DRAFT

PFAS Management Plan

Prepared for
City of Vancouver
Vancouver, Washington
December 4, 2023

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This is a draft and is not intended to be a final representation of the work done or recommendations made by Brown and Caldwell. It should not be relied upon; consult the final report.

Brown AND Caldwell
6500 SW Macadam Avenue, Suite 200
Portland, OR 97239-3552
T: 503.244.7005

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City of Vancouver:

- Tyler Clary
- Mehrin Selimgir
- Rob Weber
- Patrick Craney
- Brian Wilson

Brown and Caldwell:

- Lynn Stephens
- Joanie Stultz
- Kyle Hay
- Caylin Cyr
- Kelly Kimball
- Mia Vijanderan
- Katie Pollack
- Bill Persich

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List of Abbreviations

µg	microgram
µg/L	micrograms per liter
BC	Brown and Caldwell
CAF	Climate Action Framework
CIP	capital improvement project
City	City of Vancouver
Confluence	Confluence Engineering Group
DOH	Washington Department of Health
Ecology	Washington Department of Ecology
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
GAC	granular activated carbon
gpm	gallons per minute
GSI	GSI Water Solutions
H2O	Help to Others Program
HAL	health advisory level
hp	horsepower
IBWA	International Bottled Water Association
IX	ion exchange
L	liter(s)
lb	pound(s)
LIHEAP	Low Income Home Energy Assistance Program
MCDA	multi-criteria decision analysis
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
mg	milligram(s)
mgd	million gallons per day
mg/L	milligram(s) per liter
MRL	method reporting limit
ND	non-detect
ng/L	nanograms per liter
NSF	National Sanitation Foundation
O&M	operation and maintenance
OSHG	onsite hypochlorite generation
PFAS	per- and polyfluoroalkyl substances
PFBS	perfluorobutanesulfonic acid
PFHpA	perfluoroheptanoic acid
PFHxS	perfluorohexane sulfonic acid
PFNA	perfluorononanoic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonic acid
POU	point-of-use
ppt	parts per trillion
PQL	practical quantitation limit
Qi	instantaneous water rights
RFQ	request for qualifications
ROE	Report of Examination
SAL	state action level
SGA	Sand and Gravel Aquifer
SMCL	secondary maximum contaminant level
UCMR	Unregulated Contaminant Monitoring Rule
UCMR3	third round of the Unregulated Contaminant Monitoring Rule
UCMR5	fifth round of the Unregulated Contaminant Monitoring
WIFIA	Water Infrastructure Finance and Innovation Act
WS	water station
WTP	water treatment plant

Executive Summary

The City of Vancouver (City) has a robust water quality monitoring program that identifies potential impacts to the City's water system. This water quality monitoring program has included a proactive approach for monitoring per- and polyfluoroalkyl substances (PFAS) beyond regulatory requirements. Through that program, the City has detected PFAS concentrations in groundwater wells at or above the 2022 State of Washington state action levels (SAL) and above the Environmental Protection Agency's (EPA) 2023 proposed maximum contaminant level (MCL) for perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA); two out of the 29 PFAS compounds monitored for from the broad family of PFAS. Given the detection of PFAS in the City's water system, the City has developed this PFAS Management Plan to outline the approach to manage PFAS in the drinking water supply and summarize actions the City is taking now.

The objective of this Plan is to lay out the City's implementation steps to achieve compliance with the proposed EPA PFAS MCLs. This plan outlines the steps the City will take to implement PFAS treatment or develop an alternative water source at affected water stations with levels above the proposed MCL. The proposed timeline is based on the anticipated finalization of the EPA's proposed regulation in December 2023, followed by a 3-year compliance window and a two-year extension to implement treatment at all impacted water stations.

Additionally, while there is no requirement for interim measures ahead of the compliance deadline, this Plan outlines proactive measures the City is exploring to provide the City's vulnerable population with options to reduce exposure to PFAS from drinking water as the City works to install large-scale PFAS treatment at specific water stations.

This Executive Summary provides an overview of the Plan as follows:

- PFAS Regulatory Considerations
- PFAS Sampling Results Summary
- Interim Measures to Reduce PFAS Exposure
- Approach to PFAS Management
- Path to Compliance

PFAS Regulatory Considerations

PFAS represent a group of thousands of synthetic chemicals that persist in the environment and are used in a variety of products ranging from fire-fighting foams to coatings on water-repellent fabrics, cookware, and to-go food containers (NIH, 2023). PFAS break down extremely slowly in the environment and are often referred to as "forever chemicals." There is evidence that chronic or long-term exposure to high levels of specific PFAS compounds over many years can have adverse effects on human health (EPA, 2023a).

Table ES-1 summarizes pertinent PFAS regulations, demonstrating how the PFAS limits have become more stringent over time with developments in the testing methods and toxicity research. In 2009, the Environmental Protection Agency (EPA) established health advisory levels (HAL) for perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA). In 2016, the EPA released an updated HAL, which superseded the provisional HALs and set a combined HAL of 70 nanograms per liter (ng/L) for the sum of PFOA and PFOS. Since then, many states have set their own HALs, MCLs and state action levels (SAL), as a result of scientific data that has become available that indicate negative health impacts may occur at lower levels of exposure. In January 2022, Washington's PFAS Rule went into effect and established SALs for five PFAS compounds. The SALs were developed by State toxicologists to protect particularly sensitive groups from the harmful health effects that result from long-term exposure to PFAS. In March 2023, the EPA proposed a National Primary Drinking Water Regulation to establish maximum contaminant levels (MCL) for PFAS compounds in drinking water (EPA, 2023b). In addition to developing proposed MCLs, the EPA also proposed health-based, non-enforceable maximum contaminant level goals (MCLG) for PFAS. Under the proposed regulation, PFOA and PFOS will be regulated as individual contaminants. Alternatively, PFHxS (perfluorononanoic acid), PFNA (perfluorononanoic acid), PFBS (perfluorobutanesulfonic acid), and GenX (hexafluoropropylene oxide dimer acid [HFPO-DA]) was proposed to be regulated as a mixture, referred to as the Hazard Index.

Table ES-1. Pertinent PFAS Advisories and Proposed Regulations (ng/L)

PFAS	2009 Provisional HAL	2016 EPA HAL	2022 EPA HAL	2022 Washington SAL	2023 Proposed EPA MCL	2023 Proposed EPA MCLG
PFOS	200	70 (total of PFOS + PFOA)	0.02[a]	15	4	0
PFOA	400		0.004[a]	10	4	0
PFNA	Not Included	Not Included	Not Included	9	Hazard Index < 1.0[b]	Hazard Index < 1.0[b]
PFHxS	Not Included	Not Included	Not Included	65		
PFBS	Not Included	Not Included	2,000	345		
GenX	Not Included	Not Included	10	Not Included		

a. *Interim health advisory levels.*
b. *The Hazard Index calculation shall not exceed a value of 1.0 and is calculated based on summing the ratio of four PFAS compounds' (PFNA, PFHxS, PFBS, and GenX) measured concentrations compared to each compounds individual health-based water concentration.*

EPA's proposed MCLs are anticipated to become enforceable standards three years from when the regulation is finalized. It is anticipated that the regulation will be finalized in December 2023, and therefore the regulation is expected to become enforceable in December 2026. Utilities may be eligible for a waiver on a case-by-case basis, which would extend the compliance timeline to December 2028.

City PFAS Sampling Results Summary

In 2013, the City sampled its water supply for PFAS as part of a nationwide drinking water utility monitoring program called the Unregulated Contaminant Monitoring Rule (UCMR). UCMR is used to collect data to understand the abundance of specific contaminants in drinking water that do not have health-based standards set under the Safe Drinking Water Act. Under the Third Unregulated Contaminant Monitoring Rule (UCMR3), the City did not detect any PFAS above the method reporting limits, and thus the sampling results were reported as non-detect.

In 2019 and 2020, EPA published new monitoring methods for 29 PFAS compounds. The new methods (Methods 533 and 537.1) allow sampling of PFAS at lower concentrations; an order of magnitude lower than the sampling methods from 2013. The City took a proactive approach to sample for PFAS again in 2020 even though it wasn't required. Utilizing Method 537.1 in 2020, the City completed one round of PFAS sampling of untreated groundwater followed by three additional rounds in 2021. The City has also completed two rounds of regulatory-required sampling in 2023.

The City has analyzed water samples for 29 PFAS compounds. Based on the sampling, the City has detected PFAS in some of the City's groundwater wells and finished water samples. Five water stations, i.e., sites with multiple groundwater wells, have detected PFOS above the 2022 State of Washington SALs in the raw water and eight water stations have detected PFOS at levels above the EPA's proposed MCL in the raw water. One water station, WS14, exceeded the 2022 State of Washington SALs for PFOS and PFOA in the finished water. Only two of 29 PFAS compounds were detected at levels above proposed regulatory requirements. Twenty-one PFAS compounds sampled have not been detected. PFAS sampling results are shared in the City's annual water quality report and customers are notified if PFAS levels are detected over any Washington SALs.

Figure ES-1 shows the water stations impacted by PFAS. Figure ES-1 indicates if the station has detected PFAS above the proposed WA SALs (black star), or above the proposed MCLs and below the WA SALs (purple star) based on raw water sampling. The impacted water stations are supplied by two aquifers: Lower Orchards Aquifer supplying WS1, WS3, and WS4, and Upper Orchards Aquifer supplying WS7, WS8, WS9, WS14, and WS15. The Lower and Upper Orchard Aquifers are within unconsolidated to semi-consolidated sediments associated with deposits from the Columbia River. Generally, it appears there are more wells impacted with higher levels of PFOA and PFOS in the Upper Orchards Aquifer. One exception is WS4, which is the most impacted in the Lower Orchards Aquifer, with levels similar to WS8, WS14, and WS15.

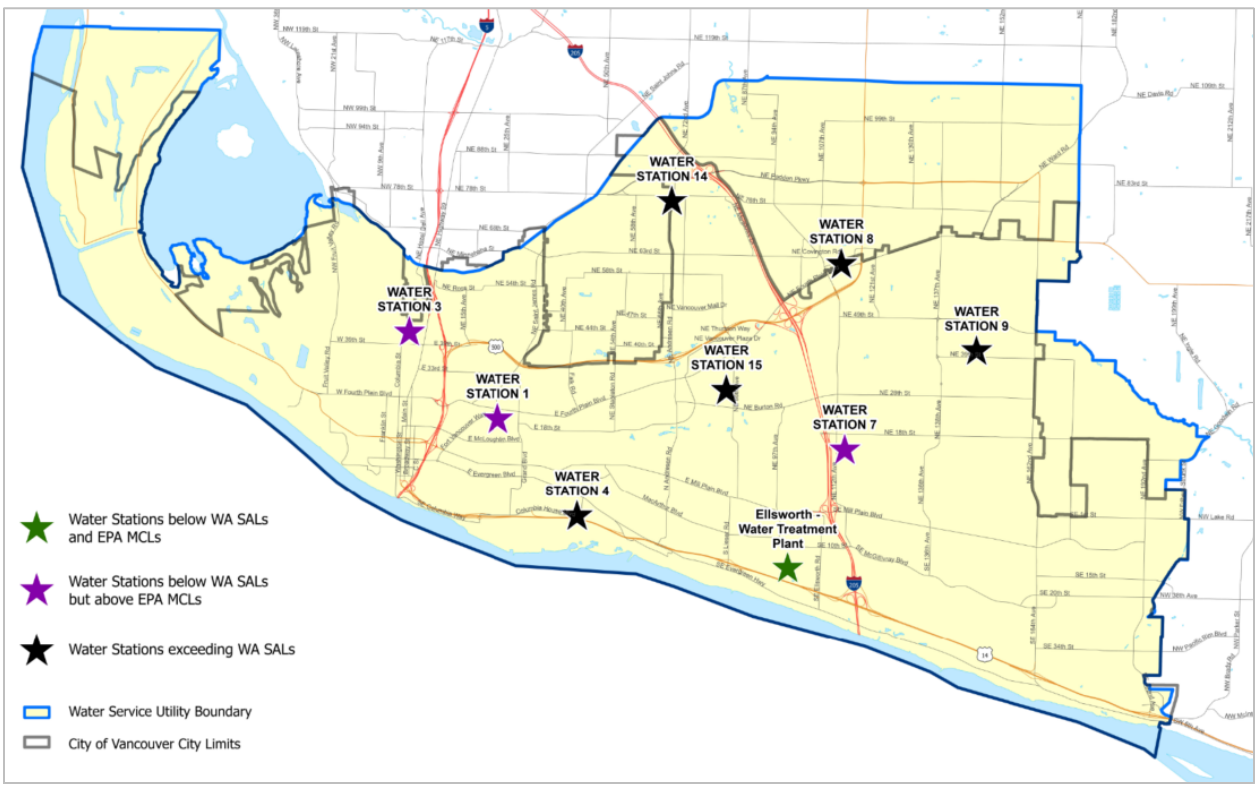

Figure ES-1. City of Vancouver water stations impacted by PFAS

The legend and the depiction of water stations compared to the WA SALs and EPA proposed MCLs is based on any raw water sampling detection.

Identification of PFAS Sources

The City contracted with GSI Water Solutions, Inc. (GSI) and Confluence Engineering Group (Confluence) to model the Upper and Lower Orchards Aquifers to understand PFAS movement in the City aquifers and to evaluate the watershed for any possible PFAS point sources. Groundwater numeric modeling indicated that PFAS contamination has likely occurred over a wider geographic region and further upgradient than the area evaluated in the analysis (Confluence, 2023).

Confluence did not find a source for PFAS contamination for any of the impacted water stations. Confluence recommended further sampling through a PFAS monitoring plan, specifically targeting wastewater liquids and biosolids, septic tanks, and stormwater impoundment structures as potential contamination sources. The City has since contracted with Farallon to conduct a PFAS source evaluation and develop an additional sampling plan.

Interim Measures to Reduce PFAS Exposure

Noting that it will take years to implement full-scale treatment systems, the City evaluated options that could be pursued before full-scale treatment can be implemented at impacted water stations. The evaluation examined measures the City could take to reduce PFAS concentrations in the distribution system by shutting down a selection of wells for a period of time (i.e., curtailment) or wheeling and blending water in the distribution system. While not a regulatory requirement, the City also researched options that could be employed in the interim for vulnerable populations.

Curtailment

The City implemented a plan to prioritize the operation of wells with lower concentrations of PFAS at each water station. The effort highlighted that there are several water stations with multiple wells that have PFOS and PFOA concentrations below the proposed MCL that could be prioritized during times of lower demands, when there is more flexibility with well selection.

In addition to shutting off individual wells, this Plan investigated the ability to shutoff certain water stations. WS15 and WS8 are two of the City's smaller stations with some of the highest PFAS levels. These two water stations can be shut down for periods of time in the future. Shut down of WS15 and WS8 is dependent on operation of other water stations to supplement the flow. Current construction at other stations has prevented the City from shutting down those stations in response to PFAS detections. Once construction is complete and the stations that are offline can be brought online, the City will have the ability to shut down WS15 and WS8 outside of high demand periods.

Blending

WS7 has a unique option to blend down the PFAS concentrations within the water station itself. WS7 is one of the only water stations that is served by a combination of wells from the shallow Upper Orchards Aquifer (Well WS7-1) and the deep Sand and Gravel Aquifer (SGA) (Well WS7-2). No PFAS has been detected from the deep aquifer well (WS7-2), whereas WS7-1 has detected PFOS below the Washington SAL, but above the proposed MCL. The plan is to blend these two wells so that the combined PFOS levels do not exceed the proposed MCL.

Interim Measures for Vulnerable Populations

While not required by EPA or the State, the City is assessing developing a program to mitigate the risk of exposure to PFAS for the City's vulnerable population prior to implementing long-term systemwide PFAS mitigation solutions. The interim measures are envisioned to be in use for 3 to 5 years prior to full-scale treatment implementation at the City's impacted water stations. Vulnerable populations are defined for this Plan as City water users who may not have the financial means to implement their own interim in-home solution if they desire. Qualifying as a vulnerable population is proposed to be based on using the Low-Income Home Energy Assistance Program (LIHEAP) income threshold levels. The City's vulnerable population was estimated to be approximately 2,300 households.

The interim measures evaluated included:

- Point-of-use treatment (e.g., under-sink filters, water pitcher filters)
- Bottled water
- Rebate program
- Pilot treatment unit
- Water filling station

To evaluate the interim measures alternatives and to develop recommendations, a decision-support framework, referred to as a multi-criteria decision analysis (MCDA), was used to engage internal City stakeholders in the decision-making process. A set of criteria was established to score the interim measures, based on the City's values for selecting an option that best serves the community in the interim. Nine criteria were weighted on a percentage basis by stakeholders, representing key City departments, including Engineering, Operations, and Communications, to score each of the alternatives. Scores ranged from 1 to 5 for each criterion with 1 not meeting the criteria and 5 exceeding the criteria. Using the weighted criteria and the criteria scores, a relative benefit score was determined. The relative benefit score for each option was plotted against the 5-year implementation costs to see how the interim measures compare, as presented in Figure ES-2. Alternatives toward the upper left of the chart score the "highest" with the highest relative benefit score and lowest cost.

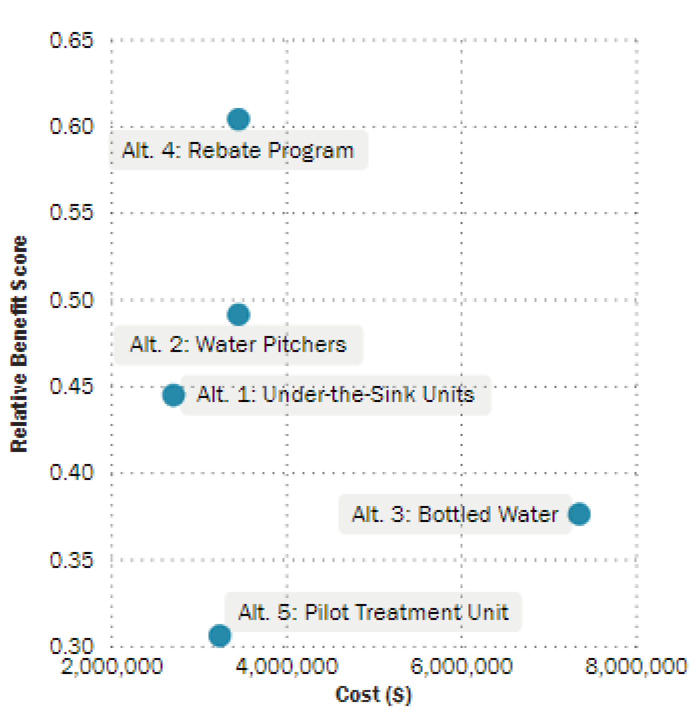

Figure ES-2. Best-value ranking based on cost and relative benefit score

Based on the assessment of the potential interim measures and scoring process, the rebate program scored the highest. This option could provide flexibility for customers to receive assistance for in-home point-of-use filters or bottled water. The next highest scoring options were the water pitchers and the under-the-sink units. The City's next steps will be to present the options to the City Council to gather input on the options, and to develop a plan around the preferred option.

The City is focusing these interim measures on vulnerable populations to assist those who may experience financial challenges in taking interim steps. The City has and will continue to provide guidance on interim measures that all customers can take as treatment improvements come online.

Approach to PFAS Management

The City is taking many actions to address PFAS. Since the first PFAS detections, the City has been committed to taking active steps to mitigate and manage PFAS in the City's water system. Over the past 5 years, as the PFAS regulations and sampling methods evolved, the City has developed an on-going sampling program and a communications outreach to customers, and since then has continued to learn of and assess the impacts in the water system and to plan for future PFAS mitigation. The City has taken the following key steps:

- Completed and implemented a communications plan that included coordination with Clark County Public Health and other local water utilities.
- Completed a PFAS Treatment Feasibility Study in 2022 (BC, 2022) to develop conceptual plans for implementing PFAS treatment at six of the nine water stations.
- Completed bench-scale testing of multiple IX resin and GAC media (HDR, 2023).
- Completed a PFAS source evaluation (Confluence) and on-going groundwater modeling by GSI to try to identify sources of PFAS in the aquifer and understand the plume of contamination (Confluence, 2023).
- Submitted and received a State Revolving Fund grant to design PFAS treatment at WS14.
- Initiated a 12-month pilot study to assess GAC and IX treatment technology (January 2023–anticipated January 2024).
- Initiated design at WS14 for a 3,200-gpm PFAS treatment system and developed design standards for PFAS treatment at other stations.
- Hired new City PM to support PFAS design projects.
- Contracted with Farallon Consulting to identify and sample potential sources of PFAS contamination.
- Completed this PFAS Management Plan to outline the necessary actions to achieve regulatory compliance.

These are just some of the steps the City has undertaken to date. This PFAS Management Plan provides the proposed roadmap for PFAS management.

Path to Compliance

The eight water stations needing treatment cannot be feasibly upgraded simultaneously. Therefore, the projects will need to be phased over the next 5 to 7 years to meet the compliance window. To develop a proposed timeline for implementation, the sites were evaluated against a set of criteria to understand different phasing options and to develop a proposed timeline that balances priorities for the City. The following criteria were used to prioritize the order of capital improvement projects:

- Sites with PFAS concentrations above the Washington SAL
- Sites with high PFAS mass loads to the distribution system
- Dependency on the specific water station to meet future demands
- Spreading capital improvement costs over time
- Equity considerations related to addressing socioeconomic vulnerability in affected neighborhoods

The proposed implementation schedule is presented in Figure ES-3. Estimated durations for design and construction were identified to inform the timeline based on recent local project experience and current anticipated construction windows. Design was estimated to be between 10 to 12 months depending on project size. Given recent long lead times, construction was assumed to be 18 months at a minimum and extended to 24 months for the larger sites (WS1, WS4, and WS9).

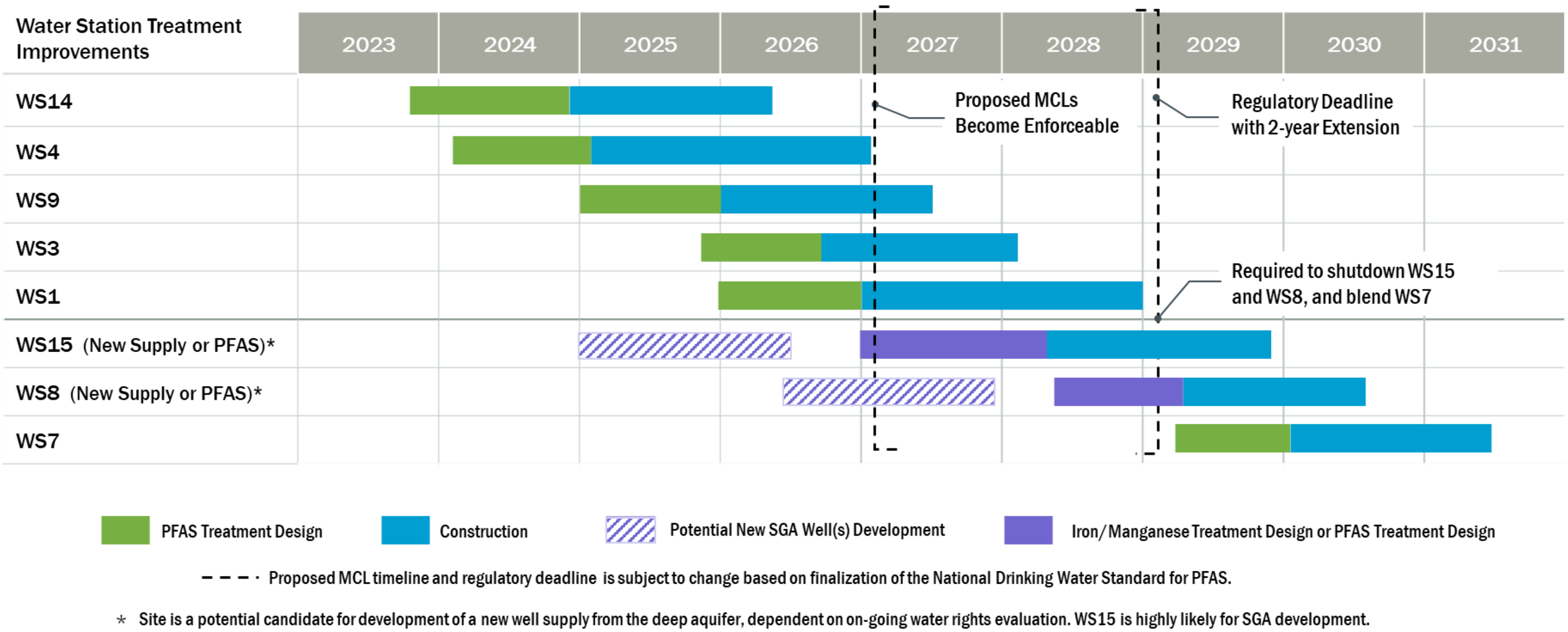

Figure ES-3. Proposed implementation plan for water treatment plant improvements

Table ES-2 presents the planning-level capital cost estimate ranges for treatment at the eight water stations, and the approximate annual operation and maintenance (O&M) costs. The total Class 5 capital cost estimates range from $13.5 million to $46 million (-50/+100 percent) with a total estimated cost of $235 million (-50+/100) for improvements at the eight water stations. The annual O&M costs are estimated to be approximately $1,258,000 annually for operating the new treatment systems. These O&M costs are based on the treatment type improvements outlined in Table ES-2 and these O&M costs do not account for when the treatment system is brought into service. Development of the deep SGA is shown for water station 8 (WS8) and WS15. The City is still determining whether a deeper well supply is added to WS8 and WS15 or PFAS treatment is added.

Table ES-2. Capital and Annual O&M Costs for Proposed Implementation Plan

Water Station	Improvement Type for Estimate [a]	Treatment Capacity (gpm) [b]	Lower Range (-50%)	Estimated Cost	Upper Range (+100%)	Annual O&M Cost [c]
WS14	PFAS Treatment	3,200	$6,800,000	$13,500,000	$27,100,000	$100,000
WS4	PFAS Treatment	10,700	$20,100,000	$40,300,000	$80,600,000	$236, 000
WS9	PFAS Treatment	10,872	$20,600,000	$41,200,000	$82,400,000	$288,000
WS3	PFAS Treatment	6,000	$12,000,000	$24,100,000	$48,200,000	$159,000
WS1	PFAS Treatment	10,000	$22,800,000	$45,600,000	$91,200,000	$236,000
WS15	New Deep Well Supply [d]	4,000	$14,150,000	$28,300,000	$56,600,000	$73,000
WS8	New Deep Well Supply [d]	3,333	$13,050,000	$26,100,000	$52,200,000	$73,000
WS7	PFAS Treatment	3,333	$8,200,000	$16,300,000	$32,600,000	$93,000
		Total	$117,700,000	$235,400,000	$470,900,000	**$1,258,000**

a. Treatment technology selected for planning-level cost estimation only. Selected treatment will be confirmed through future planning and design. PFAS treatment assumes granular activated carbon (GAC) media.

b. Treatment capacities to meet the proposed instantaneous water rights (Qi) based on City's evaluation as of September 14, 2023.

c. Costs are in 2023 dollars. PFAS treatment annual costs include media change out, staff time for typical operations and additional time for media change-out and backwashing, and PFAS sampling costs. Iron/manganese annual costs include media change out, staff time for typical operations, and raw water pumping costs.

d. Cost for new source includes new well drilling, new raw water pumps, and a new water treatment facility with a pressure filter system for iron and manganese removal. The City is still determining whether a deeper well supply is added to WS8 and WS15 or PFAS treatment is added.

This PFAS Management Plan provides the roadmap for achieving compliance with EPA's proposed MCL for PFAS. It presents PFAS sampling results and regulatory considerations, interim measure investigated by the City to reduce PFAS exposure, and the plan for the City to achieve regulatory compliance and reduce levels of PFAS in the water system. Over the next year and into the future, the City will continue to make progress toward managing PFAS to secure a safe and clean groundwater supply.

Section 1

Background

The City of Vancouver (City) has a robust water quality monitoring program that identifies potential impacts to the City's water system. This water quality monitoring program has included a proactive approach for monitoring per- and polyfluoroalkyl substances (PFAS) beyond regulatory requirements. PFAS represent a group of thousands of synthetic chemicals that persist in the environment and are used in a variety of products ranging from fire-fighting foams to coatings on water-repellent fabrics, cookware, and to-go food containers (NIH, 2023). PFAS break down extremely slowly in the environment and are often referred to as "forever chemicals." Over time, PFAS can build up in people, animals, and the environment (EPA, 2023a). There is evidence that exposure to high levels of specific PFAS compounds can have adverse effects on human health (EPA, 2023a).

The City has detected PFAS concentrations in groundwater wells at or above the 2022 State of Washington state action levels (SAL) and above the Environmental Protection Agency's (EPA) 2023 proposed maximum contaminant level (MCL) for perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA); two out of the 29 PFAS compounds monitored for from the broad family of PFAS. The City has taken a proactive approach to identifying PFAS in the water supply. Given that multiple groundwater wells have detected PFAS, the City has embarked on a strategic planning effort to holistically consider the water system and determine an approach to manage PFAS. This PFAS Management Plan summarizes that effort. This PFAS Management Plan includes the following information:

- Section 1: A description of PFAS, background on Washington state and EPA regulations, and historical water quality information.
- Section 2: An evaluation of alternatives to determine the best means to mitigate PFAS contamination.
- Section 3: Interim measures that the City can implement until further mitigation options can be implemented.
- Section 4: Water quality goals.
- Section 5: Criteria for prioritizing sites for PFAS treatment.
- Section 6: A holistic plan and approach for reducing PFAS concentrations throughout the water system.

1.1 PFAS Background

PFAS represent a group of thousands of synthetic chemicals that do not readily degrade and are persistent in the environment, primarily as a result of the very strong and stable carbon-fluorine bond that makes up the PFAS structure. The following section provides an overview of where PFAS come from and their known health effects.

1.1.1 PFAS Sources

PFAS chemicals are known for water repellency, temperature resistance, and friction resistance. They are used in a variety of industrial and chemical uses, including fire-fighting foams, water-repellent fabrics, and non-stick products. The main sources of PFAS in the environment are PFAS manufacturing and processing facilities, airports, and military facilities where fire-fighting foams have been historically used. These uses lead to contamination of surface water, groundwater, soil, and air. PFOS- and PFOA-related chemicals are no longer produced in the United States due to the phaseout of long-chain PFAS; however, they are still developed around the world and enter the United States through consumer goods, such as carpet, textiles, coatings, rubber, and plastics.

1.1.2 PFAS Health Effects

Health risks from a chemical are determined by the hazard of the chemical and the amount of exposure to it. The EPA, the Center for Disease Control's Agency for Toxic Substances and Disease Registry, and the Food and Drug Administration are conducting research to better understand how toxic or harmful PFAS are to humans and the environment.

There is evidence that chronic or long-term exposure to high levels of specific PFAS compounds over many years can have adverse effects on human health (EPA, 2023a). PFAS compounds are chains of carbon and fluorine atoms, and sometimes include oxygen, hydrogen, sulfur, and nitrogen atoms. PFAS compounds with longer chains, such as PFOA and PFOS, are more likely to bioaccumulate in wildlife and humans as compared to short-chain PFAS.

PFOA and PFOS are the most widely produced and studied PFAS chemicals. Studies on the impact of PFAS have found correlations between PFOA and/or PFOS exposure and effects on the immune system, the cardiovascular system, human development, and the suppression of vaccine response in children (Fenton et al., 2021). PFOA is a likely carcinogen. More information on potential PFAS health risks can be found on the EPA's website and the Agency for Toxic Substances and Disease Registry.

