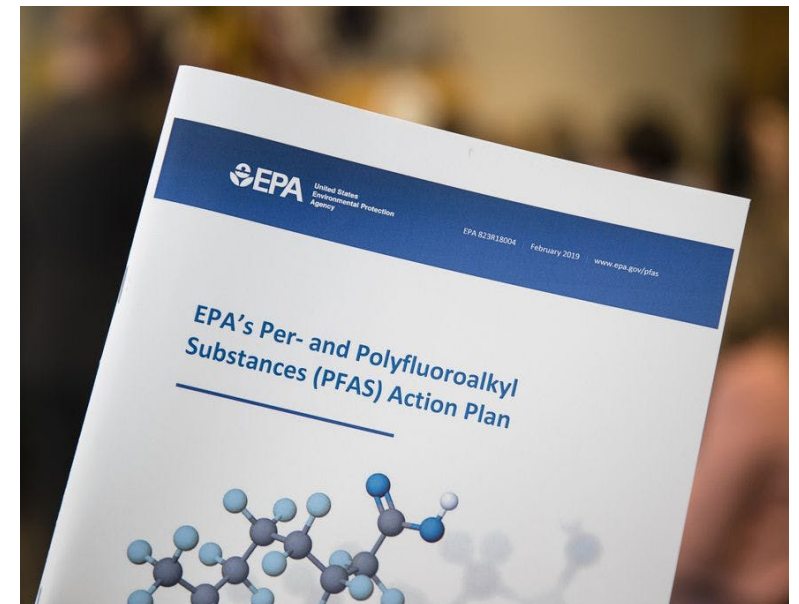


# PFAS Pilot Study: Final Update and Discussion



# Agenda

- Review of project goal
- Final treatment performance summary
- Preliminary costing
- Final report contents
- Review of project schedule



## **Study Goal**

Evaluate ion-exchange (IX) as a potential treatment process for PFAS removal both as a stand-alone process and in series with granular activated carbon (GAC).

# Background

Historical PFAS contamination affecting much of SE Minneapolis-St. Paul Metro area drinking water supplies

	PFAS Monitored in Minnesota						
	PFBA	PFBS	PFHxA	PFHxS	PFOA	PFOS	HI
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	-
Drinking Water Guidance Value <sup>1</sup>	7.000	2.000	0.200	0.047	0.035	0.015	-
Well #3 Raw Water	0.896	0.127	0.043	0.074	0.014	0.001	2.45

<sup>1</sup> For a detailed description of the Health Risk Index model see MDH's website:

<https://www.health.state.mn.us/communities/environment/risk/guidance/gw/additivity.html>

$$HI = \frac{[PFBA]}{7} + \frac{[PFBS]}{2} + \frac{[PFHxA]}{0.200} + \frac{[PFHxS]}{0.047} + \frac{[PFOA]}{0.035} + \frac{[PFOS]}{0.015}$$



# Background

Historical PFAS contamination affecting much of SE Minneapolis-St. Paul Metro area drinking water supplies

	PFAS Monitored in Minnesota						
	PFBA	PFBS	PFHxA	PFHxS	PFOA	PFOS	HI
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	-
Drinking Water Guidance Value <sup>1</sup>	7.000	2.000	0.200	0.047	0.035	0.015	-
Well #3 Raw Water	0.896	0.127	0.043	0.074	0.014	0.001	2.45

<sup>1</sup> For a detailed description of the Health Risk Index model see MDH's website:

<https://www.health.state.mn.us/communities/environment/risk/guidance/gw/additivity.html>

$$HI = \frac{[PFBA]}{7} + \frac{[PFBS]}{2} + \frac{[PFHxA]}{0.200} + \frac{[PFHxS]}{0.047} + \frac{[PFOA]}{0.035} + \frac{[PFOS]}{0.015}$$

# Treatments Evaluated

## **GAC only**

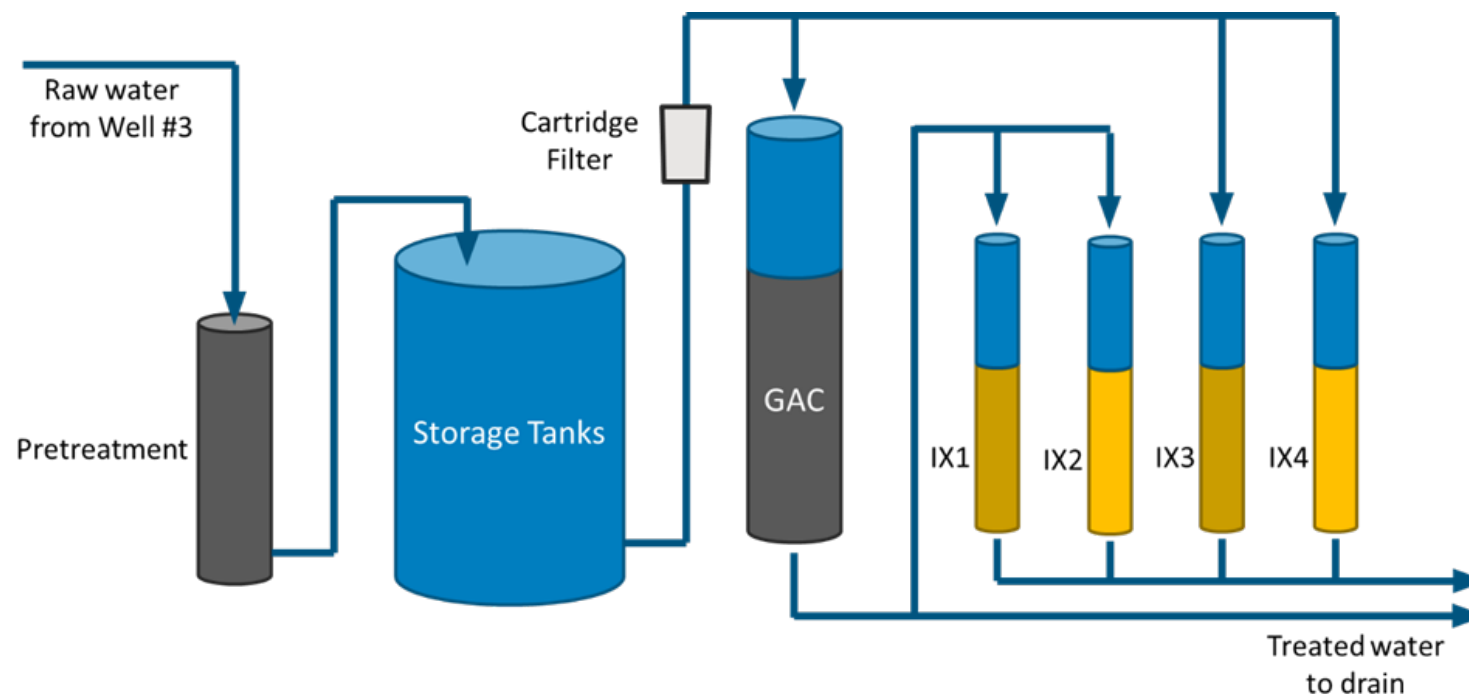
## **IX Tandems**

- IX 1 (GAC followed by Purofine 694E)
- IX 2 (GAC followed by Dow PSR2+)

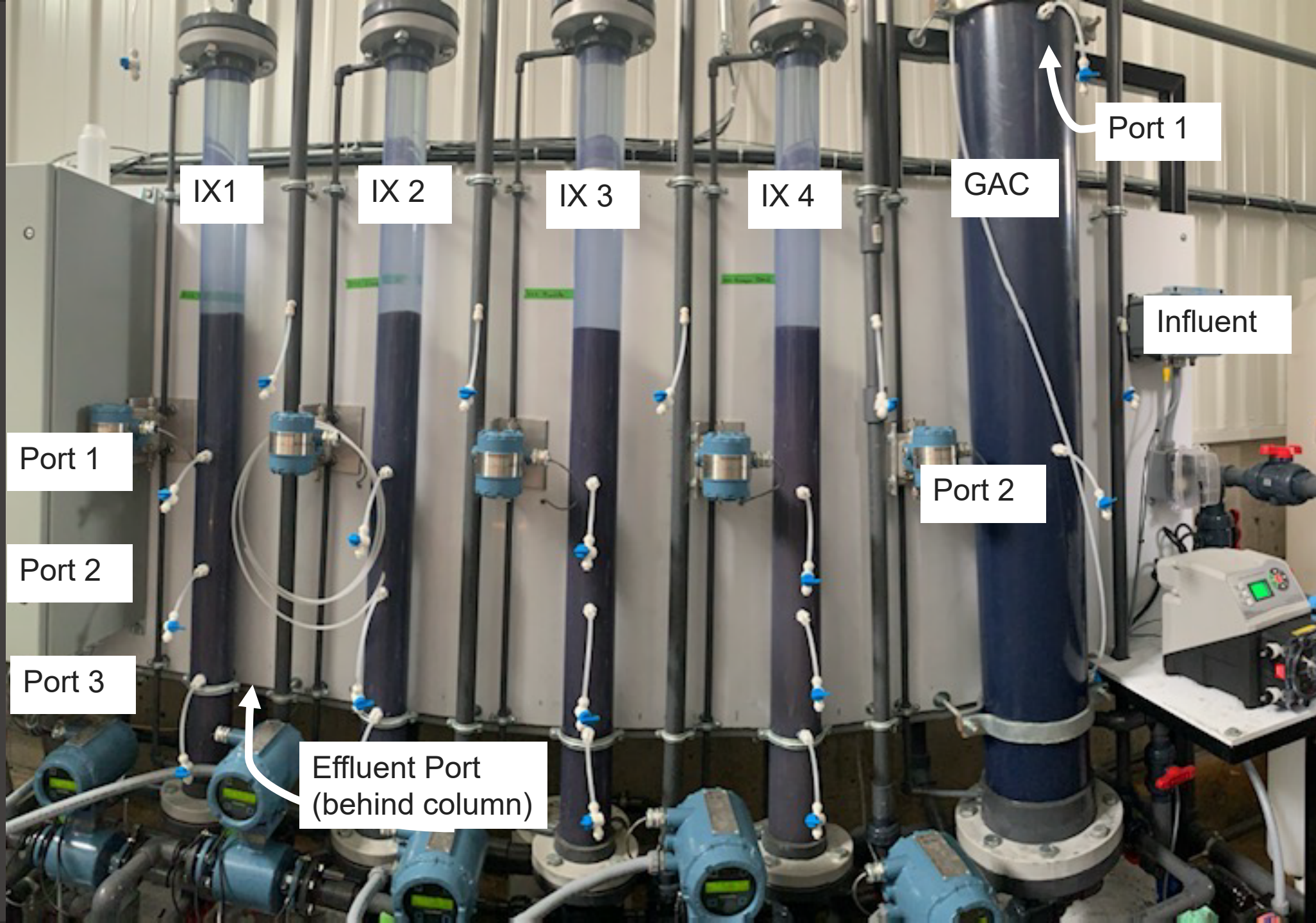
## **Resin Only**

- IX 3 (Purofine 694E)
- IX 4 (Dow PSR2+)

