

Bull Run
TREATMENT
PROJECTS

*Our water: Safe and abundant
for generations to come*

PORTLAND WATER BUREAU

Bull Run Treatment Projects

Bull Run Water: Investigating Coagulation, Flocculation and Sedimentation

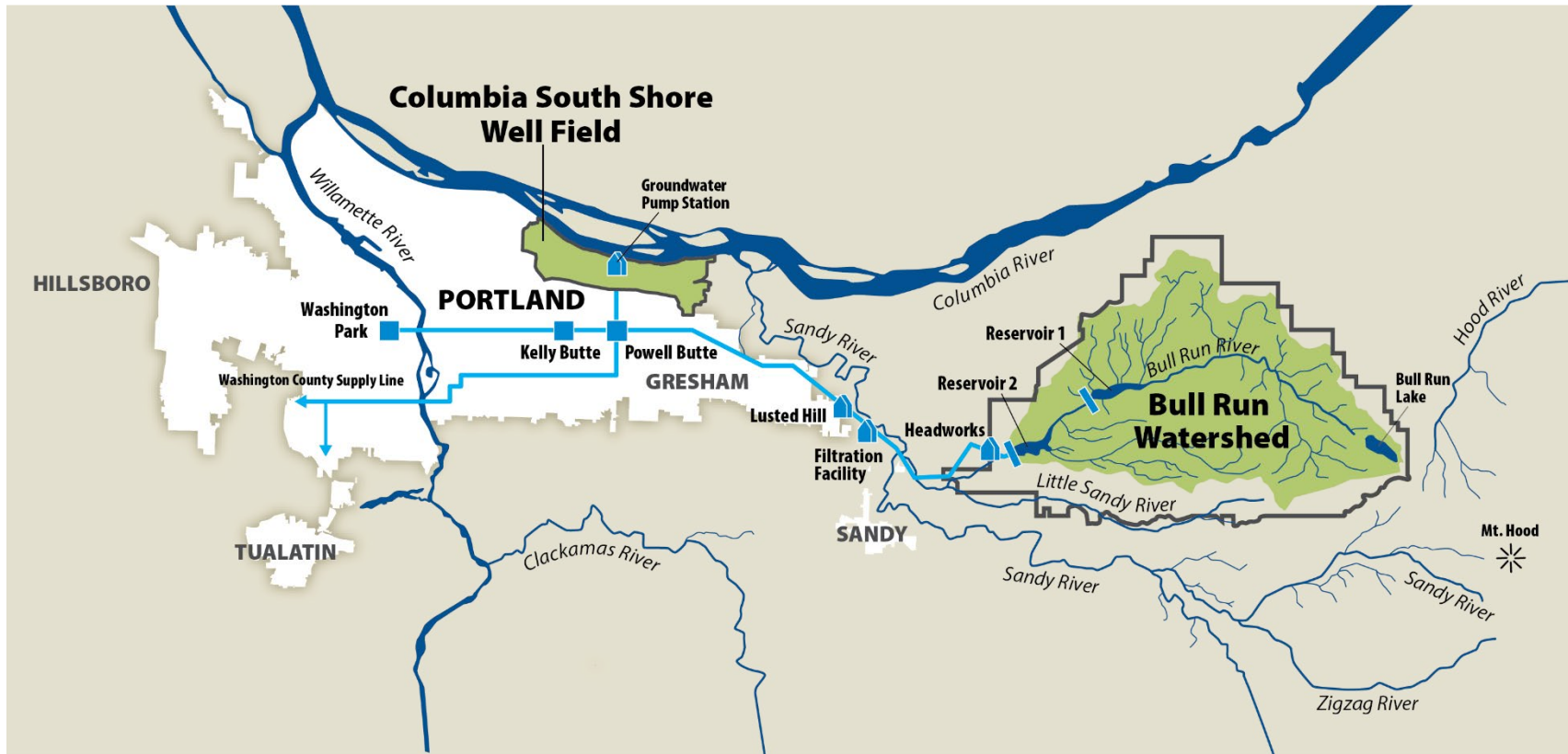
Mojtaba AzadiAghdam, PhD

Process Engineer



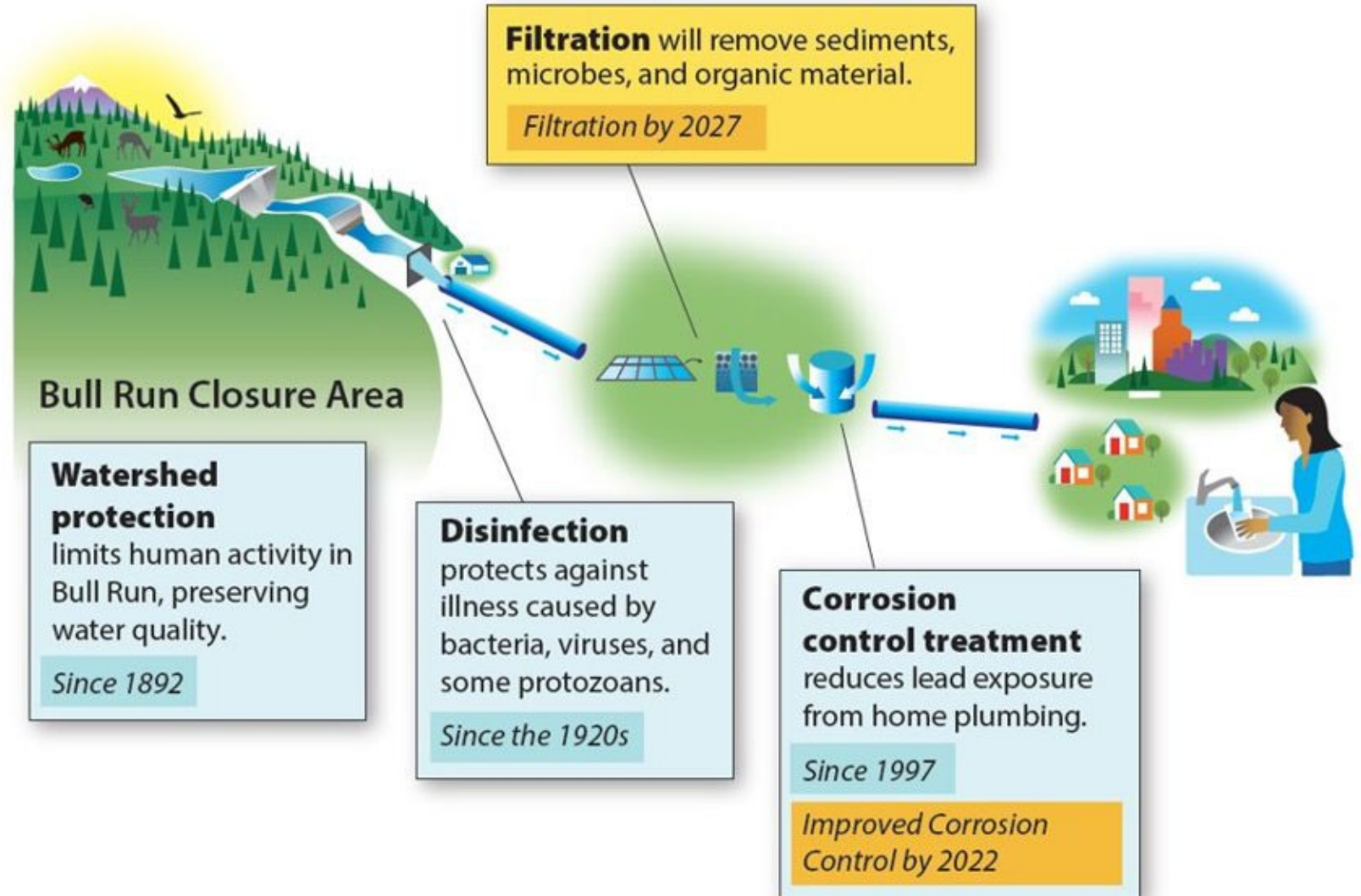
PNWS-AWWA
Water 2022
Tacoma, WA • April 27-29

Thanks to thoughtful planning, Bull Run has been a source of **excellent water since 1895**



- Serves almost 1 million people
- Serves the City of Portland and 19 wholesale customers
- Uses 100 million gallons of water on an average day

Improvements
to our system
are needed to
meet national
drinking water
standards



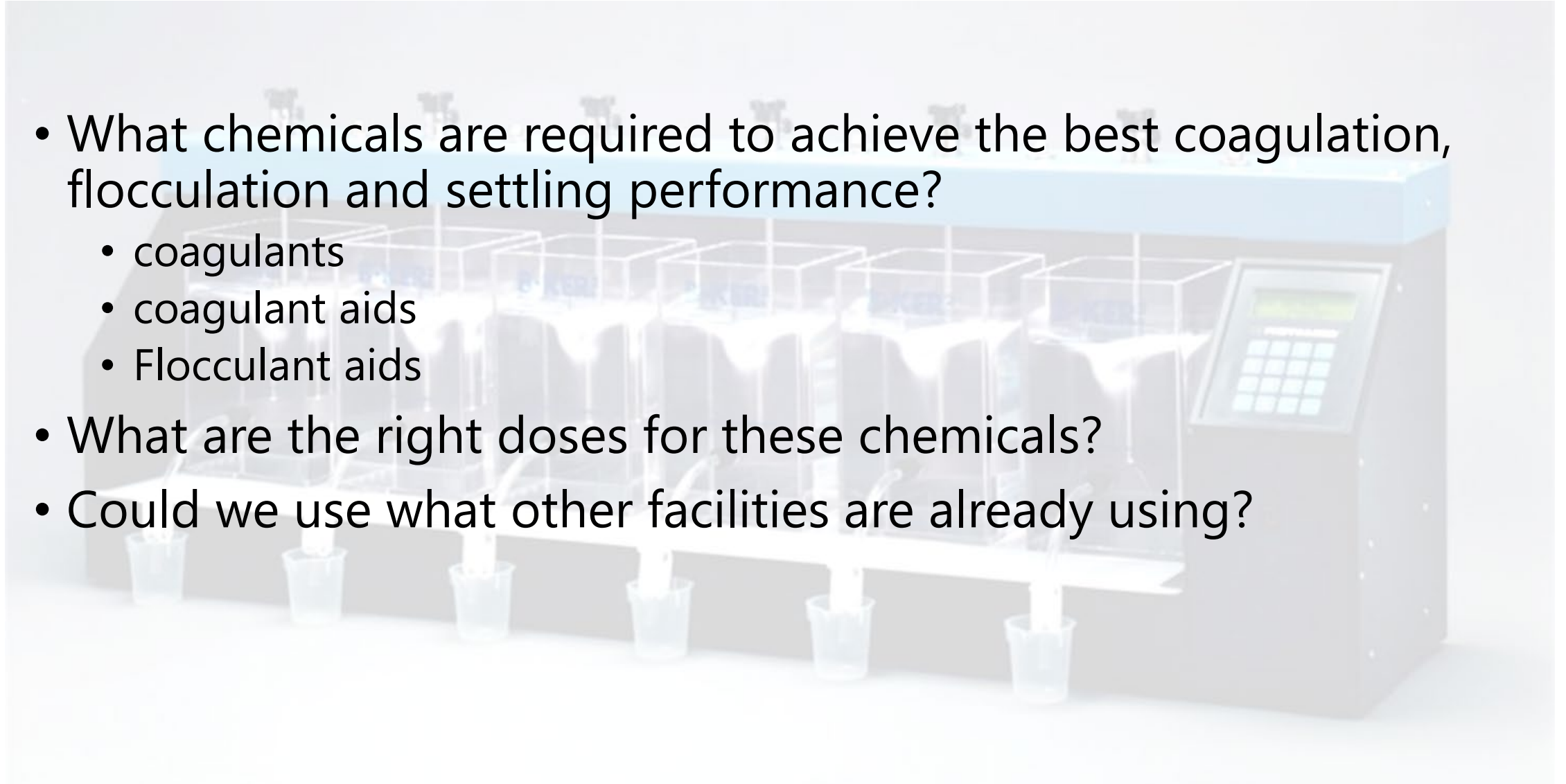
Agenda

1. Results of PACI Jar Tests
2. PACL at the pilot
3. Summary



Why Jar Testing?

- What chemicals are required to achieve the best coagulation, flocculation and settling performance?
 - coagulants
 - coagulant aids
 - Flocculant aids
- What are the right doses for these chemicals?
- Could we use what other facilities are already using?



