Appendix Q. Long-term Water Treatment Alternatives Evaluation

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Technical Memorandum (DRAFT)

To: Bob York (City of Issaquah)

From: Beth Mende and Pierre Kwan (HDR)

Date: February 7, 2018

Subject: Long-Term Water Treatment Alternatives

1.0 Background and Introduction

In 2013, the City of Issaquah (City) detected then-unregulated per- and polyfluoroalkyl substances (PFAS) in Gilman Well No. 4 as part of the UCMR 3 sampling event. In response to the PFAS detections, the City shut down Gilman Well No. 4 and evaluated a number of alternatives to eliminate the contamination from Well No. 4. A temporary granular activated carbon (GAC) filtration system was installed to treat water from Well No. 4 with the ability to be expanded to treat Well No. 5 if the PFAS migrated to the lower Well No. 5 aquifer. PFAS levels have been below the USEPA Method 537 detection limit in Well No. 4 finished water since the system went online in 2016.

In addition to PFAS in Well No. 4, the City has other water quality challenges, including manganese and arsenic, ammonia, and low pH, which adversely affect the City's groundwater supply. To further address these water quality issues, and to plan for the eventual introduction of regional water from the Cascade Water Alliance into the Valley Zone (which will require blending of groundwater and regional water in the Valley Zone), the City is evaluating long-term treatment options for PFAS and the other water quality issues. The following long-term treatment options are being considered, and are evaluated in this document:

1. Option 1: Centralized Treatment: Risdon Wells 1 and 2 and Gilman Wells 4 and 5 would be treated at a single location.
2. Option 2: Wellhead Treatment – Abandon Gilman Well Nos. 4 and 5 and provide wellhead treatment at Risdon Well Nos. 1 and 2 and wellhead treatment at Well No. 6.

This document evaluates the long-term treatment options and identifies treatment requirements, equipment sizes, chemical volumes, and associated support systems for each option. Conceptual design drawings and planning-level costs are also included.

Due to the small site at Gilman Wells 4 and 5, additional wellhead treatment is not feasible at this location. The City has another existing undeveloped well, Well No. 6, which is not currently used as a potable water source. This well is considered as a part of this treatment evaluation as water rights from the existing potable water wells could potentially be transferred to this well in the future.

2.0 City Groundwater Supply

The City receives water from two major sources of supply: the City's own groundwater resources (Risdon Well Nos. 1 and 2, and Gilman Well Nos. 4 and 5) and regional Seattle Public Utilities water purchased from the Cascade Water Alliance (referred to as regional water).

Table 1 summarizes the City's sources.

Table 1. City of Issaquah's Water System Supply

Supply	Current Pumping Capacity (gpm)	Instantaneous Well Water Right (Qi) (gpm)	2017 Supply (MG)
Risdon Well No. 1	450	630	125
Risdon Well No. 2	1,050	1,200	228
Gilman Well No. 4	250	250	64
Gilman Well No. 5	1,150	1,000	60
Well No.6	Not developed	None	-
Regional Water	8,330	Not applicable	477

3.0 Groundwater Quality

Each of the City's supplies has different water quality characteristics, some of which adversely affect groundwater quality including PFAS, manganese, arsenic, ammonia, and pH. In addition, Risdon Well Nos. 1 and 2 have low pH levels that could cause corrosion issues through the system. The City's groundwater sources are not currently fluoridated. These water quality parameters for each source are presented in Table 2 and are further discussed in this section.

Table 2. Important Water Quality Parameters of City's Water Supplies

Parameter (mg/L unless noted otherwise)	Limit	Goal	Risdon No. 1	Risdon No. 2	Gilman No. 4	Gilman No. 5	Well No. 6[5]	Regional Water Average
pH (std. units)[4]	6.5-8.5	6.5-8.5	6.9	7.0	7.1	8.1	8.4	8.1
PFOS (µg/L)	0.07 combined[2]	TBD[2]	<0.04	<0.04	See Table 3	<0.04	NA	<0.04
PFOA (µg/L)		TBD[2]	<0.02	<0.02	See Table 3	<0.04	NA	<0.02
Arsenic (mg/L)[1]	0.01	0.0	0.002	0.002	0.003	0.009	<0.001	<0.001
Manganese (mg/L)[1]	0.05	0.05	<0.01	<0.01	0.02	0.06	0.12	NA
Fluoride(mg/L)[1]	2	0.7	<0.5	<0.5	<0.5	<0.5	<0.5	0.7
Ammonia (mg/L)[6]	None	None	NA	NA	0.002	0.099	NA	NA

Notes:

1. Water quality data are from the 2016 Inorganic Chemicals Report.
2. PFAS limit is USEPA Provisional Health Advisory Limit. DOH is in the process of rulemaking to establish a State of Washington MCL.
4. Water quality data are from 2007 sampling.
5. Well No. 6 data are from the 1999 Golder Associates Report.
6. Ammonia measurements are averages taken from samples in January and February 2008.
7. NA – not available

3.1 PFAS

PFAS are fully-fluorinated compounds that are extremely persistent in the environment and resistant to chemical degradation processes. They are manmade compounds that do not occur naturally in the environment. The toxicity, mobility and bioaccumulation potential of PFAS pose potential adverse effects for the environment and human health. At this time there is an EPA established Provisional Health Advisory level of 0.7 µg/L for PFOS and PFOA at individual or combined concentrations. More recently, the Department of Health has recommended that the State Board of Health begin rulemaking to consider setting drinking water standards for specific PFAS compounds.

PFAS have been detected above the practical quantification limit in Gilman Well No. 4. Table 3 and Table 4 present the PFAS data collected from Well No. 4 and blended finished water from Well Nos. 4 and 5, respectively. PFAS levels in Gilman Well No. 4 are significantly higher than Well No. 5. The temporary GAC system was installed to treat the more contaminated Well No. 4 to PFAS levels below USEPA Method 537 detection limits before it is blended with untreated Well No. 5 water and sent out to the distribution system. Although PFAS are removed to below USEPA Method 537 detection limits from Well No. 4, Well No. 5 does contain PFAS at low levels, greater than the USEPA Method 537 detection limits but less than the practical quantification limits for the laboratory used (Anatek Labs) that are blended with Well No. 4 and put into the distribution system.

