

MTBE Degradation under Varying Oxidative and Reducing Conditions

David Laughlin, P.E.
ETEC, LLC. - Albuquerque, NM

Brian Timmins, M.S.
ETEC, LLC - Portland, OR

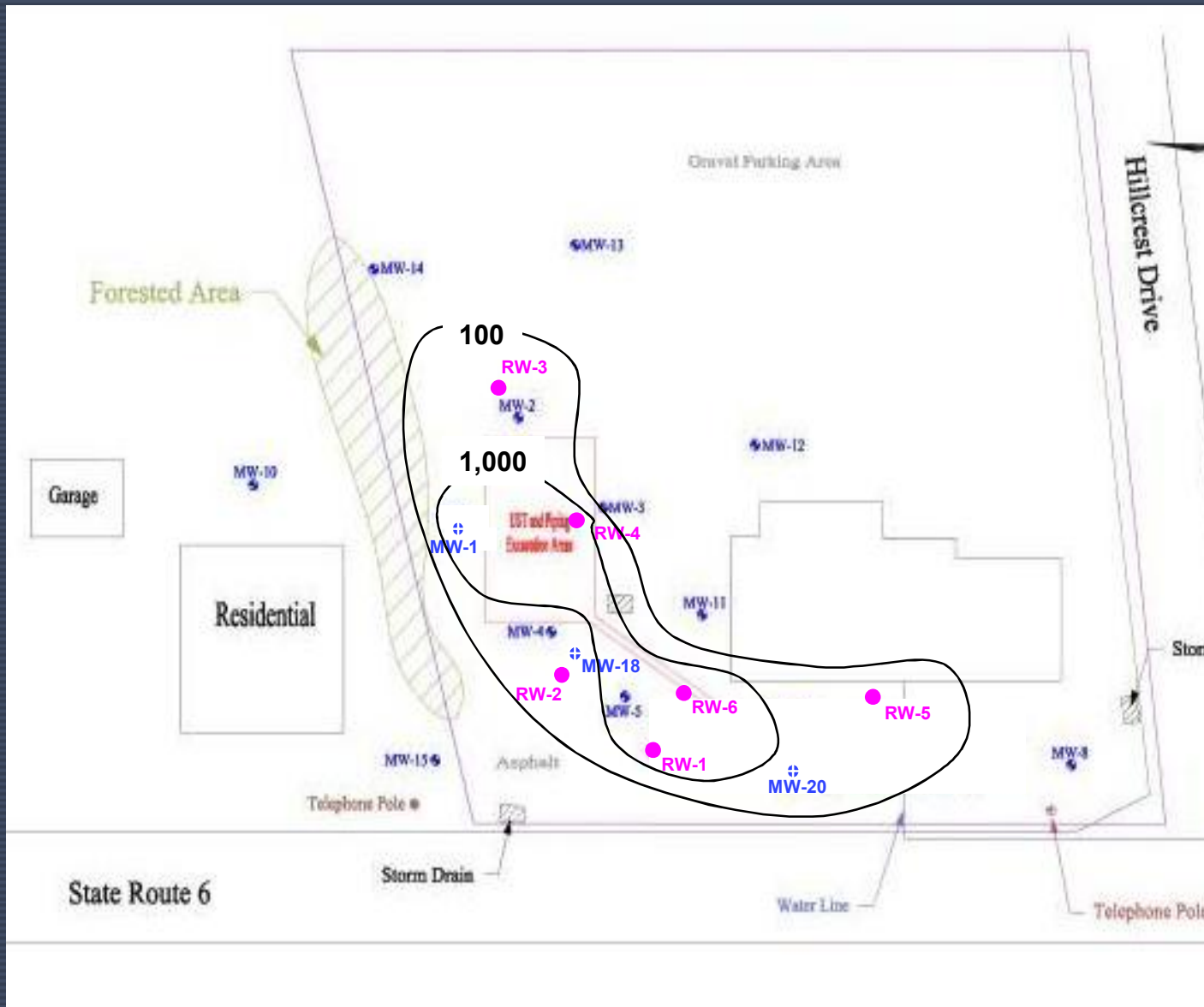
Roadmap

1) Field Data: A brief overview of field activities at an MTBE remediation project in PA, which prompted a pilot-scale demonstration and additional bench-scale evaluation.

2) Existing Research: Summary of pertinent research studies regarding aerobic and anaerobic degradation of MTBE.

