City of Bemidji PFAS Water Treatment:

Concept Development through

Full-Scale Design and Implementation

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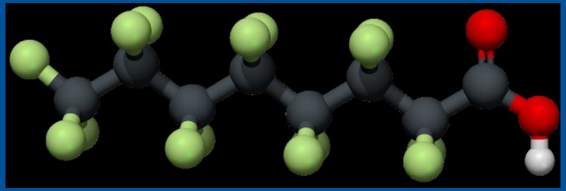

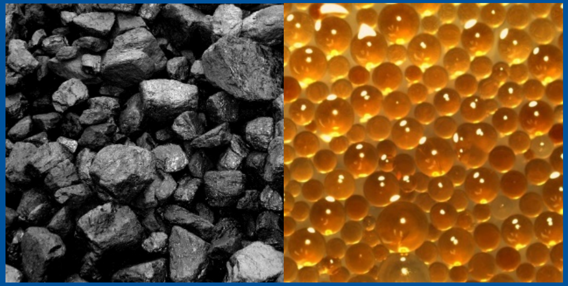

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- How does the near-term design accommodate future build-out?

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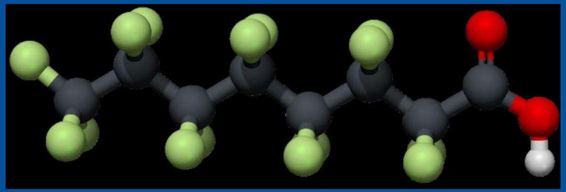

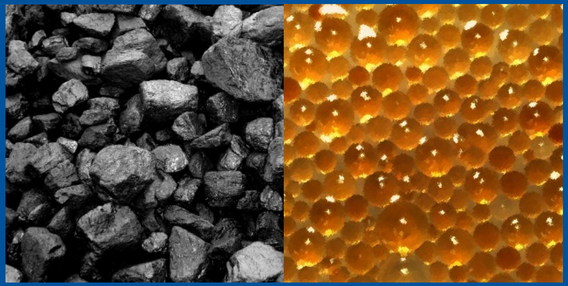

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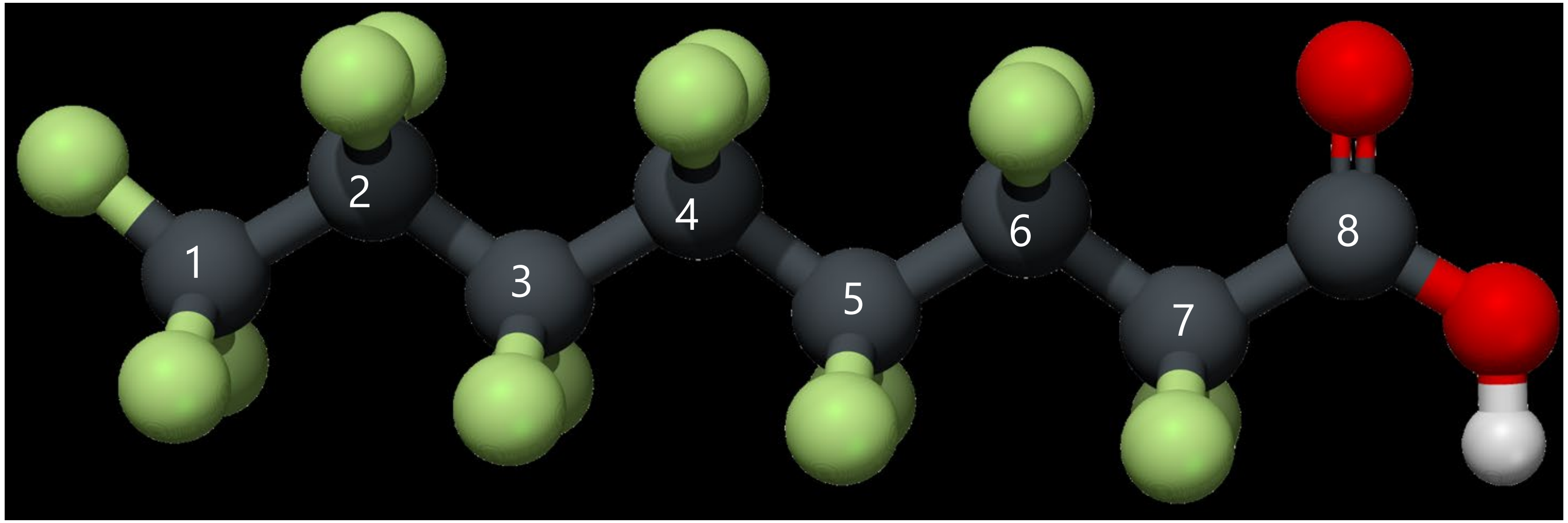
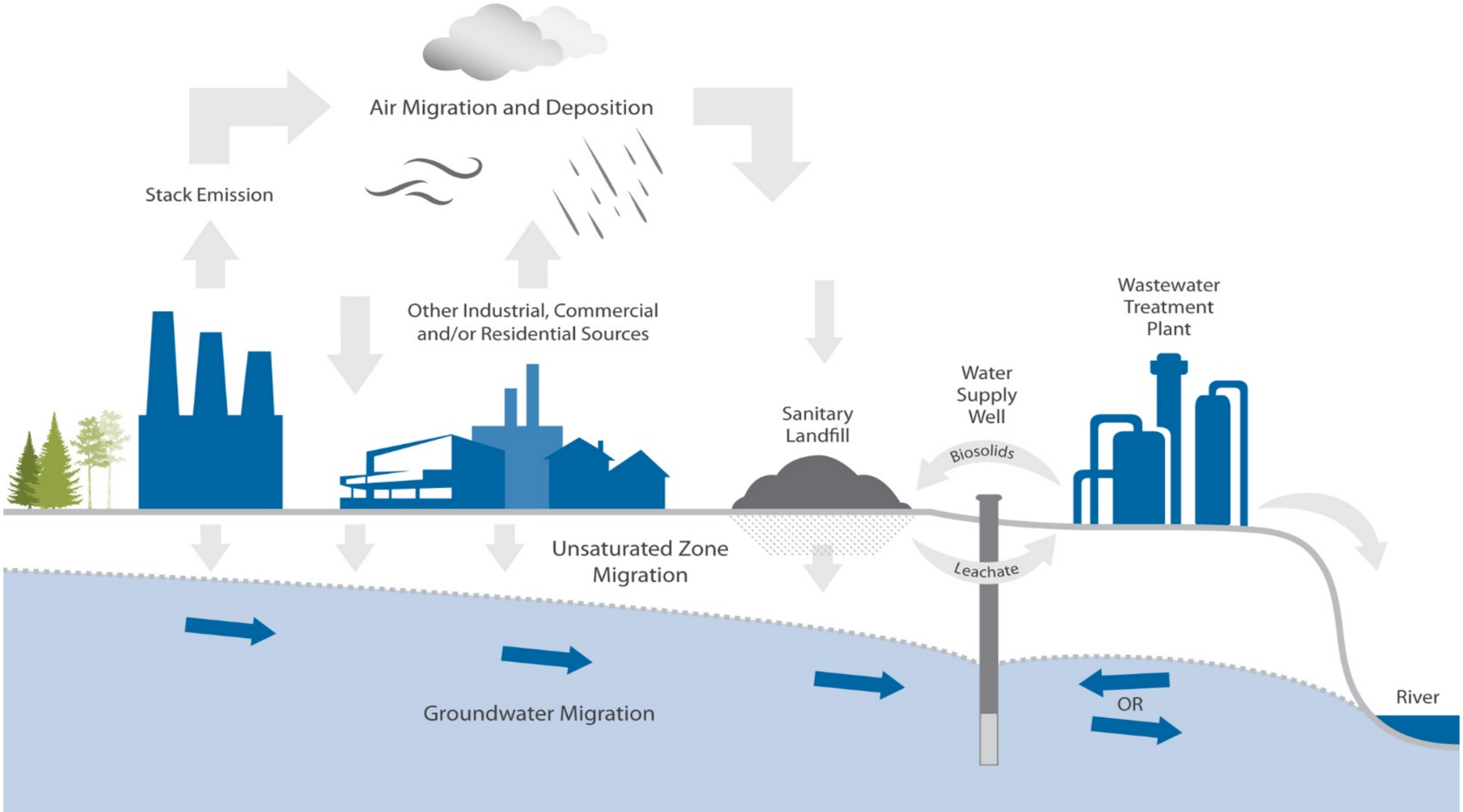
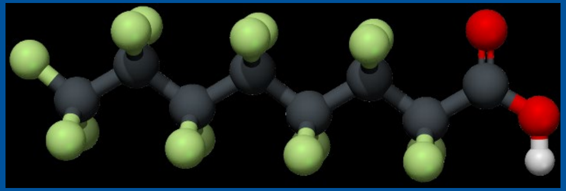
PFAS are used in heat, oil, stain, and water-resistant products

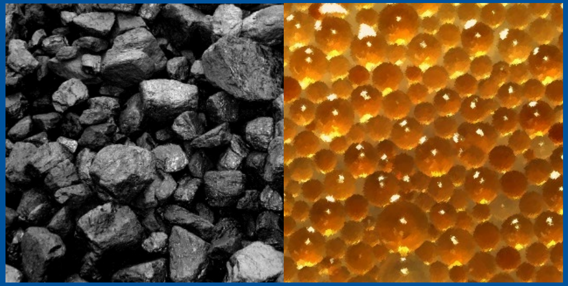
- PFAS – per and polyfluoralkyl substances
- Family of manufactured chemicals
- Non-biodegradable
- Destroyed at high temperatures
- Semi-volatile
- Miscible in water



PFAS migrate through air, soil, and water







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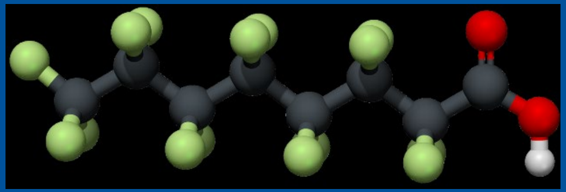
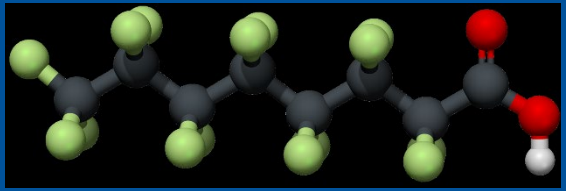
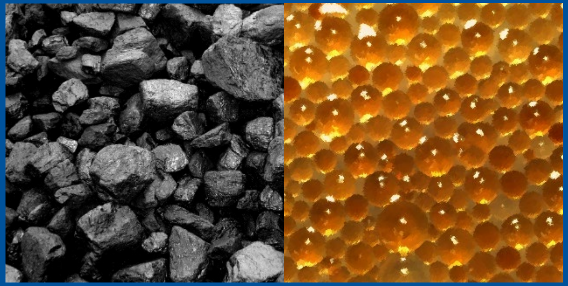


- PFAS are a contaminant of concern because
  - they do not break down
  - are a large family of chemicals, only a small number have been studied
  - widely detected throughout the environment
  - readily move through the environment





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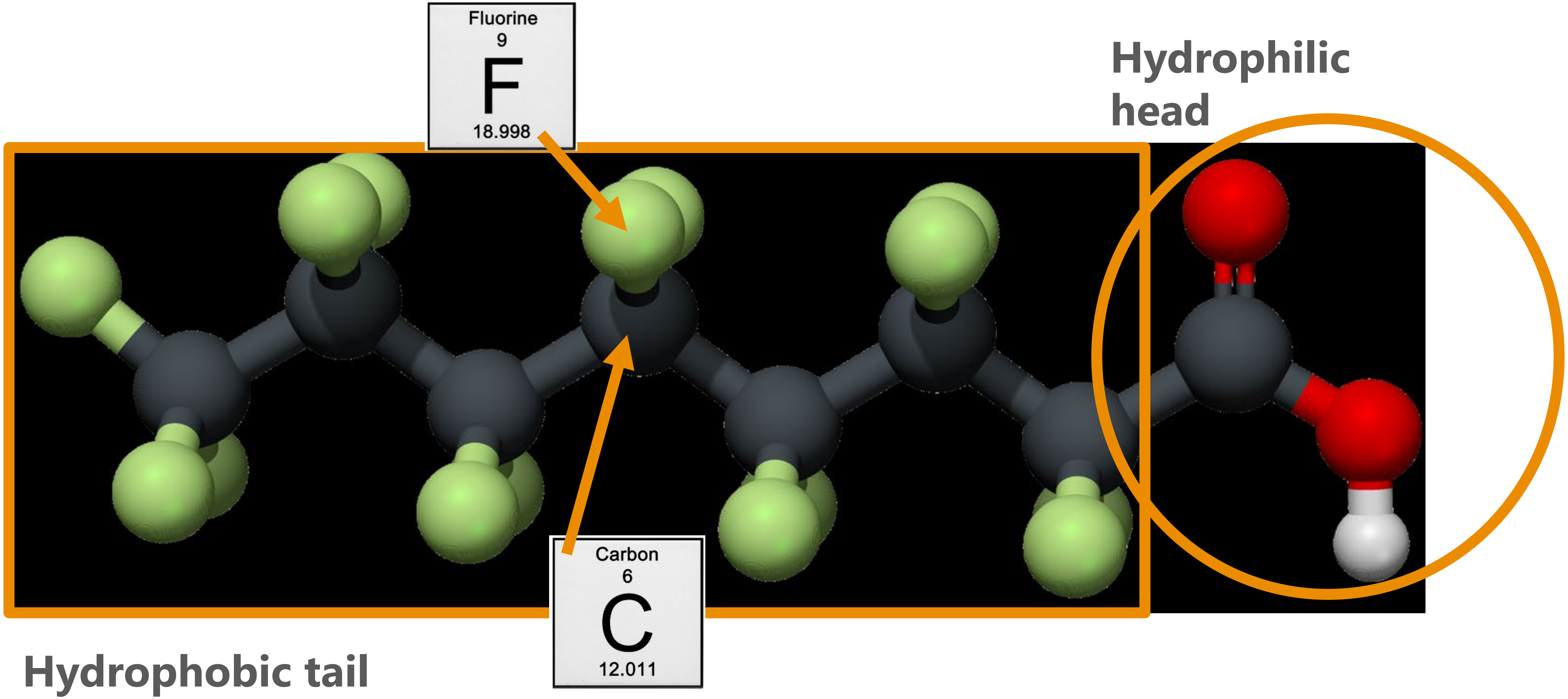
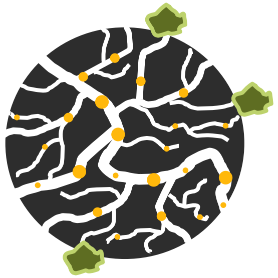
Surfactant properties influence water treatment technologies

