Cometabolic Methanotrophic Enhanced Natural Attenuation At a High Vandalism TCE Superfund Site

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Methanotrophic Cometabolic Bioremediation

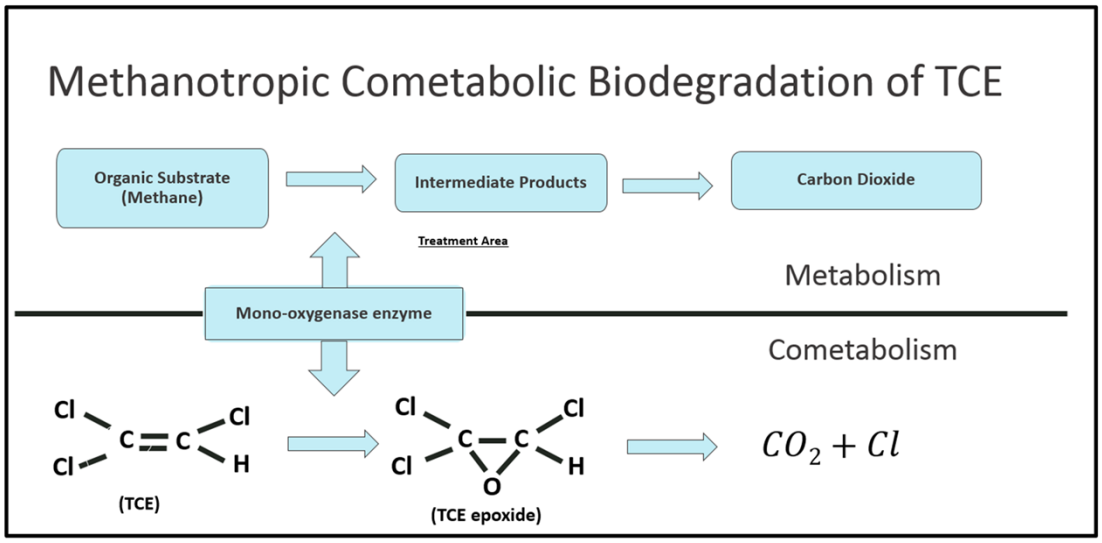
Biodegradation Process:

- ❑ Two-step process
- ❑ MOB metabolize primary substrate (CH_4) and generate CO_2
- ❑ Produce monooxygenase enzyme
- ❑ The enzyme fortuitously degrades TCE
- ❑ MOB gain no energy directly from TCE degradation

Image by J.C. Lara, University of Washington

Why at This Site:

- ❑ Aerobic
- ❑ Site not conducive for ARD
- ❑ MOB and CH_4 present
- ❑ Low concentrations of TCE only
- ❑ No potential to generate cDCE or VC



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Site Background

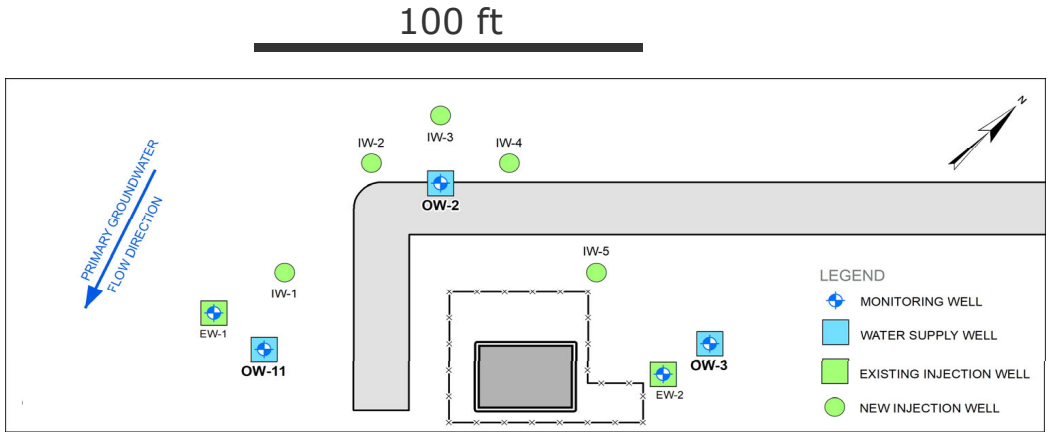
History

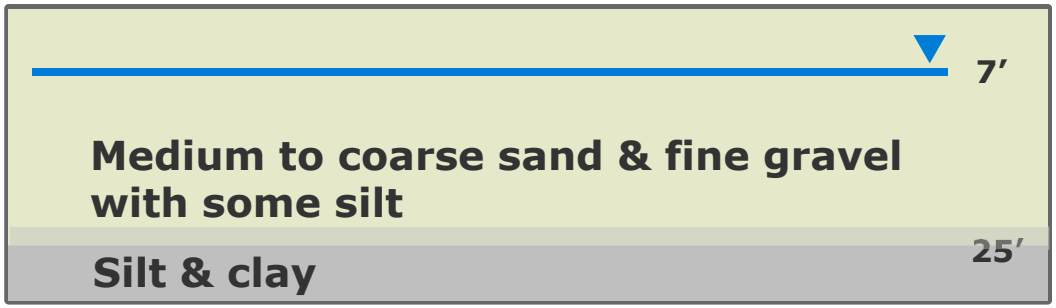
- ❑P&T: 1995-2009
- ❑All risk factors addressed
- ❑Significant system vandalism and arson
- ❑P&T shutdown approved
- ❑MNA remedy change rejected
- ❑ENA field pilot test required