Coagulant Evaluation

4 coagulants will be studied in these jar testing experiments:

- **poly-aluminum chloride (PACl)**
- aluminum sulfate
- ferric sulfate
- aluminum Chlorohydrate (ACH)

Analyses

- turbidity
- UV_{254}
- filtered UV_{254}
- color
- apparent color
- alkalinity
- pH
- zeta potential
- TOC/DOC
- Fe/Al



PACL Jar Testing



PACl Test Conditions



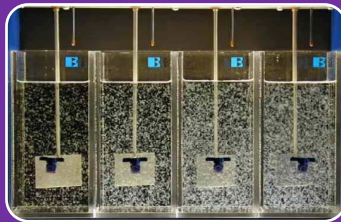
pH adjustments in acidic ranges

- Hydrochloric acid



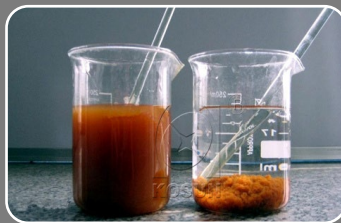
pH adjustments in alkaline ranges

- Combination of coagulant aid and soda ash



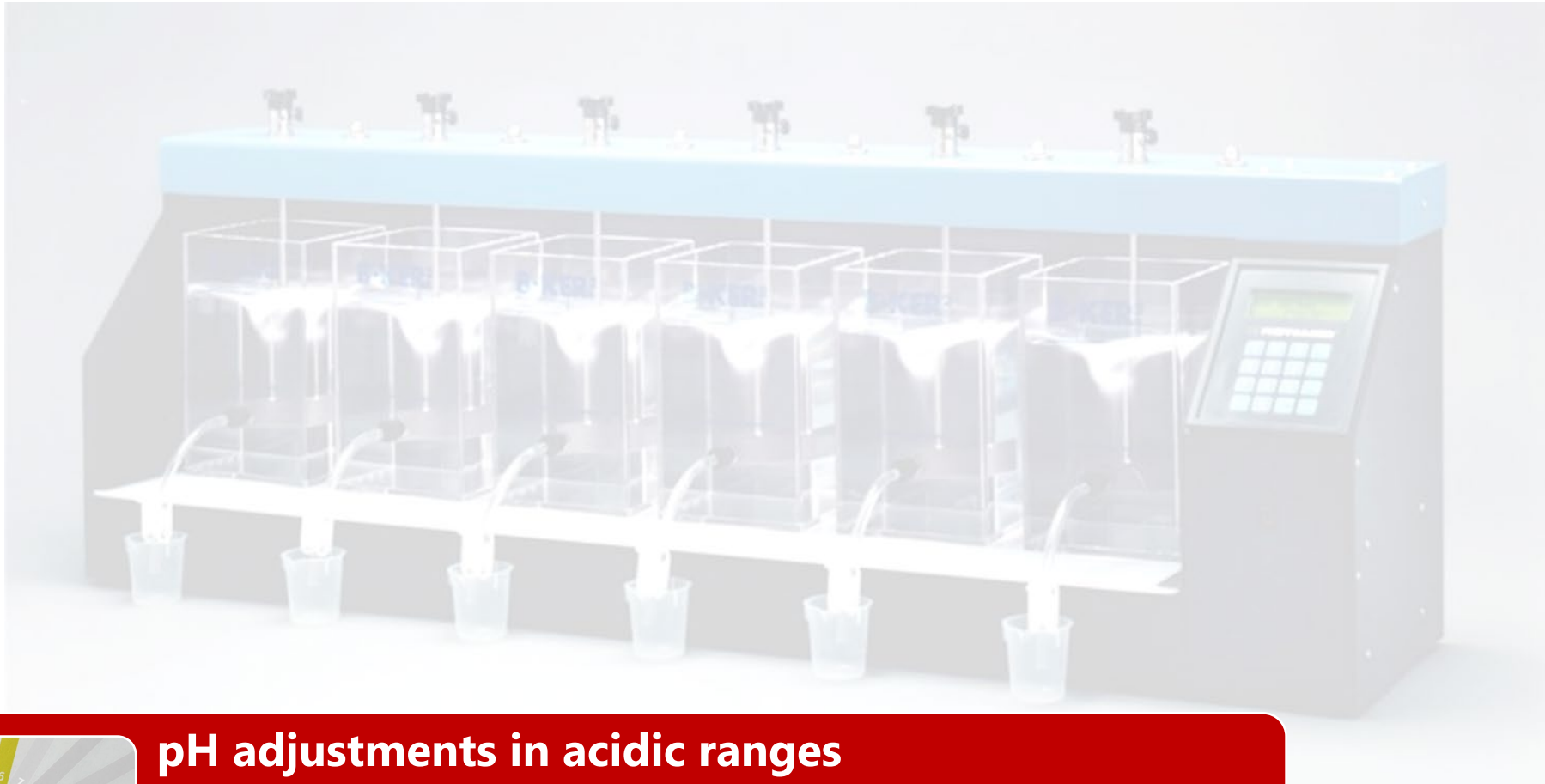
Sweep floc formation

- Sodium bicarbonate
- Sodium hydroxide
- Soda ash



Flocculant aid addition

- Anionic flocculant aid
- Nonionic flocculant aid
- Cationic flocculant aid

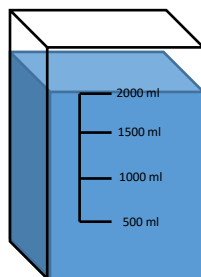


pH adjustments in acidic ranges

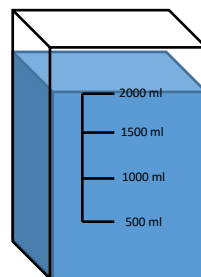
- Hydrochloric acid

pH adjustments in acidic ranges

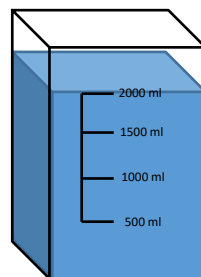
- Goal: Investigate the zeta charge reversal at acidic pH values
- Jar setup:



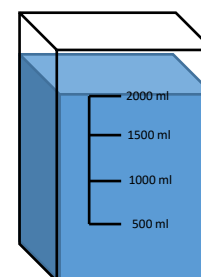
Jar 1
2.6 mg/L PACL
(charge neutral dose)



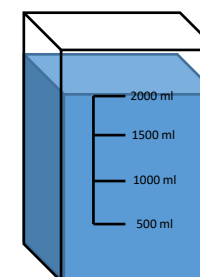
Jar 2
1.5 mg/L PACL
(charge neutral dose)
1.2 ml of 0.16 N acid



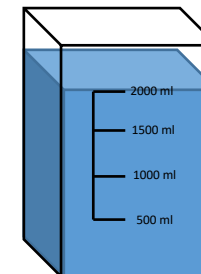
Jar 3
1.5 mg/L PACL
(charge neutral dose)
1.6 ml of 0.16 N acid



Jar 4
1.5 mg/L PACL
(charge neutral dose)
2 ml of 0.16 N acid



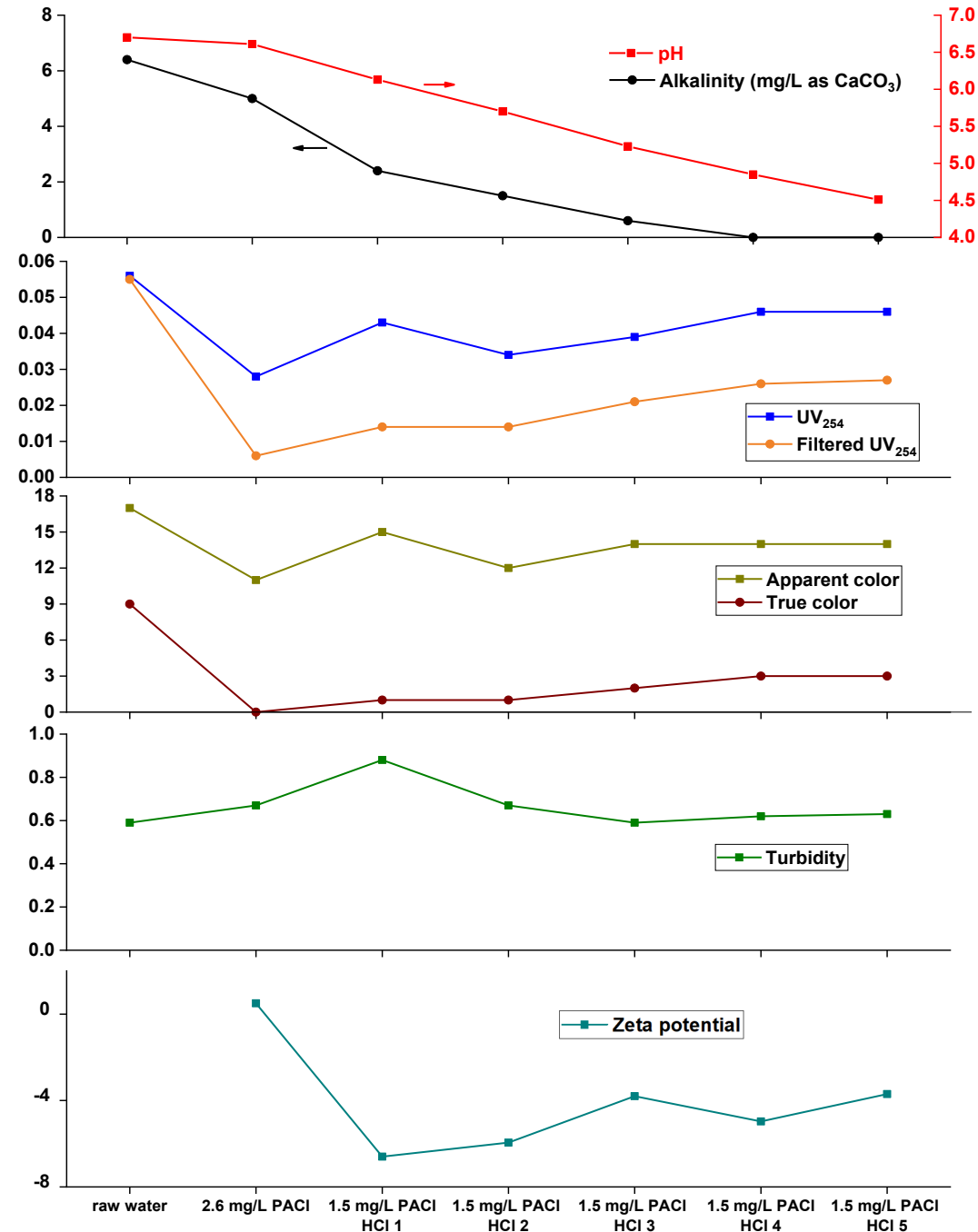
Jar 5
1.5 mg/L PACL
(charge neutral dose)
2.4 ml of 0.16 N acid



Jar 6
1.5 mg/L PACL
(charge neutral dose)
2.8 ml of 0.16 N acid

pH adjustments in acidic ranges

- Lowering the pH resulted in higher UV_{254} and color while turbidity stayed the same.



