Evaluation and Design of Ion Exchange for Optimal Treatment of Groundwater

Northeast Conference on the Science of PFAS: Public Health & the Environment

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Town of Ayer, MA

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April 5, 2022

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Water Partnership with CDM Smith

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NORTHEAST WASTE MANAGEMENT OFFICIALS' ASSOCIATION

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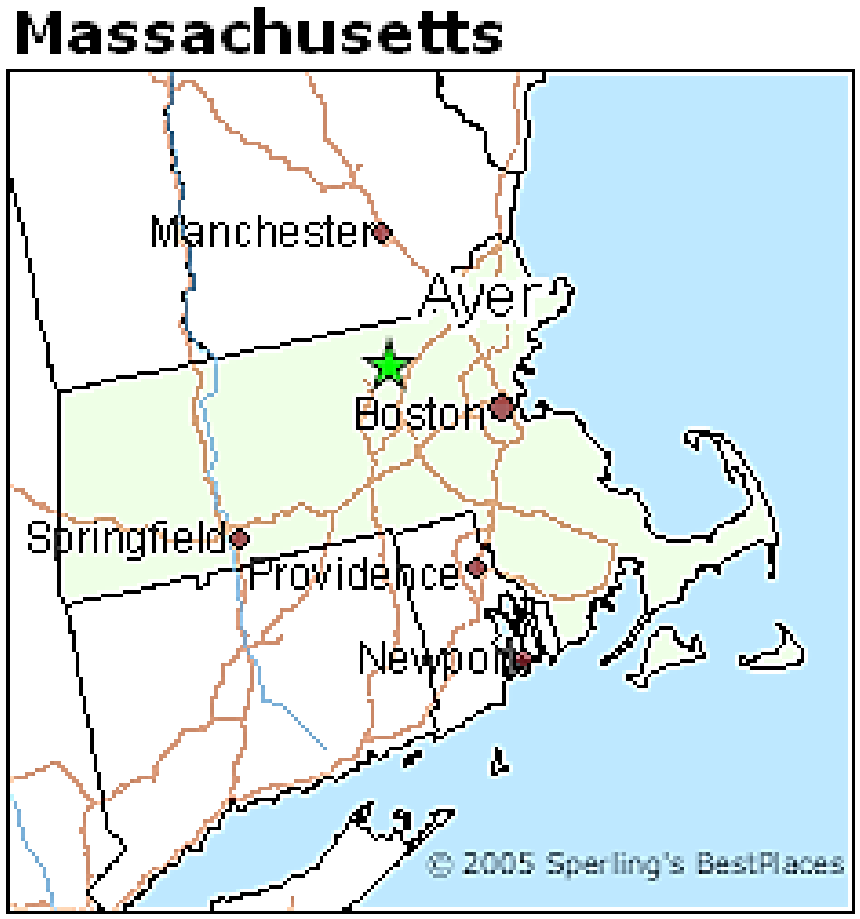
Agenda

1. Background
2. PFAS Discovery and Response Timeline
3. IX Testing and Design
4. Grove Pond IX Operations
5. Summary

Community Background

- Located in central Massachusetts
- 9.5 square miles
- Population 8,500
- Dept. of Public Works – water, wastewater, stormwater, roads & bridges, solid waste, snow plowing, streetlights, tree management, cemetery
- 90% of Town has public sewer and 95% has Town water service

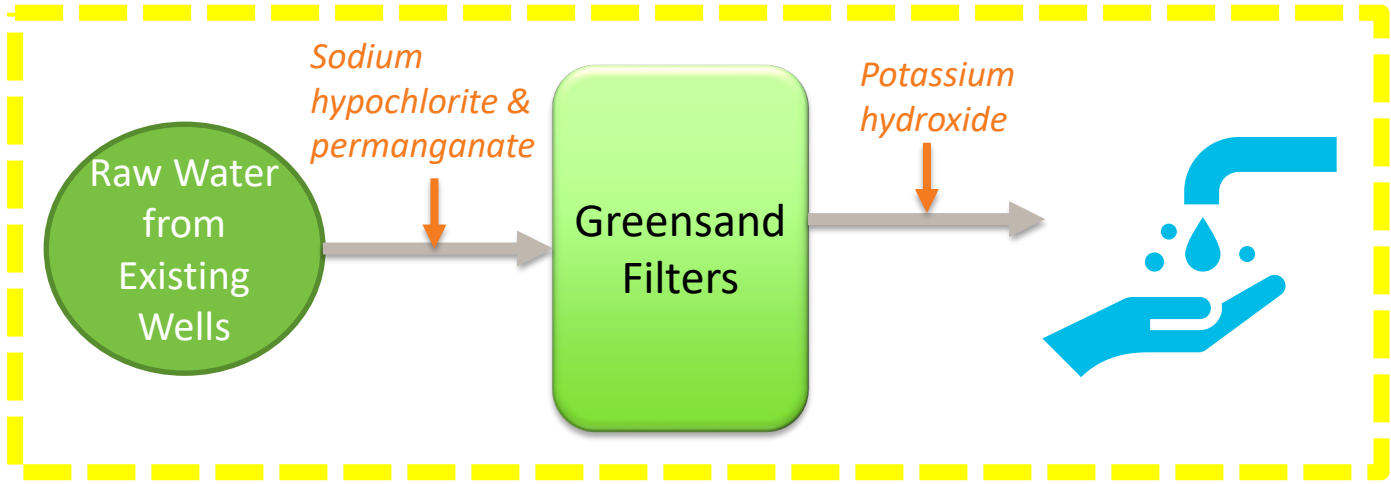


Ayer's Water Supply

- Five gravel wells – 3 at Grove Pond WTP & 2 at Spectacle Pond WTP
- Total supply yield – 3.7 MGD
- Two distribution storage tanks
- 3,330 Water Customers
- Demand: 1.4 MGD (average) & 2.7 MGD (maximum)
- 60% of water use is commercial / industrial
- Water staff – 4.5 persons
- Annual water budget is $2M

Grove Pond WTP

Current Treatment at Both WTPs



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Ayer's Water Supply Challenges

- Very high iron (2.5 to 3.4 ppm)
  - *Secondary MCL 0.3 ppm*
- Very high manganese (0.85 to 5.66 ppm)
  - *Secondary MCL – 0.05 ppm*
- Arsenic – 0.007 to 0.069 ppm
  - *MCL – 0.01 ppm*
- Lead and Copper Rule
- Total Coliform Rule
- Aging infrastructure

