
PFAS in Soil: Considering Leaching to Groundwater



NEWMOA Webinar
July 29, 2020
Harrison Roakes, PE

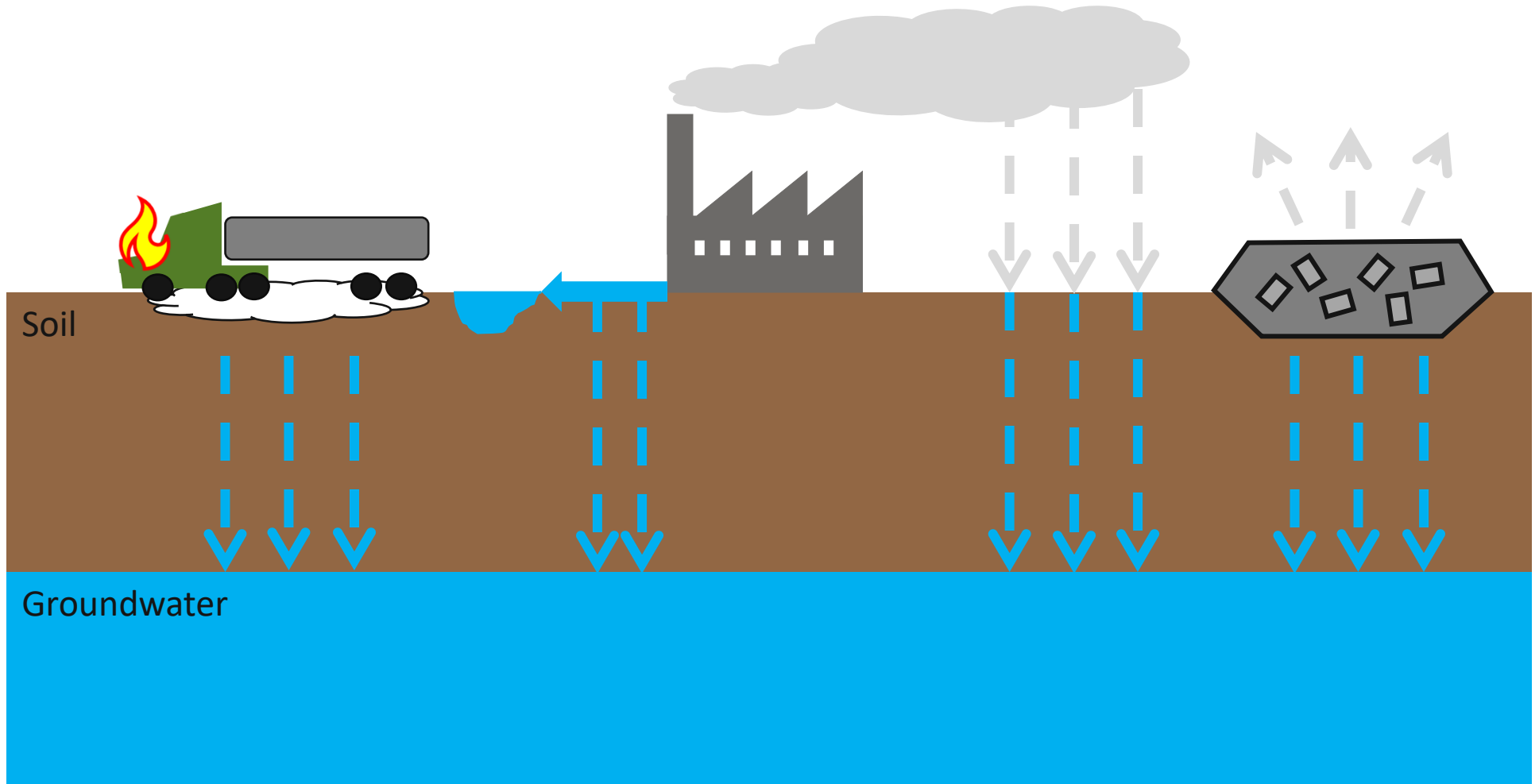


Outline

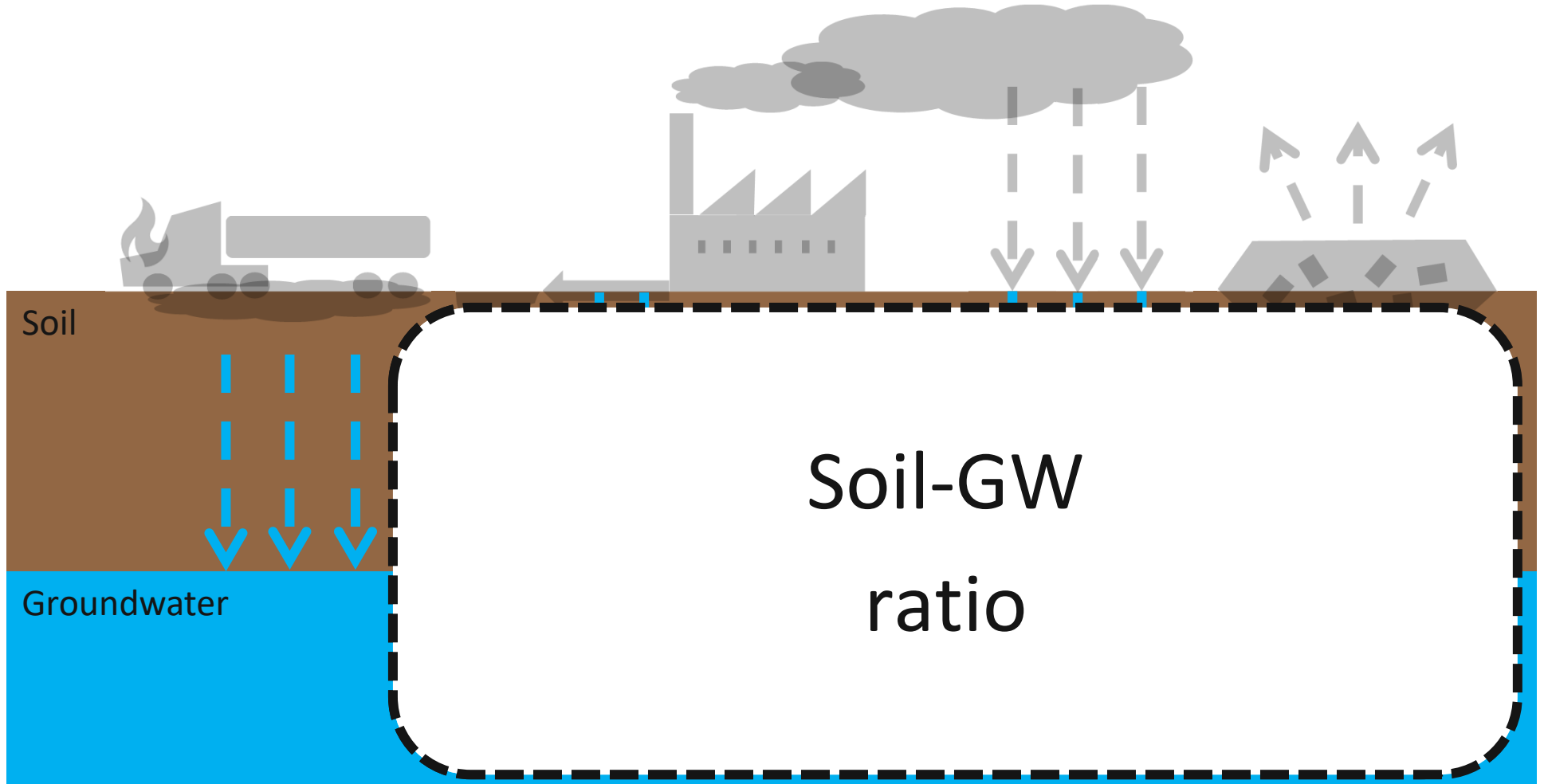
- Fundamentals and background
- Leaching-based screening values
- Anthropogenic background
- Screening approaches

The focus of this presentation is on PFOA and PFOS. PFAS, including precursors to PFOA and PFOS, have widely ranging chemistries and properties.

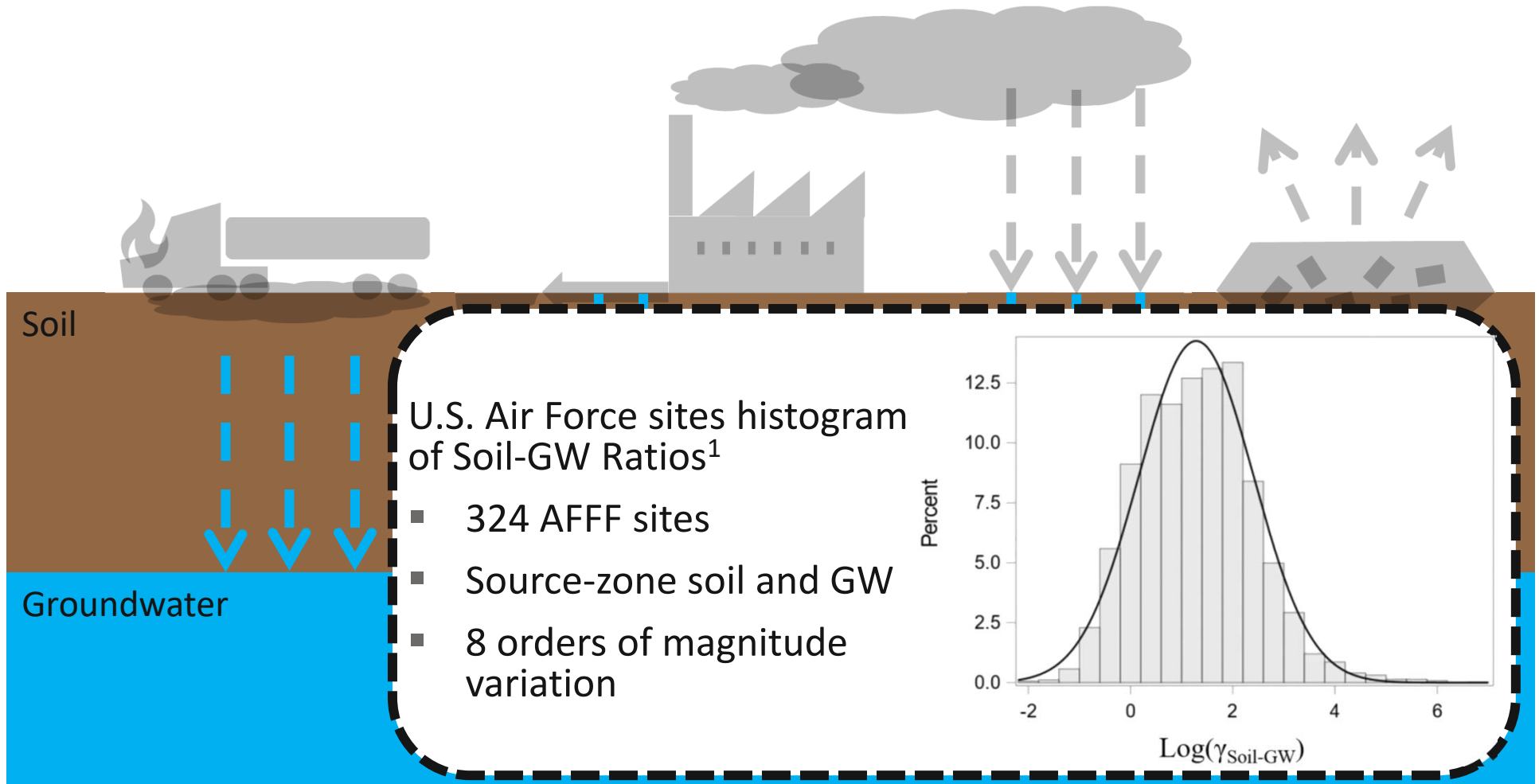
Soil is a key media for many releases



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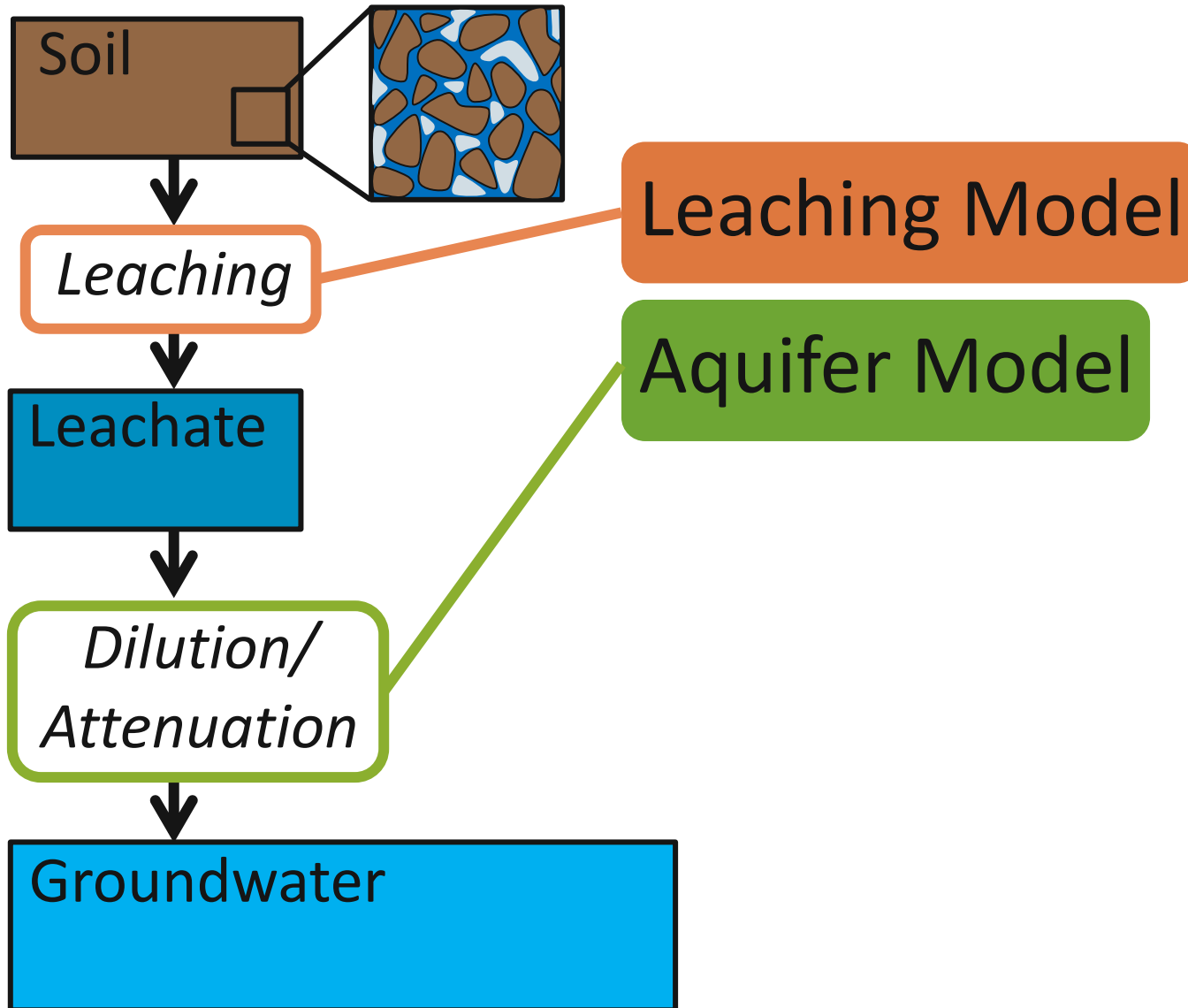