Site Characteristics / CSM

- ❑TCE < 20 µg/L
- ❑Dilute upgradient plume
- ❑GW Vs ~ 1/2 ft/day
- ❑pH ~ 5 to 6
- ❑DO ~ 3 mg/L
- ❑MOB and CH_4 present onsite

Pilot Test Area





➡ ***Complete Microcosm Study***

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Microcosm Testing

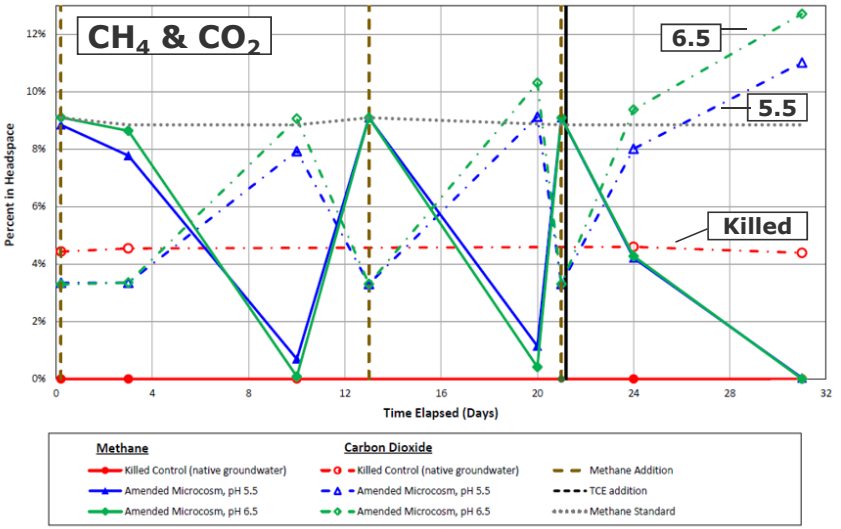
Phase 1 - MOB Growth (days 1-20):

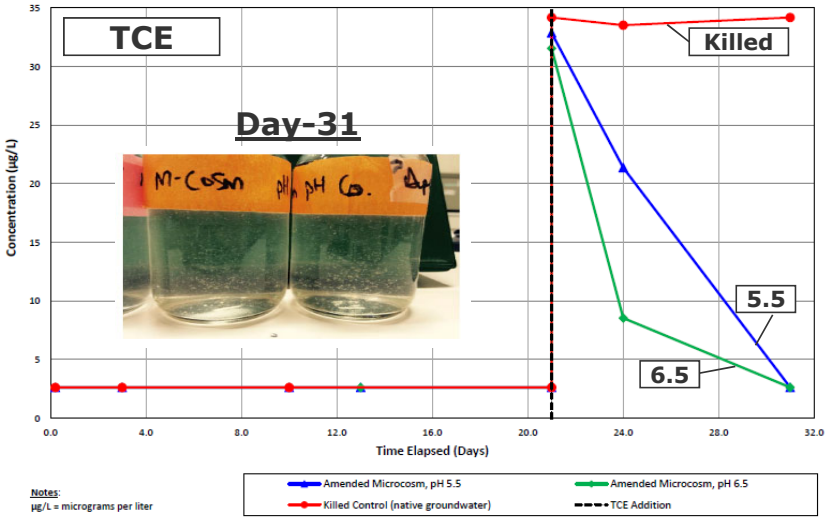
- ❑Site groundwater tested at pH 5.5 and 6.5
- ❑CH_4 added at days 1, 13, and 20
- ❑The added CH_4 was consumed by MOB
- ❑The MOB generated more CO_2
- ❑Significant increase in MOB observed

Phase 2 - TCE Degradation(days 21-31):

- ❑TCE added at day 21
- ❑Natural MOB completely degraded TCE at pH 5.5 and faster at pH 6.5
- ❑TCE concentration unchanged in killed control
- ❑Visible bacteria growth in day 31 jars

➡ ***Design/Complete Field Pilot Test***





Microcosms by XDD Environmental, Inc. Directed by Dr. Sam Fogel

Field Pilot Test: Objectives/Overview

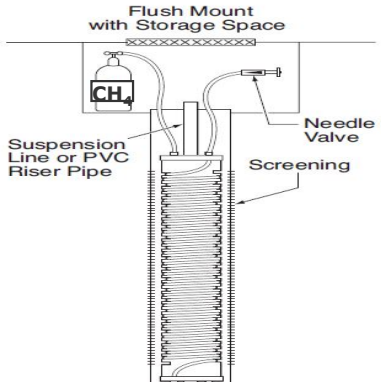
Objectives:

