NSZD at Paved Fuel Retail Site

Remediation Technologies Symposium 2021

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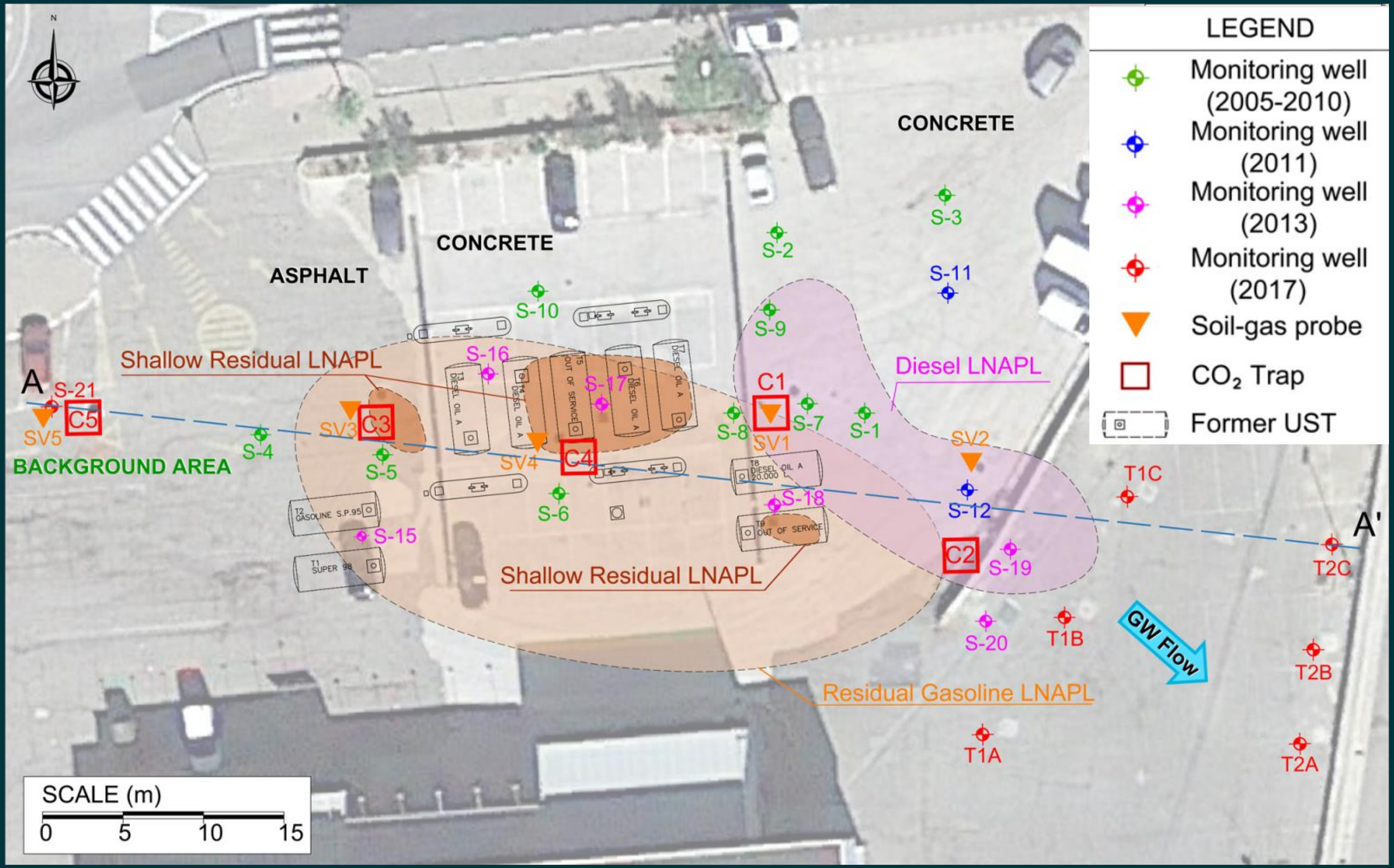
Site Description

- Former urban retail fuelling station (1966-2009)
- 9 USTs and above-ground structures decommissioned or removed in 2009
- Surface capped with asphalt and concrete.
- Water Table at 8 to 12 m bgs
- Residual gasoline impacts in western and central portion
- Diesel LNAPL accumulations in wells to east
- Shallow residual LNAPL (≤ 3 m bgs) near former USTs and dispensers

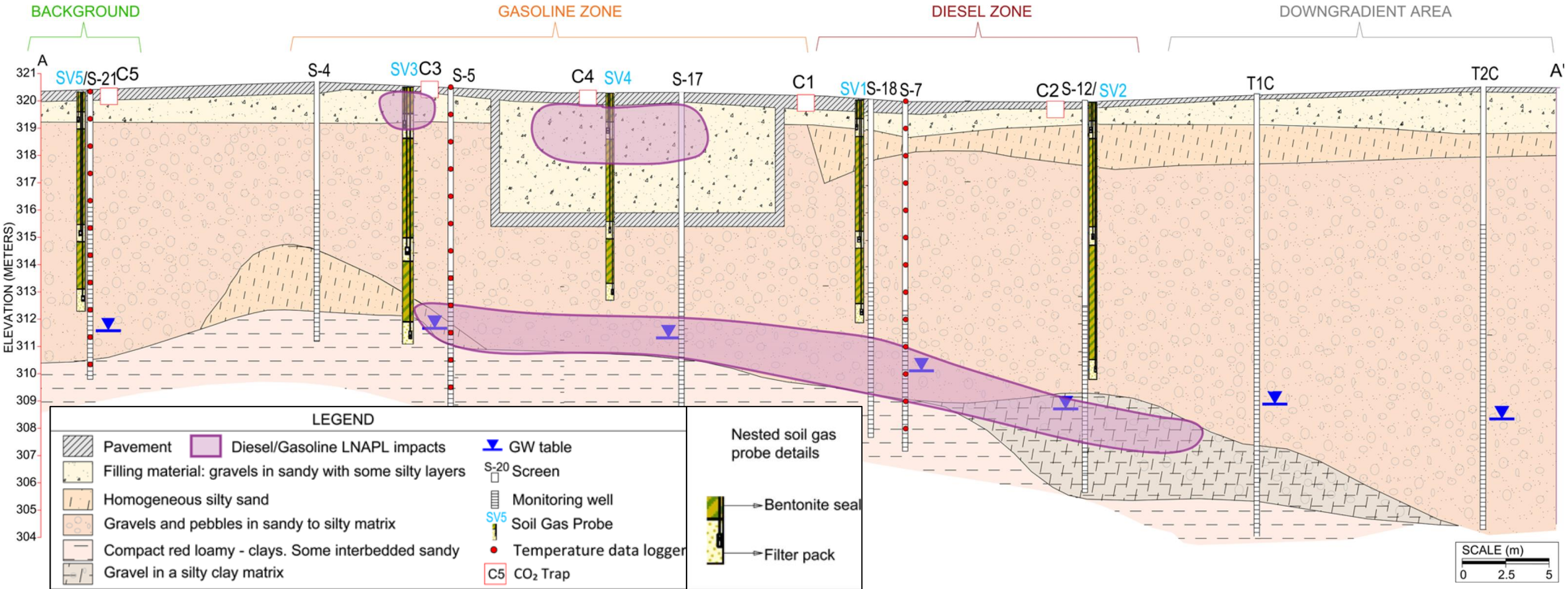
Objectives

- Evaluate common NSZD methods under typical fuel retail site conditions
- Influence of capped surface on measurements and interpretation
- Compare soil gas measurements from multi-depth vapor probes and monitoring wells.