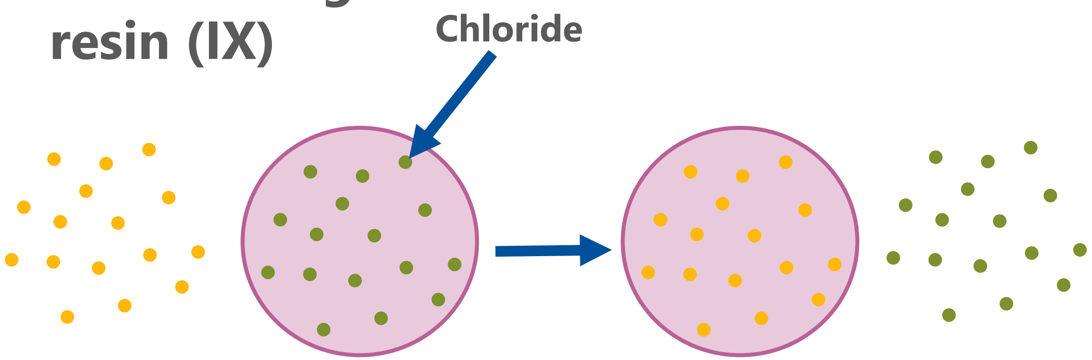


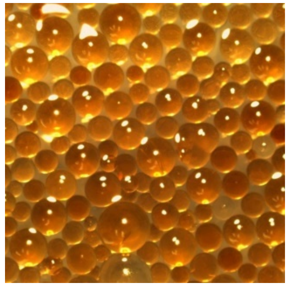
GAC and IX are two effect water treatment technologies

Granular activated carbon (GAC)

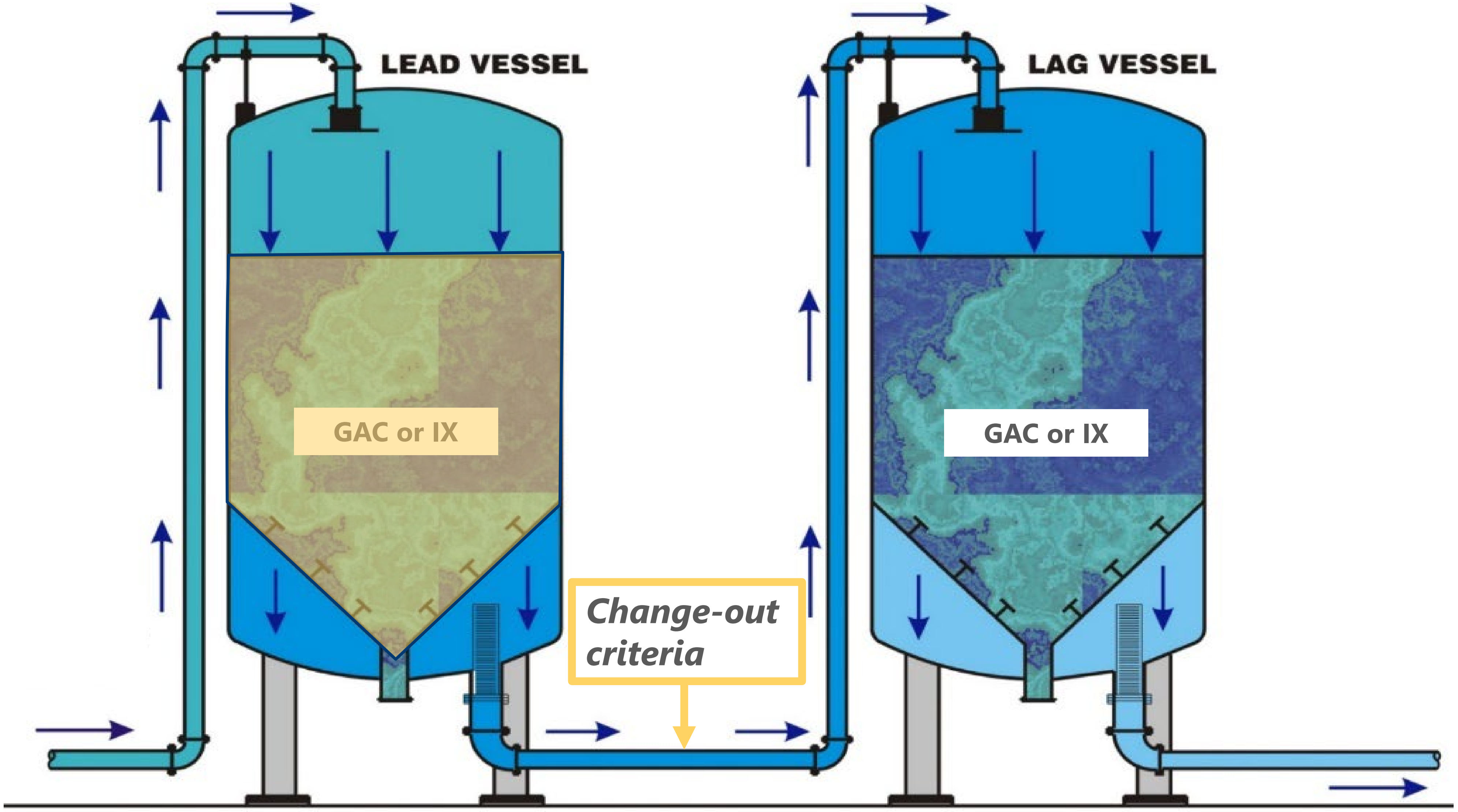


Ion exchange resin (IX)





Typical PFAS water treatment



GAC vs. Single-Pass IX

	GAC	Single-Pass IX
Demonstration for drinking water treatment	Widely-demonstrated	Not used as extensively
Pre-treatment considerations	Iron, manganese, TOC, TSS (>10 micron)	Iron, manganese, TOC, TSS (>5 micron), residual oxidants (chlorine)
Co-contaminant removal	Removal of other organic pollutants	Removal of other anionic compounds (ex. sulfates, nitrates)
Short-chain PFAS adsorption (PFBA, PFBS, etc.)	Poor removal	Minimal removal
Corrosion control considerations	Likely no effects	Impacts chloride/sulfate ratio

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GAC vs. Single-Pass IX

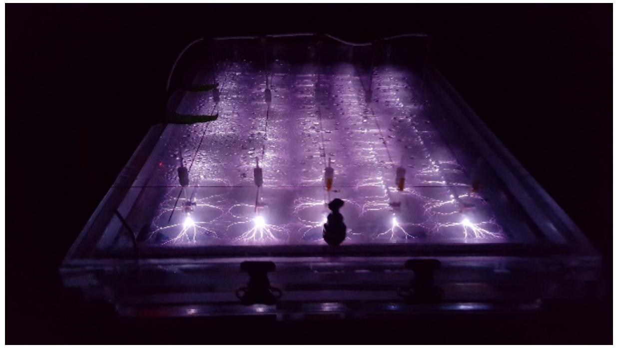
	GAC	Single-Pass IX
Reaction kinetics	Longer	Shorter
Empty-bed contact time (EBCT)	8-10 minutes	2-4 minutes
Vessel size	Larger/taller	Smaller/shorter
Footprint	Larger	Smaller
Media cost	\$1-2/lb	\$4-6/lb
Disposal	Reactivation or incineration	Incineration

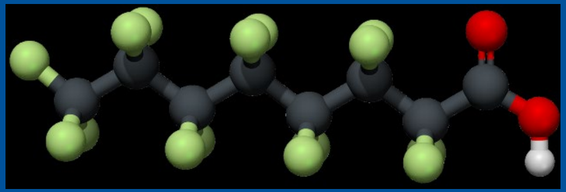
What about membranes?

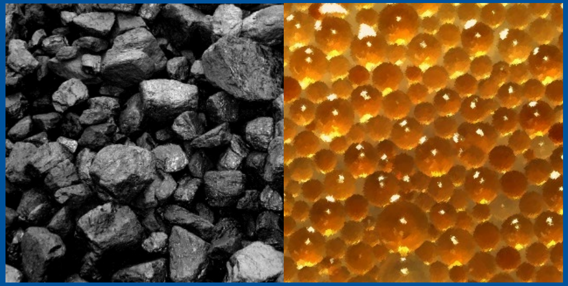
- More **advanced pretreatment** often required to mitigate fouling
- **Concentrate management** challenging
- Higher **capital and O&M costs**

Next generation of PFAS water treatment

- Media adsorption with a PFAS destruction element
  - Regenerable IX
  - Novel adsorption media
- Technologies that concentrate PFAS into a smaller stream for subsequent treatment or destruction
  - Foam fractionation
  - Membrane treatment, high-recovery/closed circuit
- Destruction technologies
  - Electrochemical oxidation
  - Plasma







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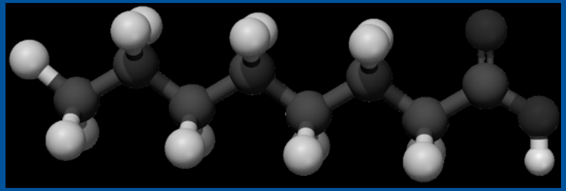
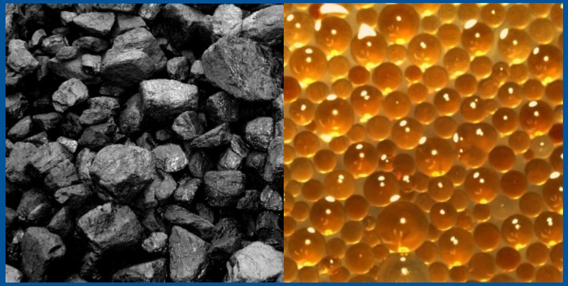
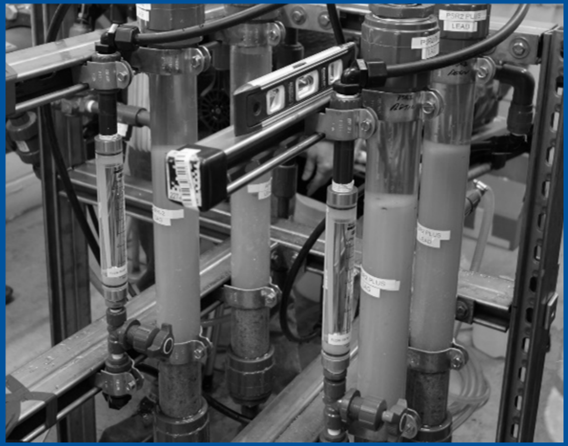
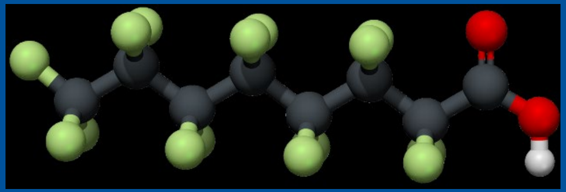
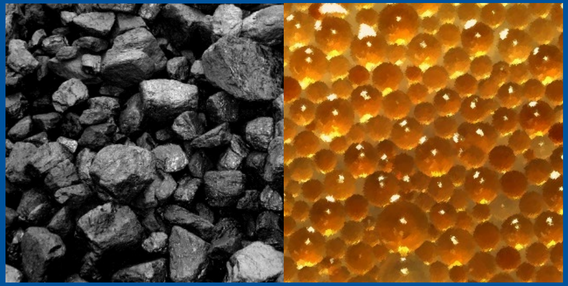






- What technologies are available for treating PFAS in drinking water?
  - Granular activated carbon
  - Ion exchange
  - Membrane separation





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Bemidji's drinking water wells have elevated PFAS concentrations

- **Groundwater** drinking water supply
- **Five supply wells** down gradient of the City's municipal airport
- No existing treatment other than **chemical addition**
- Current average daily water demand: **1.4 MGD** (~1,000 GPM)
- Current peak demand: **2.8 MGD** (~2,000 GPM)
- 2040 average daily water demand: 1.7 MGD
- 2040 peak demand: 3.2 MGD

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Minnesota has drinking water guidelines for five PFAS