- ❑ Distribute CH_4 in situ
- ❑ Increase MOB concentration
- ❑ Evaluate potential to degrade TCE in situ

Challenge:

- ❑ Significant site vandalism and arson

Waterloo Emitter™



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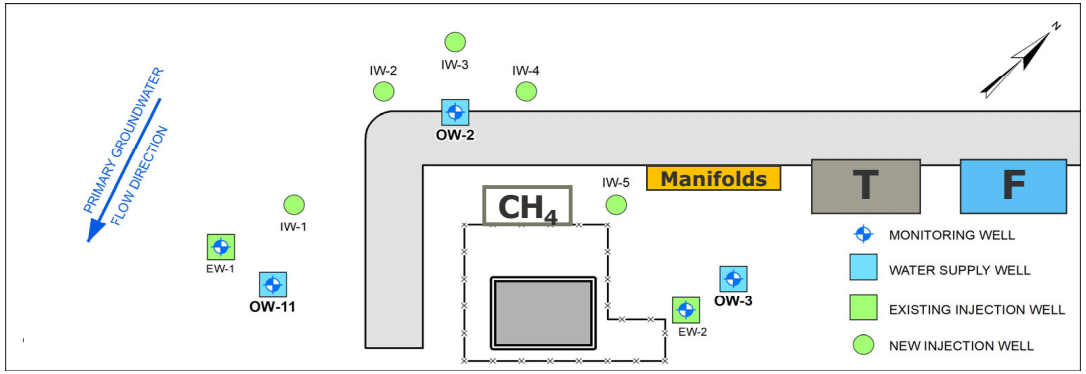
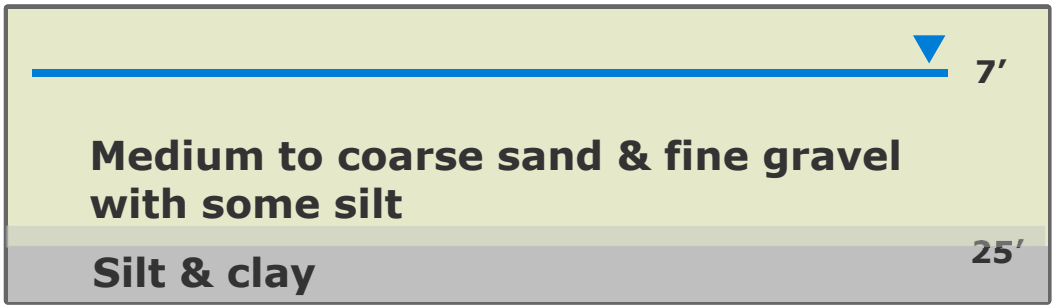
Pilot Test Layout





Amendment Mixing Mobile Trailer Design

Process Flow Diagram:

- ❑ GW extraction
- ❑ Storage
- ❑ Amendment mix
- ❑ CH_4 infusion
- ❑ Reinjection

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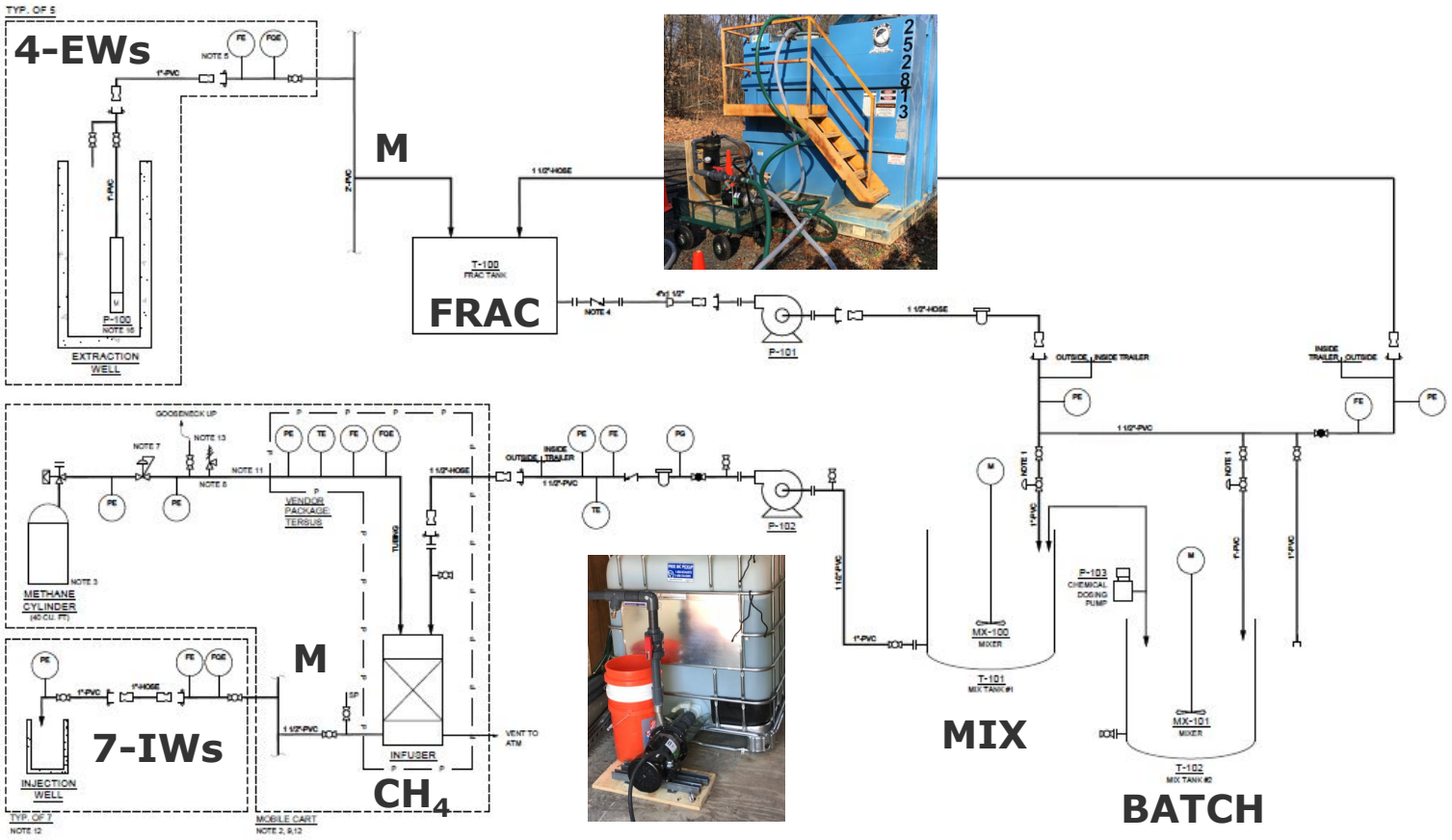
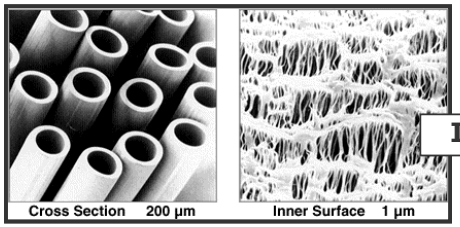