Data Acquisition/Methodology

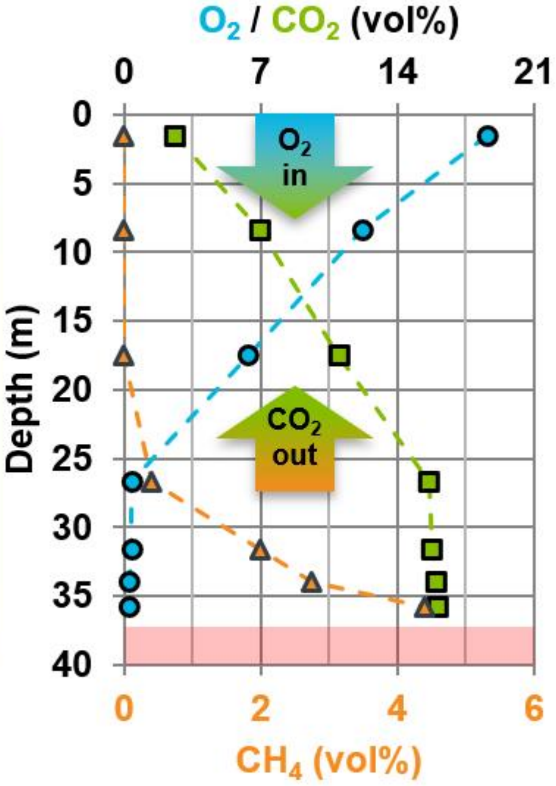
- Carbon Dioxide Traps (two events)
- Temperature profiling in wells using manual and continuous automated data collection
- Soil gas composition measured in soil gas probes and from monitoring wells screened into the unsaturated zone using low-purge methods (Sweeney and Ririe, 2017)



