REGENESIS®

YOUR EXPERT SOURCE FOR COMPLETE SOIL AND GROUNDWATER REMEDIATION

Chad Northington, PE
Southeast District Manager

Eliminating Risk of PFAS Contamination: In Situ Remediation with Colloidal Activated Carbon

Chad Northington, PE
Southeast District Manager

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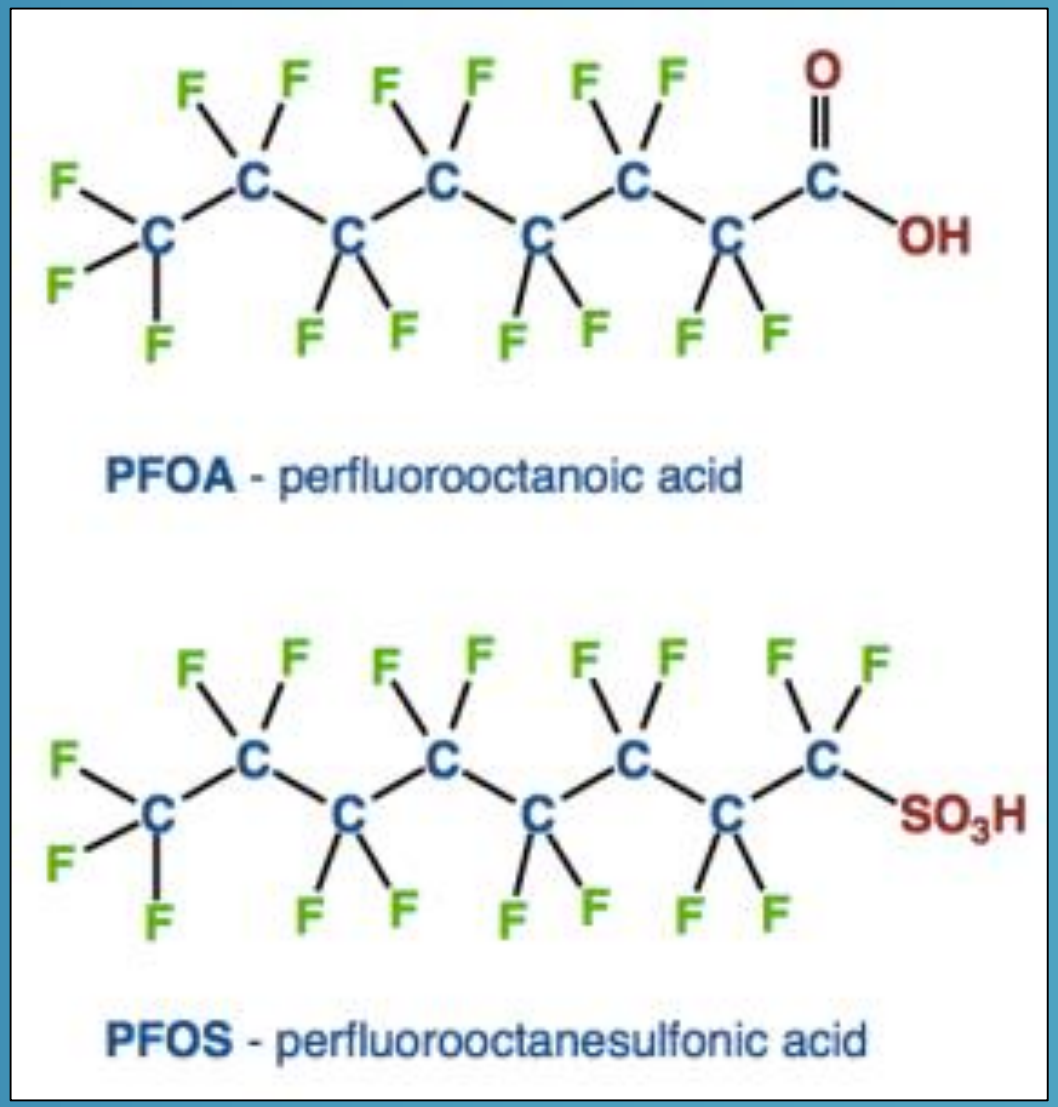
Per- and Polyfluoroalkyl Substances: PFAS

- Complex mixture of fluorinated compounds
  PFOS & PFOA (C8 species) are best known
- Have been used in many consumer products, fire fighting foams
- Probable links to human health issues



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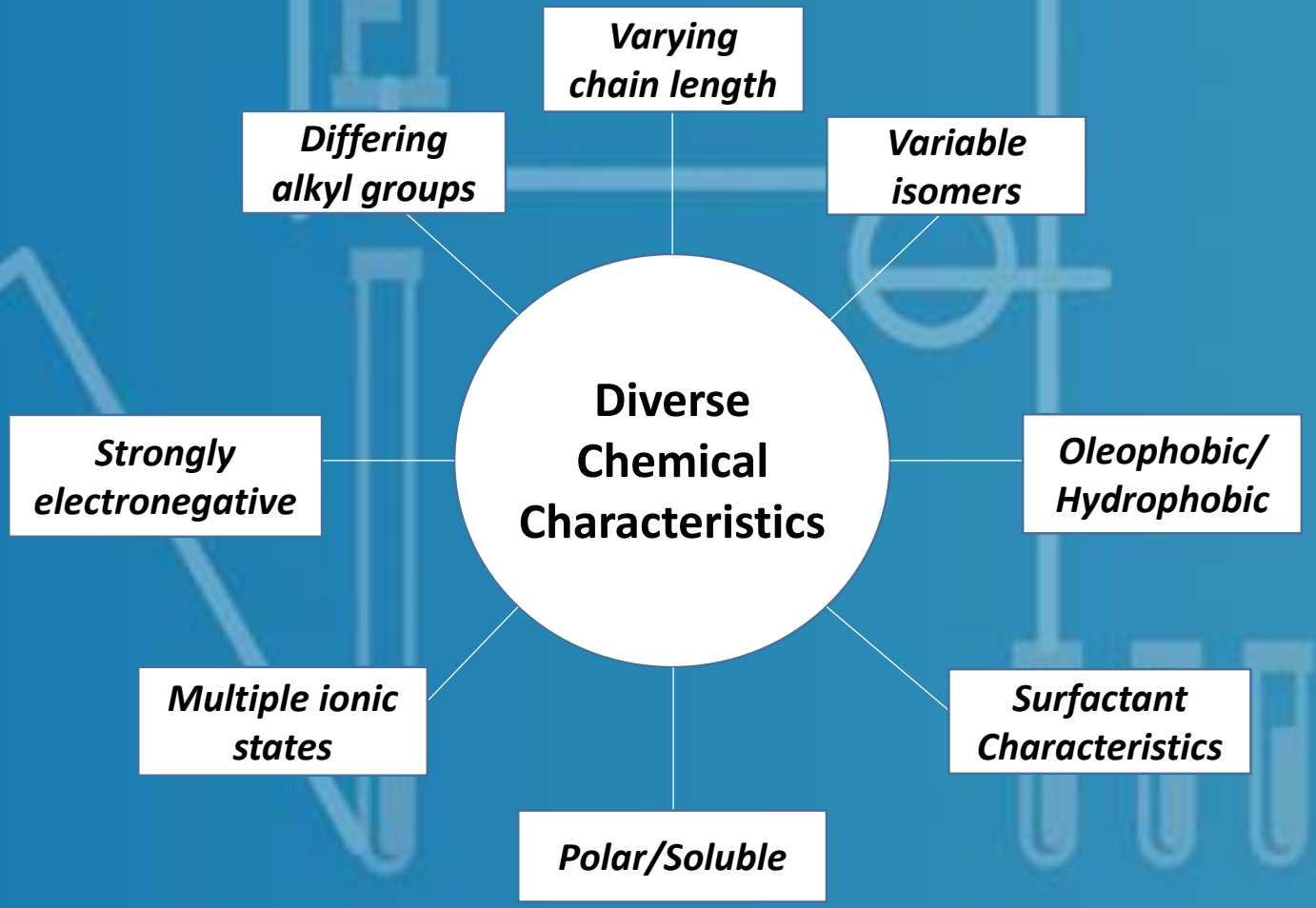
Water Treatment Obstacles

Non-Technical:

- Moving regulatory target
- Prioritization – where do we start?
- Public awareness & sensitivity
- Are closed sites closed?

Technical:

- 5,000+ compounds!
- Toxicological understanding
- Commingled plumes/co-contaminants
- Resistance to conventional treatment
- Parts per trillion criteria



Current State of Treatment for PFAS

Field-Demonstrated:

- Sorption (activated carbon/anionic resins)
- Membrane filtration/reverse osmosis
- Precipitation/flocculation/coagulation

Lab, Bench or Pilot Scale:

- Polymeric Adsorbents
- Electrochemical
- Incineration
- AOP/ARP
- Photolysis and Sonolysis

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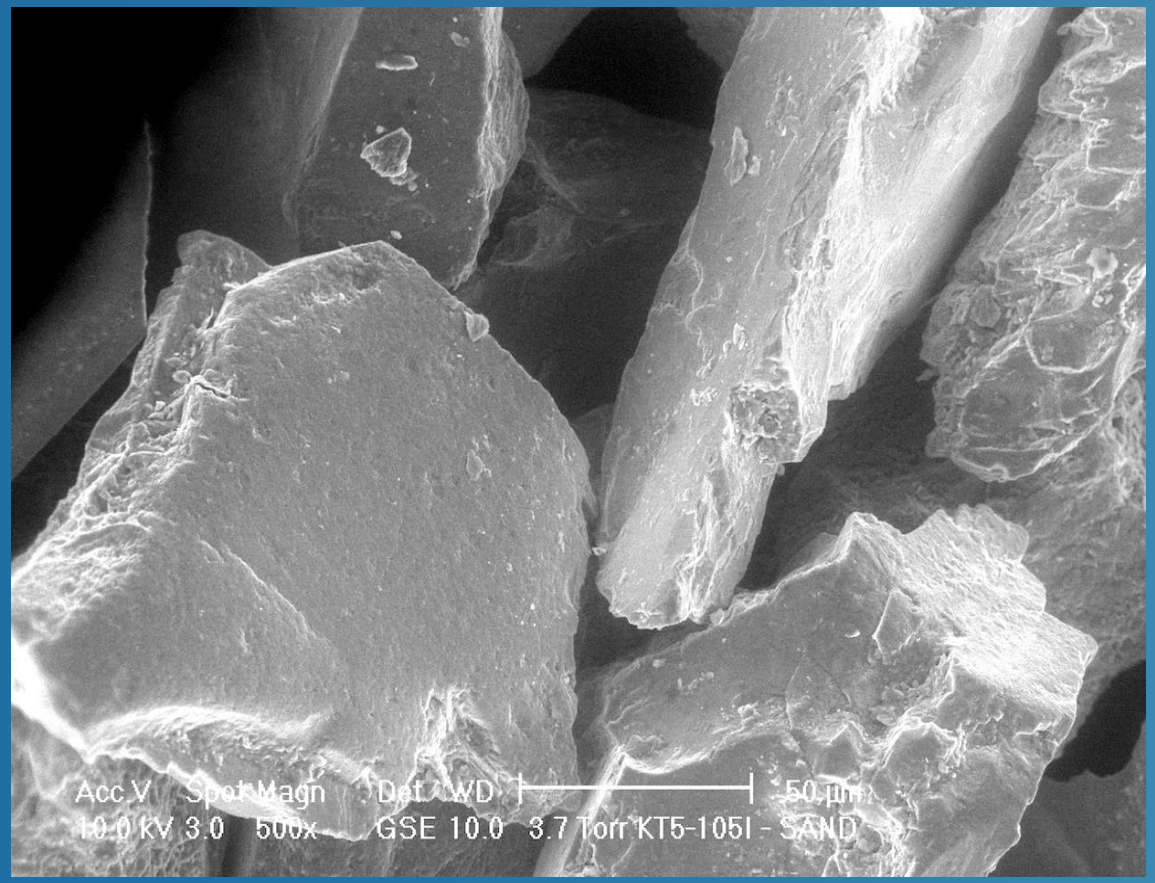
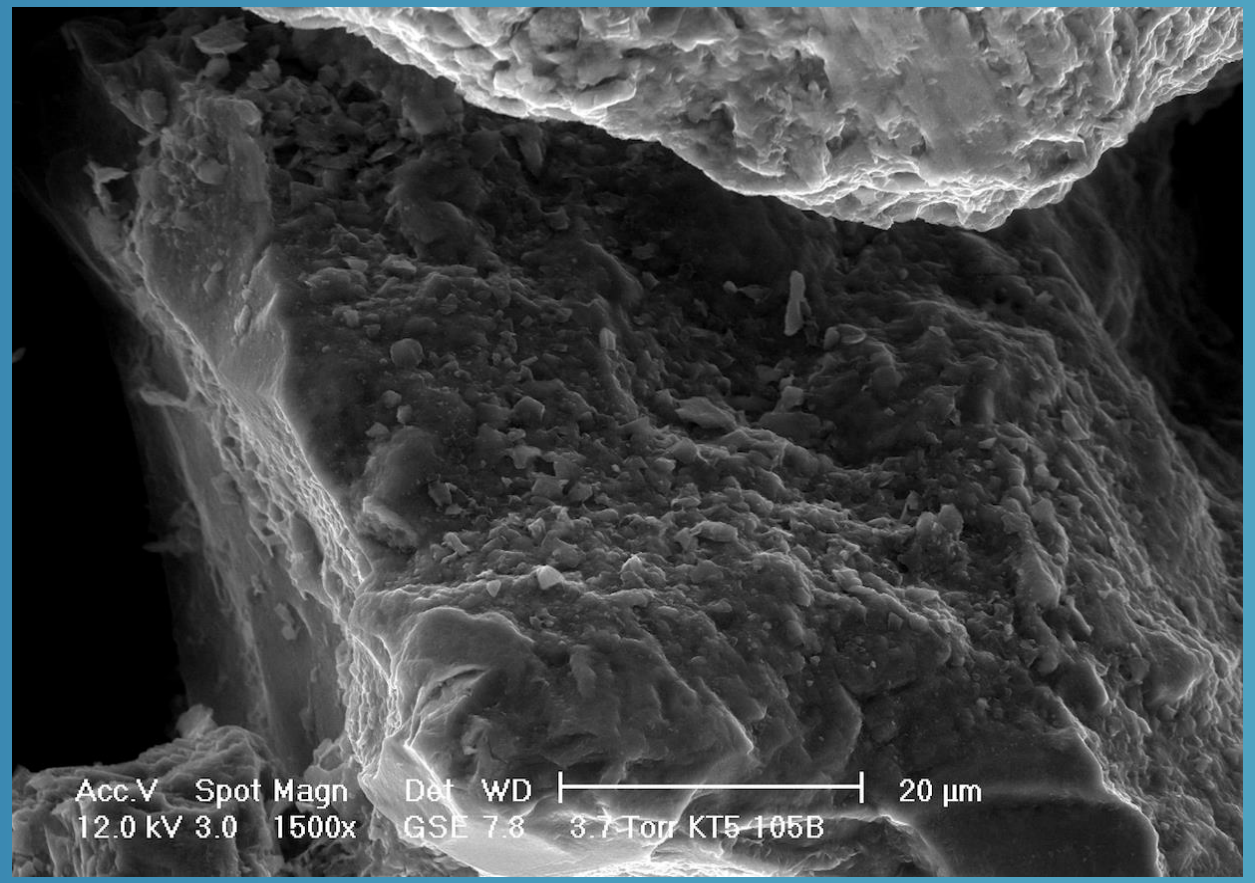
COLLOIDAL CARBON – REAGENT DISTRIBUTION