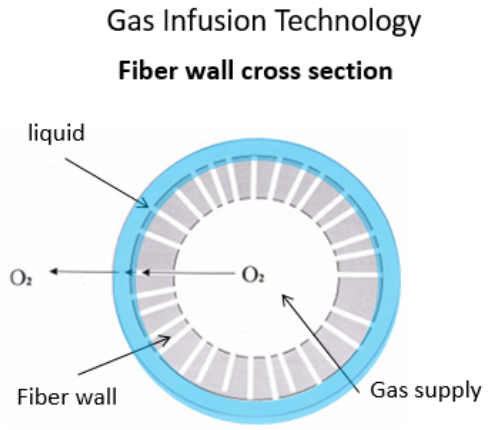
Methane Gas Infusion Technology

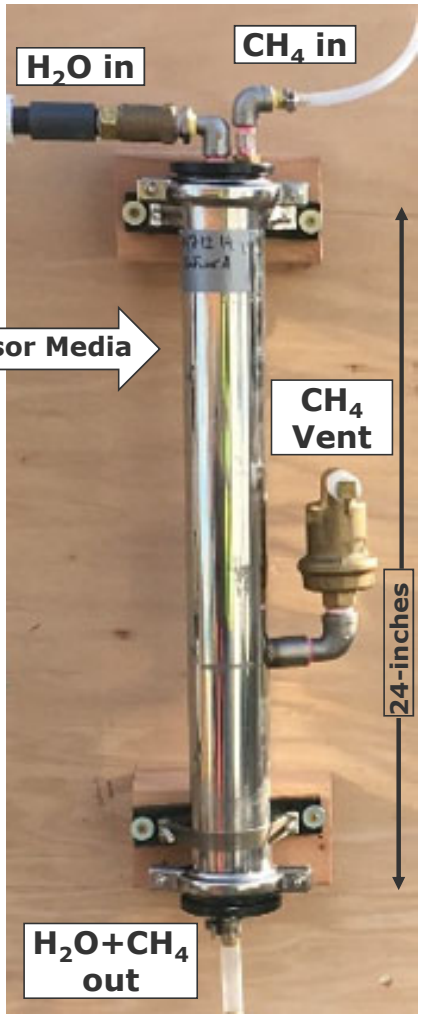
In-line Gas Infusion

- Designed to dissolve high gas concentrations into water rapidly
- Technology previously used for oxygen infusion
- Micro porous media with significant surface area
- Gas and water enter top of unit
- Gas fills the media and water passes over the large surface area
- Gas rapidly infuses into the water for immediate reinjection
- Can also be used for other gas cometabolites such as propane and other contaminants such as 1,4-dioxane



7000 sq. ft. per cu. ft.





