Naval Facilities Engineering Systems Command
EXWC Engineering and Expeditionary Warfare Center

Colloidal Activated Carbon Barrier to Reduce PFAS Migration

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Acknowledgements

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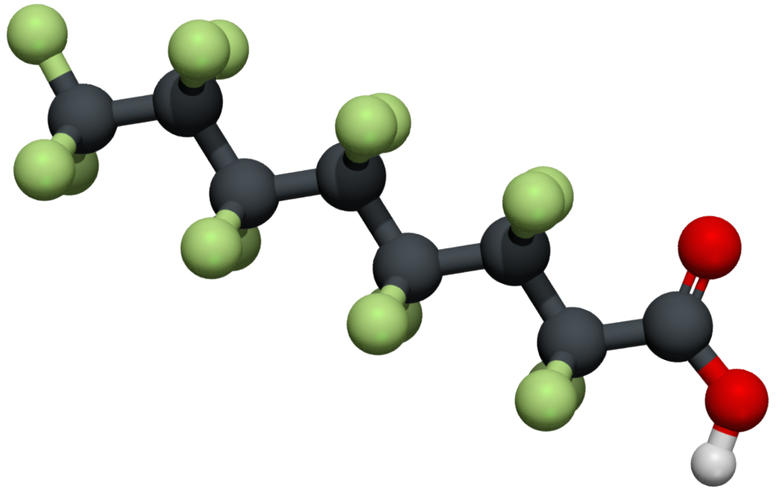
- APTIM and Jason Speicher (NAVFAC LANT)
- NESDI Project 569

PFAS Challenges

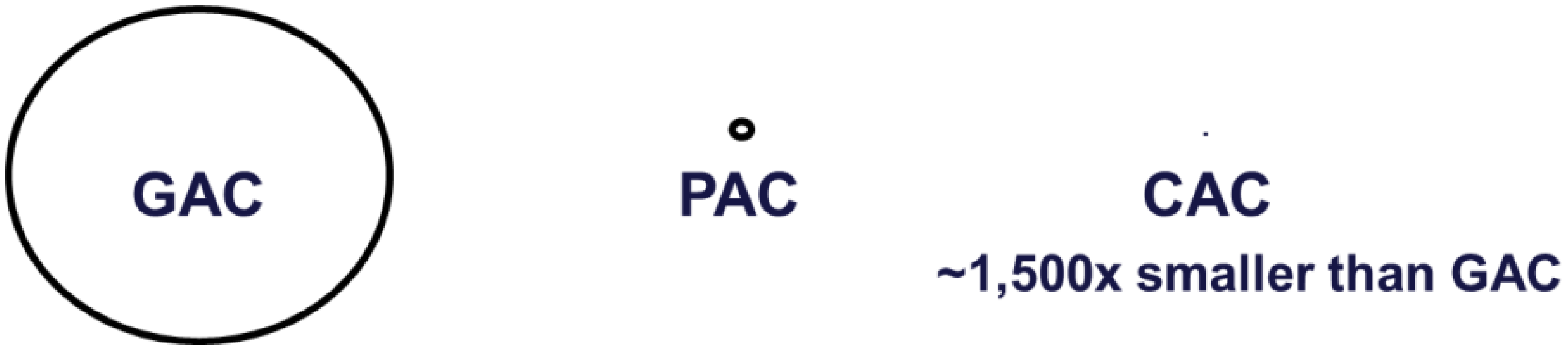
- Concern at exceeding low concentrations (ng/L)
- Complex array of structures with differing behaviors
- Extremely recalcitrant class of organic compounds
- Challenges with traditional in situ destructive approaches
  - –Bioremediation
  - –Chemical Oxidation
  - –Chemical Reduction

- P&T is current principal remedial approach
- Potential Alternatives?
  - –Foam Fractionation with Foam Destruction
  - –**In Situ Sequestration**



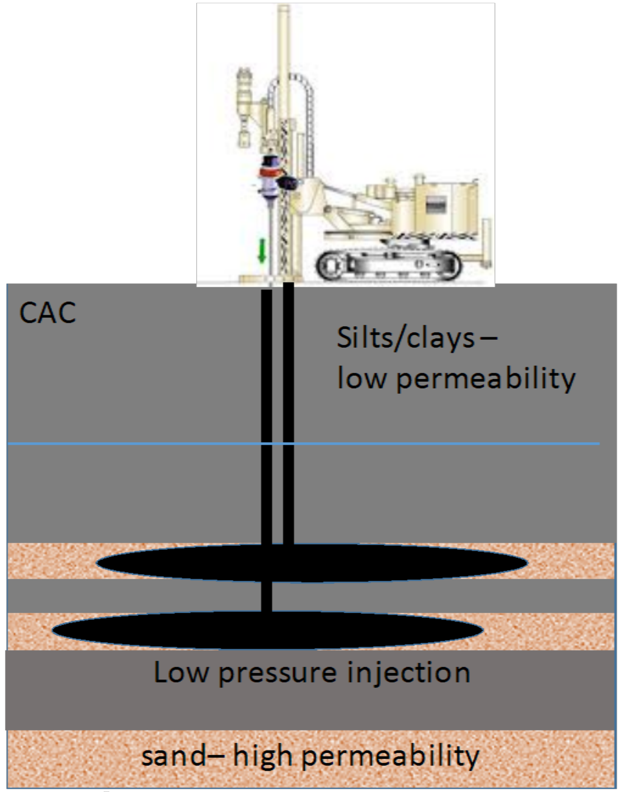
Colloidal Activated Carbon

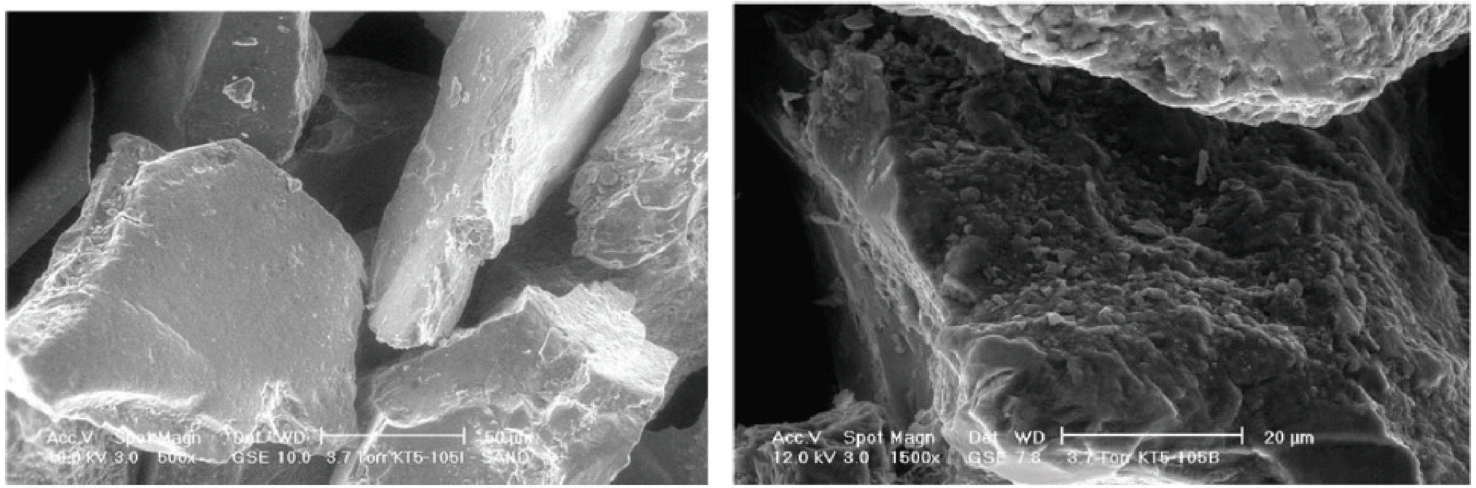
- Granular activated carbon (GAC) is the most common for PFAS removal in liquids
- PFAS binding : heterogeneous surface functional groups + microporous regions
- High affinity for long chain PFAS
- CAC → AC with a particle size in the lower µm range
  - GAC generally 0.4 – 1.2 mm; PAC ~ 0.075 mm
  - CAC can be suspended for better aquifer injection, mobility in porous media, and deposition onto soils and sediment



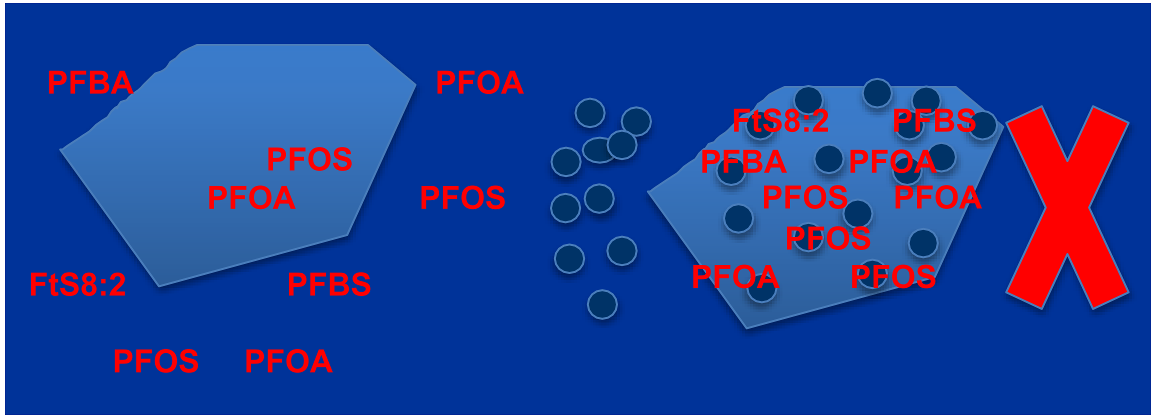
Colloidal Activated Carbon

- **Colloidal Activated Carbon** is now being marketed and applied as an in situ adsorbent and sequestrant for **PFAS**





Micrographs from Birnstingl et al (2019)



NESDI 569

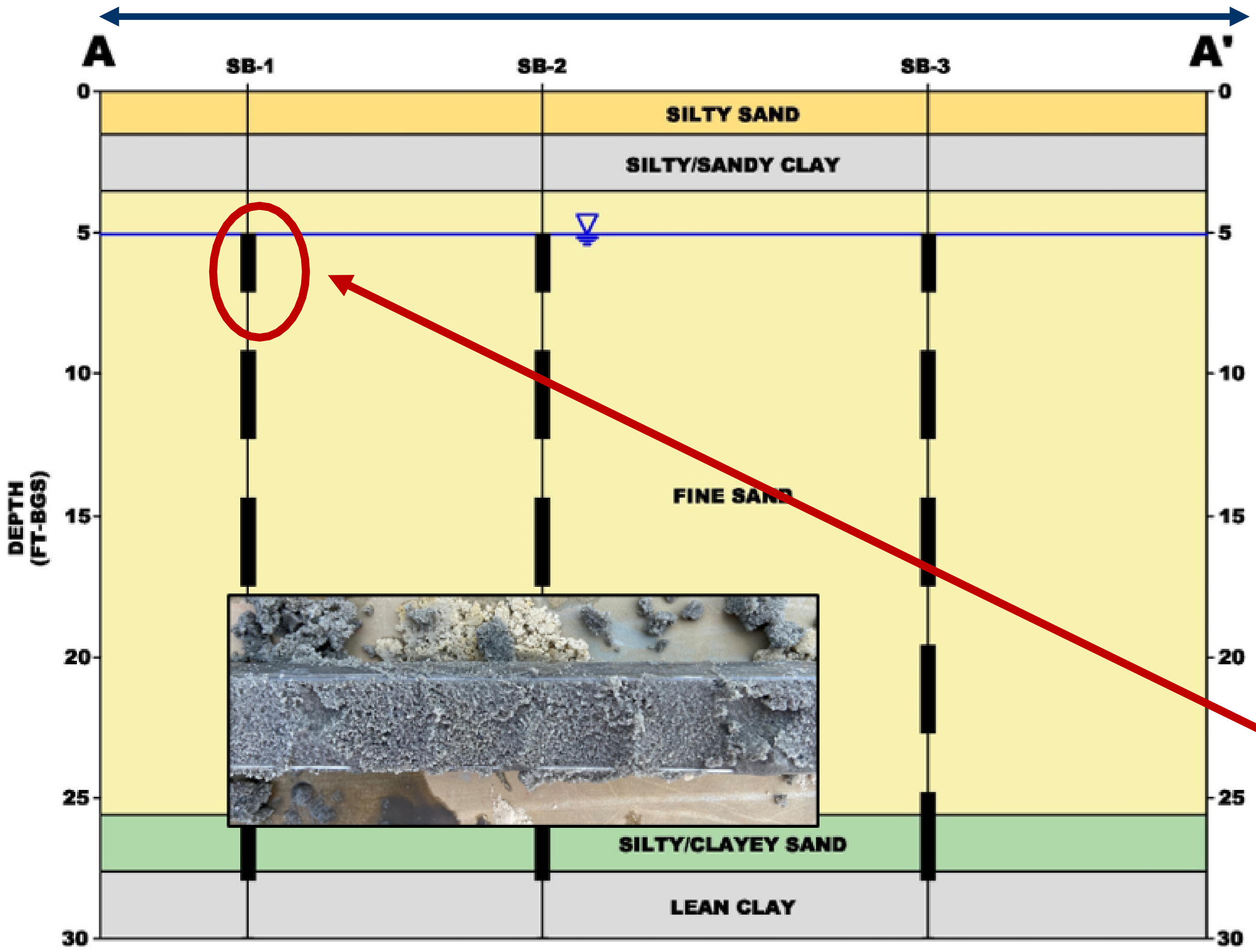
- **NESDI 569 - Field Demonstration of Colloidal Activated Carbon for In Situ Sequestration of Per- and Polyfluoroalkyl Substances**