SEM image of Sand Particles Without and With Colloidal Activated Carbon





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PLUME STOP®
Liquid Activated Carbon

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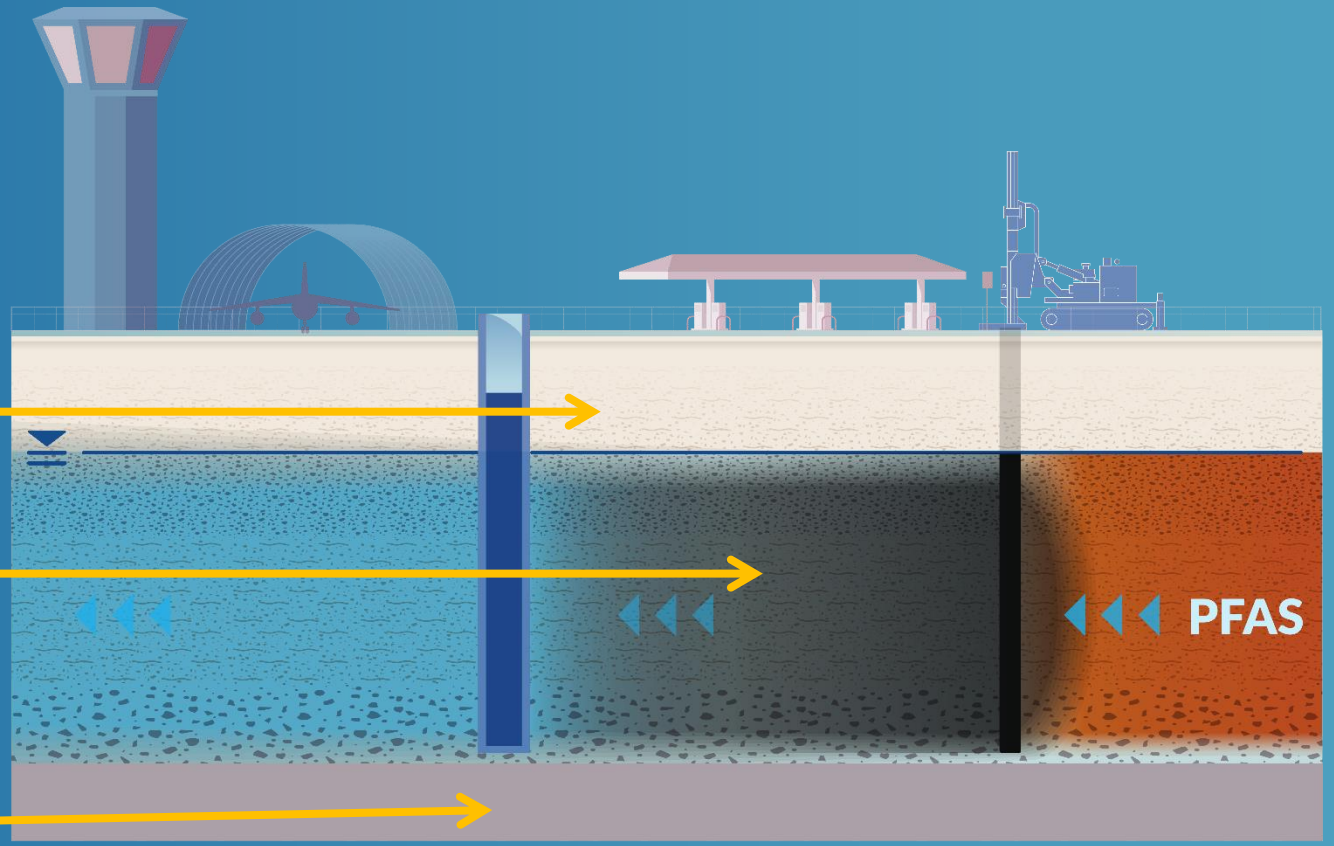
PlumeStop Distribution Confirmation



DTW ranged from 16-17.5'
throughout the site.

Clay layer is ~26'
based on our soil borings.

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COLLOIDAL ACTIVATED CARBON APPLICATION

- Commonly Used For:
  - Rapid compliance achievement
  - Coupled sorption and bio
    - Sorbed contaminants are biodegraded upon carbon surface
    - Daughter products contained during degradation
  - Back diffusion management
- Passive Management of Large Plumes (i.e. Control Without Pumping)

PASSIVE MANAGEMENT OF GROUNDWATER PLUMES LONG-TERM

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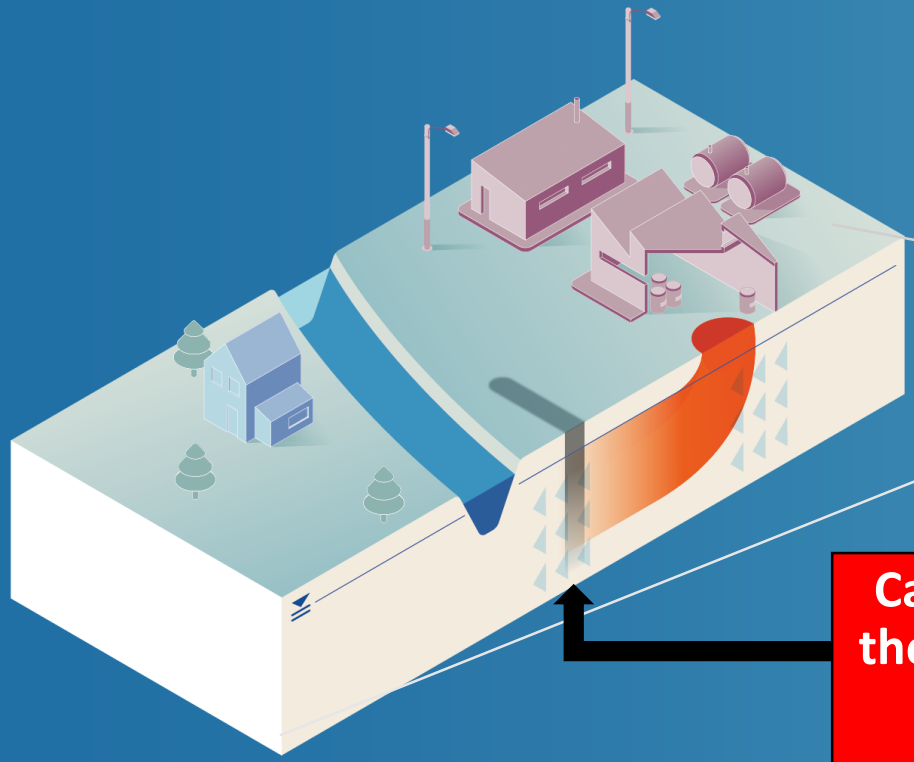
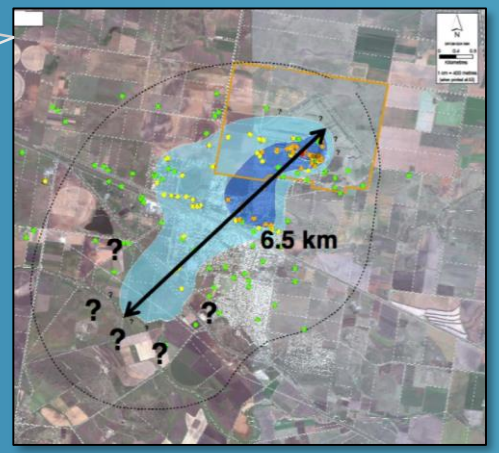
Sensitive Receptors at Risk

- Bodies of water
- Drinking water supplies
- Neighborhoods
- Property Boundaries



Can we protect these areas with an *in situ* barrier?



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ELIMINATE THE RISK FROM PFAS

Environmental RISK = (PFAS) X (Exposure)

Attributed to Dr. Frank Lawrence, ELD, Portland Maine

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ELIMINATE THE RISK FROM PFAS

- "Risk-Based Corrective Action" is commonplace throughout world since 1990's

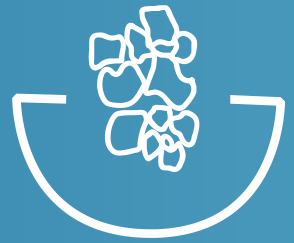
- "No Further Action" granted if plume not expanding and no receptor impacted (water well or surface water)

ELIMINATE THE RISK FROM PFAS

Examples of common “Risk-Based” no further actions granted:

Gas stations
with benzene, PAHs

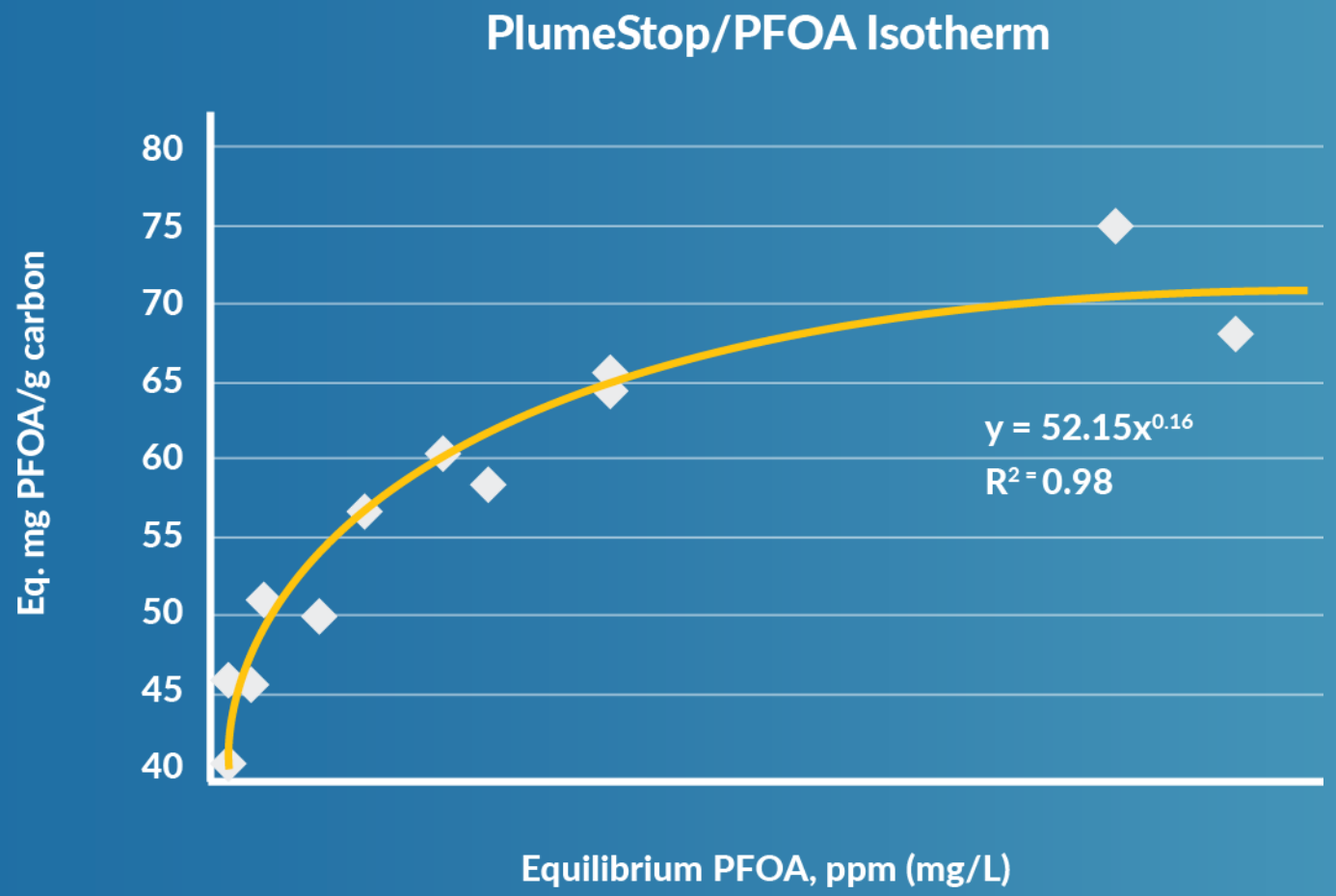
Chromium Plumes
treated with reducing agents



PCB Sediments
treated with activated carbon

PCE Sites

Colloidal Activated Carbon + PFOA/PFOS



	Kf	1/n	PS dose, mg/L: 5 ppm -> .005 ppm
PFOA	52	0.16	**224**
PFOS	135	0.28	**163**
PCE	105	0.42	**445**

Sorption only
(currently no validated destruction methods are available)

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REGENESIS R&D LAB

Should we expect GAC and PlumeStop to work the same?