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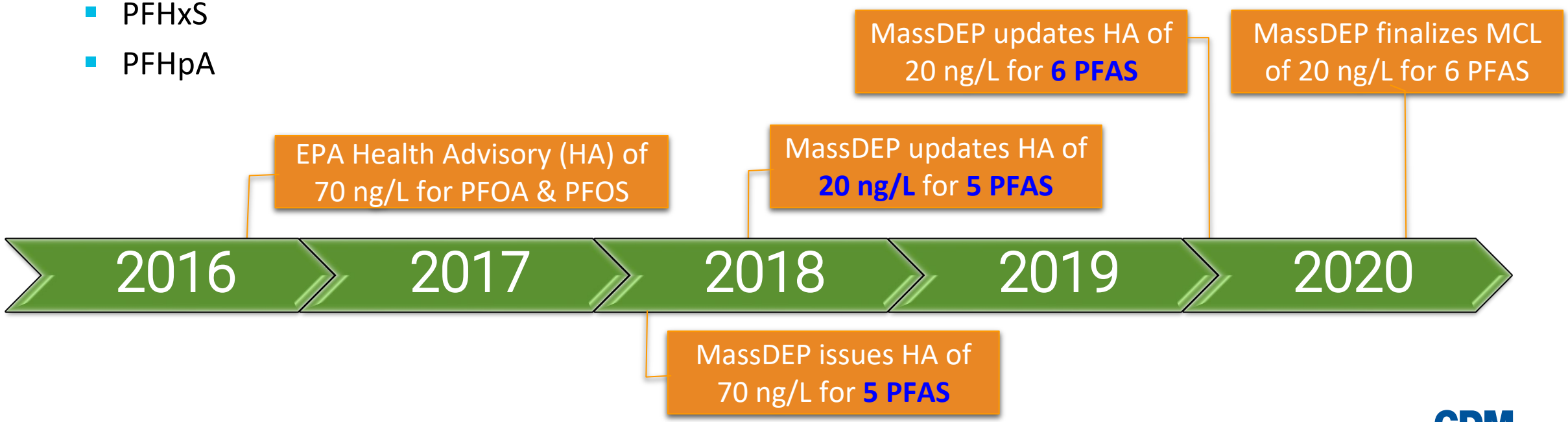
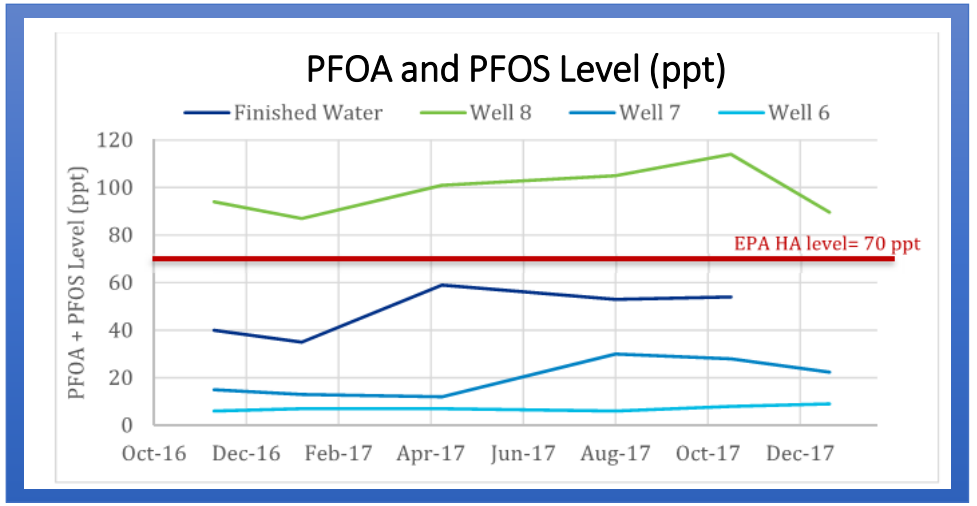
PFAS Maximum Contaminant Level (MCL) in Massachusetts

- 20 ng/L for “PFAS6”
  - PFOA
  - PFOS
  - PFNA
  - PFDA
  - PFHxS
  - PFHpA

PFAAs	C4	C5	C6	C7	C8	C9	C10	C11	C12
Carboxylates	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUnA	PFDoA
Sulfonates	PFBS	PFPeS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFUnS	PFDoS



PFAS Discovery & Response Timeline I

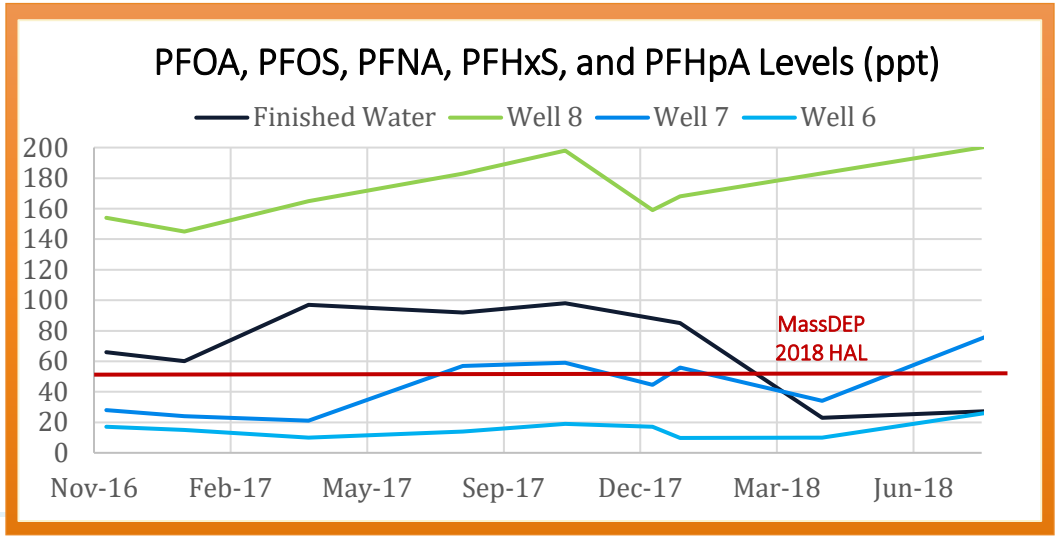


Due to proximity to Fort Devens, MassDEP required testing at the Grove Pond wells

2016 | 2017 | 2018 | 2019 | 2020

Grove Pond desktop treatability study

Grove Pond Well 8 taken offline (most contaminated)



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PFAS Discovery & Response Timeline II

Grove Pond Well 8 *temporary* treatment

Grove Pond AIX Treatment in Operation

2016 2017 2018 2019 2020

Grove Pond testing for *permanent* treatment

Grove Pond design begins

Grove Pond construction begins

Grove Pond other challenges:
- Reactivated an old well with very high Fe/Mn
- SCADA update so Well 8 never runs alone
- Dirty water complaints
- Positive Total Coliform in August
- Well 6 “plugging” requiring redevelopment
- Interconnection with Devens who later detected PFAS
- Obtained funding from U.S. Army

PFAS Discovery & Response Timeline III

The Spectacle Pond GAC facility is anticipated to start this spring!

Spectacle Pond detects PFAS (20-30 ppt) & started sampling distribution system

Spectacle Pond alternative analysis (permanent/temporary treatment, interconnections & use of emergency wells)

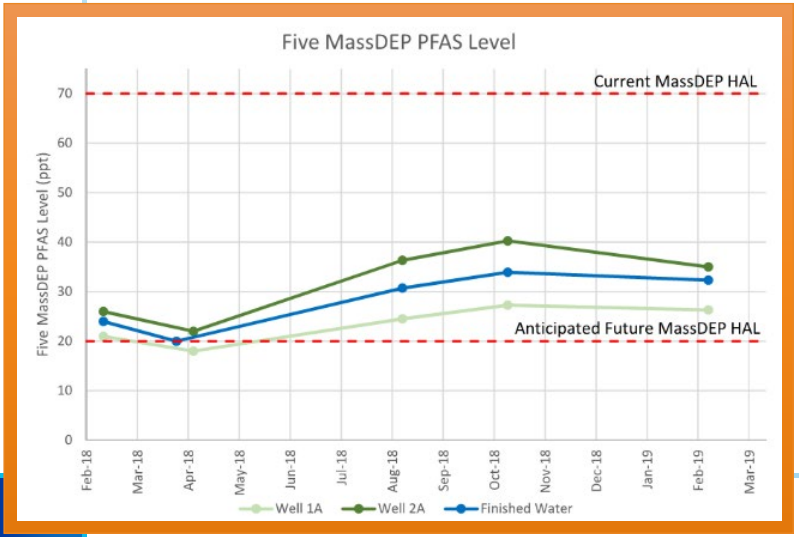
Spectacle Pond testing & design for permanent treatment

