

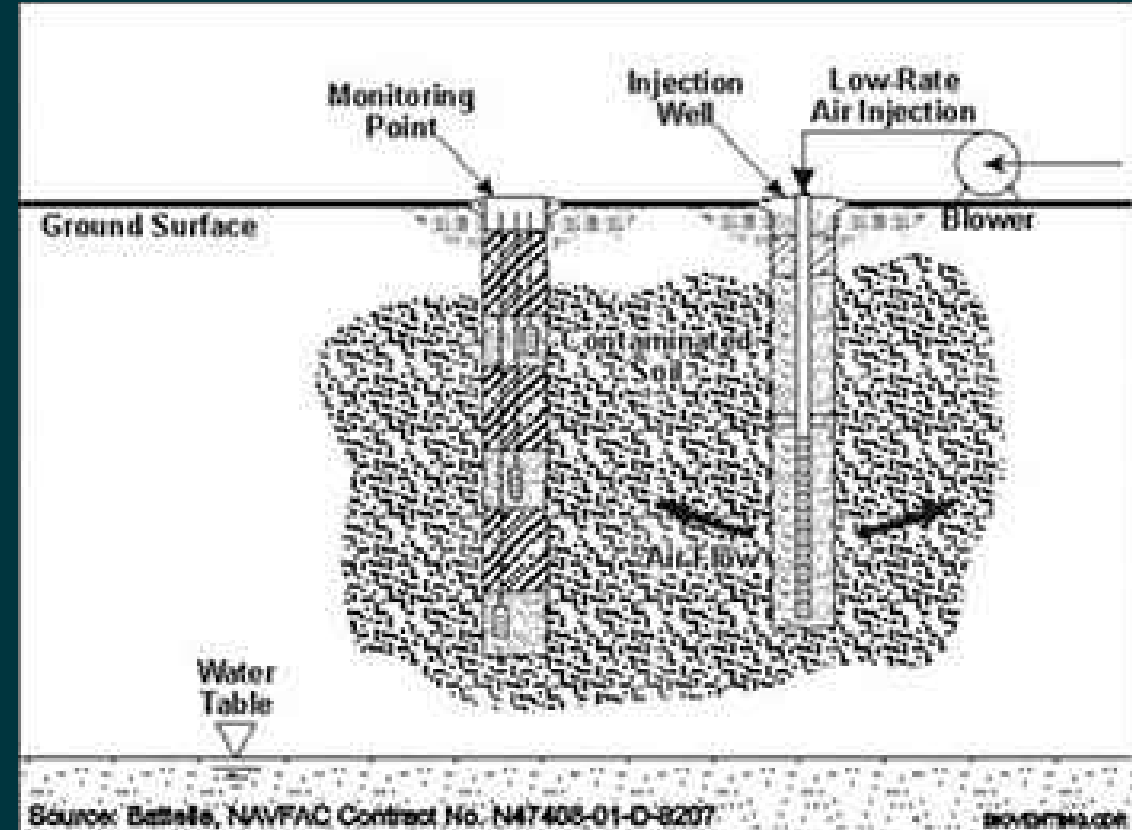
Enhancing Biodegradation of LNAPL with Bioventing

Steven Gaito

Bioventing

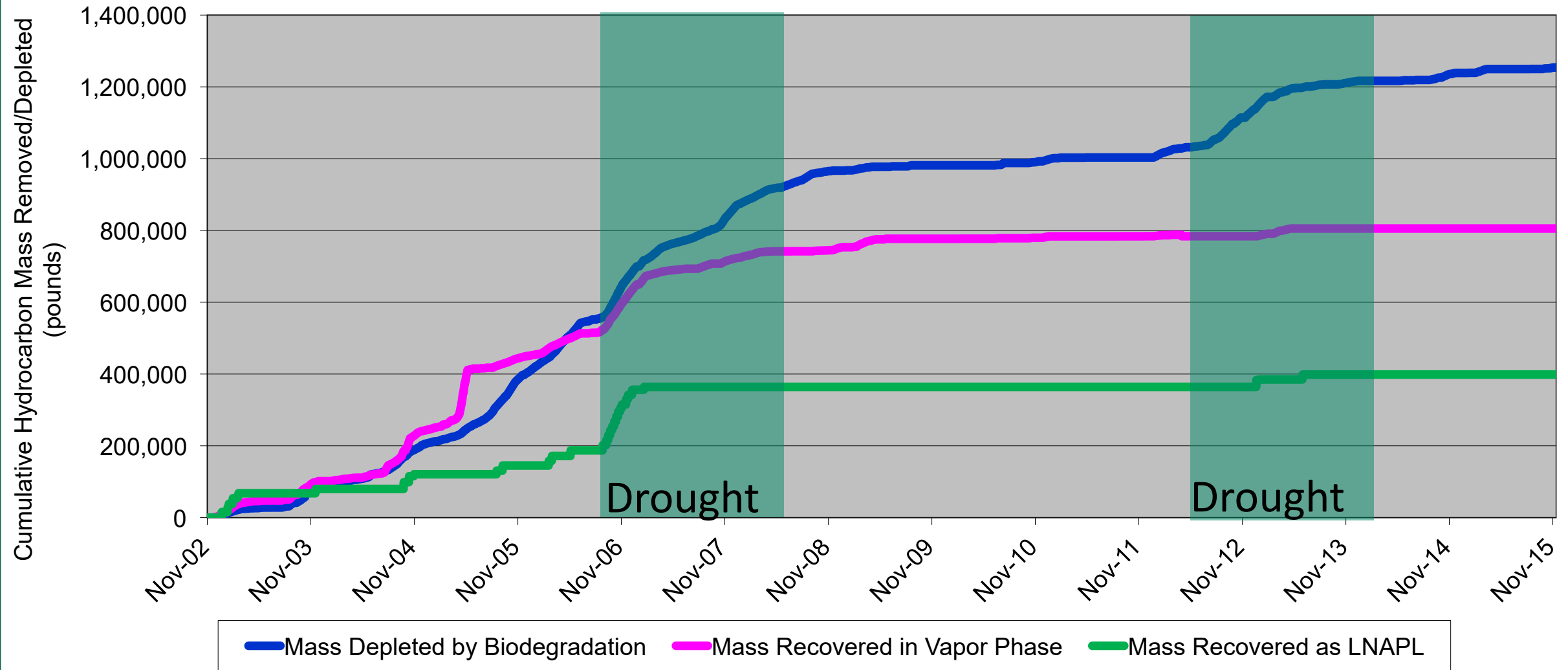
Traditionally considered a remedy for aerobically degradable contaminants in the vadose zone

Not considered applicable at sites with mobile LNAPL



Bioventing for Mobile LNAPL?