What about the shorter chain PFAS species, will they adsorb to PlumeStop?

- Lab studies
- Bench test with groundwater from an Italian site

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ACTIVATED CARBON PARTICLE SIZE AND ADSORPTION EFFICACY

- Recent study demonstrated 2 OoM improved removal with smaller activated carbon particles
  - 180–500 µm AC removed 90% PFOS
  - <53 µm AC removed 99.9+% PFOS
- *GAC particles are less efficient at adsorbing PFAS than PlumeStop because of their size

[a]Xiao, Ulrich, Chen & Higgins. Environ. Sci. Technol. 2017, 51, 6342.

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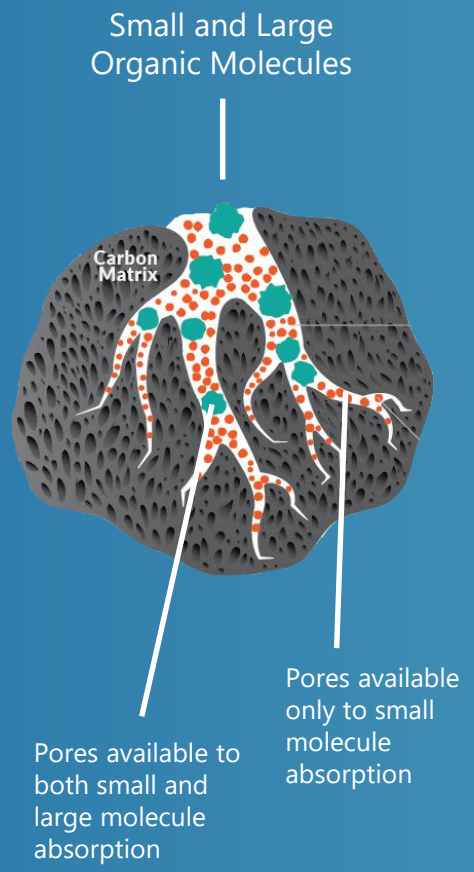
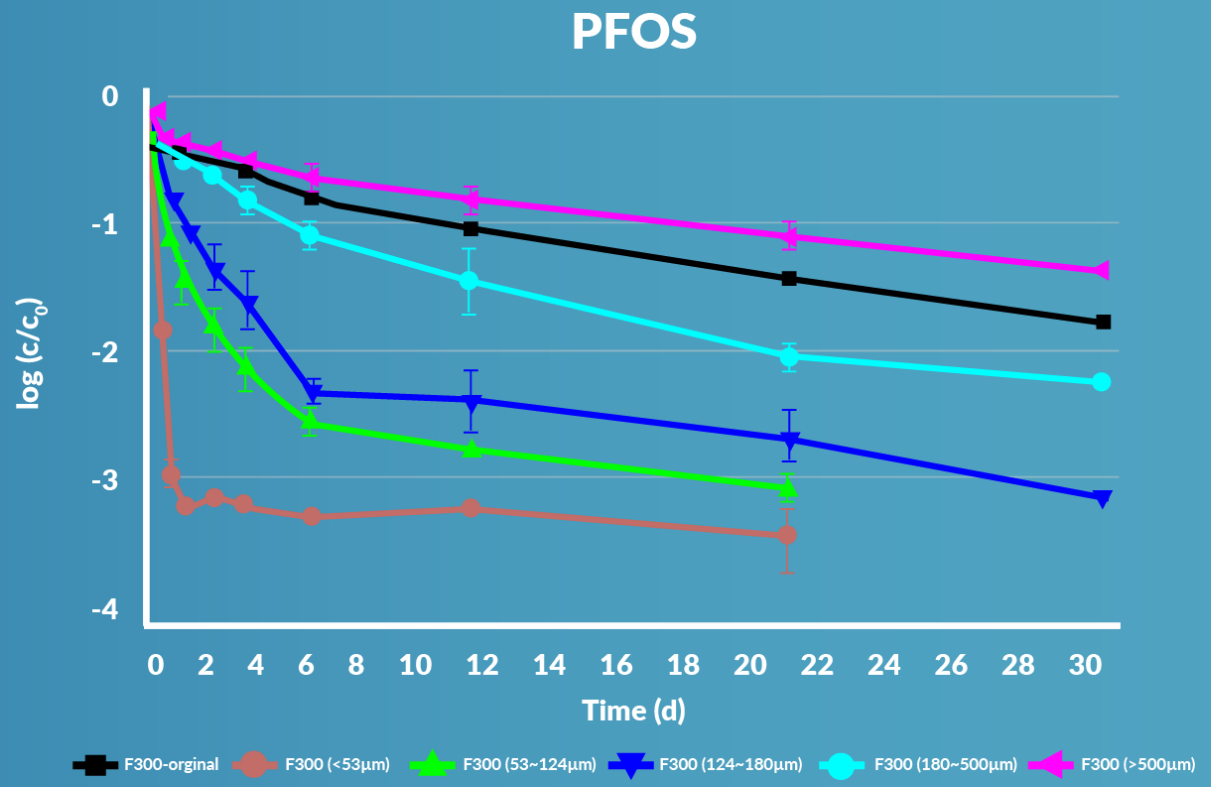
PFAS ADSORPTON KINETICS & PARTICLE SIZE

- The reason can be attributed to kinetics: intraparticle diffusion
- Smaller particles provide better access to all the sorption sites that activated carbon provides.





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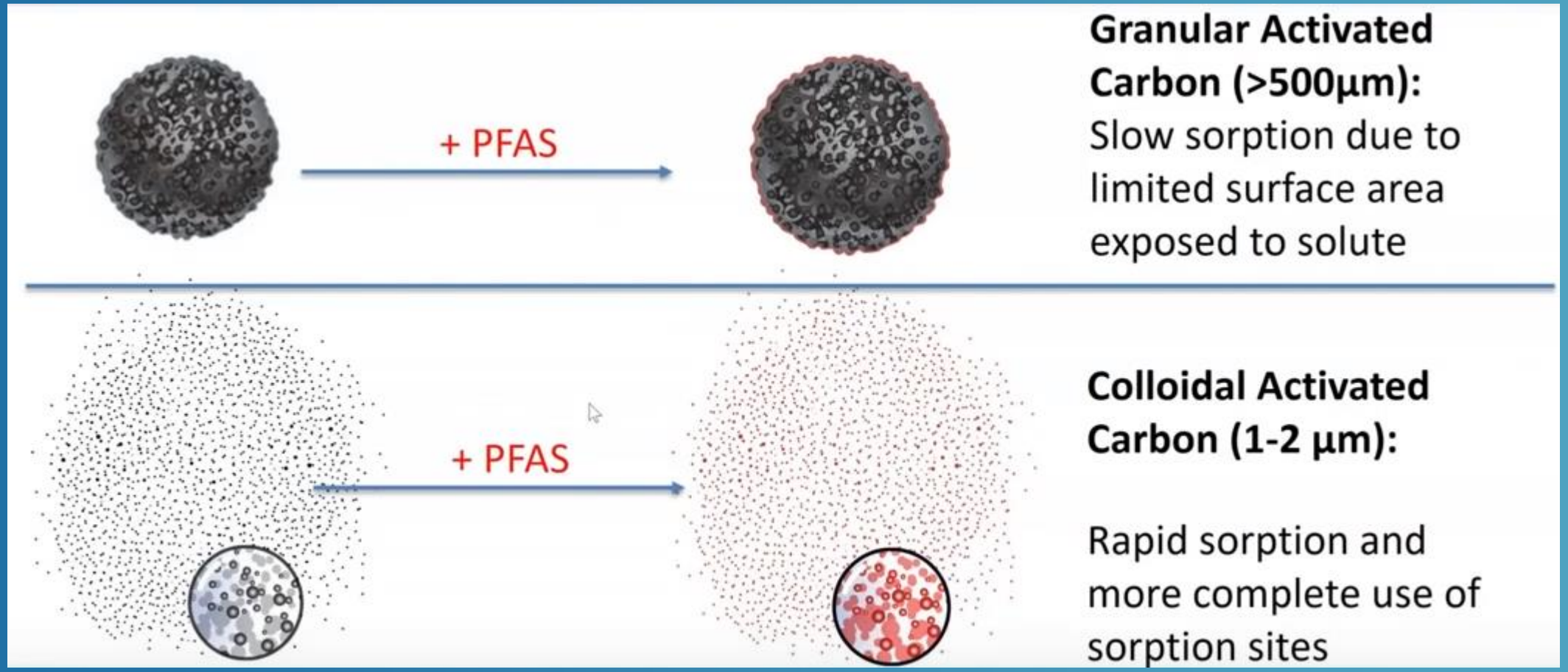
PFAS ADSORPTON KINETICS & PARTICLE SIZE



Granular Activated Carbon (>500µm):
Slow sorption due to limited surface area exposed to solute

Colloidal Activated Carbon (1-2 µm):

Rapid sorption and more complete use of sorption sites

REGENESIS R&D LAB

Should we expect GAC and PlumeStop to work the same?

What about the shorter chain PFAS species, will they adsorb to PlumeStop?

- Lab studies
- Bench test with groundwater from an Italian site

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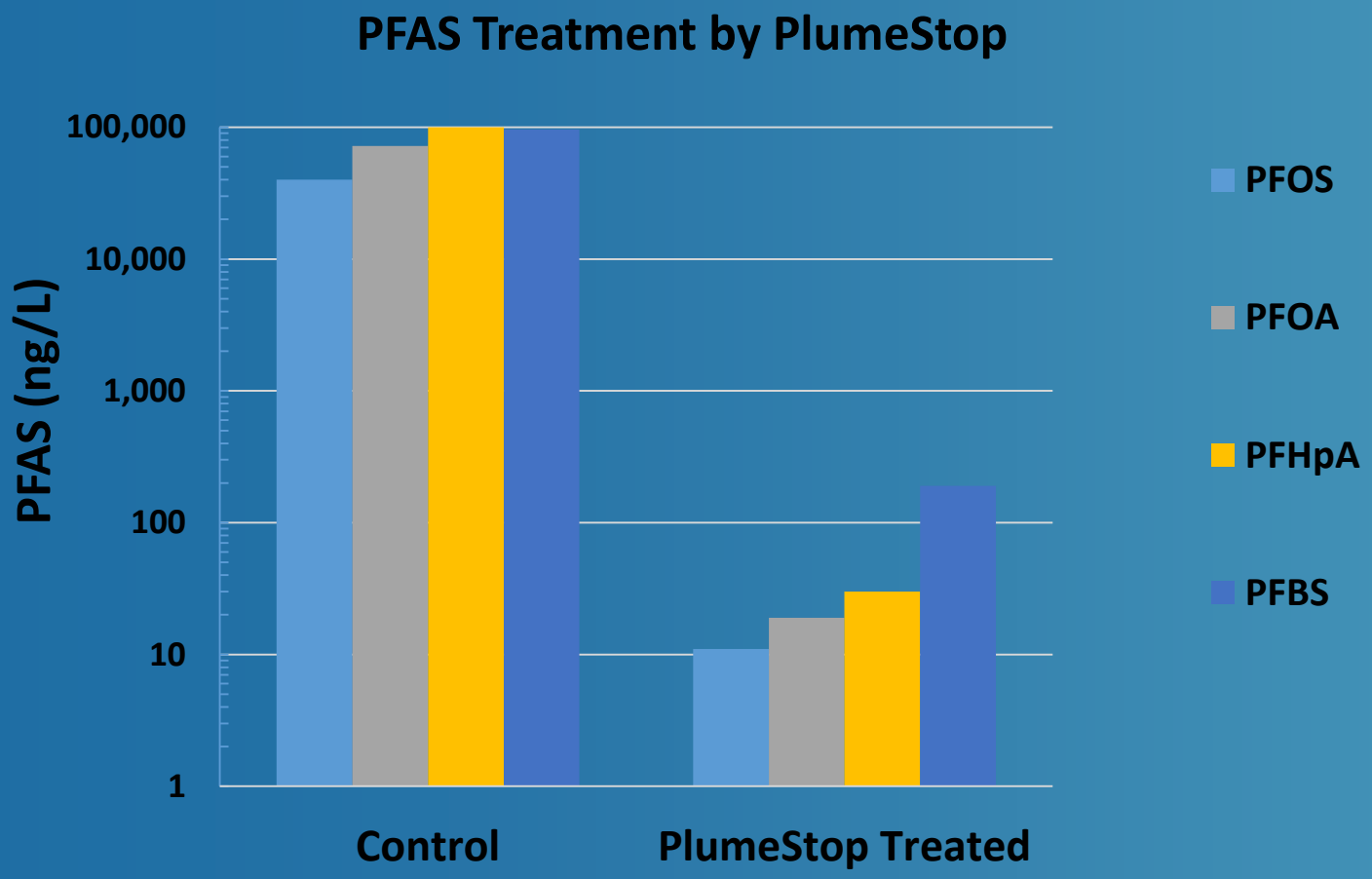
PlumeStop & Shorter Chain PFAS Compounds



