Appendix A

TASK 4 – EXISTING FACILITY CONDITION ASSESSMENT

City of Fort Lauderdale
Granular Activated Carbon Pilot and Plant Evaluation at the Fiveash Water Plant

Technical Memorandum 4
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FINAL REDACTED | December 2019

CERTIFICATE OF AUTHORIZATION NO. 8571

CITY OF FORT LAUDERDALE

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TASK 4 – EXISTING FACILITY CONDITION ASSESSMENT

Executive Summary

The City of Fort Lauderdale's Comprehensive Utility Strategic Master Plan (CUSMP 2017) was completed in 2017. This master plan acknowledged that the Fiveash Water Treatment Plant (WTP) would require extensive renewal, rehabilitation, and replacement for it to be a viable option to provide potable water throughout the identified CUSMP 2017 planning period. The CUSMP also noted that consideration should be given to replacing the facility with a new facility equipped with the latest treatment and equipment technologies.

In conjunction with this Granular Activated Carbon Pilot and Plant Evaluation project at the Fiveash WTP, it was requested that the Carollo Team perform a confirming assessment of the Fiveash WTP. This request noted that the assessment should be a "high level, from 20,000 ft" brief, general assessment. This assessment has been completed and the results are discussed herein.

Stantec, a member of the Carollo Team, agrees with the assessment findings of the CUSMP 2017.Continuing re-investment of significant funds for the long-term use of existing facility originally constructed in 1950's, while possible, may not be a prudent investment.

4.1 Background

The condition of the Fiveash (WTP) and Prospect Wellfield (Wellfield) was assessed as part of the CUSMP 2017. This assessment identified the need for significant renewal, replacement, and rehabilitation of all aspects of the WTP and the wellfield. Task 4 - Existing Facility Condition Assessment of this project, Fiveash Water Treatment Plant Evaluation and GAC Pilot Testing, entails evaluation of the CUSMP 2017 requirements mentioned above and providing a confirming assessment of the facilities. On May 28, 2019 staff from City of Ft Lauderdale, Stantec and Chen Moore conducted a site visit to evaluate the condition of the existing infrastructure at the Wellfield and at the WTP.

This memorandum is prepared to provide an overview and assessment of the existing facilities. This assessment, undertaken as part of this project, is focused on the primary treatment system components with "big picture" items analyzed from a "20,000 ft" view point as requested by City staff.

The information included in this Technical Memorandum TM consists of an overview of the Wellfield, evaluation of production wells, wellheads, electrical, and SCADA related features. In addition, it provides an overview of WTP, an evaluation of the facility by major process areas, electrical system, and SCADA related facilities. This evaluation provides an overview of improvements noted in CUSMP 2017 followed by validation or non-validation based on the information review, site visit, and input from the City staff.

4.2 Prospect Wellfield Overview

The Wellfield consists of Biscayne aquifer wells which supply raw water to the WTP. [redacted]

The Wellfield was constructed in two phases. Wells located on the west side of the road (Western Wells) were constructed in the 1950's concurrent with the first phase of the WTP. These include production wells (PW), PW 25, PW 26, PW 27 and PW 28. Production wells PW 30, PW 31, PW 32, PW 33, PW 34 and PW 35 were added in mid-1960's to early 1970's. Wells located on the east side of the road (Eastern Wells) were constructed in conjunction with WTP expansion in the late 1970's to early 1980's. The eastern wells include: PW36, PW 37, PW 38, PW 39, PW 40, PW 41, PW 42, PW 43, PW 44, PW 45, PW 46, PW 47, PW 48 and PW 49. In 2004 wells PW 50, PW 51, PW 52, PW 53 and PW 54 were added to the wellfield.

The South Florida Water Management District (SFWMD) water use permit (CUP) allows a withdrawal rate of 43.43 MGD on an annual average daily demand (AADD) basis which is equivalent to 15,853 million gallons per year (MGY) from the Prospect wellfield. The CUP allows a withdrawal rate of 1,534.5 million gallons per month (MGM) at the Prospect wellfield.

The well pumps are (3) stage Flowserve 316SS pumps equipped with 100 HP, 460 V motors. Operations staff indicated that typically 7 to 10 wells are in service at one time to meet WTP demands. Raw Water is transmitted by two separate 42-inch raw water mains from Wellfield to the WTP along two separate routes. [redacted]

[redacted]

[redacted]

[redacted]

Figure 4.1 Location of Proposed Wellfield and Five ash WTP

[redacted]

Figure 4.2 Proposed Wellfield Production Wells Location

4.3 Prospect Wellfield Evaluation

The CUSMP 2017 was reviewed in the context of the proposed improvements for the wellfield. Current conditions of the wellfield assets were documented based on visual observations and information provided by plant staff during site visit on May 28, 2019. Changes from the conditions identified in the CUSMP 2017 were noted and improvements were updated as necessary.

4.3.1 Mechanical

The CUSMP 2017 identified most wells need infrastructure improvements due to their age, wellhead designs, and out of service equipment. All but five wells were installed in 1980 or before, putting the wells at or past the typical useful life for steel cased production wells.

The CUSMP 2017 recommended wellfield testing, prioritizing and targeting wells for either rehabilitation or replacement, as well as funding for yearly well maintenance, including maintaining pumps and motors, and replacement of mechanical and electrical components before failure renders the wells inoperable. Table 4.1 identifies the wells and the planned Fiscal Years for the proposed improvements.

Table 4.1 CUSMP 2017 Prospect Wellfield Renewal and Replacement

Improvement	Year Planned for Improvement
Production Wells 25, 26, 27 & 35	FY 2018
Production Wells 28, 30, 31 & 32	FY 2019
PWs 33, 34, 36 & 37	FY 2020
PWs 38, 39, 40 & 41	FY 2021
PWs 42, 43, 44 & 45	FY 2021 -2026
PWs 46, 47, 48 & 49	FY 2021 -2026
PWs 50, 51, 52, 53 & 54	FY 2021 -2026

Notes:

(1) Information extracted from CUSMP 2017 Table WA8-2. Prospect Wellfield 2015 Renewal and Replacement Requirement Analysis

(2) Production well improvements above entails Well Replacement and Wellhead Mechanical (Pump, Motor, shutoff Valves, Backpressure Valves, Air Valves, etc.)

Based on the site visit to the Wellfield on May 28, 2019, the above grade mechanical pumps and piping appear to be in generally fair to good condition. Distribution and collection system maintenance staff has an improvement program to replace well equipment each year based on available funding. Most of the pumps, motors, and wellhead piping have been replaced within last 10 years. Based on the maintenance records provided by staff, the remaining useful life of pumps, motors, and piping was updated and is presented in Table 4.2.

Observations made during inspection of each well, and the discussions with plant staff regarding these observations, are included in Appendix 4A under 'Field Notes for Wellhead Inspections'.

Table 4.2 Prospect Wellfield – Mechanical Renewal and Replacement Summary

Well No.	Well Assets	Quantity	Year Purchased/ Rehabbed	Useful Life (Years)	Remaining Useful Life (Years)	Condition	City Staff Input
PW- 25	Production Well	1	1960	40	0	Poor	In 2017: New check valve, ARV valve, stuffing boxes and shafts were installed
	Pump & Motor	1	2017^{N}	20	18	Good	
	Wellhead Mechanical & Piping	1	2017^{N}	30	28	Good	
PW- 26	Production Well	1	1960	40	0	Poor	In 2007: Stuffing boxes and shafts reconditioned.
	Pump & Motor	1	2007^{R}	10	0	Poor	
	Wellhead Mechanical & Piping	1	2007^{R}	30	18	Good	
PW- 27	Production Well	1	1960	40	0	Poor	In 2013: New ARV valve, stuffing boxes were installed. New check valve was installed in 2016. Shafts were reconditioned.
	Pump & Motor	1	2013^{N}	20	14	Good	
	Wellhead Mechanical & Piping	1	$2013^{N,R}$	30	24	Good	
PW- 28	Production Well	1	1970	40	0	Poor	In 2005: Stuffing boxes, shafts were reconditioned.
	Pump & Motor	1	2005^{R}	10	0	Poor	
	Wellhead Mechanical & Piping	1	2005^{R}	30	16	Good	
PW- 30	Production Well	1	1970	40	0	Poor	In 2016: New check valve, ARV valve, stuffing boxes, shafts installed.
	Pump & Motor	1	2016^{N}	20	17	Good	
	Wellhead Mechanical & Piping	1	2016^{N}	30	27	Good	
PW- 31	Production Well	1	1970	40	0	Poor	In 2014: Stuffing boxes and shafts were reconditioned.
	Pump & Motor	1	2014^{R}	10	5	Good	
	Wellhead Mechanical & Piping	1	2014^{R}	30	25	Good	
PW- 32	Production Well	1	1970	40	0	Poor	In 1999: Stuffing boxes, shafts were reconditioned.
	Pump & Motor	1	1999^{R}	10	0	Poor	
	Wellhead Mechanical & Piping	1	1999^{R}	30	10	Good	
PW- 33	Production Well	1	1970	40	0	Poor	In 2018: New stuffing boxes and shafts installed. Check valve, ARV Valve, Pipe Ts, Spool Pieces were inspected.
	Pump & Motor	1	2018^{N}	20	19	Good	
	Wellhead Mechanical & Piping	1	$2018^{N,I}$	30	29	Good	

Table 4.2 Prospect Wellfield – Mechanical Renewal and Replacement Summary (continued)

Well No.	Well Assets	Quantity	Year Purchased/ Rehabbed	Useful Life (Years)	Remaining Useful Life (Years)	Condition	City Staff Input
PW- 34	Production Well	1	1970	40	0	Poor	In 2018: New check valve, stuffing boxes , shafts installed. ARV valve was rebuilt.
	Pump & Motor	1	2018^{N}	20	19	Good	
	Wellhead Mechanical & Piping		2018^{N,R}	30	29	Good	
PW- 35	Production Well	1	1960	40	0	Poor	New check valve, ARV valve, stuffing boxes, shafts installed in 2016
	Pump & Motor	1	2016^{N}	20	17	Good	
	Wellhead Mechanical & Piping	1	2016^{N}	30	27	Good	
PW- 36	Production Well	1	1970	40	0	Poor	In 2017: New stuffing boxes, shafts installed. ARV valve was rebuilt. Check valve was inspected.
	Pump & Motor	1	2017^{N}	20	18	Good	
	Wellhead Mechanical & Piping	1	2017^{N,R,I}	30	28	Good	
PW - 37	Production Well	1	1970	40	0	Poor	In 2016: New staffing boxes, shafts installed. ARV valve was rebuilt. Check valve was inspected in 2016.
	Pump & Motor	1	2016^{N}	20	17	Good	
	Wellhead Mechanical & Piping	1	2016^{N,R,I}	30	27	Good	
PW- 38	Production Well	1	1980	40	1	Poor	In 2016: New stuffing boxes, shafts installed. Check valve, ARV Valve, Pipe Ts, Spool Pieces were inspected.
	Pump & Motor	1	2018^{N}	20	19	Good	
	Wellhead Mechanical & Piping	1	2018^{N,I}	30	29	Good	
PW- 39	Production Well	1	1980	40	1	Poor	In 2014: ARV valve, stuffing boxes, shafts were rebuilt
	Pump & Motor	1	2014^{R}	10	5	Good	
	Wellhead Mechanical & Piping	1	2014^{R}	30	25	Good	
PW- 40	Production Well	1	1980	40	1	Poor	In 2011: New shafts installed. ARV valve and staffing boxes were rebuilt.
	Pump & Motor	1	2011^{N}	20	12	Good	
	Wellhead Mechanical & Piping	1	2011^{N,R}	30	22	Good	
PW- 41	Production Well	1	1980	40	1	Poor	In 1993: New stuffing boxes, shafts installed. ARV valve was rebuilt.
	Pump & Motor	1	1993	20	0	Poor	
PW- 41	Wellhead Mechanical & Piping	1	1993^{N,R}	30	4	Poor	Wellhead Mechanical & Piping

Table 4.2 Prospect Wellfield – Mechanical Renewal and Replacement Summary (continued)

Well No.	Well Assets	Quantity	Year Purchased/ Rehabbed	Useful Life (Years)	Remaining Useful Life (Years)	Condition	City Staff Input
PW- 42	Production Well	1	1980	40	1	Poor	In 2008: New stuffing boxes, shafts installed. ARV valve was rebuilt.
	Pump & Motor	1	2008	20	9	Good	
	Wellhead Mechanical & Piping	1	2008[N,R]	30	19	Good	
PW- 43	Production Well	1	1980	40	1	Poor	In 2018: New stuffing boxes, shafts installed. ARV valve was rebuilt.
	Pump & Motor	1	2018[N]	20	19	Good	
	Wellhead Mechanical & Piping	1	2018[N,R]	30	29	Good	
PW- 44	Production Well	1	1980	40	1	Poor	In 2015: New stuffing boxes, shafts installed. ARV valve was rebuilt.
	Pump & Motor	1	2015[N]	20	16	Good	
	Wellhead Mechanical & Piping	1	2015[N,R]	30	26	Good	
PW- 45	Production Well	1	1980	40	1	Poor	In 2017: New stuffing boxes , shafts installed. ARV valve was rebuilt in 1996 rebuilt. Check valve was inspected.
	Pump & Motor	1	2017[N]	20	18	Good	
	Wellhead Mechanical & Piping	1	2017[N,R,I]	30	28	Good	
PW- 46	Production Well	1	1980	40	1	Poor	In 2016: New stuffing boxes, shafts installed. ARV valve was rebuilt.
	Pump & Motor[N]	1	2011	20	12	Good	
	Wellhead Mechanical & Piping	1	2011[N,R]	30	22	Good	
PW- 47	Production Well	1	1980	40	1	Poor	In 2018: New stuffing boxes, shafts installed. ARV valve was rebuilt in 2006. New check valve installed in 2000.
	Pump & Motor	1	2018[N]	20	19	Good	
	Wellhead Mechanical & Piping	1	2018[N,R]	30	29	Good	
PW- 48	Production Well	1	1980	40	1	Poor	In 2008: New stuffing boxes, shafts installed. ARV valve was rebuilt in 2006.
	Pump & Motor	1	2008[N]	20	9	Good	
	Wellhead Mechanical & Piping	1	2008[N,R]	30	19	Good	
PW- 49	Production Well	1	1980	40	1	Poor	In 2001: Rebuilt ARV Valve, stuffing boxes, shafts installed.
	Pump & Motor	1	2001[R]	10	0	Poor	
	Wellhead Mechanical & Piping[N,R]	1	2001	30	12	Good	

Table 4.2 Prospect Wellfield – Mechanical Renewal and Replacement Summary (continued)

Well No.	Well Assets	Quantity	Year Purchased/ Rehabbed	Useful Life (Years)	Remaining Useful Life (Years)	Condition	City Staff Input
PW- 50	Production Well	1	2002	40	23	Good	In 2013: New stuffing boxes, shafts installed. ARV valve was rebuilt.
	Pump & Motor^{N}	1	2013	20	14	Good	
	Wellhead Mechanical & Piping^{N,R}	1	2013	30	24	Good	
PW- 51	Production Well	1	2002	40	23	Good	
	Pump & Motor	1	2004-2008	20	5	Good	
	Wellhead Mechanical & Piping	1	2004-2008	30	15	Good	
PW- 52	Production Well	1	2002	40	23	Good	In 2013: ARV valve, stuffing boxes, shafts were rebuilt and installed.
	Pump & Motor^{R}	1	2013	10	4	Fair	
	Wellhead Mechanical & Piping^{N,R}	1	2013	30	24	Good	
PW- 53	Production Well	1	2002	40	23	Good	In 2013: ARV valve was rebuilt and installed. New check valve, stuffing boxes, shafts were installed in 2012.
	Pump & Motor^{R}	1	2012	10	3	Fair	
	Wellhead Mechanical & Piping^{N,R}	1	2012	30	23	Good	
PW- 54	Production Well	1	2002	40	23	Good	In 2008: New stuffing boxes, shafts installed. ARV valve was rebuilt in 2014. New check valve was installed in 2014.
	Pump & Motor^{N}	1	2019	20	20	Good	
	Wellhead Mechanical & Piping^{N,R}	1	2014^{N,R}	30	25	Good	
All	Underground Raw Water Piping, Valves, and Accessories	-	1980	30	0	Poor	

Notes:

(1) Abbreviations:
N – New
R – Rebuilt / Reconditioned
I – Inspected
OOS – Out of service

4.3.2 Electrical and Instrumentation

The CUSMP 2017 identified the required electrical and instrumentation improvements at the wells due to age of equipment, obsolete equipment, safety concerns, regulatory requirements, and out of service equipment. The CUSMP 2017 noted that the equipment in the wellhouses and electrical equipment at all wells, except PW-50 through PW-54, are original vintage equipment, and while still functioning, are approaching the end of their useful life (much of the equipment is obsolete), making it difficult to find replacement parts.