Multiphase Extraction (MPE) Semi-confined Gasoline Plume



Biodegradation was most effective

LNAPL Depletion Rates



*Lundegard and Johnson (2006), Garg et al. 2017, Concawe (2020), Smith et al.(2021), CRC CARE (2020) and Kulkarni et al. (2020)

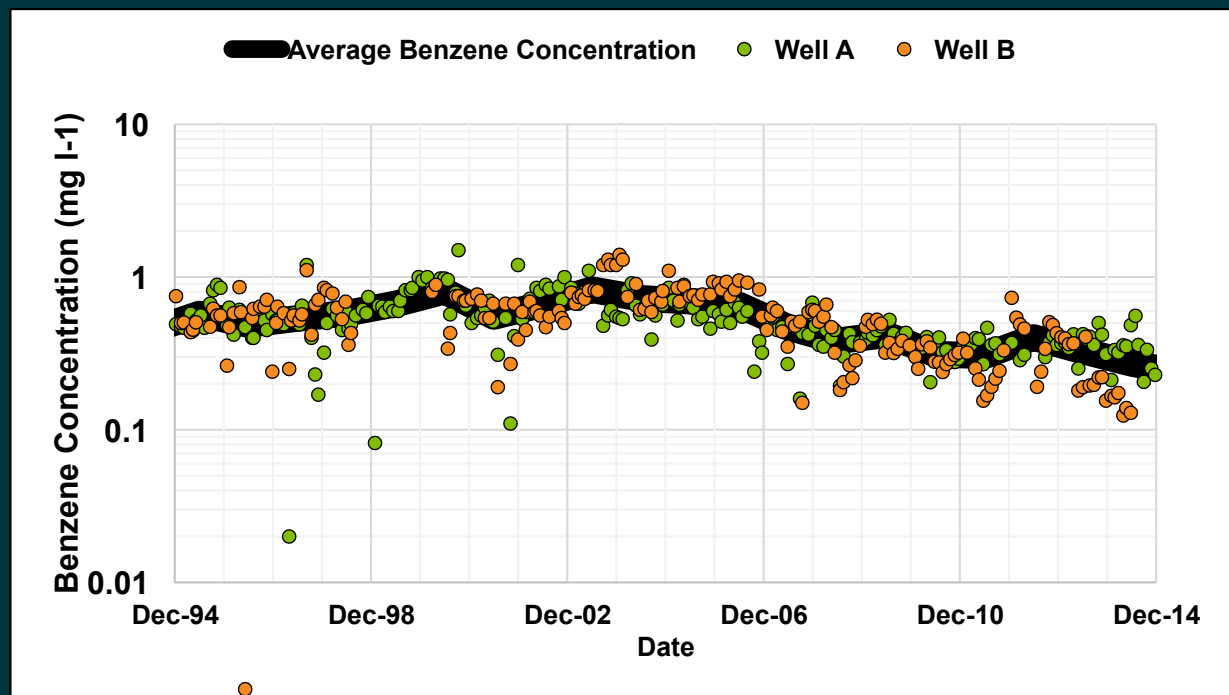
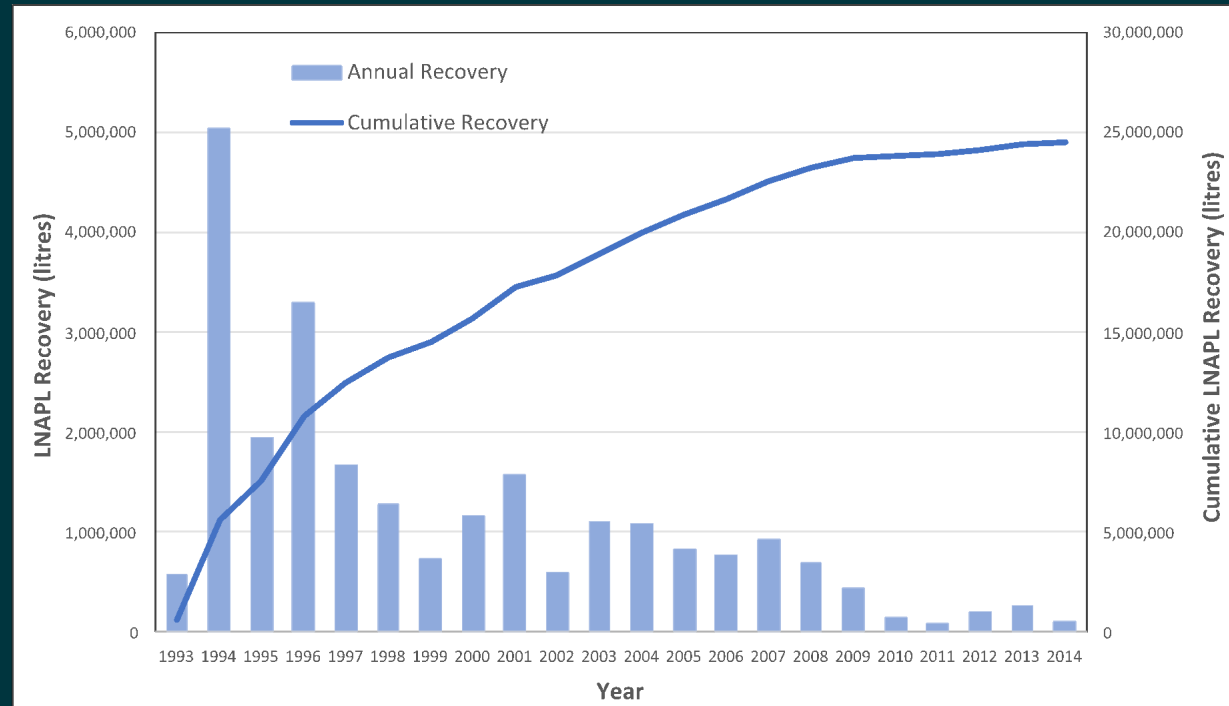
Bioventing Forum

