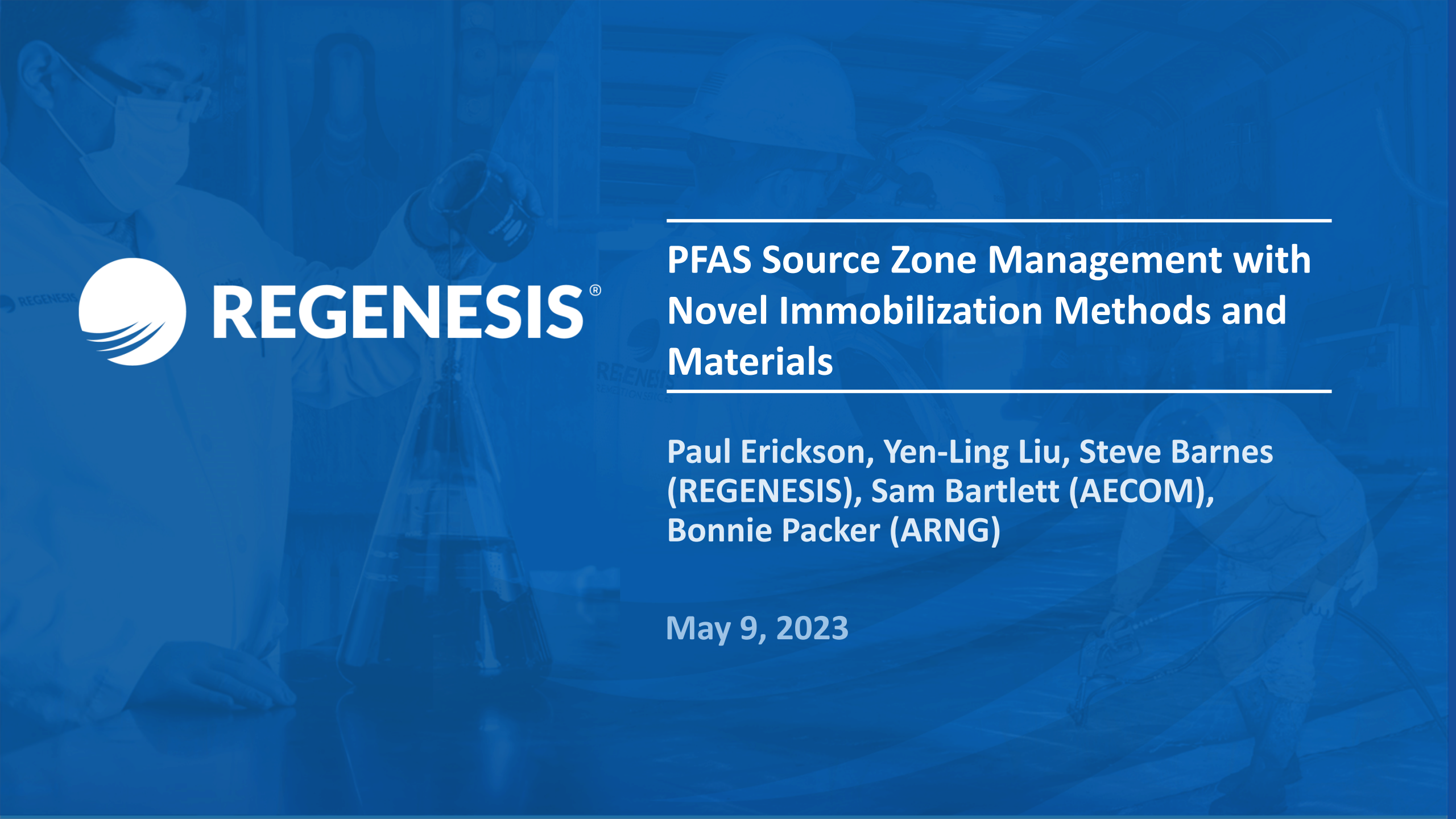

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PFAS Source Zone Management with Novel Immobilization Methods and Materials

Paul Erickson, Yen-Ling Liu, Steve Barnes (REGENESIS), Sam Bartlett (AECOM), Bonnie Packer (ARNG)

May 9, 2023

Overview

- PFAS Source Zones
- Controlling Mass Discharge
- Lab Proof of Concept
- Camp Grayling Case Study
- Conclusions & Future Work

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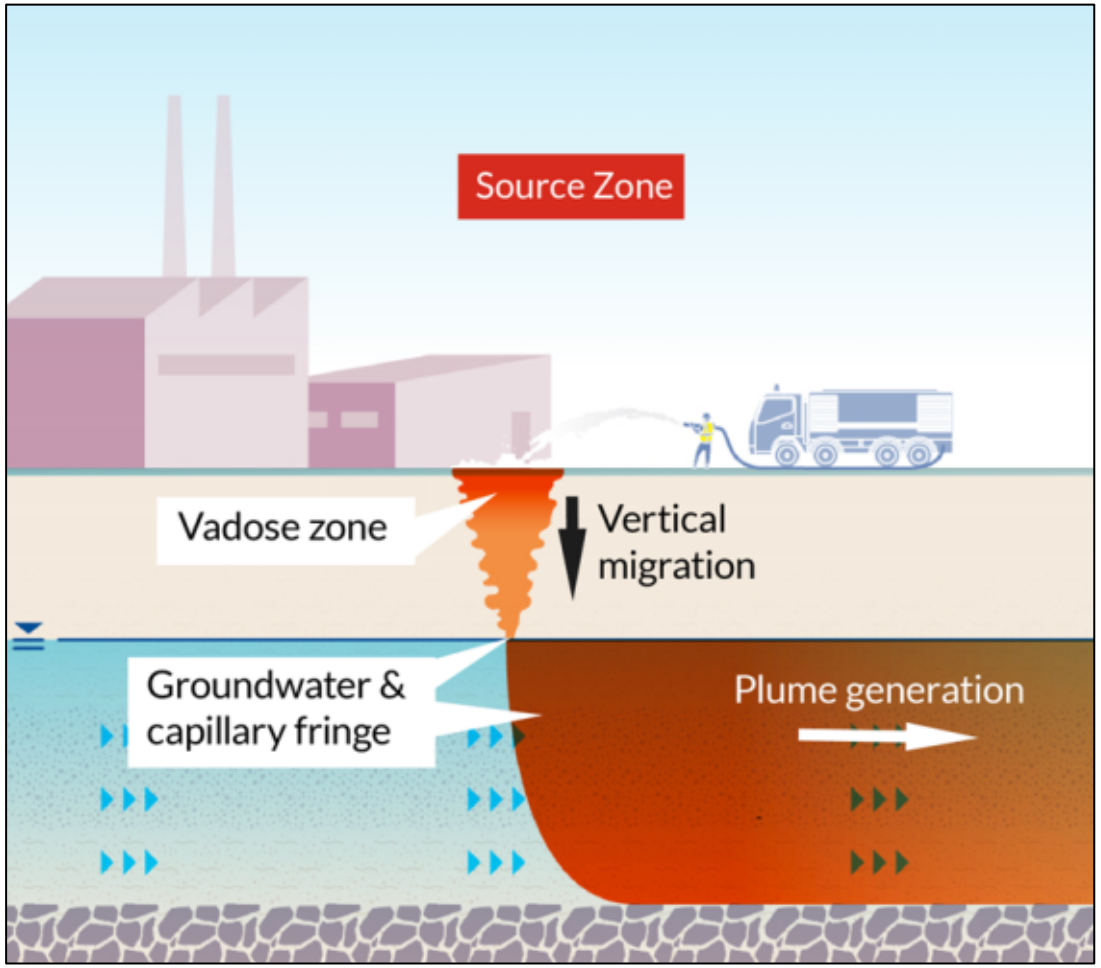
PFAS Source Zones