# Treatments Evaluated



Parameter	GAC	IX1	IX2	IX3	IX4
Media	Norit® GAC	Purofine® IX	DOWEX™ IX	Purofine® IX	DOWEX™ IX
Influent Water Source	Raw Water	GAC Effluent	GAC Effluent	Raw Water	Raw Water
Column Diameter	8"	3"	3"	3"	3"
Goal Media Bed Depth	90"	36"	36"	36"	36"
Goal Empty Bed Contact Time	10 min	2.5 min	2.5 min	2.5 min	2.5 min
Goal Flowrate	1.94 gpm	0.45 gpm	0.45 gpm	0.45 gpm	0.45 gpm



IX1

IX 2

IX 3

IX 4

GAC

Port 1

Influent

Port 1

Port 2

Port 3

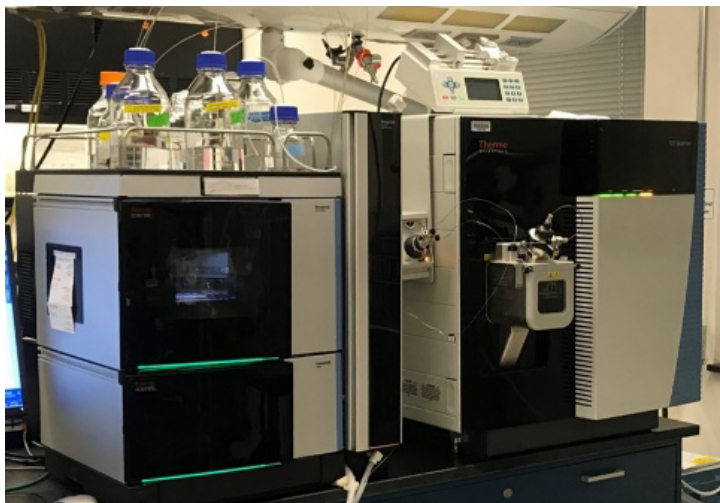
Port 2

Effluent Port  
(behind column)



# Sample Analysis

- 700 samples processed
- 32 PFAS monitored (including all EPA 537.1 compounds)
  - 16 detected (in green)
- Four-day turn-around-time



Analyte Abbreviation	Analyte Name	Method Detection Limit (ng/L)
<b>Perfluorocarboxylic Acids</b>		
PFPrA	Perfluoropropanoic acid	0.45
PFBA	Perfluorobutanoic acid	0.49
PFPeA	Perfluoropentanoic acid	0.36
PFHxA	Perfluorohexanoic acid	0.30
PFHpA	Perfluoroheptanoic acid	0.13
PFOA	Perfluorooctanoic acid	0.17
PFNA	Perfluorononanoic acid	0.21
PFDA	Perfluorodecanoic acid	0.24
PFUdA	Perfluoroundecanoic acid	0.29
PFDoA	Perfluorododecanoic acid	0.43
PFTriA	Perfluorotridecanoic acid	2.82
PFTreA	Perfluorotetradecanoic acid	0.44
<b>Perfluorosulfonic Acids</b>		
PFEtS	Perfluoroethane sulfonic acid	
PFPrS	Perfluoropropane sulfonic acid	0.11
PFBS	Perfluorobutane sulfonic acid	0.18
PFPeS	Perfluoropentane sulfonic acid	0.16
PFHxS	Perfluorohexane sulfonic acid	0.26
PFHpS	Perfluoroheptane sulfonic acid	0.24
PFOS	Perfluorooctane sulfonic acid	0.41
PFNS	Perfluorononane sulfonic acid	0.47
PFDS	Perfluorodecane sulfonic acid	0.68
<b>Fluorotelomer Sulfonates</b>		
4:2 FTS	4:2 fluorotelomer sulfonate	0.20
6:2 FTS	6:2 fluorotelomer sulfonate	10.3
8:2 FTS	8:2 fluorotelomer sulfonate	0.27
<b>Perfluorosulfonamides</b>		
FBSA	Perfluorobutane sulfonamide	0.54
FHxSA	Perfluorohexane sulfonamide	0.45
PFOSA	Perfluorooctane sulfonamide	0.29
<b>Sulfonamideoacetic acids</b>		
N-MeFOSAA	N-Methyl-perfluoro-1-octanesulfonamideoacetic acid	0.54
NEtFOSAA	N-Ethyl-perfluoro-1-octanesulfonamideoacetic acid	0.89
<b>Replacement Chemistries</b>		
HFPO-DA	Hexafluoropropylene oxide-dimer acid	0.11
NaDONA	4,8-dioxo-3H-perfluorononanoic acid	0.14
9Cl-PF3ONS	9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid	0.41
11Cl-PF3OUdS	11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid	1.04