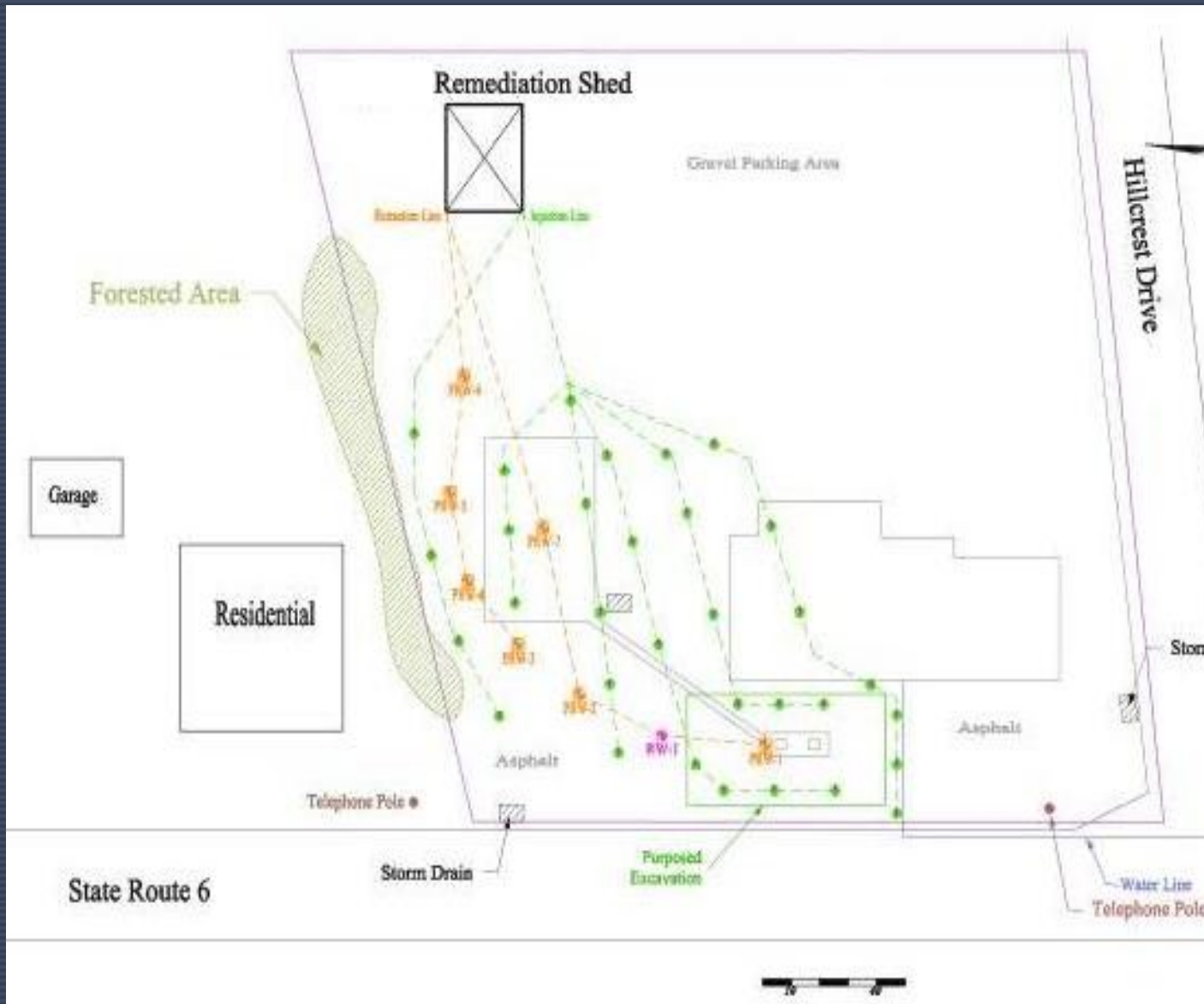
3) Bench Scale Results: A summary of the bench scale test design, and discussion/analysis of the results.

Site Description



- Former Gas Station in PA
- Shallow Groundwater at 5-7 feet bgs
- Soil type is silty sand with underlying clay
- MTBE was the only contaminant of concern (no BTEX, TPH, etc.)
- Initial MTBE concentrations were as high as 3,000 ppb
- Remediation goal for MTBE was 20 ppb (PADEP SHS)

Remediation System Layout



- Source area excavation
- Groundwater Oxygenation / Recirculation System w/ GAC pre-treatment
- Six Groundwater Extraction Wells and 25 injection wells
- Oxygenation / Injection System – 10-gpm Super-Ox unit operating continuously
- Average recirculation rate of 15-20 gpm
- Some reductions after 6 months, fluctuating MTBE levels in source area(s)