NSZD Conceptual Model

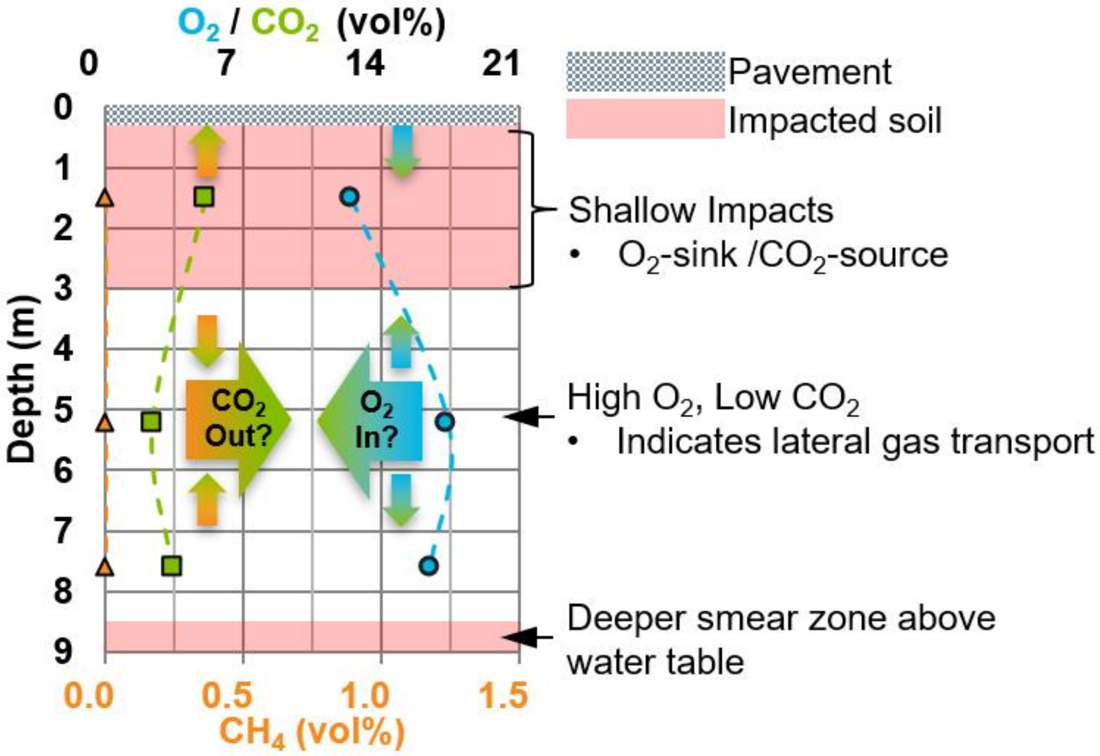
Simple Model

Free gas exchange between atmosphere and subsurface

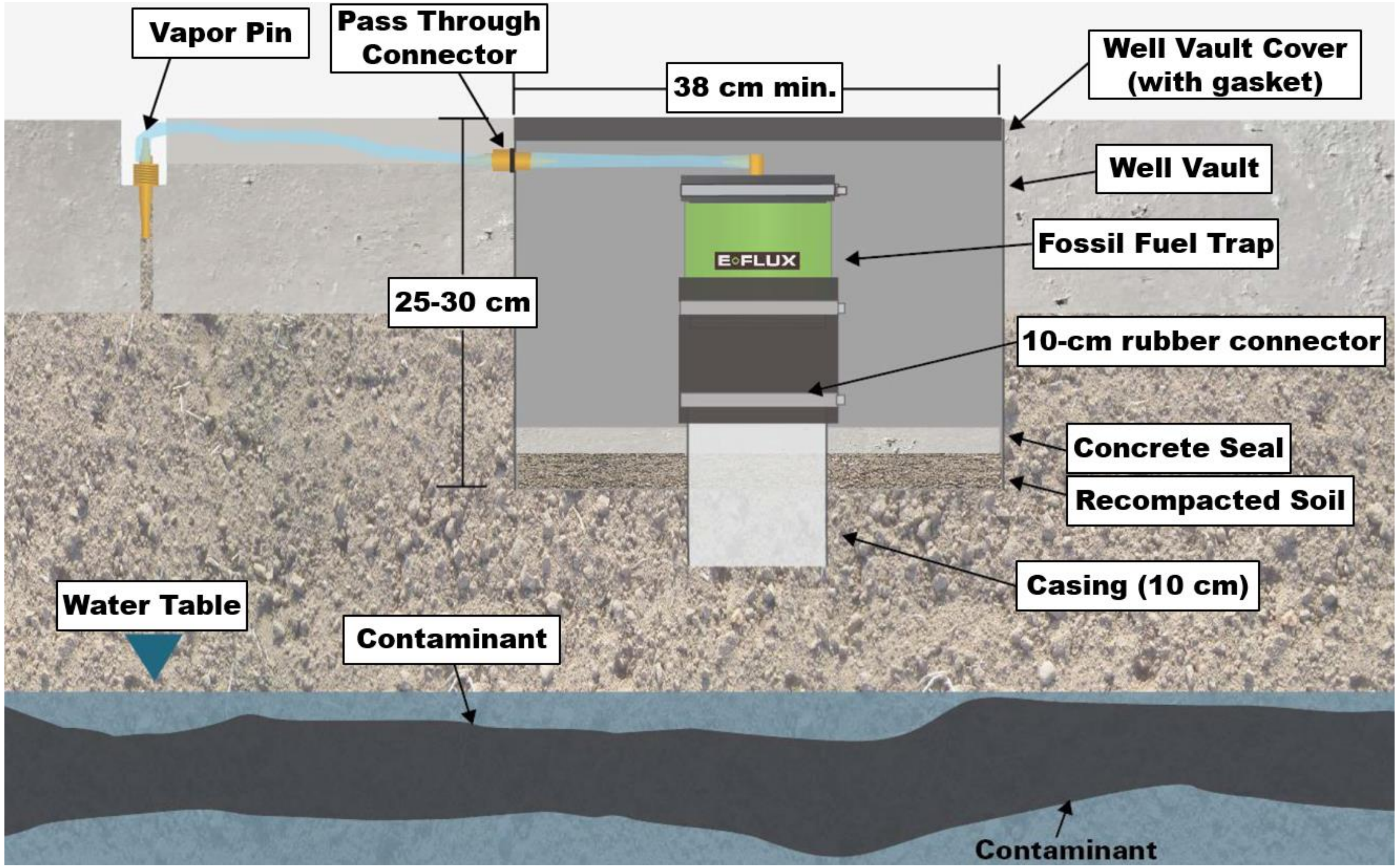


Low diffusivity layer at surface; gas exchange through cracks

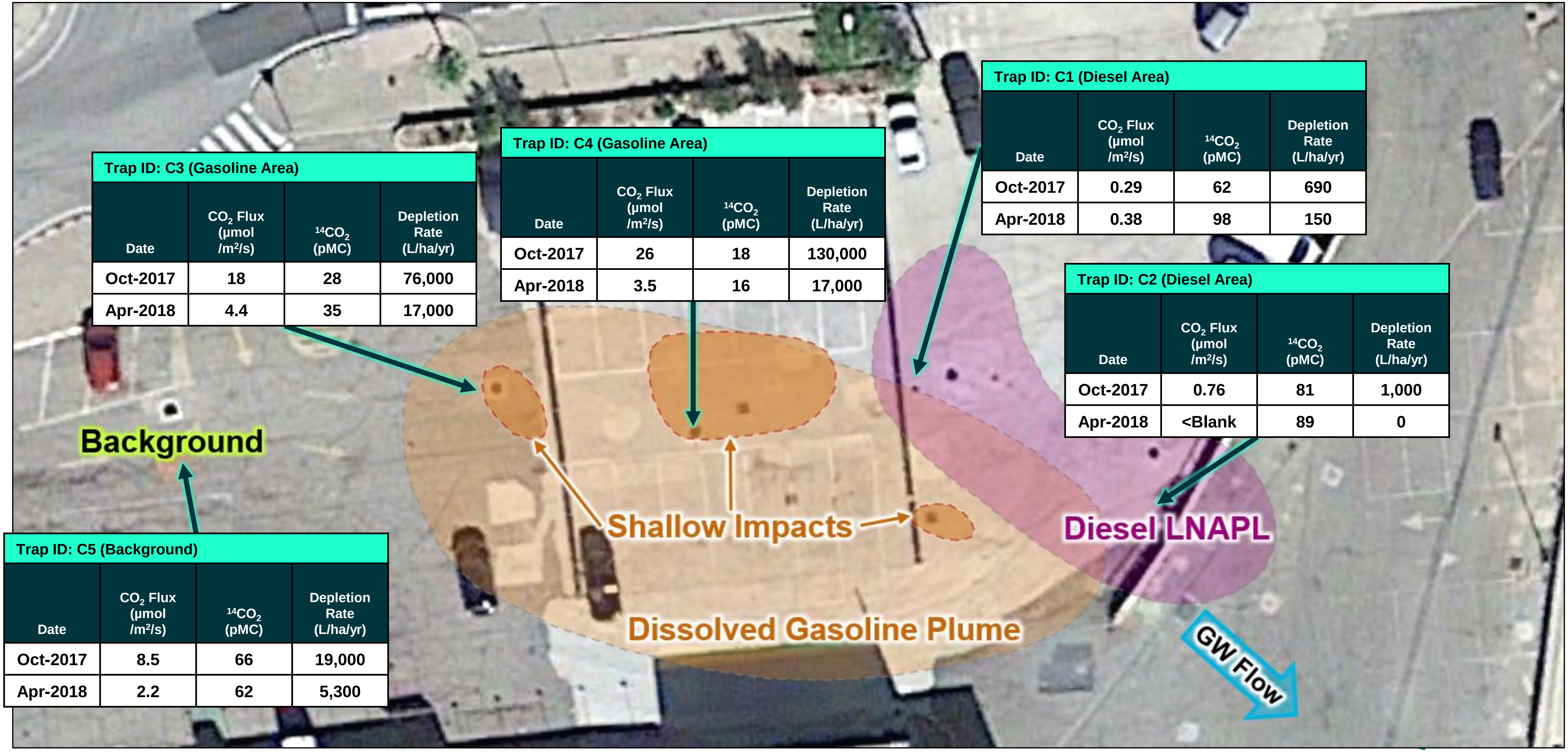
Study Site Conditions



CO_2 Trap Design



CO_2 Trap Results – Two Events



Trap ID: C3 (Gasoline Area)

