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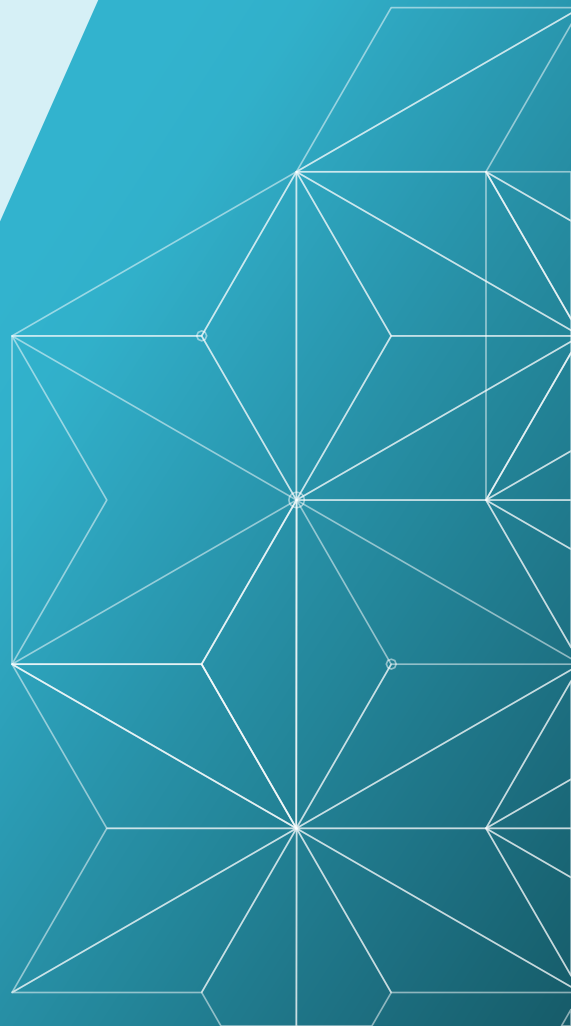
Characterization of per- and polyfluoroalkyl substances in stormwater and evaluation of fate and transport of PFAS in stormwater management systems

Tariq Hussain, Ph.D.



Introduction

Sediment contamination:

- Industrialization and poor environmental practices
- Sediments serve as an ultimate sink for these contaminants particularly persistent and strongly solids associated (PCBs, heavy PAHs)
- Contaminants in sediments can often persist longer than the original source even if the source is eliminated
- Sediment contamination poses an ecological risk to aquatic life
- The dynamics of the environment can resuspend the contaminants to the water column (sediment process, discharges, etc.)

Sources:

- Point source: ex. direct discharge of industrial or municipal waste
- Nonpoint source: ex. stormwater discharge, leaching, etc.

Introduction

Stormwater:

- Major source of contamination in urban watersheds
- Can affect the effectiveness of remediation of sediments
- Rapid urbanization has only increased this issue
- Difficult to assess

Stormwater contaminant transport:

- Dissolved
- Particulate

Introduction — summary

- Contaminated sediments pose a significant risk to ecological health of waterways
- Point sources to waterways and sediments are much better controlled than in the past
  - Much effort is currently directed toward sediment remediation
  - Concern: Are there still sources that can maintain or reverse sediment recovery?
- Stormwater is a potentially poorly controlled source that may lead to recontamination of water and sediments

Funding: SERDP projects

ER-2428

Assessment and management of stormwater impacts on sediment recontamination

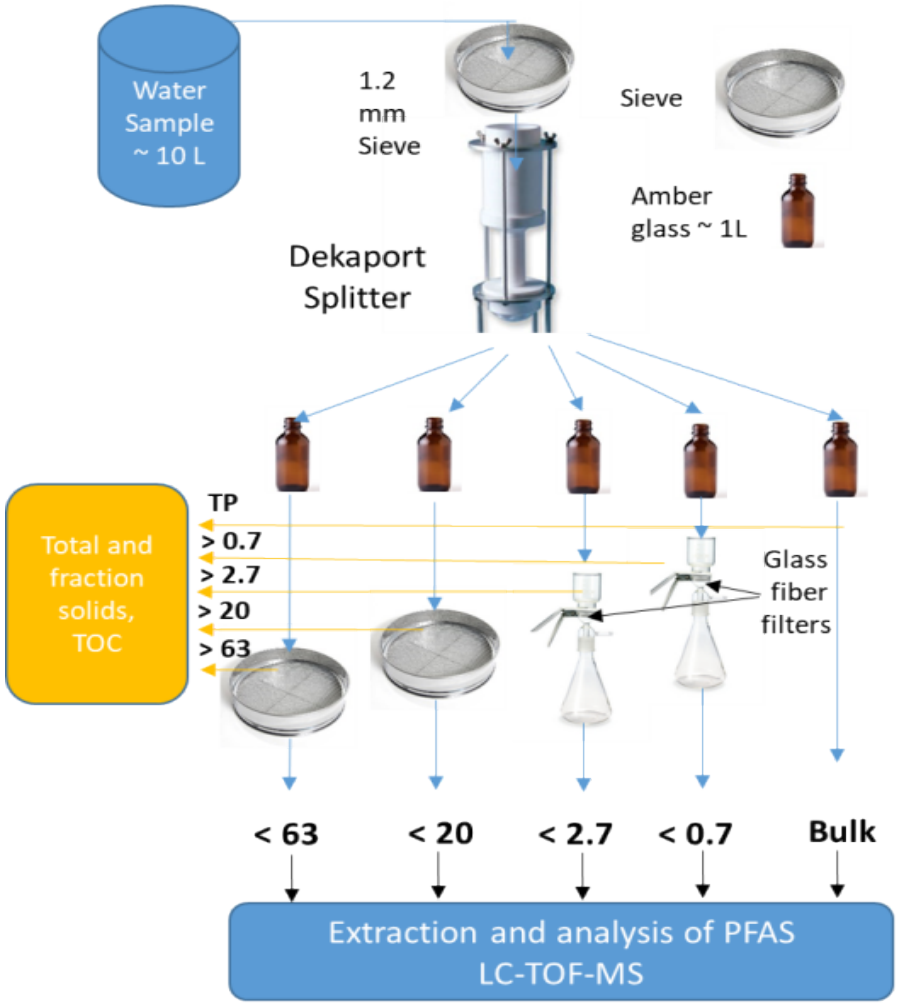
ER18-1371

Development of tools to inform the selection of stormwater controls at DoD bases to limit potential sediment recontamination

ER-2428 — Assessment and management of stormwater impacts on sediment recontamination

- Size-based characterization of stormwater contaminants from Paleta Creek watershed (mixed-use watershed including industrial, commercial, and residential)
- Effect on sediment and biota recontamination in receiving San Diego Bay (spatial and temporal)

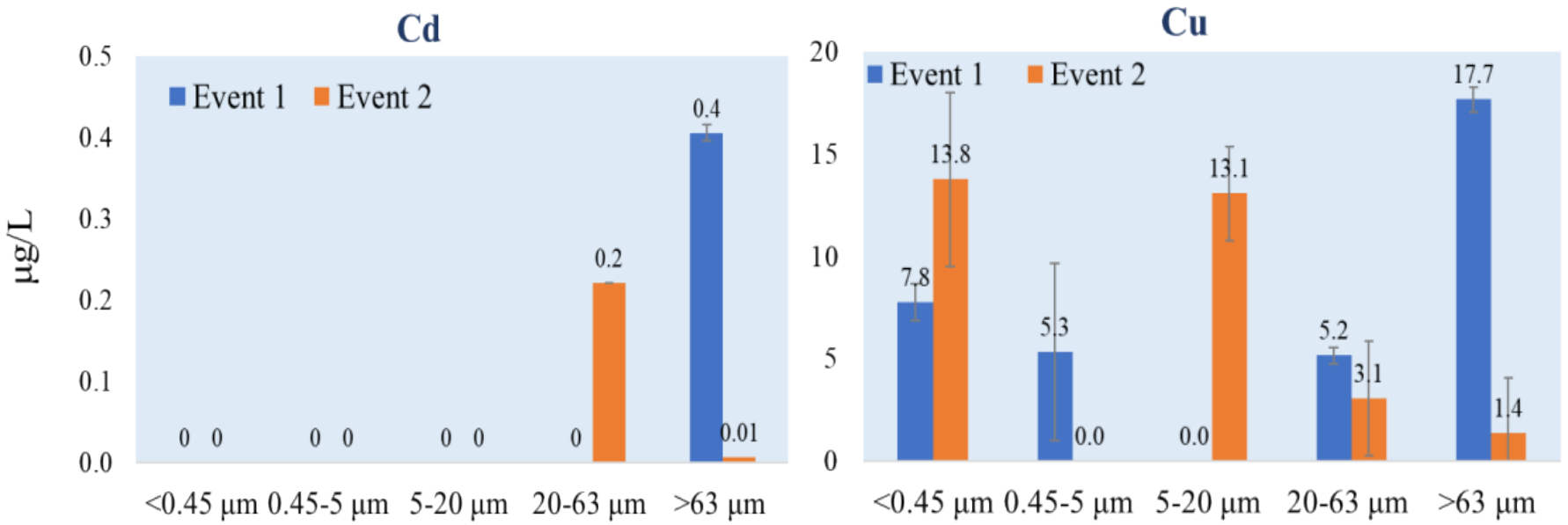
ER-2428 — Assessment and management of stormwater impacts on sediment recontamination