Short name	Full Chemical Name	Current Health Risk Limit (HRL) µg/L	Current Health Based Guidance Value (HBV) µg/L
PFBA	Perfluorobutanoic acid	7.0	No value
PFOA	Perfluorooctanoic acid	0.035	No value
PFBS	Perfluorobutane sulfonate	7.0	2.0
PFOS	Perfluorooctane sulfonic acid	0.3	0.015
PFHxS	Perfluorohexane sulfonate	No limit	0.047

$$\boldsymbol{Health\ Risk\ Index\ (HRI)} = \frac{PFBA\ conc.}{7} + \frac{PFOA\ conc.}{0.035} + \frac{PFBS\ conc.}{2} + \frac{PFOS\ conc.}{0.015} + \frac{PFHxS\ conc.}{0.047}$$

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Bemidji's drinking water wells have elevated PFAS concentrations

HRI > 1.0

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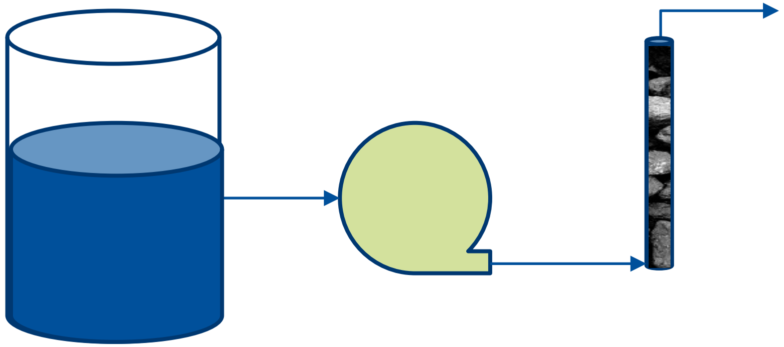
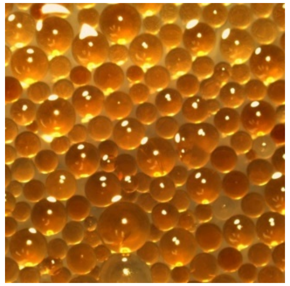
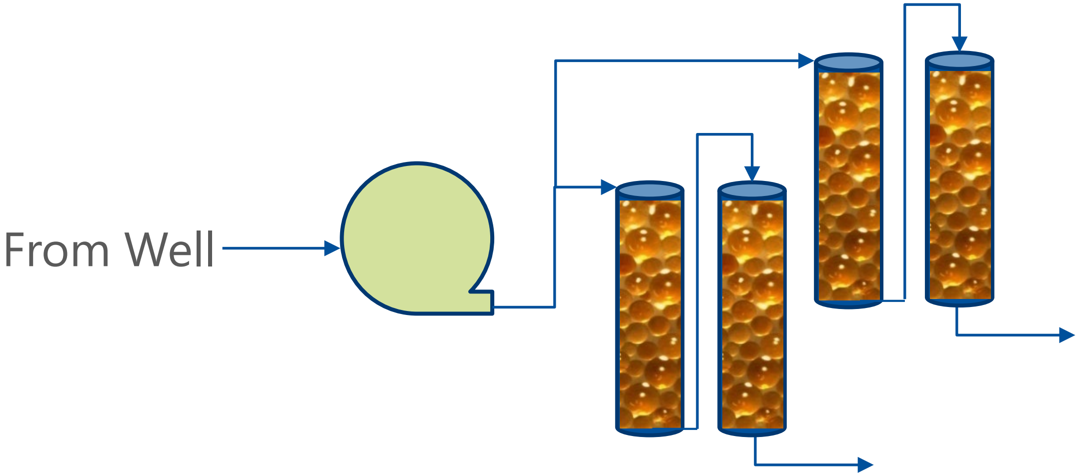
Accelerated column test and a pilot test evaluated PFAS treatment

Accelerated Column Test (ACT)
ASTM D6586



Pilot Test





City of Bemidji treatment technology testing methods

	GAC ACT	Single-Pass IX Pilot
Test location	Calgon Innovation Center (Pittsburgh, PA)	City of Bemidji - Well #4 well house
Media	Calgon Filtrasorb 400 GAC (F400)	DOW PSR2+ resin / Evoqua APR2 resin
Volume of water	50 gallons	57,000 / 62,000 gallons
Bed volumes	118,000	355,000 / 386,000
Treatment simulated	730 days	625 / 680 days
Test duration	2 months	4.5 months
Empty-bed contact time	8.8 minutes	2.5 minutes
Pretreatment	Particulate filtration (10 micron), glass wool	Birm filtration (iron/manganese), particulate filtration (5 micron)

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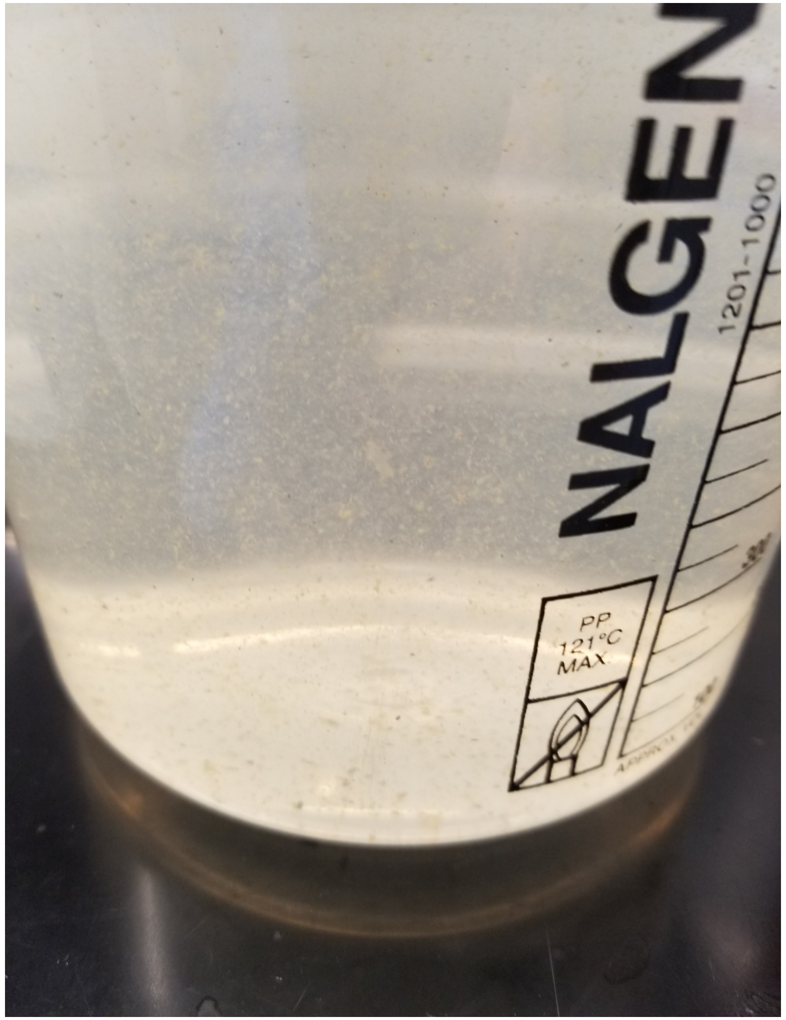
Well #4 water quality

	Units	Average
Alkalinity, total, as CaCO3	mg/l	227
Carbon, total organic	mg/l	1.0
Chloride	mg/l	1.3
Hardness, as CaCO3	ug/l	217
Nitrogen, nitrate + nitrite, as N	mg/l	< MDL
pH	SU	7.3
Solids, total dissolved	mg/l	223
Solids, total suspended	mg/l	< MDL
Specific conductance @ 25 °C	umhos/cm	435
Sulfate, as SO4	mg/l	3.1
Calcium	mg/l	60.3
Iron	mg/l	1.0
Magnesium	mg/l	16.4
Manganese	mg/l	0.6



Well #4 water quality

	Units	Average
n-Ethyl perfluorooctanesulfonamidoacetic acid (N-EtFOSAA)	ng/l	< MDL
n-Methyl perfluorooctanesulfonamidoacetic acid (MeFOSAA)	ng/l	< MDL
Perfluorobutane sulfonate (PFBS)	ng/l	**30**
Perfluorobutanoic acid (PFBA)	ng/l	**6**
Perfluorodecanoic acid (PFDA)	ng/l	< MDL
Perfluorododecanoic acid (PFDoA / PFDoDA)	ng/l	< MDL
Perfluoroheptanoic acid (PFHpA)	ng/l	**8**
Perfluorohexane sulfonate (PFHxS)	ng/l	**520**
Perfluorohexanoic acid (PFHxA)	ng/l	**37**
Perfluorononanoic acid (PFNA)	ng/l	< MDL
Perfluorooctanesulfonamide (PFOSA / FOSA)	ng/l	< MDL
Perfluorooctanesulfonate (PFOS)	ng/l	**170**
Perfluorooctanoic acid (PFOA)	ng/l	**35**
Perfluoropentanoic acid (PFPeA)	ng/l	**9**
Perfluorotetradecanoic acid (PFTA / PFTeDA / PFTeA)	ng/l	< MDL
Perfluorotridecanoic acid (PFTrDA / PFTriA)	ng/l	< MDL
Perfluoroundecanoic acid (PFUnA / PFUnDA)	ng/l	< MDL

HBV = 47 ng/L

HBV = 15 ng/L

HRL = 35 ng/L

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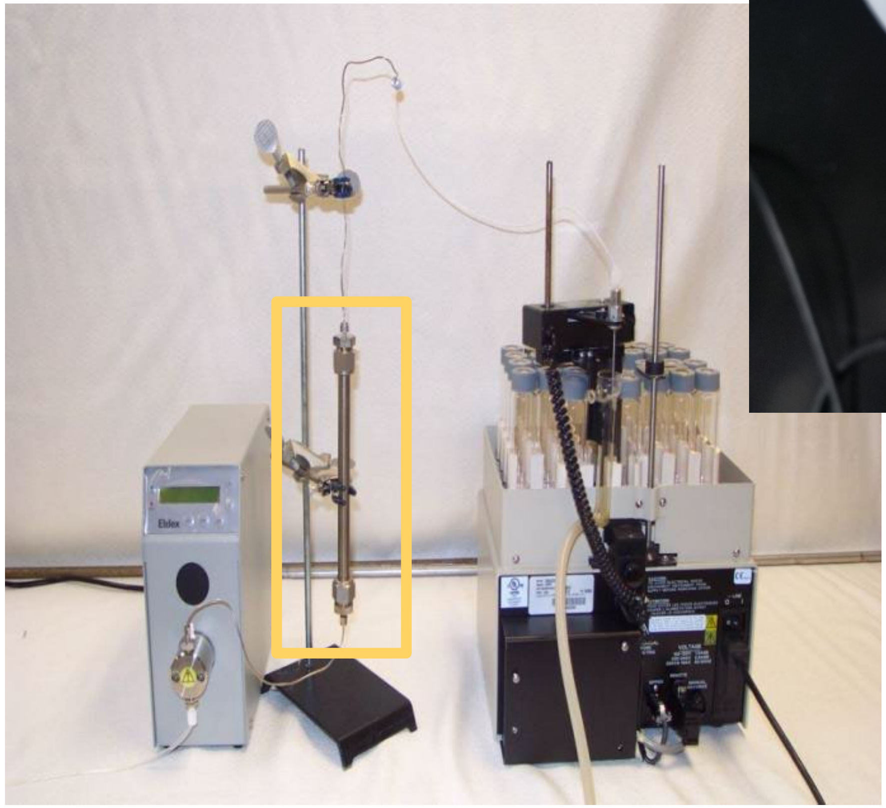
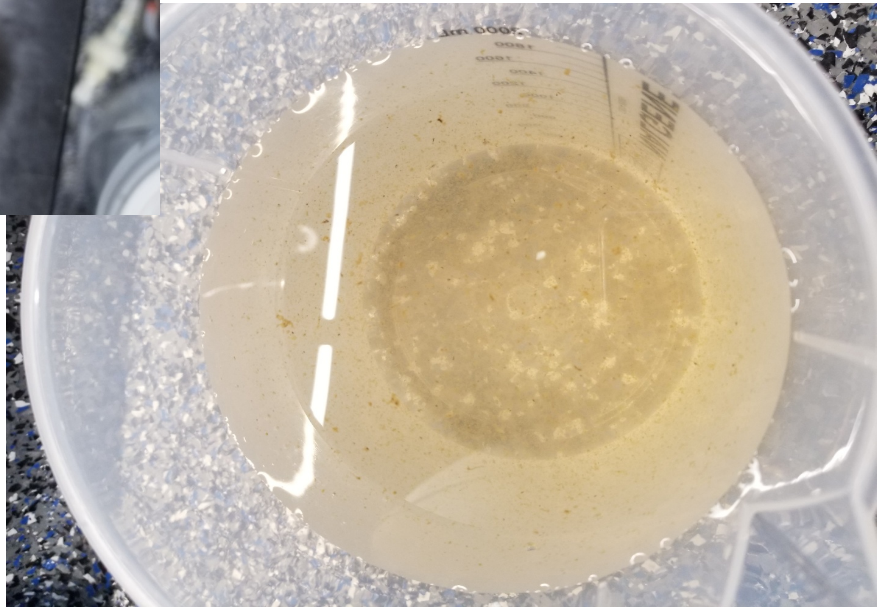
Treatment technology testing objectives