The CUSMP 2017 recommended performing an electrical system rehabilitation for all wells, except PW-50 through PW-54, including new well control houses, well pump control panel, feeder disconnect switches, low voltage transformer and circuit breaker panelboard, SCADA upgrades, and new feeder cables to the associated generator building. It also recommended the following:

- Perform short circuit device coordination and arc flash study
- Perform electrical maintenance testing
- Perform grounding/bonding system survey and testing
- Install lightning protection at West Generator and East Generator Buildings.
- Generate accurate as-built one line drawings and electrical plans of the entire wellfield
- Address the EPA emissions non- compliance of the 500 kW emergency diesel generator in the Western Generator Building by either adding a diesel oxidation catalyst to the unit or replacing the generator with an emissions compliant unit.
- Renew/rehabilitate Western Generator Building including main breaker, automatic transfer switch, motor control center, lighting transformer, circuit breaker panel board, emergency diesel generator, wiring and raceways.

Based on the site visit inspection, the electrical equipment at the wells is in fair condition and is maintained in working order. The existing motor controls utilize magnetic starters. It is recommended that these be replaced with soft starters to minimize the hydraulic surges, as well as for less load on the standby generators.

Only fourteen (14) wells at the Wellfield are connected to generator backup power. Plant Staff would like to replace existing generator with newer larger capacity generator to supply emergency power to greater number of wells.

Distribution and collection system maintenance staff have started the replacement of some instrumentation (flow meters) and feeders to the wells, but the majority of the improvements identified in the CUSMP2017 still need to be implemented. Table 4.3 presents the electrical and instrumentation renewal and replacement improvements identified in the CUSMP2017. Observations and recommendations related to the electrical and instrumentation systems are provided in Appendix 4B, under Field Notes for Electrical and Instrumentation System Inspection.

4.3.3 SCADA System

The Wellfield PWs communicates with the WTP by means of spread spectrum radio to a master radio remote telemetry unit (RTU). This RTU unit is located at the East Generator Building, which is connected to the City's fiber optic I-Net system. In addition, each production well has a local

RTU panel which is equipped with a PLC, spread spectrum radio, power supplies, relays and low voltage surge suppressors.

The following SCADA System improvements were listed in the CUSMP 2017 for the Production Wells at the Wellfield:

- Perform a study of a fiber optic network versus current radio technology, including radio surveys to identify propagation characteristics and interferences. Repeat when radios are upgraded in the future.
- The RTU, PLC and radio system are past their useful service life and the equipment is obsolete.
- Perform replacement and upgrade of existing Wellfield Master and Well RTU Panels including PLC, radios, enclosures, including power supplies, surge suppressors, control relays and all other appurtenances.
- Integrate run and fail signals from existing emergency diesel generators, and available fuel storage levels into upgraded Master RTU unit.
- Replace all uninterruptable power supplies in the wellfield every five years.
- Integrate Wellfield Fiber Optic (if recommended by the study).

Based on the site visit conducted on May 28, 2019, it appears that the recommended SCADA improvements have not been implemented for the wellfield.

Table 4.3 Prospect Wellfield – Electrical and Instrumentation Renewal and Replacement Summary

Wells Assets	Quantity	Year Purchased/ Rehabbed	Useful Life (Years)	Remaining Useful Life (Years)	Condition
Power Distribution System					
East Primary Power Distribution	-	1980	30	0	Poor
East Primary Power Distribution System Transformers	18	1980	15	0	Poor
West Primary Power Distribution	-	2009	30	20	Good
West Primary Power Distribution System Transformers	8	2009	15	5	Good
Primary Power Distribution System Maintenance	-	2007	-	-	Poor
Instrumentation					
Instrumentation and Control Hardware	-	1999	10	0	Poor
Instrumentation and Control Software and Programming	-	1999	3	0	Poor
Field Instruments	-	1999	10	0	Poor
PW Flow Meters (Mag Meters, ABB Flowmasters)	29	-	20	-	Fair
Master Flow Meter (to replace four plant meters)	1	-	20	-	Fair
Raw Water Main Flow Meters	2	-	20	-	Fair
Pressure Gauges	29	-	1	-	Fair

Table 4.3 Prospect Wellfield – Electrical and Instrumentation Renewal and Replacement Summary (continued)

Wells Assets	Quantity	Year Purchased/ Rehabbed	Useful Life (Years)	Remaining Useful Life (Years)	Condition
Emergency Power Supply					
East Emergency Generators 1 & 2	2	2009	20	10	Good
East Fuel Storage	1	1980	15	0	Poor
West Emergency Generator 1	1	2009	20	10	Good
West Fuel Storage3	1	2009	15	5	Good
Pressure Gauges	29	-	1	-	Fair
Miscellaneous					
Generator / Electrical Building Painting (East)	2	2009	7	0	Poor
Generator / Electrical Building Roofing (East)	2	2009	15	5	Good
Security Fence Replacement	-	1980	15	0	Poor

Note:

(1) Information extracted from CUSMP 2017 Table WA8-2. Prospect Wellfield 2015 Renewal and Replacement Requirement Analysis.

4.4 Fiveash Water Treatment Plant Overview

The Charles W. Fiveash WTP is located in northwest Fort Lauderdale, immediately west of I-95, between Prospect Road and NW 38th Street as shown in Section 1.1, Figure 4.1. Figure 4.6 provides the Fiveash WTP General Process Layout. The plant was originally constructed in 1950 followed by several expansions over the years. The plant has a design capacity of 70 mgd, however due to hydraulic restrictions and finished water quality issues at high flow rates (color), the effective treatment capacity is approximately 50 - 60 mgd. The plant receives raw water from the Prospect Wellfield and treats it with a conventional lime softening treatment process. The overall treatment stream consists of aeration, lime softening, recarbonation (this is a basin terminology, actual recarbonation process does not exist at the plant), filtration, disinfection, ground storage tanks and high service pumping. A high level overview of the treatment system is provided herein.

4.4.1 Process Overview

Aeration - Raw water from the Prospect Wellfield is delivered to the aeration basin which is comprised of two aeration chambers connected by slide gates. Blowers deliver air to coarse bubble diffusers located at the bottom of each chamber. As the air rises through the chamber, it facilitates removal of dissolved carbon dioxide and other volatile taste and odor-causing compounds, such as hydrogen sulfide. A small dose of chlorine is applied to the aeration basin effluent to control bacteriological growth in the downstream processes.

Lime Softening - The lime softening process uses hydrated lime to remove hardness from the raw water. Water from the aeration basin is delivered to four Hydrotreater tanks where it is slowly mixed with the lime slurry by rotating mechanisms in the tanks. Typically, only three Hydrotreaters are needed to treat the average day demands with the fourth tank serving as redundancy.

The lime slurry is generated by lime slakers and delivered to the Hydrotreaters through open troughs by gravity flow. Polymer is also added to the Hydrotreaters to aid in turbidity and color removal. Precipitated materials settle to the bottom of the hydrotreater where drain pipes remove the settled solids/lime sludge and direct it to a sludge holding tank. in addition to the sludge from the Hydrotreaters the sludge holding tank also receives sludge from the filter backwash washwater diversion structure. Sludge from the holding tank is pumped to sludge disposal lagoons located at the Prospect Wellfield.

Recarbonation - Softened water flows from the hydrotreaters to four recarbonation basins. Currently, there is no active recarbonation, but the chambers are used for chemical addition (sodium hypochlorite, ammonia, and fluoride) and mixing. Refer to the disinfection write-up below for details on the chemical addition.

Filtration - Water from the recarbonation chambers flows to twenty-two dual media gravity filters. The filters remove suspended particles not removed through settling in the Hydrotreaters. To prevent the filters from becoming clogged with solids, they are periodically backwashed to remove the accumulated solids.

Backwash water is collected by a filter waste flume and delivered by gravity to a washwater transfer pump station. Three washwater transfer pumps deliver backwash water to two washwater recovery basins, where solids are separated from the backwash water. Four decant pumps (two per recovery basin) pump recovers back water to Hydrotreaters 3 and 4. Settled solids are pumped by four sludge sumps (two per basin) to the sludge holding tank, where it is mixed with lime sludge from the lime softening process.

Clearwell and Transfer Pumps - Treated water from the filter effluent is conveyed to clearwells. There are seven (7) underground clearwells with transfer pumps. All seven clearwells are interconnected.

Disinfection – Chlorine and ammonia are added to the water stream for disinfection purposes. These are applied at the recarbonation basins to form chloramines. Chlorineand ammonia are also dosed at several locations on the transfer pump and high service pump discharge piping to provide residual disinfection. Fluoride is also dosed at the end of the recarbonation basins to provide fluoridation of the finished water.

Ground Storage and High Service Pumping - There are three ground storage tanks (GST) located at the plant. These tanks provide a total onsite storage capacity of 17 MG. GST No. 1 and No. 3 are 5 million gallons, while No. 4 is 7 million gallons.

There are a total of thirteen constant speed high service pumps (HSPs). The pumps typically operate at a pressure of 80 to 85 psi. The HSPs are split into three banks of pumps: (1) HSPs 4 and 5 are vertical turbine pumps located on the north of the site, pumps directly from Clearwell No. 1; (2) HSPs 6 through HSP 11 are located within HSP No. 2 building, these are horizontal centrifugal pumps with diesel engines and pump from a 60” header pipe connecting GSTs No. 3 and No. 4. These pumps also have the ability to pull from clearwell No. 6 and/or from the transfer pipe to the GSTs; (3) HSP 12 through 16 are vertical turbine pumps that pump directly from clearwell No. 5 and are located outside and west of HSP No. 2 Building.

[redacted]

Figure 4.3 Fiveash WTP General Process Layout

4.5 Water Treatment Plant Evaluation

As noted previously, the condition of the Fiveash WTP was assessed as part of the 2017 CUSMP. Treatment plant assets have a certain service life which refers to how long an asset will be useful. For the purpose of this evaluation, Florida Administrative Code (FAC) 25-30.140 was used to determine the service life of the plant components where available. If this information was not available in the code, industry experience was utilized. Table 4.4 identifies the expected useful life of asset/equipment at the WTP based on information provided in the FAC and Stantec's professional experience.

Table 4.4 Expected Equipment Life

Item	Useful Life (years)
Blower	15[1]
Chemical Storage and Feed	10[1]
Compressor	20[1]
Engine	20[1]
Emergency Generator	20[1]
Pump & Motor	20[1]
Pump & Motor, Small (< 5 hp)	15[1]
Concrete Structures	32[1]
Deep Injection Well	30[1]
Electrical Systems	20[1]
Instrumentation	10[1]
Hardware (Control)	6[1]
HVAC Systems	15
Piping, Valves and Accessories (> 8")	37[1]
Variable Frequency Drive	10
Roofing	15-25
Well Pump & Motor	15[1]
Well Replacement	20[1]
Sluice Gates	25[1]
Filter Media	10
Filter Under Drain	15-20
Hydrotreator Rake and Drive Unit	15
Mixer	20
Lime Storage system	20
Lime Slakers	10
Vacuum Priming System	10
Electrical Transformers	20[1]

Note:
(1) FAC 25-30.140

4.5.1 Elevation Review of Existing Structures

Considering the WTP was constructed in 1950s, many of the buildings may or may not meet the recently updated Broward County 100-year flood elevation. Therefore, a review of finished floor elevation of the existing buildings was performed based on information provided by the City staff and from ASCE, FEMA and Broward County 100 year flood elevation data. ASCE 24 classifies all structures for flood-resistant design and construction. Based on defined class, the structure needs to be elevated to or above Base Flood Elevation (BFE). BFE was estimated based on location of structures using Broward County 100-Year Flood Elevation and FEMA Base Flood Elevation. Finished Floor Elevation (FFE) of existing structures was compared with the calculated minimum FFE per ASCE 24 to determine if these elevations meet the current 100-year flood elevation requirement. Based on the FEMA Base Flood Elevation, the Broward County 100 Year Flood Elevation, as well as ASCE 24 for essential facilities, depending on location of structure within the site, FFE should be at least 9 – 10 ft NAVD 88. As shown in Table 4.5, the existing FFE of six structures is below the 9 feet elevation. These structures include fuel filling station, air conditioning cooling towers, public service admin building, mechanics shop, ground storage tank no. 1, and office trailers, most of these structures are outside of the plant fence line with the exception of mechanics shop and ground storage tank 1. These structures are not critical to keep the WTP operational therefore no action is necessary.

The following section summarizes the CUSMP 2017 and subsequent findings by process areas (1. Mechanical, civil, structural 2. Electrical and 3. SCADA).

4.5.2 Aeration

The CUSMP 2017 was reviewed in the context of the proposed improvements for the aeration basin. These improvements are summarized below:

- Turbo blowers and fine bubble diffuser system were recommended to be installed in order to replace aging equipment and to improve energy costs. Two alternatives were suggested for replacement options. The diffuser rod system was recommended to be replaced with rubber to limit the potential clogging. This would provide higher oxygen transfer efficiency, sulfide removal, and meet “Green Initiative” goals of the City.
- The Aeration chambers of the aeration basins cannot be isolated due to the existing configuration and corrosion of the gates which makes them non-operational. Slide gates and the motorized operators are recommended for replacement. This would allow a better flow split, automated control of the system and help operators to be able to isolate each chamber for maintenance, on an as needed basis. Additionally, valves on the raw water line, drain line and on adjacent chamber to Hydrotreators 3 and 4 are recommended for replacement.

Stantec evaluated the CUSMP recommendations for aeration basins. Table 4.6 below shows the existing condition and useful life for the aeration basin assets. Based on the site visit performed on May 28, 2019, the following is the summary of staff input, findings, and recommendations:

- The aeration basin is in poor structural condition. Staff reported the basin to be leaking through several cracks. Staff has also reported that there is no means to isolate and bypass the aeration basin in order to perform repairs within the basin, additionally there is no provision to keep one of its chambers operational if work was contemplated to be performed in the other chamber.
- Actuators on the effluent end are suggested to be motorized with the ability for remote operation by the staff.