Particle size fraction:

Size fraction	Particle size
Dissolved/filtered	<0.7µm
Clay	0.7µm-2.7µm
Fine silt	2.7µm-20µm
Coarse silt	20µm-63µm
Sand	>63µm

ER-2428 — Assessment and management of stormwater impacts on sediment recontamination



Science of the Total Environment article,
"Assessing sediment recontamination from metals in stormwater"

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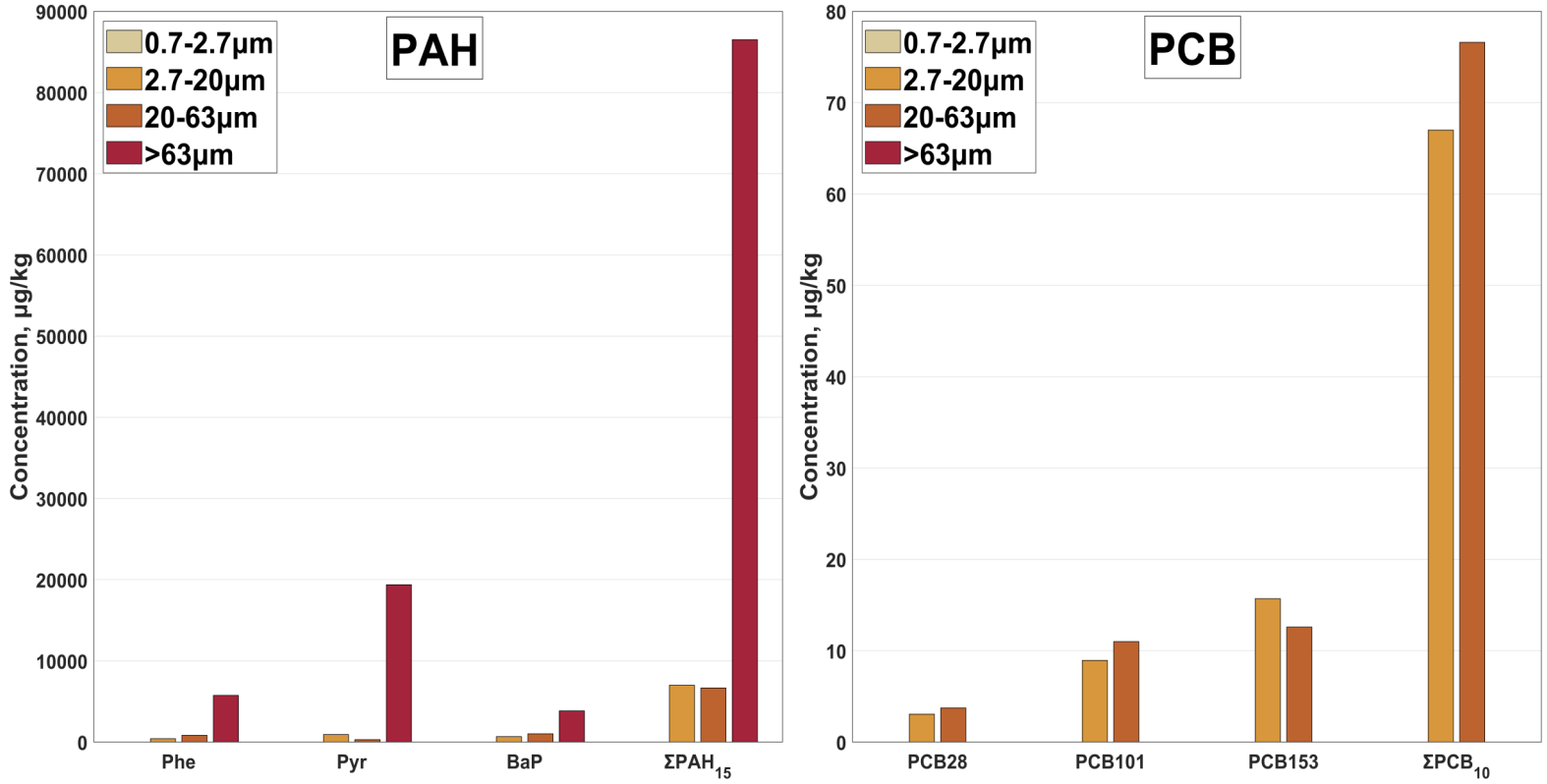
ER-2428 — Assessment and management of stormwater impacts on sediment recontamination



Science of the Total Environment article,
"Sediment recontamination potential and biological impacts of hydrophobic organics from stormwater in a mixed-use watershed"

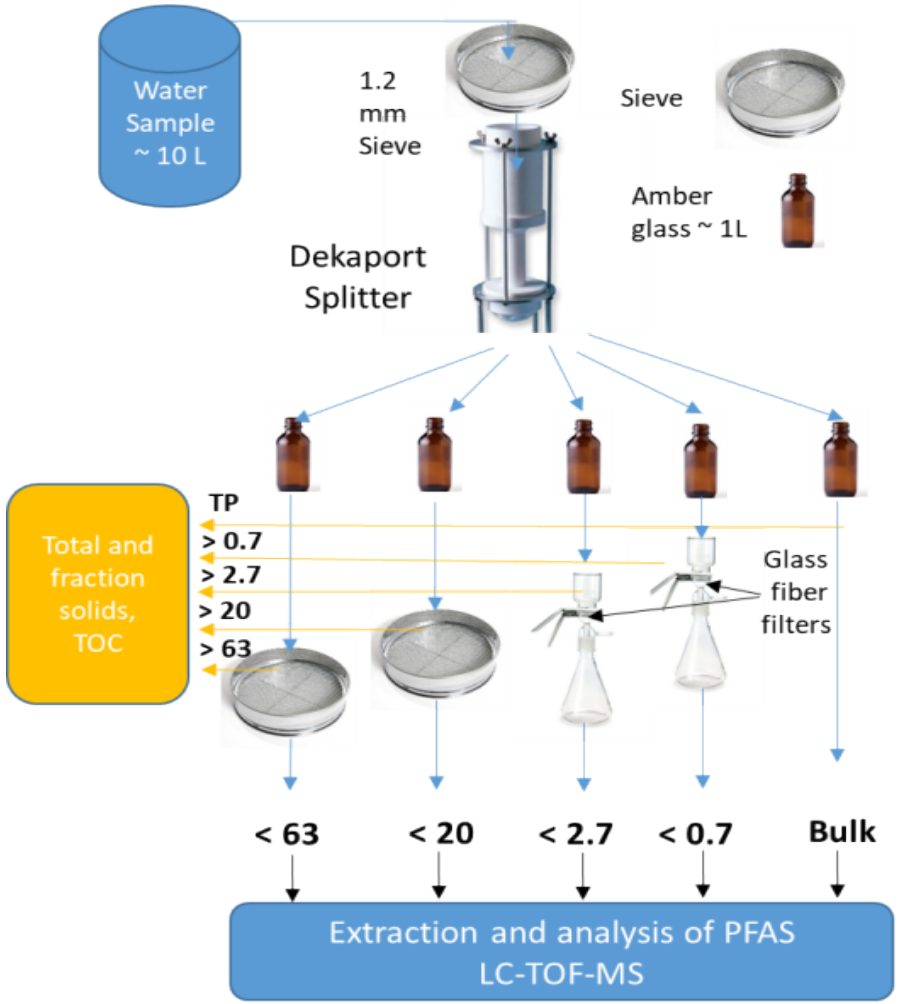
Objectives

- Gain a better understanding of stormwater characteristics and its impact in recontamination of PFAS on receiving water bodies
  - Case study: Reese Technology Center (former Air Force base)
- Evaluate the performance of BMPs in mitigating the PFAS release
  - Commonly used BMPs — retention pond, bioswale, etc.
  - Engineered BMPs — hydrodynamic cartridge filter and oil-and-water separator