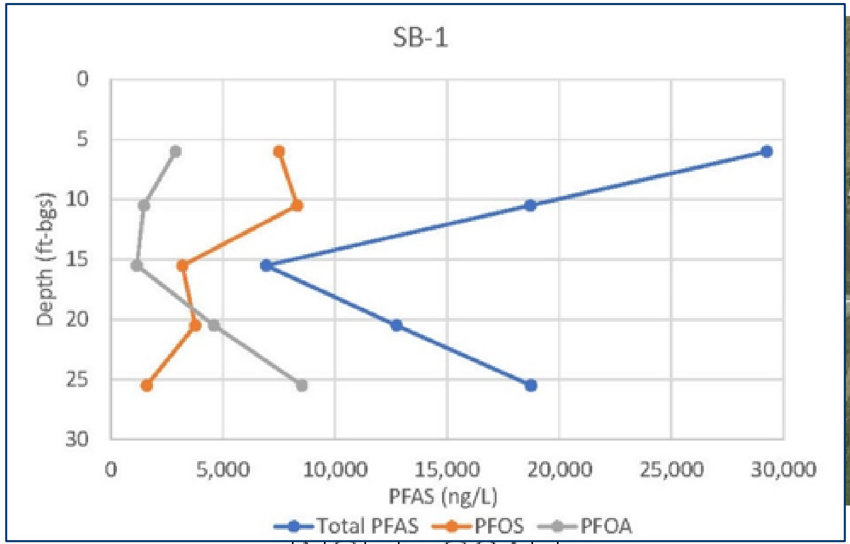
•**Key questions:**

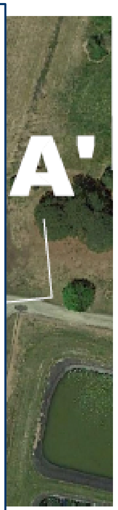
- Does CAC distribute well in aquifers – influence of lithology?
- What is the general in situ treatment effectiveness on different PFAS?
- What is the long-term adsorption capacity and potential for re-release of PFAS?
- Are there any significant near-term or long-term aquifer effects
  - CAC in monitoring wells
  - Hydraulic conductivity impacts

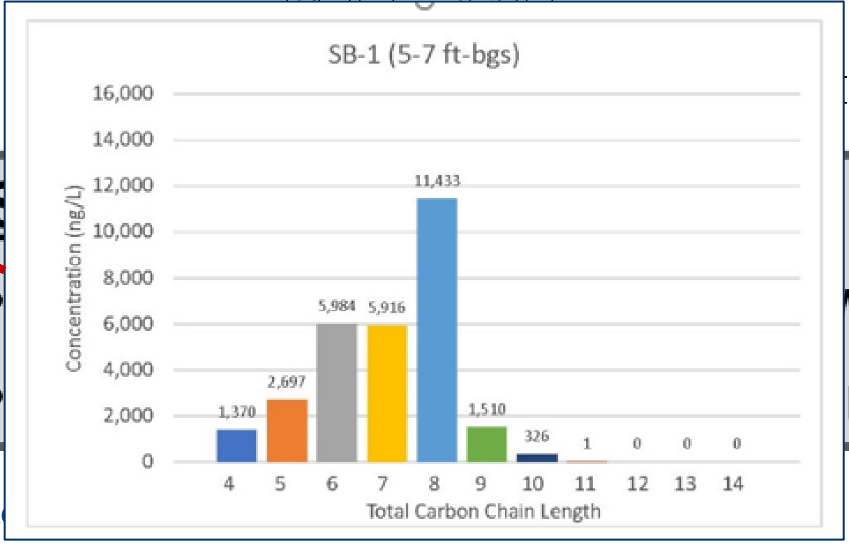
- **CAC barrier cross-gradient of groundwater flow**
- **Tasks**
  - **Site Selection**
  - **Site Characterization**
  - **Laboratory Testing**
  - **Field Activities**
  - **Monitoring**
  - **Reporting**
  - **Technology Transfer**

Site Assessment









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Column Testing

- **Evaluate PFAS removal during 2+ years of simulated GW transport**
- **Quantify carbon distribution**

Columns

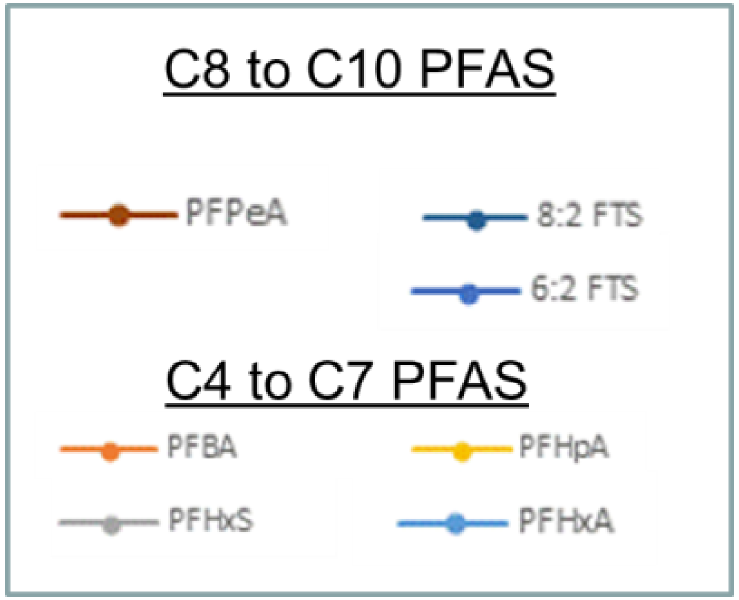
- Homogenized site sediment (SB-1)
- 30 cm x 3.5 cm diam
- ~ 100 mL pore volume
- Groundwater – nearby well
- 1.6 mL/hr flow rate
- Simulate ~ 17 ft/yr flow (1.5 mos)