Date	CO_2 Flux (µmol /m²/s)	$^{14}CO_2$ (pMC)	Depletion Rate (L/ha/yr)
Oct-2017	18	28	76,000
Apr-2018	4.4	35	17,000

Trap ID: C4 (Gasoline Area)

Date	CO_2 Flux (µmol /m²/s)	$^{14}CO_2$ (pMC)	Depletion Rate (L/ha/yr)
Oct-2017	26	18	130,000
Apr-2018	3.5	16	17,000

Trap ID: C1 (Diesel Area)

Date	CO_2 Flux (µmol /m²/s)	$^{14}CO_2$ (pMC)	Depletion Rate (L/ha/yr)
Oct-2017	0.29	62	690
Apr-2018	0.38	98	150

Trap ID: C2 (Diesel Area)

Date	CO_2 Flux (µmol /m²/s)	$^{14}CO_2$ (pMC)	Depletion Rate (L/ha/yr)
Oct-2017	0.76	81	1,000
Apr-2018	<Blank	89	0

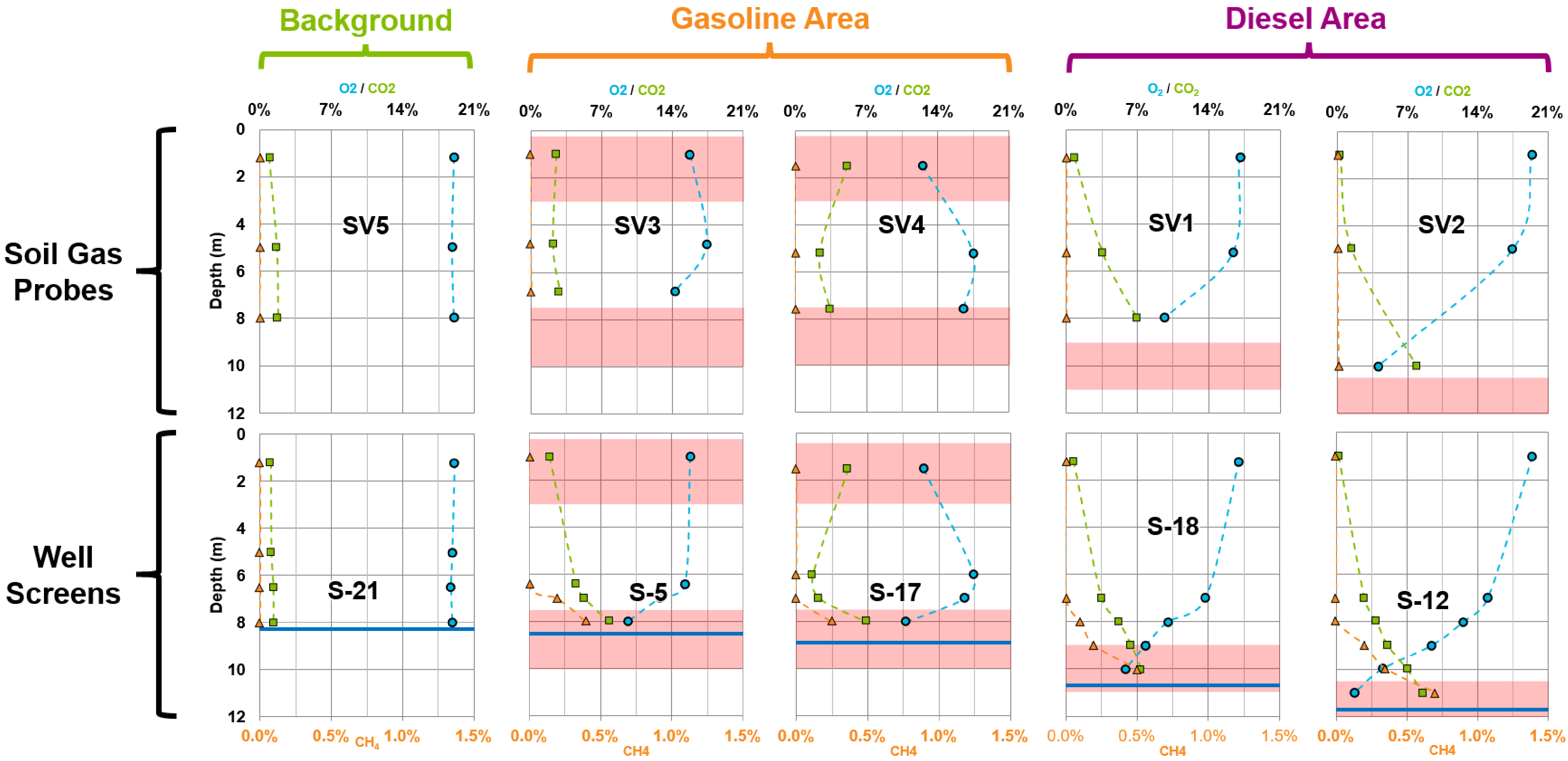
Trap ID: C5 (Background)

Date	CO_2 Flux (µmol /m²/s)	$^{14}CO_2$ (pMC)	Depletion Rate (L/ha/yr)
Oct-2017	8.5	66	19,000
Apr-2018	2.2	62	5,300

Soil Gas Concentration Gradient Method (Quarterly)

- Field analysis of soil gas (O_2, CO_2, and CH_4)
- Nested soil gas probes: 3 depths per location
- Profiling in wells: 1-meter intervals within screened interval