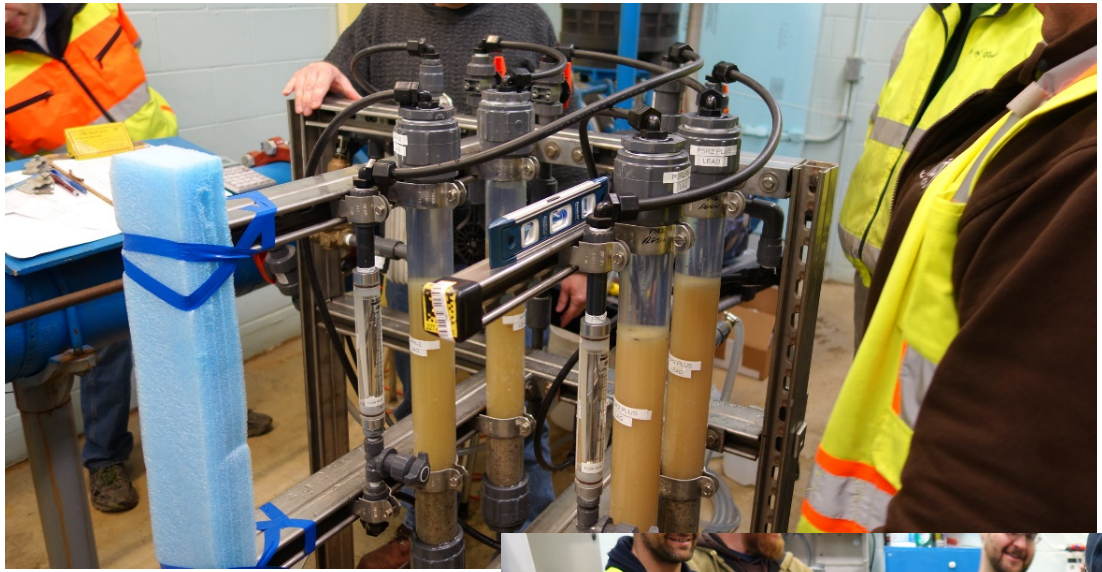
- Demonstrate ability to remove PFAS below MDH HBVs and HRLs
- Assess pretreatment needs
- Establish PFAS breakthrough order
- Evaluate change-out criteria for full scale treatment

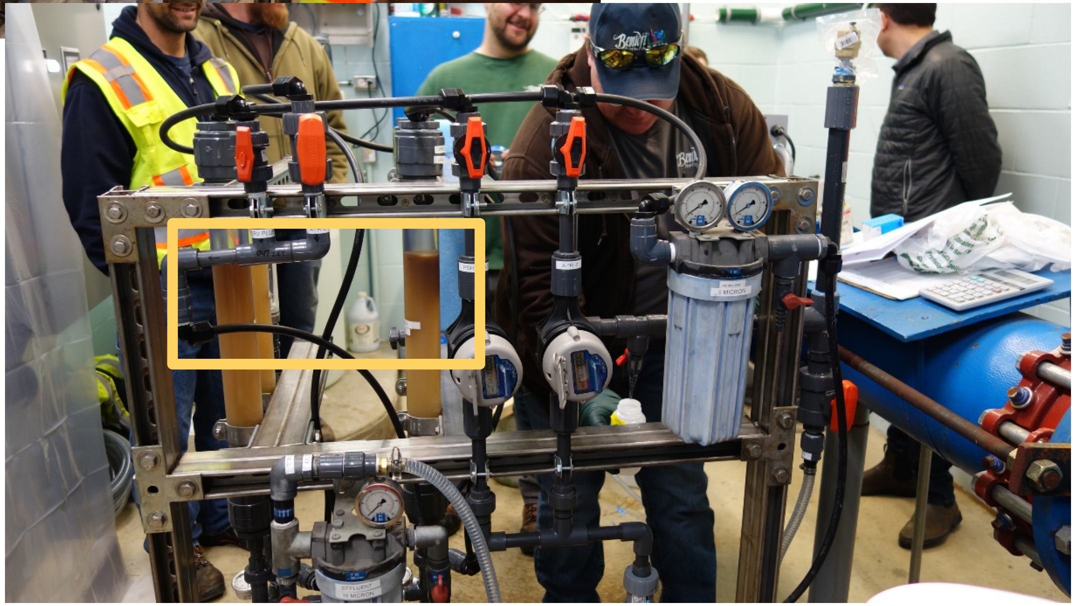
GAC accelerated column testing (ACT)





Single-pass IX pilot testing





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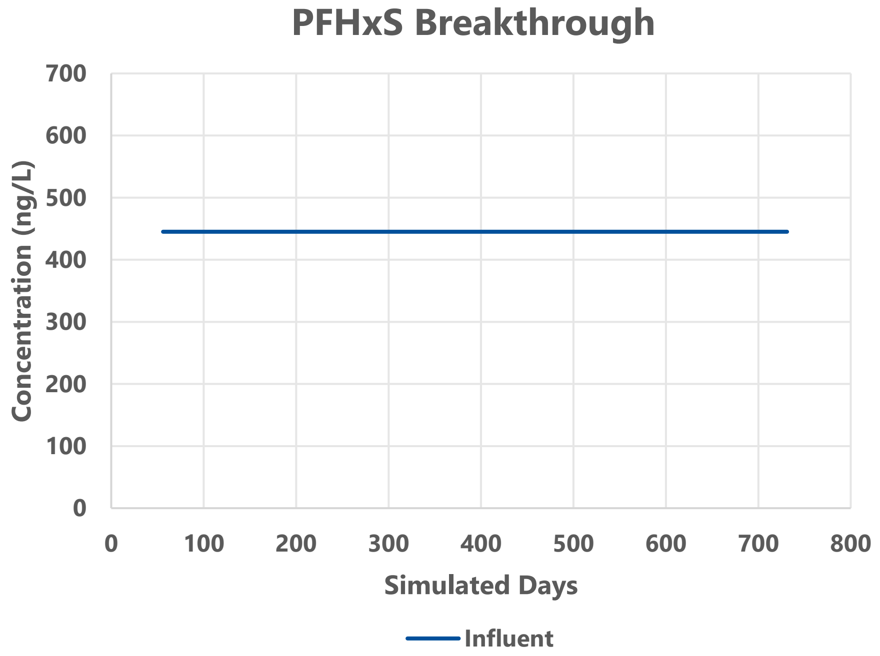
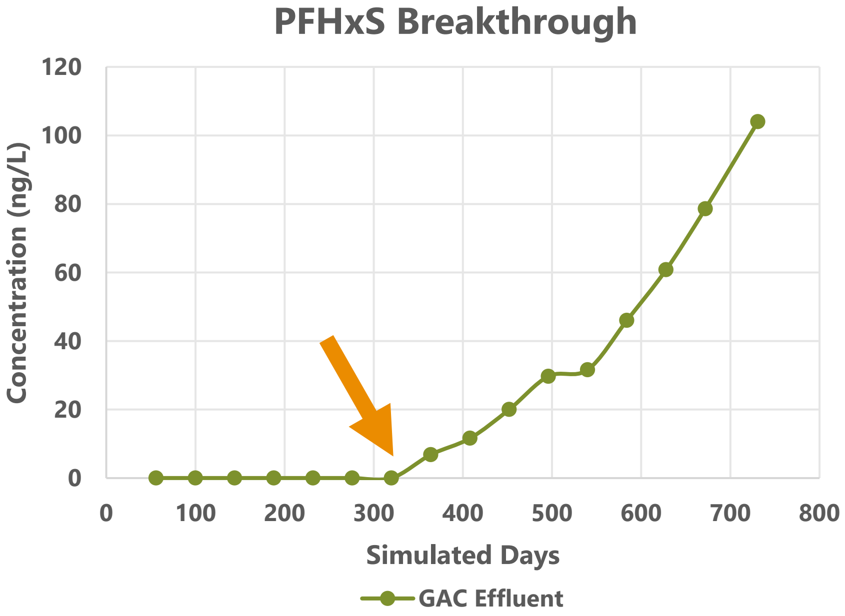
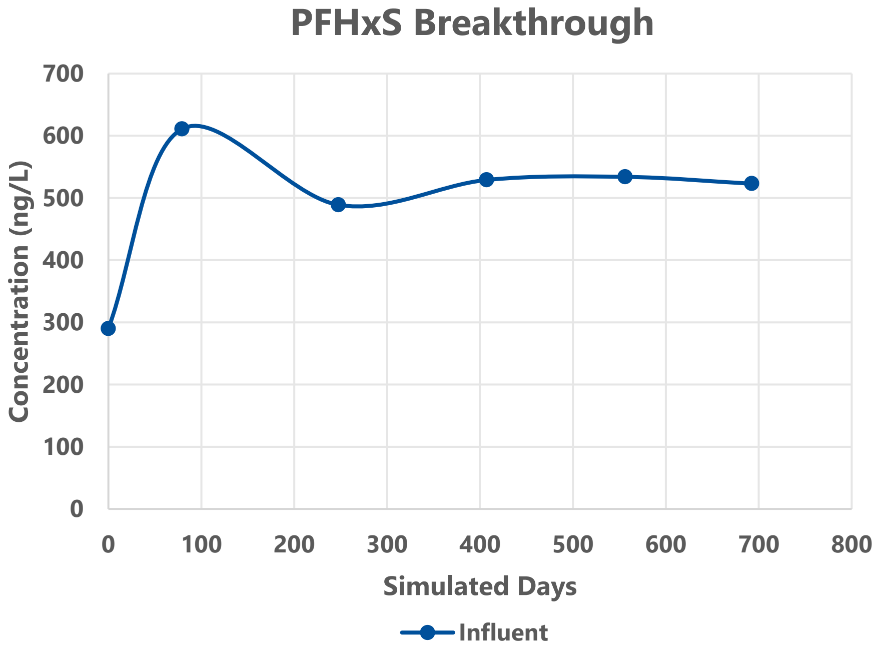
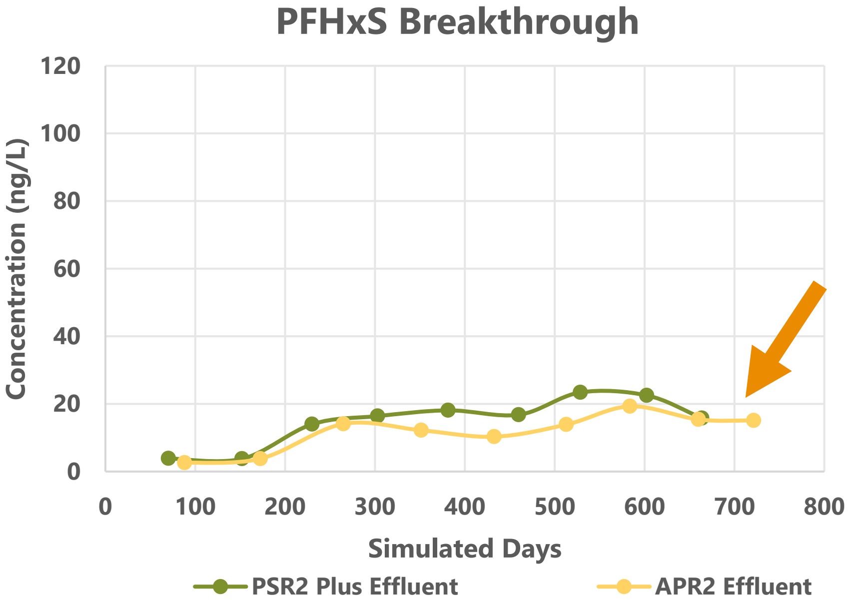




IX Pilot





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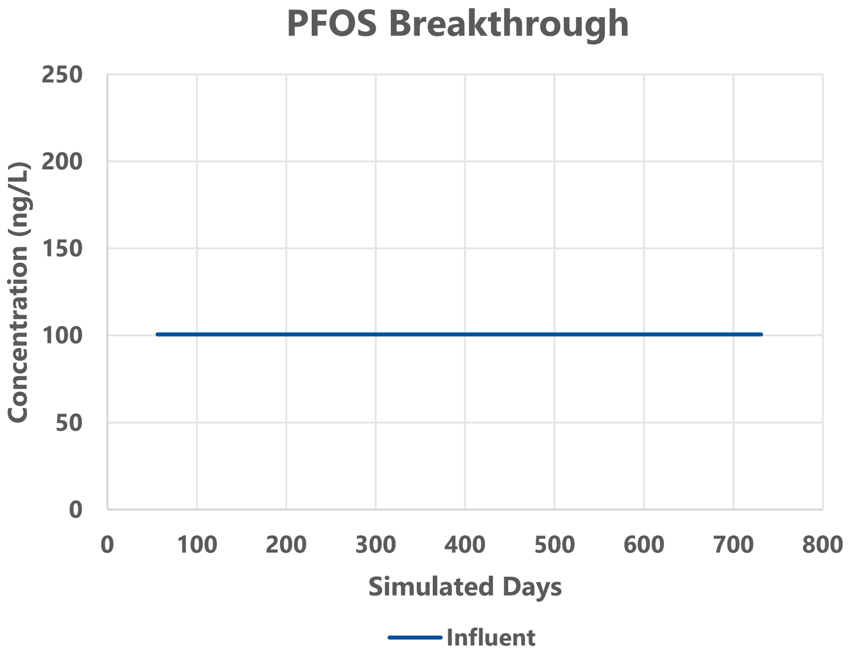