Batch sorption test

- PFOA (C8 chain)
- PFOS (C8 chain)
- PFHpA (C7 chain)
- PFBS (C4 chain)

Relative sorption:

- PFOS > PFOA > PFHpA > PFBS
- PFBS will breakthrough first
  - PFBS *was* removed from 96,000 ng/L to 190 ng/L
  - 99.8% sorption

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PLUMESTOP PERFORMANCE SITE WATER BATCH TEST

		Baseline		Control		Treated	
Analyte (ng/L)	Units	Baseline 1	Baseline 2	Control 1	Control 2	Treated 1	Treated 2
4:2 fluorotelomersulfonate	ng/l	210	230	280	260	< 0.96	< 0.95
6:2 fluorotelomersulfonate	ng/l	6,900	7,600	7,800	7,800	< 2.9	< 2.9
8:2 fluorotelomersulfonate	ng/l	200	190	240	210	< 1.9	< 1.9
Perfluoro-octanesulfonate	ng/l	8,300	8,300	9,300	8,700	< 0.39	< 0.38
Perfluorobutanesulfonate	ng/l	78	75	89	85	< 0.29	< 0.29
Perfluorobutanoic acid	ng/l	920	930	950	880	34	34
Perfluorodecanoic acid	ng/l	< 10	< 9	9.4	< 8.8	< 0.96	< 0.95
Perfluoroheptanesulfonate	ng/l	94	99	93	94	< 0.39	< 0.38
Perfluoroheptanoic acid	ng/l	1,200	1,200	1,500	1,300	< 0.29	< 0.29
Perfluorohexanesulfonate	ng/l	1,700	1,800	2,000	2,100	< 0.39	< 0.38
Perfluorohexanoic acid	ng/l	4,500	4,600	5,200	5,000	< 0.39	< 0.38
Perfluorononanoic acid	ng/l	570	590	610	620	< 0.39	< 0.38
Perfluorooctanoic acid	ng/l	990	1,000	1,100	1,100	< 0.29	< 0.29
Perfluoropentanesulfonate	ng/l	110	100	110	110	< 0.39	< 0.38
Perfluoropentanoic acid	ng/l	7,800	7,700	9,000	8,000	< 1.9	< 1.9
Perfluoroundecanoic acid	ng/l	5	5	4.8	3.9	< 0.39	< 0.38
Total PFAS		**33,577**	**34,419**	**38,286**	**36,263**	**34**	**34**

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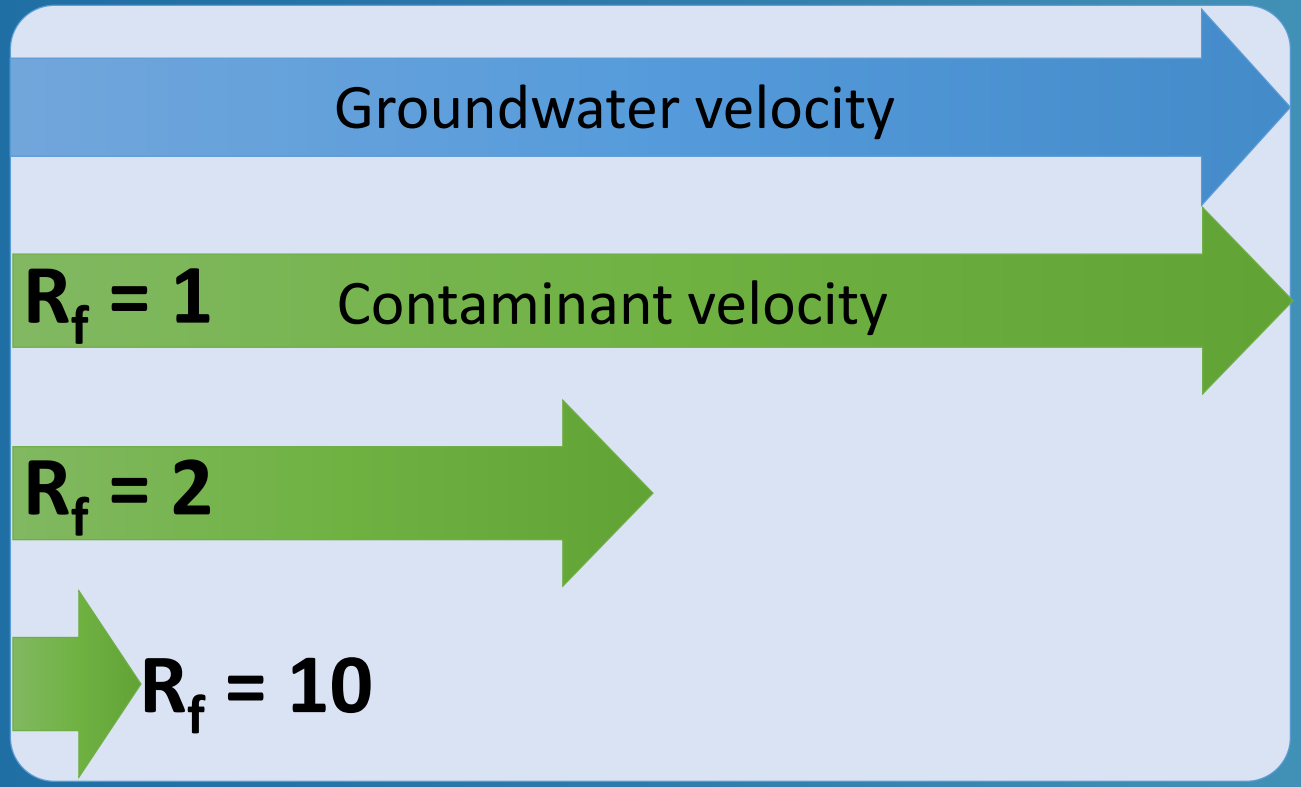
PLUMESTOP + PFOA/PFOS: CAPTURE EFFICIENCY

So what happens over time?

- Won't the barrier eventually fill up and breakthrough?
- As PFAS do not degrade, the answer is yes
- What's important is how long this will take

Engineering the Retardation factor

The Retardation Factor (R_f) determines how fast a contaminant moves relative to the groundwater.



Natural R_f:

PFOA = 3[a]

PFOS = 19[a]

R_f with PlumeStop for PFOA and PFOS:

500 – 5,000

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[a]Guelfo and Higgins, 2013. Environ. Sci. Technol.

PLUMESTOP + PFAS: RETARDATION FACTOR

For a PlumeStop Barrier at a Mid-Range Dose:

PFOA

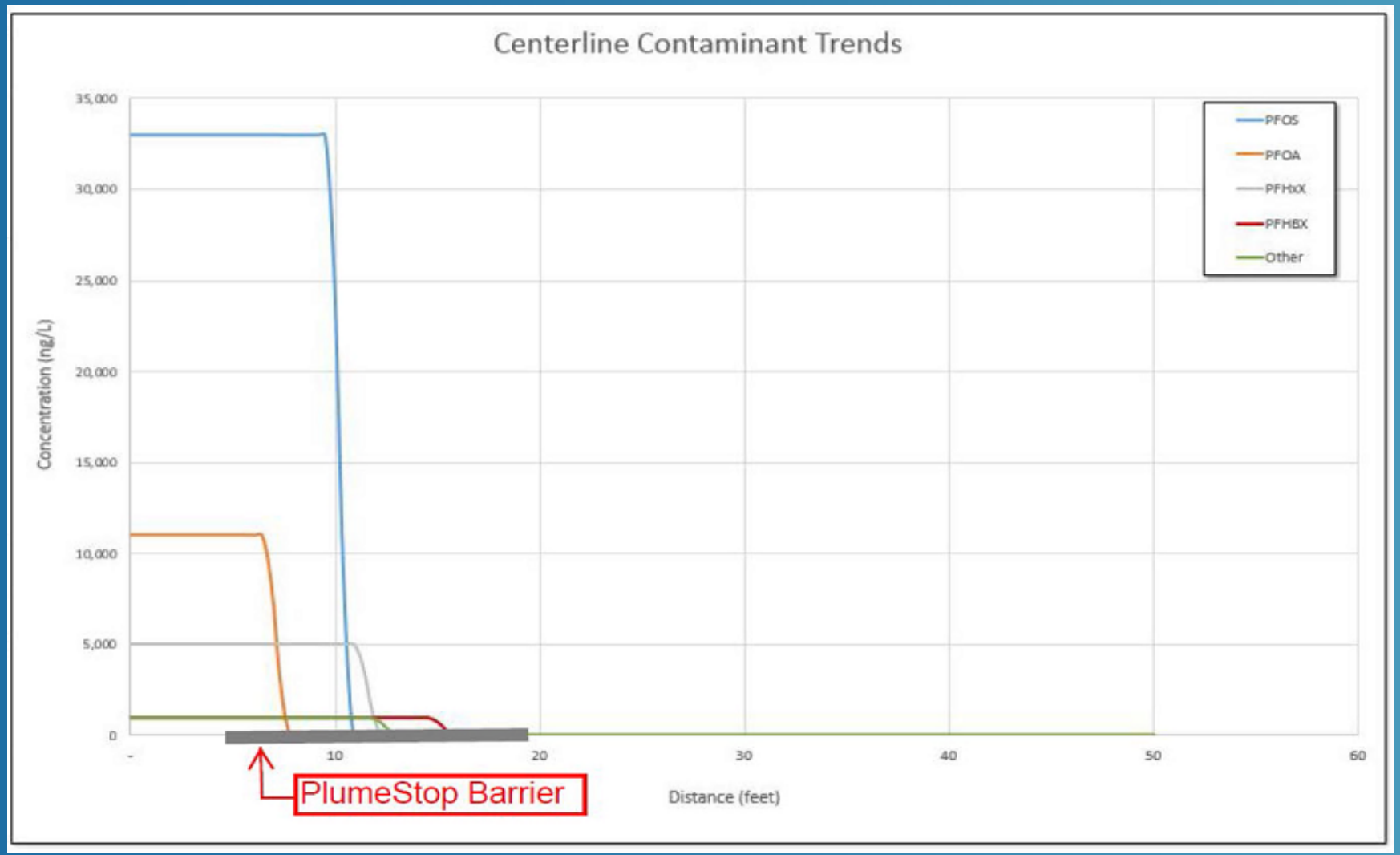
- The R of a 1,000 µg/L plume is 80
- The R of a 100 µg/L plume is 570
- The R of a 10 µg/L plume is 4,000

PFOS

- The R of a 1,000 µg/L plume is 375
- The R of a 100 µg/L plume is 2,000
- The R of a 10 µg/L plume is 10,000

*based on individual components

PlumeStop® Integration with Fate & Transport Models



Incorporate PlumeStop isotherm parameters into models

↓

Predict longevity of PlumeStop dose

↓

Optimize the dose to meet desired longevity

CASE STUDY
PFAS – FORMER FURNITURE FACILITY

ONTARIO, CANADA

INSITU REMEDIATION SERVICES

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BACKGROUND

Initial Driver: Hydrocarbons

- Mixed chain lengths, 100 – 5,000 µg/L

Formation

- Silty sand – till based with sand seams
- Water at 3 – 5’ below grade

Former Fire Training Area

- History of furniture manufacturing
- PFAS tested for just in case and found!