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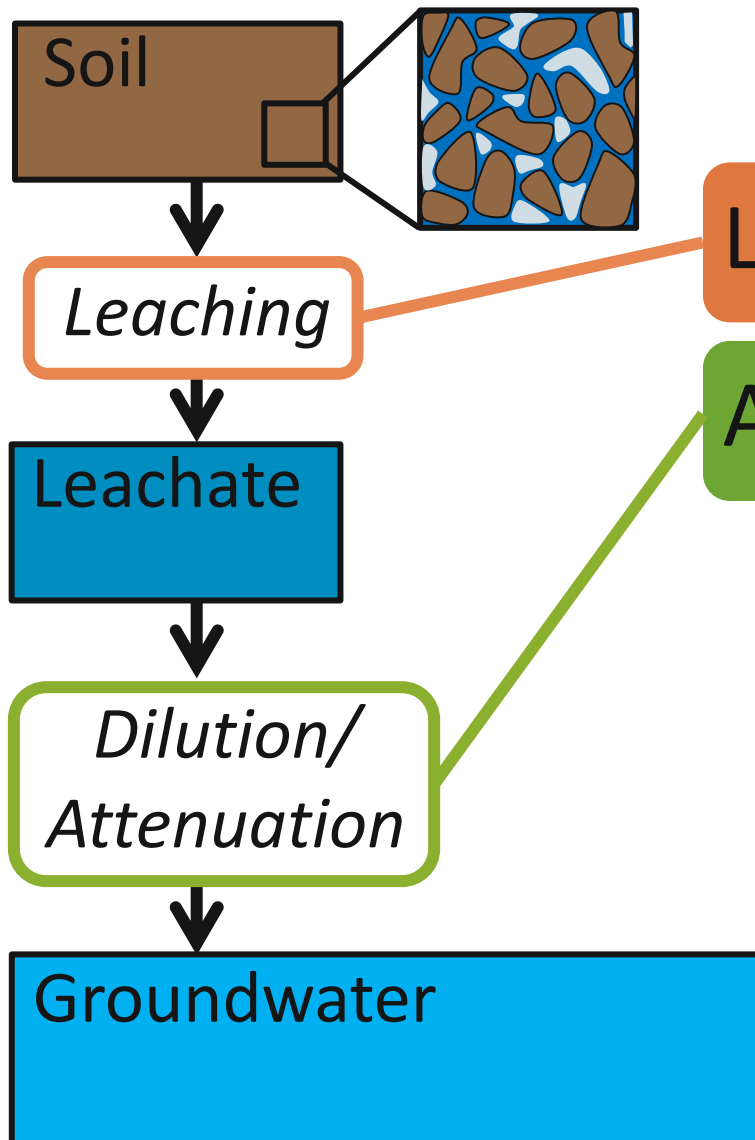


1. Anderson, Adamson, and Stroo. (2019). *Journal of Contaminant Hydrology*, 220 59-65:
<https://doi.org/10.1016/j.jconhyd.2018.11.011>

Leaching Models



Leaching Models



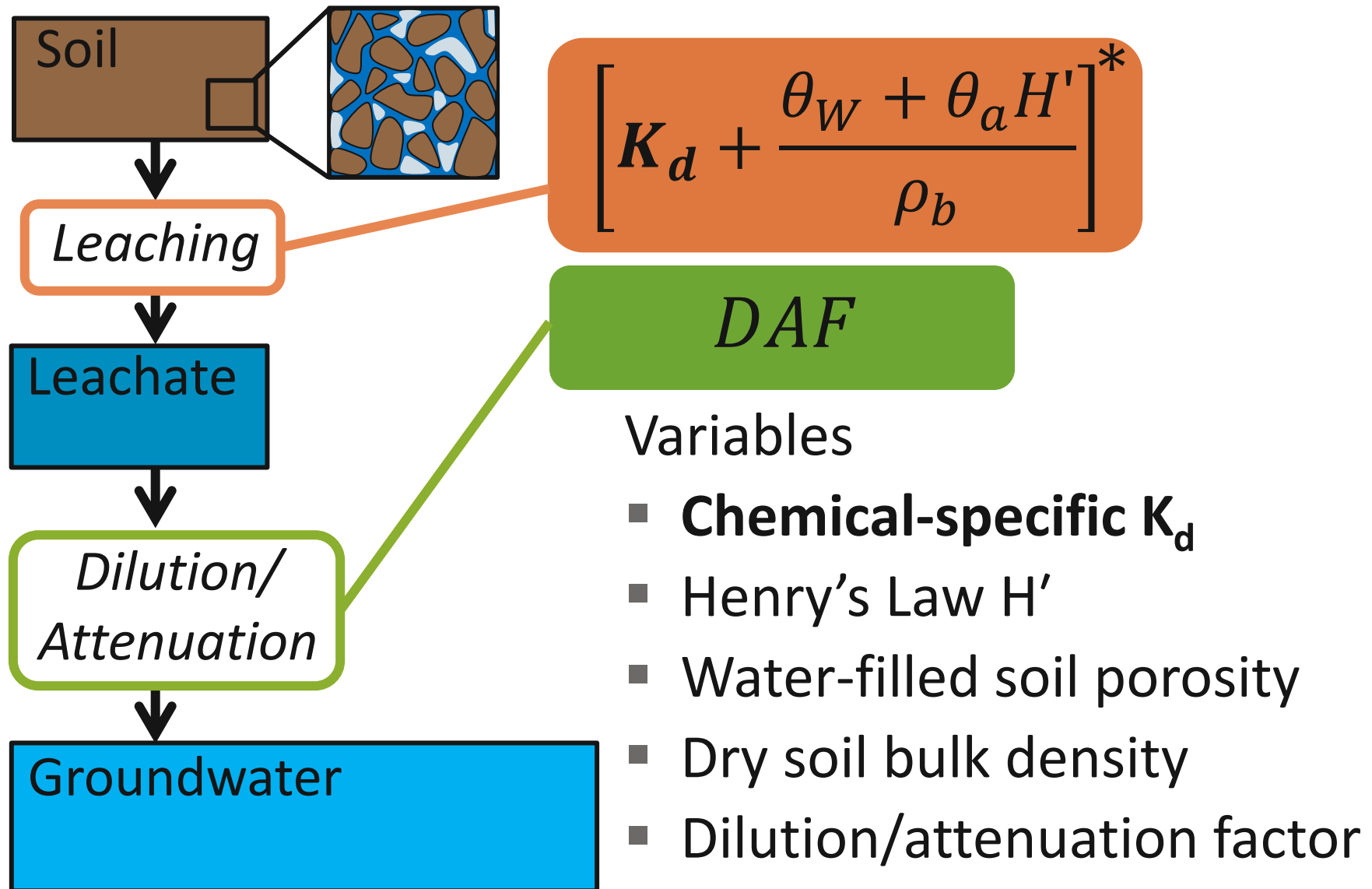
Leaching Model

Aquifer Model

Common model inputs

- Hydrogeology
- Release assumptions

USEPA Soil Screening Level

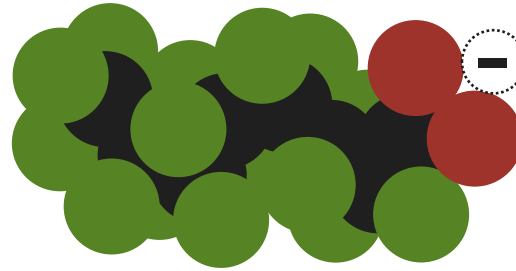


*Simplified by assuming nonionizing compound. Details: <https://semspub.epa.gov/work/HQ/175232.pdf>

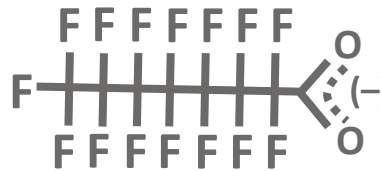
PFOA Chemical Structure

Fluorocarbon tail

- Hydrophobic
- Lipophobic

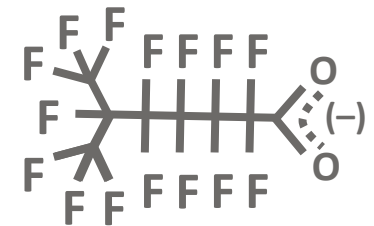
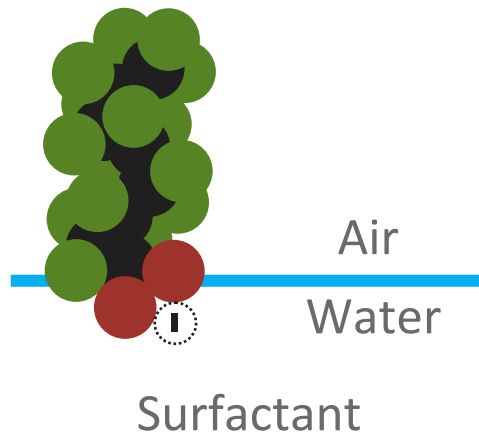


Ionic skeletal and 3D models



Functional group

- Hydrophilic
 - High solubility
 - Low volatility



Branched isomer models

Throughout the presentation, PFOA molecules are illustrated. These illustrations are not to scale, and numerous other details are not shown, including counterions, water molecules, and solids molecules.

General Phase Partitioning

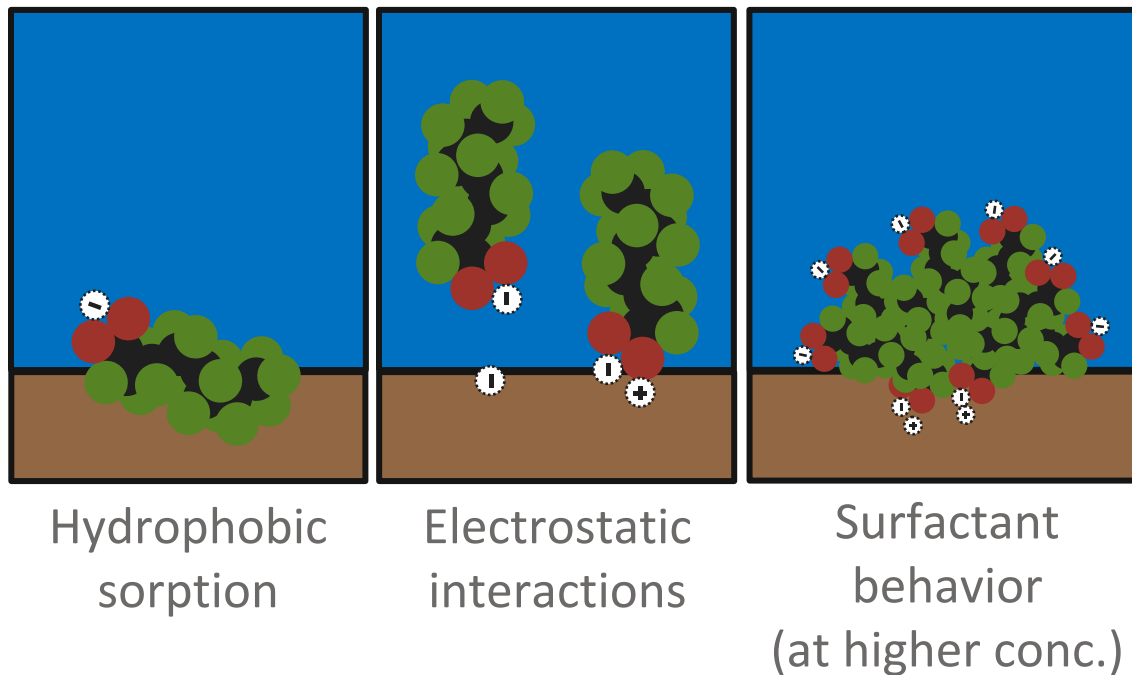


Simplified model

- Three soil phases
- Described with partition coefficients
- Steady-state, equilibrium

constant for
known or
assumed
conditions

PFOA/PFOS Phase Partitioning



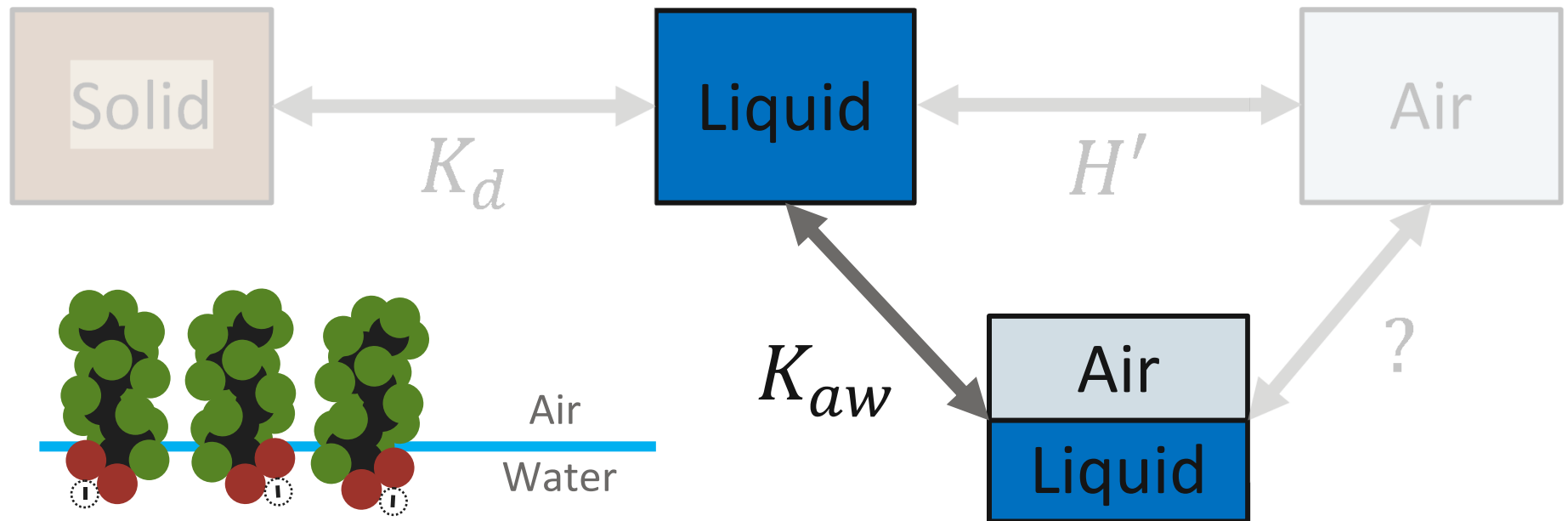
Li et al. (2018)¹

- Not just

$$K_d = K_{oc} \times f_{oc}$$

1. Li, Oliver, and Kookana. (2018). *Science of the Total Environment*, 628-629 110-120: <https://doi.org/10.1016/j.scitotenv.2018.01.167>

PFOA/PFOS Phase Partitioning



Brusseau et al. (2019)¹ and Guo et al. (2020)²

- >80% total retention
- Greater retention in sand vs. finer-grains

Dr. Linda Abriola SERDP/ESTCP air-water and NAPL-water interface partitioning presentation:
<https://www.youtube.com/user/SERDP/playlist>
 RDPESTCP

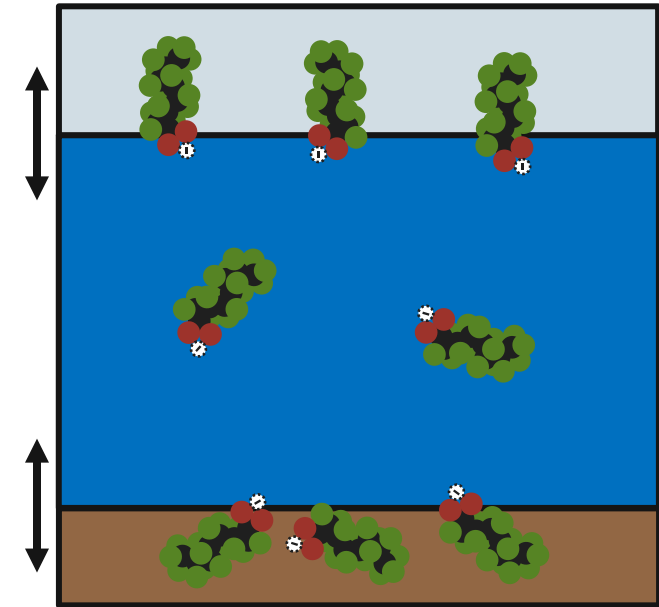
1. Brusseau, Yan, Van Glubt, Wang, Chen, Lyu, Dungan, Carroll, Holguin. (2019). *Water Research*, 148 41-50:
<https://doi.org/10.1016/j.watres.2018.10.035>

2. Guo, Zeng, and Brusseau. (2020). *Water Resources Research*, 57: <https://doi.org/10.1029/2019WR026667>

PFOA/PFOS Phase Partitioning

Key Factors:

- Soil and water chem, e.g.
 - Organic carbon
 - Co-contaminants
 - pH & surface charge
 - Major ions
- PFOA/PFOS concentration
- Previous conditions