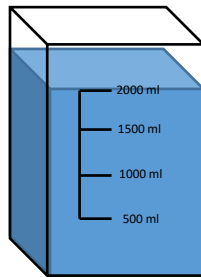


pH adjustments in alkaline ranges

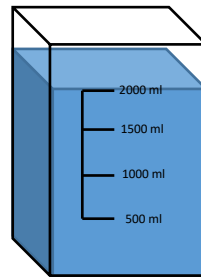
- Combination of coagulant aid and soda ash

pH adjustments in alkaline ranges

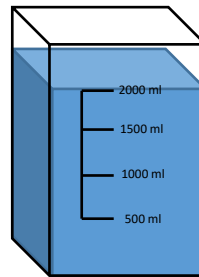
- Goal: Investigate the possibility of achieving sweep floc formation at high pH values
- Jar setup:



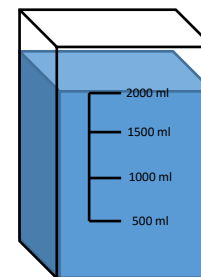
Jar 1
2.5 mg/L PACL
(charge neutral dose)



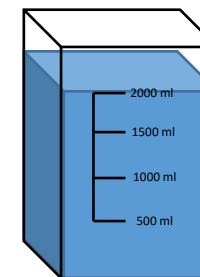
Jar 2
2.5 mg/L PACL
(charge neutral dose)
0.8 mg/L of coag. Aid
8.5 mg/L soda ash



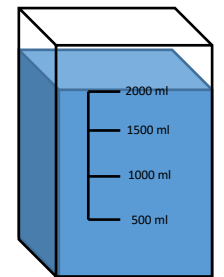
Jar 3
2.5 mg/L PACL
(charge neutral dose)
1.3 mg/L of coag. Aid
17 mg/L soda ash



Jar 4
2.5 mg/L PACL
(charge neutral dose)
1.45 mg/L of coag. Aid
25.5 mg/L soda ash



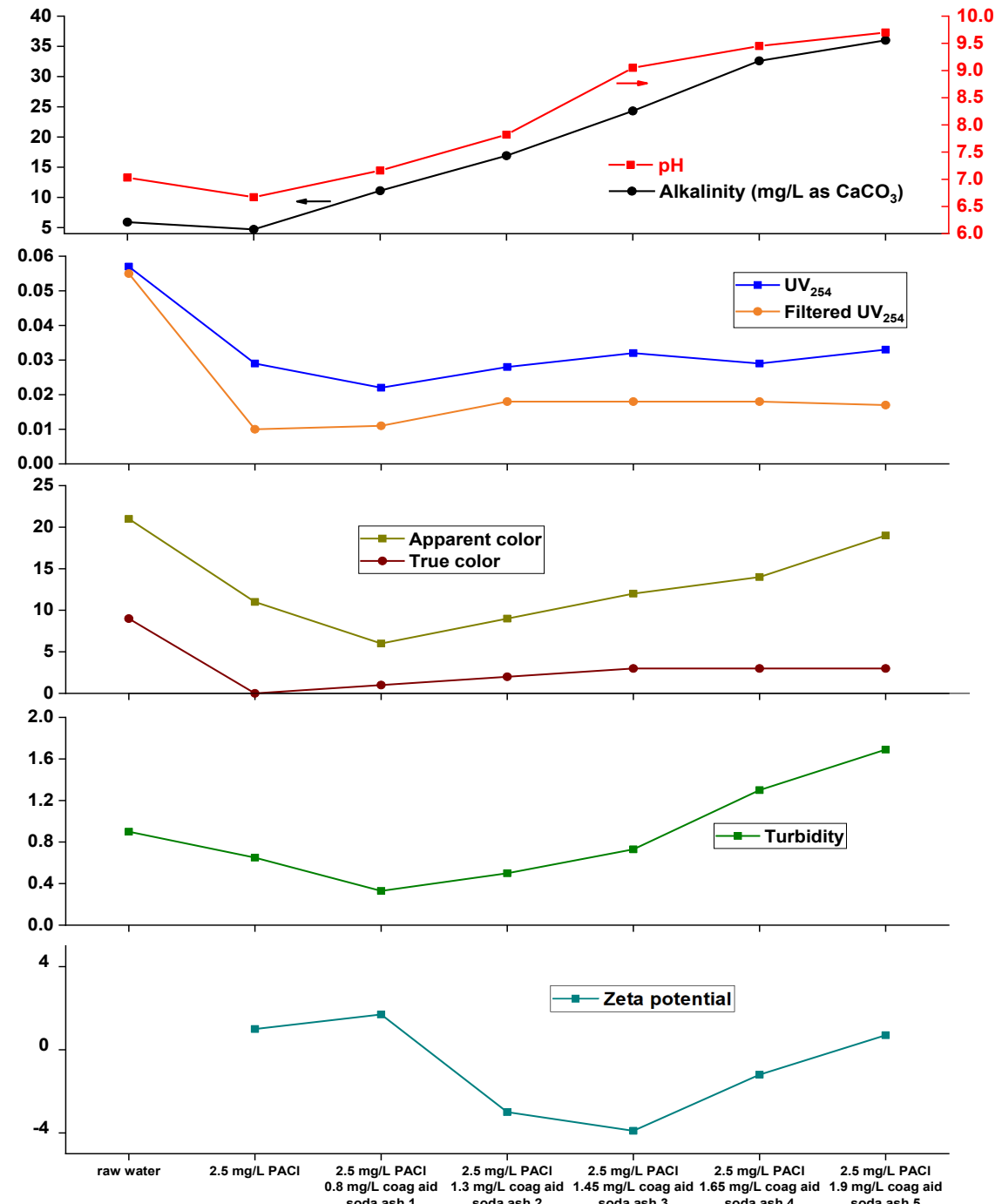
Jar 5
2.5 mg/L PACL
(charge neutral dose)
1.65 mg/L of coag. Aid
34 mg/L soda ash

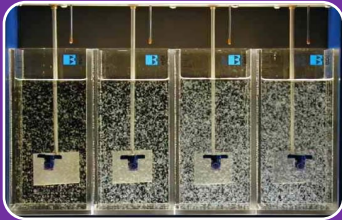


Jar 6
2.5 mg/L PACL
(charge neutral dose)
1.9 mg/L of coag. Aid
42 mg/L soda ash

pH adjustments in alkaline ranges

- Decent flocs were formed; however, the settling and water quality results are not good.



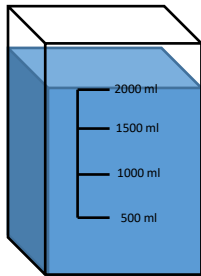


Sweep floc formation

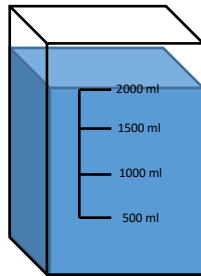
- Sodium hydroxide
- Sodium bicarbonate
- Soda ash

Sweep floc formation by Bicarbonate addition

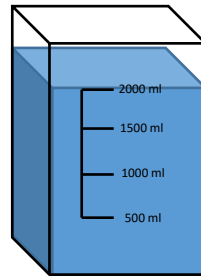
- Goal: Investigate the possibility of achieving settleable flocs.
- Jar setup:



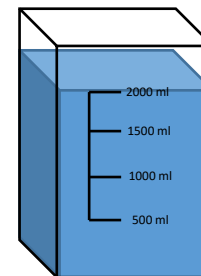
Jar 1
2.7 mg/L PACL
(charge neutral dose)



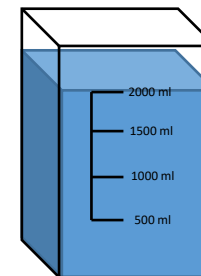
Jar 2
3.05 mg/L PACL
(charge neutral dose)
8.4 mg/L of bicarb



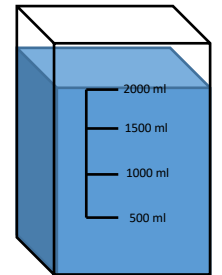
Jar 3
3.5 mg/L PACL
(charge neutral dose)
16.8 mg/L of bicarb



Jar 4
3.95 mg/L PACL
(charge neutral dose)
25.2 mg/L of bicarb



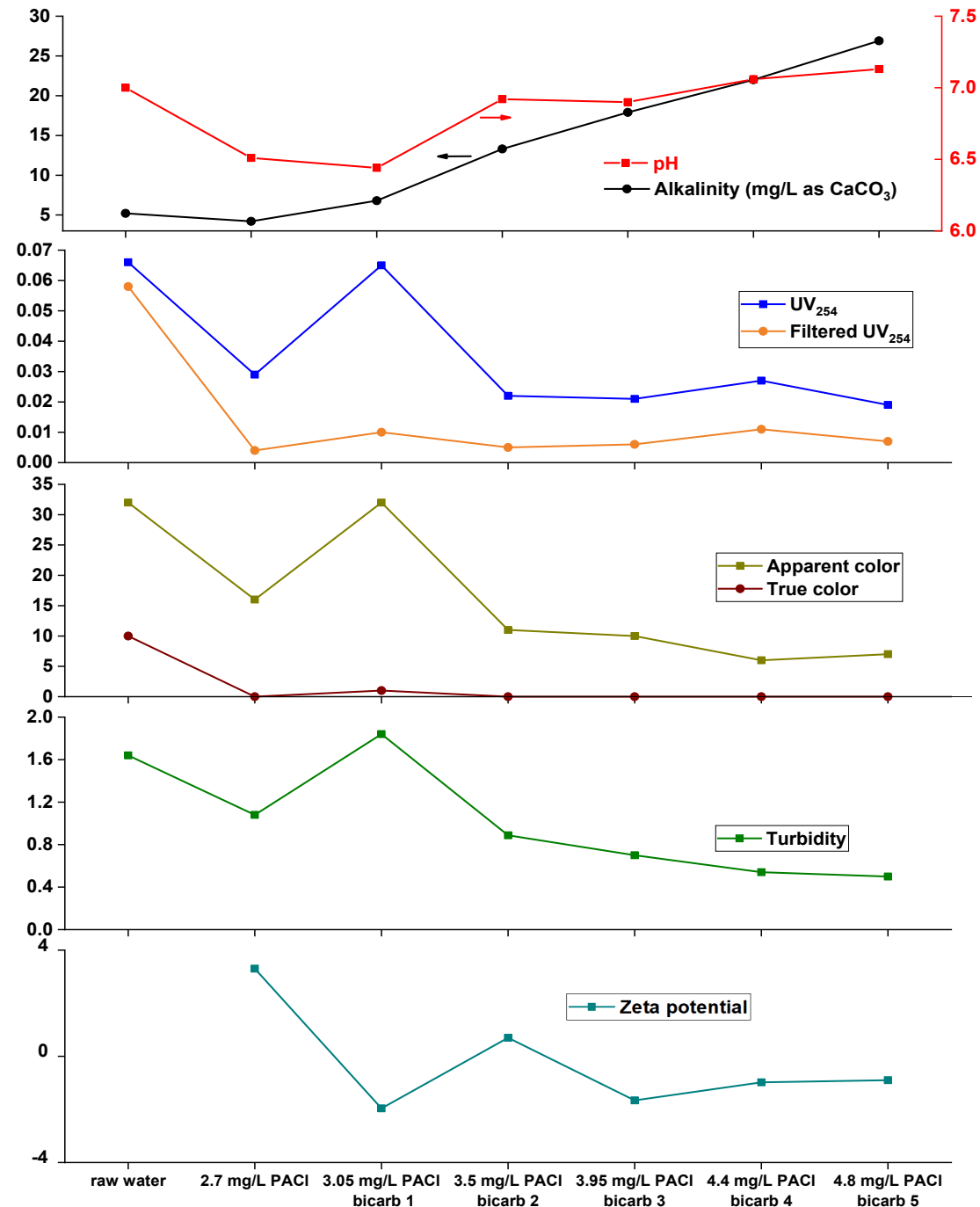
Jar 5
4.4 mg/L PACL
(charge neutral dose)
33.6 mg/L of bicarb



Jar 6
4.8 mg/L PACL
(charge neutral dose)
42 mg/L of bicarb

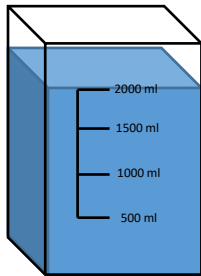
Sweep floc formation by Bicarbonate addition

- Decent flocs were formed; however, the settling performance of the flocs were not good.
- Considering the amount of bicarbonate and coagulant needed to achieve good performance, this is not a feasible alternative.

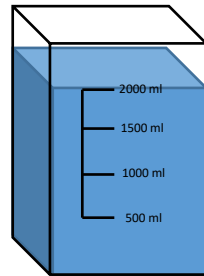


Sweep floc formation by NaOH

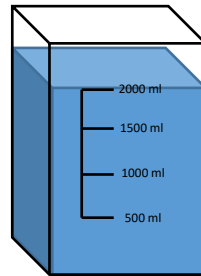
- Goal: Investigate the possibility of achieving lower turbidity and better settling.
- Jar setup:



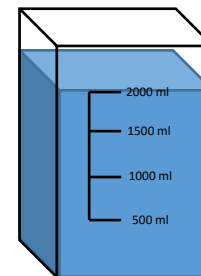
Jar 1
2.5 mg/L PACL
(charge neutral dose)



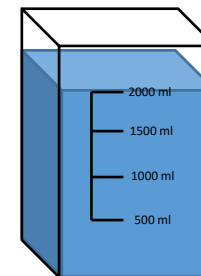
Jar 2
3.6 mg/L PACL
(charge neutral dose)
0.8 ml of 0.16 N NaOH



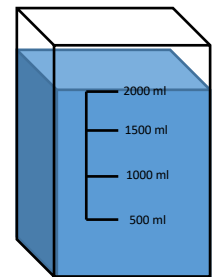
Jar 3
5.9 mg/L PACL
(charge neutral dose)
1.6 ml of 0.16 N NaOH