Soil Gas Profiling – Soil Gas Probes vs Wells



Gradient Method Results

– NSZD Rates estimated from wells generally higher than soil gas probes

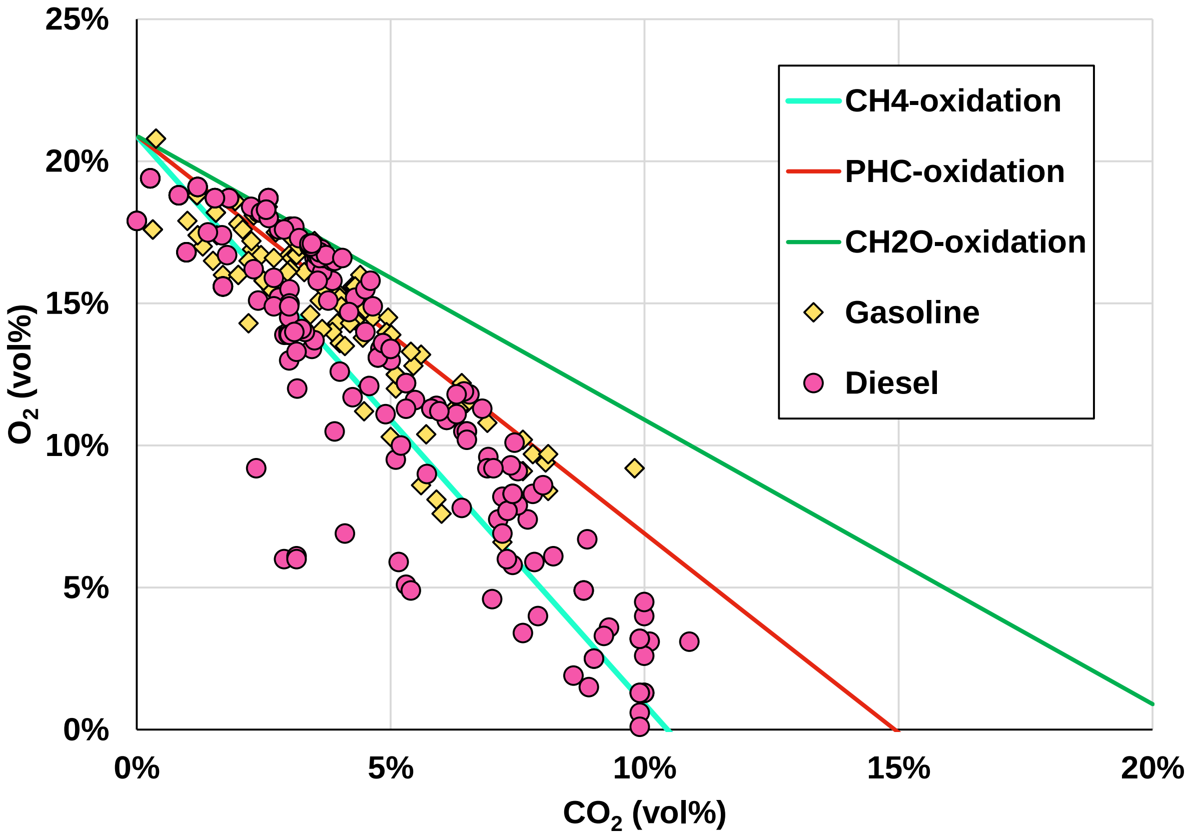
– Lower density of measurements near base of vadose zone with prescribed, fixed-depth probes

Gasoline Area (L/ha/yr)				Diesel Area (L/ha/yr)			
SV3		SV4		SV2		SV1	
O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2
280	200	290	260	1300	830	930	680

Gasoline Area (L/ha/yr)											
S-5		S-6		S-10		S-15		S-16		S-17	
O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2
970	830	1600	1500	1100	680	440	380	1400	1100	1500	1200
Diesel Area (L/ha/yr)											
S-7		S-8		S-9		S-12		S-18		S-19	
O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2	O_2	CO_2
820	580	2000	1300	1400	760	1100	820	1500	930	1100	670

– O_2 gradients yield higher NSZD rates than CO_2 gradients, particularly in diesel area

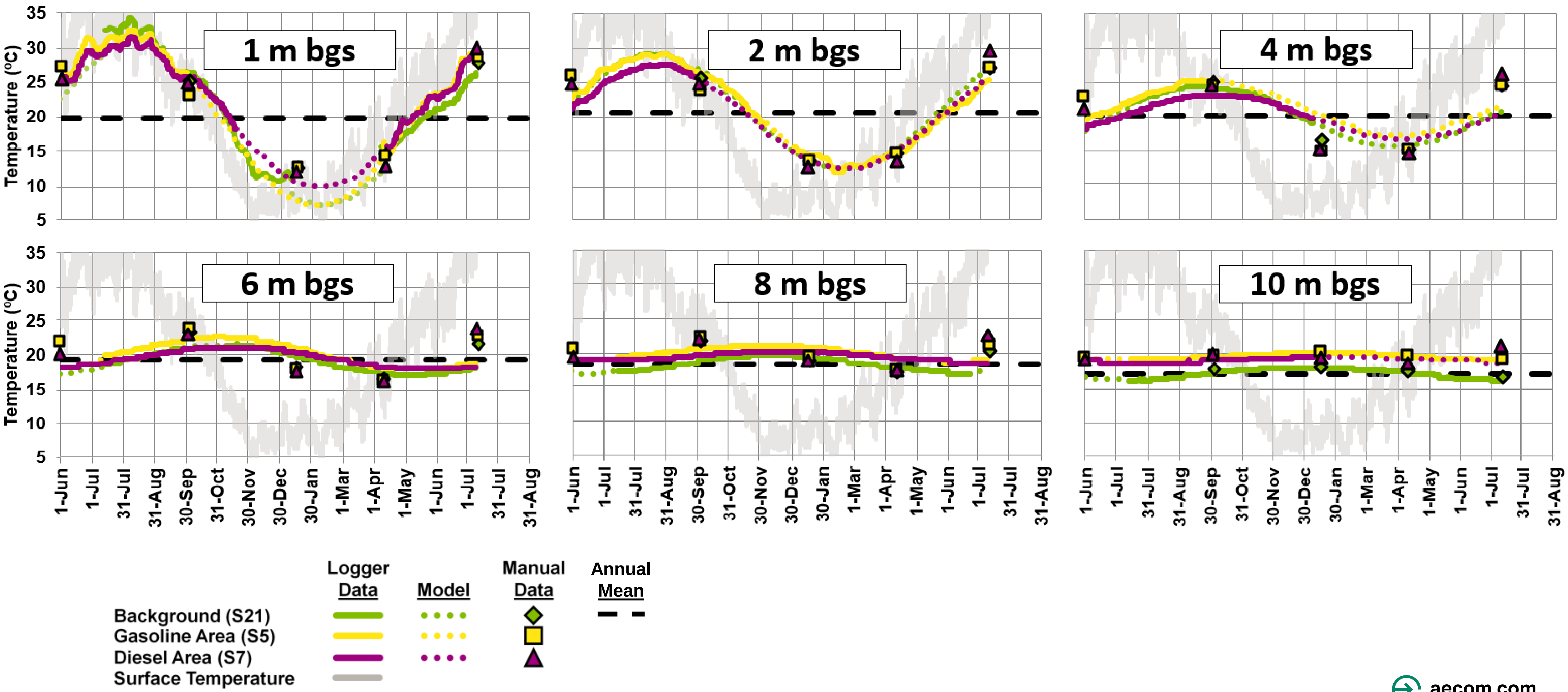
– Possible CO_2 dissolution/reaction with soil matrix minerals (USEPA, 1995; Romanak et al., 2012)