2016 2017 2018 2019 2020

Spectacle Pond cleaned, redeveloped & replaced existing wells

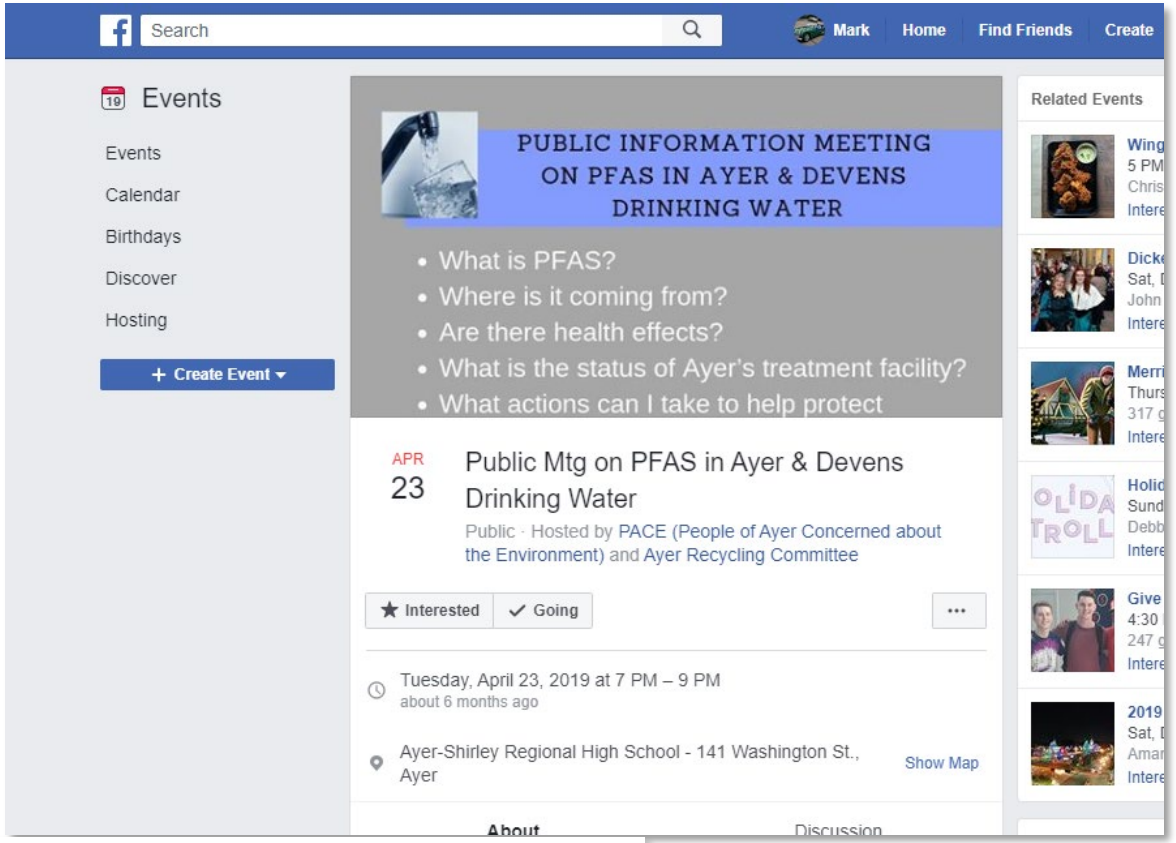
Spectacle Pond alternative analysis (permanent/temporary treatment, interconnections & use of emergency wells)

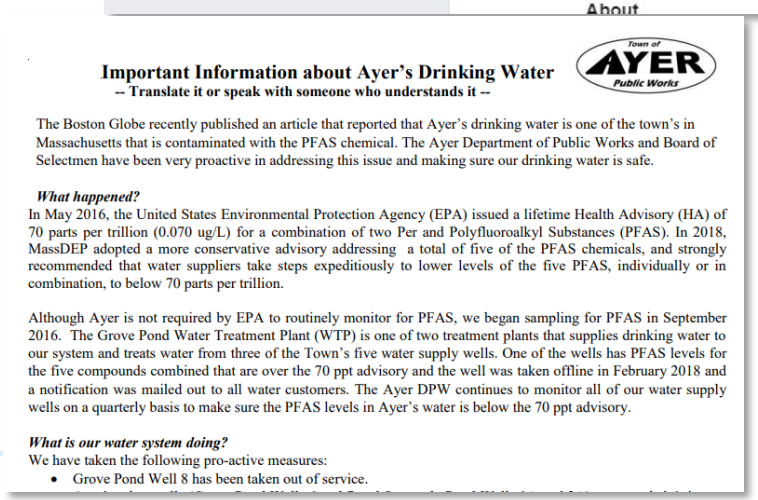
Spectacle Pond Construction begins



Ayer's Public Outreach

- Public Notifications in 2018, 2019, 2020, 2021
- Updates at Selectmen's meetings and to public on Town website and Facebook
- Town PFAS Forum in 2019
- Info in Water Quality Reports
- Coordination with PACE (People of Ayer Concerned about the Environment)





Important Information about Ayer's Drinking Water
-- Translate it or speak with someone who understands it --

Town of AYER Public Works

The Boston Globe recently published an article that reported that Ayer's drinking water is one of the town's in Massachusetts that is contaminated with the PFAS chemical. The Ayer Department of Public Works and Board of Selectmen have been very proactive in addressing this issue and making sure our drinking water is safe.

What happened?

In May 2016, the United States Environmental Protection Agency (EPA) issued a lifetime Health Advisory (HA) of 70 parts per trillion (0.070 ug/L) for a combination of two Per and Polyfluoroalkyl Substances (PFAS). In 2018, MassDEP adopted a more conservative advisory addressing a total of five of the PFAS chemicals, and strongly recommended that water suppliers take steps expeditiously to lower levels of the five PFAS, individually or in combination, to below 70 parts per trillion.

Although Ayer is not required by EPA to routinely monitor for PFAS, we began sampling for PFAS in September 2016. The Grove Pond Water Treatment Plant (WTP) is one of two treatment plants that supplies drinking water to our system and treats water from three of the Town's five water supply wells. One of the wells has PFAS levels for the five compounds combined that are over the 70 ppt advisory and the well was taken offline in February 2018 and a notification was mailed out to all water customers. The Ayer DPW continues to monitor all of our water supply wells on a quarterly basis to make sure the PFAS levels in Ayer's water is below the 70 ppt advisory.

What is our water system doing?

We have taken the following pro-active measures:

- Grove Pond Well 8 has been taken out of service.

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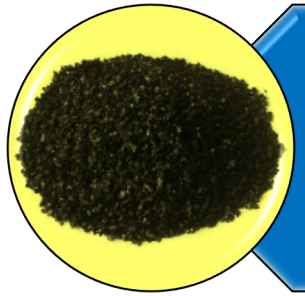
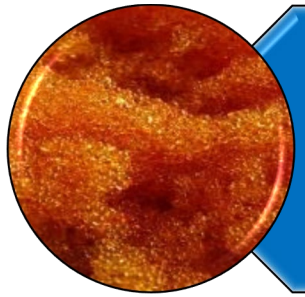
PFAS TREATMENT OPTIONS

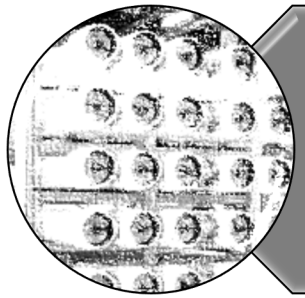
- ✓Water quality (e.g., low organic)
- ✓Town's familiarity with pressure vessels
- ✓No liquid waste stream of concern
- ✓Comparatively lower cost (vs. membrane)



Granular Activated Carbon (GAC)