Rick McGregor

INSITU REMEDIATION SERVICES

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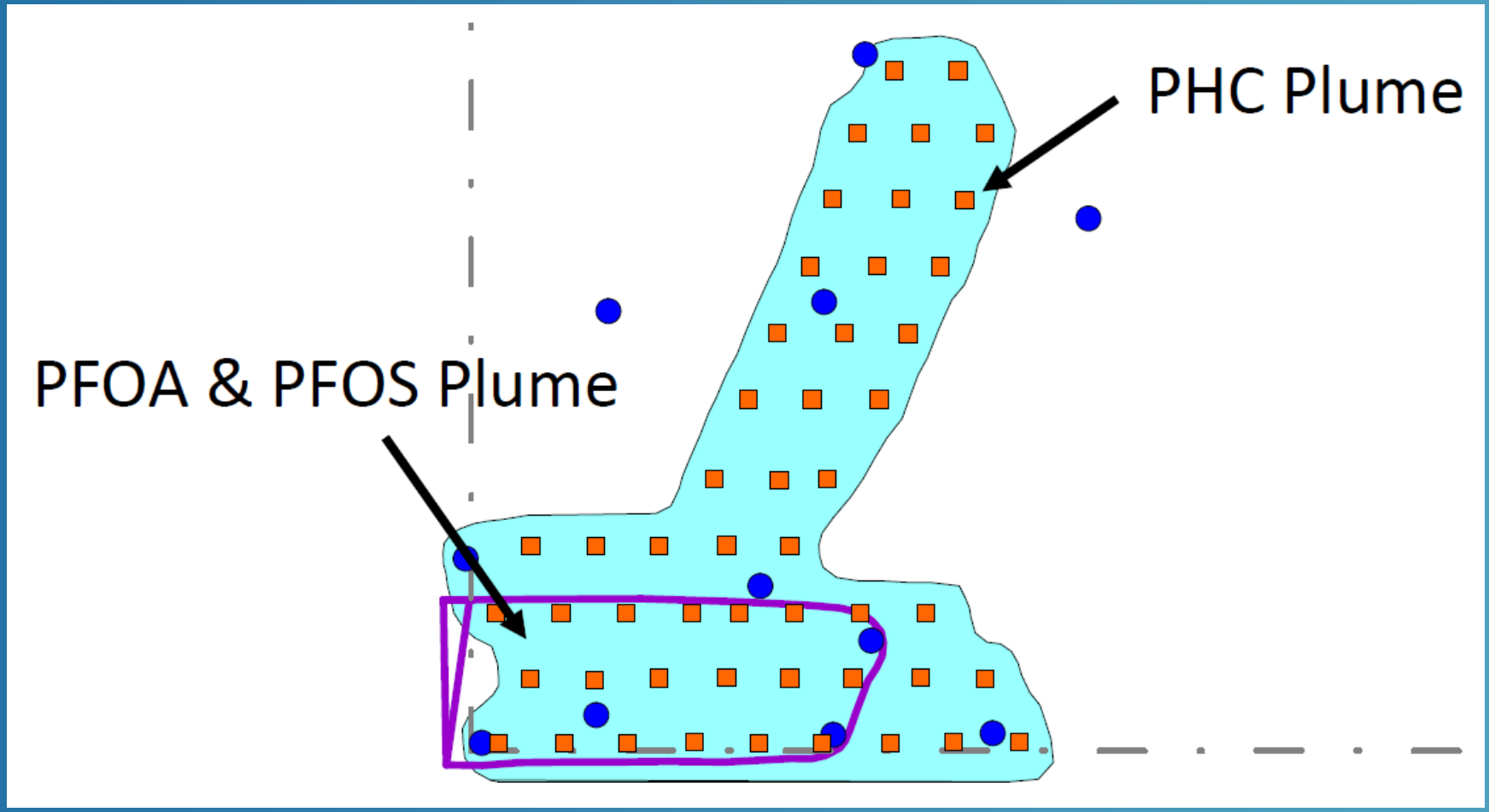
PLUME AREA DIAGRAM



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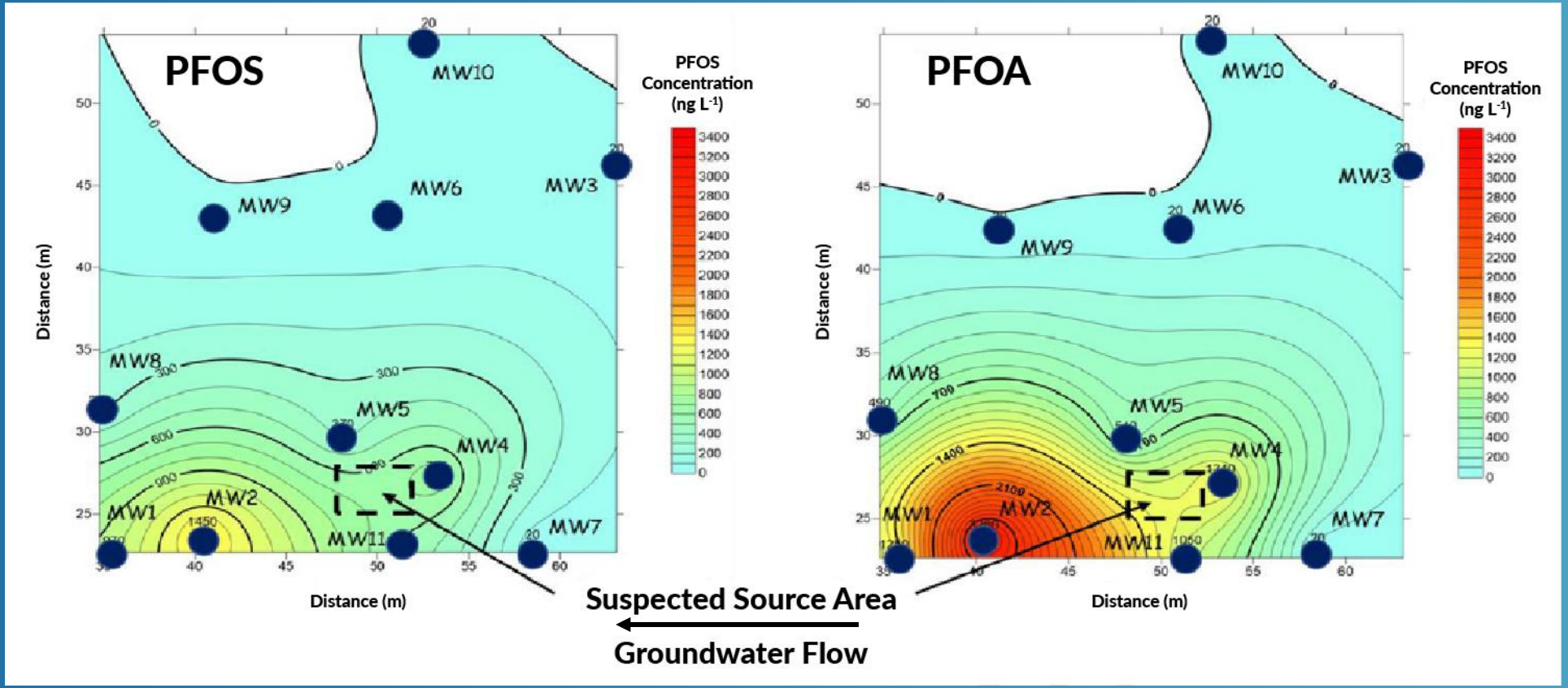
EXTENT OF PFAS AND PFOA CONTAMINATION PRE-TREATMENT



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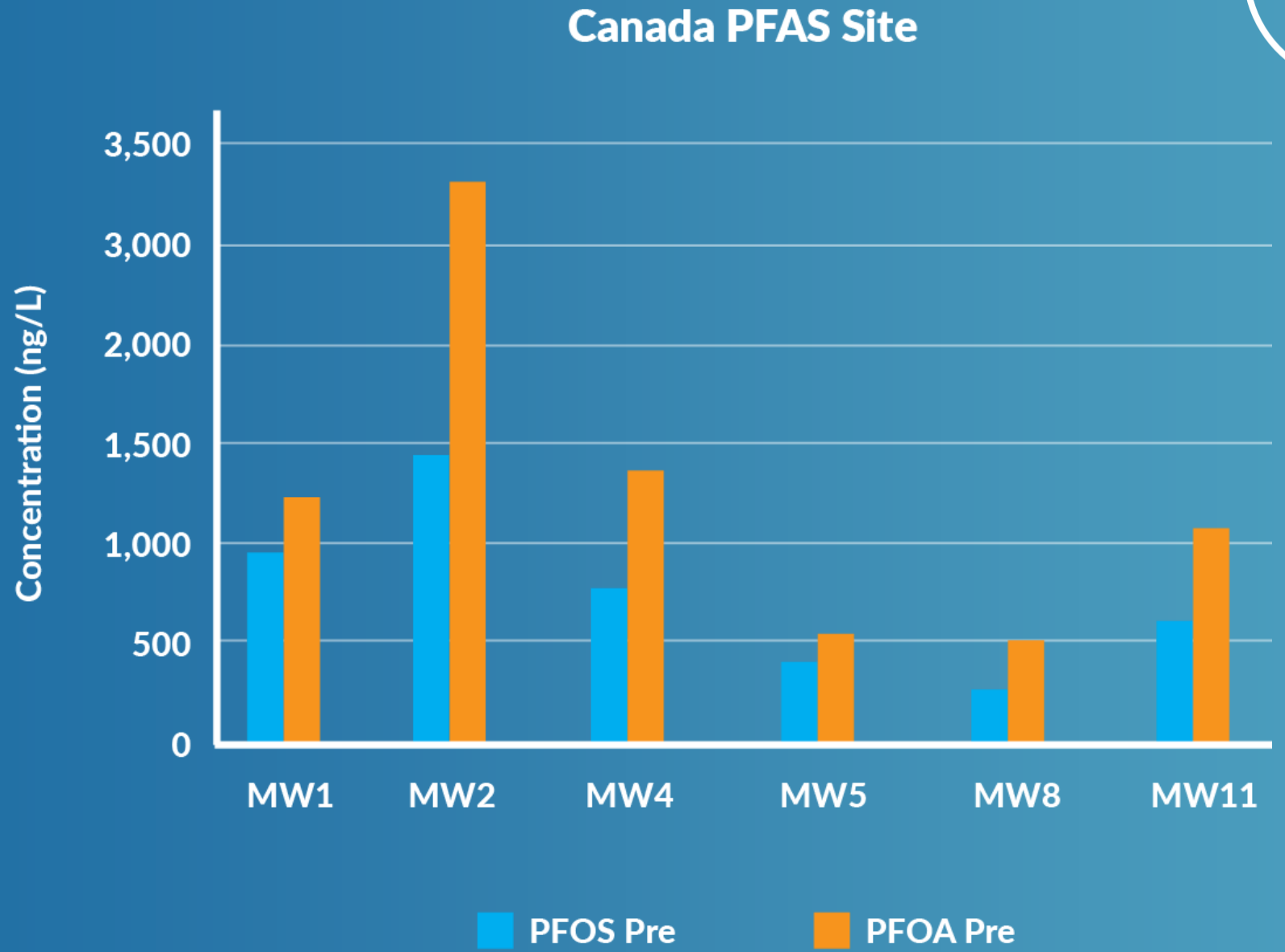
PFAS FORMER FURNITURE SITE

Site Location:
Ontario, Canada



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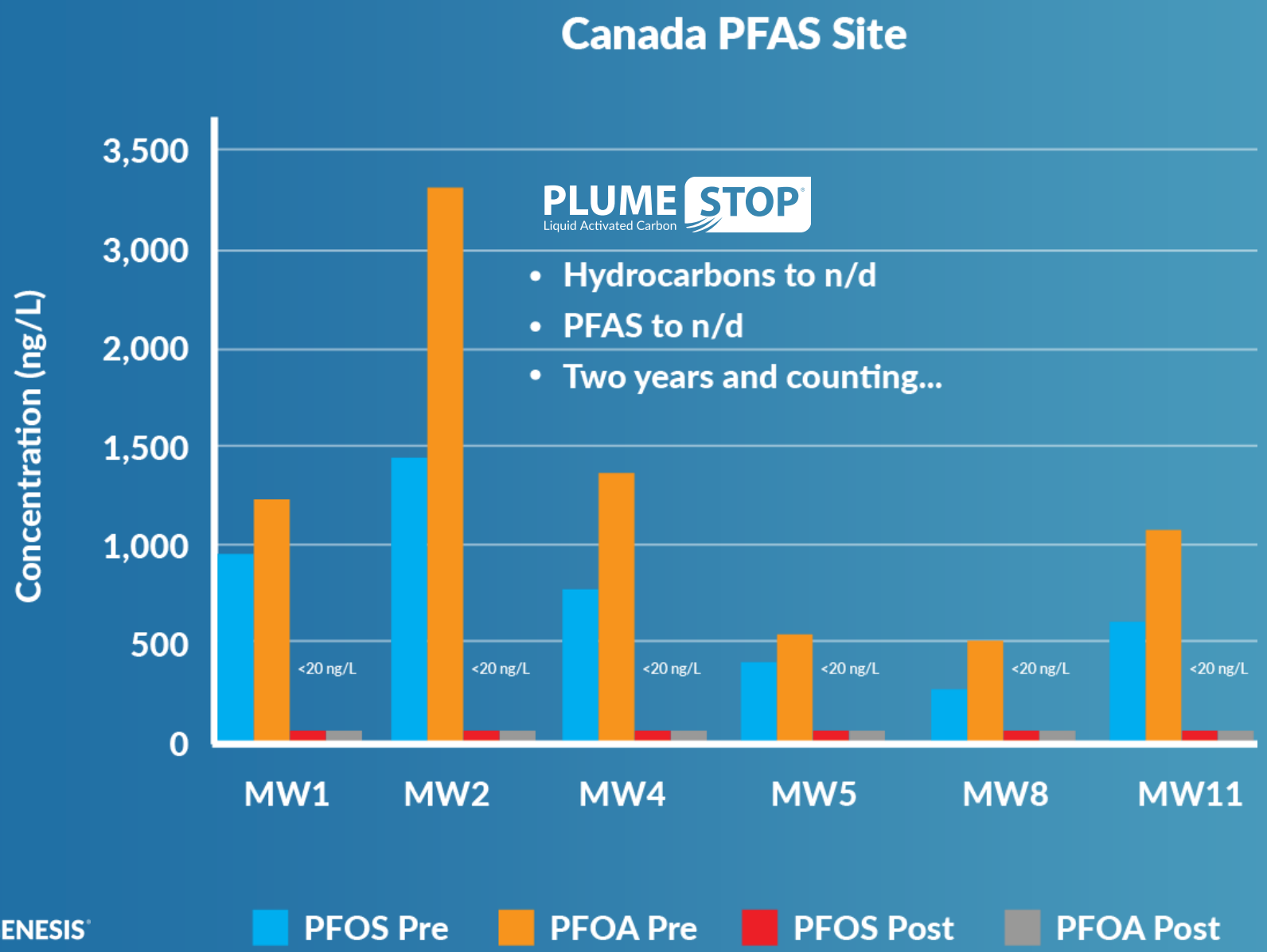

