  - High pressure
  - Fracturing
- Colloidal Activated Carbon (CAC)
  - 1-2 micron



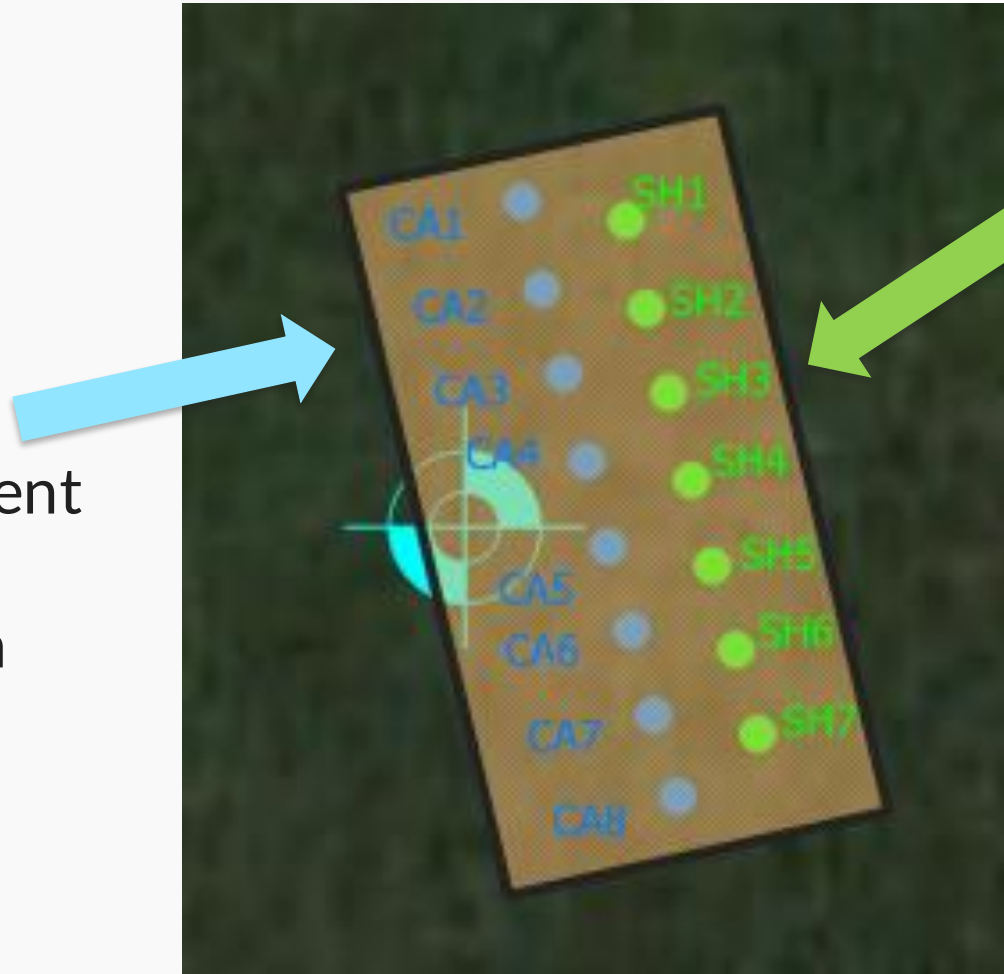
# Pilot Test



# Pilot Test Configuration

## CAC - PLUMESTOP

- 2 m spacing
- 8 injection points
- 2-12 m bgs treatment
- ab. 450 kg/point
- ab. 6500 L solution

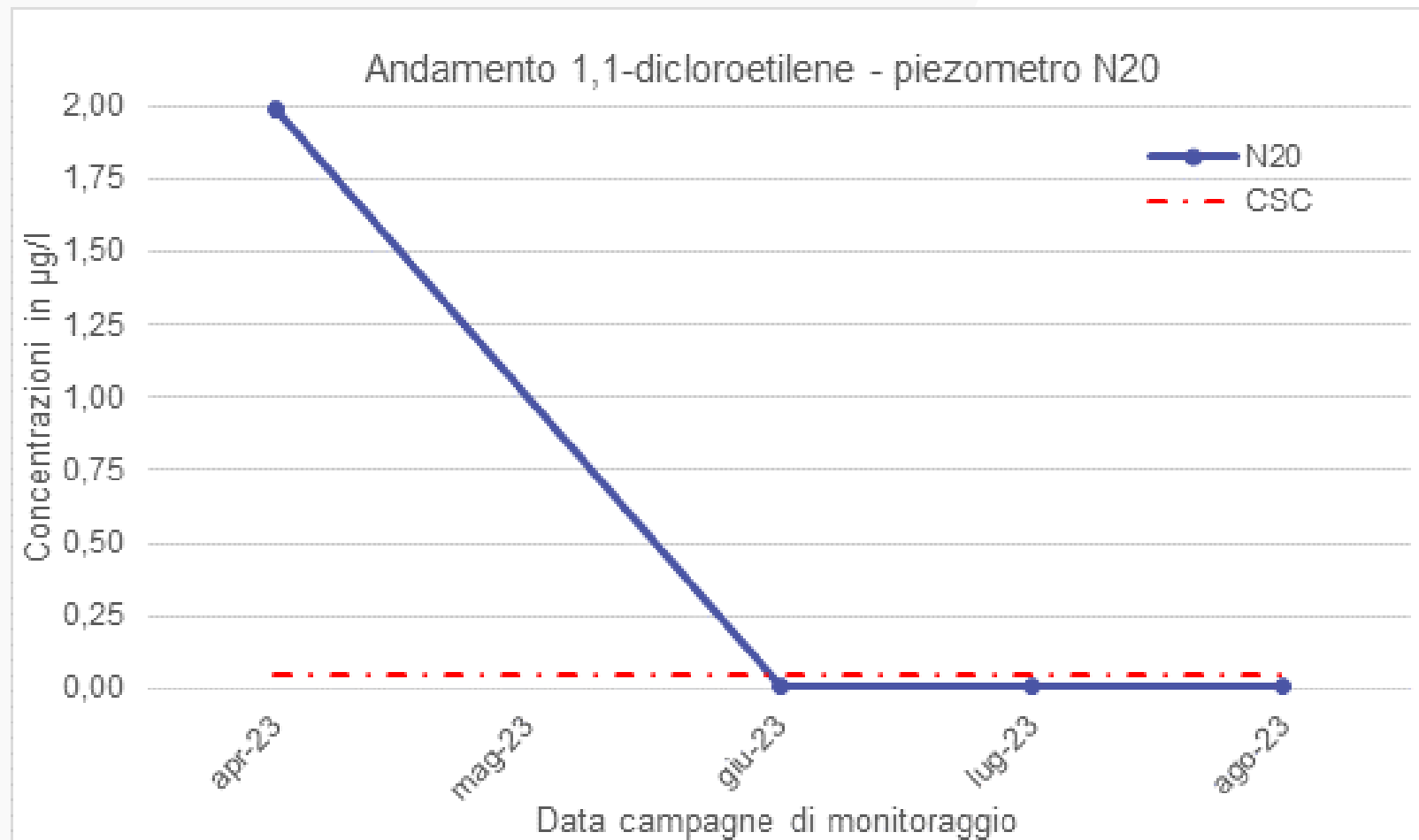


## ELECTRON DONOR - HRC

- 2 m spacing
- 7 injection points
- 2 m upgradient PSTOP barrier
- 2-12 m bgs treatment
- ab. 160 kg/point
- ab. 160 L pure product