Jar 4
7.5 mg/L PACL
(charge neutral dose)
2 ml of 0.16 N NaOH



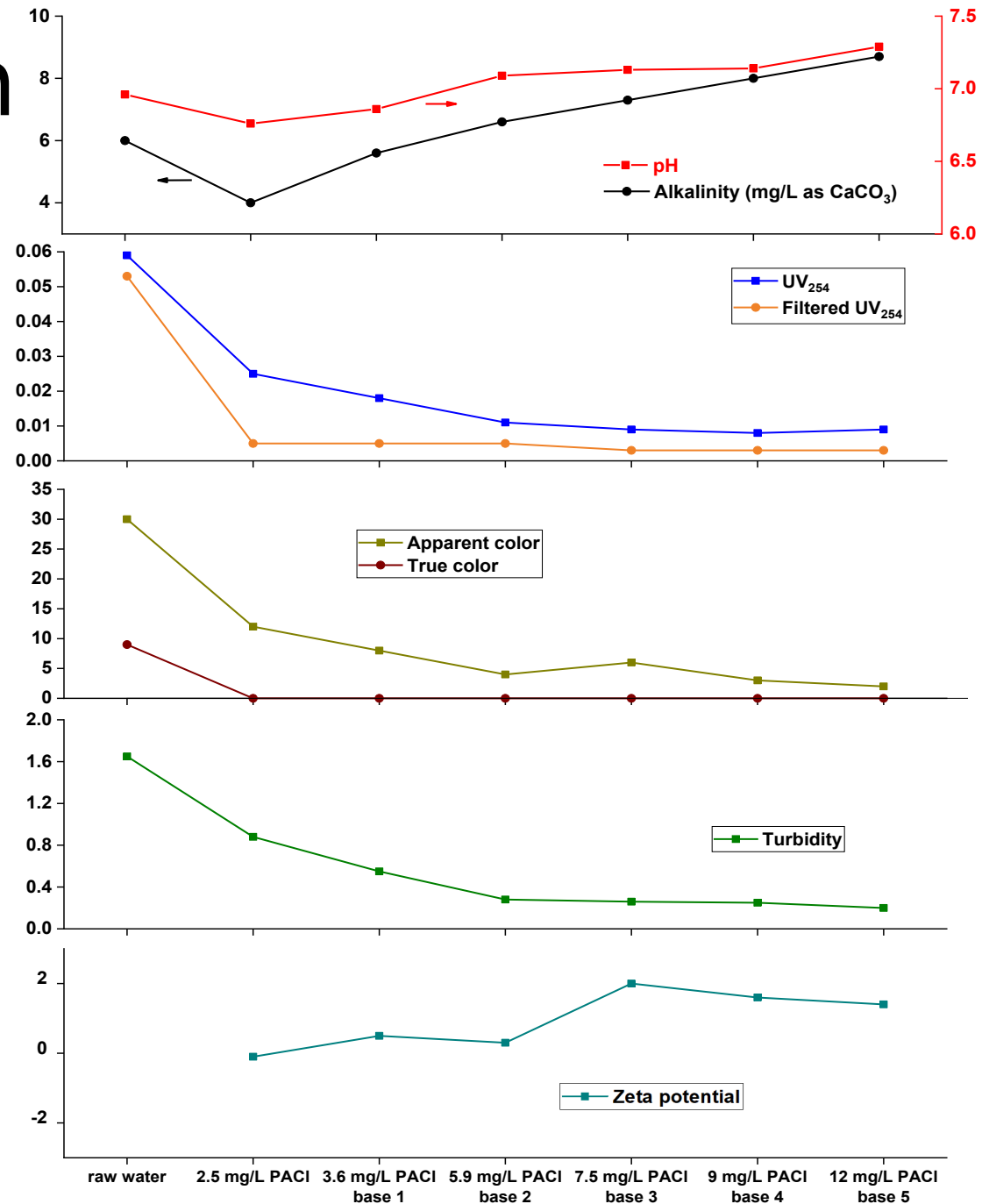
Jar 5
9 mg/L PACL
(charge neutral dose)
2.4 ml of 0.16 N NaOH



Jar 6
12 mg/L PACL
(charge neutral dose)
3.2 ml of 0.16 N NaOH

Sweep floc formation by NaOH

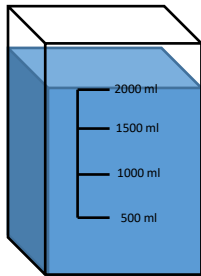
- Water quality kept improving by increasing the NaOH addition in each jar.



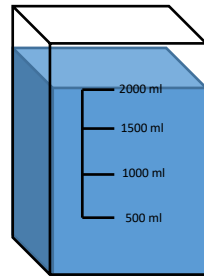
Sweep floc formation

Sweep floc formation by soda ash

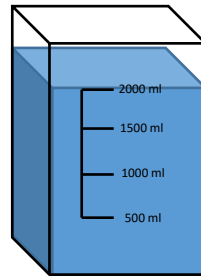
- Goal: Investigate the possibility of achieving similar great results that were achieved by NaOH.
- Jar setup:



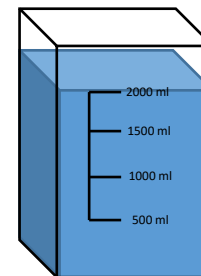
Jar 1
2.5 mg/L PACL
(charge neutral dose)



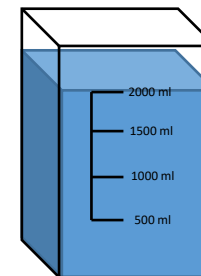
Jar 2
5 mg/L PACL
(charge neutral dose)
8.5 mg/L soda ash



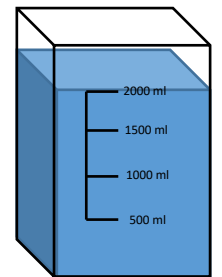
Jar 3
7 mg/L PACL
(charge neutral dose)
17 mg/L soda ash



Jar 4
11.5 mg/L PACL
(charge neutral dose)
25.5 mg/L soda ash



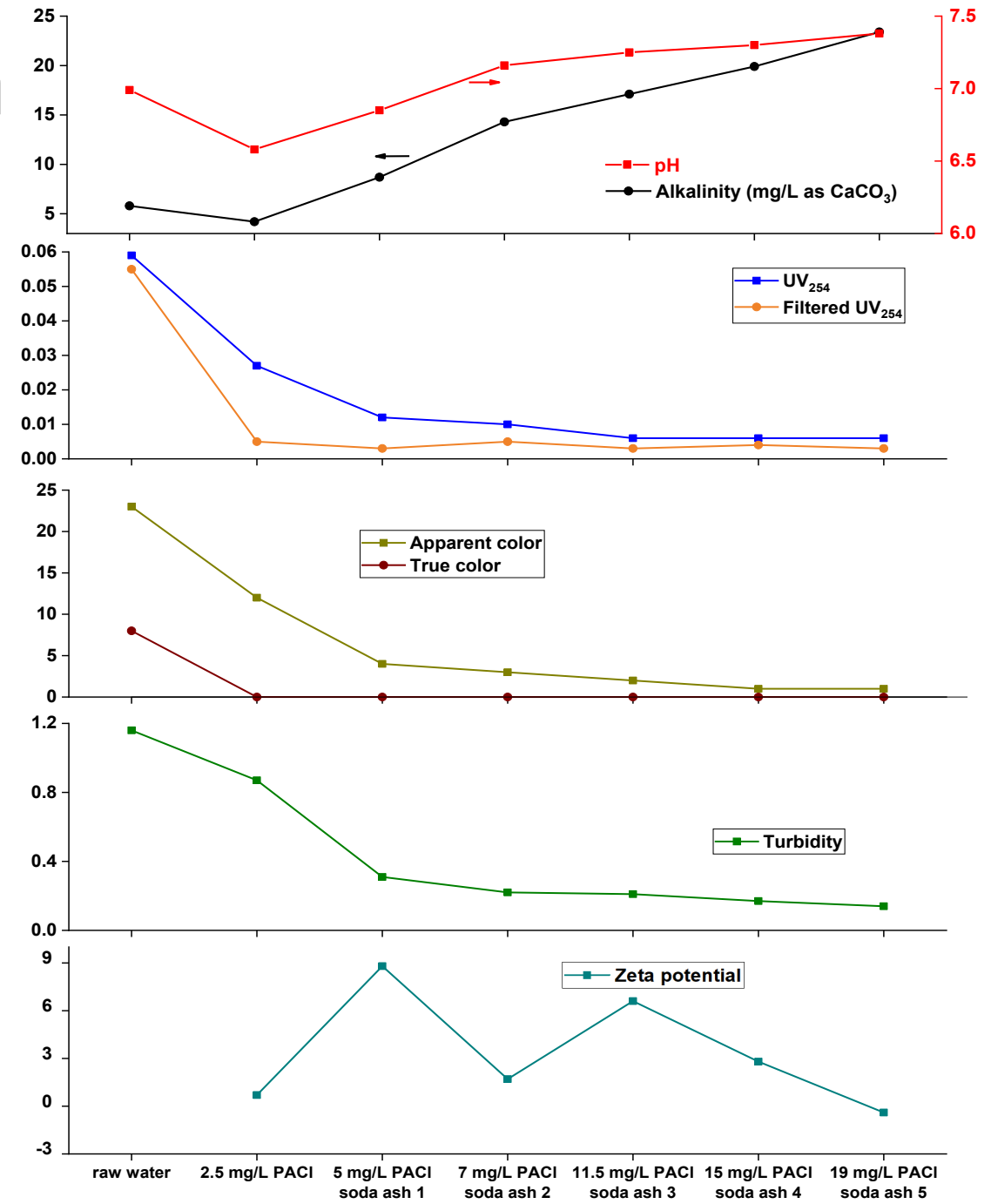
Jar 5
15 mg/L PACL
(charge neutral dose)
34 mg/L soda ash



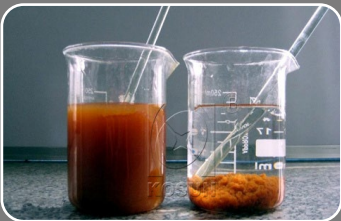
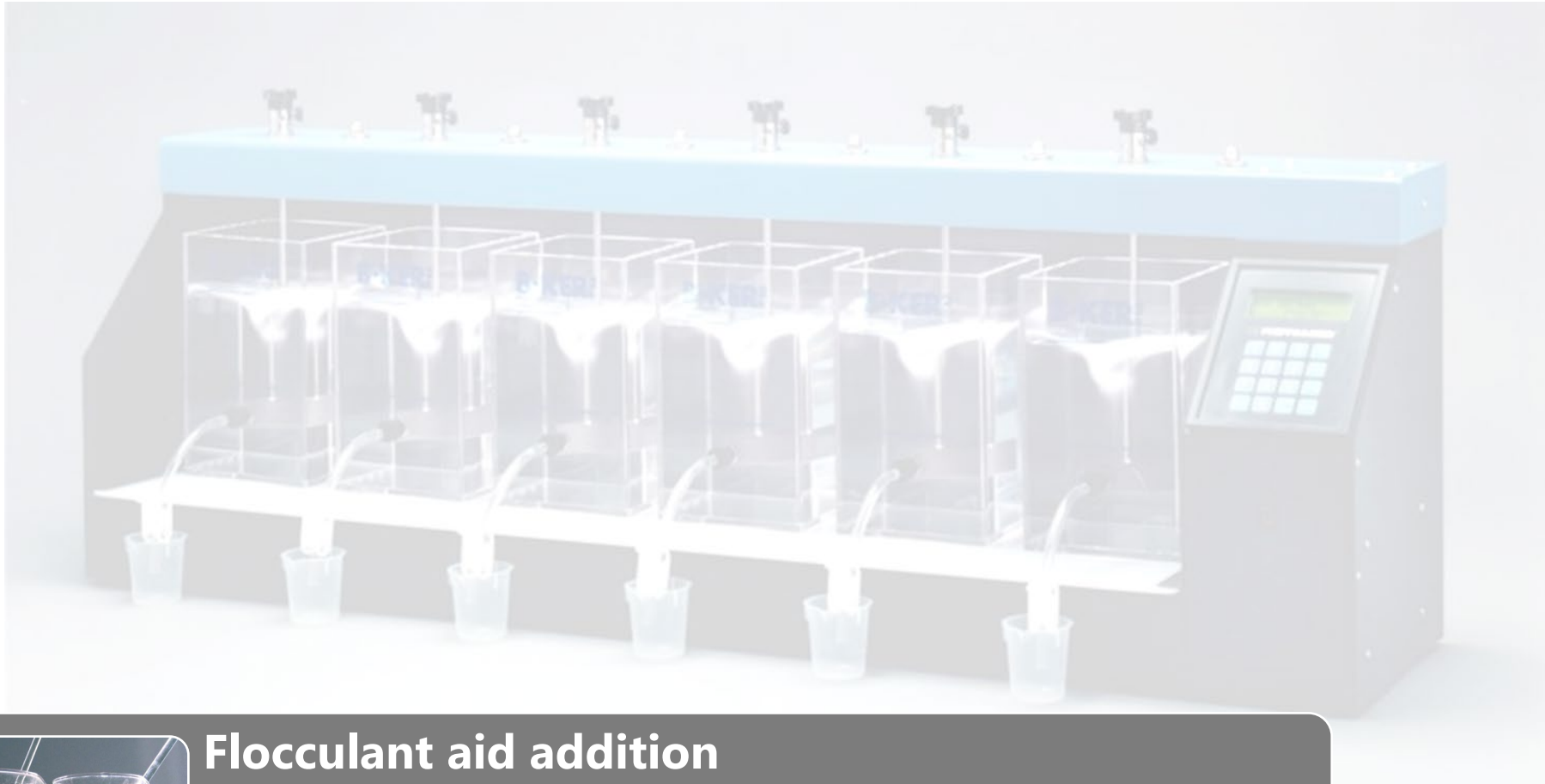
Jar 6
19 mg/L PACL
(charge neutral dose)
42 mg/L soda ash

Sweep floc formation by soda ash

- Water quality kept improving by increasing the NaOH addition in each jar.