Biogenic Heat Method

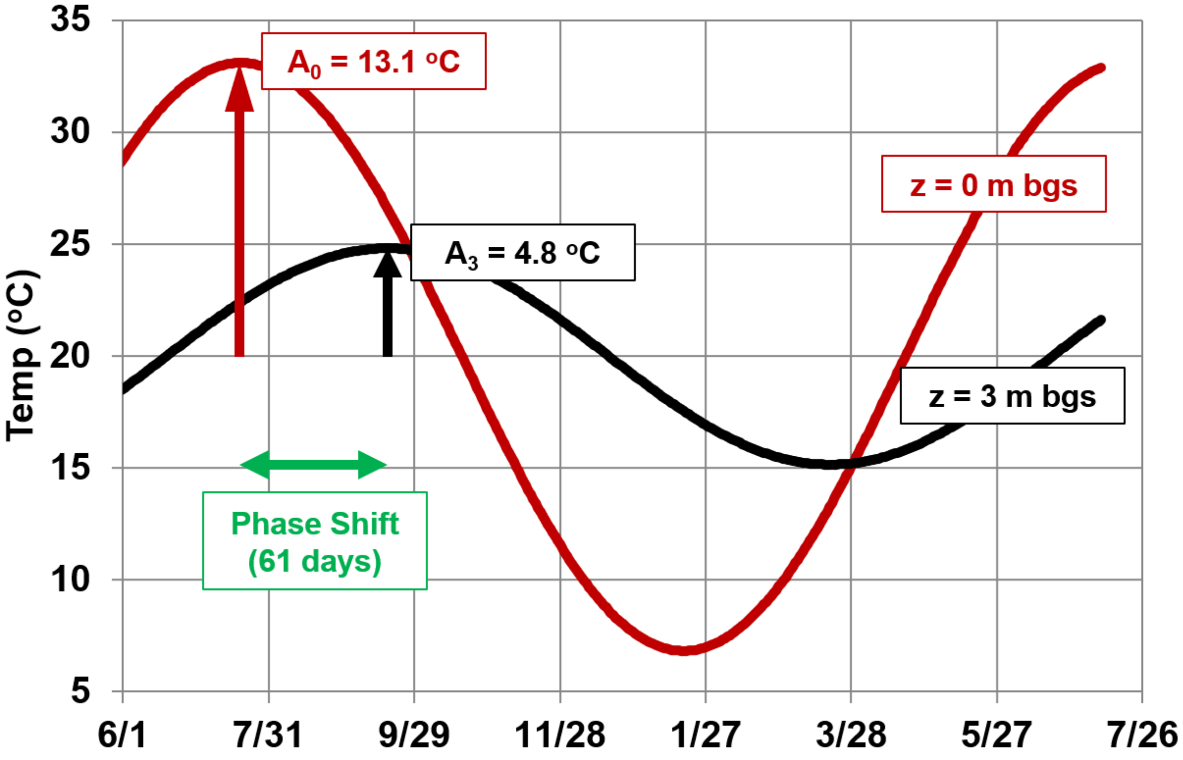
- Temperature in 1-meter depth increments
- 13 months of continuous temperature measurements using data loggers
  - Gasoline area (S-5)
  - Diesel area (S-7)
  - Background (S-21)
- Quarterly manual temperature measurements
  - Wells instrumented with data loggers
  - 15 additional wells in gasoline and diesel area