# Treatment Results

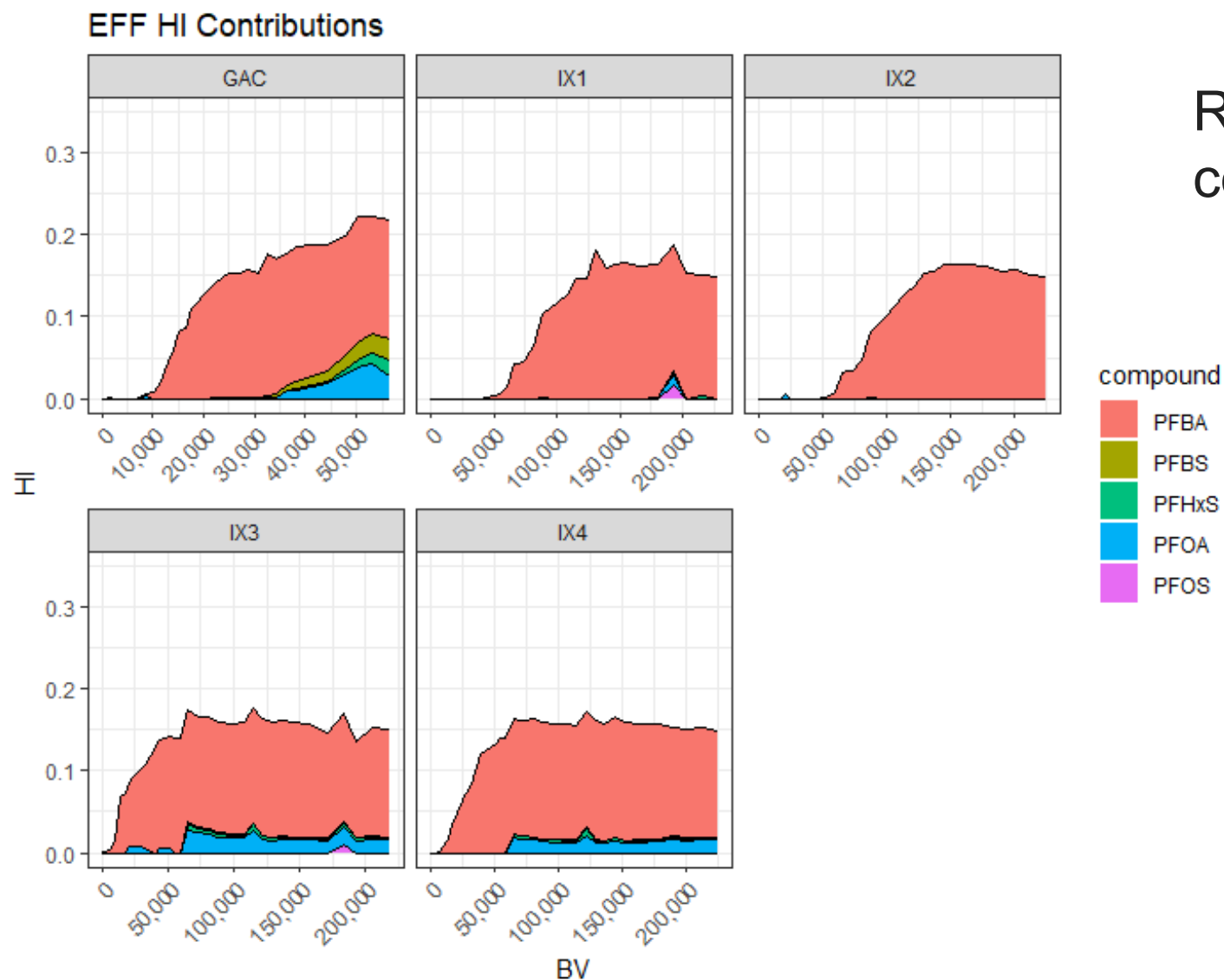


# PFAS Impacting the Health Index

- Results of final sample collected 8/25/2021 – 15 months after startup

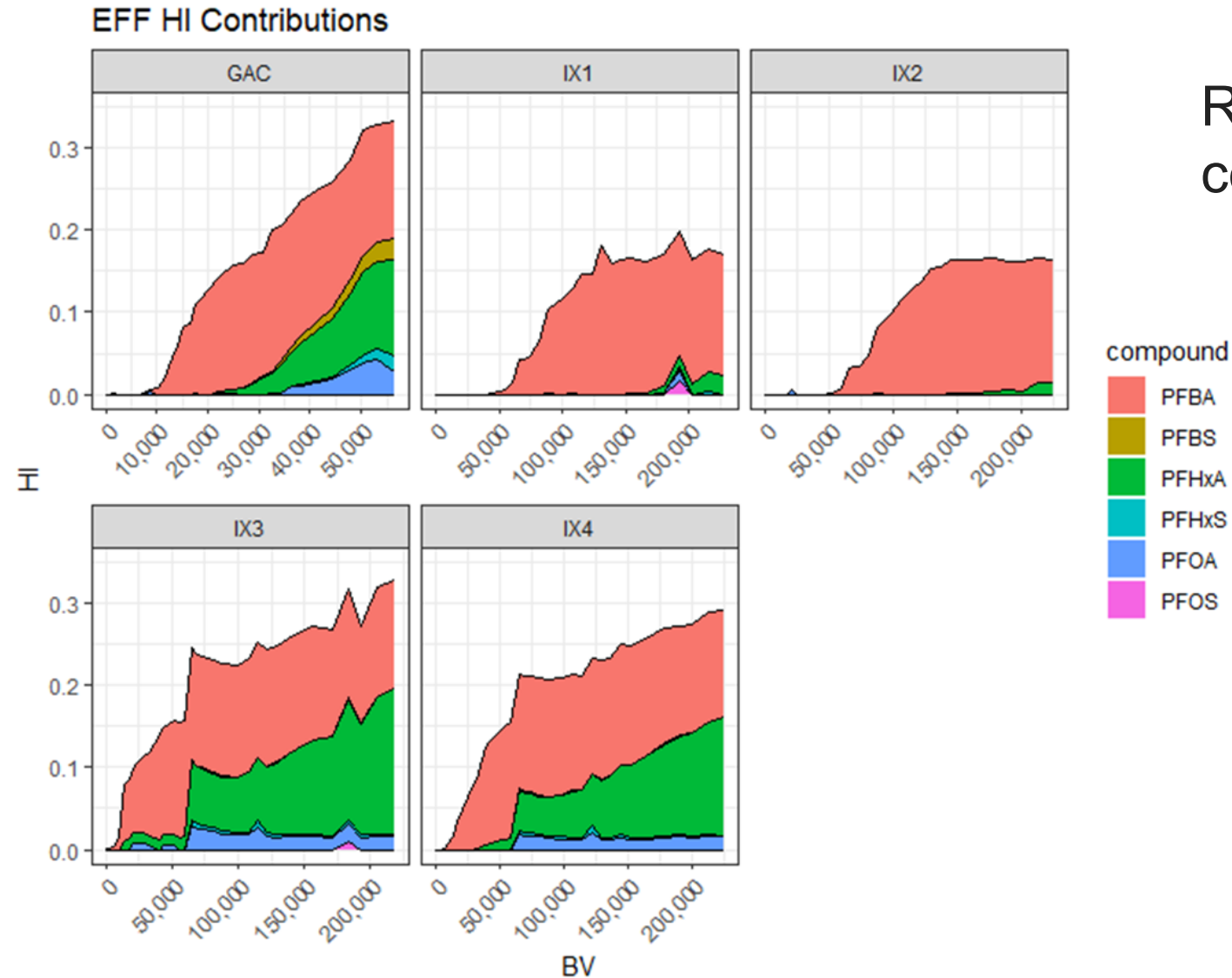
Column	Effluent Bed Volumes	PFAS Monitored in Minnesota						
		PFBA	PFBS	PFHxA	PFHxS	PFOA	PFOS	HI
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	-
Well #3 Raw Water	-	0.896	0.127	0.047	0.074	0.014	0.001	<b>2.78</b>
GAC	56,429	1.012	0.052	0.023	0.005	0.001	0.000	<b>0.42</b>
IX3: Purolite IX	217,958	0.922	0.002	0.035	0.000	0.001	0.000	<b>0.33</b>
IX4: Evoqua IX	224,970	0.913	0.001	0.029	0.000	0.001	0.000	<b>0.29</b>
IX1: GAC - Purolite	227,714	1.035	0.000	0.005	0.000	0.000	0.000	<b>0.17</b>
IX2: GAC - Evoqua	225,629	1.038	0.000	0.003	0.000	0.000	0.000	<b>0.16</b>

# HI in Effluent – before PFHxA





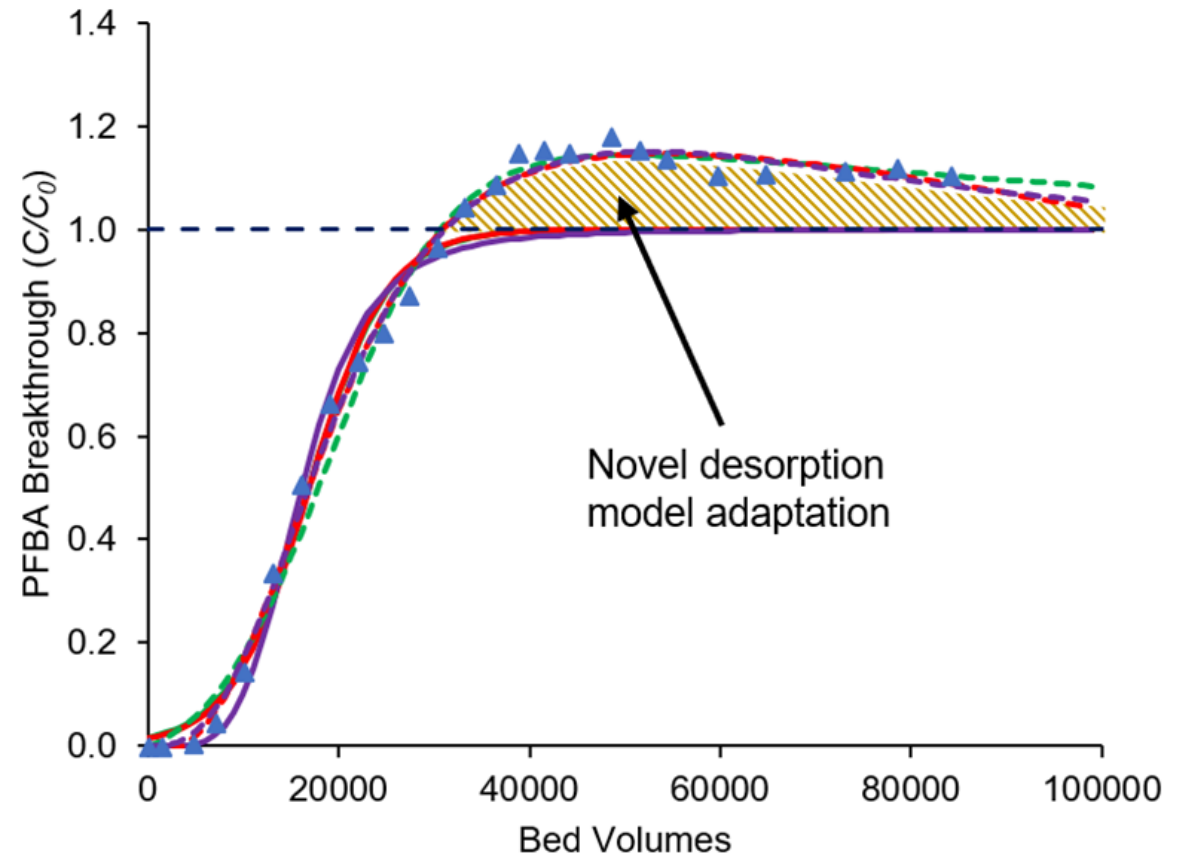
# HI in Effluent – after PFHxA



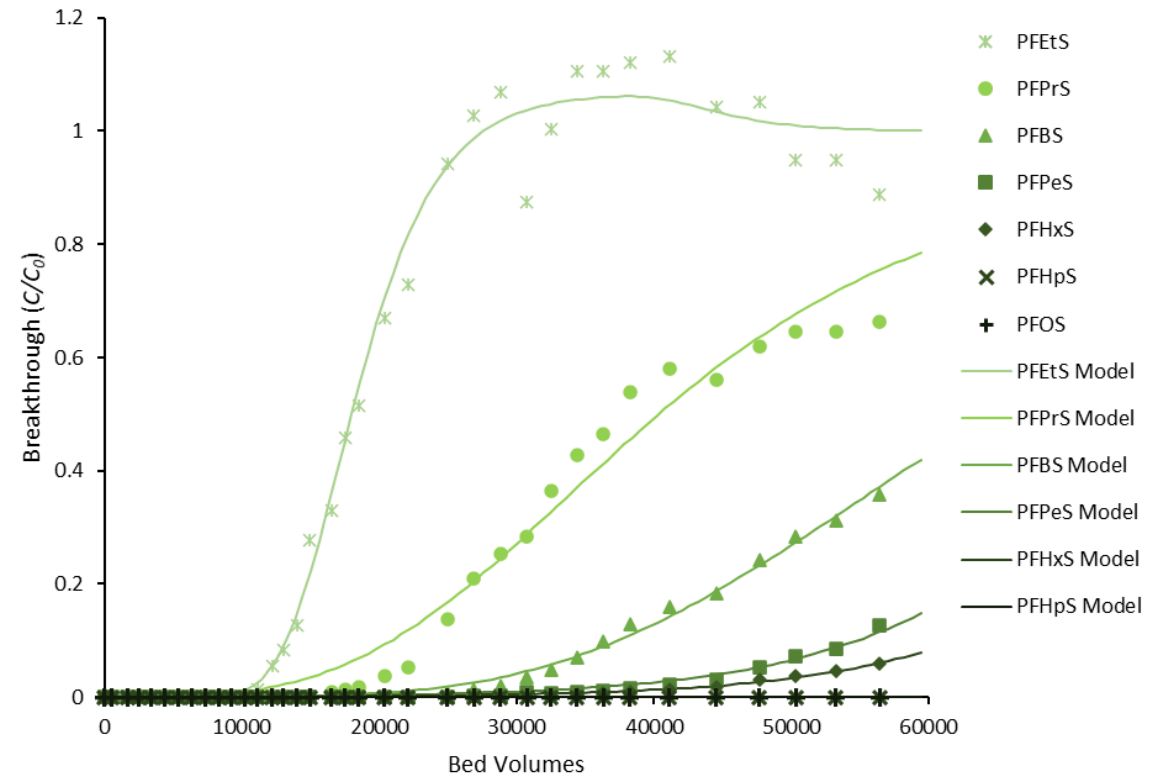
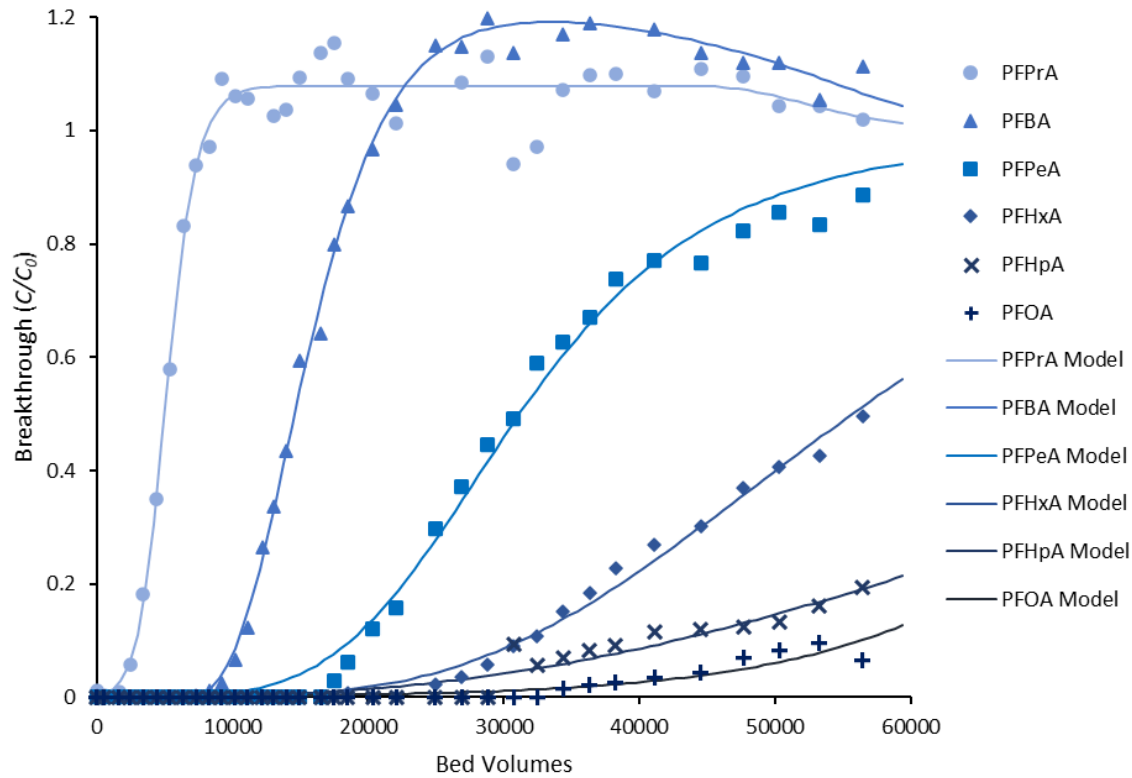
Relative contributions of HI compounds to total value