Table 4.5 Finished Floor Elevation of Existing Structures at Fiveash WTP

Mark	Structure Name	Existing or Proposed	Occupied or Unoccupied	Finished Floor Elevation (NGVD 29)	Finished Floor Elevation (NAVD 88)	Flood Zone	FEMA Base Flood Elevation (NAVD 88)	BC 100-YR Flood Elev. (NAVD 88)	Flood Design Class Per (ASCE 24 – Table 1-3)	Min. Floor Elev. Per (ASCE 24 – Table 4-3) (NAVD 88)	FFE ≥ Min.
1	FUEL FILLING STATION	EXISTING	UNOCCUPIED	8.50	7.00	AH	8.00	6.50	CLASS 1	8.00	NO
2	AIR CONDITIONER COOLING TOWERS	EXISTING	UNOCCUPIED	7.60	6.10	AH	8.00	6.50	CLASS 1	8.00	NO
3	PUBLIC SERVICES ADMIN BUILDING	EXISTING	OCCUPIED	9.46	7.96	AH	8.00	6.50	CLASS 2	9.00	NO
4	GROUND STORAGE TANK No. 4	EXISTING	UNOCCUPIED	10.50	9.00	X	-	6.50	CLASS 4	8.50	YES
5	GROUND STORAGE TANK No. 3	EXISTING	UNOCCUPIED	10.50	9.00	X	-	6.50	CLASS 4	8.50	YES
6	AQUEOUS AMMONIA BUILDING	EXISTING	UNOCCUPIED	10.50	9.00	AH	8.00	6.50	CLASS 3	9.00	YES
7	HIGH SERVICE PUMP STATION & DIESEL GENERATORS	EXISTING	UNOCCUPIED	14.25	12.75	AH	8.00	6.50	CLASS 4	10.00	YES
8	WASHWATER RECOVER BASIN AND OPERATING DECK	EXISTING	UNOCCUPIED	15.50	14.00	AH	8.00	6.50	CLASS 2	9.00	YES
9	MECHANICS SHOP	EXISTING	OCCUPIED	9.50	8.00	AH	8.00	6.50	CLASS 3	9.00	NO
10	OPERATIONS BUILDING	EXISTING	OCCUPIED	14.25	12.75	AH	8.00	6.50	CLASS 3	9.00	YES
11	TRANSFER PUMP 1 AND 2	EXISTING	UNOCCUPIED	14.00	12.50	AH	8.00	6.50	CLSSS 3	9.00	YES
12	HYDROTREATEOR No. 4	EXISTING	UNOCCUPIED	31.60	30.10	AH	8.00	6.50	CLASS 3	9.00	YES
13	HYDROTREATEOR No. 3	EXISTING	UNOCCUPIED	31.60	30.10	AH	8.00	6.50	CLASS 3	9.00	YES
14	FILTER BUILDING No. 2	EXISTING	UNOCCUPIED	14.50	13.00	AH	8.00	6.50	CLASS 3	9.00	YES
15	RECARBONATION BASIN No. 3 & 4	EXISTING	UNOCCUPIED	28.17	26.67	AH	8.00	6.50	CLASS 3	9.00	YES
16	FPL BUILDING	EXISTING	UNOCCUPIED	12.50	11.00	AH	8.00	6.50	CLSSS 3	9.00	YES
17	FILTER BUILDING No. 1	EXISTING	OCCUPIED	14.50	13.00	AH	8.00	6.50	CLASS 3	9.00	YES
18	CHEMICAL BUILDING	EXISTING	OCCUPIED	11.00	9.50	AH	8.00	6.50	CLASS 3	9.00	YES
19	HYDROTREATOR No. 2	EXISTING	UNOCCUPIED	28.00	26.50	AH	8.00	6.50	CLASS 3	9.00	YES
20	HYDROTREATOR No. 1	EXISTING	UNOCCUPIED	28.00	26.50	AH	8.00	6.50	CLASS 3	9.00	YES
21	AERATION BASIN No. 1 & 2	EXISTING	UNOCCUPIED	34.00	32.50	AH	8.00	6.50	CLASS 3	9.00	YES
22	SLUDGE PUMP STATION	EXISTING	UNOCCUPIED	12.50	11.00	AH	8.00	6.50	CLASS 4	10.00	YES
23	GROUND STORAGE TANK No. 1	EXISTING	UNOCCUPIED	9.50	8.00	AH	8.00	6.50	CLASS 4	10.00	NO
24	WASHWATER TRANSFER PUMP STATION	EXISTING	UNOCCUPIED	12.75	11.25	AH	8.00	6.50	CLASS 1	9.00	YES
25	RECARB BASIN No. 1 & 2	EXISTING									
26	LIME STORAGE SILO	EXISTING									
27	OFFICE TRAILERS	EXISTING									
28	HYPOCHLORITE FACILITY	PROPOSED									
29	GENERATOR BUILDING	PROPOSED									
30	DIESEL EXHAUST FLUID BUILDING	PROPOSED									
31	$C0_2$ BULK STORAGE TANKS	PROPOSED									

Table 4.6 Existing Condition – Aeration Basin

Process Area	Quantity	Year Purchased/ Rehabbed	Useful Life (Years)	Remaining Useful Life (Years)	Condition (Good, Fair, Poor)
Aeration Basin - Blowers	2	1998	15	0	Poor
Sluice Gates for Aeration Basins 1 & 2	14	1963	25	0	Poor
Air Compressor 1	1	2018	20	19	Good
Air Compressor 2	1	2019	20	20	Good
Diesel Engine Air Compressors 1, 2, & 3	3	1993/1999	20	0	Poor

Several improvements have been recently completed or are planned to be completed, these include following:

- Replaced diffuser pipes in aeration basin with the use of divers while the tank was in service
- Air compressor 5 (new designation air compressor 1) was replaced in December 2018. and Air compressor 6 (new designation air compressor 1) was replaced in May 2019. Air lines are scheduled to be replaced under disinfection and reliability upgrade project and
- Sluice gates are planned to be replaced by the plant staff.

Plant staff has performed some repairs on the diesel engine air start system, but the system is near the end of its useful life and should be replaced.

The evaluation indicates that aeration equipment and basins are in poor condition. The blower and diffuser equipment are outdated, gates need replacement, and the basin is leaking through several cracks. There are operational and maintenance issues with this process area where equal flow split and isolation of chambers is a challenge, automation is not available for isolation and subsequent maintenance, and there is no bypass ability to perform repairs of the structure. Although some rehabilitation work has been completed and planned, this system requires major improvements.

4.5.3 Lime Softening and Sludge Management System

The CUSMP 2017 was reviewed in the context of the proposed improvements for Lime softening and Sludge Management System. These noted improvements are summarized below.

- The existing four lime slakers were reported by the staff to be in poor condition. The system cannot accurately dose lime due to lack of automation which affects the finished water quality. Additionally, each slaker is connected to a dedicated treatment unit, thus causing a failure of entire individual treatment train when a unit is out of service.
- Replacement of the lime delivery system is expected to improve operational flexibility and water quality. Replacement with a central mixing and storage tank using automated metering pumps was suggested to achieve consistency in water quality. The new lime feed system was proposed to be constructed in the area currently occupied by the fluoride storage and transfer pumps.

- Sludge Pumps for Washwater Recovery Basins 1 & 2 are in fair condition. The sludge Line from WTP to Prospect Wellfield is in poor condition.

Stantec performed an evaluation of the CUSMP recommendations for the lime softening equipment and sludge management system. Table 4.7 shows the existing condition and useful life of the lime softening system. Table 4.8 shows the existing condition and useful life of the lime sludge management system. Based on the site visit performed on May 28, 2019, the following is a summary of staff input, findings and recommendations:

- Plant staff is in process of replacing hydraulic system with electric motors for the rake and drive units at the hydrotreaters. Work on No. 1 and No. 4 is complete, No. 2 is out for bid and No. 3 is planned to be replaced soon. Hydrotreater washdown booster pumps and motors were replaced in 2018 by the plant maintenance staff.
- Staff indicated the need for all slakers to be of same capacity, which would make operation of these units simpler and consistent. Staff reported that there is only one 12" sludge line onsite & offsite clogs frequently. This line was recently accidentally damaged by a truck approximately 2 miles away from the plant. Therefore, a redundant sludge line should be considered.
- The lime system automation was improved with the upgrade /replacements of new AB CompactLogix PLCs, AB Panelviews (touchscreens). The new PLCs are connected to the SCADA system.
- Some of the existing lime system components are problematic (malfunctioning) providing inaccurate data to new PLCS.

The lime system is in poor condition except for pumps and motors. The system has poor interconnectivity which leads to failure of the entire train in case an equipment fails. A new lime feed system was proposed which is supported if City chooses to continue investing in the Fiveash WTP. Additionally, there is only one sludge transfer line between the WTP and wellfield, a redundant line is recommended.

Table 4.7 Existing Condition – Lime Softening and Hydrotreater

Process Area	Quantity	Year Purchased/ Rehabbed	Useful Life (Years)	Remaining Useful Life (Years)	Condition (Good, Fair, Poor)
Lime Softening Blower and Diffusers (75 hp)	2	2000	15	0	Poor
Lime Blower Motor (480 V)	2	2010	20	11	Good
Lime Slakers 1, 2, 3, &4	4	2007	10	0	Poor
Lime Storage System	1	1960	20	0	Poor
Hydro Washdown Booster Pump (19 hp)	1	2018	20	19	Good
Hydro Booster Pump Motor (480 V)	1	2018	20	19	Good
Hydro Recirculation Motor 1, 2 (480 V)	2	Pre-1990	20	0	Poor
Hydro Recirculation Motor 3, 4 (480 V)	2	Pre-1991	20	0	Poor
Hydro Recirculation Pumps 1, 2 (7.5 hp)	2	Pre-1992	20	0	Poor
Hydro Recirculation Pumps 3, 4 (15 hp)	2	Pre-1993	20	0	Poor
Hydrotreater 1 - Rake and Drive Unit	1	2015	15	11	Good
Hydrotreater 2 - Rake and Drive Unit	1	1954	15	0	Poor
Hydrotreater 3 - Rake and Drive Unit	1	2010	15	6	Good
Hydrotreater 4 - Rake and Drive Unit	1	2007	15	3	Fair
Sluice Gates for Hydrotreaters 1&2 (Effluent)	2	1959	25	0	Poor

Table 4.8 Existing Condition – Lime Sludge Management

Process Area	Quantity	Year Purchased/ Rehabbed	Useful Life (Years)	Remaining Useful Life (Years)	Condition (Good, Fair, Poor)
Sludge Line to Prospect Wellfield	1	Pre 1980	37	0	Poor
Sludge Holding Tank Mixer	1	2006	20	7	Good
Sludge Lagoon Motors 7201, 7202, 7203	3	2006	20	7	Good
Sludge Pump 7201, 7202 & 7203	3	2006	20	7	Good
Sludge Pumps for Washwater Recovery Basins 1 & 2	4	2006	15	2	Fair

4.5.4 Chemical Treatment (Chlorination, Chloramination and Fluoridation)

The CUSMP 2017 was reviewed in the context of the proposed improvements for the chemical treatment process. These noted improvements from CUSMP 2017 are summarized below.

- The recarbonation basin sluice gates are approaching the end of its useful life and were recommended to be replaced. Fluoride system storage and delivery equipment is approaching the end of useful life. Construction of new fluoride system was programmed in the CIP at a nearby location from the existing Fluoride System.
- Chlorine injector motor to be replaced with high efficiency motors to reduce the energy costs at the WTP. Chlorine injector pumps were listed to be upgraded under the recently solicited Disinfection and Reliability Upgrades project.

Stantec performed validation of the CUSMP recommendations for the chemical system equipment. Table 4.9 below shows the existing condition and useful life of the chemical system. Based on the site visit performed on May 28, 2019, the following is a summary of staff input, findings and recommendations:

- Plant staff indicated that some maintenance work was performed on the chlorine injector motors. Fluoride bulk tank is leaking and needs to be replaced. Fluoride transfer system which transfers from bulk tank to day tank needs to be replaced. Based on staff input, it is difficult to find spare parts for the polymer control system, and control boards since these parts are no longer available. The staff has also reported that two new, higher capacity Polymer Pumps have been installed but the operation is not as desired. Plant staff is working on a solution.
- Flow meters need to be replaced for flow pacing.
- Flow meters on Hydrotreators 3 & 4 were replaced in mid-2018. Flow meters for Hydrotreators 1&2 have been purchased and are to be installed.

Based on the age of the aqueous ammonia system, fluoride system and recarbonation basin sluice gates, they are recommended to be replaced.

Table 4.9 Existing Condition – Chemical Treatment

Process Area	Quantity	Year Purchased/ Rehabbed	Useful Life Years	Remaining Useful Life (Years)	Condition (Good, Fair, Poor)
Coagulant Polymer System	1	2006	10	0	Poor
Aqueous Ammonia System	1	2005	10	0	Poor
Fluoride System	1	1980	10	0	Poor
Basin 1&2 Sluice Gates	1	1959	25	0	Poor
Basin 3 Sluice Gate	4	1963	25	0	Poor
Basin 4 Sluice Gate	3	1981	25	0	Poor
Chlorine Injector Pump 1, 2, 3 & 4	4	1980	20	0	Poor

4.5.5 Filtration

The CUSMP 2017 was reviewed in the context of the proposed improvements for the Filtration System. These noted improvements from CUSMP 2017 are summarized below.

- Replacement of backwash pumps 1 and 2 and surface wash Pumps 1 and 2 with high efficiency motors in order to reduce the energy costs at the WTP.
- Addition of local control switches to valve actuators for filters that are difficult to access, there are 44 such valves.

Table 4.10 shows the existing condition and useful life of the filtration system.

Table 4.10 Existing Condition – Filtration System

Process Area	Quantity	Year Purchased/ Rehabbed	Useful Life Years	Remaining Useful Life (Years)	Condition (Good, Fair, Poor)
Filters 5, 10, 15, 16, 17, 18 - Valves, Valve Operators, and Filter Underdrain	6	2007	15-20	5.5	Good
Filters 6, 7, 8, 11, 13 - Valves, Valve Operators, and Filter Underdrain	5	2008	15-20	6.5	Good
Filters 1, 2, 3, 4, 9, 14, 20, 21, 22 - Valves, Valve Operators, and Filter Underdrain	9	2010	15-20	8.5	Good
Filters 12, 19 - Valves, Valve Operators, and Filter Underdrain	2	2000	15-20	0	Poor
Filters 10, 11, 12, 13 - Filter Media	4	2010	10	1	Fair
Filters 6, 7, 8, 9, 14, 15 - Filter Media	6	2015	10	6	Good
Filters 5, 15, 16, 17, 18, 19 - Filter Media	6	1990	10	0	Poor
Filters 1, 2, 3, 4, 9, 14, 20, 21, 22 - Filter Media	9	2010	10	1	Poor
Backwash Pumps 2, 3	1	1980	20	0	Poor
Washwater Transfer PCCP	-	Varies	50	N/A	Unknown
Washwater Recovery Basin Influent Valves	2	2006	30	17	Good
Washwater Transfer Combination Submersible Pumps 1, 2 & 3 (74 hp)	3	2005	20	6	Good
Decant Pumps for Washwater Recovery Basins 1	2	1985	10	0	Poor
Decant Pumps for Washwater Recovery Basins 2	2	2015	10	6	Good

Based on the site visit performed on May 28, 2019, the following is a summary of staff input, findings, and recommendations:

- Plant staff indicated that Surface Wash Pumps 1 and 2 were recently replaced. Local control switches/buttons to local PLC panels for backwash supply pumps and surface wash pumps will be replaced under the reliability upgrade project which is under solicitation.
- Plant staff indicated that the filter automation program for control sequencing has issues with backwash/surface wash sequence. This issue results in loss of filter media and requires frequent media replacement. Plant Manager and chief Operator are working on a solution that will be implemented within the existing automation controls.

Based on staff input, actuators and pipes in the filters are in poor condition and are recommended to be replaced.
- Based on staff input A remote control station is needed since the Surface Wash valves are at an elevation that requires a ladder to access.
- Based on staff input, washwater transfer pipe is located in the basement of the building. There is no way to remove this pipe without removing the building. This pipe should be replaced to make it more accessible.
- Based on the staff input there is a project to replace media in filters 5, 15, 16, 17, 18 & 19.

The plant has structural elements that have exceeded their service life. Structures often exceed their service life and remain structurally adequate for the required loading conditions and durability particularly with proper maintenance. Without a more detailed examination, with tanks empty and a combination of visual examination and testing on the interior as well as the exterior, the appropriate remaining service life is cannot be determined. Based on the preliminary site visit conducted on May 28, 2019 and staff input, it is evident that several structures have had extensive leaking along with failed attempts at leak repairs. A more detailed structural evaluation would help determine whether appropriate repairs could be implemented to extend the remaining service life or whether the existing conditions have deteriorated to a condition that requires extensive and costly rehabilitation of the structures. A specific example is the persistent leaks. Extensive persistent leaks, not properly repaired, could cause reinforcing section loss and eventual structural failure. Generally, reinforcing section loss will be evident by spalls and concrete delamination

Overall the filtration process and equipment seem to be in fair to poor condition. Several valves, actuators and filter media needs replacement. The structures have exceeded the useful life and have reported by staff to have extensive leaks. A more detailed structural evaluation is recommended to determine the remaining useful life. Overall evaluation of filtration system shows a significant rehabilitation need.

4.5.6 Clearwell and Transfer Pumps

The CUSMP 2017 was reviewed in the context of the proposed improvements for Clearwell and Transfer Pumps. These improvements are summarized below:

- Direct withdrawal from the clearwells by high service pumps should be removed to prevent short – circuiting and to control finished water quality. In such case the high service pumps would only pull water from the GSTs.
- Replacement of the control valve and motors for the transfer pumps.
- Replacement of motors constructed pre-1997 with high efficiency motors to reduce pumping energy costs.

Stantec performed an evaluation of the CUSMP recommendations for the clearwell and transfer pumps. Table 4.11 shows the existing condition and useful life of the clearwell and transfer pumps.