- PFAS contamination commonly from AFFF 'Aqueous Film Forming Foam'
- Accumulates in the soil
- Move vertically due to leaching into infiltrating precipitation
- Mass discharge to groundwater
- Maintains a long-term downgradient risk



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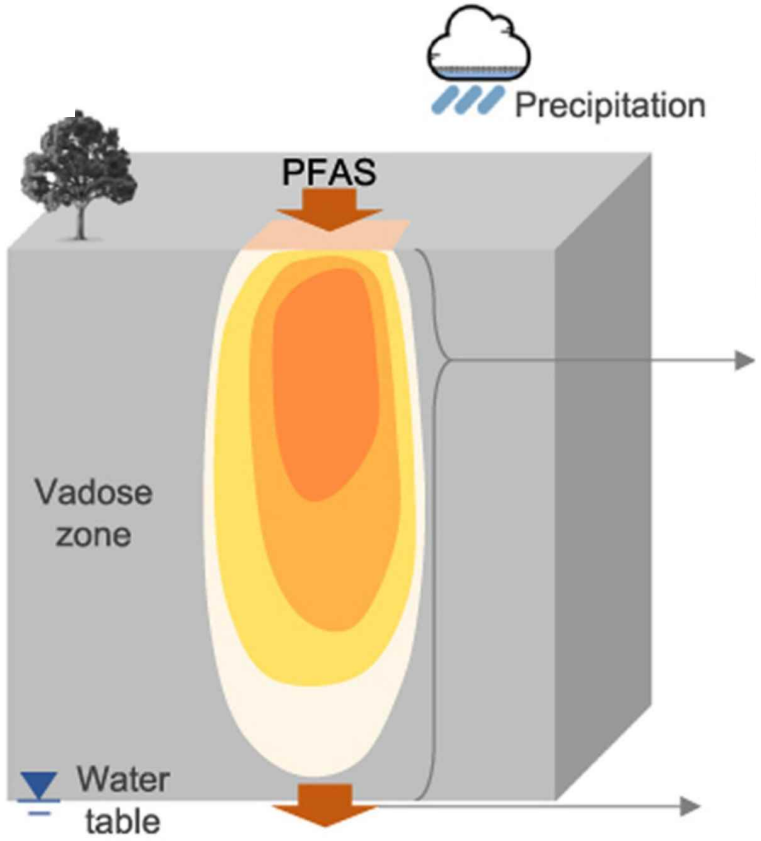
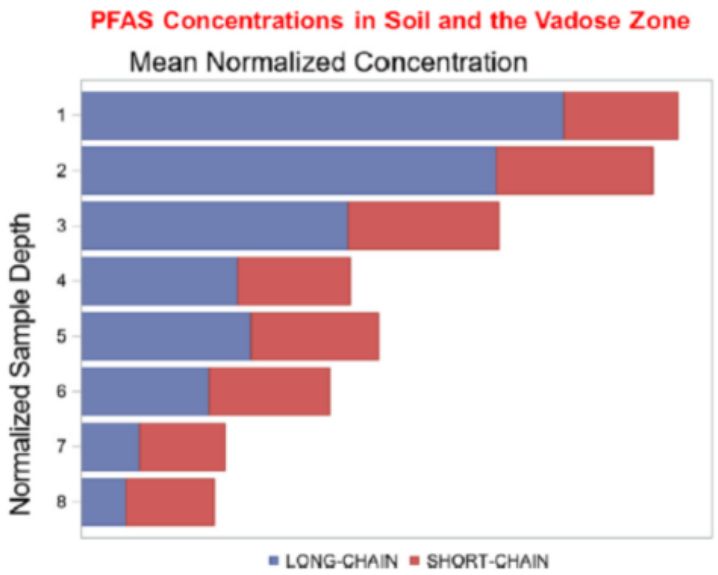
PFAS Source Zones



Most PFAS mass found near the surface



Sources:
B. Guo et al. Adv. In water res. 160 (2022) 104102
M. Brusseau et al. Sci. of the Total Env. 740 (2020) 140017

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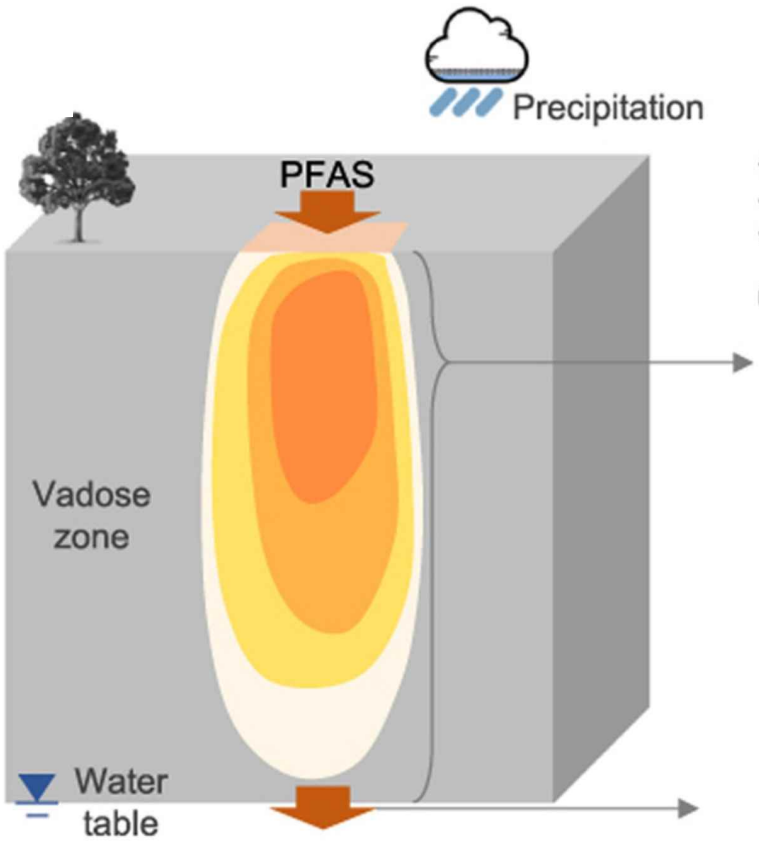
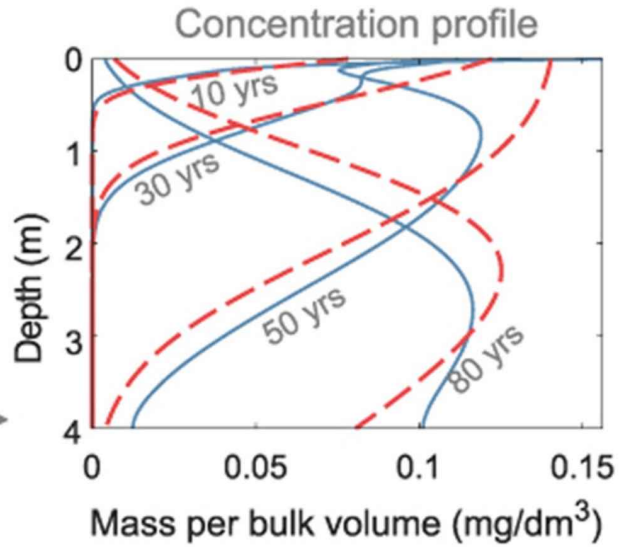
PFAS Source Zones