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COST COMPARISON

Actual Cost of PlumeStop Treatment

• Design, product and application (total)	$72,000
• Ongoing system O & M	$0
	$72,000

Estimated Cost of Pumping & Treating (Most Efficient GAC)

• Design, permitting, construction, startup	$150,000
• Ongoing system O&M	$1,200,000
• (ex. monitoring @ $60k/yr X 20 yrs)	
	$1,350,000

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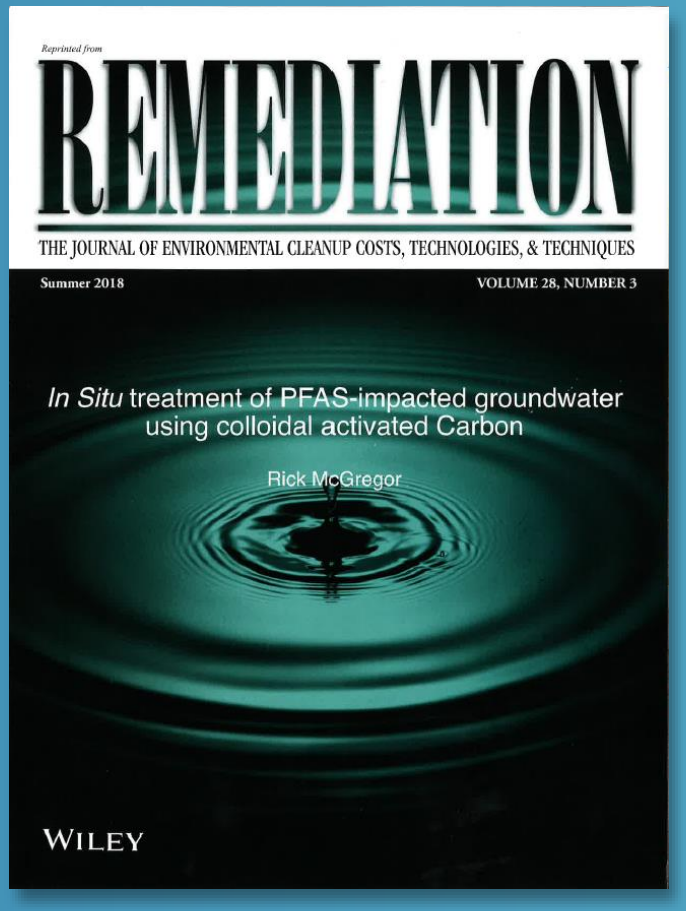
REMEDIATION MAGAZINE

Case Published:

REMEDIATION Journal

Volume 28, No. 2
Summer 2018
Wiley Press



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QUESTIONS?

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PLUME STOP®
Liquid Activated Carbon

Design & Barrier Strategies for PFAS Containment

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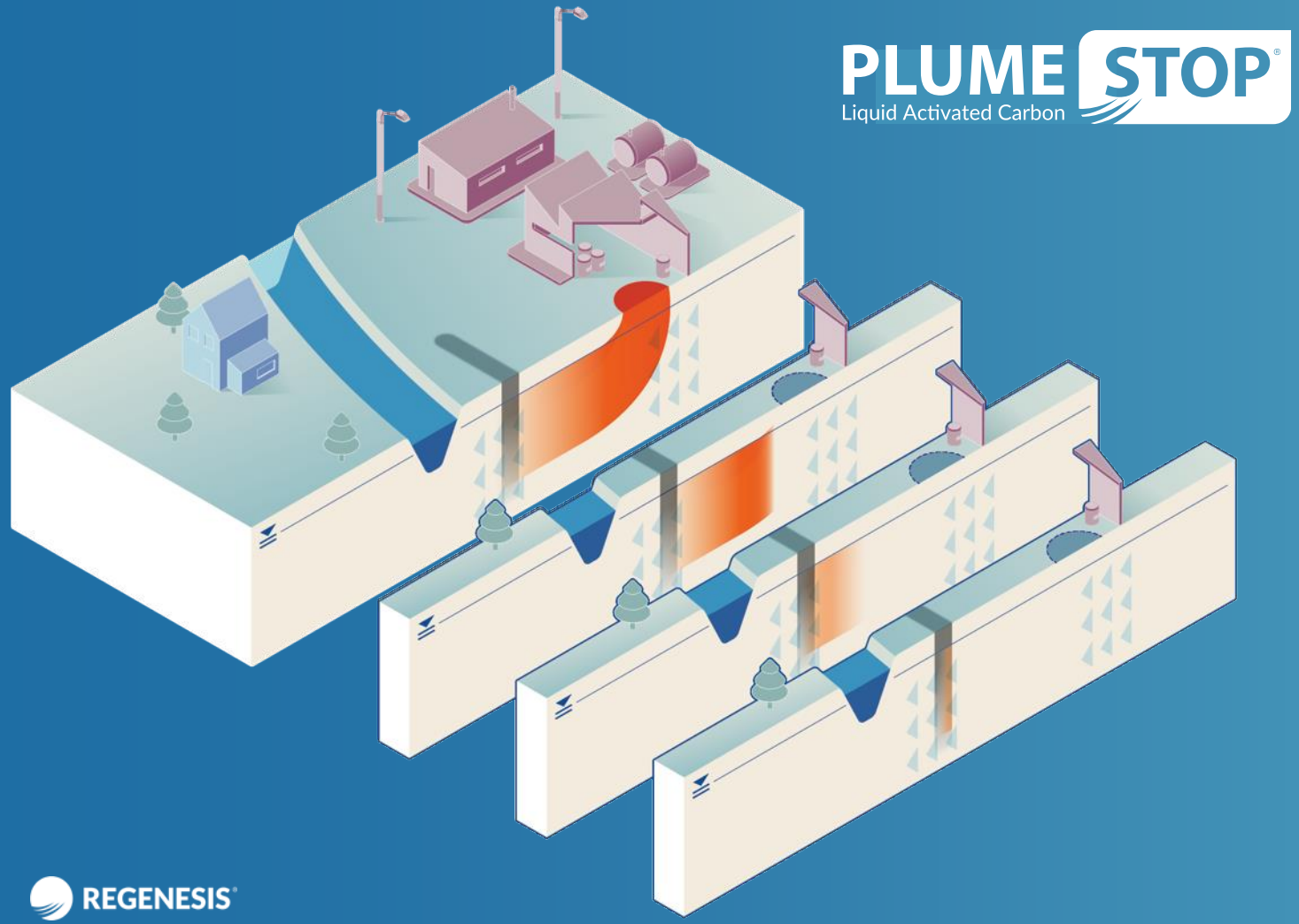
STRATEGY #1 – SIMPLE PLUME CUT-OFF BARRIER



Description

- Single barrier of PlumeStop®
- Limits plume expansion

Application

- Protection of property boundary
  - (entering site or exiting site)
- Protection of receptor (shown)
  - (e.g. water body; well)
- Plume minimization
  - Liability containment
  - (possible) regulatory compliance

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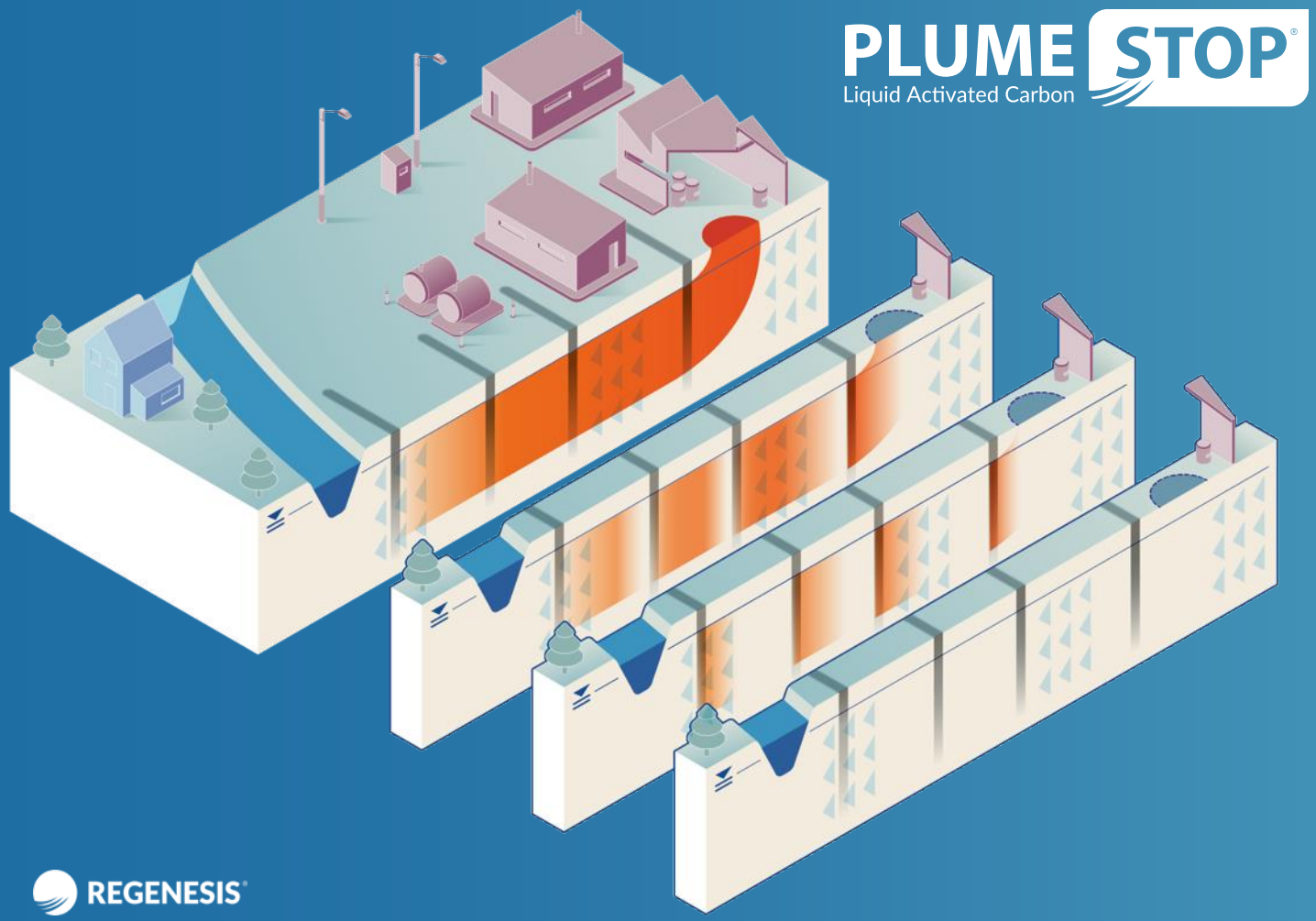
STRATEGY #2 – SEQUENCE OF BARRIERS



Description

- Multiple barriers of PlumeStop®
- Progressive elimination of plume

Application

- Addresses entire plume
- Utilizes advection for efficiency
- Particularly suited for:
  - Large plumes (compare cost of grid injection)
  - Built-up areas / restricted access
    - Barriers in access corridors / roadways