Table 4.11 Existing Condition – Clearwells and Transfer Pumps

Process Area	Quantity	Year Purchased/ Rehabbed	Useful Life (Years)	Remaining Useful Life (Years)	Condition (Good, Fair, Poor)
Clearwells 1-7	7	1954/1974/1980	50	0/5/11	Poor/Fair/Good
Clearwell 1 - Strikedown Valves	2	2006	30	17	Good
Clearwell 7 - Strikedown and Shutoff Valves	4	2006	30	17	Good
Clearwell Interconnect Valve		2006	30	17	Good
Sluice Gates for Clearwell 7	8	1983	25	0	Poor
Sluice Gates for Clearwell No. 1	1	1960	25	0	Poor
Hydraulic Operated Valve in Transfer Pump Header2,6	1	1983	30	0	Poor
Transfer Pumps 1 & 2	2	1983	20	0	Poor
Transfer Pumps 3 & 6	2	1991	20	0	Poor
Vacuum Priming System 1 &2	1	1986	10	0	Poor

Based on the site visit performed on May 28, 2019, the following is a summary of staff input, findings and recommendations:

- Visual assessment for Clearwells 1 through 7 for structural observation was limited due to insufficient exposure. The 1954 clearwell(s) are past their service life and the 1974 clearwell(s) are near the end of their service life. Interior inspections could not be performed. Environmental concrete structures complying with ACI 350 are designed for a service life of 50 to 60 years, but a more detailed structural assessment can determine the remaining useful life since many concrete tanks can exceed their useful service life, especially when properly maintained.
- The interconnectivity between clearwells, transfer pumps and storage tanks is complicated. There is a need to keep one transfer pump always running to make sure water is circulating to maintain chlorine residual within the clearwell system. Transfer pumps are constant speed pumps which are recommended to be upgraded to variable frequency drives (VFDs).
- Improvements for Transfer pump 6 are underway by the plant staff.

Overall the clearwells and transfer pumps are in poor condition with exception of valves which were replaced by the staff. The equipment is old and antiquated. The interconnectivity between clearwells, transfer pumps and storage tanks is complicated and poses challenge with water age. The clearwell structures have approached their predicted useful life based on the year of installation, a more detailed structural evaluation is recommended to determine the remaining useful life.

4.5.7 Ground Storage Tanks

The CUSMP 2017 was reviewed in the context of the proposed improvements for GSTs. They are summarized below:

- Tank 1 was constructed in 1958 and has exceeded it predicted useful life significantly. The recommended modification requires the GST No.1 to include minimum one baffle wall and a new outlet pipe that would connect to the HSP suction header with the other two (2) storage tanks. By performing these improvements along with piping improvements between clearwell and high service pumps, the plant will see stable disinfection residuals and prevent short-circuiting of water.
- The piping and hydraulic arrangement between the transfer pumps, three GSTs and the high service pumps is very complicated, inefficient and impacts finished water quality resulting from short circuiting and increased water age in tanks.

Table 4.12 shows the existing condition and useful life of the storage tanks.

Table 4.12 Existing Condition – Ground Storage Tanks

Process Area	Quantity	Year Purchased/ Rehabbed	Useful Life (Years)	Remaining Useful Life (Years)	Condition (Good, Fair, Poor)
Ground Storage Tank 1 (5 MG)	1	1958	50	0	Poor
Ground Storage Tank 3 (5 MG)	1	1980	50	11	Good
Ground Storage Tank 4 (7 MG)	1	2000	50	31	Good

Stantec performed an evaluation of the CUSMP recommendations for the storage tanks. Following are the observations and recommendations for the onsite storage tanks from the May 28, 2019 site visit:

- GST 1 (5 MG) – Storage Tank 1 is at or near its useful service life. A detailed visual assessment must occur within the interior of the tank along with possible additional testing to determine the estimated remaining service life. Many structures can exceed their useful service life with proper maintenance.
- GST 3 (5 MG) – Storage Tank 3 will be approaching its useful service life. A detailed visual assessment must occur on the interior and exterior of the tank to determine the estimated remaining service life.

GST 1 and 3 are near its predicted useful life. A more detailed structural evaluation is recommended to determine the remaining useful life of GST 1 and GST 3.

4.5.8 High Service Pumps

The CUSMP 2017 was reviewed in the context of the proposed improvements at the high service pumps. They are summarized below:

Direct withdrawal from transfer line is recommended to be removed to prevent short circuiting and eliminate the high service pumps pulling treated water directly from the clearwells. This modification would allow the HSPs to pull solely from the GSTs. Additionally, VFDs for two of the pumps are recommended for better control over finished water flows. HSPs 4, 5, 9, 10, 11 have standard efficiency motors. These should be retrofitted with premium efficiency motors.

Stantec performed an evaluation of the CUSMP recommendations for the HSPs. Table 4.13 below shows the existing condition and useful life of the HSPs. Based on the site visit performed on May 28, 2019, the following is a summary of staff input, findings, and recommendations:

- All pumps are old and have surpassed useful life, these pumps are recommended to be replaced where some of these should be upgraded to VFDs while the rest should be replaced.
- Control panels for HSPs 9, 10, & 11 are planned to be upgraded as part of the reliability upgrade project.

Overall high service pumps and relevant equipment should be upgraded according to the needs to maintain the plant operations efficiently. Majority of the High Service pumps are in fair to poor condition except for few pumps. Shutoff Valves on Finished Water Yard piping and Transfer Piping are in immediate need for replacement as they are beyond the predicted useful life. Although some of the high service motors were listed as in Good condition in Table 4.1 converting these motors to VFDs is recommended.

Table 4.13 Existing Condition – High Service Pumps

Process Area	Quantity	Year Purchased/ Rehabbed	Useful Life (Years)	Remaining Useful Life (Years)	Condition (Good, Fair, Poor)
High Service Motors 4, 5 (4160 V)	2	2006	20	7	Good
High Service Motors 9, 10 (4160 V)	2	2010	20	11	Good
High Service Motor 11 (4160 V)	1	2015	20	16	Good
High Service Motors 12, 13, 14, 15, 16 (4160 V)	5	1987	20	0	Poor
North High Service Pump Header	1	1963	30	0	Poor
Southeast High Service Pump Header	1	1982	30	0	Poor
South High Service Pump Header	1	1991	30	2	Fair
High Service Pumps 12, 13, 14, 15 & 16 (350 hp)	5	2005	20	6	Good
High Service Pumps 4 (350 hp)	1	2005	20	6	Good
High Service Pumps 5 (350 hp)	1	2010	20	11	Good
High Service Pumps 6, 7, & 8 (Diesel Drive only)	3	1983	20	0	Poor
High Service Pumps 9, 10, & 11 (Diesel/Electric Drive) 600hp	3	2005	20	6	Good
Shutoff Valves on Finished Water Yard Piping	23	1980	30	0	Poor
Shutoff Valves on Transfer Piping	3	1983	30	0	Poor

4.5.9 Electrical System

The CUSMP 2017 was reviewed in the context of the proposed improvements of the electrical system. They are summarized below:

- The power distribution system was expanded over the years without regard to redundancy or reliability where a failure of one breaker/cable could result in loss of the entire treatment process capability. The last short circuit and device coordination study was performed in 2005, this is now outdated. Additionally the study was missing an Arc Flash component which is a requirement by NFPA 70 (NEC), OSHA and NFPA 70E electrical safety codes. This is a serious deficiency and it is recommended that this be addressed as soon as possible. There could be a catastrophic failure of the aged equipment leading to loss of treatment capacity, fire, or personnel injury due to the condition of the electrical system.
- Replace transformers XFMR5501, XFMR 5502, XFMR 5612, and XFMR5603. Replace MCC_5504, MCC_5503, MCC 5301, MCC 5203, MCC 5311 (incorporate 5313), and MCC 5614. Replace MCC 5202, and MCC 5201 Medium voltage starters for high service pumps 9-16 and feeder breakers for step down transformers for MCC 5504 and MCC 5503 . Remove Panel PNL_5602 (Panel LPHS-3) from MCC_5202 and replace with a new panel and step-down transformer to replace associated XFMR5601. Replace general circuit breaker, panelboards (PNL_5631 – 5634, 5617, 5611, 5604, 5604A, 5604B, 5605).
- Replace aqua ammonia building power system. Convert motors from the 240V system to 480V, replace associated starters and re-feed from the 480V system. Add medium voltage variable frequency drives to two high service pumps for distribution pressure control.

Stantec performed an evaluation of the CUSMP recommendations for the electrical system. Various improvements have been completed by plant staff and additional ones are ongoing on the plant's electrical system. The electrical system is generally in poor condition based on the review, discussions, site A large portion of the electrical infrastructure is very old (40 to 60 years). The 240V system conductors and equipment are mostly original installations in 1950s with subsequent upgrade in 1970s. The 480V system was installed in late 1970s and early 1980s, this system is at the end of its useful life. Due to the age of the system it is hard to obtain replacement parts for maintenance.

4.5.10 SCADA System

The CUSMP 2017 was reviewed in the context of the proposed improvements of the plant SCADA system. They are summarized below:

- The existing SCADA system for process portion consists of ABB 800 series and Square D quantum PLCs connected by Ethernet network. The HMI consists of networked desktop computers and servers connected using Ethernet. CITECT HMI software version 7.40 is used for HMI and CITECT Historian version 4.50 is used for backups. Plant staff is satisfied with CITECT software and would like to continue to maintain and standardize on this platform.
- High service pumps, backwash and surface wash pumps, gravity filters utilize SCADA. While HSPs 4& 5 are controlled from their individual PLCsother HSPs do not have OITs. Backwash and surface wash pumps communicate with their process controller via ABB

800C PLCs over Ethernet communications protocol. Gravity filters also have remote I/O panels that communicate to the associated PLC based process controllers.

- Install firewall/network intrusion detection system such as Cisco ASA 5512 Adaptive Security Appliance or Checkpoint. Replace existing rack-mounted Cisco catalyst 4006 series Ethernet switches, with new Campus LAN Cisco Ethernet switches.
- Upgrade Field Mounted Hirschman Ethernet Switches to latest models. Automate third party application patching with patch management software, such as Shavlik or Dameware Patch Manager. Upgrade CITECT SCADA to latest version and reporting software. Replace and upgrade existing SCADA workstations and servers.
- Modify the control system for filters 1-22 to implement PLC based process controllers with local touch screen and basic manual controls; replace all existing filter Rotork control valve actuators with Limitorque valve actuators with discrete and analog signals; replace all filter magnetic flow meters with units communicating over traditional 4-20ma analog signals.
- Upgrade Process Control PLCs and Remote I/O's to latest products by Rockwell Automation. Modify control system for filters 1-22 to implement PLC based controllers with local touch and basic manual controls.
- CUSMP 2017 also identifies SCADA improvements to be performed under disinfection and reliability upgrades project which is currently under solicitation for construction. These improvements mainly include improvements in the primary and secondary control room, new process controllers and PLC panels for various process areas, and SCADA modifications for offsite storage monitoring and pressure monitoring in system.

The City Staff has been performing most of the improvements identified in the CUSMP 2017. Items remaining to be addressed are following:

- Upgrade Process Control PLCs and Remote I/O's to latest products by Rockwell Automation. This upgrade is in progress by plant staff.
- Modify control system for filters 1-22 to implement PLC based controllers with local touch and basic manual controls.
- ABB 800 series are being replaced 40% of the installation has been completed. Only 6 more is pending for replacement.
- The existing rack mounted Cisco Catalyst 4006 series Ethernet switches will be replaced before the end of 2019 with new Campus LAN Cisco Ethernet switches.

The SCADA system is in fair condition based on the discussions and evaluations conducted on May 28, 2019. It is noted that more than 50% of the equipment is exposed to humidity, heat, and a corrosive atmosphere which also causes the equipment to deteriorate at a faster pace.

4.6 Conclusion

Based on the general assessment and evaluation of the recommendations of the CUSMP 2017, Stantec concurs with the CUSMP assessment of the facilities at Prospect wellfield and Fiveash WTP. The majority of the wells along with the well equipment are at the end of their useful life. In addition the existing primary and backup electrical system at the wellfield is old and vulnerable to future failure. Regarding the WTP, the overall majority of the processes at the Fiveash WTP have reached or exceeded their useful life. Mechanical items such as the lime softening system utilize old and antiquated technology and equipment, and the structures such as aeration basin and filters are in poor condition. The electrical power system has exceeded its projected service life and has equipment that is mostly out of date and in need of replacement.

The Fiveash WTP not only has equipment that is old, antiquated, and at the end of its useful life, but also has several major operational and maintenance issues where quantification in terms of correction is difficult to assess. Examples of such issues include following:

- Leaking aeration tank and its unknown structural integrity,
- Single point of failure due to inability to isolate portion of aeration tank for inspection,
- Single point of failure by not having inter-connectivity in the clearwell and transfer pump system,
- Insufficient redundancy,
- Lack of access for maintenance of critical pipes under existing building.
- Lack of access to parts and spares for replacement or maintenance due to outdated equipment

Majority of the electrical equipment is not conditioned from humidity, heat, and corrosive atmosphere.

Appendix B

TASK 2 – ESTABLISHMENT OF PROJECT GOALS

CITY OF FORT LAUDERDALE

City of Fort Lauderdale
Granular Activated Carbon Pilot and Plant Evaluation at the Fiveash Water Plant

Technical Memorandum 1
TASK 2 - ESTABLISHMENT OF PROJECT GOALS

FINAL REDACTED | December 2019

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CERTIFICATE OF AUTHORIZATION NO. 8571

CITY OF FORT LAUDERDALE

City of Fort Lauderdale
Granular Activated Carbon Pilot and Plant Evaluation at the Fiveash Water Plant

Technical Memorandum 1
TASK 2 - ESTABLISHMENT OF PROJECT GOALS

FINAL REDACTED | December 2019

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TASK 2 - ESTABLISHMENT OF PROJECT GOALS

1.1 Background

The City of Fort Lauderdale Fiveash Water Treatment Plant (WTP) is the City's largest WTP, supplying approximately three quarters of all of the potable water provided to the City's service area. This facility was initially built in 1954 and has been expanded over the years multiple times to its current rated capacity of 70 million gallons per day (mgd). Current treatment capabilities of the facility are limited to an estimated 60 mgd.

Many of the treatment processes at the facility operate below optimum conditions due to several factors, including equipment being at or beyond it normal useful life expectancy, and antiquated equipment technology. The facility reliably provides potable water meeting applicable water quality standards in terms of primary requirements, but struggles to meet secondary goal of color. These treated water quality challenges result in aesthetics goals not being met on a regular basis, resulting in consumer concerns.

The objective of this project is to develop a plan which will provide a roadmap for the Fiveash facility to be upgraded to the level where a high quality potable water can be reliably produced for 30 - 50 years.

1.2 Potable Water Production Capacity

It was established by City staff that the potable water production capacity for the rehabilitated or replacement facility shall be 50 mgd as a maximum daily demand. It was noted that the provisions for expanding the capacity of the facility shall be incorporated into the design.

1.3 Finished Water Goals

The finished water goals identified in Table 1 from the 2017 Comprehensive Utility Strategic Master Plan (CUSMP) were evaluated and deliberated at the Project Kick-off meeting. It was agreed that the project finished water quality goals would remain as noted in the CUSMP, with the following adjustments:

- Iron $\leq$ 0.1 mg/l
- Manganese $\leq$ 0.02 mg/l
- Alkalinity - 40 to 110 mg/l
- Total Hardness - 80 to 160 mg/l
- Free Ammonia - 0.05 to 0.10 mg/l
- Color - 5 to 12 Color Units, with a preference to be near 5 (5 color units is undetectable by the human eye)

Table 1.1 WTP Effluent Quality from 2017 Comprehensive Utility Strategic Master Plan

Parameter	Units	Goal	Fiveash Effluent Water Quality (2014)	Primary Drinking Water Standards	Secondary Drinking Water Standards
Total Hardness	mg/L as $CaCO_3$	50-120	77.3	NS	NS
Sodium	mg/L	<50	36.5	160	NS
Total Dissolved Solids (TDS)	mg/L	<500	<500	NS	500
Iron	mg/L	<0.3	0.02	NS	0.3
Manganese	mg/L	<0.05	ND	NS	0.05
Fluoride	mg/L	<0.7	0.58	4.0	2.0
Sulfate	mg/L	<200	ND	NS	250
Chloride	mg/L	<100	66.5	NS	250
Color	Pt-Co	<8	15.2	NS	15
Turbidity	NTU	<1	0.16	NS	NS
Alkalinity	mg/L as $CaCO_3$	>40	60.7	NS	NS
H2S	mg/L	<0.1	<0.1	NS	NS
pH	Units	8.0-8.5	9.19	NS	6.5-8.5
TTHM	mg/L	<0.06	0.064	0.08	NS
HAA_5	mg/L	<0.04	0.0318	0.06	NS
Free Ammonia	mg/L	<0.2	<0.5	NS	NS
Corrosivity	-	Non Corrosive	Non Corrosive	NS	Non Corrosive
LSI	Units	>0.2	>0.3	NS	NS

In regard to the Groundwater Rule (4-log Virus Treatment), it was determined that achieving compliance with this was desired. It was noted that achieving this with a new facility would be readily attainable, but that it would be very challenging with the existing facility.

