PFAS Remediation Strategies and Research

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How Do We Treat Contaminants in Groundwater?

Powerpoint stock image

Treatment Technologies for Groundwater

Ex Situ Pump-and-Treat

- **Bioreactors**
- **GAC/IX sorptive systems**
- **Oxidation systems**
- **Air-stripping**

In Situ Bioremediation

- **Add amendments to stimulate natural bacteria**
- **Add bioaugmentation cultures**

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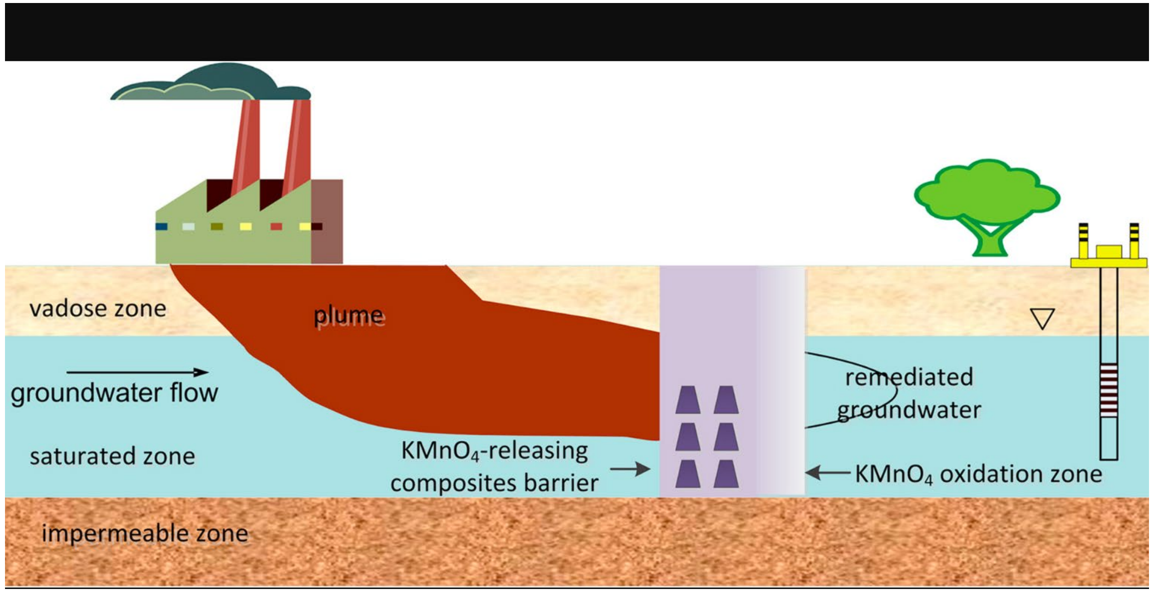
Treatment Technologies for Groundwater

In Situ Chemical Oxidation (ISCO)

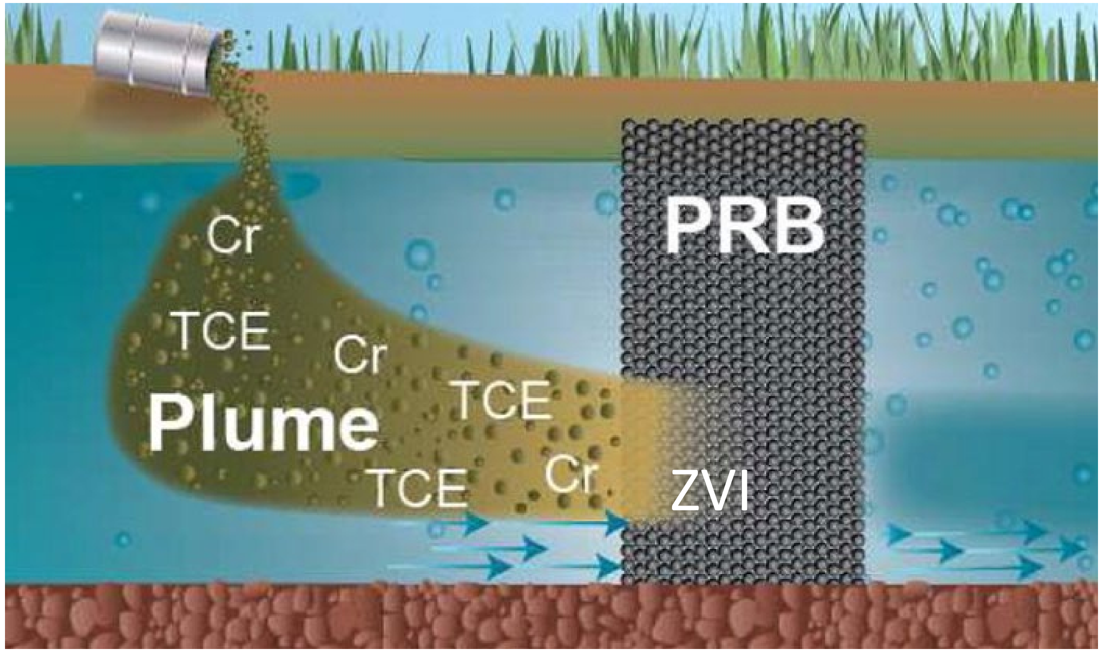
- Persulfate
- Ozone
- Peroxide
- Permanganate

In Situ Chemical Reduction (ISCR)

- Permeable Reactive Barrier (PRB) – Zero-valent iron (ZVI)
- Nano-scale ZVI injection



Graphic from Liang et al., 2014.

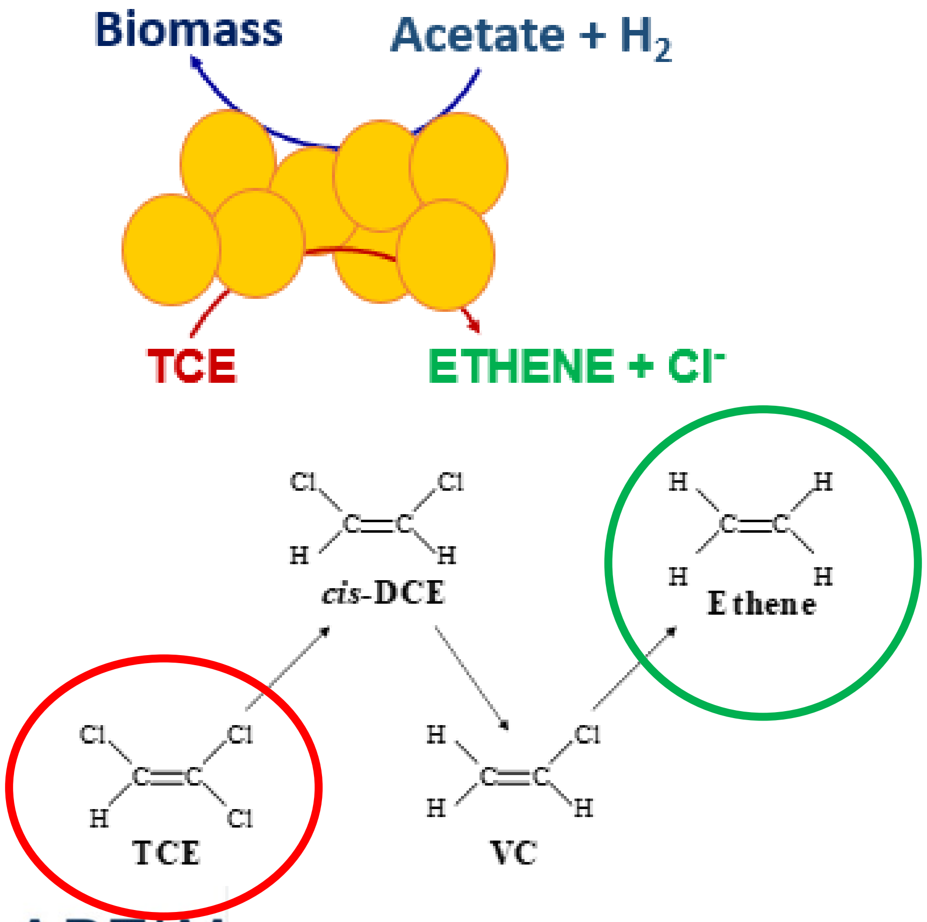


Graphic from Lawrinenko et al., 2023 (open access).

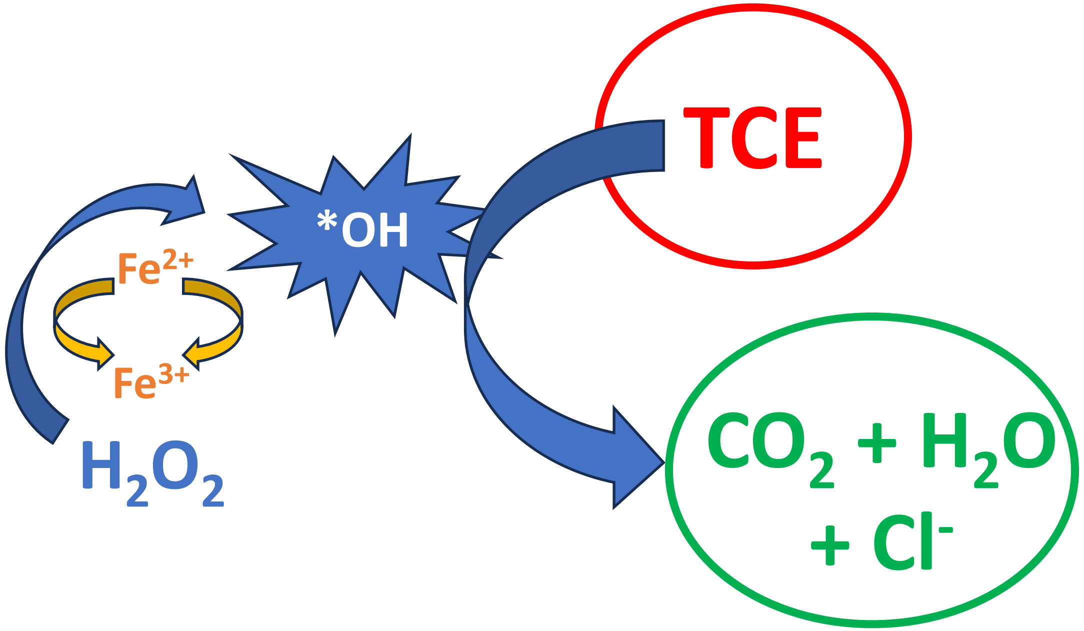
Treatment Technologies for Groundwater

- **Biodegradation, ISCO and ISCR typically result in the detoxification of pollutants**

Anaerobic biodegradation of TCE



Chemical oxidation of TCE



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Treatment Technologies for Groundwater