Depending on the soil and PFAS compound, migration may be very gradual

Sources:
B. Guo et al. Adv. In water res. 160 (2022) 104102
M. Brusseau et al. Sci. of the Total Env. 740 (2020) 140017

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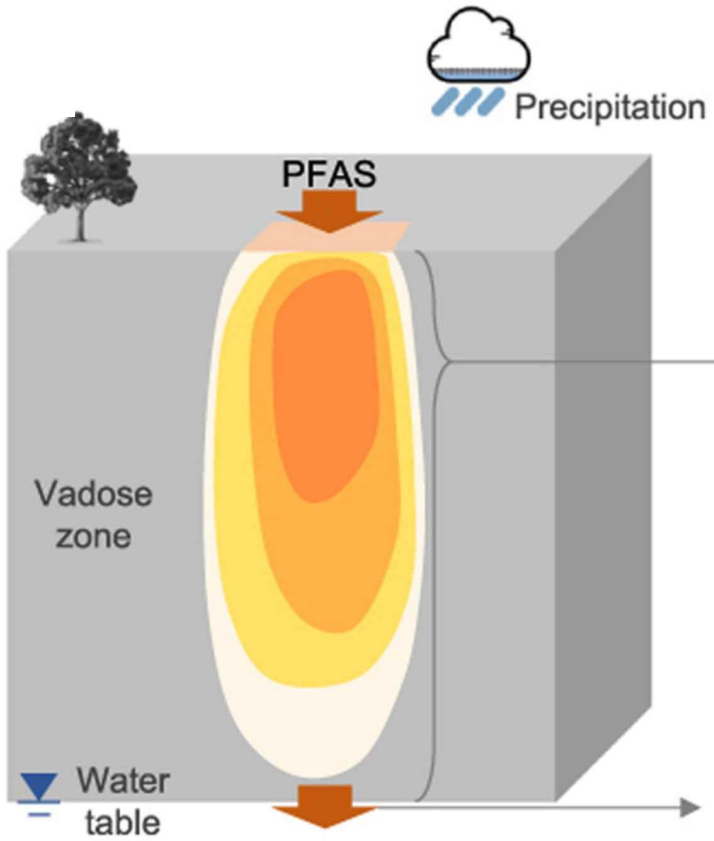
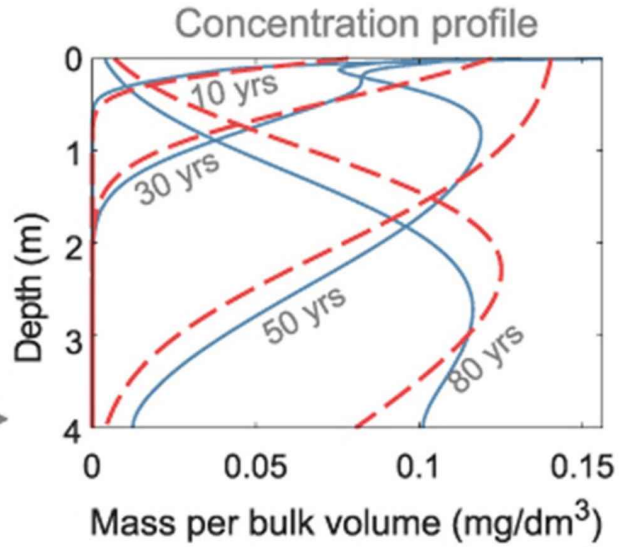
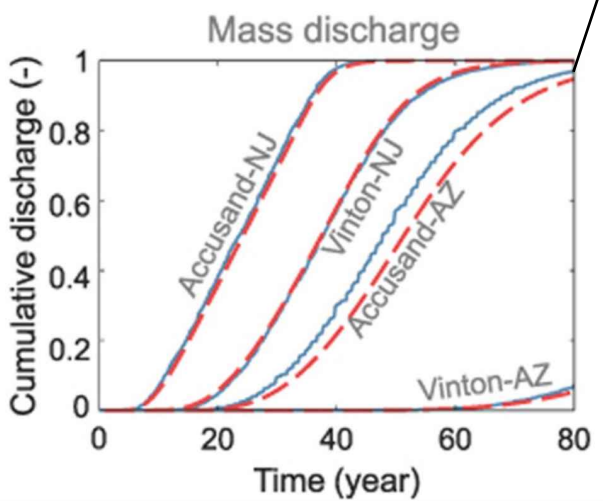
PFAS Source Zones







Eventually discharge to groundwater is seen

Sources:
B. Guo et al. Adv. In water res. 160 (2022) 104102
M. Brusseau et al. Sci. of the Total Env. 740 (2020) 140017