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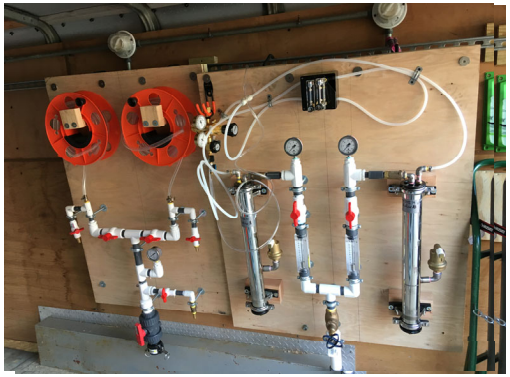
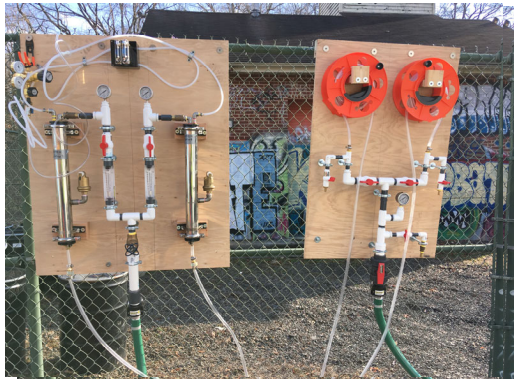
Fully Mobile System: Groundwater Extraction ➔ Aeration ➔ Amendment ➔ Infusion ➔ Reinjection





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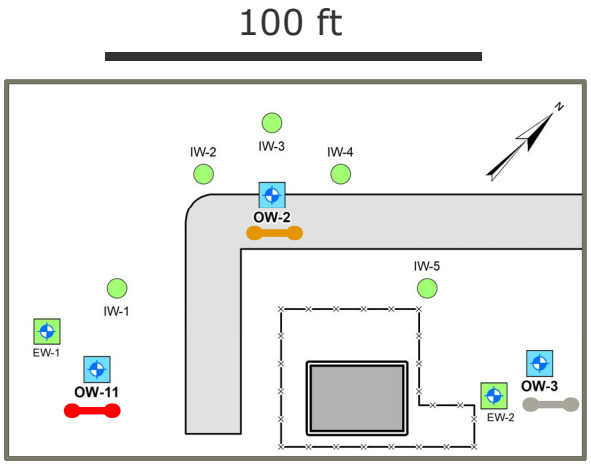
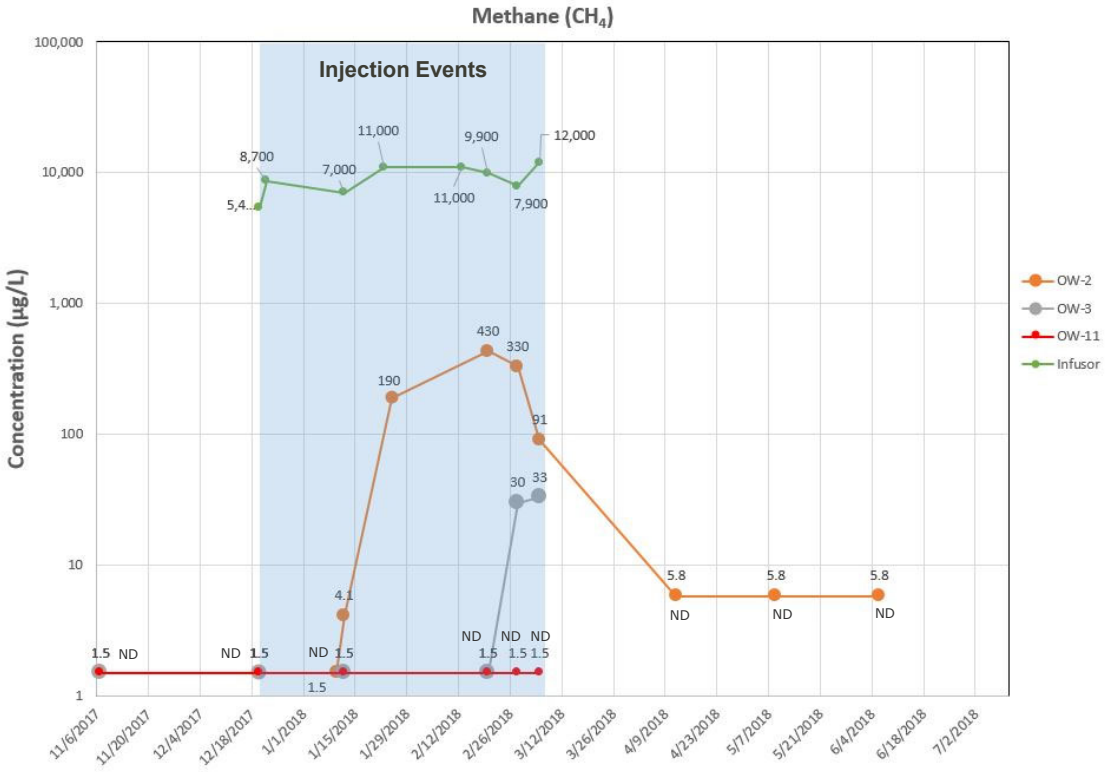
Pilot Test – Methane DATA

Results (µg/L):

- **OW-2**: ND to 430
- **OW-3**: ND to 33
- **OW-11**: ND
- **Infusor**: 5,400 to 12,000
- **Methane observed** in two OWs