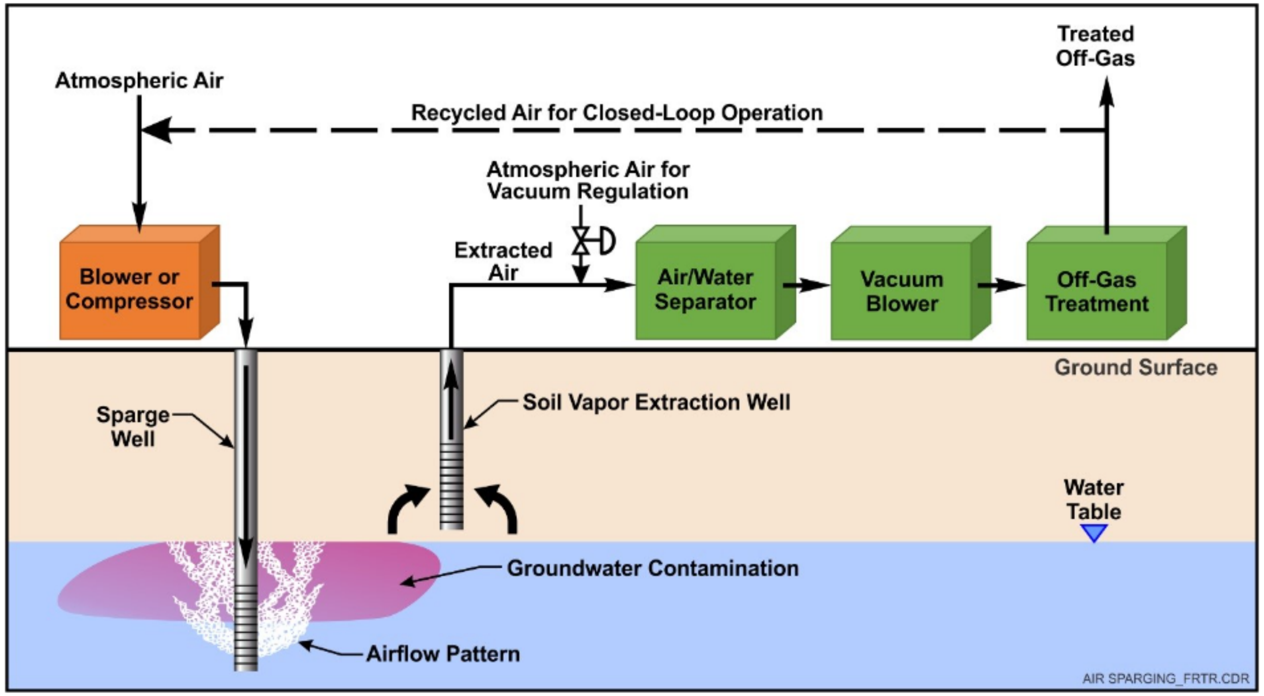
Thermal treatment

- Steam
- Electrical resistance heating (ERH)
- Optimal for unsaturated zone
- Recover contaminants in gas/vapor

ERH system cleans up contaminated soil and groundwater.

Air stripping

- Sparge air into the ground
- Recover contaminants in gas phase



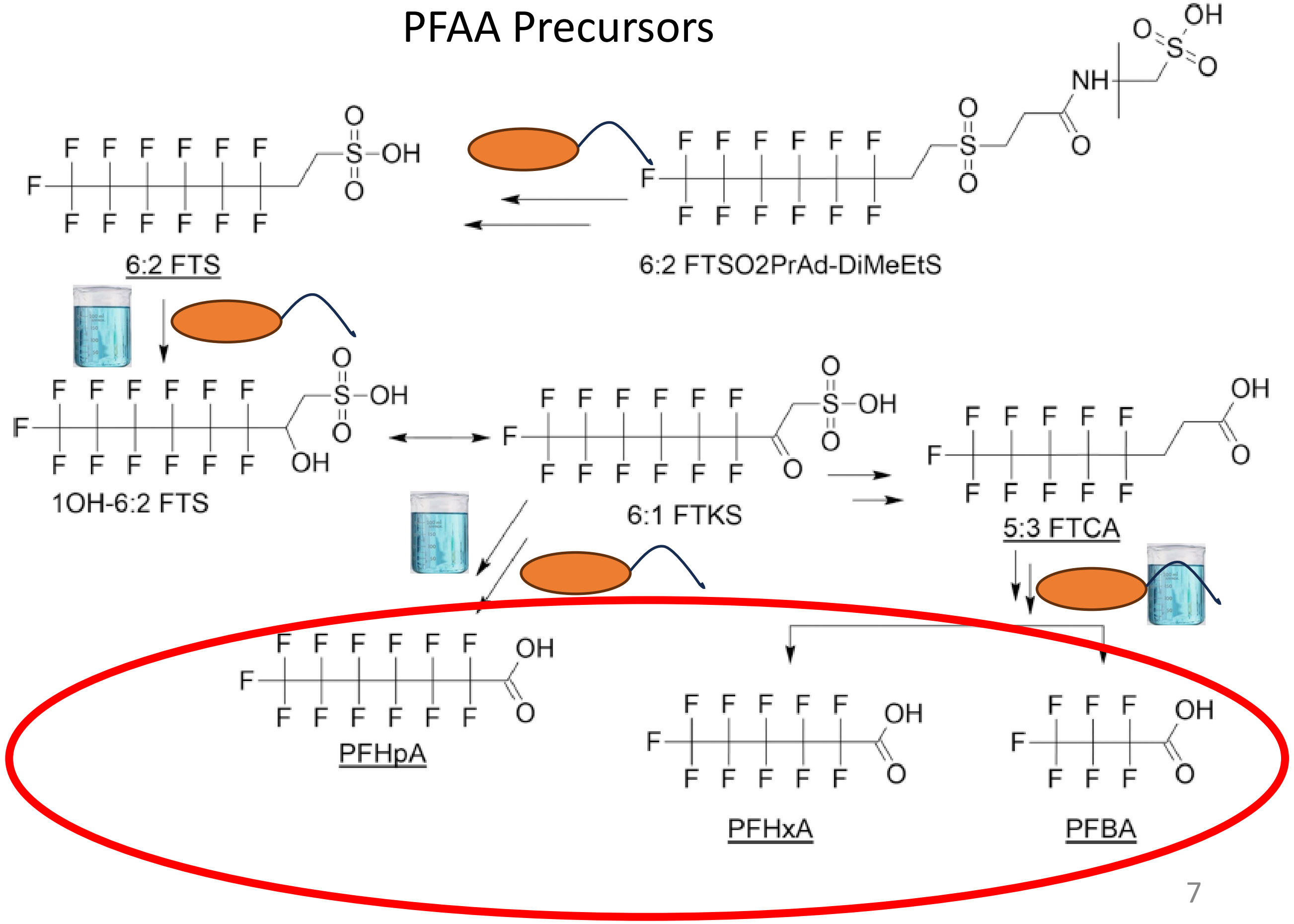
Graphics from USEPA: Office of Land and Emergency Management (5203P) | EPA-542-F-21-016 | 2021 | www.clu-in.org and Federal Remediation Technologies Roundtable https://www.frtr.gov/matrix-2019/Air-Sparging/#Schematic.

How are PFAS Different?

- **Complex array of structures with differing behaviors**
- **Concern at exceedingly low concentrations (ng/L)**
- **Perhaps most recalcitrant class of organic compounds to date**
  - In situ bioremediation X
  - In situ chemical oxidation X
  - In situ chemical reduction X

- **Most promising alternatives**
  - Pump-and-treat with IX, GAC, RO
  - Pump-and-treat with foam fractionation
  - In situ adsorption
    - Colloidal activated carbon
    - Funnel and gate w/IX resin
  - Foam fractionation w/ex situ destruction
  - Thermal removal and capture

PFAA Precursors



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Pump and Treat with Adsorption

- Applicable for groundwater or drinking water
- Media must be changed out periodically
- PFAS on media must be dealt with (landfill, thermal regeneration, regenerable IX resins, newer destructive approaches)
- Long term energy costs – diminishing returns for groundwater

Source: Ben Porter: APTIM

Anon exchange resin

Granular activated carbon

Source: Wikipedia

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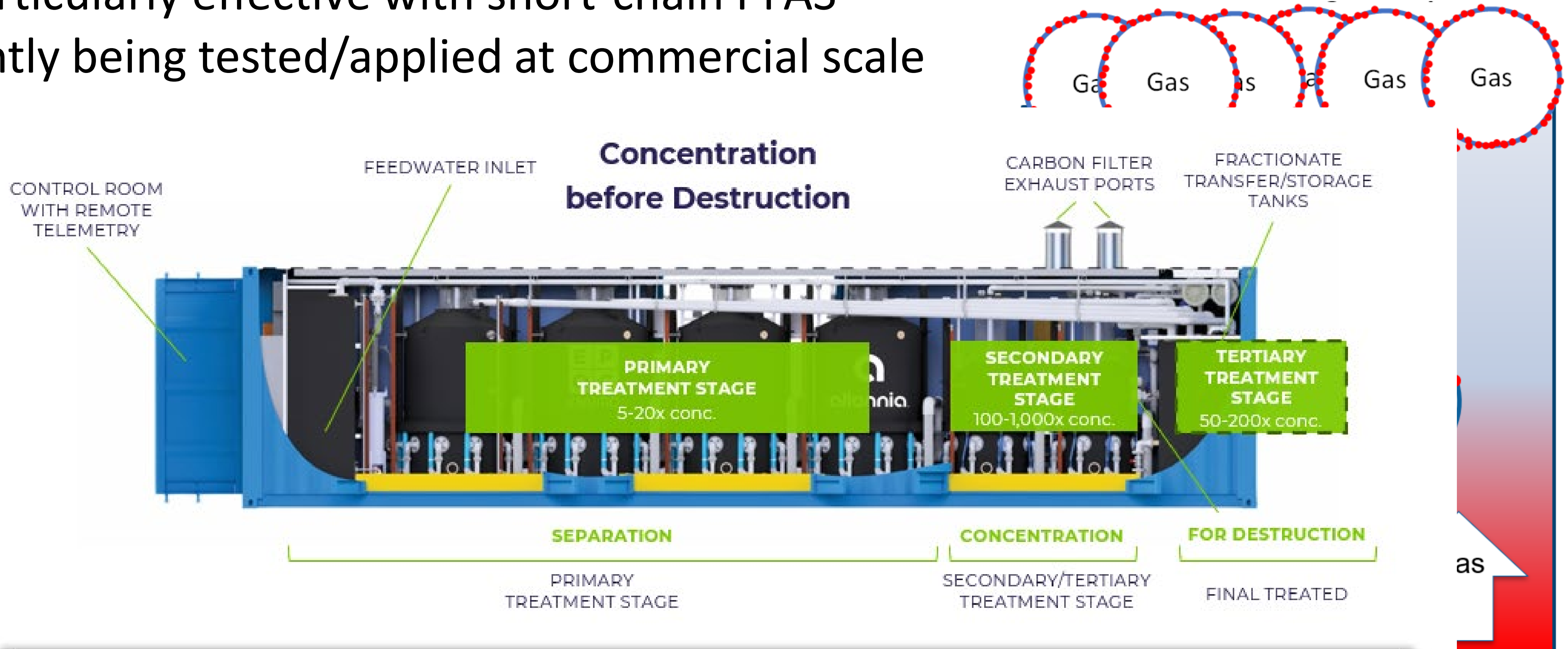
Pump and Treat with Foam Fractionation