# Pilot Test Results

## 1,1-DCE



- <D.L. (<0.005 µg/L)
- Target (CSC): 0.05 µg/L
- Fast decrease
- Stable results

# Full Scale Layout and Details

## Source Area



### HIGH SULPHATES

- 3x5/4x6 m grid
- Higher 3DMe dose splitted in
  - 2-7 m bgs
  - 7-12 m bgs
- Uniform SmZVI dose 2-12 m bgs
- ab. 5500 L injection volume

### LOW SULPHATES

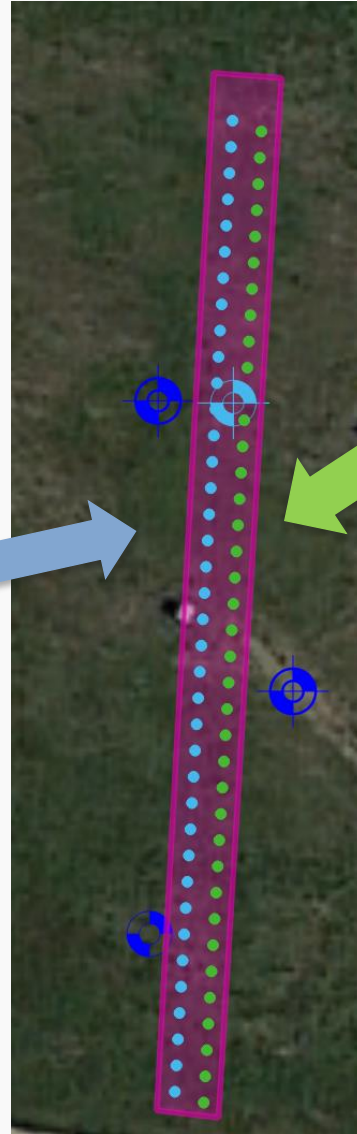
- 3x8/4x10 m grid
- Lower 3DMe dose splitted in
  - 2-7 m bgs
  - 7-12 m bgs
- Uniform SmZVI dose 2-12 m bgs
- ab. 5300 L injection volume

# Full Scale Layout and Details

## Intermediate Barrier

### CAC - PLUMESTOP

- 2 m spacing
- 30 inj. points
- 2-12 m bgs treatment
- ab. 450 kg/point
- ab. 6500 L solution



### ELECTRON DONOR - HRC

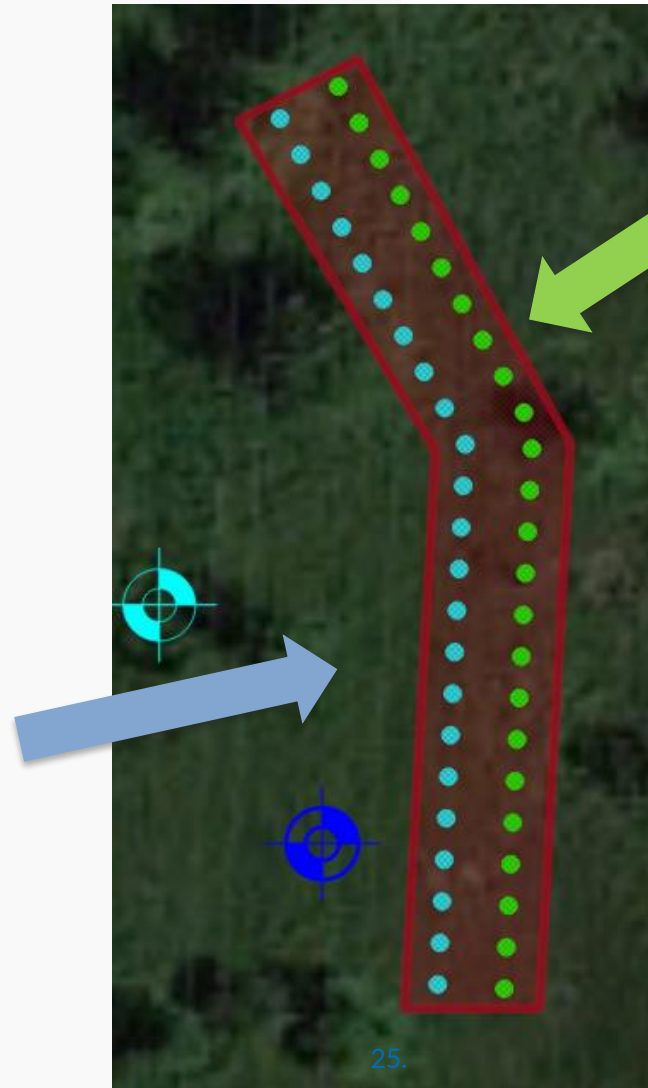
- 2 m spacing
- 31 injection points
- 2 m upgradient PSTOP barrier
- 2-12 m bgs treatment
- ab. 160 kg/point
- ab. 160 L pure product

# Full Scale Layout and Details

## Downgradient Barrier

### CAC - PLUMESTOP

- 2 m spacing
- 23 injection points
- 2-12 m bgs treatment
- ab. 450 kg/point
- ab. 6500 L solution



### ELECTRON DONOR - HRC

- 2 m spacing
- 24 injection points
- 2 m upgradient PSTOP barrier
- 2-12 m bgs treatment
- ab. 160 kg/point
- ab. 160 L pure product