Table 3. PFAS Concentrations in Well No. 4

Parameter	PFBS (µg/L)	PFHpA (µg/L)	PFHxS (µg/L)	PFNA (µg/L)	PFOS (µg/L)	PFOA (µg/L)
MDL	0.01	0.002	0.005	0.005	0.01	0.02
PQL	0.09	0.01	0.03	0.02	0.04	0.02
Sample Date						
6/13/16	<PQL	0.0154	0.212	<PQL	0.602	0.0222
8/8/16	<PQL	0.0179	0.181	<PQL	0.421	<PQL
8/22/16	<PQL	0.0184	0.177	<PQL	0.409	<PQL
9/27/16	<PQL	0.0138	0.162	<PQL	0.401	<PQL
10/24/16	<PQL	0.0113	0.141	<PQL	0.369	<PQL
11/14/16	<PQL	0.143	0.186	<PQL	0.382	<PQL
12/13/16	<PQL	0.0138	0.161	<PQL	0.367	<PQL
1/17/17	<PQL	0.0137	0.144	<PQL	0.341	<PQL
3/13/17	<PQL	0.0123	0.149	<PQL	0.354	<PQL
4/10/17	<PQL	0.012	0.147	<PQL	0.379	<PQL
5/8/17	<PQL	0.0105	0.135	<PQL	0.332	<PQL
6/12/17	<PQL	0.0118	0.129	<PQL	0.316	<PQL
7/12/17	<PQL	0.0126	0.138	<PQL	0.315	<PQL
8/14/17	<PQL	0.012	0.124	<PQL	0.304	<PQL
9/12/17	<PQL	0.0123	0.13	<PQL	0.31	<PQL
10/9/2017	<PQL	0.123	0.14	<PQL	0.339	<PQL
11/28/2017	<PQL	0.0124	0.138	<PQL	0.367	<PQL
12/12/2017	<PQL	0.0115	0.12	<PQL	0.332	<PQL

Notes:
1. MDL based on USEPA Method 537.

2. PQL established by Anatek Labs.

Table 4. PFAS Concentrations in Well 4 and 5 Blended Finished Water

Parameter	PFBS (µg/L)	PFHpA (µg/L)	PFHxS (µg/L)	PFNA (µg/L)	PFOS (µg/L)	PFOA (µg/L)
MDL	0.01	0.002	0.005	0.005	0.01	0.02
PQL	0.09	0.01	0.03	0.02	0.04	0.02
Sample Date						
8/8/16	ND	ND	<PQL	ND	<PQL	ND
8/22/16	ND	ND	<PQL	ND	<PQL	ND
8/24/16	ND	ND	<PQL	ND	<PQL	ND
9/27/16	ND	ND	<PQL	ND	<PQL	ND
10/24/16	ND	ND	<PQL	ND	<PQL	ND
11/14/16	ND	ND	<PQL	ND	<PQL	ND
12/13/16	ND	ND	<PQL	ND	<PQL	ND
1/17/17	ND	ND	<PQL	ND	<PQL	ND
3/13/17	ND	ND	<PQL	ND	<PQL	ND
4/10/17	ND	ND	<PQL	ND	<PQL	ND
5/8/17	ND	ND	<PQL	ND	<PQL	ND
6/12/17	ND	ND	<PQL	ND	<PQL	ND
7/12/17	ND	ND	<PQL	ND	<PQL	ND
8/14/17	ND	ND	<PQL	ND	<PQL	ND
9/12/17	ND	ND	<PQL	ND	<PQL	ND
10/9/2017	ND	ND	<PQL	ND	<PQL	ND
11/28/2017	ND	ND	<PQL	ND	<PQL	ND
12/12/2017	ND	ND	<PQL	ND	<PQL	ND

Notes:
1. Detection limits based on USEPA Method 537.
2. PQL established by Anatek Labs.

Monthly PFAS data show PFOS and PFHxS concentrations in Well No. 5 have increased slightly since the GAC treatment system for Well No. 4 went online, although, still remain lower than the practical quantification limits. The Well No. 4 and No. 5 aquifers are adjacent to each other and this indicates that contamination could be migrating from the Well No. 4 aquifer to the lower Well No. 5 aquifer.

3.2 Arsenic

Arsenic enters drinking water supplies from natural deposits in the earth or from industrial and agricultural pollution. Currently, the USEPA and DOH have an established MCL for arsenic of 0.010 mg/L. Arsenic levels in Gilman Well No. 5 have been reported to be up to 0.009 mg/L. While the concentration is below the MCL, it is above an industry guidance level of 0.008 mg/L (80 percent of the MCL) for which reduction is generally initiated. The City currently blends Wells No. 4, which has only 0.003 mg/L arsenic, with the higher arsenic Gilman No. 5 to reduce arsenic concentrations prior to the distribution system point of entry. The City would like to evaluate treatment for further arsenic reduction in the groundwater sources.

3.3 Manganese

Manganese occurs naturally in many groundwater sources in Western Washington and is present at elevated levels in Gilman Wells Nos. 4 and 5, as well as in the City's undeveloped Well No. 6. Manganese can become noticeable in tap water by imparting several negative attributes to water, most noticeably, a black to brown color to the water, but also occasionally odor and/or taste. Exposure to elevated concentrations of manganese over long periods of time have been associated with toxicity to the nervous system. The EPA secondary MCL (SMCL) for manganese is 0.05 mg/L. A SMCL relates primarily to aesthetics. However, DOH enforces all secondary standards in the State of Washington and requires utilities to either implement treatment or provide strong justification for why the secondary standard can be exceeded without detriment to users. Studies done by the Water Research Foundation recommend that manganese be controlled even further, to 0.015 mg/L, to be effective in controlling manganese discoloration in water.

The groundwater from Gilman wells has manganese levels at or above the SMCL. High-volume and unidirectional flushing are routinely completed in the entire northwest section of the city, the primary distribution area for Gilman Well No. 5, because of elevated manganese levels. Sequestrant is also injected at Gilman Well No. 5 to temporarily mask the manganese discoloration. The City would like to evaluate treatment for manganese removal in the groundwater sources to achieve concentrations as low as 0.015 mg/L.

3.4 pH and Lead and Copper Rule Compliance

The EPA developed the Lead and Copper Rule (LCR) to reduce lead and copper concentrations in drinking water that can occur when corrosive source water, typically water with a pH of less than 7.5, causes lead and copper to leach from water system components and other plumbing fixtures/materials. The LCR establishes an action level (AL) of 0.015 mg/L for lead and 1.3 mg/L for copper based on the 90th percentile level of tap water samples. Revisions are currently being considered for the LCR. Potential revisions include greater attention to the potential risks associated with elevated levels of copper in drinking water which may include modifications to the sample site criteria for copper sampling. One change that has been proposed is to have copper-specific sampling at newly constructed homes, where the bare copper plumbing has no time to passivate and would have the highest releases of copper into the drinking water. Such a change would be have a large impact to the City as there is significant new home construction in many parts of the service area.