- Engage stakeholders on maximum extent practicable (MEP)
- Hydraulic recovery vs. bioventing vs. natural source zone depletion (NSZD)
- Series of meetings
 - AECOM
 - API Members
 - EPA HQ and Regions
 - ~15 States
- Journal article
 - Not explicitly endorsed by forum



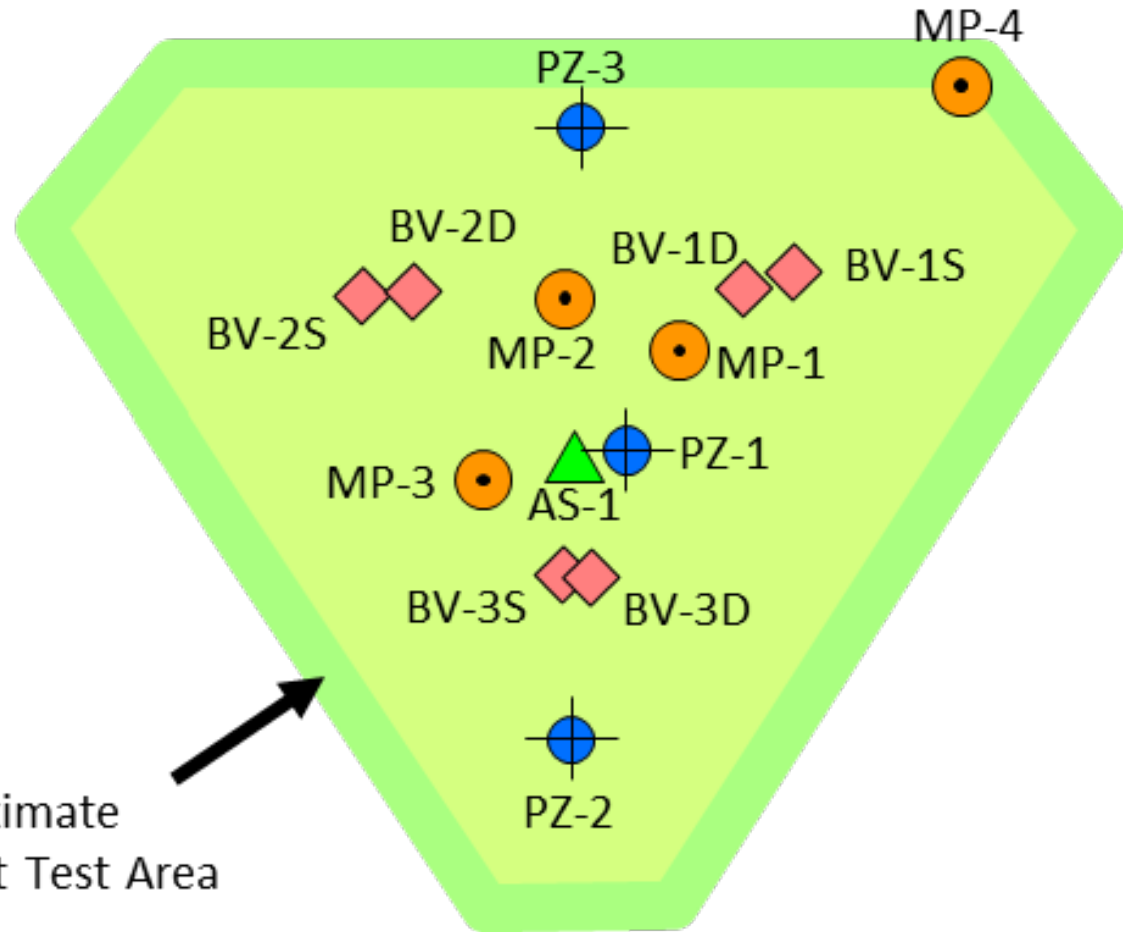
Case Study

- Site Conditions
 - Fine grained soils overlying sand
 - Water ~10 meters below ground
 - LNAPL smear zone
 - 3-6 meters above water table
 - 10 meters below water table
- Historical Remedial Actions
 - LNAPL recovery
 - Groundwater pumping
- Remedial Goals
 - Recover LNAPL to Maximum Extent Practicable
 - Reduce benzene concentrations
- Challenges
 - Asymptotic hydraulic LNAPL Recovery
 - Elevated benzene concentrations