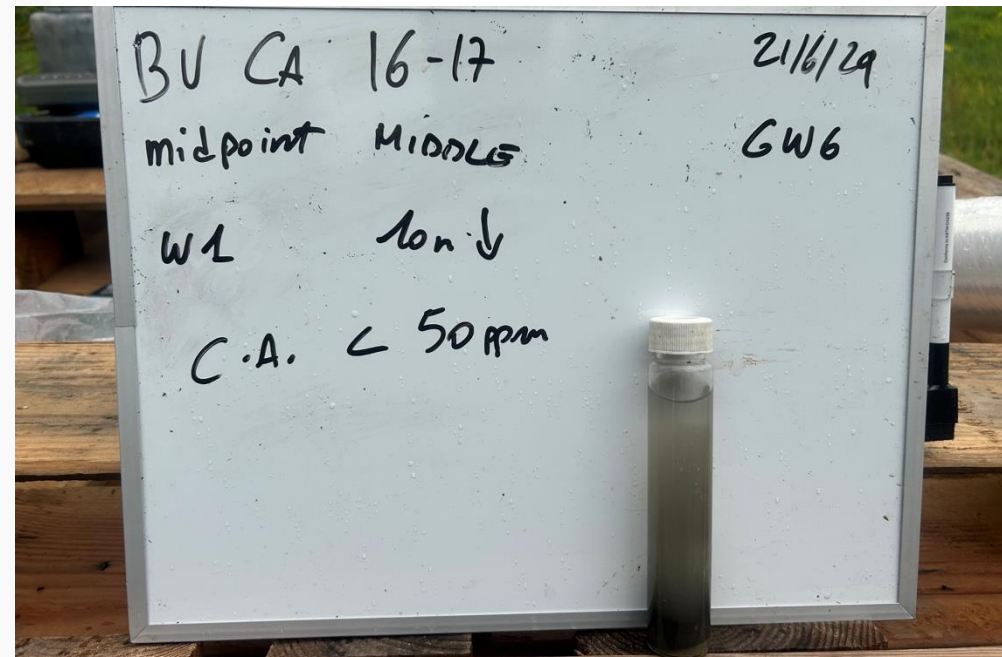


# Source area injections



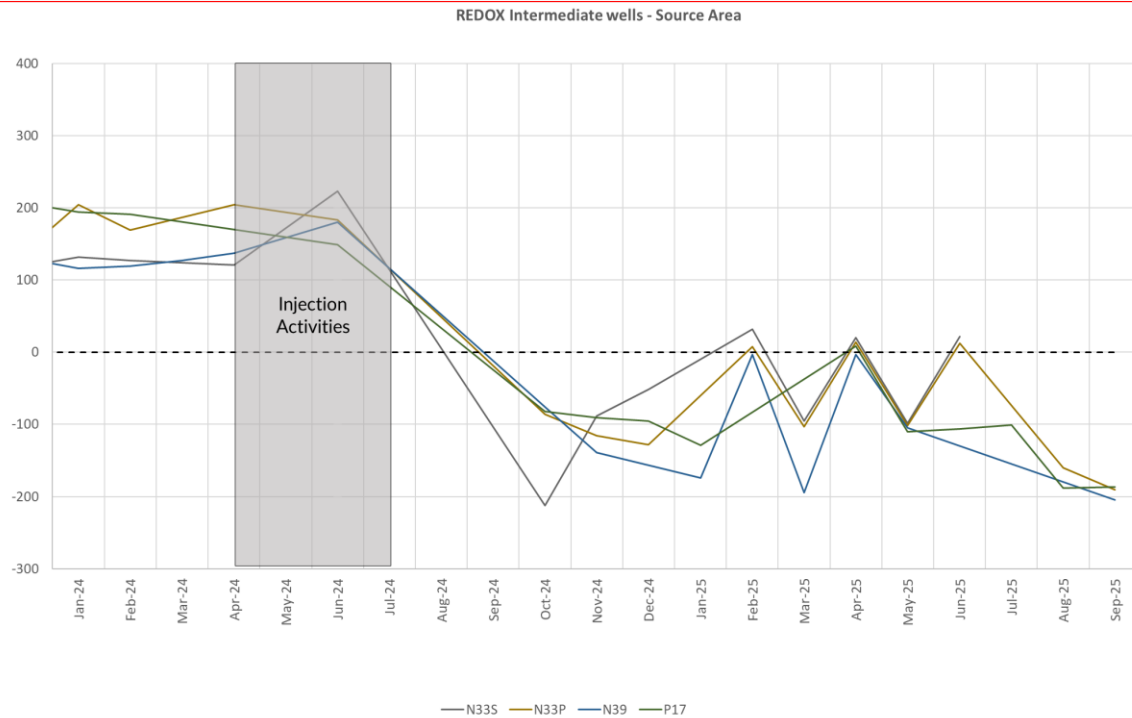
# Verification Testing

- Soil cores
  - 4 points in the Intermediate Barrier 6 to 9 m deep
  - 6 in the Downgradient Barrier 13 to 15 m deep
- Groundwater samples
  - 10 direct push GW sampling points with 3 samples per point (30 samples in total)
  - daily groundwater checking in monitoring wells close to injection points