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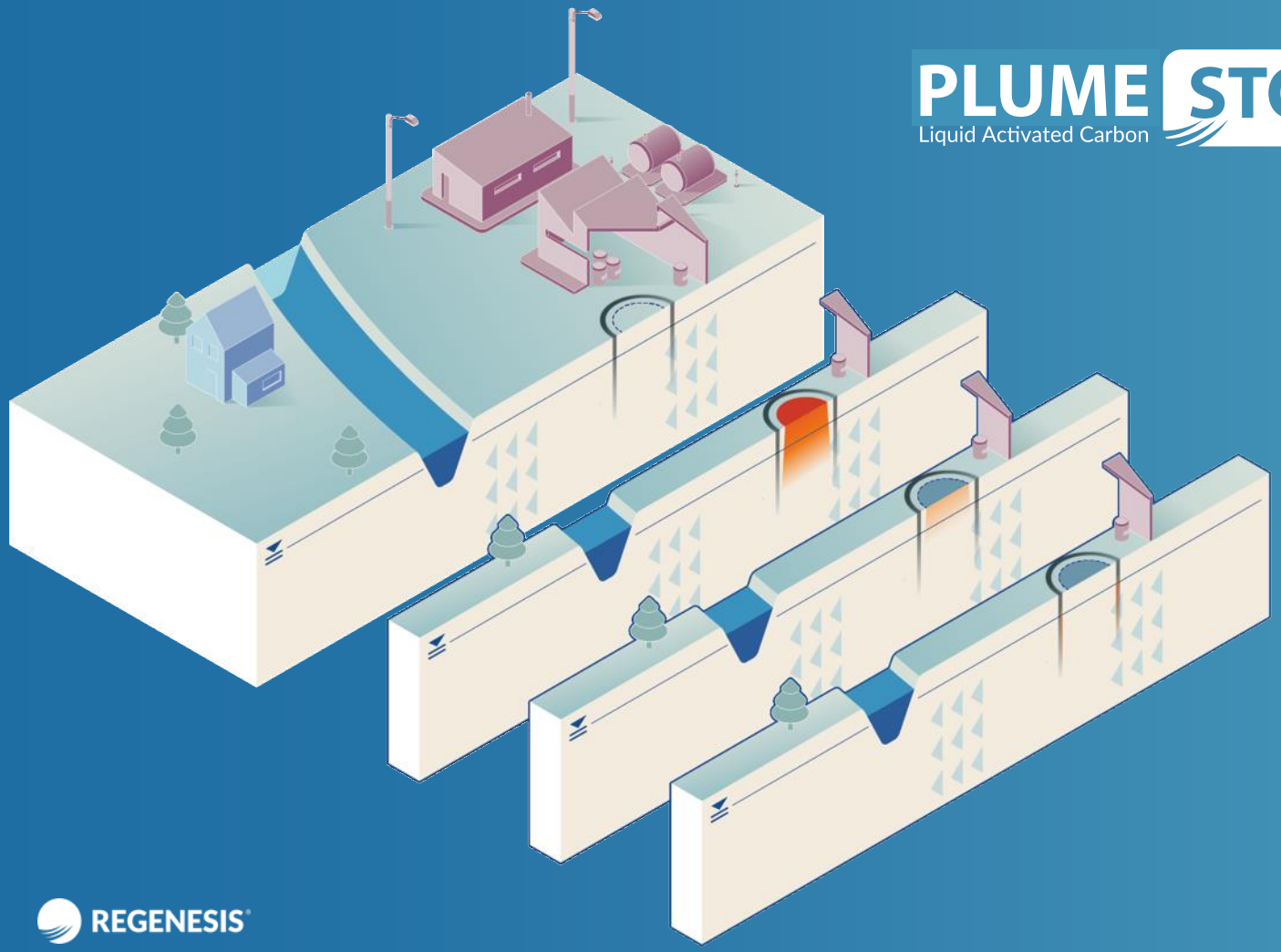
STRATEGY #3 – POTENTIAL SOURCE CONTAINMENT



PLUME STOP®
Liquid Activated Carbon

Description

- Pre-emptive source control
- PlumeStop® *in situ* 'berm'

Application

- Ring-fence known ***potential*** source
- Avoidance of plume generation
- Provide extra time for emergency response

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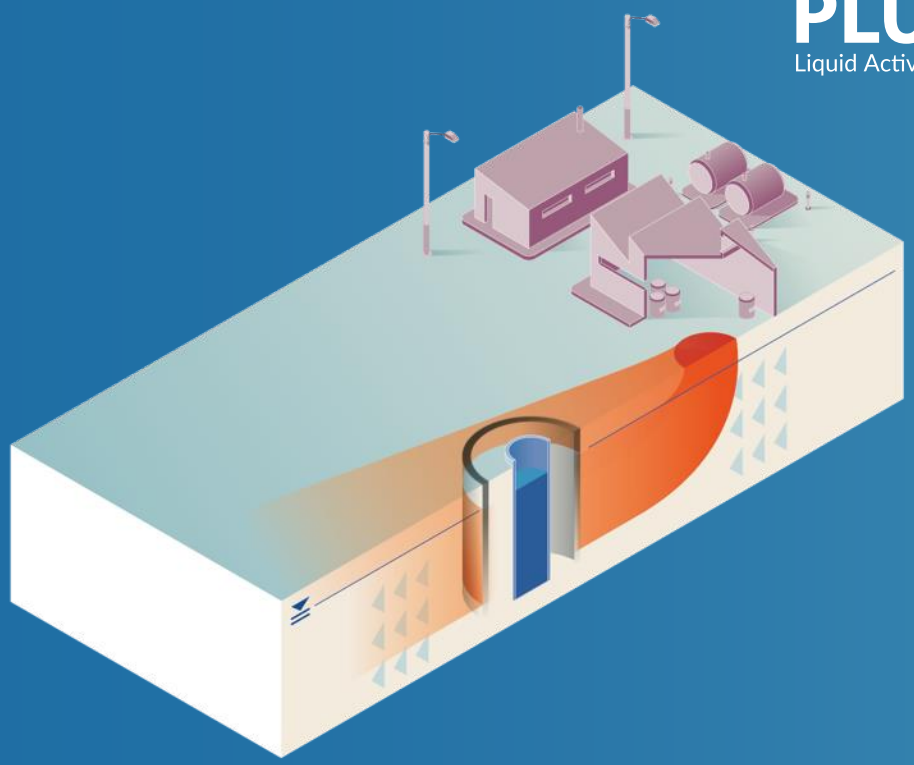
STRATEGY #4 – LOCALIZED RECEPTOR PROTECTION



PLUME STOP®
Liquid Activated Carbon

Description

- Individual receptor protection
- 'Brita®' filter in-ground

Application

- Protection of supply wells
- Interim measure where plume is large

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QUESTIONS?

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CASE STUDY
PFAS – SUPERFUND SITE

CONNECTICUT

de maximis, inc.

GEI Consultants

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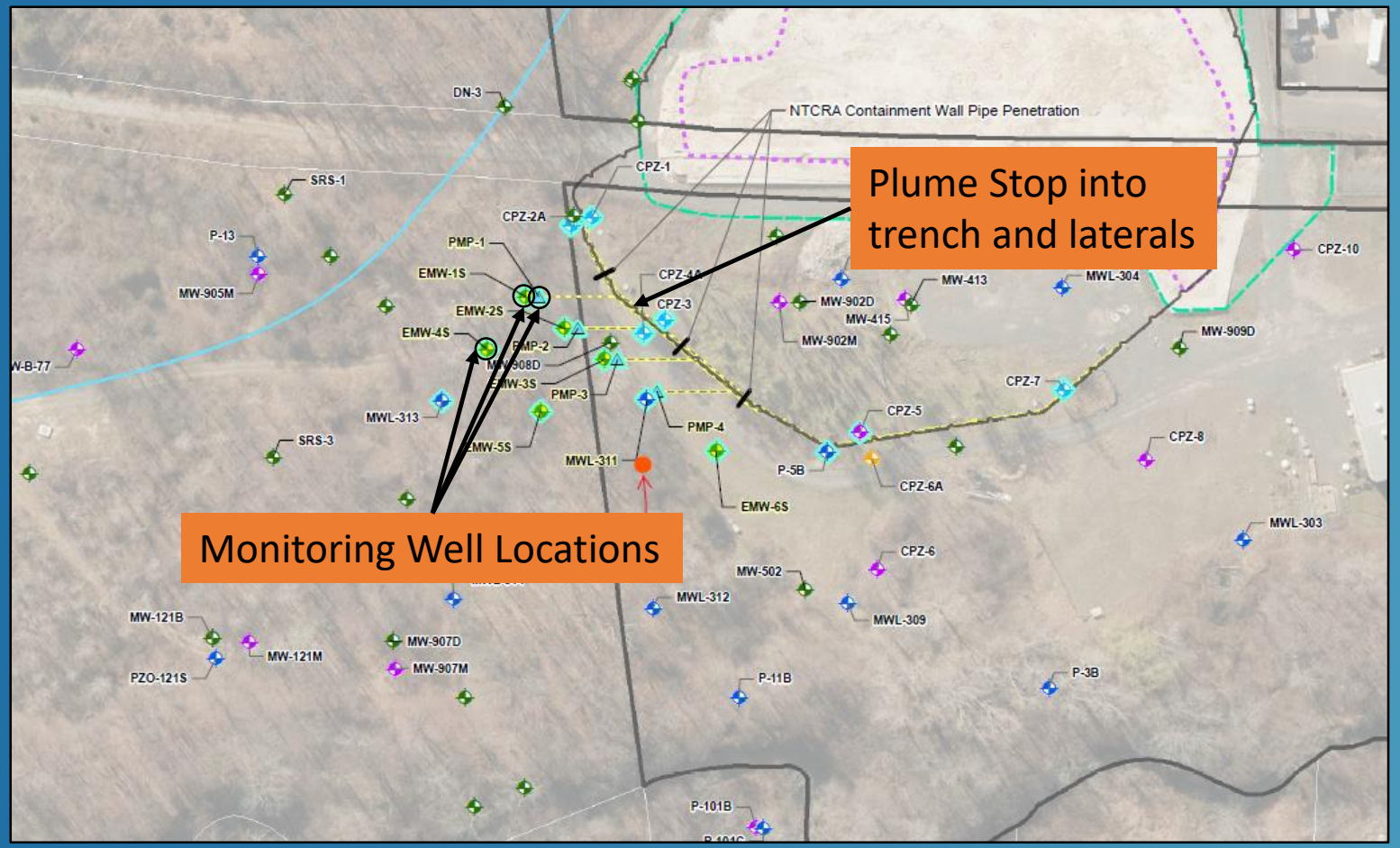
Solvent Recovery Services of New England - Superfund Site in CT

- Plume Stop and Aqua ZVI Application to address cVOC and PFAS contamination
- Target combined 5 compounds 70 ppt: PFOA, PFOS, PFNA, PFHxS, PFHpA
- Starting concentration: max 148 ppt
- Applied Reagents in Trench and Laterals
- Application July 23-25, 2018
- Aqua ZVI: 4,000 lbs
  Plume Stop: 21,600 lbs

Solvent Recovery Services of New England - Superfund Site in CT



- 8,800 lbs of PlumeStop and 4,000 lbs of ZVI into the upgradient trench
- 12,800 lbs of PlumeStop into the downgradient trench (including four 50' distribution trenches)

AEHS Poster 2018 Thompson et.al

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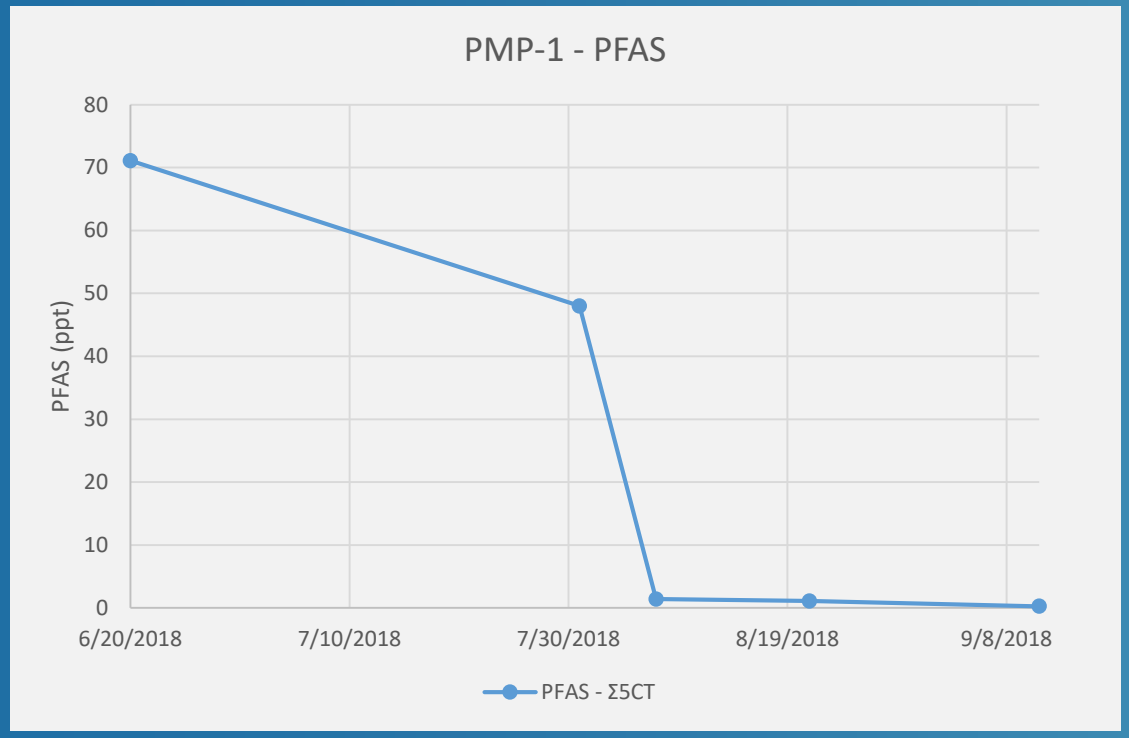
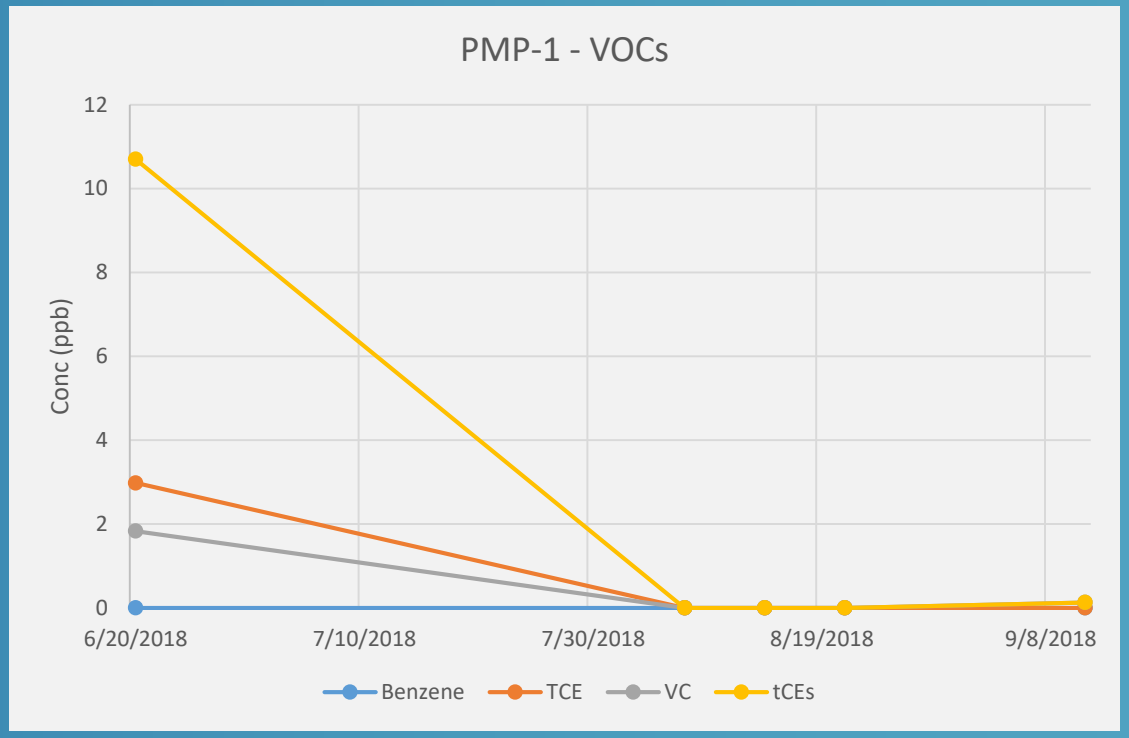
de maximis, inc.

