Progress Toward Cleanup of Operable Unit 1 Groundwater at the US DOE Mound, Ohio, Site: Success of a Phase-Combined Remedy – 15310

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Introduction

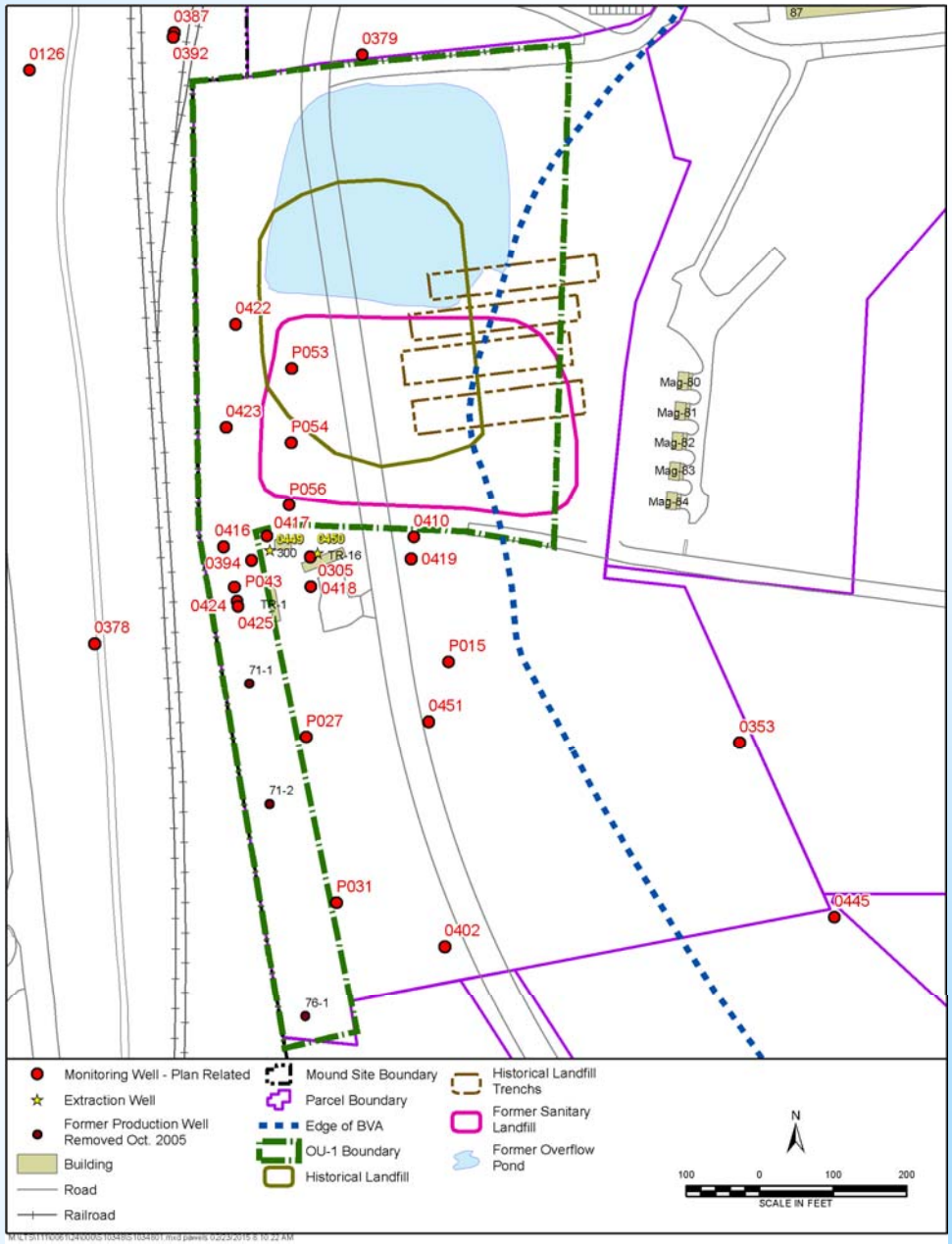
- Operable Unit 1 (OU-1) soil and groundwater have been affected by volatile organic compounds (VOC)
  - Present groundwater remedy is collection, treatment, and disposal (pump and treat [P&T])
  - Several combinations of technologies were used to address soil and groundwater contamination
- Monitored natural attenuation (MNA) is a viable alternative
  - Majority of source term has been excavated
  - VOC concentrations in groundwater have decreased
  - Attenuation mechanisms have been observed in the subsurface at OU-1

Background

- Placed on National Priorities List in 1989
- Remediated to U.S. Environmental Protection Agency (EPA) risk-based standards for industrial and commercial use
- Institutional controls manage land and groundwater use
- Property sold in 1998 for commercial/industrial reuse

Background (continued)

- Sanitary landfill used for waste disposal
  - Utilized from 1948 to 1974
  - Cap placed after use
- OU-1 adjacent to the Buried Valley Aquifer (BVA)
  - Sole-source aquifer
- Pathways of concern
  - Contaminant leaching from soils or disposed wastes
  - Contaminant entrainment into groundwater and migration to potential receptors



Historical features of the OU-1 area

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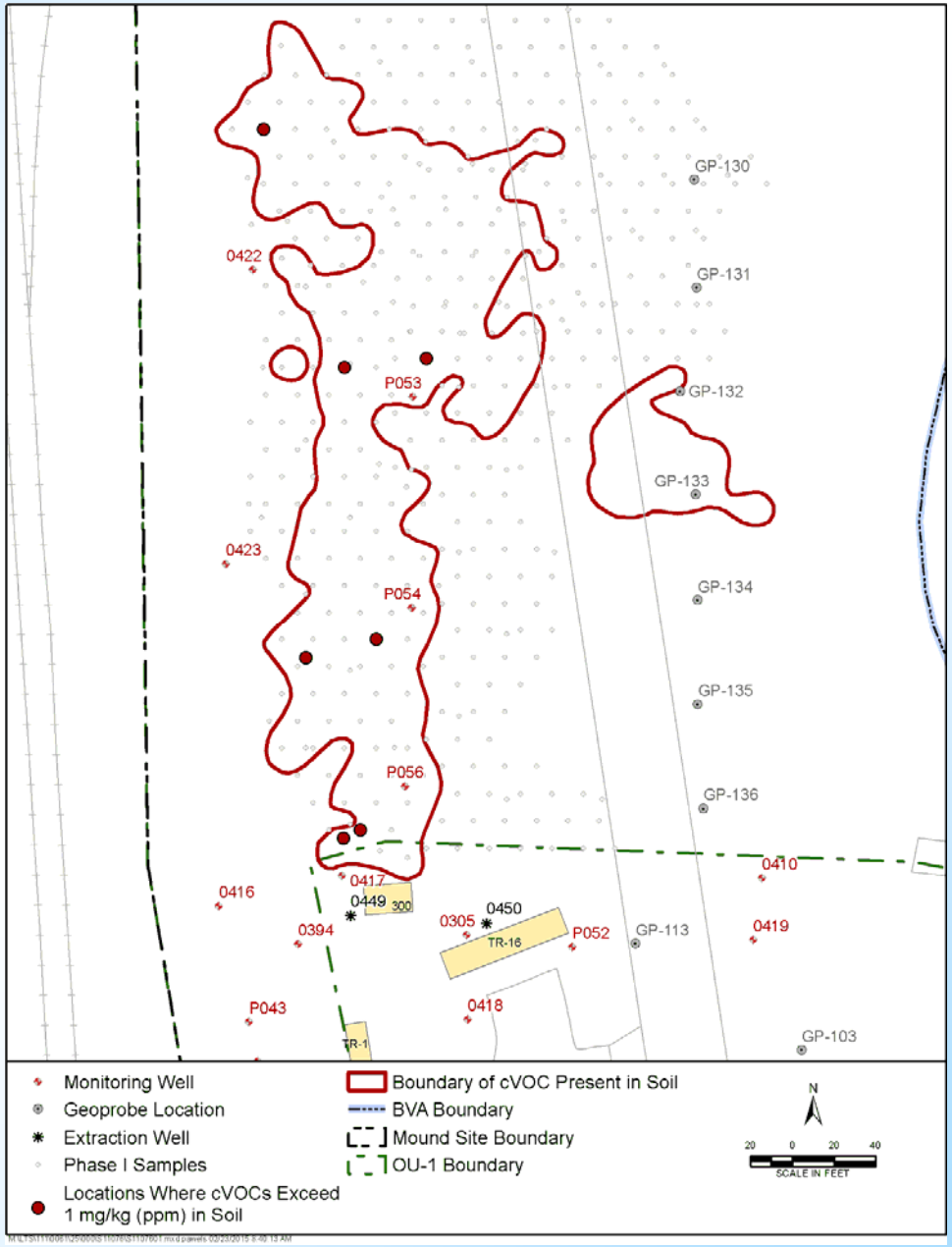
Historical VOC Impact in OU-1
Soil

- Industrial solvents
  - Perchloroethylene (PCE)
  - Trichloroethylene (TCE)
- Soil beneath former landfill