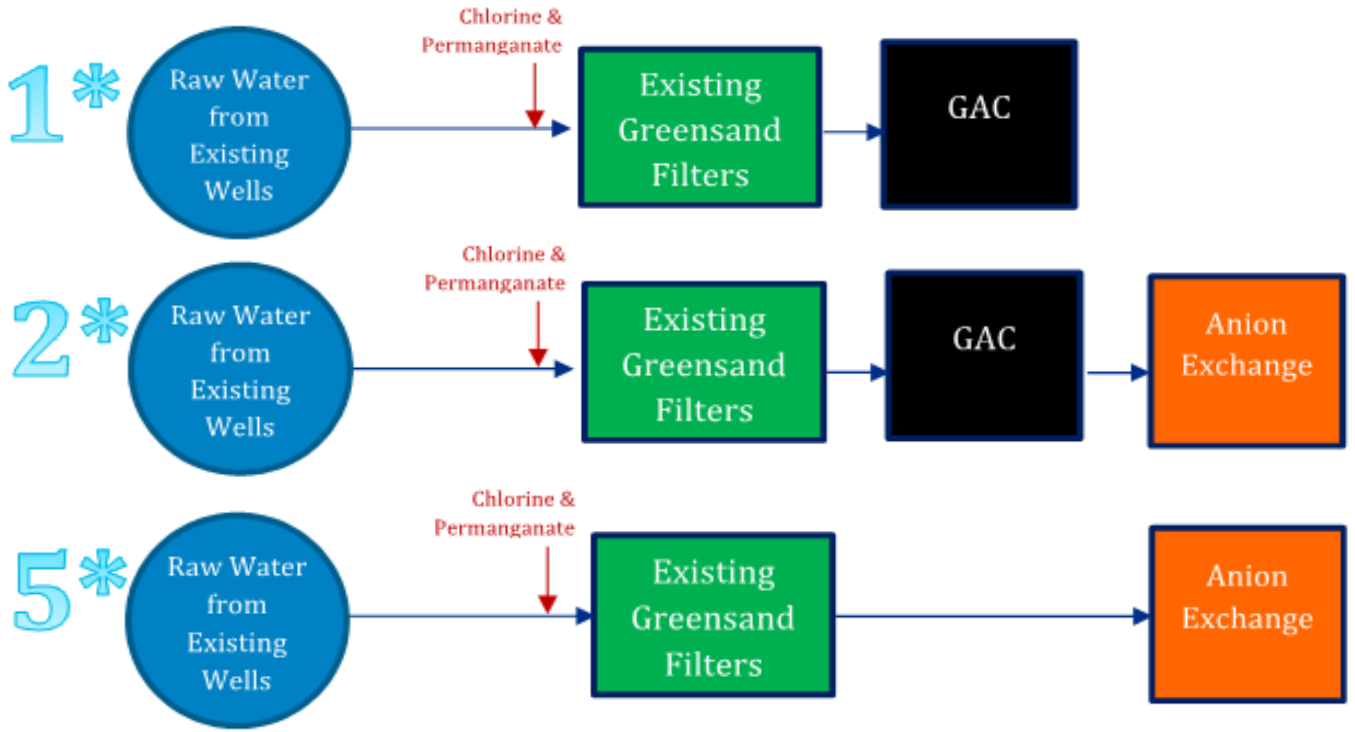
Anion Exchange (AIX)



Membrane

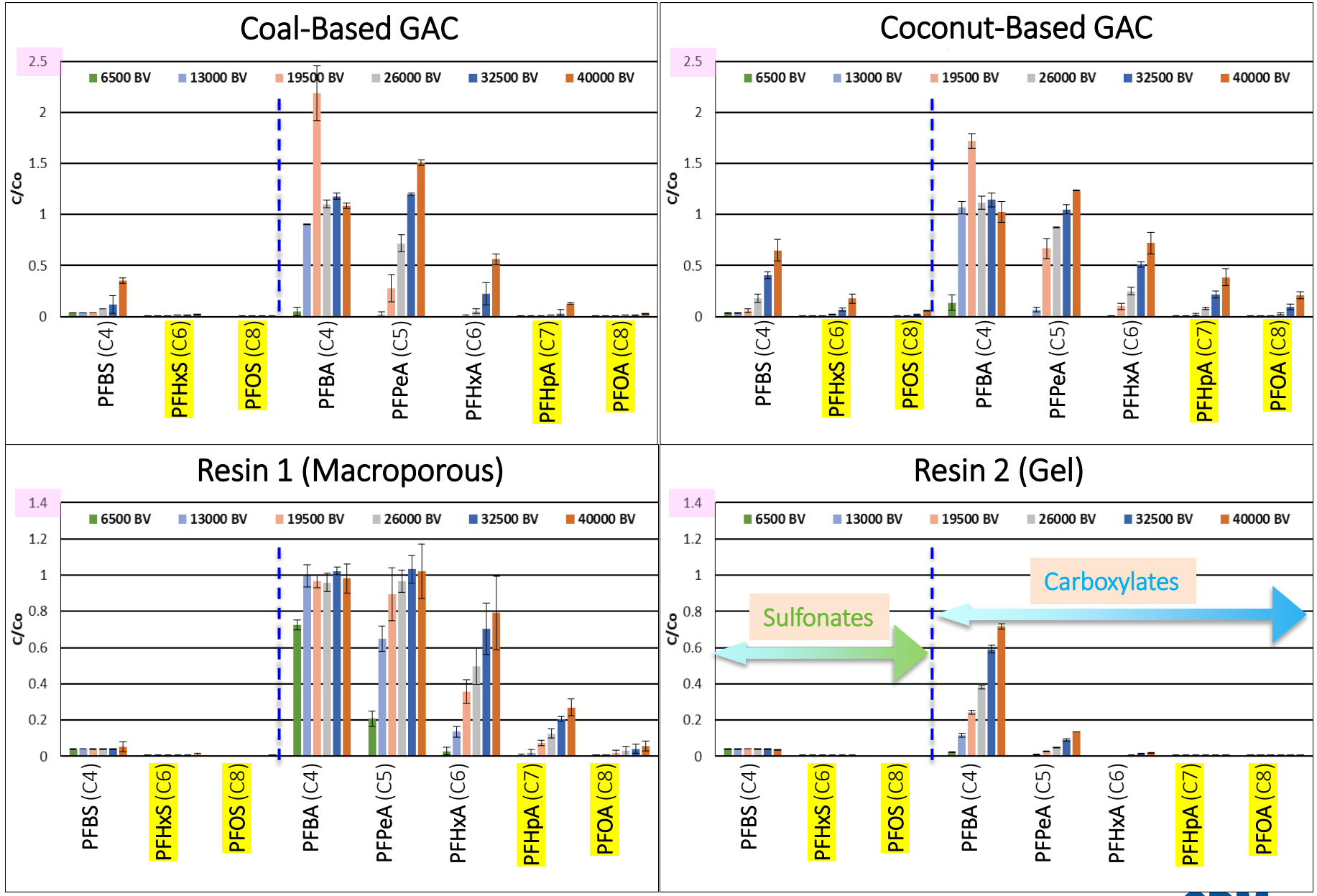
PFAS Treatment Placement at Grove Pond WTP

- PFAS treatment process to be placed downstream of the existing greensand filters (post iron & manganese removal)
- Rapid small-scale column testing (RSSCTs) performed to evaluate the three options