GEI Consultants

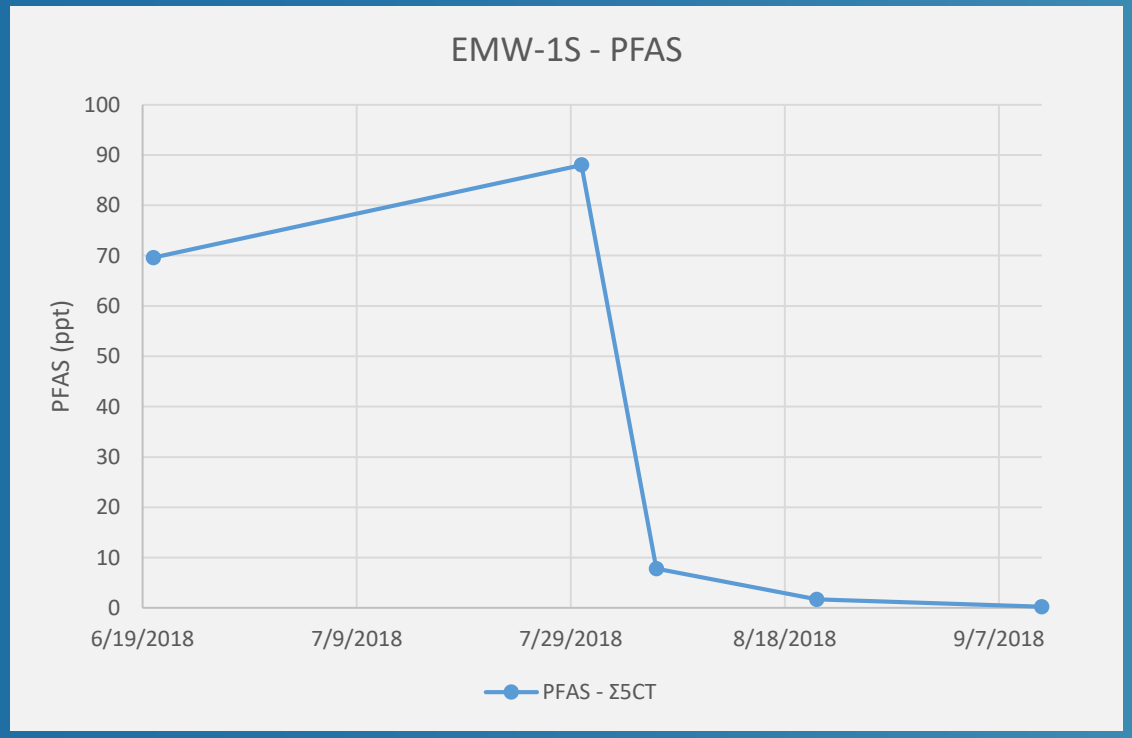
Results from PMP-1 (within trench)

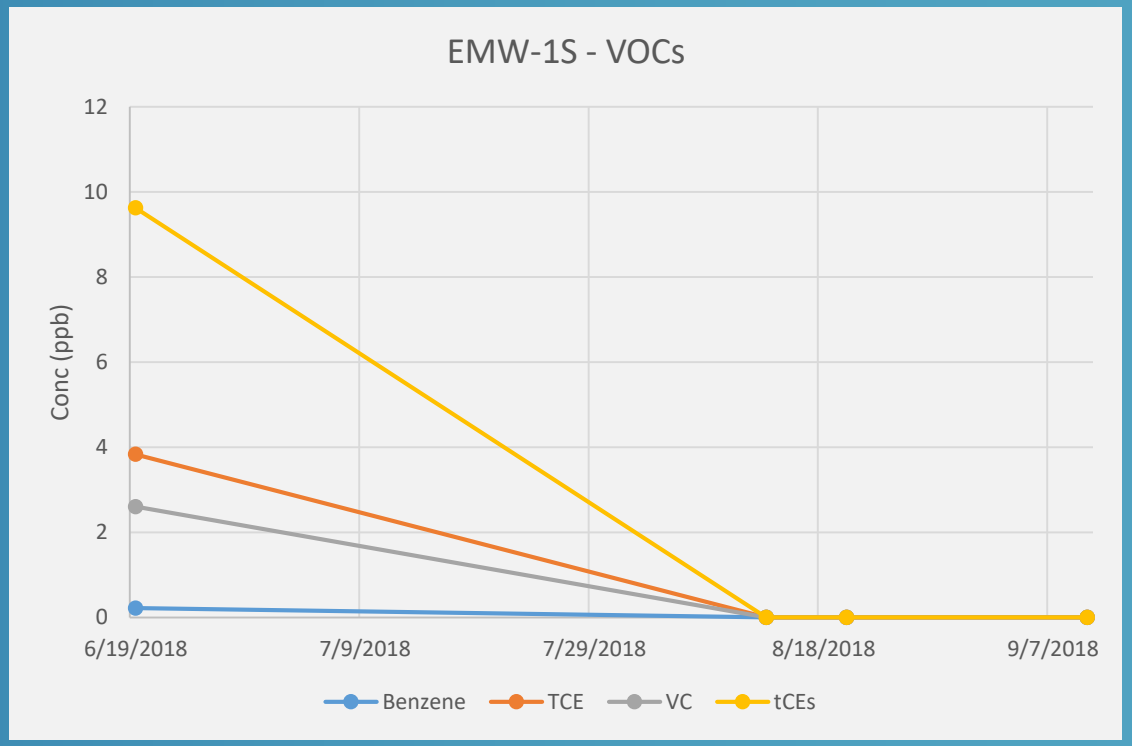




Σ5CT is sum of 5 PFAS compounds (PFOA, PFOS, PFNA, PFHpA, and PFHxS)

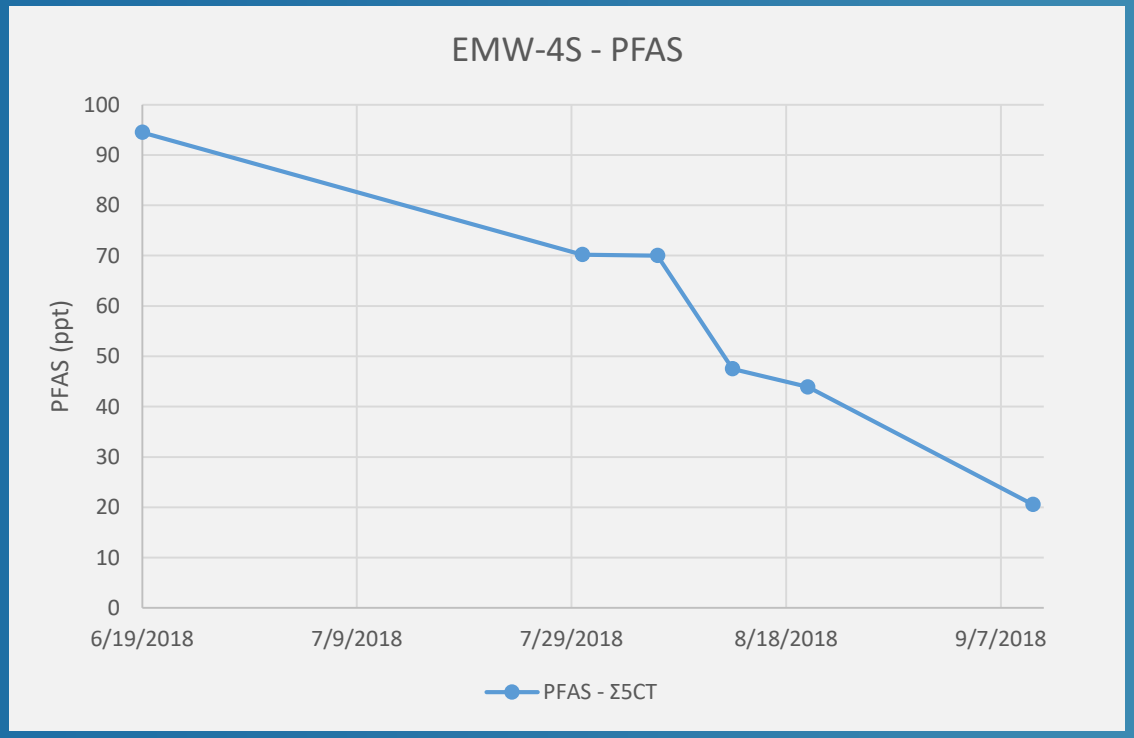
Results from EMW-1S (10 ft downgradient of trench)

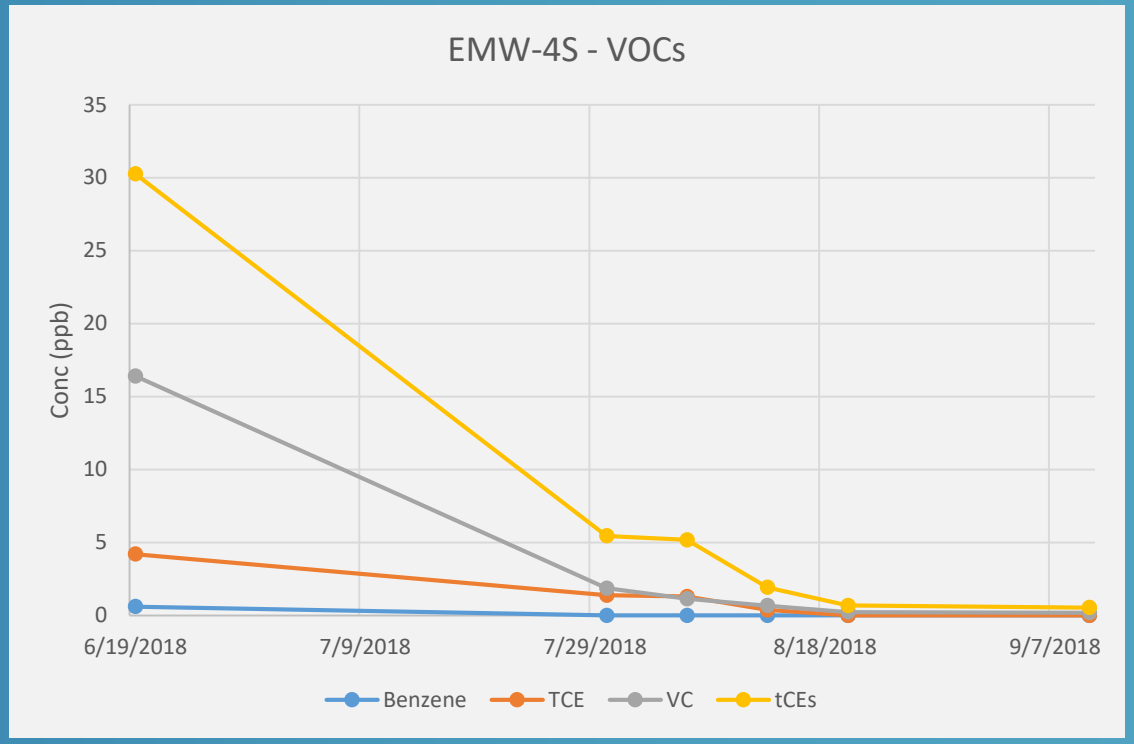




Σ5CT is sum of 5 PFAS compounds (PFOA, PFOS, PFNA, PFHpA, and PFHxS)

Results from EMW-4S (about 50 ft downgradient of trench)





Σ5CT is sum of 5 PFAS compounds (PFOA, PFOS, PFNA, PFHpA, and PFHxS)

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RESULTS

- Rapid Reduction Target PFA compounds and cVOCs
- Water is not exceeding any EPA-determined downgradient triggers
- Anticipated cost savings $400,000 per year
- Long terms success is based on allowing the valves to remain open and allow the trench to serve as a long-term permeable reactive barrier.
- Current results from the Plume Stop/Aqua ZVI treatment suggest it will be possible to turn off 12 pumping wells and reduce onsite treatment because water clean enough for discharge to sanitary sewer

QUESTIONS?

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