Methodology — stormwater sampling

- Stormwater was collected by Teledyne autosamplers
- Automatic sampling based on level increase and storm conditions
- Twenty samples of 500ml at five-minute intervals

Methodology — sample processing



Water samples: 70%:30% water and methanol + mass-labeled internal standard

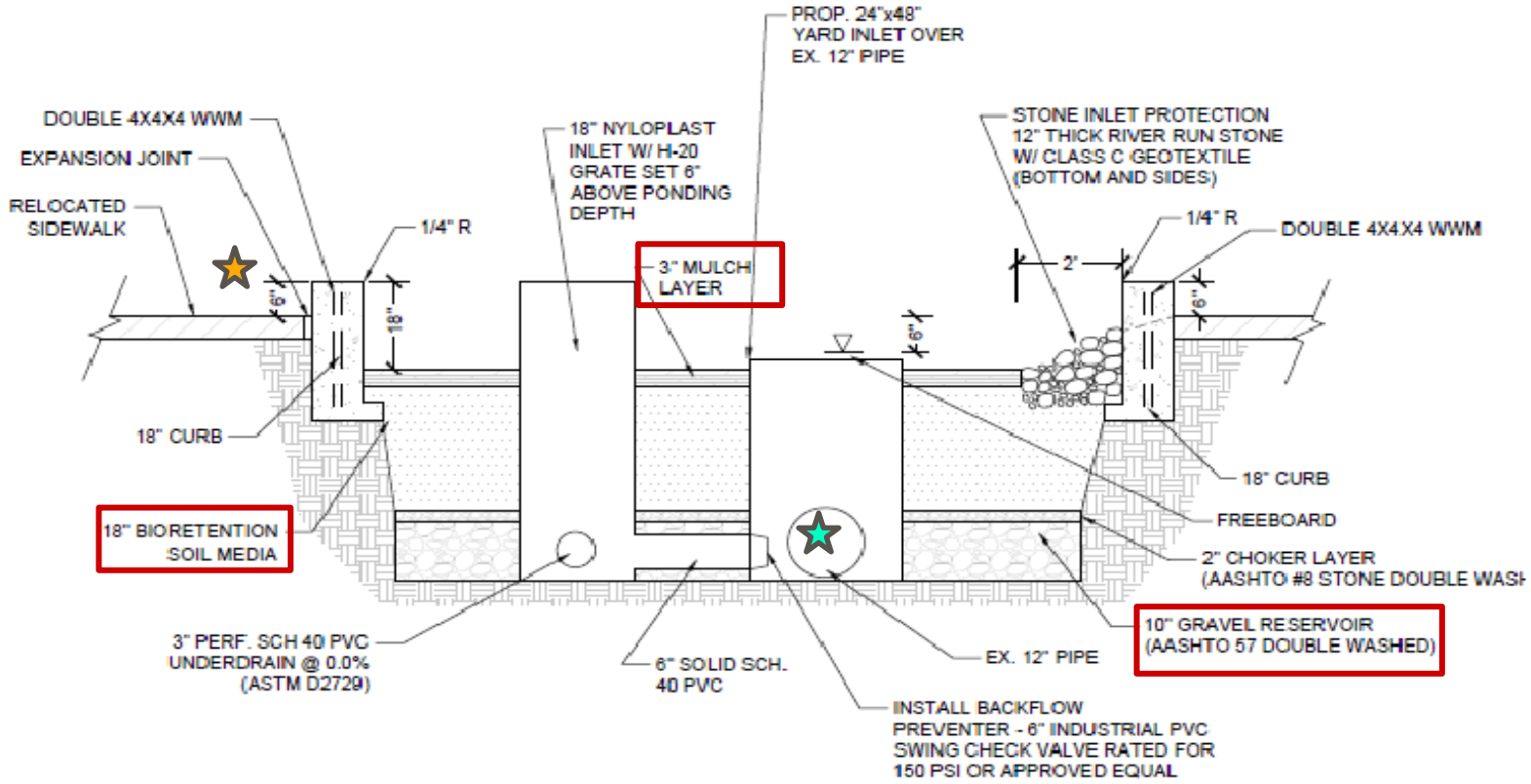
Samples analyzed for 30 PFAS including PFCA, PFSA, FASA and FTS, SCIEX QTOF-LCMS

Performance of BMPs

Four types of BMPs were compared for their performance in removal of solids and PFAS:

1. Retention Pond (RP)
2. Bioinfiltration system (BI)
3. Bioinfiltration system with media filter (BI+MF)
4. Hydrodynamic separator and cartridge filter systems (H+CF)