Exposure to PFAS is from multiple pathways in differing proportions depending on one's diet, personal habits, home environment, occupation, local air quality, and drinking water, etc. In a review of six studies on the distribution of PFAS exposure, Sunderland et al. (2018) found the majority of exposure to be through diet for both PFOA and PFOS, presented in Figure 1-1, for all studies except one with a larger contribution from food packaging. The study demonstrated that drinking water (tap water) is a smaller proportion of exposure in most cases and is location specific.

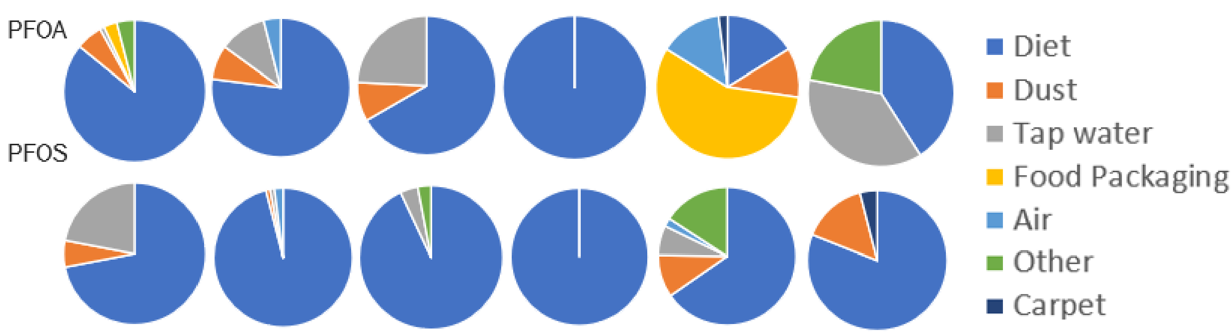

Figure 1-1. Distribution of PFAS exposure in six studies

Source: Sunderland et al. 2018. Each pie chart represents the results of a different study reviewed by the authors

1.2 PFAS Regulations

In 2009, the EPA established health advisory levels (HAL) for PFOS and PFOA. Monitoring for six of the most prevalent PFAS compounds was required for drinking water systems as a part of the third round of the Unregulated Contaminant Monitoring Rule (UCMR3). As a part of UCMR3, required sampling of drinking water from 2013 to 2015 included sampling for the following:

- PFOA
- PFOS
- PFBS (perfluorobutanesulfonic acid)
- PFHxS (perfluorononanoic acid)
- PFHpA (perfluoroheptanoic acid)
- PFNA (perfluorononanoic acid)

During that time, the analytical methods were limited to method reporting limits (MRL) from 10 to 90 nanograms per liter (ng/L) (EPA, 2012). Levels of PFAS present at levels below the MRL would not be detected. Since that time, analytical methods have improved and the MRL for many PFAS has decreased by an order of magnitude, as low as 3 to 5 ng/L, which allows detection of 29 PFAS at much lower levels.

In 2016, the EPA released an updated HAL, which superseded the provisional HALs, and set a combined HAL of 70 ng/L for the sum of PFOA and PFOS (see Table 1-1). Since then, many states have been setting their own HALs, MCLs and SALs as a result of scientific data that has become available, which indicate negative health impacts may occur at lower levels of exposure. In January 2022, Washington's PFAS Rule went into effect and established SALs for five of the six PFAS compounds sampled in the original UCMR3. The SALs were developed by state toxicologists to protect particularly sensitive groups from the harmful health effects that result from long-term exposure to PFAS. The harmful effects include impacts to the immune system and reproductive health, as well as the potential to cause cancer.

The EPA released a PFAS Strategic Roadmap in October 2021, which aimed to establish a national primary drinking water regulation for PFAS. In June 2022, the EPA updated its 2016 HALs for PFAS. As shown in Table 1-1, the new HALs established by the EPA are orders of magnitude lower than those in 2016 and are below currently available lab detection levels.

In March 2023, the EPA proposed a National Primary Drinking Water Regulation to establish MCLs for six PFAS compounds in drinking water (EPA, 2023b). In addition to setting new MCLs, the EPA also proposed health-based, non-enforceable maximum contaminant level goals (MCLG) for these six PFAS. Under the proposed regulation, PFOA and PFOS will be regulated as individual contaminants. Alternatively, PFHxS, PFNA, PFBS, and GenX (hexafluoropropylene oxide dimer acid [HFPO-DA]) was proposed to be regulated as a mixture, referred to as the Hazard Index. The Hazard Index calculation shall not exceed a ratio of 1 based on individual health-based water concentrations for those four compounds, and is calculated based on summing the ratio of four PFAS compounds' measured concentrations compared to each compounds' individual health-based water concentration.

The Hazard Index is calculated as follows:

$$Hazard\ Index = \frac{GenX_{water}}{10} + \frac{PFBS_{water}}{2000} + \frac{PFNA_{water}}{10} + \frac{PFHxS_{water}}{9}$$

The EPA proposed MCLs are based on meeting a running annual average from quarterly samples. Based on the EPA's proposed regulation, it is anticipated that the MCLs will be finalized by December 2023. The proposed MCLs are anticipated to become enforceable standards in December 2026. Utilities may be eligible for a waiver on a case-by-case basis, which would extend the compliance timeline to December 2028.

Table 1-1. Pertinent PFAS Advisories and Proposed Regulations (ng/L)

PFAS	2009 Provisional HAL	2016 EPA HAL	2022 EPA HAL	2022 Washington SAL	2023 Proposed EPA MCL	2023 Proposed EPA MCLG
PFOS	200	70 (total of PFOS + PFOA)	0.02[a]	15	4	0
PFOA	400		0.004[a]	10	4	0
PFNA	Not Included	Not Included	Not Included	9	Hazard Index < 1.0[b]	Hazard Index < 1.0[b]
PFHxS	Not Included	Not Included	Not Included	65		
PFBS	Not Included	Not Included	2,000	345		
GenX	Not Included	Not Included	10	Not Included		

a. Interim health advisory levels.

b. The Hazard Index calculation shall not exceed a value of 1.0 and is calculated based on summing the ratio of four PFAS compounds' measured concentrations compared to each compounds' individual health-based water concentration.

1.2.1 Sampling and Notification Requirements

Per the Washington Administrative Code Chapter 246-290-315, water systems with a PFAS sample result that exceeds a SAL should collect a confirmation sample. If the average of the results from the initial and confirmation sample exceeds the SAL, or if the system does not collect a confirmation sample, the system must notify its customers of the SAL exceedance event. Community water systems must include detections in their consumer confidence reports. If samples are greater than the SAL, the following actions are required:

- The public must be notified.
- The cause must be investigated.
- Action is to be taken as directed.

Per the EPA's Proposed PFAS National Primary Drinking Water Regulation, the City is required to take quarterly samples at the entry point to the distribution system. If results are under 1/3 of the practical quantitation limit (PQL), for example 1.3 ng/L or 0.33 health index, sampling can then be reduced to twice per year, every 3 years. For calculating the running annual average, samples under the PQL will count as zero, and any additional samples will have to be included in the average.

1.2.1.1 Unregulated Contaminant Monitoring Rule 5 Sampling

The fifth round of the Unregulated Contaminant Monitoring Rule (UCMR5) includes 29 PFAS compounds along with one metal. The rule was published at the end of 2021, and the monitoring cycle spans from 2022 to 2026, with sample collection taking place between 2023 and 2025. Since the City of Vancouver's water system relies on groundwater sources, it is required to monitor two times during a consecutive 12-month monitoring period, with each sampling event occurring 5 to 7 months apart. This amounts to six total sampling events during the monitoring period between January 2023 and December 2025. Samples are to be collected at the entry point to the distribution system for all contaminants. When groundwater systems have multiple entry points, a representative sampling location can be used when prior approval is obtained. The City conducted its first round of sampling in the second quarter of 2023.

1.3 Historical PFAS Levels

The City participated in the UCMR3 sampling in 2013, at which time PFAS were non-detect and below the EPA HALs at that time. The samples were non-detect because the measured values were below the laboratory report limits. In 2020, the City completed one round of PFAS sampling followed by three additional rounds in 2021. All samples in 2020 and 2021 were raw groundwater samples, not sampled at the entry point to the distribution system. In 2023, the City completed the first compliance sampling event in March and the second compliance and first round of UCMR5 sampling event in May. State compliance and UCMR5 sampling events were sampled at the entry point to the distribution system.

Table 1-2 summarizes the range of PFOS and PFOA levels detected at City groundwater wells from 2020 to 2021. Eight of the nine water stations (WS) have PFAS detections over the EPA's proposed MCLs for PFOS and PFOA.

Table 1-2. Summary of PFAS detection in City of Vancouver Groundwater Wells (2020-2021)[a]

Water Station[b]	Aquifer	Current Capacity (gpm)	Number of Wells with PFAS Detection > MCL/ total number of wells[c]	Wells with PFOS > MCL (4 ng/L)	Wells with PFOA > MCL (4 ng/L)	Range of Detections for PFOS[d] (ng/L)	Range of Detections for PFOA[d] (ng/L)
WS1*	Lower Orchards	23,400	9/10	8	1	2.4 – **6.3**	ND – **5.4**
WS3*		6,000	3/3	3	1	**5.9 – 15.0**[e]	1.6 – **5.0**
WS4*		8,550	6/6	6	6	**14.0 – 25.0**	**5.5 – 14.0**
WS7*	Upper Orchards	1,300	1/2	1	0	**4.9 – 8.7**[f]	ND – 3.0
WS8*		1,250	2/2	2	2	**15.0 – 20.0**	**6.4 – 8.5**
WS9*		9,800	5/5	5	5	**12.0 – 17.0**	**4.9 – 7.2**
WS14*		3,200	3/3	3	3	**19.0 – 27.0**	**11.0 – 19.0**
WS15*		1,000	3/3	3	2	**9.4 – 20.0**	2.6 – **5.0**
Ellsworth	Sand and Gravel	6,000	0/3	0	0	ND	ND

a. *PFAS results from voluntary sampling in September 2020, February 2021, and July 2021 for all water stations, and two supplemental samples in April 2021 for well WS4-1 and WS14-3 only.*

b. *Water stations with PFAS detection above proposed MCL are indicated by an *.*

c. *Only includes operational wells*

d. *Values in **bold** are above the proposed MCL.*

e. *one sample to date with PFOS at 15 ng./L. All other samples have been closer to 6 ng/L.*

f. *Values shown are for Well 1 only from WS7. Well WS7-2 (Well 2B) is in the deep Sand and Gravel Aquifer (SGA) and has no PFAS detections.*

gpm = gallons per minute

ND = non-detect

Figure 1-2 shows the water stations impacted by PFAS, and indicates if the station has detected PFAS above the proposed WA SALs (black star), or above the proposed MCLs and below the WA SALs (purple star) based on raw water sampling. The impacted water stations are supplied by two aquifers: Lower Orchards supplying WS1, WS3, and WS4, and Upper Orchards supplying WS7, WS8, WS9, WS14, and WS15. The Lower and Upper Orchard Aquifers are within unconsolidated to semi-consolidated sediments associated with deposits from the Columbia River. The aquifers are generally recharged by stormwater runoff from rainfall infiltration, dry wells, septic tank return flows, and infiltration from rivers and other surface water bodies. The Ellsworth Water Treatment Plant (WTP) is served by the deep Sand and Gravel Aquifer (SGA), which has been non-detect for all PFAS compounds, with the exception of low detections in February 2021, which are attributed to lube water running back into the well from the distribution system.

Generally, it appears there are more wells impacted with higher levels of PFOA and PFOS in the Upper Orchards Aquifer. One exception is WS4, which is the most impacted in the Lower Orchards Aquifer, with levels similar to WS8, WS14, and WS15.

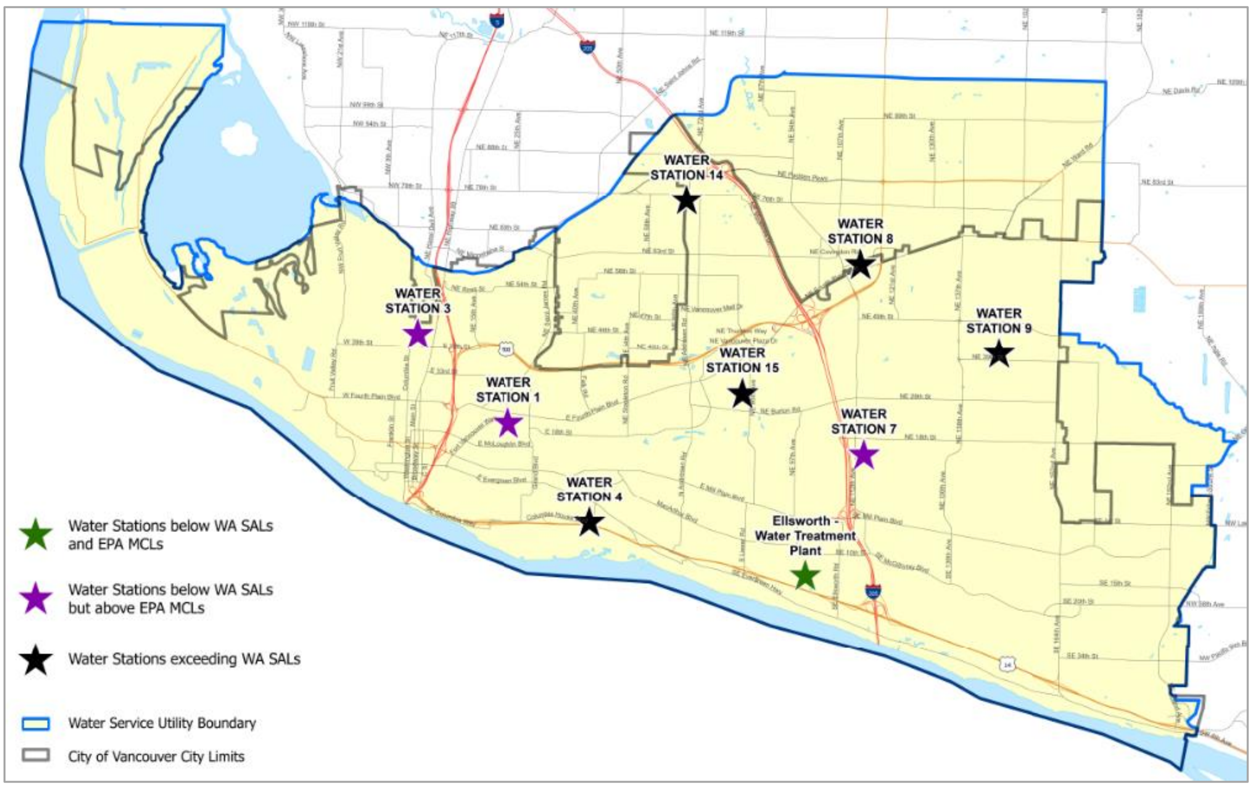

Figure 1-2. City of Vancouver water stations impacted by PFAS

The legend and the depiction of water stations compared to the WA SALs and EPA proposed MCLs is based on any raw water sampling detection.

Individual wells were sampled in September 2020, February 2021, and July 2021. These samples are of raw water, taken prior to any chemical addition or treatment. Each water station, with the exception of WS-7, was sampled again in March 2023 for Washington (WA) Department of Health (DOH) compliance. These samples are finished water, taken at the entry point to the distribution system. Additionally, each water station, with the exception of WS7, was sampled in May 2023 for UCMR5 monitoring, testing for the 29 PFAS compounds required by the UCMR5 sampling program.

These samples are finished water, taken at the entry point to the distribution system. Finished water samples are a composite of all wells at that water station. Only WS14 exceeded the Washington SALs for PFOS and PFOA. PFNA was not detected in any of the water station samples. PFHxS was detected 10 times lower than the Washington SALs. PFBS was 100 times lower than the Washington SALs. All of the other PFAS compounds were non-detect for all samples, indicating that the PFAS compounds detected at the water stations to date are the compounds included in the proposed EPA National Primary Drinking Water Regulation for PFAS.

Average PFAS levels by water station (from 2020 to 2023) are summarized in Figure 1-3 to Figure 1-6. for PFOA, PFOS, PFBS, and PFHxS, respectively. Sample results in 2020 and 2021 are an average of multiple wells for water stations that had multiple wells operational. Sample results in 2023 are finished water samples from each water station. The EPA-proposed MCL is referenced on the plots for PFOA and PFOS. The EPA's individual Health-based Water Concentrations used to calculate the Hazard Index level is referenced on the plot for PFHxS. In general, if a sample is not shown for a specific date and water station, the results were less than the MRL. PFNA is non-detect for most of the sample results; therefore, a chart for those results is omitted from the summary. HFPO-DA (also referred to as GenX) was non-detect in samples collected in September 2020 and is therefore not presented in a chart in this summary. May 2023 UCMR5 sample results are consistently lower than previous samples for all PFAS compounds across all water stations. This can be attributed to a different laboratory analyzing the UCMR5 samples.

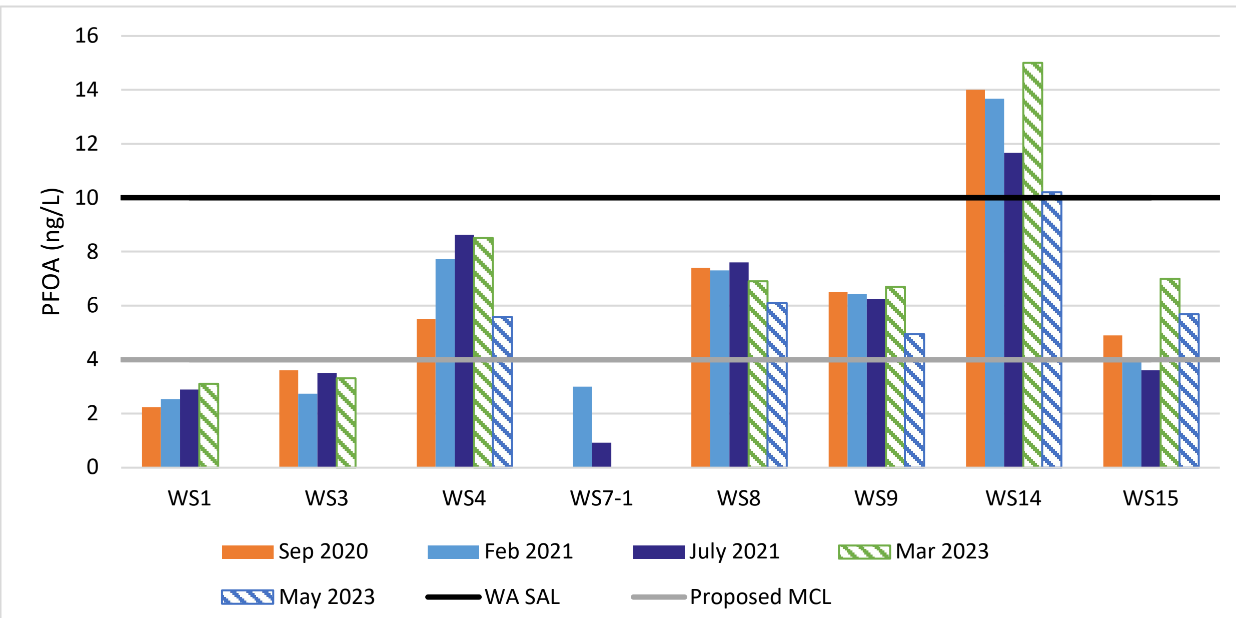

Figure 1-3. PFOA levels detected from City water stations (2020–2023)

Hatched bars indicate finished water samples. Solid bars indicate raw water samples. Raw water samples represent an average value of the wells sampled. WS7 was not sampled in 2023.

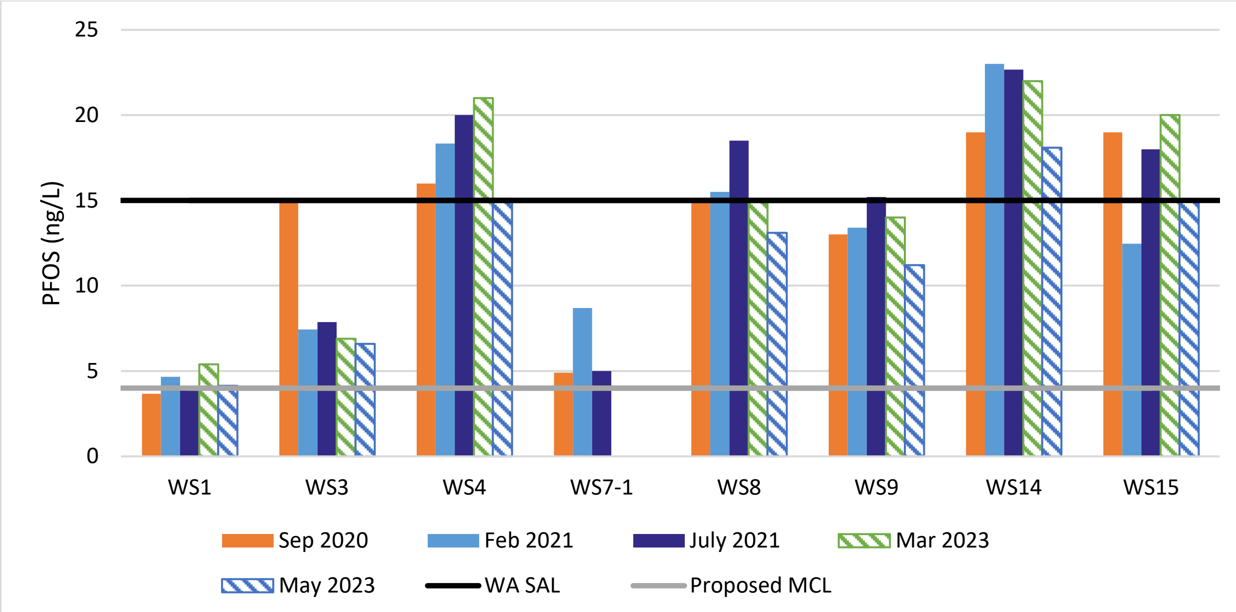

Figure 1-4. PFOS levels detected from City water stations (2020–2023)

Hatched bars indicate finished water samples. Solid bars indicate raw water samples. Raw water samples represent an average value of the wells sampled. WS7 not sampled in 2023.

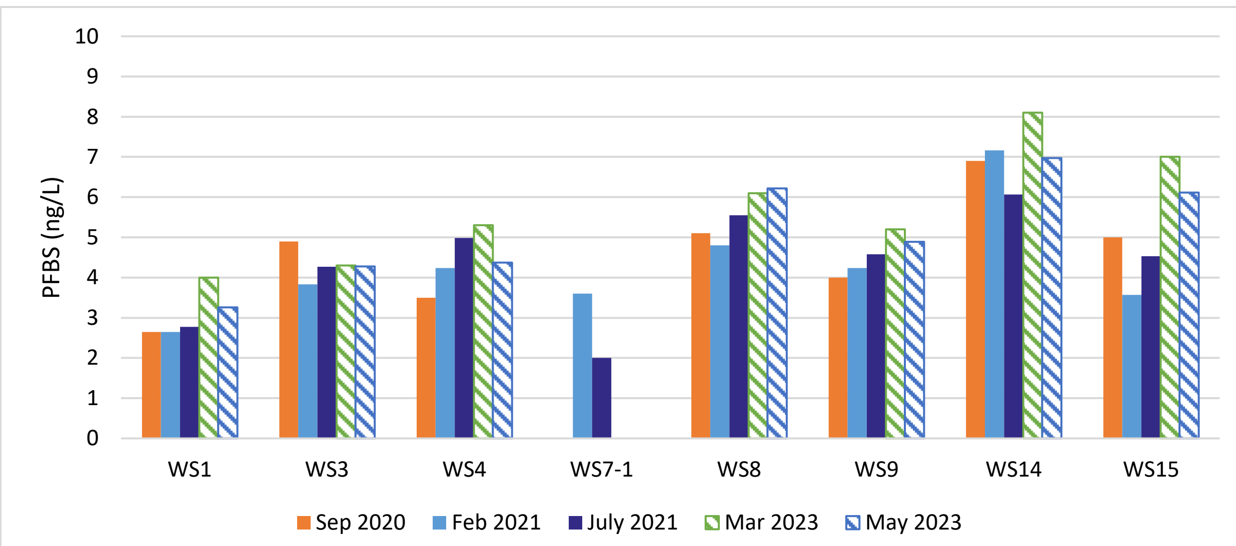

Figure 1-5. PFBS levels detected from city water stations (2020–2023)

Note: The Hazard Index individual health-based concentration for PFBS is 2,000 ng/L. Hatched bars indicate finished water samples. Solid bars indicate raw water samples. Raw water samples represent an average value of the wells sampled. WS7 not sampled in 2023.

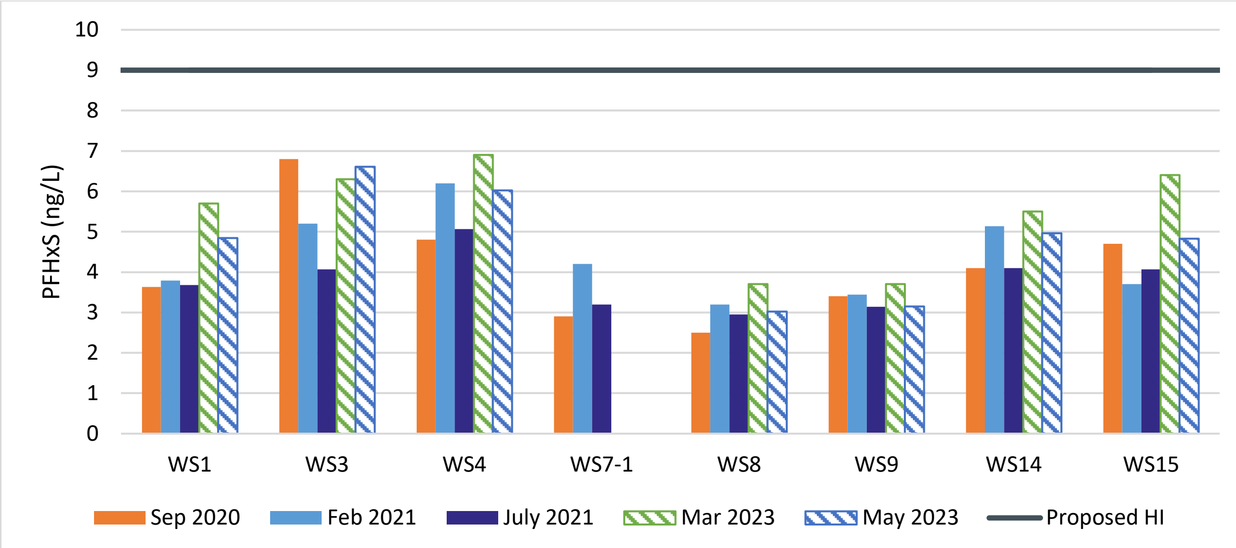

Figure 1-6. PFHxS levels detected from City water stations (2020–2023)

Note: The Hazard Index individual health-based concentration for PFHxS is 9 ng/L, abbreviated on the plot as "Proposed HI". Hatched bars indicate finished water samples. Solid bars indicate raw water samples. Raw water samples represent an average value of the wells sampled. WS7 not sampled in 2023.

The average PFAS results are included in Table 1-3. These values are an average of 2020, 2021, and March 2023 results. The May 2023 results were omitted because they were analyzed by a different laboratory, and are consistently lower than previous samples for all PFAS compounds across all water stations.

Table 1-3. Average PFAS Results[a]

Water Station	PFOS	PFOA	PFBS	PFHxS	PFNA
WS1	4.4*	2.7	3.0	4.2	0.0
WS3	9.3*	3.3	4.3	5.6	0.0
WS4	18.8*	7.6*	4.5	5.7	0.5
WS7[b]	6.2*	1.3	1.9	3.4	0.0
WS8	16.0*	7.3*	5.4	3.1	0.6
WS9	13.9*	6.5*	4.5	3.4	0.0
WS14	21.7*	13.6*	7.1	4.7	0.0
WS15	17.4*	4.9*	5.0	4.7	0.0
Ellsworth	ND	ND	ND	ND	ND

a. Average PFAS results from samples collected in 2020, 2021, and March 2023.

b. Sampling at WS7 included only Well 1. Well WS7-2, which draws from the SGA, had non-detect samples

*c. Samples with an asterisk * were detected over the proposed MCL.*

ND= non-detect

With the Hazard Index now proposed by EPA, the results for the contributing compounds were assessed against their individual health-based concentration levels, and the hazard indices were calculated for each water station based on sampling results from September 2020 through July

2021 from the individual wells and March 2023 entry point to distribution system compliance samples. The calculated Hazard Index for each water station is presented in Figure 1-7, compared to the Hazard Index limit of 1.0.

For PFBS, the detections are orders of magnitude below the Hazard Index's individual health-based concentration, so it is not shown on Figure 1-7 in order for the sampling results to be distinguishable. While there were some PFNA results greater than the detection level, there were no results higher than the reporting level, and therefore the results were omitted from the calculation. PFHxS is the closest PFAS to its health-based water concentration, and therefore had the largest contribution to the Hazard Index.

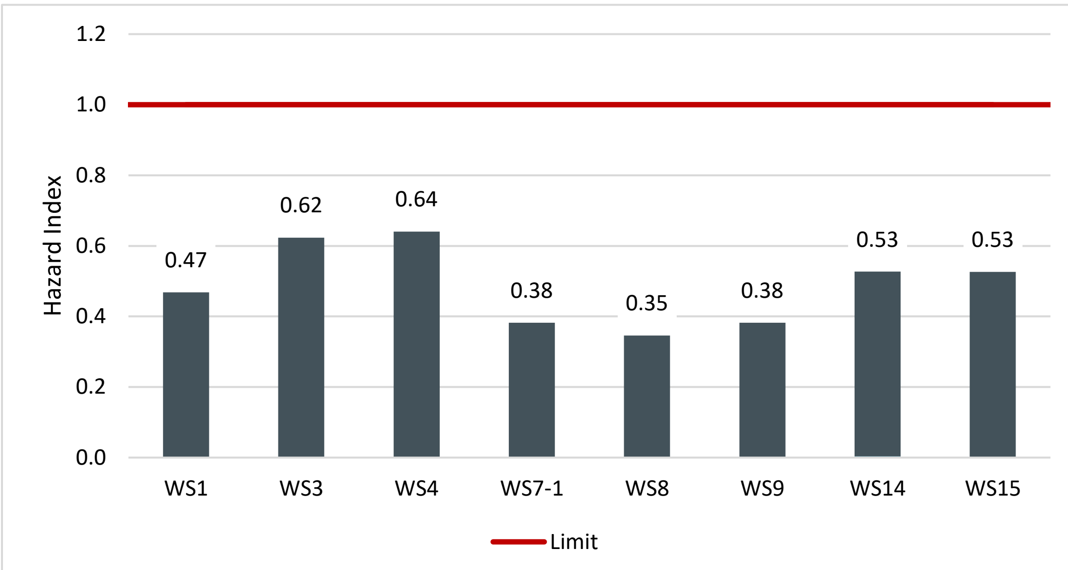

Figure 1-7. Calculated Hazard Index for City water stations (2020–2023)

Note: Results for PFNA were below the reporting limit and were omitted from this calculation

All of the Hazard Index values for each water station are less than the proposed regulatory limit of 1.0. The greatest Hazard Index value is 0.64 from WS4. This result demonstrates that the PFAS compounds that are driving regulatory compliance are PFOS and PFOA, and not PFBS, PFHxS, or PFNA.

1.4 City Monitoring Programs

Regulatory compliance sampling for WADOH began in 2023 for compliance monitoring with the WA SALs. The results from the sampling in 2023 will determine ongoing monitoring frequency. Water stations with low levels (<20 percent of SAL) will be sampled once every 3 years. Water stations with PFAS levels >20 percent but <80 percent of the SAL will be sampled once annually. Water stations with PFAS levels >80 percent of the SAL will be monitored quarterly. Customers will be notified if PFAS levels are detected over the SAL. PFAS results will be included in the annual water quality report. The primary PFAS compounds of concern are PFOS and PFOA in the City's supply. Those two compounds are detected at the highest levels of the PFAS compounds detected to date.