# PFAS Breakthrough Modeling

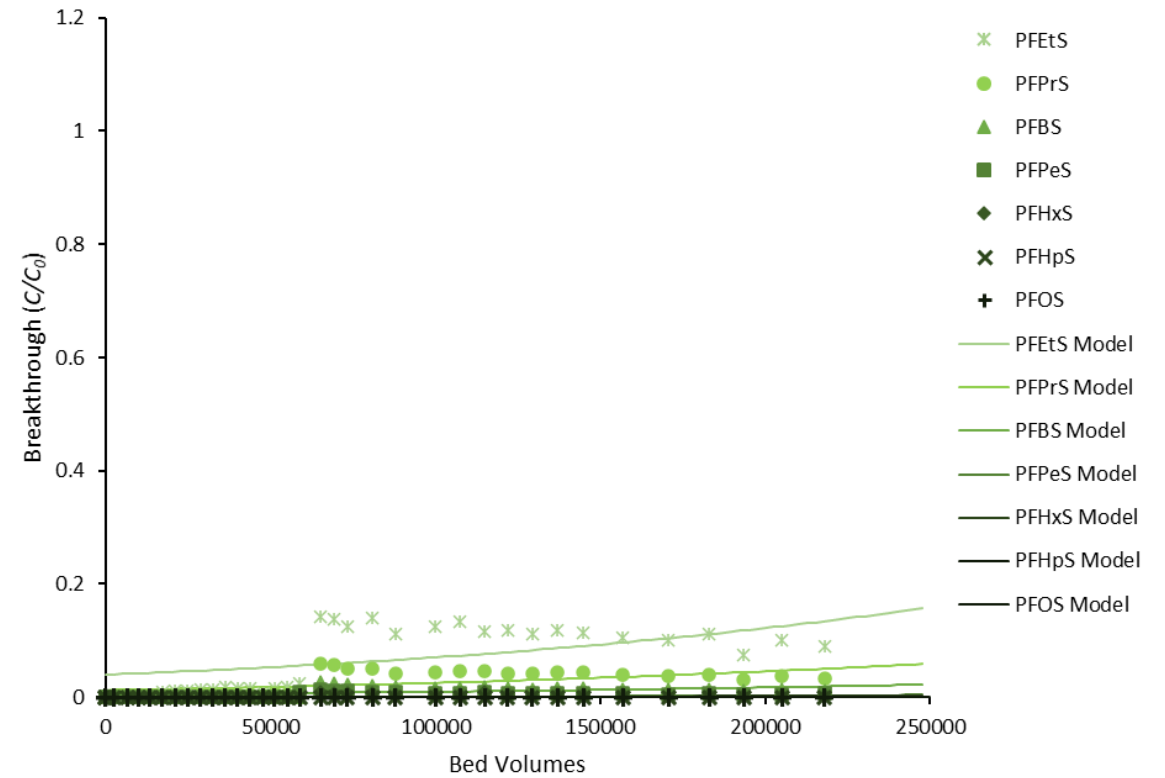
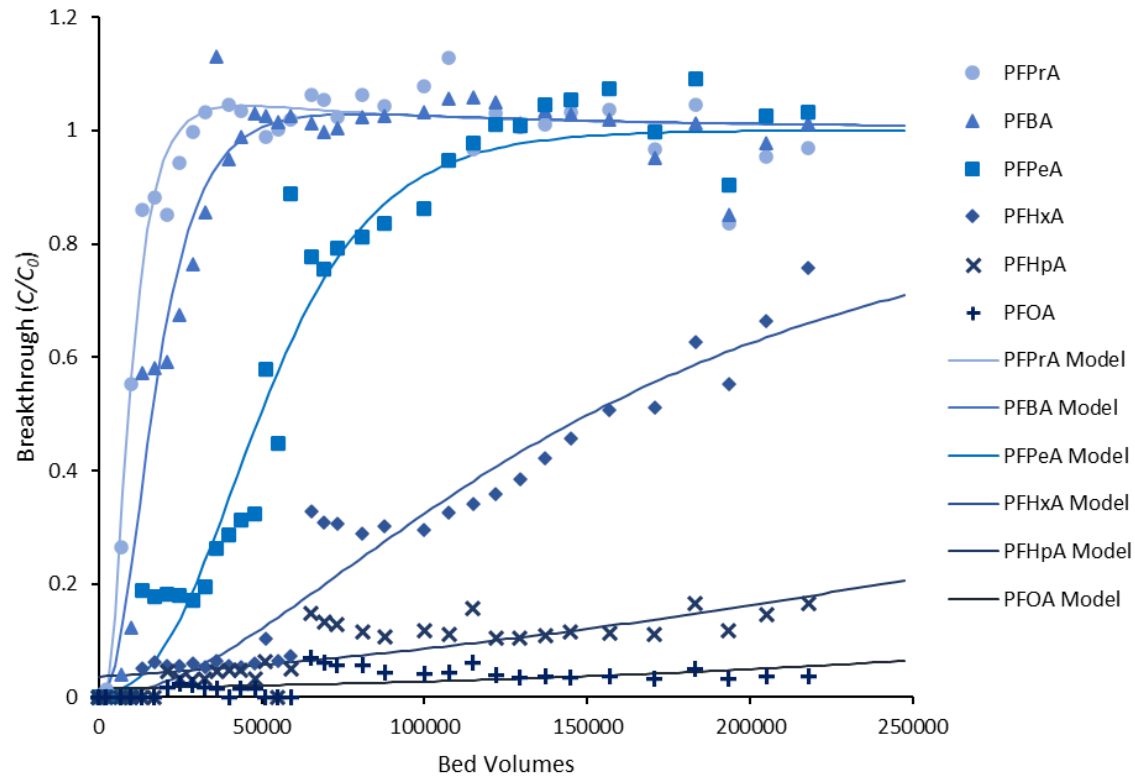
- Common empirical models were used
  - Yoon-Nelson
  - Clark
  - Dose Response
- Modification used to adapt models for desorption