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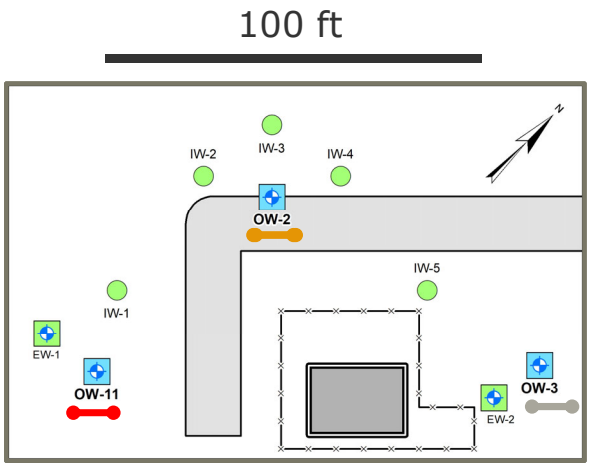
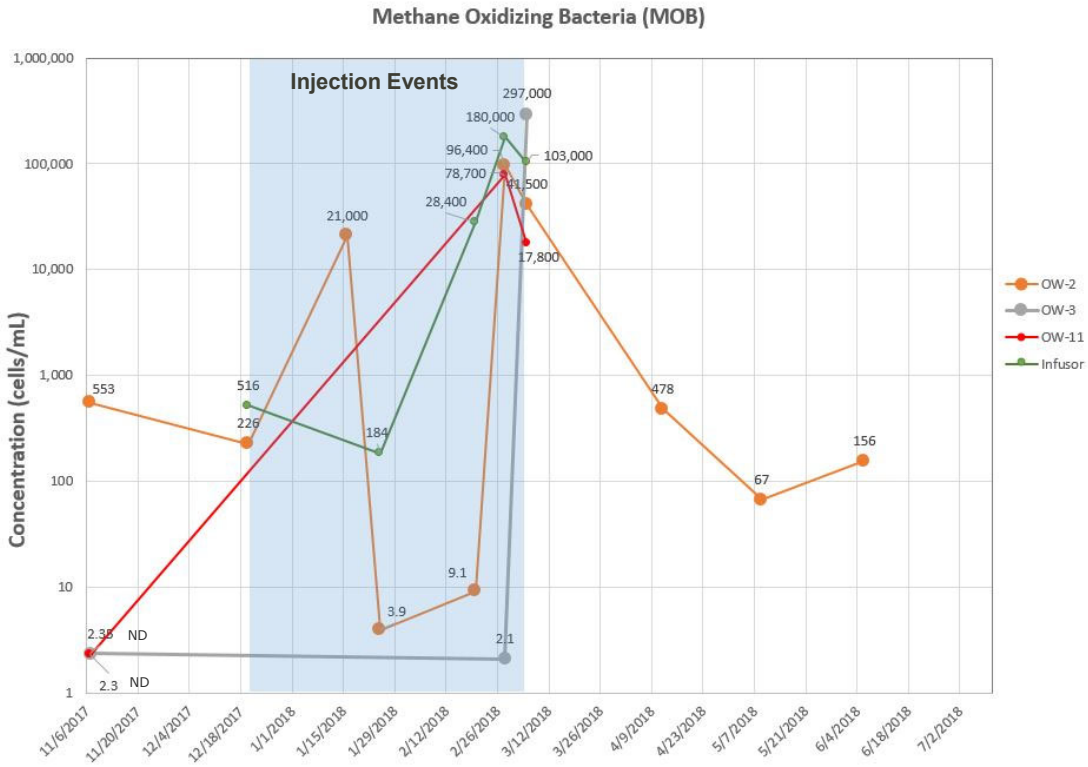
Pilot Test – Methanotrophic Bacteria Data

Results (cells/mL):

- **OW-2**: 226 to 96,400
- **OW-3**: ND to 297,000
- **OW-11**: ND to 41,500
- **Infusor**: 184 to 180,000
- **Significant MOB increase**





