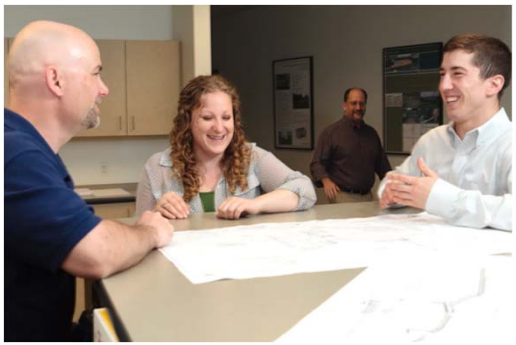
PFAS In Soil: Background Concentrations and Considerations for Leaching to Groundwater

Harrison Roakes, P.E.

April 5, 2022

The Science of PFAS Conference, Marlborough, MA



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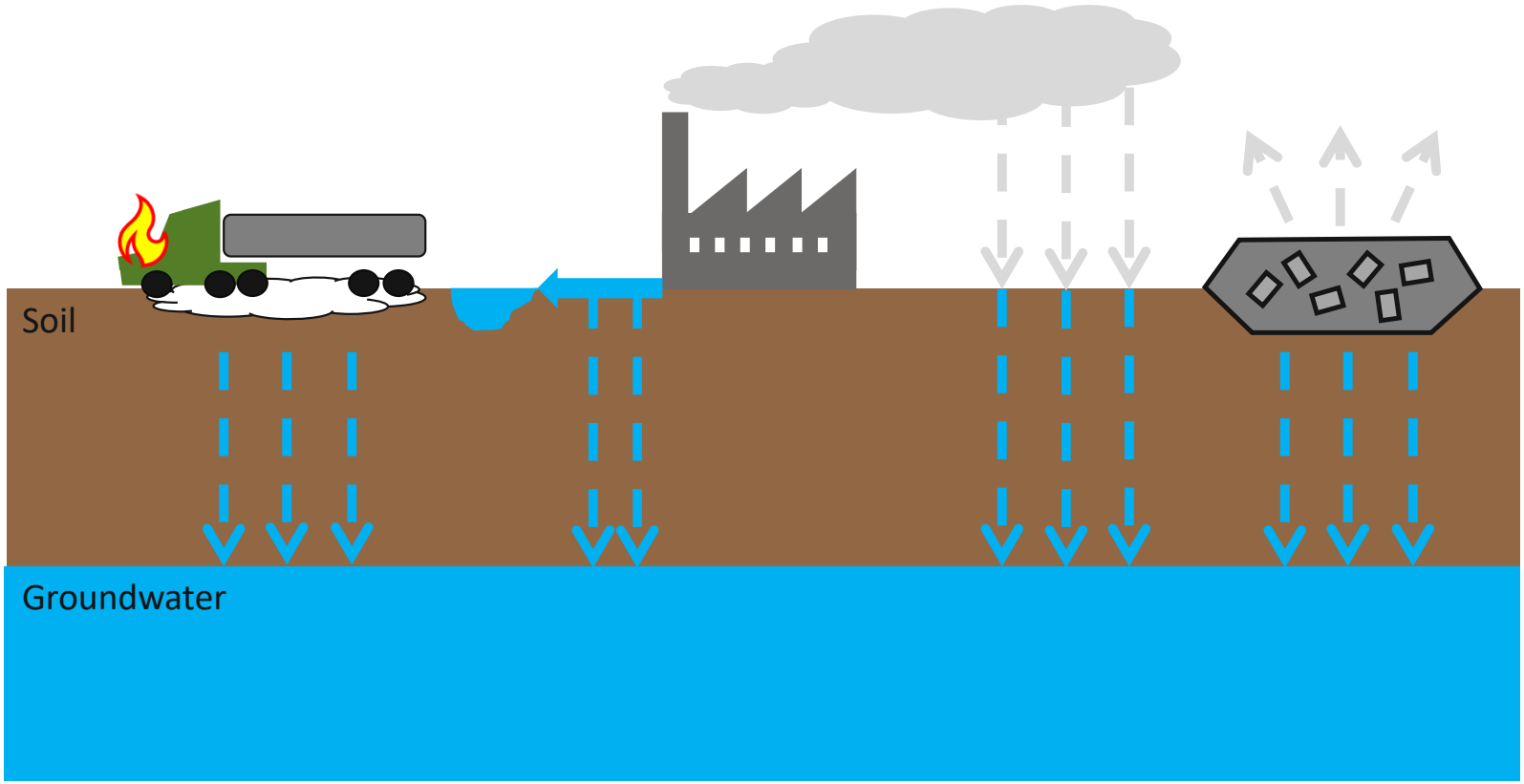
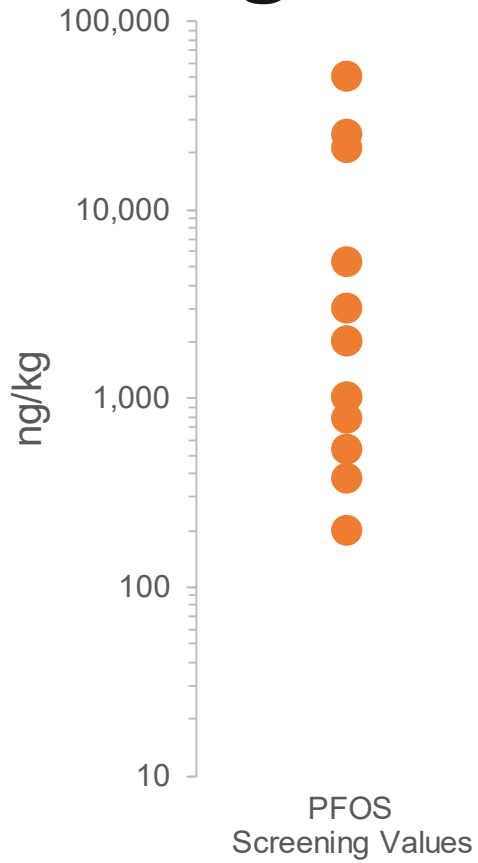
Soil is a key media for many releases



Soil Leaching Values



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.***
2. "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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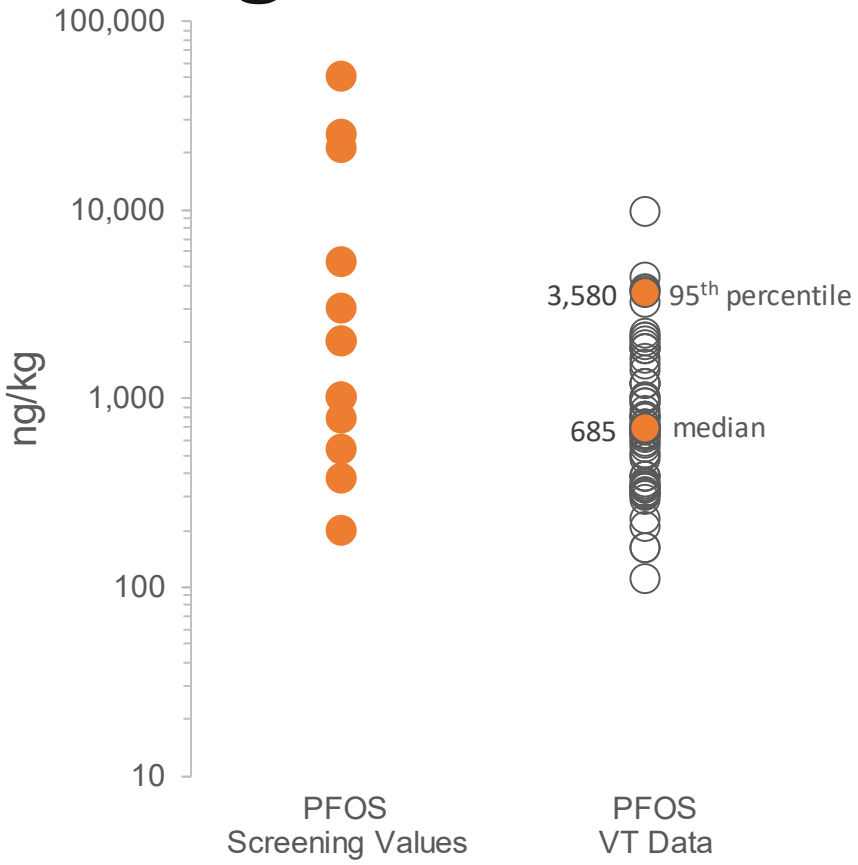
Soil Leaching Values & VT Background