Not to scale

nonlinear

hysteresis

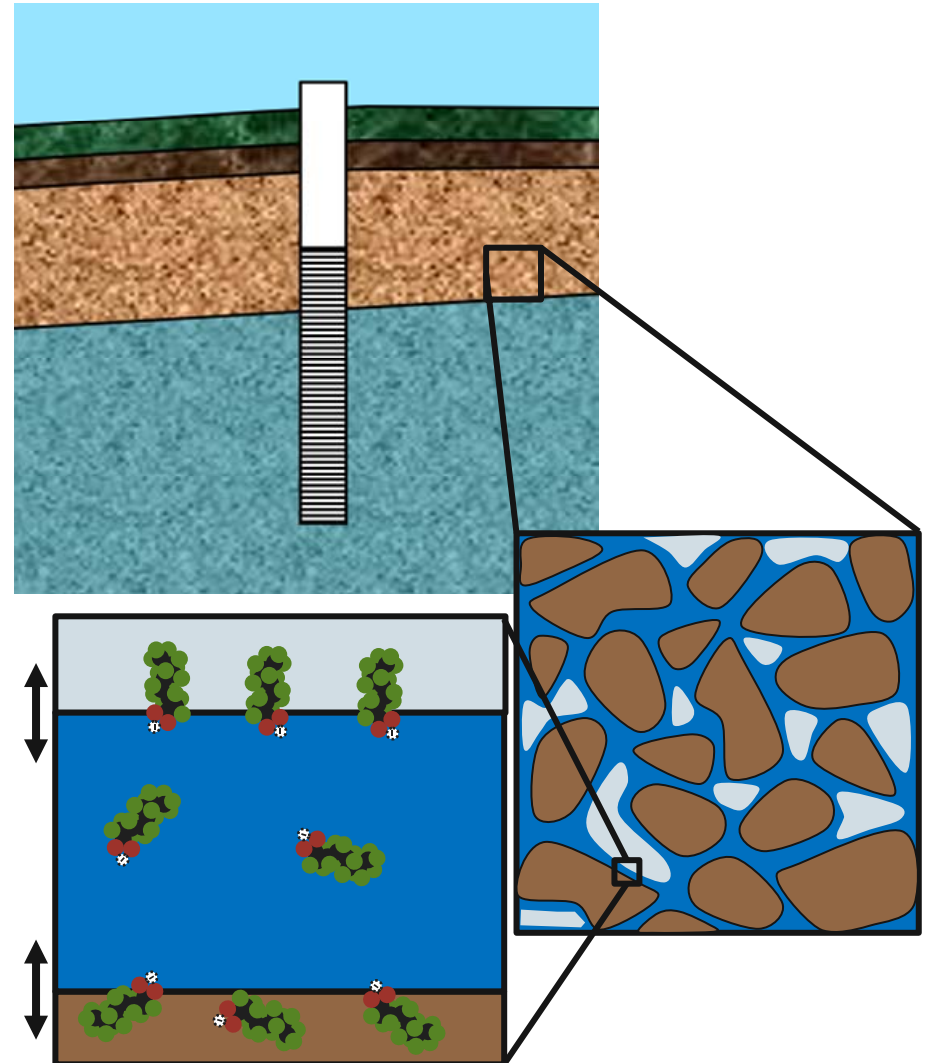
For more information, see ITRC PFAS Technical and Regulatory Guidance Document:
https://pfas-1.itrcweb.org/5-environmental-fate-and-transport-processes/#5_2

Field Conditions Phase Partitioning

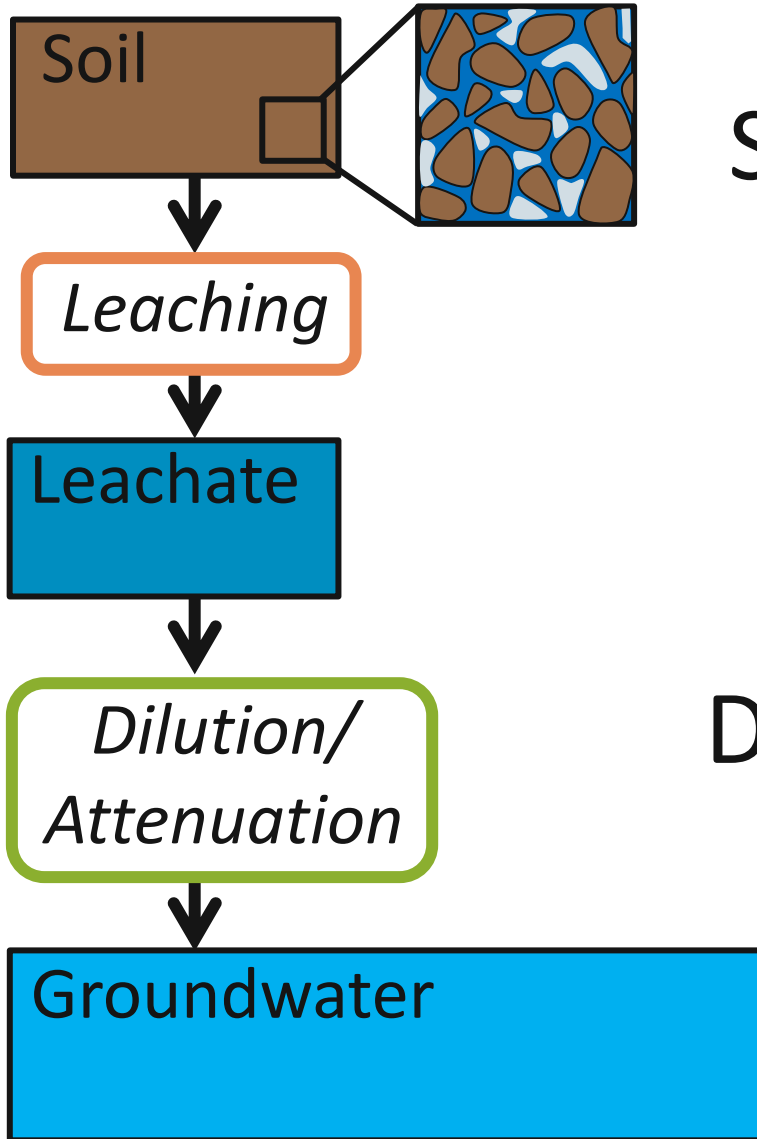
- Hydraulics
 - Microscale
 - Macroscale
- Kinetics/mass transfer

Field conditions:

- *Approach* equilibrium
- Complex/variable
 - Heterogeneous
 - Cannot replicate in a lab
- Delicate
 - Disturbed by sampling



Soil Screening Value Calculation



Soil Screening Value

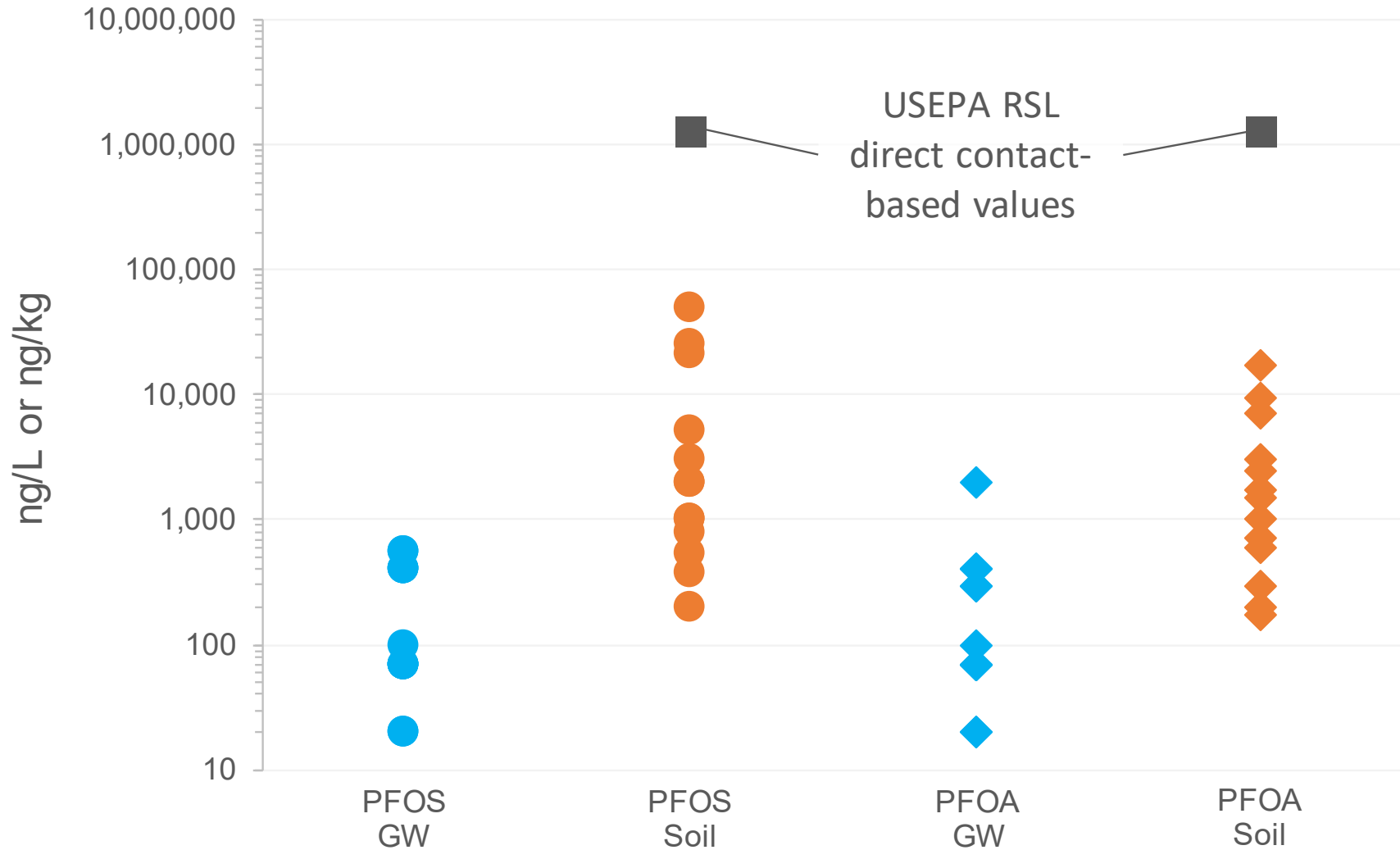
Leaching

Dilution/attenuation

Target GW value

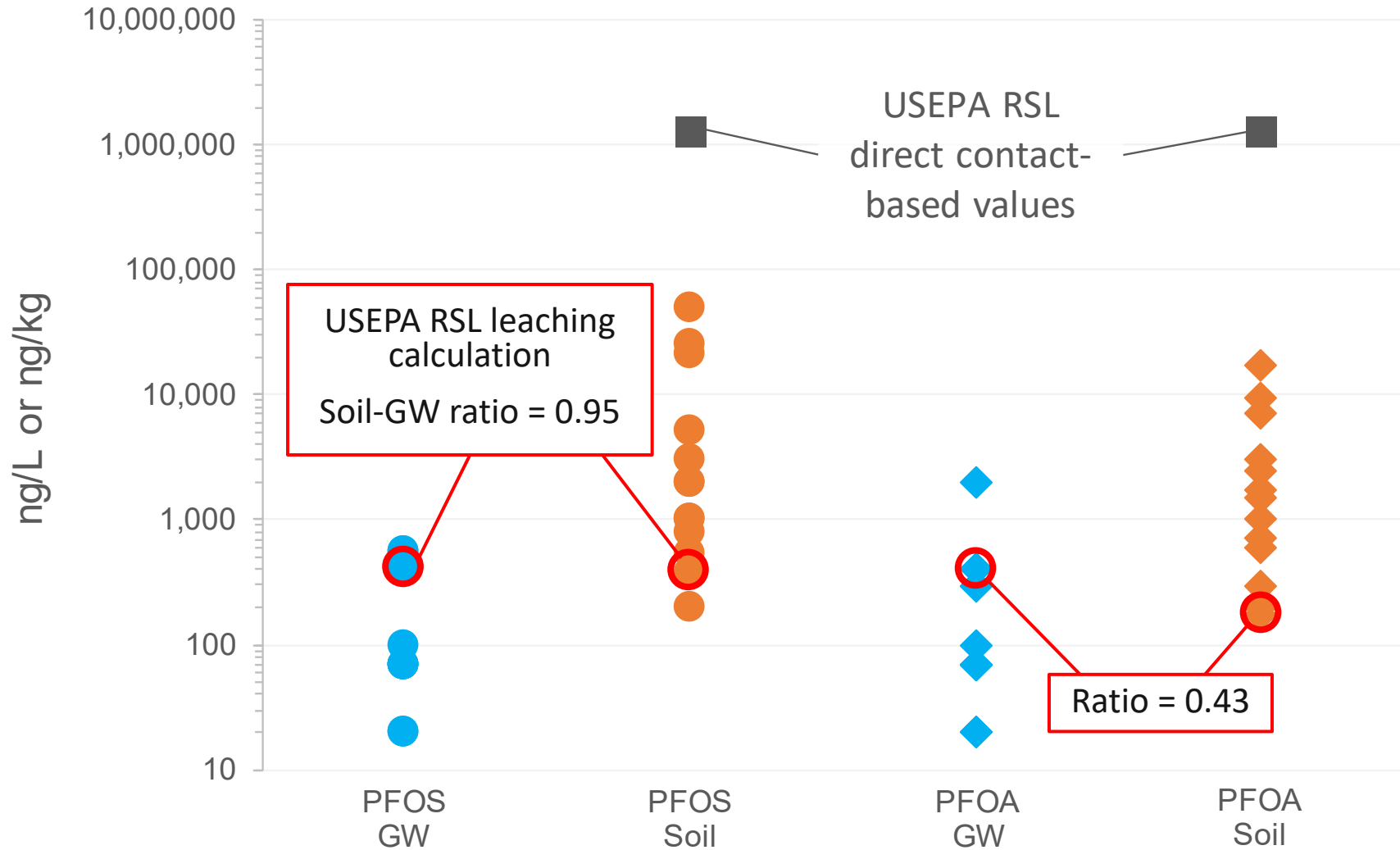


GW and Soil Leaching Values



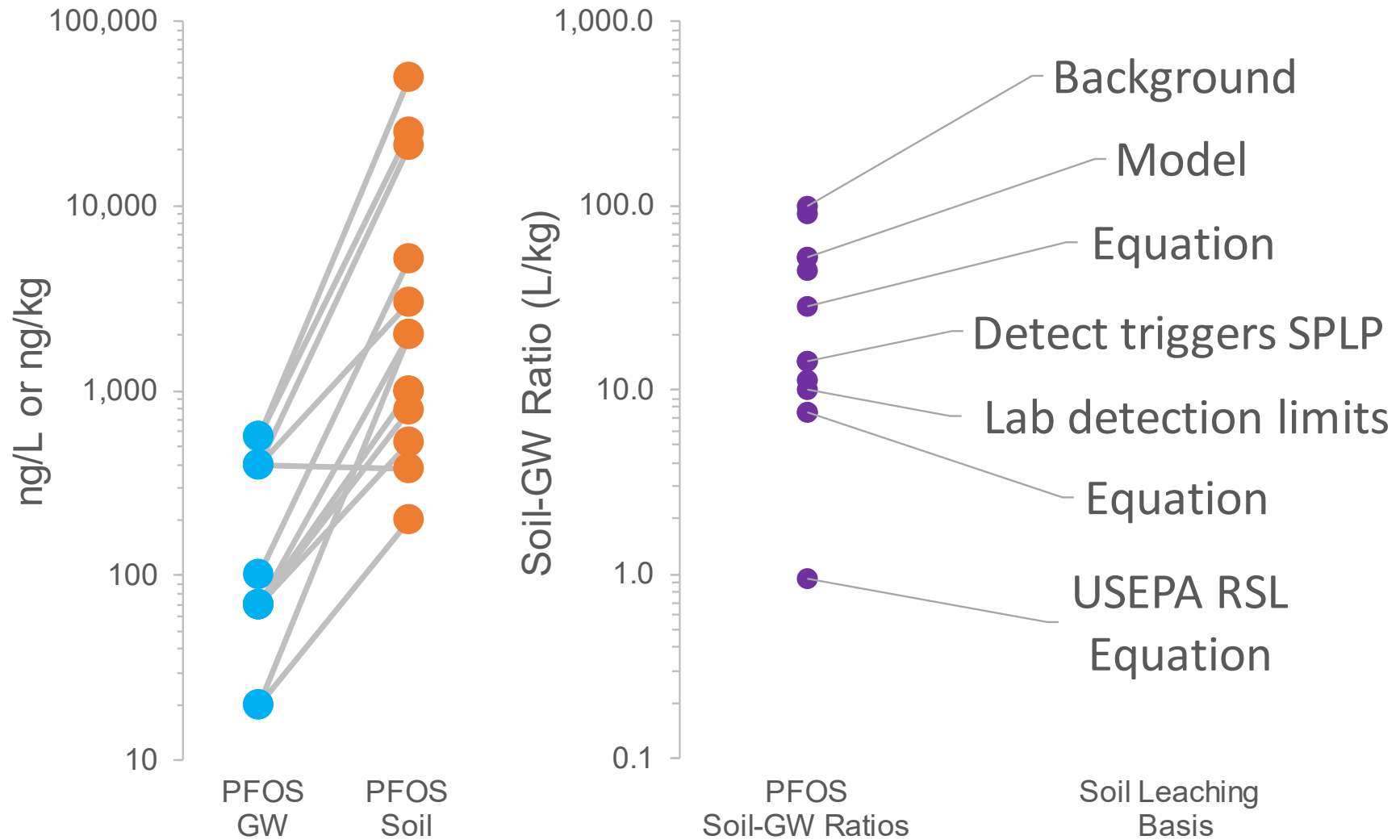
1. "GW Values" and "Soil to GW Protection Values" were largely obtained from the ITRC fact sheet spreadsheet updated June 2020 (<https://pfas-1.itrcweb.org/fact-sheets/>). Some proposed or draft values, which may be on-hold or now replaced with updated values, are also included.
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GW and Soil Leaching Values