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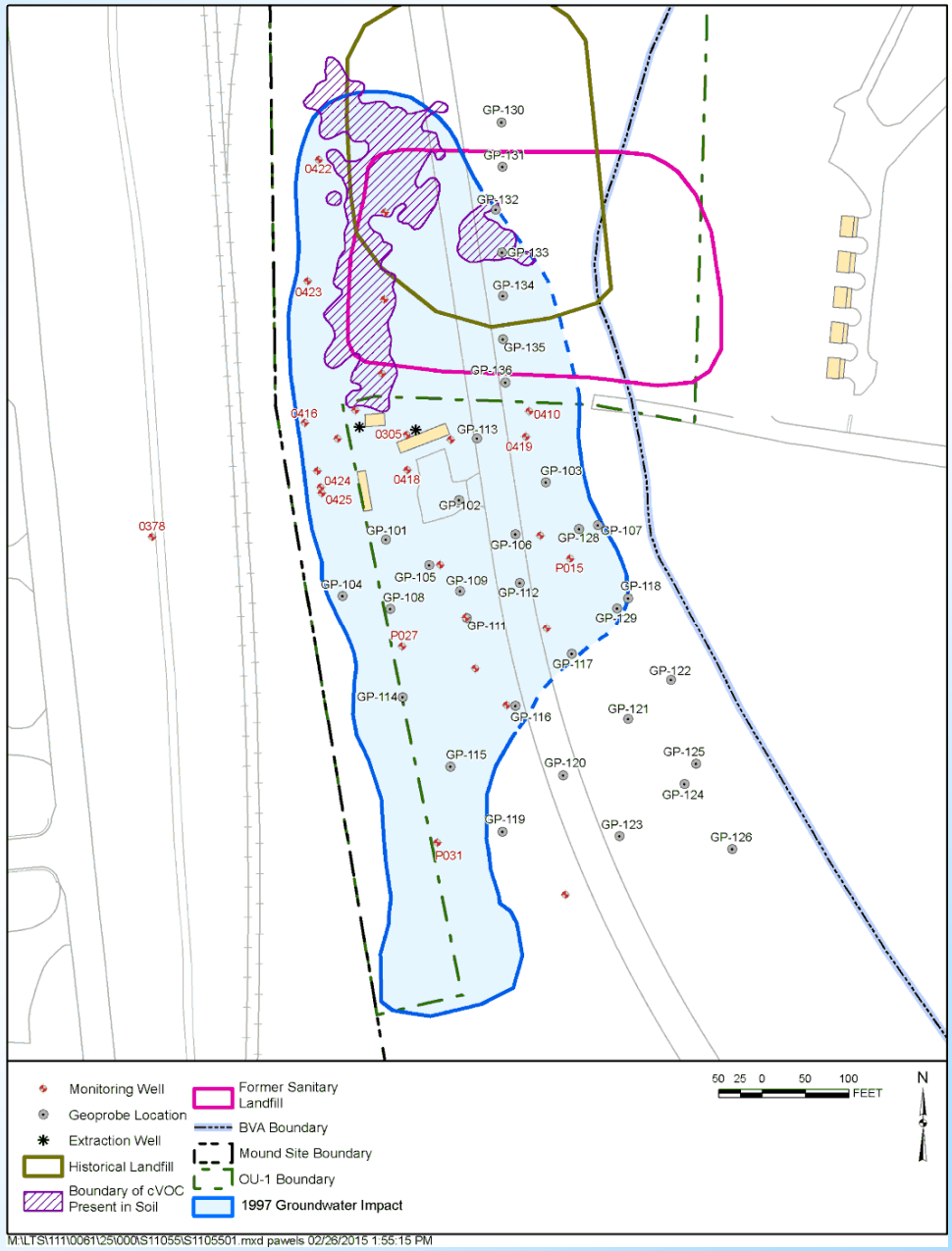
Historical VOC Impact in OU-1
Groundwater

- Industrial solvents
  - PCE
  - TCE
  - Some daughter products
- VOCs in groundwater extended from beneath landfill area



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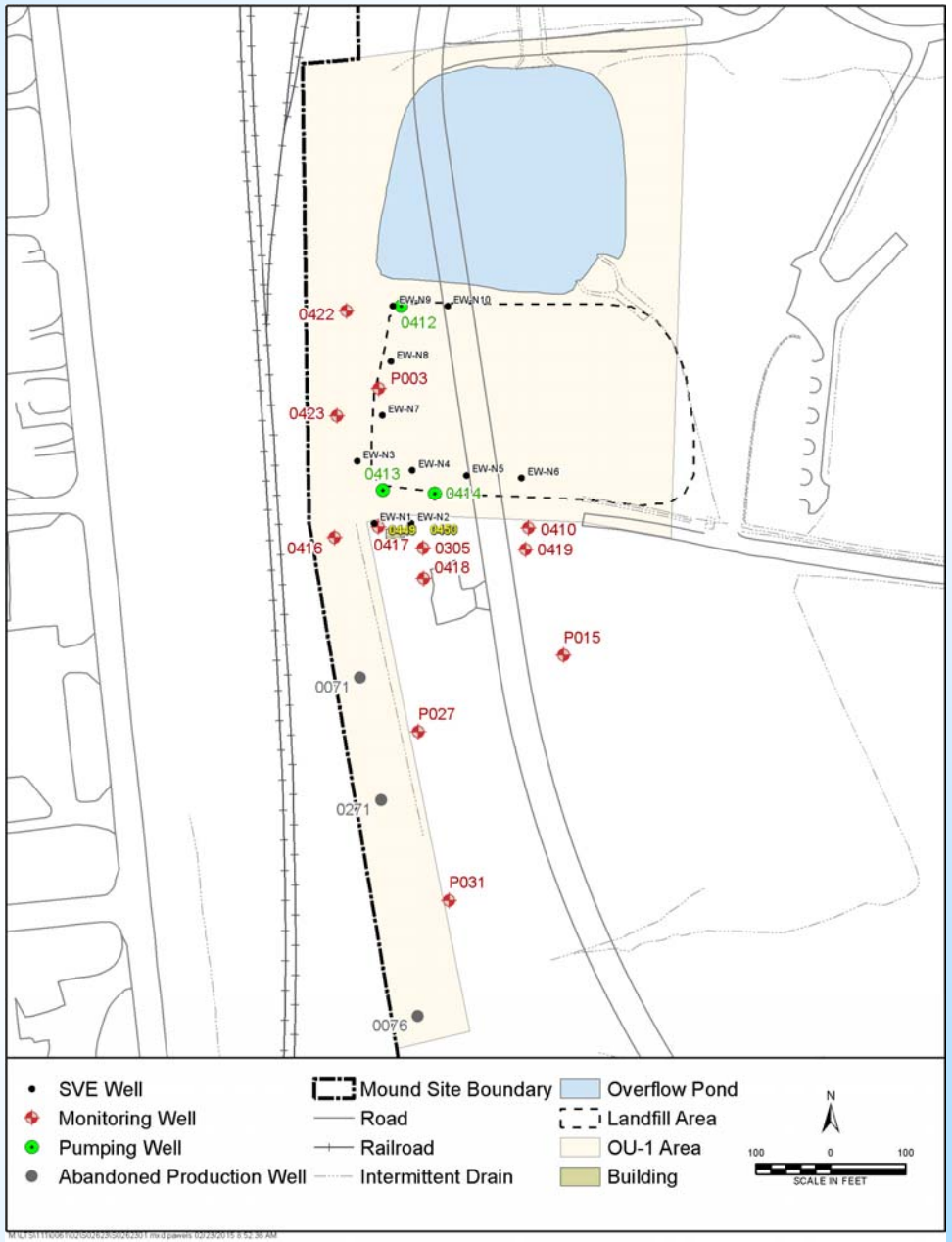
Phase-Combined Remedy Approach

Several actions were performed to address VOC-impacted soil and groundwater:

- **Pump and Treatment**: Groundwater
  - System was started in 1997 and continued until August 2014
  - System in standby to support the field demonstration
- **Soil vapor extraction (SVE)**: Vadose zone
  - System operated from 1997 to 2003
- **Landfill excavation**: Soil/waste materials
  - Two actions between 2007 and 2010
- **OU-1 Enhanced Attenuation Field Demonstration**: Vadose zone and groundwater
  - Injection of edible oil in 2014
- **Testing and Characterization Studies:** Groundwater and soil
  - Performed to track progress throughout remedy periods