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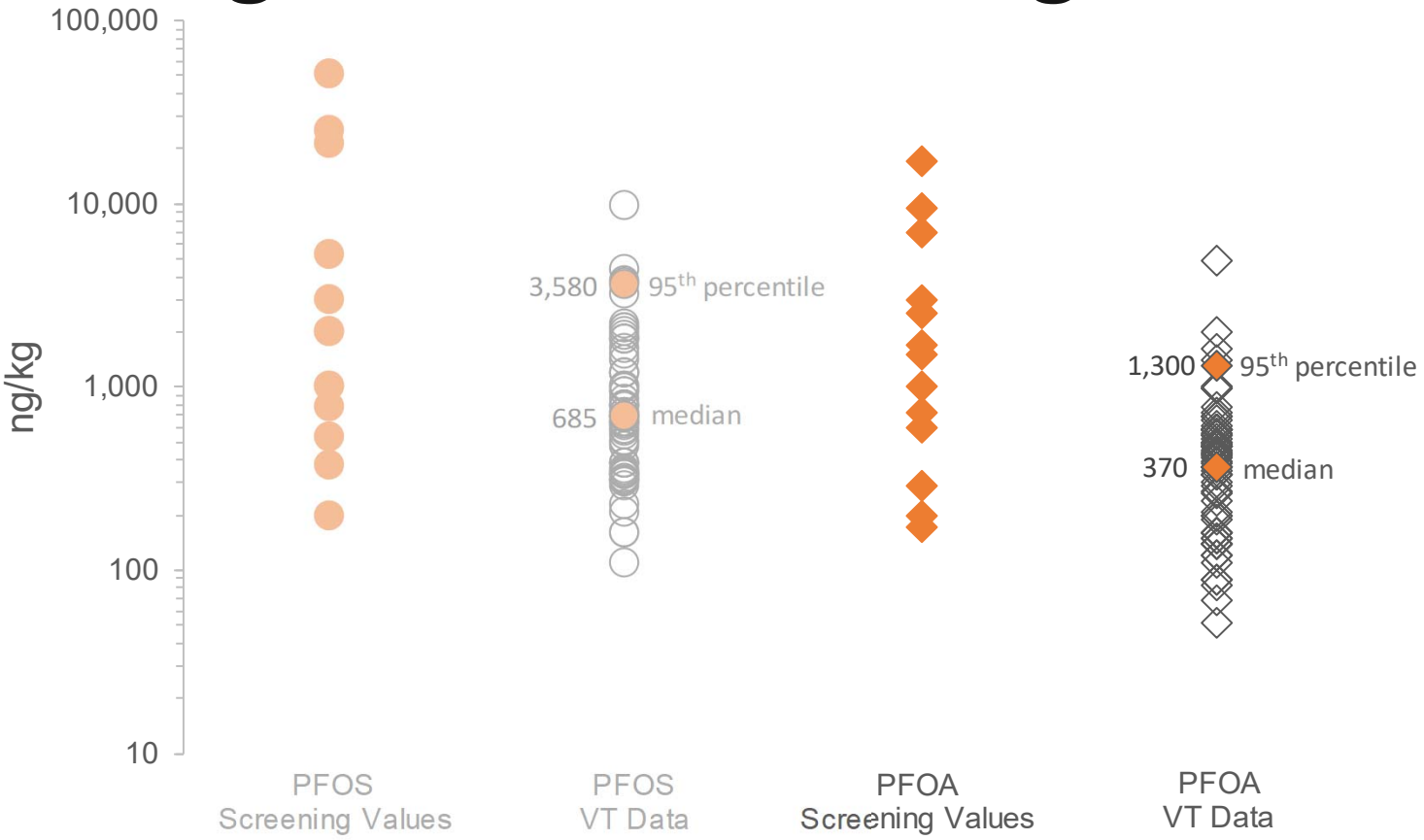

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Our Map

Screening value calculation

Soil-GW ratio

- Dilution/Attenuation Factor
- Partitioning

Background leaching model

X

Insights!

Looking ahead

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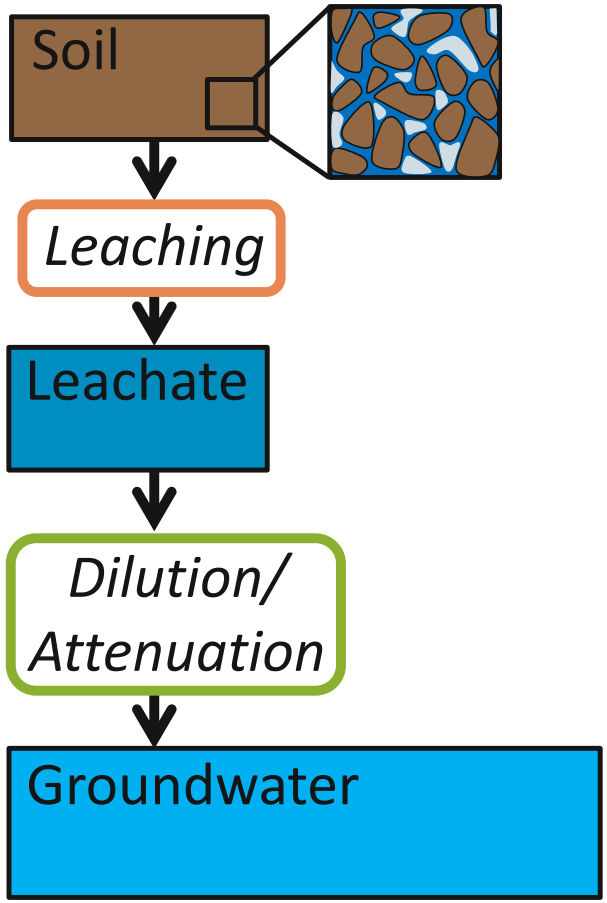
Soil Screening Value Calculation