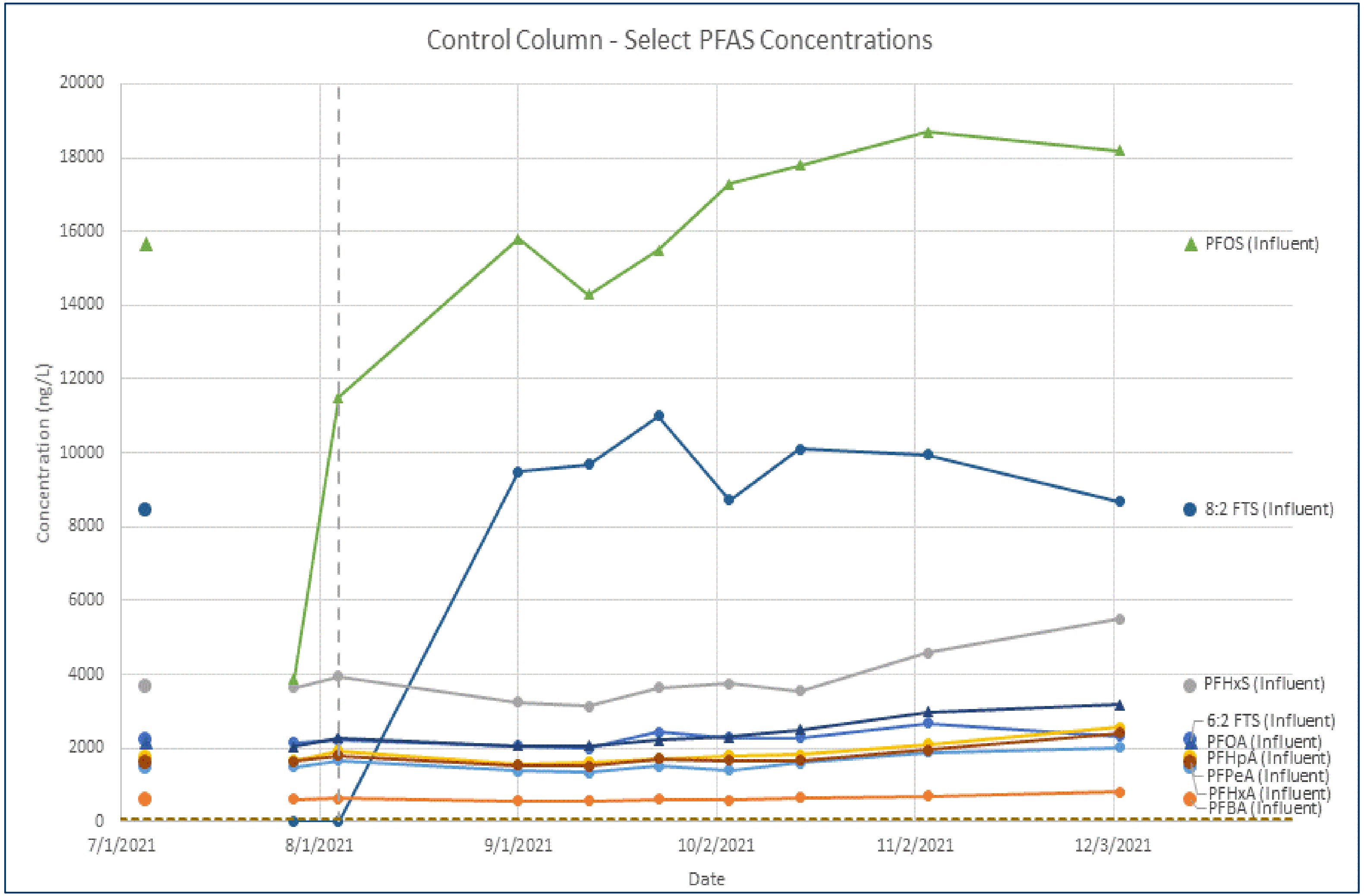
CAC Addition

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

Control Column

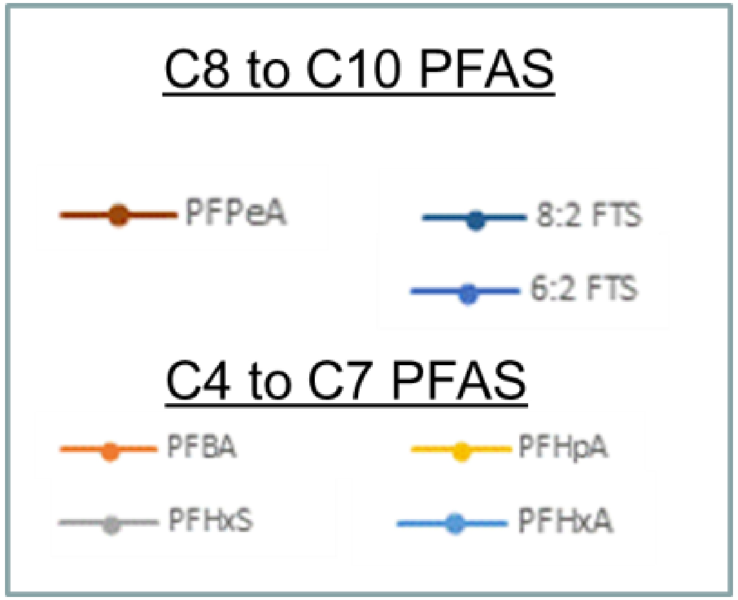
CONTROL COLUMN DATA

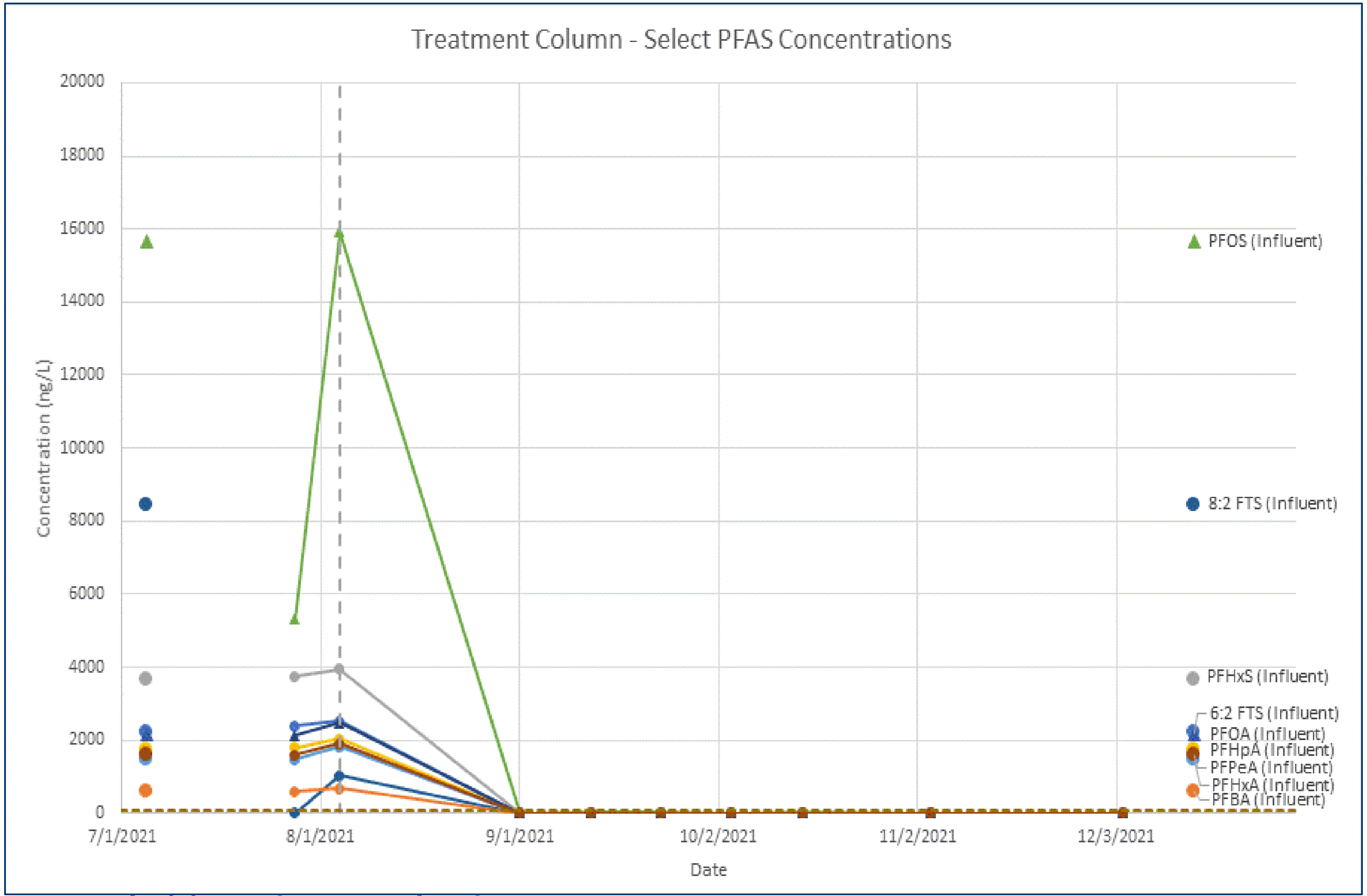




Carbon Column

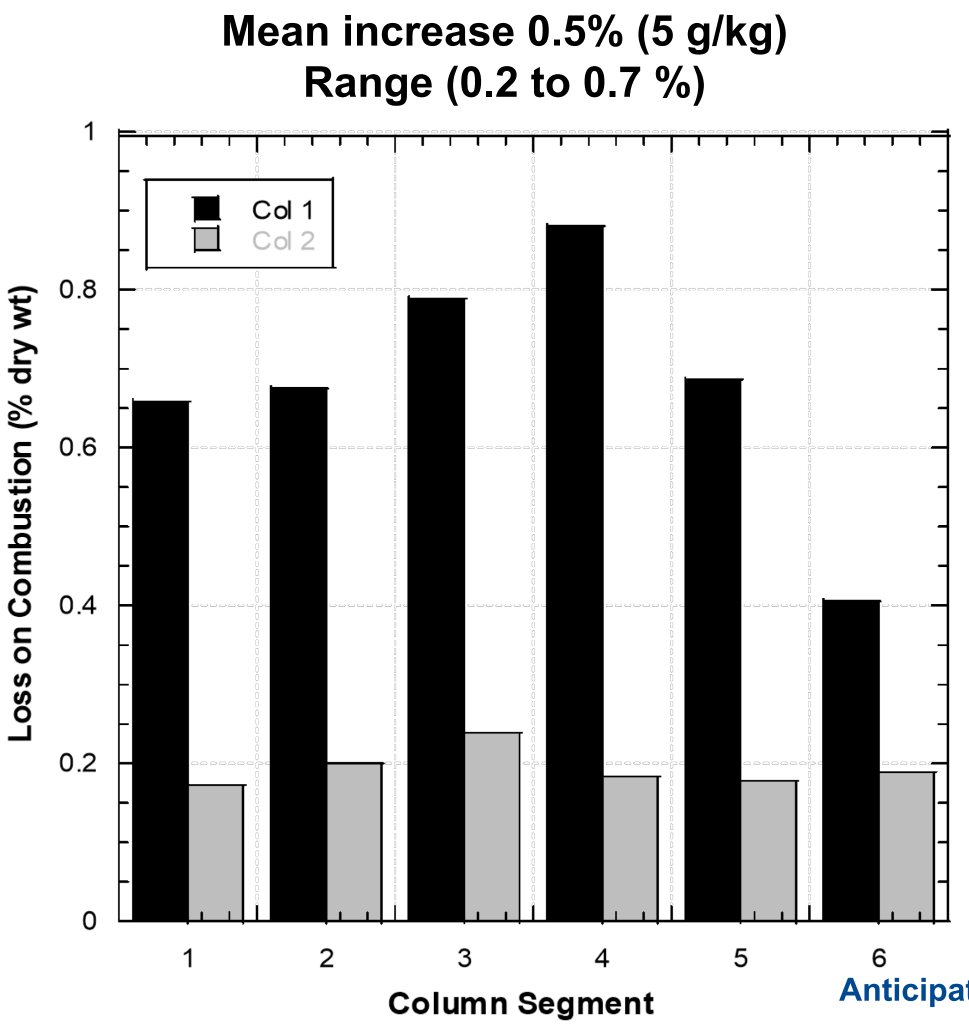
CARBON COLUMN DATA





Carbon Distribution

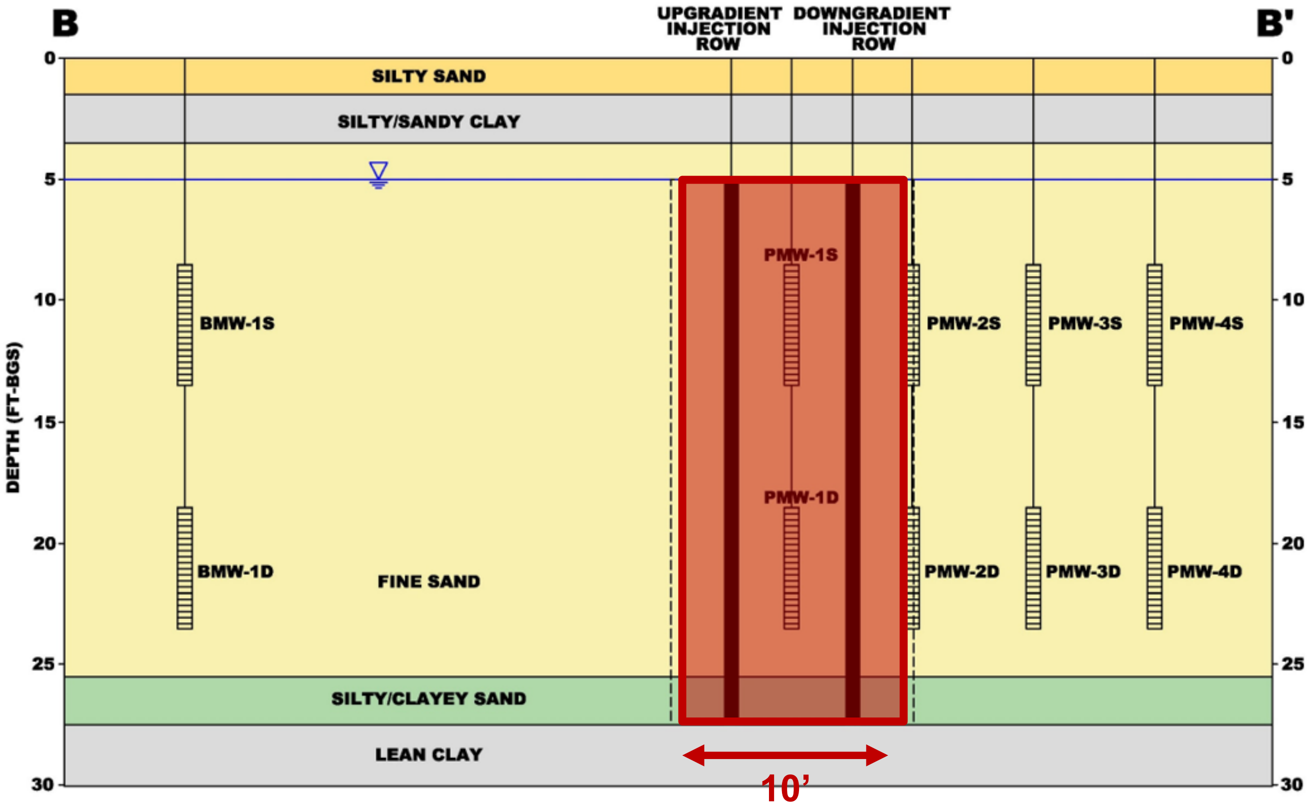
CAC DISTRIBUTION DATA – COMBUSTION METHOD



CAC in Sediment

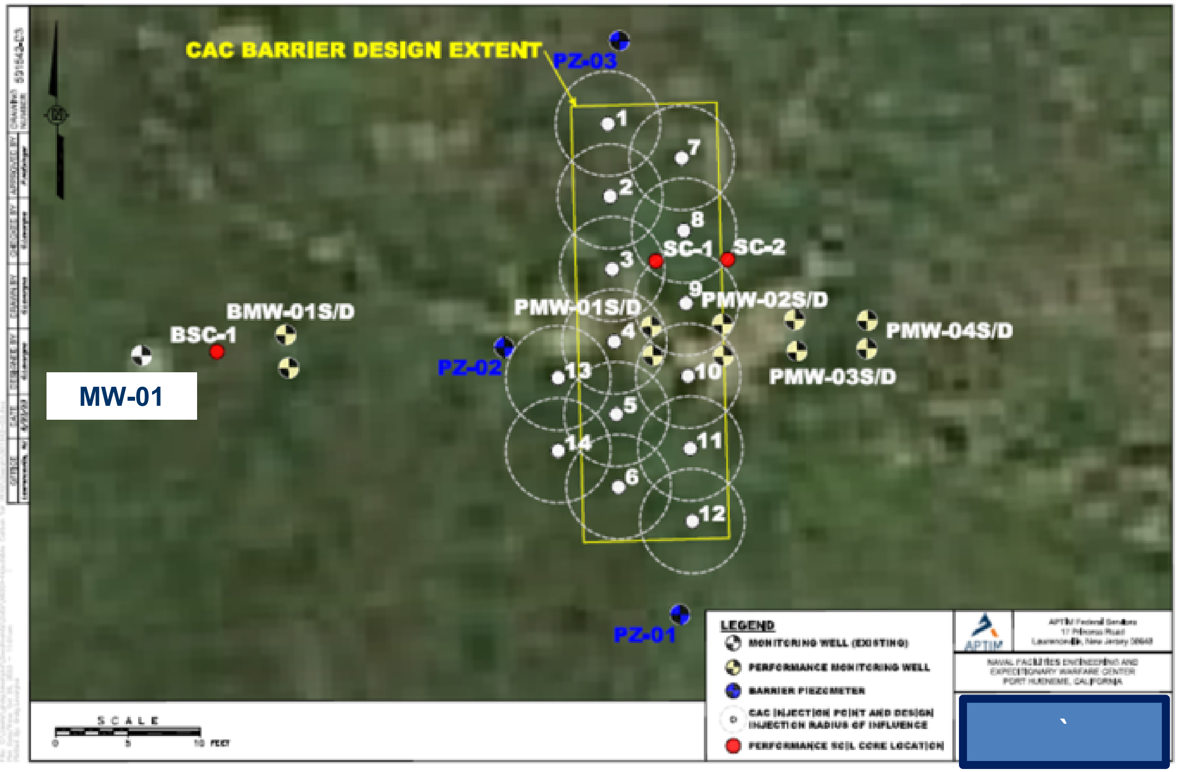
- Freeze columns at -80°C
- Cut into segments (~ 5 cm)
- Remove sediment, homogenize
- Weigh 50 g wet wt
- Dry sediment @ 105°C for 24 hrs
- Weigh
- Combust @ 550°C for 4hrs
- Weigh and calculate loss