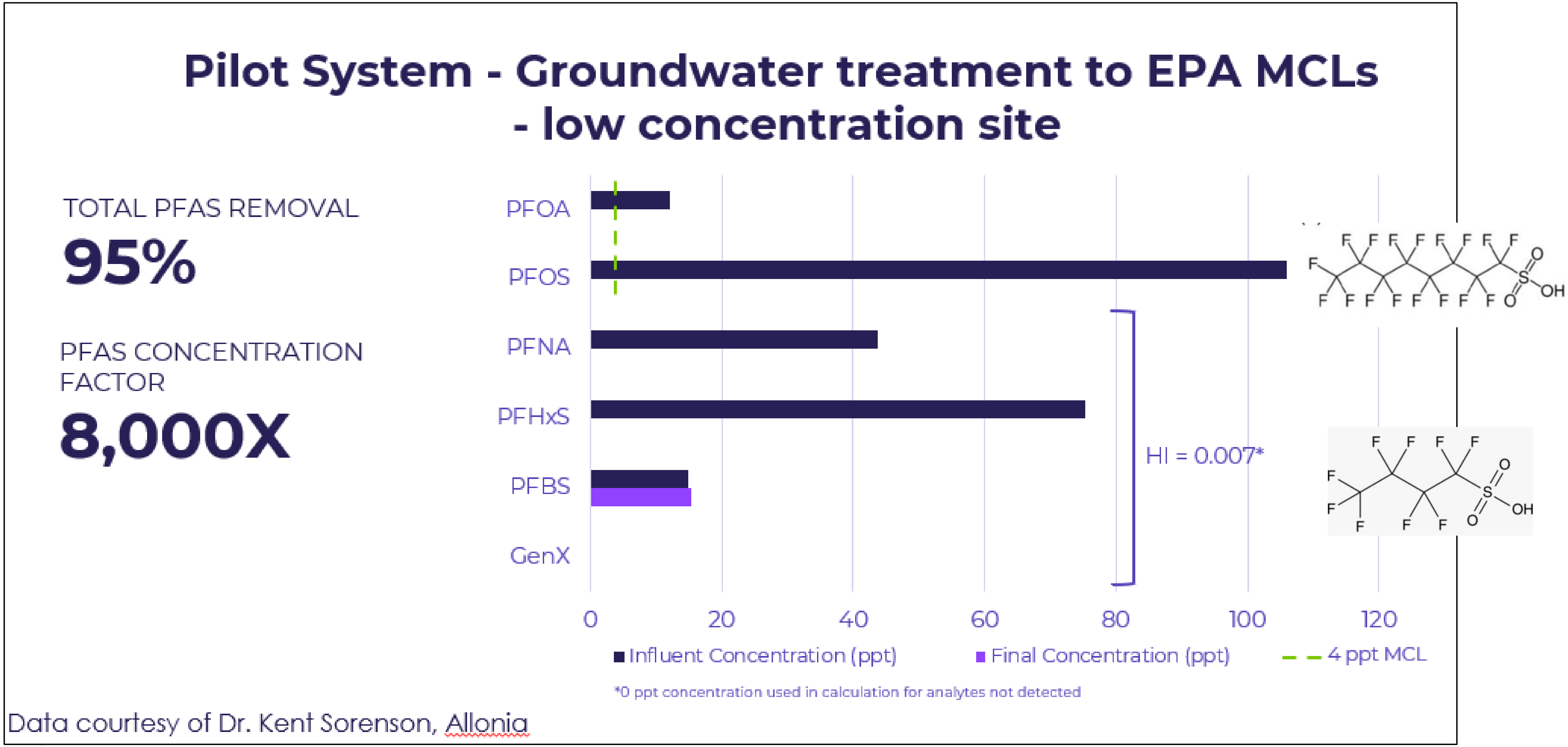
- Many PFAS are surfactants and migrate to an air-water interface
- PFAS will accumulate in the foam - which can then be removed & treated
- Not particularly effective with short-chain PFAS
- Currently being tested/applied at commercial scale



For every 1 million gals of groundwater into SAFF, you have <100 gals of concentrated PFAS for destruction.

Graphic courtesy of Dr. Kent Sorenson, Allonia

Pump and Treat with Foam Fractionation



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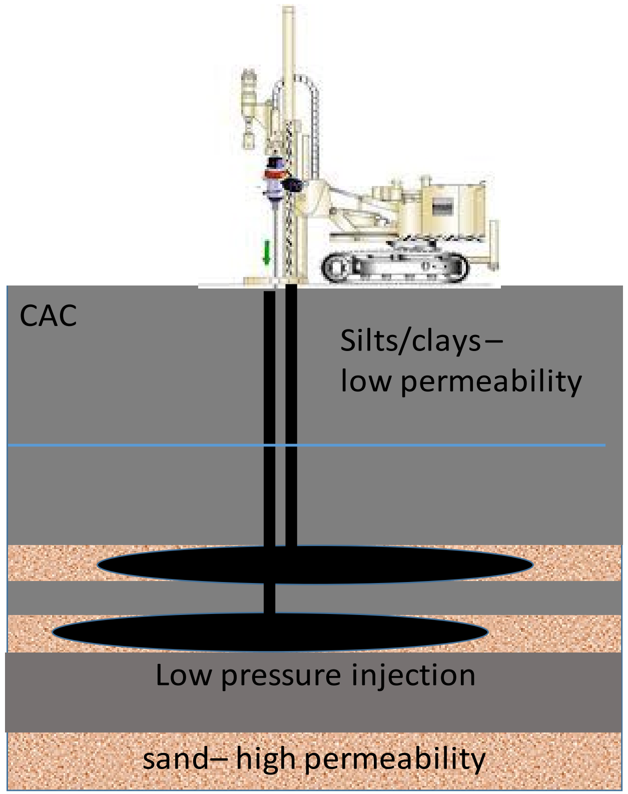
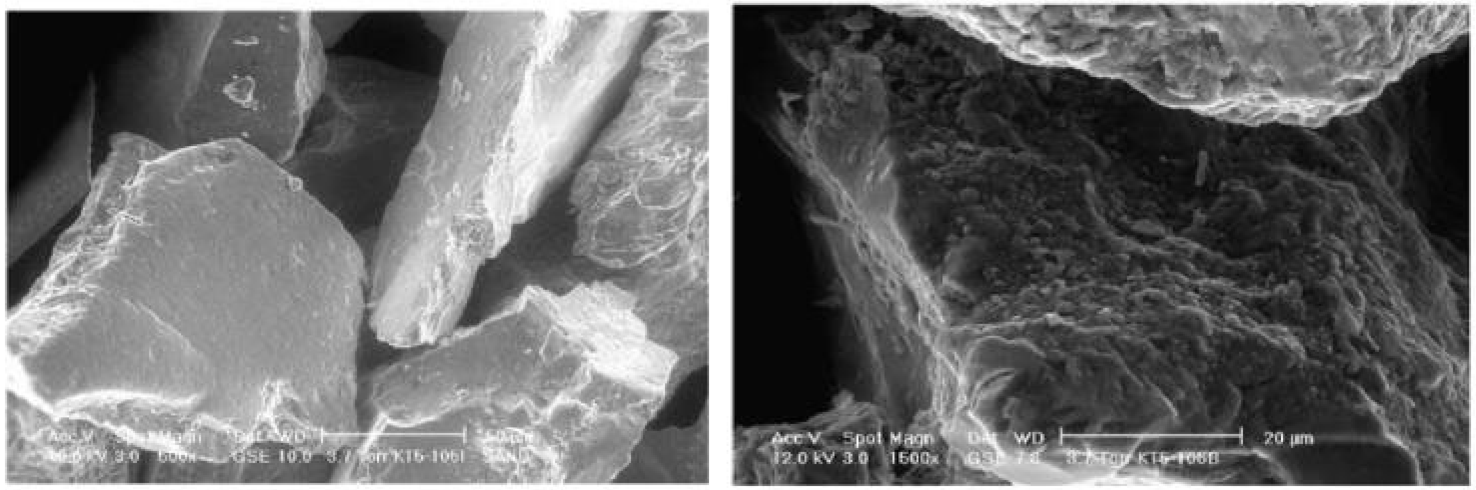
In Situ Adsorption

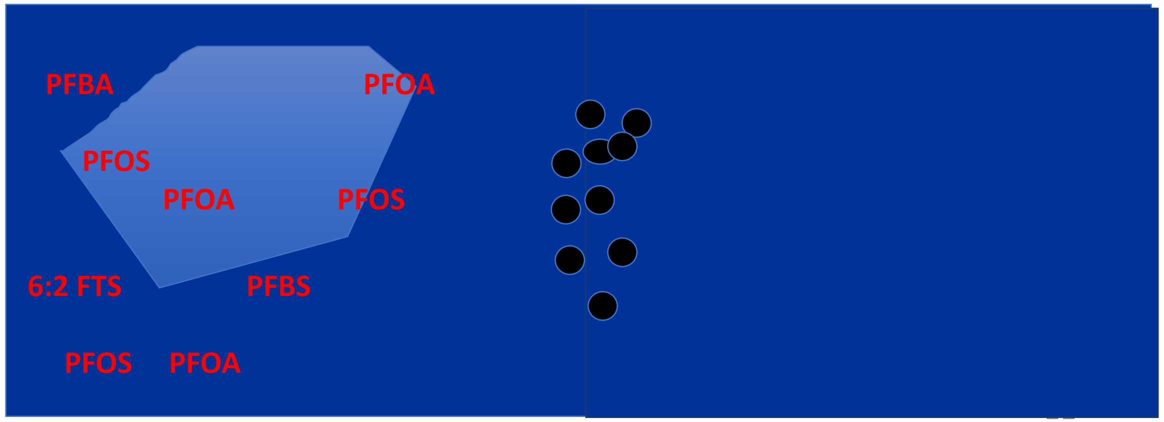
Colloidal Activated Carbon

Colliodal Activated Carbon (CAC) is being applied as an in situ adsorbent and sequestrant for **PFAS**