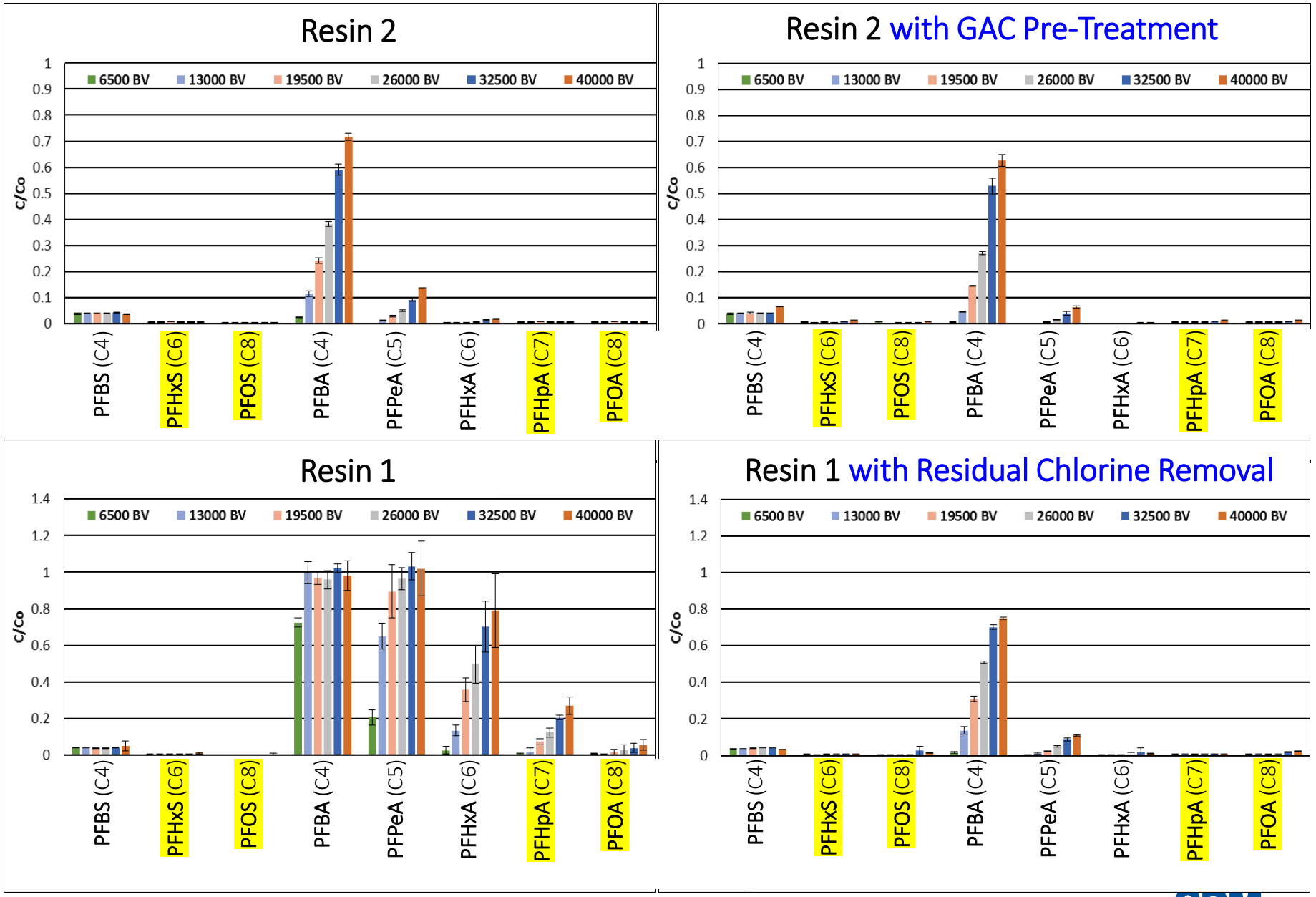
GAC vs. AIX

- Both AIX & GAC treated the target PFAS effectively, but differences in performance among the media products observed.
- AIX chosen as the treatment technology for removing a wider range of PFAS, including shorter chain compounds



Pre-GAC Treatment & Chlorine Removal on AIX Treatment

- Marginal improvement in AIX effectiveness by GAC pre-treatment upstream. *(TOC=~0.5 mg/L)*
- Removal of free chlorine residual *(0.2-0.5 mg/L)* with calcium thiosulfate resulted in enhanced PFAS treatment.



Chloride to Sulfate Mass Ratio (CSMR)

- Increased CSMR is associated with galvanic corrosion of lead solder connected to copper pipes
  - Raw water
    - Average sulfate = 16.6 mg/L
  - After 1,000 BVs:
    - Resin 1: sulfate = 6.4 mg/L
    - Resin 2: sulfate = 16.6 mg/L
  - After ~30,000 BVs:
    - Both Resin 1 and Resin 2 at the raw water sulfate level

$$CSMR = \frac{Chloride}{Sulfate}$$

Scenario	CSMR
Current	7.7
After 1000 BVs – Resin 1	20
After 1000 BVs – Resin 2	7.7

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Grove Pond PFAS Treatment Facilities

- $3.1M facilities in operation
  - Two 12-ft diameter AIX vessels
  - Two bag filters
  - Two chemical systems (calcium thiosulfate & zinc orthophosphate)

Now for Spectacle Pond WTP…

- Careful water quality evaluation was conducted, including comparison to Grove Pond WTP, and did not suggest concerns with AIX treatment.
  - Higher hardness in Spectacle Pond's water (115 mg/L vs. 190 mg/L)
- RSSCT to evaluate 3 resins & 1 GAC out of caution.

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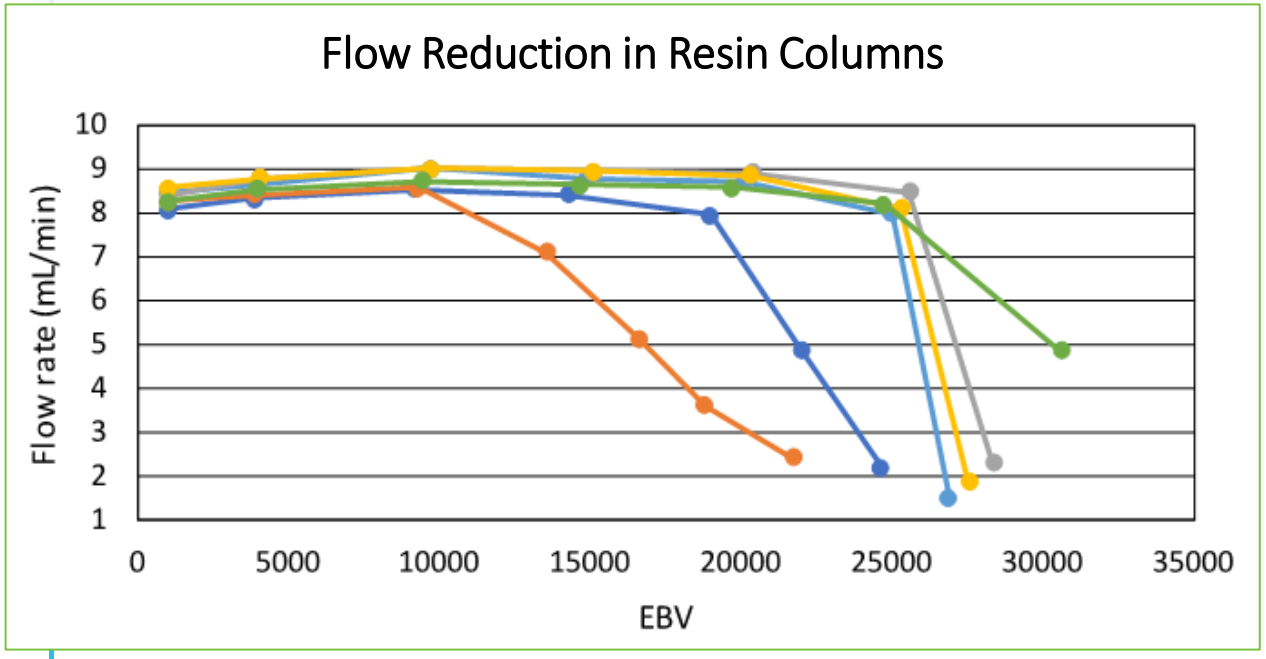
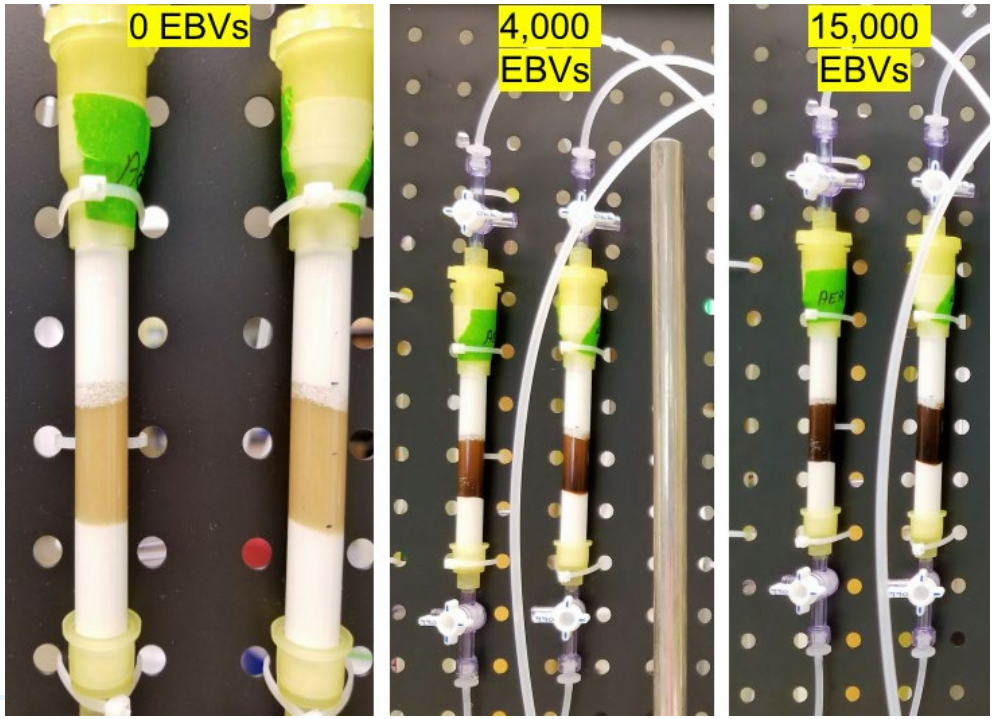
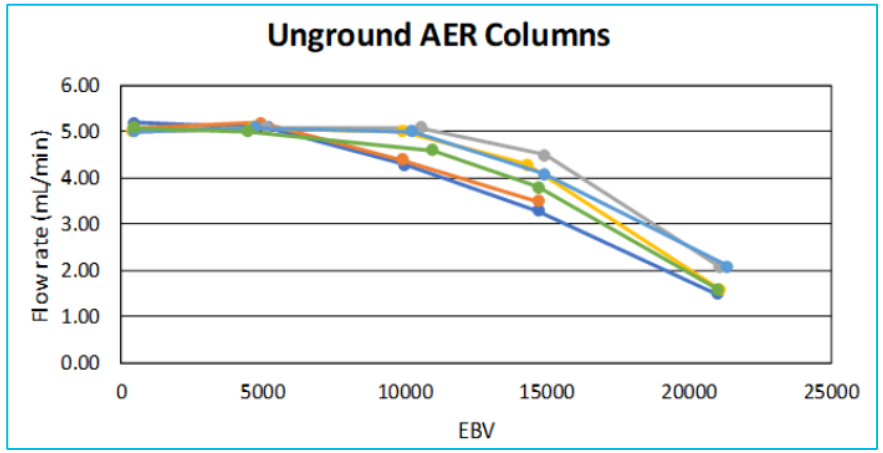