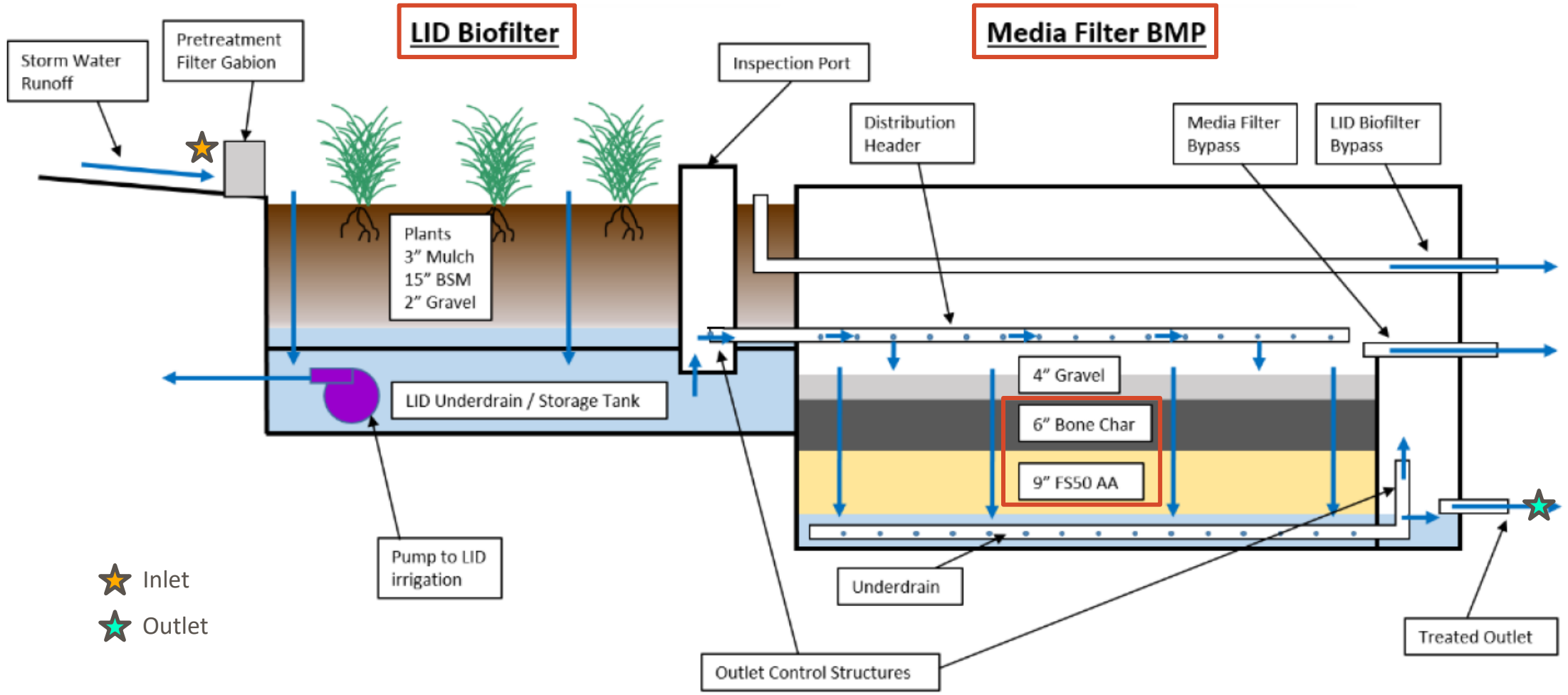
Bioinfiltration system



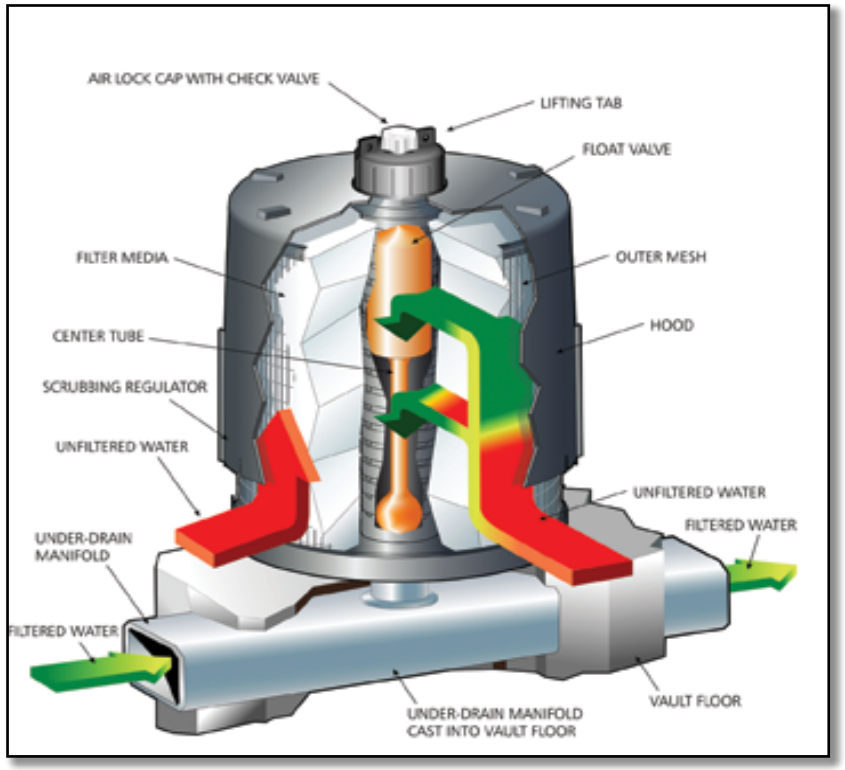
Inlet

Outlet

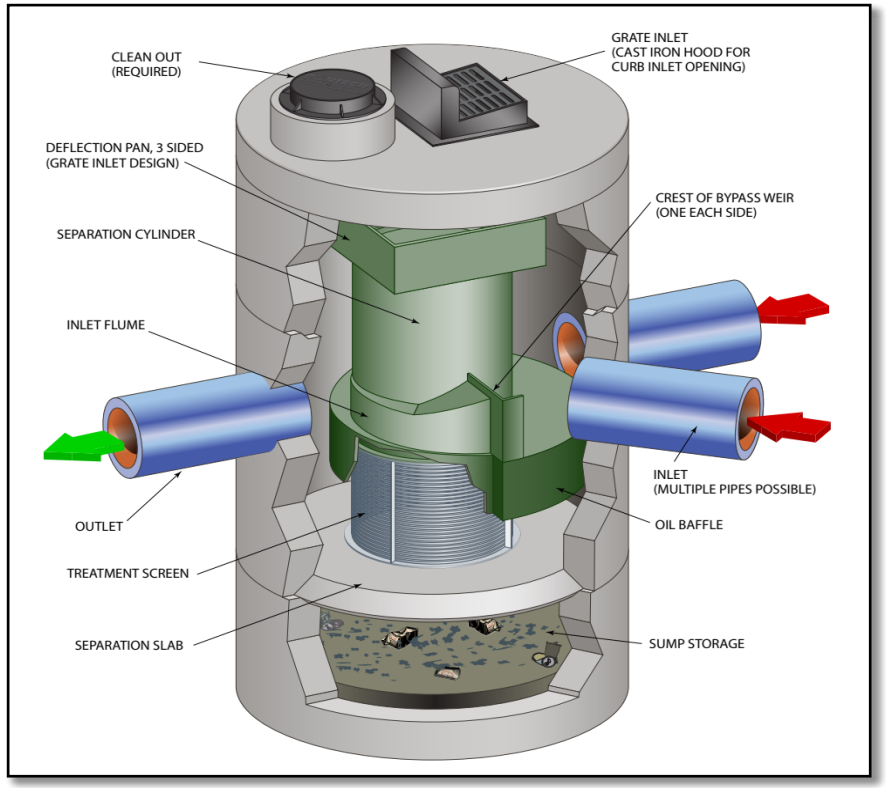
Bioinfiltration system and media filter



Hydrodynamic separator and cartridge filter



Cartridge filter – ZPG filter media



Hydrodynamic separator

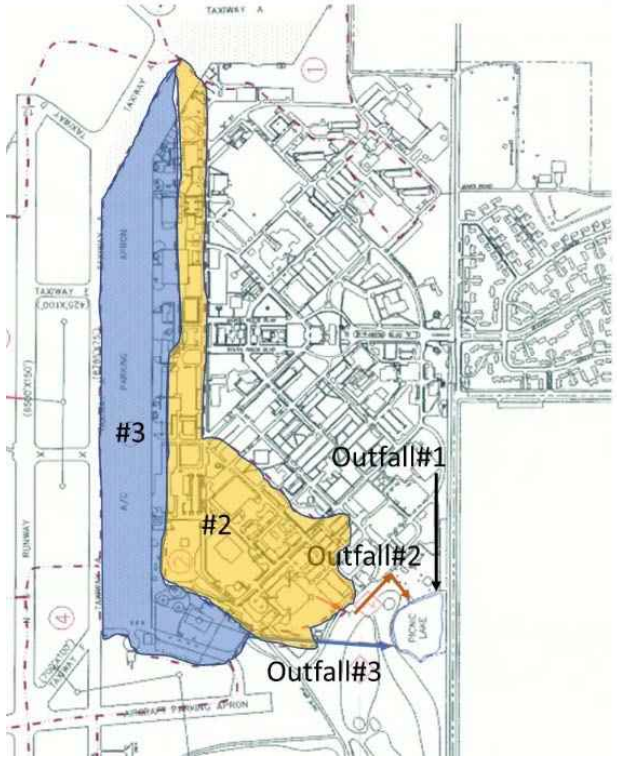
CONTECH. *The Stormwater Management StormFilter®*. https://www.conteches.com/stormwater-management/treatment/stormwater-management-stormfilter

ZPG – Zeolite, perlite and granulated activated carbon

Site 1 — Reese Technology Center, Lubbock, TX

Former U.S. Air Force base

- Converted to multiuse technology center
- History of AFFF use
- PFAS impacts
  - >1,000-7,000ng/L in water samples
  - 20,000ng/kg in lake sediments
- Site characteristics
  - ~255 acres
  - Four primary discharge areas



Site 1 — Reese Technology Center, Lubbock, TX

Outfall	Drainage area (acres)	Majority land use	Impervious
Outfall-1	105	Facility offices	<50%
Outfall-2	43	Facility offices*	76%
Outfall-3	78	Parking apron	85%
Outfall-X	30	Golf course	<10%

Results

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Characterization of PFAS in stormwater case study: Reese Technology Center, Lubbock, TX

