ENHANCED LNAPL NATURAL SOURCE ZONE DEPLETION BY SOLAR-POWERED BIOVENTING AT THE GUADALUPE OIL FIELD

Justin Eichert, Ben McAlexander, and Chris Smith: Trihydro

Eric Daniels and Natasha Sihota: Chevron

Sixth International Symposium on Bioremediation and Sustainable Remediation Technologies
Austin, Texas

Trihydro

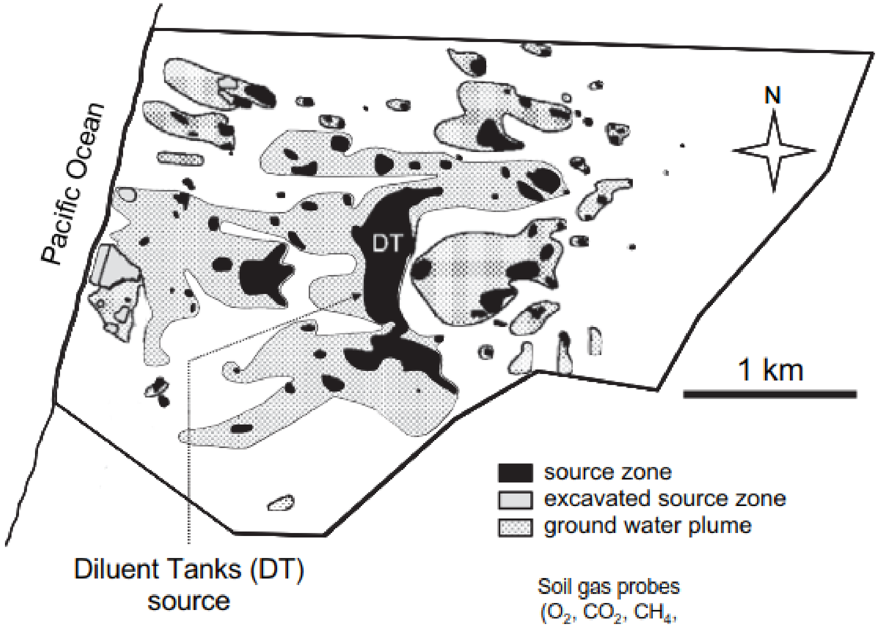
BACKGROUND

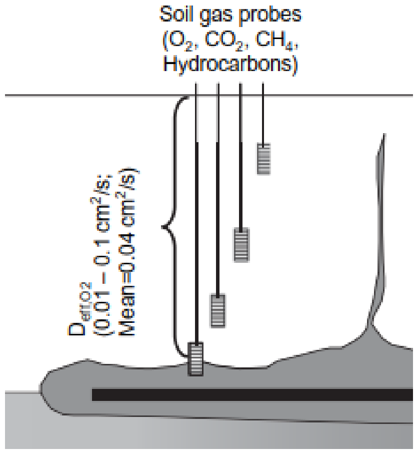

Ground Water Monitoring&Remediation

Source Zone Natural Attenuation at Petroleum Hydrocarbon Spill Sites—II: Application to a Former Oil Field

by Paul D. Lundegard and Paul C. Johnson

- The former Guadalupe Oil Field is a 3,000-acre property in Central Coast California. From 1955 to 1990, petroleum distillate (diluent) was used for crude oil production. Releases resulted in multiple LNAPL bodies across the site.
- The "source zone natural attenuation" concept was developed using this site as a case study (data collection 2002; publication 2006) of NSZD data collection.
- Data collection methods included soil gas profiling and groundwater geochemistry characterization to estimate hydrocarbon fluxes from the LNAPL bodies.
- Footprint of data collection was limited due to the invasive monitoring approach.
- The case study identified higher hydrocarbon removal rates associated with gas transport than for groundwater transport.

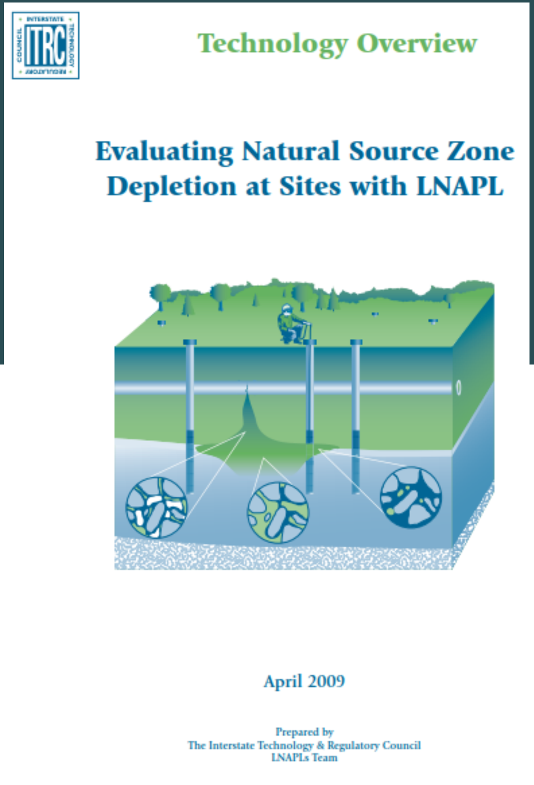




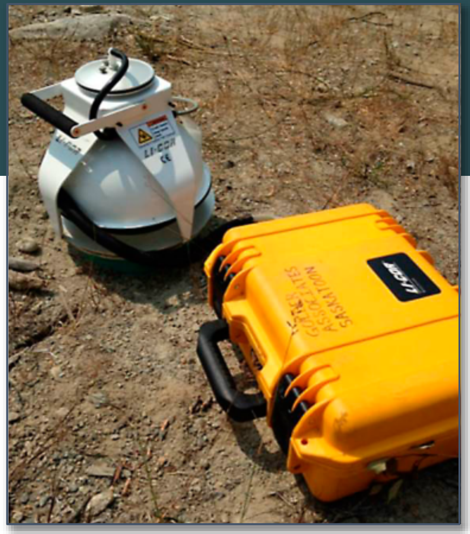
Trihydro

BACKGROUND

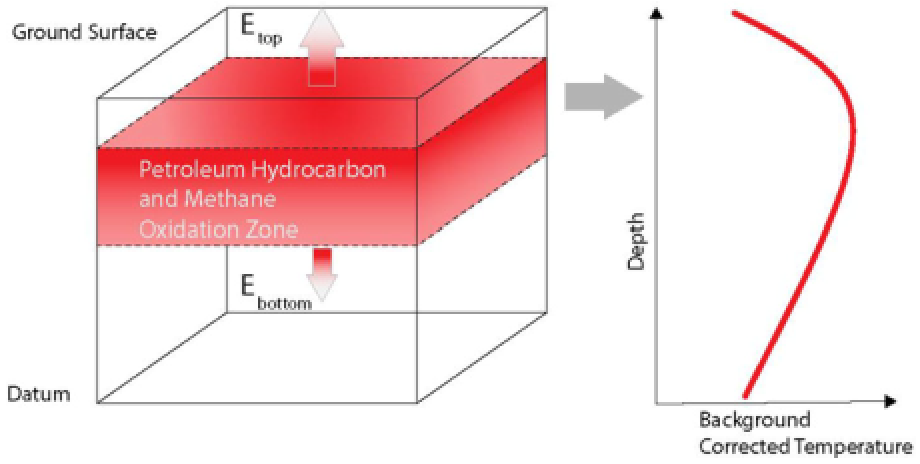
- The “concentration gradient method” presented for the site became popular for estimating hydrocarbon removal rates from LNAPL bodies (ITRC LNAPL-1; 2009).
- Subsequent to that, additional NSZD data collection methods have come available.
  - CO_2 efflux measurements by dynamic closed chamber – ideal for large footprints.
  - Subsurface temperature profiling – ideal for time series
- In 2019, the Guadalupe project team applied these methods to cover a wider footprint, assess current NSZD rates, and compare with the original measurements.
- 2019 results will serve as baseline for future “enhanced NSZD” pilot testing and for comparisons to LNAPL recovery.



a) ITRC LNAPL-1 (2009) cover page.