Given that multiple groundwater wells have detected PFAS, the City has embarked on a strategic planning effort to holistically consider the water system and determine an approach to manage PFAS. This PFAS Management Plan provides the approach to addressing PFAS found in the City's source water.

Section 2

Alternatives Evaluation

This chapter outlines the options considered by the City to manage PFAS contamination from the impacted groundwater wells. The alternatives considered include:

- Remediation of point sources with pump-and-treat systems.
- Alternative water sources, specifically drilling deeper to the SGA.
- PFAS treatment of groundwater sources at the impacted water stations.

The tradeoffs between the options are presented in this section, followed by overall implementation recommendations.

2.1 Remediation of Point Sources

PFAS can typically be found near military sites or fire-fighting training facilities where PFAS-based flame retardants were used. GSI Water Solutions, Inc. (GSI) completed hydrogeologic modeling of the Upper Orchards and Lower Orchards aquifers to assess area of influence to try to identify areas where PFAS sources could be contributing. Confluence Engineering Group (Confluence) developed a PFAS monitoring plan to assist the City in investigation of possible PFAS sources (Confluence, 2023). The City has continued this effort to identify and test potential sources with Farallon Consulting.

2.1.1 Plume Modeling

GSI used three-dimensional numerical groundwater modeling to evaluate the areas of influence (i.e., the areal extents/locations of the capture zones) for City water stations, and estimated groundwater travel times to City water stations that have experienced PFAS detections. The numerical modeling work incorporated the City's water stations data into the refinement of an existing groundwater flow model that encompassed the Portland Geologic Basin, which includes the entire City water service area and other portions of Clark County located south of the East Fork Lewis River.

The WS14 capture zone showed a possible influence from the Leichner Landfill. Particle-trace analysis did not find water station areas that overlapped, indicating that PFAS contamination has likely occurred over a wider geographic region and further upgradient than evaluated in the analysis (Confluence, 2023)

2.1.2 Point Source Identification

The City contracted with Confluence to evaluate the watershed for any possible PFAS point sources. For this effort, Confluence reviewed the City's current monitoring programs and conducted data review and analysis to identify potential/likely sources. Using information from previous studies, Confluence compiled a table of potential PFAS point sources. These sources include metal finishing companies, transportation companies, businesses that rely heavily on chemicals, landfills, septic systems, and historical fire events.

Confluence did not find a point source for any of the impacted water stations. Confluence recommended further sampling through a PFAS monitoring plan. In particular, wastewater liquids and biosolids, septic tanks, and stormwater impoundment structures have been identified as potential contamination sources. Since it has been determined that domestic wastewater can have high levels of PFAS, it was recommended that wastewater streams and septic tank pumping trucks servicing the Vancouver area be sampled. If these two sources are found to be significant contributors of PFAS, the City can use this information for long-term planning of wastewater handling strategies. Stormwater has the potential to be a high contributor of PFAS as most systems have subsurface disposal. Sampling in stormwater impoundment structures could also help identify potential PFAS hotspots and point sources.

2.1.3 Remediation Options Summary

Since no point source has been identified, there are no remediation options to consider at this time. The City advocates for all active contaminated sites within the Vancouver water service area to include PFAS in their next sampling event. This would cast a wide net that may identify a point source.

If a future point source is identified, it can typically be remediated with a pump-and-treat system. A pump-and-treat system consists of groundwater pumps and an aboveground treatment system. Treated water is often reinjected into the well or discharged to another water source. Over time, the source of the contamination can be removed from the water supply. Point source treatment would require either a granular activated carbon (GAC) treatment system or strong base ion exchange (IX) to remove PFAS. This alternative can only be implemented if a point source is identified.

2.2 New Supply Development

With the current groundwater supply impacted by PFAS contamination, an alternative approach to PFAS treatment at the existing water stations is to evaluate the options for new water sources. The City water supply is served by three aquifers: Lower Orchards, Upper Orchards, and the deep Sand and Gravel Aquifer (SGA). The Lower and Upper Orchards unconfined aquifers are impacted by PFAS, whereas the SGA has been non-detect generally for all PFAS compounds with the exception of low detections in February 2021, which can be attributed to lube water running back into the well from the distribution system. An alternative option to implementing PFAS treatment at all the impacted water stations would be to drill deeper into the SGA to increase production from the deep aquifer and reduce reliance on the shallow aquifer supply. This section outlines the considerations for this alternative option, including water quality considerations, water rights and availability, and new supply development and treatment.

2.2.1 Water Quality Considerations

Of the City's current water supply, the Ellsworth Water Station and WS7 (Well WS7-2, also referred to as Well 2B, only) are the only water stations that use the SGA as its supply source. Other municipalities in the Columbia River Basin also withdraw water from this aquifer and have similar water quality. Table 2-1 summarizes raw water quality from Ellsworth Water Station wells that are representative of the deep aquifer water quality. It is assumed that if the wells were drilled deeper at the other City water stations that the expected water quality would be similar.

Table 2-1. Raw Water Quality for the Ellsworth Water Station						
Water quality parameters	Units	Average[a]		Minimum[b]	Maximum[b]	MCL
		July 2012 (at well start-up)	December 2015 (3 to 5 months after startup)			
pH	value	7.0	7.7	7.0	7.8	6.5 – 8.5[c]
Total Dissolved Solids	mg/L as $CaCO_3$	163	150	121	178	500[c]
Conductivity	µm or µS/cm	226	208	168	247	
Hardness	mg/L as $CaCO_3$	80	96	72	120	
Calcium	mg/L as $CaCO_3$	56	52	32	72	
Magnesium	mg/L as $CaCO_3$	24	44	24	48	
Chloride	mg/L as Cl	13.1	17.0	12.4	18.8	250[c]
Nitrate	mg/L as N	2.4	2.3	0.6	4.0	10
Iron	mg/L as Fe	0.57	0.51	0.06	0.99	0.3[c]
Manganese	mg/L as Mn	Non-detect	0.5	0.2	0.7	0.05[c]
Sulfate	mg/L as SO_4	8	7	7	9	250[c]
Silica	mg/L as SiO_2	52.6	56.1	48.7	59.7	
Total Organic Carbon	mg/L	0.5	0.6	0.2	0.7	

a. Raw water quality results from well sampling for Ellsworth Water Station from two events: July 2012 after the well start-up for Wells 1, 2, and 3; and December 2015 approximately 5 months after Well 1 start-up and 3 months after Well 2 start-up. Well 3 was not sampled in December. The results were sampled from the casing.

b. Minimum and maximum of the two sampling events in July 2012 and December 2015.

c. National Secondary Drinking Water Standards are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. The EPA recommends secondary standards but does not require systems to comply with secondary MCLs.

µm or µS/cm = micrometers or microsiemens per centimeter
$CaCO_3$ = calcium carbonate
mg/L = milligrams per liter

Raw water from the deep aquifer contains high levels of manganese. The maximum recorded manganese result was 0.7 mg/L as Mn, which exceeds the secondary maximum contaminant level (SMCL) of 0.05 mg/L as Mn. High manganese levels in source water are relatively common and there are many strategies for removing manganese (typically paired with iron) from water. Pressurized filter vessels with a media, such as Pryolox Advantage, is recommended to reduce the manganese levels to below the SMCL in a new deep aquifer supply, like the current treatment at the Ellsworth Water Station and WS7 Well 2B.

Silica levels are also elevated. Silica is an essential nutrient for animals and is related to bone development. In the presence of magnesium, silica can form scale in boilers and turbines. Concentrations greater than 30 mg/L are considered high. All City sources have silica levels between 45-60 mg/L as SiO_2. The EPA has not established a SMCL for silica. Currently, the City does not treat for silica at the Ellsworth Water Station. Therefore, silica treatment was not included in the deep aquifer treatment costs discussed in Section a.a.

2.2.2 Water Rights and Permitting Considerations

The City is evaluating options for changing existing water rights between water stations and to different aquifers, including new supply wells in the SGA. Based on the alluvial aquifer characteristics of the aquifer system and discussions with Washington Department of Ecology (Ecology) and GSI, the SGA and overlying alluvial aquifers are considered the same body of groundwater, allowing water rights to be shifted and consolidated, so long as the total water rights are not exceeded and no impairment is caused.

The City has submitted a water rights application to Ecology to consolidate all existing water rights making them supplemental to each other. The water budget neutral application does not increase either instantaneous pumping rates or annual water right quantities. Although this approach does not increase the City's water rights, it would allow distributing use of the existing authorized withdrawals among other well locations (points of withdrawal) within the water system. Priority dates would be maintained under the individual water rights under the consolidation permit. Moreover, no additional points of withdrawal or locations are requested with the application. However, the City is exploring options for and the feasibility of redistributing some of its well pumping operations to deeper alluvial aquifer units that have less PFAS risks. Water Resources Policies includes POL 1021 Priority Processing – Water Budget Neutral Projects would apply to this effort.

The City has requested a Cost Reimbursement Agreement to have GSI perform a Report of Examination (ROE). This ROE would document results from the hydrogeologic analyses for the planned new/replacement well pumping scenarios listed under this PFAS Management Plan. Results from the pumping scenarios must demonstrate no impairment to senior water rights, including surface water bodies having instream flows or closures. The consolidation approach also would include an analysis to quantify other potential detrimental impacts and identify potential mitigation alternatives.

Ecology reviews and decides whether to approve the consolidated water rights application based on the ROE findings. The process timeline is unknown at this time but can be on the order of 12 months or more. The processing mechanism and timeline are dependent upon Ecology to execute the Cost Reimbursement Agreement and approve the Application resulting in a (new) Permit.

The consolidated water rights application is a unique process that has been used by Ecology Southwest Region Office that works administratively like a water right change application. In this process, the City does not lose the "perfected" status of any of their water right certificates. The permit and ROE impairment analysis could be used to authorize construction and use of new wells in any aquifer. Furthermore, with issuance of the permit, the City would have the option to construct new/replacement wells within the authorized points of withdrawal through a Showing of Compliance.

Additional risks of new supply development of the SGA are discussed in Section 2.4.1, followed by details of the City's on-going water rights evaluation in Section 2.5.

2.2.3 New Supply Water Treatment

Development of a new well in the SGA would not eliminate the need for new treatment. The SGA is a confined aquifer with elevated levels of iron and manganese, both naturally occurring. If the SGA is developed as an alternative source, treatment for iron and manganese would be needed.

Due to the elevated levels of iron and manganese in the deep aquifer, treatment of this source would require filtration to reduce iron and manganese levels to below the SMCL. There are different filter media options, including greensand, pyrolusite, and other proprietary media like Pyrolox Advantage, of which all are a type of filter media used in pressurized filter vessels that are specifically designed to remove iron and manganese. Development of a new groundwater source would require drilling a new well, installing a new raw water pump, and constructing a new treatment facility that includes pre-treatment and filtration.

Since the SGA is located below the Lower and Upper Orchards aquifers, the new wells would need to be drilled much deeper than the existing shallow wells. Once the well is drilled, a new ~~submersible~~ well pump would be installed (e.g., submersible pump or vertical turbine pump). The pump would deliver raw water to the treatment plant. The pump could be operated with a variable-frequency drive. A building would be constructed to house the pump as well as all required instrumentation and controls. Due to the depth of the well, this would be a high horsepower (hp) pump (likely greater than 300 hp).

For this option, raw water from the well would be dosed with caustic soda (sodium hydroxide) for pH adjustment, sodium hypochlorite for disinfection and oxidation, and potassium permanganate for oxidation. Oxidation enables the manganese to be removed by the Greensand filter media, and pH adjustment helps with the kinetics (speed of reaction) of the process. Sodium hypochlorite would be dosed in sufficient quantities to maintain a chlorine (disinfectant) residual throughout the treatment process and in the distribution system.

After chemical addition, the water would be filtered with an iron/manganese filtration system (e.g., ATEC filter unit). Post-filtration, there could be a need for additional corrosion control treatment, which would depend on the specific water quality and an assessment of distribution system water quality impacts. If corrosion control treatment is needed, then the system would require chemical storage and a feed system.

The treatment process may be housed in a new building, typically a concrete masonry unit building, depending on the specific type of filters used. Filter units can be housed outside as well, like at the City's existing Ellsworth WTP. For cost estimation of the proposed new supply option, a building was assumed to contain all of the chemical storage and feed systems, the pressurized filter vessels, and all required instrumentation and monitoring equipment. Since some water stations are currently dosed with sodium hypochlorite for disinfection and may be sized adequately to support additional demand, these systems can be reused in the new treatment systems if this option is implemented. Sites where gas chlorination is still in use will be converted to onsite sodium hypochlorite generation (OSHG) before or during treatment system installation.

A summary of tradeoffs and costs between options for new supply development compared to PFAS treatment at the impacted water stations are provided in Section 2.4.

2.3 PFAS Treatment of Existing Source Water

Rather than adding a new source, one option to address elevated PFAS levels is to implement PFAS treatment at each of the impacted water stations. Brown and Caldwell (BC) previously assisted the City with a preliminary evaluation of the feasibility to add PFAS treatment at six water stations, determined based on elevated PFAS levels above the Washington SAL's prior to release of the proposed MCL. The PFAS Treatment Feasibility Study (BC, 2022) included a conceptual site-specific evaluation to identify site constraints, treatment type, size, and layout for the six water stations. In addition, BC provided an estimate for capital and average annual operation and maintenance (O&M) costs. Since preparation of the study, the proposed MCL was released with lower levels, which impacts WS1 and WS7 as well (see PFAS level presented in Section 1).

Two popular technologies for PFAS treatment are GAC and strong base anion IX. GAC is often used as a filter media in pressurized vessels in a lead-lag configuration, meaning there are two pressure vessels in series. The outlet of the first pressure vessel is the inlet for the second pressure vessel. Over time, the GAC's adsorptive sites become exhausted and the media needs to be replaced. One benefit of GAC media is that the media can be reactivated to avoid incineration and landfill. Regenerated GAC has a lower cost than virgin GAC and can reduce media O&M costs.

IX involves the interchange of ions on the surface of a media with other ions of like charge present in solution. When used with PFAS-contaminated water, the PFAS compounds will adsorb to the surface of the IX media and another anion will be deposited into the water. IX media is single use and cannot be regenerated, meaning that once it is used up it will need to be replaced with new media.

For either media, a lead-lag configuration ensures that when the media in the first vessel is exhausted, the second vessel will act as a backup and there will be no accidental PFAS contamination. Valves between the vessels are used to change the flow path either to switch the order of the vessels or backwash the vessels to clean the media.

The treatment systems were all initially sized for GAC treatment. WS4 was the most space constrained; therefore, the site layout was developed with strong base anion IX to compare the footprint and costs between GAC and IX. Site constraints in the PFAS Treatability Study were outlined for each water station, including media delivery access, discharge options (sewer or storm), and available space for the proposed facility. Table 2-2 summarizes the proposed design capacity and treatment system sizing for each water station, including WS1 and WS7. The number of vessel pairs range from three for the smallest sites up to 10 vessel pairs for the largest site.

Table 2-2. Design Summary for PFAS-impacted Water Stations[a]

Water Station ID	Current Capacity (gpm)	Available Water Rights, Qi (gpm)[b]	Proposed Design Capacity (gpm)	Vessel Diameter (feet)	Volume per Vessel (lb)	Media Type	No. of Vessel Pairs Proposed for Build Out
WS1_GAC	23,400	23,400	10,000[c]	12	40,000	GAC	10
WS1_IX	23,400	23,400	10,000[c]	12	20,000	IX resin	6
WS3	6,175	6,000	6,000	12	40,000	GAC	6
WS4_GAC	8,500	10,700	10,700	14	60,000	GAC	8
WS4_IX	8,500	10,700	10,700	12	20,000	IX resin	6
WS7	800[d]	1,250	3,333[e]	12	40,000	GAC	3
WS8	1,250	2,750	3,333[e]	12	40,000	GAC	3
WS9	9,800	10,872	10,872	12	40,000	GAC	10
WS14	3,200	3,200	3,200	12	40,000	GAC	3
WS15	1,000	5,000	4,000[e]	12	40,000	GAC	4

a. Design summary from the PFAS Treatment Feasibility Study (BC, 2022), for all water stations except WS1 and WS7, which were developed as a part of this plan.

b. Available instantaneous water rights (Qi) are based on current water rights as of October 2023 and are not reflective of future water rights changes.

c. Proposed design capacity is approximately 50 percent of the water station capacity based on blending with other wells at this station to reduce the PFAS concentration below the proposed MCL.

d. Current capacity listed for well WS7-1 (800 gpm) from the shallow aquifer only. WS7 also includes WS7-2 (500 gpm) from the SGA.

e. Proposed design capacity assumes new well development in the shallow aquifer to increase production capacity based on proposed water rights assessment as of September 14, 2023 (refer to Section 2.5).

2.4 Comparison of Options

This section includes a comparison of the two alternatives, including tradeoffs and costs, and the overall considerations for implementation. Since a point source has not been identified, the remediation alternative discussed in Section 2.1 has been excluded from this comparison.

2.4.1 Tradeoffs

Table 2-3 outlines the advantages and disadvantages between a) new supply development from the deep aquifer, and b) PFAS treatment at the impacted water stations.

The new source alternative has the advantage of being PFAS-free but has many disadvantages when compared to the PFAS treatment alternative. Development of a new source will have a much higher capital cost and higher electrical (O&M) costs due to the high-hp pumps. In addition, this alternative has some uncertainties, including potential impact on neighboring water systems that rely on the same aquifer, potential construction delays or additional costs associated with new well development, and the risk of future contamination of the aquifer, which would require PFAS treatment. Risk of future SGA contamination is discussed further in the Risk of PFAS Migration from the Upper and Lower Orchards Aquifers to the Deep Regional Aquifer System memorandum (GSI, 2023).

Table 2-3. Tradeoffs of Alternatives: New Source vs PFAS Treatment

Alternative	Pros	Cons
New Supply Development from Deep Aquifer	• Alternative source without PFAS • If new source is developed to replace some of the PFAS treatment systems, this option could add resiliency to the water system with a new supply	• Higher capital cost • Impact of new wells on Clark Public Utilities (CPU), Shin-Etsu Handotai (SEH) America, City of Portland, Rockwood Water People's Utility District, and City of Gresham systems are unknown • Potential for future SGA contamination[a] • Potential for future demand on SGA • Potential unknowns with new well development add risk of unforeseen costs and/or schedule delays • Higher energy use • Treatment still needed for iron and manganese
PFAS Treatment of Existing Source Water	• Allows existing water supply to stay in operation • New water rights permitting is not required.	• Higher O&M cost for media change-out • Filter vessels are taller

a. *Risk of future SGA contamination is discussed further in the Risk of PFAS Migration from the Upper and Lower Orchards Aquifers to the Deep Regional Aquifer System Memorandum (GSI, 2023).*

2.4.2 Cost Comparison

This section compares the capital and O&M costs for the two alternatives. These comparisons will allow the City to take the short- and long-term costs into consideration when choosing between the two alternatives. Costs were developed for both a large and small site as representative of the options. Developing new supply at all the well sites is not feasible, so this comparison is specific to the sites where new supply development is a possibility versus implementing PFAS treatment. Cost is not the only factor in determining what approach works for each water station, as discussed in Section 2.4.1, but is an important factor to understand as one of the tradeoffs.

2.4.2.1 Capital Costs

Table 2-4 compares the estimated construction costs for the two alternatives. These costs were developed for a representative large and small site to capture the range of costs for the City's water stations, with the large site with capacity of 10,900 gpm (15.7 million gallons per day [mgd]) and small site with capacity of 4,000 gpm (5.8 mgd). Costs were escalated to the mid-point of construction estimated to be November 2028 based on the proposed timing of the WS15 treatment upgrades) for the purposes of this comparison, with an escalation by 22.6 percent, based on an escalation rate of 4.0 percent.

For a large site, the new well supply development with iron and manganese treatment is about 20 percent higher than PFAS treatment. For a smaller site, PFAS treatment becomes more economical, as an alternative water source cost is about 35 percent higher.

Table 2-4. Capital Cost Comparison for New Source Development Compared to PFAS Treatment

Site Type	Alternative	Upper Range (+100%)	Estimated Cost	Lower Range (-50%)
Large Site - 10,900 gpm (15.7 mgd)	New Supply Development from Deep Aquifer [a]	$107,000,000	$53,500,000	$26,750,000
	PFAS Treatment of Existing Source Water [b]	$90,400,000	$45,200,000	$22,600,000
	Cost Difference		*$8,300,000*	
Smaller Site – 4,000 gpm (5.8 mgd)	New Supply Development from Deep Aquifer [a]	$56,600,000	$28,300,000	$14,150,000
	PFAS Treatment of Existing Source Water [b]	$39,900,000	$19,900,000	$10,000,000
	Cost Difference		*$8,400,000*	

a. *Cost for new source includes drilling new well, new raw water pumps, and new water treatment facility (greensand treatment system, e.g., ATEC, and water treatment facility building).*

b. *Cost for PFAS treatment is at WS9 with GAC treatment for large site (10,900 gpm), and at WS15 for the smaller site (4,000 gpm).*

2.4.2.2 O&M Costs

Estimated annual O&M costs were developed for each alternative for the large and small representative sites and are summarized in Table 2-5. The costs include the main cost drivers, including the annualized cost for media change out for the given treatment system and the electrical power costs for raw water pumping, as well as staffing costs for typical O&M of the facility and media change out and backwashing for PFAS treatment. Costs also include sampling costs for the PFAS treatment option.

For the new supply development option, O&M costs were estimated based on the City's Ellsworth WTP, which is supplied by the deep SGA via high-hp pumps (300 to 500 hp) and includes a greensand filtration system. Raw water pumping costs were estimated for the Ellsworth WTP based on the deep well pump hp (500 hp) and typical operational conditions. The cost/MGD for the raw water pumping for Ellsworth was used to estimate costs for the large and small sites based on the sites average flow. The estimated costs were compared to operational electrical usage data and costs from Ellsworth WTP operations over the previous year (2022) for raw water pumping as a reference cost. The media replacement cost was estimated based on the change-out frequency for the Ellsworth filters (approximately 20 years) and the media replacement cost from 2015, escalated to 2023 dollars and converted to an annual cost. The annual media cost/MGD was used to estimate the costs for the large and small sites based on the average flow for each site. Staffing costs for the treatment facility were estimated for typical O&M tasks.

For the PFAS treatment option, O&M costs were based on estimated raw water pumping costs developed for WS4 as a part of the PFAS Treatment Feasibility Study (BC, 2022). The main O&M cost for the PFAS treatment systems is pumping due to added head loss of the pressure vessels on the system, with approximately 80-hp pumps. Pumping costs were developed for WS4 to account for the head loss through the vessels, based on head loss curves for the media and vessels provided by the vendors, assuming Calgon F400 media for GAC. In addition to the pumping costs, the PFAS treatment alternative also includes an annualized cost for media change out. The change-out frequency differs by water station based on the percent of time each water station is operational. For this estimate, the media replacement costs for the large and small sites were estimated based on the same cost/MGD as the WS4 reference project, and an estimated change out frequency of 5-years. Refer to Section 6.3.1 for detail on the City's pilot study at WS4 and determination for the estimated frequency of media change outs used to inform the O&M costs. Staffing costs for the treatment facility were estimated for typical operation and maintenance tasks, similar to the new supply option, as well as staffing costs for media change out and backwashing based on the costs for the reference project (WS4), and adjusted to reflect the large and small site average flows.

In addition to the media replacement and raw water pumping costs, the PFAS operational costs include costs for sampling PFAS monthly. This is an added cost specific to the PFAS treatment systems for compliance, and is a notable cost increase compared to typical operational monitoring for an iron/manganese treatment system.

Table 2-5. O&M Cost Comparison for New Source Development Compared to PFAS Treatment

Site Type	Alternative	Annualized Media Change-out Costs	Annual Electrical Costs for Raw Water Pumping	Annual Sampling Costs	Annual Staffing Costs	Total Annual O&M Costs
Large Site - 10,900 gpm	New Supply Development from Deep Aquifer [a]	$50,000	$110,000	NA	$18,000	$178,000
	PFAS Treatment of Existing Source Water [b]	$188,000	$50,000	$27,000	$25,000	$290,000
					Cost Difference	*$112,000*
Small Site – 4,000 gpm	New Supply Development from Deep Aquifer [a]	$17,000	$39,000	$0	$18,000	$74,000
	PFAS Treatment of Existing Source Water [b]	$69,000	$17,000	$18,000	$20,000	$124,000
					Cost Difference	*$50,000*

a. *Costs were estimated based on operating costs at Ellsworth WTP in 2022 for well pumping and annualized greensand filter media replacement costs from Ellsworth WTP's filter replacement in 2015, adjusted to 2023 dollars.*

b. *PFAS treatment media replacement costs based on GAC media with an assumed bed life of 5 years for the reference site (WS4), with GAC media cost of $2.30/pound (lb) (quote from Calgon Carbon for F-400 media as of October 2023). Raw water pumping costs based on $0.0469/kilowatt-hour (Clark Public Utilities average annual 2023 energy rate for COV). Staffing cost includes costs for media change out and backwashing.*

Figure 2-1 compares annual O&M costs between the new supply option and PFAS treatment, including the costs for media replacement, raw water pumping, sampling and staffing costs.

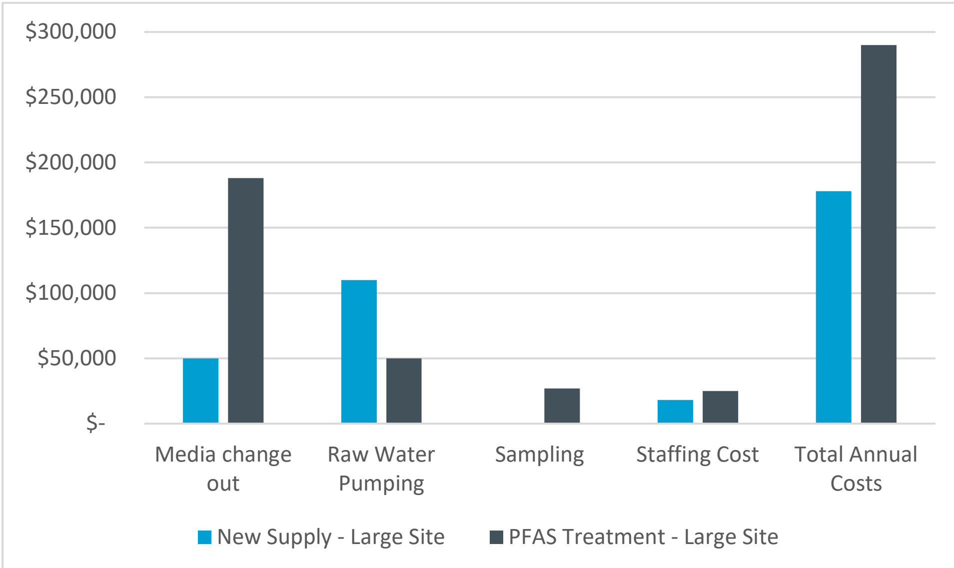

Figure 2-1. Annual O&M costs comparison between the new supply and PFAS treatment options

Overall, the total annual O&M costs for the new supply option were about 50 percent less than the PFAS treatment systems for the large and small sites. For both the large and small sites, the media change out is about four times the cost for the PFAS Treatment system compared to the new supply development option. The cost for PFAS change out is expected to be more given the greensand media has a long lifespan. Greensand media typically lasts at least 20 years, if not more, once the media breaks down due to repeat backwashing over the years. PFAS media on the other hand will be changed out more frequently with PFAS breakthrough. The media replacement cost will be realized as a total lump cost when the media is replaced, so the actual cost at the time of replacement is likely to be greater for the greensand filter(s) compared to the PFAS vessels, depending on the media costs and how many PFAS vessels need to be changed out in the given year.

For both the small and large sites, the estimated annual pumping cost is approximately twice the cost to pump from the deep aquifer with higher-hp pumps than required for the PFAS treatment systems. Overall on an annual basis, there will be more energy costs for the new supply systems for pumping.

2.4.3 Implementation Timelines

Approximate timelines to implement the two options are presented in Table 2-6 for new supply development and Table 2-7 for PFAS treatment. The timelines highlight the differences in implementation to consider when determining the approach for each water station.

Table 2-6. Approximate Implementation Duration For New Supply Development		
Task	Description	Duration Range (Months)
1	Water Rights Consolidation Application	12 to 18
2	Piloting (if required)	4 to 6
3	Procure On-Call Well Designer (City task)	1 to 2
4	Test Well (design and drilling)	6 to 9
5	Well Drilling (bid, construction, testing, and design)	6 to 12
6	WA DOH Well Approval/Ecology Showing of Compliance	1 to 2
7	Prepare Request for Qualifications (RFQ) for Treatment Designer and Execute Contract [a]	3 to 4
8	Design (pumping and treatment design) [a]	10 to 12
9	Construction (pumping and treatment design) [b]	12 to 16
10	Start-up/Commissioning	1 to 3
	Approximate Total Duration	**48 to 78**

a. Treatment designer will be procured during Task 5 and the design will begin following completion of Task 5.

b. Construction timeline could be impacted by long electrical equipment lead times.

Table 2-7. Approximate Implementation Duration For PFAS Treatment		
Task	Description	Duration Range (Months)
1	Prepare RFQ and Select Designer (City task)	3 to 4
2	PFAS Treatment Facility Design	10 to 12
3	Construction [a]	9 to 18
4	Start-up/Commissioning	1 to 3
	Approximate Total Duration	**24 to 36**

a. Construction timeline could be impacted by long electrical equipment lead times.

The PFAS treatment facilities would take approximately 24 to 36 months to construct for each site. In comparison, a new source and associated treatment facility would take approximately 48 to 78 months to construct for each site, or about 50 percent longer. Implementing a new source and associated treatment facility may require a pilot study to determine optimal treatment technologies, which would occur prior to the preparation of Request for Qualifications (RFQ) and selection of a designer. The main difference in time occurs from the test well and production well development. The timing assumes the design engineer for the water treatment system can be procured while the production well is being drilled and approved.

2.5 City Water Rights Evaluation

The City is conducting an on-going evaluation of its water rights portfolio to identify opportunities for drilling new/replacement wells in the SGA. Based on initial discussions with Ecology, the City is assuming that it can reallocate water rights between its deep and shallow wells so long as the total water rights stay the same. This provides opportunity to set production limits on existing wells closer to the current production while reallocating the surplus to a new/replacement well in the deep aquifer that would replace a well impacted by PFAS. Based on the City's current evaluation as of

September 2023, the City identified three water stations to consider for SGA supply development: WS6, WS8, and WS15. WS15 has historically been unable to produce water at any rates close to those defined in its development as a water station in the early 1980's. For this reason, WS15 will likely convert to a dominant SGA supply in the future. On the other hand, no decision has been made yet for WS6 and WS8 on whether or not they would stay in the Orchards Aquifer or go deeper into the SGA. Table 2-8 shows these different scenarios that will be guided in part by the hydrogeologic analyses with the consolidated water rights application. The rationale and considerations for developing these three water stations are discussed in the following section.

2.5.1 Top Sites for New Supply Development

Table 2-8 summarizes the proposed future instantaneous water rights (Qi) and treatment capacities, and rationale for potential new supply development for WS6, WS8, and WS15.