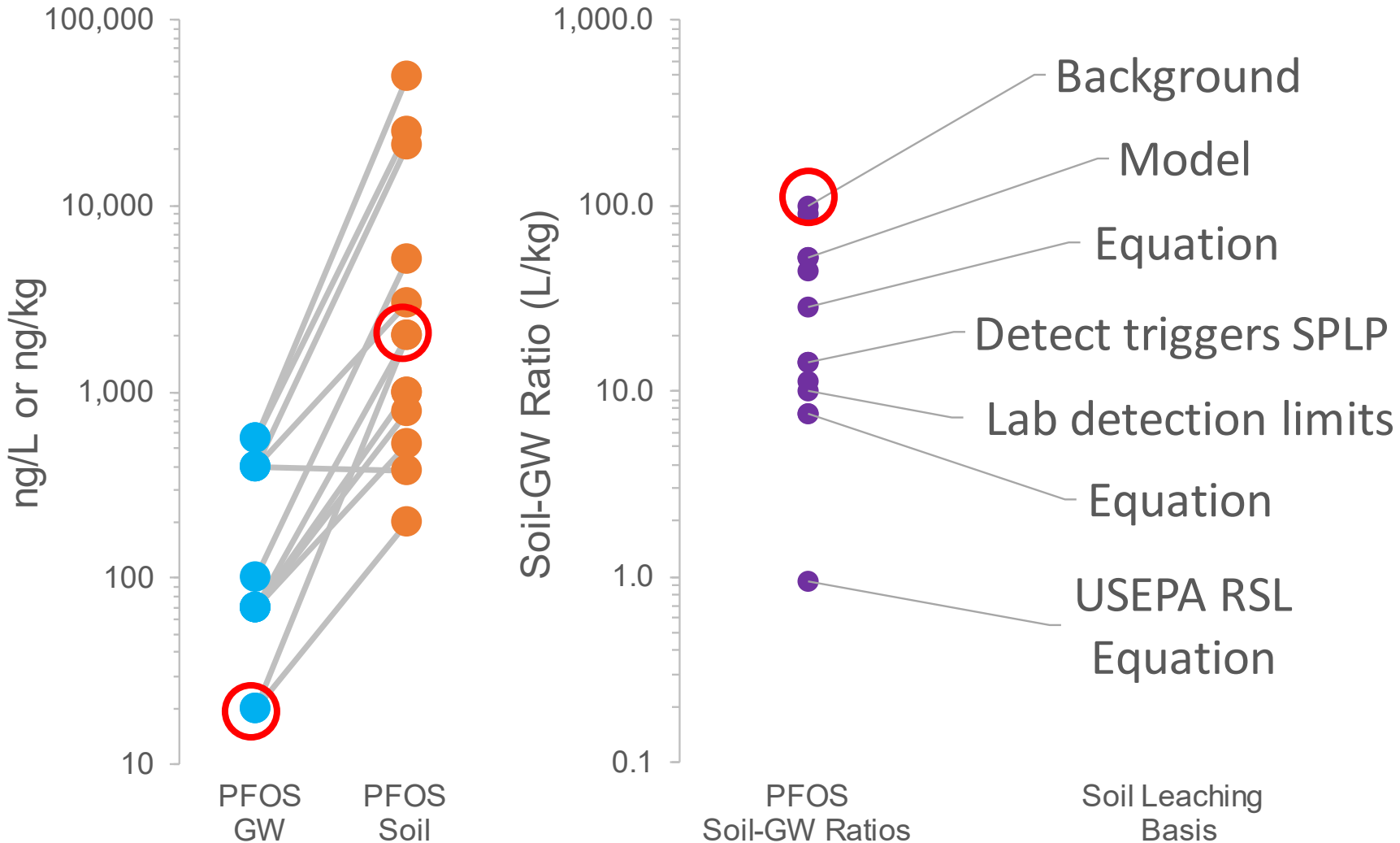
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PFOS Soil Leaching Soil-GW Ratios



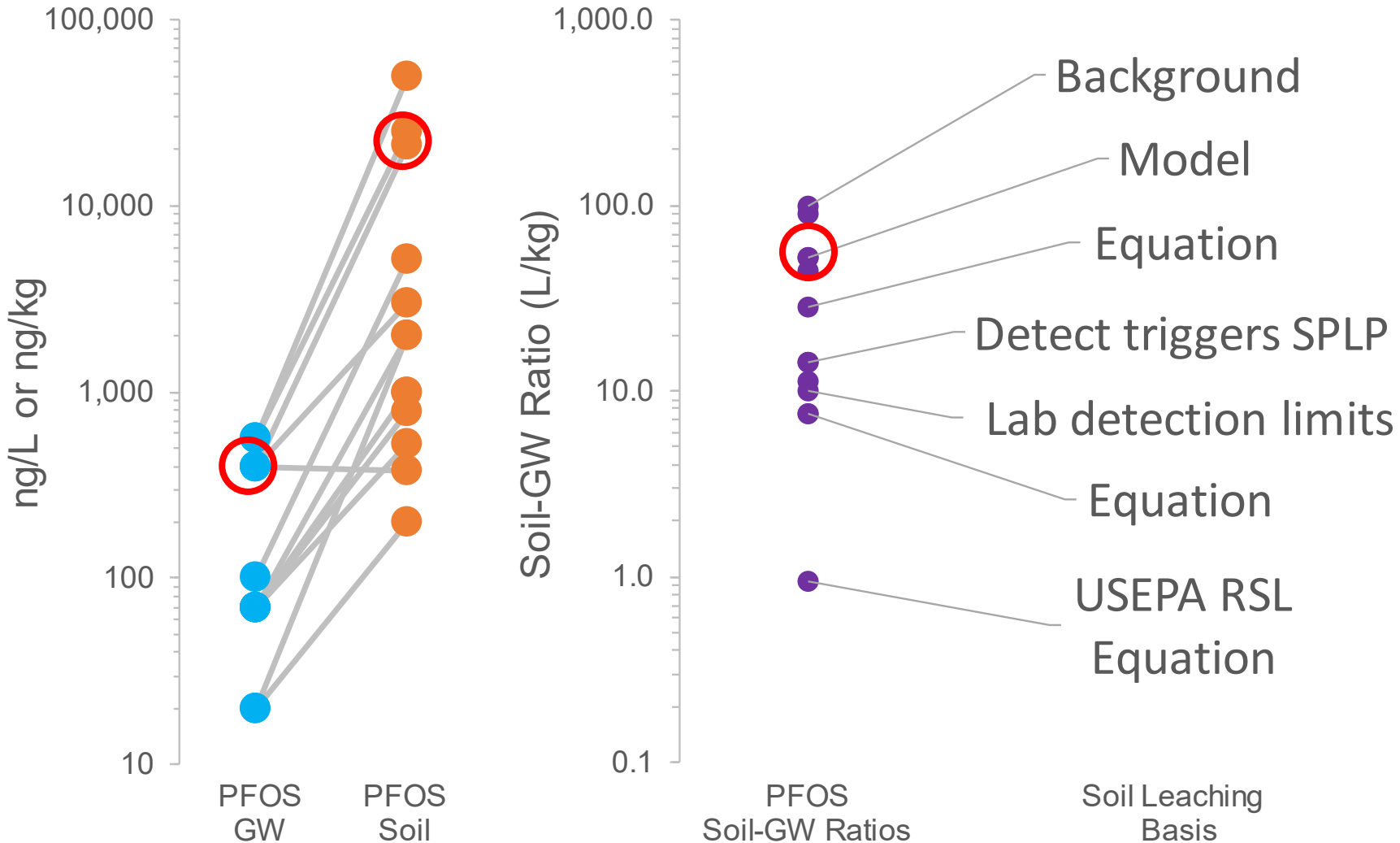
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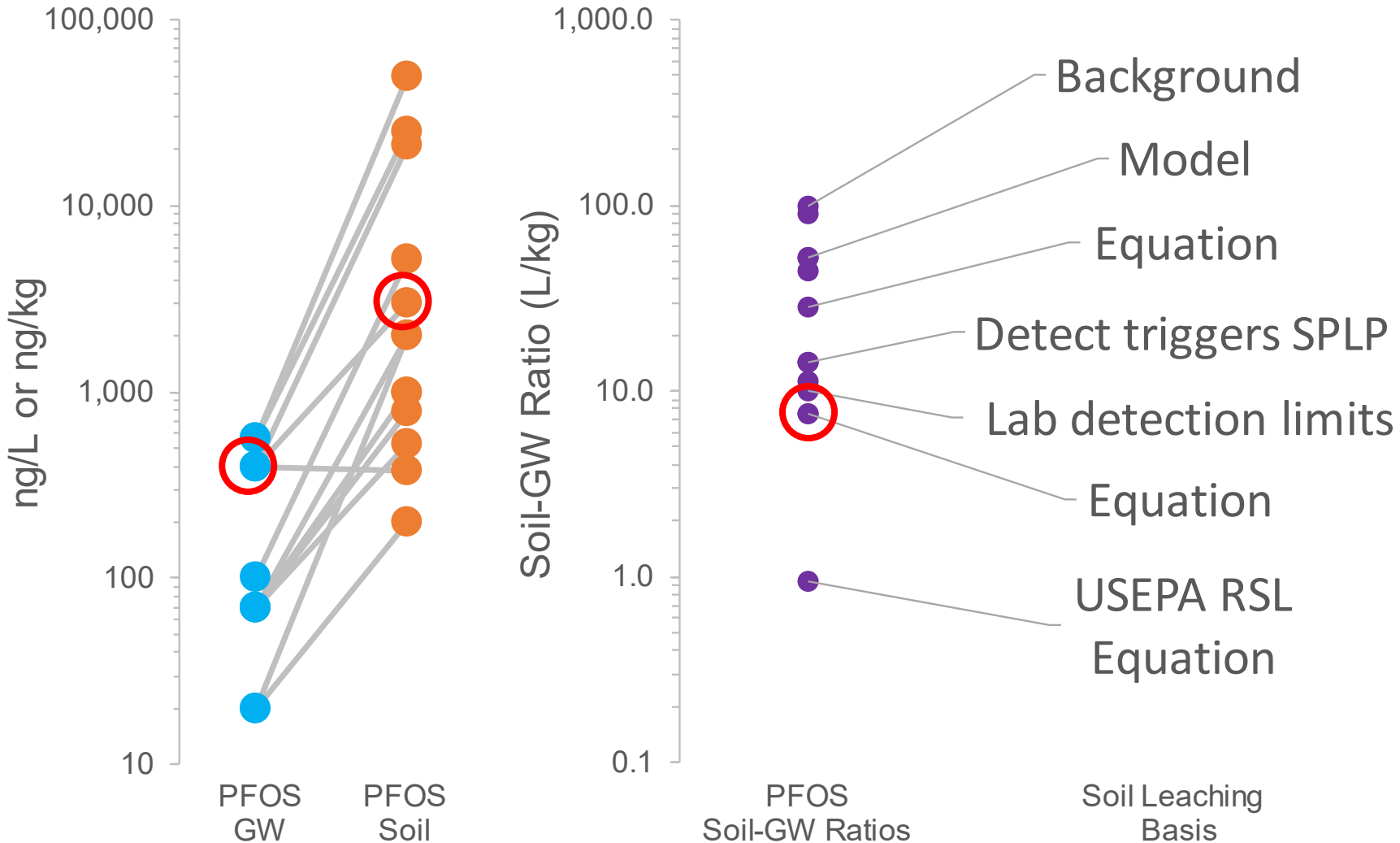
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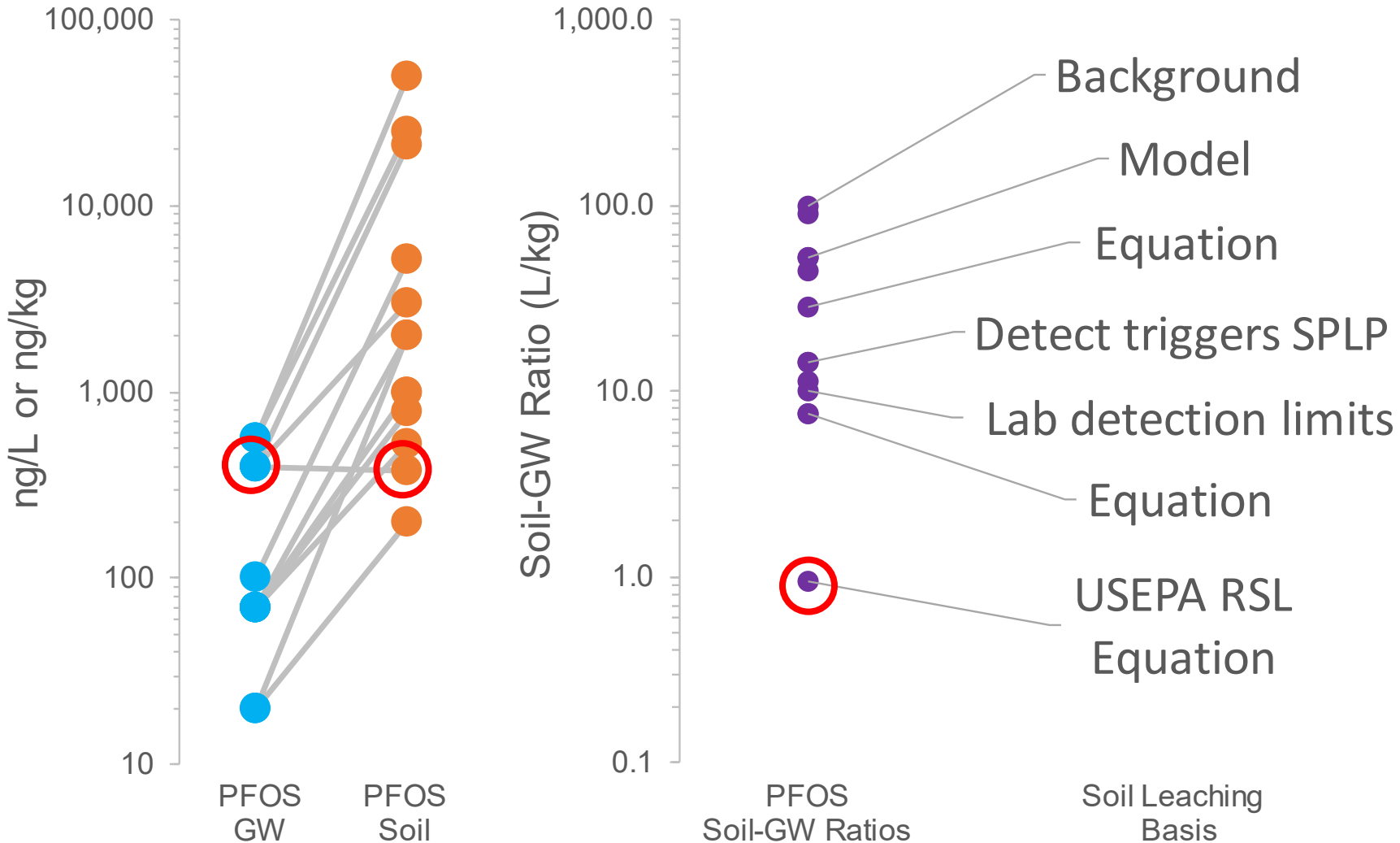
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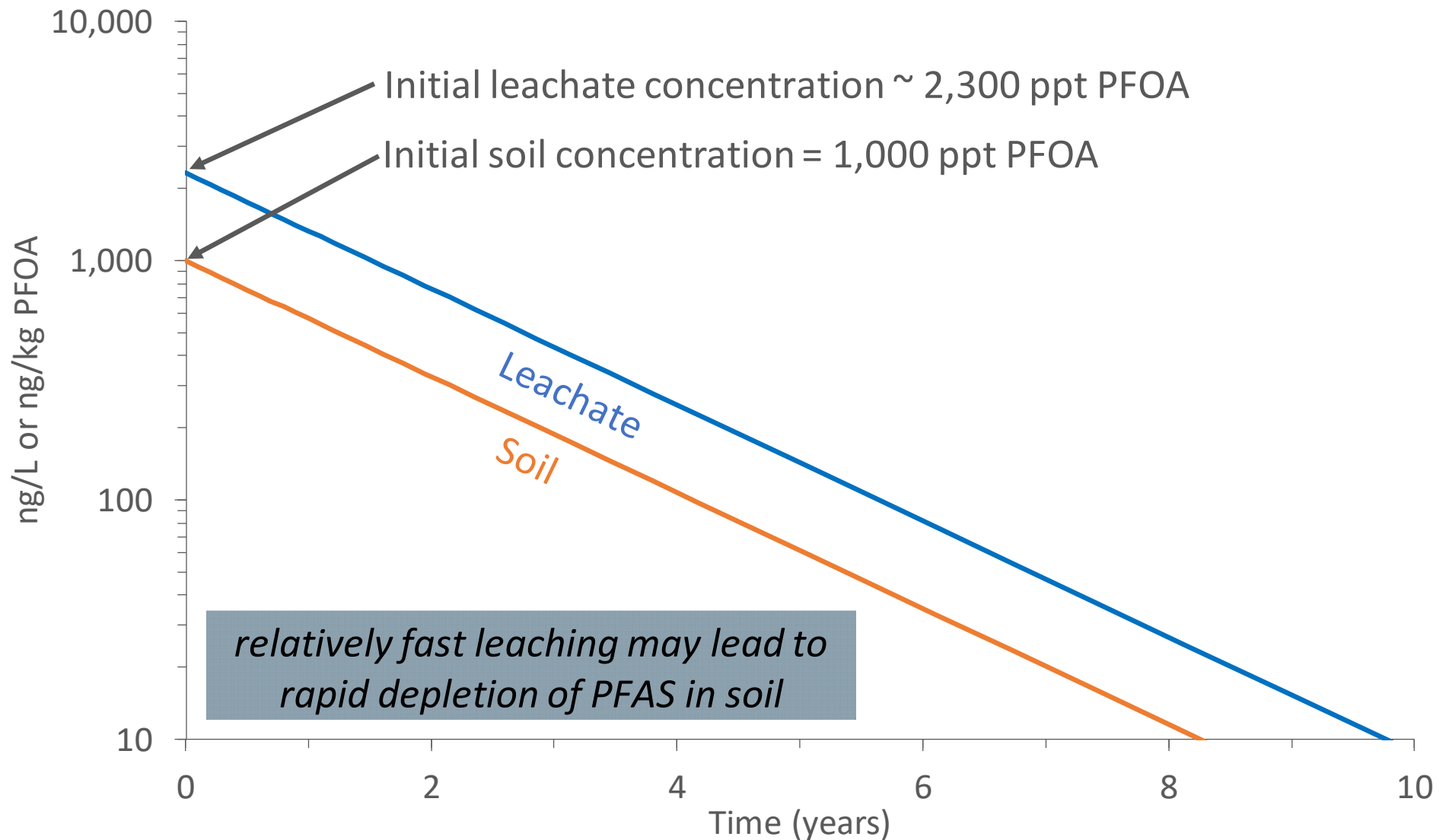
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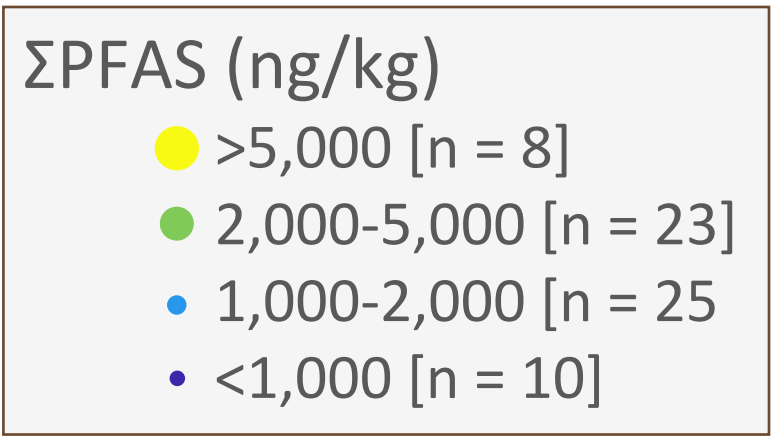
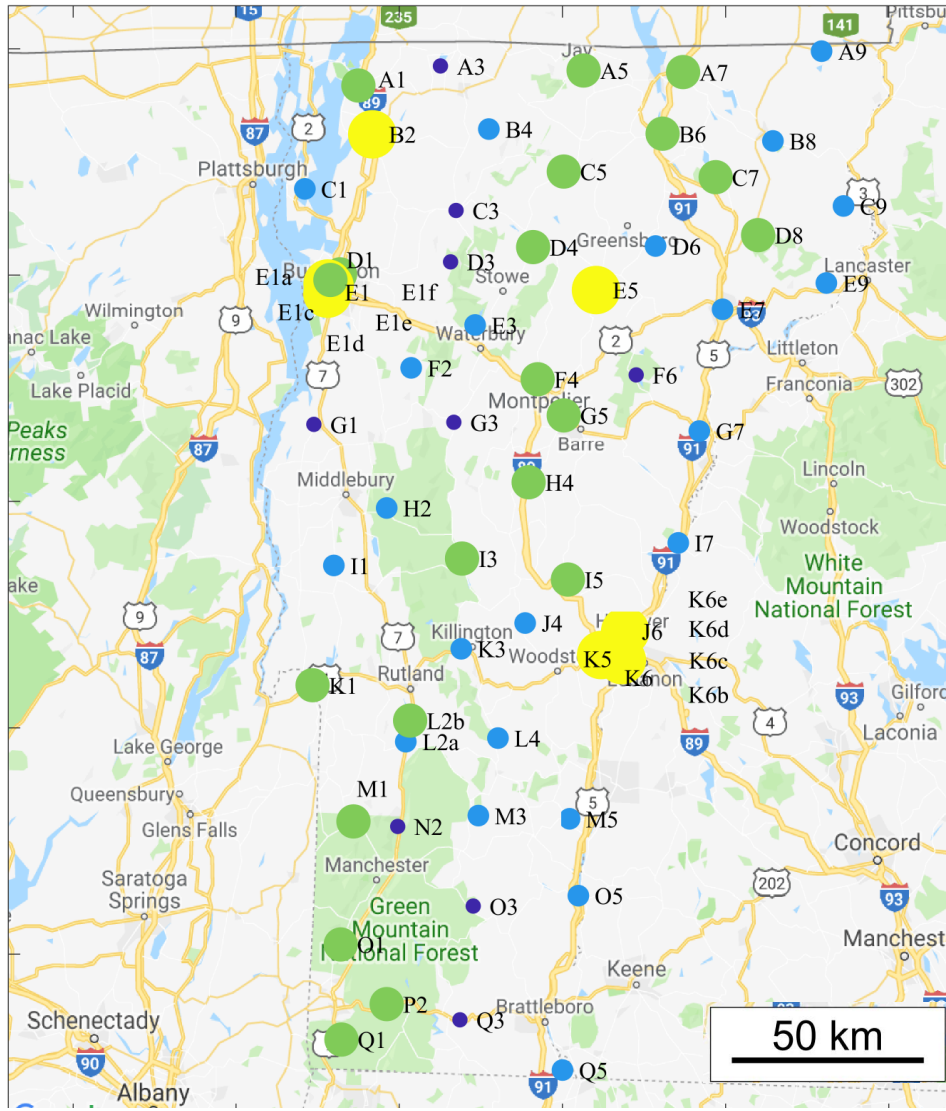
Depletion Model Check