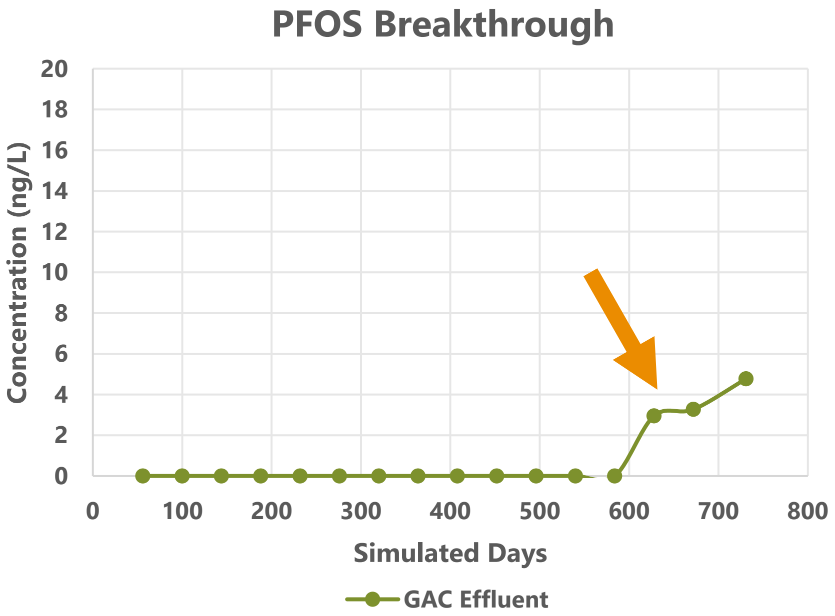

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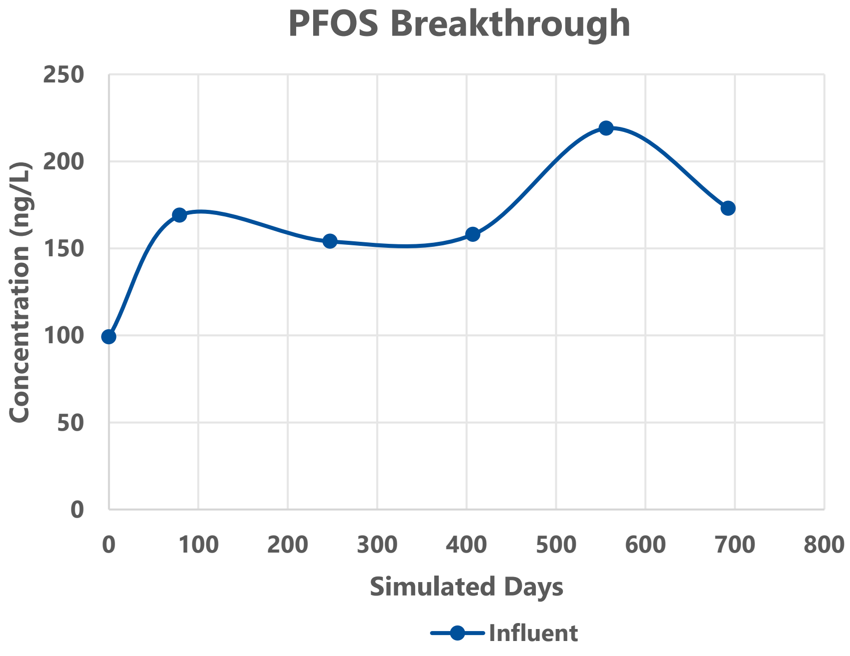

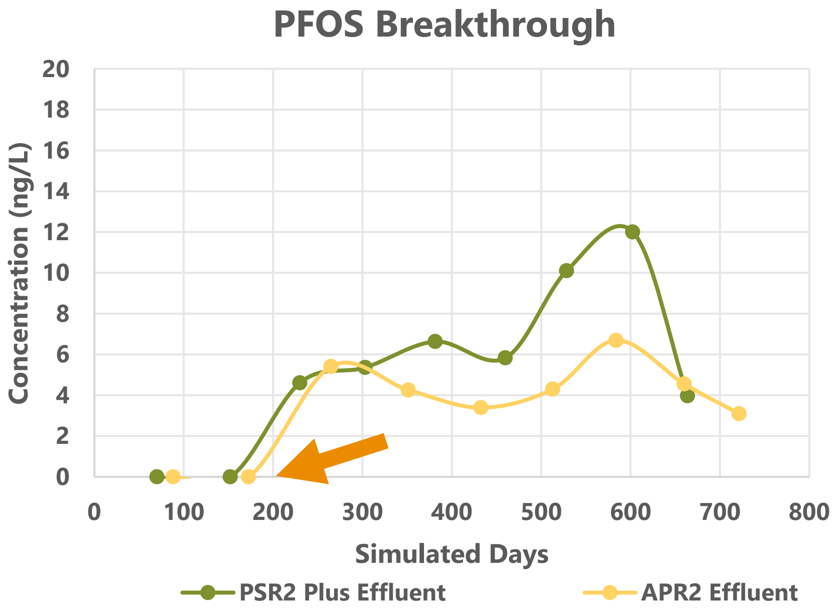

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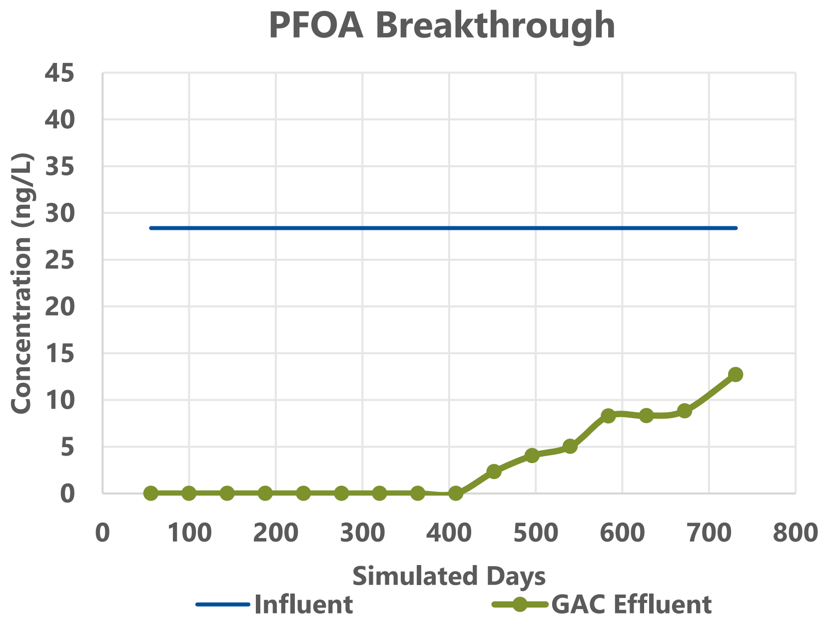

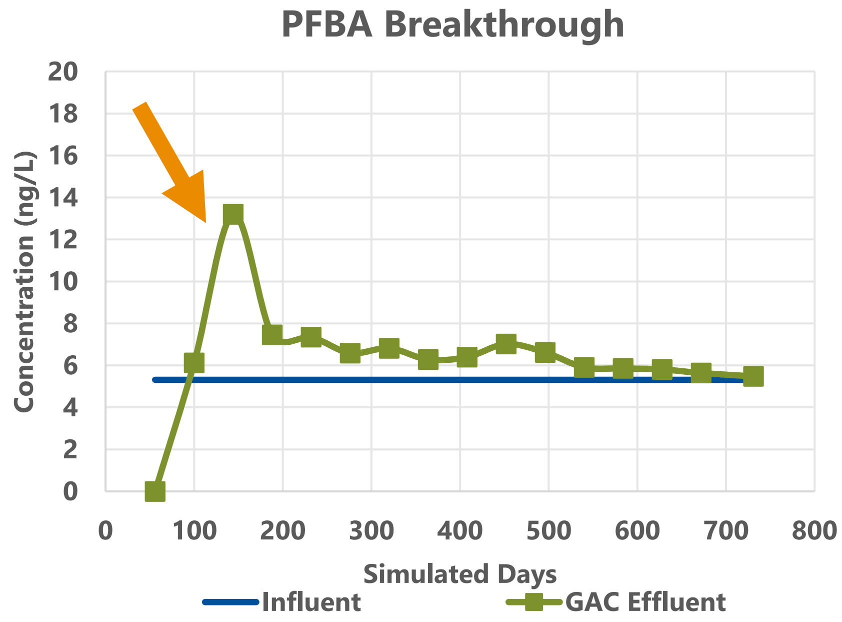

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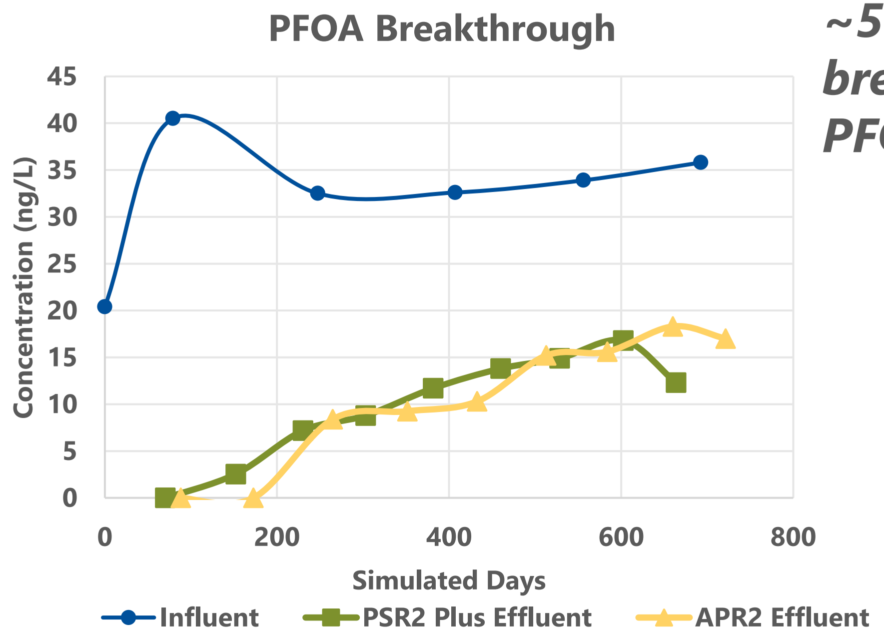
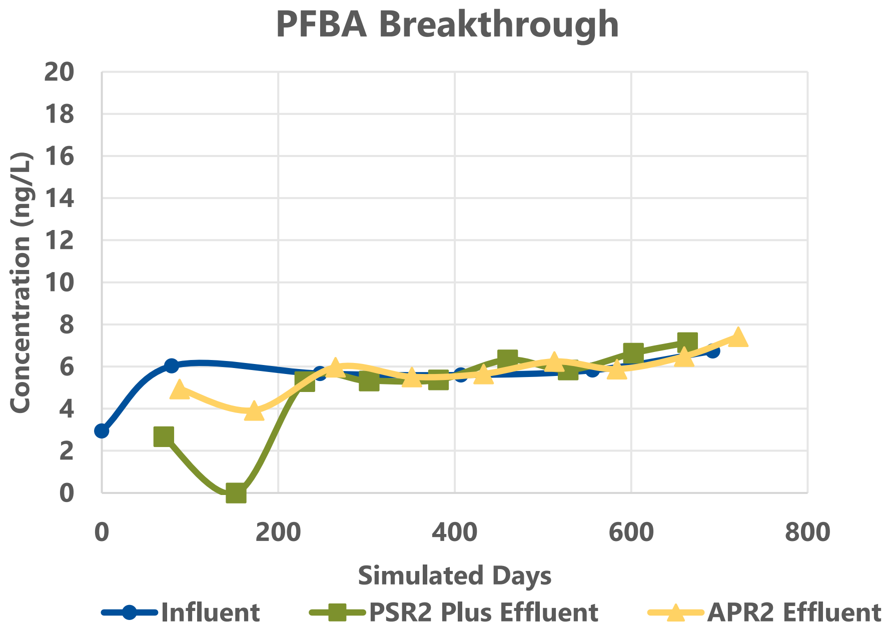


~50% breakthrough PFOA, both tests



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City of Bemidji treatment technology testing summary

	GAC	Single-Pass IX
Meets PFAS treatment objectives	Yes	Yes
Time until initial breakthrough of PFAS (exceeding MDH HBV or HRL)	364 days (PFHxS)	70-88 days (PFHxS)
Initial lead vessel change-out (50% breakthrough of PFHxS)	950 days	1,002 days
Subsequent lead vessel change-out	700 days	857 days

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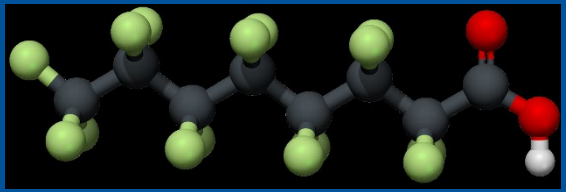

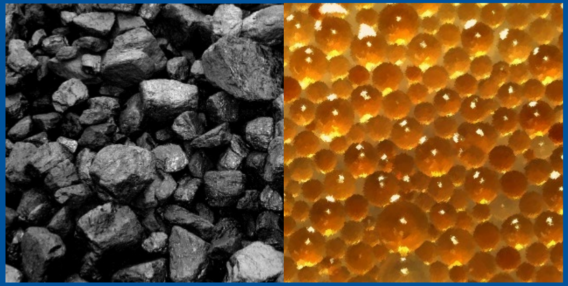

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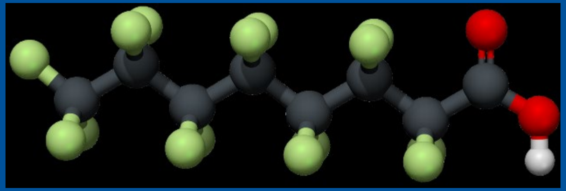
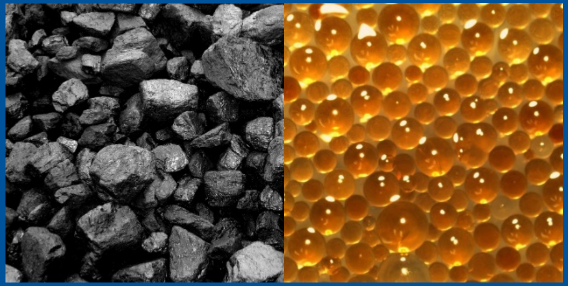
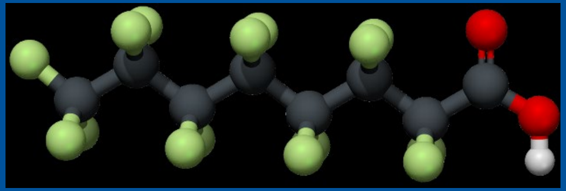