One of the main factors that define the corrosion rates of lead and copper release into drinking water is pH. Water pH exerts an effect on the solubility, reaction rates and the surface chemistry of corroding metals. Low pH levels, typically lower than 7, potentially increase the solubility of copper and lead from piping, solder, and brass fixtures. At higher pH values, there is a lower tendency for copper surfaces in contact with drinking water to dissolve and release metals into water. A similar trend is observed between lead release and pH. Maintaining a relatively consistent pH (>7.8) throughout the distribution system is important to minimizing lead and copper levels. The pH levels in Risdon Wells Nos. 1 and 2 are typically 6.8 and 7.0, respectively.

The pH in Gilman Well No. 4 is typically 7.3 and the pH in Gilman Well No.5 is typically 8.3. While the pH levels are generally adequate for LCR compliance, the difference between the groundwaters, as well as their difference with regional water, has the potential to cause increased lead and copper release in customer plumbing and affect LCR compliance results. The City would like to raise the groundwater pH, using a pH target that is consistent with that of the regional water to avoid corrosion issues when regional water is introduced into the Valley Zone, with options for further adjustment in the future.

3.5 Fluoride

Seattle Public Utilities adds fluoride to the regional water supply to achieve a concentration of 0.7 mg/L whereas Issaquah does not fluoridate the Risdon and Gilman well supply. Currently, the Valley Zone is supplied only by unfluoridated groundwater.

The Talus and Highlands zones are supplied by regional water, though they have the ability to receive both regional water and groundwater. And, groundwater used to supply the Talus and Issaquah Highlands are fluoridated at the Holly and Talus Booster Pump Stations.

Current demand projections indicate that regional water needs to be introduced into the Valley Zone to meet demands within the next ten years, which will require the City to make a decision whether to fluoridate the Valley Zone. The City has three options regarding fluoride introduction:

1. Blend groundwater and regional water, and increase fluoride concentrations to DOH recommended concentration of 0.7 mg/L.
2. Blend groundwater and regional water, without adjusting fluoride within the system, providing fluoride at a level less than the standard recommend by DOH.
3. Removing fluoride from regional water and blending with groundwater.

Removing fluoride from the regional water is not financially practical for the City. Defluoridation is very rarely practiced in Washington State and throughout the country, and most of the time is used only when raw water fluoride concentrations are so high (i.e. 2.0 mg/L and higher) as to cause aesthetic or health issues. HDR is not aware of any utility in the United States that defluoridates water with only 0.7 mg/L fluoride. The reason for lack of installations is that the capital cost, labor cost, and chemical/material costs for such an activity is typically so high that the overall cost of the water treatment is impractical. As a result, defluoridation is not further evaluated in this document.

4.0 Long-Term Treatment Options

This section evaluates the two long-term treatment options in terms of treatment requirements, equipment sizing, along with implementation constraints. The City desires the removal of anthropogenic PFAS contamination to non-detect levels as based on USEPA Method 537 (as listed in Table 3 and Table 4). Continued partial treatment and blending to below regulatory limits is not considered for PFAS in this evaluation. Blending to achieve lower concentrations of naturally occurring arsenic and manganese, however, is considered in this evaluation. The long-term treatment goals considered in this evaluation are:

1. Reduction of manganese concentrations to 0.015 mg/L from the Gilman water prior to blending.
2. Reduction of arsenic to at least half of the MCL (0.005 mg/L).
3. Removal of PFAS to levels below the USEPA Method 537 detection limits from the Gilman water prior to blending.
4. Fluoridation of groundwater to 0.7 mg/L to match that of the regional water supply.
5. Disinfection to maintain a minimum of 0.2 mg/L chlorine residual throughout the distribution system.
6. Corrosion control to adjust the groundwater pH target to 8.1, to be consistent with the pH of the regional water supply.

4.1 Option 1 – Centralized Treatment (Risdon Wells 1&2 and Gilman Wells 4&5)

4.1.1 Treatment Process

Due to the varying water quality between the City's four wells, each groundwater source has different treatment requirements. Centralized treatment consists of the following systems and processes:

1. PFAS removal – GAC filtration system or ion exchange system
2. Manganese and arsenic treatment – Greensand filtration system
3. Corrosion Control – sodium hydroxide
4. Disinfection – sodium hypochlorite

5. Fluoridation (optional) – sodium fluoride

Figure 1 shows the process diagram for the centralized treatment option and Table 5 presents the predicted water quality through the treatment process.