Table 2-8. Proposed Instantaneous Water Rights (Qi) and Treatment Capacities for New Supply Development

Water Station	Scenario	Proposed Upper Orchards Shallow Water Rights (Qi) gpm [a]	Proposed SGA Deep Aquifer Water Rights (Qi) gpm [a]	Proposed Treatment Capacity (gpm)[b]	Rationale
WS6	Orchards	3,333	0	3,333	• Past wells produced excessive sand and have been shutdown so new well development necessary regardless of which aquifer • Detected levels of PFAS in the shallow aquifer requires treatment • City evaluating Upper Orchards Aquifer's ability to meet demand
	SGA	0	3,333	3,333	• Past wells produced excessive sand and have been shutdown so new well development necessary regardless of which aquifer. • City considering deep aquifer alternative. WS6 is a good candidate for developing a deep well(s).
WS8	Orchards	3,333	0	3,333	• Detected levels of PFAS in shallow aquifer requires treatment • Existing wells budgeted for replacement in 2028
	SGA	0	3,333	3,333	• Limited capacity from existing wells • City evaluating Upper Orchards Aquifer's ability to meet demand and considering deep aquifer alternative
WS15	SGA Only	0	4,000	0	• Increased production out of shallow aquifer is not be feasible. Preference to develop full capacity from SGA
	SGA blended with Orchards	500	3,500	3,500	• The 500/3,500 gpm proportions are anticipated to keep blended water below the current 4 ng/L PFOS/PFOA thresholds without PFAS treatment of Orchards water source.

a. *Proposed instantaneous water rights (Qi) based on water rights evaluation as of September 14, 2023, provided by the City.*

b. *Proposed treatment capacity for PFAS treatment for the SGA only options, and for iron/manganese treatment for the SGA options.*

WS6 is currently not operational due to high sand production from the four historical wells, all drilled from the Upper Orchards aquifer. One of the wells is abandoned due to excessive sand production and two wells are inactive, and the fourth well showed sand production when the well was first tested and is now only maintained to be available to the Urban Forestry Department for tank filling purposes. It has a maximum capacity of 65 gallons per minute (gpm) and does not pump into the distribution system. PFAS has not historically been sampled at this site due to the inoperability of the water station. Recently, the water station was sampled for PFAS with results above the proposed MCL Given WS6's proximity to other water stations in the Upper Orchards Aquifer with PFAS detections, the City would plan for PFAS treatment if wells are replaced in the shallow aquifer. This water station is a candidate site for developing the deep aquifer in the future, with new wells drilled deeper. Both GSI (2023) & Aspect Consulting (2021) have indicated that the Upper Orchards Aquifer should be capable of producing the planned water rights usage amounts at the site.

WS8 is one of the City's smallest-capacity stations, with a current capacity of 1,250 gpm from two wells supplied by the shallow aquifer. A third well is abandoned due to deteriorating well screens. The City is considering development of new wells from the deep aquifer or PFAS treatment at this site.

WS15 consists of four wells supplied from the shallow aquifer with equal production of 500 gpm each; however, one of the four wells is not used due to excessive sand. The long-term sustainable rate for this water station from the shallow aquifer is estimated to be limited to 500 gpm; therefore, this water station is a top candidate site for development of the deep aquifer for long-term production. The City is considering development of the deep aquifer to provide the full proposed production of 4,000 gpm. If the full capacity cannot be realized, then the existing shallow wells will be maintained, and PFAS treatment can be added to treat the capacity of the shallow well.

2.6 Key Takeaways

Based on the evaluation of alternatives, the City has options beyond PFAS treatment to consider as part of the City's overall PFAS management strategy, along with some options that are not applicable or viable at this time, as follows:

- **Point Source treatment:** Pump and treat is not a viable option for the City given no PFASt sources were identified as part of the source evaluation completed by Confluence (Confluence, 2023).
- **New Supply Development**: New supply development has notable tradeoffs to consider compared to PFAS treatment. The overall conclusions are:
  - New water source development capital cost is notably higher (between 10 to 30 percent higher),
  - New water source development would take longer to implement, with a large range depending on the water rights determination (from 12 months to several years longer),
  - The unknowns in timing for water rights determination could limit implementation and risk meeting the EPA compliance timeline,
  - A new deeper water source will have higher pumping costs from the deep aquifer related to higher HP pumps (estimated to be upwards of 200 HP more for the deep well pumps compared to the PFAS treatment raw water pumps for some of the sites),
  - Equivalent production capacity in deep aquifer to existing shallow aquifer is not viable for all existing wells and will not be feasible at all the water stations.

In summary, new supply development from the SGA is a viable option to explore but not for all water stations, and it is not an option to fully replace PFAS treatment. The City is considering a “hybrid” approach instead, with a combination of new supply development at select stations and PFAS treatment at the remaining sites. The proposed treatment approaches for each station are presented as part of the implementation plan in Section 6.

Section 3

Interim Mitigation Measures

This section evaluates options that the City could pursue before treatment can be implemented at impacted water stations. The evaluation examines measures the City can take to reduce PFAS concentrations in the distribution system by shutting down a selection of wells for a period of time (i.e., curtailment) or wheeling and blending water in the distribution system.

This section also investigates options that can be employed in the interim for vulnerable populations. An overview of the options is provided, along with the evaluation results and the City's recommendations for options to consider for managing PFAS in the interim.

3.1 Curtailment

In systems with PFAS detections, a first action can be to shut down the source with elevated PFAS levels. However, the City cannot shut down all water stations with PFAS levels that exceed the Washington SAL prior to implementing treatment and still meet the City's water demands. Although the City has already prioritized the operation of wells with lower concentrations of PFAS at each water station, the City is further considering options to limit production at select water stations until treatment can be implemented.

To understand the prioritization of individual wells and where there is opportunity to reduce PFAS exposure, the wells were sorted by PFOS levels at each station (Appendix A). Based on review of the ordered list, there are several water stations with multiple wells that have PFOS and PFOA concentrations below the proposed MCL that could be prioritized during times of lower demands, when there is more flexibility with well selection. At high demand times, however, some of the water stations have to operate all wells (so long as production can keep up). One tradeoff of shutting off certain wells is the concern about equipment sitting for long periods of non-use, which results in potentially more start-up issues. To mitigate some of that concern, an alternative standard operating procedure could be developed to have the wells operated for short periods to exercise the equipment. Unfortunately, this can lead to increased electrical utility demand charges if not managed correctly.

In addition to shutting off individual wells, there are options to shutoff certain water stations in the future. WS15 and WS8 are two of the City's smaller stations with some of the highest PFAS levels. These two water stations can be shut down for periods of time and supplemented by other stations with lower PFAS levels. Specifically, WS15 supplies water into an elevated reservoir that serves the Heights High distribution system. If WS15 is shutoff, WS9 can supply the necessary production to the elevated reservoir to serve Heights High. Additionally, WS8 can be shut down and supplemented by WS7, WS9, or Ellsworth. An added benefit of the flexibility to shut down WS15 and WS8 is the ability to delay treatment at these stations beyond the compliance timeline. Delaying those projects can reduce pressure on the timeline to implement treatment at all stations by the compliance deadline (estimated to be by the end of 2028 as of October 2023). The ability to delay treatment upgrades at both WS15 and WS8 is advantageous as well because these two stations are potential candidates for development of new wells from the deep aquifer to replace the existing shallow aquifer wells. It takes more time to drill new wells and design and construct a new treatment system (as discussed in Section 2.4.3Implementation Timelines).

Shut down of WS15 and WS8 is dependent on operation of other water stations to supplement the flow. Current construction at other stations has prevented the City from shutting down those stations in response to PFAS detections, but in the future once construction is complete and the stations that are offline can be brought online, the City will have more flexibility to shut off WS15 and WS8 outside of high demand periods. At this time, WS15 and WS8 are often needed to meet the full system needs.

3.2 Blending

This section outlines considerations for blending to reduce PFAS levels in the distribution system. The City's water system was intentionally designed to create redundancy. Therefore, most water stations can serve multiple pressure zones. As PFAS treatment or deeper wells are implemented, there will be the ability to continue to lower PFAS concentrations in the distribution system.

Some of the options the City is already implementing or considering for blending in the interim are as follows:

- **Operating the Ellsworth WTP longer and at an increased capacity.** The Ellsworth WTP is served by the SGA, and has no PFAS detections. For most years in the past, this station was offline for a portion of the year during lower demand season (typically shut down November–April) because the cost of operation is higher than existing water stations with shallow wells. The Ellsworth well pumps require a higher horsepower to pump from the deep wells. The Ellsworth WTP could be operated for a longer portion of the year and at a higher capacity to supplement reduced production from other water stations with wells containing PFAS. This strategy is limited by an annual usage water right.
- **Operate WS1 at a higher priority over other water stations.** WS1 is the City's largest water station (23,400-gpm capacity) and is arranged with the flexibility to supply all the City's pressure zones. WS1 could be operated closer to its full capacity to supplement other water stations operated at lower production. There are limitations to long-term operation of the WS1 wells, and considerations for equipment wear. WS1 is currently operated to optimize the operational efficiency to reduce pumping costs. If wells are operated instead to supplement reduced production at other water stations, there will be an overall cost increase for operations in order to move the water across the service area.
- **WS7 blending.** WS7 has a unique option to blend down the PFAS concentrations within the water station itself. WS7 is one of the only water stations that is served by a combination of wells from the shallow Upper Orchards Aquifer (Well WS7-1) and the deep SGA (Well WS7-2). No PFAS has been detected from the deep aquifer well, whereas WS7-1 has detected an average PFOS of 6.2 ng/L and PFOA of 1.3 ng/L (Appendix A, Table A-1). Assuming the current station capacities and average concentrations, the combined flow-weighted concentrations from WS7 would be below 4 ng/L for PFOS and PFOA. If the average PFOS levels stay relatively consistent in the next several years, the combined flow from the two wells can blend PFOS and PFOA below the MCL.
- **Rental Treatment Unit.** Evoqua Water Technologies can provide a rental treatment unit (Figure with a 900-gpm capacity. The rental treatment unit (Evoqua's MitiGATOR™) includes an insulated trailer with two bag filters followed by six media vessels with either IX resin or GAC media (Figure). The MitiGATOR holds 40,000 lbs. of media. The GAC media is estimated to last 450 days, and the IX media is estimated to last 560 days if operated continuously. A final disinfection system is also needed. A rental unit could also be considered. Evoqua can rent the MitiGATOR. The initial mobilization with GAC media fill is $180,000 and the monthly rental cost is $18,000.

This rental unit could be utilized to blend PFAS levels down at specific sites or to help achieve compliance if for some reason the design/construction of a project was extending longer than anticipated.

Figure 3-1. Evoqua MitiGATOR mobile water treatment unit

3.3 Interim Mitigation for Vulnerable Populations

While not required by EPA or the State, the City is assessing options for a program to mitigate the risk of exposure to PFAS for the City's vulnerable population prior to implementing long-term systemwide PFAS mitigation solutions. This section outlines the interim measures the City evaluated, and tradeoffs between the different measures. The considerations for implementation, along with costs, are also presented, which the City used to identify recommendations for the preferred options. This section concludes with the City recommendations moving forward, and next steps, including developing an implementation plan for the interim measures.

The interim measures evaluated in this section are:

- Point-of-use treatment (e.g., under-sink filters, water pitcher filters)
- Bottled water
- Rebate program
- Pilot treatment unit
- Water filling station

The interim measures are envisioned to be in use for 3 to 5 years prior to treatment at the City's impacted water stations. Point of entry mitigation where supply enters the distribution system (i.e., full scale PFAS treatment) is considered a long-term mitigation option and is not included in the interim mitigation options discussed below. Additionally, whole-home units were discussed as an option, which would treat all water entering the home. However, given the risk for PFAS is chronic and not a main concern for non-drinking water uses (e.g., showering), the whole-home units were not considered an interim measure. Moreover, the long-term goal is to provide water that meets the EPA's proposed MCLs to all customers through full-scale treatment. Providing whole-home units didn't appear to be an efficient option as an interim solution.

Vulnerable populations are defined for this Plan as City water users who may not have the financial means to implement their own interim solution if they desire. Qualifying as a vulnerable population is proposed to be based on using the federally Low-Income Home Energy Assistance Program (LIHEAP) income threshold levels. LIHEAP is a grant program with established low-income thresholds that Clark Public Utilities utilizes to determine income eligibility; it could be expanded for determining customer qualification for financial support for the interim measures. The specifics of how the program will be administered will be developed as part of the implementation for the selected measures. Approaches for administering the program are discussed in Section 3.3.3.1.

To estimate the anticipated number of residents in need that qualify for City assistance, a vulnerable household was defined based on income using the LIHEAP income threshold levels. Clark Public Utilities (CPU) reported there are currently 4,000 vulnerable households served by the electric utility that already receive energy assistance through the existing Clark Public Utilities LIHEAP program (CPU, 2023). According to the 2022 Census, there are 184,173 households in Clark County, of which 75,663 are located in the City. This provides a ratio of Clark County households to City households equaling 2.43. Additionally, the City of Vancouver's water service area is about 40 percent larger than the City limits. Based on these assumptions, the City's vulnerable population was estimated to be approximately 2,300 households.

The following sections summarize how the City evaluated the interim measures based on value-based criteria to identify the best options to consider for implementation. Details of the evaluation and scoring are provided in the Interim Measures Alternatives Evaluation Technical Memorandum (Appendix B).

3.3.1 Interim Mitigation Options

The interim measures included in this evaluation are described in the sections below, followed by the estimated implementation costs in Section 3.3.2, and a summary of the tradeoffs in Section 3.3.3.

3.3.1.1 Point-of-Use Treatment

In the interim, one approach for mitigating the risk of PFAS exposure is to add a filtration unit at the point-of-use in individual homes. A public water system cannot rely on point-of-use treatment for primary treatment to achieve a regulatory standard. Therefore, these measures would be temporary and interim, and these treatment units would not become points of compliance for the public water system.

There are currently no federal, state, or local regulations that require in-home water treatment systems to meet safety and performance standards. However, the National Sanitation Foundation (NSF) is a global independent organization that develops public health standards and certifies in-home water treatment systems that voluntarily meet NSF standards for safety and performance (NSF, 2023a).

Standards for point-of-use systems include (NSF 2023b):

- **NSF/ANSI 42**. Filters reduce aesthetic impurities such as chlorine and taste/odor.
- **NSF/ANSI 53.** Filters reduce a contaminant with a health effect that is regulated by the EPA.
- **NSF/ANSI 401.** Treatment reduces emerging contaminants that may not yet be regulated by the EPA.

It's important to note that these standards have not been updated to reflect EPA's recent proposed MCL for PFAS. NSF will update its standards once the EPA finalizes the national standard for PFAS in drinking water. Per email correspondence to BC in August 2023, the Vice President of the Water Division at NSF estimated that NSF standards would be updated at the end of 2024. Once the standard is updated, certification organizations can set implementation periods, which are typically 1 to 3 years. Given this timeline, interim measures will most likely not have NSF certification data available before they may be implemented.

A selection of filters with cartridge-style filter replacements that meet NSF standards and have available data on the reduction of PFAS are presented in Table 3-1. A more extensive State-provided list of filters that the public can consider using for PFAS removal is provided in Appendix C. The options evaluated include under-sink units, faucet-mounted units, and water pitchers with replaceable filters.

Table 3-1. Point-of-Use Treatment Interim Mitigation Options

Type	Make and Model	Filter Media	NSF Certification Standards	PFOS and PFOA Concentration in Treated Water	Treatment Capacity per Filter Cartridge
Under-sink three-stage filtration system that dispenses treated water via a new faucet (in addition to existing)[a]	Aquasana Claryum® AQ-5300	20-micron sediment filter, activated and catalytic carbon media, and IX resin	42, 53, and 401	< 70 ng/L	600 gallons
Under-sink filter that dispenses treated cold water via existing faucet[b]	Hydroviv	Blend of carbon and ceramics	42 and 53	< 10 ng/L[c]	720 gallons
Faucet-mounted filter attached on the end of existing faucet	ExtremeLife	Carbon fiber technology	42 and 53	< 16 ng/L[c]	400 gallons
Water pitcher that treats the faucet water as the pitcher is filled	Clearly Filtered	Proprietary Affinity® filtration technology (mesh screen, coconut GAC, composite shell)	42, 53[d]	< 5 ng/L[c]	100 gallons
Under-sink three-stage filtration system that treats cold water for existing faucet[b]	Clearly Filtered model CF-UTSF	Proprietary Affinity® filtration technology (priming filter, GAC, fluoride filter)	42[d]	< 2 ng/L[c]	2,000 gallons

a. This new faucet would dispense only treated cold drinking water.

b. This existing faucet would dispense treated cold drinking water when the cold water line is all that is opened; when the warm water line and cold water line are both open on this existing faucet, a blend of treated cold and untreated hot water would be dispensed.

c. Concentrations shown are the limits of quantification, where neither PFOS or PFOA were detected at or above the respective concentration shown.

d. Tested by third party and not-NSF.

Some products, like the under-sink Aquasana AQ-5300, have NSF 42, 53, and 401 certifications and available data showing treatment can meet EPA's 2016 HAL of 70 ng/L for the concentrations of PFOS and PFOA (Aquasana, 2022). ExtremeLife's faucet-mount unit is another option, with testing showing removal below the EPA's 2016 HAL's, but does not have data showing the filter can remove PFAS below the SALs. Other products, like the Hydroviv under-sink filter (Hydroviv, 2017) and the Clearly Filtered water pitcher and three-stage filtration system have data showing treatment can meet the SALs of 10 ng/L for PFOA and 15 ng/L for PFOS. Testing of the Hydroviv filter by the City has shown it can decrease the levels of PFOA and PFOS to non-detectable, with influent PFAS levels around the average levels measured in the City's water supply. The Hydroviv filter is NSF 42 and 53 certified, whereas the Clearly Filtered water pitcher (in-pitcher filter) was tested by a third party that meets NSF 42 and 53 standards, but has not been certified by NSF. A photo of an under-the-sink product is shown in Figure 3-2. A photo of a pitcher water filter is shown in Figure 3-2.

Figure 3-2. Under-sink treatment unit

Figure 3-2. In-pitcher water filter

Table 3-2 shows performance data for the Clearly Filtered water pitcher. This filter is close to meeting the EPA's proposed MCL of 4 ng/L (Clearly Filtered, 2023a), with performance data indicating PFOS and PFOA concentrations of less than 5 ng/L.

Table 3-2. PFAS Removal Data for Clearly Filtered Water Pitcher

Contaminant	Challenge Water (ng/L)	Filtered Water (ng/L)	% Removal
EPFB	100	<5	>95.0%
GenX	900	<5	>99.4%
NFBS	100	<5	>95.0%
PFBS	100	<5	>95.0%
PFBA	100	<5	>95.0%
PFNA	100	<5	>95.0%
PFOS	1000	<5	>99.5%
PFOA	500	<5	>99.0%
PFHA	100	<5	>95.0%

ng/L = nanograms per liter

Clearly Filtered also makes an under-sink filtration system that can meet EPA's proposed MCL of 4 ng/L (Clearly Filtered, 2023b). Table 3-3 presents the performance data for the Clearly Filtered three-stage under-sink water filter system. This system was tested by a third party to meet NSF 42, but no additional NSF standards.

Table 3-3. PFAS Removal Data for Clearly Filtered 3-Stage Under-Sink Water Filter

Contaminant	Challenge Water (ng/L)	Filtered Water (ng/L)	% Removal
Fluorotelomer alcohol 8:2	1040	<2	>99.8%
PFBS	1040	<2	>99.8%
PFDA	520	<2	>99.6%
PFHxS	1040	<2	>99.8%
PFHxA	520	<2	>99.6%
PFNA	520	<2	>99.6%
PFOS	1040	<2	>99.8%
PFOA	520	<2	>99.6%
PTFE	1040	<2	>99.8%

ng/L = nanograms per liter

Based on review of the point-of-use options, there are options that have data showing compliance with the proposed MCL, including the in-pitcher water filter, and under-sink units. The faucet-mount filter option has more-limited data, and no available products have published removal data showing effluent concentrations below the proposed MCL. Additionally, when discussing with Denver Water regarding their point-of-use filter program for lead removal, they ruled this option out given the variability in faucet types, and that this option did not work for households with detachable faucet heads (A. Woodrow, personal communication, October 30,2023). Additionally, it has been shown that use of hot water through the faucet-mount filter can cause water quality issues with the filter. For those reasons, the faucet-mount unit was screened from the list from further scoring and not included in the list of options for consideration.

Table 3-4 summarizes implementation considerations for the initial installation of the in-home mitigation options. The options are grouped by the type of filtration system including pitcher filters, under-the-sink filters attached to existing faucets, and under-the-sink filters with a new separate faucet installed.

Table 3-4. In-Home Interim Mitigation Implementation Considerations

Implementation Consideration	Pitcher Filtration	Existing Faucet Filtration	New Faucet Filtration
Direct to user delivery option from vendor for filter housing and replacements	✓	✓	✓
Small and lightweight for user to self-transport easily from central pickup location or can be easily shipped to homes	✓	✓	✓
Replacement cartridge easily installed or replaced	✓		
May require plumber to install filter and not easily installed by all users		✓	✓

Logistics for delivery to home addresses would be part of the implementation program for all of these options. The City could consider setting up a centralized distribution hub for product pickup as an option for the initial filter installation and for filter replacements. This option may not be equitable for those with limited or no transportation. To mitigate that limitation, the City could offer an option to deliver filters for community members who request delivery. Additionally, all three options have a "direct to user delivery" subscription service through the filter company that can be considered to mitigate limitations for some customers who may not have transportation available. Another benefit of this option is that the City could allow customers that do not meet the low-income threshold to join the program at their own cost.

Pitcher filters have the benefit of not requiring any installation or set-up. The replacement cartridge is easily changed out from the pitcher unit. Under-sink filtration options, however, will require tools and possibly a plumber to ensure proper installation, depending on the existing sink and the filter unit type. Given the range of accessibility within the vulnerable population, the City may consider multiple means to provide customers with the tools necessary for installation. In some cases, it may be necessary to have a plumber install the units and replace the filter cartridges regularly, which the City could provide support for with a specific list of available plumbers and financial assistance for the service. Additionally, the City may consider preparing educational videos to show the installation process, prepared in accessible formats and in multiple languages representative of the community, for customers who would have access to the required tools necessary for the installation. The costs conservatively assume an installation cost for the filters by a hired plumber. This service may not be needed for all households.

Denver Water Point-of-Use Filter Program

Denver Water, serving the greater Denver, CO area has an active point-of-use filter program for lead compliance. To address lead in household plumbing and meet the Lead and Copper Rule (LCRR) requirements, Denver Water developed a program to provide point-of-use water pitchers to 105,000 households. The point-of-use filter program is an alternative treatment technique to achieve regulatory compliance.

Denver Water selected point-of-use water pitchers over other in-home mitigation options. Data from faucet mount systems showed many homeowners did not use them correctly and there was concern about applicability for households with faucets with hoses that detach. Denver Water only investigated under-the-sink options that needed a dedicated spout and so there was a concern about applicability. Similarly, refrigerator filters are not widespread and so this option was also ruled out. Denver Water considered a rebate program, but because this program was considered as an alternative treatment technique, it was critical to have confidence that households were utilizing a lead-free treatment option and a rebate program couldn't provide that assurance.

To implement their program, they put out a request for proposals to request services for managing the program and then another RFP for delivery of the initial water pitchers and managing the routine replacement of water cartridges. The City could consider this approach and either set up a contract with one filter manufacturer that can administer the subscription service or put out a request for proposals to hire someone to administer the initial delivery of a filter, replacement filters, and manage changes in residency for qualified families.

3.3.1.2 Bottled Water

There are currently no federal, state, or local regulations requiring bottled water to be certified or documented as PFAS free. However, the International Bottled Water Association (IBWA) requires bottled water companies that are members of the association to test their bottled water products yearly for PFAS. IBWA requires members to limit PFAS in bottled water to 5 parts per trillion (ppt) for any one PFAS, or 10 ppt for more than one PFAS. This level does not meet the EPA's proposed draft rule of 4 ppt for PFOS and PFOA (IBWA, 2023), but it would meet the Washington SALs.

Purchased bottled-water options considered for this evaluation include 5-gallon jugs affixed to water towers (Figure 3-4). Specifically, Culligan and Crystal Springs water cooler delivery services were evaluated. Costs presented in Section 3.3.2 are reflective of the delivery service, which includes the water cooler and tower (a combined system) and 5-gallon bottled water jugs. Delivery services would be limited to bottled water that are part of the International Bottled Water Association (IBWA), which require bottled water companies that are members of the association to test their bottled water products yearly for PFAS. The bottled water jugs are traded back to the delivery service and switched out for new filled bottles on a monthly basis. The household would need space to store the five 5-gallon water jugs through the month, and a location for the water cooler tower.

Figure 3-3. 5-gallon water cooler tower

The City could work with the bottled water companies directly to establish subscription services for households, or have customers apply for payment set-up by the City. Administration of the program would depend on the selected bottled water supplier and the options they have for subscription services. The City of Benton Harbor, MI operated a bottled water program where they offered pick up of bottled water from a central location, as well as an option for homebound delivery of bottled water for those in need of that service. Customers in need were able to arrange water delivery to the homebound or residents without transportation, with staff available to provide the service (Sutfin, 2023).

Small individual-sized bottled water containers are not included in this evaluation because they are less desirable from a logistics and environmental impact standpoint. The City's Climate Action Framework (CAF) was adopted in December 2022, with a blueprint to reduce greenhouse gas emissions and build resiliency to climate change impacts. One of the six key areas for the City's vision is to reduce waste per capita. Providing bottled water as an interim measure, while not contributing to plastic waste generation in the long-term, will still result in an increase in plastic waste from plastic water jugs, that would otherwise not have been used by households who drink City tap water. Additionally, there will be additional greenhouse gas emissions from the truck transport for delivery of bottled water to homes through a subscription service. Regardless of which bottled water option is used, bottled water has a negative environmental impact in this regard.

3.3.1.3 Rebate Program

An alternative approach to the City purchasing and distributing in-home mitigation measures is for the City to instead provide financial assistance to the public so they can purchase their own bottled water or point-of-use treatment systems. This could be implemented as a rebate program coordinated through the City's public utility billing department that would give vulnerable members of the public an automated rebate on their utility bill or as a retroactive payment to reimburse a purchase. Customers would need to submit an application to determine eligibility for either option. Once eligibility is confirmed through an application process, there are different approaches to disperse the rebate. Either eligible customers automatically receive the rebate amount dispersed through the automated monthly billing system, or as a reimbursement through a request form.

Rebate as Monthly Stipend

Approaches for rebate programs vary depending on the utility and regulatory agency. The City of Woburn, MA, and the Town of Wayland, MA, have implemented rebate programs while addressing the PFAS issue in their water systems, guided by the Massachusetts Department of Environmental Protection framework for implementing a rebate program during a drinking water emergency (MassDEP, 2021). The City of Woburn has implemented a rebate program specifically for their sensitive population (Woburn, 2023). The sensitive population is defined as pregnant women, nursing mothers, infants, and people diagnosed by their health care provider to have a compromised immune system. A monthly rebate of $30 is provided as a monthly stipend, not as a reimbursement. Massachusetts Department of Environmental Protection (MADEP) has a state MCL of 20 ppt for the sum of six PFAS compounds. Compliance is required quarterly. The City assesses compliance on a quarterly basis and if the average of three months of samples exceeded the state MCL, then the City provides the monthly rebate for each month that exceeded the state MCL. For example, if a quarter's (October, November & December) average was 23 ppt with November and December exceeding the 20ppt then the City would provide a rebate of $60 for the two months that were non-compliant in the quarter that was non-compliant. Only one rebate is provided per household.

The application process begins when the water bills are mailed out semi-annually so they can use the water bill as proof of residency. Customers need to provide proof of residency and submit letters from their doctors stating that they are immunocompromised. This letter is required once. Continual letters are required for pregnant, nursing mothers, and infants. Approximately 150 customers participate in the program and the program is administered by the Billing Manager. The program takes roughly 5 hours per week to execute. More of the Billing Manager's time is spent to answer PFAS related calls to increase customer understanding. A description of the City of Woburn's Bottled Water Rebate Program is provided in Appendix D.

Another example of a stipend program is from the Town of Wayland, MA. The Town provided a rebate specifically for bottled water in a monthly stipend of $32, based on the estimated cost of bottled water for a household. Over 600 customers have participated in the program based on the status of a member of a household being in a sensitive population. \

This is an example the City could use for developing a similar program either for bottled water or POU filters, with some notable differences. The City could take a similar approach, however the program would need to involve an application process to confirm eligibility for financial assistance. This could be done through one of the City's existing programs or partner programs, like the Help to Others (H2O) Program, which is a Utility program to help qualifying low-income residents pay for their water and/or sewer charges. Refer to Section 3.3.3.1 for additional program administration considerations for determining eligibility.

Rebates for Point-of-Use or Bottled Water Purchases

One concern of the automated stipend, is that the rebate would not ensure a household receives water treated for PFAS, since any money received could be used for other household needs that take priority at the time of receipt. To try to ensure that the rebate goes towards its intended goal, the program could be organized with as a reimbursement where the customer would provide proof of purchase and receive a reimbursement through their utility account or check. This would be similar to the City's existing Tree Refund Program where customers can be reimbursed for purchasing and planting trees. Customers fill out an application form, provide a receipt of tree purchase, and City staff visit the tree at the site. A refund is received via mail.

Another example of this type of program would be the Medford Water Commissions water conservation toilet rebate program. Customers with an active water account can fill out a two-page reimbursement form with proof of purchase, and photos of the installed unit. Medford Water reimburses customers a set amount depending on the type of toilet and water savings from $40 to $85. An example of Medford Water Commission's toilet rebate application form is provided in Appendix D.

Compared to the rebate program that is more similar to a stipend, the administration of this rebate program would be more onerous for City staff and the customer.

Summary

While the rebate program would not require City staff or vendors contracted by the City to perform field work to distribute or install a mitigation option, it would require a registration or application process for qualifying vulnerable households and staff time to administer the program depending on the approach. Tying the qualification process to an existing utility bill assistance program could reduce the amount of coordination needed from City staff to process applications.

3.3.1.4 Pilot Treatment Unit

As an alternative to providing bottled water, the City could consider using a pilot treatment unit(s) near an existing groundwater water station. The units are mobile and can be transported where needed in the water system. For this option, customers could fill reusable water containers on select days or times with City staff present. The City could provide to vulnerable households an initial set of high-quality fillable water jugs with attached spigots. This alternative assumes that the treatment unit is designed to treat to less than EPA's proposed MCL. The City would test the water monthly to ensure PFAS removal continuously meets the proposed EPA MCL and Washington SALs.

Evoqua provided a quote for a 20-gpm or 50,400-gpd pilot treatment unit that would cost roughly $81,000, with media change out costing approximately $15,000. This option would likely require multiple units at multiple locations to meet the demand and to provide multiple options for filling throughout the City. The costs presented in Section 3.3.2 are based on building two custom Evoqua pilot treatment units capable of treating 20 gpm each. A third unit could be necessary. The costs and design of this type of system could be fine-tuned if the City decides to pursue this option in the future.

A raw water and finished water equalization tank would also most likely be needed for managing flows from the supply to allow for more continuous production and for storage of finished water for distribution to customers. The finished water tank would need the option for the community to fill jugs of water or a water filling station would be required. The City's existing water filling station could also be utilized for one of the pilots.

A 7-gallon jug and spigot are estimated at $26 each. One-gallon containers could also be used. Four 7-gallon jugs per household were assumed for cost-estimating purposes. This is a standard size for emergency water supplies; however, each jug weighs approximately 60 pounds when filled, so this option willy present transportation challenges and not be feasible to all of the vulnerable households.

A key consideration for this option is where it is feasible to locate a pilot treatment unit that has capacity for the added traffic of customers entering and existing a pickup location. Not all existing water stations would accommodate this option. One initial concept was to place the pilot unit at WS8 and to park the water filling station in the Covington Middle School near NE Rosewood Avenue and across the street from WS8. This would allow for easy refilling of pilot treated water into the water filling station. The school's permission would be required.