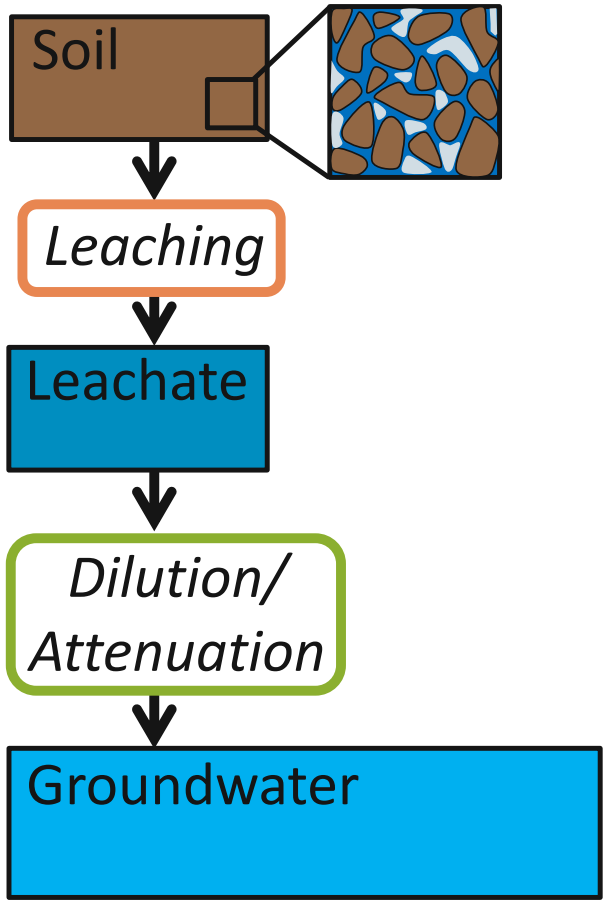
Soil Screening Value Calculation

Soil Screening Value

Partitioning

DAF

Target GW value



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Soil Screening Value

Soil-GW Ratio

Partitioning

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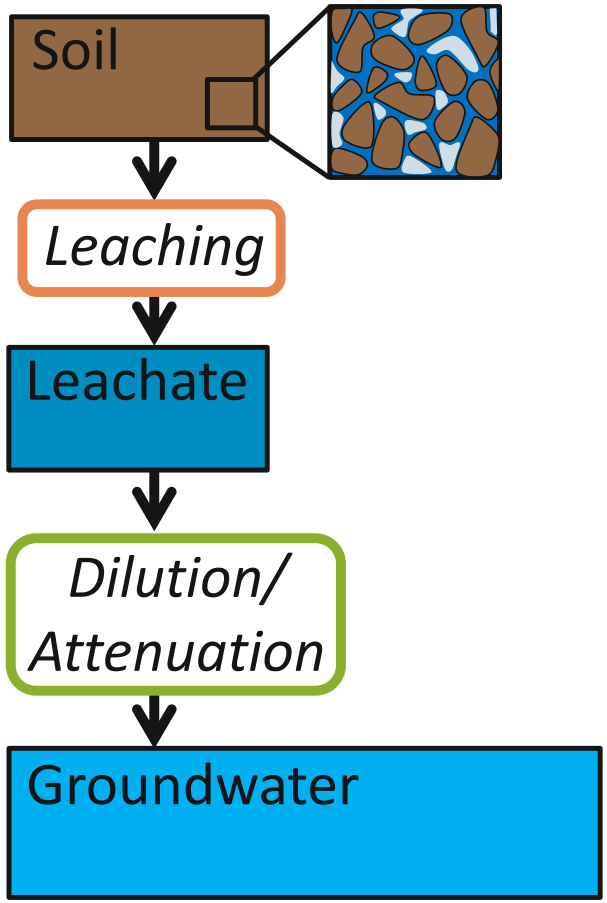
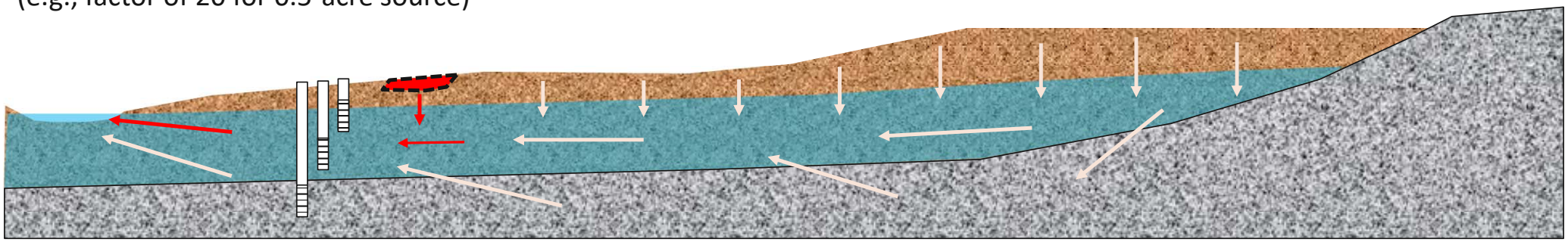


Dilution/Attenuation Factor

Smaller source area → higher DAF
(e.g., factor of 20 for 0.5-acre source)[1]



1. Soil Screening Guidance Technical Background Document, Part 2: Development of Pathway-Specific Soil Screening Levels, USEPA, https://semspub.epa.gov/work/HQ/175232.pdf

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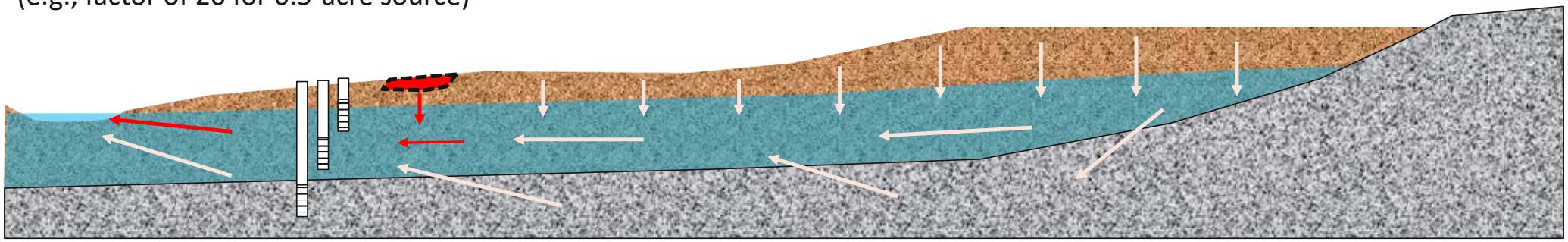
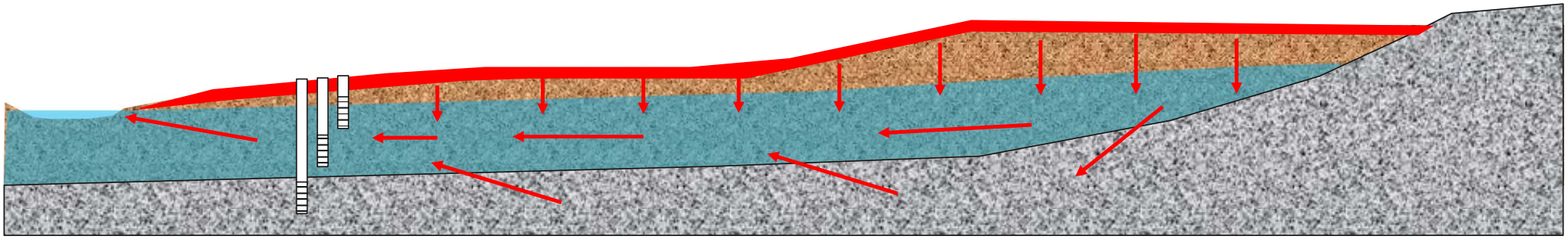


Larger source area → lower DAF
(e.g., factor of 10 for 30-acre source)[1]



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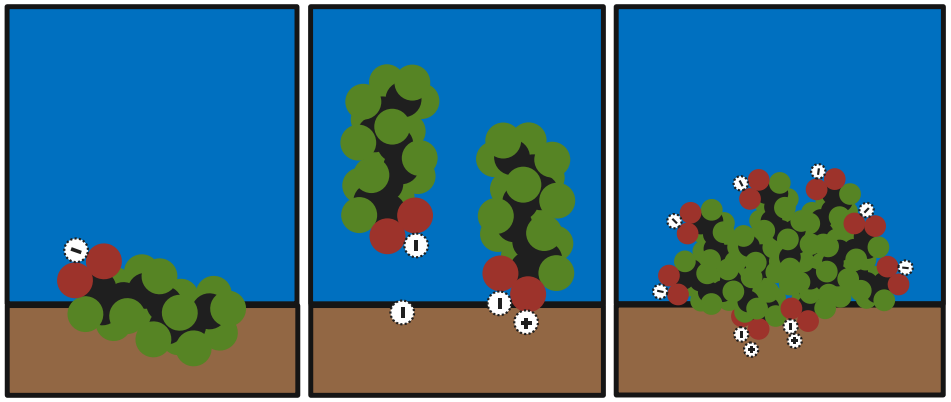
General Phase Partitioning

Simplified model

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

constant for known or assumed conditions

PFOA/PFOS Phase Partitioning



Hydrophobic sorption

Electrostatic interactions

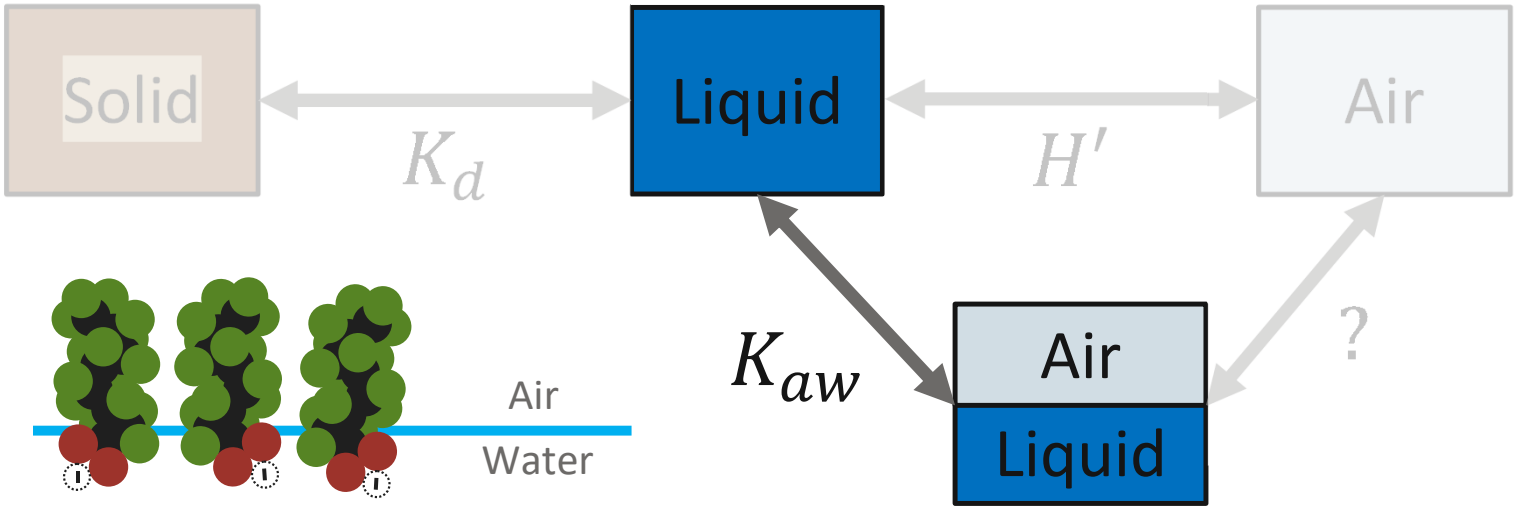
Surfactant behavior (at higher conc.)