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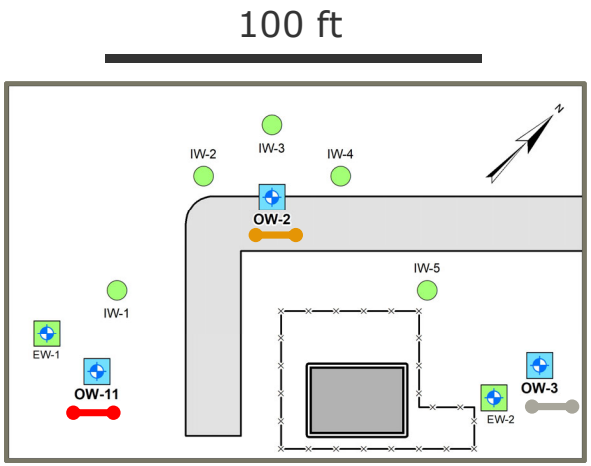
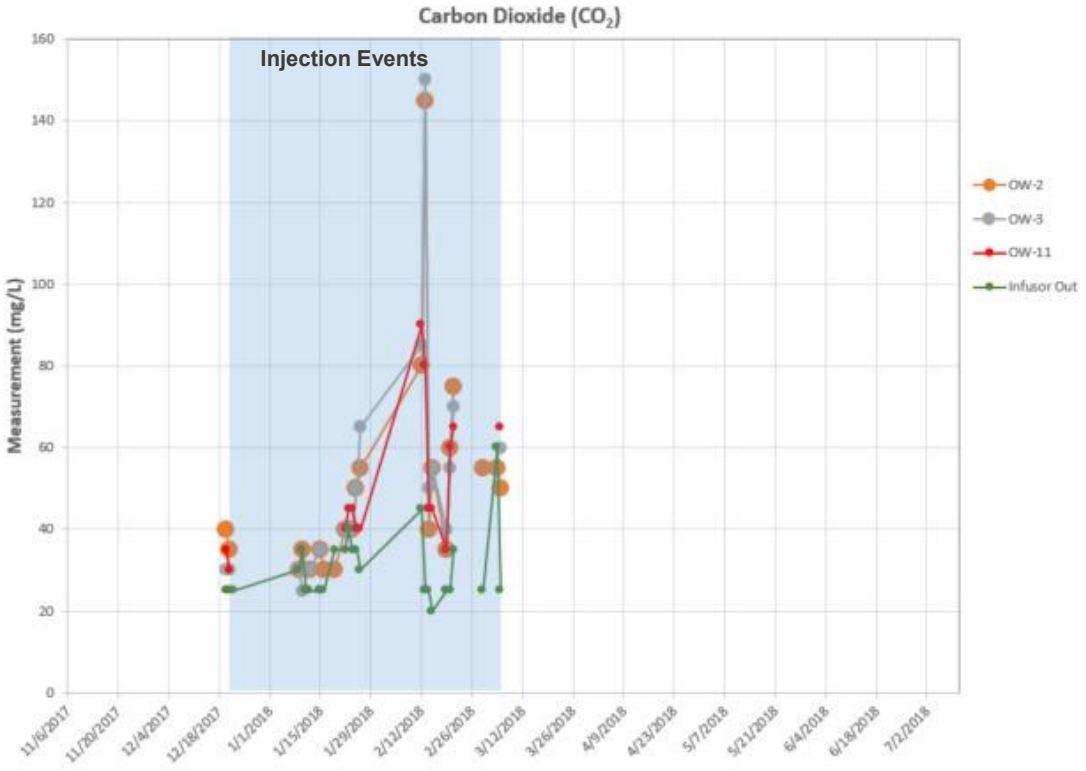
Pilot Test – Carbon Dioxide Data

Results (mg/L):

- **OW-2:** 40 to 145 (+105)
- **OW-3:** 30 to 150 (+120)
- **OW-11**: 35 to 90 (+55)
- **Infusor**: 35 to 60 (+25)
- **CO_2 increased** 30 to 80 mg/L





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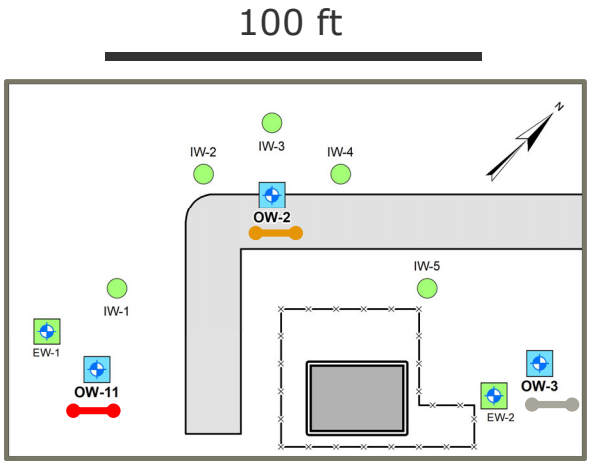
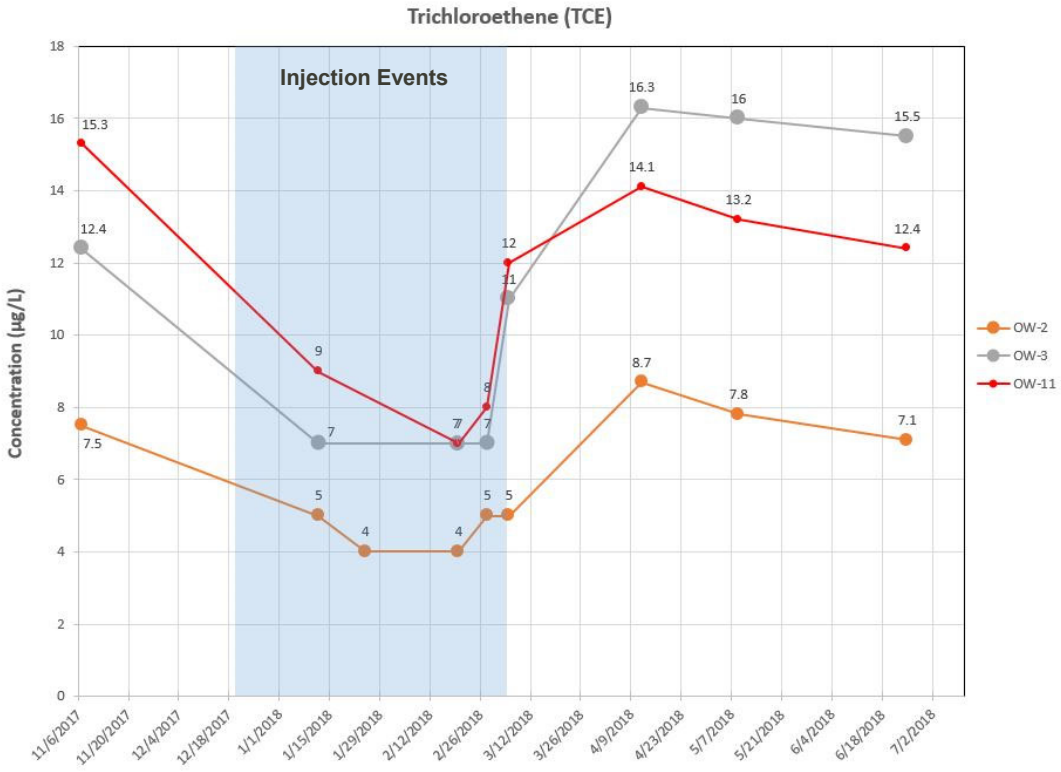
Pilot Test – TCE Data