Pilot Study

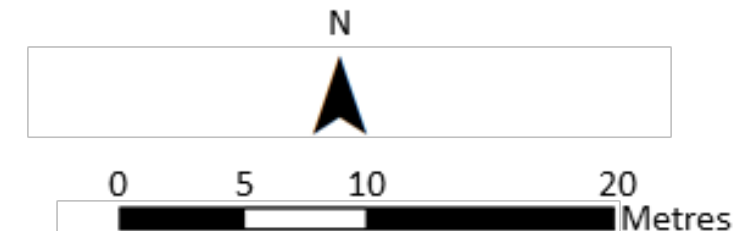
Bioventing to Enhance Biodegradation



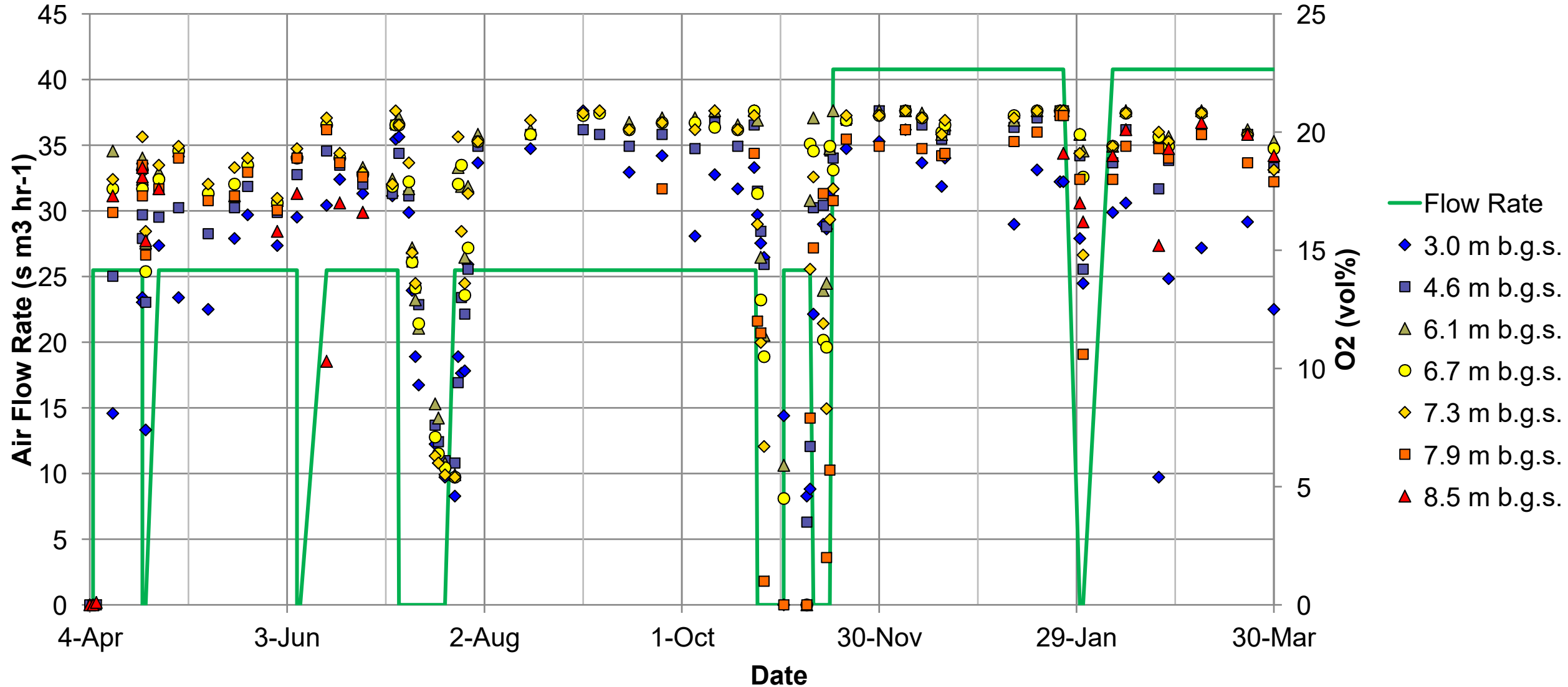
Legend

-  Air Sparge Well
-  Biovent Well
-  Piezometer
-  Vapor Monitoring Points

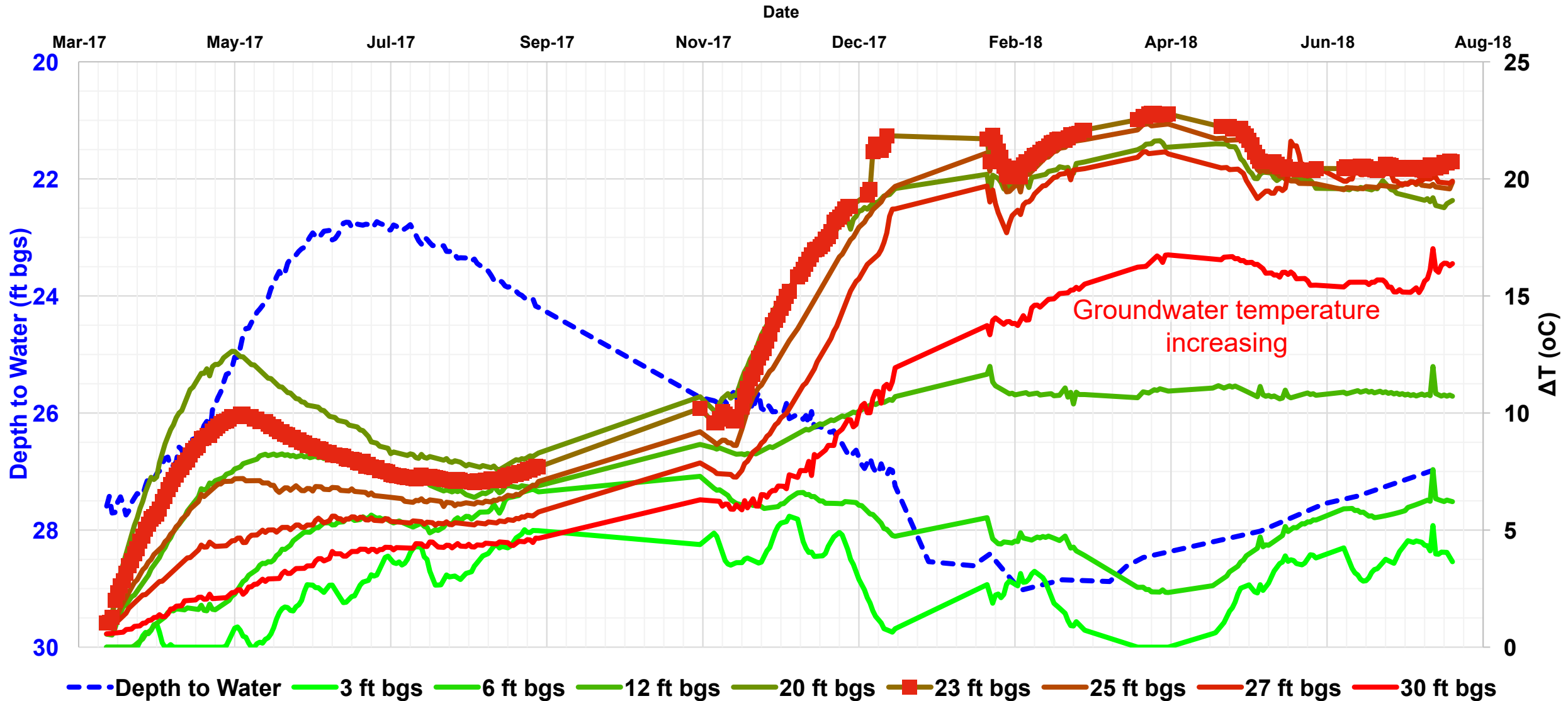
 Biovent Building