Carbon Barrier Design



30’ Long x 10’ Wide barrier

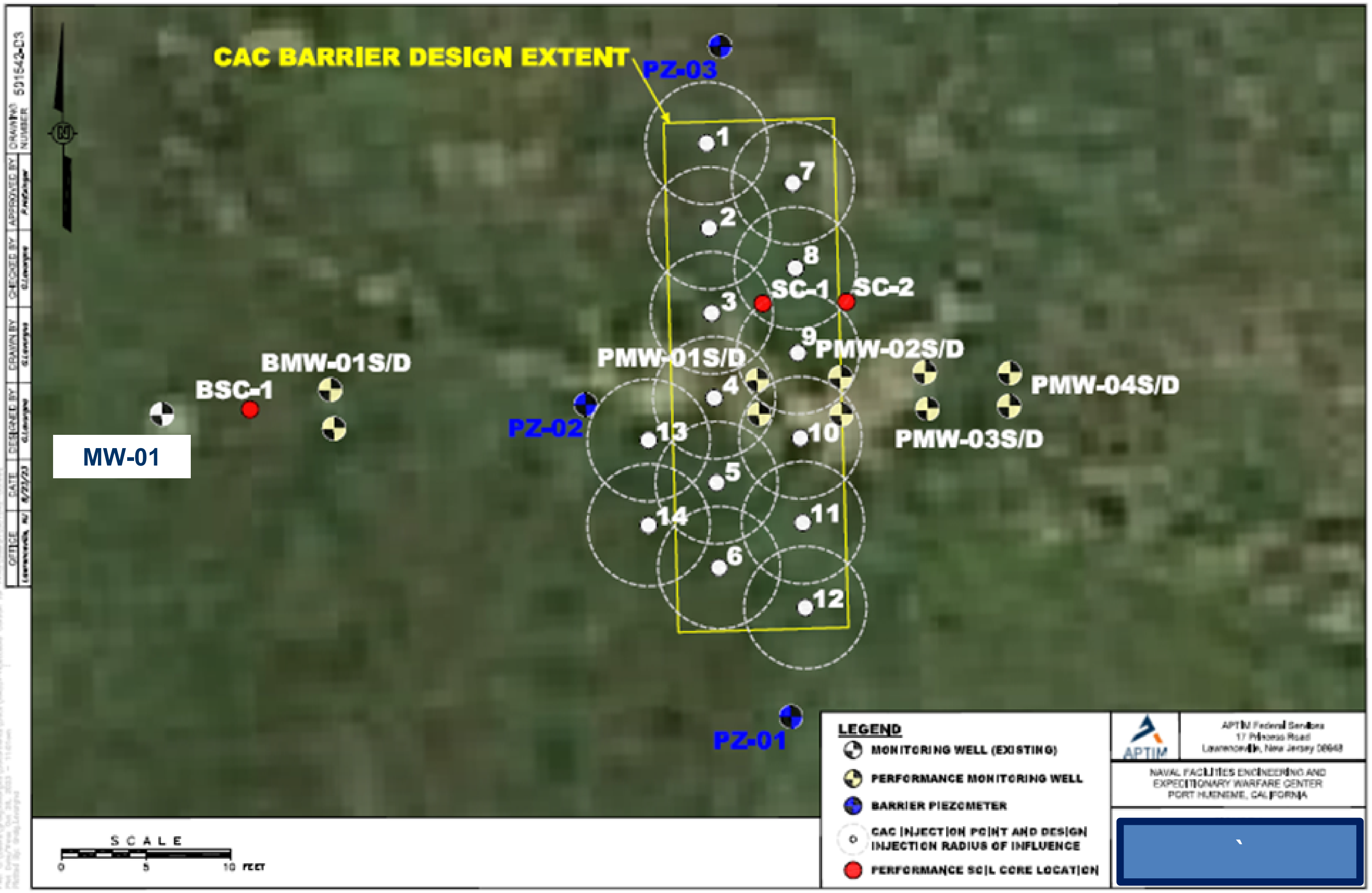
DEMONSTRATION WELL AND INJECTION POINT LAYOUT



Carbon Injection

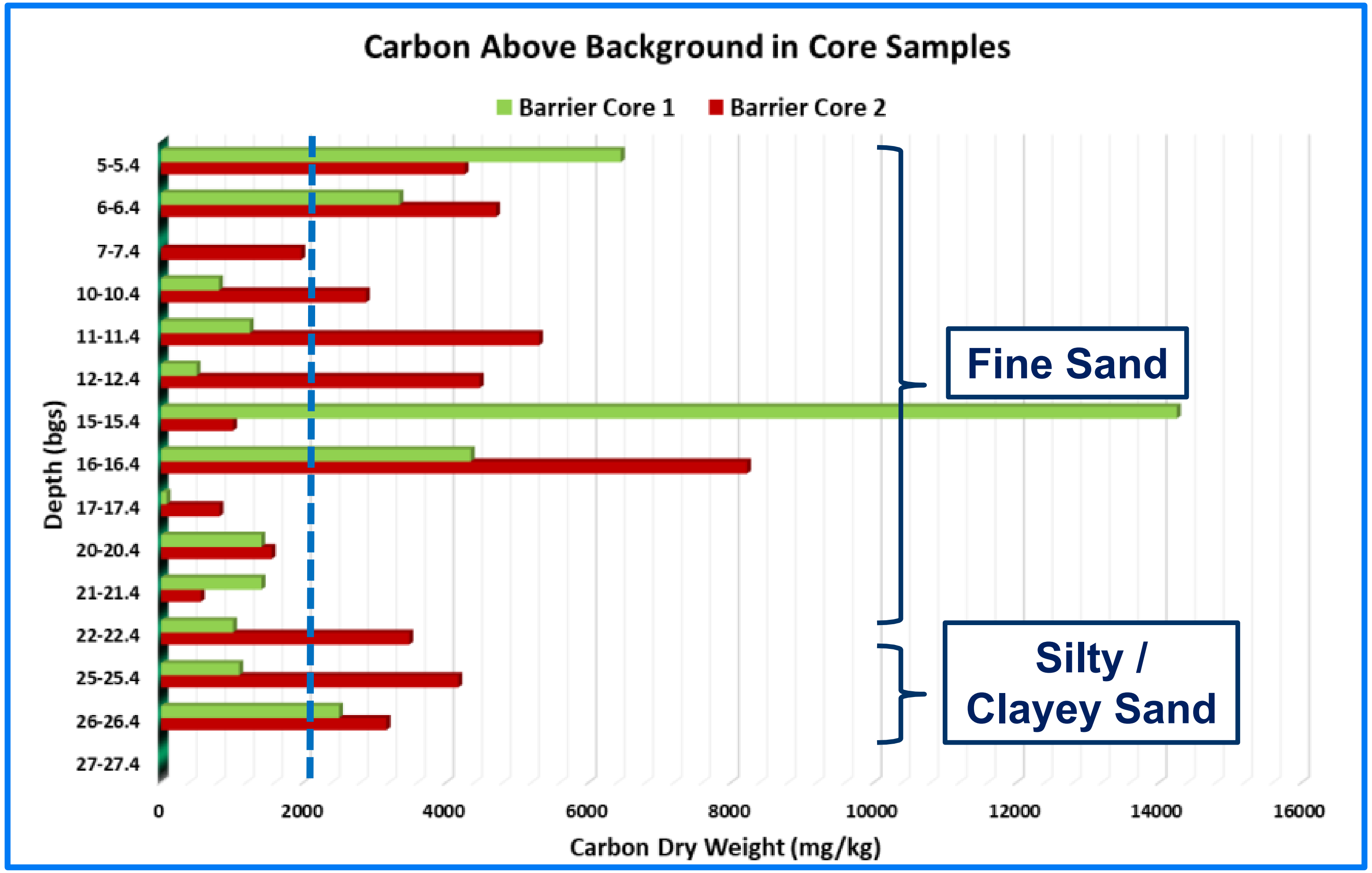
9,600 lbs / 1,065 gal of CAC and 10,456 gal mix water
Target concentration = 2,000 mg carbon per kg soil

Performance Monitoring

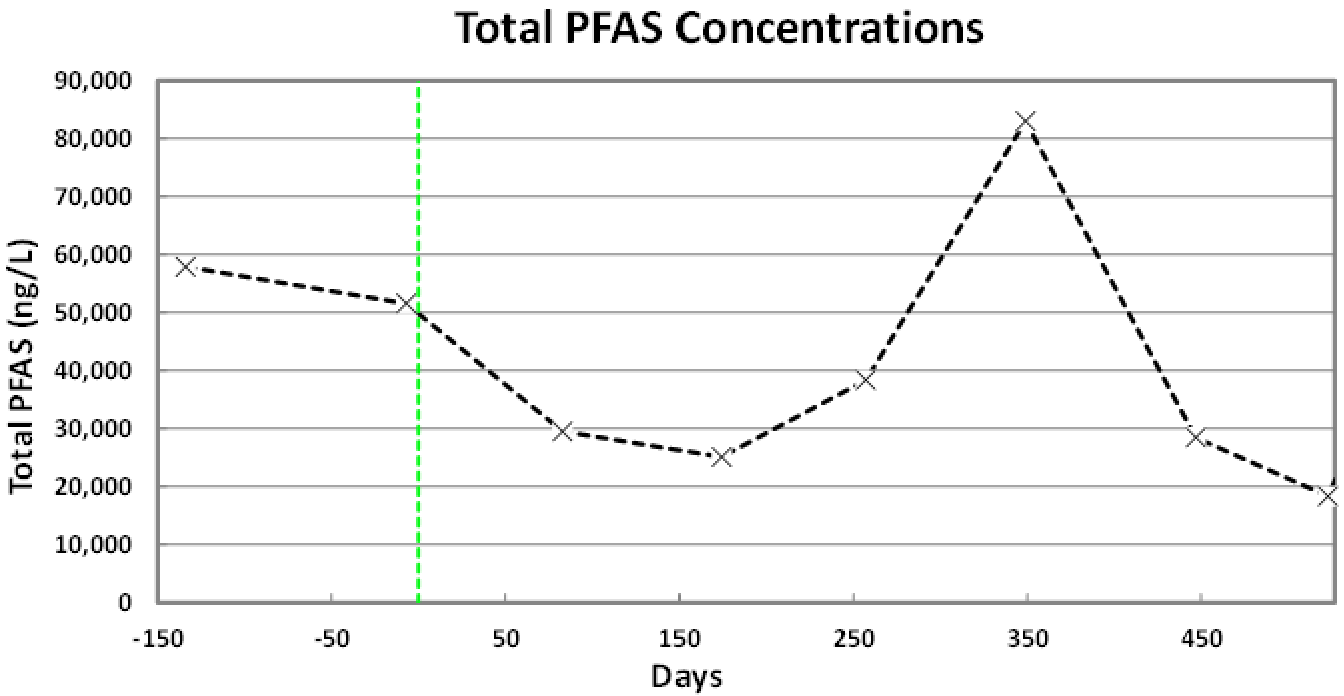


- **Quarterly Groundwater Monitoring**
  - Field parameters (meter)
  - Anions (EPA 300.0)
  - PFAS (EPA 537; LC-MS-MS)
- **Soil Cores**
  - 1 & 24-months post injection
  - Continuous (5 locations)
  - Measure CAC (combustion method)
- **Passive Flux Meters (6)**
  - Before barrier Installation
  - 1 and 2 years after barrier installation