Supporting MTBE Research

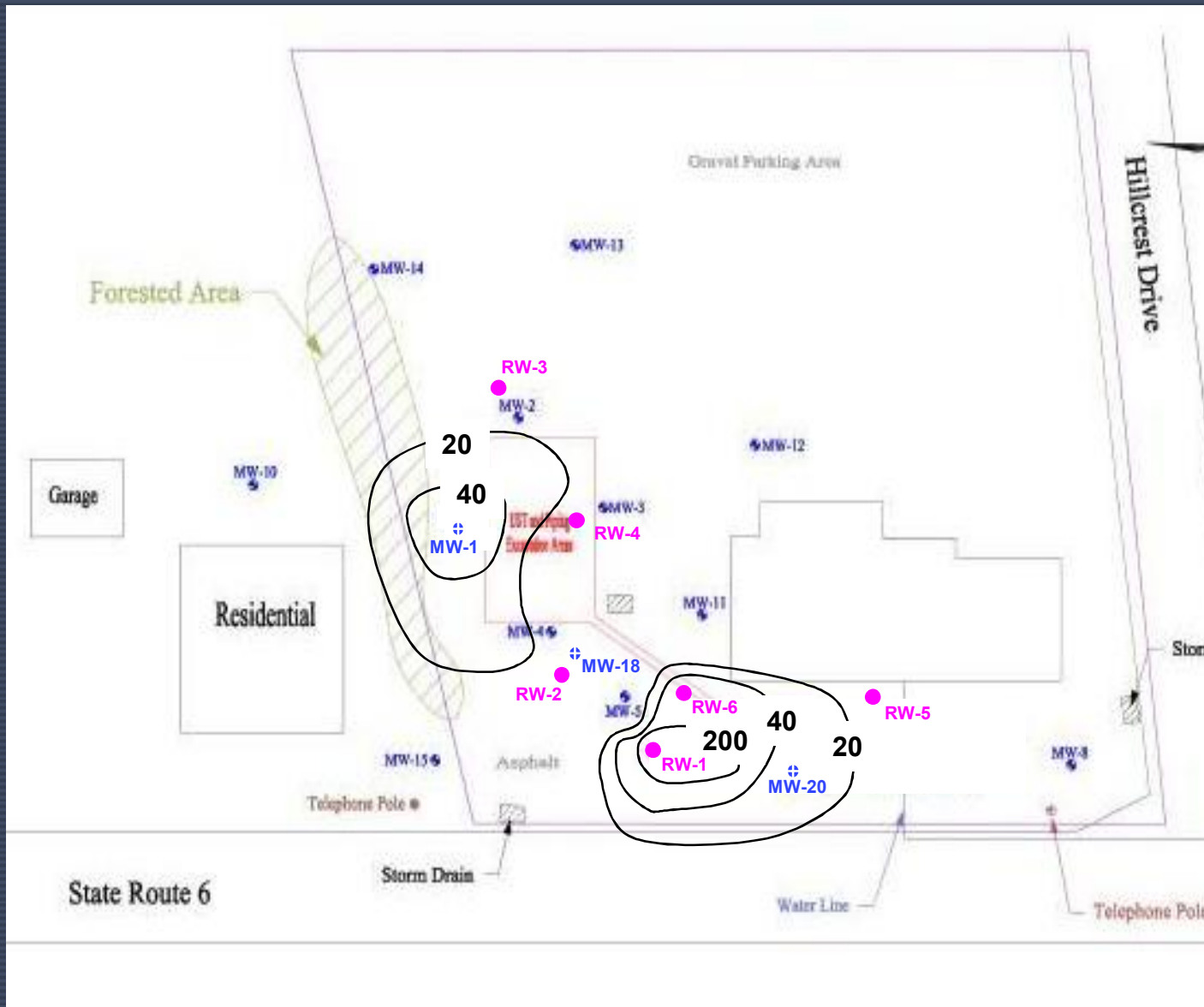
Aerobic Degradation of MTBE

- Enrichment/identification of MTBE-degrading consortia: Jensen & Arvin (1990), Salanitro et. al. (1994), and others.
- Identification of alkanes as a co-metabolic source of carbon & energy produced significant research efforts: Steffen et. al. (1997), Hyman et. al. (1998), Garnier et. al. (1999), Smith et. al. (2003), and others. (Role of mono-oxygenase enzyme activity identified).
- Isolation of pure strains capable of degrading MTBE as a sole carbon & energy source: Mo et. al. (1997), Hanson, Ackerman & Scow (1999), Hatzinger et. al. (2001), Francois et. al. (2002), and Nakatsu et. al. (2006), Rohwerder et. al. (2006)
- Rittman et. al. (2003) showed that favorable aerobic MTBE degradation required high dissolved oxygen concentrations and microorganisms with oxygenase activity.