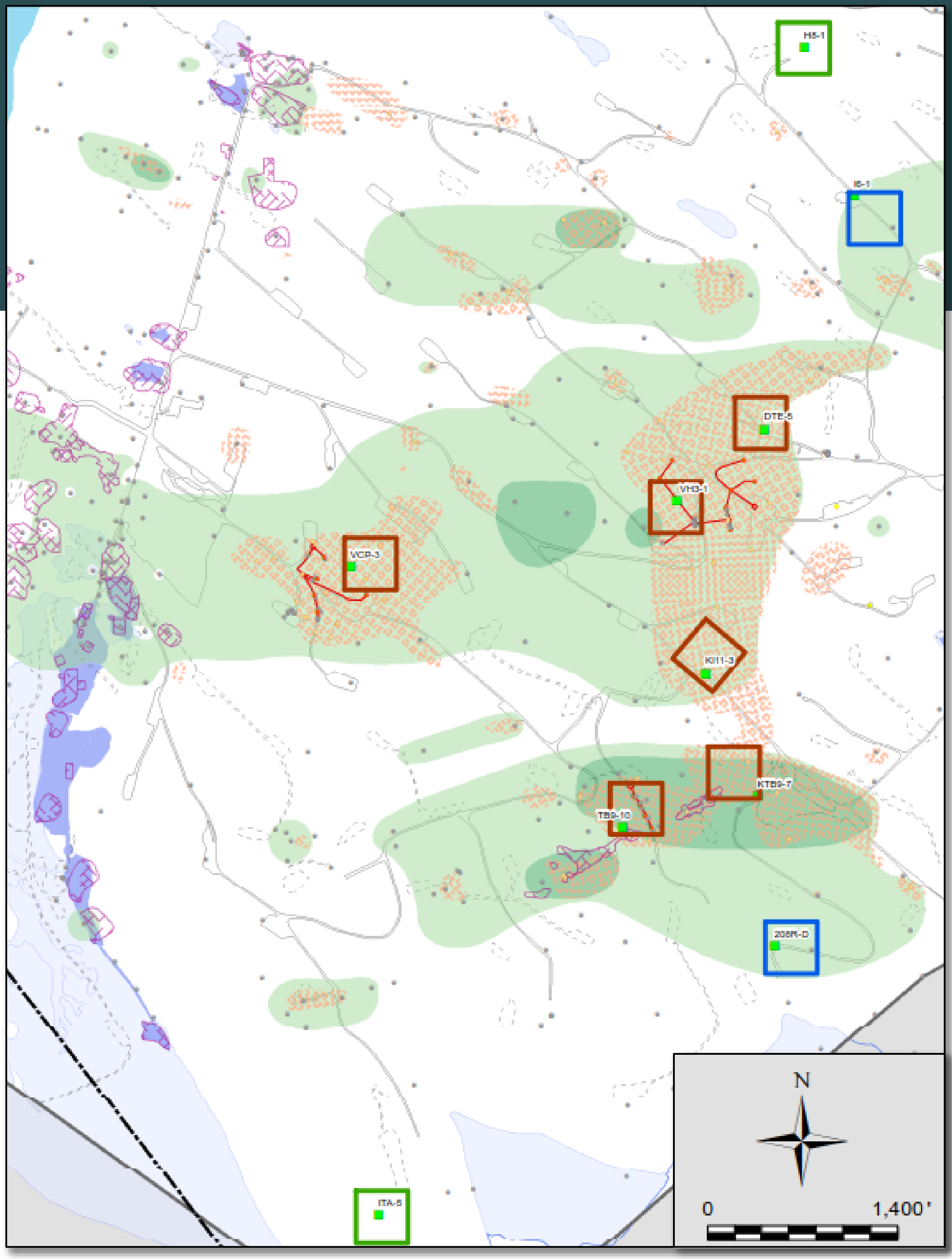
b) Dynamic closed chamber image from ITRC LNAPL-3 (2018)



c) Subsurface temperature profiling image from ITRC LNAPL-3 (2018)

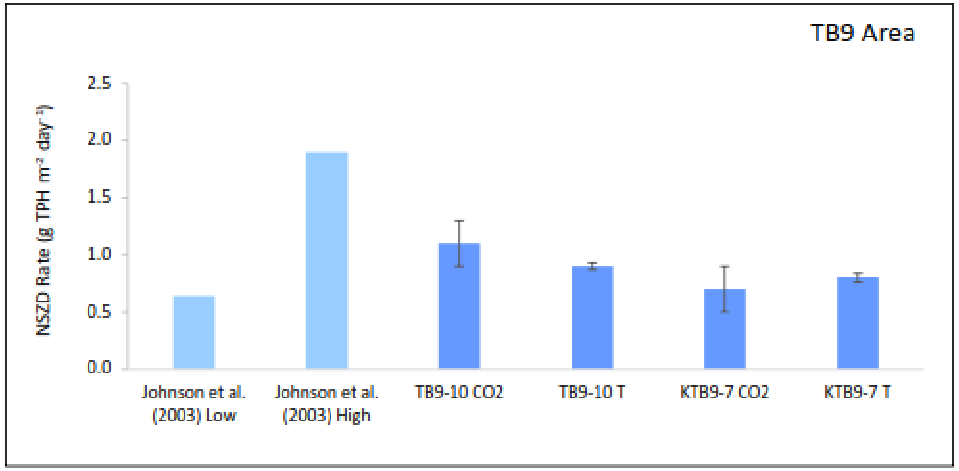
2019 SITEWIDE NSZD MEASUREMENTS

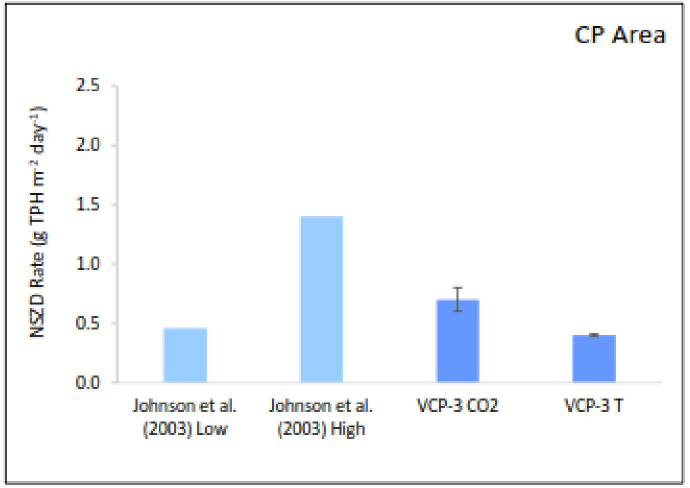
- 9 grids established across the site for CO_2 efflux measurements (5 x 5 for 25 monitoring points)
  - 6 grids above the 3 main LNAPL bodies
  - 2 grids above dissolved phase plumes where LNAPL has not been identified.
  - 2 grids in background areas
- Subsurface temperature profiling within each grid.
- CO_2 efflux measurements in April and October 2019, and temperature measurements approximately monthly during this time period.