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PFAS Source Zones

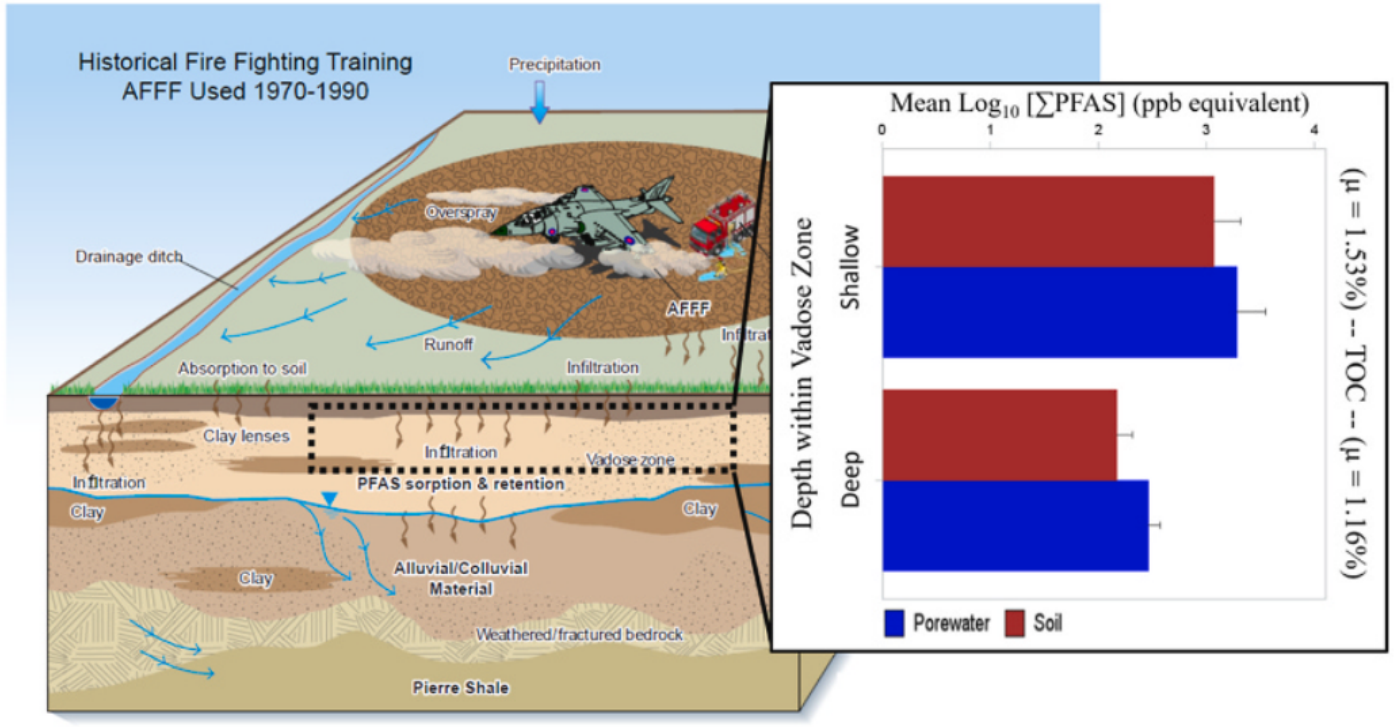

Table 3
Soil-to-groundwater mass discharge (Md)[a] and total mass[b] estimates for OU1.

PFAS	Md (g/yr)	Total Mass (kg)
PFOS	10.17	130.2
PFOA	16.69	27.99
PFBS	8.380	4.383
6:2 FTS	22.07	50.86
PFHxS	90.45	81.58
PFHxA	38.69	17.24

[a] Md estimates are calculated using data from only the deep lysimeters.
[b] Total mass estimates are calculated using the cumulative mass in both the shallow and deep soil samples.

0.1% of mass discharged annually

- **Potential treatment strategy: Further enhance mass retention**
  - **Permits plume attenuation**

Source: R. Anderson et al. Chemosphere 308 (2022) 136247

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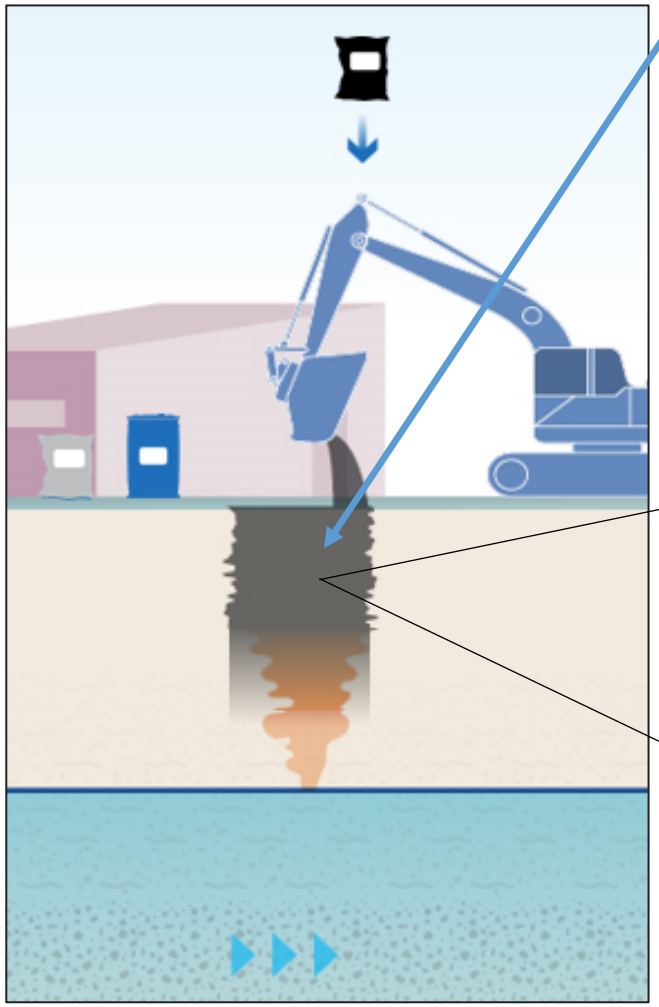
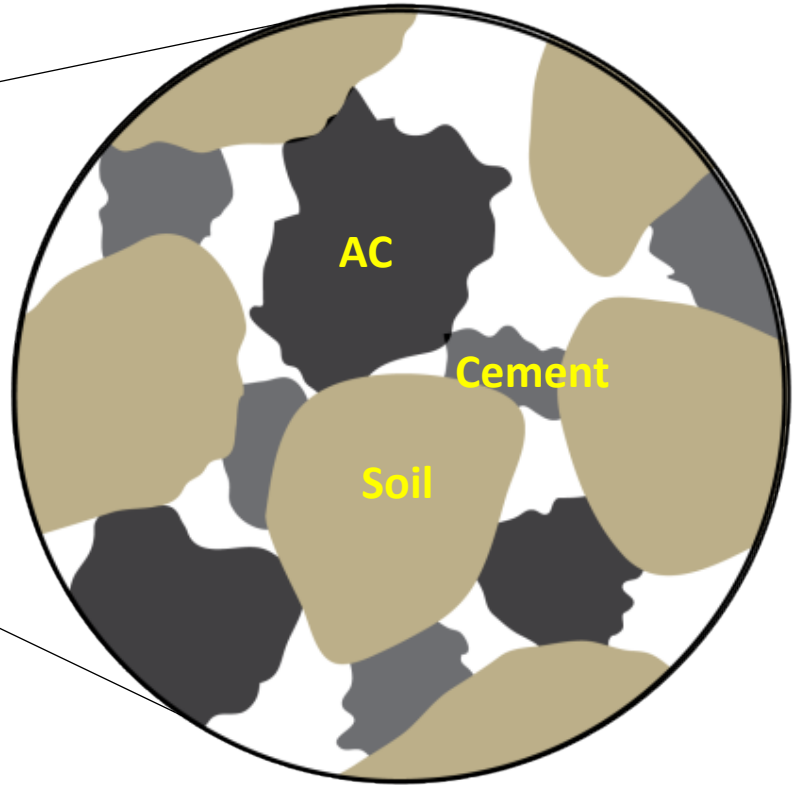
Source Treatment in Vadose Zone