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

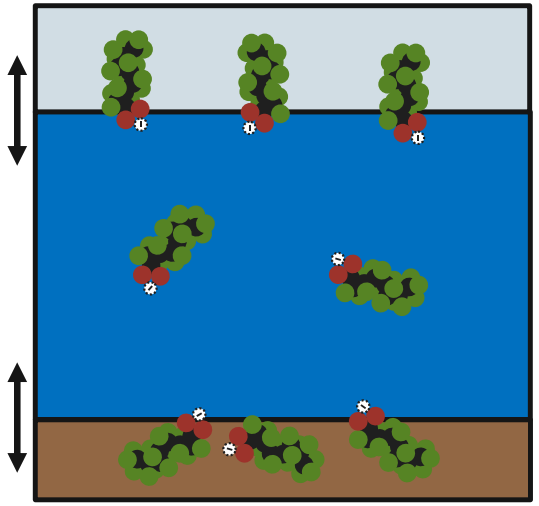
Dr. Linda Abriola SERDP/ESTCP air-water and NAPL-water interface partitioning presentation: https://www.youtube.com/user/SERDPESTCP

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 — *nonlinear*
- Previous conditions — *hysteresis*



Not to scale

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

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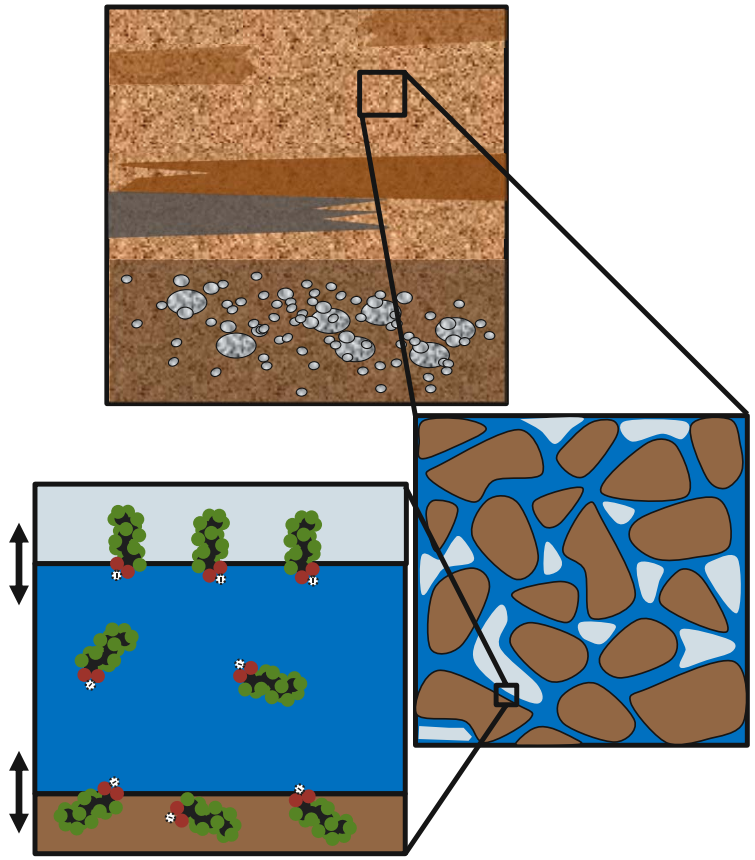
Field Phase Partitioning

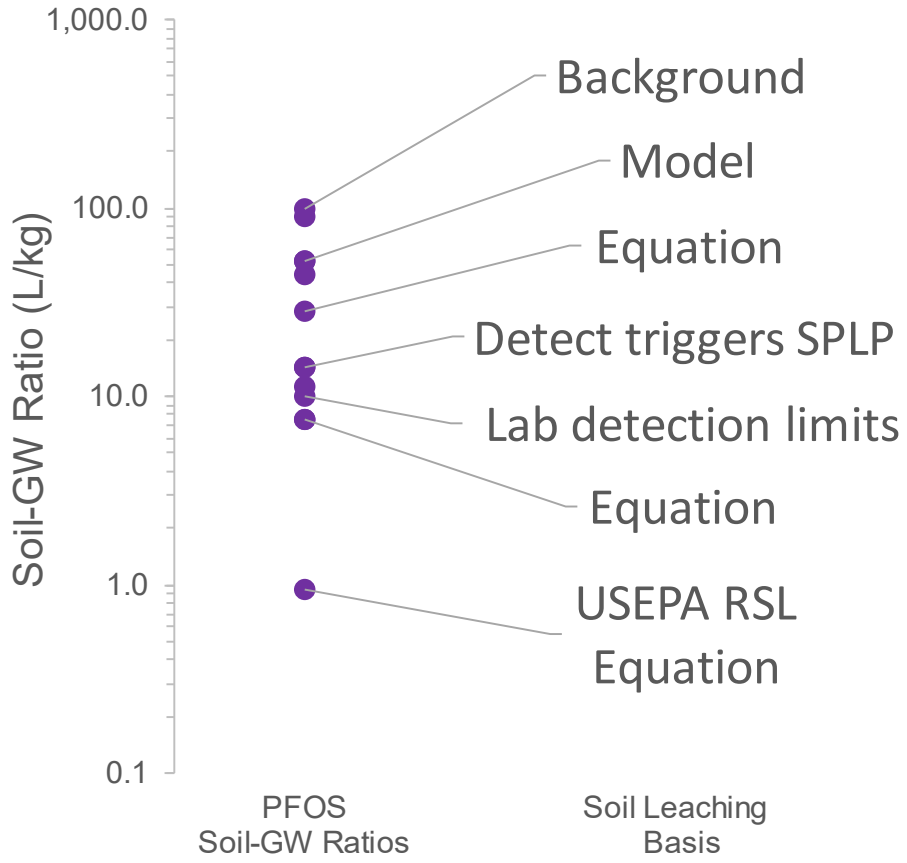
- Hydraulics
  - Microscale
  - Macroscale
- Kinetics/mass transfer

Field conditions:

- *Approach* equilibrium
- Heterogeneous
- Cannot replicate in a lab
- Disturbed by sampling



PFOS Implied Soil-GW Ratios



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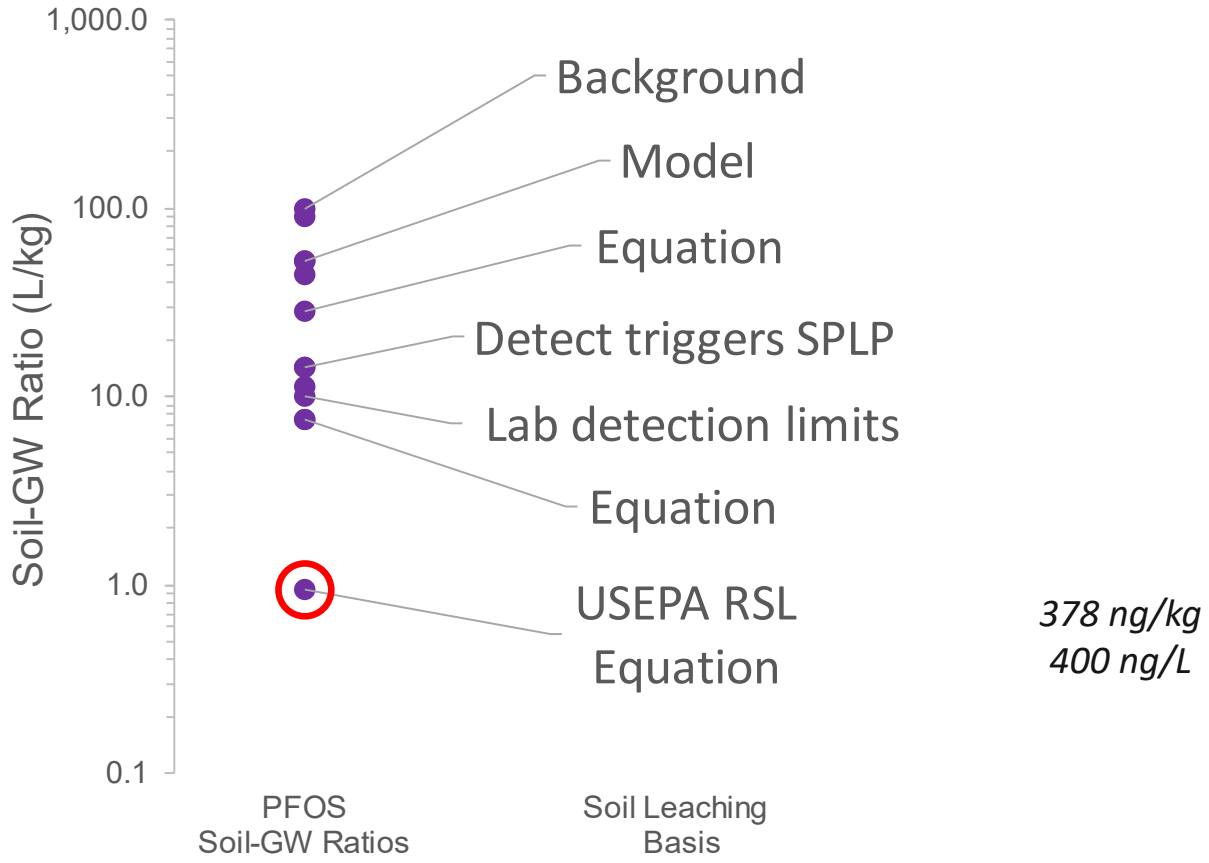