1.4 Treatment System Infrastructure Goals

Infrastructure goals associated with the new or rehabilitated facility shall meet or exceed the requirements outlined in FAC 25-30.115 and 25-30.140. In general the average service life of water treatment system components are outlined in the table below.

Table 1.2 Average Service Life of Water Treatment System Components

Type	Time (in years)
Wells	20-30
Water Treatment Plant	
• Structures	32
• Water Treatment Equipment	22
• Miscellaneous Equipment	25
• Storage Reservoirs	40
• Transmission & Distribution Mains	43

Redundancy and reliability goals will be established in accordance with applicable Florida Administrative Code and Florida Department of Environmental Protection requirements. Established City energy efficiency targets, and operation and maintenance objectives will be considered within the design of all treatment features.

1.5 Operation and Maintenance Goals

An efficient and effective treatment system requires that operations be optimized, and maintenance efforts minimized. Table 3 outlines specific operation and maintenance goals.

Table 1.3 Operation and Maintenance (O&M) Goals

Water Treatment O&M Goals
Optimize chemicals
Optimize power
Reduce labor to monitor and maintain systems
Develop efficient byproduct disposal strategy (solids & liquids)

Appendix C

TASK 3 & 7 – EVALUATION OF TREATMENT ALTERNATIVES

City of Fort Lauderdale
Fiveash Water Treatment Plant Evaluation

TASK 3 & 7 - EVALUATION OF TREATMENT ALTERNATIVES

FINAL REDACTED | December 2019

CERTIFICATE OF AUTHORIZATION NO. 8571

City of Fort Lauderdale
Fiveash Water Treatment Plant Evaluation

EVALUATION OF TREATMENT ALTERNATIVES

FINAL REDACTED | December 2019

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Abbreviations

AC	acre
Carollo	Carollo Engineers, Inc.
C	Celsius
$CaCO_3$	calcium carbonate
CaO	lime
cf	cubic feet
cfs	cubic feet per second
coag	coagulation
CU	platinum-cobalt units
DBP	disinfection byproduct
EC	enhanced coagulation
F	Fahrenheit
$Fe_2(SO_4)_3$	ferric sulfate
floc/sed	flocculation and sedimentation
ft	feet
GAC	granular activated carbon
H_2S	hydrogen sulfide
gpcd	gallons per capita day
gpm	gallons per minute
IX	ion exchange
MG	million gallons
MIEX	magnetic ion exchange
N	nitrogen
NF	nanofiltration
NOM	natural organic matter
NTU	nephelometric turbidity units
O&M	operations and maintenance
µg/L	micrograms per liter
mg/L	milligrams per liter
$MgCl_2$	magnesium chloride
mgd	million gallons per day
Na_2CO_3	soda ash
NaOH	sodium hydroxide (caustic soda)
NF	nanofiltration
PS	pump station
psi	pounds per square inch
RO	reverse osmosis

SBC	sand ballasted clarification
SCADA	supervisory control and data acquisition
sq ft	square feet
TDS	total dissolved solids
TOC	total organic carbon
WTP	water treatment plant

Section 1

INTRODUCTION

1.1 Background

The City of Fort Lauderdale Fiveash Water Treatment Plant (WTP) is the City's largest WTP, supplying approximately 75 percent of all of the potable water provided to the City's service area. This facility was initially built in 1954 with an original capacity of 8 million gallons per day (mgd). Since that time it has been progressively expanded to its current nameplate capacity of 70 mgd. Current treatment capabilities of the facility are limited to an estimated 60 mgd, and current daily production averages approximately 33 mgd. An aerial view of the WTP is shown in Figure 1.1.

The facility reliably provides potable water meeting applicable water quality standards in terms of primary requirements (maximum contaminant levels – MCL), but struggles to meet the secondary threshold (secondary maximum contaminant levels – SMCL) of color. These treated water quality challenges result in aesthetics goals not being met on a regular basis, especially with respect to water coloration, resulting in consumer concerns. Inability to meet color goals results primarily from the fact that the current plant technologies have not been specifically designed for color removal. Furthermore, many of the existing treatment processes are at or beyond their normal life expectancy and therefore operate at below optimum conditions.

1.2 Purpose

The purpose of this report is to evaluate treatment alternatives for the Fiveash WTP for the future production of potable water, and to specifically identify processes to remove color to non-objectionable levels. Treatment alternatives are evaluated based on their ability to meet all applicable water quality goals. Results of Fiveash WTP bench-scale testing are also presented and have been incorporated into the alternatives analysis.

[redacted]

Figure 1.1 Aerial View of Fiveash WTP

1.3 Water Quality Goals

Plant finished water quality goals have been established based on historical data, MCLs and SMCLs, a recently completed utility master plan, and input from project stakeholders. The plant's main water quality issue is color which has a mean finished water value of 16 platinum-cobalt units (CU), for which the plant has received complaints from customers. A target color range of less than 12 CU has been established, with less than 5 CU being preferred as this is the lower limit of visual detection. Figure 1.2 below shows the differences in visual color across a range of color readings.

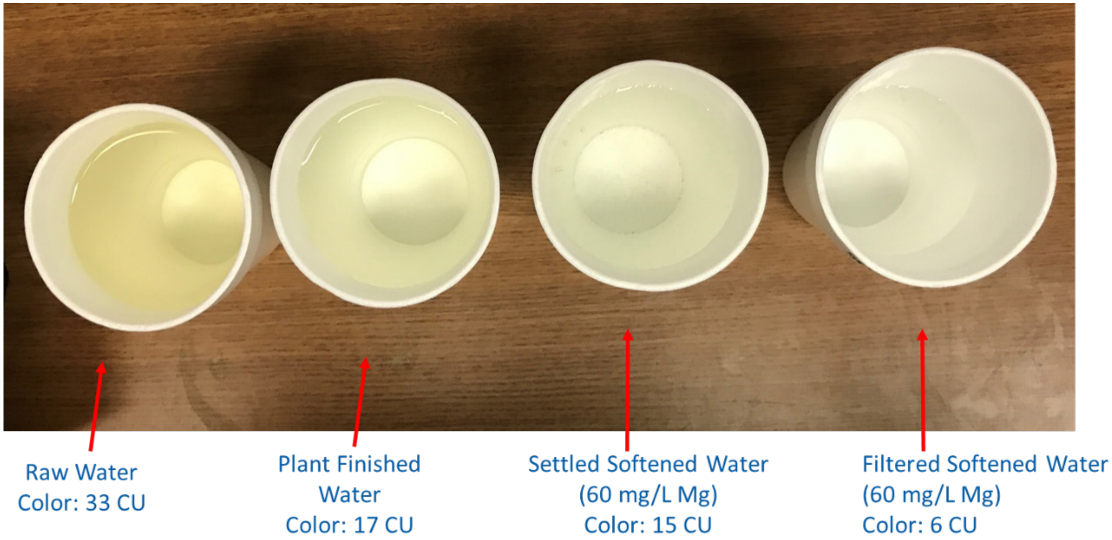

Figure 1.2 Water Coloration across a Range of Color Readings

Finished water goals have also been established for total hardness, alkalinity, pH, free ammonia, iron, manganese, hydrogen sulfide, total dissolved solids (TDS), and various other parameters. Specific goals for total organic carbon (TOC) have not been established as TOC is directly correlated with color. Therefore, it is assumed that if finished color goals are met, TOC will be reduced to levels that will not interfere with disinfection.

The WTP is not currently considered at risk for microbiological contamination, but in order to accommodate any future changes to this classification or future regulations, a 4-log virus inactivation goal has been established.

Finished water quality goals are summarized in Table 1.1. Bolded items indicate water quality parameters that do not reliably fall within the goal range under current plant operations. Primary and secondary MCLs are also listed for reference. The state of Florida has adopted the secondary MCLs into state law (with the exception of pH), and therefore the levels are enforceable.

Existing plant operations and finished water quality are further discussed in subsequent sections of this report.

Table 1.1 Finished Water Quality Goals

Parameter	Units	Goal	Fiveash Finished Water Mean Value [5th and 95th Percentiles](1)	Primary Drinking Water Standards	Secondary Drinking Water Standards
Color	**CU**	**< 5 (< 12)(4)**	**16 [8 – 21]**	**NA**	**< 15**
Alkalinity	**mg/L as $CaCO_3$**	**40 – 110**	**81 [52 – 116]**	**NA**	**NA**
Free ammonia	mg/L as N	0.05 – 0.10	No data	NA	NA
Total hardness	**mg/L as $CaCO_3$**	**80 – 160**	**84 [66 – 116]**	**NA**	**NA**
Iron	mg/L	< 0.1	0.03 [0.02 – 0.05]	NA	< 0.3
Manganese	mg/L	< 0.02	No data	NA	0.05
Sodium	mg/L	< 50	No data	< 160	NA
Total dissolved solids (TDS)	mg/L	< 500	No data	NA	< 500
Fluoride	**mg/L**	**~0.7**	**0.56 [0.47 – 0.66]**	**< 4.0**	**< 2.0**
Sulfate	mg/L	< 200	No data	NA	< 250
Chloride	mg/L	< 100	67 [59 – 80]	NA	< 250
Filtered Turbidity	NTU	< 1	0.16 [0.09 – 0.29]	NA	NA
Settled Turbidity	**NTU**	**< 2**	**8 [2 – 17]**	**NA**	**NA**
H2S	mg/L	< 0.1	No data	NA	NA
pH	**----**	**8.0 – 8.5**	**9.2 [8.6 – 9.6]**	**NA**	**6.5 – 8.5**
TTHM	**µg/L**	**< 60**	**71.7(2) [2.0 – 75.5]**	**< 80**	**NA**
HAA5	**µg/L**	**< 40**	**41.0(2) [4.5 – 54.4]**	**< 60**	**NA**
Langelier Saturation Index (LSI)	----	> 0.2	0.08(3)	NA	NA
Calcium Carbonate Precipitation Potential (CCPP)	**mg/L as $CaCO_3$**	**4-10**	**17.5(3)**	**NA**	**NA**
Disinfection	----	4-log virus	No data	NA	NA

Notes:
(1) Years analyzed: 2014-2019.
(2) 2018 Water Quality Report.
(3) Calculated
(4) A 5 CU color goal has been established but the City is also interested in exploring options that achieve between 5 and 12 CU.

1.4 Infrastructure Reliability

Based on current water demand forecasting, the required future capacity of the Fiveash WTP is estimated to be 50 mgd maximum daily flow (MDF) and this report is based on this premise (maximum plant capacity). Required service lives for existing and new infrastructure are based on the Water and Wastewater Utility Rules from the Florida Administrative Code (FAC 25-30.115 and 25-30.140), and are presented in Table 1.2 Design service lives should meet or exceed these goals.

Table 1.2 Infrastructure Service Lives

Parameter		Service Life (years)
Wells		20-30
WTP	Structures	32
	Water Treatment Equipment	22
	Miscellaneous Equipment	25
	Storage Reservoirs	40
	Transmission and Distribution Mains	43

Section 2

CURRENT PLANT PERFORMANCE

A process flow diagram of the Fiveash Water Treatment Plant is shown in Figure 2.1. Raw water is pumped from the Biscayne Aquifer and sent sequentially to aeration basins for hydrogen sulfide and free carbon dioxide removal, Hydrotreators for softening, and filters for turbidity removal. Filtered water is stored in several clearwells and storage tanks and pumped to the distribution system. Chlorine is added for disinfection, ammonia is added to achieve chloramine-based disinfection, polymer is added to aid the softening process, and fluoride is added to raise levels to those adequate for public health.

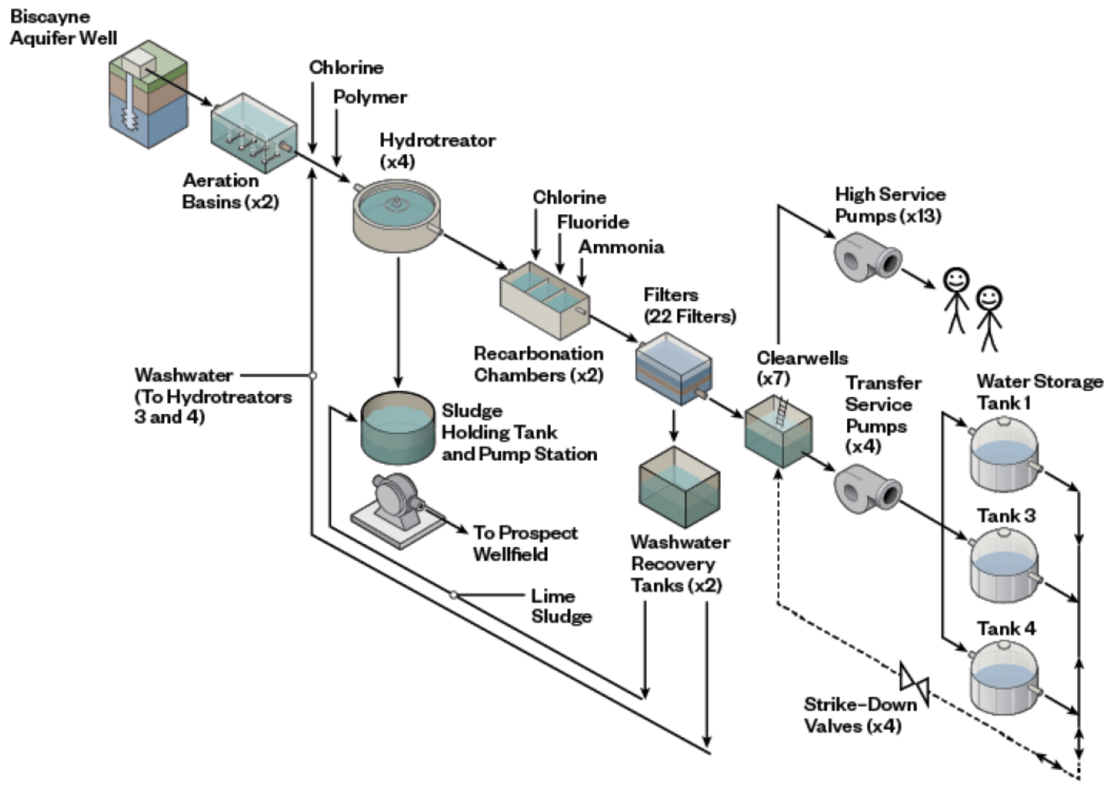

Figure 2.1 Fiveash WTP Process Flow Diagram

2.1 Plant Water Quality

The WTP's current performance is discussed below with respect to the water quality goals established in Section 1.

2.1.1 Color

Raw water color into the plant is considered high, averaging 42 CU with a 95th percentile value of 51 CU. Well data shows an even higher 95th percentile value of 70 CU. Mean finished water color is 16 CU with a 95th percentile value of 21 CU, meeting neither the conservative target of 5 CU nor the moderate target of 12 CU. Color trends over time and percent exceedance curves for 5 years of data are shown below in Figures 2.2 and 2.3. As shown in the figures, the aeration basins, chlorination, and lime softening process are providing a moderate amount of color removal but not enough to reach the threshold of visibility.