Basic model assumptions include: 1st-order, USEPA RSL leaching; complete mixing, steady-state hydraulics; 0.5 meters of soil, 0.18 meters per year infiltration

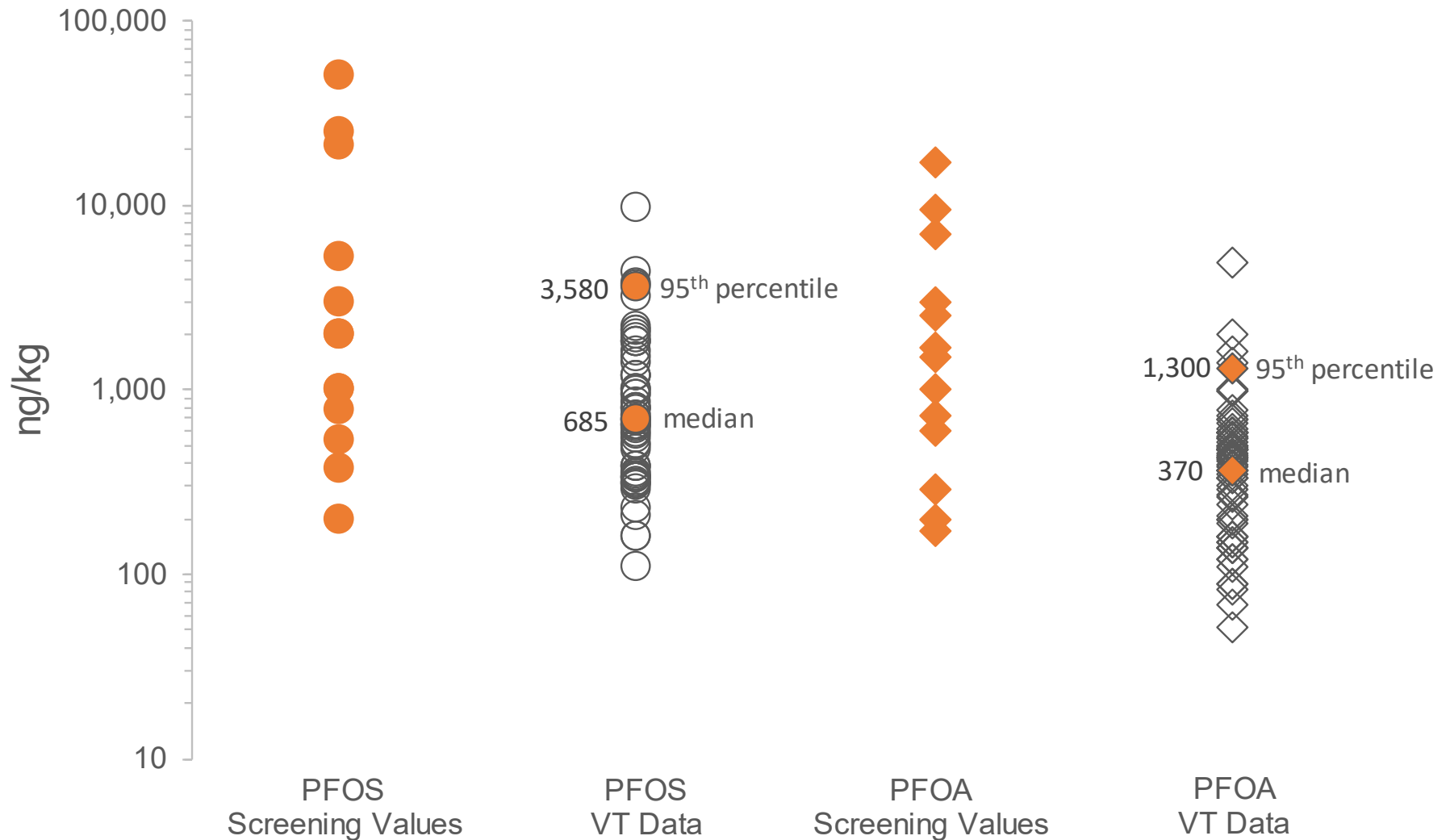
PFAS in Background Vermont Shallow Soils

- 66 locations, 0-6" depth
- Parks, grass areas, forests
- 13 PFCAs & 4 PFSA



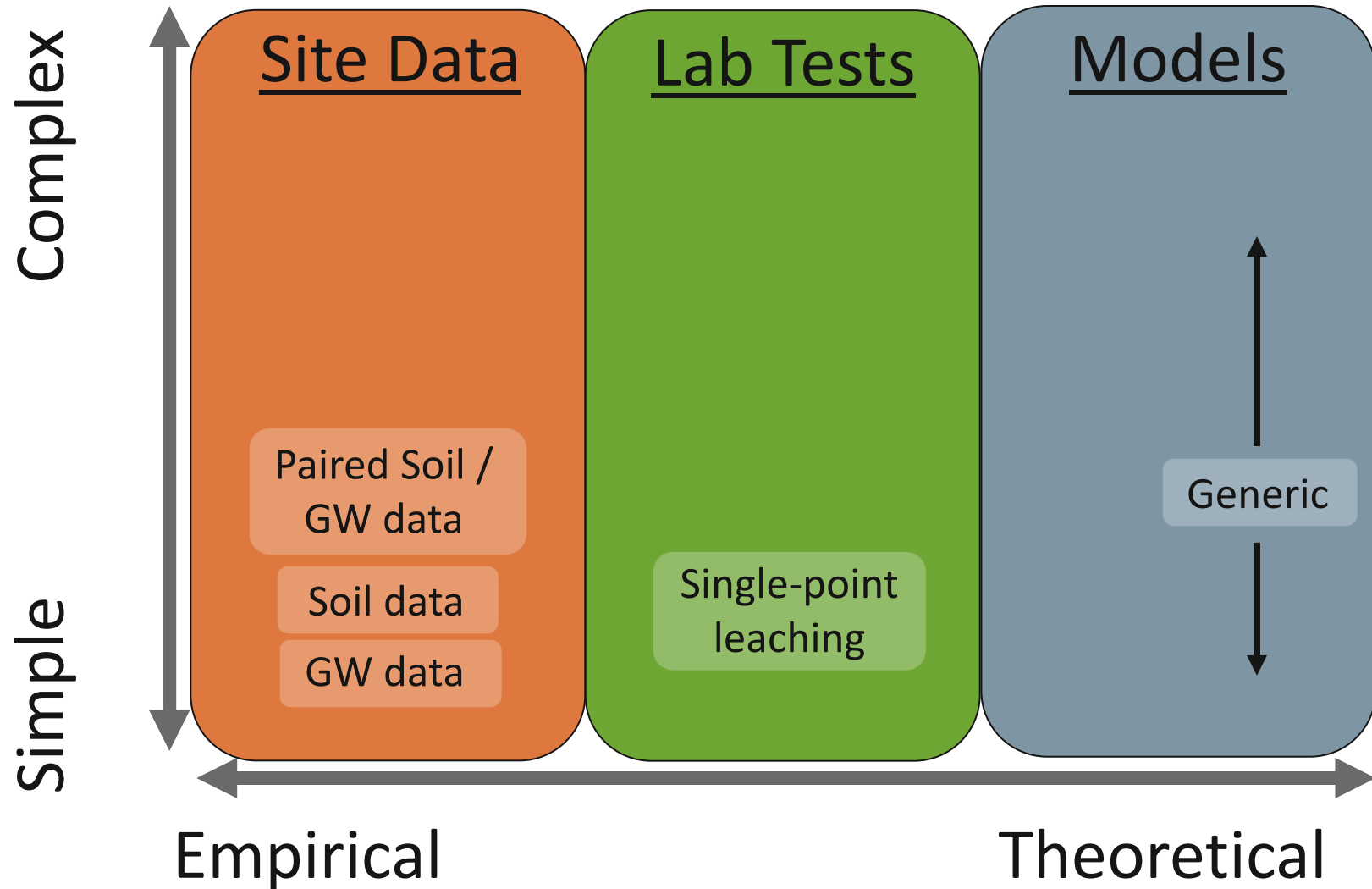
Source, University of Vermont and Sanborn Head:
<https://anrweb.vt.gov/PubDocs/DEC/PFOA/Soil-Background/PFAS-Background-Vermont-Shallow-Soils-03-24-19.pdf>