378 ng/kg
400 ng/L

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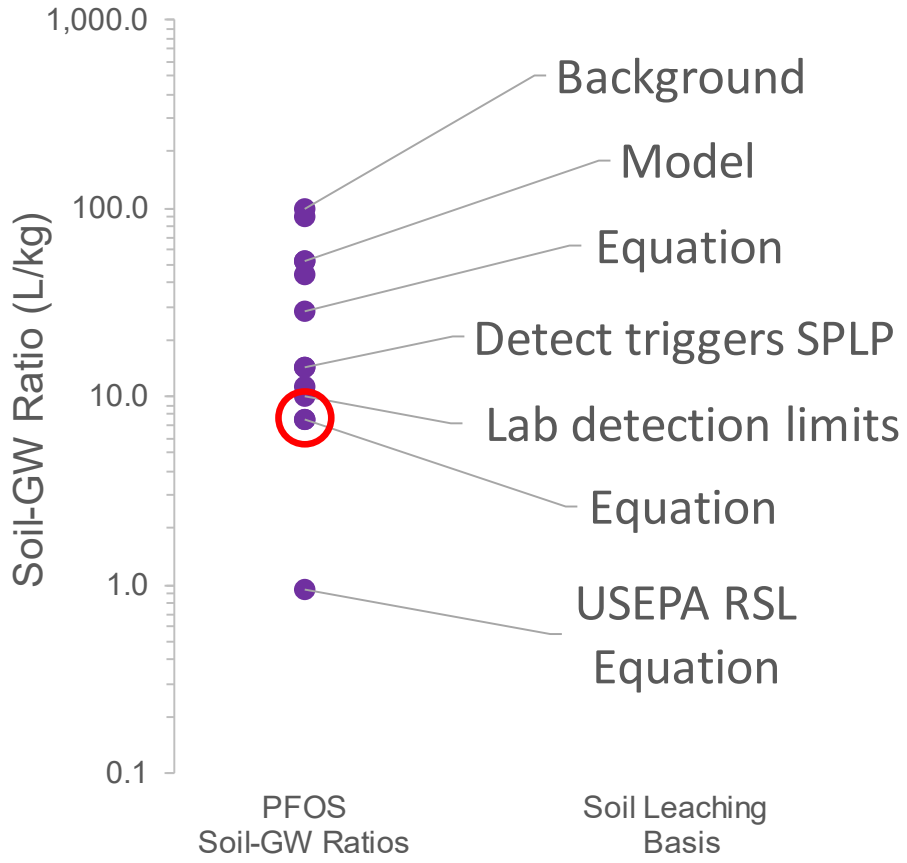

530 ng/kg
70 ng/L

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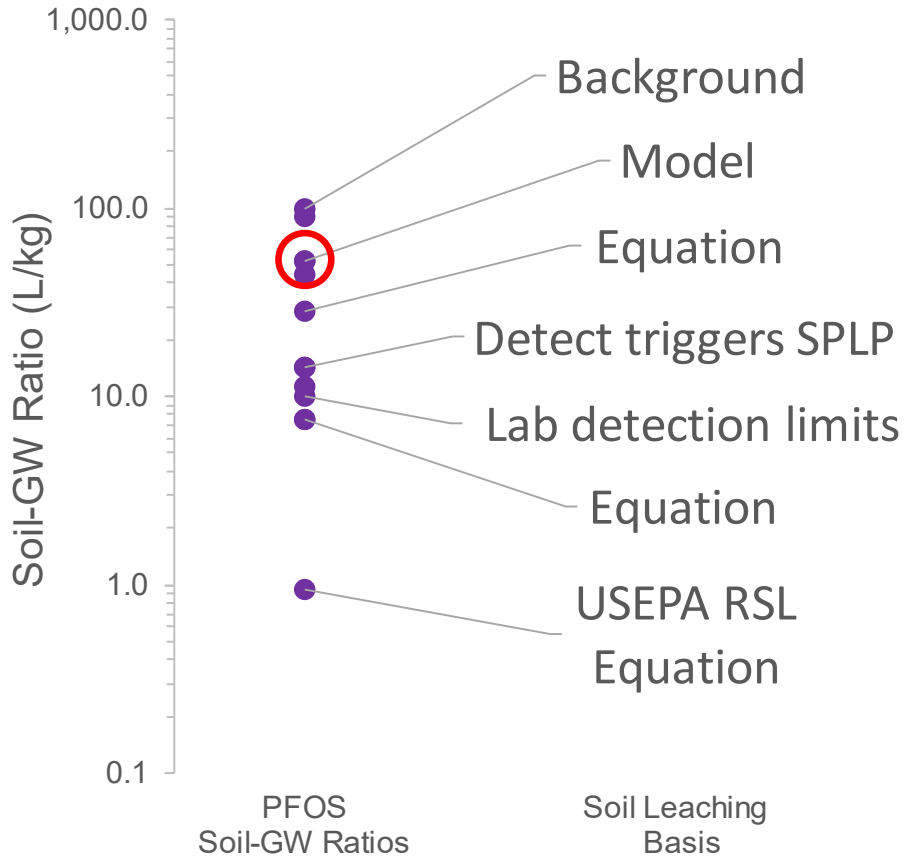

5,200 ng/kg
100 ng/L
SESOIL + AT123D

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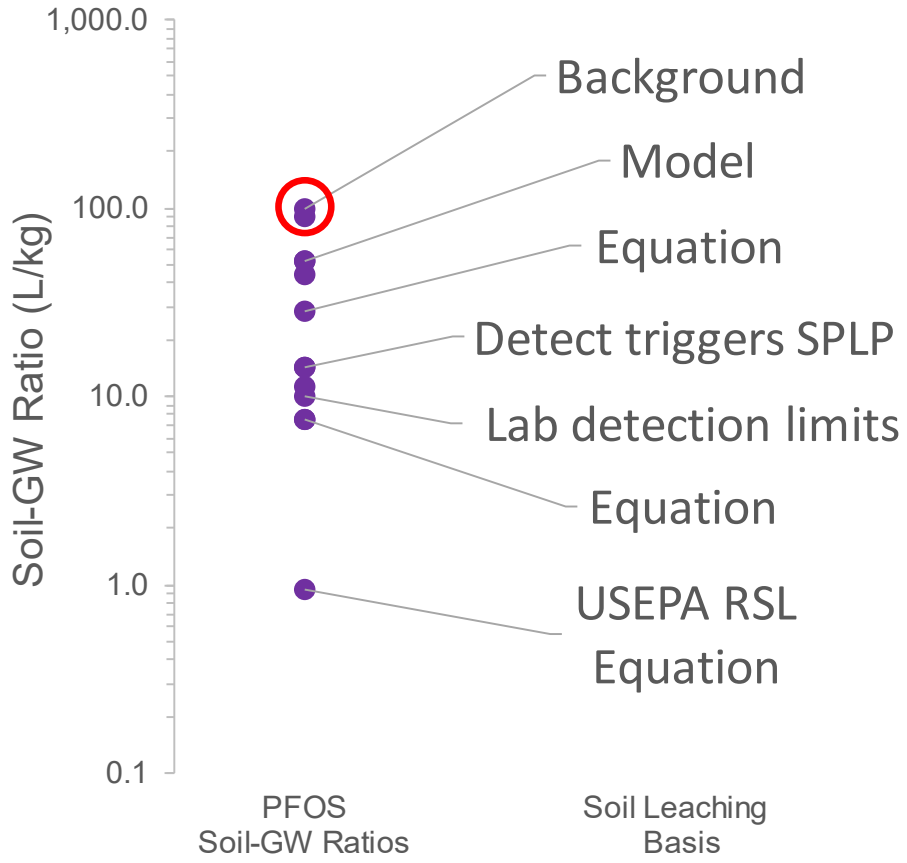