Evidence of Biodegradation

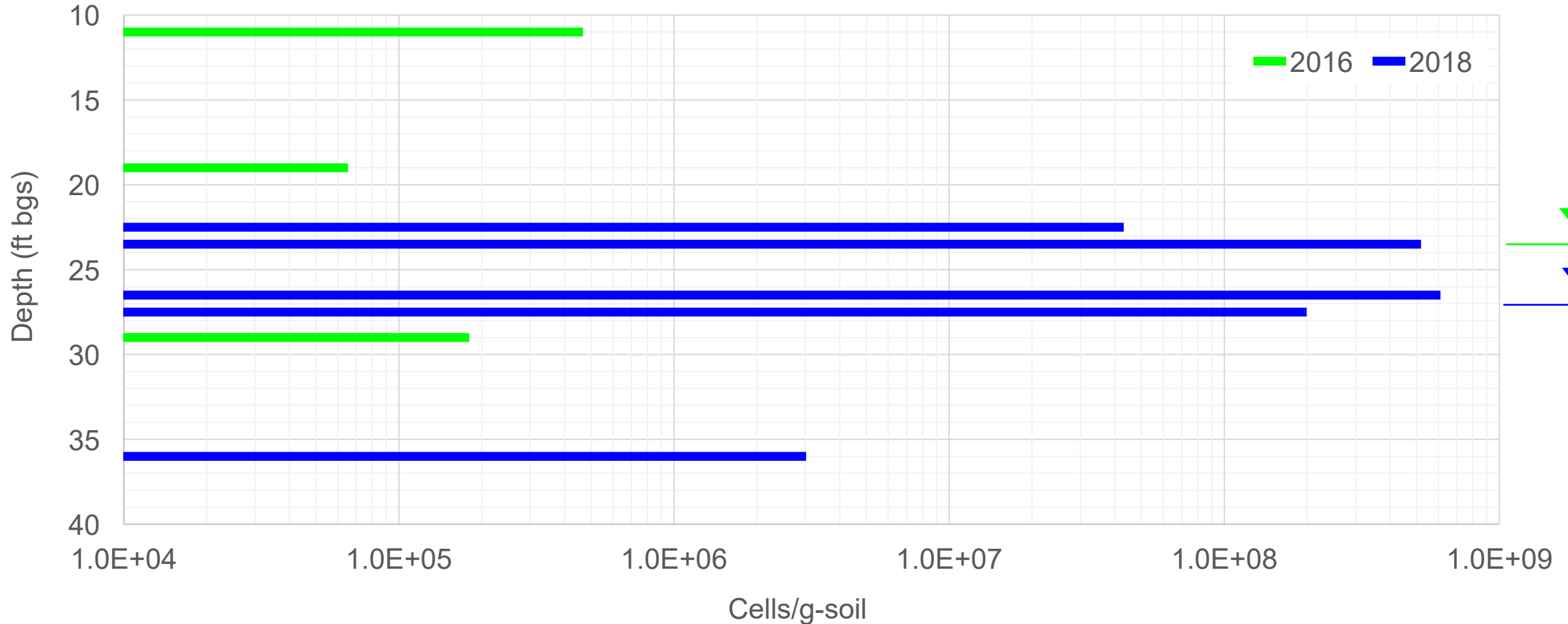


Evidence of Biodegradation

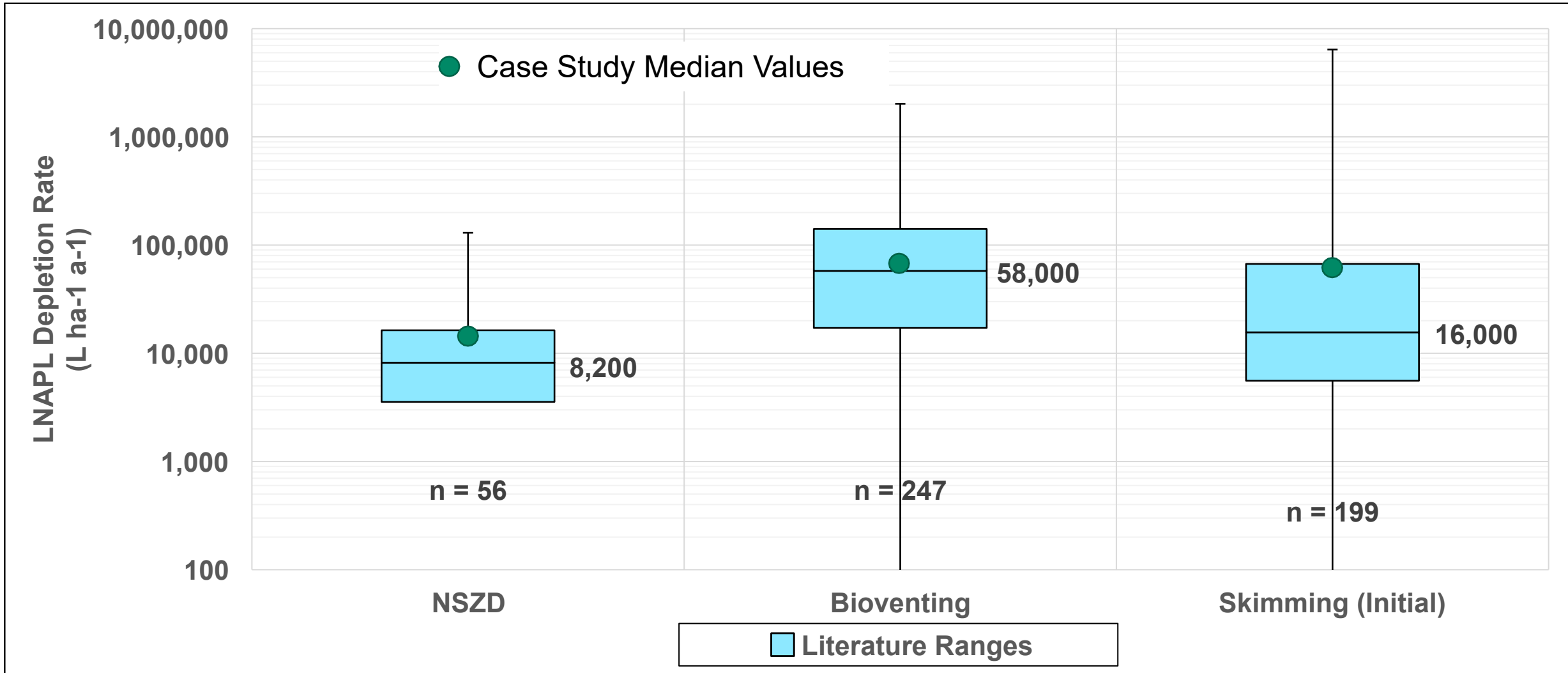


Evidence of Biodegradation

DNA - Aerobic BTEX Degraders
Baseline (2016) vs. April 2018

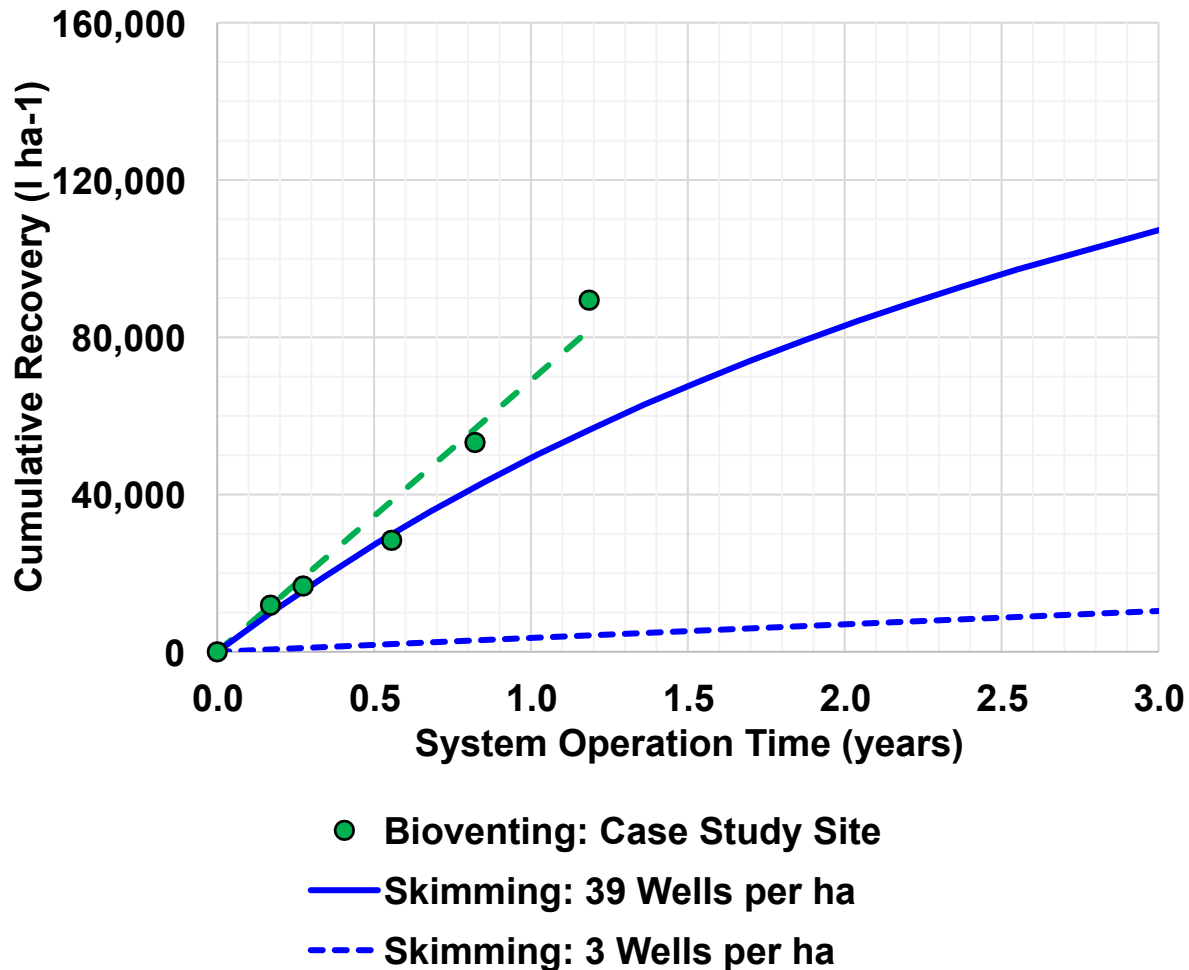


LNAPL Depletion Rates