Mechanical mixing of site-specific blend of activated carbon and permeability modifiers

Activated carbon:
- Reduces leachability
- Immobilizes PFAS mass

Cement/clay:
- Reduces permeability
- Prevents rainwater infiltration



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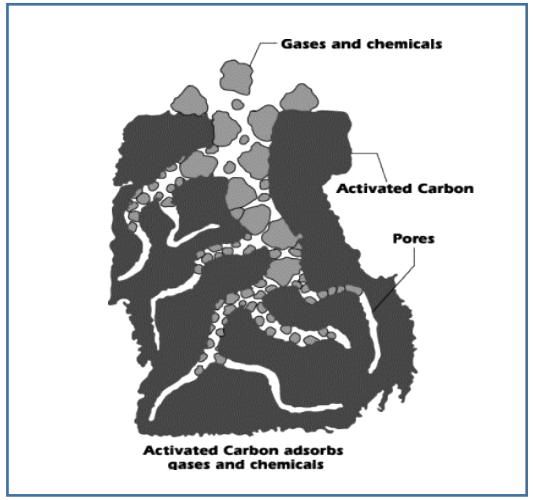
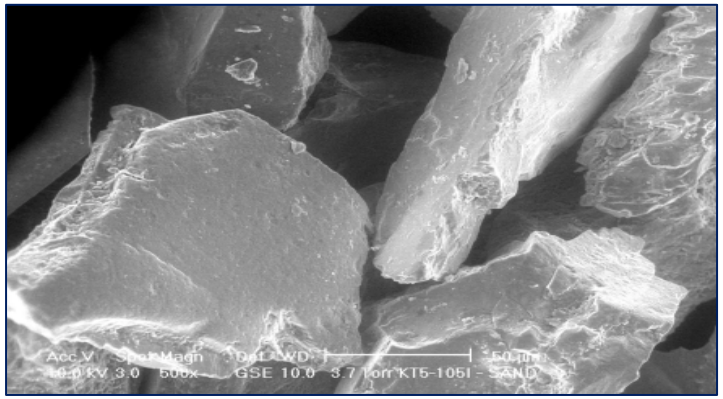
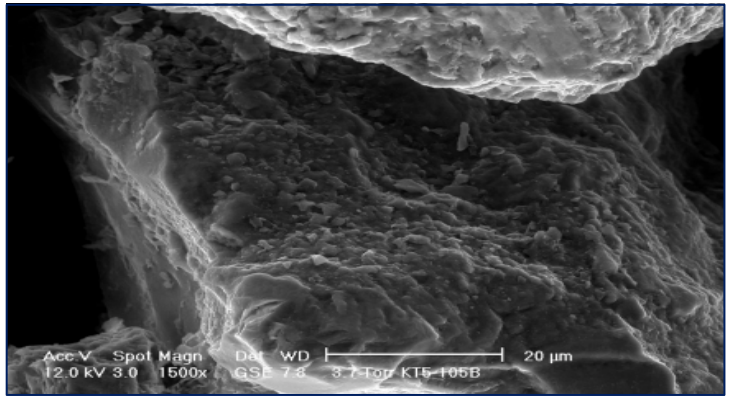
Colloidal Activated Carbon: SourceStop and PlumeStop

- **Size: 1 – 2 µm**
  - **Suspended in water**
  - **Wide area distribution**
    - No high-pressure fracturing needed
  - **Coats aquifer, soil surfaces**
    - Creates subsurface activated carbon filter
  - **Rapid sorption of PFAS**
    - Smaller particles provide more exterior surface
    - Shorter distance to all the sorption sites compared to GAC
    - Xiao, Ulrich, Chen & Higgins. Environ. Sci. Technol. 2017, 51, 6342-6351.







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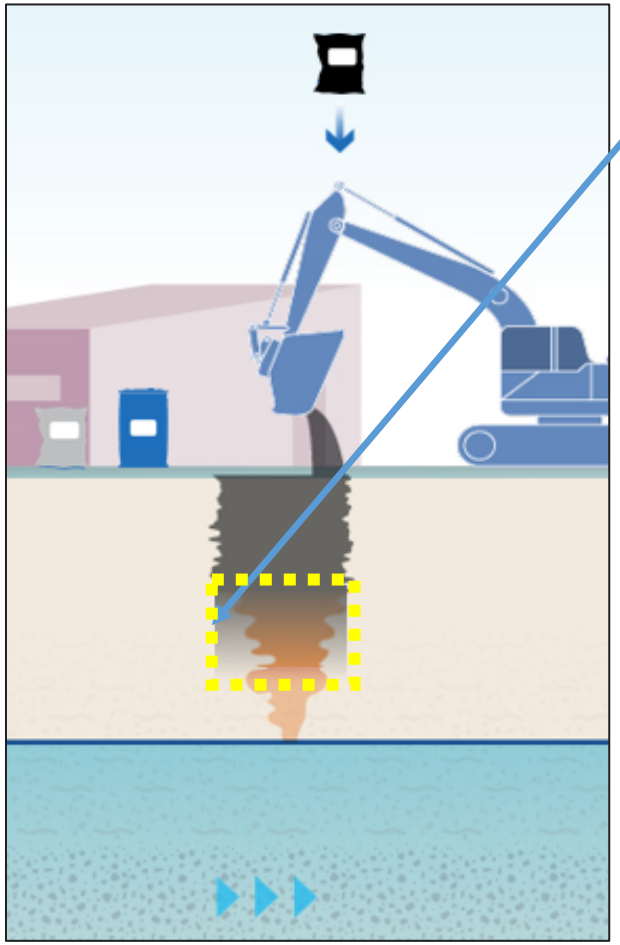
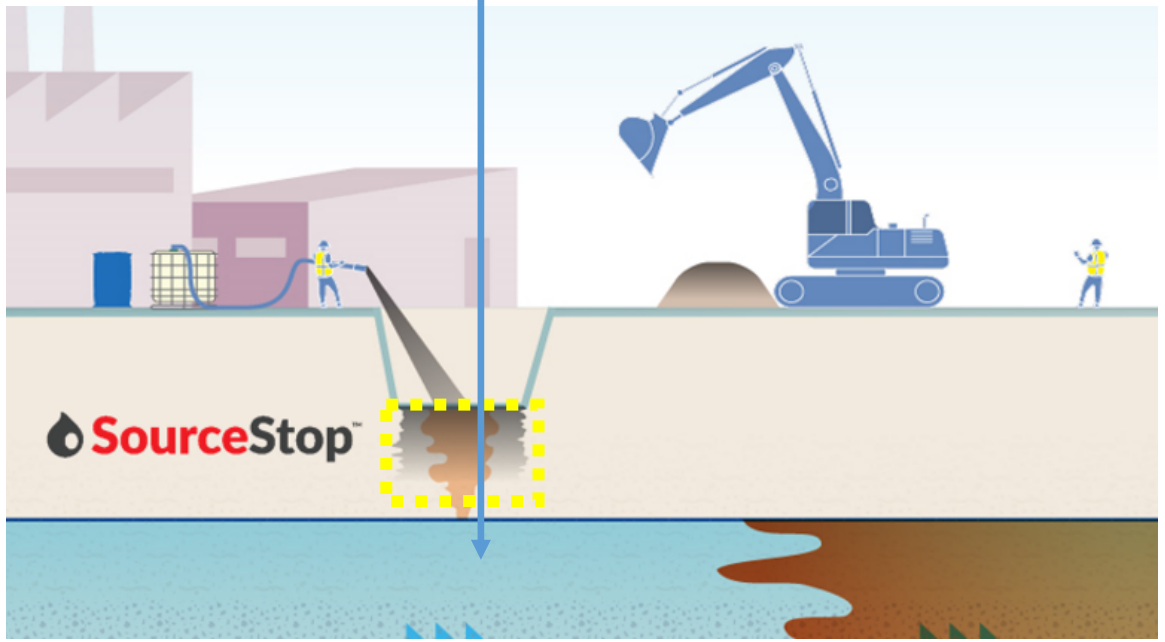
Source Treatment in Vadose Zone