Micrographs courtesy of Regenesis



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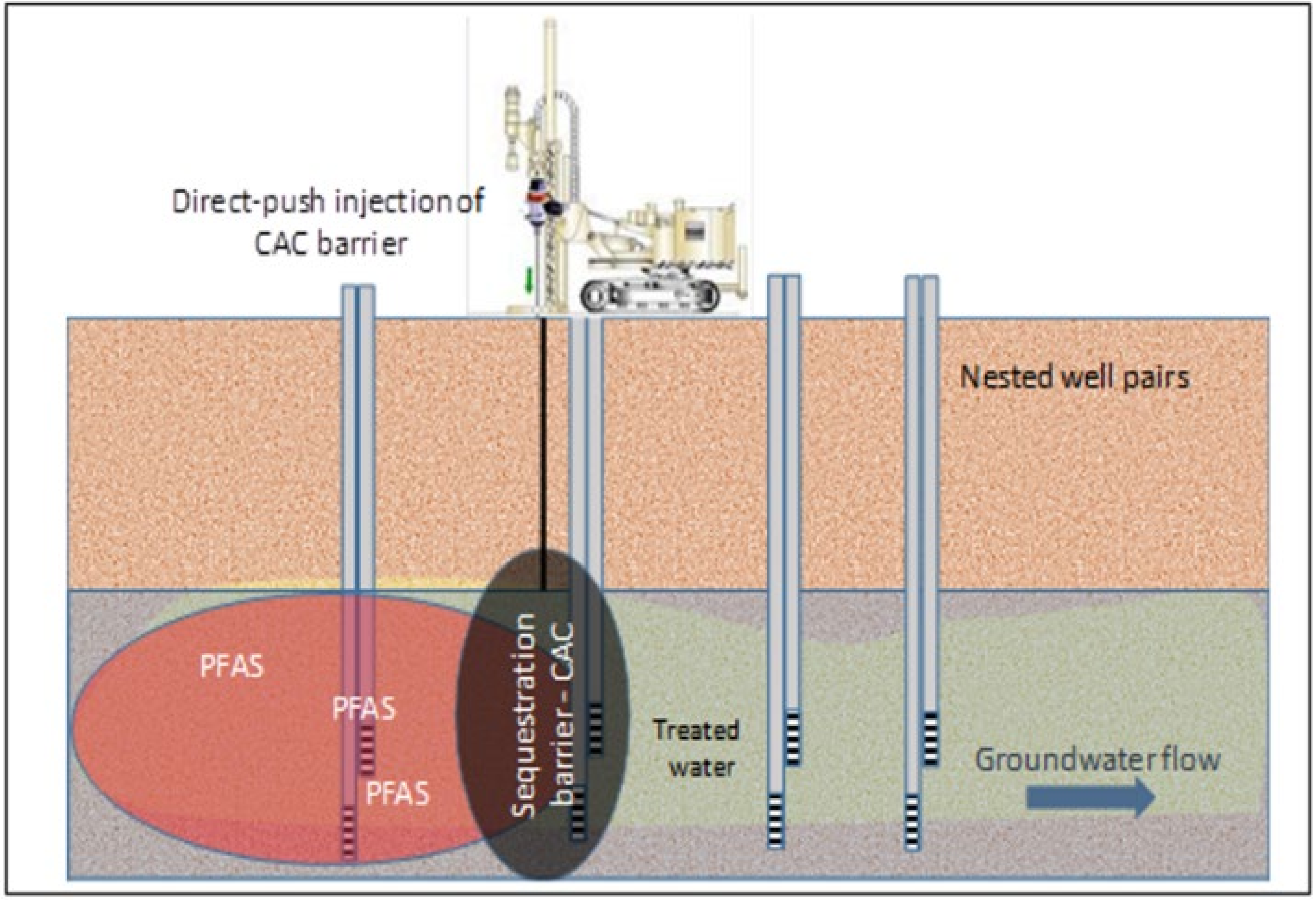
In Situ Adsorption - Colloidal Activated Carbon

Barrier Case Study

AFFF source area plume at US Navy site

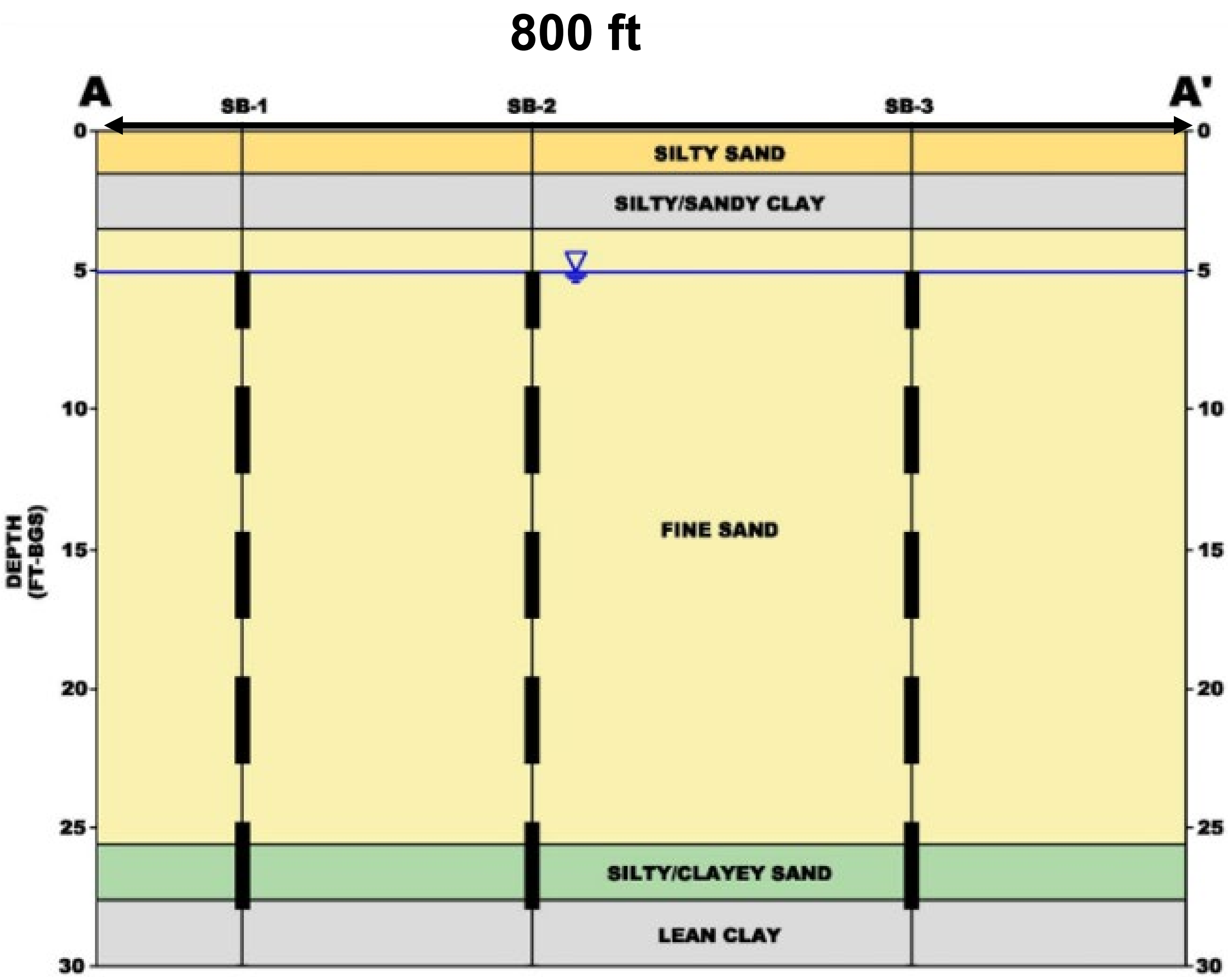


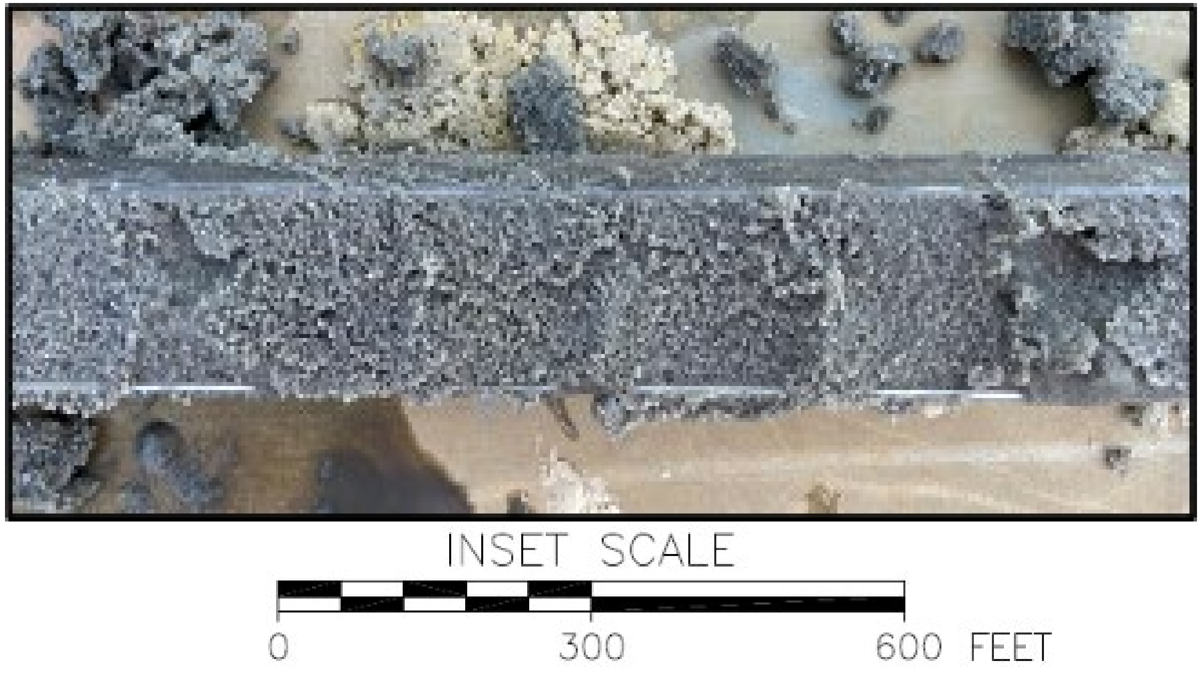
Project Tasks

- **Site assessment**
- **Laboratory column test**
- **Barrier design**
- **Barrier installation**
- **Groundwater sampling (24 Months)**
- **Core collection (before/after)**