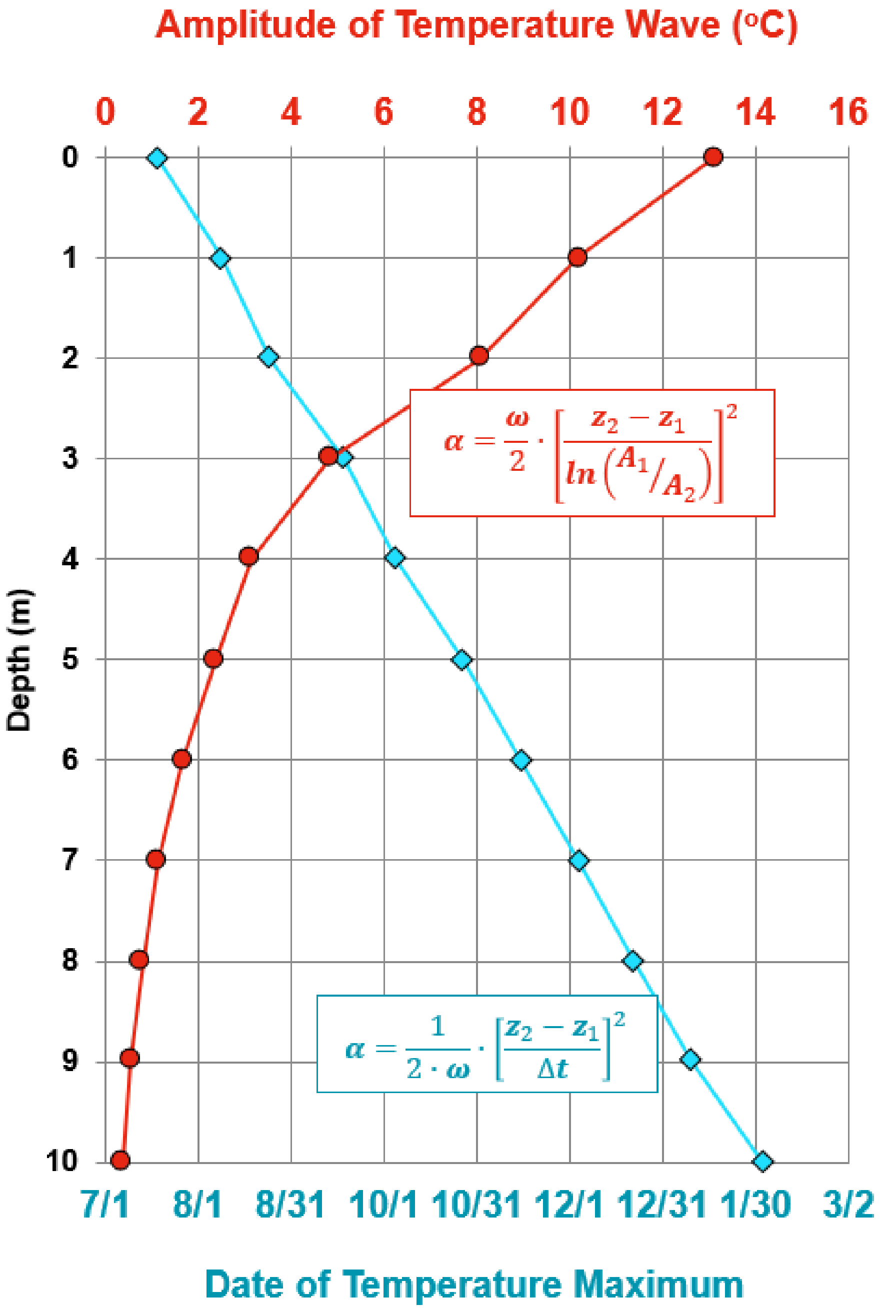
Temperature Data



Temperature Data Analysis

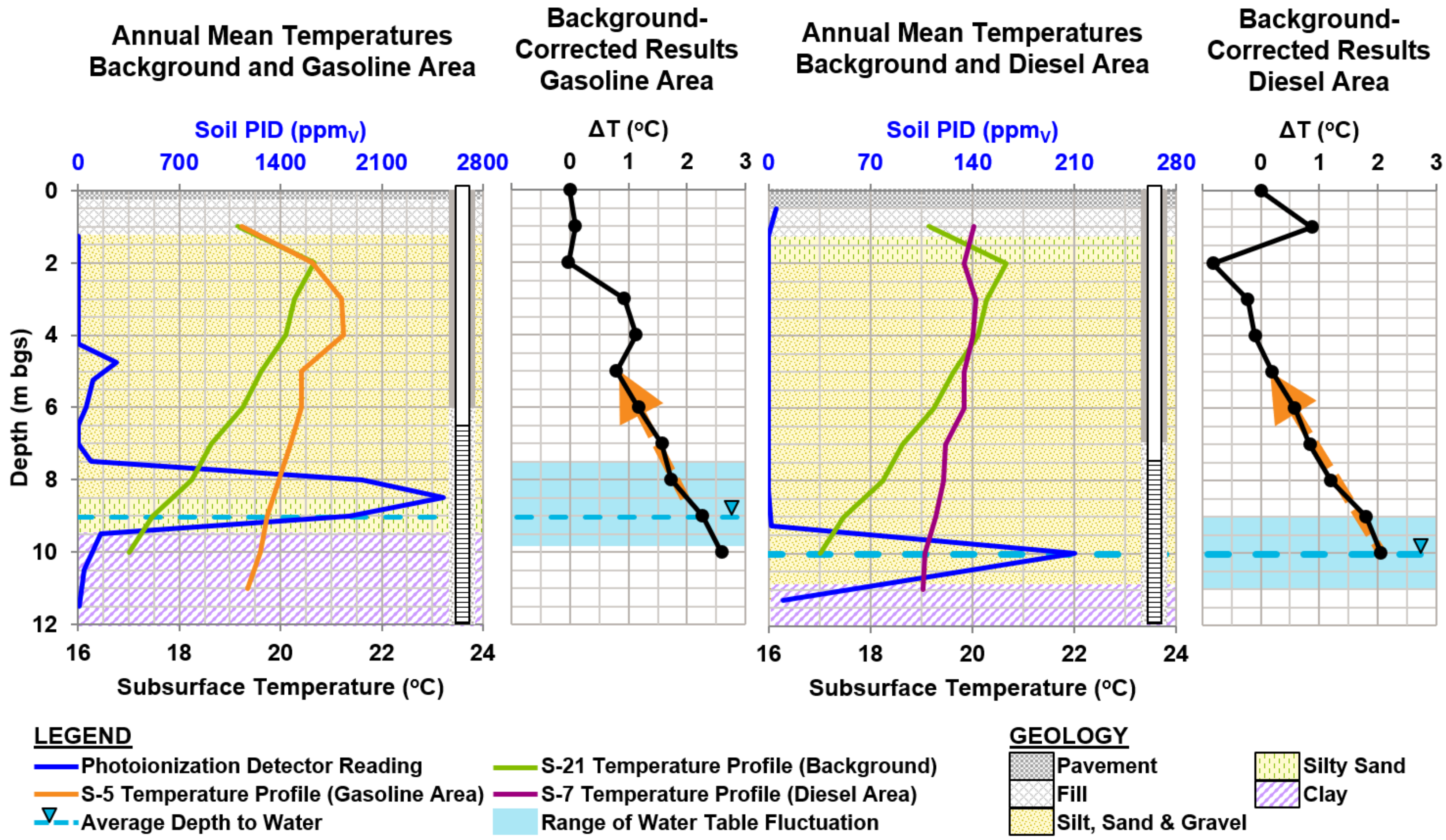
- Site-specific thermal diffusivity (α) estimated from data logger measurements
- Amplitude ratio and phase lag methods for 1st harmonic (Carson 1963; Sweeney and Ririe, 2014)
- Thermal conductivity estimated from diffusivity and heat capacity measurements.





Thermal Diffusivity (α) 10^{-6} m²/sec
1.1
1.2
1.0
0.92
1.3
0.7
0.85
1.4
1.2
1.2

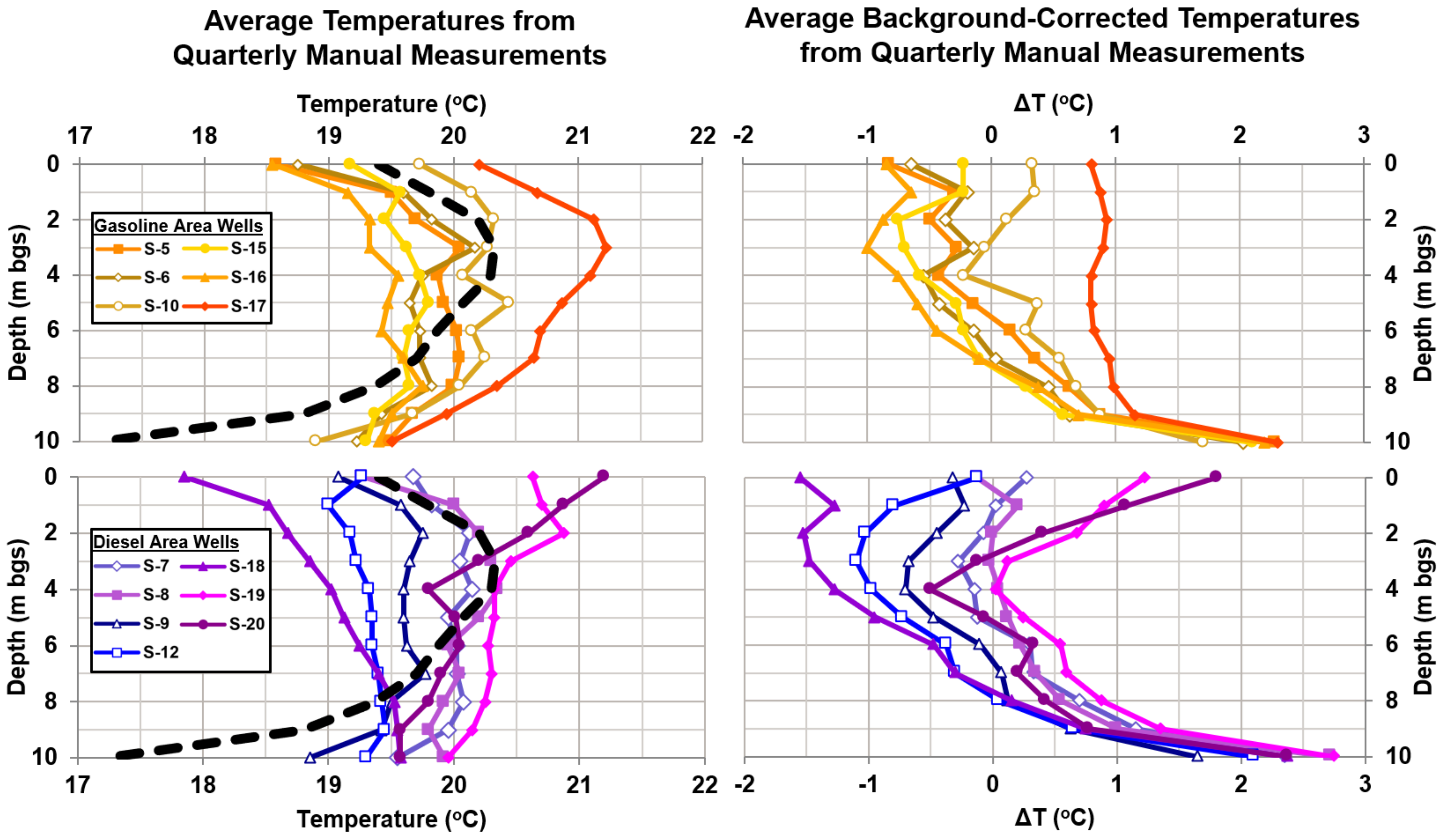
Temperature Data Analysis – Data Loggers