WHY DIDN'T AIX WORK AT SPECTACLE POND WTP?

Investigation 1: resin grinding

Flow loss still observed with unground resin



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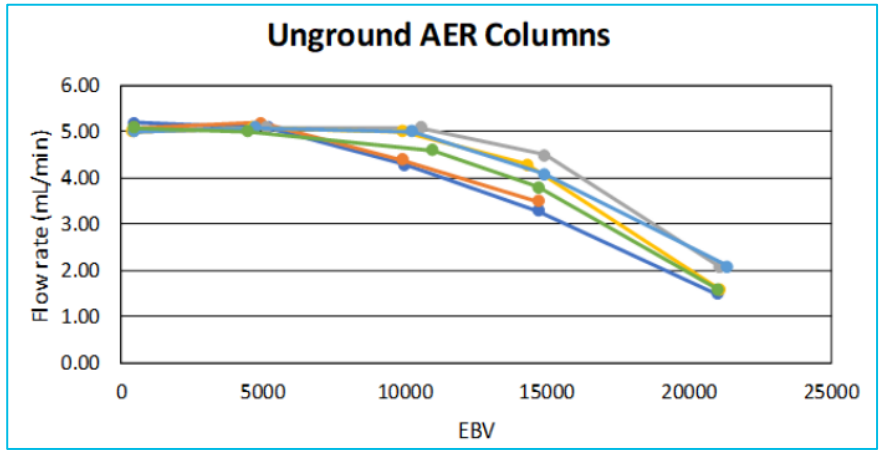
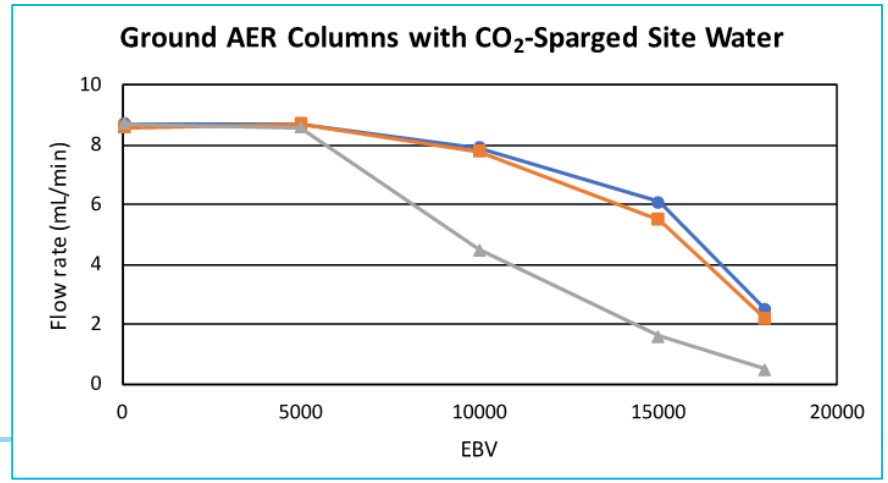


Investigation 2: CO_2 loss during water shipment

Flow loss still observed with pH adjustment



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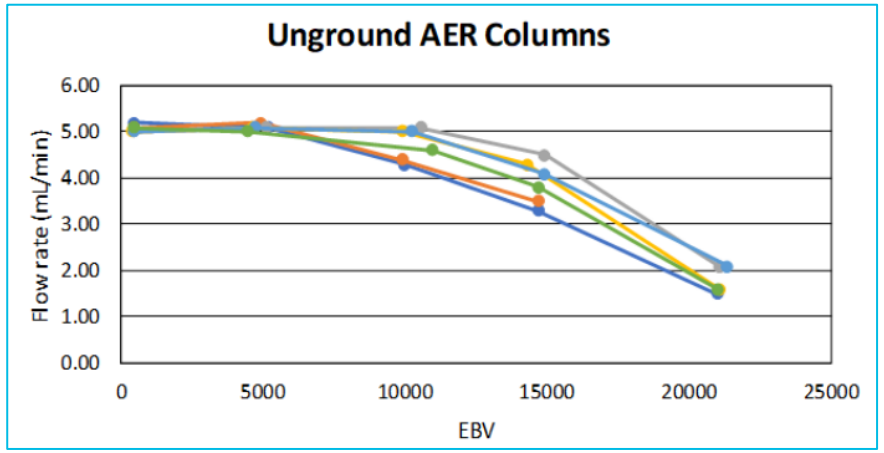

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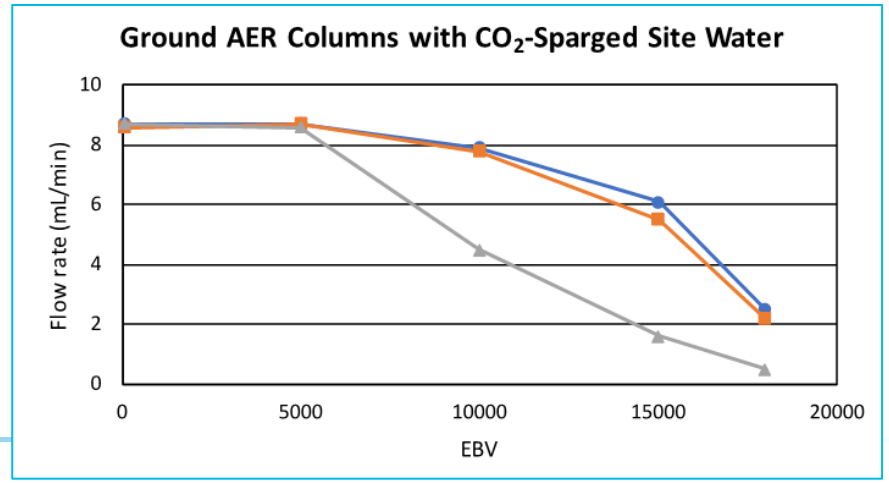

Investigation 3: Electron microprobe analysis:

No significant differences observed between clogged and virgin resins

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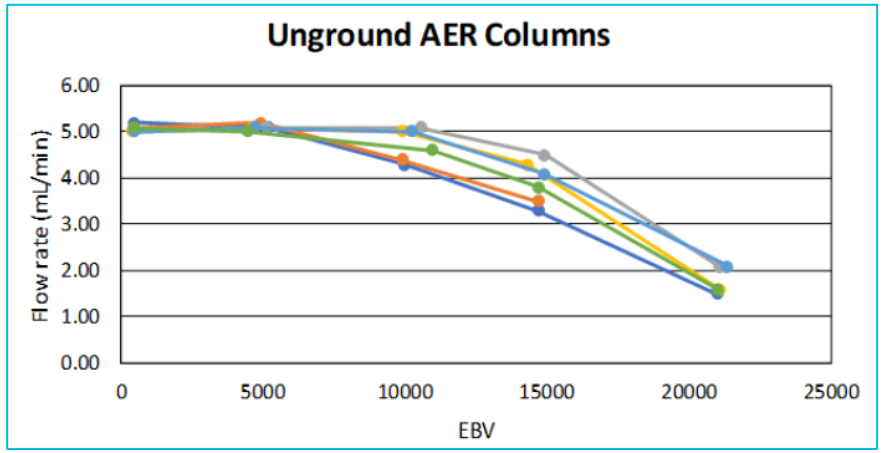
WHY DIDN'T AIX WORK AT SPECTACLE POND WTP?