2,000 ng/kg
20 ng/L

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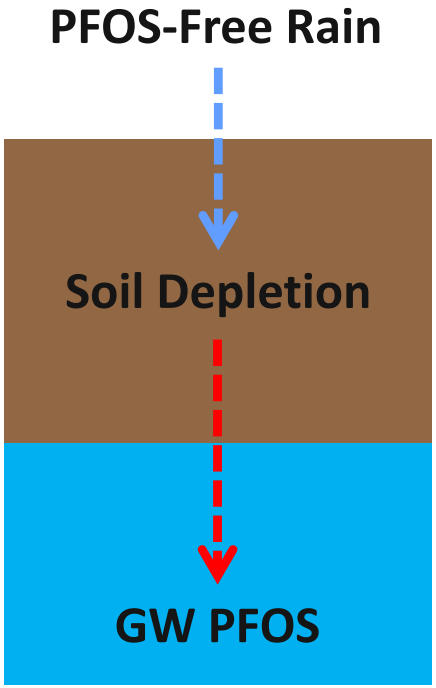
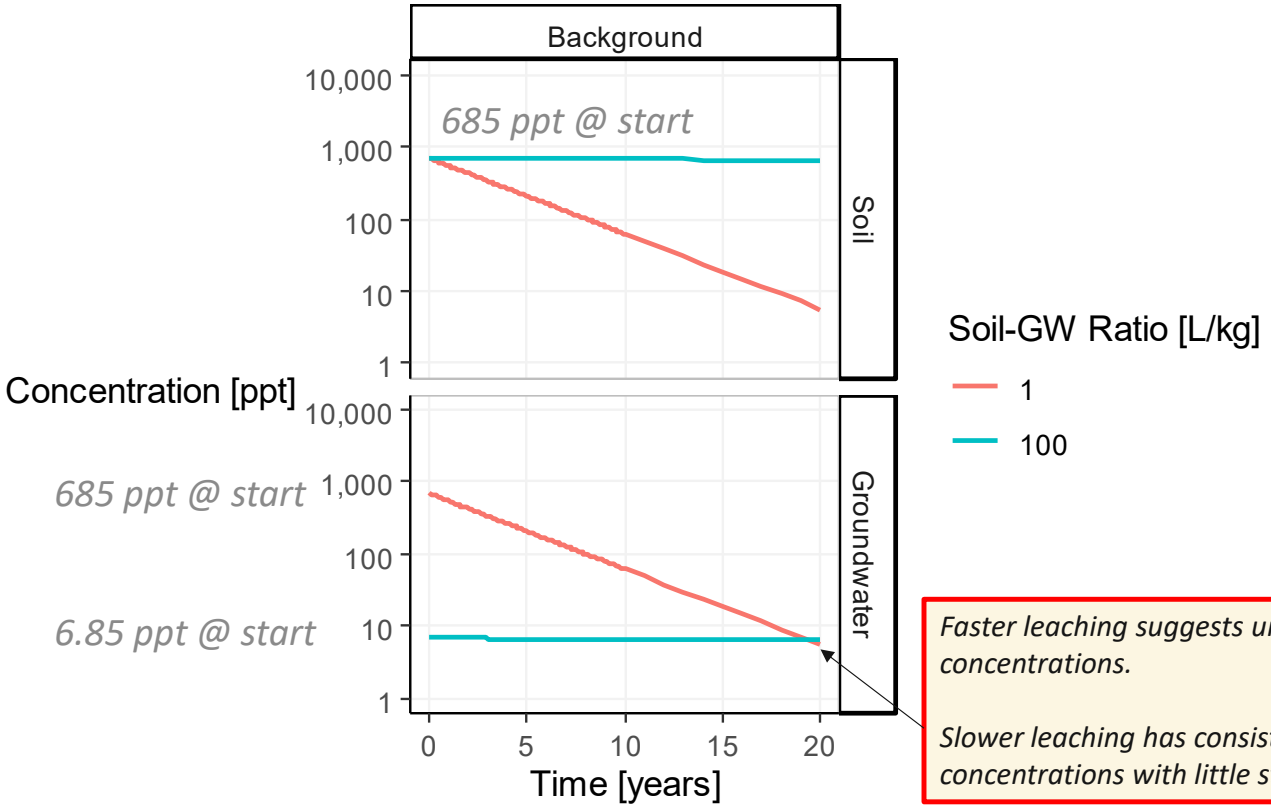
Background Depletion Model Assumptions



- 685 ppt PFOS
- 0.5 meters of soil, 0.18 meters per year infiltration
- Complete mixing and steady-state hydraulics
- No dilution-attenuation
- Soil-groundwater ratio
  - 1 L/kg for faster leaching, or
  - 100 L/kg for slower leaching

Depletion Model



Basic model assumptions include: 1st-order leaching; complete mixing, steady-state hydraulics; 0.5 meters of soil, 0.18 meters per year infiltration; no dilution-attenuation.

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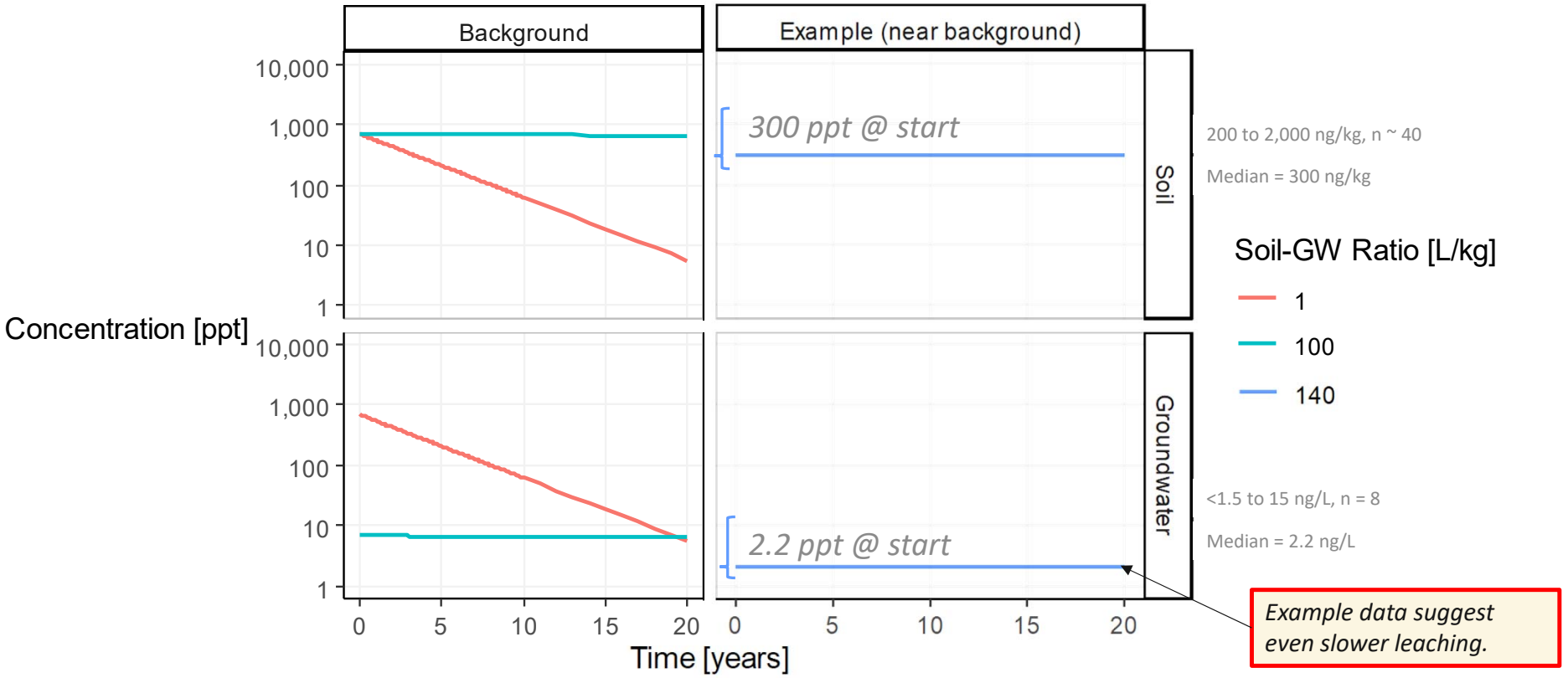
Example, Near-Background Site



Basic model assumptions include: 1st-order leaching; complete mixing, steady-state hydraulics; 0.5 meters of soil, 0.18 meters per year infiltration; no dilution-attenuation.