Carbon Distribution



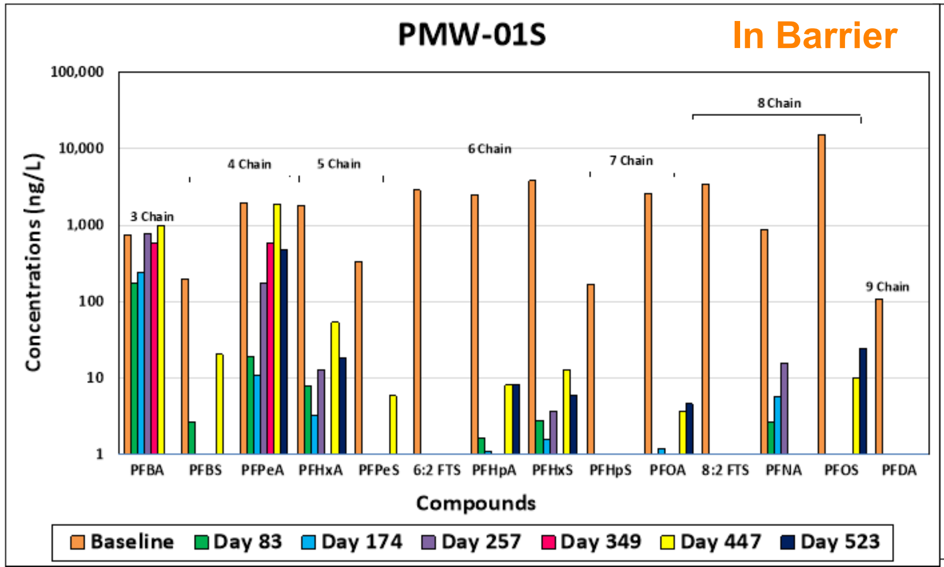
PFAS Data - Upgradient

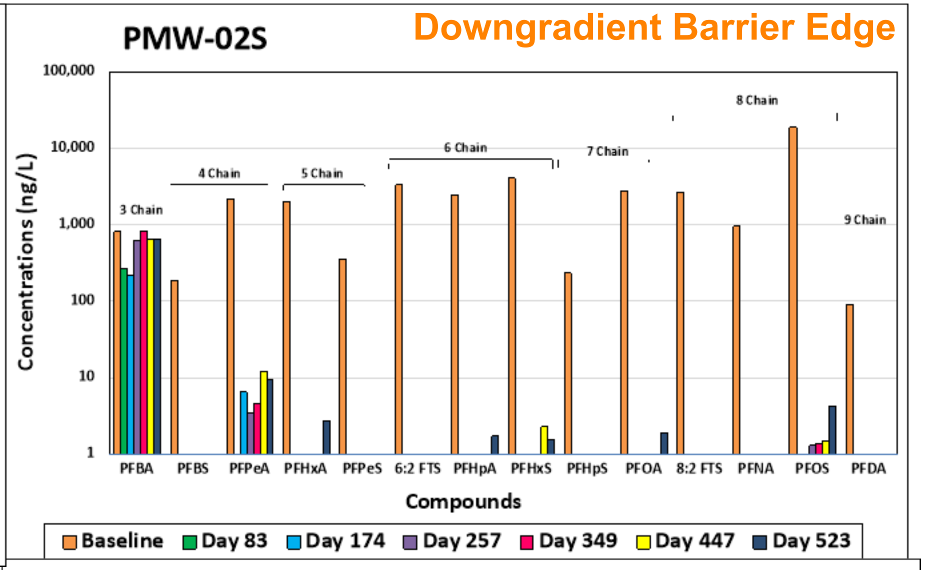


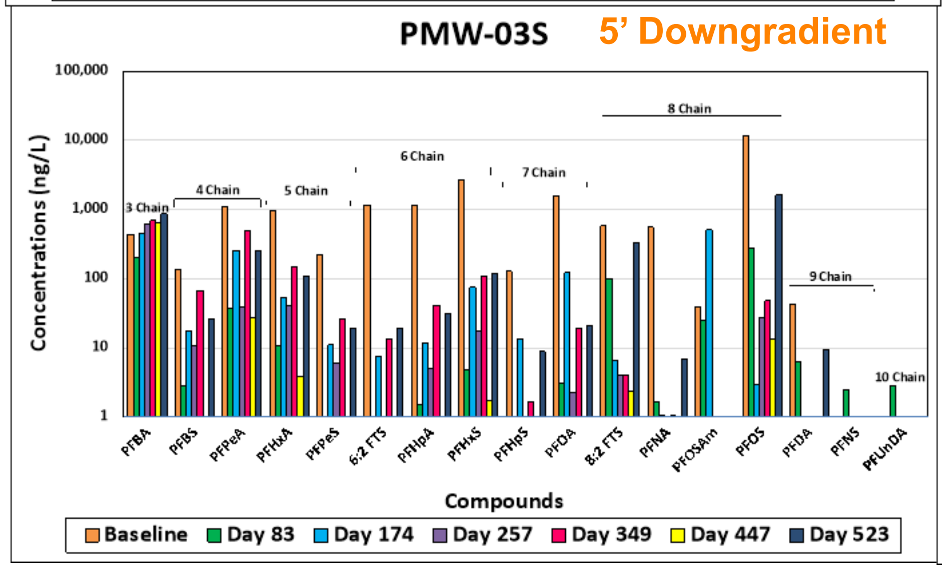
Upgradient– 1.5 YRS

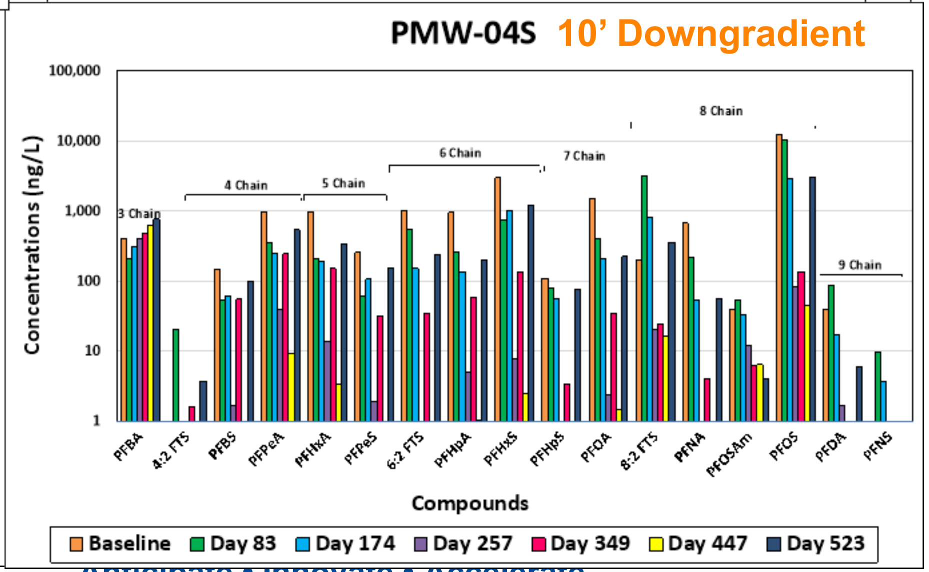
- Pre-injection baseline values ~ 52,000 to 58,000 ng/L.
- Over time, concentrations range from 18,000 ng/L (Day 523) to 83,000 ng/L (Day 349)
- Quarterly variability suggests vadose zone impacts - groundwater elevation/rainfall events?
- Will evaluate further as we get more data

PFAS Data – Shallow Zone





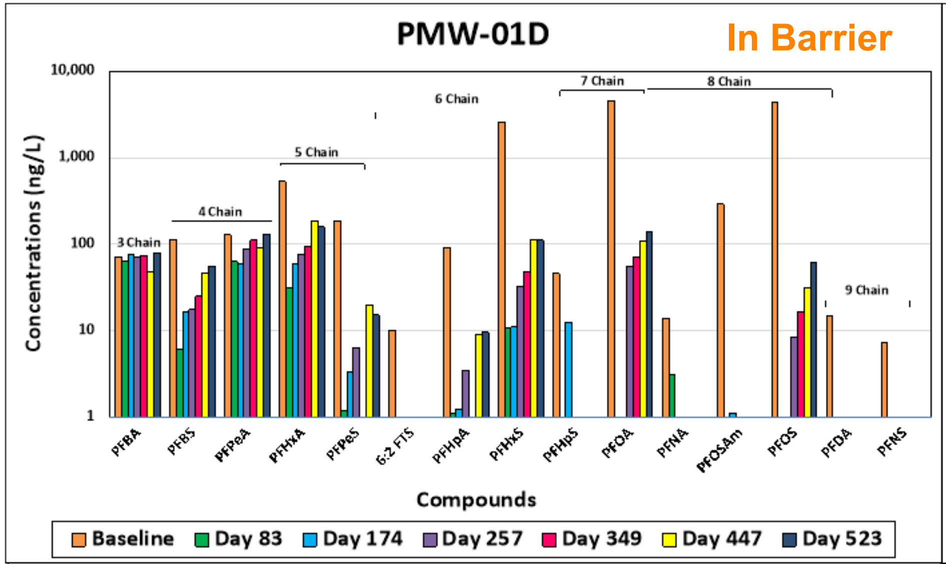


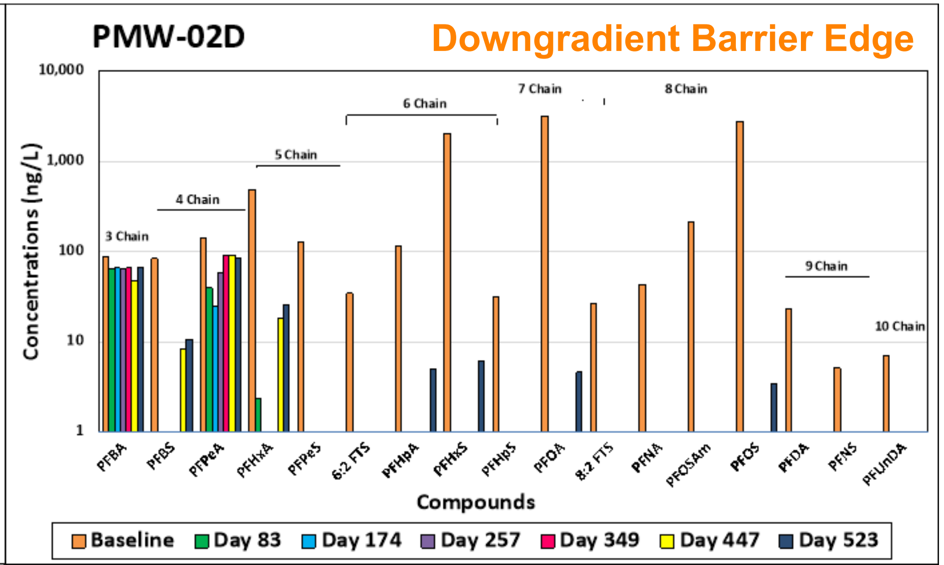


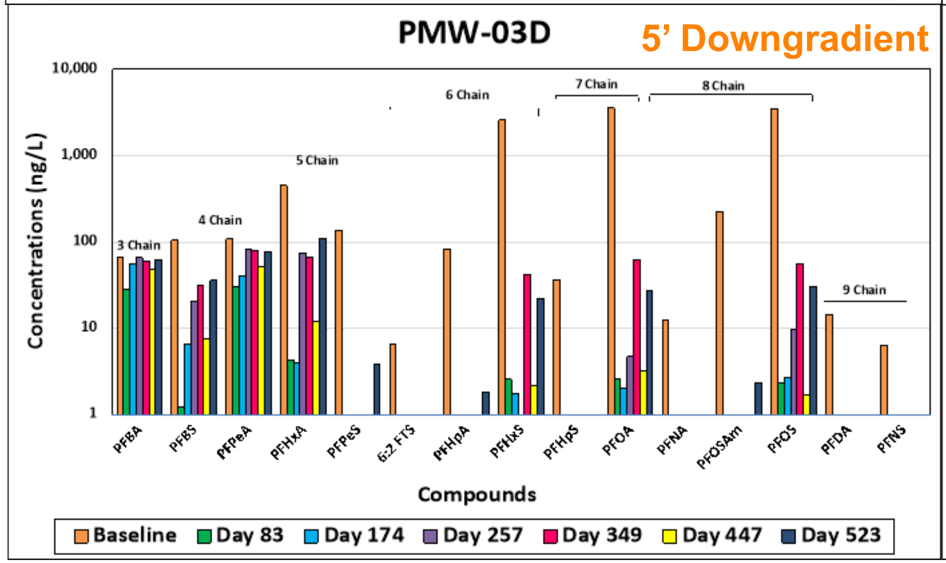
<u>Shallow Monitoring Wells – 1.5 YRS</u>