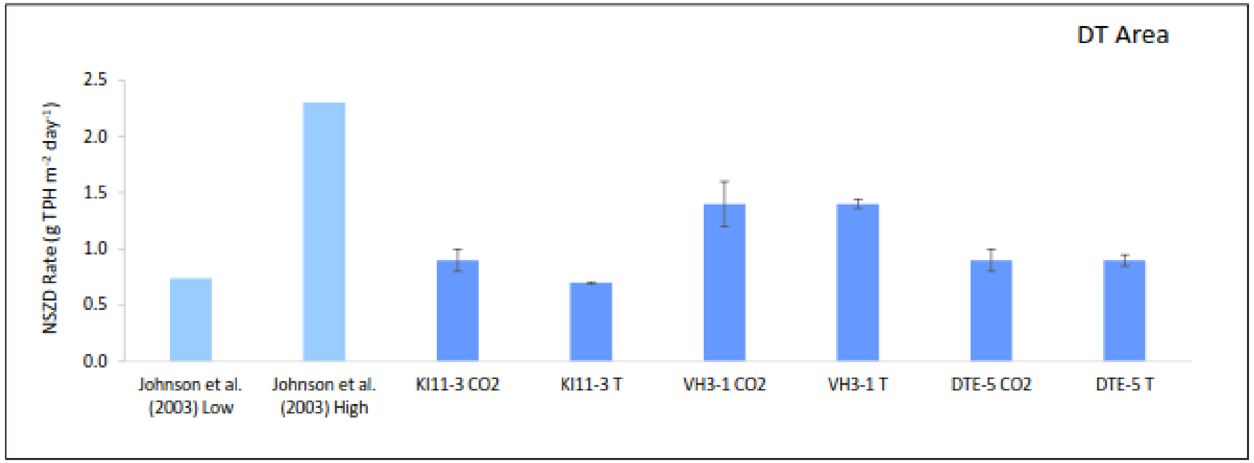


NSZD RATES

- 2019 NSZD rates by CO_2 effluxes and temperature profiling were in the approximate 0.5 to 1.5 g TPH m^{-2} day^{-1} range (200 to 1,000 gal $acre^{-1}$ yr^{-1}).
- Over the full LNAPL body footprints, the NSZD rates correspond to ~100 gallons per day.
- The 2003 NSZD rates by the concentration gradient method had a wider range due to variability in the vapor diffusion coefficient. The 2019 rates fell within the 2003 range.
- NSZD rates by CO_2 effluxes had relatively low standard errors for a given area because a large number of samples was taken and there was low variability over time.
- NSZD rates by temperature had relatively low standard errors for a given area because temperatures did not vary much over time, and the thermal conductivity has low variability.