Soil Leaching Values & VT Background

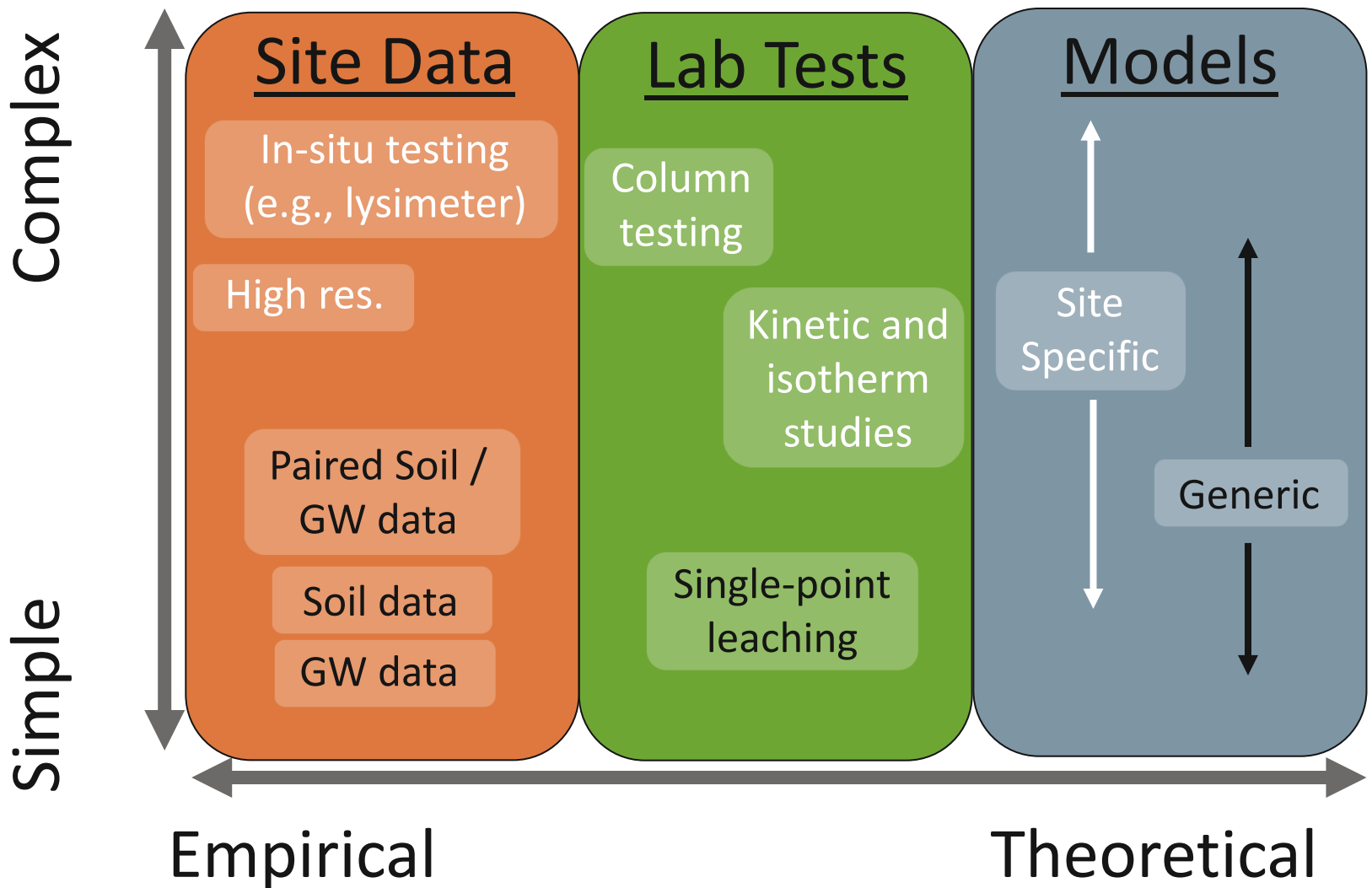


1. **The intent of this aggregate comparison is to contextualize the regulatory and guidance values. The individual data in this study were not collected for comparison to regulatory or guidance values and should not be used for that purpose.**
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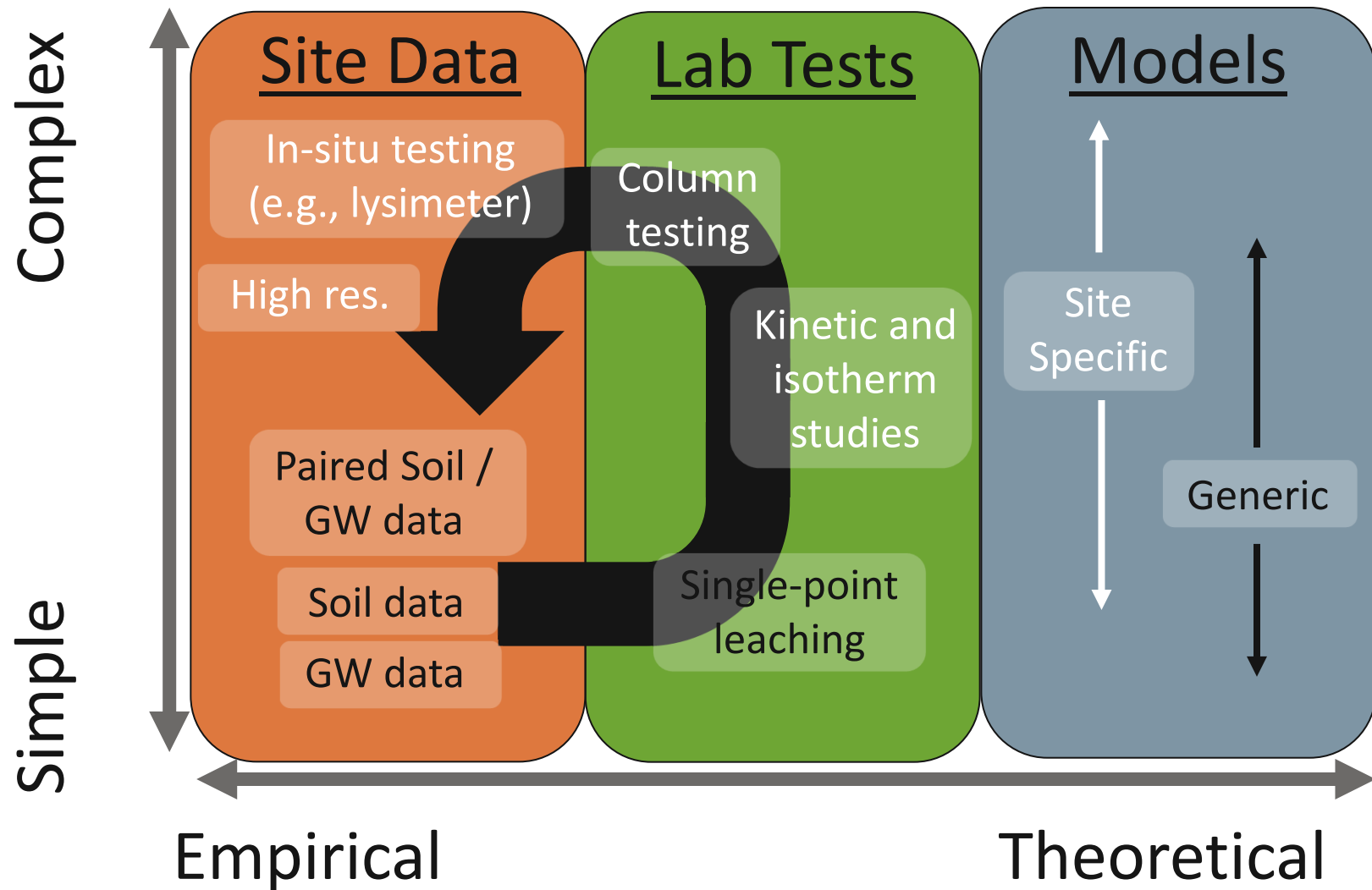
Common Tools Rely on Key Assumptions and Interpretation



Consider Empirical and Complex Tools

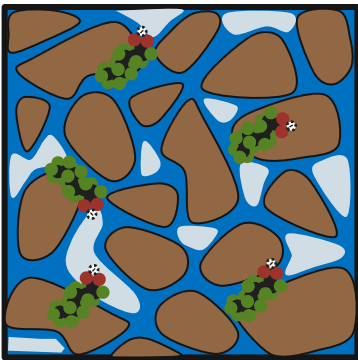


Build Multiple Lines of Evidence

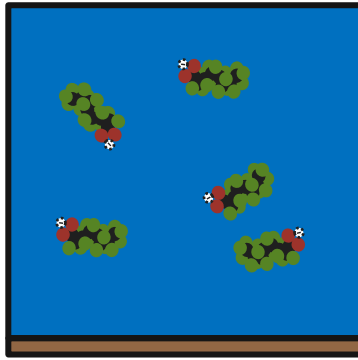


Soil Analysis Methods

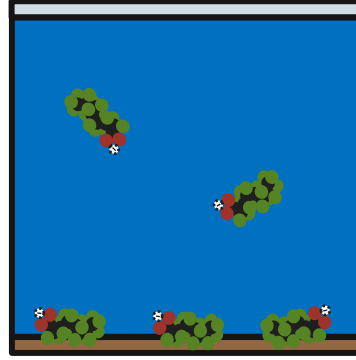
Soil
sample



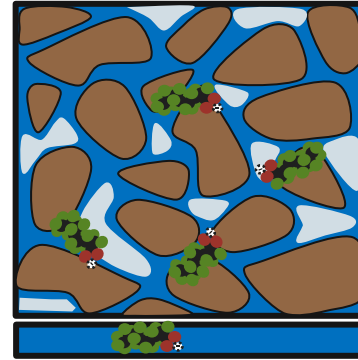
Solids
analysis



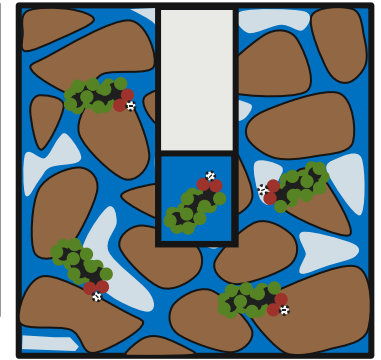
SPLP



Column
testing



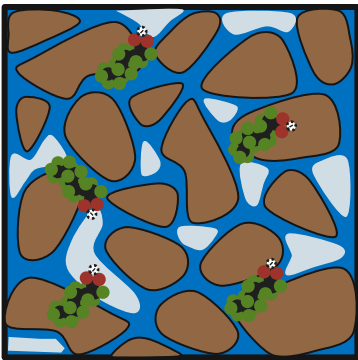
Lysimeter



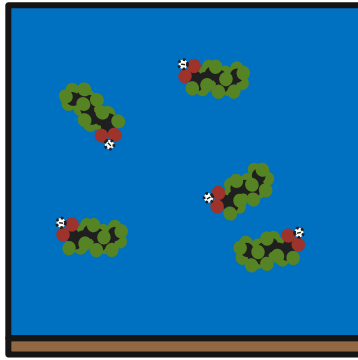
- Three phases:
Air,
Water,
Solids

Soil Analysis Methods

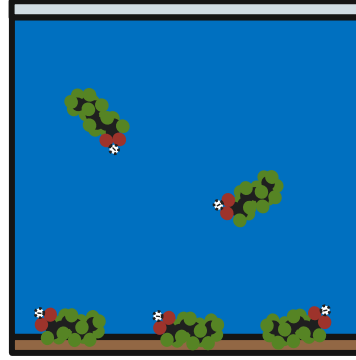
Soil sample



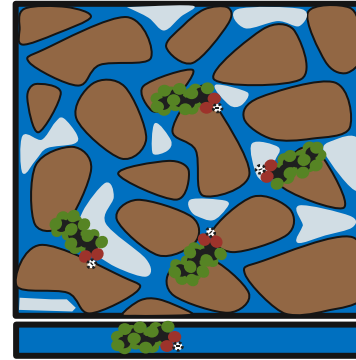
Solids analysis



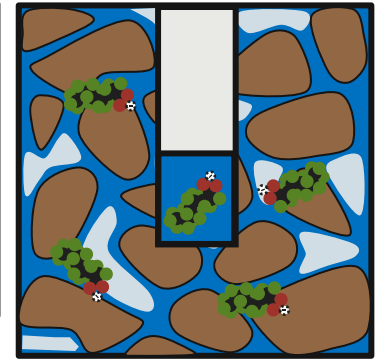
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Column testing



Lysimeter testing

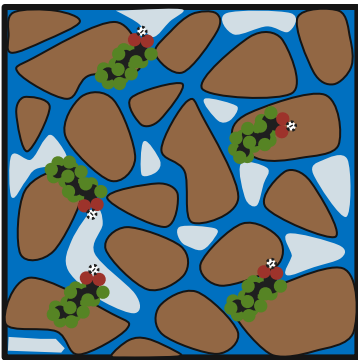


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- Solvent extraction
- High lab RLs

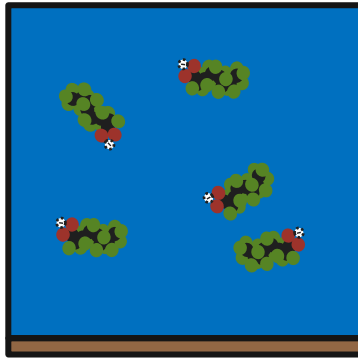
Soil Analysis Methods

Soil sample



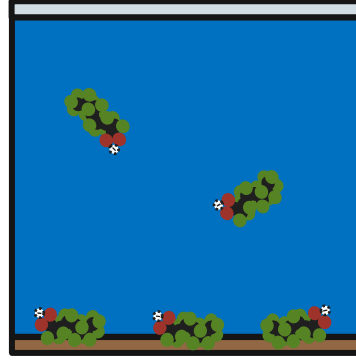
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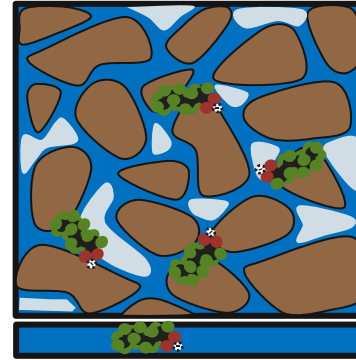
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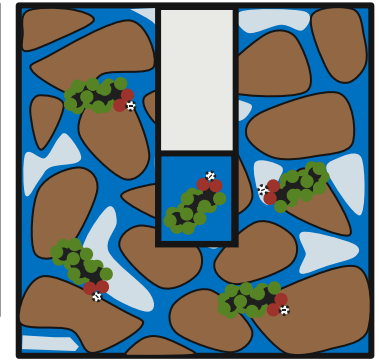