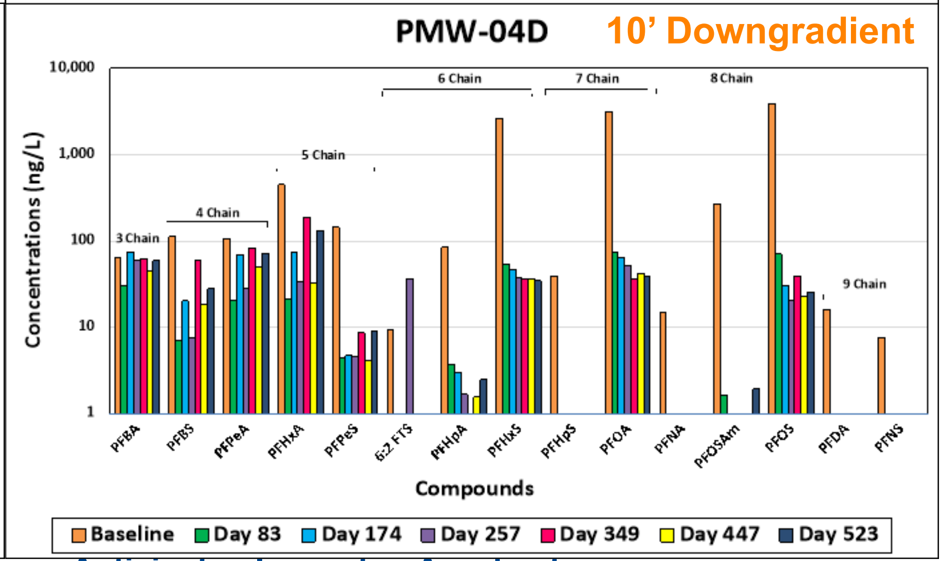
- 98.2% reduction in total PFAS at downgradient edge of barrier after ~ 1.5 yrs (PMW-02S)
- Complete breakthrough of PFBA – least sorbed common PFAS.
- Excluding PFBA, > 99.94% removal at downgradient edge
- Five ft downgradient 84.7% decline
- Unexplained increase from Q5 to Q6

PFAS Data – Deep Zone





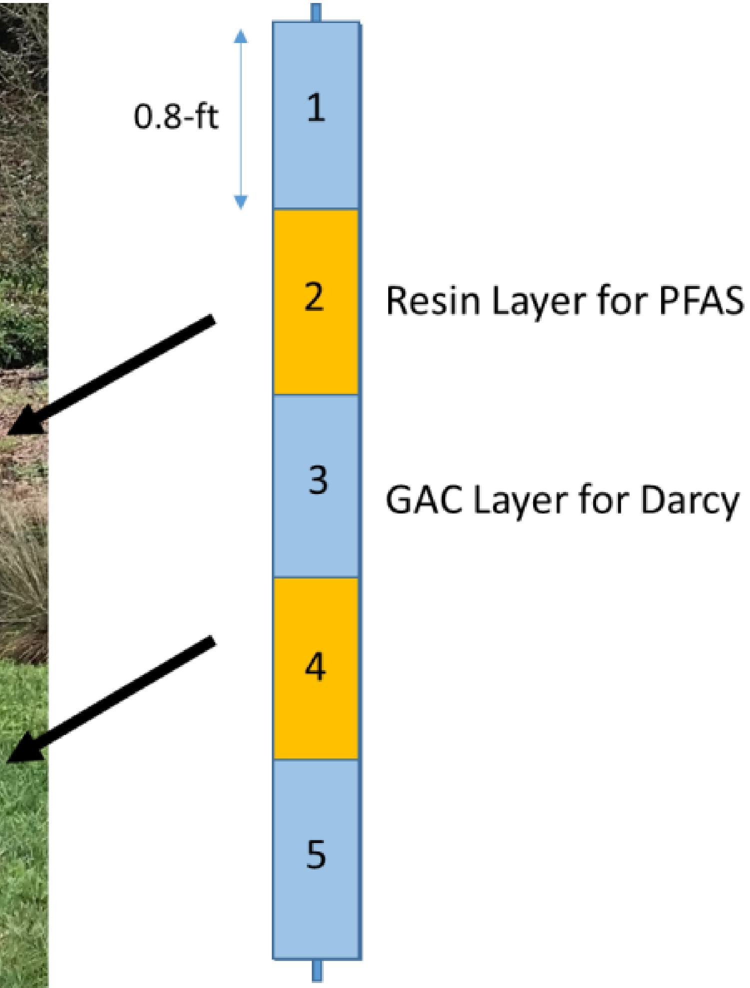




Deep Monitoring Wells

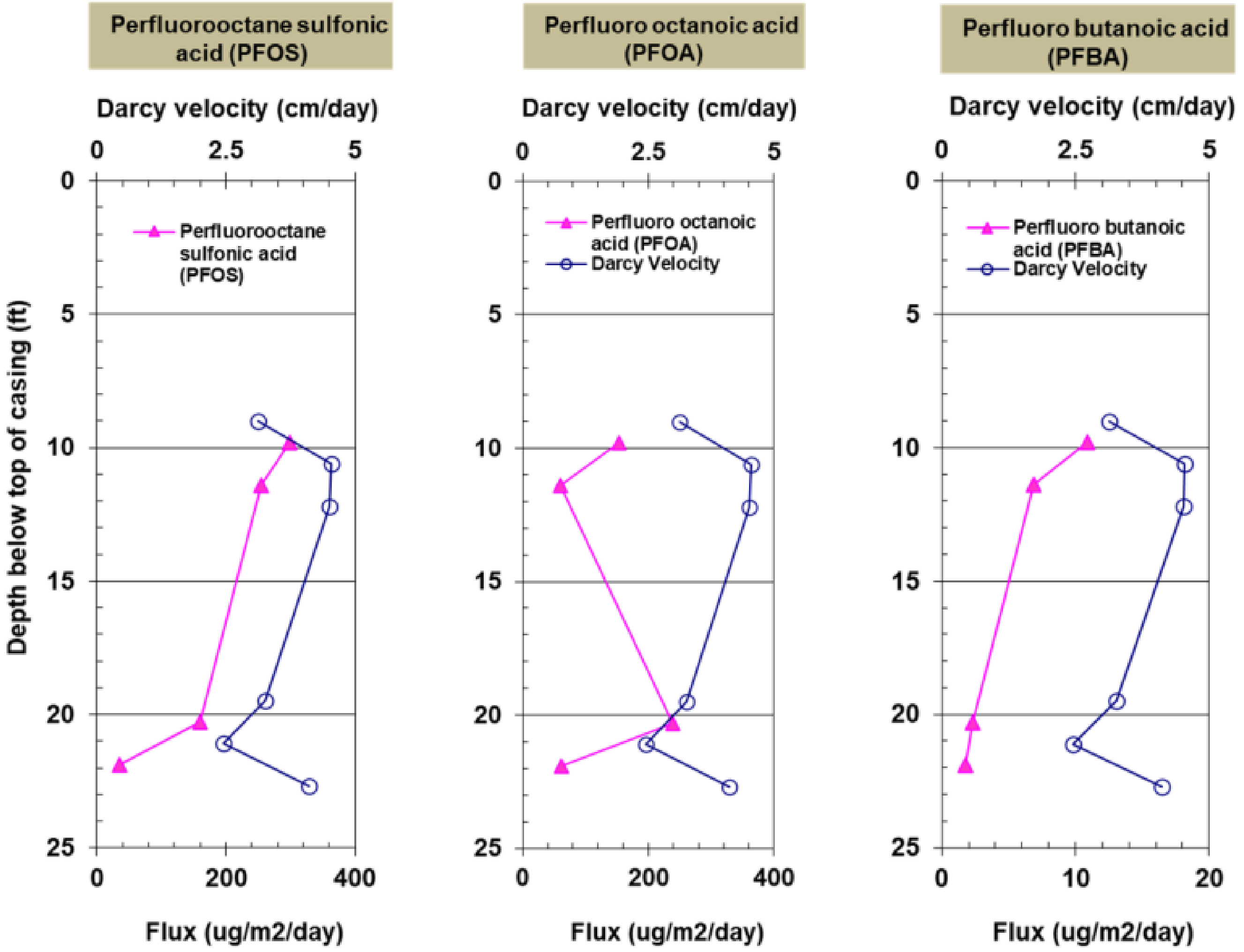
- 97.8% reduction in total PFAS at downgradient edge of barrier after ~ 1.5 yr (PMW-02D)
- Complete breakthrough of PFBA & appreciable for PFPeA
- Excluding PFBA and PFPeA, > 99.0% removal at downgradient edge
- Five ft downgradient 96.6% decline

Passive Flux Meters



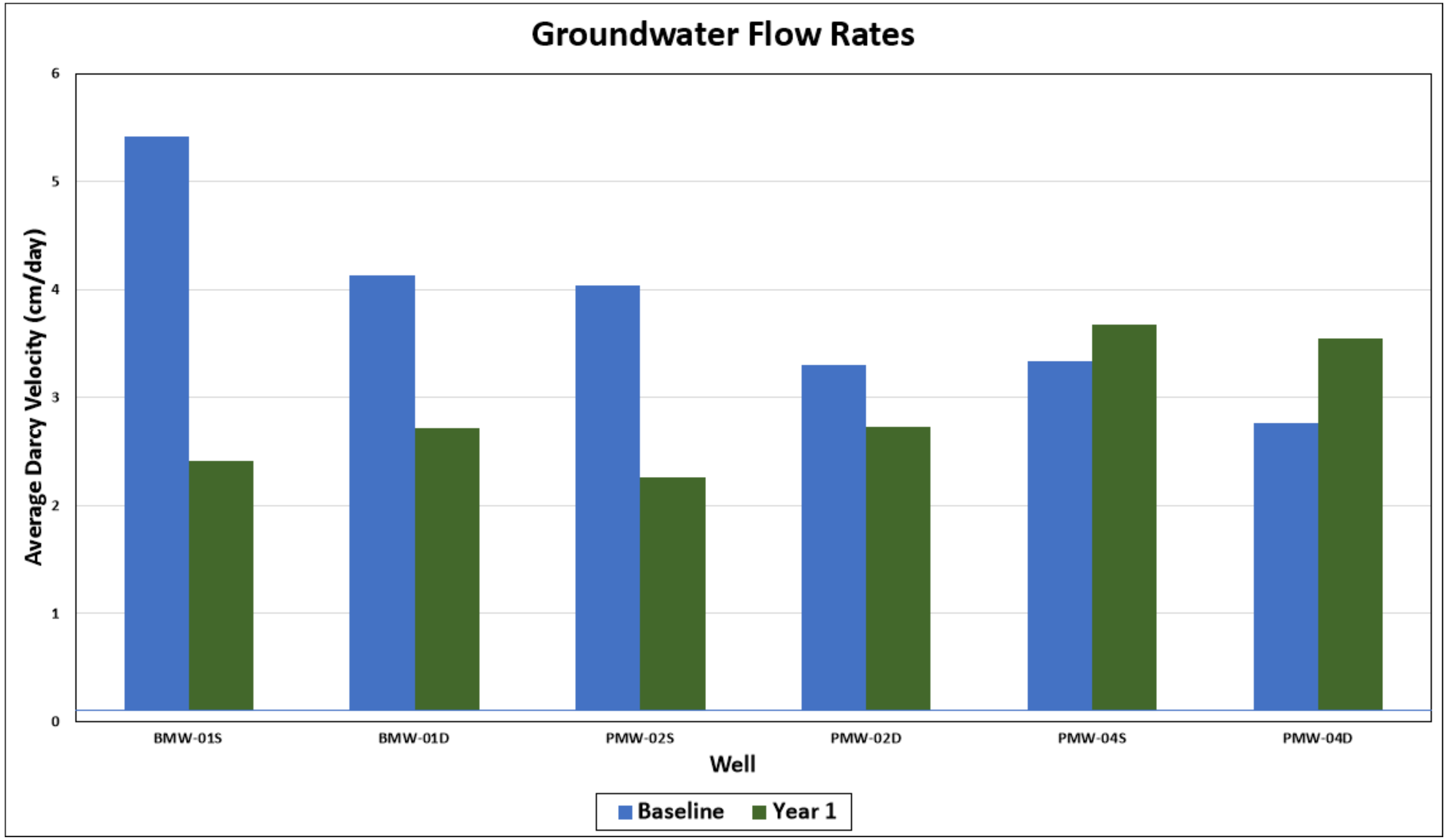
Baseline and First Year Passive Flux Meters

- Darcy velocities ranged from ~ 3-6 cm/day (0.1-0.2 ft/day)
- Residence time in the barrier ~ 50-100 days
- Baseline data to be compared to year 1 and year 2 PFM data