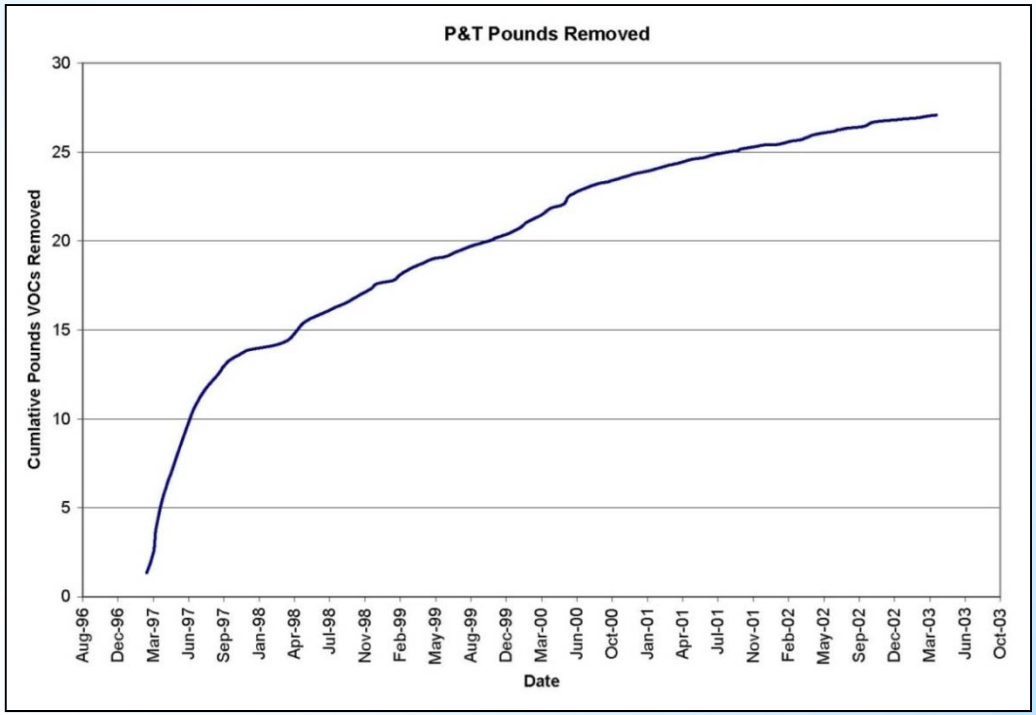
Groundwater Extraction and SVE (1996–2007)

- Groundwater extraction
  - Capture contaminated groundwater originating from beneath former landfill
  - Reduce concentrations to drinking-water standards
  - Prohibit VOC-contaminant movement into BVA
- SVE system
  - Accelerate removal of vadose zone VOCs



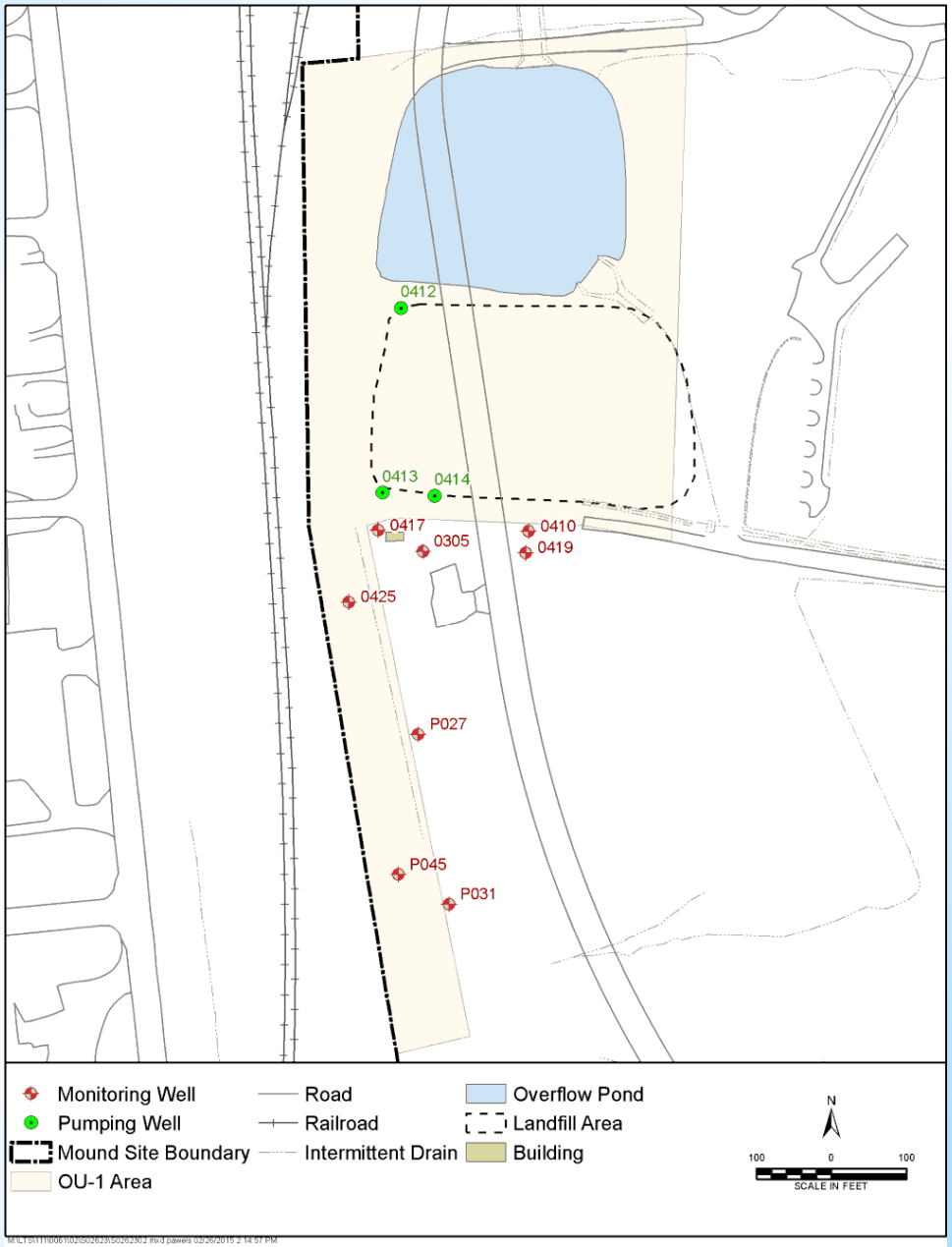
Groundwater Extraction and SVE (1996–2007) (continued)

- P&T system started in 1996
  - Approximately 12 kg (26 lb) of TCE removed between December 1996 and April 2003
- SVE operated from 1997 to 2003
  - 1862 kg (4105 lb) of TCE removed



Rebound Test (2003)

- Contaminant rebound test performed
  - May 2003 through February 2004
  - Prior to 2007 removal of landfill; therefore, source term was still present
- Conclusion
  - VOC concentration increases were a result of contact between groundwater and landfill materials



Landfill Excavation (2007–2011)

2007–2008

- 65,000 cubic yards removed

2009–2010

- 34,500 cubic yards removed

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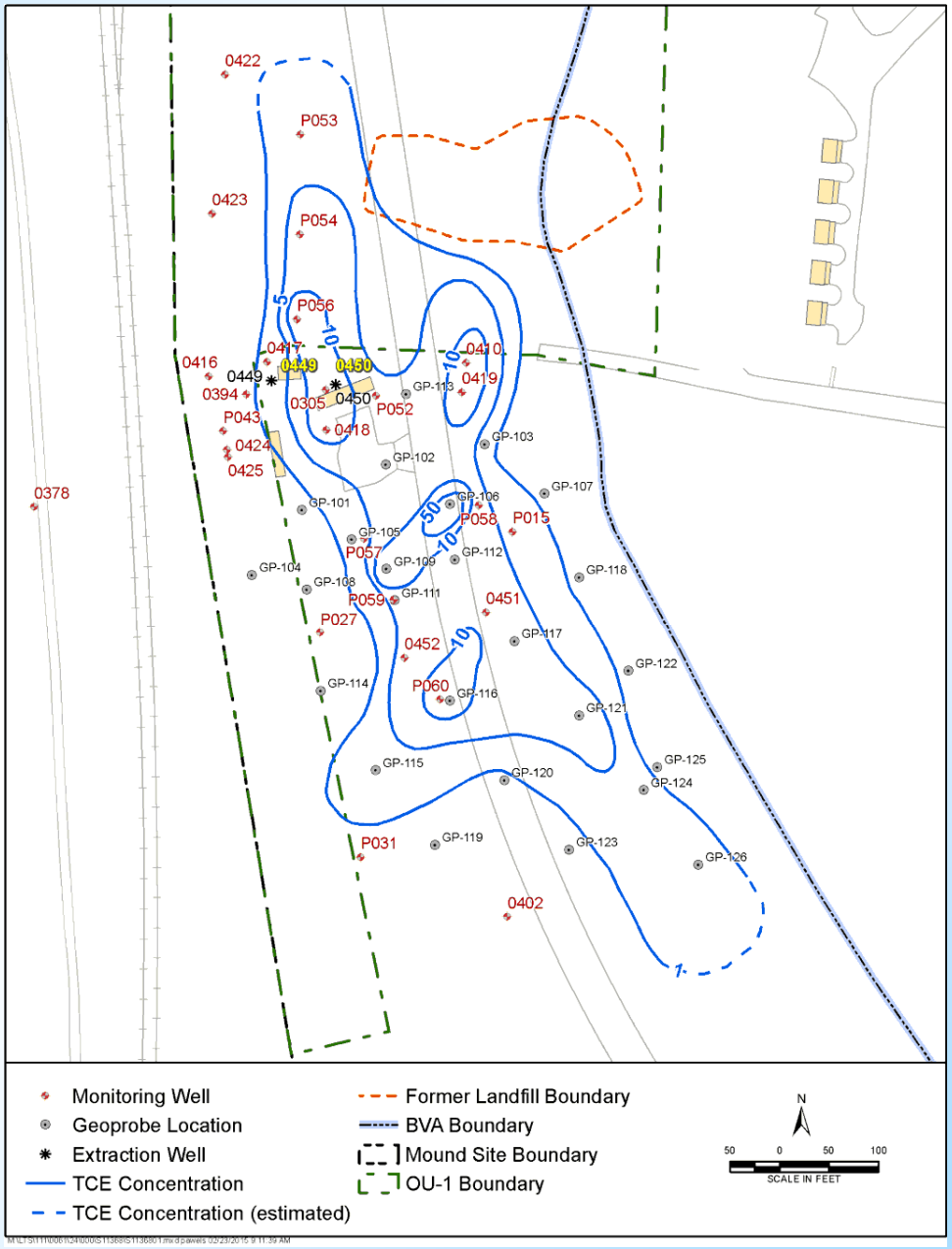
Rebound Test (2011)