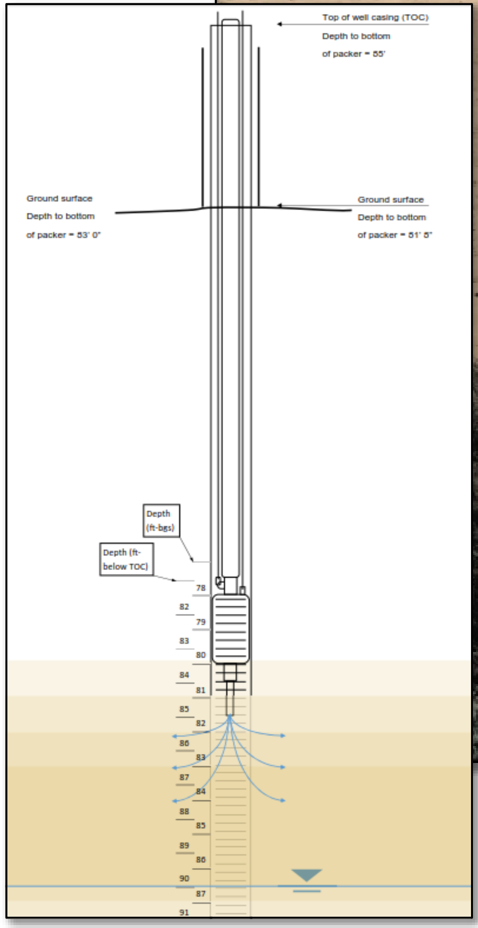


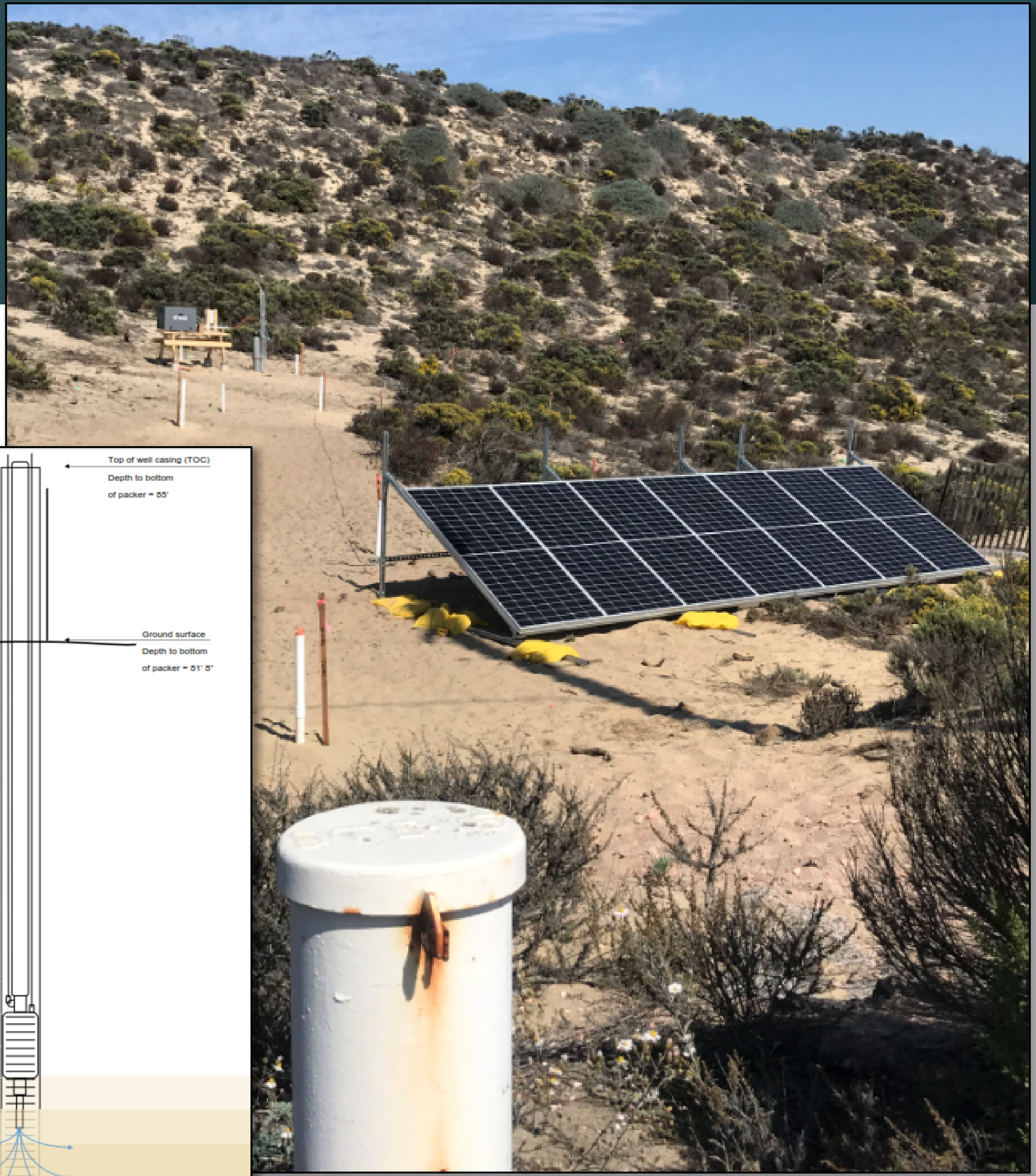




NSZD RATES

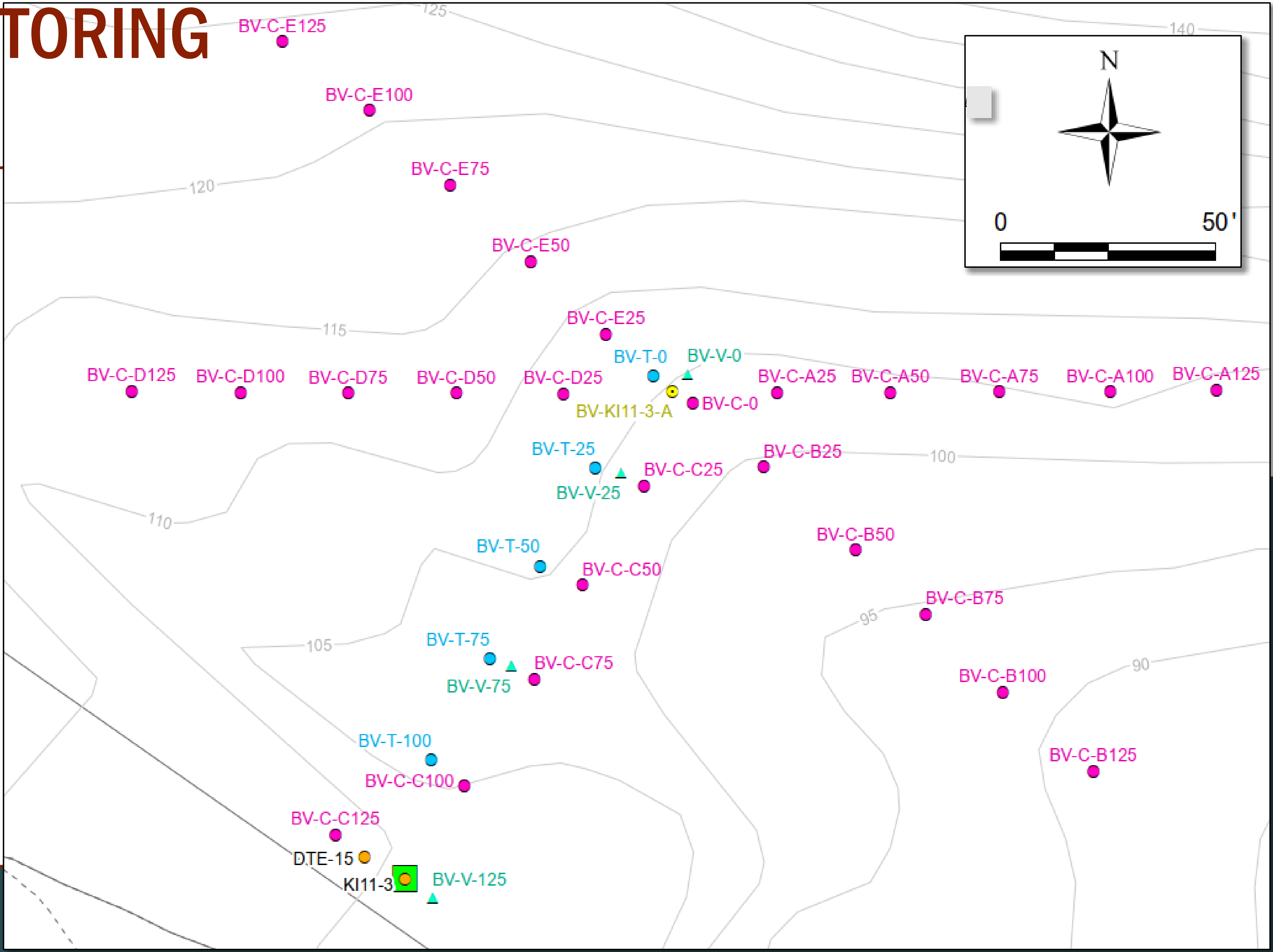
- Seven (7) 400-W photovoltaic solar panels operate a 0.8 horsepower regenerative blower.
- Air blown into a 4-inch diameter well. The well is screened across the smear zone and the top of the (low) aquifer.
- A packer was placed at the top of the well screen through May 2022.
- System operation October 2021 to May 2022 with packer in place.
  - Operates when the sun is out (~ 30 cfm).
  - Shut down 1/23/22 to 2/15/22 for wet switch.
  - In situ respiration test late March and May 2022.
- System operation July to September 2022 with packer removed.