- Water extraction
- High liquid-solid ratio

Column testing

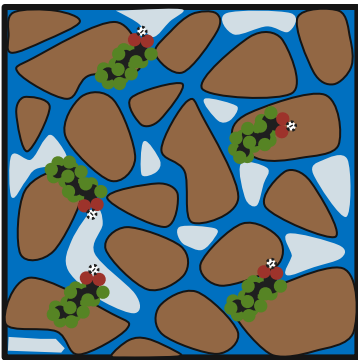


Lysimeter testing



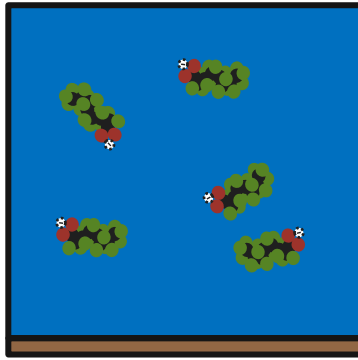
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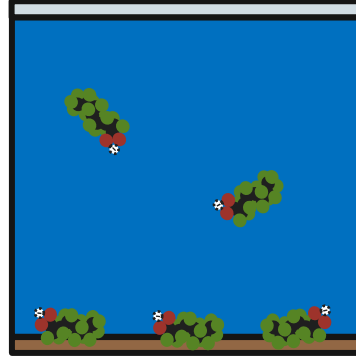
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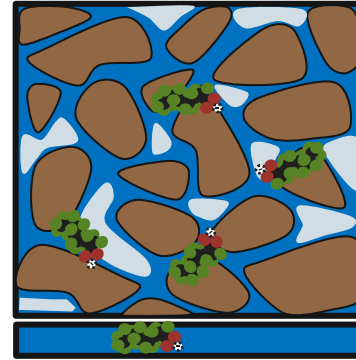
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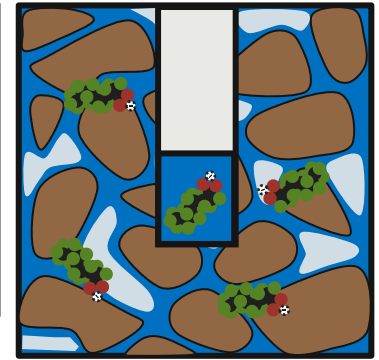
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Column testing



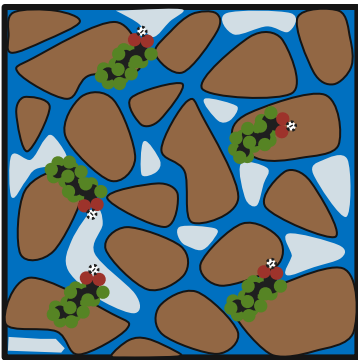
- May customize conditions
- Lower liquid-solid ratio

Lysimeter



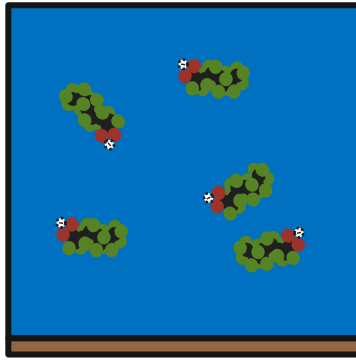
Soil Analysis Methods

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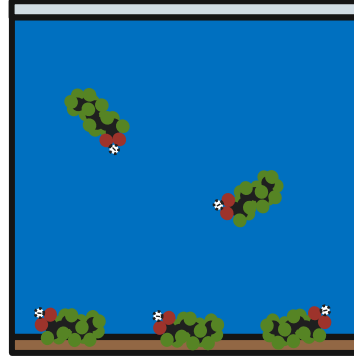
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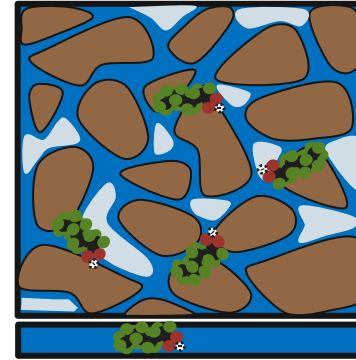
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SPLP



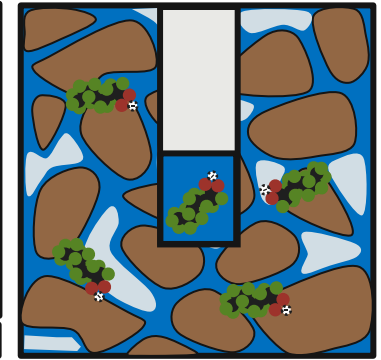
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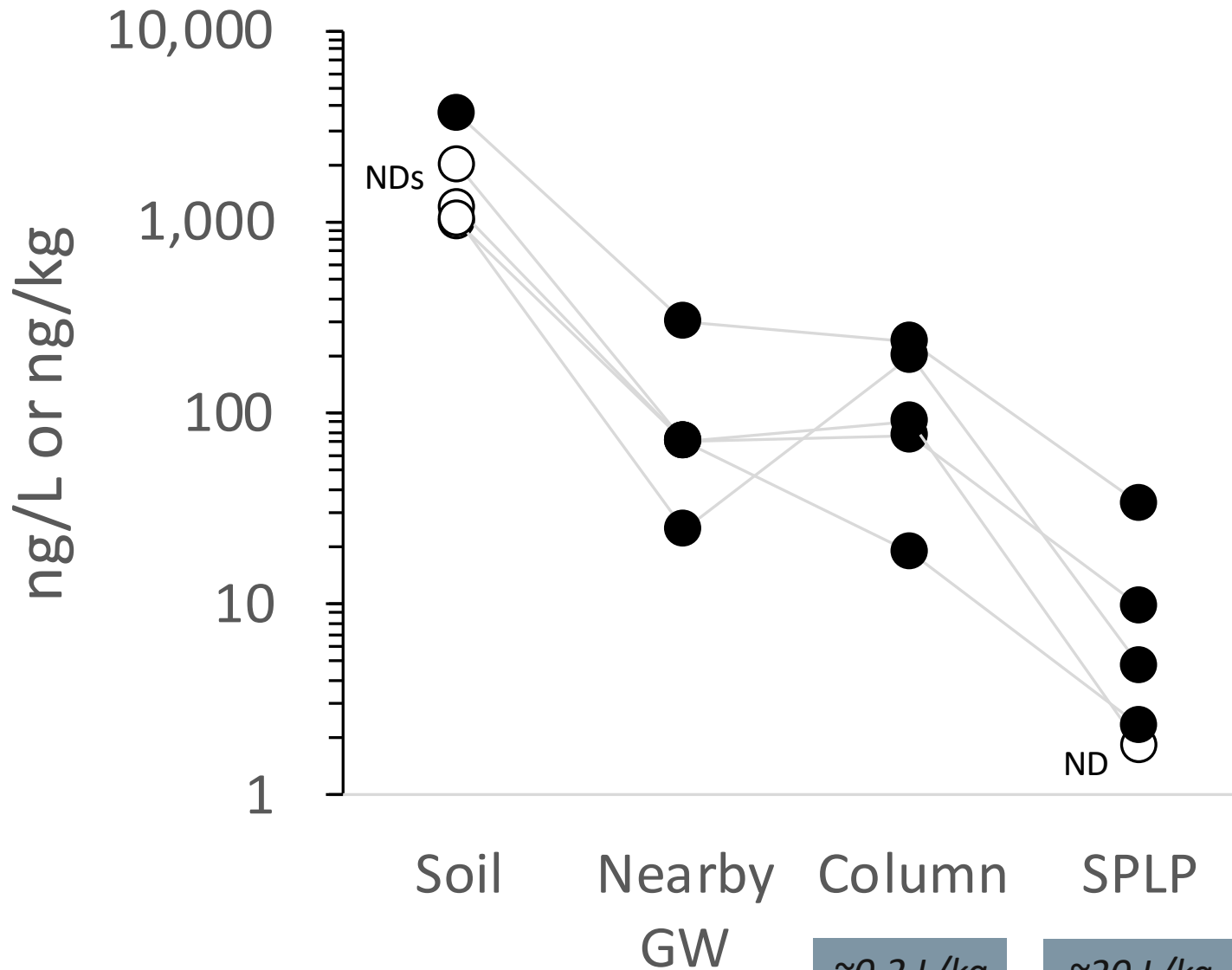
- May customize conditions
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Lysimeter testing



- Vadose zone liquids
- Near field conditions

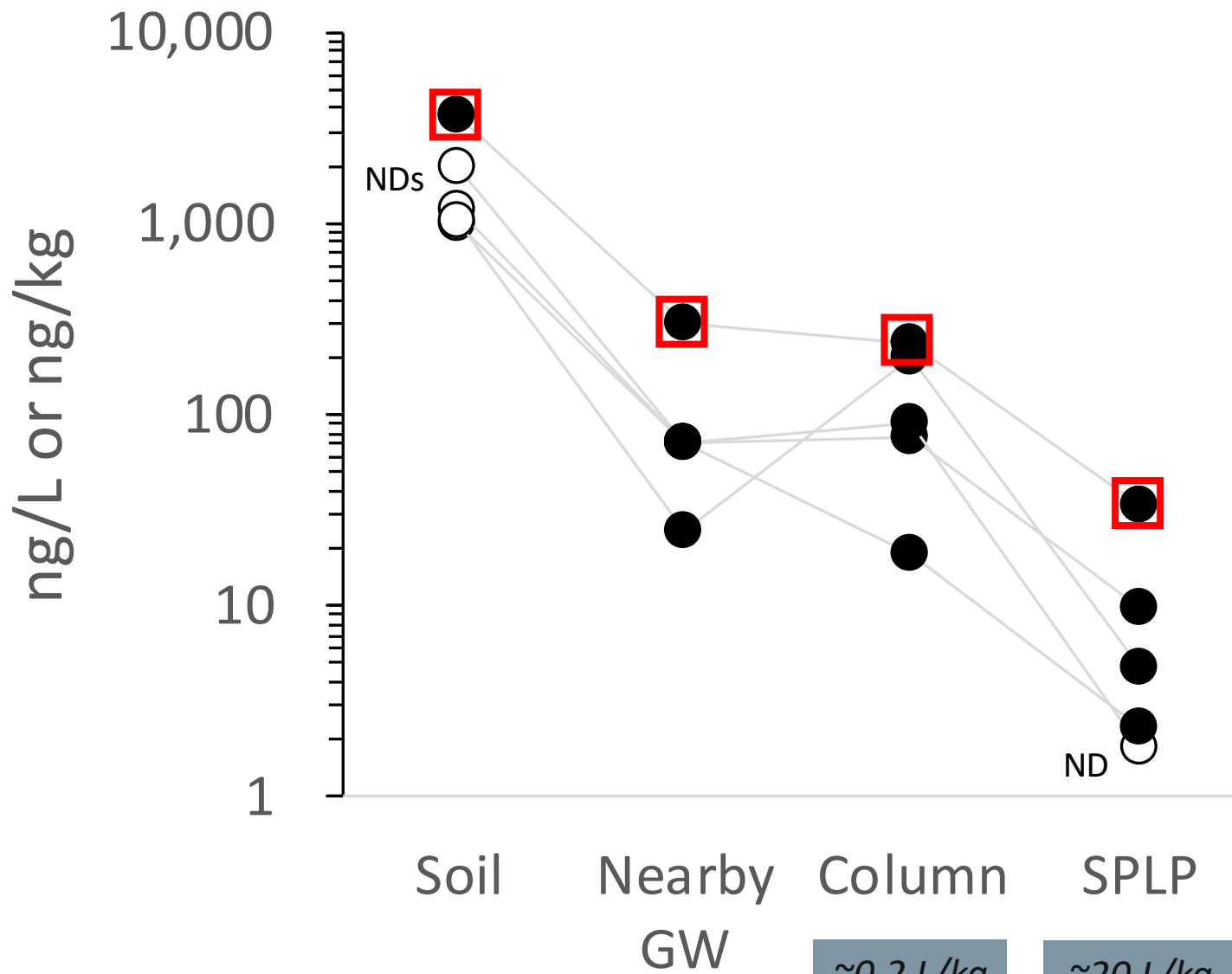
PFOA Atmospheric Deposition Case Study



Column testing and photographs by XDD Environmental, LLC.