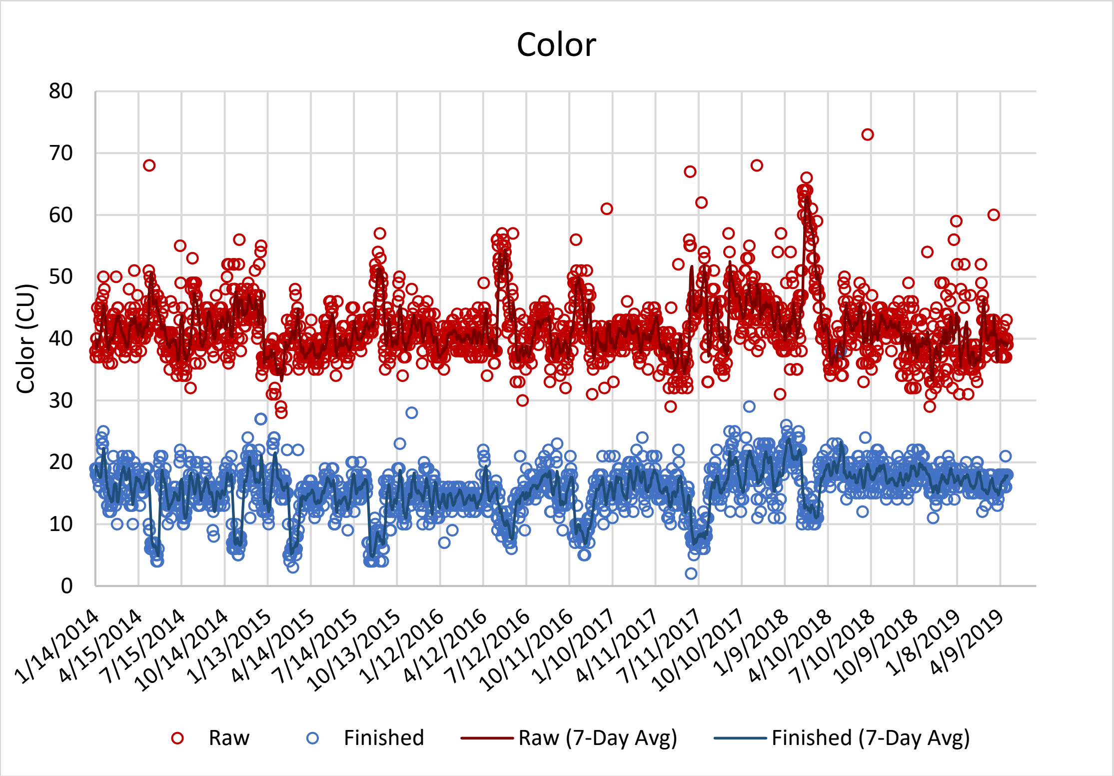

Figure 2.2 Raw and Finished Color

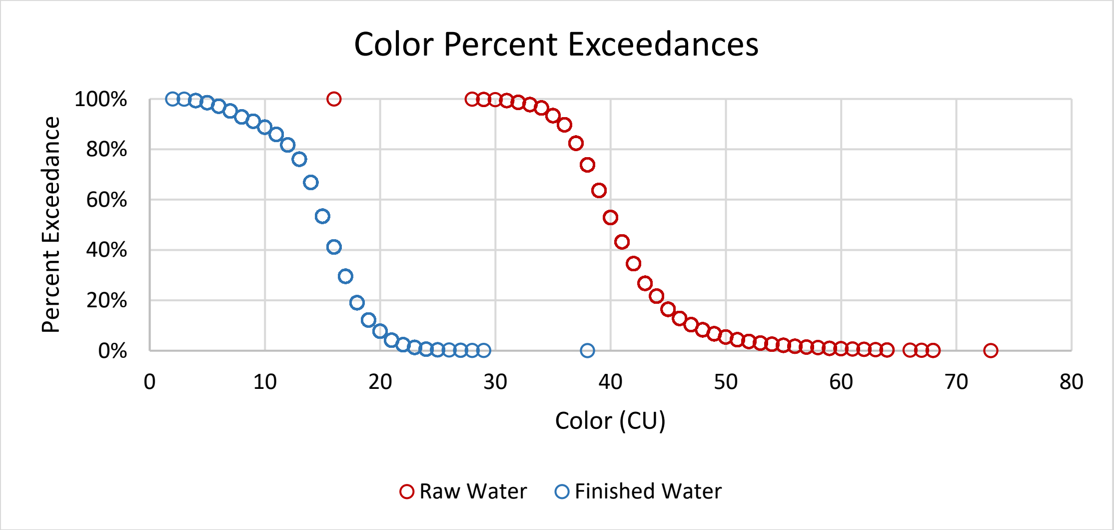

Figure 2.3 Raw and Finished Color Percent Exceedances

2.1.2 Hardness

A summary of hardness data is shown in Figures 2.4 and 2.5. Mean finished water hardness is 84 mg/L as $CaCO_3$ with 5th to 95th percentiles of 66 – 116 mg/L as $CaCO_3$. This falls roughly within the lower end of the water quality goal parameters (80 – 160 mg/L as $CaCO_3$) but slightly higher finished water hardness is desirable. Mean raw water hardness is 226 mg/L as $CaCO_3$ and mean settled water hardness is 101 mg/L as $CaCO_3$. Approximately 10 percent of the raw water hardness is due to magnesium, which may aid in color removal in an enhanced softening process (discussed in Section 3).

It should be noted that an ancillary data set from recent well sampling showed that raw total hardness may reach more extreme values (> 300 mg/L as $CaCO_3$). These values represent a 'worst case scenario' for hardness, and therefore were utilized in the water quality predictions in Section 5.

An average of 20 mg/L as $CaCO_3$ hardness is removed by the dual media filters which is not ideal, and can cause additional operational and maintenance issues. Removal of more than 10 mg/L as $CaCO_3$ of hardness results in precipitation on the filter media which increases the media size, resulting in a reduction of L/d (depth of filter media divided by the effective size of the media) and an increase in media depth (which can impact media carryover during backwash). Precipitation may also change the specific gravity of the media, which can result in inadequate fluidization during the normal backwash procedure. Finally, if precipitation of calcium carbonate is severe enough, deposition can occur in the underdrains resulting in over-pressurizing of the underdrains and catastrophic failure (underdrain blowout).

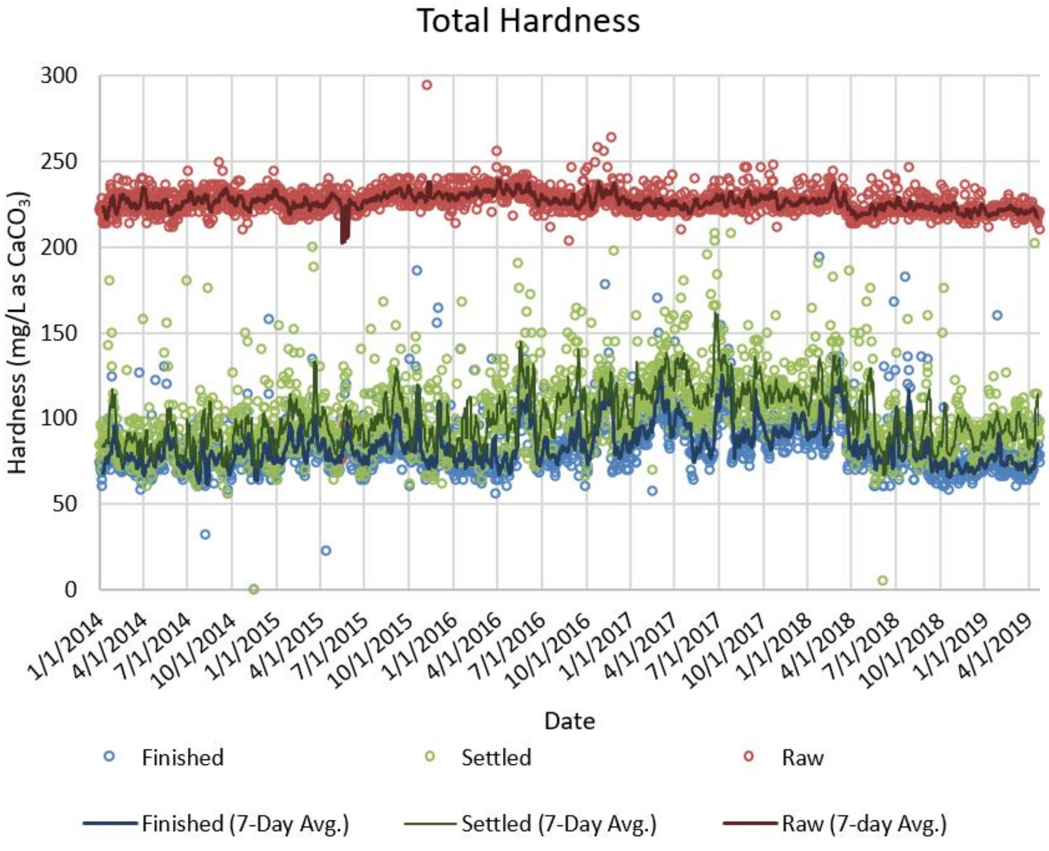

Figure 2.4 Raw, Settled, and Finished Total Hardness

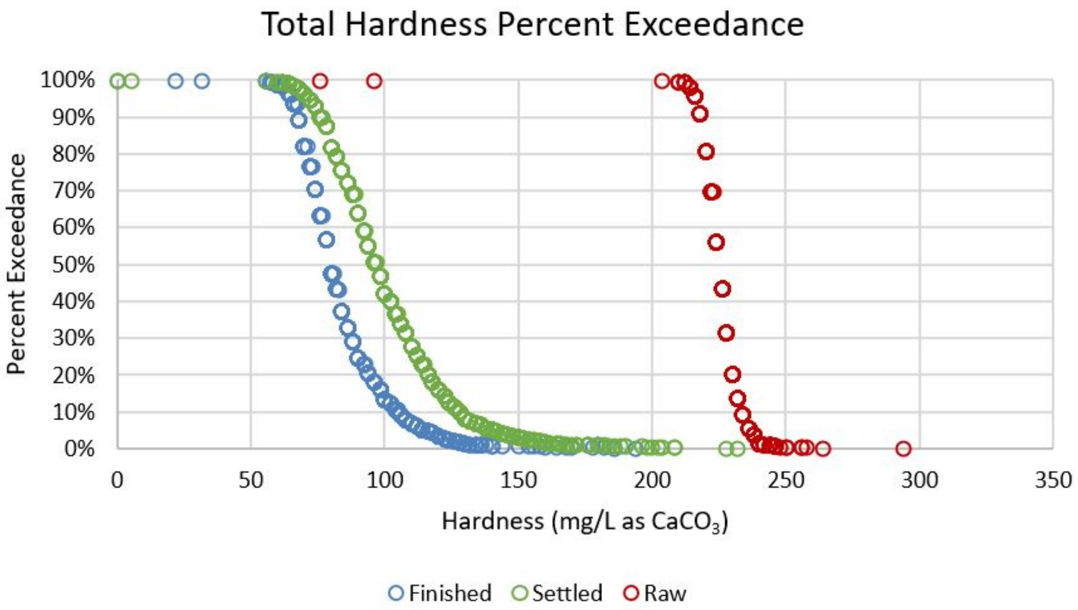

Figure 2.5 Total Hardness Percent Exceedance

2.1.3 Alkalinity

A summary of alkalinity data is shown in Figures 2.6 and 2.7. Mean finished water alkalinity is 81 mg/L as $CaCO_3$ with 5th and 9th percentiles of 52 – 116 mg/L as $CaCO_3$. This falls roughly within the upper end of the water quality goal parameters (40 – 110 mg/L as $CaCO_3$).

An ancillary data set from recent well sampling indicates that raw water alkalinity may be lower than the plant data suggest (averaging 188 mg/L as $CaCO_3$). These most recent values represent a limiting case for softening, and therefore they were utilized in the water quality predictions in Section 5.

Mean raw water alkalinity is 225 mg/L as $CaCO_3$ and mean settled water alkalinity is 110 mg/L as $CaCO_3$. An average of 29 mg/L as $CaCO_3$ alkalinity is removed by the dual media filters, and, as with hardness removal through the filters, this is not ideal. Both hardness and alkalinity removal through the filters implies that calcium carbonate is precipitating on the filter media. Inadequate pH control may be contributing to this precipitation.

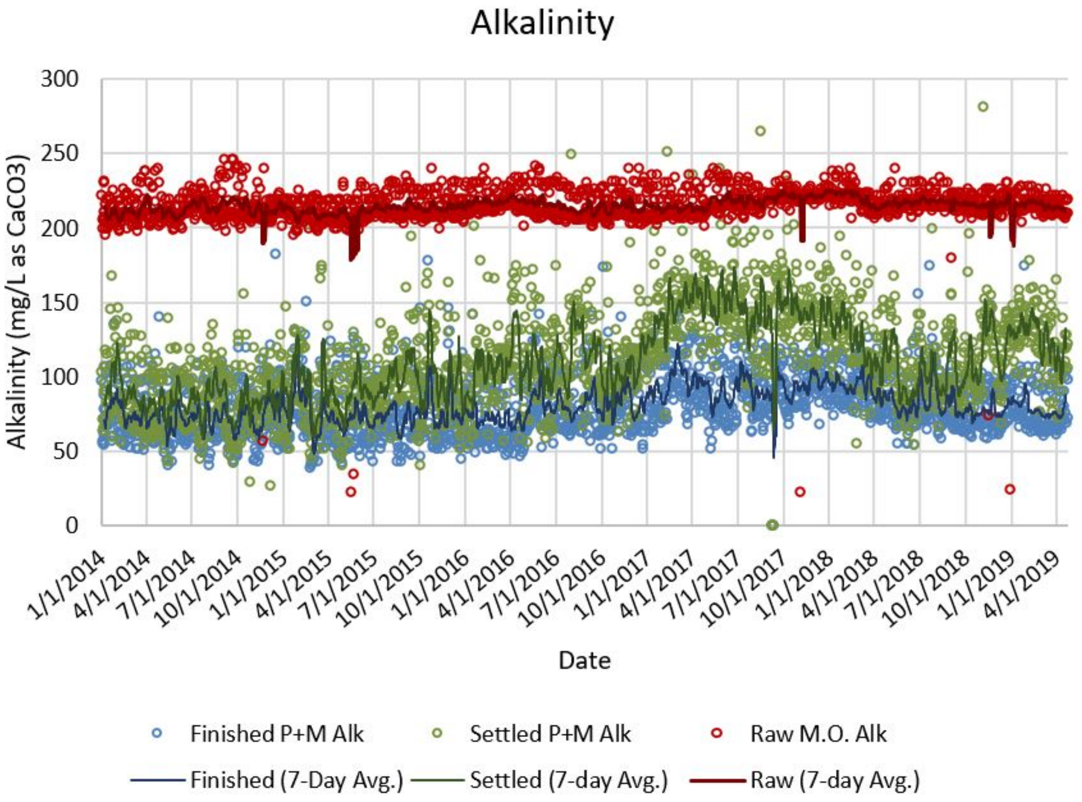

Figure 2.6 Raw, Settled, and Finished Water Alkalinity

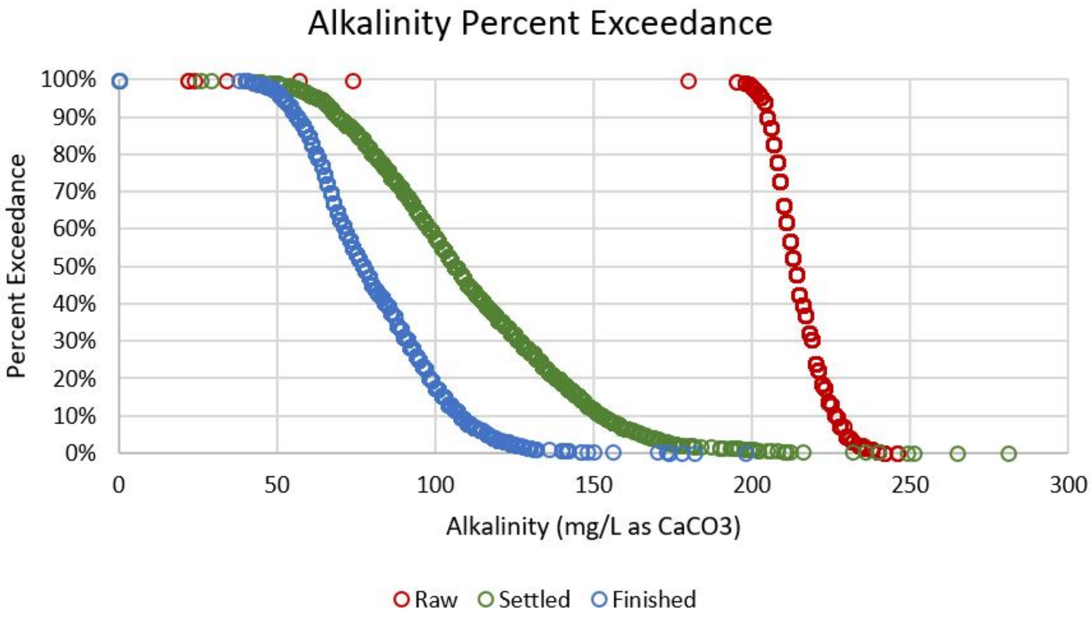

Figure 2.7 Alkalinity Percent Exceedance

2.1.4 pH

Summaries of plant pH data are shown in Figures 2.8 and 2.9. Average finished water pH is approximately 9.2 with 5th and 95th percentiles of 8.6 to 9.6, implying that at least 95 percent of recorded pH values exceed the target pH range of 8.0 – 8.5. The average settled water pH from the softening process is approximately 9.4, which is what is needed for calcium carbonate precipitation. The high pH to the filters is likely contributing to the calcium carbonate precipitation.