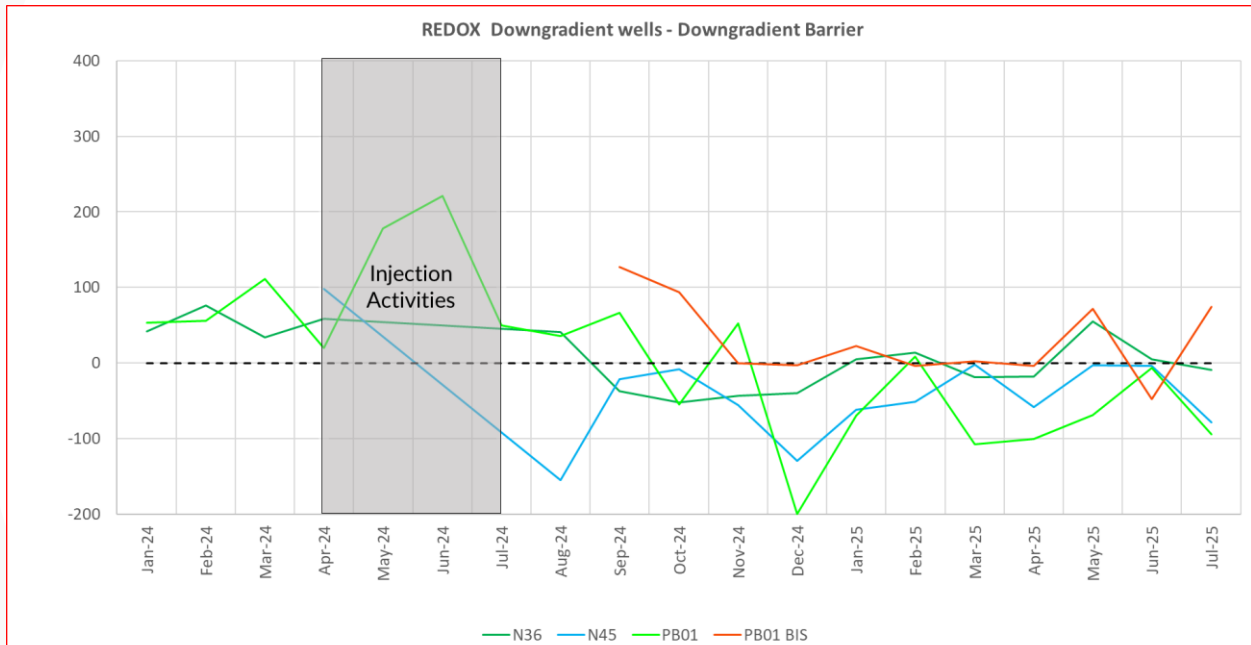


# Full Scale results – RedOx Potential

## Source Area



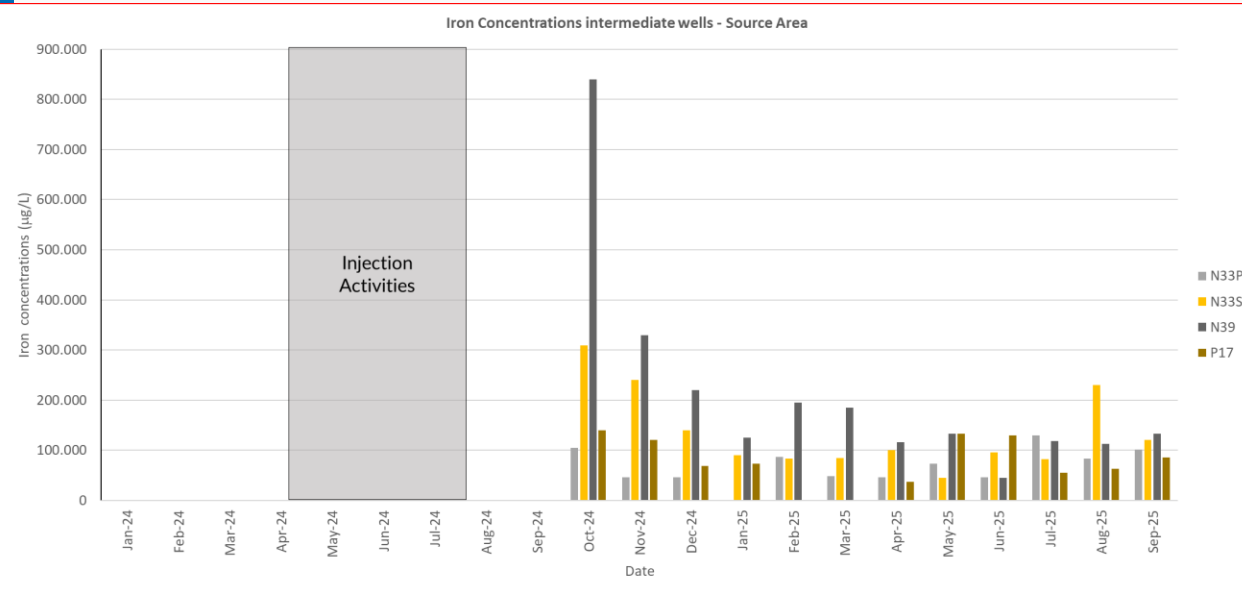
## Barriers



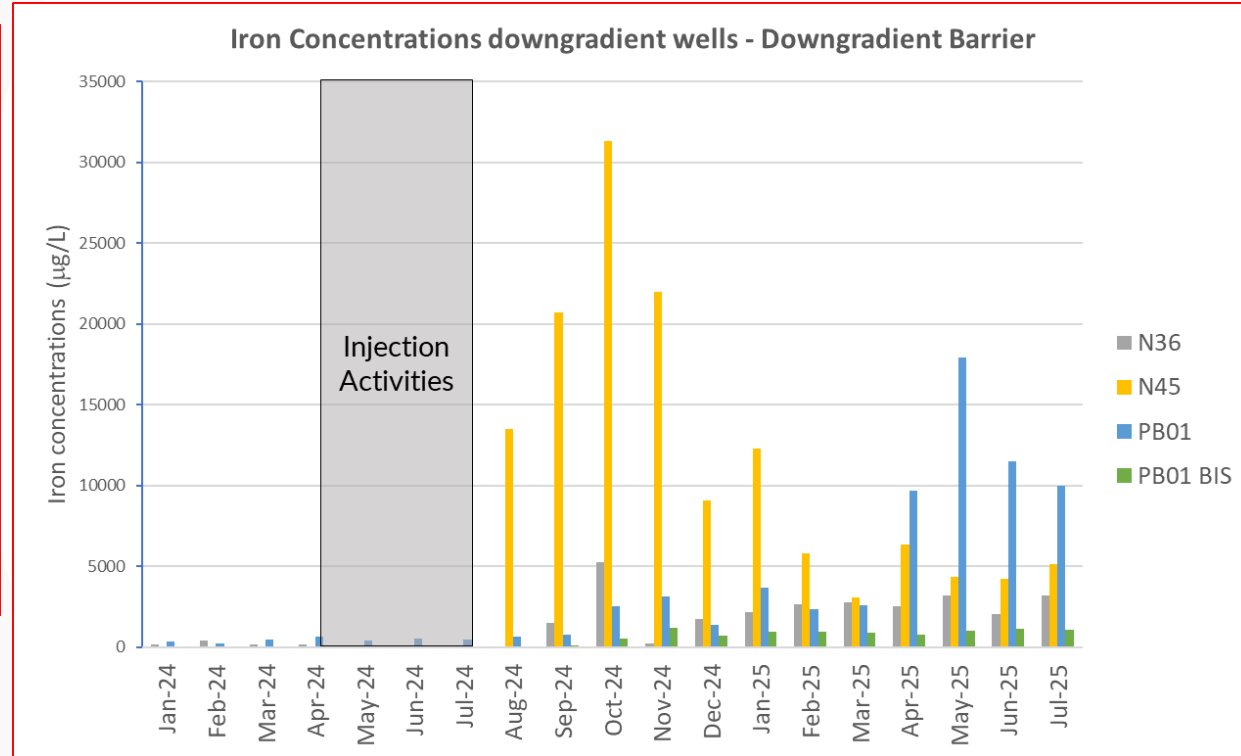
- Similar decrease observed during pilot test
- Values remain low over the entire monitoring period available (>1 year): long term release