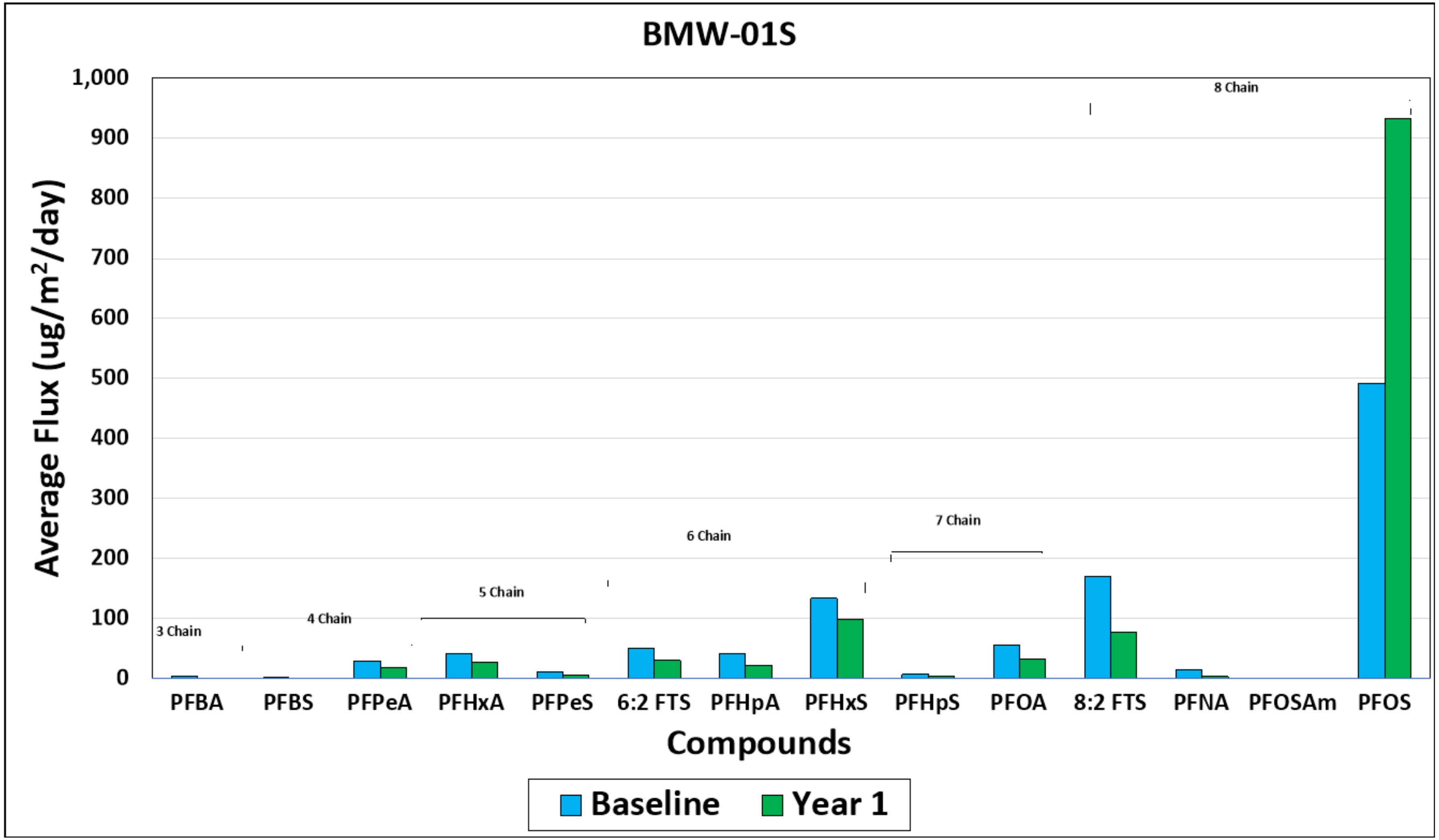
Baseline vs Year 1 groundwater velocity data

- **Baseline average Darcy Velocities ranged from ~ 2.8-5.4 cm/day (Avg: 3.8 ± 0.9 cm/day)**
- **Year 1 average Darcy Velocities ranged from ~ 2.3-3.7 cm/day (Avg: 2.9 ± 0.6 cm/day)**
- **Most significant reduction upgradient shallow well**
- **No evidence of aquifer clogging at one year**



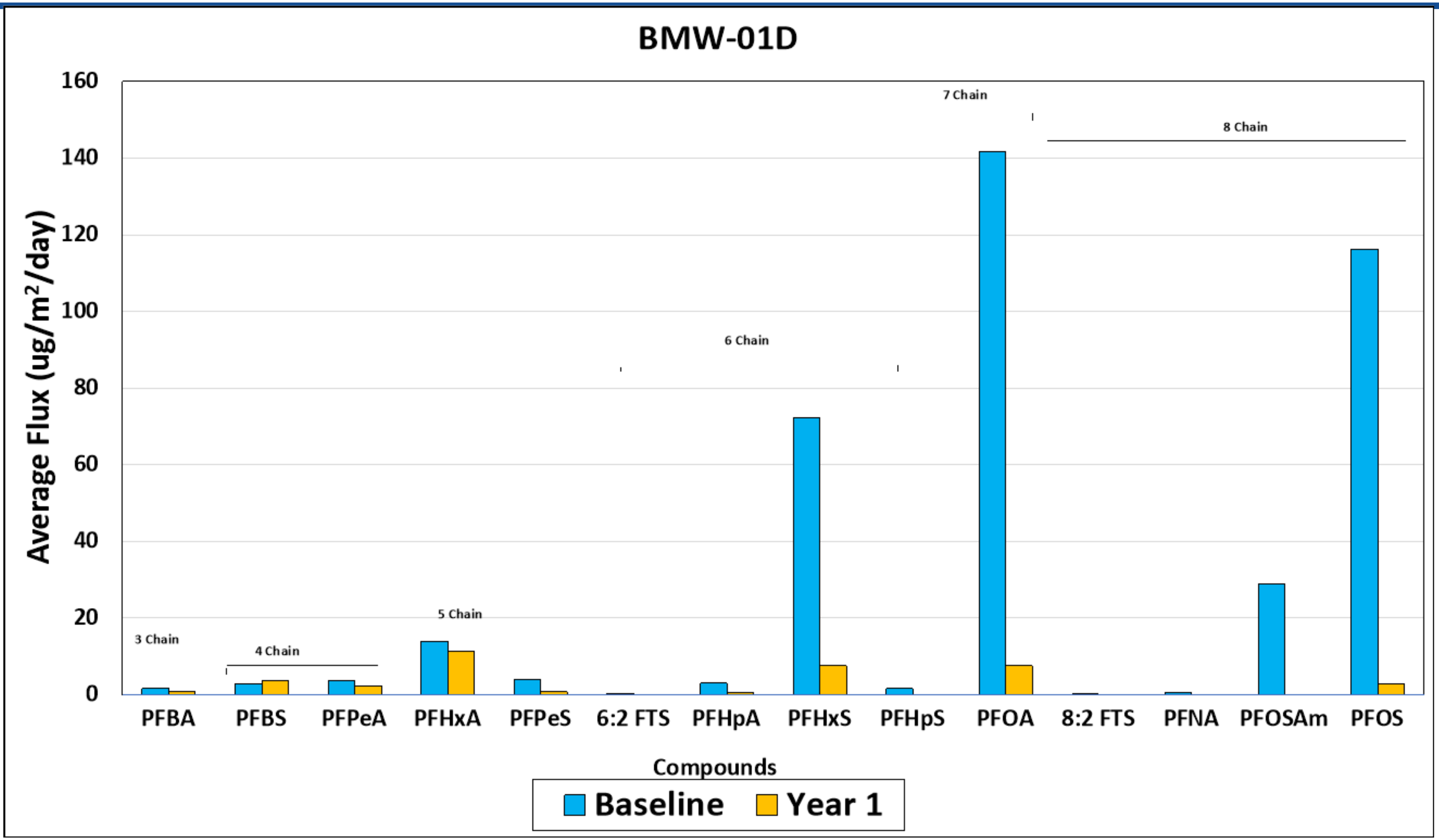
Baseline vs Year 1 PFM data – Upgradient (shallow)

- **9% increase in PFAS mass flux (ug/m²/day) upgradient of barrier after 1 yr in shallow zone (BMW-01S)**



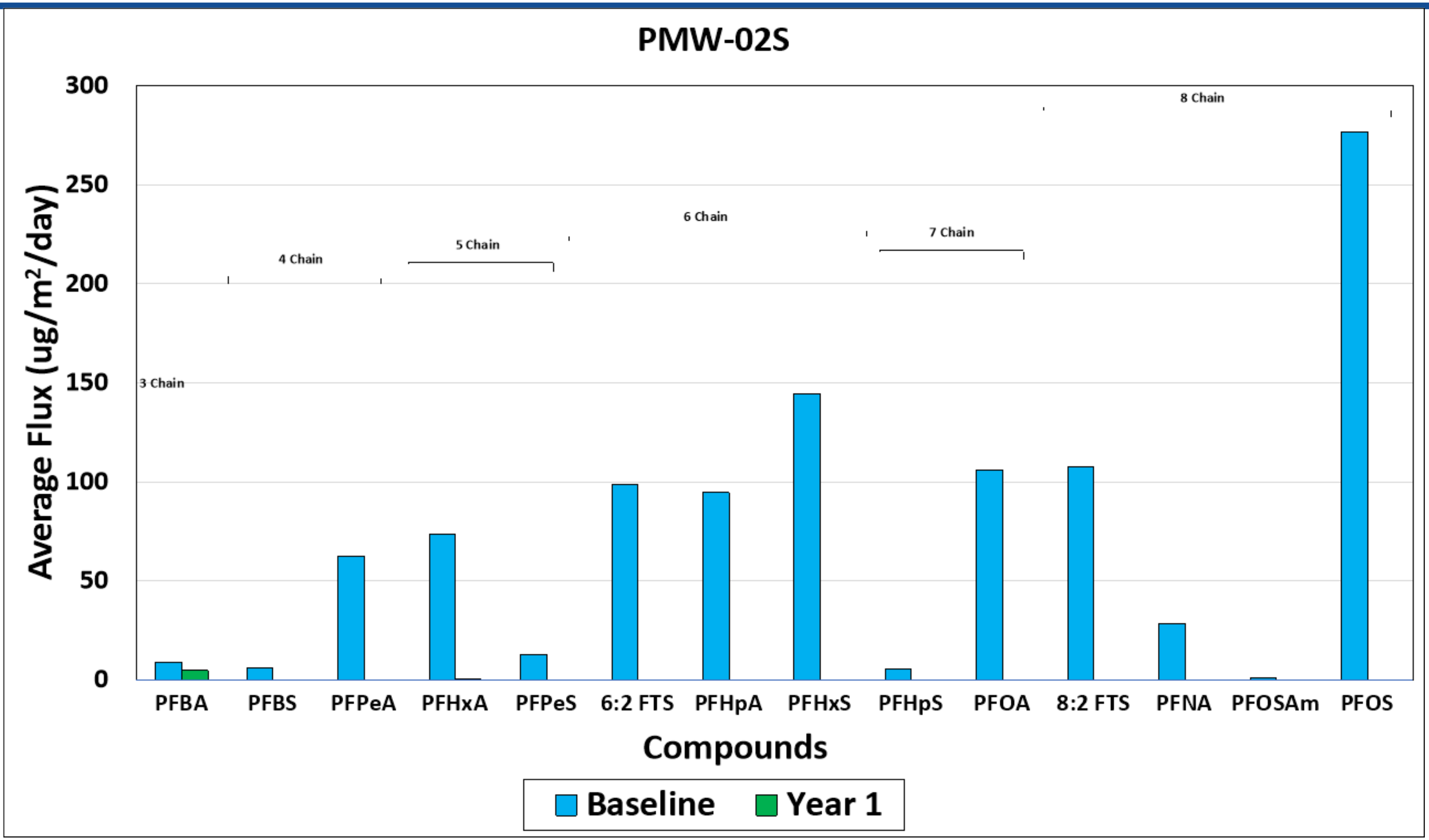
Baseline vs Year 1 PFM data – Upgradient (deep)

- 90% decrease in PFAS mass flux (ug/m²/day) upgradient of barrier after 1 yr in deep zone (BMW-01D)
- Most of the decline reflects PFOS, PFOA, PFHxS
- Did a small amount of CAC reach the zone?