- How can PFAS treatment technologies be tested for site specific applications?
  - Accelerated column tests and pilot tests



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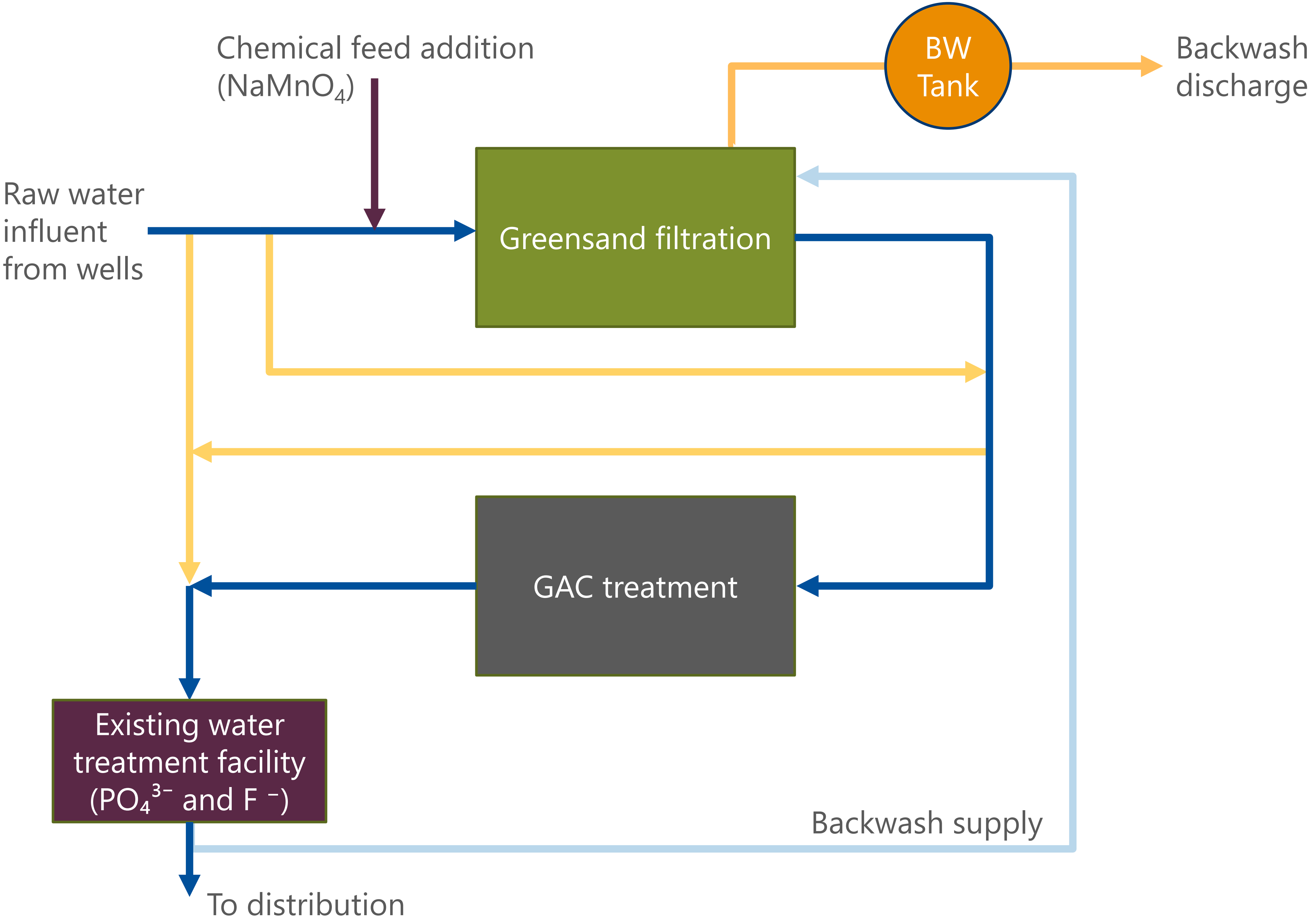
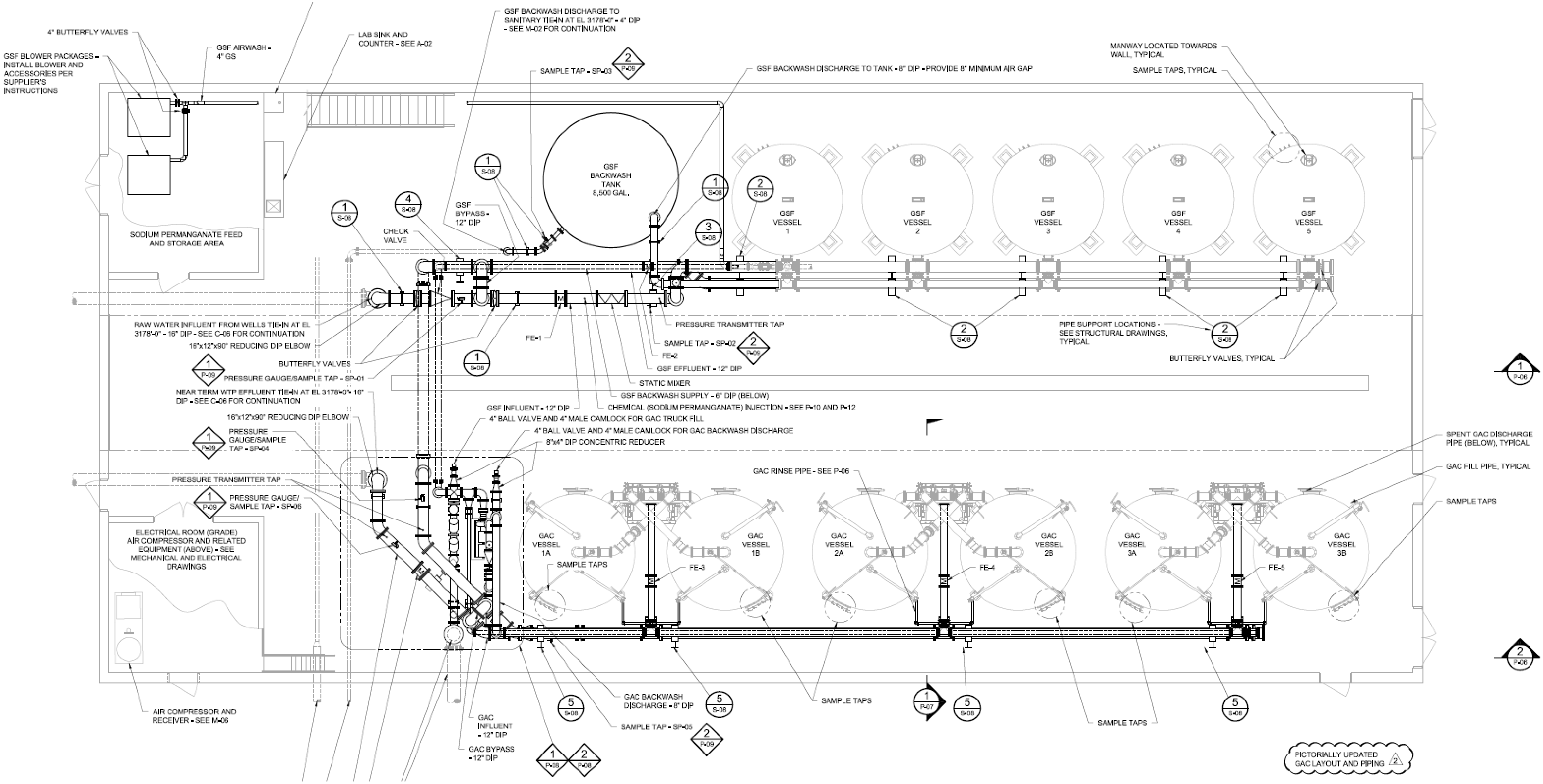
Pretreatment considerations – iron and manganese removal

	Fe (mg/L)		Mn (mg/L)	
	Average	Max	Average	Max
Well 3	0.01	0.02	0.03	0.03
Well 4	1.8	1.8	0.6	0.6
Well 5	0.4	0.4	0.2	0.2
Well 6	0.6	0.6	0.2	0.2
Well 7	0.2	0.2	0.1	0.1
Secondary MCL	0.3		0.05	



Chemical feed addition
($NaMnO_4$)
BW
Tank
Backwash
discharge
Raw water
influent
from wells
Greensand filtration
GAC treatment
Existing water
treatment facility
(PO_4^{3-} and F^-)
Backwash supply
To distribution



4" BUTTERFLY VALVES
GSF BLOWER PACKAGES - INSTALL BLOWER AND ACCESSORIES PER SUPPLIER'S INSTRUCTIONS
GSF AIRWASH - 4" GS
LAB SINK AND COUNTER - SEE A-02
GSF BACKWASH DISCHARGE TO SANITARY TIE-IN AT EL 3178'-0" - 4" DIP - SEE M-02 FOR CONTINUATION
SAMPLE TAP - SP-03
GSF BACKWASH DISCHARGE TO TANK - 8" DIP - PROVIDE 8" MINIMUM AIR GAP
MANWAY LOCATED TOWARDS WALL, TYPICAL
SAMPLE TAPS, TYPICAL
GSF BACKWASH TANK 8,500 GAL.
GSF BYPASS - 12" DIP
CHECK VALVE
SODIUM PERMANGANATE FEED AND STORAGE AREA
GSF VESSEL 1
GSF VESSEL 2
GSF VESSEL 3
GSF VESSEL 4
GSF VESSEL 5
PRESSURE TRANSMITTER TAP
RAW WATER INFLUENT FROM WELLS TIE-IN AT EL 3178'-0" - 16" DIP - SEE C-06 FOR CONTINUATION
16"x12"x90° REDUCING DIP ELBOW
FE-1
SAMPLE TAP - SP-02
FE-2
GSF EFFLUENT - 12" DIP
PIPE SUPPORT LOCATIONS - SEE STRUCTURAL DRAWINGS, TYPICAL
BUTTERFLY VALVES, TYPICAL
BUTTERFLY VALVES
PRESSURE GAUGE/SAMPLE TAP - SP-01
STATIC MIXER
NEAR TERM WTP EFFLUENT TIE-IN AT EL 3178'-0"- 16" DIP - SEE C-06 FOR CONTINUATION
GSF BACKWASH SUPPLY - 6" DIP (BELOW)
GSF INFLUENT - 12" DIP
CHEMICAL (SODIUM PERMANGANATE) INJECTION - SEE P-10 AND P-12
16"x12"x90° REDUCING DIP ELBOW
4" BALL VALVE AND 4" MALE CAMLOCK FOR GAC TRUCK FILL
PRESSURE GAUGE/SAMPLE TAP - SP-04
4" BALL VALVE AND 4" MALE CAMLOCK FOR GAC BACKWASH DISCHARGE
8"x4" DIP CONCENTRIC REDUCER
SPENT GAC DISCHARGE PIPE (BELOW), TYPICAL
GAC RINSE PIPE - SEE P-06
GAC FILL PIPE, TYPICAL
PRESSURE TRANSMITTER TAP
PRESSURE GAUGE/ SAMPLE TAP - SP-06
SAMPLE TAPS
ELECTRICAL ROOM (GRADE) AIR COMPRESSOR AND RELATED EQUIPMENT (ABOVE) - SEE MECHANICAL AND ELECTRICAL DRAWINGS
GAC VESSEL 1A
GAC VESSEL 1B
GAC VESSEL 2A
GAC VESSEL 2B
GAC VESSEL 3A
GAC VESSEL 3B
SAMPLE TAPS
FE-3
FE-4
FE-5
GAC BACKWASH DISCHARGE - 8" DIP
SAMPLE TAPS
SAMPLE TAPS
AIR COMPRESSOR AND RECEIVER - SEE M-06
GAC INFLUENT - 12" DIP
GAC BYPASS - 12" DIP
SAMPLE TAP - SP-05
PICTORIALLY UPDATED GAC LAYOUT AND PIPING