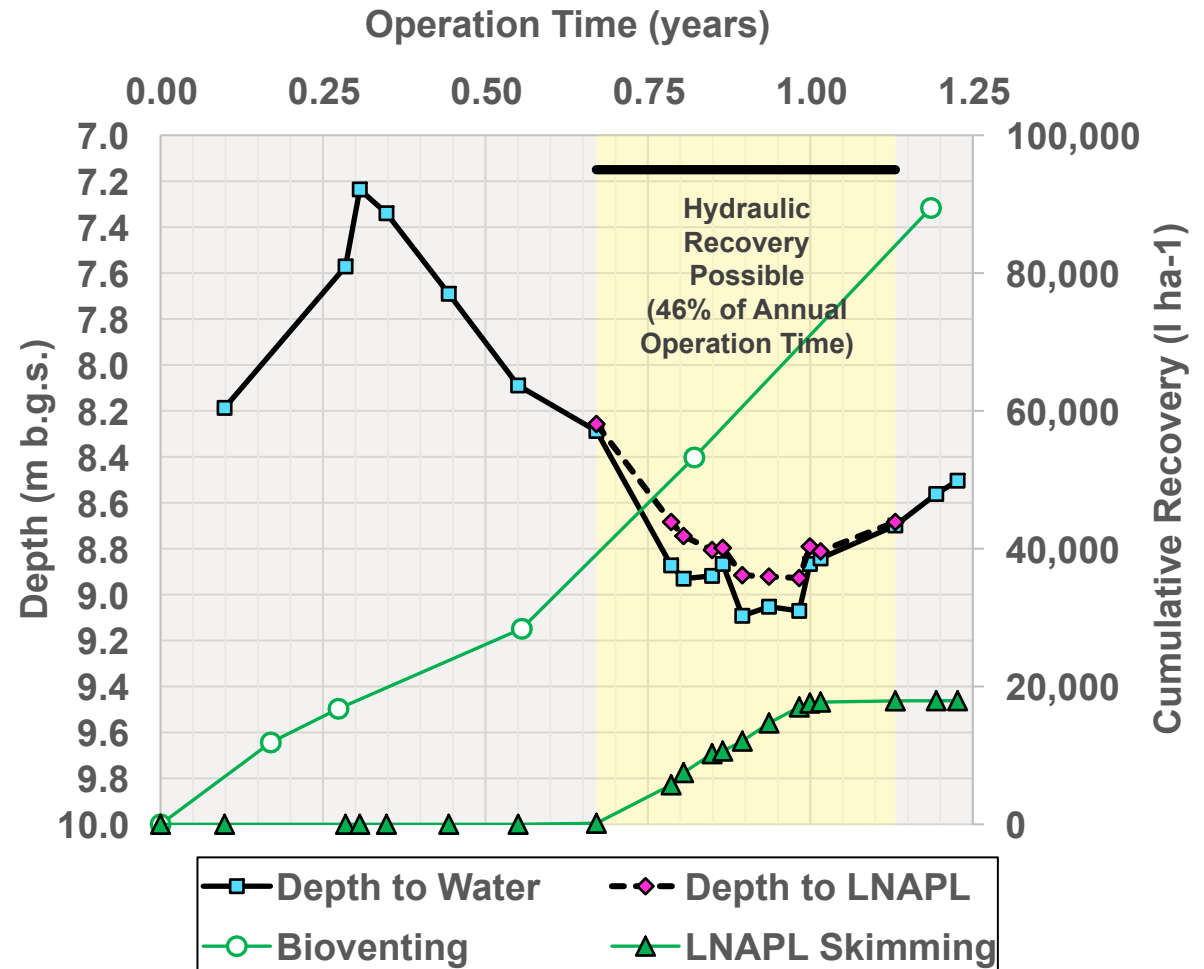


LNAPL Mass Depletion Skimming vs. Bioventing

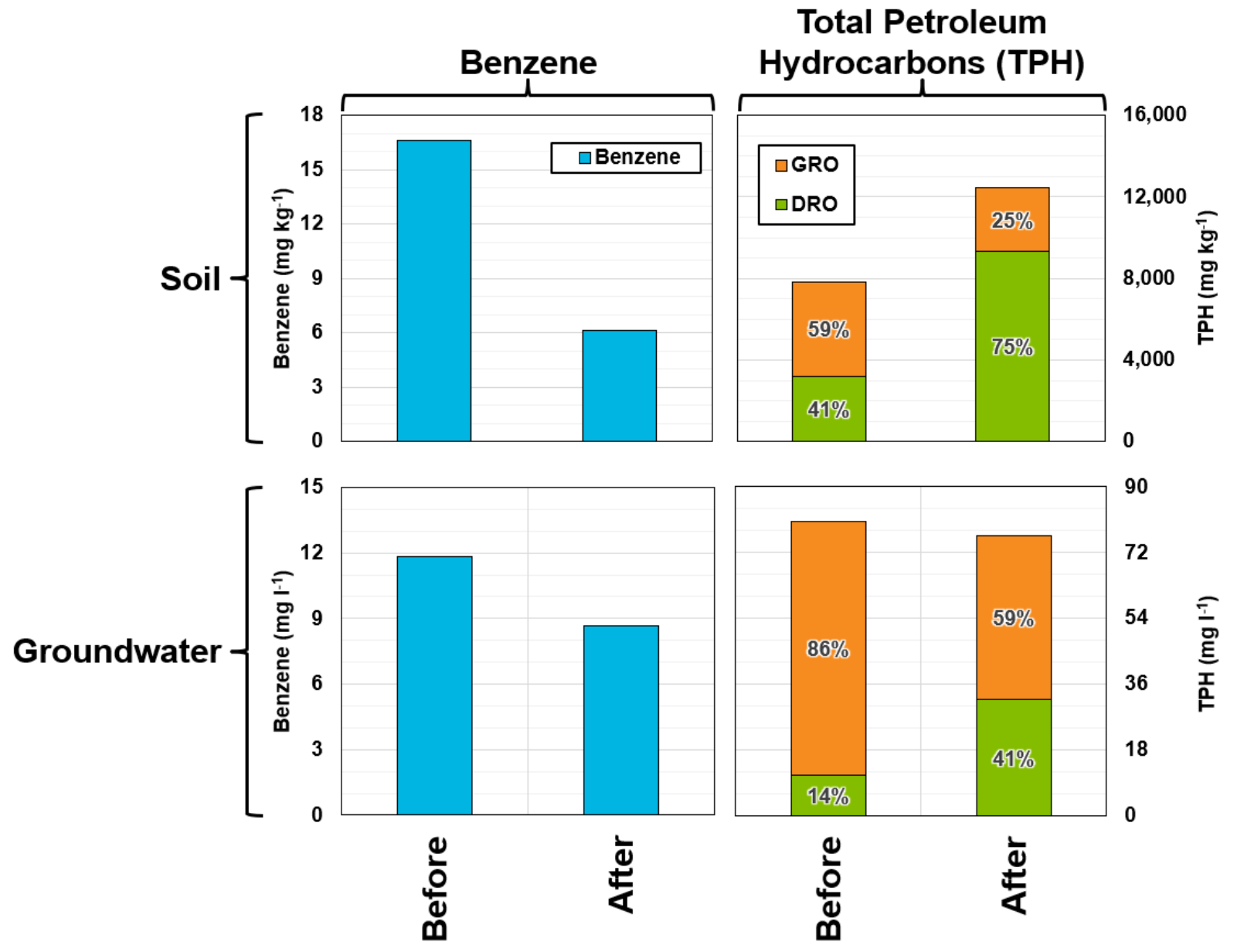
Bioventing vs. Modeled Skimming



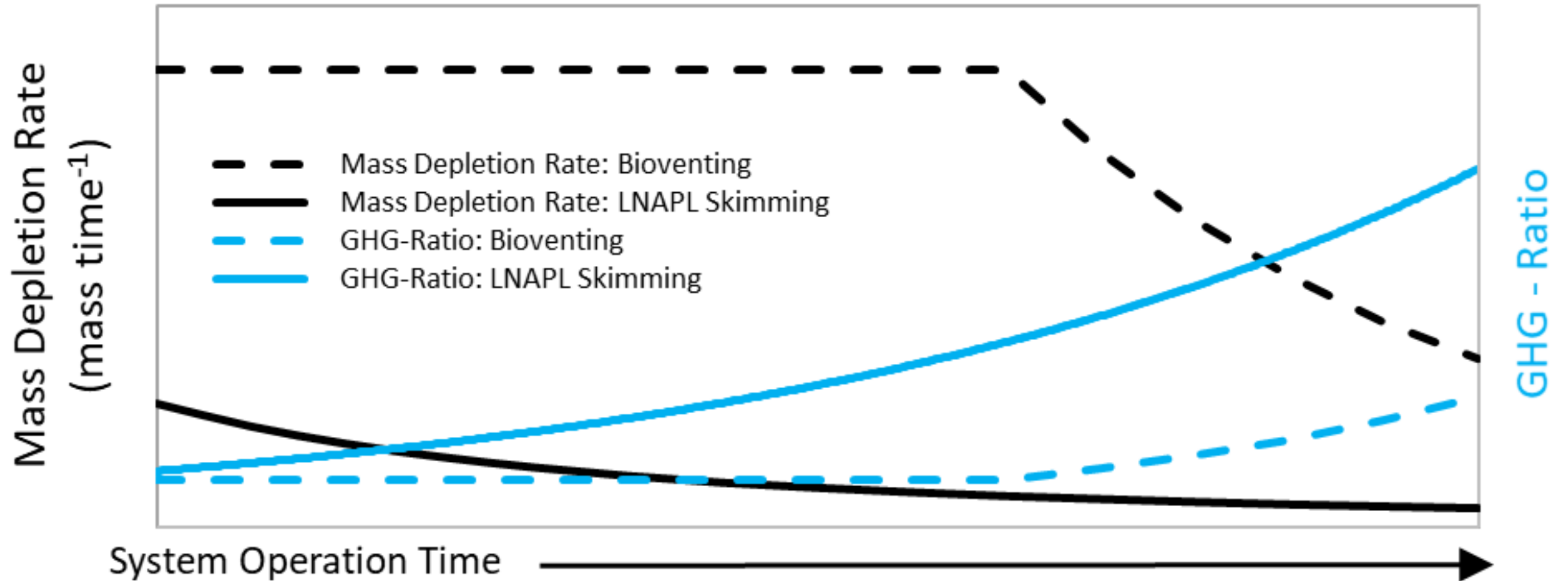
Bioventing vs. Realistic Skimming



Evidence of Compositional Change



Sustainability Considerations