Sweep floc formation



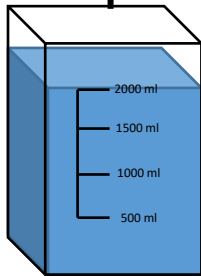
Flocculant aid addition

- Anionic flocculant aid
- Nonionic flocculant aid
- Cationic flocculant aid

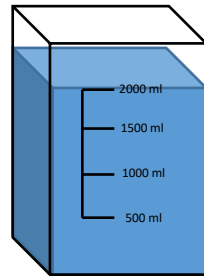
PACl with anionic floc aid

- Goal: Investigate the possibility of achieving lower turbidity and lower

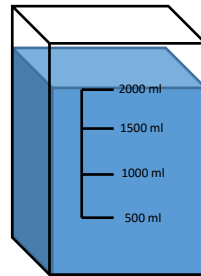
- Jar setup:



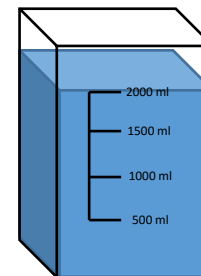
Jar 1
2.5 mg/L PACL
(charge neutral dose)



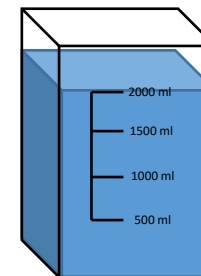
Jar 2
2.5 mg/L PACL
(charge neutral dose)
0.02 mg/L A-1820



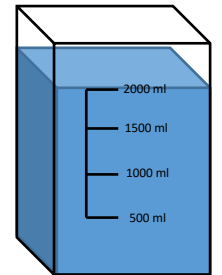
Jar 3
2.5 mg/L PACL
(charge neutral dose)
0.04 mg/L A-1820



Jar 4
2.5 mg/L PACL
(charge neutral dose)
0.06 mg/L A-1820



Jar 5
2.5 mg/L PACL
(charge neutral dose)
0.08 mg/L A-1820



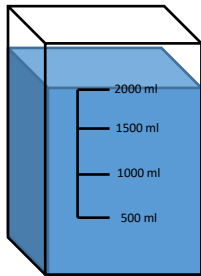
Jar 6
2.5 mg/L PACL
(charge neutral dose)
0.1 mg/L A-1820

PACl with anionic floc aid

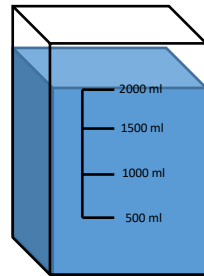
- Addition of anionic floc aid into charge neutral jars resulted in stopping the floc growth in third flocculation time.
- This resulted in worse settling for all jars compared to charge neutral that had some settling.
- This is due to having a more negatively charged solution during the third flocculation.

PACl with nonionic flocc aid

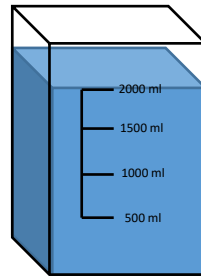
- Goal: Investigate the possibility of achieving bigger flocs, better settling and lower turbidity.
- Jar setup:



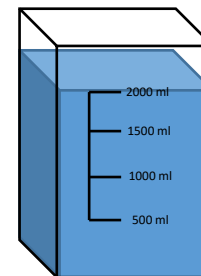
Jar 1
2.2 mg/L PACL
(charge neutral dose)



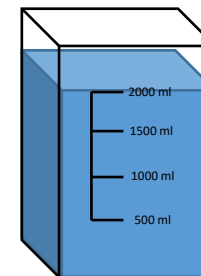
Jar 2
2.2 mg/L PACL
(charge neutral dose)
0.02 mg/L of N-1986



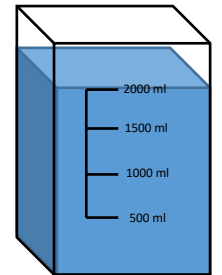
Jar 3
2.2 mg/L PACL
(charge neutral dose)
0.04 mg/L of N-1986



Jar 4
2.2 mg/L PACL
(charge neutral dose)
0.06 mg/L of N-1986



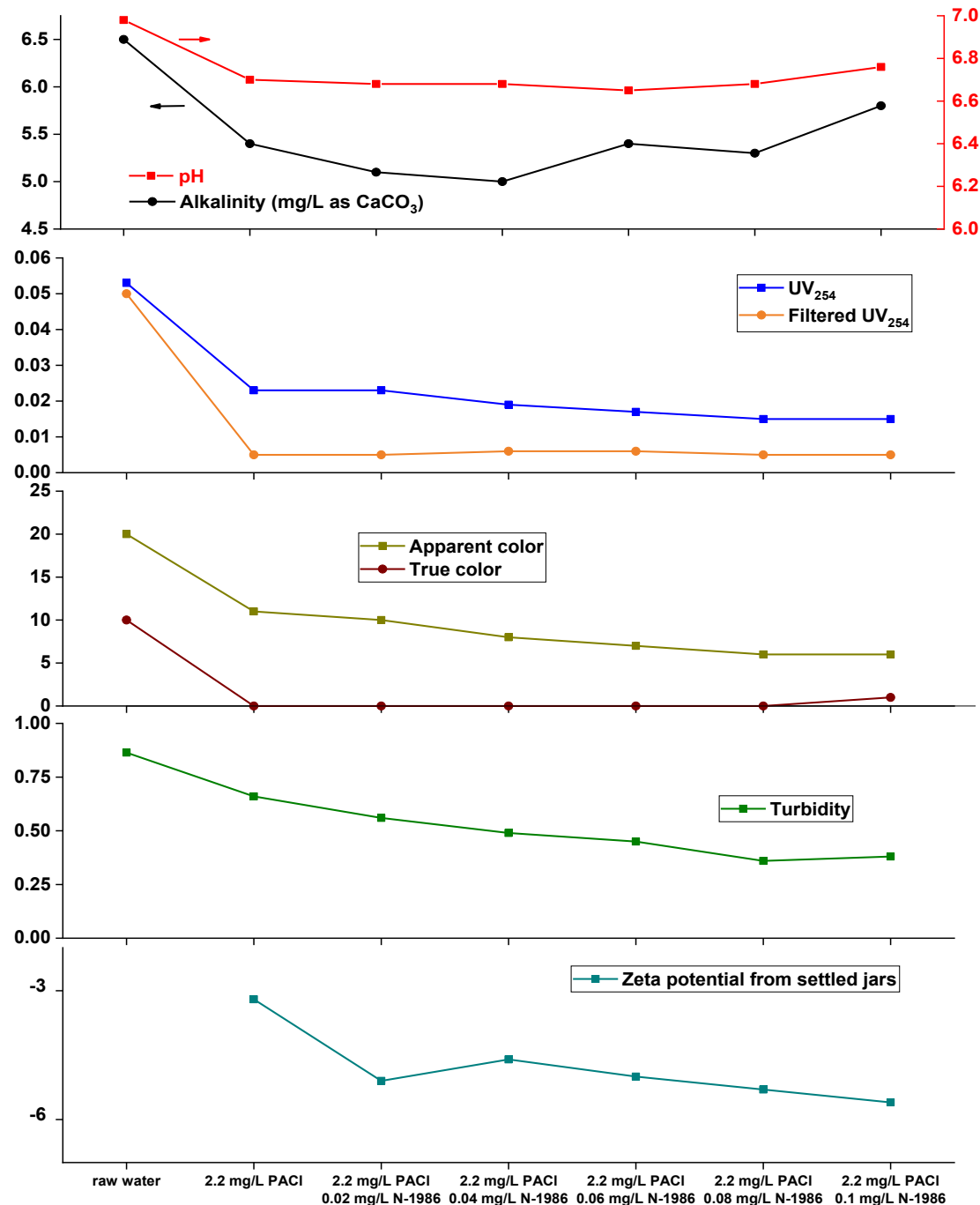
Jar 5
2.2 mg/L PACL
(charge neutral dose)
0.08 mg/L of N-1986



Jar 6
2.2 mg/L PACL
(charge neutral dose)
0.1 mg/L of N-1986

PACl with nonionic flocc aid

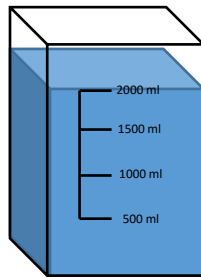
- Turbidity and color demonstrates a downward trend due to the addition of flocculant aid.



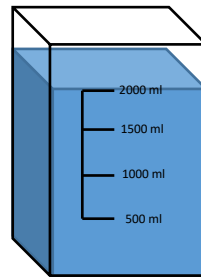
Flocculant aid addition

PACl with cationic flocc aid

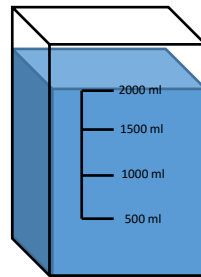
- Goal: Investigate the possibility of achieving bigger flocs, better settling and lower turbidity.
- Jar setup:



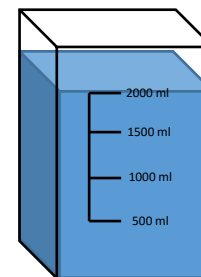
Jar 1
2.2 mg/L PACL
(charge neutral dose)



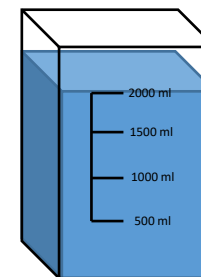
Jar 2
2.2 mg/L PACL
(charge neutral dose)
0.02 mg/L of C-1594



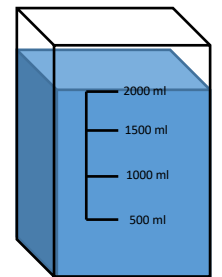
Jar 3
2.2 mg/L PACL
(charge neutral dose)
0.04 mg/L of C-1594