- Performed from June to December 2011
  - Evaluate changes in VOC concentrations and groundwater flow when extraction wells are not operating
- VOC concentrations in downgradient locations exceeded maximum contaminant level (MCL)
- VOC concentrations near landfill increased gradually



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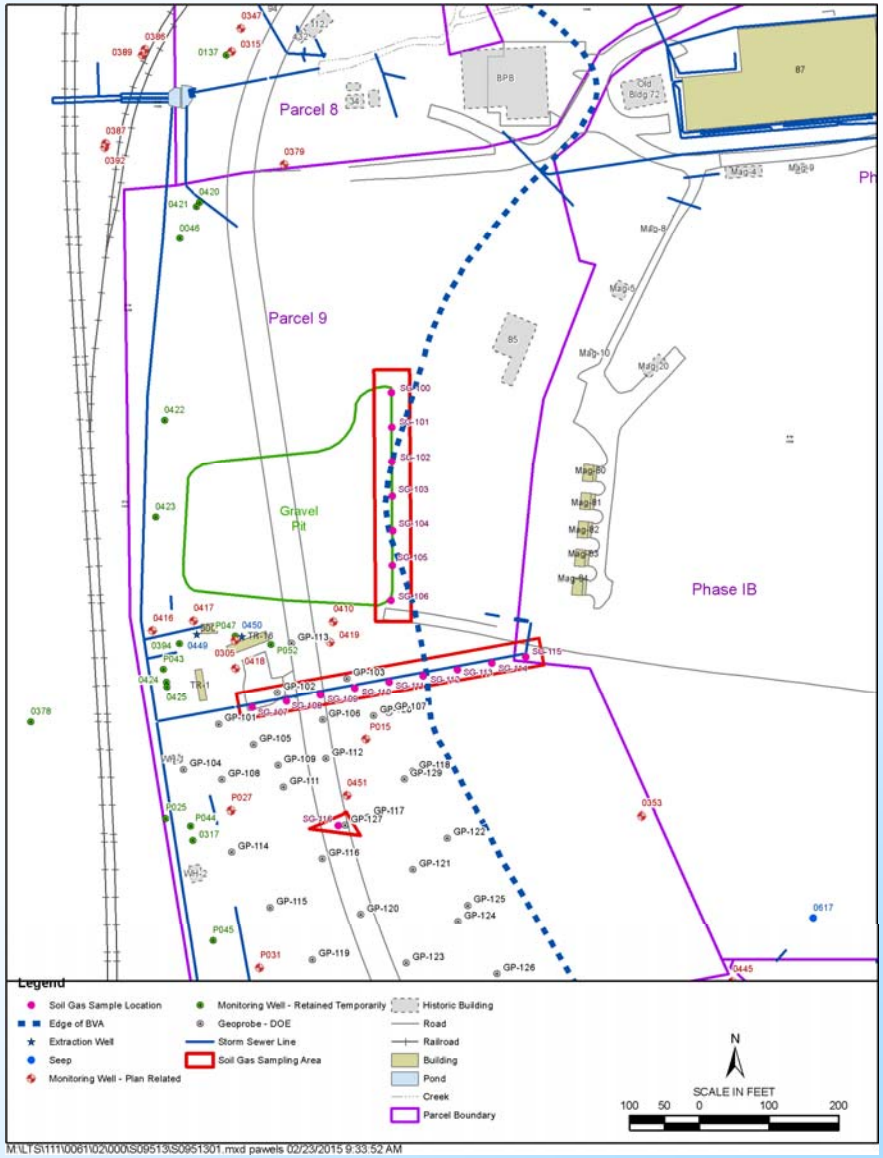
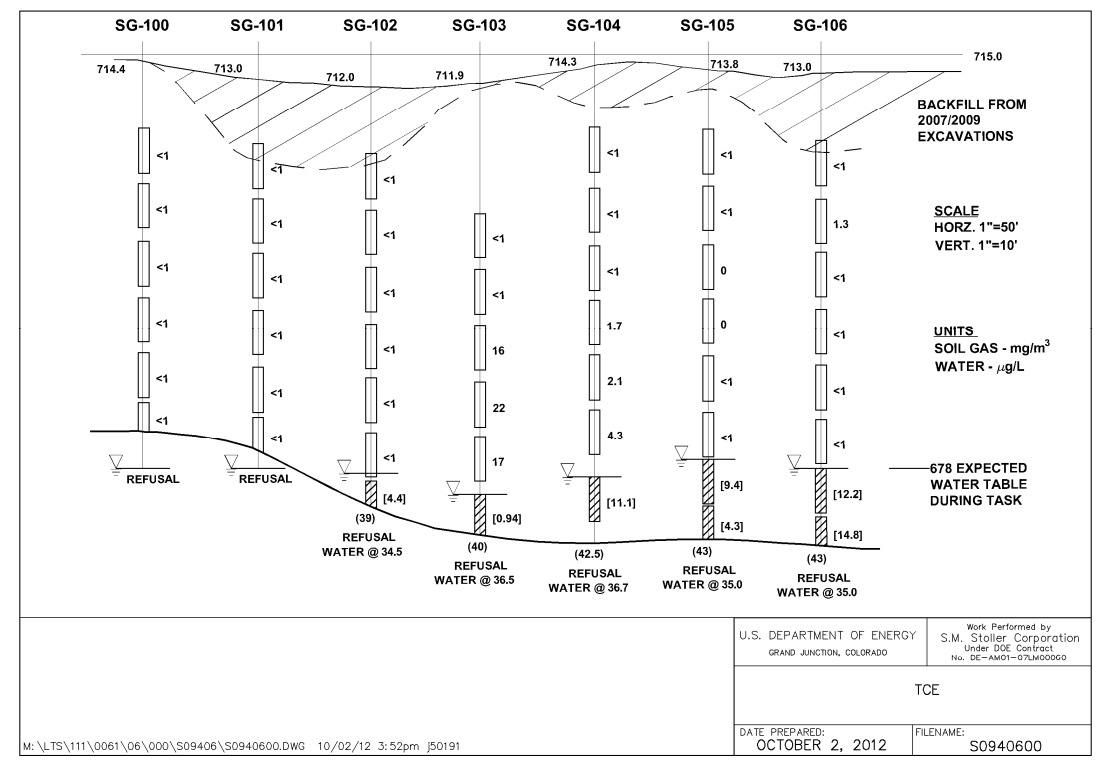
Enhanced Attenuation Field Demonstration (2012–2014)

- Extensive evaluation of occurrence of VOC in groundwater
- Focus on VOC effect outside hydraulic capture of P&T system
- Performed from 2012 through 2013
- Evaluation consisted of:
  - Additional source investigation
  - VOC investigation
  - Integral pumping test
  - MNA characterization



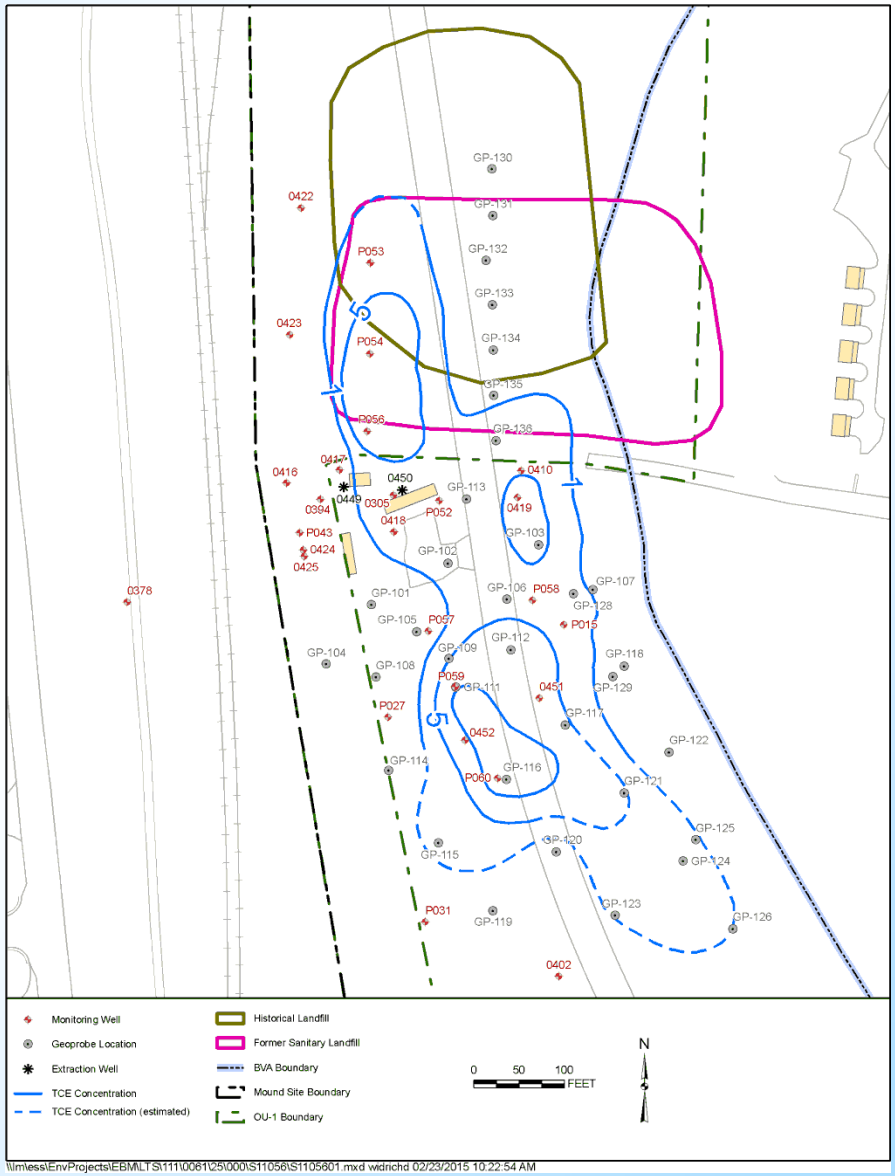
Potential Source Investigation (2012)