# Full Scale results – Dissolved Iron

## Source Area



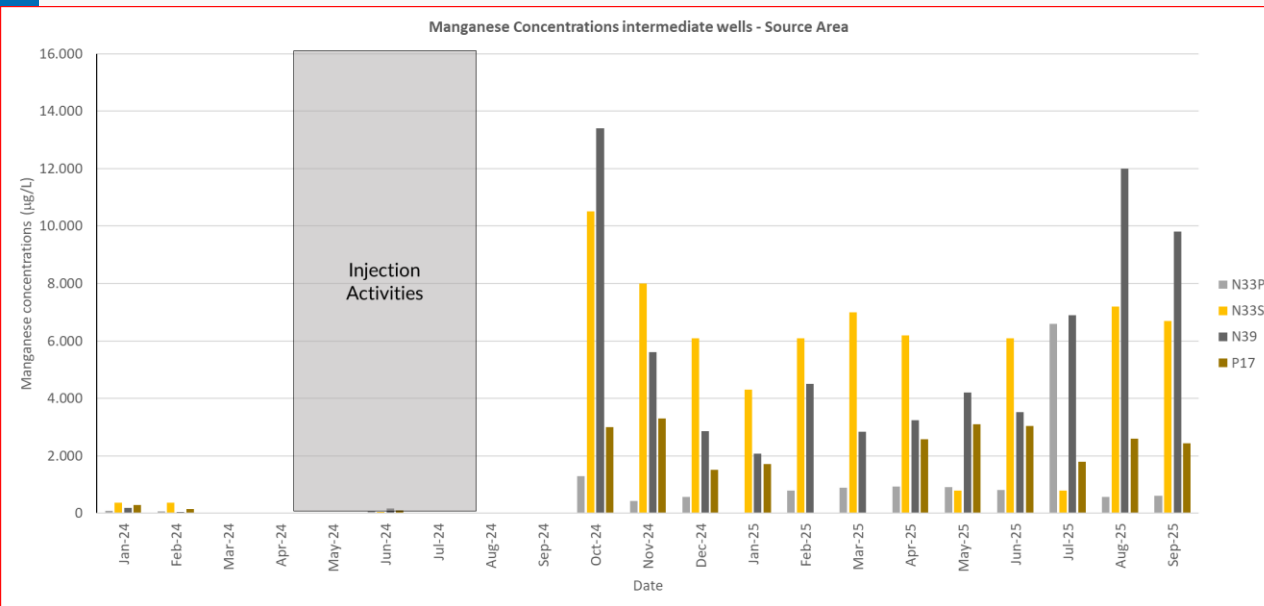
## Barriers



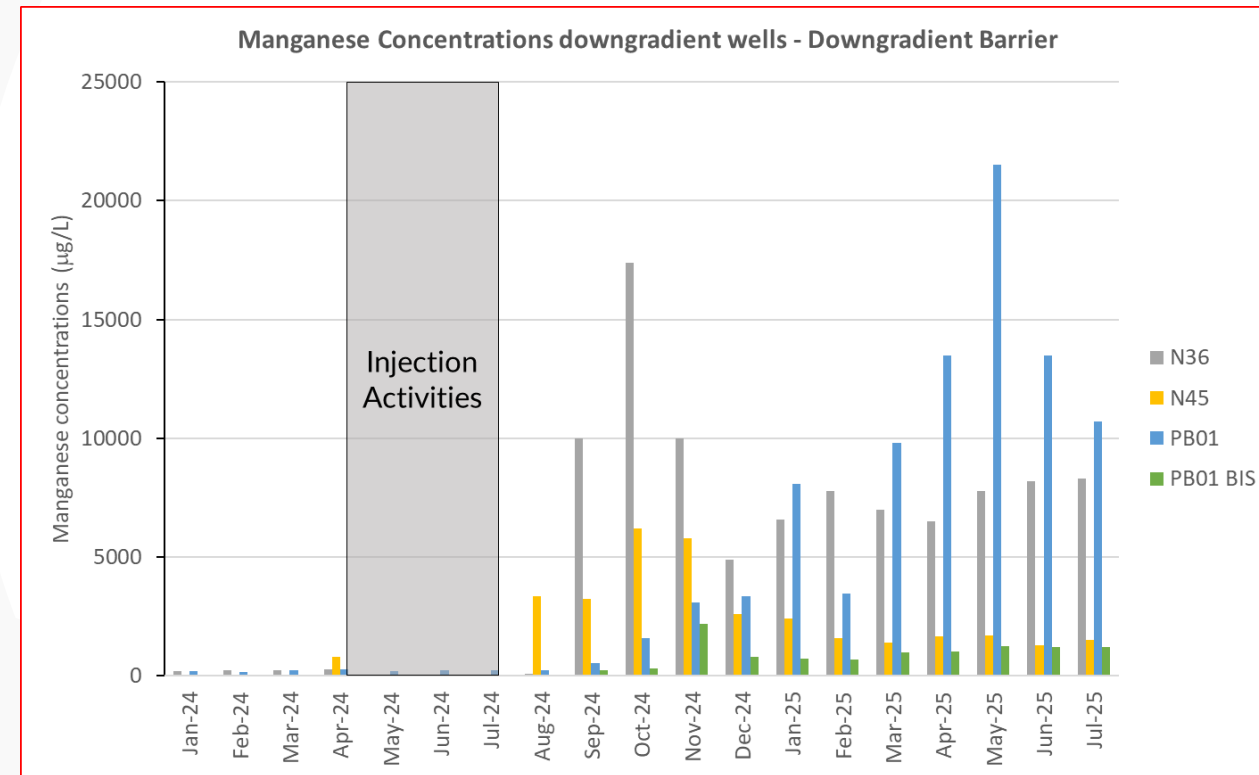
- Significant increase in dissolved iron ( $\text{Fe}^{2+}$ ) – reduced form
  - Effect of reducing conditions
  - Values maintained high over the entire monitoring period (>1 year)