In Situ Adsorption - Colloidal Activated Carbon

Site Assessment



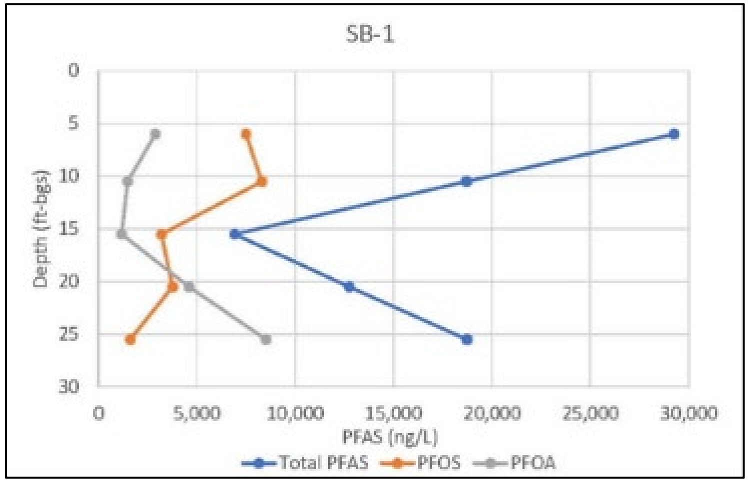


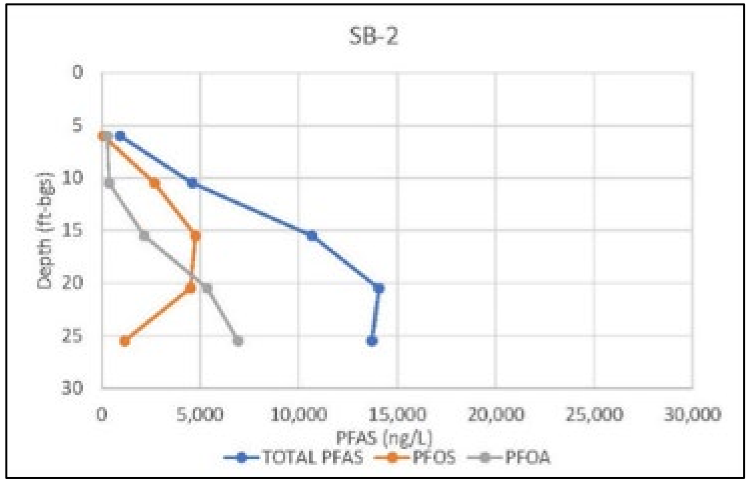
Site Characterization

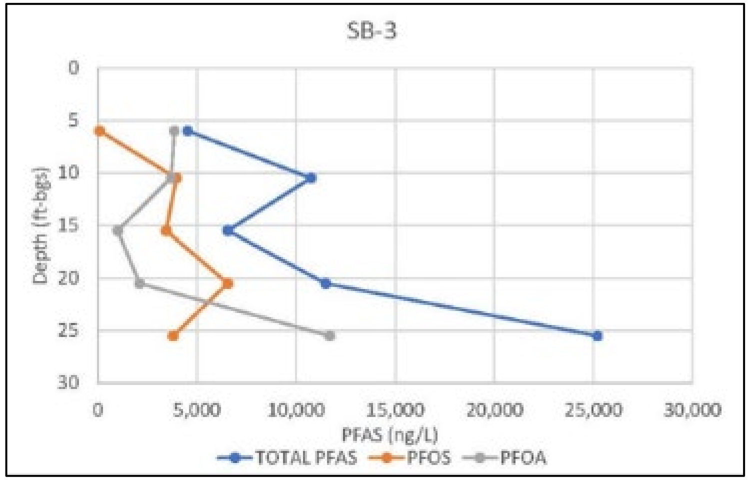
- Soil cores for lithology & labwork
- Discrete groundwater sampling

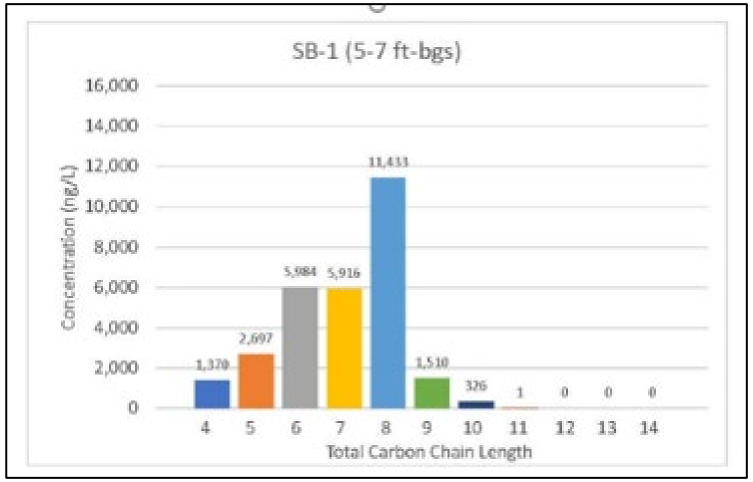
In Situ Adsorption - Colloidal Activated Carbon

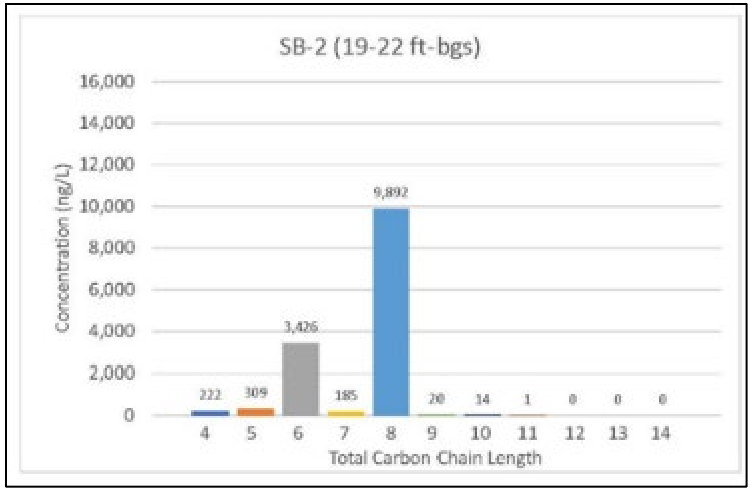
Site Assessment Results

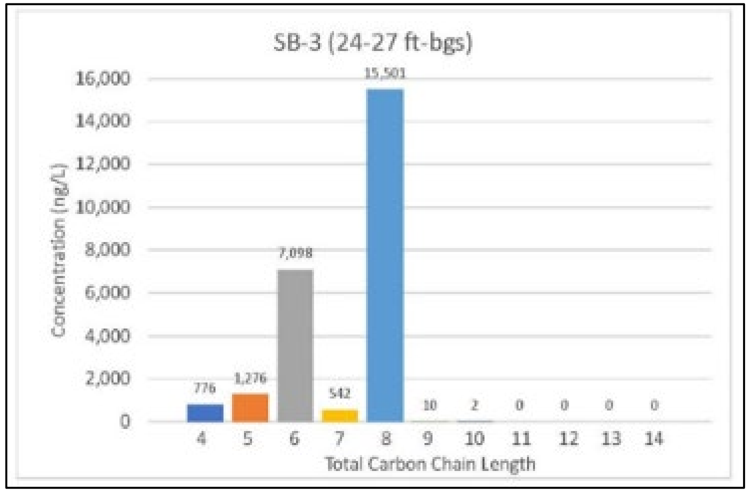












In Situ Adsorption - Colloidal Activated Carbon

Laboratory Column Testing

EVALUATE PFAS BREAKTHROUGH DURING 2 YRS SIMULATED GW TRANSPORT
QUANTIFY ORGANIC CARBON DISTRIBUTION

<u>Columns</u>

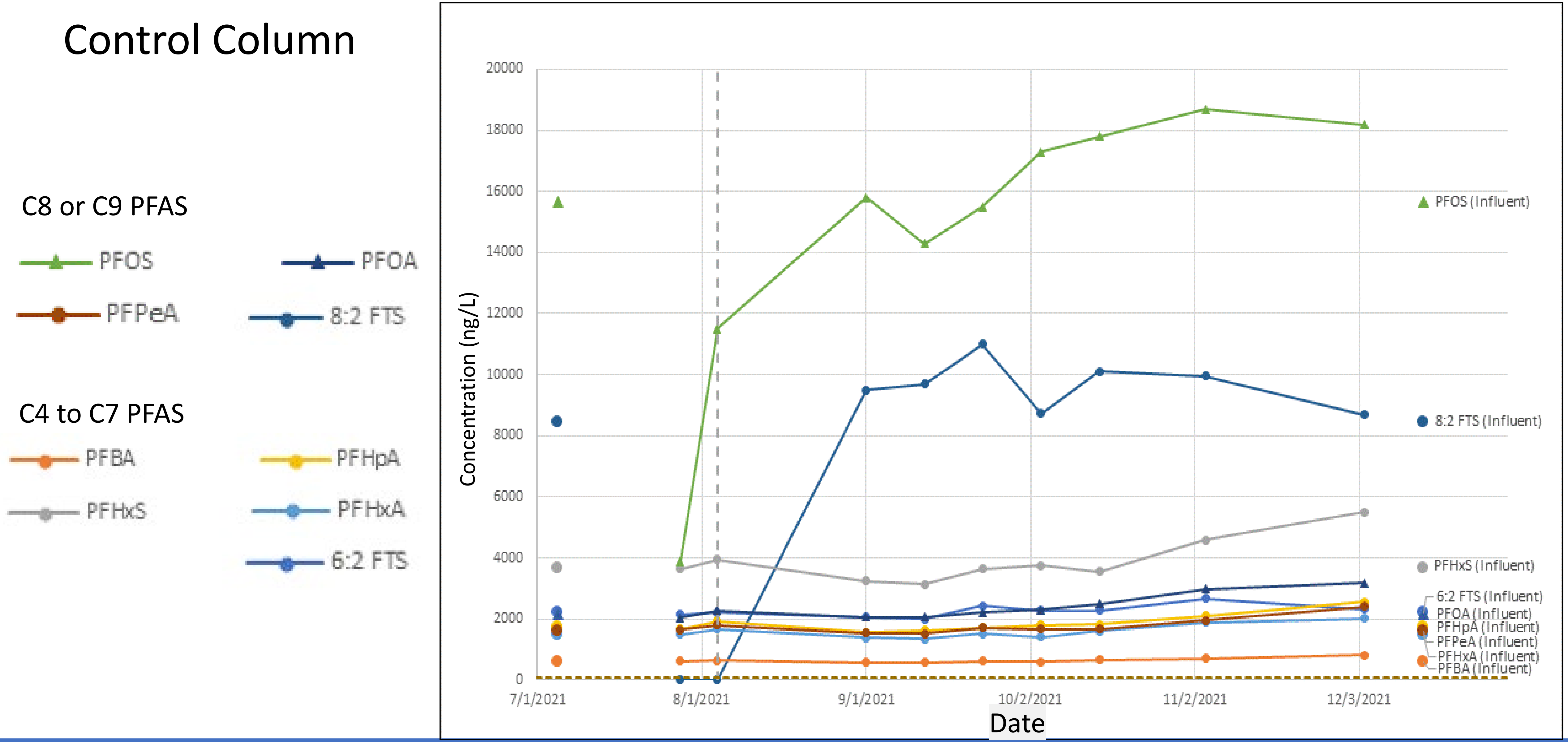
- Homogenized Site Sediment (SB-1)
- 30 cm x 3.5 cm diam
- ~ 100 mL pore volume
- GW – nearby well
- 1.6 mL/hr flow rate
- Simulate ~ 5.2 M/yr flow (1.5 mos)

<u>CAC Addition</u>

- 4% CAC in site groundwater
- 1.5 pore volumes added
- Flush until effluent clear