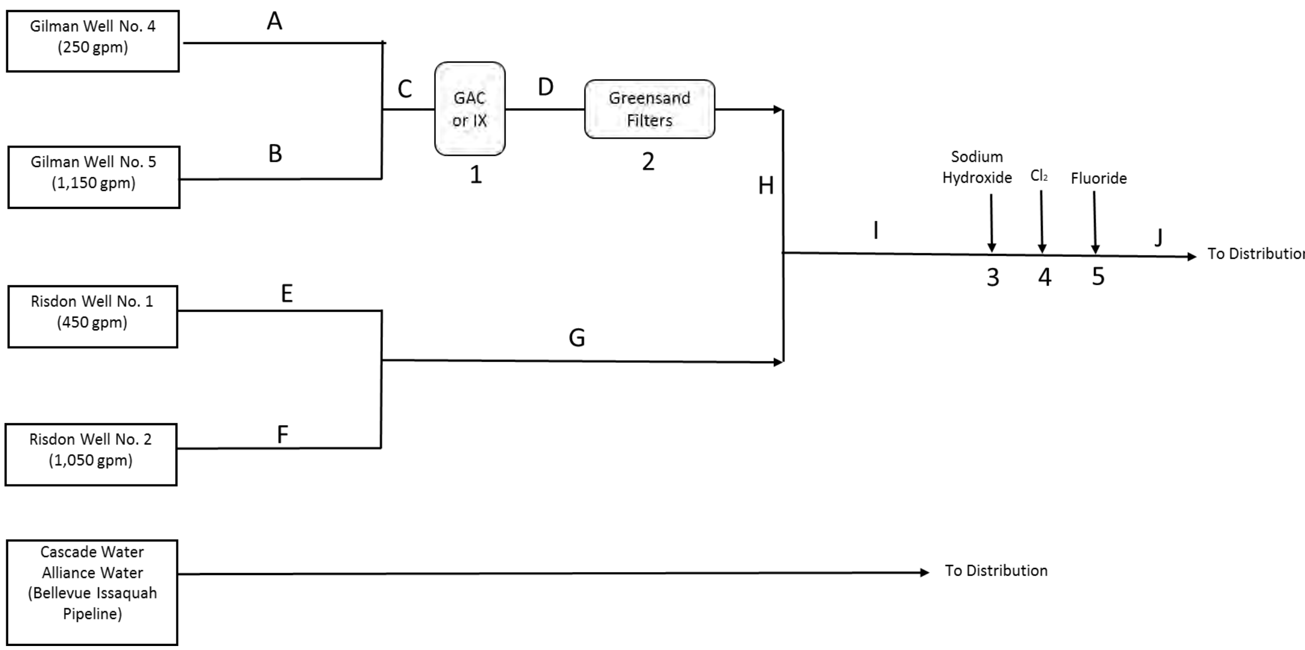

Figure 1. Centralized Treatment Process Schematic

Table 5. Centralized Treatment Plant Water Quality

Line	Flow (gpm)	pH	Alkalinity (mg/L as CaCO3)	PFOS (ug/L)	Arsenic (mg/L)	Manganese (mg/L)	Fluoride (mg/L)
A	250	7.1	103	0.60	0.003	0.02	<0.2
B	1,150	8.1	99.5	0.03	0.009	0.07	<0.2
C	1,400	7.7	100	0.13	0.008	0.06	<0.2
D	1,400	7.7	100	<0.04	0.008	0.06	<0.2
E	450	6.8	60	<0.04	0.002	<0.01	<0.2
F	1,050	7	70	<0.04	0.002	<0.01	<0.2
G	1,500	6.94	66	<0.04	0.002	<0.01	<0.2
H	1,400	7.7	100	<0.04	0.006	0.015	<0.2
I	2,900	7.2	82	<0.04	0.004	0.012	<0.2
J	2,900	8.1	92	<0.04	0.004	0.012	0.7

4.1.2 Equipment Sizing and Design Criteria

Granular activated carbon (GAC) contactors will be installed to remove PFAS from the Gilman well supply. The GAC contactors could be located inside or outside of the process building. High service pumps would be installed to convey water from the Gilman Well site to the centralized treatment facility where it would be treated by the GAC contactors before blending with the PFAS-free water from the

Risdon Wells. Blended water would then be sent to the greensand filtration system. Backwash pumps would be installed for backwashing of the contactors along with a backwash storage tank. The backwash waste would be stored in the backwash tank and slowly released to the sewer.

GAC was selected because it is the current process that the City is using at Well No. 4. However, since the system was installed at Well No. 4, other adsorption technologies for PFAS removal have come to the market that may potentially have better performance and lower cost. A treatability evaluation should be conducted to determine the most effective treatment technology in removing PFAS. Implementation of GAC would allow for the reuse of the GAC contactors from the Gilman Well site at the centralized treatment plant location.

The greensand filtration system consists of horizontal vessels. The greensand filters would be installed to reduce manganese levels to approximately 0.015 mg/L. As an ancillary benefit, greensand filters would reduce influent arsenic concentrations to reach 0.005 mg/L with the addition of a ferric chloride feed system. The system would be capable of treating the full groundwater supply of 2,900 gpm to reduce levels of manganese and arsenic. Each vessel would contain three cells and would require backwashing approximately once a day. The finished water from two of the cells would be used to backwash the third cell. The vessel being backwashed would not produce any finished water for the backwashing period which is typically about 28 minutes. All filter backwash waste would be stored in a backwash waste tank and drained to the sewer through a new sewer connection.

The corrosion control system would consist of a sodium hydroxide feed system, dosing approximately 10 mg/L, to raise the finished water to a target pH to 8.1, equal that of the regional water. The sodium hydroxide would be injected after the greensand filtration system. The feed system would consist of two, 5,000 gallon, sodium hydroxide storage tanks and would require bulk deliveries to the site approximately every 24 days at peak water demands.

Based on a combined flow of 2,900 gpm and a chlorine dosage of 1.5 mg/L of hypochlorite, the chlorine demand would be approximately 60 pounds equivalent chlorine per day. The sodium hypochlorite system would consist of two, 2,000 gallon storage tanks. Sodium hypochlorite (12.5 percent) would be delivered in mini-bulk delivery loads to the site every month at peak demands.

A sodium fluoride saturator would be installed to produce 1 to 2 percent sodium fluoride solution by dissolving sodium fluoride salts into solution. A 50 gallon saturator would be capable of holding 300 pounds of sodium fluoride. Sodium fluoride salt would be stored onsite and would need to be added into the saturator. The sodium fluoride saturator would be stored in a contained area in the main process room.

Design criteria for each system required for the centralized treatment plant is summarized in Table 6.

Table 6. System Design Criteria for Option 1 – Centralized Treatment

System Design Criteria	Value
GAC System	
Design System Flowrate (gpm)	1,400
Number of vessels	2
Greensand Filtration System	
Design System Flowrate (gpm)	1,400
Number of Vessels	2 (N+1)
Corrosion Control System	
Capacity (gpm)	2,900
Sodium Hydroxide Dose (mg/L)	10
Days of storage	24
Sodium Hydroxide Volume (gallons)	4,000
Storage Tank Volume (gallons)	4,500
Number of Storage Tanks	2
Disinfection System	
Capacity (gpm)	2,900
Sodium Hypochlorite Dose (mg/L)	1.6
Days of storage	40.0
Sodium Hypochlorite Volume (gallons)	2,100
Storage Tank Volume (gallons)	2,500
Number of Storage Tanks	2
Fluoridation System	
Capacity (gpm)	2,900
Sodium Fluoride Dose (mg/L)	0.7
Storage Tank Volume (gallons)	50
Days of storage	6

4.1.3 Implementation Constraints

A new parcel of land would need to be selected and purchased for construction of the centralized treatment plant. The most feasible location for the treatment plant is a central location between the Gilman and Risdon well sites and south of Interstate 90 to avoid having to convey water under the Interstate. Figure 2 shows the feasible region for the location of the treatment plant. Further evaluation on plant locations will be completed during the initial design phase.