While the City could provide fillable jugs to only vulnerable households, the pilot treatment units and fill locations would not be limited to just vulnerable households. The filling locations would be open to anyone in the community to use and would likely need staff present during filling hours. Additional staff time would be needed for the design, construction, and commissioning of the pilot treatment units. There would also be time associated with the unit operation. This option would likely require one to two additional full-time equivalents that would most likely not be an interim hire, meaning this cost would be continually incurred by the City after treatment is implemented. These new staff persons could likely support PFAS treatment operation in the future. Two certified water treatment plant operators were assumed for cost-estimating purposes, with a burdened salary (i.e., including employee benefits). In addition to adding staff time, safety is a concern with having staff in contact with customers. Staff monitoring the filling hours would need to receive additional training to handle potentially confrontational customers, which is not something City operators would typically have to deal with in their current roles.

Grant funding from the Federal Emergency Management Agency (FEMA) may be available as part of a pre-emergency preparedness. The City of Lake Oswego was able to secure FEMA grant funding from the Nonprofit Security Grants Program (Duncan, 2014). Other municipalities have employed emergency treatment units for added resiliency. For example, Eugene Water and Electric Board built its own mobile/pilot treatment unit.

One benefit of the pilot treatment unit option is that either GAC or IX media can be installed and operated, so the pilot treatment units could be an outreach tool for the City to use to educate the community about the future treatment that will be installed full-scale at other water stations. The units could also be used for operator training.

For vulnerable populations, it would be more challenging to access the clean water. This option was scored with the other measures to evaluate against the scoring criteria, discussed in Section 3.3.4.

3.3.1.5 Water Filling Station

Another concept is to use mobile water filling stations instead of a pilot treatment unit. Water filling stations could provide water supply from the Ellsworth WTP or Well WS7-2 at WS7, where PFAS concentrations have not been detected. The water filling stations could be trailer-mounted and mobilized to select City locations where customers can fill water jugs with Ellsworth finished water.

The City already has one water filling station that can be connected to a distribution system hydrant. For this option, the City's existing filling station unit would need to be located at a hydrant only served by the Ellsworth WTP and in an area accessible by the public. Unfortunately, finding a location only served by Ellsworth accessible to the public would be difficult and would not be in a low-income area. This is a major logistical challenge for this option, with the need to fill multiple trailer-mounted water filling stations with Ellsworth water on a routine basis (potentially daily) and mobilize to select City locations. The mobile filling stations would also require a dedicated truck fleet to transport the fill stations to and from the Ellsworth WTP (or WS7).

An example mobile water filling station is from Wastecorp Pumps, LLC that has a capacity of 1,600 gallons and costs $64,000. This unit is designed to hold drinking water and includes sample taps that disperse water from the unit. The trailer-mounted systems are self-service, and include a generator and pump (Figure 3-4).

Figure 3-4. Trailer-mounted water filling station

To meet the needs of the vulnerable population, assuming a community member would bring jugs to fill up once per the week, roughly nine mobile water stations would be needed. If the capacity of the system could be increased to 2,500 gallons, then roughly six water stations would be needed. Four 7-gallon jugs may be an option for the community to fill water; however, as mentioned, each jug weighs approximately 60 pounds when filled, so this option may not be feasible to all vulnerable households. Additionally, the water stations would be difficult to limit to just the vulnerable populations; therefore, additional filling stations may be needed to provide enough to serve customer demand.

Water quality would need to be managed in the water station tanks, with daily monitoring of the chlorine residual. Daily refills may be needed, which would create a significant operational burden on the City's current operations.

Conversely, a benefit of water filling stations are that they could be used in emergencies or at other public events where potable water needs exist.

This option was screened out from further consideration for not meeting the Council's expectations for equity. These water filling stations would make access to water more inaccessible (i.e., the previously discussed transportation challenges it presents to some vulnerable populations). Additionally, there are numerous logistical challenges associated with establishing fill stations throughout the City.

3.3.2 Interim Mitigation Costs

Costs for the interim mitigation options are summarized in Table 3-5 and Figure 3-5. The interim measures would be implemented during the period ahead of when the long-term solutions can be implemented. Based on the proposed EPA compliance timeline, the long-term treatment solutions would be online within 3 to 5 years. Therefore, the costs for the interim measures are presented for the 1-year and 5-year timeline.

Staffing costs are included for the pilot treatment unit because it is assumed that two additional water treatment operators will be needed. The other options assume that additional staff time will be needed, but it can be absorbed into the existing customer service team demands.

Table 3-5. Interim Measures Mitigation Costs for City Vulnerable Population										
Program Name	Brand/Type	Components	Initial Equipment Cost	Household Installation Cost	Replacement Filter[a]/Bottle[a]/Media	Replacement Interval[d]	Annual Staffing Costs	Annual Sampling Costs	1-Year Cost for Vulnerable Households[b]	5-year Cost for Vulnerable Households[b]
Point-of-Use Treatment	Aquasana AQ-5300 Under-sink Filter	Filter + 1pk of replacement cartridges	$175	$300[c]	$80	6 months	Assume programs can be implemented with existing staff	Assume no additional sampling required	$1,261,000	$2,715,000
	Hydroviv Under-sink Filter	Filter + cartridge	$175	$300[c]	$86	6 months			$1,275,000	$2,843,000
	Clearly Filtered Under-sink	Filter housing + cartridge	$495	$300[c]	$396	9 Months			$2,706,000	$7,205,000
	Clearly Filtered Pitcher	Filter pitcher + cartridge	$86	$0	$50	2 Months			$758,000	$3,457,000
Bottled Water	Culligan Water Coolers	Dispenser tower + 5-pk of 5-gallon bottles	$59	$0	$59	Monthly			$1,614,000	$8,070,000
	Crystal Springs Water Coolers	Dispenser tower + 5pk of 5-gallon bottles	$54	$0	$54	Monthly			$1,471,000	$7,353,000
Rebate Program	Clearly Filtered Pitcher	Filter pitcher + cartridge	$86	$0	$50	2 Months			$758,000	$3,457,000
Pilot Treatment Unit	Evoqua Custom Mobile Treatment Unit	Two, 20-gpm mobile treatment units + 2,300 sets of four 7-gallon refillable jugs[b]	$635,000	$318,000	$19,000	12 months	$437,000	$6,000	$1,396,000	$3,244,000

a. Costs assume subscription service where vendors directly deliver to households.

b. Number of vulnerable households was estimated to be 2,300 households for cost-estimating purposes, based on an approximate number of City of Vancouver customers that would qualify for federal LIHEAP assistance.

c. Assumes a licensed plumber and 2 hours per installation and includes insurance. Assumes no other plumbing costs or repairs would be required; does not include O&M costs such as gaskets or seals for filter housings.

d. Replacement intervals for filters and bottled water are based on vendor-provided information for an average family size of four.

e. Rebate program could be offered with an equal value of the other options; point-of-use filters, water pitchers, or bottled water, or a combination of options depending on the preferred approach. Costs presented for point-of-use water pitchers.

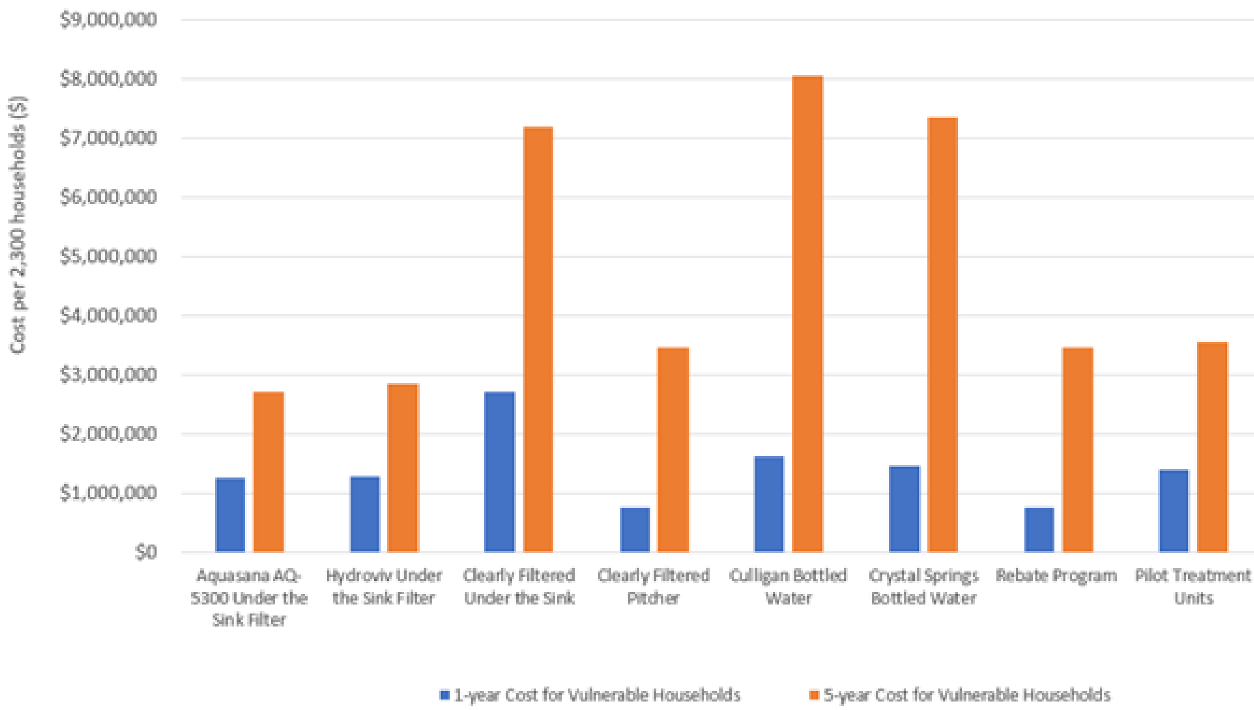

Figure 3-5. Interim measure mitigation costs for vulnerable populations

Rebate program cost presented for Clearly Filtered Pitcher option. Rebate program could be provided for Under-sink units or bottled water.

The lowest cost option over a 1-year period is the Clearly Filtered water pitcher. The next most-affordable options are the Aquasana and Hydroviv under-sink units. The cost for 5 years of service for bottled water or the Clearly Filtered under-sink unit are similar and have the highest costs of the options considered. The rebate program is proposed to be equal cost to the POU water pitchers option for comparison purposes. The exact rebate amount would be refined based on the selected rebate program options, and the market prices for filter units or water pitchers and install costs at the time of the program implementation.

3.3.2.1 Cost for Full Water Service Area Implementation

Table 3-6 summarizes the costs for implementing the preferred interim measures for the full City of Vancouver water service area. The service area as of September 2023 is 69,896 households. The cost would exceed the cost to implement PFAS treatment in the long term. These costs assume all customers would participate in the program for the point-of-use option with water pitchers, or the City would provide the rebate program to all current customers. Given the City's plan to implement PFAS treatment within the proposed EPA compliance timeline, and efforts to limit exposure long-term to reduce the chronic risk of PFAS, the City is not planning to implement interim measures beyond the vulnerable population.

Table 3-6. Interim Measures Mitigation Costs for Full Service Area [a]		
Program Name	1-Year Cost for Full Service Area	5-Year Cost for Full Service Area
Point-of-Use Treatment or Rebate Program - Water Pitchers [b]	$23,310,000	$106,340,000

a. Full service area of 69,896 households, from the City's Water Inventory Form (WFI) for 2023.

b. Costs assume subscription service where vendors directly deliver to households.

c. Rebate program could be offered for point-of-use filters, water pitcher, or bottled water, depending on the preferred approach. Costs presented for point-of-use water pitcher option.

3.3.3 Tradeoffs of Interim Measures

Table 3-7 summarizes the tradeoffs of the interim measures and the 5-year implementation costs.

Table 3-7. Summary of Interim Measures Comparison				
Program Type	Description	Advantages	Disadvantages	5-year cost for Vulnerable Households (range for multiple manufacturers)[a]
Point-of-Use Treatment Under Sink Filter [b]	Under-the-sink filtration system that dispenses treated water from existing faucet. Customer would need to have unit installed, and maintained, but cost would be reimbursed by City up to set amount. City would reimburse cost of delivery of replacement filters after 600 gallons use. Service cold water only.	• Filters available with performance data demonstrating PFOS and PFOA levels < proposed MCL • Maintains water supply from source customer is familiar with • Delivery service available to ease installation and filter replacement administration	• There is a variety of filter set-ups at households that require different installations for the point-of-use filters. Plumber may be needed for some filters, which adds logistics for the City to navigate • Not all filters demonstrate treatment to proposed MCL and so replacement timing could be more frequent for those options.	$2,715,000 - $7,205,000
Point-of-Use Treatment - Water Pitcher Filter [b]	A water pitcher that treats the water as the pitcher is filled from the faucet by the user. Cartridge filter would need to be replaced every 100 gallons treated. City would reimburse cost of Pitcher and bimonthly delivery of replacement filters.	• A water pitcher filter may be how some households are normalized for drinking water, and would continue that service. • Cheaper replacement cost compared to under-the-sink options • Simplistic and easy to adopt for customers	• Limited amount of water provided by pitcher at one time. • Households may still use untreated tap instead of filter when demand exceeds the pitcher's capacity. • Potential for negative public perception if not viewed as robust	$3,457,000
Bottled Water	Purchased bottled water includes 5-gallon jugs affixed to water towers, to be delivered to the customer's home. Five jugs delivered at a time, roughly monthly. Delivery services would be limited to bottled water that are part of the International Bottled Water Association (IBWA), which require bottled water companies that are members of the association to test	• Subscription service options available for direct delivery to customers • Does not require installation or impact to existing household infrastructure	• Bottled water is not aligned with the City's Climate Action Framework to reduce waste. • Bottled water use could contribute to reduced use of City water service long-term. • Jugs are heavy and challenging to handle.	$7,353,000 - $8,070,000

Table 3-7. Summary of Interim Measures Comparison				
Program Type	Description	Advantages	Disadvantages	5-year cost for Vulnerable Households (range for multiple manufacturers)[a]
	their bottled water products yearly for PFAS.			
Rebate Program[c]	City provides initial set-up fees for install and filters, or water pitchers. City provides monthly stipend for filter (under-the-sink or pitcher) replacements (or alternatively can provide a monthly stipend for bottled water).	• Provides flexibility for the City to offer more than one option to customers • Reduces administrative burden on City staff to oversee delivery and installation of filter systems	• If administered as a monthly stipend, there could be potential for customers to use funds for other purposes and not for water filters or bottled water • May require additional staff to administer the program	$3,457,000[c]
Pilot Treatment Unit	Pilot treatment unit to treat groundwater at several locations. Residents would fill reusable water containers on select days or times with City staff present. The City could provide an initial set of high-quality fillable water jugs with attached spigots to vulnerable households. This alternative would provide PFAS to less than EPA's proposed MCL.	• Option to provide treated water to more than the vulnerable population. • Pilot treatment unit can be used for operator training or community demonstration.	• Requires customers to have transportation to and from the pilot treatment unit locations. • The logistics for operating the pilot and making the treated water accessible to the public are onerous and will require additional City staff.	$3,244,000

a. Number of vulnerable households was estimated to be 2,300 households for cost-estimating purposes, based on an approximate number of City of Vancouver customers that would qualify for federal LIHEAP assistance.

b. Costs assume subscription service where vendors directly deliver to households.

c. Rebate program could be offered for point-of-use filters, water pitchers, or bottled water, or a combination of options depending on the preferred approach. Costs presented for water pitcher option.

3.3.3.1 Program Administration Considerations

The City will need to develop a system to determine eligibility for the interim measures and on-going program administration. There are opportunities that the City is considering to partner with Clark Public Utilities, with which the City already partners to oversee the City's Help 2 Others (H20) Program. One approach is to have City customers apply through this existing program to qualify for the interim measures assistance, and program staff determine eligibility. The City could use the vendor directly to fulfill the subscription requirements, they could also use a third party that could package up the systems with City of Vancouver information pamphlets, or leverage City staff.

3.3.4 Interim Measures Evaluation

To evaluate the interim measures alternatives and to develop recommendations, a decision-support framework, referred to as a multi-criteria decision analysis (MCDA), was used to engage City stakeholders in the decision-making process. A set of criteria was established to score the interim measures, based on the City's values for selecting an option that best serves the community in the interim. The evaluation criteria are summarized in Table 3-8. Additional background and detail on the MCDA process is provided in the supplemental TM in Appendix B.

Table 3-8. Evaluation Criteria for Interim Measures		
No.	Criteria	Description
1	Accessibility	How easily can alternative be communicated to and accessed by the vulnerable population?
2	Staffing Burden	How much additional staff time does the alternative require, or will additional hires be required to execute the alternative?
3	Reach	Is this alternative accessible to more than just the vulnerable population of the City (i.e., serve the entire City service area and has a larger reach)?
4	Disruption Risk	How fool-proof is the measure (i.e., what is the likelihood of the alternative breaking down or a disruption (e.g., supply chain shortage) occurring that results in the public losing some access to reduced-PFAS water)?
5	Effectiveness in Reducing PFAS Exposure	What is the level of confidence that the alternative will reduce the exposure to PFAS for customers that use the alternative?
6	Time to Implementation	How long will it take for the City to implement the alternative (i.e., the time it takes for the public to get reduced PFAS exposure)?
7	Alignment with the City's Climate Action Framework	How aligned is the alternative's environmental footprint with the City's Climate Priority Resolution? [a]
8	Public Perception	Will the public like the alternative (i.e., feeling good about what the City did in the interim)?
9	Safety	How safe is the alternative for City staff and the public?

a. City's Climate Action Framework (https://www.cityofvancouver.us/cmo/page/climate-action)

The nine criteria were weighted on a percentage basis by 17 individual stakeholders, representing key City departments, including Engineering, Operations, and Communications. The weighted criteria previously shown in Table 3-8 were used to score each of the alternatives. Scores ranged from 1 to 5 for each criteria with 1 not meeting the criteria and 5 exceeding the criteria. Using the weighted criteria and the criteria scores, a relative benefit score was determined, presented in Figure 3-6.

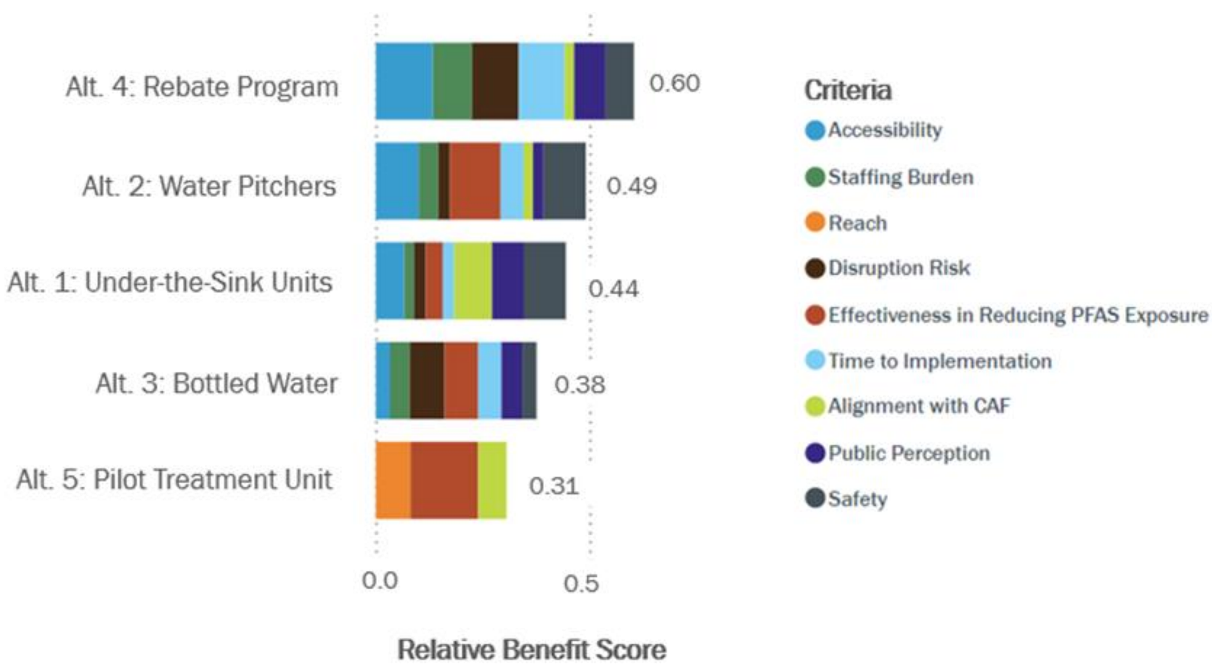

Figure 3-6. Interim measures relative benefit scores

The relative benefit score for each option was plotted against the 5-year implementation costs to see how the interim measures compare, as presented in Figure 3-7. Alternatives toward the upper left of the chart score the “highest” with the highest relative benefit score and lowest cost.

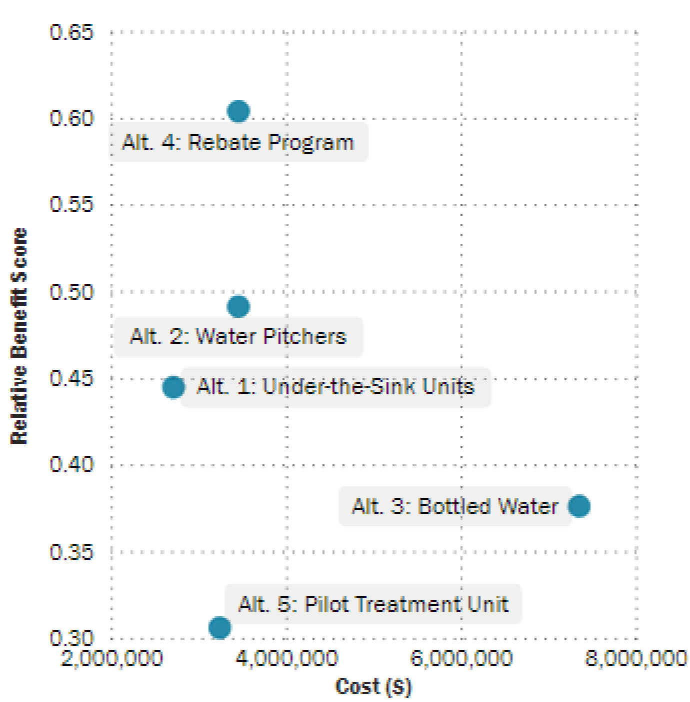

Figure 3-7. Best-value ranking based on cost and relative benefit score

Based on the assessment of the potential interim measures and scoring process, the rebate program scored the highest. This option could provide flexibility for customers to receive assistance for in-home point-of-use filters, water pitchers, or bottled water. The next highest scoring options were the water pitchers followed by the under-the-sink units (administered not as a rebate program). The City’s next steps will be to present the options to the City Council to gather input on the options, and to develop a plan around the preferred option.

The City is focusing these interim measures on vulnerable populations to assist those who may experience financial challenges in taking interim steps. The City has and will continue to provide guidance on interim measures that all customers can take as treatment improvements come online.

Section 4

Water Quality Goals Assessment

As mentioned above, the City has six water stations with groundwater wells that have detected PFAS concentrations at or above the Washington SALs for PFOS and PFOA, and two additional water stations that have PFOA and PFOS levels above the lower proposed EPA MCL levels. The treatment target for PFAS impacts which water stations need treatment and the media change-out frequency, with a direct impact on initial capital and longer-term O&M costs.

This section highlights the status of the proposed EPA PFAS rule in the context of the PFAS levels detected in the City's system and provides an assessment of costs to meet the Washington SAL (current regulation) compared to proposed federal MCL (anticipated future regulation).

Additionally, there are considerations for how close to the proposed MCL the City sets the target for triggering a media change out. This section will discuss considerations for setting the treatment target and will present the City's recommended treatment goals to meet the anticipated federal regulation to protect public health in the long-term.

4.1 Water Quality Goals Assessment

Table 4-1 summarizes the current Washington state regulations (discussed in Section 1.2) and the proposed MCL. Currently, under Washington State regulations, the City must test entry point samples. Sampling frequency requirements are dictated by the percent of the SAL detected:

- ≤ 20% of SAL: Monitor once every 3 years
- > 20% but ≤ 80% of SAL: monitor annually
- ≥ 80% of SAL: monitor quarterly

State regulation requires quarterly sample collection to confirm these ranges. If the average results of the initial and confirmation samples exceed the SAL or if the City does not collect a confirmation sample, customers must be notified.

Under the proposed EPA regulations, the City must test entry point samples for PFAS every quarter. Violations are based on a running annual average of samples at each point of entry to the distribution system. Refer to Section 1.2 for a full overview of the latest regulations.

Drinking water MCLs are set at levels to be protective of public health. Table 4-1 presents the City's proposed treatment goal. Water utilities develop water quality treatment goals to target levels below regulatory requirements that provides a band for flexibility to achieve regulatory compliance. Often utilities set water quality goals at a 50th to 75th percentile of the MCL. The running annual average goal is proposed to be set at 3 ng/L for PFOS and PFOA. The goal for the HI is set at a ratio of less than 0.75, three-quarters of the proposed MCL. The minimum reporting limit for PFOS and PFOA is 2.0 ppt for Method 537.1. By setting the goal at the 75th percentile, the goal is above the level of detection. This goal serves as a lower internal operational target to provide a buffer from the proposed compliance requirement. It allows for operational flexibility and blending as the City upgrades water stations with water treatment systems to address PFAS. The internal treatment goal would aim to achieve compliance in an assumed 5-year compliance window.

It's important to recognize that the level of health concern for PFAS compounds is not the same. For example, the health-based water concentration for PFBS is 500 times higher than the proposed MCL for PFOS and PFOA because it has a lower health risk and requires a higher level of exposure to be harmful. This point demonstrates that goals should be based on individual PFAS compounds (as currently regulated). If not, treatment media changeout costs and capital improvement costs increase.

This water quality goal is aligned with the proposed rule to be protective of public health. PFAS is a chronic health risk; therefore, compliance based on an annual running average is appropriate and recommended by the health toxicity data used to set the proposed EPA PFAS compliance requirements.

Table 4-12. Proposed Treatment Goal

PFAS Compound	Washington SAL (ng/L) [a]	Proposed EPA MCL (ng/L) [b]	Proposed Treatment Target Goal (ng/L) [c]
PFOA	10	4	3
PFOS	15	4	3
PFNA	9	Hazard Index < 1.0[c]	Hazard Index < 0.75[d]
PFHxS	65		
PFBS	345		
GenX	Not included		

a. *Washington Board of Health PFAS Rulemaking, effective January 1, 2022.*

b. *Based on proposed EPA MCLs released March 2023.*

c. *Proposed treatment target goal set at 75 percent of the proposed MCL to provide a buffer for compliance.*

d. *The Hazard Index calculation shall not exceed a value of 1.0 and is calculated based on summing the ratio of four PFAS compounds' measured concentrations compared to each compounds individual health-based water concentration. The proposed goal is set below the proposed EPA MCL*

4.2 Impact of EPA Proposed MCL

Under the SAL, six of the City's nine currently operational water stations have PFOS or PFAS above the limits. With the proposed EPA MCL for PFOS and PFOA set at 4 ppt, two additional water stations exceed the limit: WS1 and WS7.

Table 4-3 estimates the capital cost impacts of the regulatory change and WS1 and WS7 requiring treatment. The total capital cost increase under the proposed MCL scenario with the two additional water stations is $62 million (+100/-50 percent) with GAC, and $50 million (+100/-50 percent) with IX for WS1.

Table 4-3. Capital Costs for Additional Water Stations Under Proposed MCL Scenario[a]					
Station	Proposed Treatment Type for Estimate	Proposed Treatment Capacity (gpm)	Upper range (+100%) Cost	Capital Planning Cost	Lower Range (-50%) Cost
WS1	GAC	10,000	$91,200,000	$45,600,000	$22,800,000
WS1	IX	10,000	$67,800,000	$33,900,000	$16,900,000
WS7	GAC	3,333[b]	$32,600,000	$16,300,000	$8,200,000
Total Addition with WS1-GAC and WS7			$123,800,000	$61,900,000	$31,000,000
Total Addition with WS1-IX and WS7			$100,400,000	$50,200,000	$25,100,000

a. Capital costs were adjusted for escalation based on a proposed implementation timeline, presented in Section 6.

b. WS7 PFAS treatment would be 3,333 gpm in the future to meet the proposed Qi, along with 600 gpm from the existing deep well (WS7-2).

WS7 costs are for a system with a capacity of 3,333 gpm to meet the future proposed instantaneous water rights (Qi) for the water station from the shallow aquifer. This future capacity is assuming additional wells will be drilled at the station to provide the higher production in the future. The water station would also maintain production from an existing deep well, with a proposed Qi of up to 600 gpm.

Out of all of the water stations, WS1 has the lowest measured PFOS levels and is the City's largest capacity water station. Given the proposed treatment goal, the capital costs for WS1 are for a system with 50 percent treatment capacity. The PFAS levels are low enough to achieve below the water quality goal by bypassing a portion of the raw water around the treatment unit. A 50% blend ratio allows annual average concentrations to increase in the raw water from what the City has measured historically from PFAS monitoring thus far.

WS1's site is pretty constrained for a treatment system. Given there are site constraints at WS1, IX may be a preferred treatment option to reduce the footprint. Table 4-3, above, presents costs for both GAC and IX treatment. Proposed treatment layouts for WS1 and WS7 are provided in Appendix E. Section 6.2 provides additional details on the assumptions around the capital cost.

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Section 5

Criteria For Prioritization

The eight water stations needing treatment cannot be feasibly upgraded simultaneously. Therefore, the projects will need to be phased in over the next 5 years to meet the compliance window. To develop a proposed timeline for implementation, the sites were evaluated against a set of criteria to understand different phasing options and to develop a proposed timeline that balances priorities for the City. This section outlines the prioritization criteria and options for phasing the water station treatment upgrades and concludes with the key drivers for the preferred implementation order.

5.1 Prioritization Criteria

To explore the potential water station phasing options, the water stations were initially ordered based on the following prioritization criteria:

- Average PFOS concentrations
- Average annual combined PFOS and PFOA loads (concentration multiplied by the average flow)
- Cost/Size to balance costs over the implementation timeline

5.1.1 PFAS Concentration Levels

Table 5-1 presents the water stations in order of average PFOS levels from highest (red) to lowest (green). The order of PFOS levels generally follows the order of the other PFAS compounds. The order shows that WS14 has the highest PFOS levels, while WS1 has the lowest levels. Ellsworth WTP has no PFAS detections to date.

Table 5-1. Water Stations Sorted by Average PFOS Levels

Water Station	Average PFAS (ng/L)[a]				
	PFOS	PFOA	PFBS	PFHxS	PFNA
WS14	21.7	13.6	7.1	4.7	ND
WS4	18.8	7.6	4.5	5.7	0.5
WS15	17.4	4.9	5.0	4.7	ND
WS8	16.0	7.3	5.4	3.1	0.6
WS9	13.9	6.5	4.5	3.4	ND
WS3	9.3	3.3	4.3	5.6	ND
WS7[b]	6.2	1.3	1.9	3.4	ND
WS1	4.4	2.7	3.0	4.2	ND
Ellsworth	ND	ND	ND	ND	ND

a. Average PFAS results from samples collected in 2020, 2021, and March 2023.

b. Sampling at WS7 included only Well WS7-1. Well WS7-2, which draws from the SGA, had non-detect samples.

ND = non-detect

Brown AND Caldwell

5.1.2 PFAS Load to the Distribution System

Table 5-2 presents the water stations ordered by highest to lowest combined PFOS and PFOA average annual loads. The loads were estimated based on the average PFOS and PFOA concentrations and average flow for the water station. The loading order is indicated with color formatting (red = highest, green = lowest). As anticipated, the three largest water stations are listed first, whereas WS7 is ordered last with the lowest PFAS and average flow of the water stations.