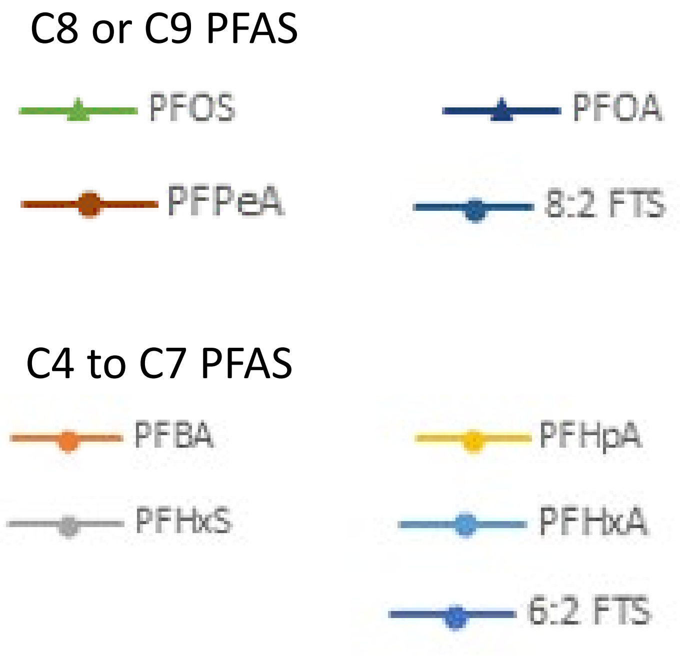
Column Test Results

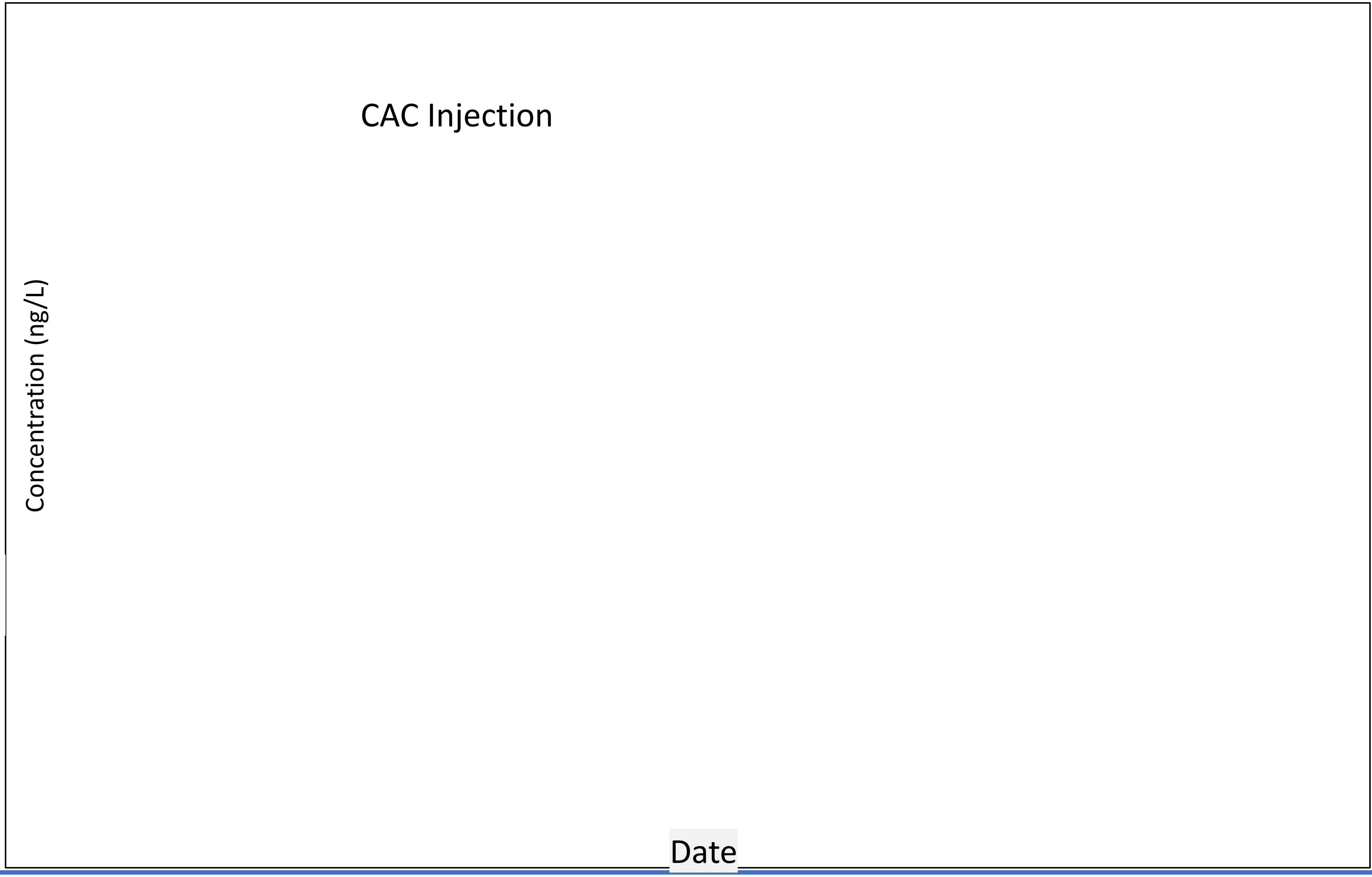
Control Column



Column Test Results

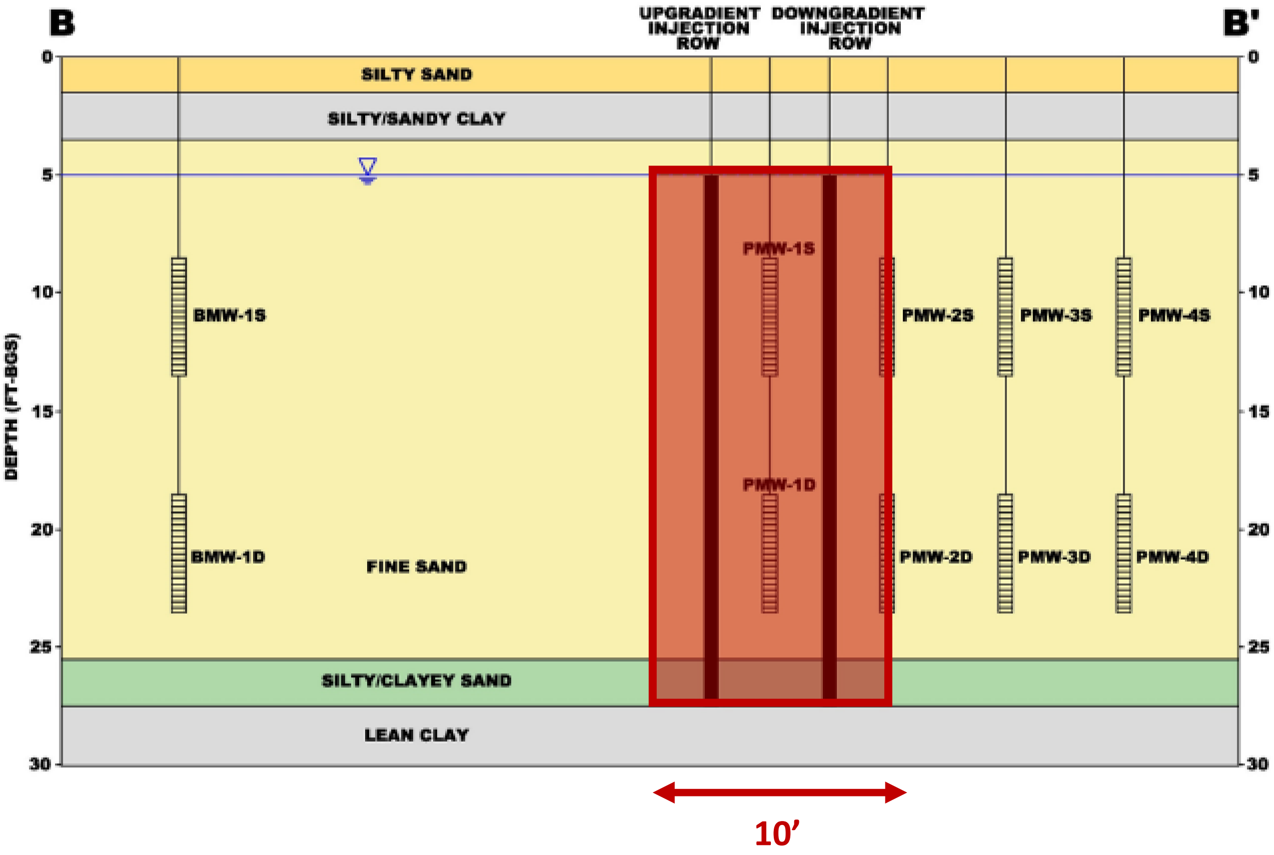
CAC-Treated Column

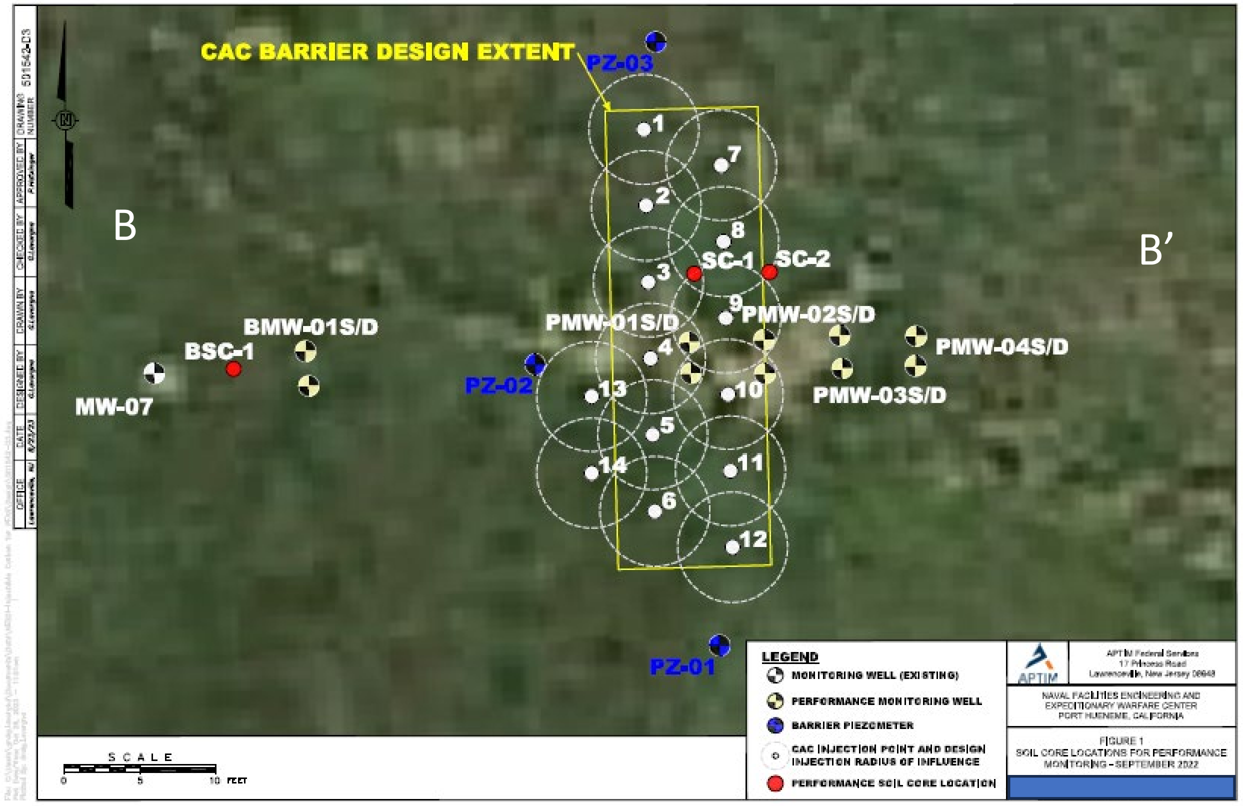




In Situ Adsorption - Colloidal Activated Carbon

Demonstration Well and Injection Point Lineup





- Target concentration = 2,000 mg carbon per kg of soil
- 12 injection points (30' x 10' x 27')