- Identification of non-alkane substrates capable of stimulating co-metabolic degradation: Johnson, Smith, O'Reilly & Hyman (2003) evaluated growth of a microbial strain with proven co-metabolic degradation of MTBE on various non-alkane substrates, and demonstrated that sugars, alcohols, and organic acids were able to successfully stimulate co-metabolic degradation of MTBE.
- Muller et. al. (2007) evaluated MTBE degradation using a growth-related kinetic model and showed that due to slow degradation kinetics, there was a minimum substrate concentration below which MTBE would not support further direct oxidation.

Anaerobic Degradation of MTBE

- Anaerobic degradation under varying reductive conditions (denitrifying, methanogenic, etc.): Bradley et. al. (2001), Finneran & Lovley (2001), Somsomak et. al. (2001), Wilson et. al. (2000), and others.

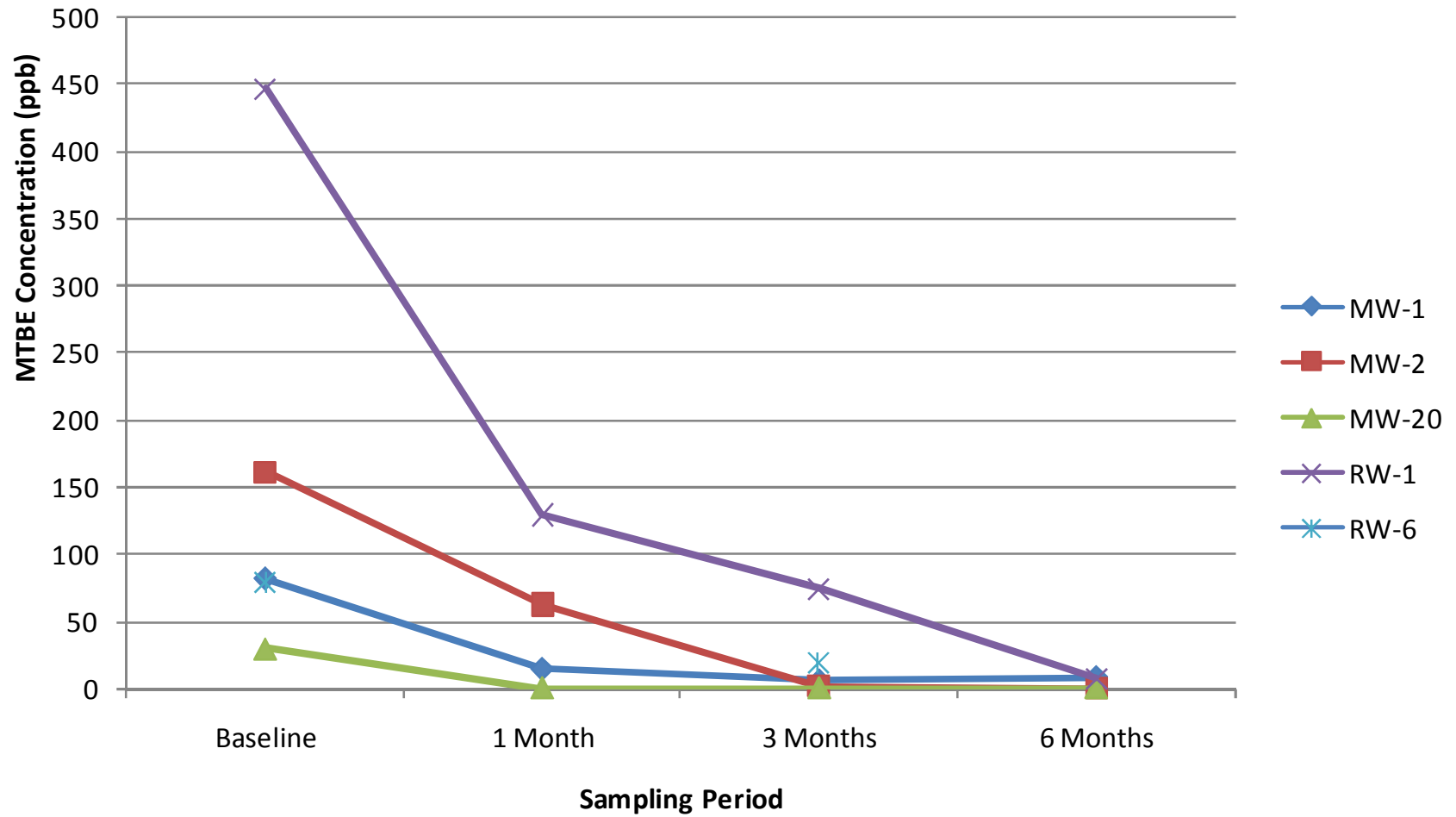
Adjusted Remedial Approach



- Injected 50 lbs. of nutrient-amended substrate into the two impacted zones
- Continued with oxygenation and recirculation of groundwater
- Subsequent quarterly results showed dramatic MTBE reductions in the source area(s)