SourceStop Colloidal Activated Carbon applied into the base of the treatment

- Penetrates underlying soils
- Coats vertical flow-paths
- Creates ‘horizontal’ barrier
- Prevents further infiltration of residual PFAS



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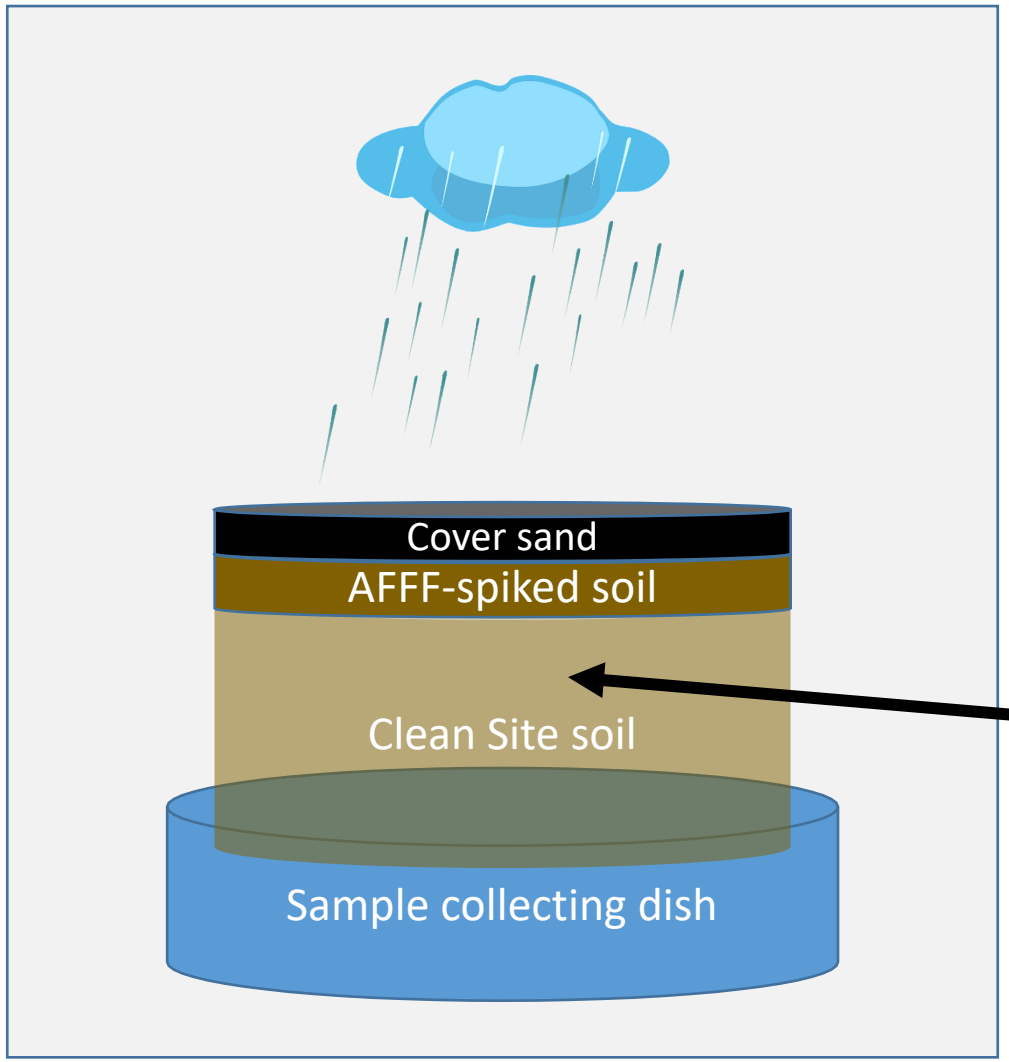
CAC Barrier Validation Experiments



Simulated Rainfall:

1. Acid rain
2. Heavy/very heavy rain
3. 3 times/week

Soil:

1. 100 g AFFF-spiked soil
2. 900 g pristine soil
3. 10 g carbon sprayed onto pristine soil
4. Only tap water onto the control