Description	Date	Average rainfall, in	Outfall-1, ft^3	Outfall-2, ft^3	Outfall-3, ft^3	Outfall-X, ft^3
Storm 1	Dec. 26-28, 2019	0.43	58,000	23,000	60,000	6,000
Storm 2	Oct. 8-10, 2022	0.42	58,000	22,000	60,000	6,000
Storm 3	Nov. 24-28, 2022	0.60	86,000	35,000	90,000	10,000

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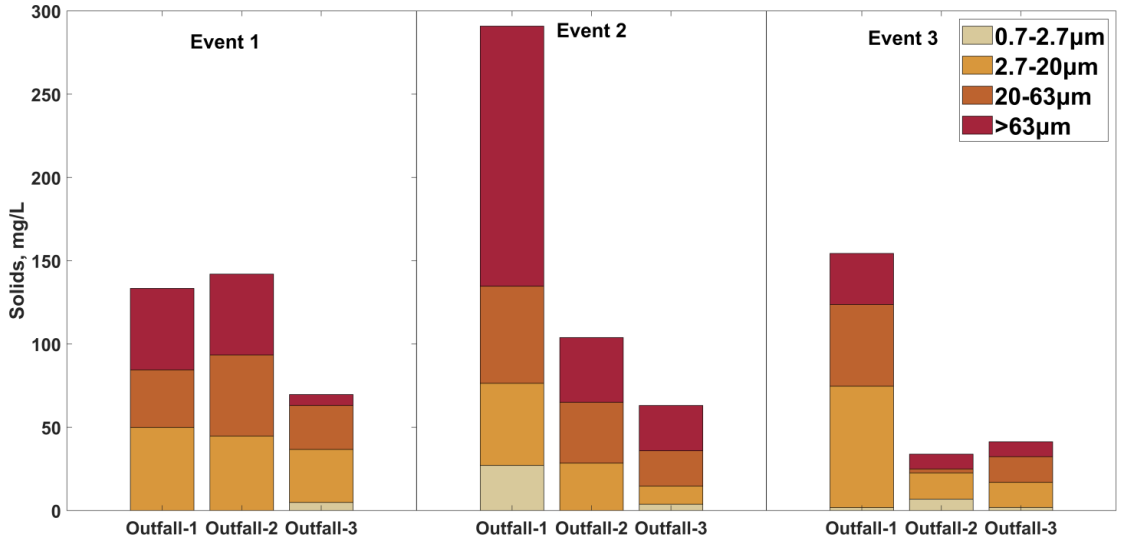
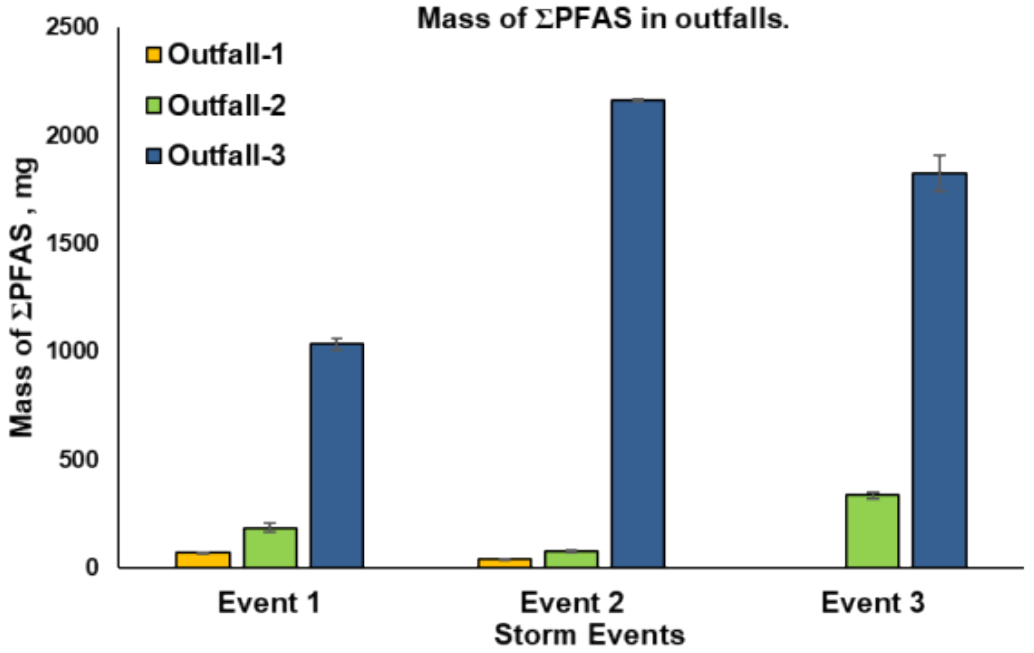
Characterization of PFAS in stormwater





- Outfall-1 shows similar distribution except in event two, which has a higher abundance of larger solids
- Outfalls 2 and 3 show very similar distribution

- Outfall-3 dominates the PFAS input into retention pond

Characterization of PFAS in stormwater

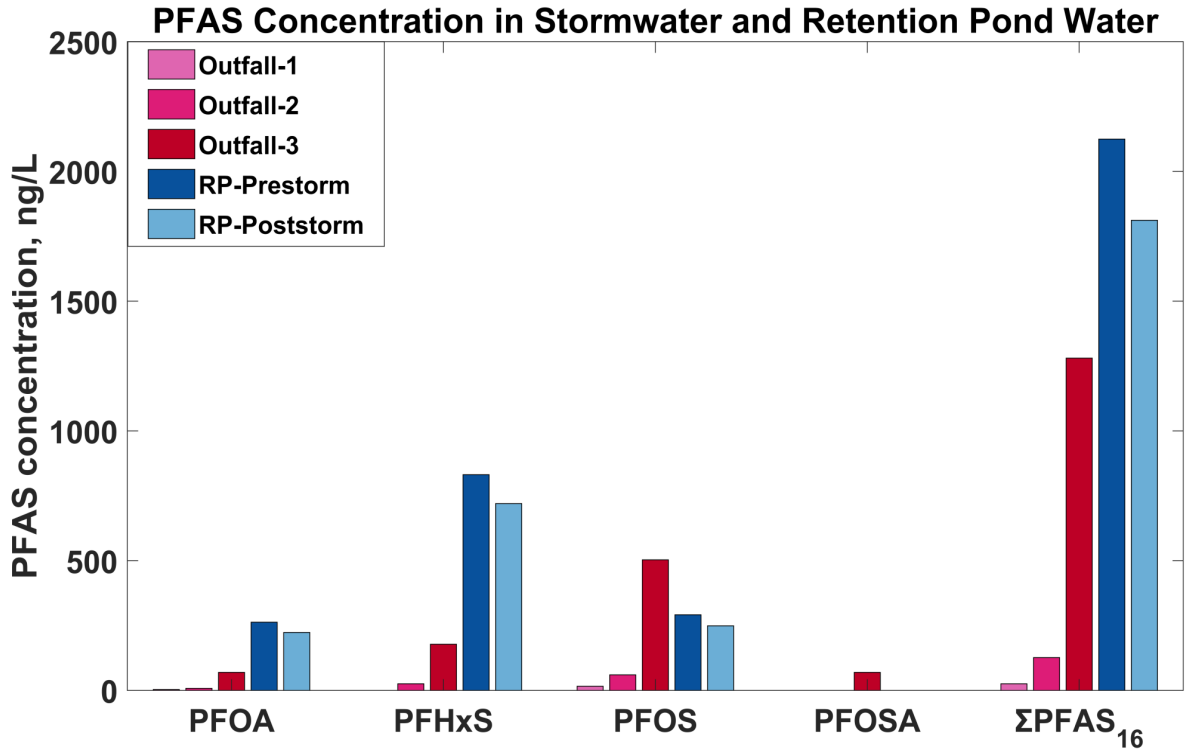
Source (Outfall-3 vs. lake)

- Mobility of PFAS from the source area
- Outfall-3 shows a snapshot of the contaminated zone
- Lake represents contamination over the period of time
- Outfall-3 possibly higher in other events/time and lake over the period has been very contaminated