Jar 4
2.2 mg/L PACL
(charge neutral dose)
0.06 mg/L of C-1594



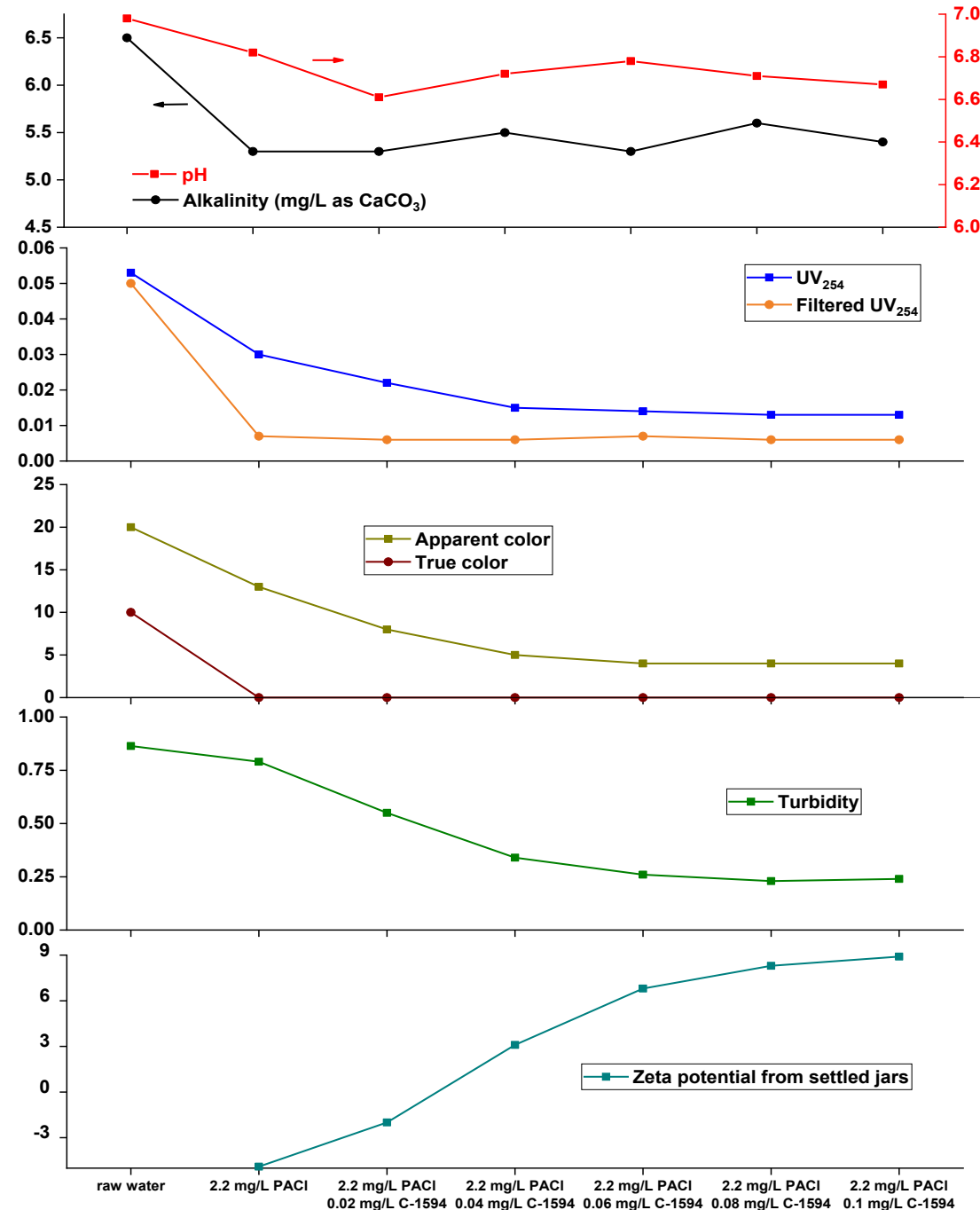
Jar 5
2.2 mg/L PACL
(charge neutral dose)
0.08 mg/L of C-1594



Jar 6
2.2 mg/L PACL
(charge neutral dose)
0.1 mg/L of C-1594

PACl with cationic flocc aid

- Turbidity and color demonstrates a downward trend due to the addition of flocculant aid.



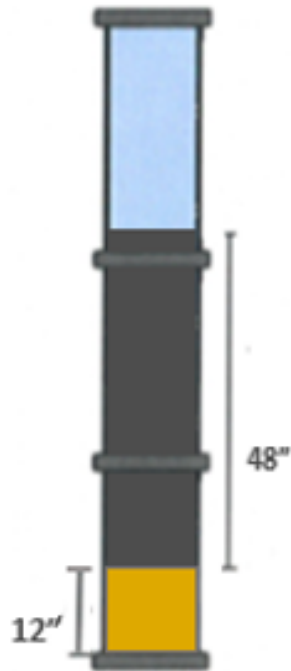
Flocculant aid addition

Pilot

PACL

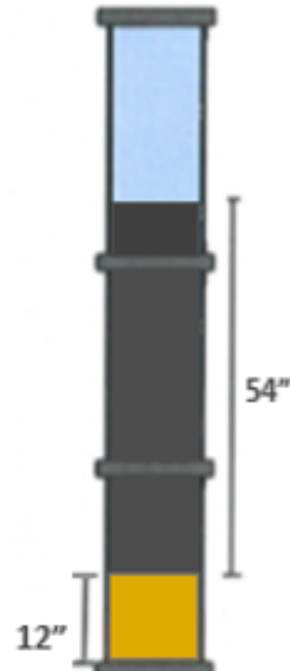
Filter Configuration

ANTH-60
Filters 1/6



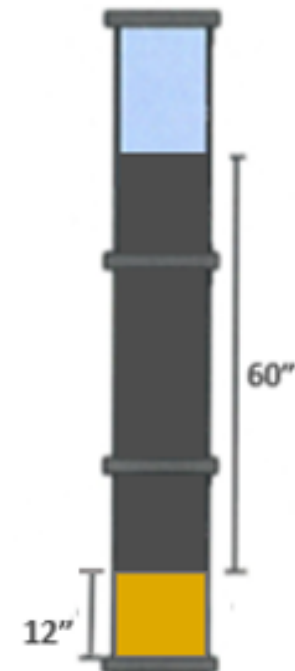
1.1 mm Anthracite
0.55 mm Sand
8 gpm/sf

ANTH-66
Filters 2/5



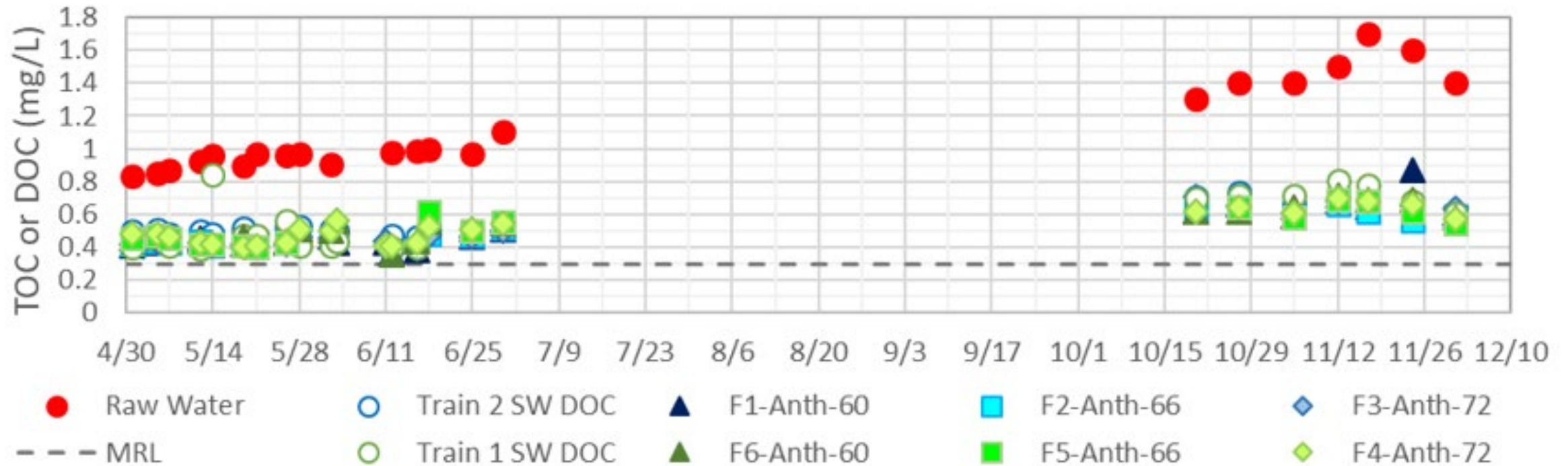
1.2 mm Anthracite
0.60 mm Sand
10 gpm/sf