# PFAS Breakthrough: GAC Effluent

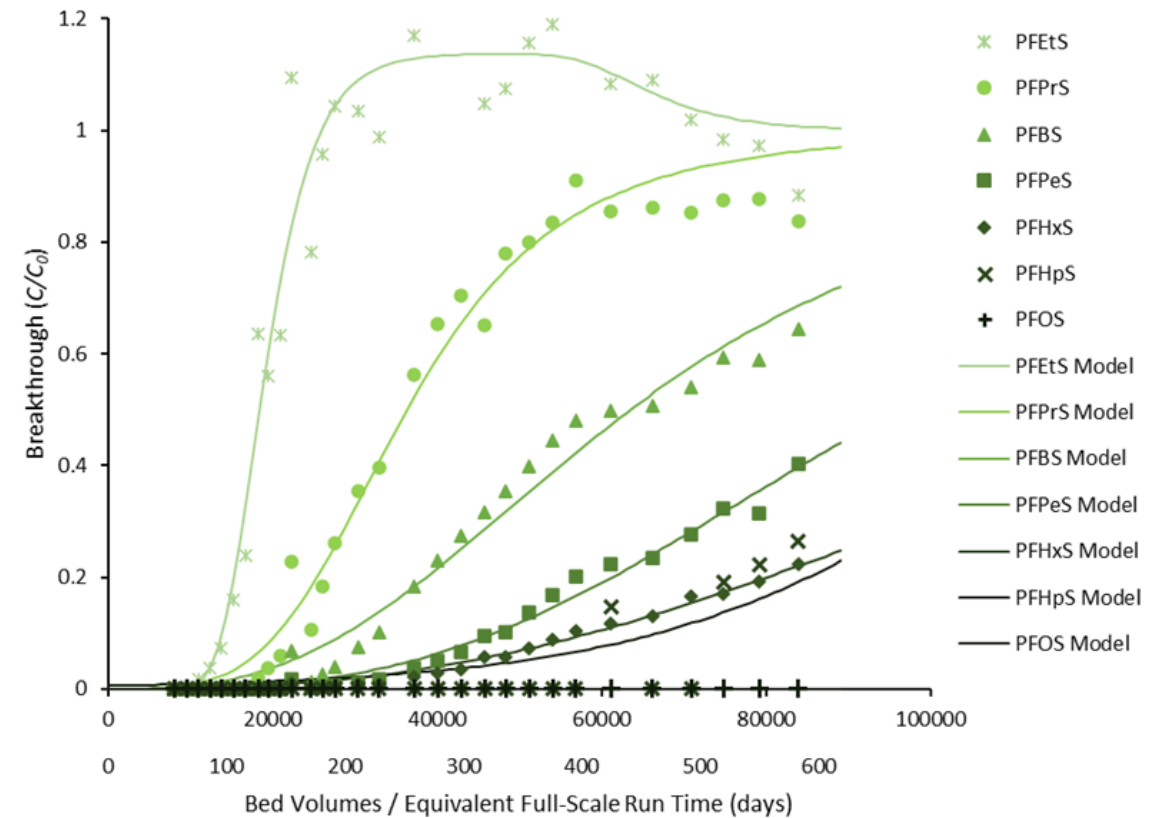
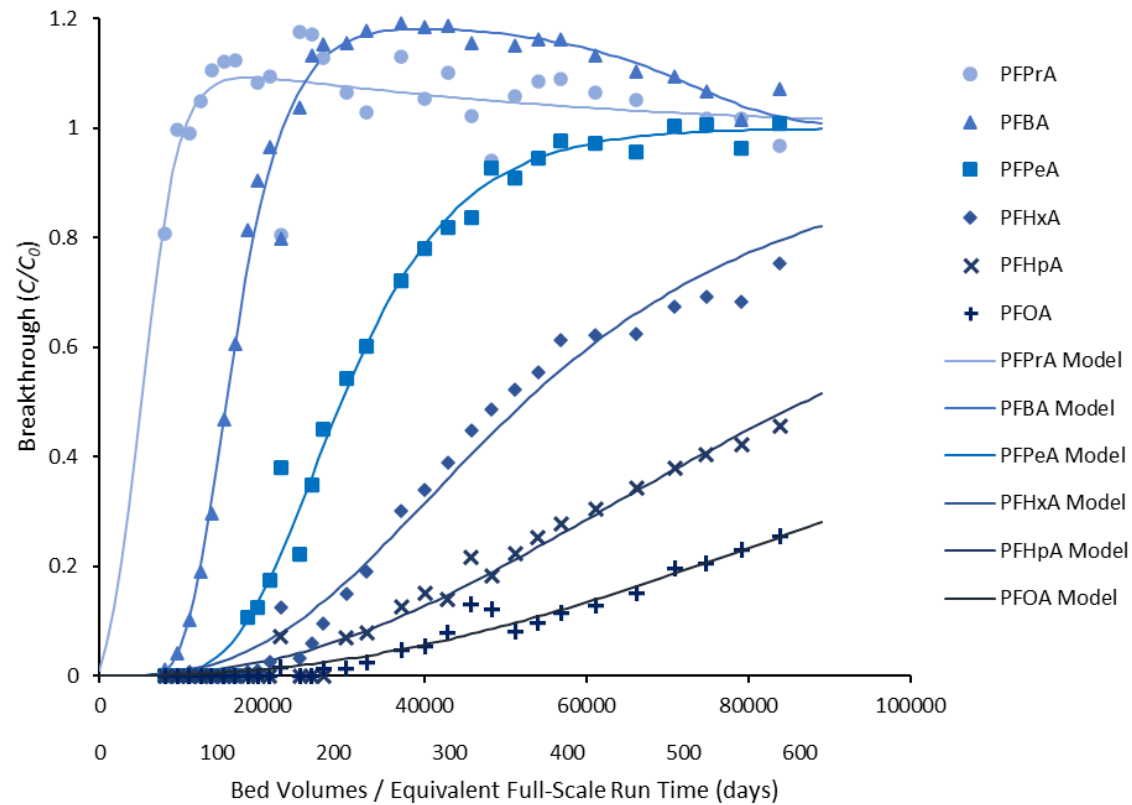


# PFAS Breakthrough: IX3 Effluent

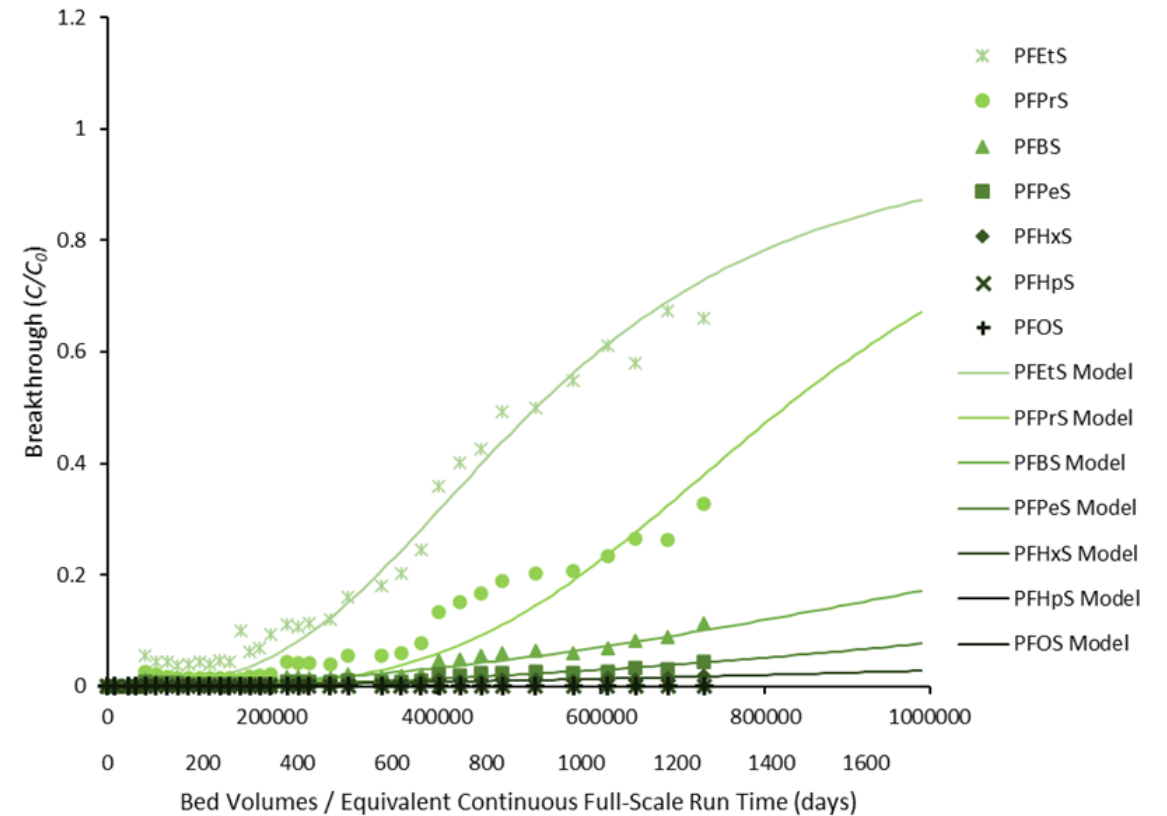
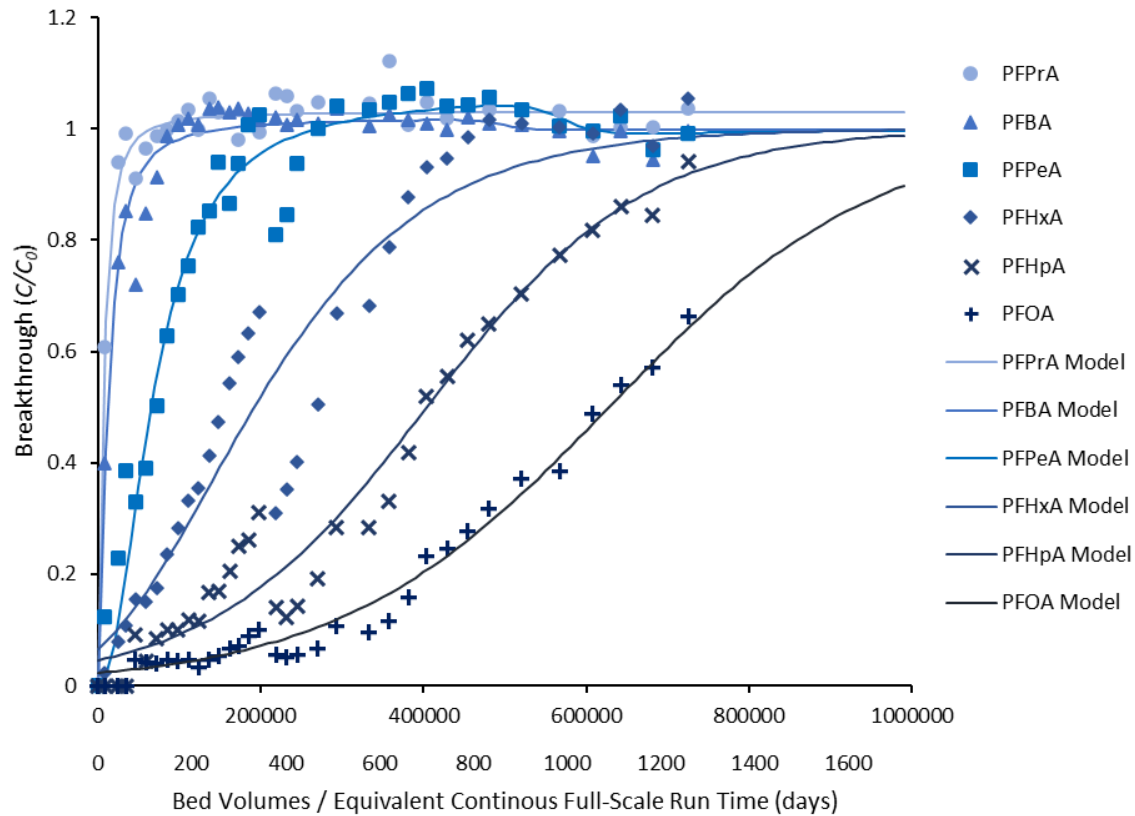