Characterization of PFAS in stormwater

Source (Outfall-3 vs. lake)

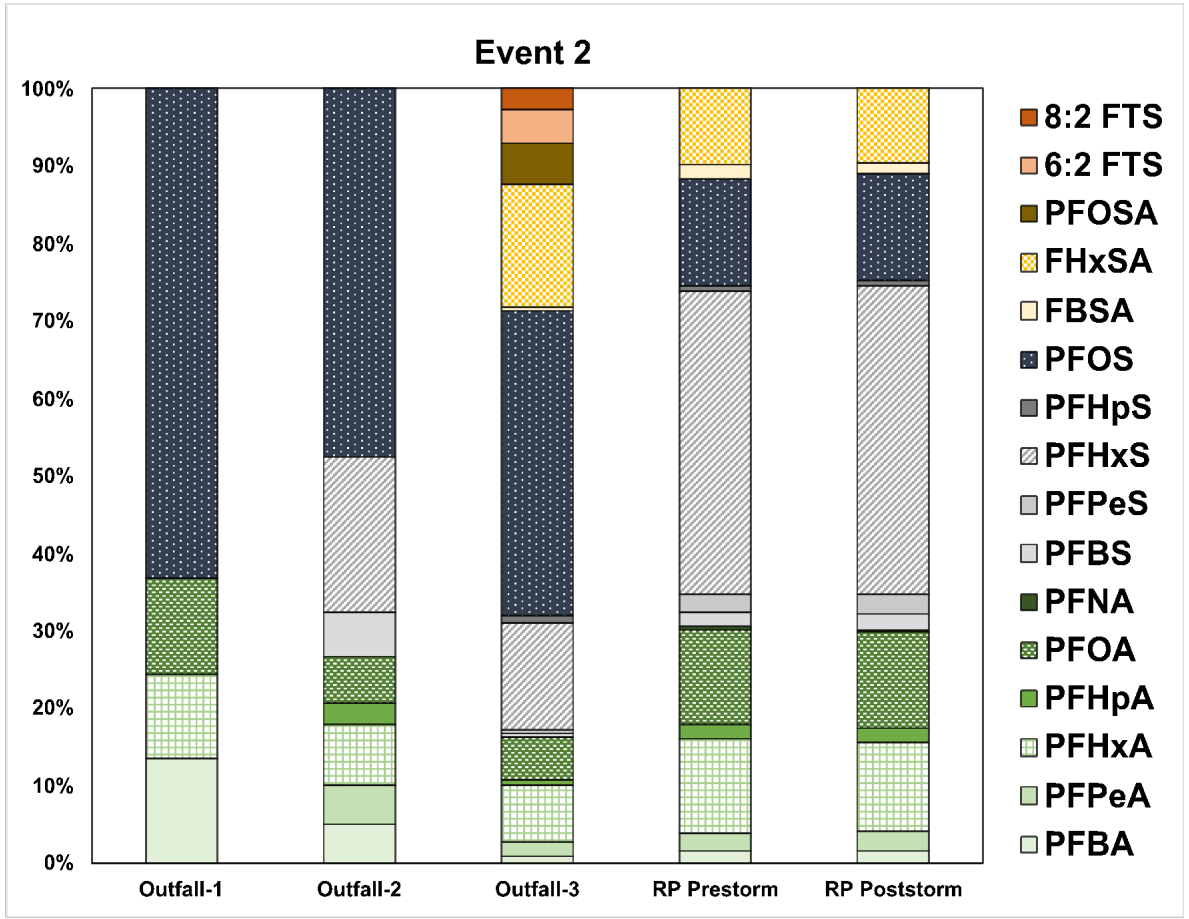
- Higher concentrations of PFOA and PFHxS in lake than in outfalls
- PFOS shows similar concentrations
- PFOSA shows lower in lake



Characterization of PFAS in stormwater

PFAS distributions

- Outfall-3 closest to lake distribution with more solid associated PFAS and precursors
- PFOA, PFHxS accumulate in the lake due to inputs, low deposition, and precursor oxidation
- PFOS and PFOSA lower in the lake due to solid deposition