Figure 2. Approximate Area of Centralized Treatment Plant Location

4.1.4 Conceptual Layout

The centralized treatment facility would consist of a main process building with a separate chemical room for sodium hydroxide storage and sodium hypochlorite storage. The main process building would contain the fluoride system, if the City chooses to fluoridate the system, backwash storage tank, high service pumps, backwash pumps, an electrical room, an office space, and a restroom. The GAC contactors and greensand filters would be located inside the process building. Figure 3 shows a conceptual treatment plant layout that could be altered based on the selected site location.

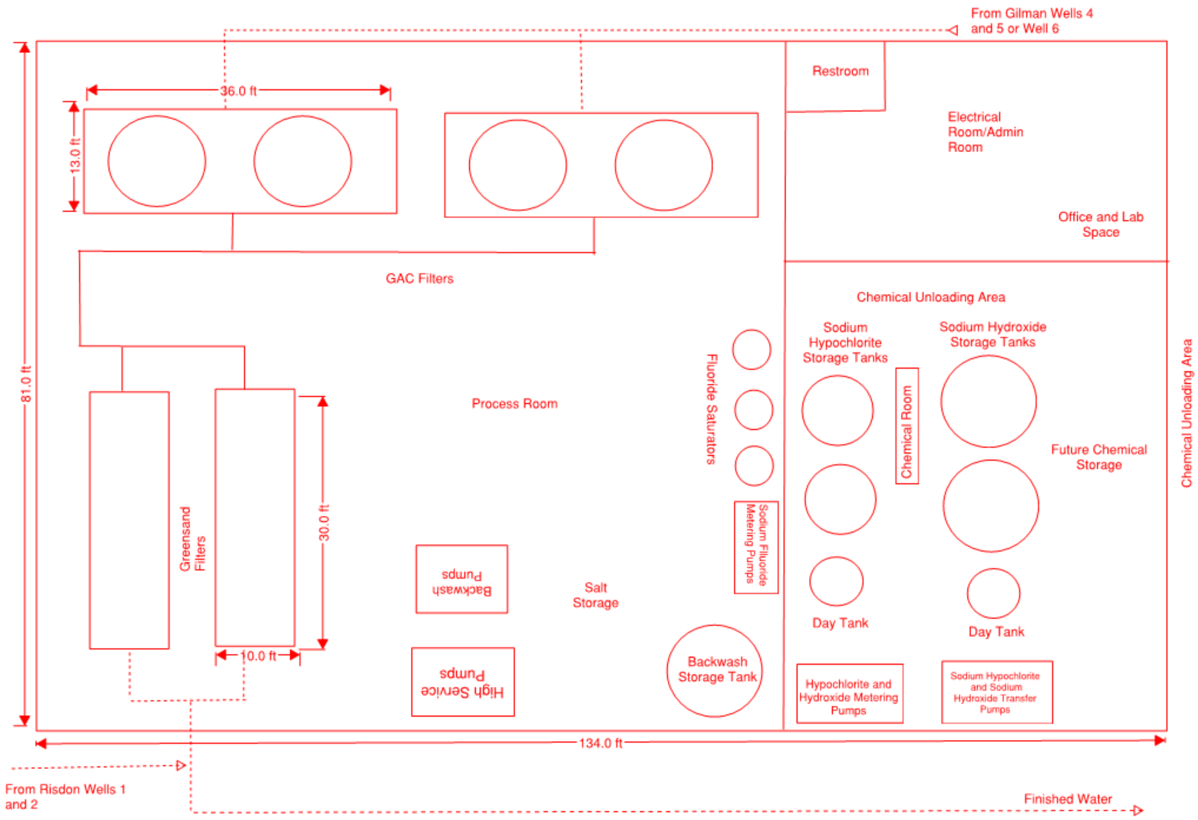

Figure 3. Conceptual Centralized Treatment Facility Layout

4.1.5 Conceptual Cost Estimate

The costs associated with this long-term treatment option are considered a Class 4 (concept study) estimate per AACE International for which an allowance of 50 percent is added for undefined scopes of work. Table 7 presents the conceptual cost for Option 1.

Table 7. Conceptual Cost Estimate for Option 1 – Centralized Treatment Plant

	Quantity	Unit	Unit Cost	Total Cost	Comment
Demolition and Clearing					
Site Clearing, TESC	1	LS	$20,000	$20,000	HDR Estimate
Tree Removal	1	LS	$2,000	$2,000	RS Means Code: 7160
			Subtotal	$22,000	
Belowgrade Piping/Site Civil					
Excavation	3,200	CY	$10	$32,000	RS Means Code: 0300
Asphalt Paving	10,000	SF	$5	$50,000	RS Means Code: 0055
12" ductile iron piping	5,400	LF	$80	$605,000	Including piping from Gilman and Risdon sites to centralized plant. Assumed 40% for fittings. RS Means Code: 2100
8" ductile iron	200	LF	$40	$8,000	RS Means Code: 2060
1" PVC Piping	100	LF	$15	$3,000	assumed 1" pvc and 40% for fittings
Fencing	558	LF	$25	$14,000	RS Means Code: 2100
Landscaping	1	LS	$20,000	$20,000	HDR Estimate
Sewer Line	1	LS	$10,000	$10,000	HDR Estimate
Storm Drainage	1	LS	$20,000	$20,000	HDR Estimate
			Subtotal	$762,000	
Treatment Equipment and Abovegrade Piping					
GAC Vessels	1	LS	$300,000	$390,000	Placement and initial GAC fill cost. Vendor quote
Backwash Tank	2	EA	$25,000	$50,000	20,000 gallon tank
Sodium Hydroxide Storage Tank	2	EA	$10,000	$20,000	5,000 gallon storage tanks
Sodium Hydroxide Day Tank	1	EA	$4,000	$4,000	400 gallon day tank.
Greensand Filters	2	EA	$333,000	$866,000	Or a single larger unit for $500,000. Vendor Quote. Media included.
Hypochlorite Storage Tank	2	EA	$6,000	$12,000	2,500 gallon storage tank
Hypochlorite Day Tank	1	EA	$4,000	$4,000	300 gallon day tank
Metering Pumps	4	EA	$6,000	$32,000	N+1 pumps. Vendor quote
Transfer Pumps	4	EA	$4,000	$21,000	N+1 pumps. Vendor quote
Backwash Pumps	2	EA	$15,000	$30,000	HDR Estimate. N+1
High Service Pumps	2	EA	$30,000	$60,000	HDR Estimate. N+1
1" PVC Piping	500	LF	$15	$11,000	assumed 1" pvc and 40% for fittings
8" ductile iron	100	LF	$40	$4,000	RS Means Code: 2060
			Subtotal	$1,504,000	
Treatment Building					
Building Cost (CMU/Concrete/Wood)	10,000	SF	$300	$3,000,000	HDR Estimate
Equipment Pad	4	EA	$6,000	$24,000	HDR estimate based on Q4/2015 bids
			Subtotal	$3,024,000	
Land Acquisition					
Land Acquisition	1	LS	$4,000,000	$4,000,000	
			Subtotal	$4,000,000	
Decommissioning					
Decommissioning	4	EA	$10,000	$40,000	Decommissioning of equipment at 4 facilities
			Subtotal	$40,000	
Optional					
Fluoride System	1	LS	$25,000	$33,000	Vendor Quote
			Subtotal	$33,000	
			Subtotal	$9,385,000	
			Electrical and Instrumentation (30%)	$2,816,000	
			Mobilization (10%)	$939,000	
			Contractor's Overhead and Profit (15%)	$1,408,000	
			Contractor's Bonds and Insurance (1.5%)	$141,000	
			Undefined Scope of Work (50%)	$4,693,000	
			Subtotal	$19,382,000	
			Sales Tax (10%)	$1,938,000	
			Subtotal Direct Costs	***$21,320,000***	
			Engineering Pre-design (5%)	$1,066,000	
			Engineering Design (7%)	$1,492,000	
			Services During Construction (5%)	$1,066,000	
			Administrative Costs (3%)	$640,000	
			Permitting (2%)	$427,000	
			Bidding	$54,000	
			Subtotal Indirect Costs	$4,745,000	
			Total Project Cost	**$26,065,000**	