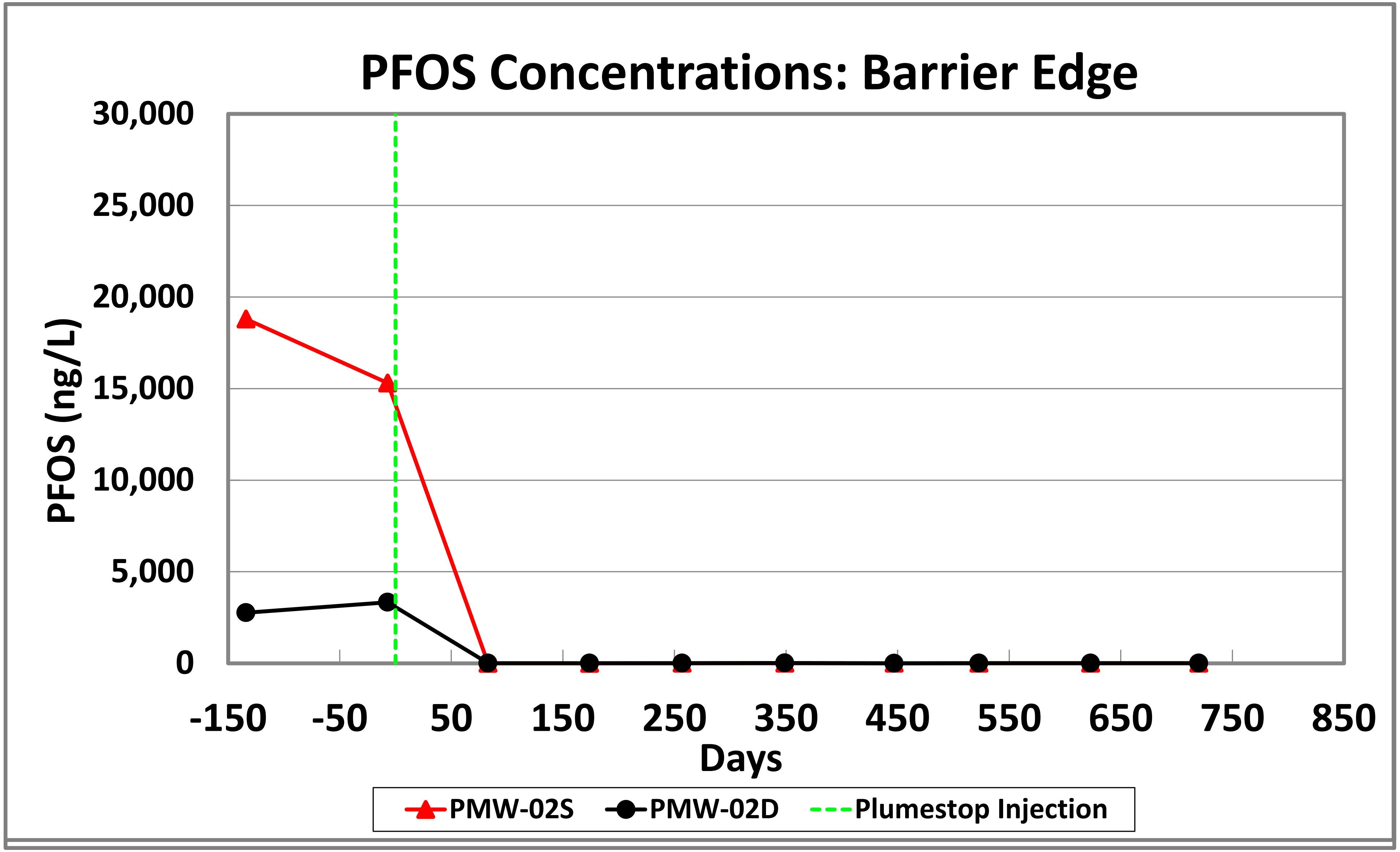
In Situ Adsorption

CAC Injection

Photos courtesy of Regenesis

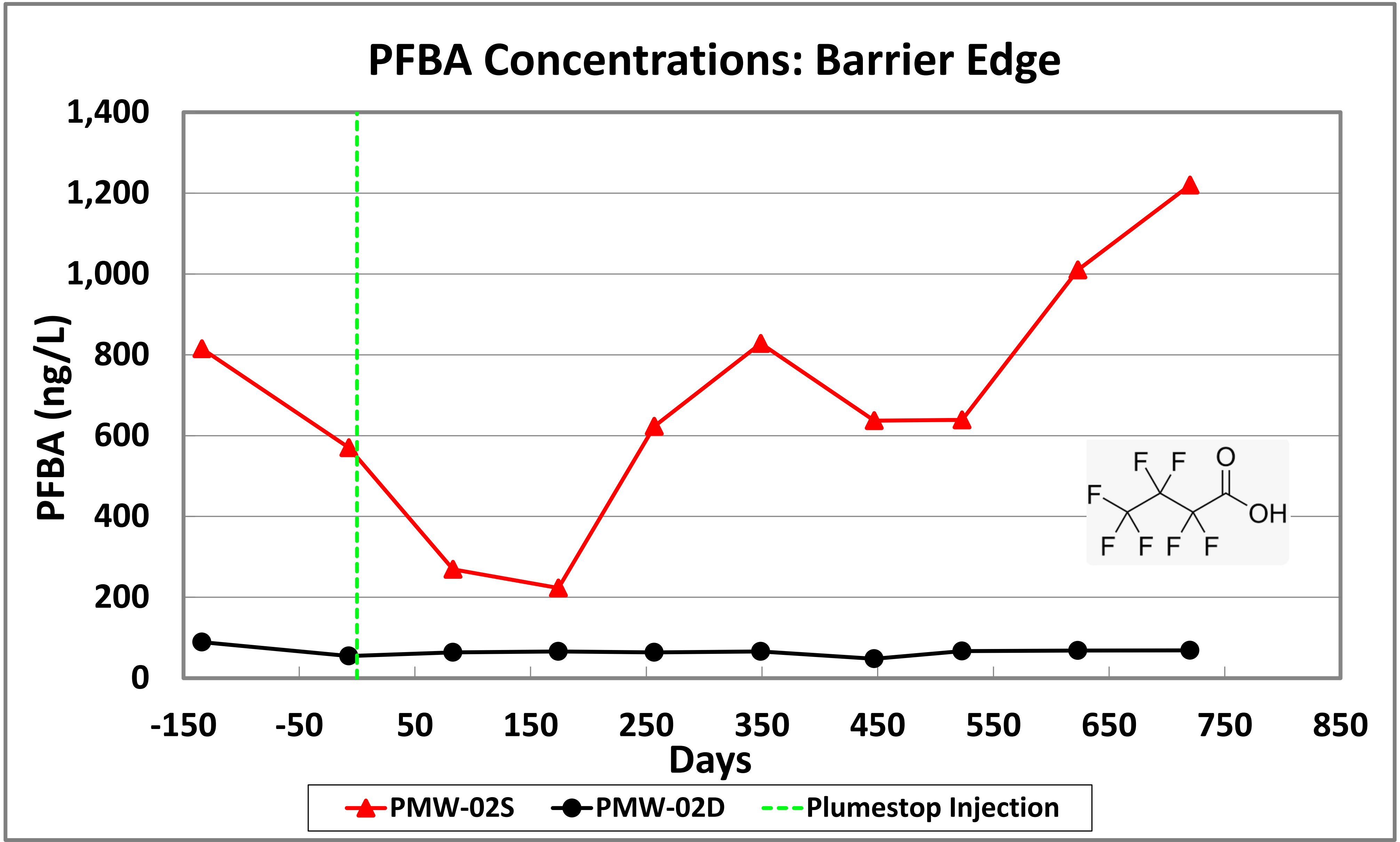
In Situ Adsorption

Barrier Performance



In Situ Adsorption

Barrier Performance



CAC Summary

CAC Injection represents a viable option to:

- ➢ Cut-off dilute PFAS plumes and protect downgradient receptors
- ➢ Reduce source area concentrations and downgrdient flux

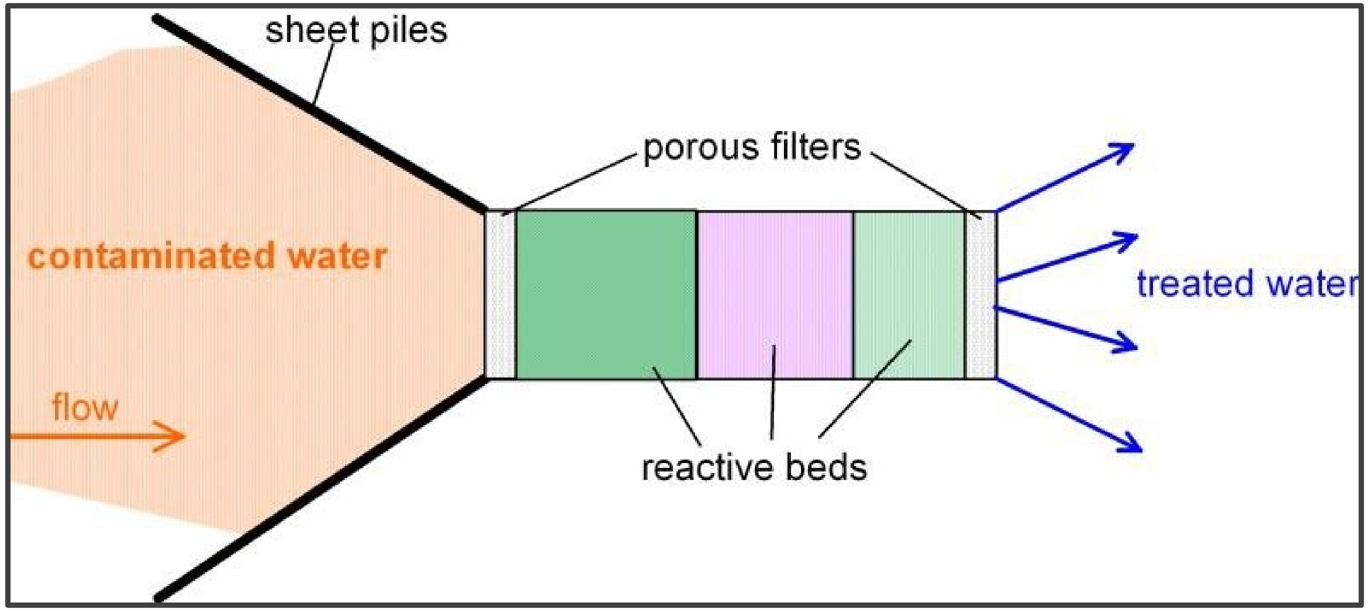
NESDI Field Study Results :