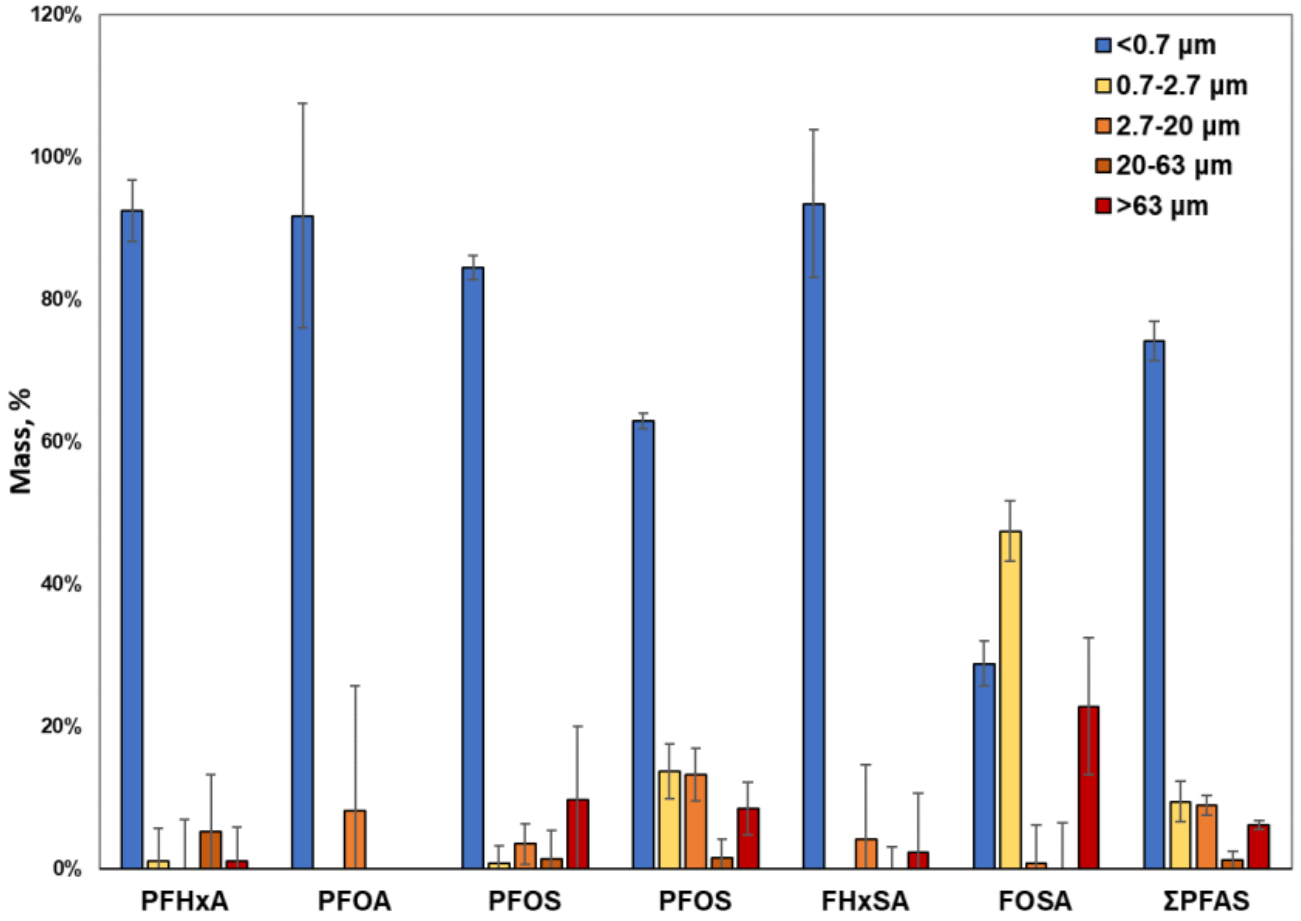


Cosine θ 0.12 0.42 0.74 1.0

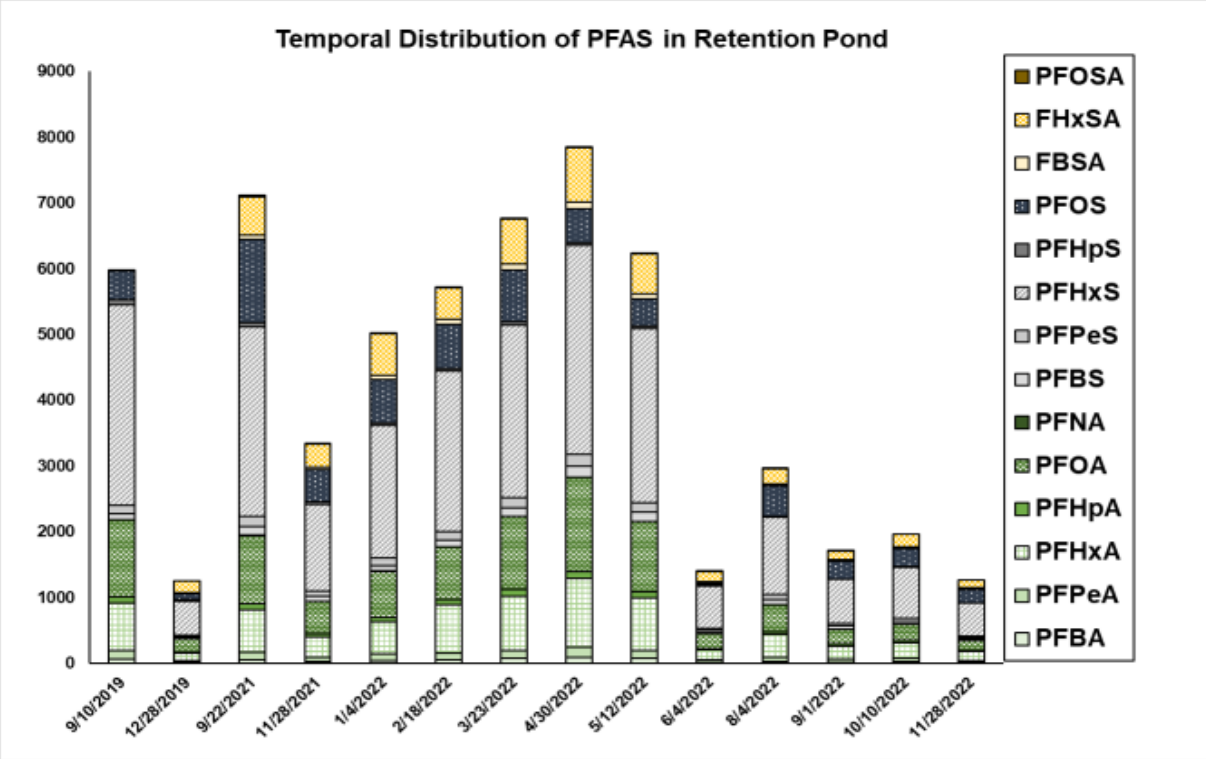
Characterization of PFAS in stormwater

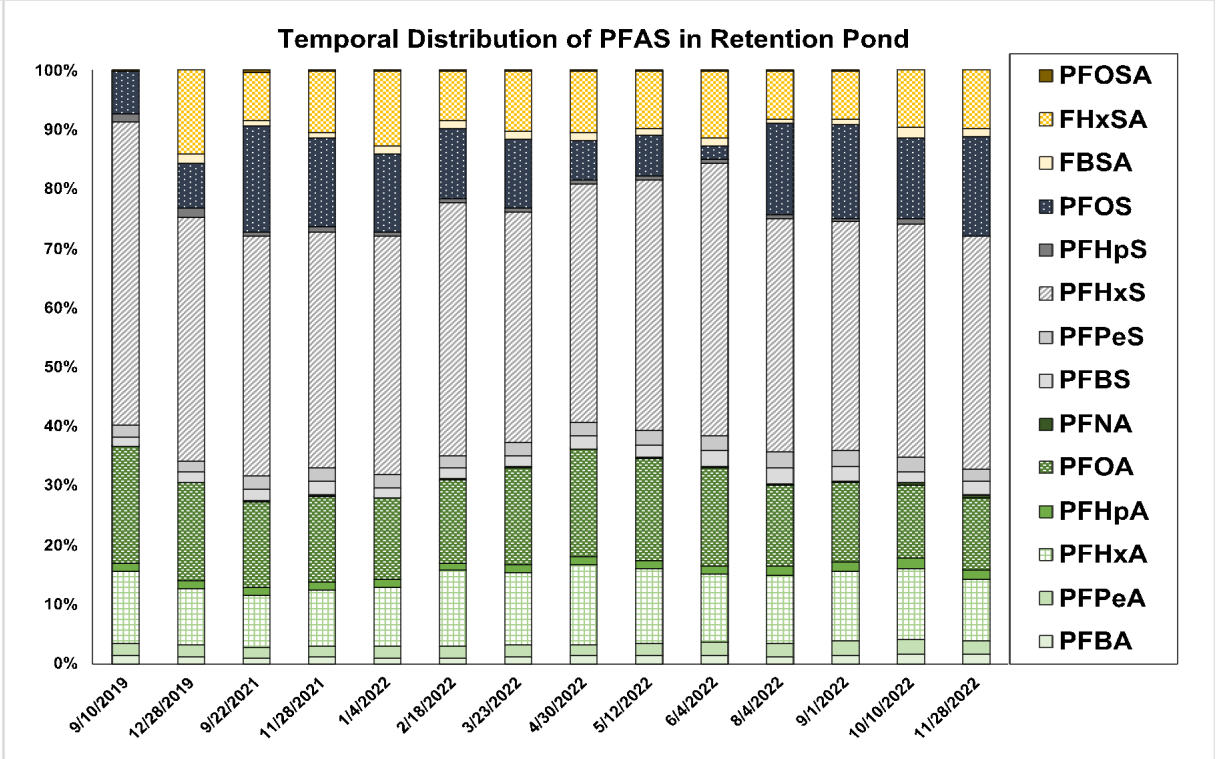
Distribution of dominant PFAS in stormwater

- Majority of the PFAS associated with the dissolved fraction of stormwater
- Ninety percent of PFHxA, PFHxS, and PFOA in dissolved fraction and more likely to accumulate in lake water
- PFOS and FOSA distributed between dissolved and particulate and likely to accumulate in both lake water and lake sediment



Long-term PFAS trends in retention pond





- The distribution of PFAS stable for the duration of sampling in surface water
- PFHxS dominant PFAS >40%