4.2 Option 2 – Wellhead Treatment

4.2.1 Treatment Requirements

Wellhead treatment would consist of the following systems and processes at the Risdon Well No. 1 and No. 2 site:

1. Corrosion Control – sodium hydroxide
2. Disinfection – sodium hypochlorite (existing)
3. Fluoridation (optional) – sodium fluoride

Wellhead treatment would consist of the following systems and processes at the Well No. 6 site:

1. Manganese treatment – greensand filtration system
2. Disinfection – sodium hypochlorite
3. Fluoridation (optional) – sodium fluoride

Figure 4 shows the process diagram for the wellhead treatment option and Table 8 presents the predicted water quality of the Well No. 6 wellhead treatment system.

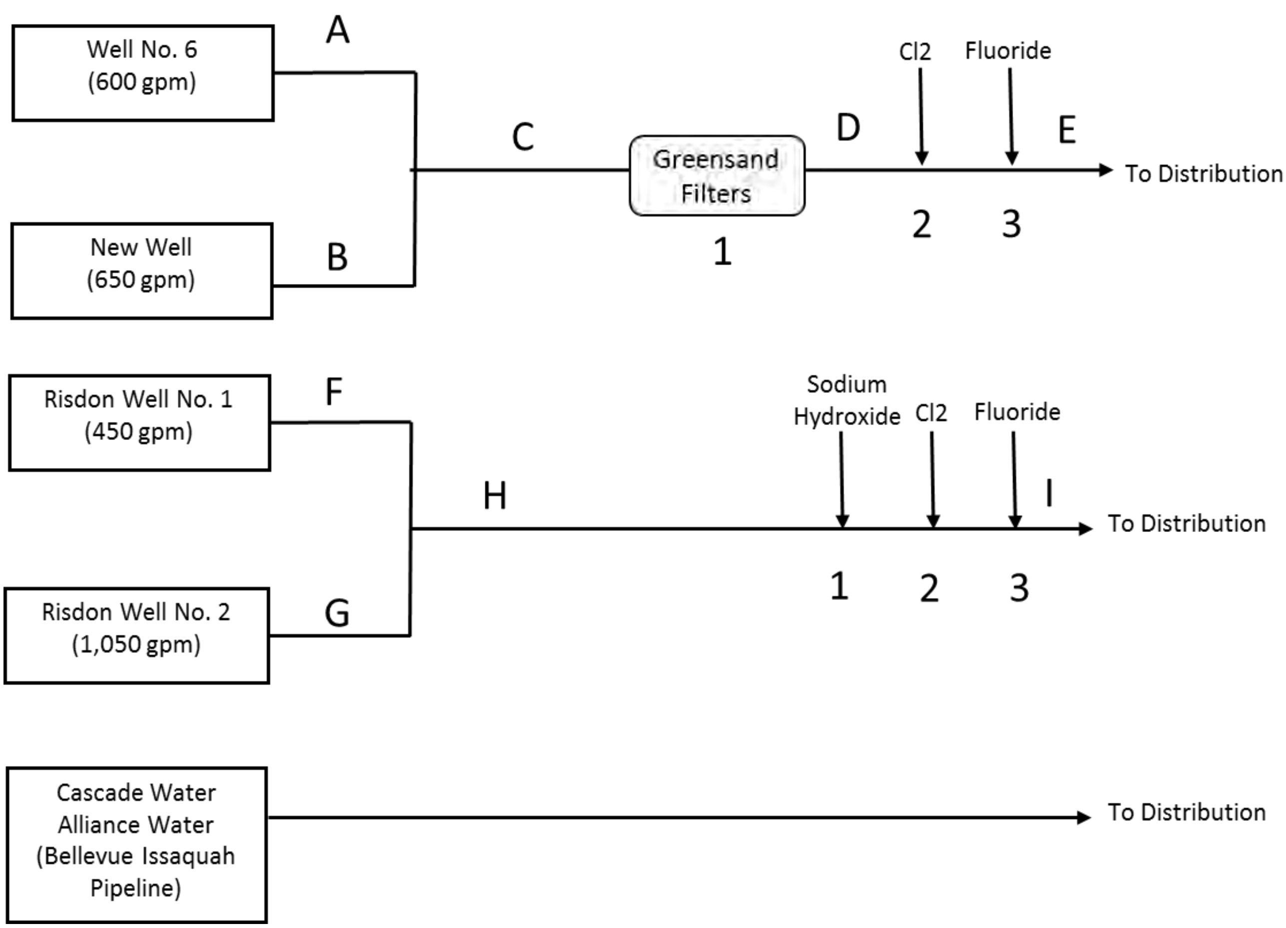

Figure 4. Wellhead Treatment Process Schematic

Table 8. Wellhead Treatment Water Quality

Line	Flow (gpm)	pH	Alkalinity (mg/L as CaCO3)	Arsenic (mg/L)	Manganese (mg/L)	Fluoride (mg/L)
A	700	8.4	NA	<0.001	0.12	<0.2
B	700	8.4	NA	<0.001	0.12	<0.2
C	1,400	8.4	NA	<0.001	0.12	<0.2
D	1,400	8.4	NA	<0.001	0.015	<0.2
E	1,400	8.4	NA	<0.001	0.015	0.7
F	450	6.8	60	0.002	<0.01	<0.2
G	1,050	7	70	0.002	<0.01	<0.2
H	1,500	6.94	66	0.002	<0.01	<0.2
I	1,500	8.1	66	0.002	<0.01	0.7

4.2.2 Equipment Sizing and Design Criteria

Risdon Well Site

Risdon Wells 1 and 2 have lower than desired pH and would require an adjustment to raise the pH target to match that of the regional water (8.1). Treatment is required to reach the treatment goal.