~0.2 L/kg ~20 L/kg

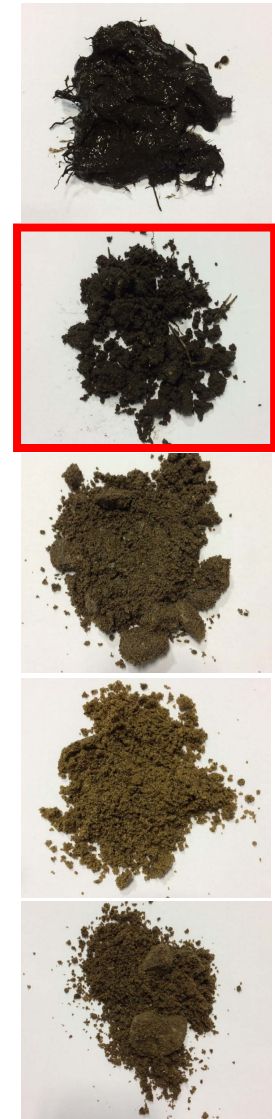
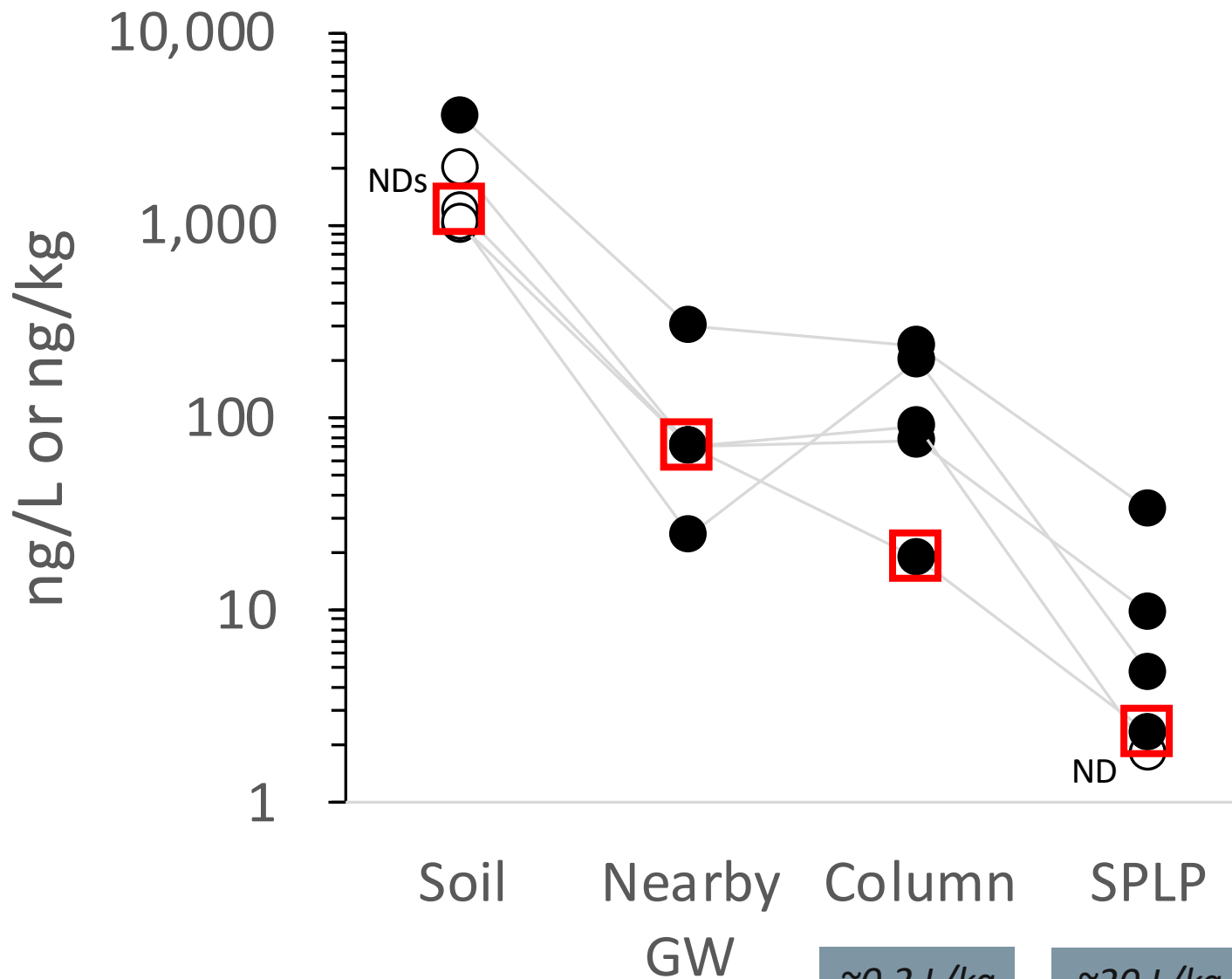
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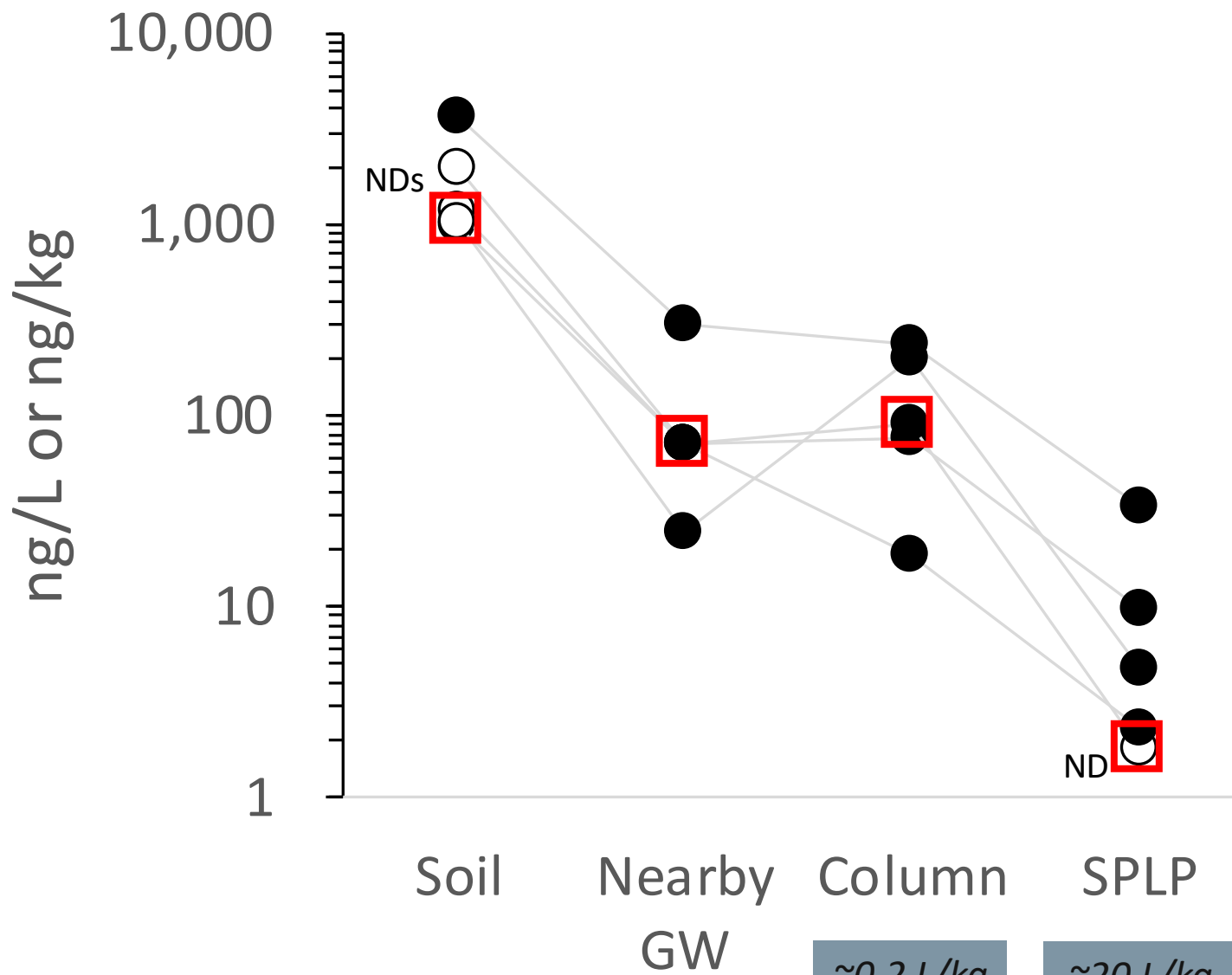
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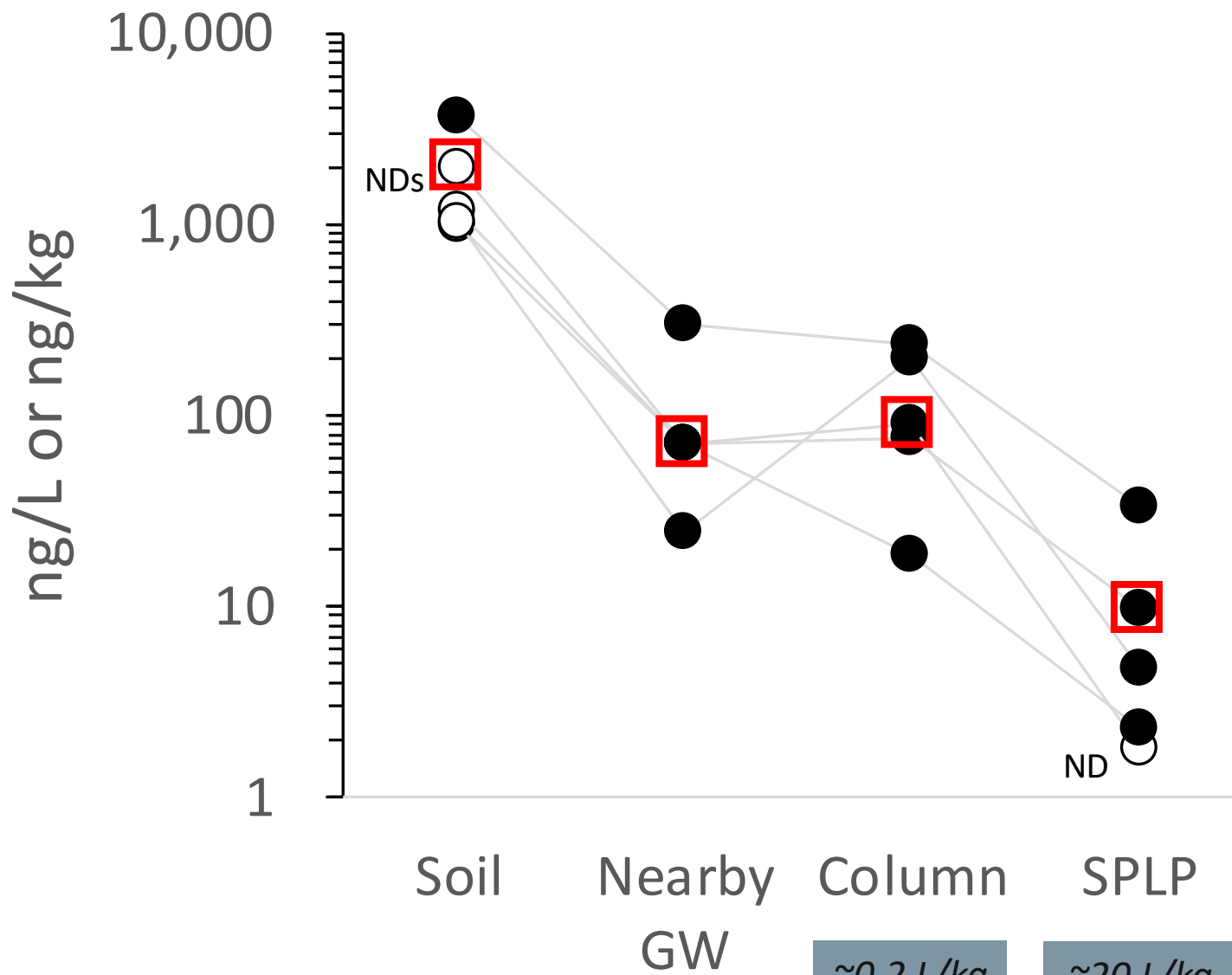
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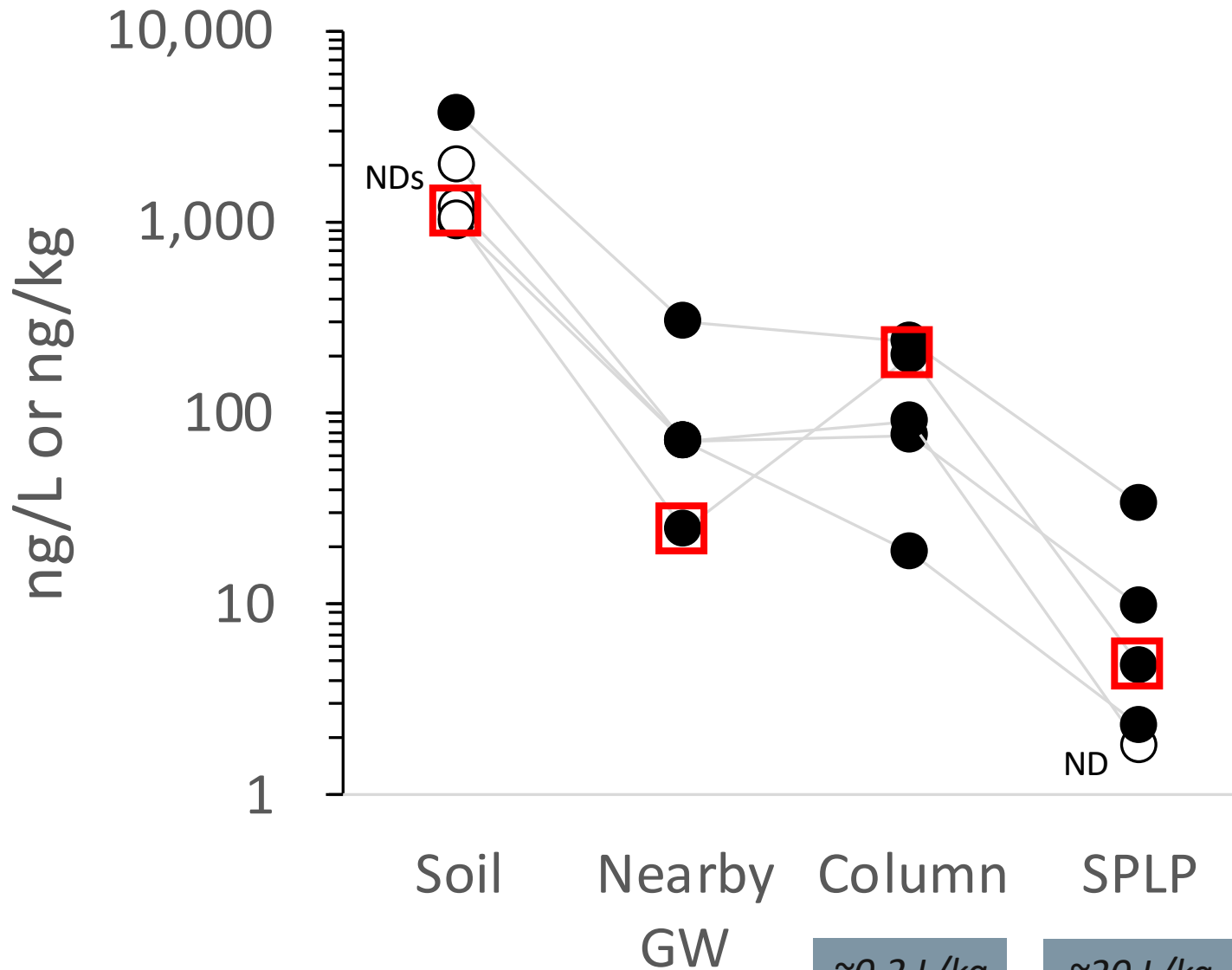


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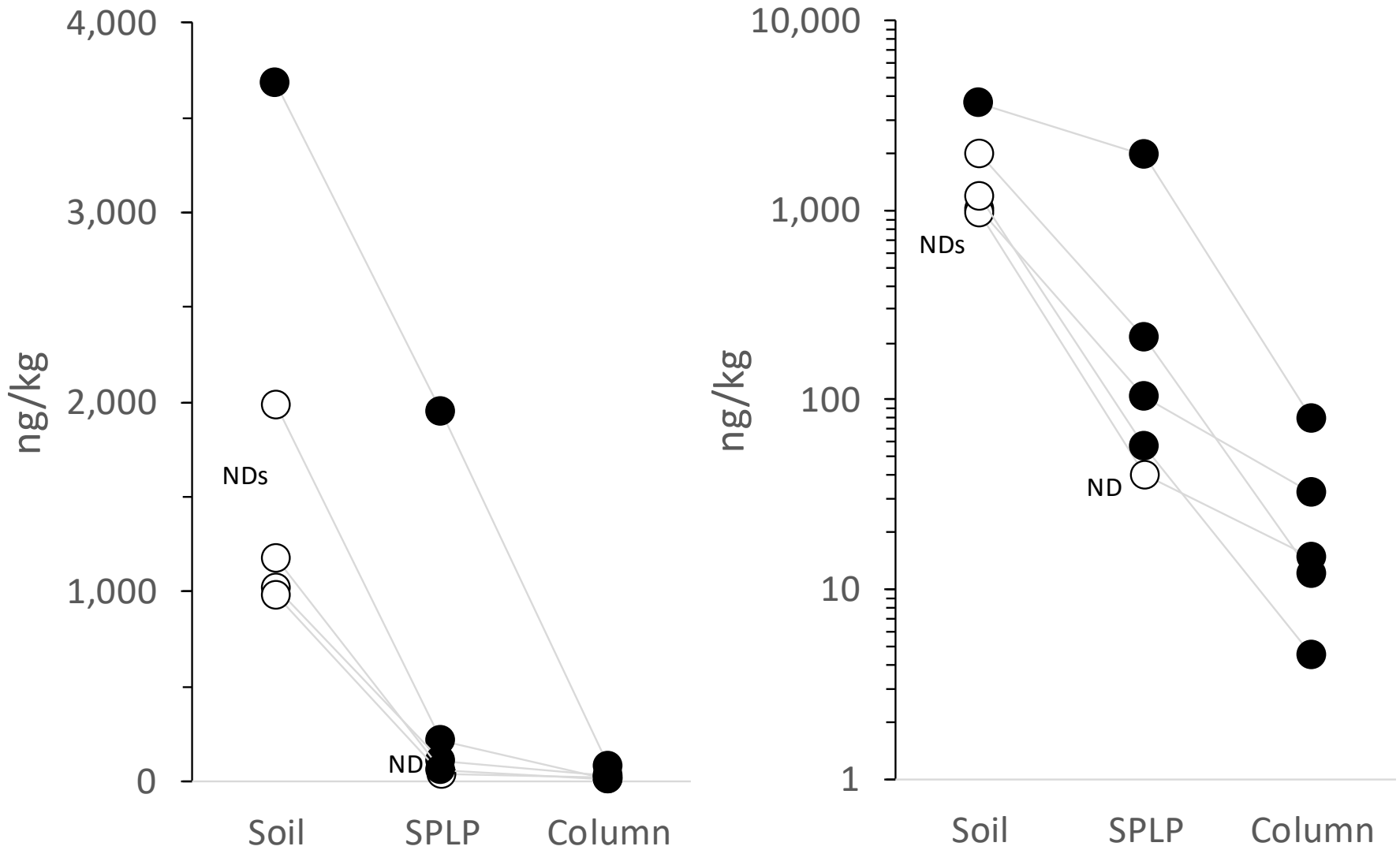


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Normalized to Soil Dry Weight



Summary

Leaching

- Wide-ranging field data
- Default models not built for PFOA/PFOS

Leaching-Based Screening Values

- Typically lower than direct contact-based values
- Variety of methods and large range of values

Anthropogenic Background

- PFOA and PFOS present in many background soils
- Lower leaching-based screening values at or below VT background
- Background leaching values not known

Screening Approaches

- Underlying assumptions for interpretation are important
- Consider more empirical and complex tools
- Multiple lines of evidence

Questions and Comments Appreciated!

Thank you to collaborators, including:

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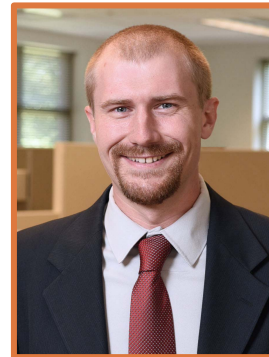
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