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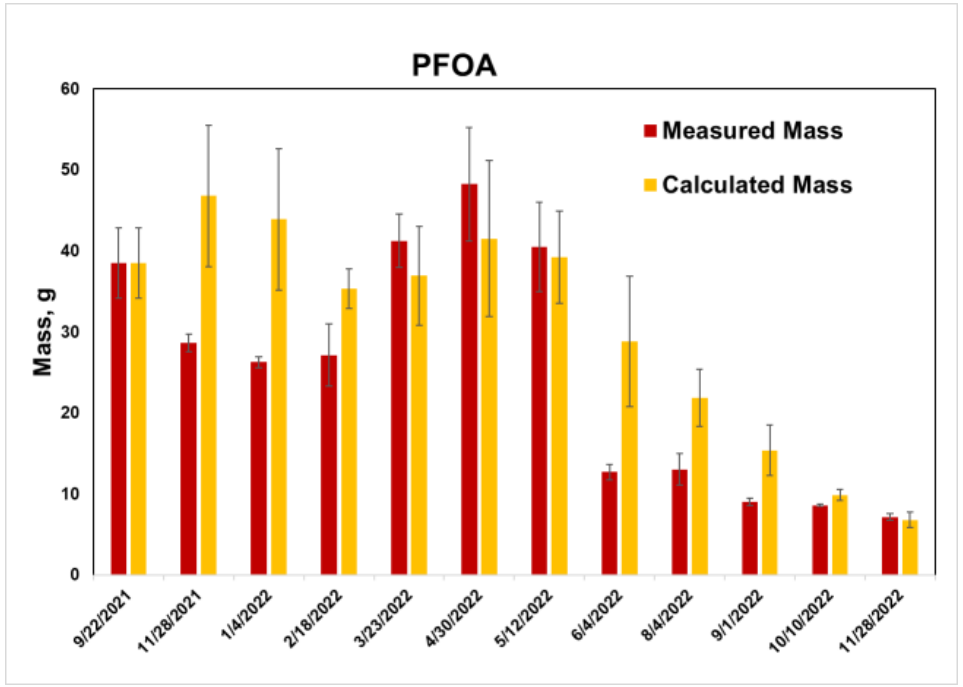
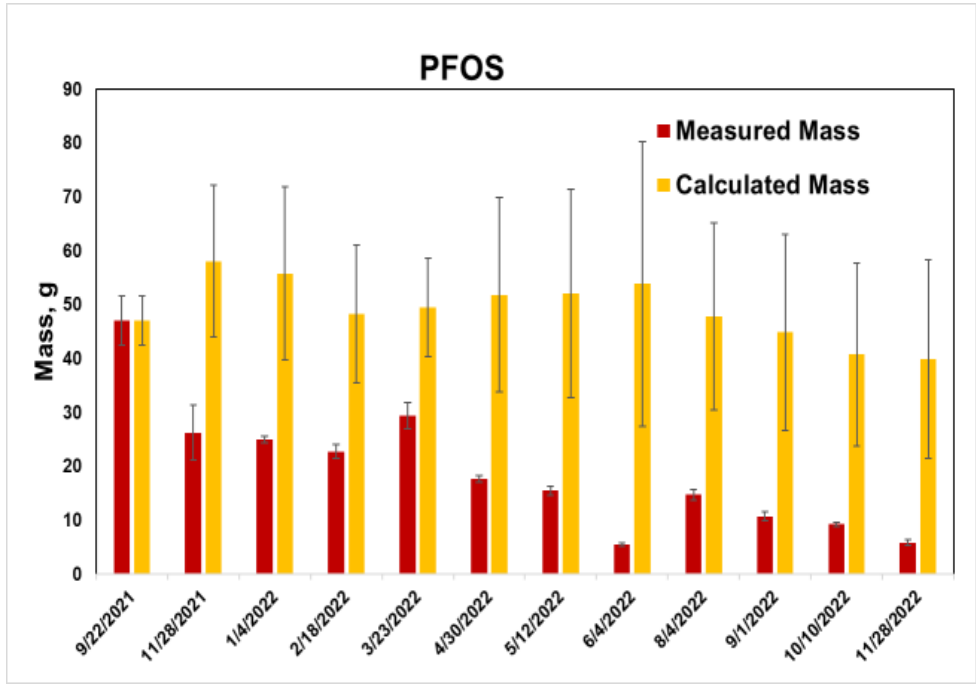
Long-term PFAS trends in retention pond





- The mass of PFAS compounds associated with dissolved fraction (PFOA, PFHxS) can be estimated by volume fluctuations and inputs from the stormwater
- PFAS associated with solids (PFOS, PFOSA) is overestimated due to settling and partitioning to sediments and biota

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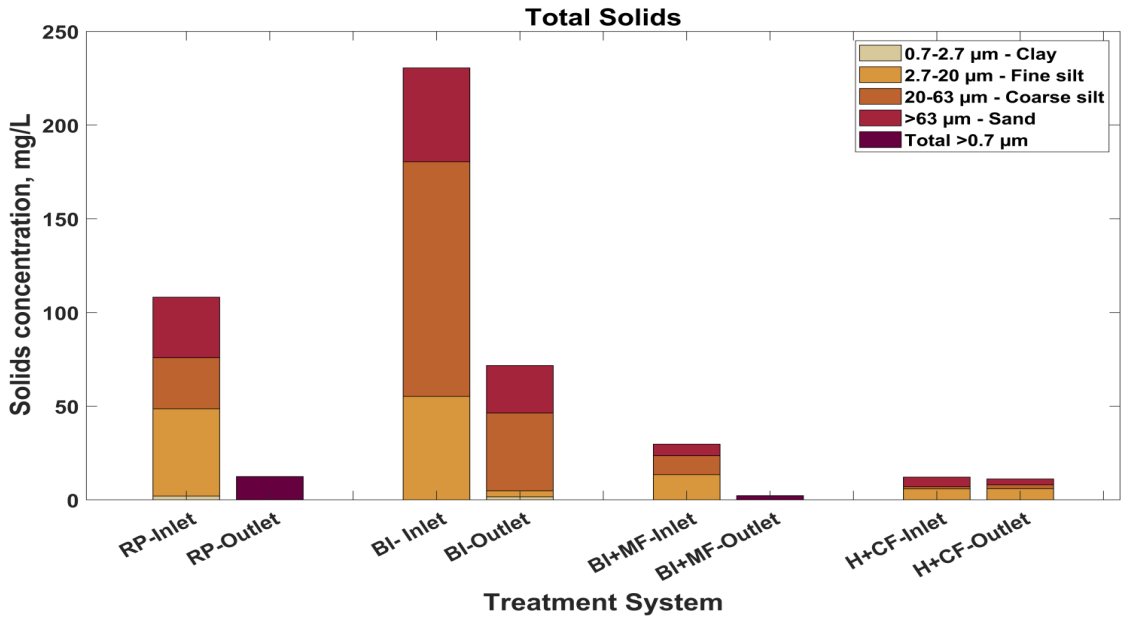
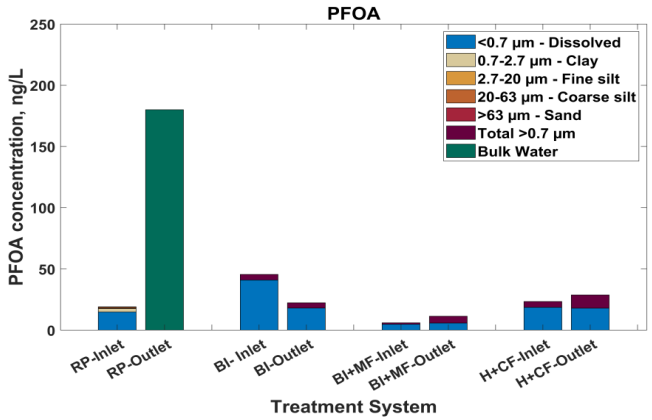
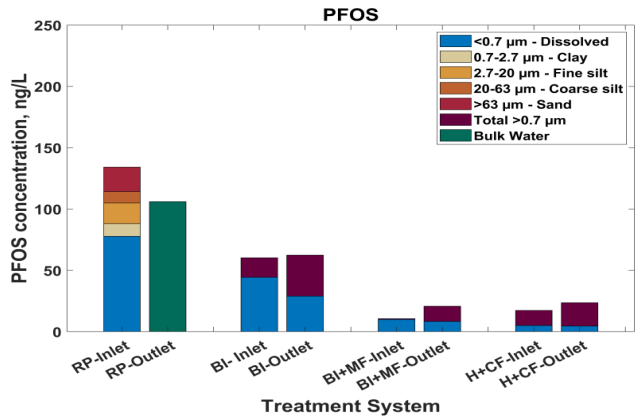
Performance of BMPs

- All BMPs were effective in removal of suspended solids except H+CF
- Retention pond effective in removal of solids associated PFAS (PFOS, PFOSA) but ineffective in removal of PFAS associated with dissolved fraction
- Increase in PFOA in retention pond due to accumulation over time and water evaporation
- All engineered BMPs were ineffective in the removal of PFAS, which can be due to:
  - Lower concentration of PFAS in inlet stormwater (urban background)
  - Saturation of filter media due to maintenance
  - Ineffective sorbent in cartridge filter







Conclusions

- Majority (>70%) of analyzed PFAS in dissolved (<0.7µm) form
- PFAS compounds associated with dissolved fraction of stormwater are likely to accumulate in retention pond while solids associated PFAS compounds are expected to settle
- Solids associated PFAS (PFOS, PFOSA, etc.) are removed by retention pond but for majority of the PFAS it is not effective
- Most of the BMPs are ineffective for most PFAS due to the preponderance in dissolved form and the lack of effective PFAS sorbents in cartridge filters

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