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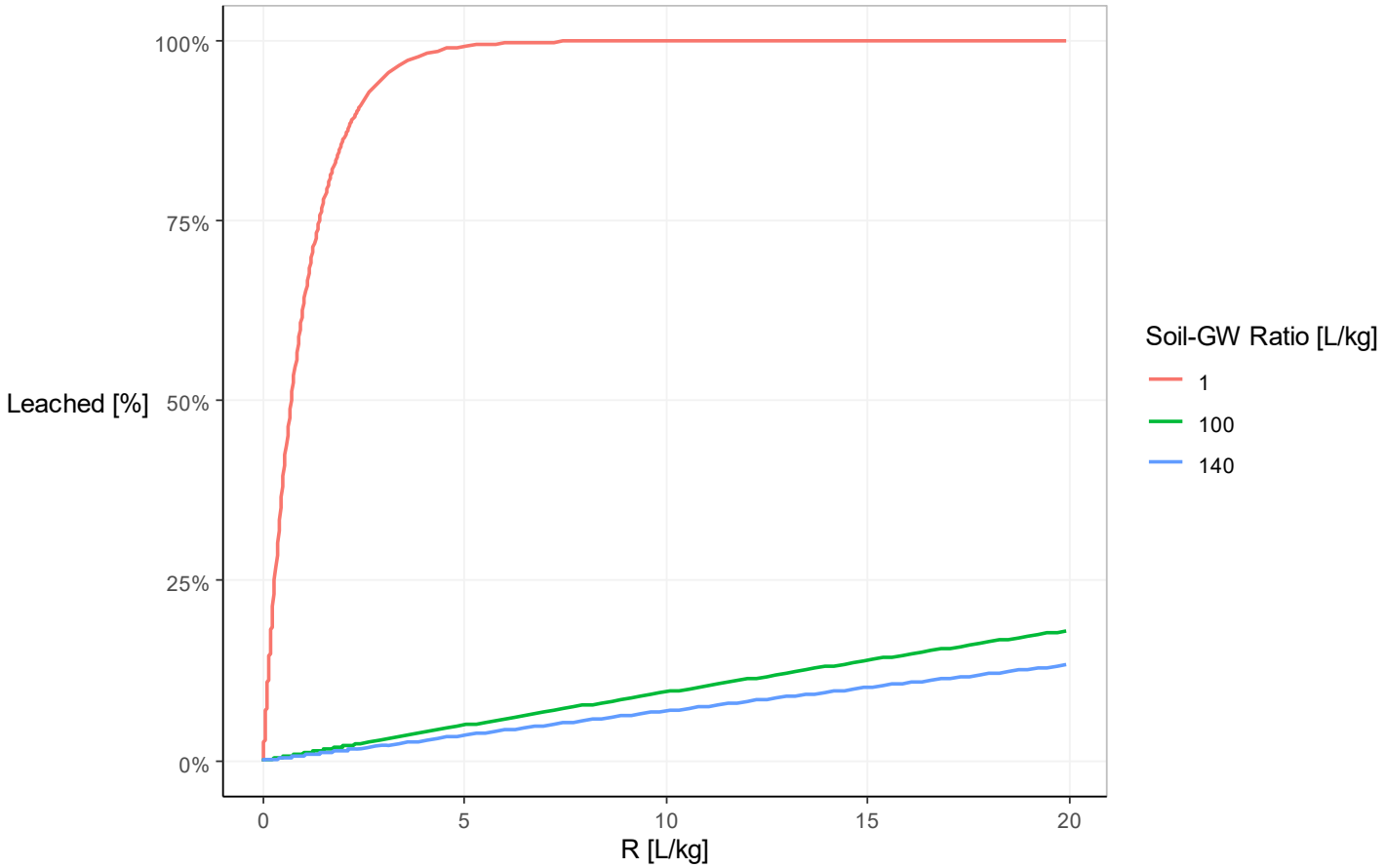
Same models, but transformed axes



Conversion factor from Time [years] to R [L/kg] is 0.24 L/kg per year. Each 5 L/kg is about 21 years, and the maximum 20 L/kg is about 83 years.

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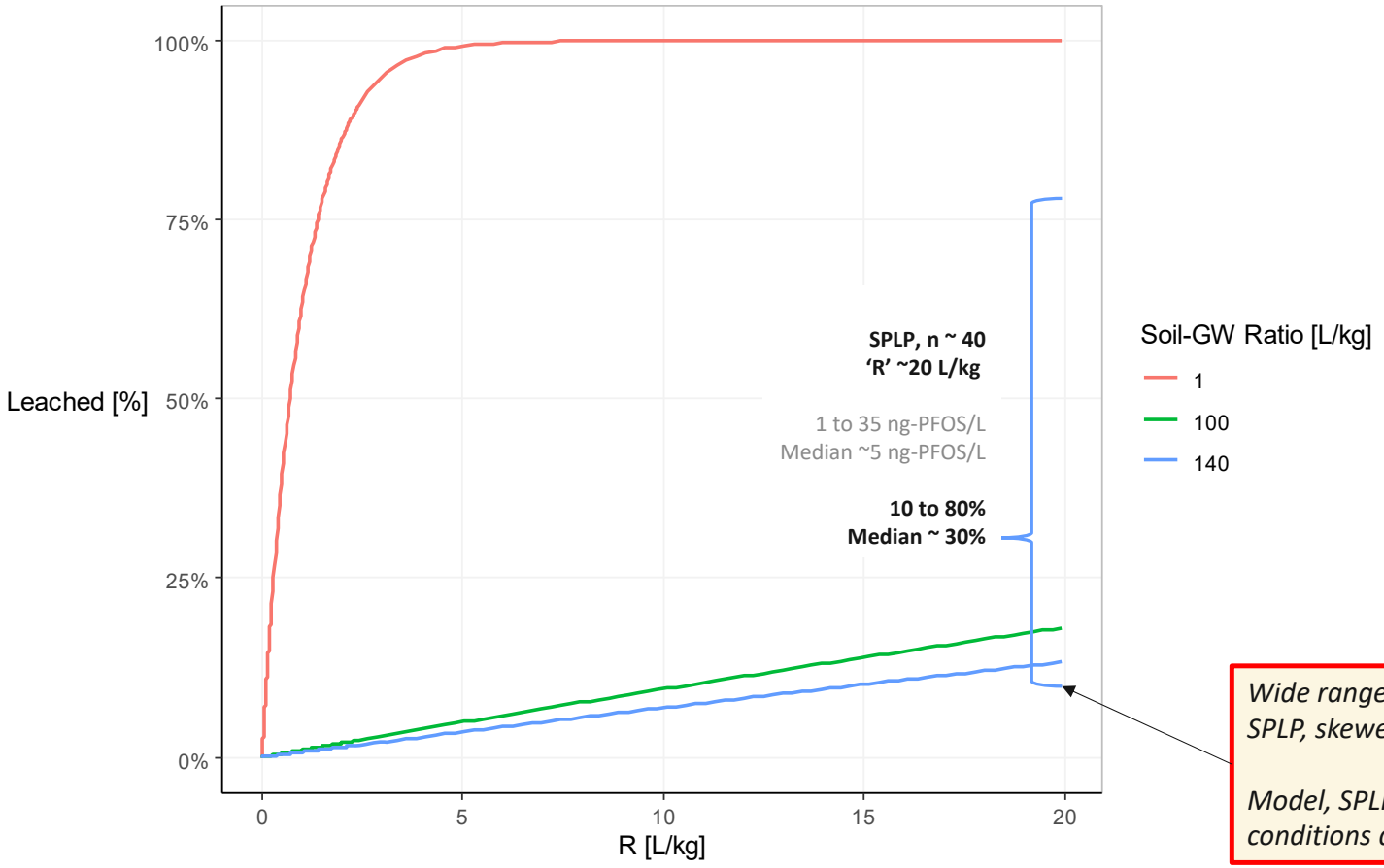

Wide range in '% Leached' for SPLP, skewed high.

Model, SPLP, and field conditions are all very different.