Table 5-2. Water Stations Sorted by Average Annual PFOS and PFOA Loading

Water Station	PFOS Average (ng/L)[a]	PFOA Average (ng/L)[a]	Average flow (gpm)	PFOS Load (ppy)[b]	PFOA Load (ppy)[b]	Combined PFOS + PFOA (ppy)[b]
WS9	13.9	6.5	6,090	0.37	0.17	0.54
WS4	18.8	7.6	4,342	0.36	0.14	0.50
WS1	4.4	2.7	10,450	0.20	0.12	0.33
WS14	21.7	13.6	1,716	0.16	0.10	0.27
WS3	9.3	3.3	2,134	0.09	0.03	0.12
WS8	16.0	7.3	755	0.05	0.02	0.08
WS15	17.4	4.9	784	0.06	0.02	0.08
WS7[c]	6.2	1.3	700	0.02	0.00	0.02

a. Average PFAS results from samples collected in 2020, 2021, and March 2023.

b. Average annual load in terms of pounds per year (ppy) assuming operation 365 days/year for estimation purposes.

c. Sampling at WS7 included only Well WS7-1. Well WS7-2, which draws from the SGA, had non-detect samples.

5.1.3 Balancing Costs

Given the water station upgrades need to be phased in over time, their capital costs, too, will be spread out over the implementation timeline. To further balance out costs and prevent instances of back-to-back large capital projects, the water stations were ordered altering between larger and smaller systems, as presented in Table 5-3, which correlates to altering between a lower cost project and a higher cost project. The order took into account PFAS concentrations to the extent possible, while pairing larger and smaller cost projects. WS1 and WS7 were fixed in the timeline as the last projects with the lowest priority. WS1 is the largest station with the lowest PFAS levels, and was moved to the end of the list. WS7 was fixed as the last project for implementation because the PFAS levels can be blended down with the deep aquifer well, WS7-2, and is lower priority for treatment. The costs are based on all the impacted water stations implementing PFAS treatment. Refer to Section 6 for details on the capital cost basis and assumptions, and costs for the proposed implementation plan with the anticipated management approach for each station, including new supply development at some of the sites.

Table 5-3. Water Stations Ordered By Balancing Costs over Timeline				
Water Station[a]	Proposed Treatment Capacity (gpm)[b]	Upper Range (+100%)	Estimated Cost	Lower Range (-50%)
WS14*	3,200	$27,100,000	$13,500,000	$6,800,000
WS4	10,700	$80,600,000	$40,300,000	$20,100,000
WS8	3,333	$32,300,000	$16,100,000	$8,100,000
WS9	10,872	$82,400,000	$41,200,000	$20,600,000
WS15	4,000	$39,900,000	$19,900,000	$10,000,000
WS3	6,000	$48,200,000	$24,100,000	$12,000,000
WS1*	10,000	$91,200,000	$45,600,000	$22,800,000
WS7*	3,333	$32,600,000	$16,300,000	$8,200,000

a. Costs presented for PFAS treatment for all stations with GAC. Treatment technology selected for planning-level cost estimation only. Selected treatment will be confirmed through planning and design in the future.

b. Treatment capacities to meet the proposed Qi based on City's evaluation as of September 14, 2023.

*c. Sites marked with * were fixed in the timeline. WS1 is the largest site with the lowest PFAS levels with lower priority, and WS7 can blend with the deep aquifer well (WS7-2) to get PFAS below the proposed MCL, and is lower priority.*

The order in Table 5-3 represents one possible phasing approach to pair the stations and balance the costs over the timeline, taking into account the PFAS concentrations to the extent possible, while pairing smaller cost and higher cost projects. There are funding options to bundle projects for funding assistance, like Water Infrastructure Finance and Innovation Act (WIFIA) loans that may reduce the financial burden of implementing multiple larger projects back-to-back. Funding assistance opportunities and considerations will be part of the City's on-going planning efforts for implementing this Plan.

5.1.4 Equity Lens

Equity is a top priority for the City in all aspects of its operations and is an important consideration when planning City projects. To understand how the water stations line up against the City's equity mapping, the City prepared an analysis of its water service area involving areas mapped by an equity index classification based on the socioeconomic vulnerability of the households, from lowest to highest vulnerability. The water station locations were overlaid on the City's equity index map presented in Figure 5-1 and were classified based on the PFAS concentrations detected to date. The water stations are classified based on whether the water station has PFOS or PFOA above the MCLs (lower levels), or higher levels exceeding both the MCLs and the Washington SAL. Only Ellsworth WTP has no detections of PFAS, which is the only water station primarily served by the deep aquifer.

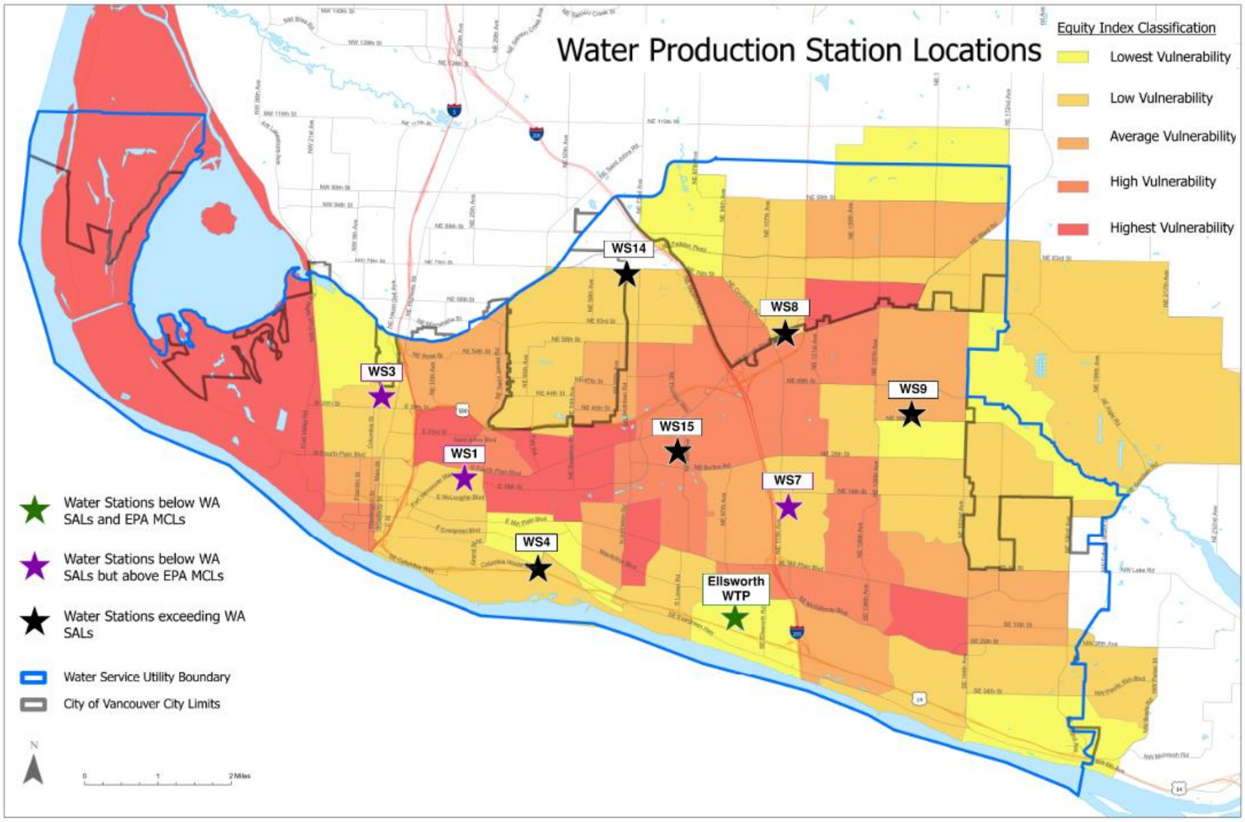

Figure 5-1. City of Vancouver equity index map

Given the water station upgrades will have to be phased in overthe next several years, there will be stations that serve PFAS-treated water to the distribution system before others. A benefit of the City's water system is that the water stations are all connected, meaning water can be sent from one water station to serve another area, so there is less of a localized impact of one station having higher PFAS levels compared to another station. Based on this equity index map, none of the water stations are located in an area with the highest vulnerability. The area surrounding WS15 is mapped as high vulnerability. This station can be shut off, and the area can be served by PFAS-treated water by other water stations, reducing the station-specific impact on the local population surrounding the water station. However, shut down of WS15 is dependent on operation of other water stations to supplement the flow. Current construction at other stations has prevented the City from shutting down this station in response to PFAS detections, but in the future once construction is complete and the stations that are offline can be brought online, the City will have more flexibility to shut off WS15 outside of high demand periods.

The other water stations are generally in areas of low vulnerability, and not a priority over others for implementation.

5.2 Water Station Prioritization

The water station prioritizations based on the specific criteria were overlaid with other schedule drivers to develop several capital improvement project (CIP) ordering for the water stations. Three of the water stations were fixed in the CIP phasing options:

- WS14: With WS14 design underway as of October 2023, WS14 was fixed as the first project.
- WS1: WS1 has the largest capacity and lowest PFAS detections, with the ability to blend down to below the MCL levels. Additionally, the PFAS levels are below the Washington SALs.

- WS7: WS7 levels are the lowest of the water stations and are below the Washington SALs. Additionally, WS7 is served by a smaller well (WS7-2) that pulls from the deep aquifer, which can be operated to blend down the PFAS concentrations to below the MCL.

Table 5-4 presents the potential water station ordering based on the prioritization criteria as follows:

- CIP1: PFOS concentrations
- CIP2: Combined PFOS and PFOA annual average loading
- CIP3: Balancing costs over the implementation timeline

Table 5-4. CIP Options for Water Station Phasing

Order	CIP1 – PFOS Concentrations	CIP2 – Combined PFOS + PFOA Loading	CIP3 – Balancing Costs
1*	WS14	WS14	WS14
2	WS4	WS9	WS4
3	WS15	WS4	WS8
4	WS8	WS3	WS9
5	WS9	WS8	WS15
6	WS3	WS15	WS3
7*	WS1	WS1	WS1
8*	WS7	WS7	WS7

*Sites marked with * were fixed in the timeline and not based on the prioritization criteria for the CIP order.*

5.2.1 Preferred Water Station Order

Table 5-5 presents the preferred water station implementation order based on the balance of the proposed criteria and ability to push WS15, WS8, and WS7 further out the schedule. As discussed in Section 3, in the interim, the City can shut off wells and blend to reduce the impact from specific water stations that would otherwise be prioritized sooner based on the PFOS concentrations and PFAS loading. Specifically, WS15 and WS8 can be shut down for a period of time and supplemented by other water stations and are, therefore, less priority for treatment implementation. Additionally, WS15 and WS8 are being considered for new supply development, which will involve initial well development prior to installing treatment and can be pushed out further in the proposed timeline. WS7, as noted above, can be blended down with the existing deep well to meet the proposed MCL and reduce the need for treatment within the compliance window.

Table 5-5. Proposed Water Station Implementation Order

Order	Water Station
1	WS14
2	WS4
3	WS9
4	WS3
5	WS1
6	WS15
7	WS8
8	WS7

Section 6

Roadmap for PFAS Reduction

This section presents the City's proposed roadmap for PFAS management over the next 8 years to secure a safe and clean groundwater supply for the future. This proposed implementation plan synthesizes the planning efforts outlined in the previous sections to present a prioritized order of improvements for each water station and a timeline to implement the treatment upgrades.

The proposed compliance timeline for the draft EPA PFAS Rule is aggressive—just 3 years (2026)—as of Fall 2023. The City can request a 2-year extension from DOH, but there are significant improvements that the City needs to accomplish even in an extended time frame. The water stations needing treatment cannot feasibly be upgraded simultaneously; therefore, project phasing is needed to meet the goal while balancing resource limitations. As discussed in Section 5, the order of the water stations was reviewed against a set of priorities to develop a defensible rationale for the proposed phasing of treatment implementation. While a proposed timeline is presented within this Plan, other forces could impact the implementation order in the future.

The following sections present the proposed phasing schedule to meet the compliance timeline, estimated capital costs adjusted for the proposed timeline, and annual O&M costs for the treatment systems, followed by an outline of the City's key action steps for PFAS management.

6.1 Treatment Implementation Plan

The preferred implementation schedule is presented in Figure 6-1. Estimated durations for design and construction were identified to inform the timeline based on recent local project experience and current anticipated construction windows. Design was estimated to be between 10 to 12 months depending on project size. Given recent long lead times, construction was assumed to be 18 months at a minimum and extended to 24 months for the larger sites (WS1, WS4, and WS9). There is currently wide variability for electrical equipment lead times, with lead times between 1.5 years to 2.5 years. This proposed schedule assumes long lead-time electrical equipment will be pre-procured to reduce delay in the overall schedule.

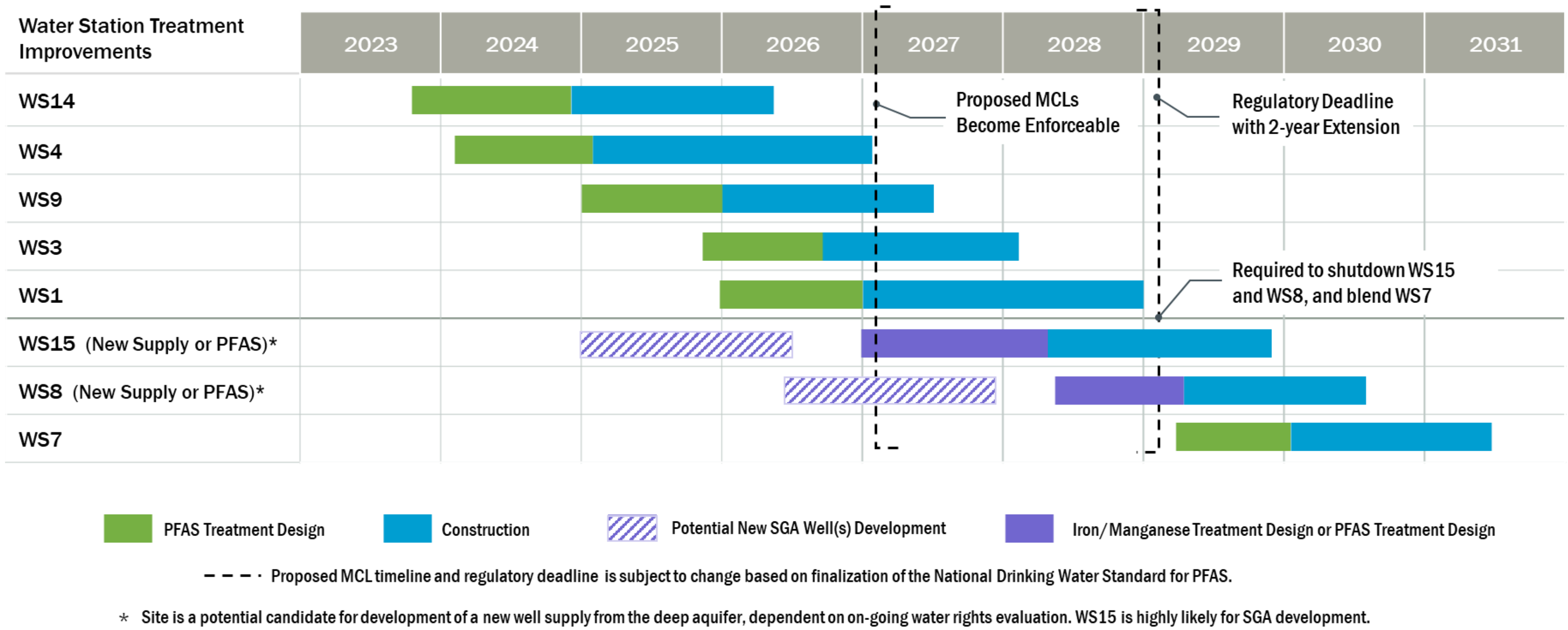

Figure 6-1. Proposed implementation plan for water station improvement projects

The proposed schedule is based on several key assumptions for operations, with unknowns that may require the City to revisit the order and be adaptive:

- Stations WS8 and WS15 will have to be shut down after the compliance window (assuming a 2-year waiver is granted) if samples do not meet the proposed MCLs.
- WS7 is anticipated to be blended down with deep well (WS7-2) operation while the City plans for drilling additional wells at that site and implements PFAS treatment.
- WS8 and WS15 well development is an unknown. The proposed timeline assumes well development and planning for WS8 and WS15 will be done in parallel with the design of other water stations. This is important to get started to determine the feasibility of drilling the deeper aquifer and the production yield. If the new well evaluation does not confirm the anticipated yield, then the City will plan for PFAS treatment. The timing would be similar to the new well supply, with WS8 and WS15 turned off after the compliance window until treatment is online.
- WS3 is also going through a major plant upgrade to replace an existing above-ground reservoir and elevated storage tank, as well as other system upgrades. Planning for PFAS treatment will be in parallel with the other site upgrades; however, that also means there could be schedule impacts given the scale of the site upgrades and integration of this project with the other site improvements.
- If WS3 is shutdown, WS1 needs to be operational to supplement production; therefore, the construction windows for WS3 and WS1 need to be coordinated. The proposed schedule presented shows some overlap in the schedules with the assumption that the cut-over period and shutoff window will be coordinated between the project schedules.

The City will also have to balance competing projects for other station upgrades that could impact priority, such as:

- WS8 and WS15 disinfection treatment systems are both nearing the end of their service life and are planned for future replacement to onsite hypochlorite generation (OSHG) in the future. For WS15, there are also plans to expand production in the future, which needs to be planned for. Currently, there is a hold on the WS15 OSHG project in order to plan around future PFAS upgrades.
- Other planned OSHG conversions at WS4 and WS9 in the next few years.
- Planning for a new operations center, anticipated to come online in 2027.

Along with the specific water station considerations, overall there are forces that are unanticipated that may impact the implementation timeline, like unexpectedly long lead times. Electrical equipment lead times can be upwards of 2+ years as of October 2023. Consideration for anticipated lead times and how to mitigate that for the schedule will be evaluated as part of the early planning steps for each water station, along with options for pre-procurement.

6.2 Capital Costs

Class 5 planning-level cost estimates were prepared for each of the impacted water stations. Costs for GAC are presented for all the stations. The selected PFAS treatment type (GAC and IX) for each station will be determined based on further evaluation of the on-going pilot testing and evaluation of the specific sites in the future. Additionally, PFAS treatment could be installed at the sites planned for new supply development if the well development does not produce the anticipated yield.

A Class 5 estimate has an associated accuracy range of -50 to +100 percent per the Association for the Advancement of Cost Engineering International. The Class 5 cost estimates were prepared using

2023 vendor quotes as of October 2023, equipment pricing, historical project data, and other costs specific to the project locations.

Several typical markups were applied to the gross cost estimate, including a 35 percent contingency for undesigned/undeveloped details, also referred to as the construction contingency. This contingency level is typical for planning-level costs. A 30 percent markup for indirect soft costs was also applied to account for costs sustained by the City outside of the cost for facility construction. These indirect soft costs include engineering during design and construction, construction management, legal and administrative fees, and other allied costs required for project execution.

The eight projects are anticipated to be phased in over about 8 years between 2024 and 2031. Escalation was adjusted for each project based on the preferred timeline presented in Section 6.1., with an escalation rate of 4.0 percent per year to the mid-point of construction. Table 6-1 presents the escalation rates to the mid-point of construction applied to the cost estimate for each water station.

Table 6-1. Escalation to Construction Mid-point

Water Station	Escalation to Construction Mid-point
WS14	7.3%
WS4	9.1%
W9	11.7%
WS3	14.7%
WS1	18.2%
WS15	22.6%
WS8	26.8%
WS7	33.3%

Table 6-2 presents the planning-level cost estimate ranges for treatment at the eight water stations, assuming GAC for PFAS treatment. The plan includes costs for new supply treatment at WS15 and WS8, as one option. The City could decide to implement PFAS treatment at those sites in the future. The total Class 5 capital cost estimates range from $13.5 million to $46 million (+100/-50 percent) with a total estimated cost of $235 million (+100/-50) for all the stations.

Table 6-2. Capital Costs for Proposed Implementation Plan						
Water Station	Treatment Type for Estimate [a]	Treatment Capacity (gpm) [b]	Treatment Capacity (mgd)	Upper Range (+100%)	Estimated Cost	Lower Range (-50%)
WS14	PFAS Treatment	3,200	4.6	$27,100,000	$13,500,000	$6,800,000
WS4	PFAS Treatment	10,700	15.4	$80,600,000	$40,300,000	$20,100,000
WS9	PFAS Treatment	10,872	15.7	$82,400,000	$41,200,000	$20,600,000
WS3	PFAS Treatment	6,000	8.6	$48,200,000	$24,100,000	$12,000,000
WS1	PFAS Treatment	10,000	14.4	$91,200,000	$45,600,000	$22,800,000
WS15	New Deep Well Supply [c]	4,000	5.8	$56,600,000	$28,300,000	$14,150,000
WS8	New Deep Well Supply [c]	3,333	4.8	$52,200,000	$26,100,000	$13,050,000
WS7	PFAS Treatment	3,333	4.8	$32,600,000	$16,300,000	$8,200,000
			Total	$470,900,000	$235,400,000	$117,700,000

a. Treatment technology selected for planning-level cost estimation only. Selected treatment will be confirmed through future planning and design.

b. Treatment capacities to meet the proposed Qi based on City's evaluation as of September 14, 2023.

c. Cost for new source includes new well drilling, new raw water pumps, and a new water treatment facility with a pressure filter system for iron and manganese removal. The City is still determining whether a deeper well supply is added to WS8 and WS15 or PFAS treatment is added.

Figure 6-2 presents the capital costs over the implementation timeline. The cost for the new supply development and treatment sites includes the cost for the new well drilling and new treatment facilities.

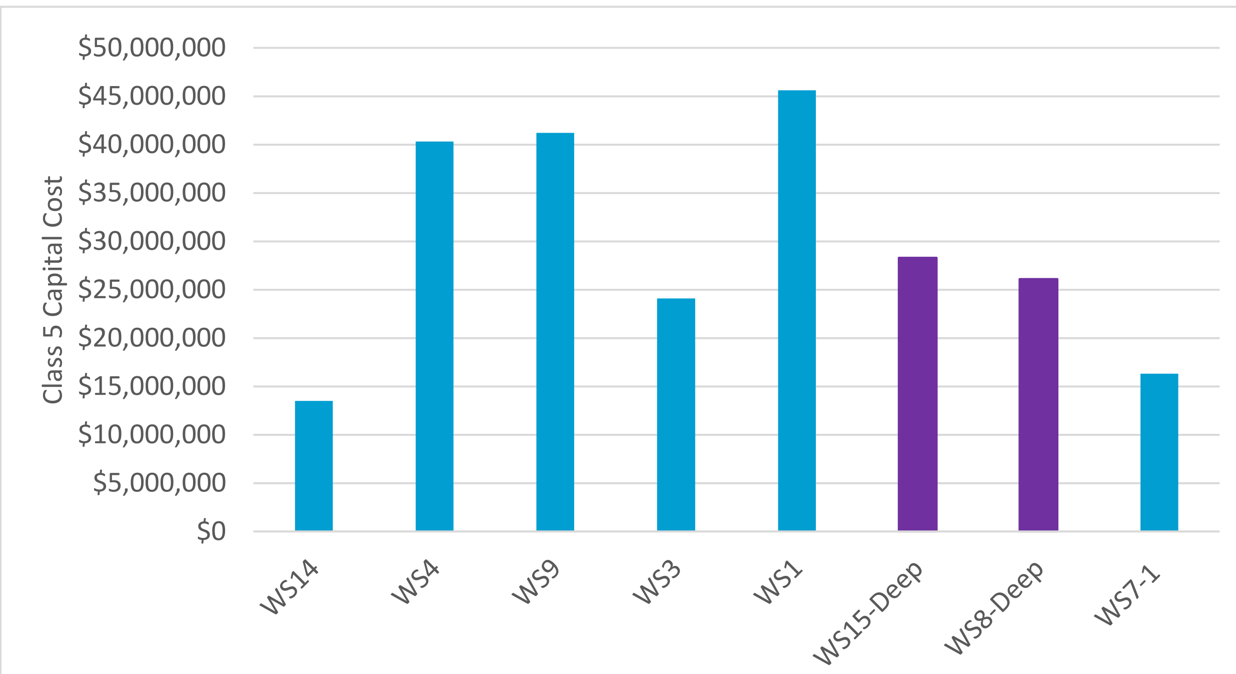

Figure 6-2. Capital costs for proposed implementation plan (+100/-50%)

Water station treatment upgrades are presented in order of proposed implementation (left to right)

Purple bars indicate new supply development of the deep aquifer with Fe/Mn treatment, whereas blue represents PFAS treatment.

6.3 Annual O&M Costs

Annual O&M costs were developed for each water station based on the proposed treatment for the implementation plan. Annual O&M costs for the PFAS treatment systems were estimated including costs for media replacement as well as staffing costs for typical O&M tasks, and for additional sampling for PFAS. The O&M costs associated with the PFAS treatment system are largely driven by the costs for media replacement, which is related to the time the system is operational and the anticipated performance of the media. In addition to costs for added operator time to run the treatment systems, additional pumping will be required to account for the head loss through the treatment systems. This planning effort was limited to a planning-level assessment and did not include a detailed hydraulic evaluation for each water station; therefore, the costs do not include energy costs associated with pumping for the PFAS systems. The evaluation also excluded estimation of water used for backwashing that doesn't go to production, or additional sewer fees related to backwash discharge.

The following sections outline the cost basis for the PFAS treatment system O&M cost estimates and the overall annualized O&M costs for all water stations, including WS8 and WS15, with iron/manganese treatment.

6.3.1 Media Replacement Frequency Determination

The media will need to be replaced periodically to ensure the finished water meets the water quality goal (Section 4.5). The media change-out frequency will determine the overall O&M cost for PFAS treatment. The change-out frequency is determined as the number of bed-volumes prior to detection of PFAS above the treatment goal (e.g., proposed MCL for PFOA and PFOS) at the outlet of the lead vessel. Since the vessels are a lead-lag pair, the outlet of the lead vessel will be used to determine the bed-volumes of the media for estimation purposes. Breakthrough will be sampled from the lead; however, compliance with the goal itself will be determined based on the outlet of the pair.

As part of the PFAS Treatment Feasibility Study the average media change out was estimated to occur every 50,000 bed-volumes for GAC and 300,000 for IX (BC, 2022). Since then, the City has contracted work with HDR to conduct a pilot-scale test to directly compare the performance of four types of media and determine expected bed-volumes. The pilot data was reviewed to estimate PFOS and PFOA breakthrough to help inform costs (HDR, 2023). Overall, the GAC and IX media are lasting longer than the estimates assumed for the previous study.

The estimated bed life for the GAC and IX medias are summarized in Table 6-3, including the theoretical bed life based on anticipated performance of the media under average operating conditions, and the actual bed life anticipated for operations cut off sooner to reflect a more realistic change-out frequency and cost. For the GAC media, the theoretical bed volume was assumed to be an average of 90,000 bed-volumes based on reviewing the pilot study data for when breakthrough would occur above the proposed MCL for PFOA and PFOS. Based on the testing to date, PFOS may breakthrough above the treatment goal ahead of the other compounds. The bed-volume of 90,000 translates to a change-out frequency between 3.9 and 9.5 years of operation for the six water stations at the given pump utilization rate (i.e., the percent of time a water station was operational). The initial media change-out frequency will be longer than subsequent media changeouts. The theoretical bed life is based on subsequent media changeouts following the first.

For IX, the theoretical bed volume was assumed to be an average of 560,000 bed-volumes based on reviewing the pilot study data. For WS4, at a 54 percent utilization (operating approximately 13 hours/day on average), these bed-volumes equate to a bed life of approximately 9.5 years (Table 6-3). For WS1, which is estimated to operated at 80 percent utilization (19 hours/day on average), the change-out frequency was estimated to be 6.3 years.

Table 6-3. PFAS Media Change-out Frequency					
Water Stations	Water Station Average Flow (gpm) [a]	Average Flow per Vessel Pair (gpm)	Percent Time Operational (%) [a]	Theoretical Bed Life (years) [b]	Estimated Actual Bed Life (years) [b]
WS1_GAC	4,412	441	80%	5.0	5.0
WS1_IX	4,412	735	80%	6.3	6.3
WS3	2,134	356	54%	9.1	5.0
WS4_GAC	4,342	434	54%	7.5	5.0
WS4_IX	4,342	724	54%	9.5	6.5
WS7	1,500	500	54% [c]	6.5	5.0
WS9	6,090	609	74%	3.9	3.9
WS14	1,716	572	69%	4.4	4.4

a. Average flow and percent operational time calculated from SCADA operational data from the past 3 years (2019-2021). Average flows for the sites are not expected to increase overtime, with the exception of WS8 and WS15, which are anticipated to increase based on planned water station improvements and demand increase. Average flow for WS1 was based on review of SCADA data in 2022, and assumes the average flow for the treatment system is 50 percent of the total station average flow. Data was not available for WS7 given periodic operation of the wells and was estimated to be about half of the future treatment system capacity.

b. The theoretical bed life (i.e., change-out frequency) is based on the assumed bed-volumes for each media type determined from the pilot study performance; 90,000 bed-volumes (GAC), 563,000 bed-volumes (IX) and the utilization rate for the water station. The lead vessel in each active pair will be replaced at that time. The actual bed life is the estimated media change out used for the cost estimate, cut off at 5 years for GAC and 6.5 years for IX. Operational cost estimates did not desire to be overly optimistic and were meant to reflect start-stop operation and other operational considerations for media changeout.

c. Operational time was estimated. SCADA data was not provided for this water station.

There are operational conditions that may result in a need to change out the media sooner than required by the PFAS treatment target (i.e., theoretical bed life). For example, there could be a buildup of constituents that make disposal of the media more difficult or impact the ability to regenerate the GAC. Additionally, the longer the media is left in the vessels between changeouts, the more difficult to it is to remove, which can lead to extended downtime and higher labor costs. Based on media supplier guidance on the assumed cut off for bed life and unknowns at this planning level, a cap was set on the total bed life for the annual O&M cost estimate of 5 years for GAC and 6. 5 years for IX. In operation, its recommended to monitor the media over time to check for other constituents to inform media changeout.

6.3.1.1 Media Costs

The media cost is dependent on the current market price for the product and the disposal costs. For this Plan, a GAC media cost of $2.30/lb was used for Calgon F400 media, based on the higher end for GAC media from Calgon in October 2023. F400 is one of the GAC media tested in the pilot study. The cost assumes a turnkey exchange, including haul away of the spent media for reactivation. If the media must go to the landfill or incineration, the cost would be higher.

The IX resin cost can range widely depending on the manufacturer and type. For the pilot study at WS4, the IX media testing includes Purolite, PFA694E, Calgon Carbon CalRes 2304, and Evoqua APR-2. The costs range from $480/cubic foot to $549/cubic foot, again based on vendor quotes from October 2023. For estimating purposes, the higher cost for CalRes 2304 was used ($549/cubic foot), which includes the cost for incineration disposal after changeout.

6.3.2 Staffing Costs Basis

For the PFAS treatment systems, additional staff resources are anticipated beyond what the City is currently operating with for its water stations. Labor costs associated with the new PFAS treatment systems include operator time for the media replacement, as well as time on a daily basis to operate and maintain the new treatment systems. Additional time for monitoring PFAS will also be required.

Staffing costs for the media replacement were estimated assuming 40 hours per change out based on experience at other similar treatment sites. A burdened hourly rate of $45.14, based on the 2023 salary for a Lead Water Production Operator of $7,825/month, was multiplied by the annualized changeout frequency to estimate an annual labor cost for each site.