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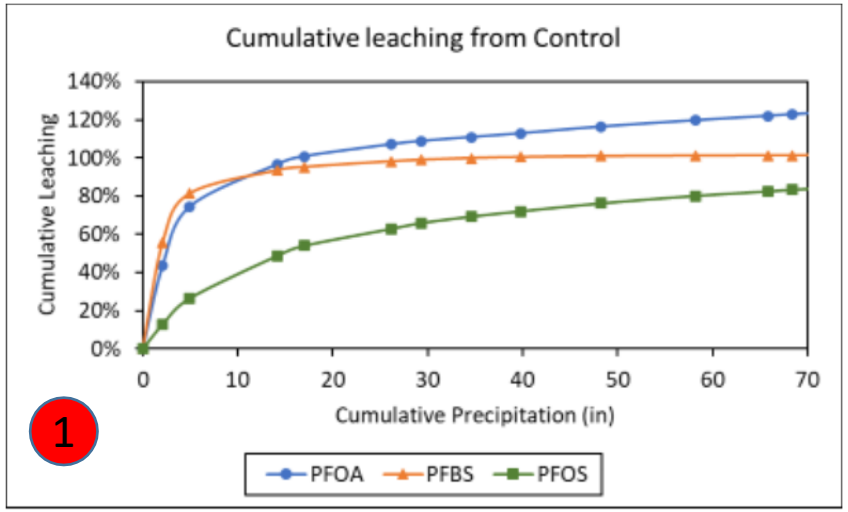
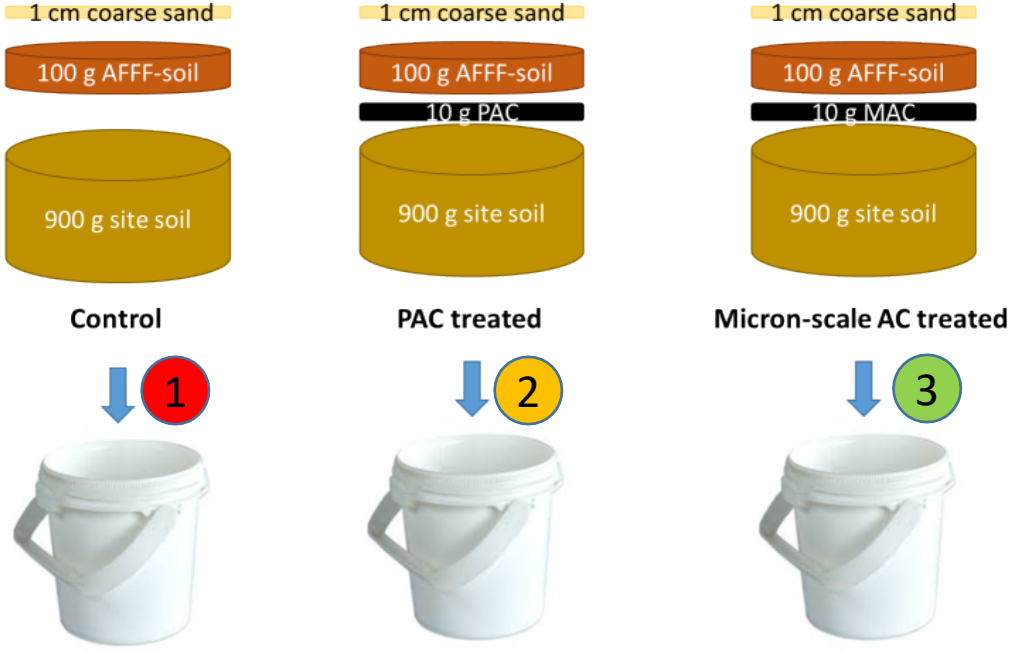
CAC Barrier Validation Experiments

- Infiltrated water is stripped of PFAS by CAC
- Outperforms PAC of a matched mass dose





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Put to Practice:

Beta Testing Source Treatment

Field Testing: Grayling Army Airfield

Background

- Founded 1913
- 147,000 Acres
- Largest National Guard Training Center in the Country
- Home to Grayling Army Airfield (900 Acres)

Treatment Area

- Airfield Operations building
- Previous fire truck (ARFF) activity
- AFFF Impacted soils

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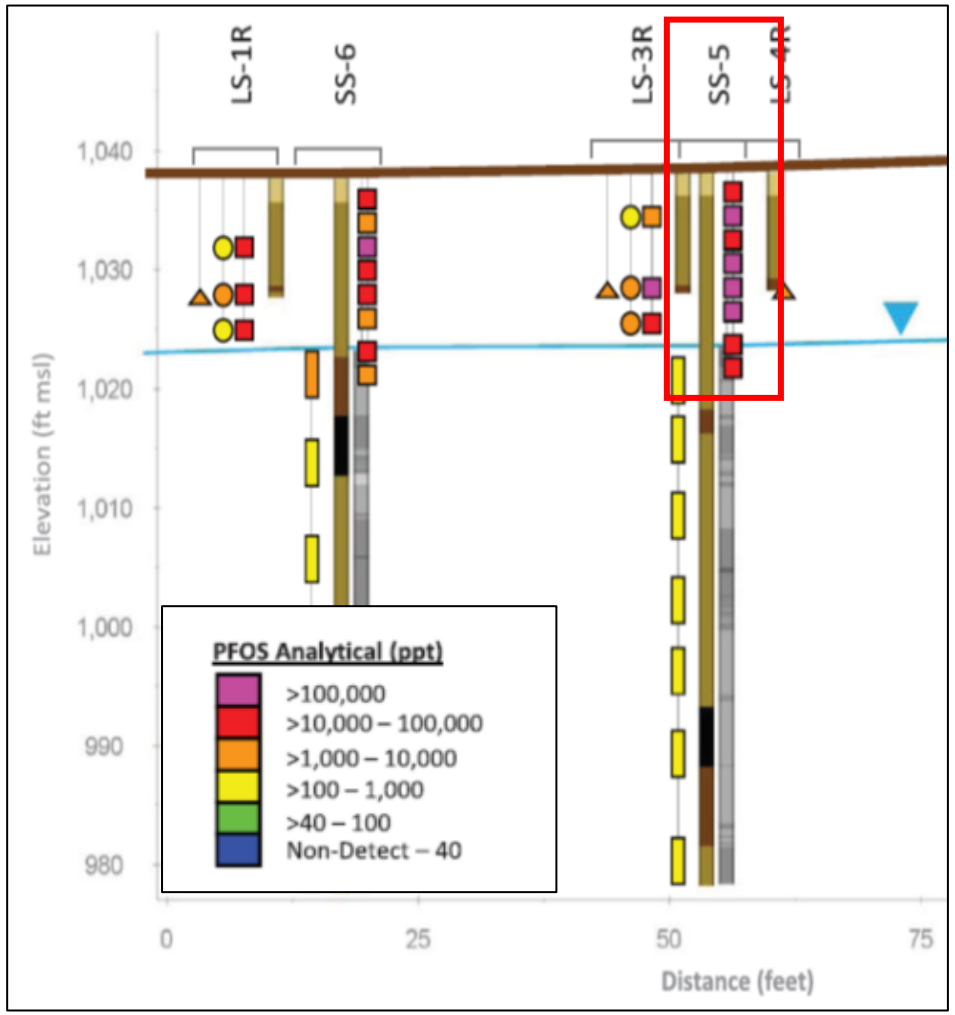
Beta Site – Camp Grayling

- Testing within hot spot (SS-5)
- PFOS > 100,000 ppt



Soil Mix Test Treatment Area
Soil Stockpile Area

Prepared By: SRB

Figure 1
Source Soil Treatment
Camp Grayling Army Airfield

Date Prepared: October 2022

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REMEDIATION SERVICES
Technology-Based Solutions for the Environment

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Beta Site – Camp Grayling

- Site Preparation
- Soil & GW Collection
- Barrier Treatment
- Soil Mixing
- Grading and Restoration