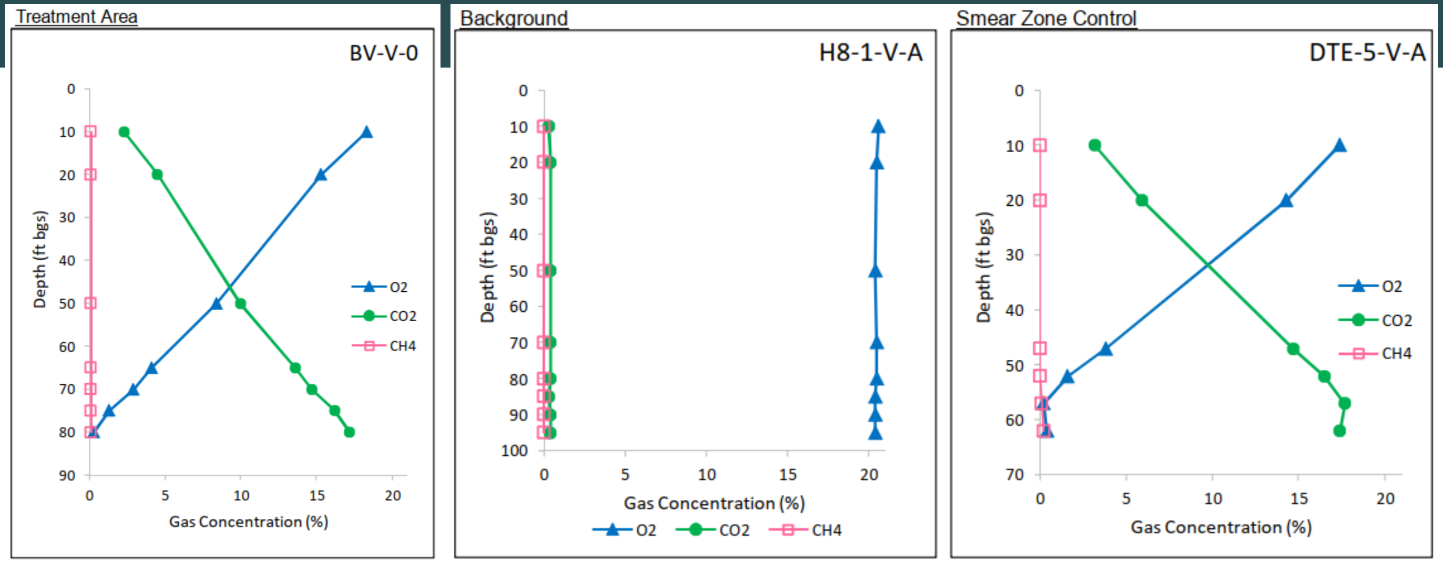
PILOT TEST MONITORING

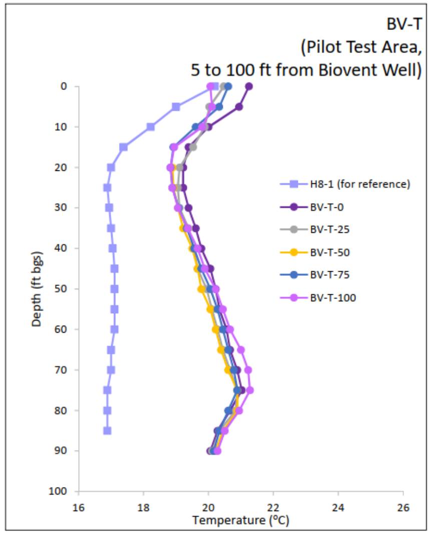
- BIOVENT WELL
- SUBSURFACE TEMPERATURE MONITORING PIPE
- NESTED VAPOR WELL
- CO_2 EFFLUX MEASUREMENT LOCATION
- PASSIVE RECOVERY SYSTEM WELL
- MONITORING WELL FITTED FOR THERMAL MONITORING

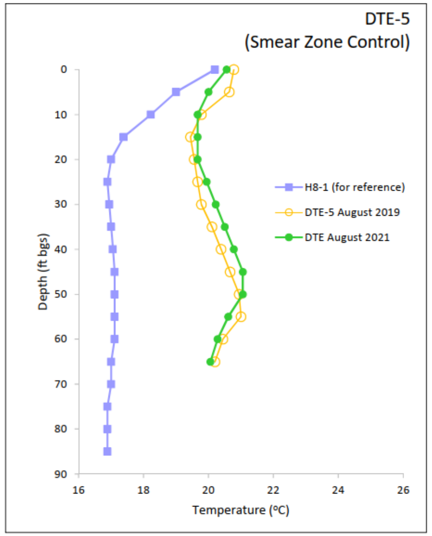


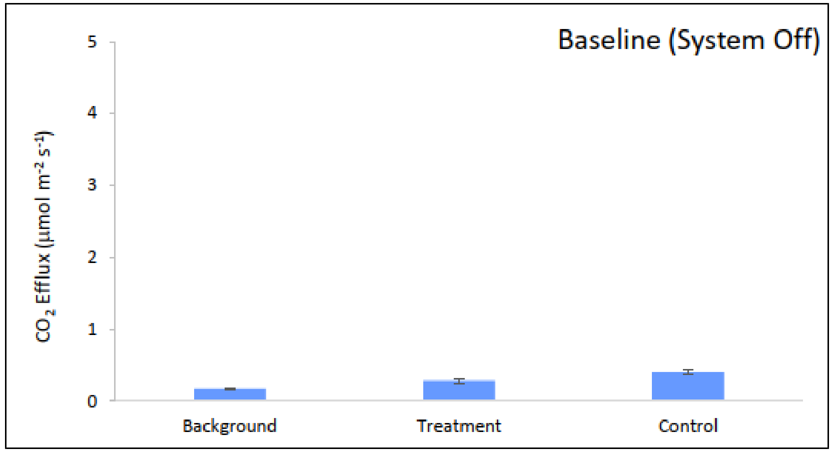
BASELINE NATURAL SOURCE ZONE DEPLETION

- Baseline data confirm NSZD conceptual model of oxygen-limited hydrocarbon biodegradation with heat generation in the deep vadose zone.
- Prior to bioventing, the treatment and control areas had similar NSZD rates: 0.1 to 0.7 g HC m^{-2} day^{-1}.