ANTH-72
Filters 3/4

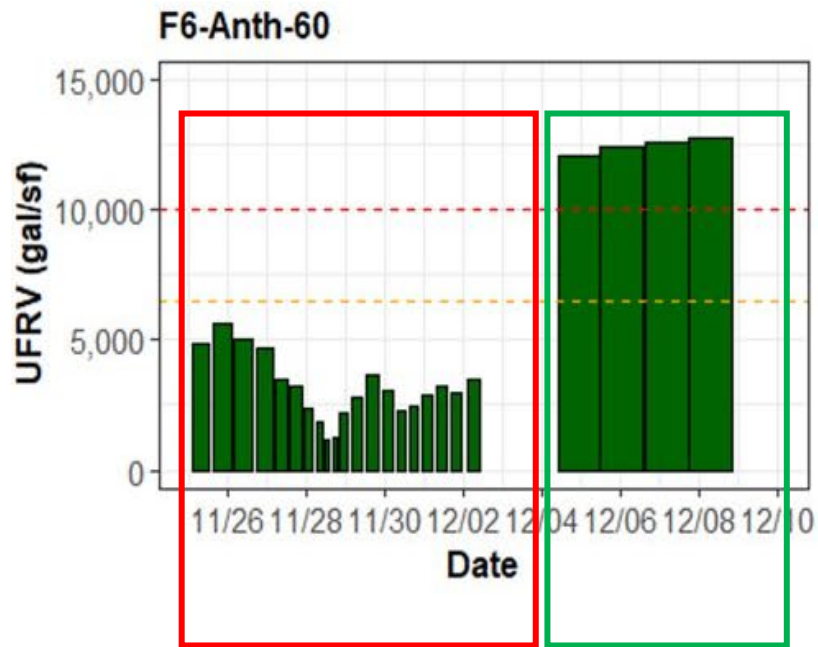


1.3 mm Anthracite
0.65 mm Sand
12 gpm/sf

TOC and DOC

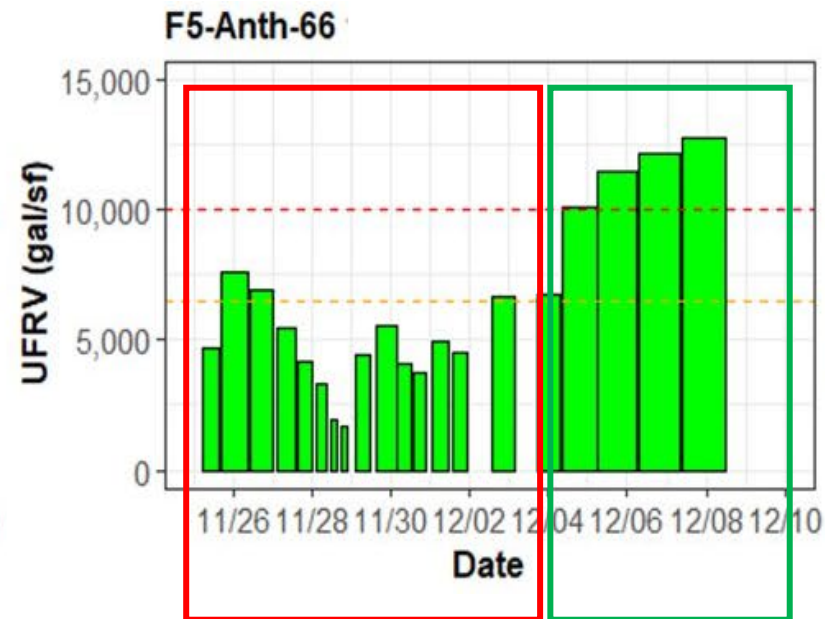


Filter UFRVs



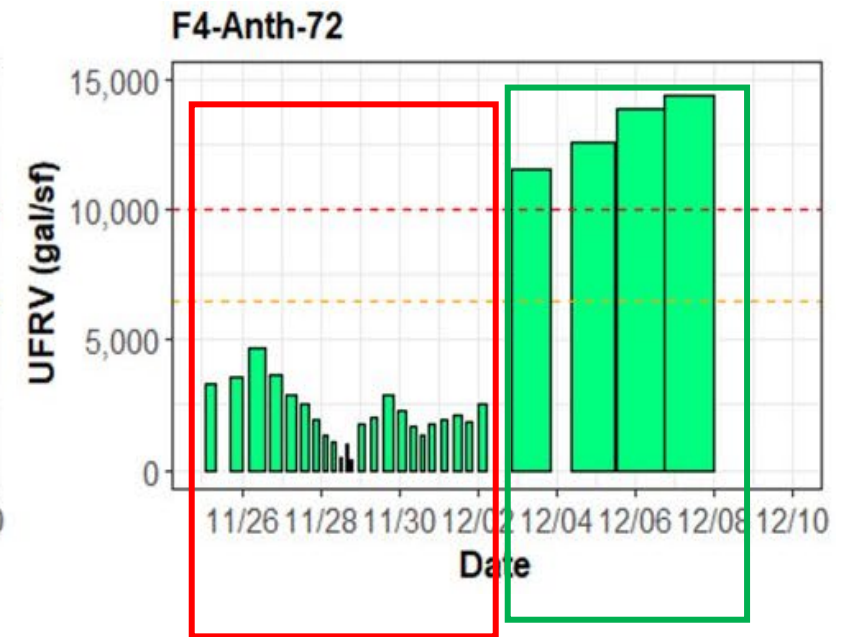
PACL targeting
charge neutral

PACL targeting
charge neutral
+
Nonionic
Flocculant aid



PACL targeting
charge neutral

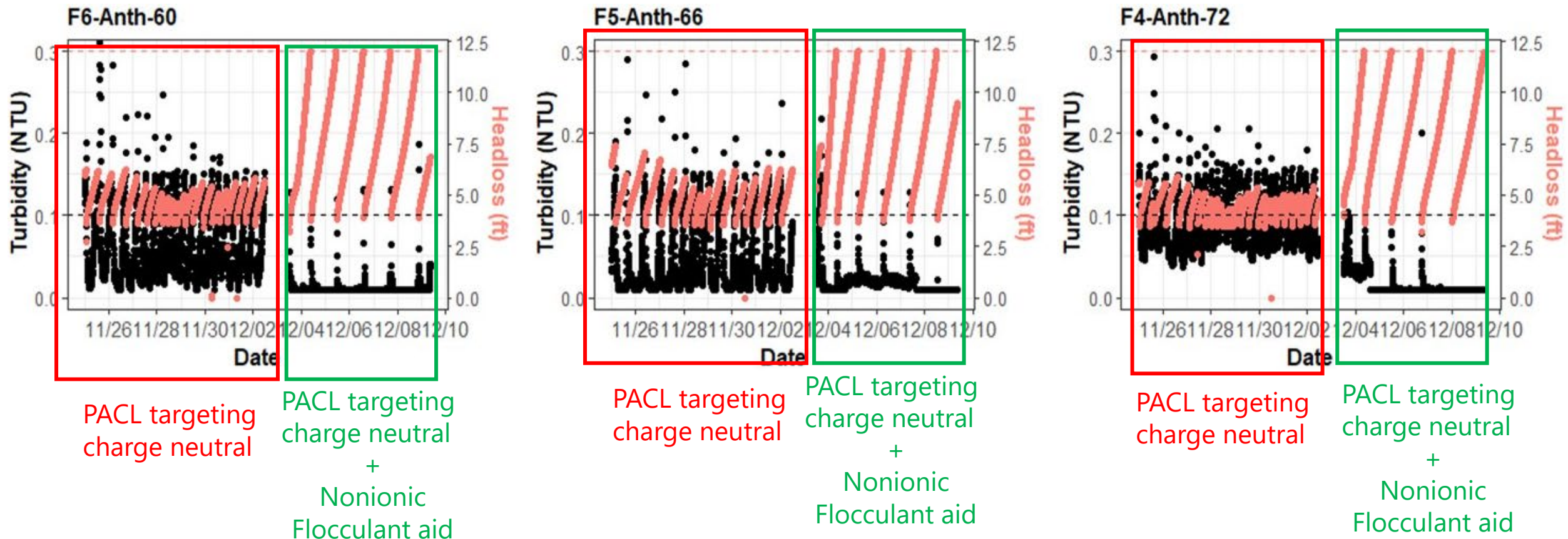
PACL targeting
charge neutral
+
Nonionic
Flocculant aid



PACL targeting
charge neutral

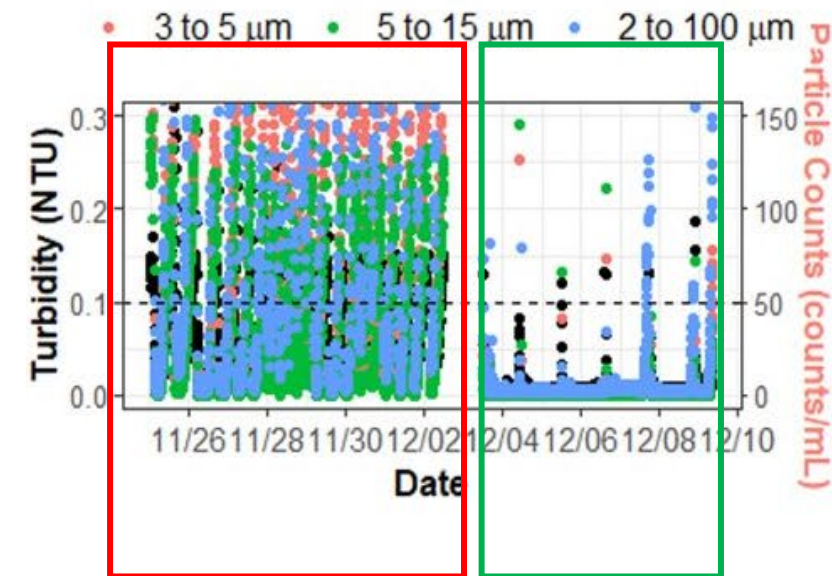
PACL targeting
charge neutral
+
Nonionic
Flocculant aid

Filter Turbidity and Headloss accumulation



Filter particle control

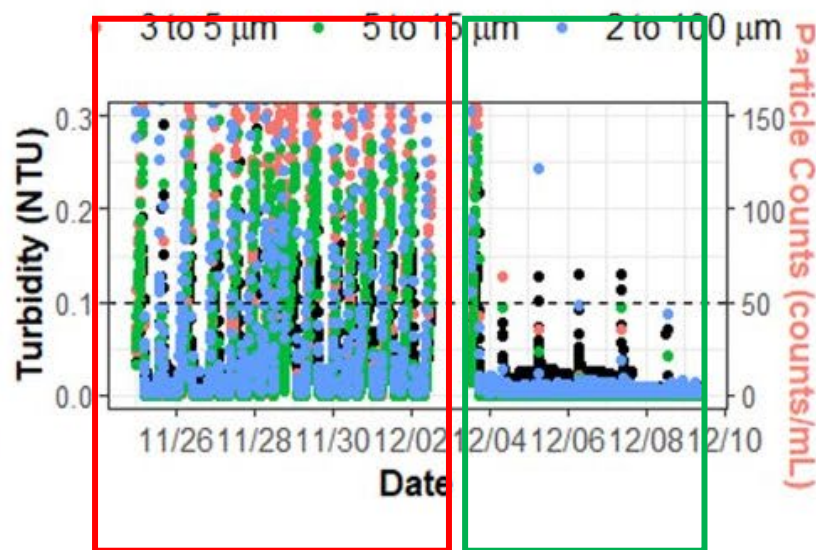
F6-Anth-60



PACL targeting
charge neutral

PACL targeting
charge neutral
+
Nonionic
Flocculant aid

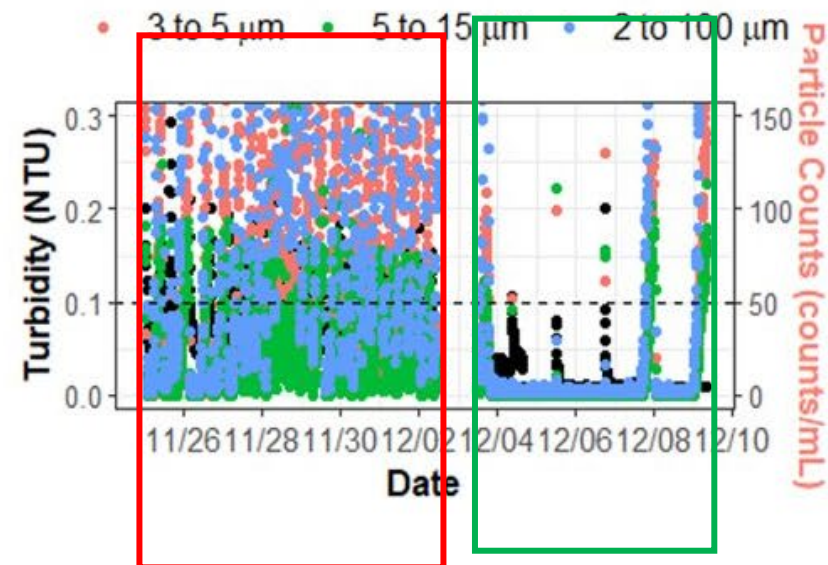
F5-Anth-66



PACL targeting
charge neutral

PACL targeting
charge neutral
+
Nonionic
Flocculant aid

F4-Anth-72



PACL targeting
charge neutral

PACL targeting
charge neutral
+
Nonionic
Flocculant aid

Summary

- Acidic or Alkaline pHs did not improve the PACl coagulation.
- Bicarbonate was not as successful as other chemicals in forming sweep flocs.
- Sweep floc was achieved with both NaOH and soda ash when the pH of the raw water was raised to above 9.
- Targeting sweep floc requires increasing PACl dose.

	NaOH vs. Soda ash	NaOH	Soda ash
Cost effective			√
Less chemical usage		√	
Possible smaller chemical tank and pump sizing		√	
Safety			√
Less coagulant dose therefore less cost		√	
Smaller sludge handling sizing and less sludge production		√	
Alkalinity increase in the raw water (lesser chemical need in corrosion control)			√

Summary

- Flocculant aids improved the floc bridging when PACl dosed at charge neutral doses as follows:

Cationic>nonionic>anionic

Next steps

- Following 2 scenarios showed promising results and can be moved to the pilot scale for further testing:
 - PACl at charge neutral with 0.1 mg/L of cationic flocculant aid
 - Dose of flocculant aid could be reduced based on the performance of the floc/sed.
 - PACl with soda ash (targeting pH 10 in rapid mix 1) at charge neutralization
 - Dose of soda ash (pH target) could be brought down based on the performance of the floc/sed.

The Bull Run Treatment Projects will help keep our water **safe and abundant** for generations to come



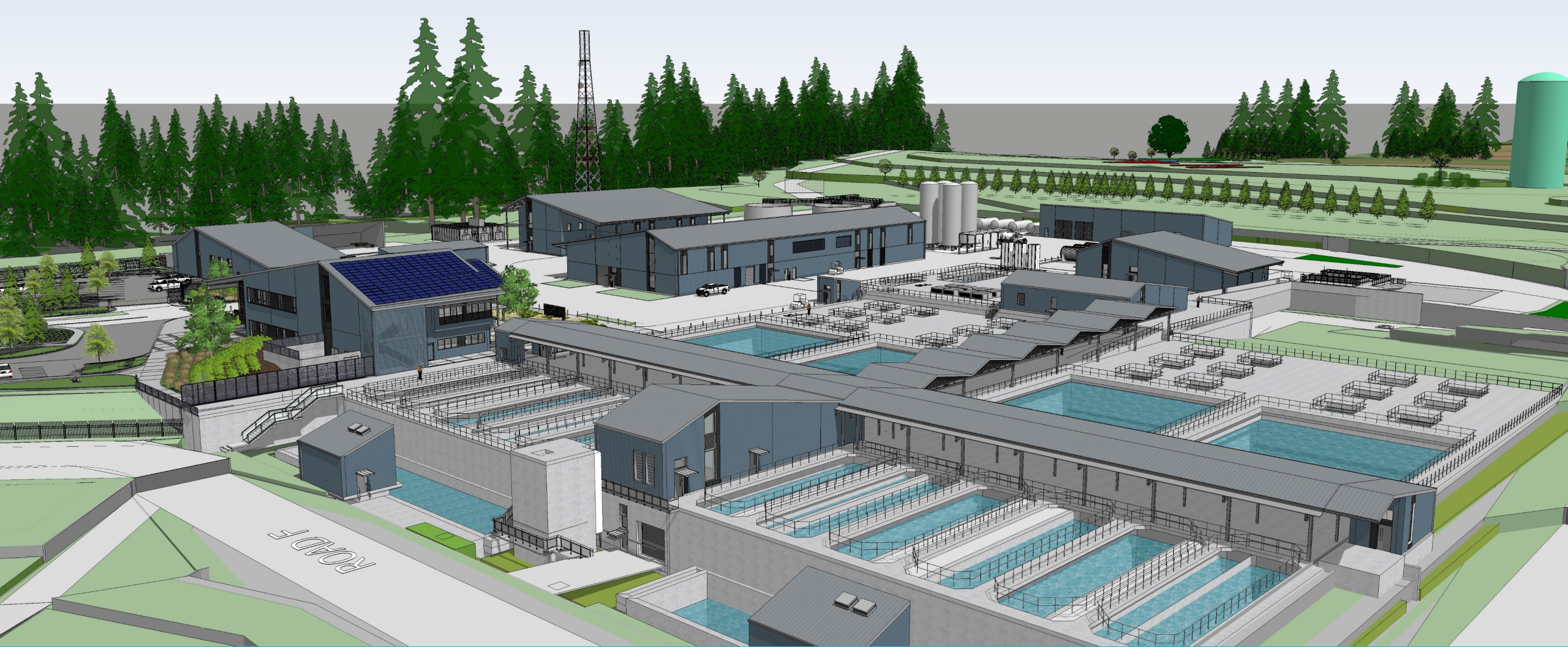
**For our
health**



**For our
economy**



**For our
future**



Bull Run
TREATMENT
PROJECTS

***Our water: Safe and abundant
for generations to come***

Learn More portland.gov/bullrunprojects

Thank you!