# Full Scale results – Dissolved Manganese

## Source Area



## Barriers

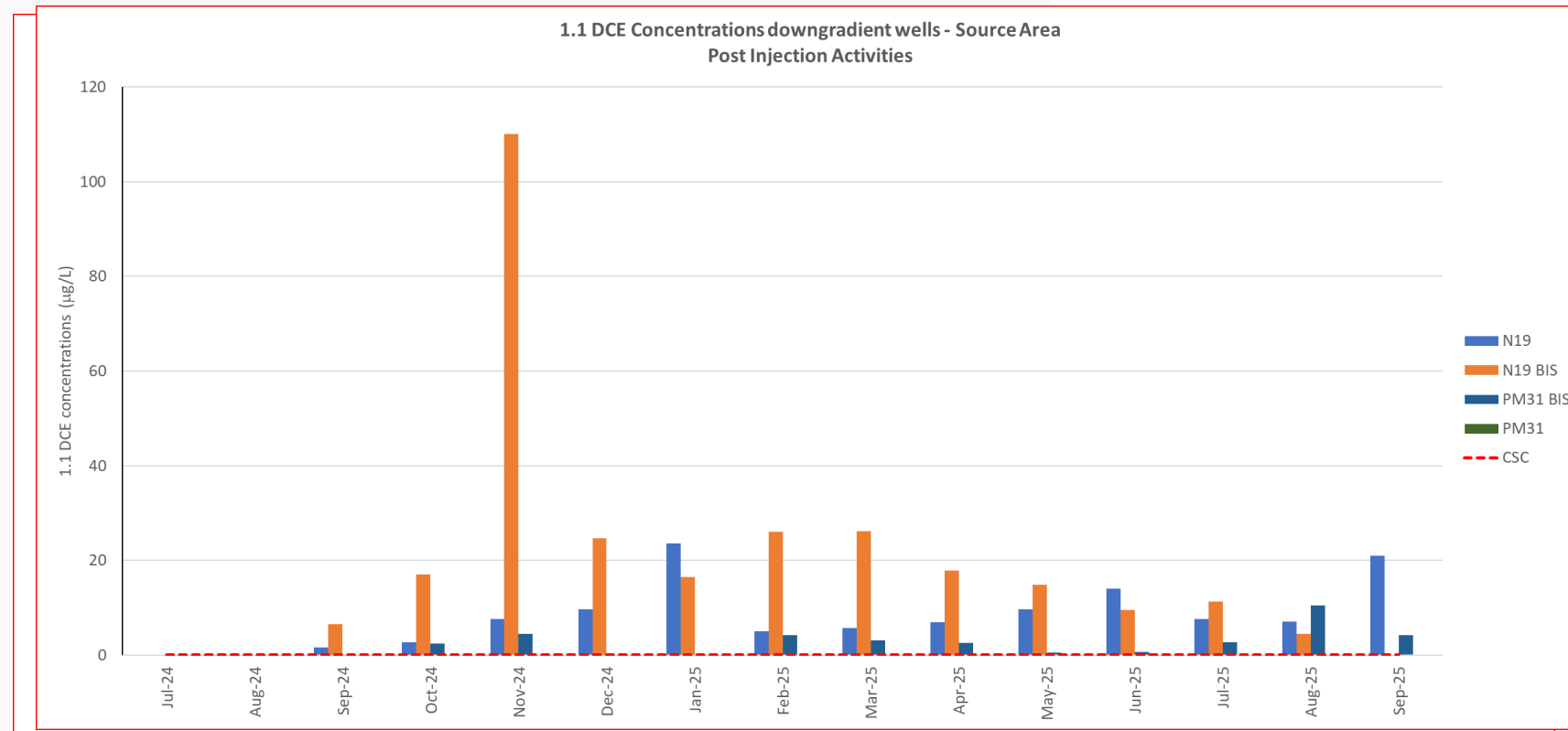


- Significant increase in dissolved manganese ( $Mn^{2+}$ ) – reduced form
  - Effect of reducing conditions
  - Values maintained high over the entire monitoring period (>1 year)

# Full Scale results - Contaminants

Source Area: 1,1-DCE

ZOOM POST-INJECTIONS

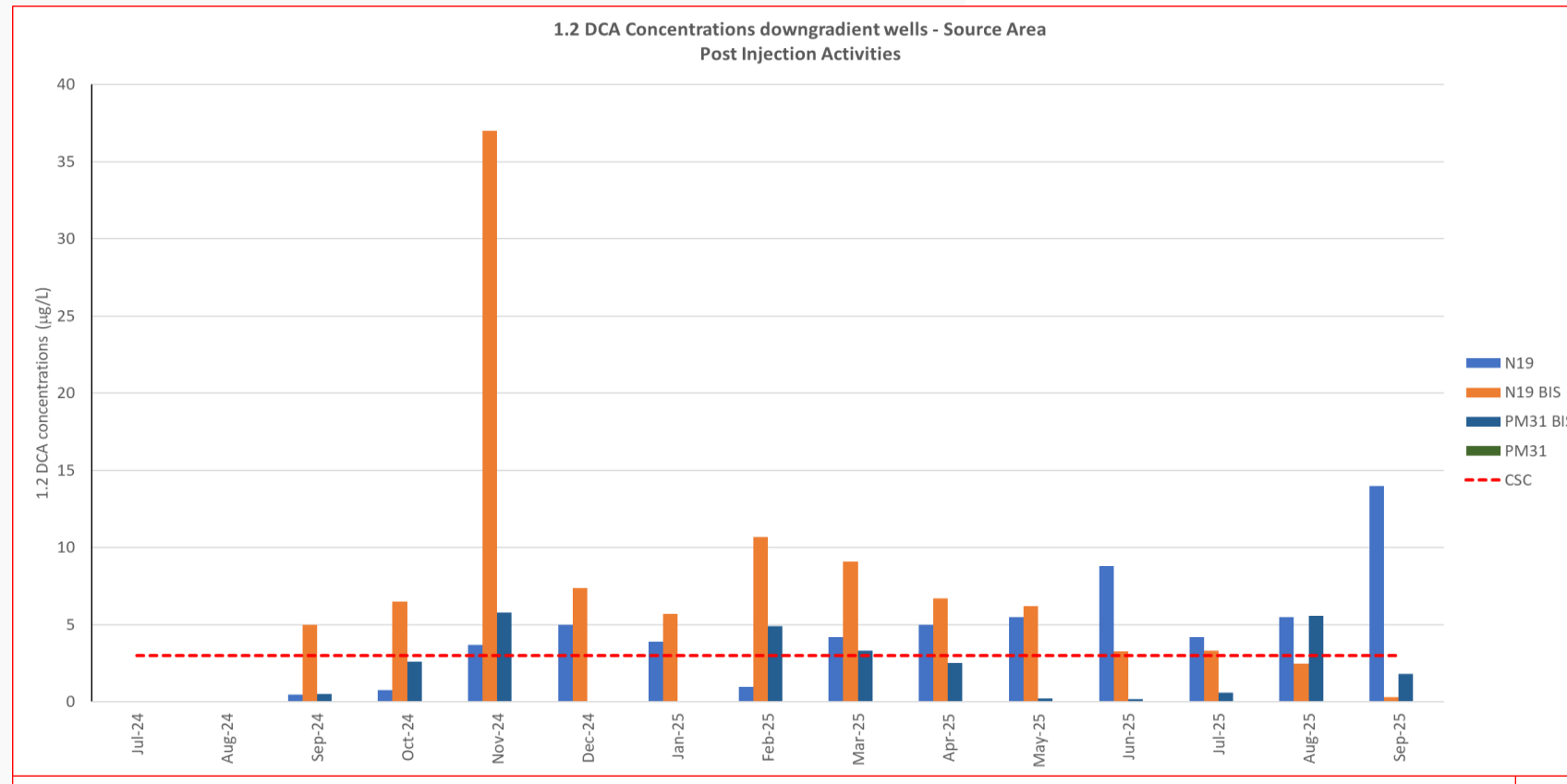


- Average values 1 OoM lower than baseline
- Declining trend
- Still further reduction to be observed