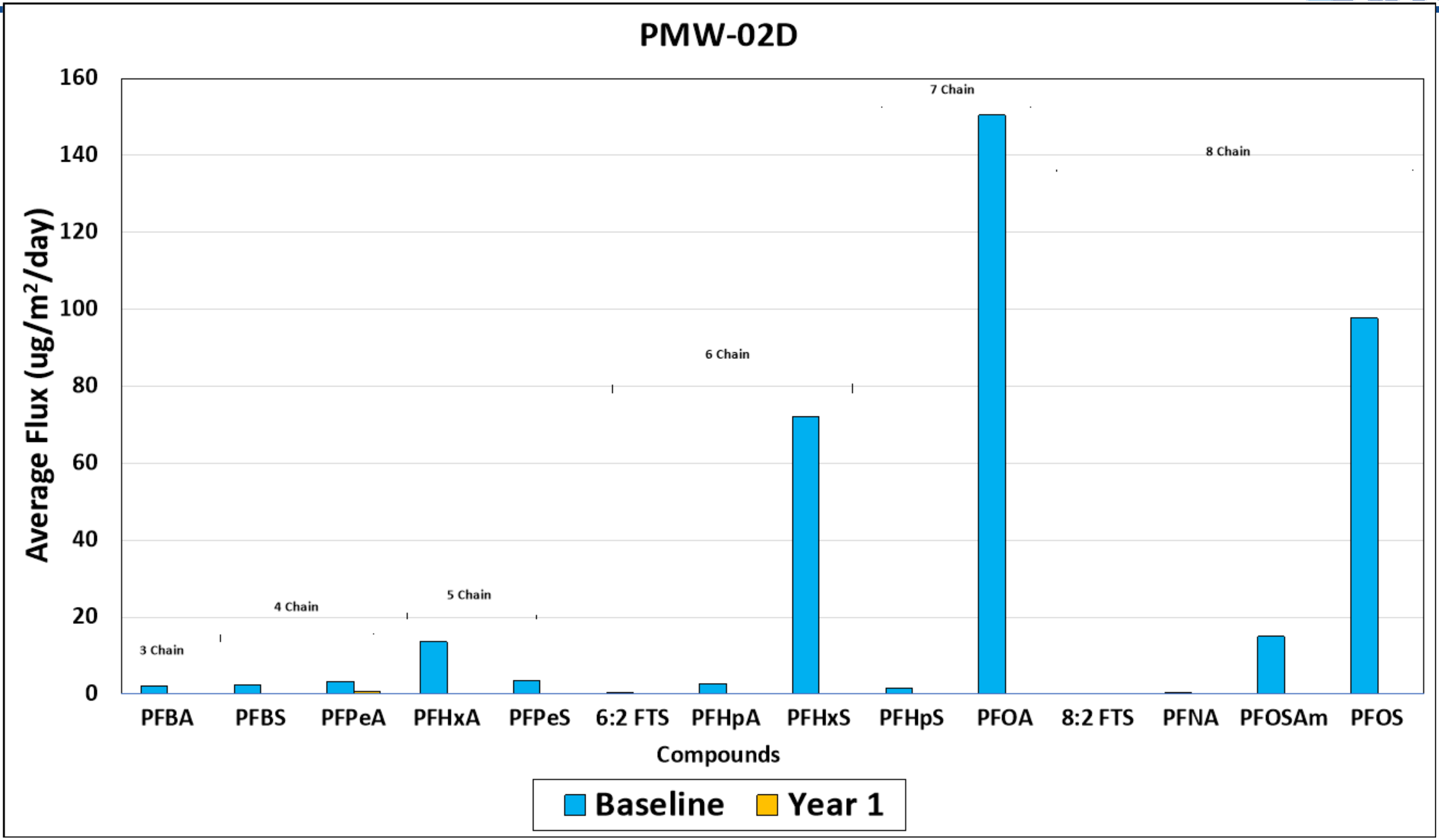


Baseline vs Year1 PFM data – Downgradient barrier edge (shallow)

- **95.5% decrease in PFAS mass flux (ug/m^2/day) at downgradient barrier edge after 1 yr in the shallow zone (PMW-02S**



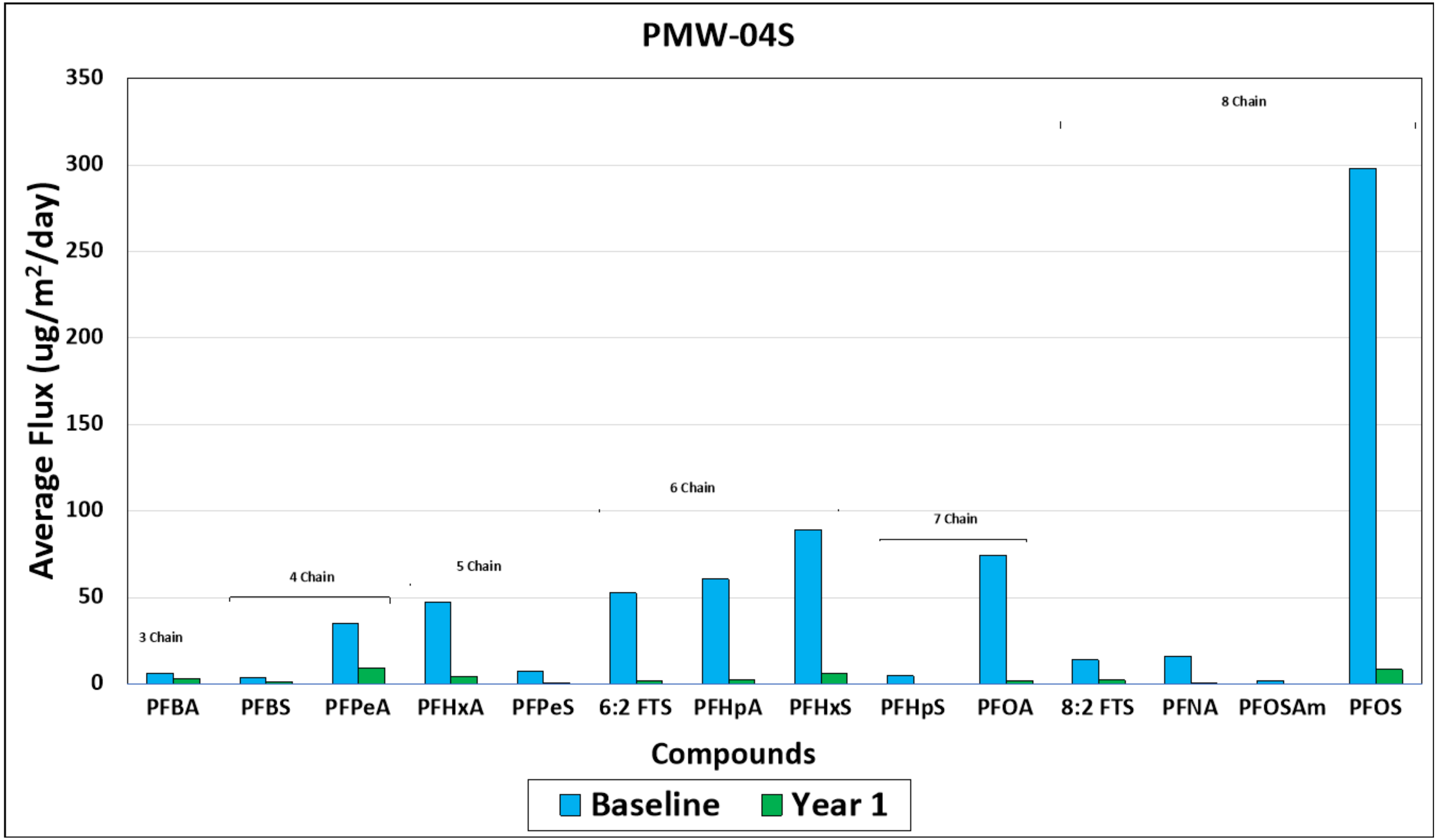
Baseline vs Year 1 PFM data – Downgradient barrier edge (deep)



- **99.7% decrease in PFAS mass flux (ug/m^2/day) at downgradient barrier edge after 1 yr in the deep zone (PMW-02D)**

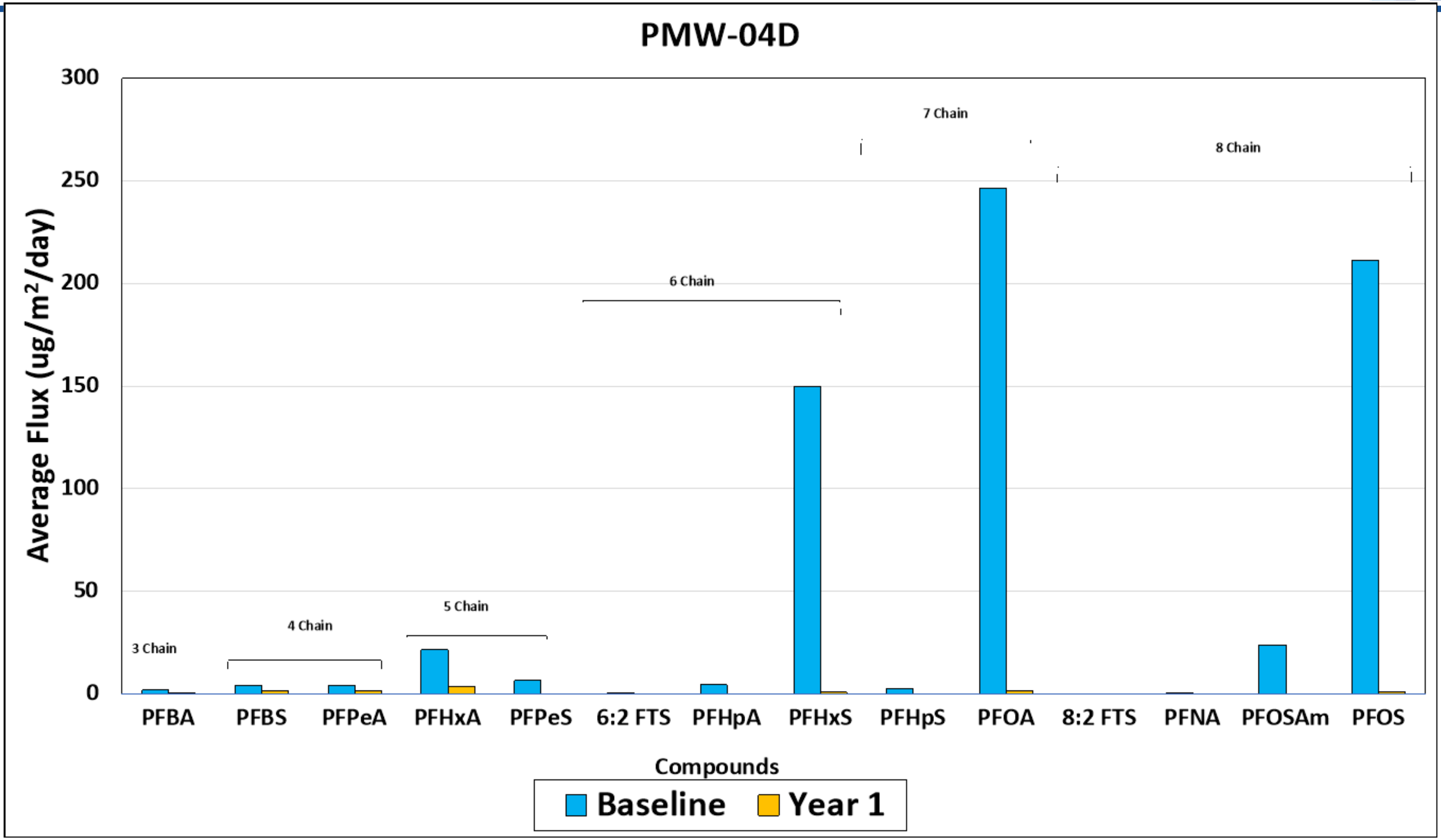
Baseline vs Year 1 PFM data – 10 ft downgradient (shallow)

- **94.2% reduction in PFAS mass flux (ug/m²/day) 10 ft downgradient of barrier after 1 yr (PMW-04S)**



Baseline vs Year 1 PFM data – 10 ft downgradient (deep)

- 98.2% reduction in PFAS mass flux (ug/m²/day) 10 ft downgradient of barrier after 1 yr (PMW-04D)



Summary

CAC Injection represents a potential option to:

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

NESDI Field Study Results to Data:

- Overall good CAC distribution in aquifer
- Good effectiveness for 1.5 years overall: > 98% PFAS Reduction
- PFBA and PFPeA show rapid breakthrough – not unexpected from isotherms
- No signs of hydraulic conductivity changes at 1 yr
- Need modeling to predict downgradient response

Acknowledgements and Questions?

- Tony Danko, Ph.D., P.E.
  - anthony.s.danko.civ@us.navy.mil

- Jillian Wheeler (East Coast NAS RPM)
- APTIM and Jason Speicher (NAVFAC LANT)
- NESDI