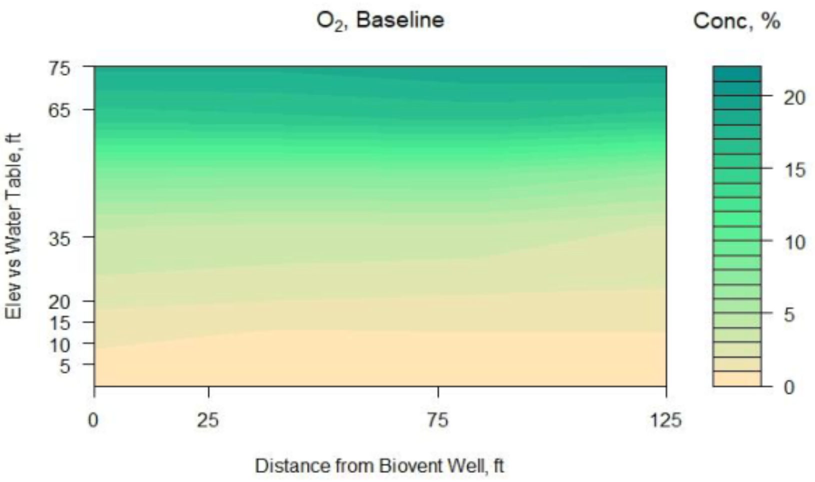


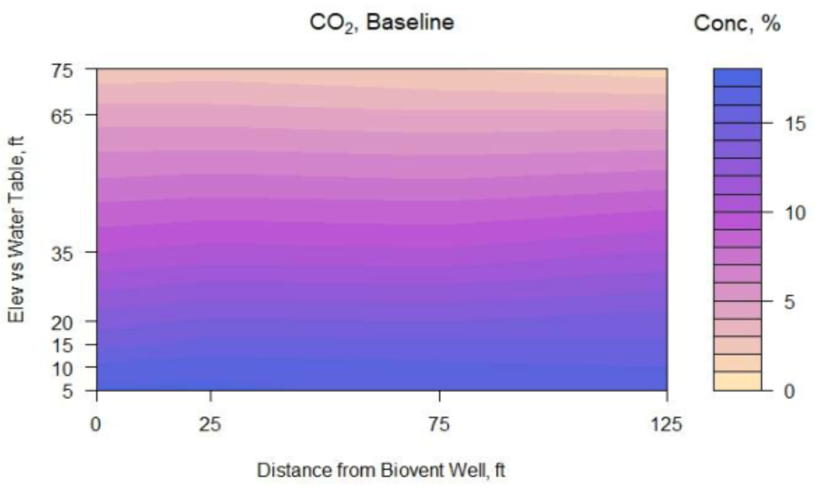




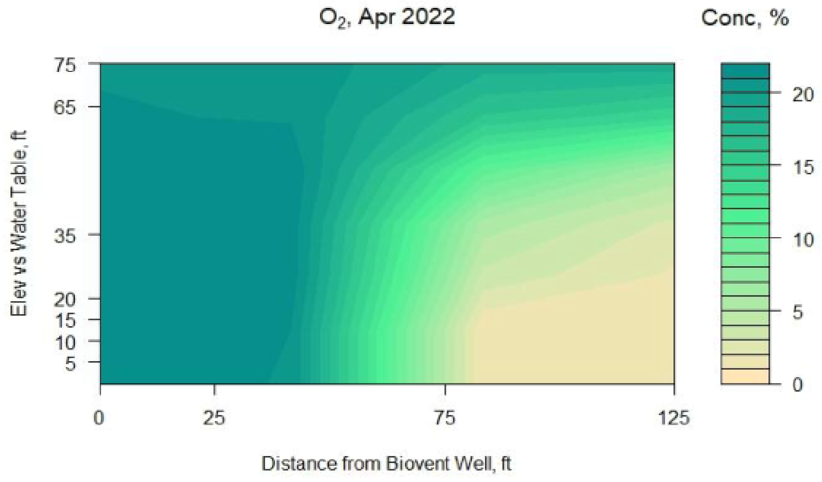
BIOVENTING SOIL GAS PROFILES

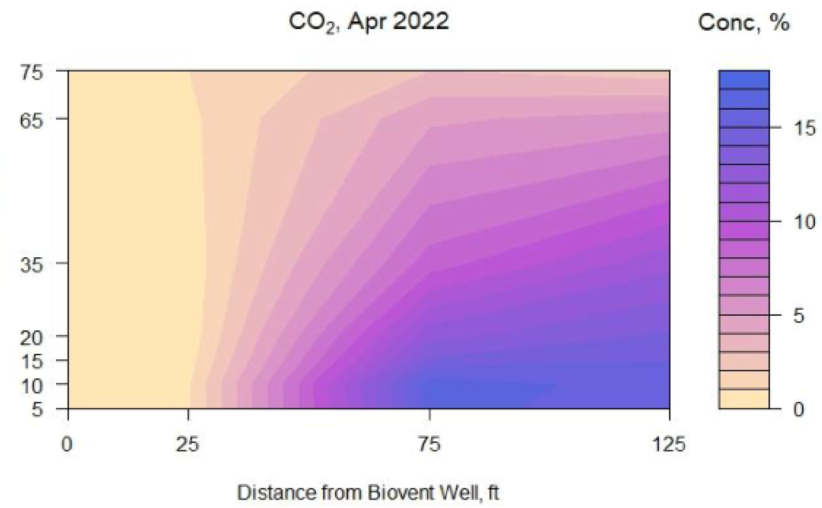
Baseline



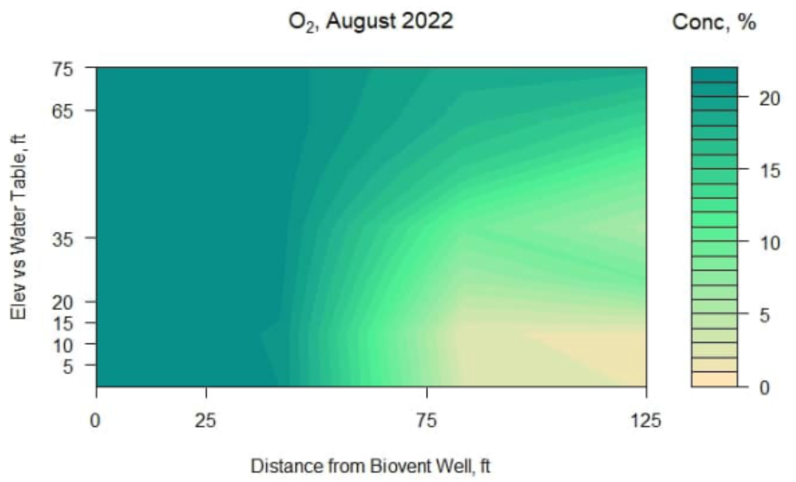


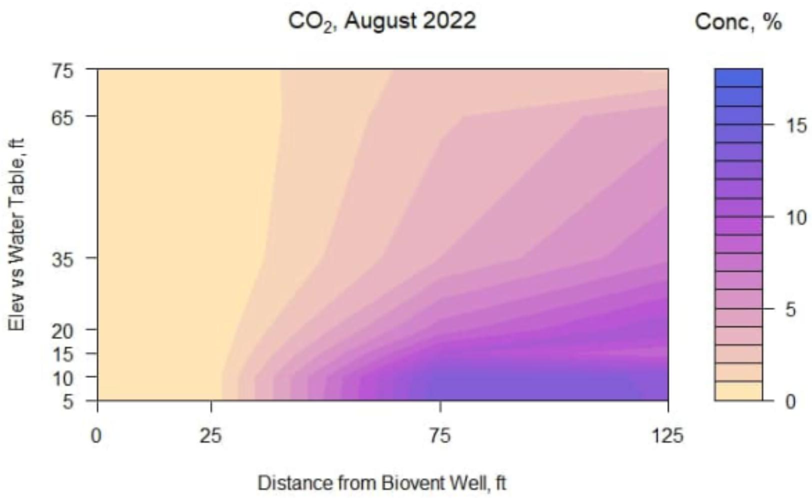
With Packer



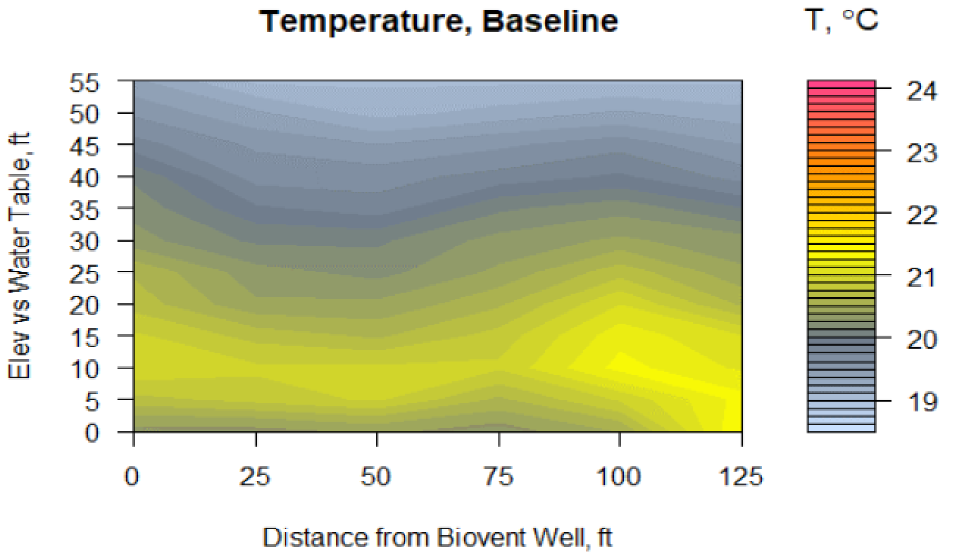


No Packer

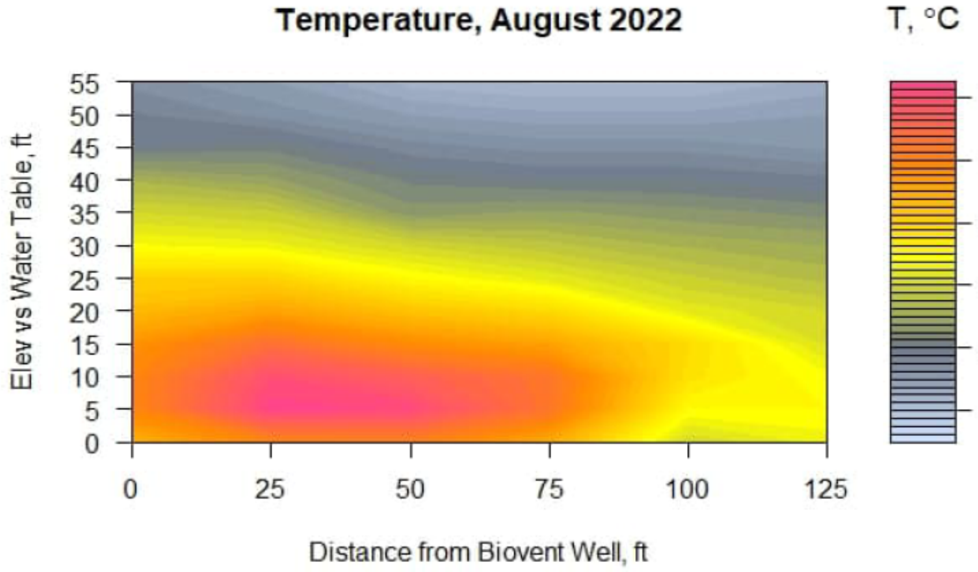




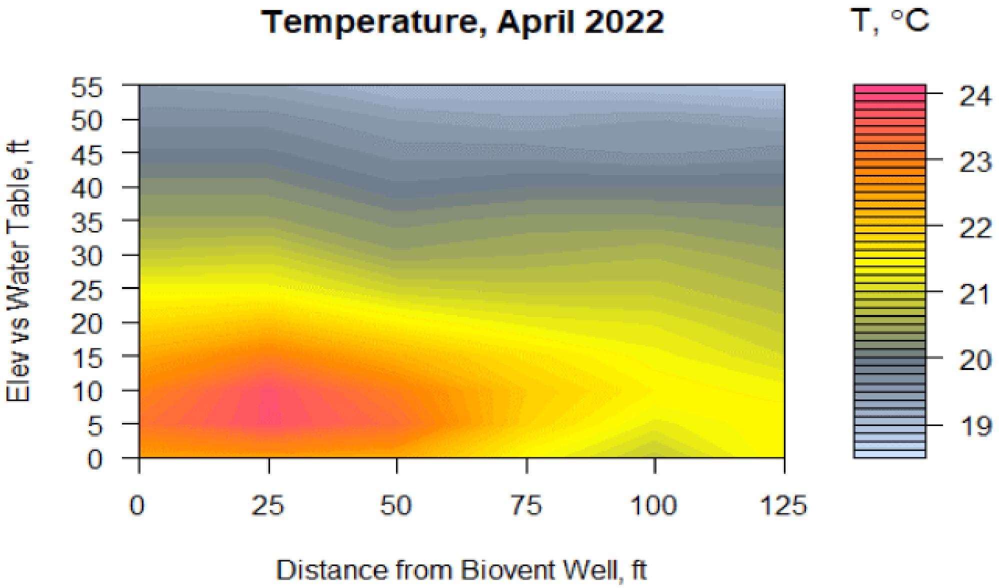
BIOVENTING SUBSURFACE TEMPERATURES



Baseline



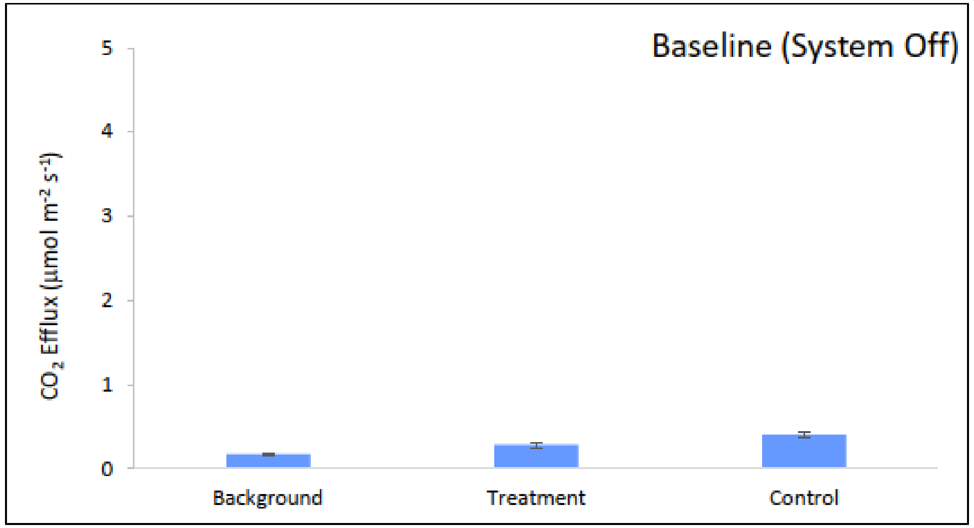
No Packer



With Packer

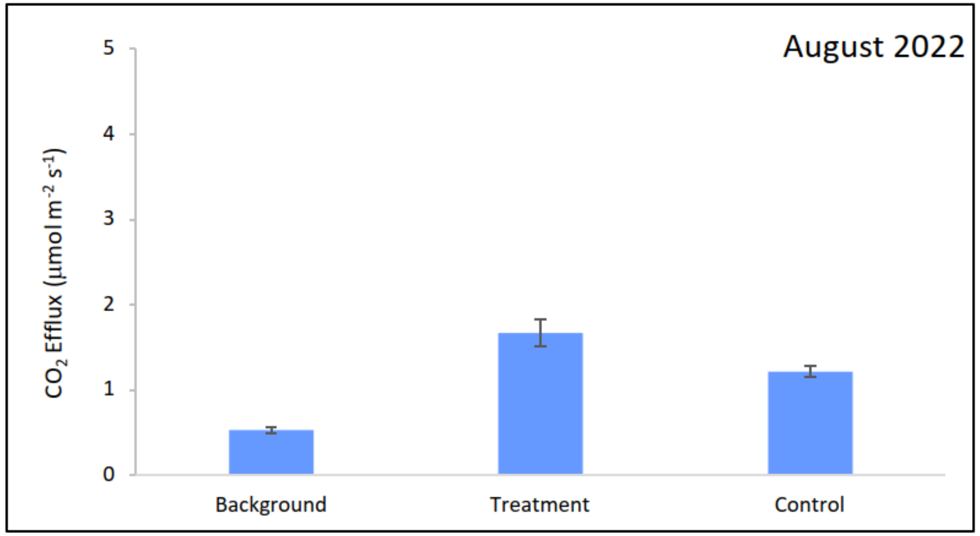
Trihydro

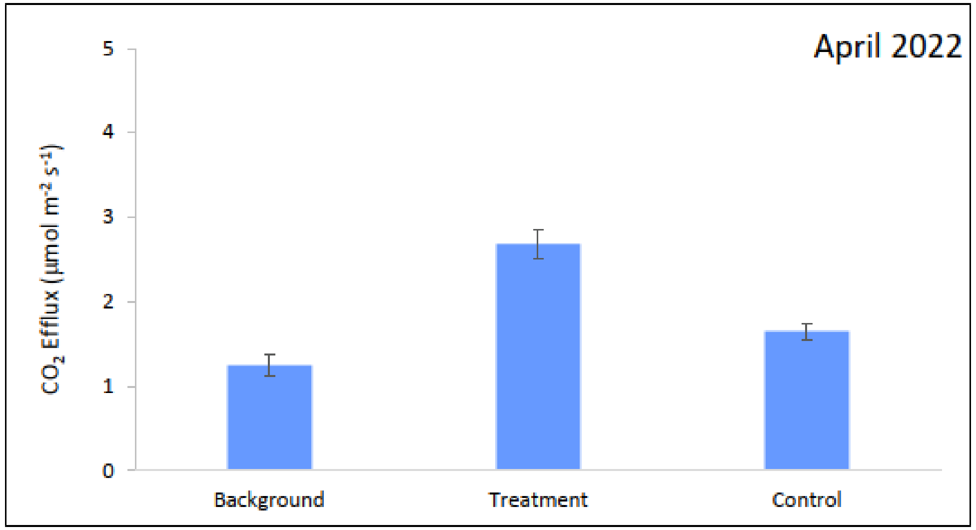
BIOVENTING CO_2 EFFLUXES



Baseline

No Packer