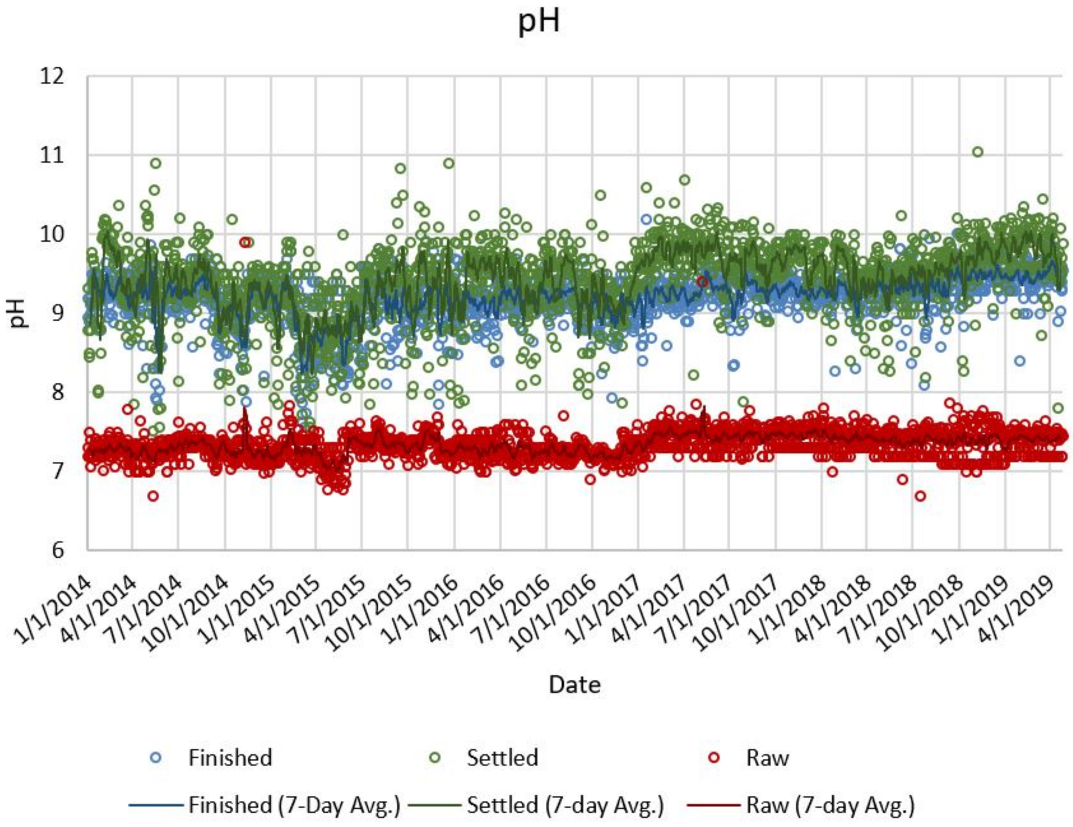

Figure 2.8 Raw, Settled, and Finished Water pH

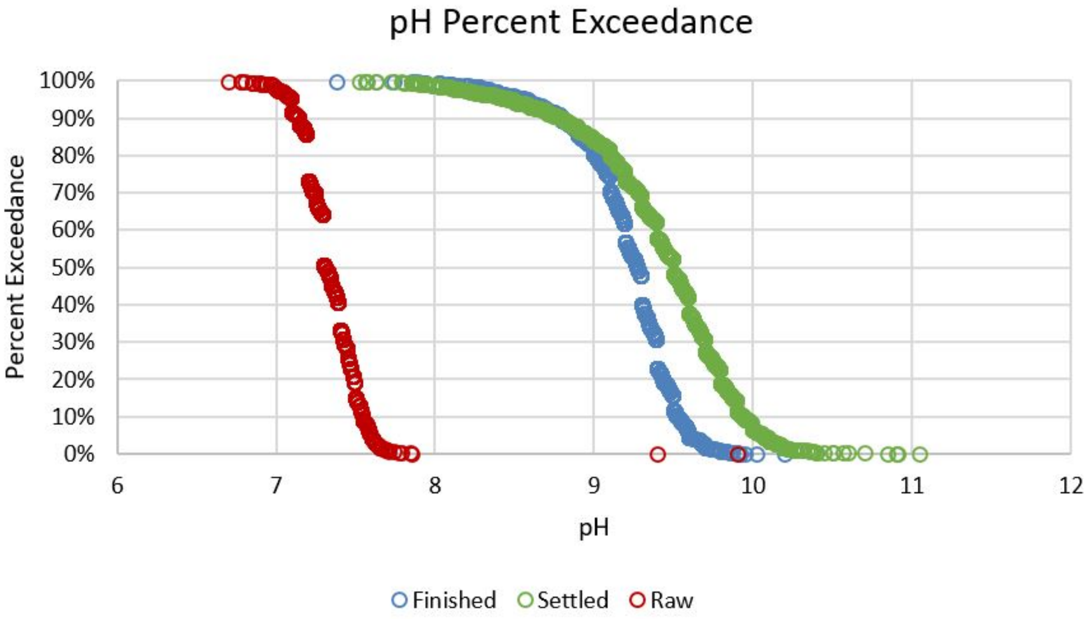

Figure 2.9 pH Percent Exceedance.

2.1.5 Turbidity

As shown in the well data in Figure 2.10, average raw water turbidity is roughly 0.8 NTU, with 5th and 95th percentiles of 0.19 to 2.41 NTU. This level of turbidity is considered normal and manageable for a groundwater plant. It should be noted that this turbidity is due to the precipitation of dissolved iron in the raw water during the sampling process and is not indicative of particulate or microbiological contamination.

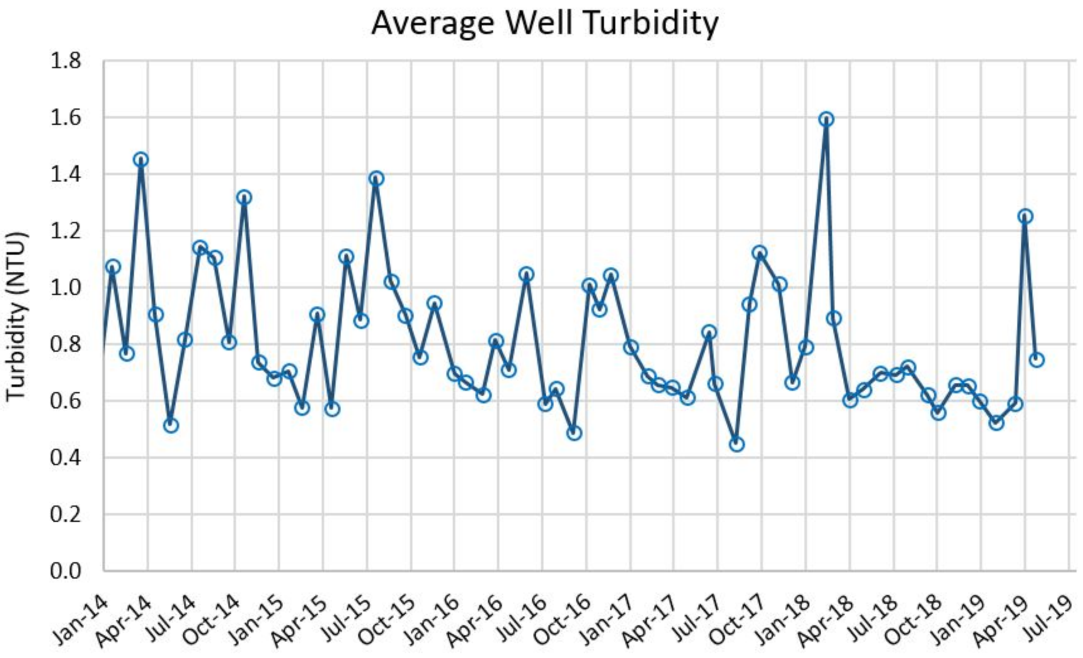

Figure 2.10 Raw Water Well Turbidity

Settled water and finished water turbidities are summarized in Figures 2.11 and 2.12. Average settled water turbidity is approximately 8 NTU, with 5th and 95th percentiles of 2 to 17 NTU. A desirable post-softening turbidity (and the softening settled water turbidity goal of the Partnership for Safe Water) is 2 NTU, and more than 95 percent of existing post-softening turbidities exceed this target. This high turbidity is likely caused by the fact that the solids contact process in a softening reaction requires high concentration of solids to provide a large surface area for the precipitation reaction, and the existing Hydrotreators cannot achieve high solids concentrations. High settled water turbidity results in decreased unit filter run volume (UFRV), more frequent backwashing, and higher backwash waste percentages. Hydrotreator performance is further discussed in subsequent sections.

Finished water turbidity averages approximately 0.16 NTU. This is within the established water quality goals, but filter performance can likely be improved to provide a more typical < 0.1 NTU for dual media filtration.

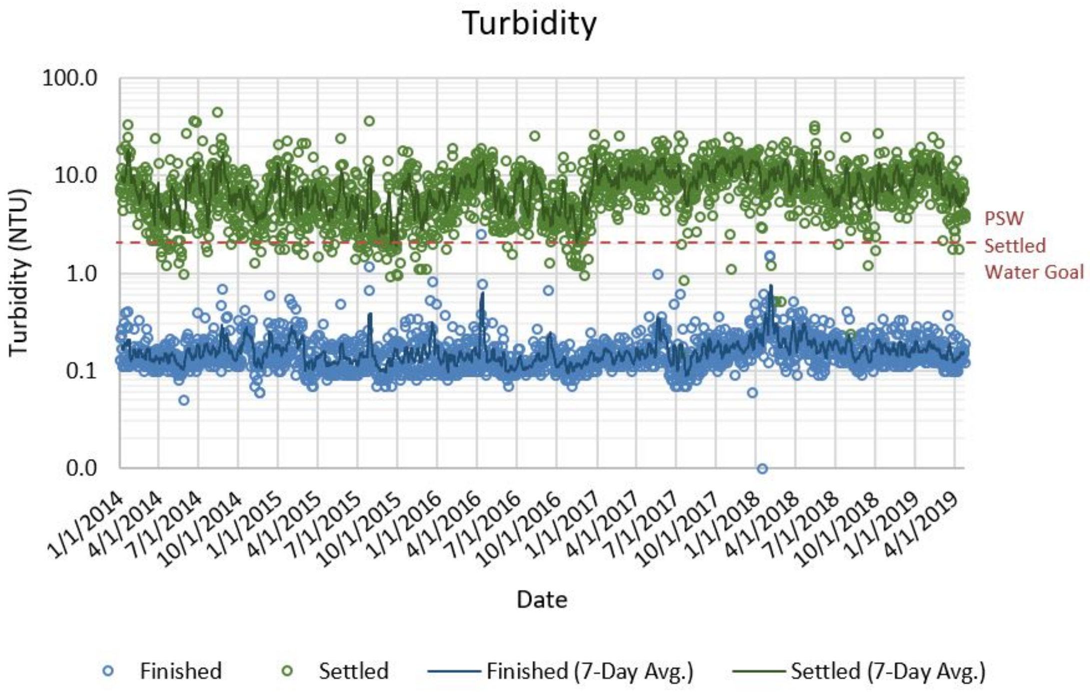

Figure 2.11 Settled and Finished Water Turbidity

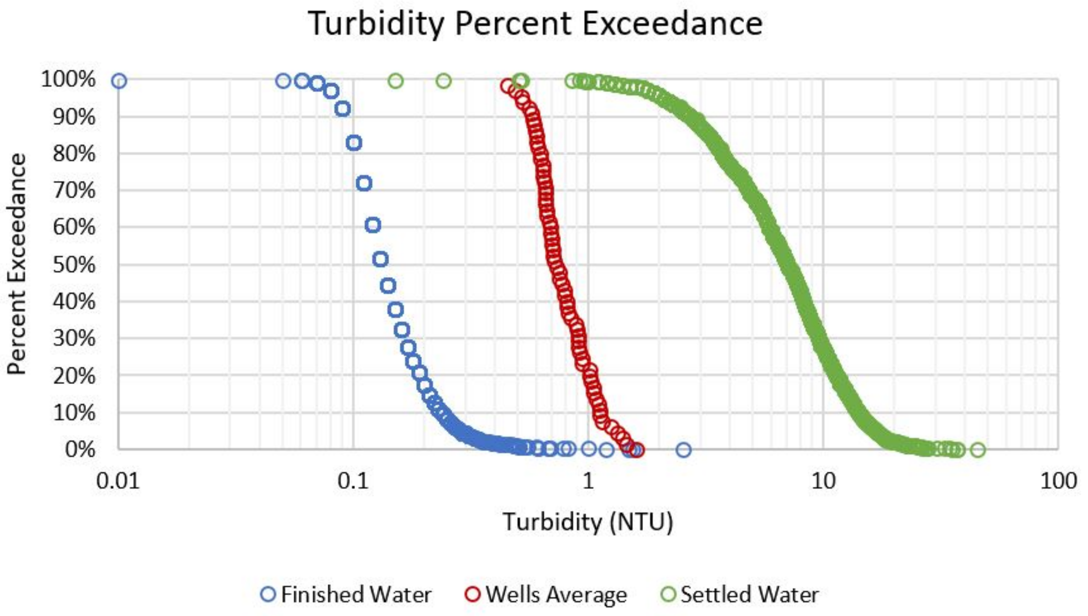

Figure 2.12 Turbidity Percent Exceedance

2.1.6 Iron

Current raw water iron averages 0.44 mg/L with 5th – 95th percentiles of 0.26 – 0.60 mg/L. Data taken directly from wells was slightly higher but still below 1 mg/L. Finished water iron averages 0.03 mg/L with 5th – 95th percentiles of 0.02 – 0.05 mg/L, which is within the finished water goal of less than 0.1 mg/L. Iron data is summarized in Figures 2.13 and 2.14.

Iron can be removed by several different types of treatment processes. It is oxidized by oxygen via aeration (or almost any other oxidant) and removed by coagulation, through the softening process, or by any filtration process. Iron is problematic in nanofiltration (NF) and reverse osmosis (RO) processes if precipitation occurs prior to the membranes. Most NF and RO membranes will remove all forms of dissolved iron. Iron becomes difficult to remove in water treatment plant processes if it is organically bound; organically bound iron is removed using stronger oxidants in combination with metal salt coagulation.