Results (µg/L):

- **OW-2**: 7.5 to 4
- **OW-3**: 12.4 to 7
- **OW-11**: 15.3 to 7
- **TCE decreased** in all three OWs then rebounded after test





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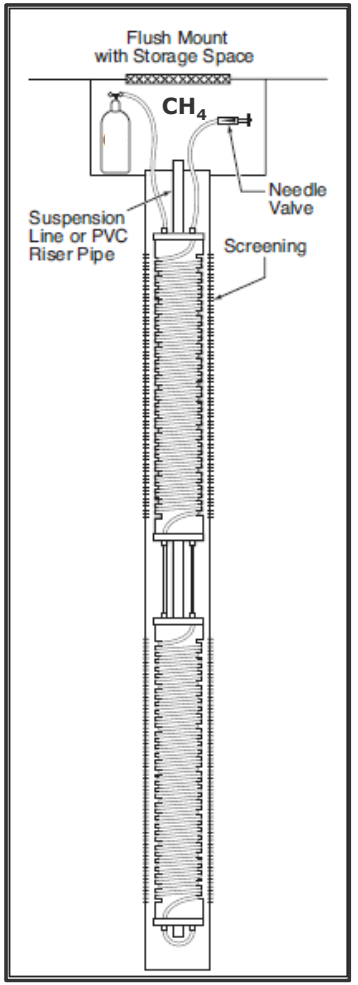
Path Forward

- ❑ Continue long term monitoring of TCE, CH_4, DO, and MOB
- ❑ Continue to update and evaluate TCE trend analysis
- ❑ Reevaluate MNA depending on results of LTM trend analysis
- ❑ If additional enhancement is determined necessary and vandalism sufficiently declines, consider secured subsurface slow-release methane infusors

Image by J.C. Lara, University of Washington



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Lessons Learned

- Methane infusors did not achieve manufacturer specified water flow rate (10 gpm) at target methane concentration (10 mg/L)
- Infusor methane and water flow balancing were very sensitive
- Length and diameter of infusor outlet tubing and water and methane pressures were critical to achieving target methane infusor concentration

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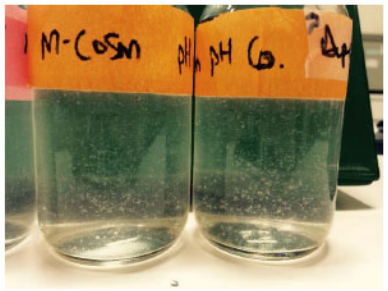
Findings – Microcosm and Field Testing

- Fully mobile treatment system design enabled completion of this field pilot test despite the significant vandalism problem
- CH_4 amended water distributed across the pilot test area
- Increased CH_4 concentrations resulted in significant MOB concentration increases
- Increased MOB concentration degraded TCE in situ
- Lower pH did not prevent biodegradation
- Dissolved oxygen was not depleted during tests
- TCE degradation rate is directly related to methane abundance



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Thank You!

From the Project Team

Michael Baker, International

- Matthew Maloney, PG – Program Manager

OBG, Part of Ramboll

- Rick Breneman – Senior Craftsman
- Thomas Cornuet, PG – Technical Manager
- Nick DiMarcello, CQM – QA/QC
- Andrew Dougherty – Craftsman
- Christine, Fogas, EIT – Environmental Engineer
- Jesse Garvey, PE – Project Manager
- Matt Hencken, EIT – Design Engineer
- Eric Redfern – Project Geologist

XDD Environmental

- Laurel Crawford – Microcosm Project Manager
- Dr. Sam Fogel, PE – Microcosm Technical Director

Questions?

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