Remediation Results

MTBE Groundwater Concentrations after Substrate Addition



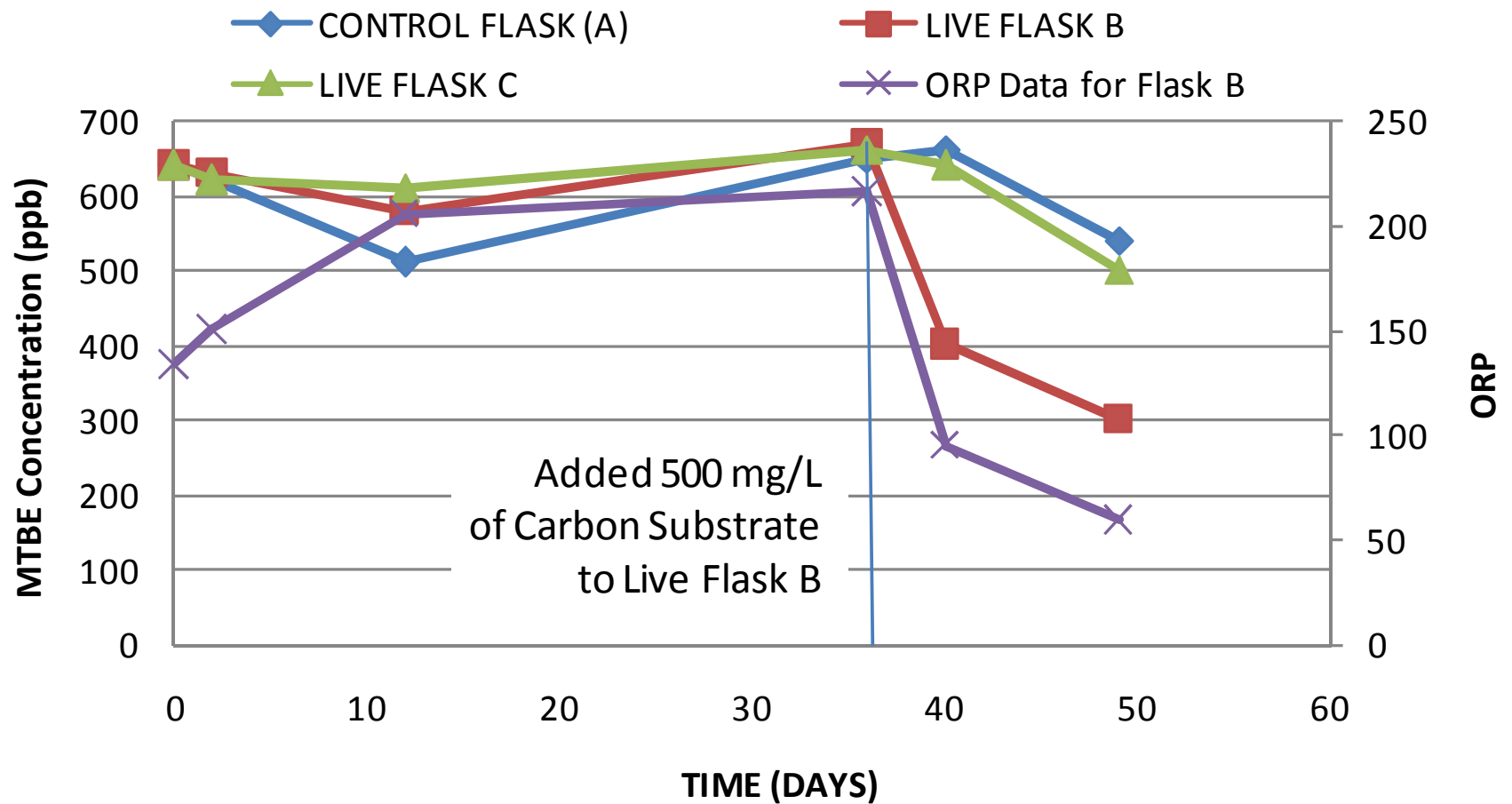
Laboratory Confirmation

- Wanted to verify that aerobic-cometabolism was responsible for field results:
 - Treatability Test #1 – Evaluate MTBE degradation under aerobic conditions, both before and after substrate addition.
 - 1 Live Control Flask
 - 1 Aerobic Test Flask
 - 1 Aerobic Co-Metabolic Test Flask
 - Used site groundwater – no nutrient or bacterial addition
 - Substrate consisted of 95% glucose, 5% micro-nutrient/trace metals
- Verify potential for stimulating anaerobic MTBE degradation under methanogenic conditions.
 - Treatability Test #2 – Evaluate MTBE degradation under aerobic, aerobic co-metabolic, and methanogenic conditions
 - 1 Killed Control Flask
 - 1 Aerobic Test Flask
 - 1 Aerobic Co-Metabolic Test Flask
 - 1 Anaerobic Test Flask
 - Same substrate as above