Appendix



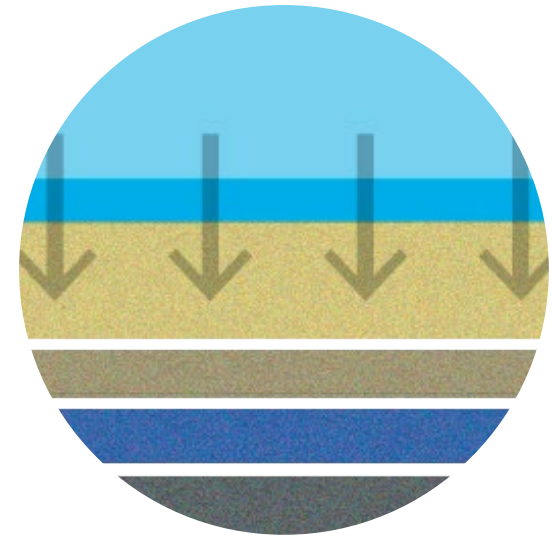
Bull Run
TREATMENT
PROJECTS

***Our water: Safe and abundant
for generations to come***

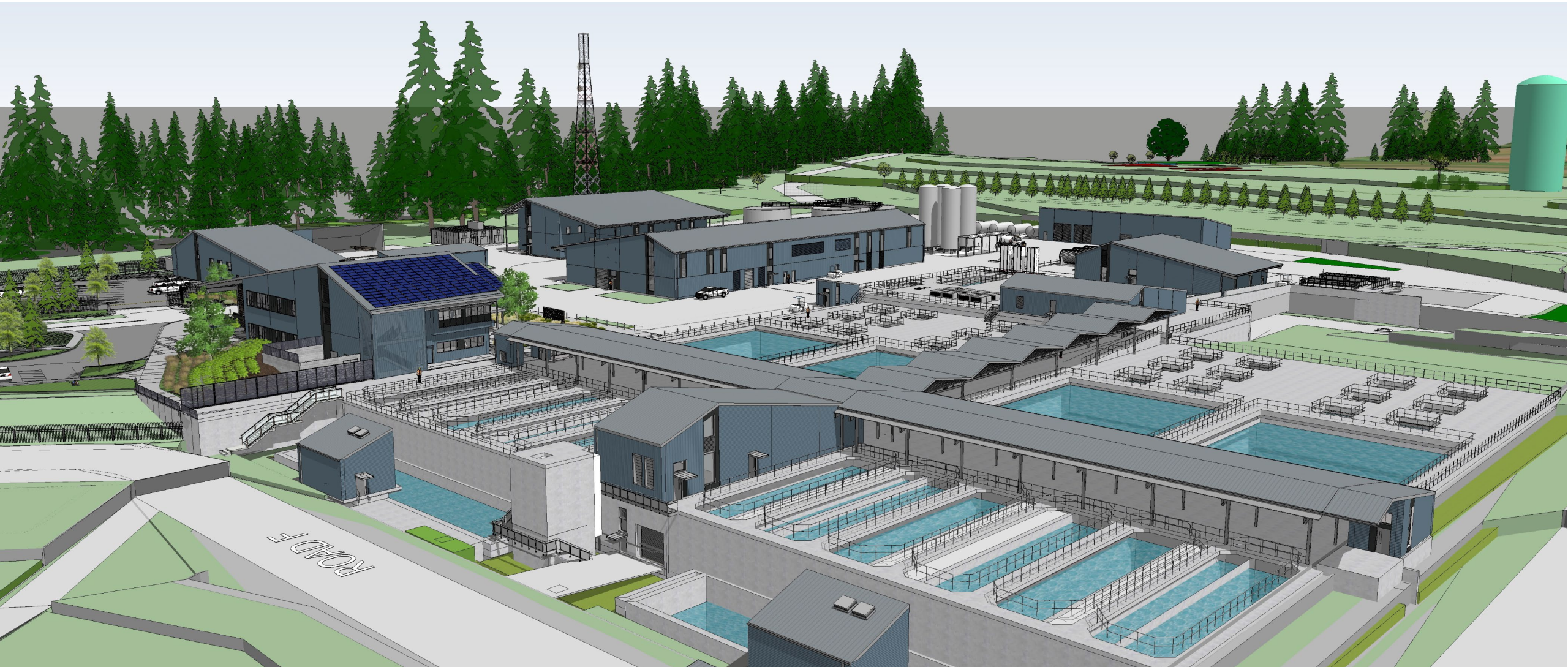
Learn More portland.gov/bullrunprojects

Why filtration?

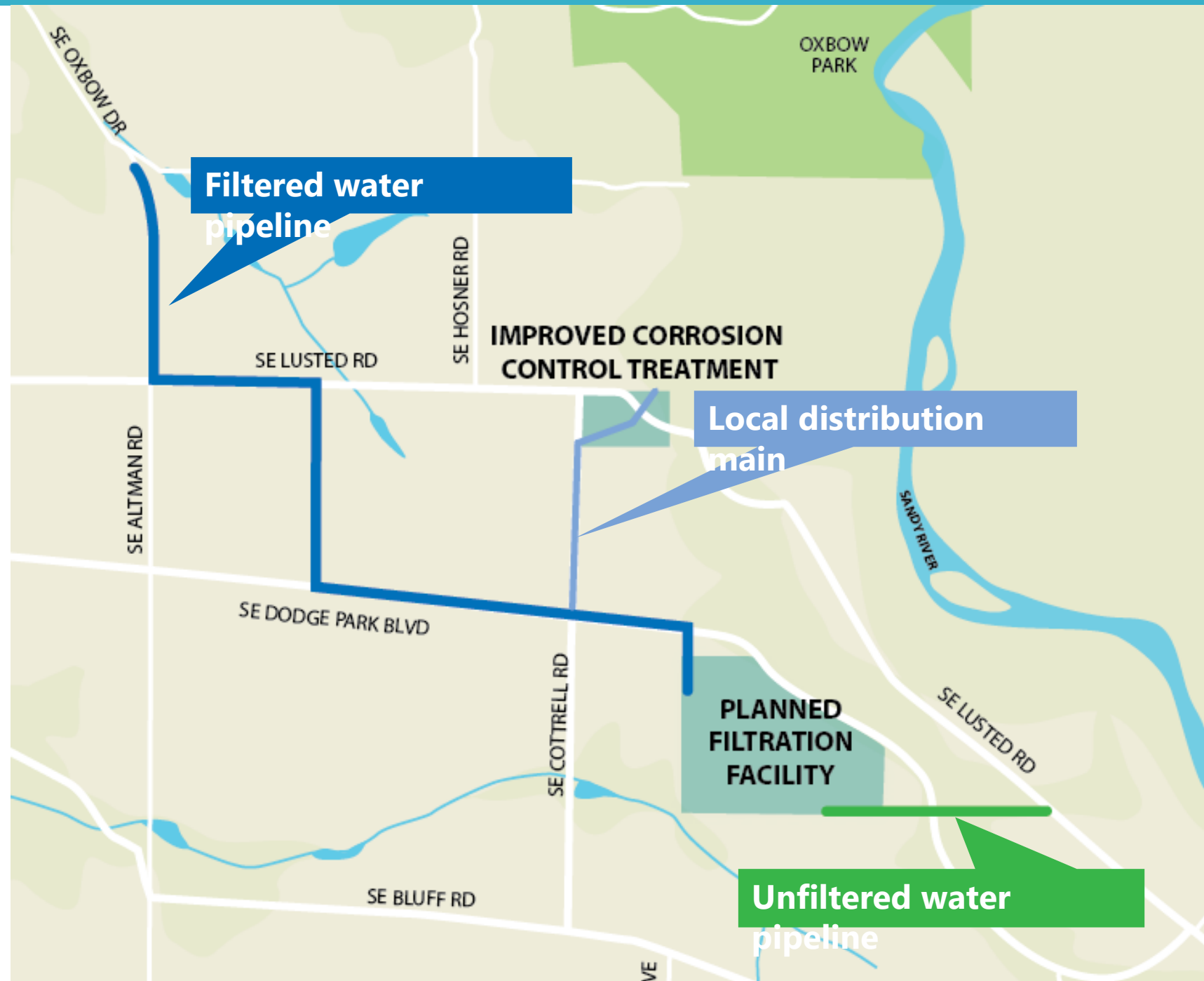
- ✓ Excellent treatment option for *Cryptosporidium*
- ✓ Reduces disinfection byproducts
- ✓ Addresses high turbidity (fire or storms)
- ✓ Addresses algae concerns
- ✓ Keeps sediment out of distribution system
- ✓ Helps prepare for future regulations and emerging contaminants



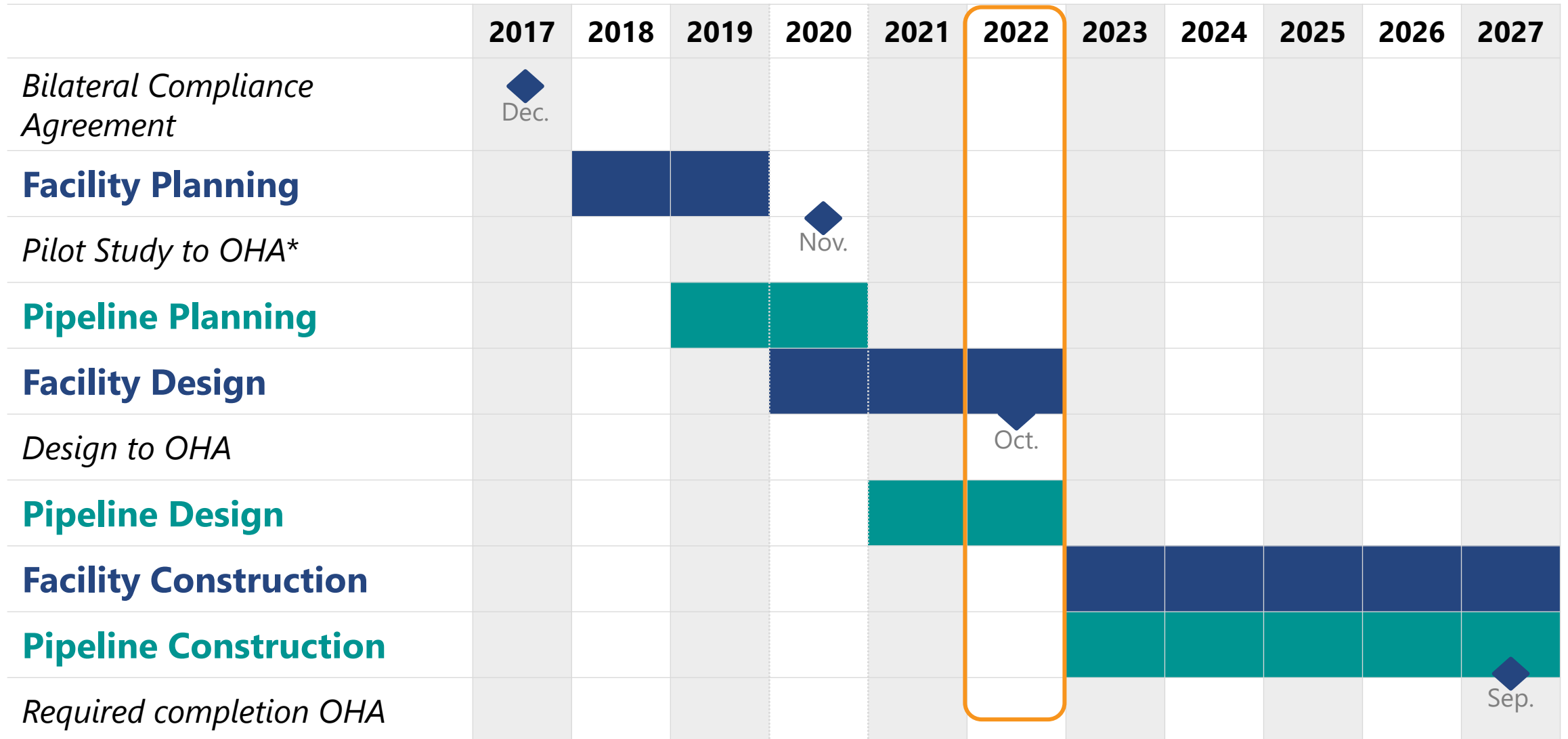
Design of the filtration facility is taking shape



New pipelines will tie the water filtration facility into the existing system

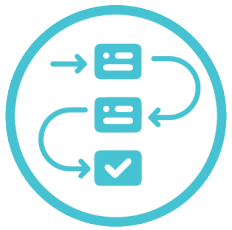


Construction anticipated to start mid-2023



*Oregon Health Authority (OHA)

On track to deliver filtered Bull Run water to customers beginning September 2027



**Planning
Completed
2018-2020**



**Design
Underway
2020-2022**



**Construction
Expected
2023-2027**