# Full Scale results - Contaminants

## Source Area: 1,2-DCA

## ZOOM POST-INJECTIONS

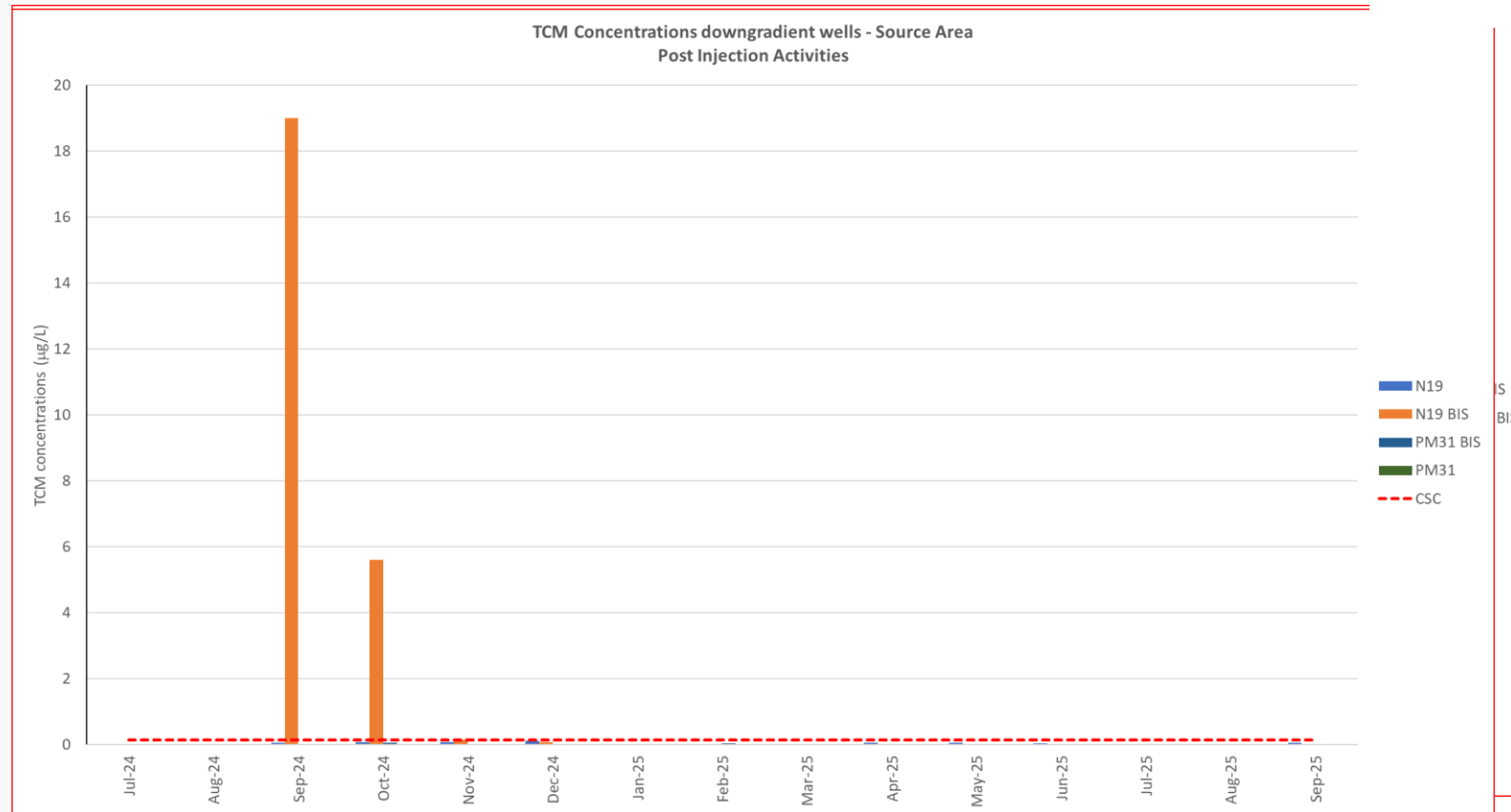


- Oscillating trend, with final decline
- Still some wells over the stringent target CSC