- Combination of groundwater and soil-gas sampling
- Performed to determine potential sources of VOCs downgradient of landfill
- Results
  - Residual soil source along eastern side of landfill
  - Impacted soil acts as residual (secondary) source to groundwater along eastern side of OU-1 area
  - No primary or secondary sources identified outside landfill boundary



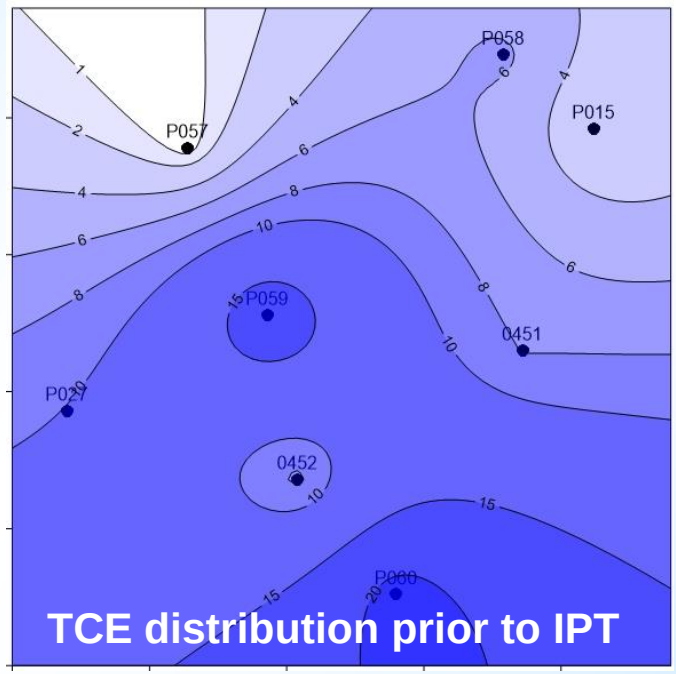
VOC Investigation (2013)

- Concentrations of TCE greater than MCL
  - Beneath former landfill
  - Downgradient of hydraulic capture of P&T system

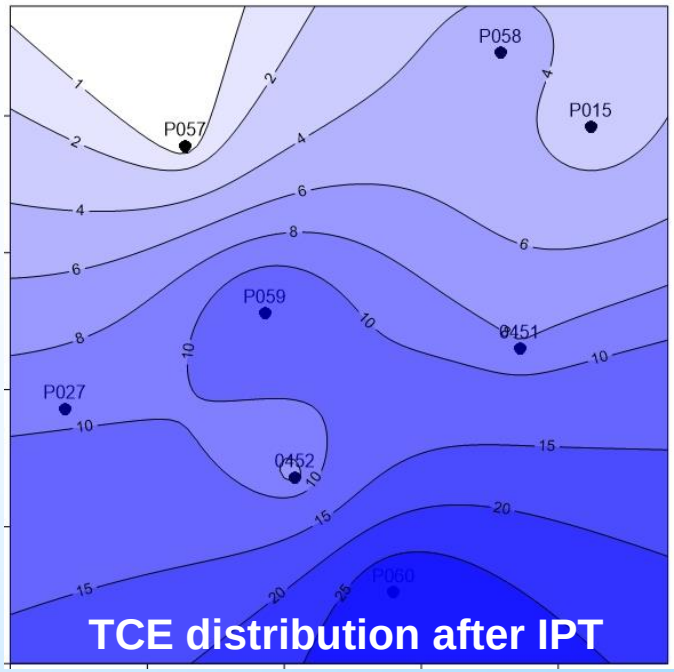


Integral Pumping Test (IPT) (2013)

- Long-term test
- Performed downgradient of hydraulic capture of P&T system
- Data provided:
  - Aquifer characteristics
  - Mass flux and flow rates of VOCs in groundwater
  - Location of potential VOC sources to groundwater



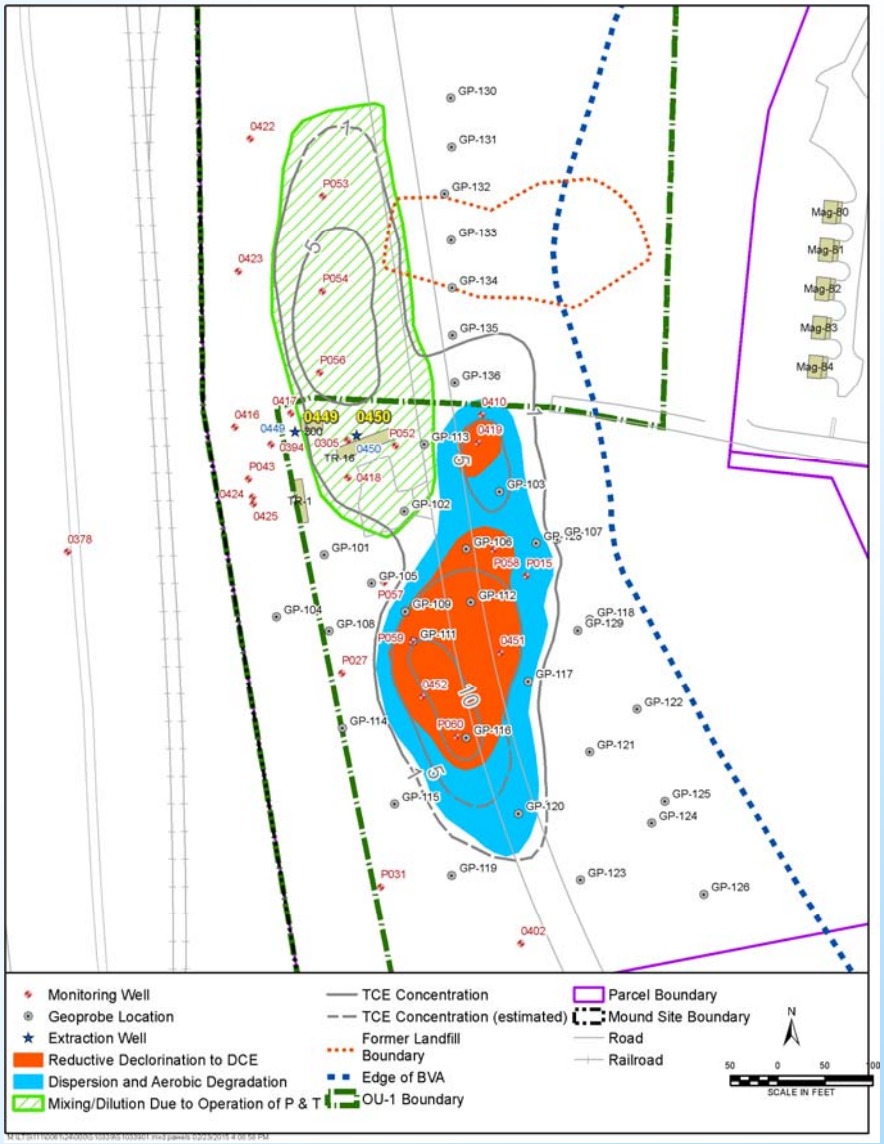
TCE distribution prior to IPT



TCE distribution after IPT

MNA Characterization (2013)

- Evaluation of potential attenuation processes
- Data indicated:
  - Reductive dechlorination of PCE to TCE
  - Subsequent reductive dechlorination of TCE to *cis*-1,2-dichloroethylene (DCE) is limited
  - Cometabolic aerobic oxidation of TCE and *cis*-1,2-DCE is feasible