Annual Average Temperature Profile Results:

- Gasoline Source Zone 3,000 L/ha/yr
- Diesel Source Zone 3,200 L/ha/yr

Temperature Data Analysis – Manual Measurements

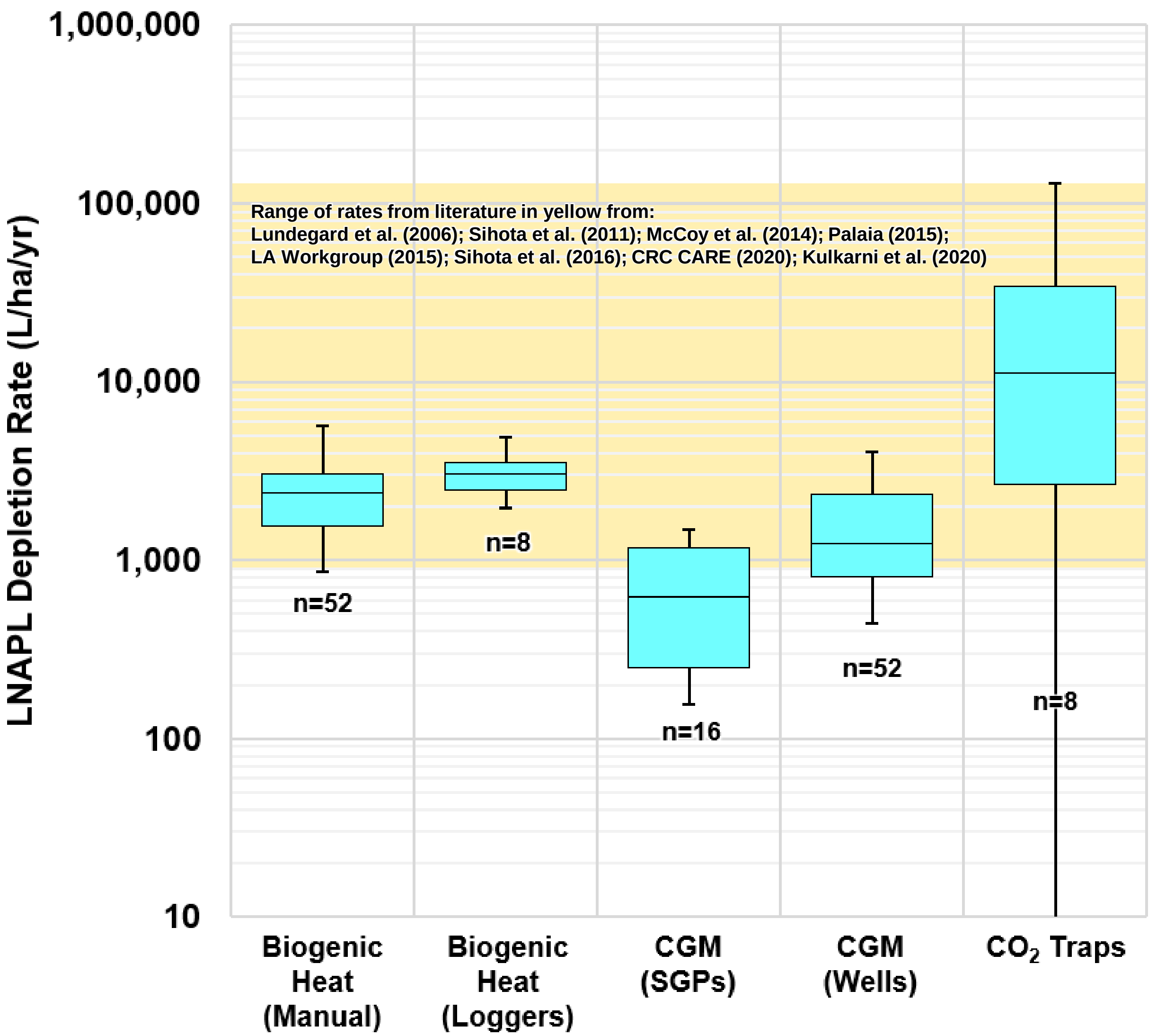


Temperature Profile Results:

- Gasoline Source Zone 2,000 – 2,700 L/ha/yr
- Diesel Source Zone 1,900 – 3,200 L/ha/yr

Study Results

- Large variability in rates, but all methods demonstrate NSZD
- CSM is key to interpreting data and identifying potential interferences
  - Lateral soil gas transport in upper 5 to 6 m
  - O_2 utilization and CO_2 production in multiple depth horizons
  - Possible consumption of CO_2 by dissolution and reaction with soil minerals
- Results highlight value of measurements of soil gas and temperature in existing wells
  - CSM testing and method screening
  - Can be qualitative or quantitative



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