- ➢ Overall good CAC distribution in aquifer
- ➢ Good effectiveness for ~2 years overall: > 98% PFAS Reduction
- ➢ PFBA shows rapid breakthrough – not unexpected from isotherms
- ➢ No signs of hydraulic conductivity changes at 1 yr

In Situ Adsorption

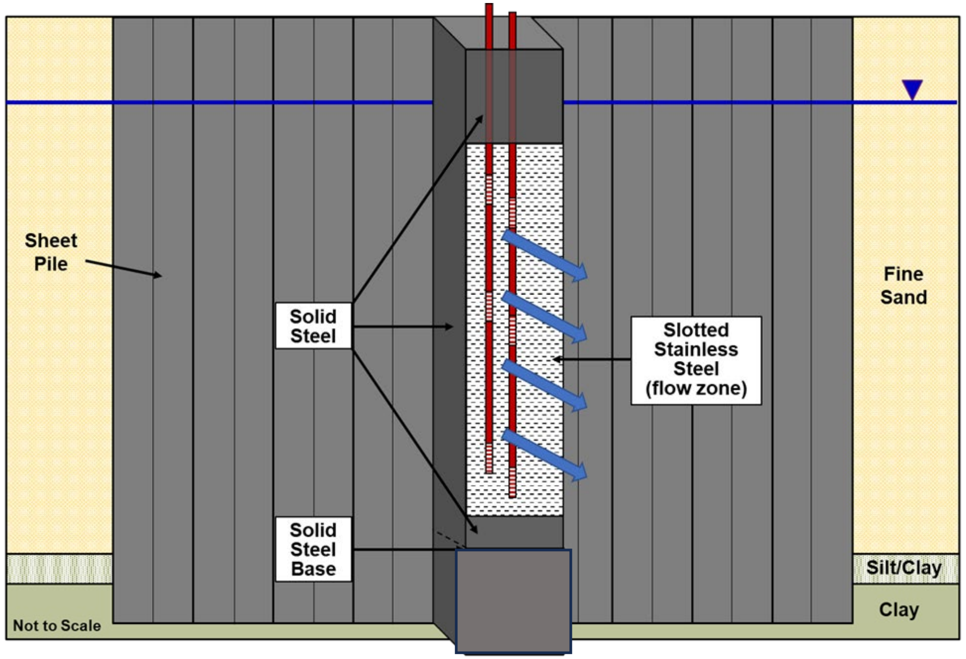
Funnel and Gate with Ion Exchange Resin

Overhead view of a funnel and gate system



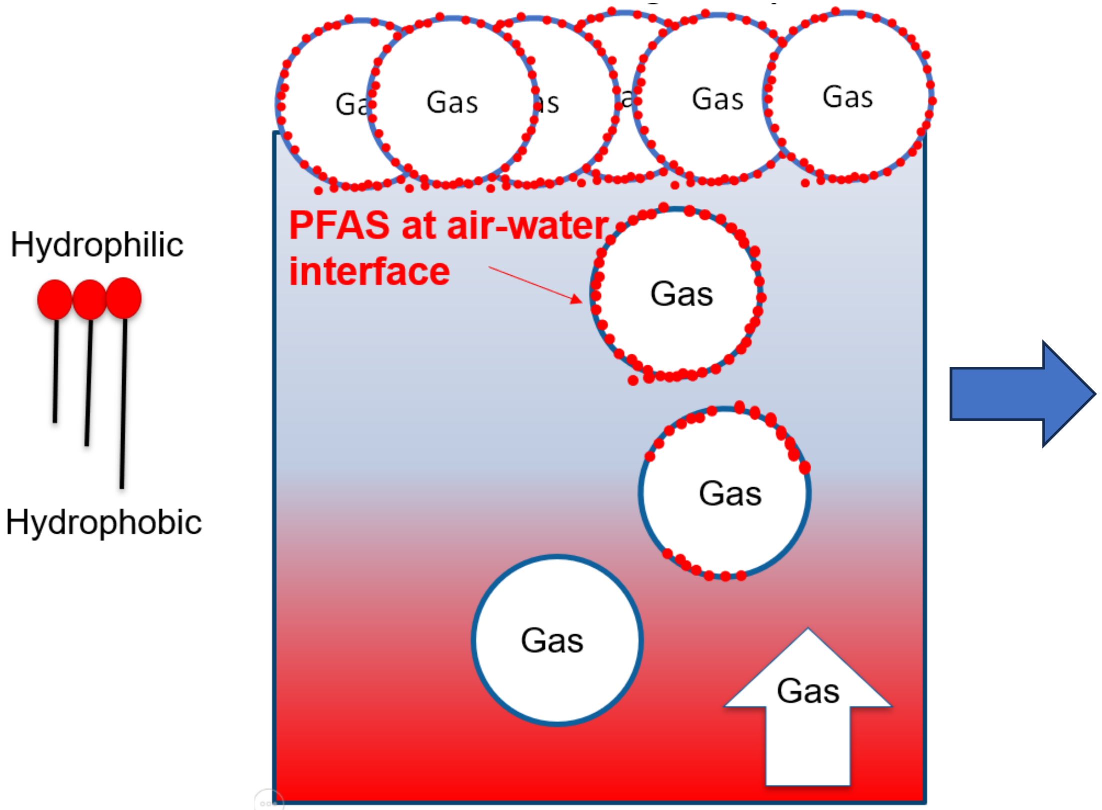
Source: Kouretzis, G. 2018.

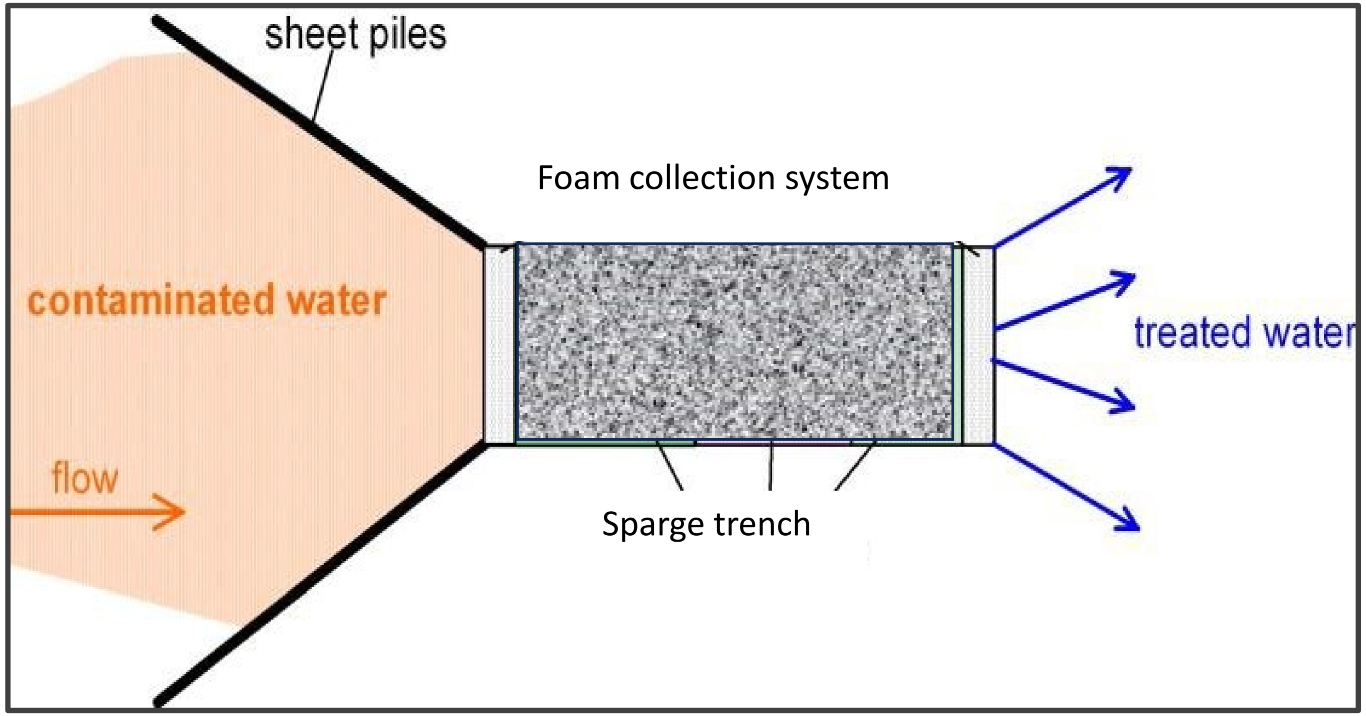
Front view of a funnel and gate system



In Situ Foam Fractionation

- ➢ Application of foam fractionation in a trench barrier
- ➢ Pilot scale testing ongoing





Modified from: Kouretzis, G. 2018.

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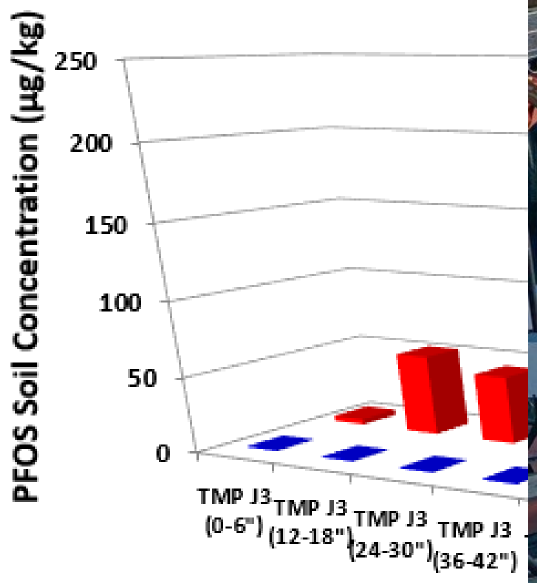
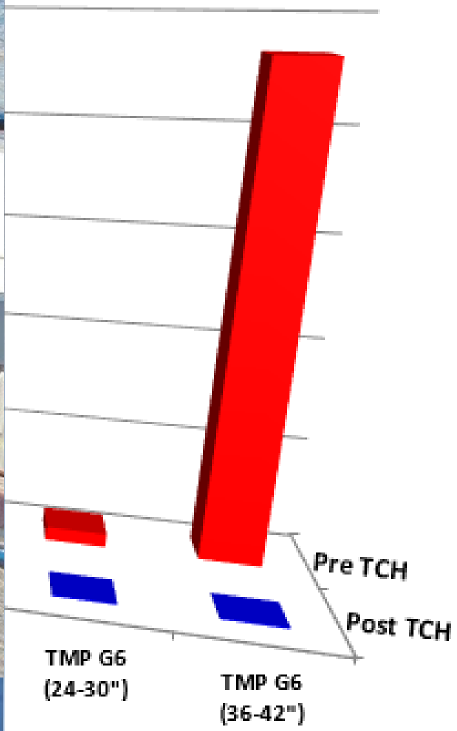
In Situ Thermal

- Application primarily to soils, but also applicable to shallow groundwater
- Thermal drives off PFAS via volatilization
- PFAS in vapor captured aboveground
- Pilot scale





Photos and data courtesy of Mark Kluger, TRS

Questions?

More information
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SERDP ESTCP

https://serdp-estcp.mil/projects

Powerpoint stock image

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