The corrosion control system would use sodium hydroxide, dosed at 16 mg/L, to raise the finished water to a target pH to 8.1. The new sodium hydroxide tank and feed system will not fit in the existing well house and would be stored in a new chemical building. The existing well house would be torn down and a new building would be constructed. Sodium hydroxide would need to be delivered to the site every two weeks at peak demands.

A fluoride saturator that prepares 1 to 2 percent sodium fluoride solution by dissolving sodium fluoride salts into solution could also be installed. The 50 gallon saturator would be capable of holding 300 pounds. Sodium fluoride salt would be stored onsite. The sodium fluoride saturator would be stored in a new chemical building that would also house the sodium hydroxide.

Well No. 6 Site

Well No. 6 has manganese over the SMCL and would require treatment. A greensand filtration system, similar to what would be required at the Risdon Well site, would be installed. High service pumps would convey water from Well No. 6 and a potential new well to the greensand filters. The filters would be capable of treating the full groundwater supply to reduce levels of manganese. Like the greensand filter at the Risdon Well site, each vessel would have 3 cells. Backwashing would take place approximately once a day and the finished water from two of the cells would be used to backwash the third. The vessel would not produce any finished water for the backwashing period which is typically about 28 minutes. Backwash waste would be stored in a storage tank and slowly released to the sewer.

Fluoridation could be added at the Well No. 6 site which would consist of a fluoride saturator that prepares 1 to 2 percent sodium fluoride solution by dissolving sodium fluoride salts into solution would also be installed. The 50 gallon saturator would be capable of holding 300 pounds. Sodium fluoride salt would be stored onsite. The sodium fluoride saturator would be stored in the new chemical building.

Based on a well pump rate of 1,400 gpm and an assumed chlorine dosage of 1.5 mg/L of hypochlorite, the chlorine demand would be approximately 10 to 30 pounds equivalent chlorine per day. Sodium hypochlorite (12.5 percent) would be delivered to the site every two weeks at peak demands.

Table 9. System Design Criteria for Option 2 – Wellhead Treatment

System Design Criteria	Option 2- Risdon Well Site	Option 2 - Well No. 6 Site
GAC System		
Design System Flowrate (gpm)	-	-
Number of vessels	-	-
Greensand Filtration System		
Design System Flowrate (gpm)	1,500	1,400
Number of Vessels	1	1
Corrosion Control System		
Capacity (gpm)	1,500	-
Sodium Hydroxide Dose (mg/L)	16	-
Days of storage		
Sodium Hydroxide Volume (gallons)	2,200	-
Storage Tank Volume (gallons)	2,500	-
Number of Storage Tanks	1	-
Disinfection System		
Capacity (gpm)	-	1,400
Sodium Hypochlorite Dose (mg/L)	-	1.5
Days of storage		30
Sodium Hypochlorite Volume (gallons)	-	700
Storage Tank Volume (gallons)	-	500
Number of Storage Tanks	-	2
Fluoridation System		
Capacity (gpm)	1,500	1,400
Sodium Fluoride Dose (mg/L)	0.7	0.7
Storage Tank Volume (gallons)	50	50
Days of storage	9	10

4.2.3 Implementation Constraints

Risdon Well Site

The Risdon wells are on a very constrained site with power lines running directly over the site. Installing a new chemical building would not be feasible at this site as the minimum safe distance from the power lines could not be maintained by a permanent facility and/or during the construction of a permanent facility. Relocation of the power lines would provide more space on the site, however, would still not provide enough space for access to the necessary facilities required to meet the overall treatment goals. A wellhead treatment system to meet the overall treatment goals at the Risdon Well site is not feasible unless more land is to be acquired from the adjacent property, which is not evaluated as part of the scope of this project.