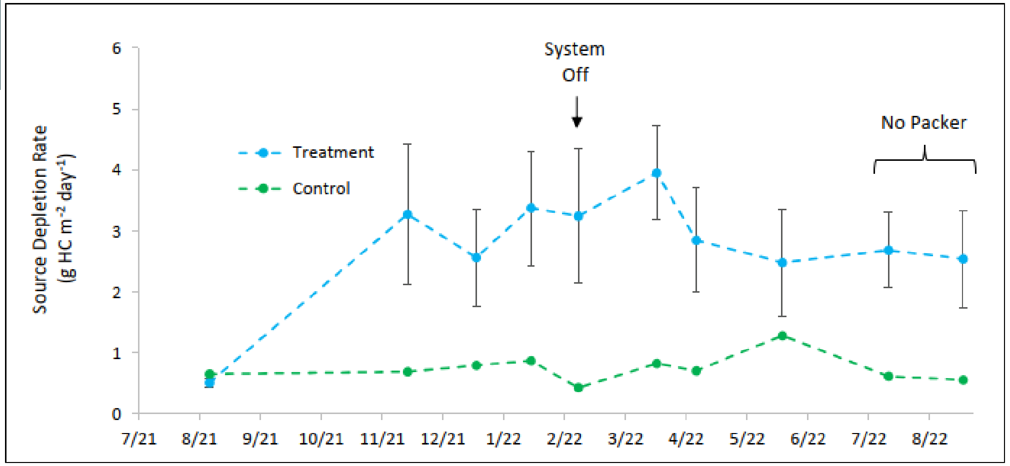
With Packer

Trihydro

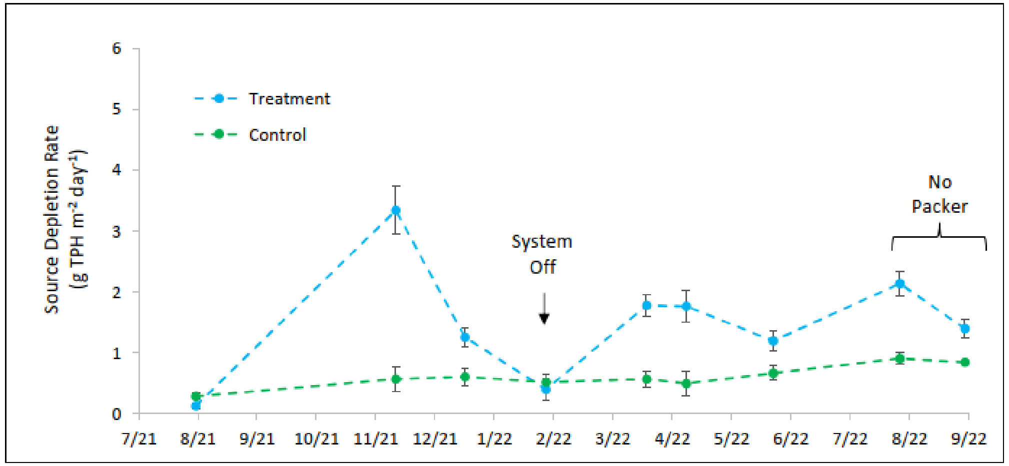
SOURCE DEPLETION RATES

- Source depletion rates are similar with and without packer, further demonstrating a packer is not needed.
- ROI for subsurface temperature is 100 ft and ROI for CO_2 effluxes is at least 125 ft.
- Using these two ROIs, source depletion rates are:
  - Subsurface temperature: 2.4 to 3.1 gal/day
  - CO_2 efflux: 1.6 to 4.4 gal/day
- Reference values
  - Baseline pilot NSZD rate: 0.2 to 0.4 gal/day
  - Site average NSZD rate: 0.7 to 0.9 gal/day (0.8 to 1.0 g HC m^{-2} day^{-1} on 100 ft ROI)
  - LNAPL recovery rate on low transmissivity wells: generally less than 1.5 gal/day.