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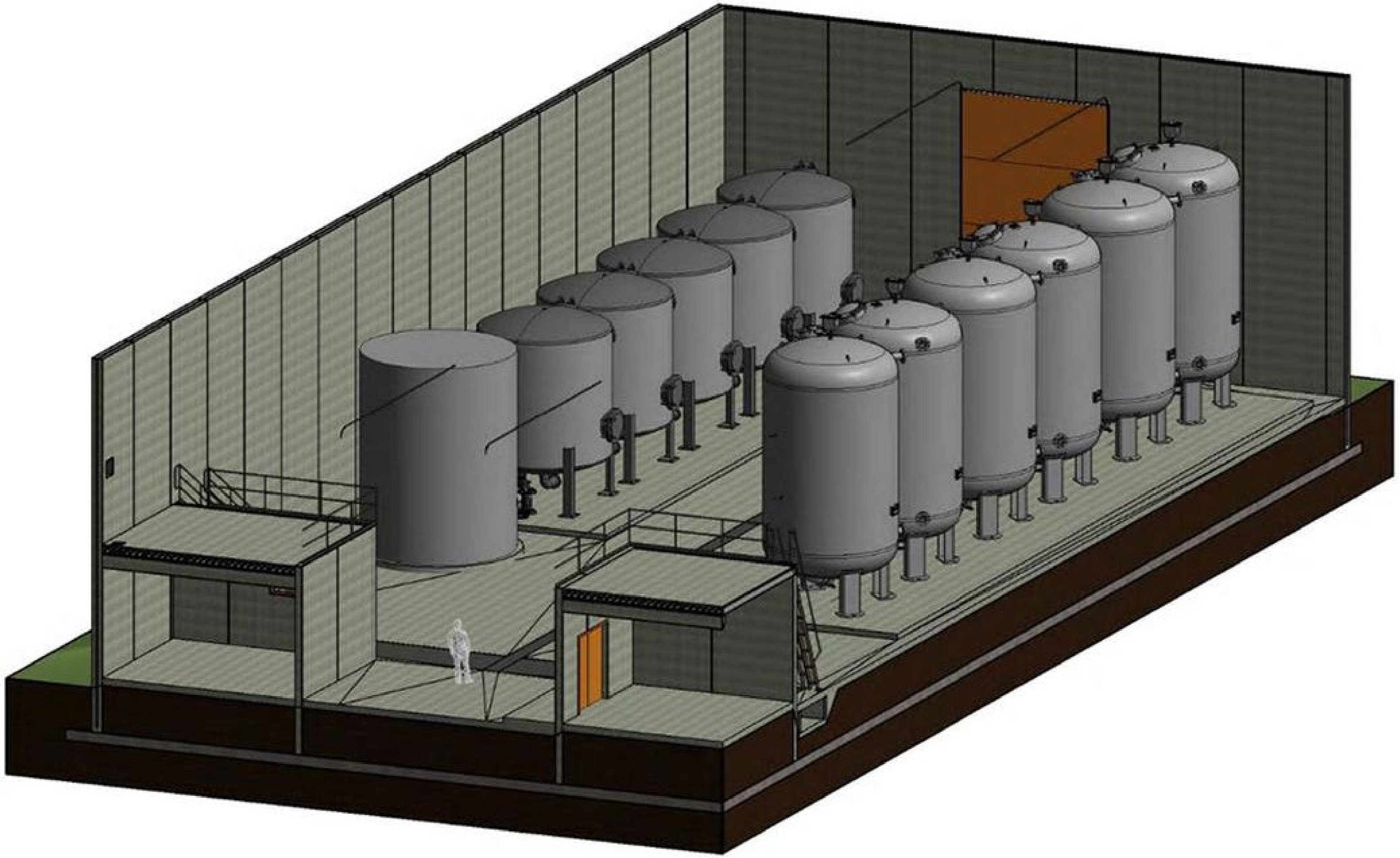
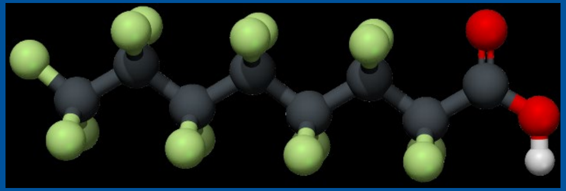
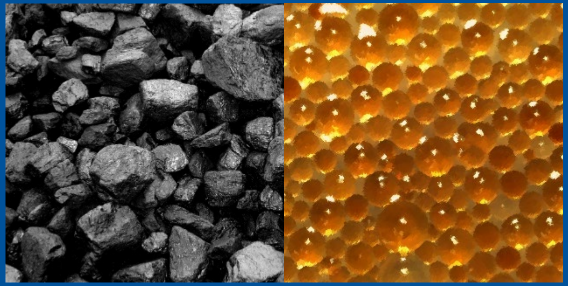
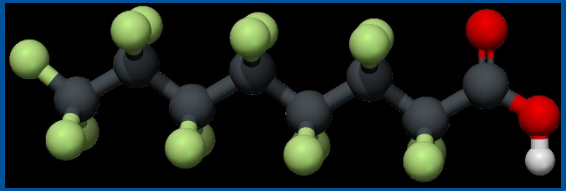
Water treatment plant includes greensand filtration + GAC

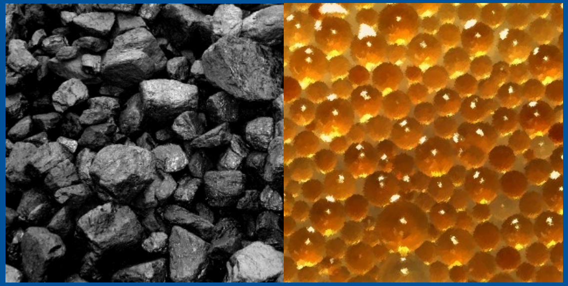




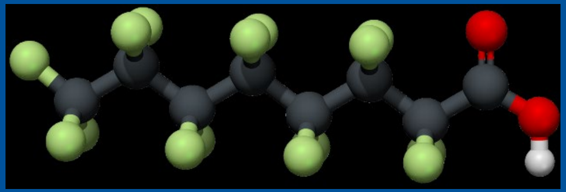


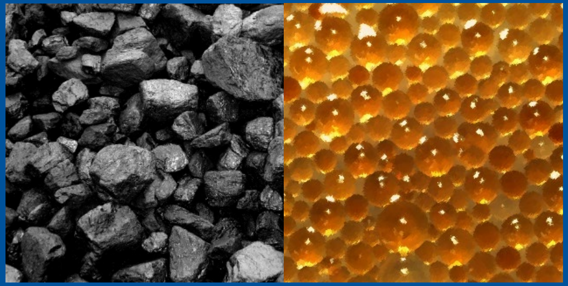
- Why are PFAS a contaminant of concern?
- What technologies are available for treating PFAS in drinking water?
- How can PFAS treatment technologies be tested for site specific applications?
- How did testing inform full scale design and operations?
- How does the near-term design accommodate future build-out?





- How did testing inform full scale design?
  - Informed pre-design water quality sampling
  - Provided indication that iron and manganese pretreatment was needed
  - Informed GAC treatment empty-bed contact time (carbon volume, vessel size)
  - Informed range of operational flow rates
  - Provides preliminary indication of GAC change-out frequency





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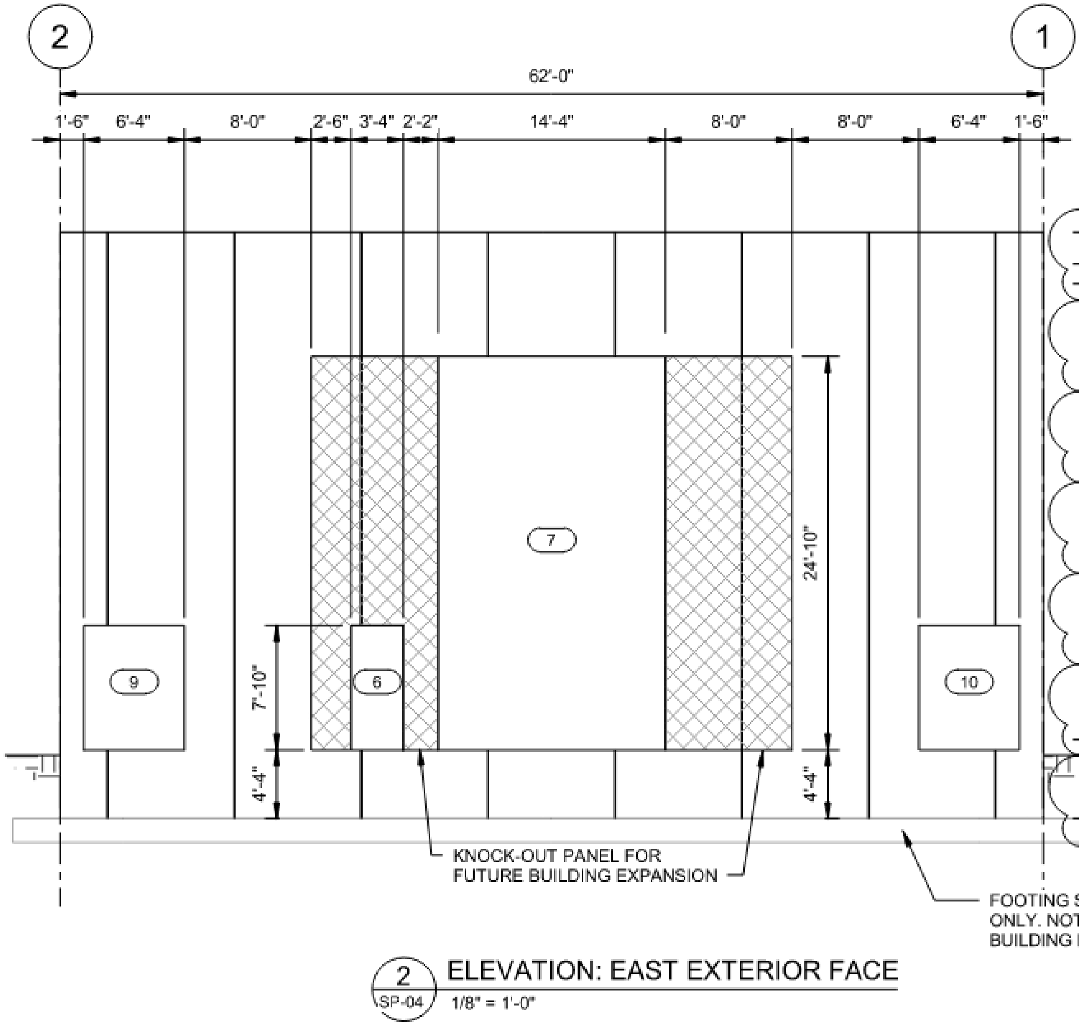
Knock-out panels were added for connection to future vessels



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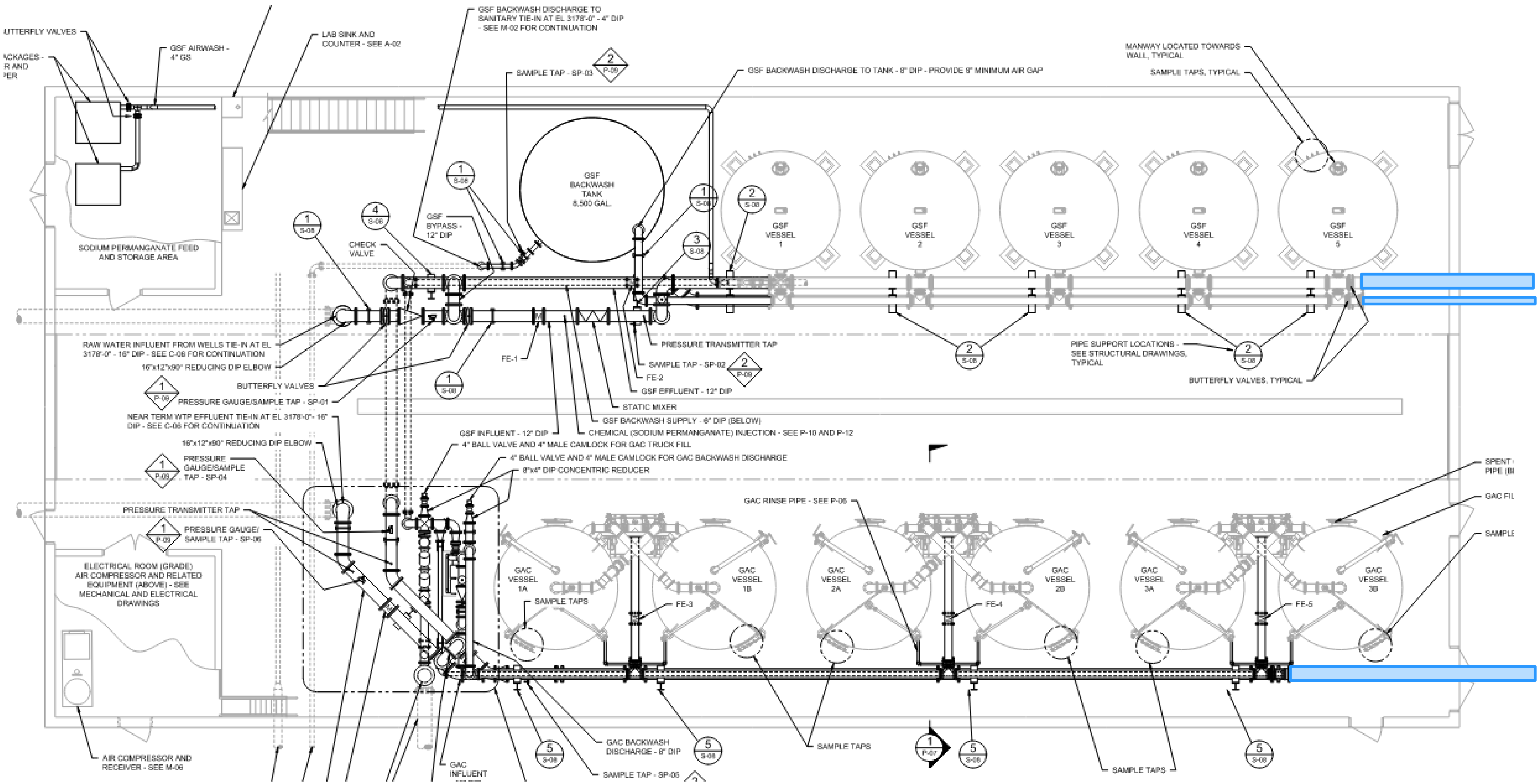
Piping will connect through knock-out and temporary doors