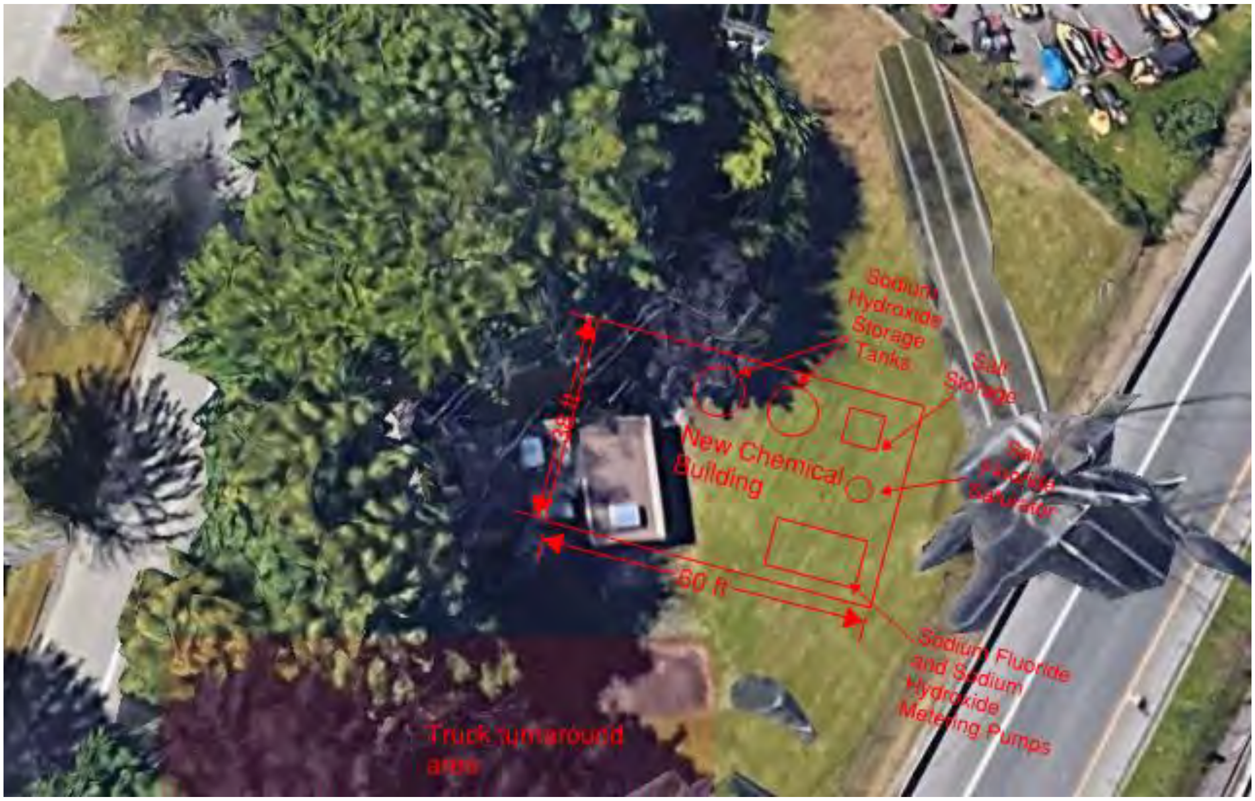

Figure 5. Risdon Well Site Wellhead Treatment

Well No. 6 Site

A new parcel of land would need to be selected and purchased for construction of a treatment building for Well No. 6 and an additional well at Confluence Park. Possible implementation constraints include the residents of the City being unwilling to give up park property or commercial land for a municipal facility. However, the wellhead treatment system will have a smaller footprint and may have less of an impact of park land.

4.2.4 Conceptual Layouts

Well No. 6 Site

The wellhead treatment at the Well No. 6 site would consist of a chemical process building for the disinfection and fluoride system. Greensand filters would be located outside of the process building. A conceptual treatment facility layout drawing is shown in Figure 6.

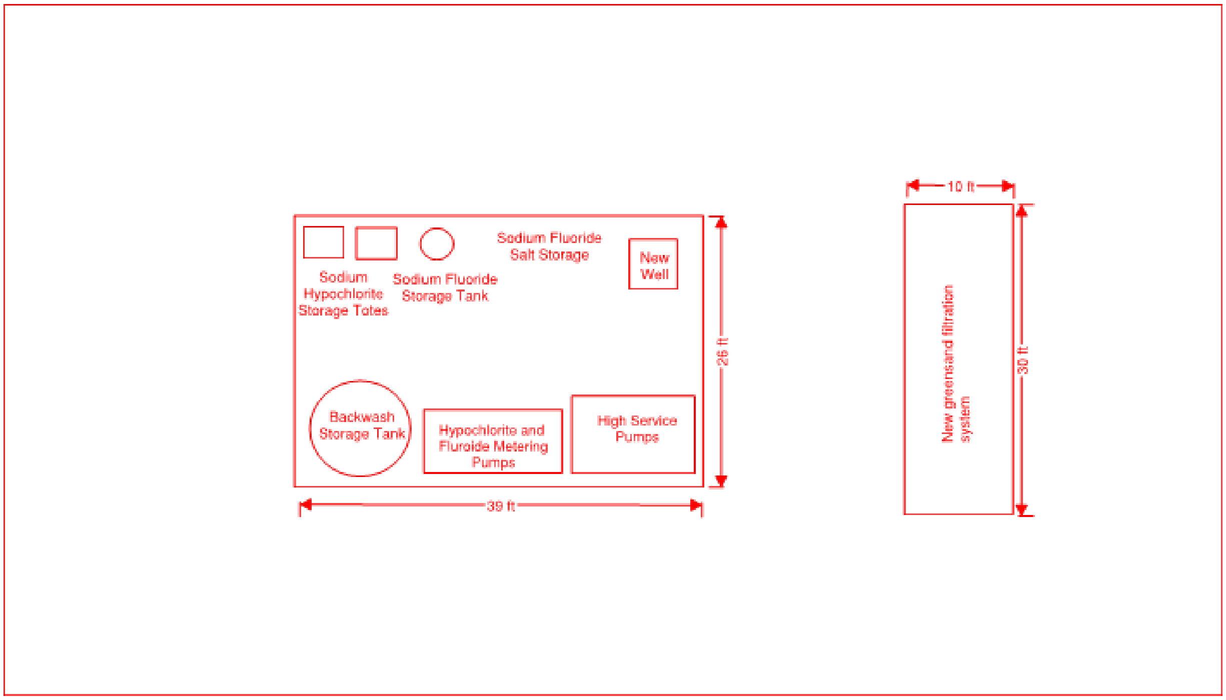

Figure 6. Well No. 6 Site Wellhead Treatment

4.2.5 Conceptual Cost Estimates

Option 2 requires wellhead treatment to be installed at the Well No. 6 and Risdon well sites. Due to the limited space on the Risdon Well site, wellhead treatment would not be able to fit on the current site. Although wellhead treatment may be feasible at the Well No. 6 site, Option 2, overall, would not be feasible due to the constraints at the Risdon well site.

5.0 Treatment Options Summary

Table 10 presents a summary of all options along with the total capital and indirect costs associated with each.

Table 10. Long-Term Treatment Option Summary

Option	Advantages	Disadvantages
Option 1- Centralized Treatment Plant	• All treatment located in a central location • Does not require transferring of water rights • Reduces labor costs • Reduces O&M costs	• Major modifications need to be made to City transmission mains • Requires the City to acquire more land
Option 2 – Wellhead Treatment Risdon Wells	Not Feasible	Not Feasible
Option 2 - Wellhead Treatment Well No. 6	• PFAS treatment is likely not necessary • Does not require major modifications to transmission mains	• Transferring of water rights • Higher manganese concentrations • Develop park land • Higher labor for wellhead treatment

6.0 Conclusion and Next Steps

The City's preferred option is treating water from the Risdon and Gilman wells at a centralized treatment plant. Centralized treatment will reduce the overall labor and operation and maintenance costs and avoid any issues that could occur by transferring water rights. The centralized plant will give the City the flexibility to expand in the future for treatment of emerging contaminants or changes to existing drinking water regulations.

The overall capital cost for the centralized treatment plant cost is estimated to be $21,300,000. Indirect costs associated with the treatment plant are estimated to be $4,700,000, with an overall total project cost of $26,100,000.

To move forward with the selected option, the following next steps should be taken:

1. Land acquisition
2. Environmental assessment on selected site
3. Zoning and permitting
4. Geotechnical study
5. Treatability study

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