Summary of Evaluation of VOCs in Groundwater

- Two areas of elevated VOCs in groundwater
  - Former landfill area
  - Downgradient of OU-1 capture zone
- Residually contaminated soil present in base of landfill
- No primary or secondary sources identified outside landfill boundary
- Impact downgradient of hydraulic boundary in dissolved phase
- Plume is not stagnant
- Migration rate is slow

Summary of Evaluation of VOCs in Groundwater (continued)

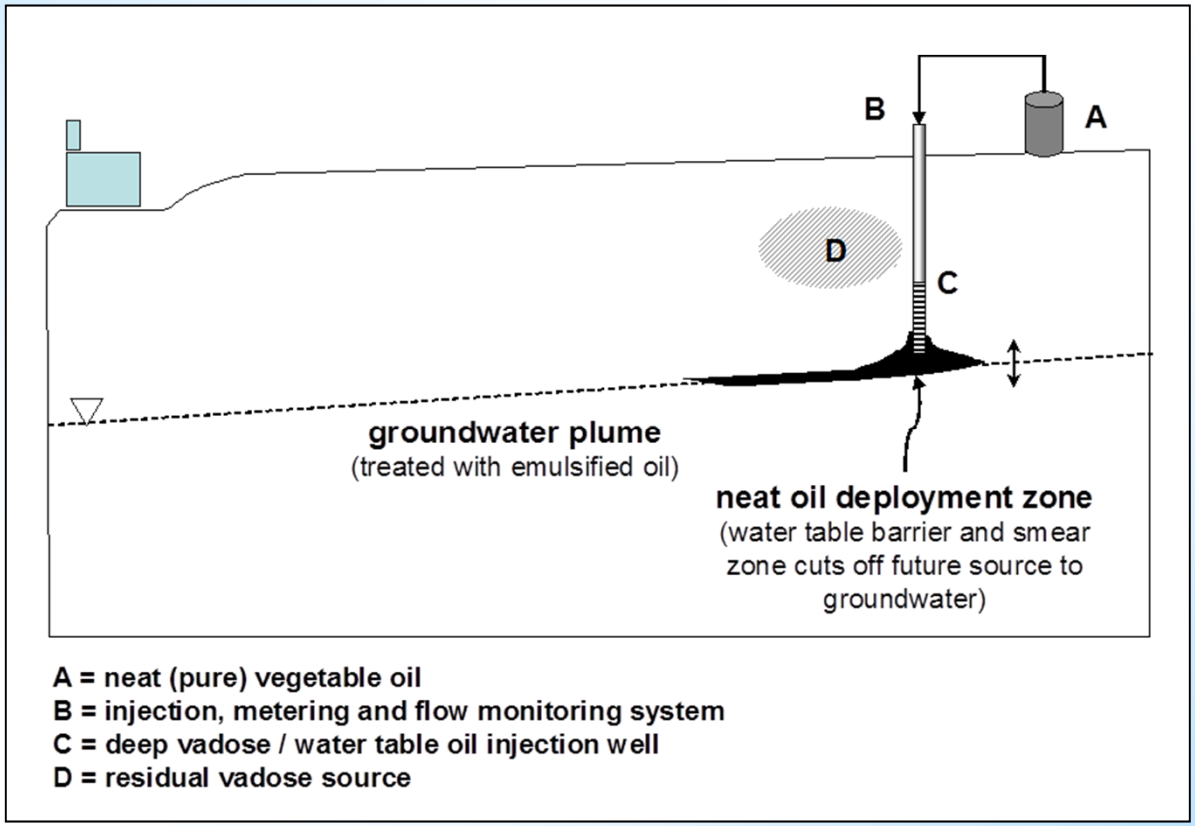
- Aerobic and generally oxidizing conditions dominate groundwater system
- Groundwater quality in contaminated areas depict anaerobic and more reducing environments
- Reductive dechlorination of PCE to TCE
- Subsequent reductive dechlorination of TCE to *cis*-1,2-DCE is limited
- Cometabolic aerobic oxidation of TCE and *cis*-1,2-DCE is feasible

Field Demonstration (2014)

- Enhanced attenuation strategies focus on altering a target site so that it will transition to natural attenuation
- Development of structured treatment zones to enhance natural attenuation mechanisms in the OU-1 aquifer

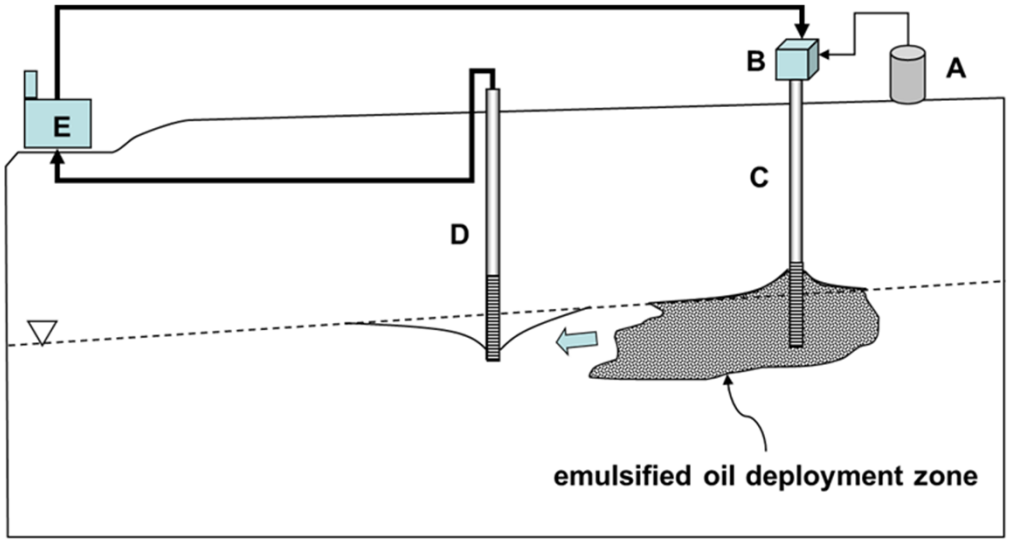
Field Demonstration (2014) (continued)

- Reduce future VOC loading from vadose zone (neat oil)
- Reduce oxygen inputs to local aquifer (neat oil)



Field Demonstration (2014) (continued)

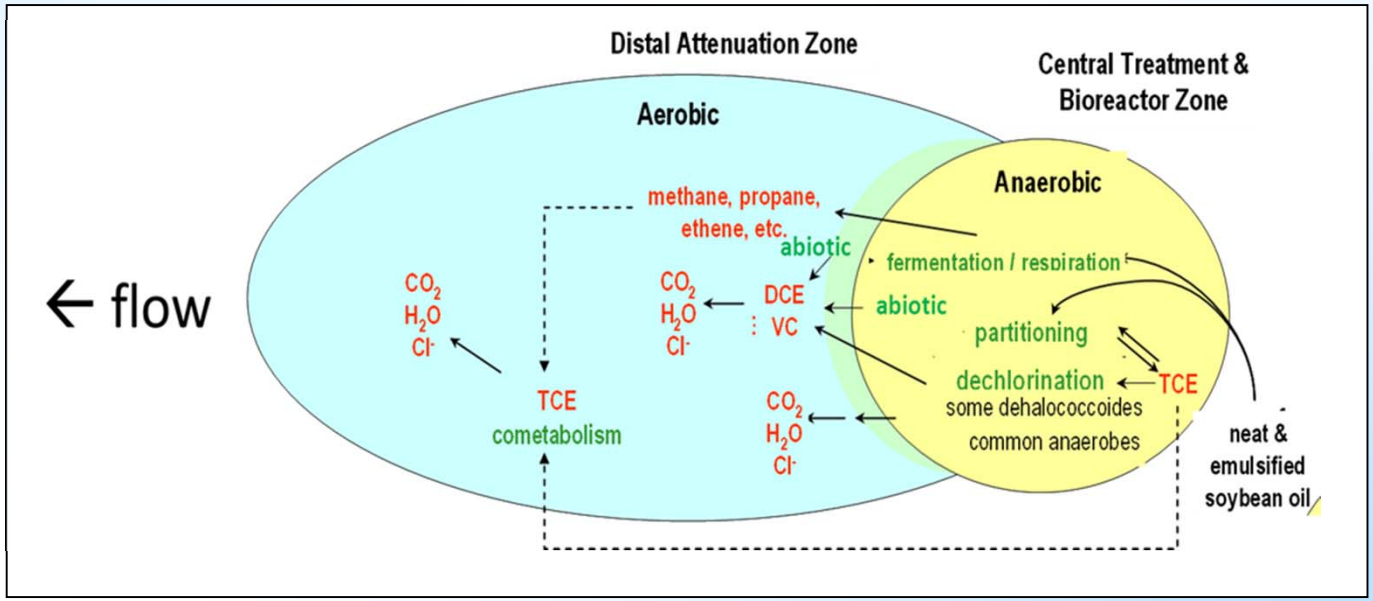
- Form active bioremediation treatment zones within plume footprint (emulsified oil)
- Stimulate long-term attenuation capacity (emulsified oil)



A = concentrated emulsified food grade vegetable oil, nutrients and buffer/base
B = metering and flow monitoring system
C = emulsified oil injection well
D = extraction well
E = air stripper – VOC water treatment system (equipped with tank/pump for recirculation)