Treatability Test #1 - Results

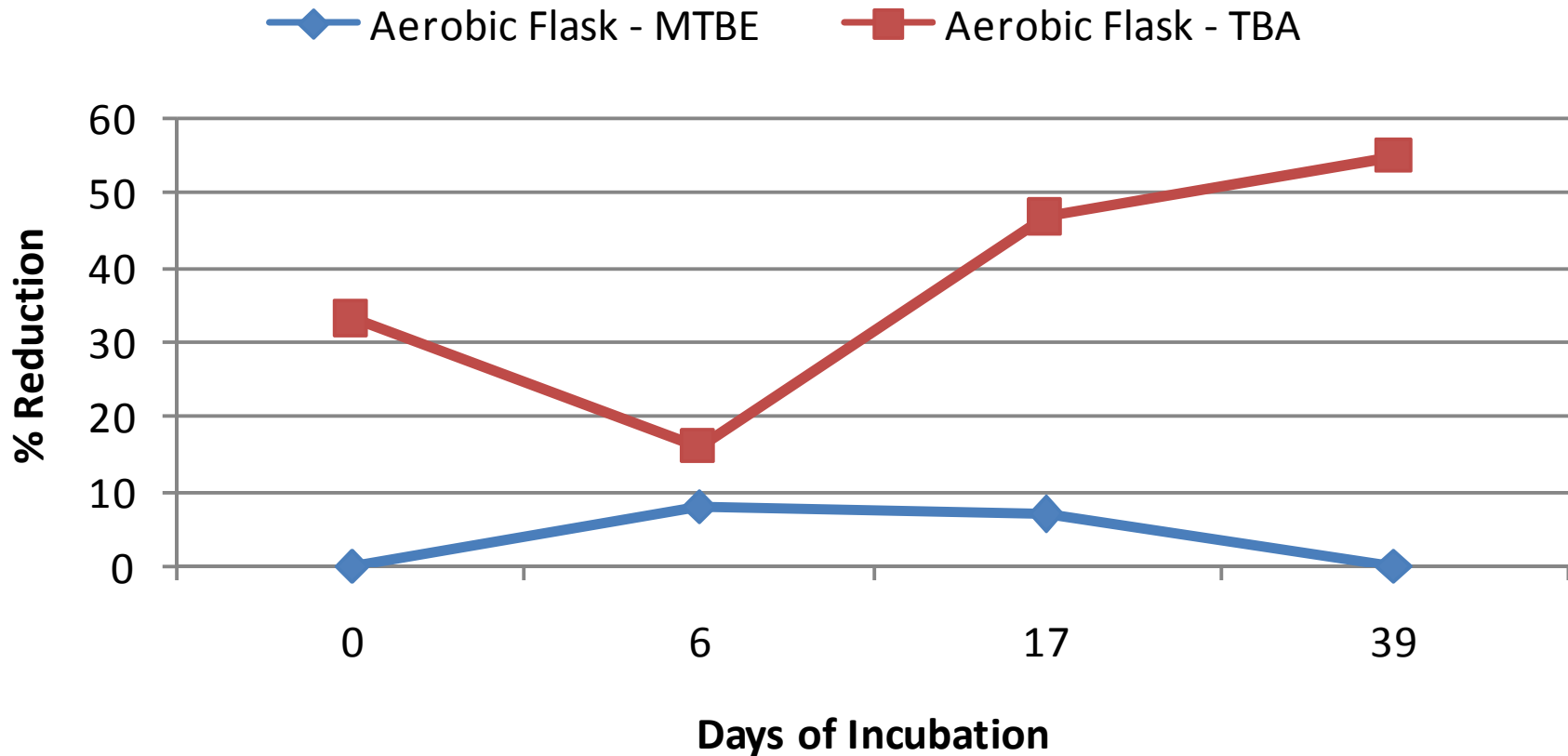
Treatability Test #1

Impact of Substrate on Aerobic MTBE Degradation



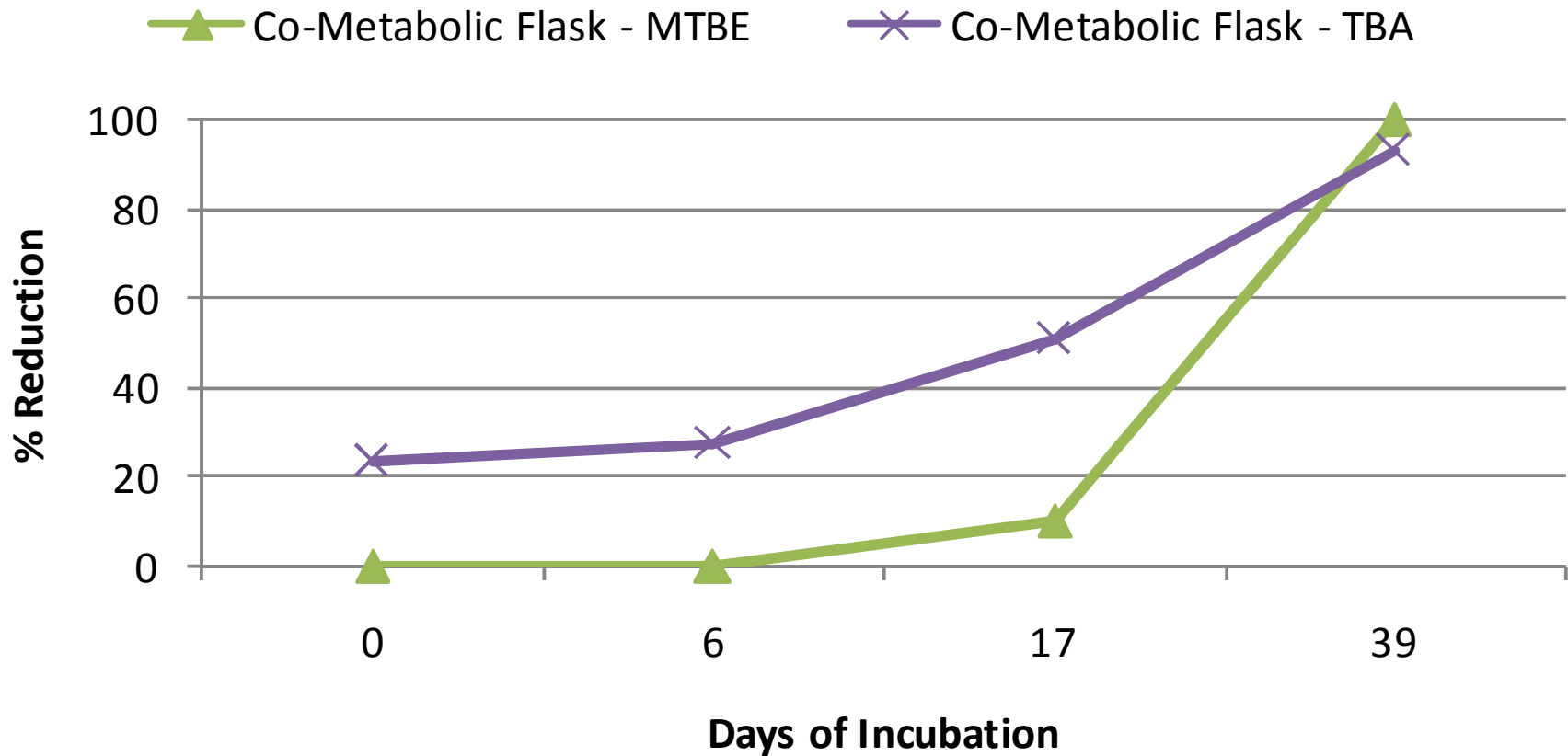
Treatability Test #2 - Results

Aerobic Flask Results



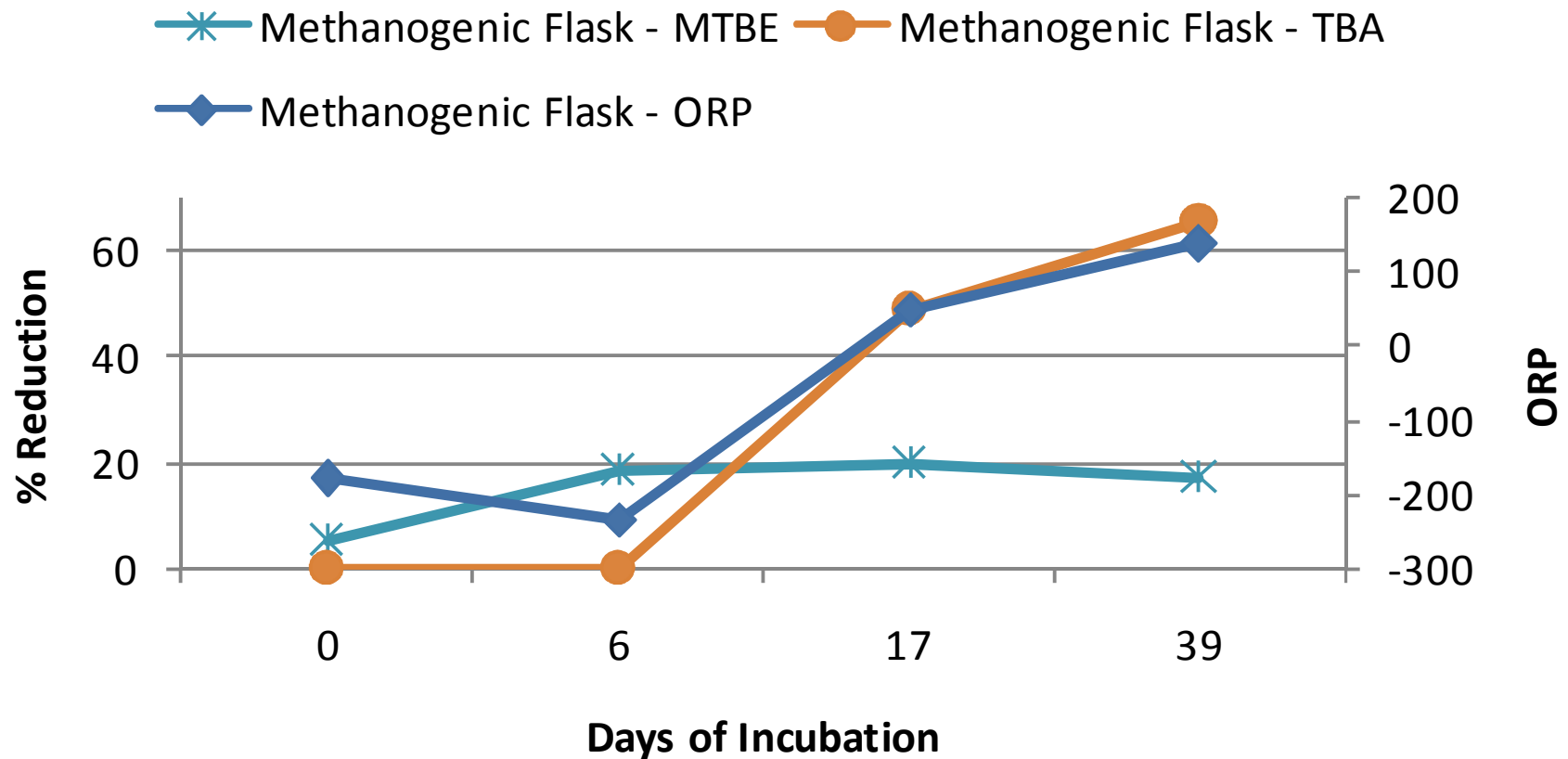
Treatability Test #2 - Results

Aerobic Co-Metabolic Flask Results



Treatability Test #2 - Results

Methanogenic Flask Results



Conclusions

- Field Results and Treatability Tests confirmed that aerobic co-metabolism significantly enhanced degradation of low-concentration MTBE in a shallow GW aquifer.
- The GW Oxygenation/Recirculation System successfully maintained aerobic conditions and effectively delivered the co-metabolic substrate.
- The indigenous bacterial population was able to degrade MTBE in the presence of a non-alkane substrate

Lessons Learned

- Lessons Learned
 - MTBE degradation under methanogenic conditions may also be viable as a field-scale technology.
 - Anaerobic treatability tests need a strict protocol and design to maintain desired anaerobic conditions.
 - TBA Degradation may be inhibited under methanogenic conditions.
- Costs
 - Field-scale remediation system (equipment, amendments, installation) - \$95,000
 - Laboratory-scale verification - \$10,000