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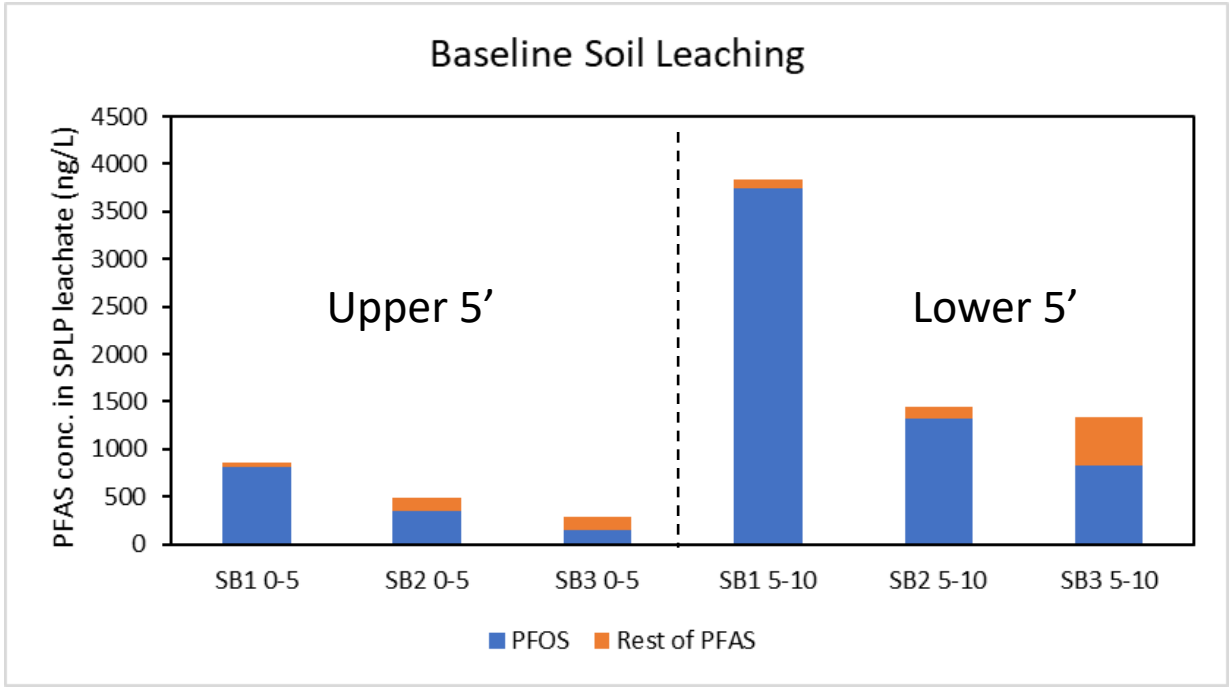
Beta Site – Camp Grayling

- **Baseline sampling showed higher PFAS in lower 5’**
  - **Assessment by Synthetic Precipitation Leaching Procedure (SPLP)**



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Beta Site – Camp Grayling

- Site Preparation
- Soil & GW Collection
- Barrier Treatment
- Soil Mixing
- Grading and Restoration

- CAC horizontal barrier
- Easy to apply and zero dust

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Beta Site – Camp Grayling

- Site Preparation
- Soil & GW Collection
- Barrier Treatment
- **Soil Mixing**
- Grading and Restoration

- Further mixing
- Performed in lifts

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Beta Site – Camp Grayling

- Site Preparation
- Soil & GW Collection
- Barrier Treatment
- Soil Mixing
- Grading and Restoration

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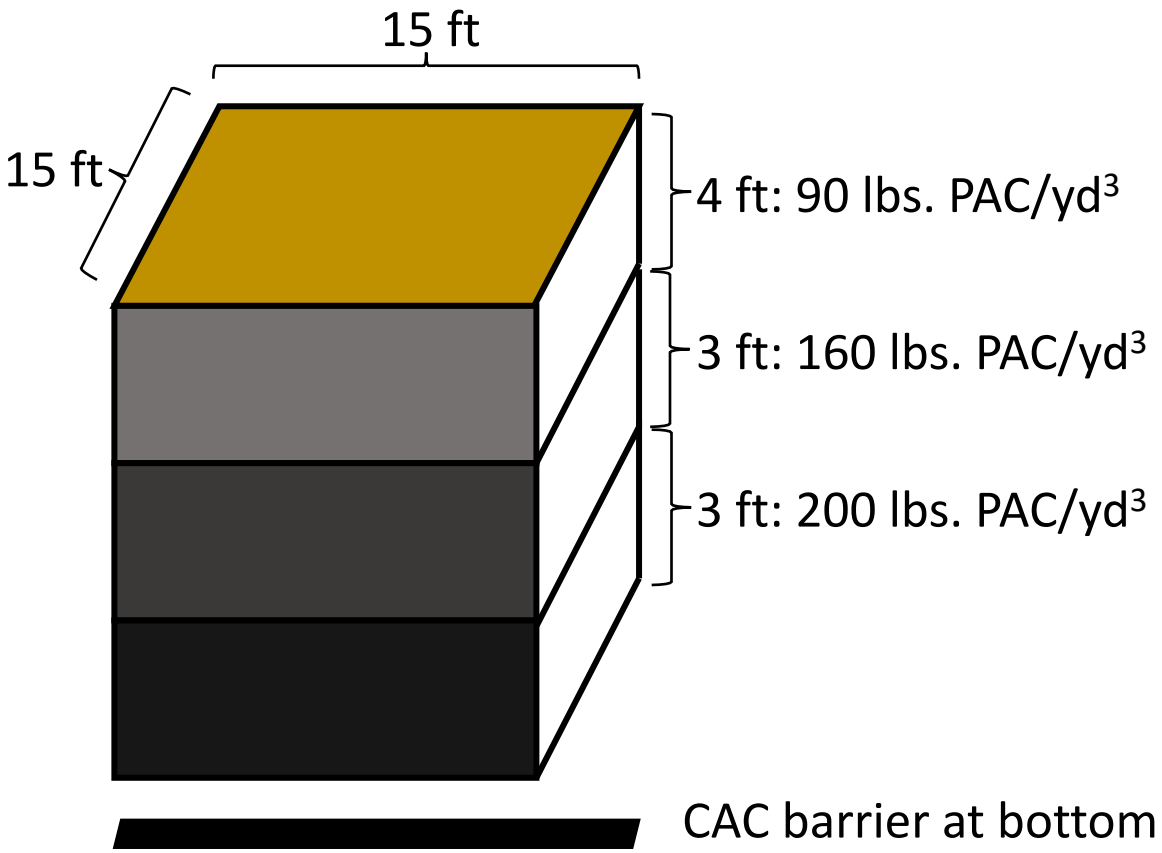
Initial Results- Post-treatment SPLP



SPLP after Treatment		
Depth	PFOS	Rest of PFAS
0-4 ft	25.5 ng/L	ND
4-7 ft	ND	ND
7-10 ft	ND	ND

Reduction = 99.4%

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Conclusions

- **Initial results encouraging**
  - 6- Month sampling done, awaiting data
  - Sampling at 1 year mark
- **Ongoing & future developments**
  - Two beta tests successfully conducted
  - Use of lysimeters to understand net treatment effects
  - Discharge modeling to inform groundwater influence

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Thank You!

Paul Erickson, PhD

Director of Research & Development
REGENESIS

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