The operator time was assumed to be about the same effort for both the GAC and IX media. Operator time for typical O&M tasks was estimated for the GAC and IX systems to be an average of just over 1 hour per day, or roughly 390 hours per year. Time for monitoring the vessels for PFAS was also estimated, including time for analyzing results and preparing monitoring reports. Time for sampling assumed PFAS samples will be collected monthly to monitor performance for operations, and collected quarterly for compliance. Monitoring time was estimated at approximately 160 hours per year. The total time for O&M and monitoring equates to 0.19 full-time equivalent. The costs were estimated based on the 2023 salary for a Lead Water Production Operator as stated above.

6.3.3 Analytical Costs Basis

Analytical costs for PFAS sampling were estimated assuming $250/sample, on a monthly basis. Collected samples would include one from the raw water, three from each treatment train lead vessel (25 percent, 50 percent, and bottom tap locations), and one from the combined treatment outlet. A field blank was included for each monthly sampling event at each water station.

6.3.4 PFAS Treatment O&M Costs

Table 6-4 provides a summary of the planning-level annual average O&M costs for media replacement, labor, and analytical costs for sampling at the six water stations where PFAS treatment is proposed (does not include WS15 and WS8, which are proposed for new deep well development). Costs for GAC treatment are presented. The assumed change-out frequency was based on pilot testing results, as discussed in Section 6.2; however, the costs presented could be higher or lower than presented depending on actual performance at full scale. Additionally, as discussed, costs associated with additional pumping and sewer fees are not accounted for and will increase the annual operating costs from what is presented in this Plan for all sites.

Table 6-4. Annual Average O&M Costs for PFAS Treatment

Water Station ID	Media Replacement Costs[a]	Staffing Costs	Analytical Costs[b]	Total Annual Average O&M Costs[c]
WS1_GAC	$185,000	$24,000	$27,000	$236,000
WS3	$111,000	$21,000	$27,000	$159,000
WS4_GAC	$184,000	$24,000	$27,000	$236,000
WS7	$55,000	$20,000	$18,000	$93,000
WS9	$236,000	$25,000	$27,000	$288,000
WS14	$62,000	$20,000	$18,000	$100,000

a. GAC media replacement costs include costs for turn-key replacement.

b. Analytical costs vary based on the number of trains for the proposed system, and assume monthly sampling for monitoring purposes.

c. Additional pumping and energy costs are not included.

6.3.5 New Supply Treatment O&M Cost

Table 6-5 provides a summary of the planning-level annual average O&M costs for media replacement, pumping costs, and typical staffing costs for WS15 and WS8, where the new well supply development and iron/ manganese treatment is proposed. The annual cost is estimated to be approximately the same for both stations because they have the same estimated average flow. WS6 is not included in the overall implementation plan given the water station is not operational at this time. The City may develop deep wells at WS6 at the same capacity as WS8, which would be the same approximate cost with the exception of specific differences in the well drilling costs depending on the number of deep wells that are developed at WS6. Refer to Section 2 for more detailed information on the cost basis.

Table 6-5. Annual O&M costs for New Source Development Compared to PFAS Treatment

Water Station	Annualized Media Change-out Costs	Annual Electrical Costs for Raw Water Pumping[a]	Annual Staffing Costs	Total Annual Costs
WS15	$17,000	$38,000	$18,000	$73,000
WS8	$17,000	$38,000	$18,000	$73,000

a. Operating costs at Ellsworth WTP in 2022 for well pumping and annualized greensand filter media replacement costs were used to estimate costs at the new well supply sites based on the average flows.

6.3.6 Total O&M Costs

Table 6-6 and Figure 6-3 presents a summary of the annual O&M costs for each water station in the proposed implementation plan. The costs show a range for WS1 and WS4 to include costs for GAC and IX treatment. A range is provided for WS1 and WS4 with IX, as those sites are particularly site constrained for GAC. The total estimated annual cost is between $1,260,000 to $1,360,000 per year, assuming the media replacement timing is capped at 5 years for GAC, and 6. 5 years for IX. If the City decided to go to IX for all of the water stations with PFAS treatment (not including WS15 and WS8 for this estimate), the O&M costs would increase to roughly $1,400,000.

Table 6-6. Annual O&M Costs for Proposed Implementation Plan

Water Station ID	PFAS Treatment Annual O&M Cost[a,b]	Iron/Manganese Treatment Annual O&M Cost[c]
WS1	$236,000 to $288,000	---
WS3	$159,000	---
WS4	$236, 000 to $281,000	---
WS7	$93,000	---
WS8	---	$73,000
WS9	$288,000	---
WS14	$100,000	---
WS15	---	$73,000
Total Annual O&M Cost	$1,260,000 to $1,360,000	

a. Costs include range for treatment with GAC (lower) and IX (higher).

b. PFAS treatment costs include media change out, staffing costs for typical operations and additional staff time for media change out and backwashing, and PFAS sampling costs.

c. Iron/manganese annual costs include media change out, staffing costs, and raw water pumping costs.

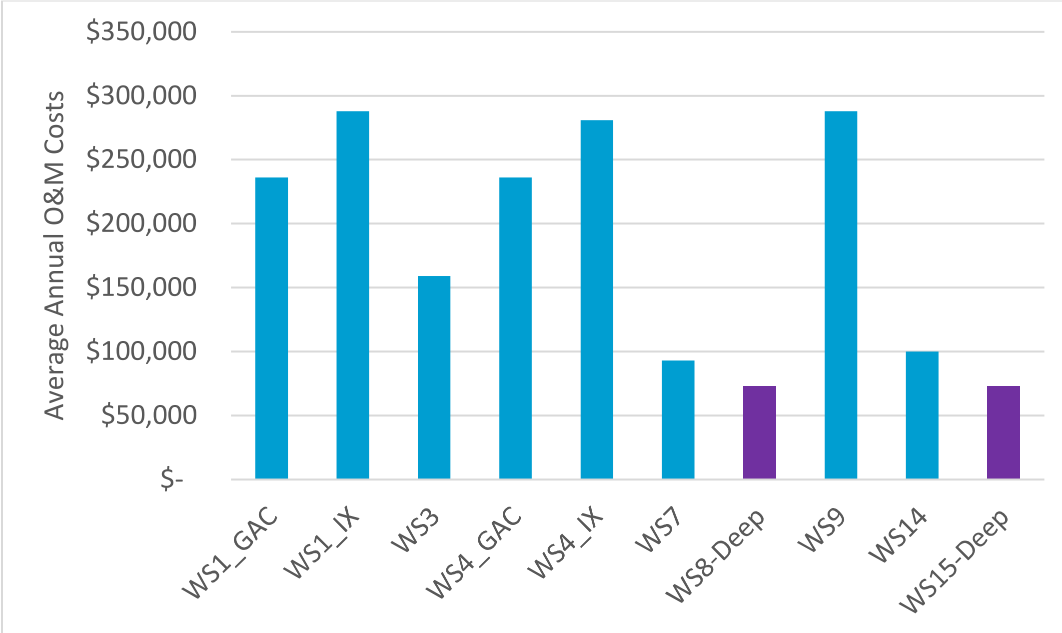

Figure 6-3. Annualized O&M Costs

Purple bars indicate new supply development of the deep aquifer with Fe/Mn treatment, whereas blue represents PFAS treatment.

6.4 City Action Steps

Since the first PFAS detections, the City has been committed to taking active steps to mitigate and manage PFAS in the City's water system. Over the past 5 years, as the PFAS regulations and sampling methods evolved, the City has developed an on-going sampling program and communications to customers, and since then has continued to learn of and assess the impacts in the water system and to plan for future PFAS mitigation. The City has taken the following key steps:

- Completed and implemented a communications plan that included coordination with Clark County Public Health and other local water utilities.
- Completed a PFAS Treatment Feasibility Study in 2022 (BC, 2022) to develop conceptual plans for implementing PFAS treatment at six of the nine water stations.
- Completed bench-scale testing of multiple IX resin and GAC media (HDR, 2023).
- Completed a PFAS source evaluation (Confluence) and on-going groundwater modeling by GSI to try to identify sources of PFAS in the aquifer and understand the plume of contamination (Confluence, 2023).
- Submitted and received a State Revolving Fund grant to design PFAS treatment at WS14.
- Initiated a 12-month pilot study to assess GAC and IX treatment technology (January 2023–anticipated January 2024).
- Initiated design at WS14 for a 3,200-gpm PFAS treatment system and developed design standards for PFAS treatment at other stations.
- Hired new City PM to support PFAS design projects.
- Contracted with Farallon Consulting to identify and sample potential sources of PFAS contamination.
- Completed this PFAS Management Plan to outline the necessary actions to achieve regulatory compliance.

These are just some of the steps the City has undertaken to date. Over the next year and into the future, the City will continue to advance toward managing PFAS and providing a safe and resilient water supply for City of Vancouver's future.

Next Year Look-ahead (2024)

In the upcoming year, the City will be focused on the following key activities:

- Complete pilot testing at WS4 to inform design at other water stations
- Establish interim measures program
- Initiate design for WS4
- Continue design of WS14 and initiate construction
- Plan for Request for Qualifications for next water station design
- Continue to look for sources of PFAS in local groundwater
- Evaluate need for new staffing resources specifically to manage PFAS projects
- Seek additional funding options in order to reduce rate payer burden
- Continue to communicate actions with customers
- Evaluate legal options to recover costs

Future Look-ahead (2025–2031)

Longer term, the City will be focused on the following activities to manage PFAS:

- Implement interim measures program
- Continue to implement plan with treatment at other water stations
- Plan for new water supply from the deep aquifer at select sites (WS15, and possibly WS6 and WS8)

This PFAS Management Plan provides the proposed roadmap for PFAS management over the next 8 years. Over the next year and into the future, the City will continue to make progress toward managing PFAS to secure a safe and clean groundwater supply.

Section 7

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Section 8

Limitations

This document was prepared solely for City of Vancouver in accordance with professional standards at the time the services were performed and in accordance with the contract between City of Vancouver and Brown and Caldwell dated October 7, 2022. This document is governed by the specific scope of work authorized by City of Vancouver; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by City of Vancouver and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

Further, Brown and Caldwell makes no warranties, express or implied, with respect to this document, except for those, if any, contained in the agreement pursuant to which the document was prepared. All data, drawings, documents, or information contained in this Plan have been prepared exclusively for the person or entity to whom it was addressed and may not be relied upon by any other person or entity without the prior written consent of Brown and Caldwell unless otherwise provided by the Agreement pursuant to which these services were provided.

Appendix A: Well Average PFAS Concentrations

Table B-1. Wells Ordered by Average PFAS Concentrations							
Water Station	Well	Well Capacity (gpm)	Average PFAS (ng/L)[a]				
			Perfluoro-1-octanesulfonic acid (PFOS)	Perfluoro-n-octanoic acid (PFOA)	Perfluoro-1-butanesulfonic acid (PFBS)	Perfluoro-1-hexanesulfonic acid (PFHxS)	Perfluoro-n-nonanoic acid (PFNA)
WS1	WS1-1	2,340	5.8	2.1	2.0	2.8	0.0
	WS1-7	2,260	5.0	2.1	2.2	3.2	0.0
	WS1-8	1,660	4.7	1.2	2.4	2.9	0.0
	WS1-9	1,860	4.6	3.3	2.4	3.0	0.0
	WS1-10	3,400	4.1	3.1	2.7	3.6	0.0
	WS1-11	2,560	4.0	2.0	2.9	3.4	0.0
	WS1-12	2,060	3.8	2.4	2.9	5.3	0.0
	WS1-13	2,340	3.7	4.5	4.0	4.5	0.0
	WS1-3	2,100	3.5	2.7	2.9	4.2	0.0
	WS1-2	2,260	2.7	3.2	2.9	4.8	0.0
WS3	WS3-3	2,000	10.9	4.1	4.8	5.5	0.0
	WS3-1	2,175	7.4	2.1	3.4	4.6	0.0
	WS3-2	2,000	6.8	2.9	4.0	4.5	0.0
WS4	WS4-1	950	23.7	12.0	5.0	6.1	0.8
	WS4-4	1,500	22.0	9.4	5.2	6.4	0.7
	WS4-5	1,500	19.7	7.0	4.2	5.1	0.0
	WS4-9	600	17.0	7.7	4.4	5.3	0.0
	WS4-3	2,000	16.5	7.1	4.5	5.5	0.0
	WS4-2	2,000	14.0	6.2	4.2	5.2	0.0
WS7	WS7-1	800	6.2	1.3	1.9	3.4	0.0
	WS7-2[b]	500	0	0	0	0	0
WS8	WS8-3	750	18.0	8.4	5.3	3.6	0.8
	WS8-2	500	15.7	6.8	5.1	2.6	0.6

Table B-1. Wells Ordered by Average PFOS Concentrations

Water Station	Well	Well Capacity (gpm)	Average PFAS (ng/L)[a]				
			Perfluoro-1-octanesulfonic acid (PFOS)	Perfluoro-n-octanoic acid (PFOA)	Perfluoro-1-butanesulfonic acid (PFBS)	Perfluoro-1-hexanesulfonic acid (PFHxS)	Perfluoro-n-nonanoic acid (PFNA)
WS9	WS9-4	800	16.0	7.1	5.0	3.9	0.0
	WS9-7	2,400	15.5	6.7	4.7	3.0	0.0
	WS9-3	1,600	14.0	6.3	4.4	2.9	0.0
	WS9-6	2,400	13.7	6.3	4.1	3.5	0.0
	WS9-5	2,600	12.0	5.4	3.9	3.1	0.0
WS14	WS14-3	1,200	25.0	15.7	6.8	4.8	0.0
	WS14-1	1,000	23.0	13.0	6.6	4.7	0.0
	WS14-2	1,000	20.3	12.0	6.7	4.3	0.0
WS15	WS15-2	500	18.5	5.0	5.4	4.9	0.0
	WS15-1	500	16.7	4.3	4.0	3.9	0.0
	WS15-3	500	11.7	3.0	3.3	3.3	0.0

a. Average PFAS levels from September 2020, February and July 2021 sampling of individual wells.

b. Well WS7-2 is served by the SGA, and has not PFAS detections.

Appendix B: Interim Measures Alternatives Evaluation TM

Technical Memorandum

6500 S Macadam Avenue, Suite 200
Portland, OR 97239
T: 503.244.7005

Prepared for: City of Vancouver (COV)

Project Title: PFAS Management Plan

Project No.: 159139

Technical Memorandum

Subject: Interim Measures Alternatives Evaluation Technical Memorandum - DRAFT

Date: November 2, 2023

To: Tyler Clary, PE (COV)

From: Joanie Stultz, PE (BC)

Copy to: Mehrin Selimgir, PE (COV)

Prepared by: ______________________________

Joanie Stultz, P.E., WA

Reviewed by: ______________________________

Katie Pollock, P.E., WA

Limitations:

This is a draft memorandum and is not intended to be a final representation of the work done or recommendations made by Brown and Caldwell. It should not be relied upon; consult the final report.

This document was prepared solely for City of Vancouver in accordance with professional standards at the time the services were performed and in accordance with the contract between City of Vancouver and Brown and Caldwell dated October 7, 2022. This document is governed by the specific scope of work authorized by City of Vancouver; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by City of Vancouver and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

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Section 1: Interim Measures Alternatives Evaluation

As a part of the City of Vancouver's PFAS management approach, the City is developing a voluntary program to mitigate the risk of exposure to PFAS for the City's vulnerable population prior to implementing long-term system-wide PFAS mitigation solutions. Brown and Caldwell (BC) prepared this Technical Memorandum (TM) to supplement Section 3 – Interim Measures of the PFAS Management Plan (Plan) that identifies and evaluates interim measures for the City to consider implementing. This TM describes the evaluation and scoring process, and evaluation results.

For this evaluation, five interim measures alternatives were evaluated using a multiple criteria decision analysis framework (MCDA) framework. Criteria were developed to evaluate the alternatives as part of the analysis. The evaluation includes consideration of annual operating costs of alternatives as well as non-monetary factors to determine which alternatives provide the best value. The criteria and scoring were reviewed during a workshop with City staff on September 6th, 2023, at which time the City provided feedback and discussion on the options. Following this screening effort, the best value options will be brought to the City Council for input and to inform the City's Plan moving forward.

1.1 Vulnerable Population Threshold

As Discussed in Section 3 of the Plan, the interim measures program is focused on providing services to vulnerable customers in the interim, prior to long-term system-wide solutions, given vulnerable populations may not have the financial means to implement their own interim in-home solution. The Plan proposes qualifying vulnerable populations for financial support using Low-Income Home Energy Assistance Program (LIHEAP) income threshold levels. LIHEAP is an established program with a structure in place to determine income eligibility and it could be expanded to include customer qualification for use in implementing the interim measures. The specifics of how the program will be administered will be developed as part of the implementation plan for the selected measures.

1.2 Interim Measures Alternatives

BC completed an initial literature review of in-home mitigation measure options available, and the extent to which those options are able to mitigate PFAS exposure to levels below the proposed MCL. Refer to Section 3 of the PFAS Management Plan for detail on the review of the interim measure options.

The options were reviewed and the following alternatives were identified for consideration by the City for the alternatives evaluation, summarized in Table 1-1.

Table 1-1. Interim Measures Alternatives for PFAS Mitigation

Alternative	Program Type	Description of Program	Components
Alternative 1	Point-of-Use Treatment – Under Sink Filter	Under-the-sink filtration system that dispenses treated water from existing faucet. Customer would need to have unit installed, and maintained, but cost would be reimbursed by City up to set amount. City would reimburse cost of delivery of replacement filters after 600 gallons use. Service cold water only.	Filter + 1pk of replacement cartridges
Alternative 2	Point-of-Use Treatment – Water Pitcher Filter	A water pitcher that treats the water as the pitcher is filled from the faucet by the user. Cartridge filter would need to be replaced every 100 gallons treated. City would reimburse cost of Pitcher and monthly delivery of replacement filters.	Pitcher + cartridge

Table 1-1. Interim Measures Alternatives for PFAS Mitigation			
Alternative	Program Type	Description of Program	Components
Alternative 3	Bottled Water	Purchased bottled water includes 5-gallon jugs affixed to water towers, to be delivered to the customer's home. Five jugs delivered at a time, roughly monthly. Delivery services would be limited to bottled water that are part of the International Bottled Water Association (IBWA), which require bottled water companies that are members of the association to test their bottled water products yearly for PFAS.	Dispenser tower + 5pk of 5-gallon bottles
Alternative 4	Rebate Program (POU or Bottled Water)	City provides initial set-up fees for install and filters and monthly stipend for filter replacements (or alternatively can provide cost for water pitcher and replacement, or a monthly stipend for bottled water delivery)	Filter + 1pk of replacement cartridges (filters) / Tower + 5-pk of 5-gallon bottles (bottled water)
Alternative 5	Pilot Treatment Unit	Pilot treatment unit to treat groundwater at several locations. Residents would fill reusable water containers on select days or times with City staff present. The City could provide an initial set of high-quality fillable water jugs with attached spigots to vulnerable households. This alternative would provide the most confidence in serving supply with PFAS to less than EPA's proposed MCL.	Two, 20 gpm mobile treatment units + 2,272 sets of four 7-gallon refillable jugs

1.3 MCDA Approach

To provide a recommendation for the preferred interim measures alternative(s) for implementation, BC leveraged a decision-support framework that includes engagement with stakeholders in the decision-making process. The steps of the decision-support process and groups engaged in each step are outlined in Figure 1-1. This process is often referred to as MCDA.

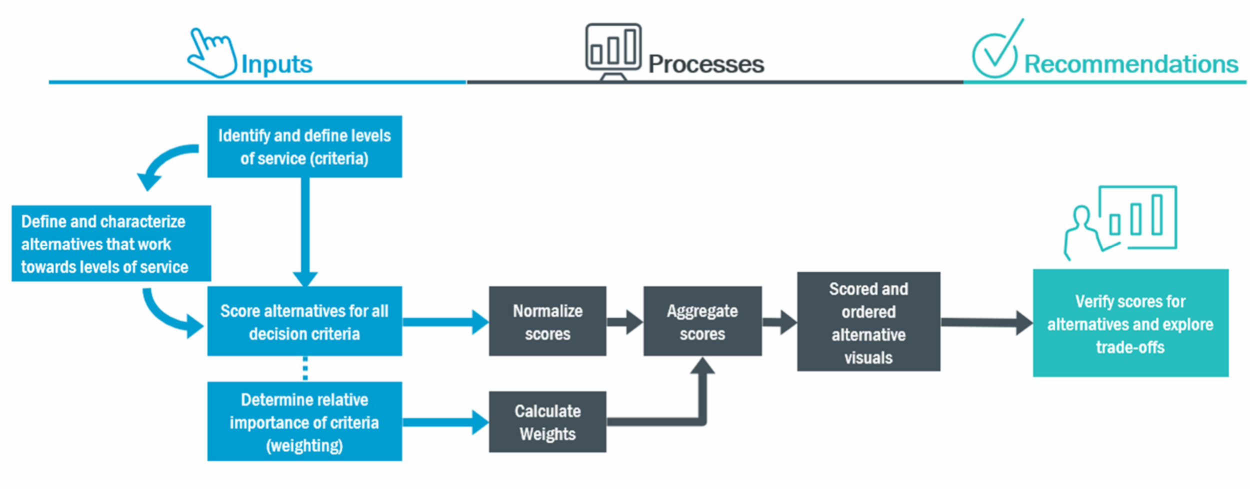


Figure 1-1. Decision-Support process flow diagram

1.4 Criteria Selection

Decision criteria were identified to differentiate and prioritize the five alternative interim measures. Non-monetary criteria are critical to the decision-making process and require a defensible, repeatable approach that makes use of project information available at the time of the evaluation.

BC formulated an initial set of criteria and through discussion with City Staff, nine decision criteria were formulated to highlight the City's values for selecting an option that best serves the community in the interim. The final list of nine decision criteria was formulated to highlight the relative non-monetary benefits associated with alternatives. The descriptions associated with the decision criteria are shown in Table 1-2.

Table 1-2. Evaluation Criteria for Interim Measures

No.	Criteria	Description
1	Accessibility	How easily can alternative be communicated to and accessed by the vulnerable population?
2	Staffing Burden	How much additional staff time does the alternative require, or will additional hires be required to execute the alternative?
3	Reach	Is this alternative accessible to more than just the vulnerable population of the City (i.e., serve the entire City service area and has a larger reach)?
4	Disruption Risk	How fool-proof is the measure (i.e., what is the likelihood of the alternative breaking down or a disruption (e.g., supply chain shortage) occurring that results in the public losing some access to reduced-PFAS water)?
5	Effectiveness in Reducing PFAS Exposure	What is the level of confidence that the alternative will reduce the exposure to PFAS for customers that use the alternative?
6	Time to Implementation	How long will it take for the City to implement the alternative (i.e., the time it takes for the public to get reduced PFAS exposure)?
7	Alignment with the City's Climate Action Framework (CAF)	How aligned is the alternative's environmental footprint with the City's Climate Priority Resolution ?[a]
8	Public Perception	Will the public like the alternative (i.e., feeling good about what the City did in the interim)?
9	Safety	How safe is the alternative for City staff and the public?

a. *City's Climate Action Framework (https://www.cityofvancouver.us/cmo/page/climate-action)*

1.5 Criteria Weighting

Key City stakeholders were surveyed via a Microsoft Forms survey ahead of the Interim Measures Workshop to provide an initial set of category weightings in association with the criteria list. The survey received seventeen (17) responses, with participants representing the following departments:

- Water - Engineering
- Operations and Maintenance
- Communications
- Wastewater - Engineering

- Finance and Asset Management
- Streets/Transportation
- Surface Water - Engineering
- Environmental Resources

The survey asked stakeholders to rate each criterion on a scale of 0 to 100, where 0 indicates that a criterion should not be impactful in decision making and a 100 indicates that a criterion is the most important factor in decision making. Weights were derived from survey results for each criterion using Equation 1.

$$\mathrm{Weight_i} = \frac{\mathrm{Priority\ Value_i}}{\sum_{i=1}^{9} \mathrm{Priority\ Value_i}} \qquad \text{Equation 1}$$

Where:

Weight = Relative prioritization weight for each criterion

Priority Value = Importance rating of criteria on scale of 0 to 100

i = Refers to the i^{th} criterion among 9 criteria

Weights were based on an average of all survey responses and are presented in Table 1-3. The average was used for MCDA as differentiating between stakeholder group had minimal impact on weights.

Table 1-3. MCDA Criteria Weights

Criteria	Average Weight
Accessibility	13.3%
Staffing Burden	9.3%
Reach	8.3%
Disruption Risk	11.0%
Effectiveness in Reducing PFAS Exposure	15.4%
Time to Implementation	10.6%
Alignment with CAF	9.0%
Public Perception	10.0%
Safety	13.1%

Section 2: Alternatives Scoring

The next step of the alternatives evaluation is scoring each alternative. The nine criteria were used to score each of the alternatives under consideration. For each alternative, BC developed a score for how well the alternative met the criteria. Scores ranged from 1 to 5. Table 2-1 summarizes the alternatives scoring key.

Table 2-1. Alternatives Scoring Key	
Score	Score Description
1	Doesn't meet criteria
2	Not all criteria met
3	Meets Criteria
4	Slightly Exceeds Criteria
5	Exceeds Criteria

During the Interim Measures Workshop on September 6th, 2023, these initial scores were reviewed and discussed with the City staff. Final scores for each of the alternatives are summarized in Table 2-2.

Table 2-2. Interim Measures Alternatives Scoring

Criteria	Alternative					Rationale for Scoring
	Alt. 1 (A-1) Under-the-Sink Units	Alt. 2 (A-2) Water Pitchers	Alt. 3 (A-3) Bottled Water	Alt. 4 (A-4) Rebate Program	Alt. 5 (A-5) Pilot Treatment Unit	
Accessibility	3	4	2	5	1	• 1: Requires personal transportation; 2. Have to lift and store bottled water jugs, 3: Has to be installed and maintained, 4: No plumbing fix needed, but limited by water amount, 5: Flexibility to buy what customer wants with stipend (bottled water jugs or individual bottles)
Staffing Burden	2	3	3	4	1	• 1: Requires multiple new staff for Pilot treatment unit, 2: One or two new program staff to develop program, 3: One new staff, with most absorbed by current staff, 4: Time from existing staff, 5: No extra staff time needed.
Reach	1	1	1	1	4	• 1: All options except the Pilot unit would be limited to vulnerable population. 5: Pilot unit could be utilized by all customers.
Disruption Risk	3	3	4	5	2	• 2: More equipment susceptible to breakdown/interruption 3: Disruption in service by homeowner forgetting to replace filter, 4: Missed delivery, 5: Control of purchase is on customer, and no reliance on delivery
Effectiveness in Reducing PFAS Exposure	2	4	3	1	5	• 1: Lack of control of what is purchased with rebate funds, 2: Under-sink filters limited to cold water tap, which can be forgotten 3: Delivery service for water most likely IBWA product that is periodically tested for PFAS, 4: More confidence in Water Pitcher filter than bottled water, 5: Pilot unit will undergo rigorous testing and control
Time to Implementation	2	4	4	5	1	• 1: Pilot Unit would take the longest to ramp up for design, construction. 3: Under-the-sink units require program to coordinate plumbing services to install new filters 4: Bottled water requires added program step of delivery service, 5: Time needed only for program development
Alignment with CAF	5	3	1	3	4	• 1: Bottled water requires transport (GHG emissions) and plastic bottle use, 2: Rebate program, while using bottled water, requires less separate trips to the store, 3: Less frequent delivery for water pitcher filters so less GHS emissions, 4: Less wasteful (limited one-use items) 5): Less frequent change outs so less material wasted and less GHG emissions.

Table 2-2. Interim Measures Alternatives Scoring						
Criteria	Alternative					Rationale for Scoring
	Alt. 1 (A-1) Under-the-Sink Units	Alt. 2 (A-2) Water Pitchers	Alt. 3 (A-3) Bottled Water	Alt. 4 (A-4) Rebate Pro-gram	Alt. 5 (A-5) Pilot Treatment Unit	
Public Percep-tion	5	2	3	5	1	1: Assuming least favorable is picking up water from station. 2: Public have disliked water pitchers at other Utilities with interim measures, 3: Confi-dence in bottled water and ease of use once delivered, 4: Provides freedom to choose what to purchase, 5: Keeps status quo to use existing faucet for tap water.
Safety	5	5	2	3	1	1: Pilot unit with pick up could be unsafe for City staff to interact with pub-lic. 2: Customer needs to lift 70 lbs. bottles, and potential for injury, 3: Re-bate program could involve handling large water jugs (not required), 5: No safety concerns with Water Pitchers and under-the-sink units.
Total Score	28	29	23	32	20	---

2.1 Alternative Costs

To determine the City's cost to implement the program for qualifying residents, a vulnerable household was defined based on income using the LIHEAP income threshold levels. Clark Public Utilities reported there are currently 4,000 vulnerable households served by the City that already received energy assistance through an existing Clark Public Utilities LIHEAP. According to the 2022 Census, there are 184,173 households in Clark County, of which 75,663 are located in the City. This provides a ratio of Clark County households to City household equaling 2.43. Additionally, the City of Vancouver's water service area is about 40 percent larger than the City limits. Based on these assumptions, the City's vulnerable population was estimated to be ap-proximately 2,300 households.

Annualized 5-year implementation costs for the interim measure alternatives are summarized in Table 2-3. The interim measures would be implemented during the period ahead of when the long-term solutions can be implemented. Based on the proposed EPA compliance timeline, the long-term treatment solutions would be online within 3 to 5 years. Therefore, the costs for the interim measure are presented for the 5-year time-line. Costs include a range from multiple manufacturers based on 2023 vendor quotes for the equipment and installation, as well as replacement filters, pitchers, or bottled water. Refer to Section 3 of the Plan for more detail on the interim measures and cost details.

All point-of-use treatment options and bottled water options include costs assuming a subscription service is set up with the manufacturer. The costs presented for the Rebate program represent the cost for the water pitchers option to simplify the presentation, but could be implemented to provide the point-of-use and/or the bottled water options.

Staffing costs are included for the pilot treatment unit because it is assumed that two additional water treat-ment operators will be needed. The other options assume that additional staff time will be needed, but it can be absorbed into the existing customer service team demands. There will be an initially staff time demand to set up the program and subscription services for those options, but then a decrease in time to maintain the program for qualifying customers. This is an approximation at this time, and there could be additional staff costs associated with some of these options based on further development of the program.

Table 2-3. Alternatives 5-year Implementation Costs		
Alternative	Program Type	5-year cost for Vulnerable Households (range for multiple manufacturers)[a]
Alternative 1	Point-of-Use Treatment - Under Sink Filter [b]	$2,715,000 - $7,205,000
Alternative 2	Point-of-Use Treatment -Water Pitcher Filter [b]	$3,457,000
Alternative 3	Bottled Water	$7,353,000 - $8,070,000
Alternative 4	Rebate Program[c]	$3,457,000
Alternative 5	Pilot Treatment Unit	$3,244,000

a. *Number of vulnerable households was estimated to be 2,300 households for cost-estimating purposes, based on an approximate number of City of Vancouver customers that would qualify for federal LIHEAP assistance. Costs based on 2023 vendor quotes.*

b. *Costs assume subscription service where vendors directly deliver to households.*

c. *Rebate program could be offered for point-of-use filters, water pitchers, or bottled water, or a combination of options depending on the preferred approach. Costs presented for water pitcher option.*

The cost for 5 years of service for bottled water or the under-sink units are similar and have the highest costs of the options considered.

2.2 Results

As shown in Table 2-1, comparing alternatives requires normalizing the alternative scores (Table 2-2), applying weights (Section 1.5), and exploring cost and non-monetary tradeoffs (see Figure 1-1 for full MCDA process).