- AIX resin clogging predicted at full-scale.
- Investigations confirmed this is not an artifact of the lab work but couldn't provide an explanation.
- Emphasizes the importance of testing with the actual water to be treated.

Investigation 1: resin grinding

Flow loss still observed with unground resin



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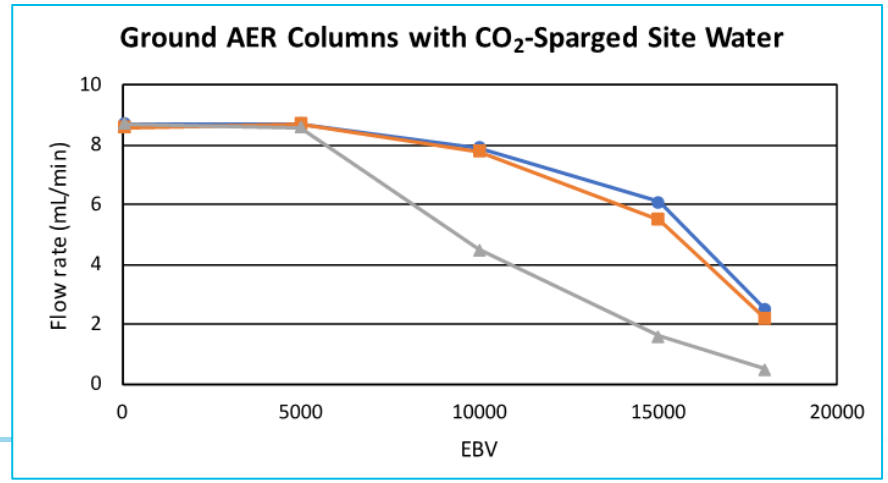

Investigation 3: Electron microprobe analysis:

No significant differences observed between clogged and virgin resins

Investigation 4: Metals analysis:

Did not provide meaningful insights into the clogging mechanisms

Analyte	Unimpacted			Impacted			Unit
	1A	*2A*	*3A*	*1A*	*2A*	*3A*	
Calcium	39	49	40	29	22	32	mg/kg
Copper	11	27	1.9	35	18	26	mg/kg
Iron	4.7	17	3.9	29	12	100	mg/kg
Potassium	190	200	200	20	19	19	mg/kg
Sodium	150	160	160	16	15	15	mg/kg

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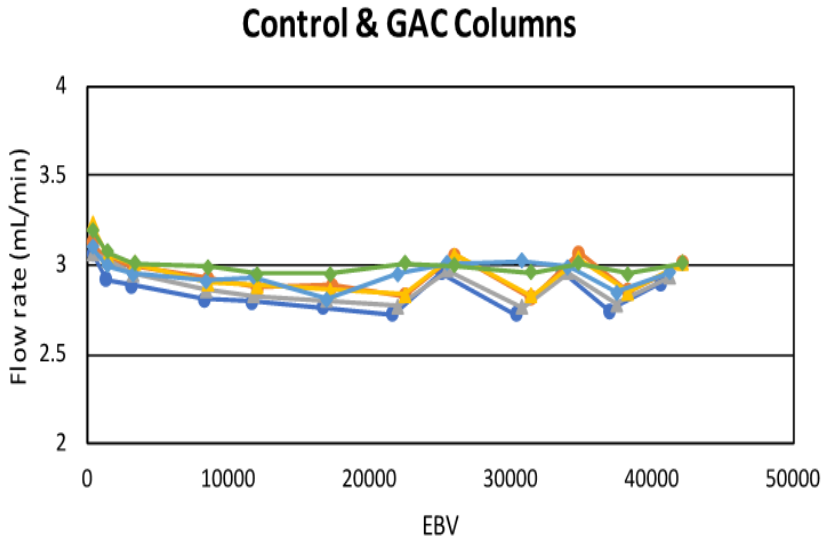
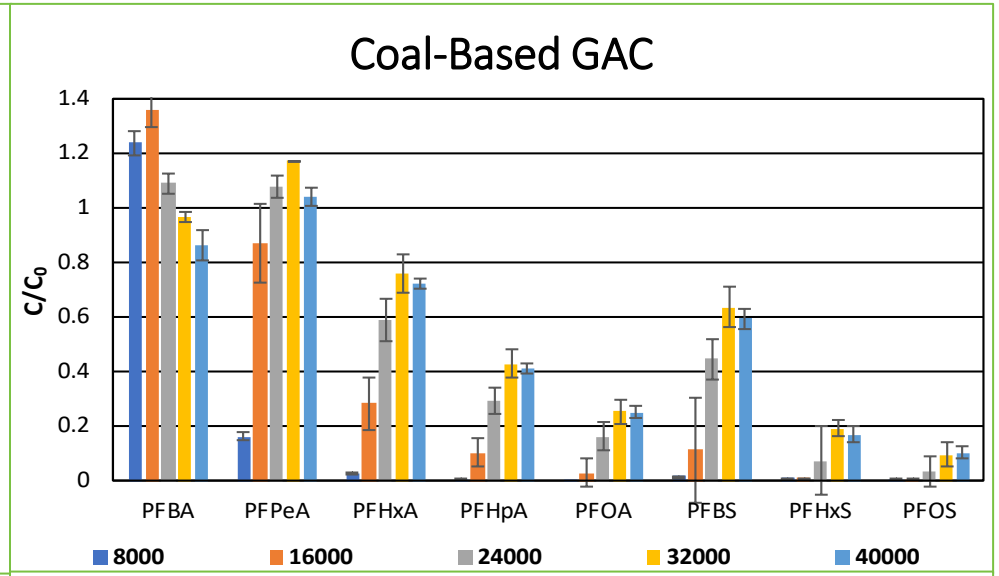
GAC AT SPECTACLE POND WTP

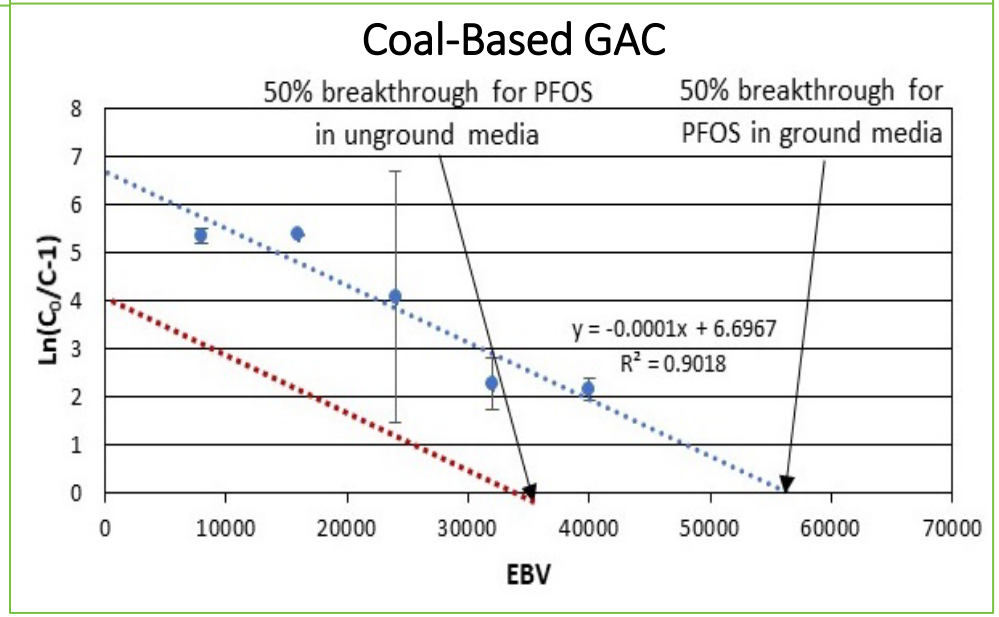
- No loss of flow observed.
- Bituminous coal-based GAC performed slightly better than coconut-based GAC.
- GAC changeouts predicted after 35,000 EBVs.
- No arsenic release by coal-based GAC observed.
- No impact on CSMR anticipated.