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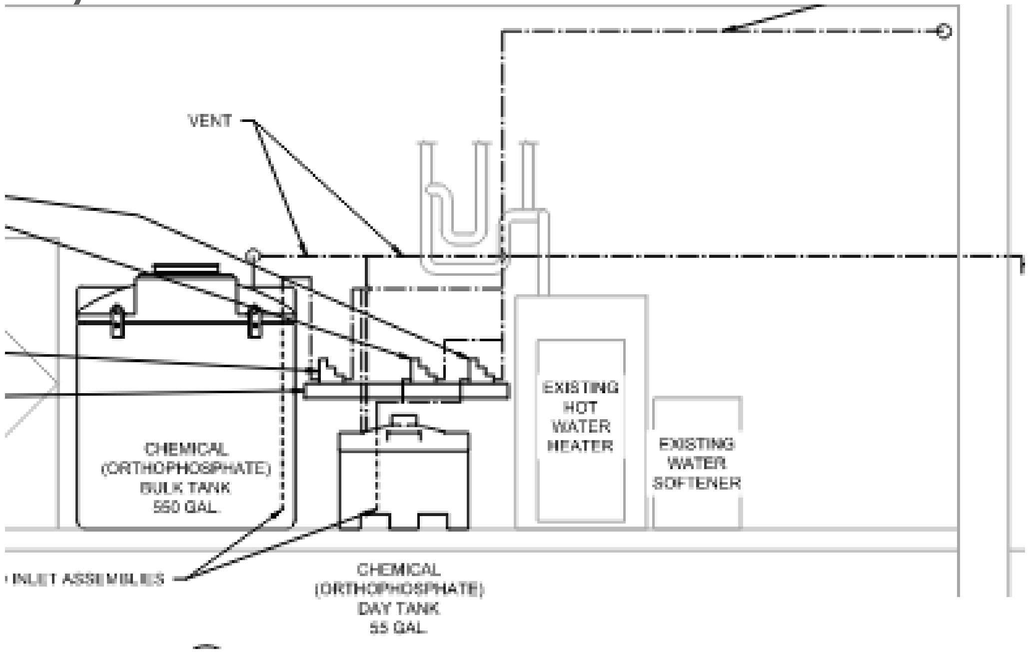
Chemical tanks sized for expansion

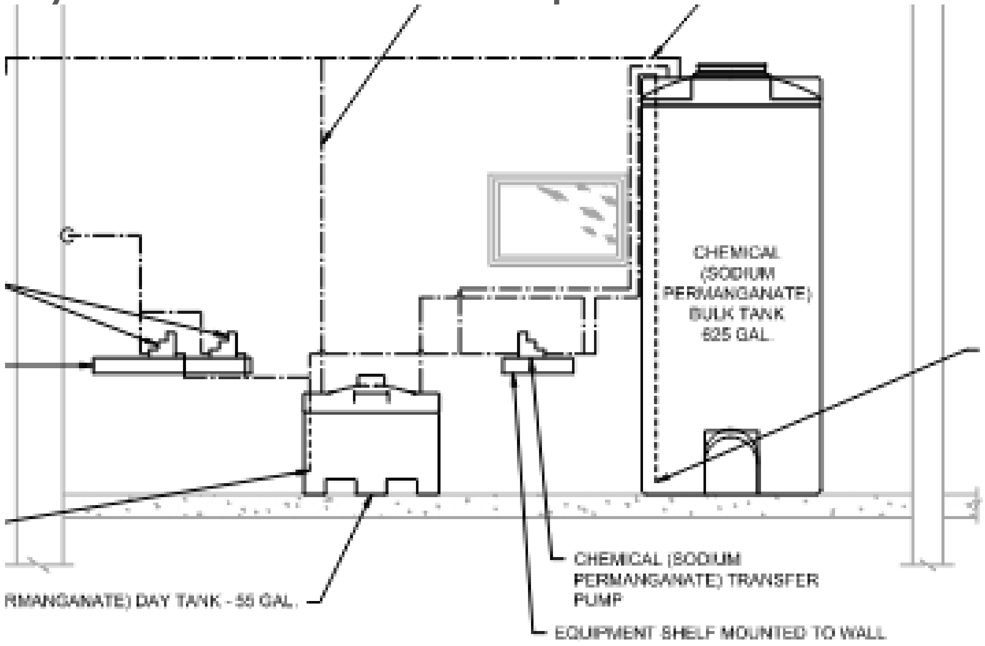
Orthophosphate

- System sized for near-term flow



Sodium Permanganate

- System sized for expansion flow



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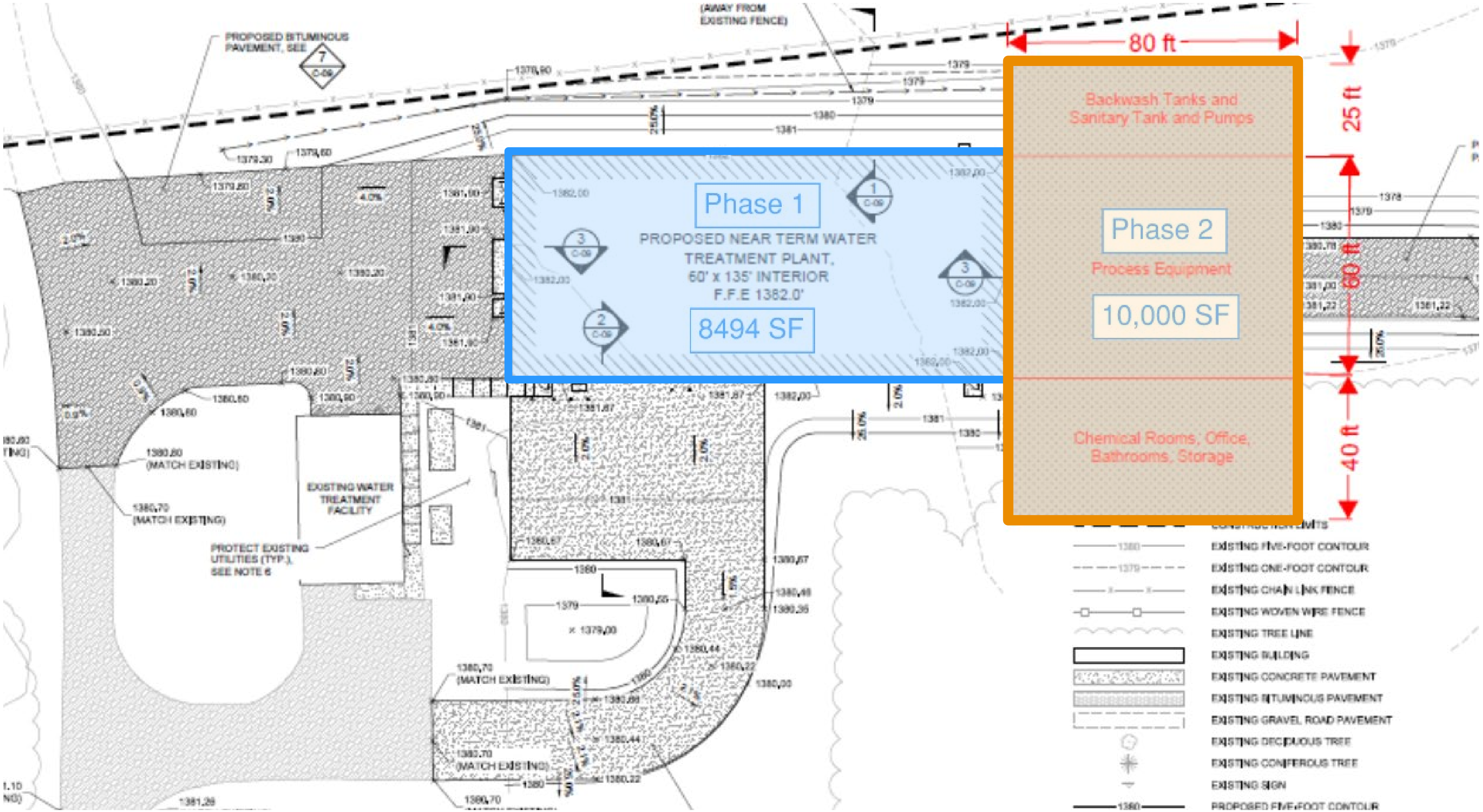
Near-term system designed with a temporary backwash tank

Expansion

- Backwash system will include a settling and recycling system

Temporary backwash tank



80 ft
25 ft
60 ft
40 ft
Backwash Tanks and Sanitary Tank and Pumps
Phase 2
Process Equipment
10,000 SF
Chemical Rooms, Office, Bathrooms, Storage
Phase 1
PROPOSED NEAR TERM WATER TREATMENT PLANT, 60' x 135' INTERIOR F.F.E 1382.0'
8494 SF
PROPOSED BITUMINOUS PAVEMENT, SEE
(AWAY FROM EXISTING FENCE)
EXISTING WATER TREATMENT FACILITY
PROTECT EXISTING UTILITIES (TYP.), SEE NOTE 6
1380.80 (MATCH EXISTING)
1380.70 (MATCH EXISTING)
EXISTING FIVE-FOOT CONTOUR
EXISTING ONE-FOOT CONTOUR
EXISTING CHAIN LINK FENCE
EXISTING WOVEN WIRE FENCE
EXISTING TREE LINE
EXISTING BUILDING
EXISTING CONCRETE PAVEMENT
EXISTING BITUMINOUS PAVEMENT
EXISTING GRAVEL ROAD PAVEMENT
EXISTING DECIDUOUS TREE
EXISTING CONIFEROUS TREE
EXISTING SIGN
PROPOSED FIVE-FOOT CONTOUR

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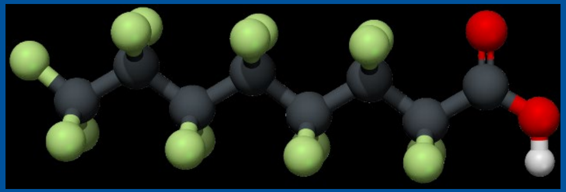

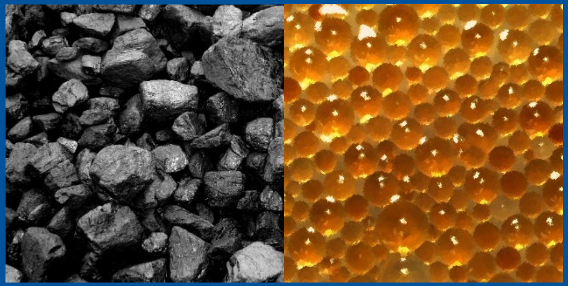

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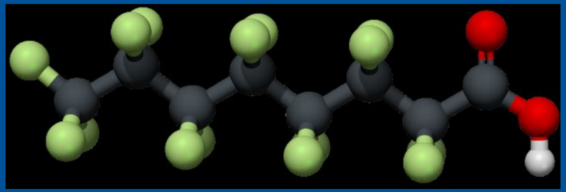
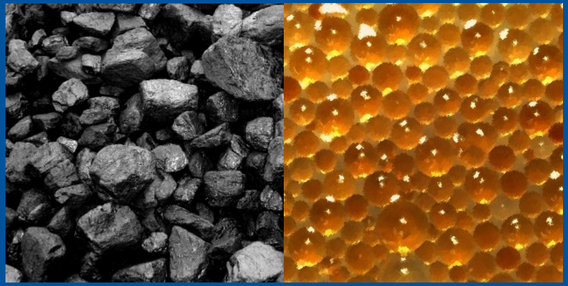
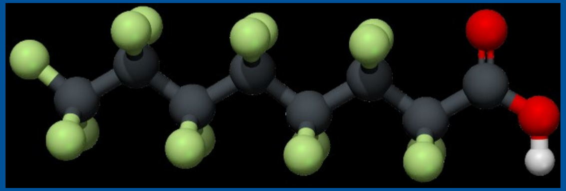
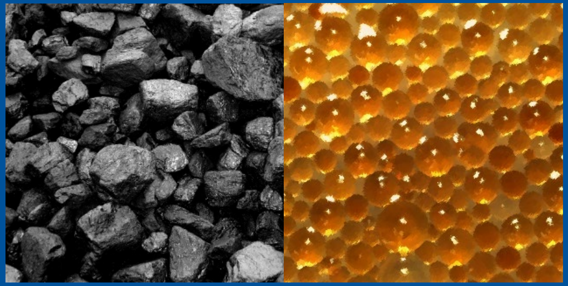




- How does the near-term design accommodate future build-out?
  - Near-term building was configured for expansion to the east with planned knock-out panels and piping routes with space for:
    - the permanent/underground backwashing
    - relocation of chemical processes





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City of Bemidji, Minnesota Near Term Water Treatment Plant

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Acknowledgements

- **City of Bemidji**
  - Craig Gray, Todd Anderson, Sam Anderson, Al Felix, Nate Matthews
- **Minnesota Department of Health**
  - Todd Johnson, Eric Weller, Brian Noma, David Weum, Ginny Yingling, Jane de Lambert
- **Barr Engineering**
  - Brian LeMon, Julie Macejkovic, Katie Wolohan, Becca Vermace, Jeff Ubl, John Greer, Terri Olson, Erin Dietrich, Cory Anderson

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Bemidji
First City On The Mississippi

Thank you!

GOVERNMENT AND POLITICS

'A success story for our community': Bemidji officials take Gov. Walz on tour of water treatment plant

Written By: Matthew J. Liedke | Oct 30th 2020 - 7am.

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Time-lapse construction video