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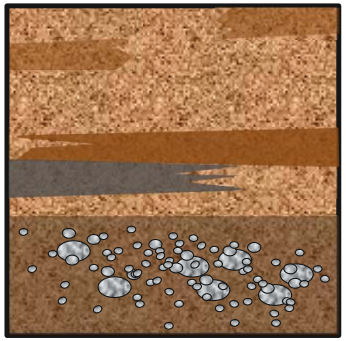
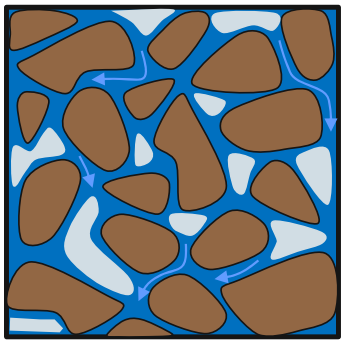
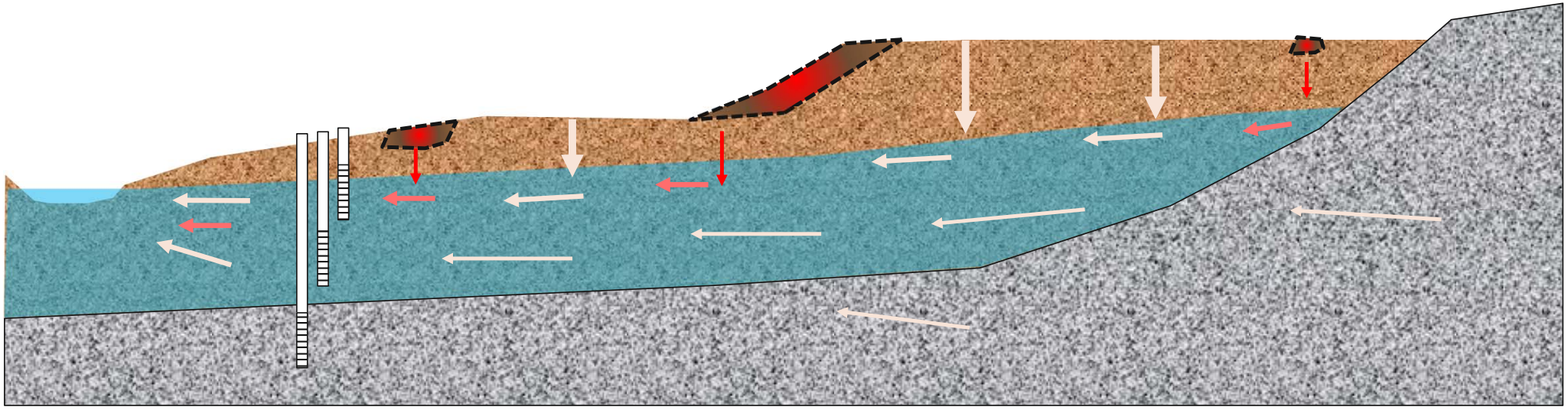
Heterogeneity

- Multiple scales







Environmental setting, e.g.: Wet and dry deposition; infiltration patterns
Soil type, e.g.: Soil chemistry and soil physical properties
Soil matrix structure, e.g.: Pore size and connectivity

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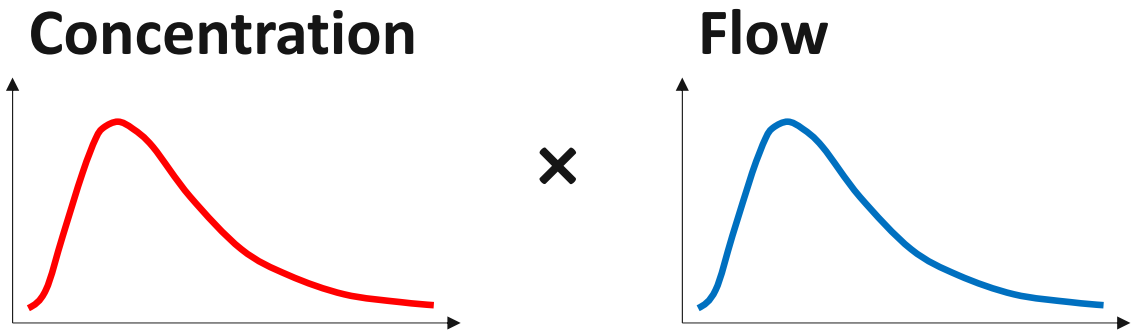
Heterogeneity

- Multiple scales
- **Skewed**
- **Interacting**

Flux =



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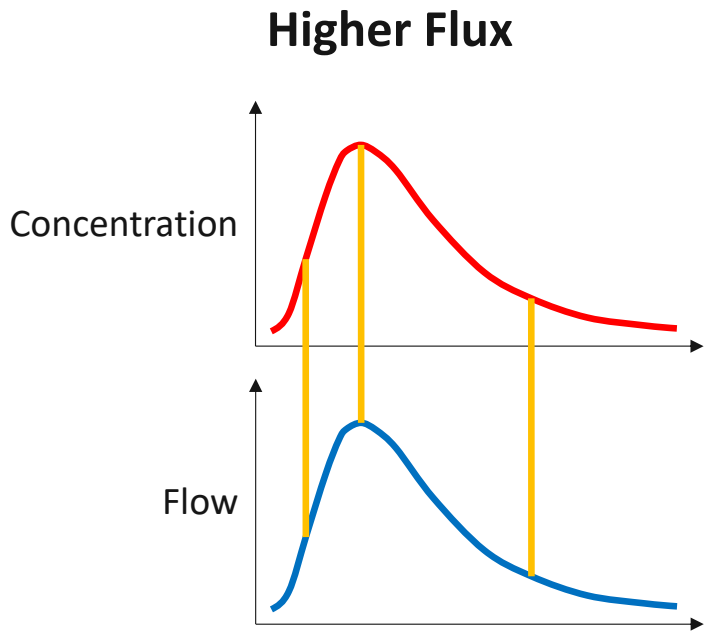

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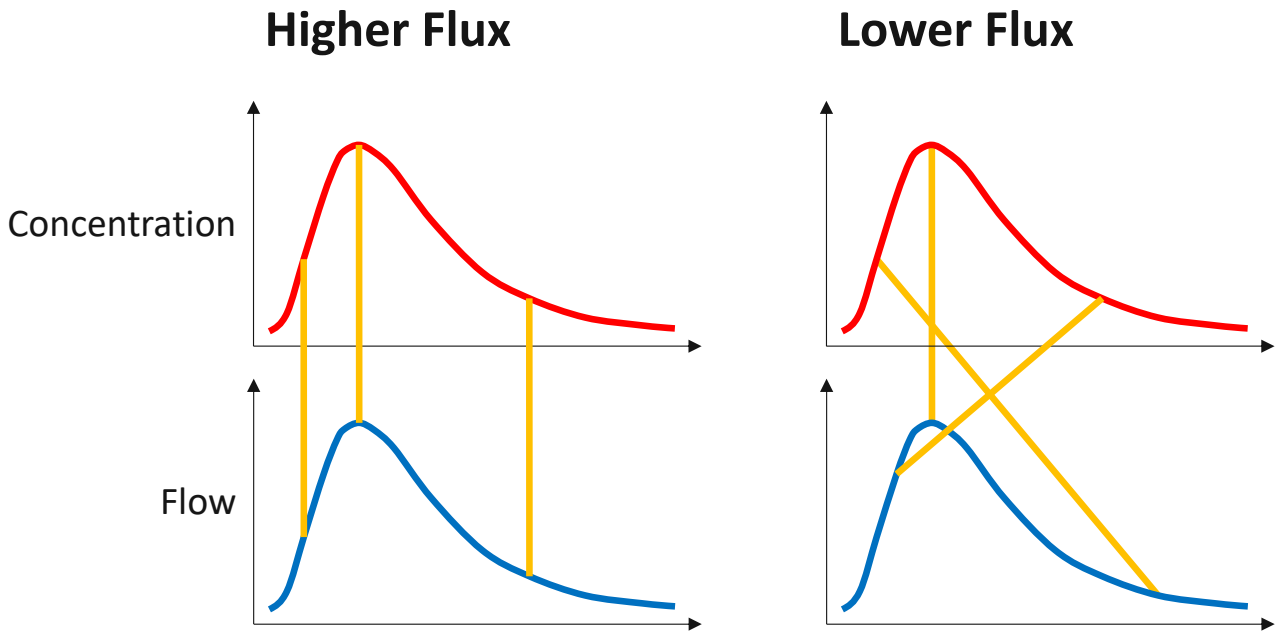

What is Next for 'Low-Level' PFAS in Soil?

- More information:
  - Background Levels of PFAS and PAHs in Maine Shallow Soils[1]
    - Chemistry analytes (pH, CEC, etc.)
    - Soil physical properties (grain size, TOC)
    - SPLP and TOP Assay
  - Growing experience with 'low-level' sites

1. "Background Levels of PFAS and PAHs in Maine Shallow Soil", prepared by Sanborn Head for the Maine Department of Environmental Protection. To be published in 2022.

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  - Growing experience with 'low-level' sites
- Pressure for regulatory guidance:
  - Reuse and disposal
  - Characterization and source attribution
  - Remediation and monitoring

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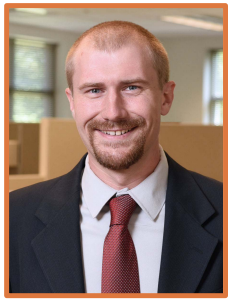
Questions and Comments Appreciated!

Thank you to collaborators, including:

ITRC Team
Sanborn Head Team
University of Vermont
VTDEC
MEDEP
NHDES
NHDOT



Harrison Roakes, PE

hroakes@sanbornhead.com
D 603.415.6156
M 207.337.3662

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[Boston, MA | Burlington, VT | Concord, NH | Denver, CO | Philadelphia, PA | Westford, MA]