# PFAS Breakthrough: GAC P2



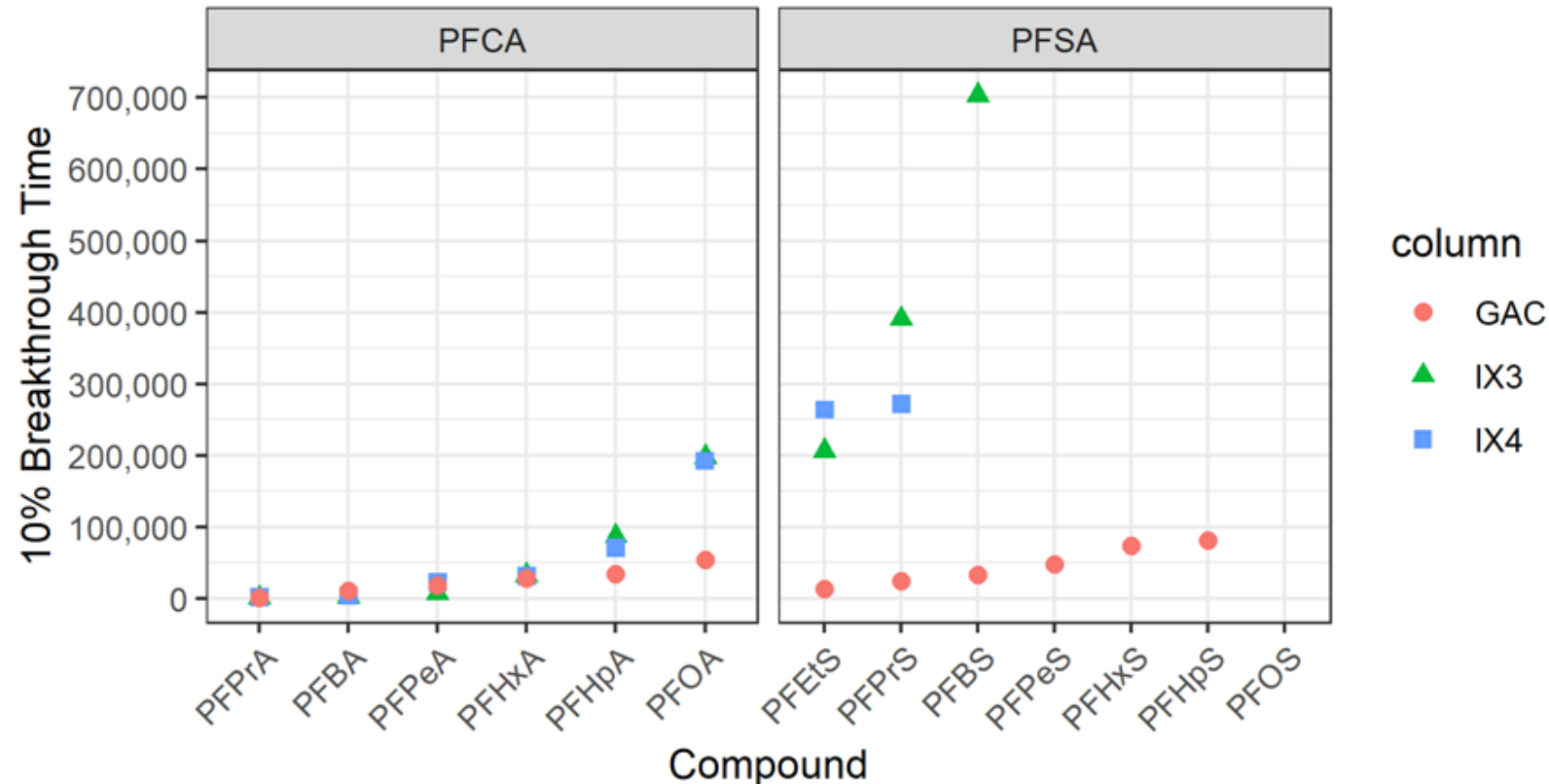
# PFAS Breakthrough: IX3 P1



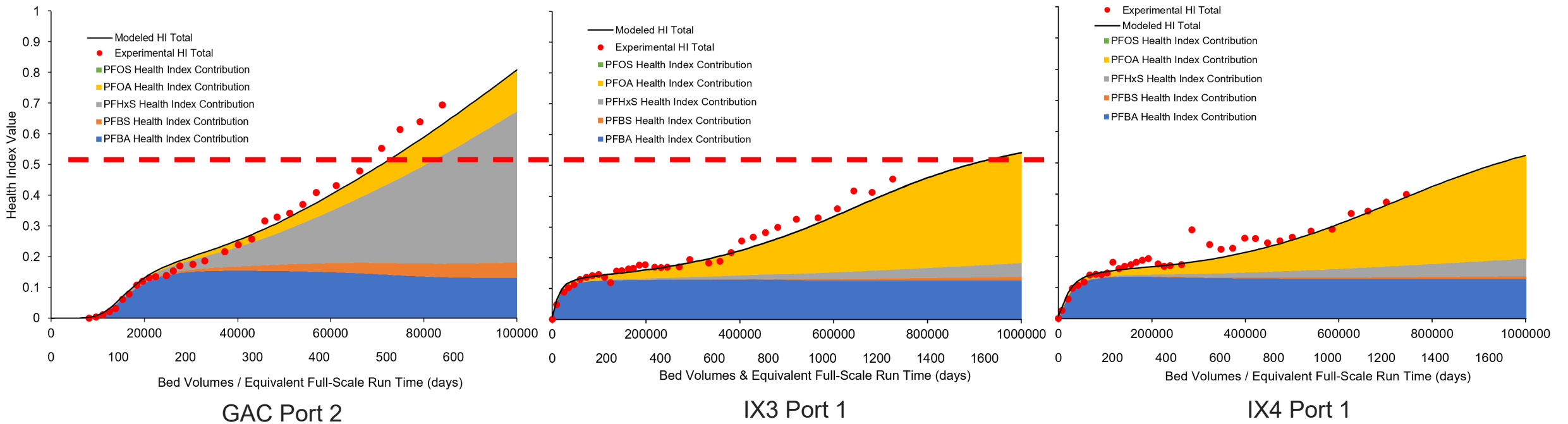
# Breakthrough and Chain Length

Relationship between 10% breakthrough time and chain length is well documented  
– we saw similar trends