Field Demonstration (2014) (continued)

- Develop structured geochemical zones and decrease chlorinated VOC through:
  - Physical sequestration to reduce effective aqueous concentration and mobility
  - Stimulation of degradation processes

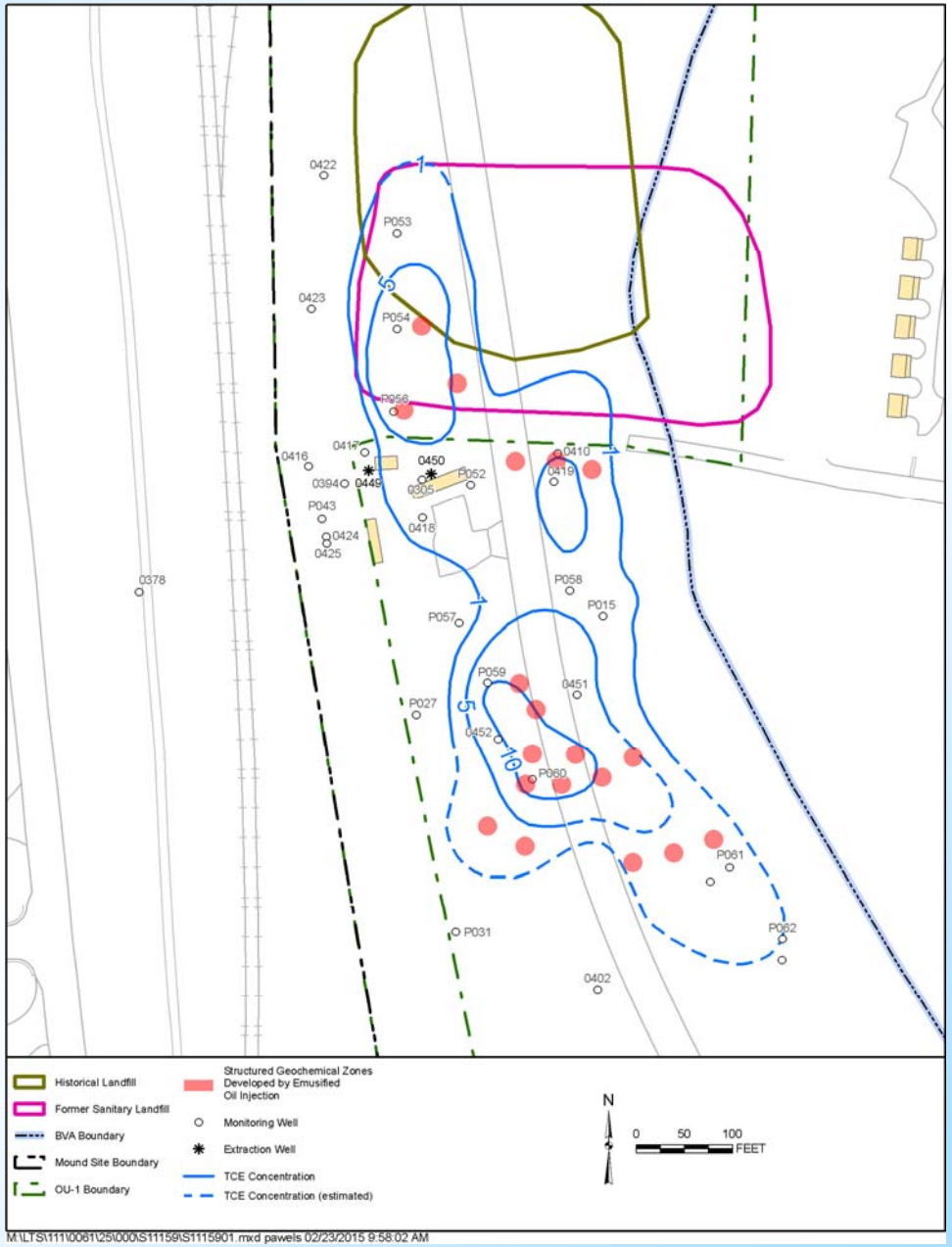


Deployment Approach

- **Former Source Area:** Soil
  - Areas with elevated soil concentrations of PCE and TCE

Deployment Approach (continued)

- **Former Source Area**: Groundwater
  - Flow paths originating from beneath former landfill
- **Downgradient of OU-1**: Groundwater
  - Area of groundwater impact downgradient of former landfill



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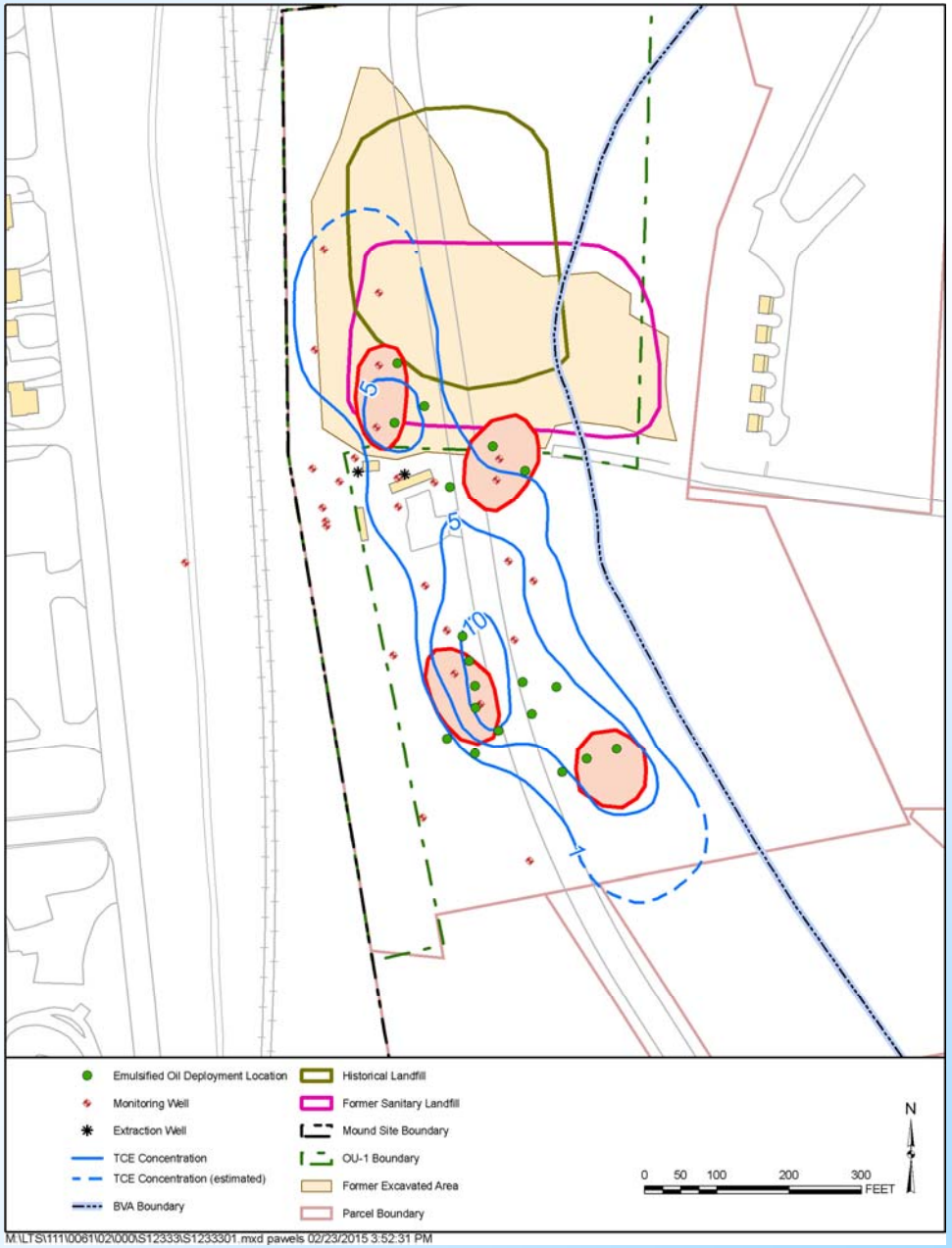
Field Demonstration Results (2015)