Approx. Breakthrough after 40,000 BVs

MassDEP PFAS	Coal-Based GAC	Coconut-Based GAC
PFOA	20%	50-70%
PFOS	10%	25-50%
PFHxS	20%	40-60%
PFHxA	80%	90-95%



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Design and Operational Considerations for AIX

- **Shorter EBCT:** 2 to 3 minutes for AIX vs. 8-10 minutes for GAC
- **Smaller and shorter infrastructure footprint** (~17 ft vessel height for AIX vs. ~24 ft for GAC)
- **CSMR impacts during start-up**
- **Vulnerable to oxidant presence:** some resins might be more resilient than others
- **Cannot be backwashed:** vulnerable to pressure buildup or biological fouling
- **Fate of spent resin:** No regeneration offered for municipal application – disposal is on utilities

Operational Observations

- Plant has been in operation for 16 months

Additional manpower required for new facilities:

- Change bag filters every 2 weeks
- "Bio-fouling" of IX media requiring hydrogen peroxide disinfection
  - Resulting headloss through system can limit treatment capacity and lead to blowing rupture disks

Additional sampling & monitoring requirements:

- Monthly PFAS sampling at IX vessel mid-point and finished water and more
- Daily sampling for chlorine, Fe, Mn, pH between greensand filters and IX vessels
- ZOP chemical feed and monitoring
- Chloride and sulfate sampling during start-up

Approximate additional manpower associated with new PFAS treatment

Task	Frequency	Hours
Influent water quality testing	Daily	5
Record operating data	Daily	5
Change bag filters	Weekly	12
Maintain chem. feed pumps	Weekly	3
General building maintenance	Weekly	8
Distribution system orthophosphate monitoring	Weekly	7.5
Prepare monthly reports	Monthly	6
Media peroxide treatment	As needed	24

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Potential Future Modifications

- Install pressure relief valves with SCADA alarm in place of rupture disks
- Construct clearwell storage system to:
  - Reduce pressure through IX treatment system
  - Better flexibility in operations for treated water supply to distribution system
  - Provide adequate greensand filter backwash supply
- Continue investigating the cause of resin fouling or consider UV disinfection system

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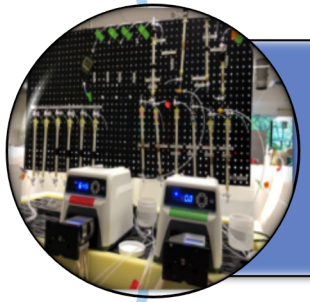
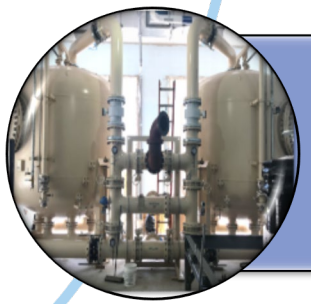
Takeaways & Summary

Proactive actions, holistic treatment approach, and collaborative working relationships were critical part of the success in addressing the moving regulatory target in Ayer.



Careful site-specific investigations are important for determining treatment selection and compatibility with the existing treatment while avoiding unintended consequences.



GAC and AIX are established technologies for PFAS removal, but there is still more to be learned. Their effectiveness should be not be assumed without pre-design study and testing.

ACKNOWLEDGEMENT

- Town of Ayer DPW
  - Dan Van Schalkwyk, P.E.
- MassDEP Central Region
- CDM Smith team
  - Lisa Gove, P.E., BCEE
  - Alan LeBlanc, P.E., BCEE
  - Charles Schaefer, Ph.D.

CONTACT US!

Water Partnership with CDM Smith

Find more insights through our water partnership at cdmsmith.com/water and @CDMSmith

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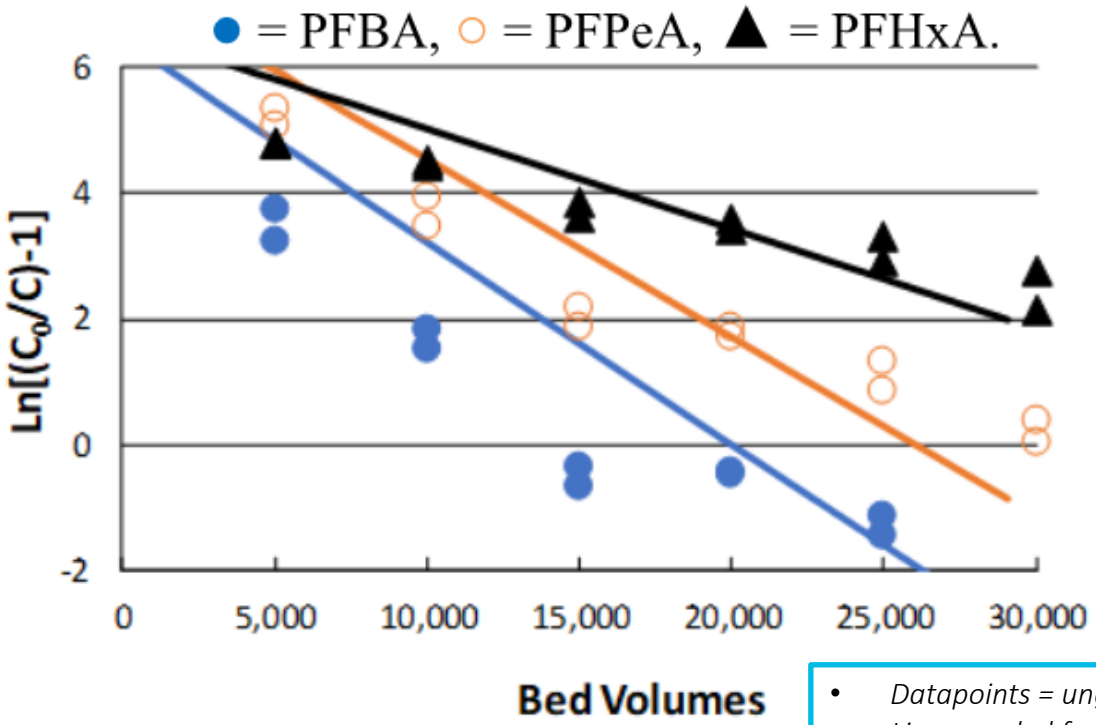
Validating Use of RSSCTs for PFAs on AIX



- *Datapoints = unground resin testing*
- *Line = scaled from ground resin data*

I&EC research
Industrial & Engineering Chemistry Research

Research Note

Cite This: *Ind. Eng. Chem. Res.* XXXX, XXX, XXX−XXX

pubs.acs.org/IECR

Assessing Rapid Small-Scale Column Tests for Treatment of Perfluoroalkyl Acids by Anion Exchange Resin

Charles E. Schaefer,*,† Dung Nguyen,‡ Paul Ho,‡ Jihyon Im,§ and Alan LeBlanc§

Rapid Small-Scale Column Testing (RSSCT)

$$\frac{EBCT_G}{EBCT_U} = \left(\frac{d_G}{d_U}\right)^2$$

constant diffusivity for scaling

Transport Eqn. (Thomas Model):

$$ln\left[\frac{C_0}{C} - 1\right] = \left(\frac{kmq_0}{Q}\right) - [EBCT]kC_0BV$$

where q_0 scales to account for surface sorption

- RSSCT, assuming constant diffusivity and coupled with the Thomas model, were effective for scaling PFAS removal with ground AIX resin in low TOC water

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