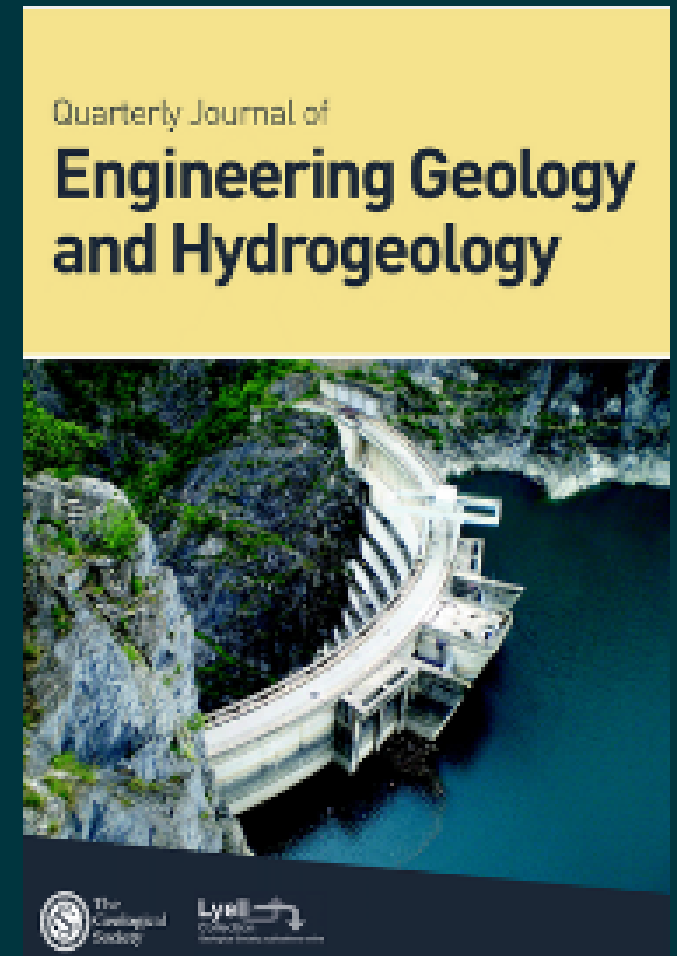
Summary

–Meeting MEP

- Bioventing is a viable remedy for addressing mobile LNAPL (if needed)
 - Not satisfactory to control imminent migration or dissolved phase concerns
- Bioventing can outperform hydraulic LNAPL recovery
 - Accessible smear zone is a key consideration

–Sustainability

- less infrastructure and OM&M
- greater mass removal over time



Bioventing Revisited: Efficacy of Enhanced Biodegradation for Sites with Mobile LNAPL

<https://doi.org/10.1144/qjegh2022-085>

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