- GAC and IX follow different chain length-breakthrough bed volume relationships

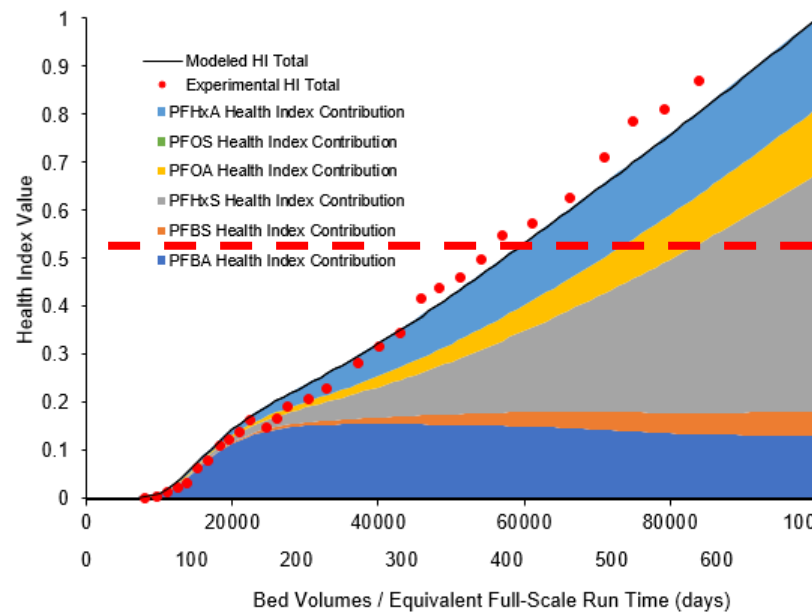


# HI Breakthrough – before PFHxA

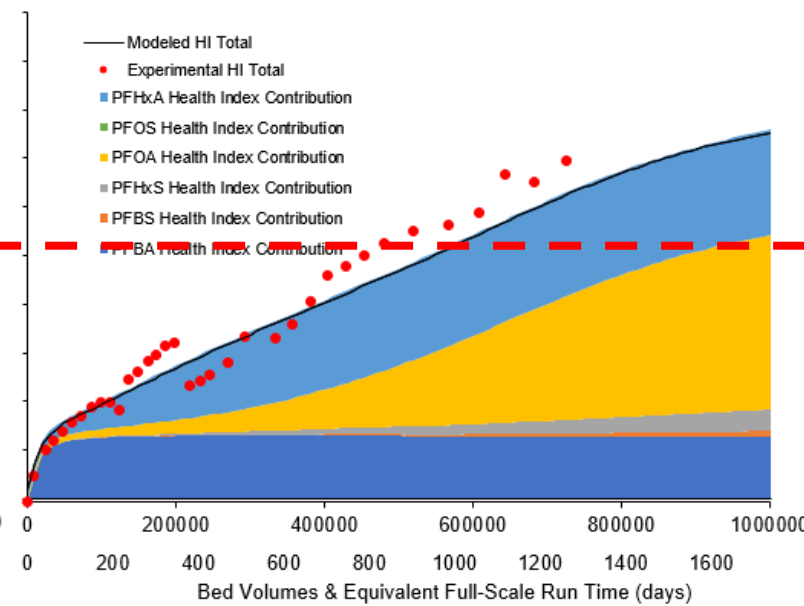




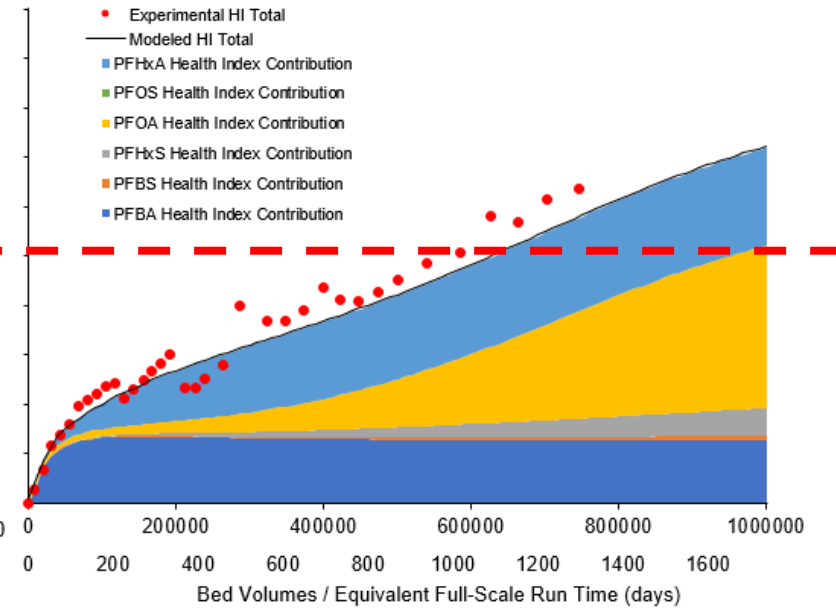
# HI Breakthrough – including PFHxA



GAC Port 2

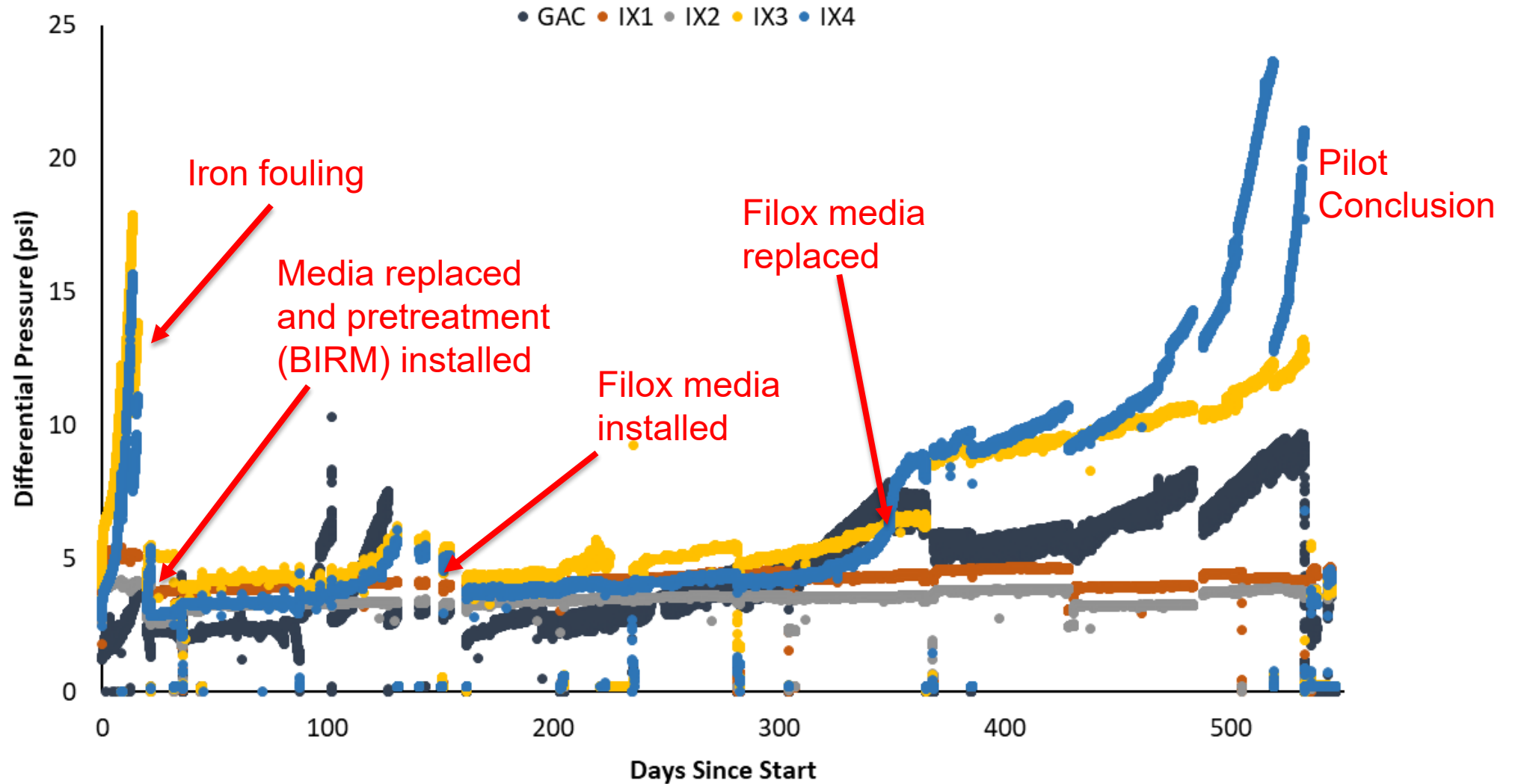


IX3 Port 1



IX4 Port 1

# Pretreatment Results



# **Treatment Cost Estimates**

# Cost Considerations

- Highly site specific:
  - Differences in water quality from one well to the next
- Capital cost:
  - PFAS treatment equipment, pretreatment equipment, building, land/footprint
- Operational Cost
  - Media change out frequency
  - Media disposal or regeneration
  - Pretreatment costs
  - Utilities

# Summary of Media Cost Comparisons

	Evoqua GAC	Evoqua IX	Purolite IX
<b>Media Changeout (Lead ONLY)</b>			
Media volume (cuft)	840	350	350
Media unit cost (\$/ft <sup>3</sup> )	\$ 88.93	\$ 404.25	\$ 278.10
Disposal unit cost (\$/ft <sup>3</sup> )	\$ 60.00	\$ 80.85	\$ 40.00
Total Media and Disposal (\$)	\$ 125,101.20	\$ 169,785.00	\$ 111,335.00
<b>Media Information per Pilot: GAC P2, IX P1</b>			
Media life (BV)	58,000	630,000	540,000
Media life (days)	644	1750	1500
Media life (years)	1.77	4.79	4.11
Media Cost per year (\$)	\$ 70,854.73	\$ 35,412.30	\$ 27,091.52

# Full-Scale Costs

- Includes PFHxA treatment
- Capital costs included full, greenfield facility
- O&M costs included pumping costs, chemical costs, and media replacement/disposal costs

**Table 3-2: Estimated capital costs for each treatment category**

		Total Facility Capital Cost with Pretreatment	Total Facility Capital Cost without Pretreatment	Percent of Total Cost for Pre-treatment
1.0 MGD	GAC	\$5.37M	\$4.04M	25%
	IX	\$5.01M	\$3.65M	27%
	GAC-IX	\$5.43M	\$4.11M	24%
4.5 MGD	GAC	\$14.7M	\$10.5M	28%
	IX	\$14.1M	\$10.0M	29%
	GAC-IX	\$15.0M	\$10.8M	28%
10 MGD	GAC	\$25.9M	\$18.5M	28%
	IX	\$24.6M	\$17.3M	30%
	GAC-IX	\$26.5M	\$19.2M	28%

**Table 3-3: Estimated annual operational costs**

	O&M Breakdown	GAC	Purolite Resin	Dow/Evoqua Resin	GAC and Putolite Resin	GAC and Evoqua/Dow Resin
1.0 MGD	Total	\$131,000	\$51,000	\$57,000	\$110,000	\$117,000
4.5 MGD	Total	\$562,000	\$245,000	\$278,000	\$480,000	\$511,000
10.0 MGD	Total	\$1,143,000	\$509,000	\$576,000	\$981,000	\$1,041,000



# Full-Scale Costs

- Includes PFHxA treatment
- Capital costs included full, greenfield facility
- O&M costs included pumping costs, chemical costs, and media replacement/disposal costs

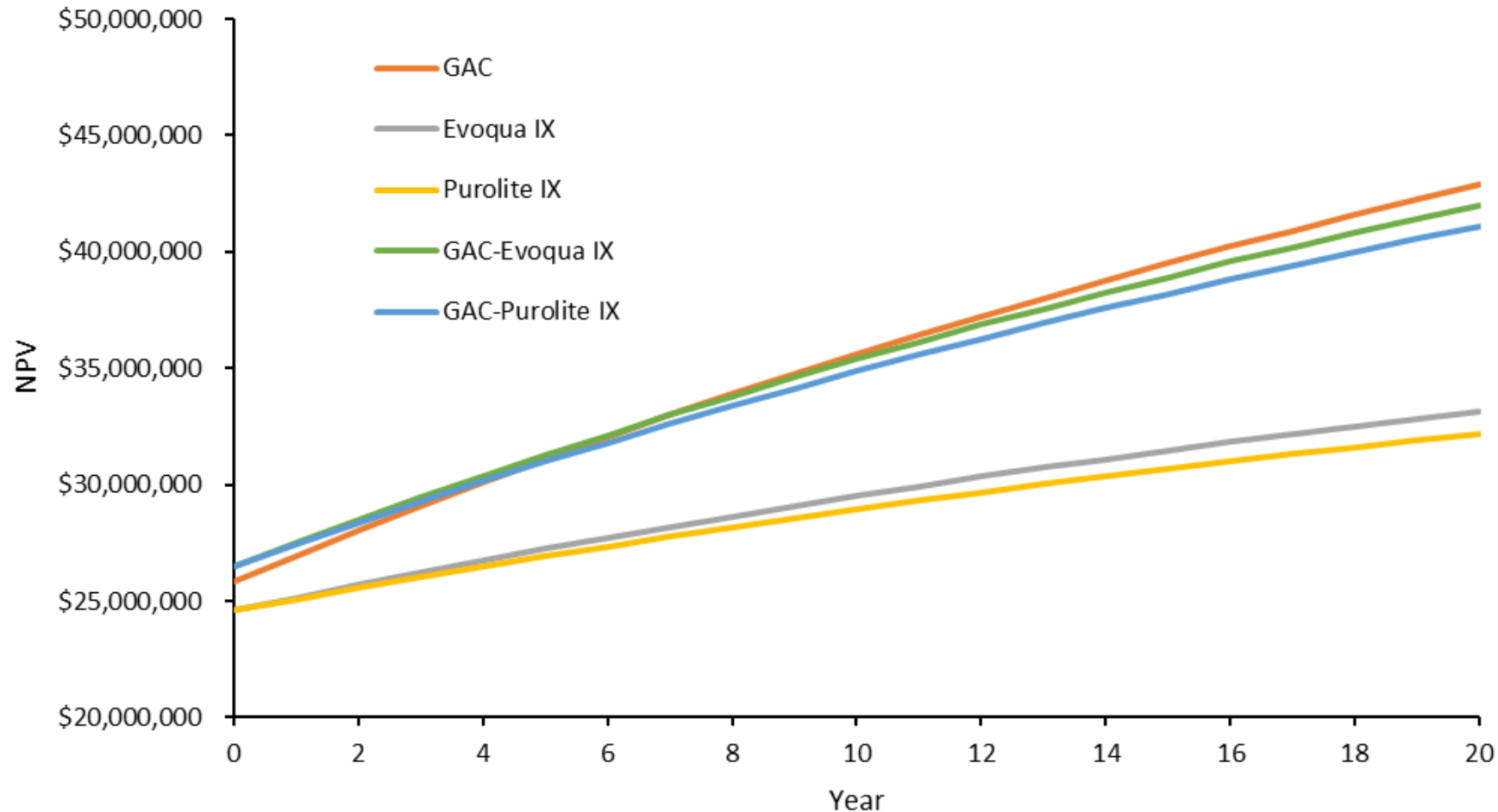
**Table 3-2: Estimated capital costs for each treatment category**