# Full Scale results - Contaminants

## Source Area: TCM (chloroform)

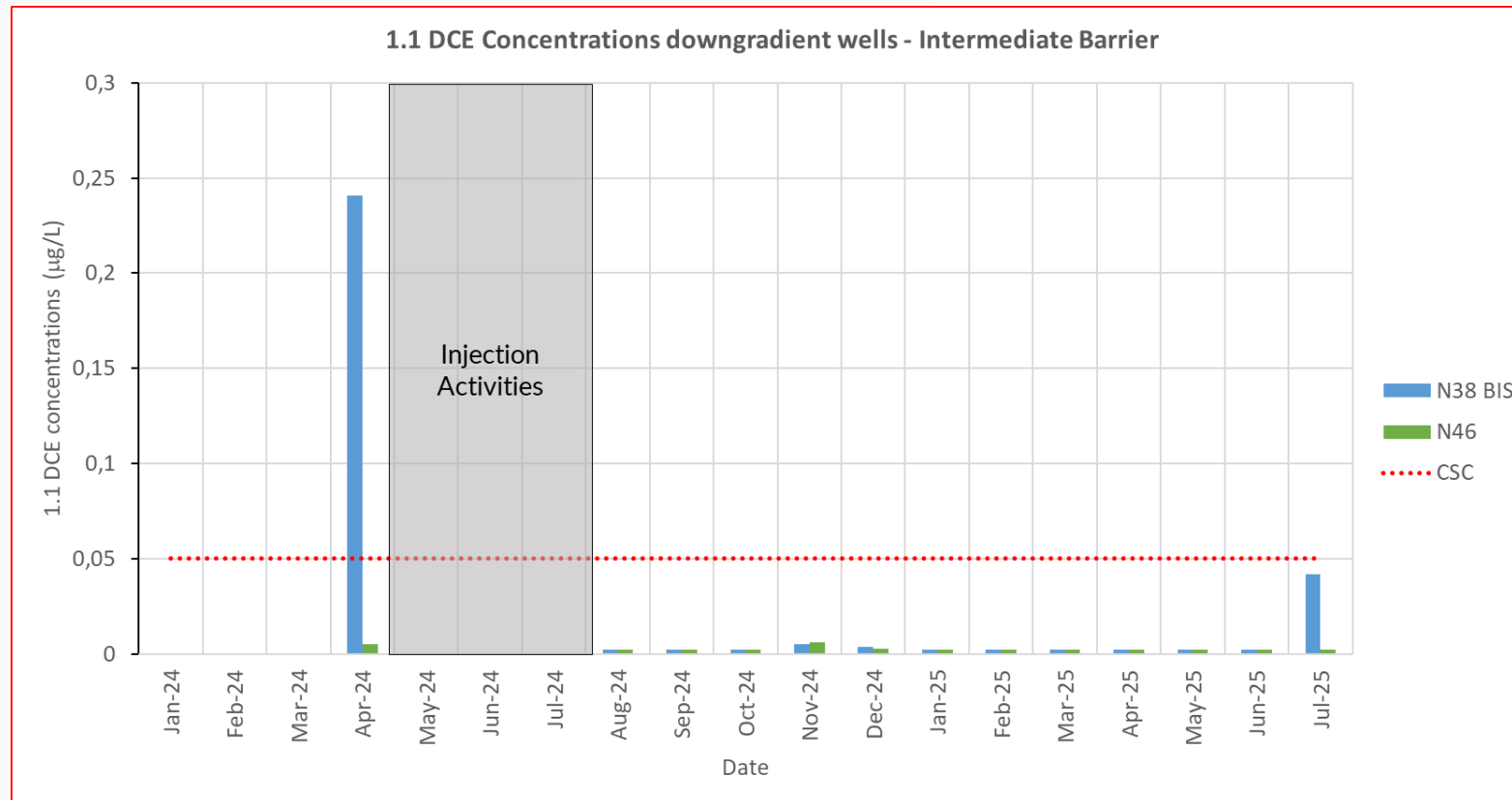
## ZOOM POST-INJECTIONS



- Good decline
- Already below stringent target (0.15 µg/L)
- High stability of results

# Full Scale results - Contaminants

## Intermediate Barrier: 1,1-DCE

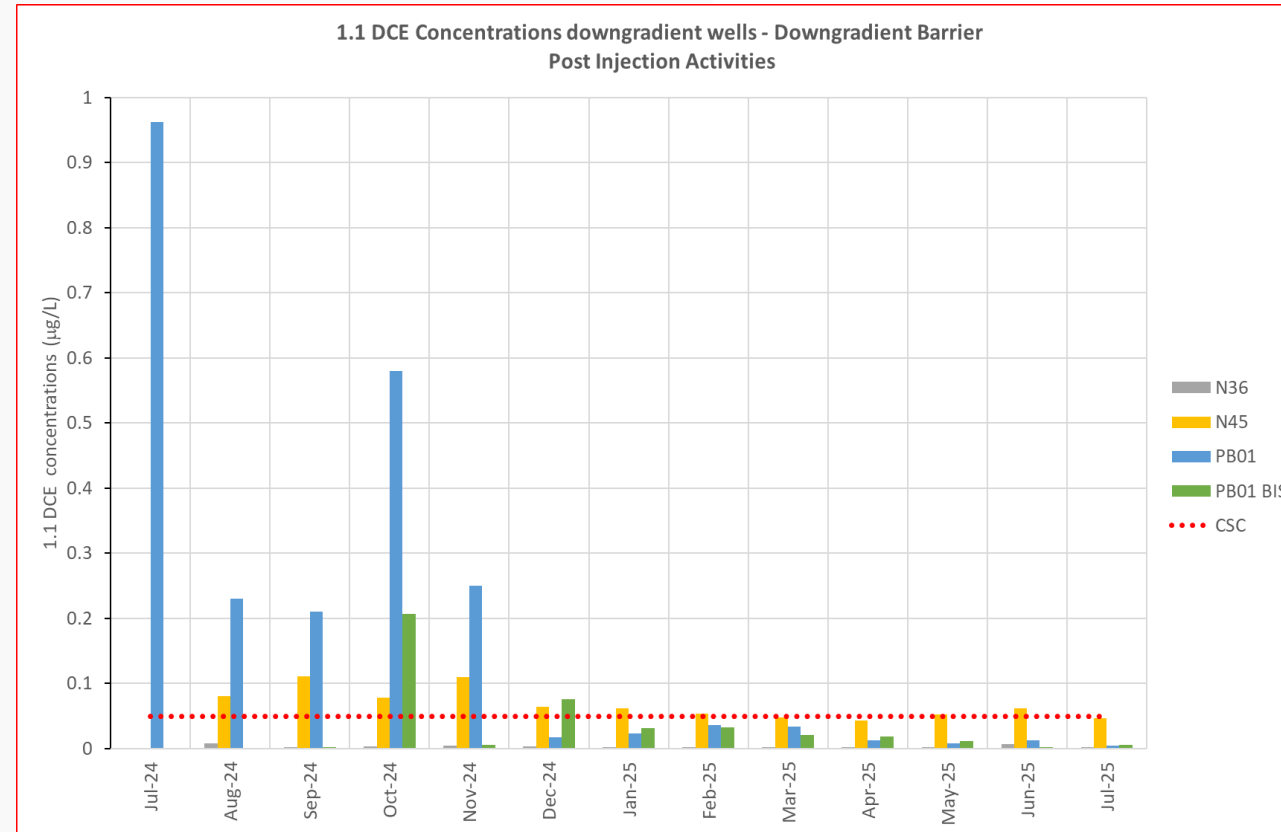


- Already extremely low baseline concentrations
- Good further decline
- Stable below stringent target (0.05 µg/L)

# Full Scale results - Contaminants

## Downgradient Barrier - 1,1-DCE

## ZOOM POST-INJECTIONS



- Good decline
- Stable below stringent target (0.05 µg/L)

# Conclusions

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- Both barriers compliant, in all monitoring wells
- Source area still ongoing
- Monitoring will last until the end of 2026
- Construction of the WTE has started Q2 2025 and is ongoing (expected duration of the works 2 years)
- Strong collaboration between all parties has been crucial to manage such a complex site

# Questions?



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