The first step, normalizing the alternative scores, avoids the issue where magnitude doesn't have meaning for qualitative scores. Scores were normalized as the fraction of other alternatives that an alternative performed better than (e.g., better than all other alternatives = 1, and better than no other alternatives = 0).

The collective weighted criteria were used to score each of the alternatives. Using the weighted criteria and the criteria scores, a relative benefit score was determined, presented in Figure 2-1.

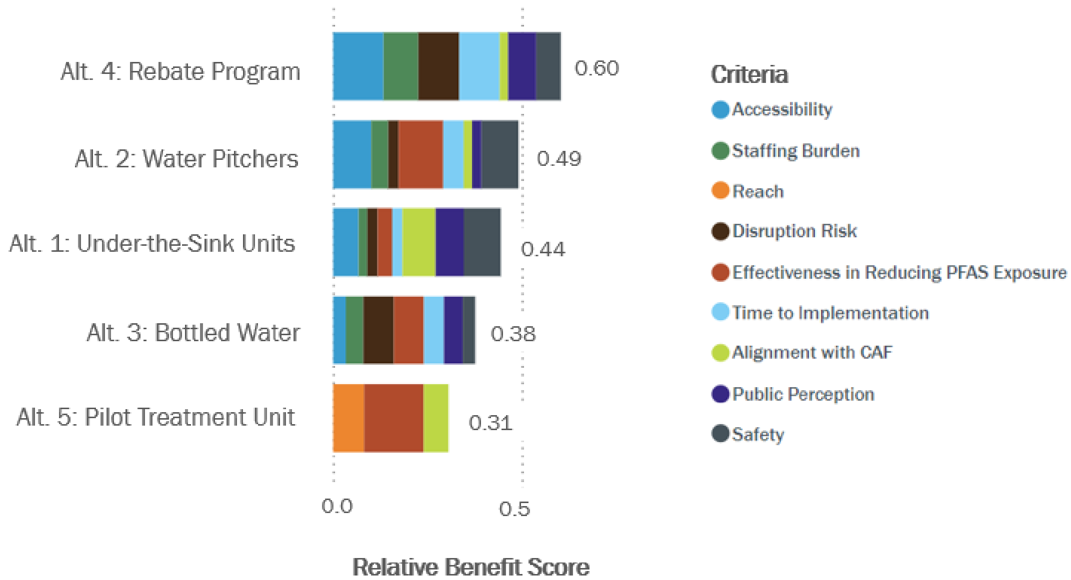


Figure 2-1. Interim measures relative benefit scores

Higher score indicates more benefit

As shown, the rebate program (Alt 4) performed the best as it has the highest relative benefit for accessibility, staffing burden, and time to implement based on the stakeholder weighting (Section 1.5) and scoring (Section 2). Alt 4 only performed poorly in the Alignment with CAF, given the option could offer bottled water has a higher environmental impact. The Pilot Treatment unit, while scoring the highest in the effectiveness in reducing PFAS exposure with the ability to control the treatment, this alternative scored the lowest in many of the other categories, with the lowest overall relative benefit score.

Best Value Option

While aggregate non-monetary benefit characterization aids in identifying what the best alternatives are on their surface, it does not account for cost. The relative benefit score for each option was plotted against the 5-year implementation costs to see how the interim measures compare, as presented in Figure 2-2. Alternatives toward the upper left of the chart score the “highest” with the highest relative benefit score and lowest cost. The rebate program scored the highest with the highest relative benefit. Figure 2-2 presents the results with the rebate program proposed to be equal to the water pitchers option for comparison purposes. The exact rebate amount would be refined based on the selected rebate program options, and the market prices for filter units and install costs at the time of the program implementation.

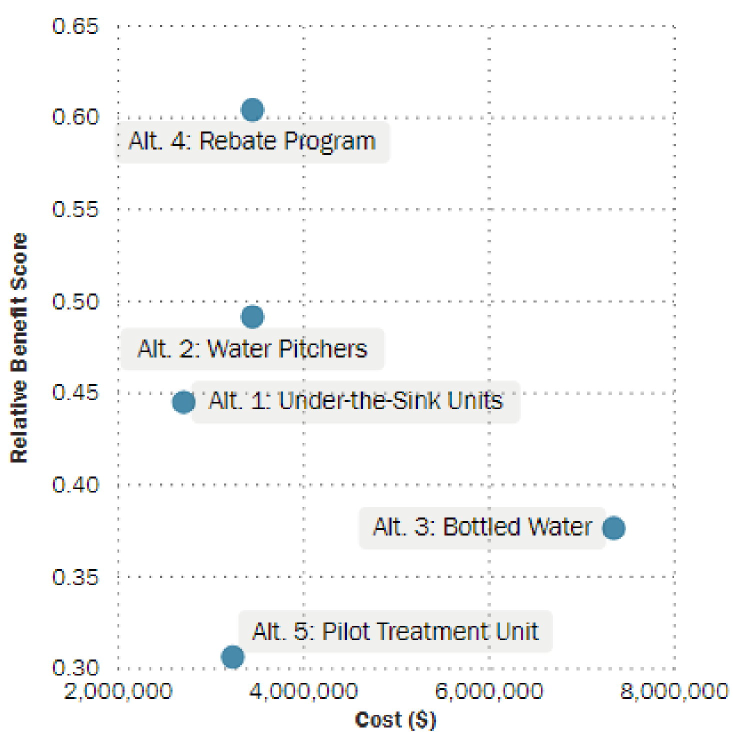


Figure 2-2. Best-value ranking based on cost and relative benefit score

Section 3: Recommendations

At the Interim Measures Workshop held on September 6th, 2023, results of the evaluation summarized in Section 2 were reviewed and discussed with City staff. This section summarizes the workshop discussion outcomes and trade-offs between the alternatives.

Options Screened Out

Based on the discussion at the workshop and the scoring process, the Pilot Treatment Unit is not a viable option. This option has some major logistical challenges with having community members drive to locations to fill water jugs. More notably though is the equity issue of having a higher amount of the vulnerable population not having access to transportation. While the City could offer exceptions with delivery service for the homebound or those without transport, the process could be a significant burden on the City's current operations, and more risk with not providing customers with water treated to move PFAS to below the treatment target.

Options to Consider Further

The point-of-use treatment options with water pitchers or under-the-sink units, as well as the bottled water delivery option are all potential options for the City to consider further. Providing those options as a rebate program may be preferred for the reduce administrative burden on the City, and for providing the most flexibility to customers.

3.1 Next Steps

Based on the assessment of the potential interim measures and scoring process, the rebate program scored the highest. This option could provide flexibility for customers to receive assistance for in-home point-of-use filters, water pitchers, or bottled water. The City's next steps will be to present the options to the City Council to gather input on the options, and to develop a plan around the preferred option.

Appendix C: State-Provided List of Approved POU Filters

Contaminants

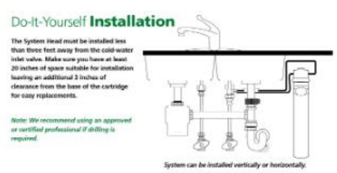
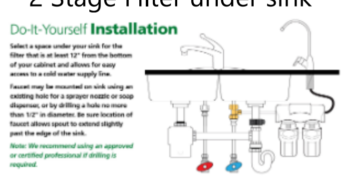
PFAS Point-Of-Use Filter Options

331-713 • 2/8/2023

NSF Certified, PFAS-Reducing Water Filter Brands (Point-of-Use type)

NSF is an independent organization that verifies manufacturer claims about water filters. To be certified for PFAS removal, a filter must reduce a water concentration of 1,500 parts per trillion (ppt) PFOS +PFOA to less than 70 ppt PFOA and PFOS over the life span of the filter.

Filters listed below are not endorsed by DOH. We compiled this information in January 2023. Check the manufacturer website and NSF website for the most current information. Do-it-yourself installation instructions are included with all units, but some people may want a plumber's help. For additional home water treatment information, see Home Water Treatment for PFAS 331-699 (PDF) on how to reduce PFAS levels in your household tap water.

Company	PFAS Filter Model	Filter Type	Filter Cost	Filter lifespan (Replacement Schedule)	Water Flow Rate	Replacement Filter Cost	Additional Considerations
A.O. Smith Clean Water Filter for Refrigerators & Freezers | A. O. Smith (aosmithatlowes.com)	AO-FF	Fridge/Freezer 	$55	200 gallons or 6 months	½ gallon per minute	$30	1 year warranty
A.O. Smith The Clean Water Filter For Main Faucets | A. O. Smith (aosmithatlowes.com)	AO-MF-ADV	Under sink 	$110	784 gallons or 6 months	1 ½ gallons per minute	$77	1 year warranty
A.O. Smith 2-Stage Brushed Nickel Water Filtration System | A. O. Smith (aosmithatlowes.com)	AO-US-200	2 Stage Filter under sink 	$139	500 gallons or 6 months	½ gallon per minute	$66 (two pack)	1 year warranty

Company	PFAS Filter Model	Filter Type	Filter Cost	Filter Replacement Schedule	Water Flow Rate	Replacement Filter Cost	Additional Considerations
Aquasana [Aquasana Clean Water Machine | Powered Countertop Water Filter]	AQ-CWM2-B	Counter-top unit 	$200	300 gallons or 6 months	½ gallon per minute	$60 (two pack)	1 year warranty, a 2-pack of filters is provided with unit.
Aquasana [3-Stage Fast Flow Rate Under Sink Water Filter | Aquasana]	AQ-5300+.55	3 Stage Filter, under sink with dedicated faucet 	$225	800 gallons or 6 months	¾ gallon per minute	$80 (set of three)	1 year warranty
Cyclopure [Purefast™ | Cyclopure]	Purefast	Filter Cartridge for Brita pitcher 	$45	65 gallons per filter	1 pitcher load of water takes about 20 min to filter	$45 per filter	Fits inside a Brita water filter, Brita pitcher is not included. Filters come with prepaid return shipping for used filters.

Company	PFAS Filter Model	Filter Type	Filter Cost	Filter Replacement Schedule	Water Flow Rate	Replacement Filter Cost	Additional Considerations
Hydroviv [Hydroviv Filters For Your Home | Hydroviv]		Can be installed on Fridge/Freezer or Under Sink connected to existing faucet. 	$175 each	6 months		$87	Filters are optimized for water quality in your area
KineticoPRO [KPMF HC610-PFAS - PFAS Series, 10" PFOA/ PFOS reduction filter cartridge | KineticoPRO]	HC Series KPMF HC610-PFAS	Under sink, connected to existing faucet 		2000 gallons	2¾ gallons per minute		Contact the company directly for cost WaterCare@KineticoPRO.com 1-800-321-5022

Company	PFAS Filter Model	Filter Type	Filter Cost	Filter Replacement Schedule	Water Flow Rate	Replacement Filter Cost	Additional Considerations
ZeroWater [5-Stage Water Filter Pitchers & Dispensers - Pure Tasting Water – ZeroWater]	5-Stage	Countertop units (sizes range from 7-40 cup pitchers) 	$24-$75	25-40 gallons depending on level of PFAS in water	6.5 ounces per minute (slow).	$90 for a 6-pack of filters	Filter discounts for multiple purchases
Multipure [Under Counter Water Filter - Aquaperform | Multipure]	Aquaperform MP880	Below Sink or Countertop Filter 	$590	600 gallons	1 gallon per minute	$145	Lifetime housing warranty, additional fees based on type of filter purchased
Multipure [Aqualuxe - The Ultimate Water Filter Machine | Multipure]	Aqualuxe	Below Sink or Countertop Filter 	$1250	500 gallons	3/4 gallon per minute	$175	Lifetime housing warranty, additional fees based on type of filter purchased

Reverse Osmosis Filter Options (Point-Of-Use filters)

No reverse osmosis (RO) filters are currently NSF certified for PFOA/PFOS reduction, but independent research shows RO filters are highly effective for removing many types of PFAS. Below are some examples of RO filters on the market. Note that RO filters block PFAS from entering your tap water but send the blocked PFAS to your septic tank or sewer where PFAS can re-enter the environment. RO systems also waste water. On average, three to four gallons of water are sent down the drain for every one gallon of filtered water.

Company	PFAS Filter Model	Filter Type	Filter Cost	Filter and Membrane Replacement Schedule	Water Flow Rate	Replacement Filter and Membrane Costs	Additional Considerations
A.O. Smith Clean Water Filter With Reverse Osmosis Boost | A. O. Smith (aosmithatlowes.com)	AO-US-RO-4000	Under sink unit.	$219	Filter lasts 365 gallons or 6 months, membrane lasts 1 year	½ gallon per minute	Filter: $100 Membrane: $100	2 year warranty
A.O. Smith Clean Reverse Osmosis Water Filtration System | A. O. Smith (aosmithatlowes.com)	AO-US-RO-MB-4000	Under sink unit	$269	Filter lasts 365 gallons or 6 months, membrane lasts 1 year	½ gallon per minute	Filter: $100 Membrane: $100	2 year warranty RO System with Microbial Boost
Aquasana Reverse Osmosis Under Sink Drinking Water Filter | Aquasana	AQ-RO-3.55	Under sink unit	$250	Filter lasts 365 gallons or 6 months, membrane lasts 1 year		Filter: $70 Membrane: $60 Remineralizer: $40	2 year warranty

Washington State Department of HEALTH

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Appendix D: City of Woburn Bottled Water Rebate Program and Medford Water Commission Toilet Rebate Form

Bottled Water Rebate Program – UPDATE – 1/6/2023

The Massachusetts Department of Environmental Protection (DEP) issued a new drinking water regulation that limits the sum of six PFAS compounds (known as the PFAS6) to 20 parts per trillion (ppt).

The new drinking water standard requires public water suppliers to test for the presence of PFAS6.

DEP recommends consumers in sensitive populations, including pregnant or nursing women, infants under one year of age and people diagnosed by their health care provider to have a compromised immune system not to consume, drink or cook with water when the level of PFAS6 is above 20 ppt. These individuals are advised to use alternative sources of water such as bottled water tested for PFAS6.

The City of Woburn will be offering a residential rebate program only for qualifying customers in the previously mentioned sensitive populations to offset the cost of purchasing bottled water. The rebate program will work as follows:

1.) A household/unit with a resident in a sensitive population (defined above) will be eligible for a $30.00 credit /month (only one credit per household/unit)

2.) A check will be mailed semiannually for any quarter the city is DEP non-compliant.

3.) You must re-apply every six months after issuance of semiannual water bill (February and August).

4.) From January 1, 2022 thru June 30, 2022 (1st and 2nd quarter) the City complied with the new state standard.

5.) The rebate program for the 3rd and 4 th QUARTER (which is for the water billing period from July 1, 2022 thru December 31, 2022) will open in February of 2023.

6.) The City was non-compliant in the 3rd quarter (7/1/22 thru 9/30/22), a rebate in the amount of $90.00 will be available for qualifying customers.

7.) The City complied with the DEP standard for the 4th quarter (10/1/22 thru 12/31/22). See https://www.woburnma.gov/water-pfas-testing-results/

This rebate program is not intended to operate as a guarantee regarding any exposure to PFAS6 and does not imply that it limits exposure to PFAS from other sources, nor does it operate as an admission of liability by the City if exposure to PFAS6 does occur. The City reserves the sole right to change the terms of rebate program at any time.

To qualify for this rebate program, you need to provide written proof from a medical professional that you fall into one of sensitive populations defined above. Letter does not need to specify which group you fall into and why, but you will need to identify which resident qualifies for this rebate. You do not need a new medical letter if you have already been approved and received a rebate.

Proof of residency by water bill, tax bill or signed lease. Birth certificate for child under one year old. You will need to provide an update for proof of residency regardless of prior approval.

The application is online only and will require you to upload documents. Please do not mail or drop off your application. If you need assistance please call the Water Department 781-897-5945

WATERSENSE TOILET REBATE PROGRAM APPLICATION

See 2nd page for complete instructions.

MEDFORD WATER ACCOUNT INFO (Property must have a water account with Medford Water to qualify)

Account #(s):	Customer Name:			☐ Owner ☐ Renter
Installation Street Address:	City:		State:	Zip:
Number of toilets on property:	Number of toilets replaced / installed:			

CONTACT INFO FOR PERSON REQUESTING REBATE

Name:	Email:		
Mailing Address:	City:	State:	Zip:
Phone: ☐ Home/Cell ☐ Work	Installation involves: ☐ New construction ☐ Replacement of Existing Toilet(s)		

NEW TOILET INFORMATION (MUST be WaterSense® Certified model)

Purchase Date(s):	Purchase Price (each):	Number Purchased:
Brand Name(s):	Model #(s):	
Purchased From:	☐ Email pictures of new and old toilets to conserve@medfordwater.org.	

AGREEMENT AND SIGNATURE

Medford Water may deny any application that does not comply with all of the WaterSense Toilet Rebate Program Eligibility Instructions. Medford Water makes no representation or warranty regarding the toilets eligible for rebate. Any claim based upon any defect or failure of performance of a toilet purchased by the applicant should be pursued with the manufacturer or distributor. By participating in the program, the applicant waives and releases Medford Water from any and all claims and causes of action arising out of the purchase, installation, or use of the toilets purchased in connection with the rebate program. Verification inspections are not a certification, warranty, or other approval with respect to the applicant's compliance with applicable laws, ordinances and building codes. Medford Water reserves the right to alter this program at any time. Rebates will be issued on a first come first served basis; program may end if funds are depleted.

By signing my name, I hereby agree to all terms and conditions set forth herin.

Applicant / Owner Signature: ______________________________ Date: ____________

Questions Call (541) 774-2436 or email conserve@medfordwater.org

For Office Use Only:

Date Received:	Year Built:	Date Inspected:	Flush Volume:
Rebate Approved: ☐ Yes ☐ No If no, reason:			

MEDFORD WATER

EPA WaterSense

PROGRAM ELIGIBILITY & REBATE AMOUNTS

- Rebate applies to the installation of **WaterSense® labeled** dual flush and 1.28 (or less) gallon per flush toilets.
- Property must have a water account with Medford Water in good standing.
- Toilet pictures, application and sales receipt ***must be received by Medford Water staff before rebate is issued.***
- Rebate for 3.5 gallons or higher per flush is $85 for first toilet, and $40 thereafter per toilet.
- Program is generally limited to 25 rebates per site (call for details).
- Old toilets **must** be taken to Rogue Disposal Transfer Station **with** Voucher from Medford Water to receive full rebate.
- Rebates requested by non-owners require property owner's written consent with signature on provided form.

$85	$40	$40
Replacement and recycling of a toilet flushing 3.5 gallons or more.	Replacement and recycling of a toilet flushing 1.6 gallons per flush (gpf).	Installing a qualified 1.28 gpf toilet in lieu of a 1.6 gpf model in new construction.
Free recycling voucher	Free recycling voucher	

INSTRUCTIONS CHECKLIST

1	☐ **Select and purchase WaterSense toilet(s).**	Eligible models are identified with a WaterSense® label. Verify eligibility by reviewing the list of qualifying toilets at: http://www.epa.gov/watersense. Toilet model number(s) must match the numbers on the WaterSense® list exactly. No mixing of tanks and bowls from the list is allowed, as each model has been tested in specific combinations for performance and efficiency.
2	☐ **Install WaterSense toilet(s).**	Installation is the responsibility of the applicant. Keep the box the new toilet came in until after pictures are received. ***DO NOT dispose of old toilets until Medford Water has received and confirmed pictures are clear and acceptable and you have received your recycling voucher.***
3	☐ **Complete and submit the rebate application and attach the sales receipt.**	Submit the application to Medford Water by email, mail or delivery to our office. Email: conserve@medfordwater.org.
4	☐ **Email pictures of old and new toilet(s) and receive recycling voucher.**	Once pictures of old and new toilets are received, a recycling voucher will be issued. If you submit an application in advance, Medford Water will contact you to gather any additional information. Applicant's signature on this form authorizes Medford Water to perform an onsite inspection, if necessary.
5	☐ **Recycle old toilet(s) at Rogue Disposal Transfer Station.**	This is **required** to receive the full rebate amount. Vouchers for free recycling will be provided by Medford Water. If you hire a plumber, be sure to inform them of this requirement and work out any details ahead of time. Rogue Disposal will validate the voucher and direct you to the designated recycle container. Remove all metal and plastic parts from the old toilet before recycling. ***If the recycling voucher is NOT received by Rogue Disposal, the rebate amount will be $20 per toilet.***

Lower the Flow and Save H2O!

Appendix E: WS1 and WS7 Proposed Treatment Layouts

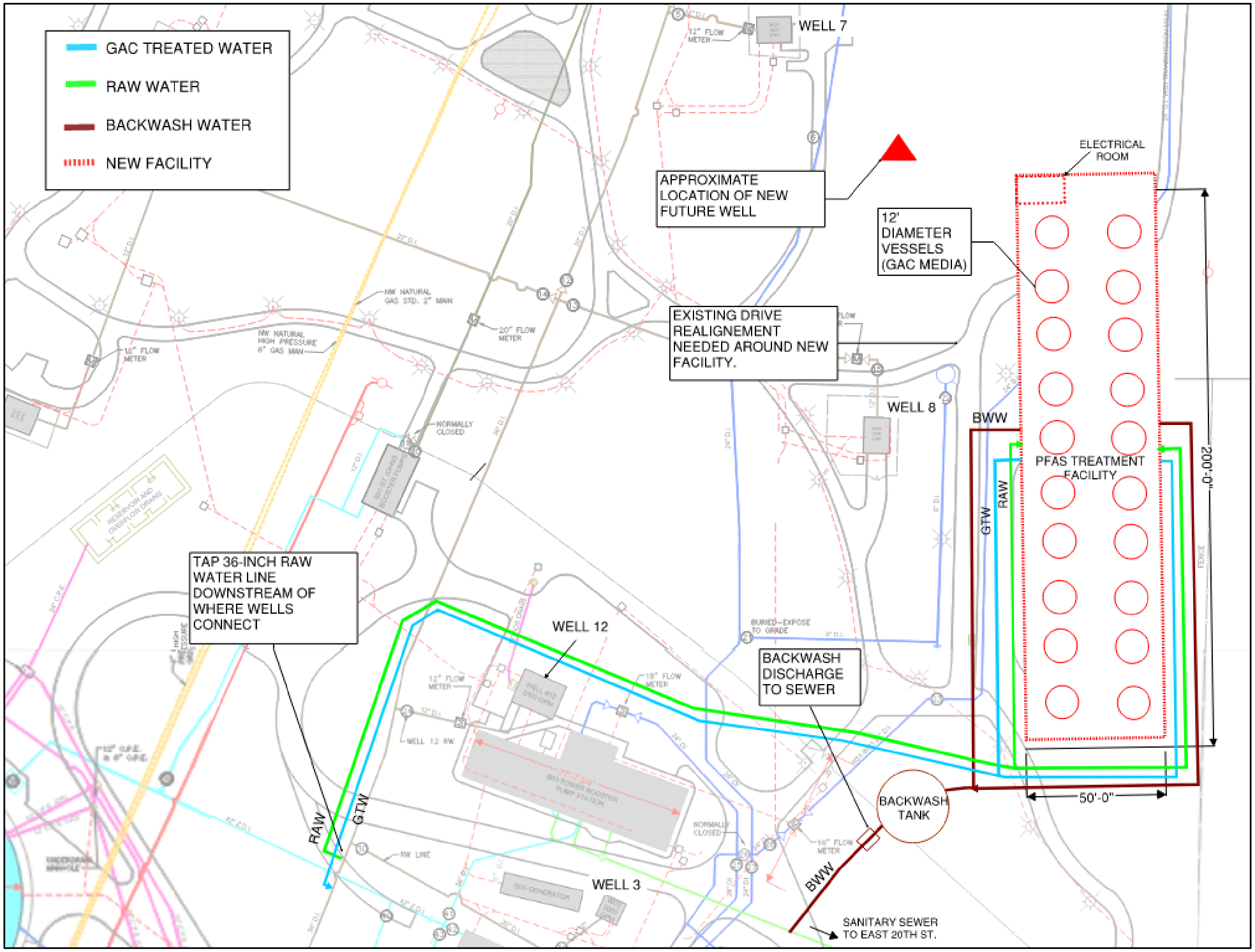

Figure E-1 WS1 proposed treatment layout – GAC

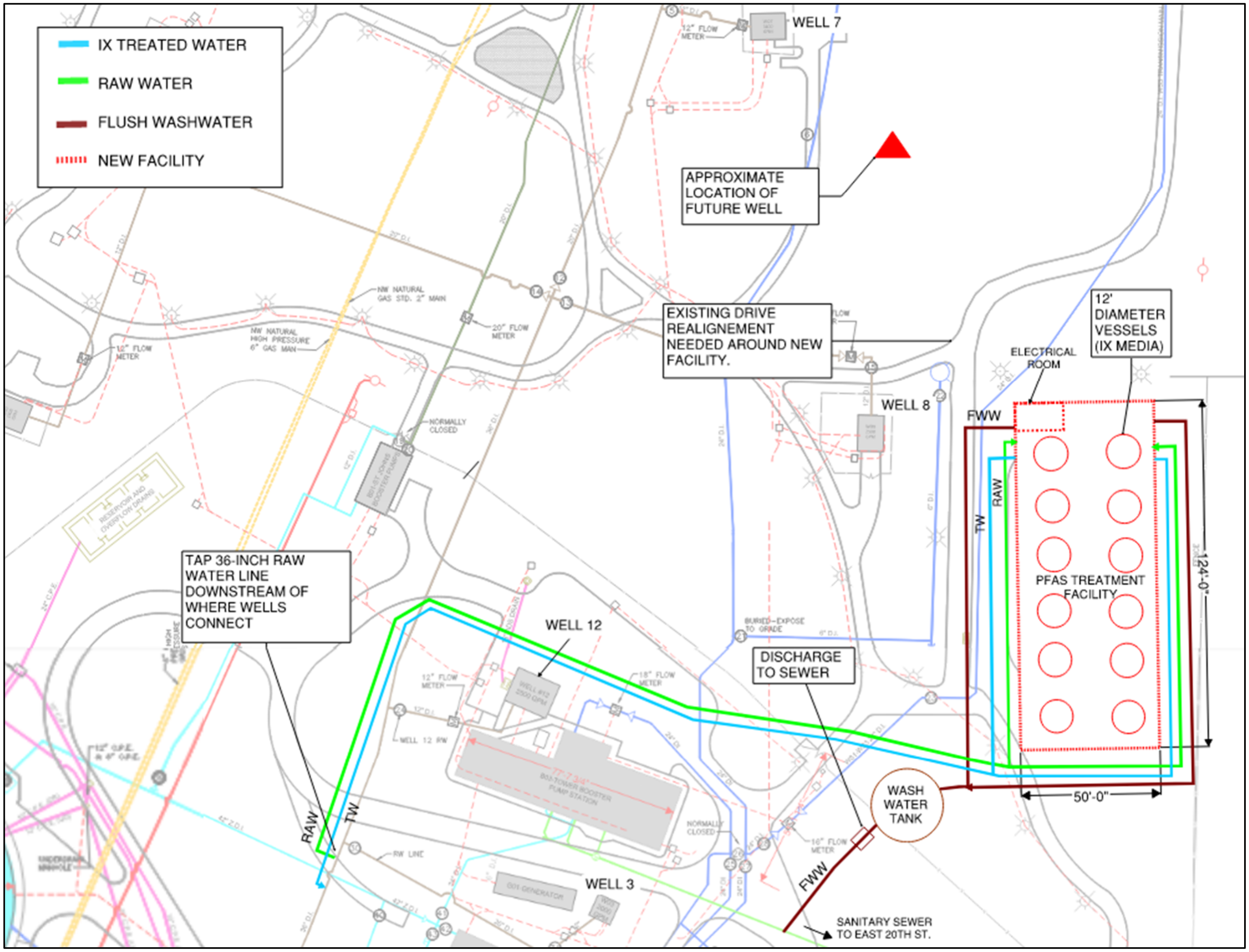

Figure E-2. WS1 proposed PFAS treatment layout – IX

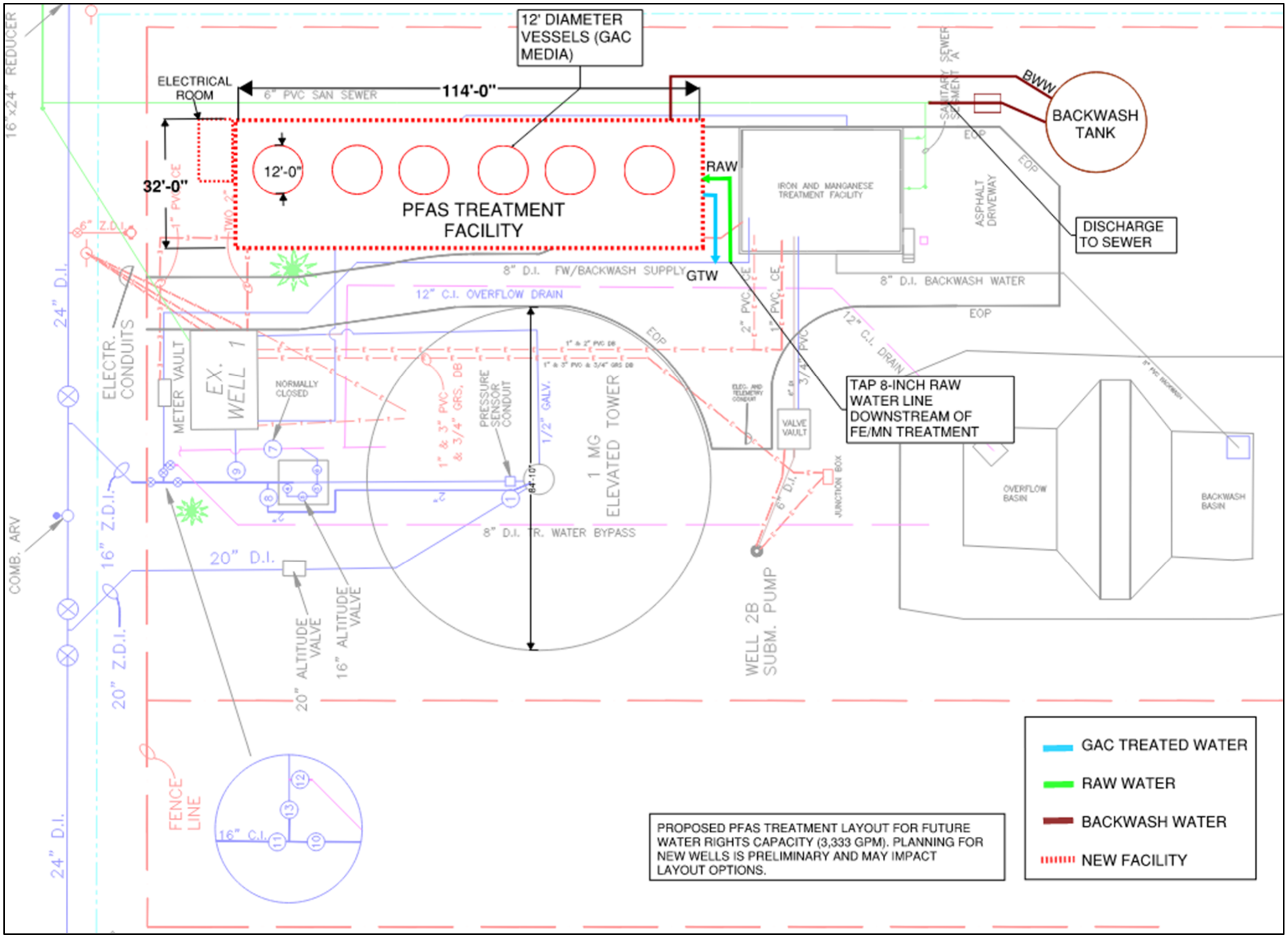

Figure E-3. WS7 proposed PFAS treatment layout - GAC