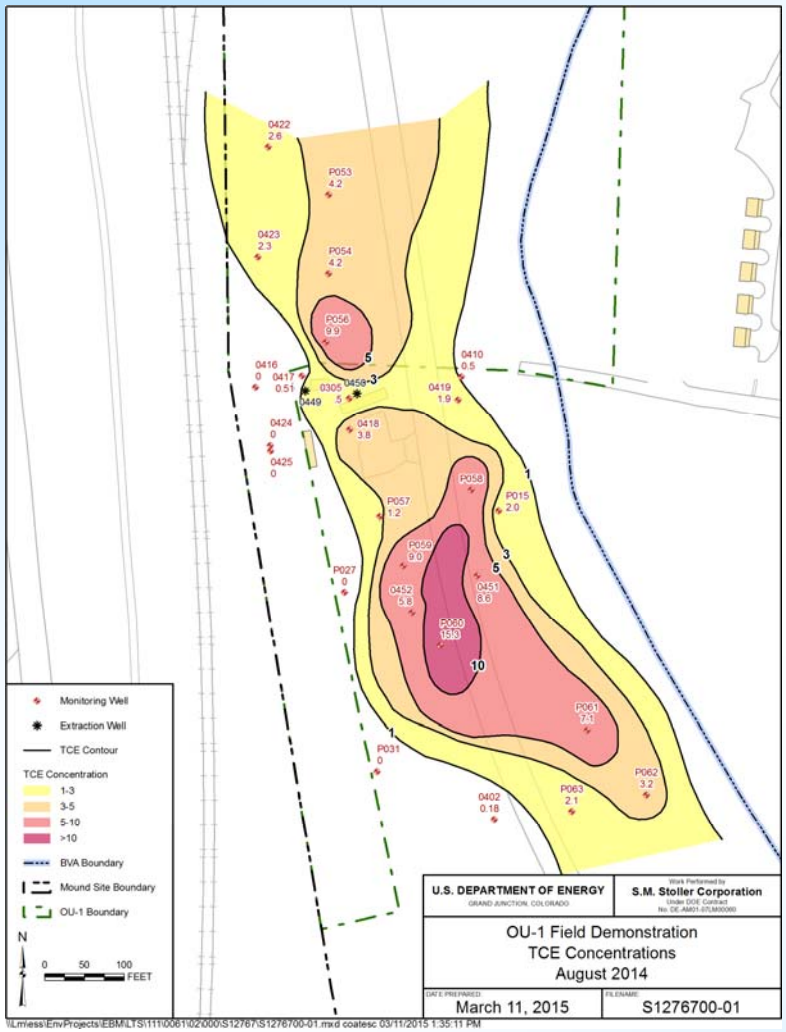
- Zones display:
  - Increased concentrations of *cis*-1,2-DCE
  - Negative oxidation-reduction potential values
  - Declining dissolved oxygen concentrations
  - Increased concentrations of metabolic byproducts
  - Groundwater exhibiting foul odor and color changes
  - Increased bacterial count

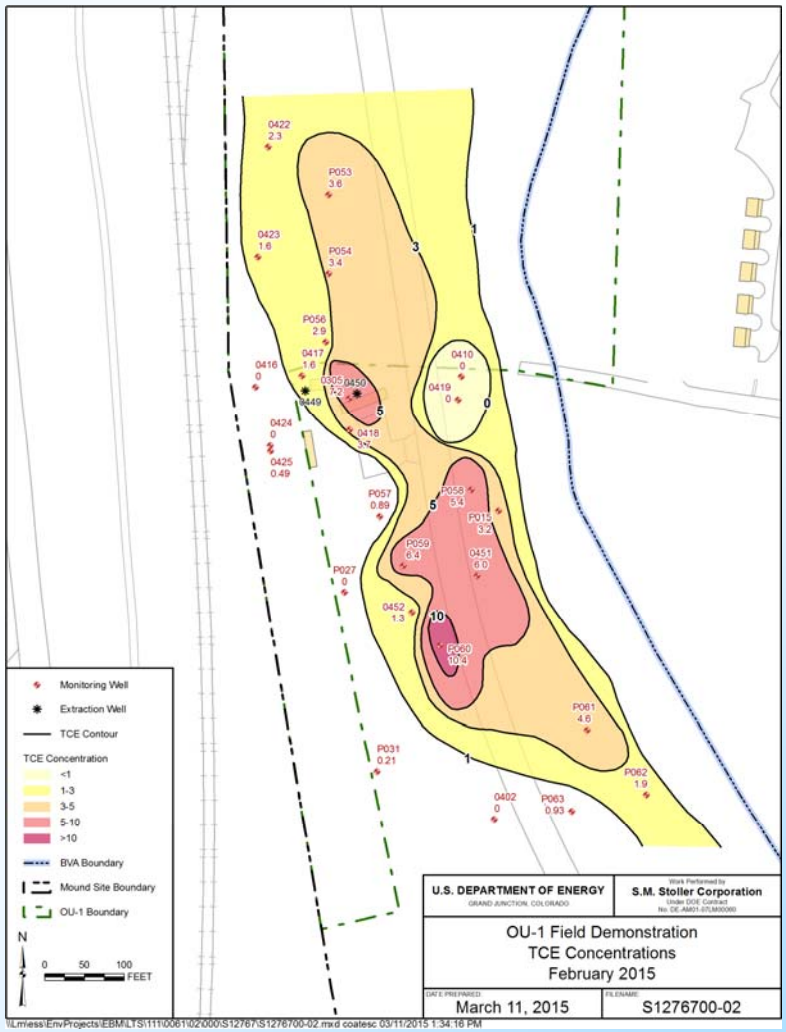


Field Demonstration Results (2015) (continued)

Summary of Microbial Data												
Location	Well 0419	Well 0419	Well P031	Well P031	Well P056	Well P056	Well P058	Well P058	Well P060	Well P060	Well P061	Well P061
Date	8/11/2014	11/18/2014	8/11/2014	11/18/2014	8/11/2014	11/18/2014	8/11/2014	11/18/2014	8/11/2014	11/18/2014	8/11/2014	11/18/2014
Analyte (cells/mL)												
REDUCTIVE DECHLORINATION												
Dehalococcoides spp. (DHC)	2	1.4	0.6	< 0.5	0.8	0.3 (J)	1.8	0.9	< 0.5	< 0.5	< 0.5	0.8
tceA Reductase (TCE)	< 0.5	0.3 (J)	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	0.6	< 0.5	< 0.5	< 0.5	< 0.5
BAV1 Vinyl Chloride Reductase (BVC)	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Vinyl Chloride Reductase (VCR)	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Dehalobacter spp. (DHBt)	< 5	32600	< 5	< 5	< 5	95.9	< 4.8	12.3	< 4.9	49.9	< 5	1380
Dehalobacter DCM (DCM)	< 5	< 5	< 5	< 5	< 5	< 5	< 4.8	< 5	< 4.9	< 5	< 5	25.8
Dehalogenimonas spp. (DHG)	< 5	1870	49.9	< 5	322	479	561	< 5	< 4.9	106	< 5	106
Desulfitaobacterium spp. (DSB)	< 5	1620	< 5	0.3 (J)	< 5	146	< 4.8	128	< 4.9	20.1	< 5	1790
Dehalobium chlorocoercia (DECO)	< 5	< 5	< 5	< 5	< 5	< 5	< 4.8	< 5	< 4.9	< 5	< 5	< 5
Desulfuromonas spp. (DSM)	< 5	86100	82	< 5	< 5	25900	< 4.8	< 5	< 4.9	112	< 5	78500
Chloroform reductase (CFR)	< 5	53.7	< 5	< 5	< 5	10	< 4.8	< 5	< 4.9	0.4 (J)	< 5	102
AEROBIC (Co)METABOLIC												
Soluble Methane monooxygenase (SMMO)	225	700	53.6	33.9	126	836	125	1070	< 4.9	1580	113	1600
Particulate Methane monooxygenase	2.7 (J)	6.5	< 5	75.4	0.7 (J)	6.3	1.6 (J)	61.1	1 (J)	1.5 (J)	1.4 (J)	8.1
Toluene Dioxygenase (TOD)	15.2	138	7.4	11.1	3.9 (J)	116	26.4	105	< 4.9	9.5	4.6 (J)	86.3
Phenol Hydroxylase (PHE)	< 5	1870	1.7 (J)	< 5	< 5	2310	< 4.8	535	< 4.9	< 5	< 5	289
Tricholorobenzene Dioxygenase (TCBO)	< 5	< 5	< 5	< 5	< 5	< 5	< 4.8	< 5	< 4.9	< 5	< 5	< 5
Toluene Monooxygenase 2 (RDEG)	< 5	587	< 5	36.9	< 5	182	< 4.8	110	< 4.9	11.9	< 5	886
Toluene Monooxygenase (RMO)	< 5	410	< 5	< 5	< 5	178	< 4.8	17.5	< 4.9	< 5	< 5	< 5
Ethene Monooxygenase (EtnC)	< 5	< 5	< 5	< 5	< 5	< 5	< 4.8	< 5	< 4.9	< 5	< 5	< 5
Epoxyalkane transferase (EtnE)	< 5	< 5	< 5	< 5	< 5	< 5	< 4.8	< 5	< 4.9	< 5	< 5	< 5
OTHER												
Total Eubacteria (EBAC)	11000	724000	14500	35200	49700	859000	105000	503000	1090	84500	22700	2460000
Sulfate Reducing Bacteria (APS)	3590	21400	8.6	< 5	9030	169000	13800	36600	< 4.9	126	< 5	41200
Methanogens (MGN)	11.8	139	41.7	4.2 (J)	2.8 (J)	84.7	17.4	613	2 (J)	43.1	0.7 (J)	362

Field Demonstrations Results (2105) (continued)





Conclusions

- Performance of phase-combined remedies has resulted in significant reductions in concentrations of PCE and TCE in groundwater
- The areas where the concentrations of PCE and TCE exceed the MCLs are defined and limited
- PCE and TCE concentrations have not increased since the injection of the edible oils to stimulation attenuation
- Operation of the P&T system has been suspended to allow for natural groundwater flow though the OU-1 area
- Downgradient water quality has not been impacted
- Data supports creation of zones conducive to the degradation of PCE and TCE