Subsurface Temperatures



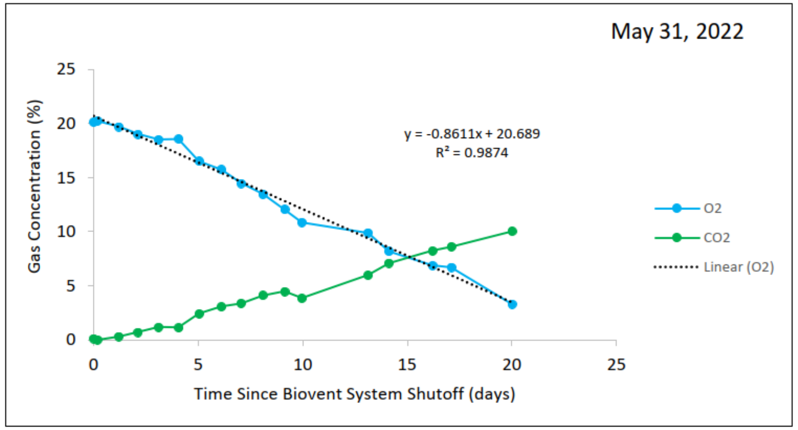
CO_2 Effluxes

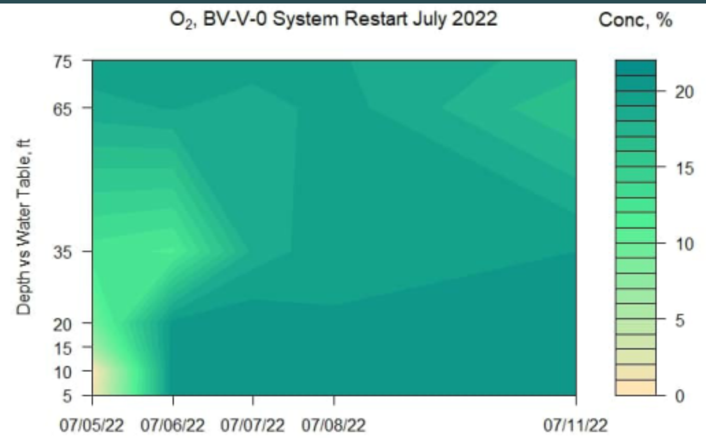


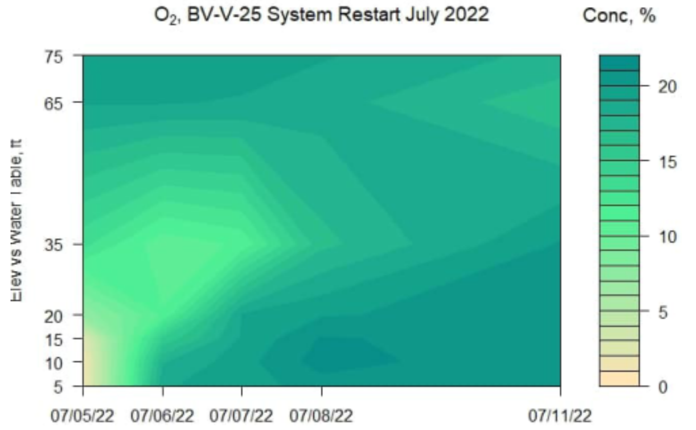
Trihydro

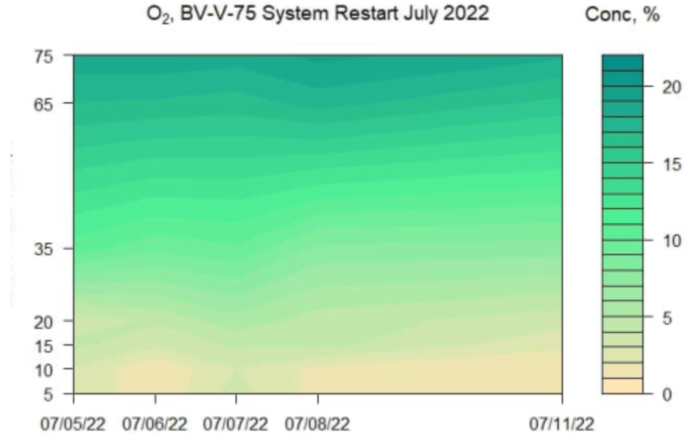
OXYGEN DELIVERY AND UTILIZATION

- In situ respiration test for deep vadose zone indicates approximately 17 days for oxygen concentrations to decrease from near atmospheric to 5%.
- Oxygen concentrations during July 2022 restart indicate approximately 3 days to reach steady state bioventing conditions.
- Inference: on full scale, multiple wells can be piped to one blower that rotates on approximate 3-day frequency.





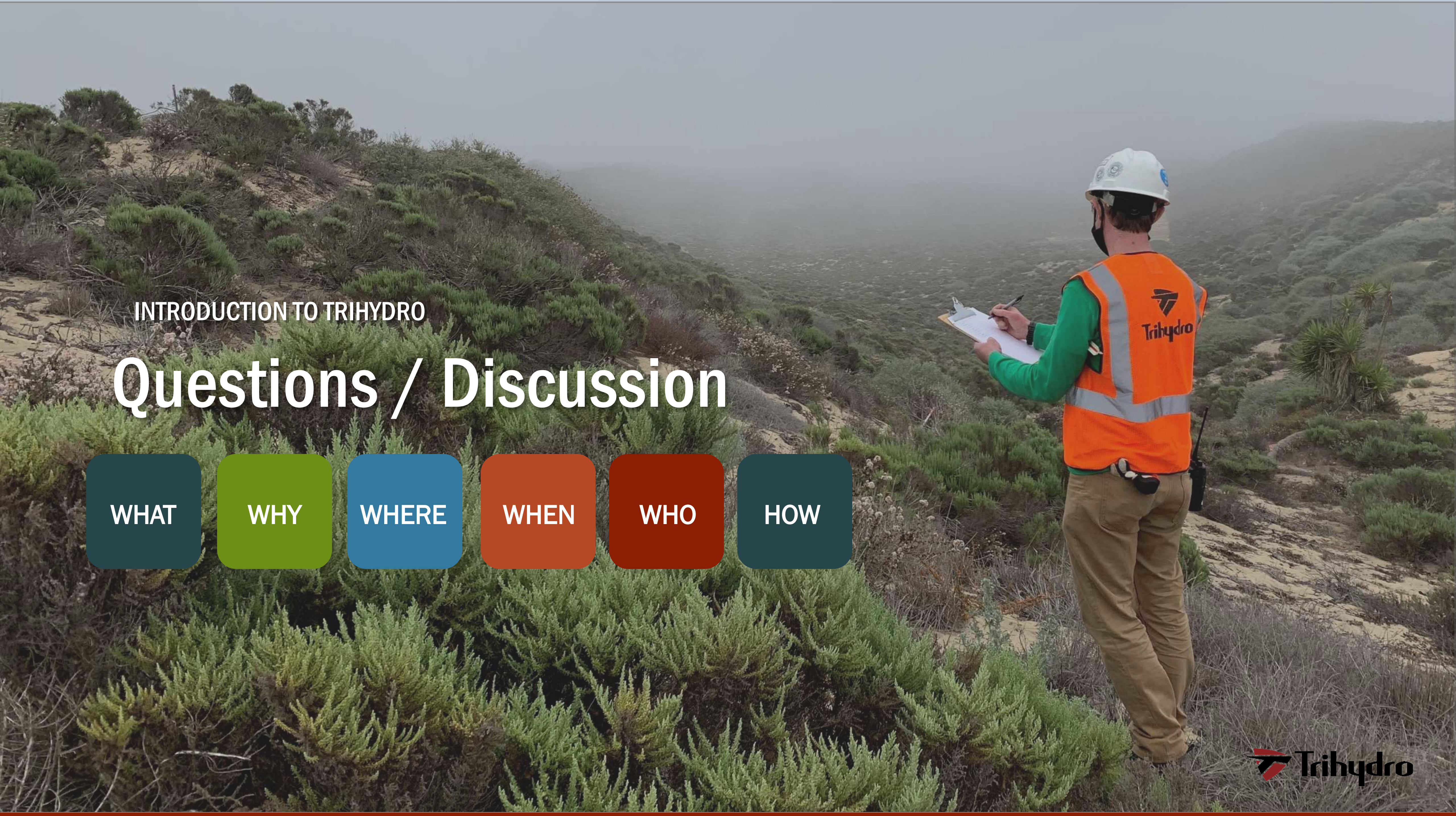




SUMMARY AND FULL-SCALE CONSIDERATIONS

- Solar-powered bioventing increases source zone depletion by moving from oxygen-limited conditions in the deep vadose zone to oxygen abundance.
- The bioventing hydrocarbon removal rate is higher than NSZD, and higher than LNAPL recovery on low LNAPL transmissivity wells.
- Full scale bioventing makes sense for this site, especially for low LNAPL transmissivity wells within relatively large LNAPL bodies.
- Multiple wells can be piped to one solar-powered blower.
- Long term monitoring can use oxygen measurements (operations), subsurface temperatures (source depletion rate), and CO_2 effluxes (source depletion rate).
- Endpoints for bioventing can consider a nominal NSZD rate that is confirmed by shutdown test.

Trihydro


INTRODUCTION TO TRIHYDRO
Questions / Discussion
WHAT
WHY
WHERE
WHEN
WHO
HOW
Trihydro
Trihydro