		Total Facility Capital Cost with Pretreatment	Total Facility Capital Cost without Pretreatment	Percent of Total Cost for Pre-treatment
1.0 MGD	GAC	\$5.37M	\$4.04M	25%
	IX	\$5.01M	\$3.65M	27%
	GAC-IX	\$5.43M	\$4.11M	24%
4.5 MGD	GAC	\$14.7M	\$10.5M	28%
	IX	\$14.1M	\$10.0M	29%
	GAC-IX	\$15.0M	\$10.8M	28%
10 MGD	GAC	\$25.9M	\$18.5M	28%
	IX	\$24.6M	\$17.3M	30%
	GAC-IX	\$26.5M	\$19.2M	28%

**Table 3-3: Estimated annual operational costs**

	O&M Breakdown	GAC	Purolite Resin	Dow/Evoqua Resin	GAC and Putolite Resin	GAC and Evoqua/Dow Resin
1.0 MGD	Total	\$131,000	\$51,000	\$57,000	\$110,000	\$117,000
4.5 MGD	Total	\$562,000	\$245,000	\$278,000	\$480,000	\$511,000
10.0 MGD	Total	\$1,143,000	\$509,000	\$576,000	\$981,000	\$1,041,000

# Net Present Value – 10 MGD Facility



# Key Criteria for Decision Making

- Media material costs
- Media life expectancy
- Pretreatment requirement
- Sulfonic acid removal performance
- Carboxylic acid removal performance
- Facility capital cost
- Maintenance and Operation cost
- Versatility for future technology
- Availability of material

# Final Report

# Table of Contents for Final Report

## Table of Contents

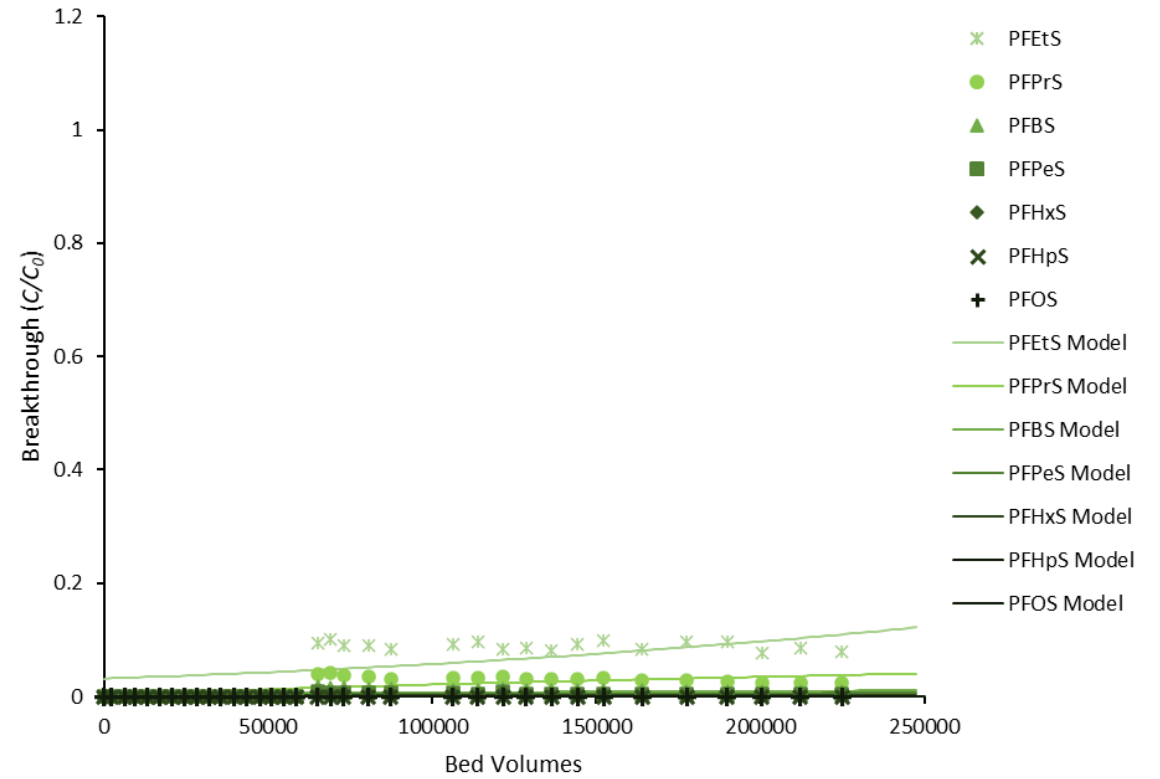
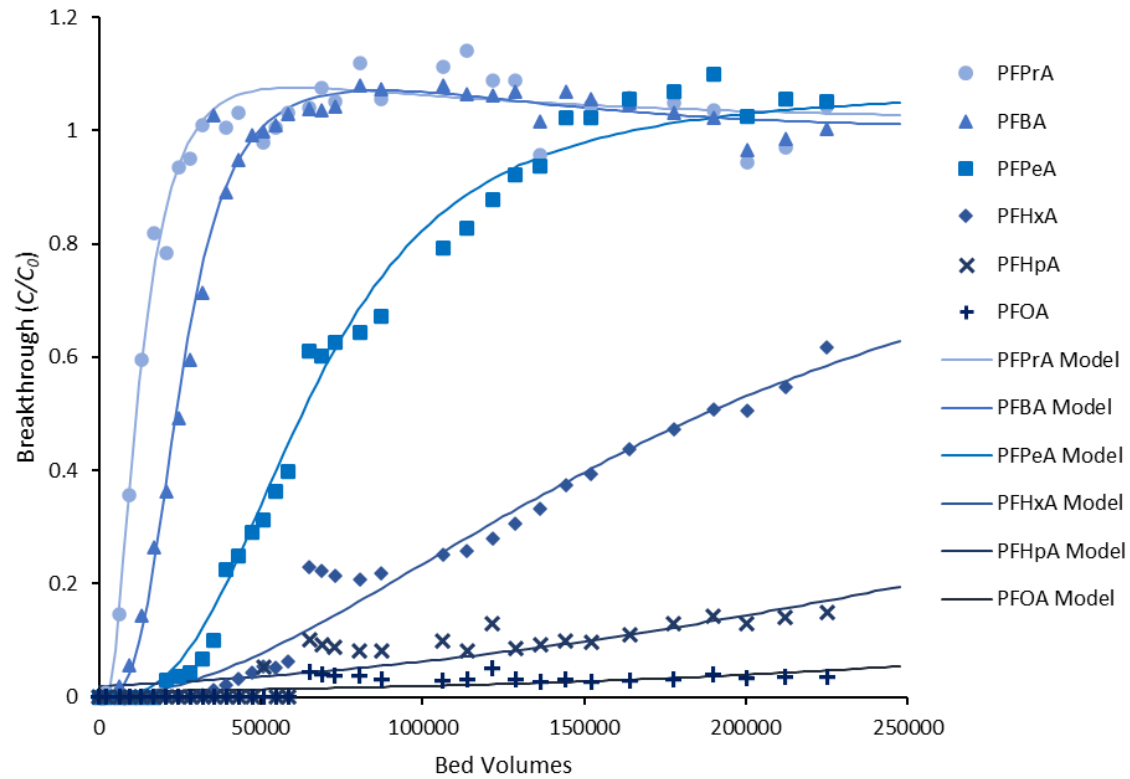
<b>EXECUTIVE SUMMARY .....</b>	<b>III</b>
<b>ABBREVIATIONS .....</b>	<b>IV</b>
<b>1.0 BACKGROUND AND OBJECTIVES .....</b>	<b>1</b>
1.1 BACKGROUND.....	1
1.2 GOALS AND OBJECTIVES .....	4
1.3 PILOT DESIGN .....	4
<b>2.0 TREATMENT RESULTS .....</b>	<b>5</b>
2.1 PRETREATMENT NEEDS, EFFORTS AND RESULTS.....	5
2.2 PILOT OPERATIONS .....	8
2.2.1 Operational Challenges .....	8
2.2.2 Differential Pressure .....	8
2.3 WATER QUALITY .....	11
2.4 PFAS TREATMENT RESULTS .....	11
2.4.1 Using Ports for PFAS Treatment Results .....	11
2.4.2 PFAS Breakthrough Results.....	13
2.4.3 Health Index Breakthrough.....	17
2.4.4 GAC-IX Treatment Results.....	20
2.4.5 Final HI Breakthrough.....	23
<b>3.0 COST COMPARISON.....</b>	<b>23</b>
3.1 CAPITAL COST .....	23
3.2 OPERATIONAL COST.....	25
3.3 NET PRESENT VALUE .....	27
<b>4.0 SUMMARY AND CONCLUSIONS .....</b>	<b>29</b>
4.1 PFAS TREATMENT CAPABILITIES AND COST .....	29
4.2 PRETREATMENT MAY BE REQUIRED .....	29
4.3 CONTINUED INVESTIGATION .....	30

A solid orange vertical bar is positioned on the far left side of the image, extending from the top to the bottom.

**Thank you  
and please be safe!**



# PFAS Breakthrough: IX4 Effluent



# PFAS Breakthrough: IX4 P1