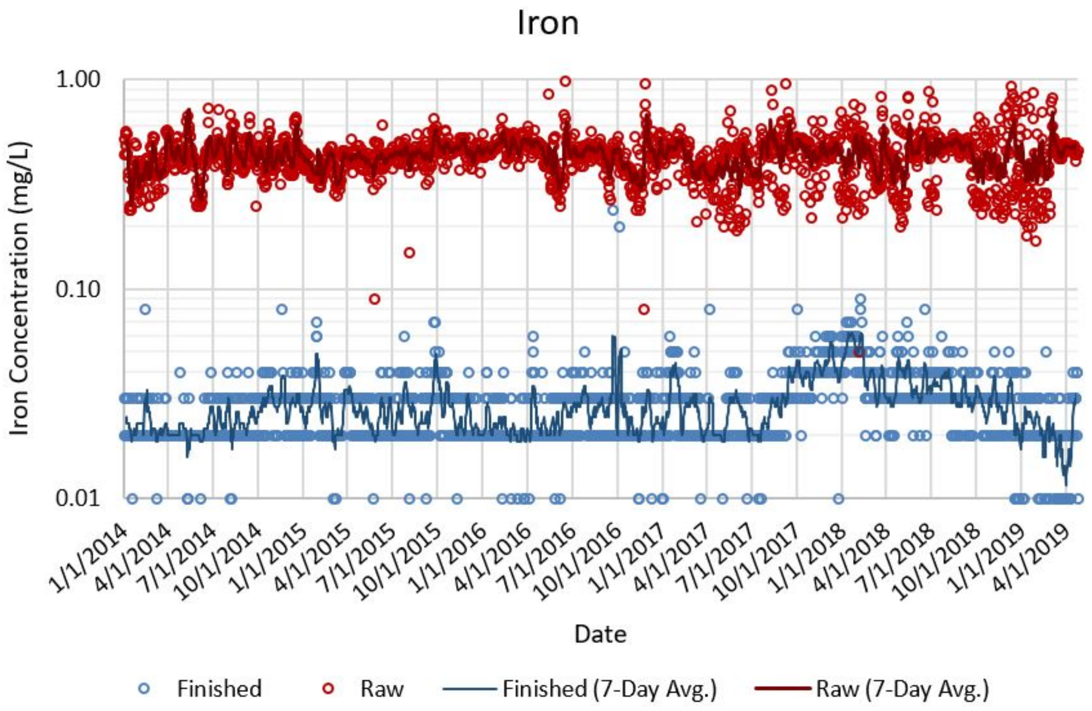

Figure 2.13 Raw and Finished Iron Concentrations

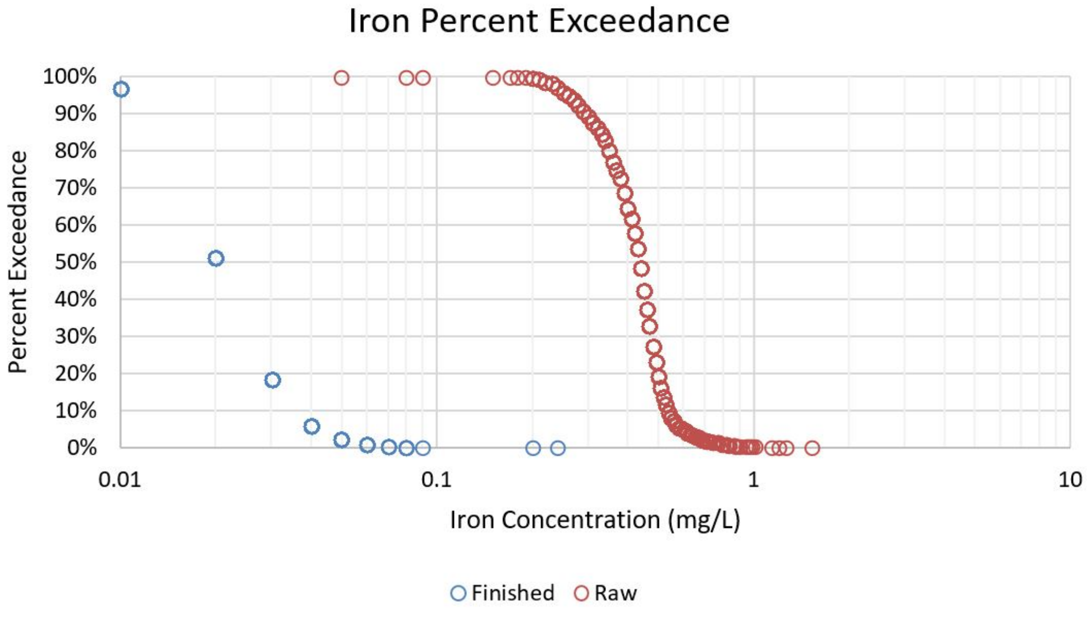

Figure 2.14 Iron Percent Exceedance

2.1.7 Chlorides

Chloride data is summarized in Figures 2.15 and 2.16. Raw water chloride averages 59 mg/L and finished water chloride averages 67 mg/L. This small change is somewhat negligible and remains within the quality goal of less than 100 mg/L. None of the existing plant processes should have a major impact on chloride levels and this appears to be reflected in the data.

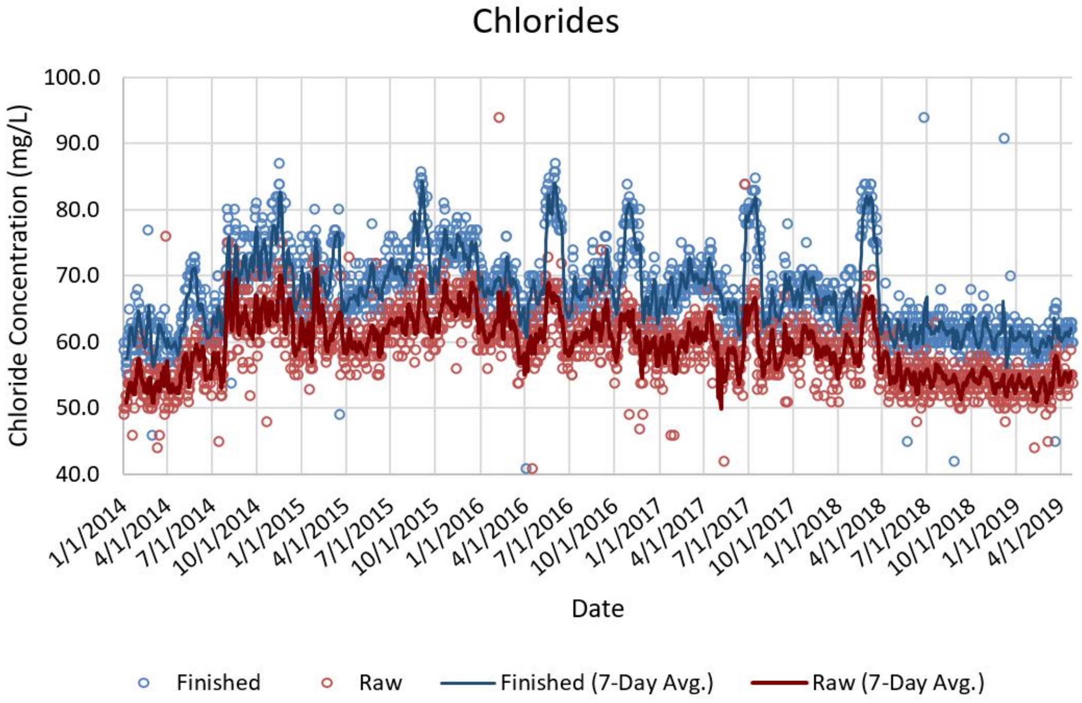

Figure 2.15 Raw and Finished Water Chlorides

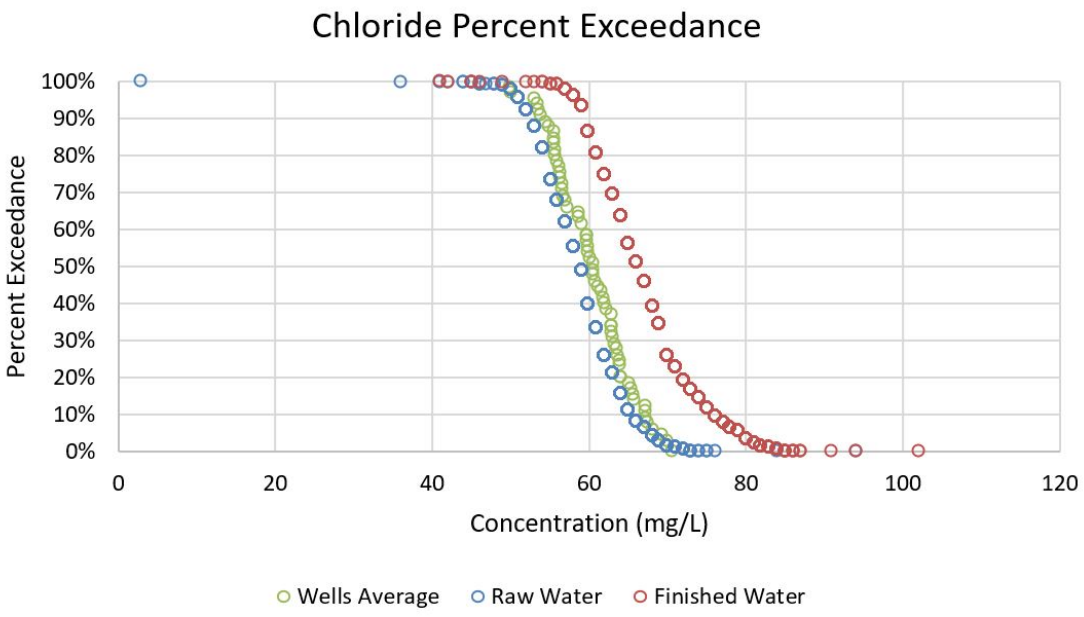

Figure 2.16 Chloride Percent Exceedance

2.1.8 Fluoride

The water quality goal for fluoride has been established as 0.7 mg/L based on the official recommendation of the Center for Disease Control (CDC). Fluoride is currently fed in the recarbonation contact basins at an average dose of 0.32 mg/L and finished water levels average 0.56 mg/L with 5th – 95th percentiles of 0.47 – 0.66 mg/L. This is slightly low but not a threat to public health. Fluoride is partially removed during softening and filtration, so dosing the chemical at the end of the treatment train would offer more control than the current location. Fluoride data is presented in Figures 2.17 and 2.18.

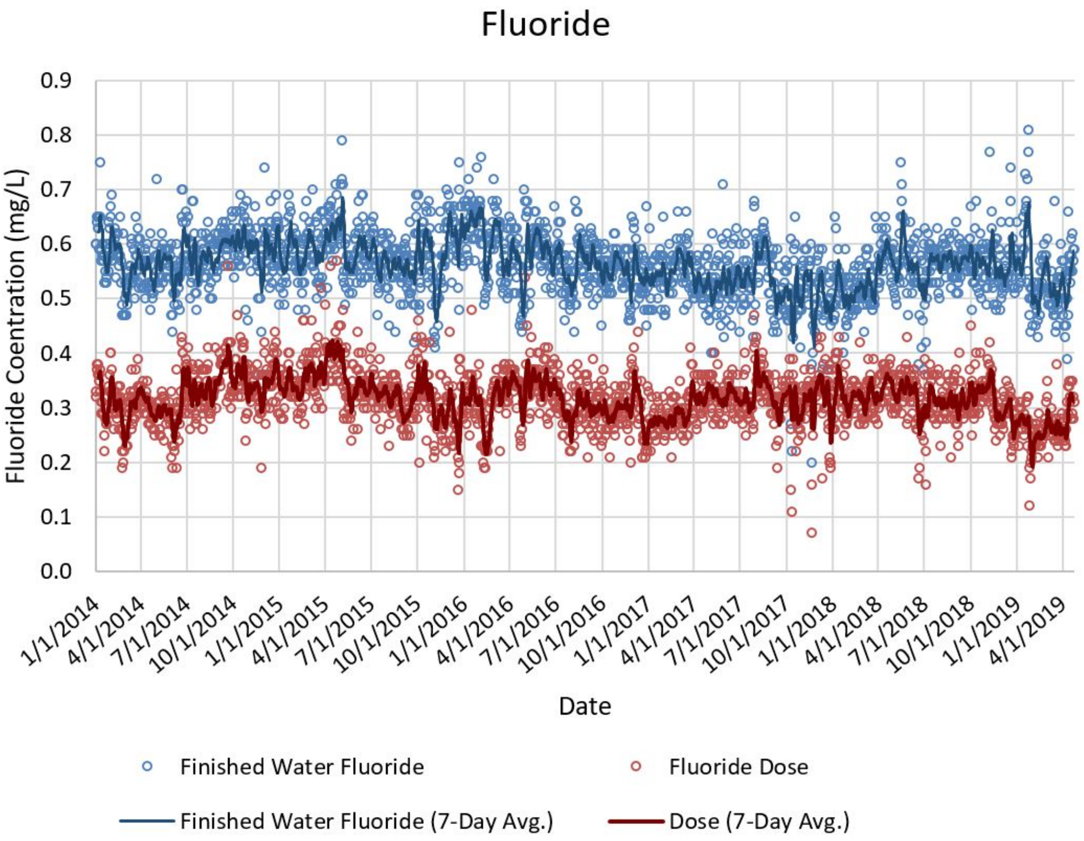

Figure 2.17 Dosed Fluoride and Finished Water Concentration

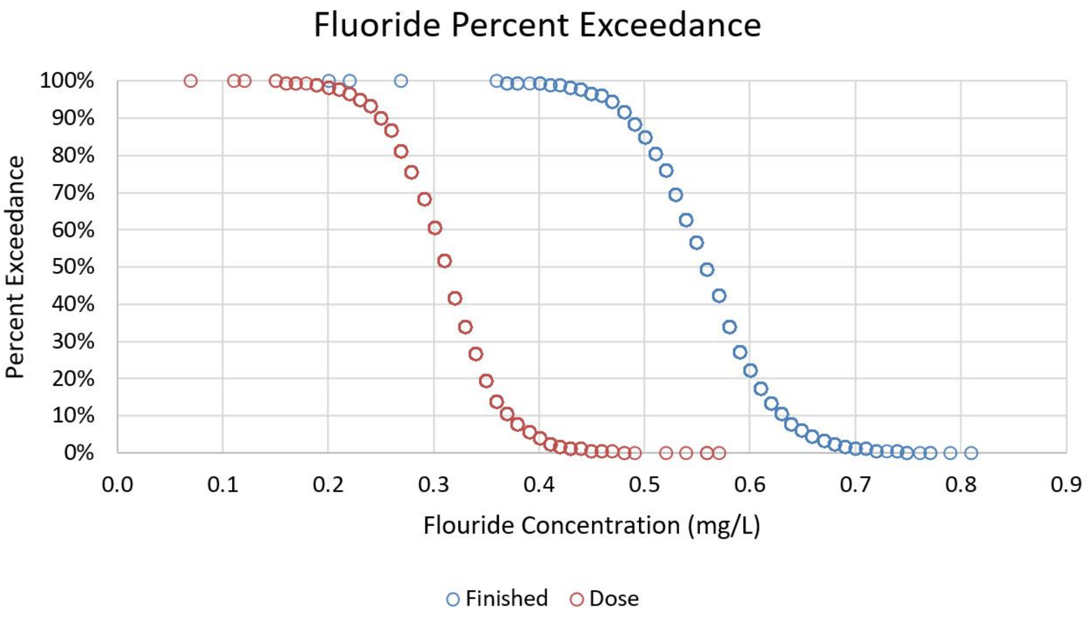

Figure 2.18 Fluoride Percent Exceedance

2.1.9 TDS, Sodium, and Sulfate

Available data for total dissolved solids (TDS), sodium, and sulfates is limited. Average raw water TDS concentrations are estimated to be approximately 400 mg/L with sulfate comprising approximately 2 percent of TDS (average 8 mg/L). This is considered a particularly low sulfate level and sulfate to chloride ratios should be considered during the treatment process (discussed in subsequent section). No sodium data is currently available.

2.1.9.1 Chloride to Sulfate Mass Ratio

The chloride to sulfate mass ratio (CSMR) is of concern in distribution systems that have lead piping, as excessive CSMRs can result in lead release. Although the sulfate data is limited, the estimated average raw water CSMR at Fiveash WTP is approximately 8 – 10. Research has shown that a desirable CSMR for protection from lead release in distribution system piping is less than 0.5, and therefore if there is a significant amount of lead piping in the distribution system, Fiveash WTP may want to consider a corrosion inhibitor if the CSMR is not reduced by new treatment processes.

2.1.10 Total Organic Carbon

Total organic carbon (TOC) data is limited, but recent well sampling showed raw water averaging 14.4 mg/L and ranging from 9.9 to 17.6 mg/L. This is exceedingly high for a typical groundwater, but is consistent with the Biscayne Aquifer water quality in Southeast Florida. Specific finished water TOC goals have not been established since TOC removal should be achieved if color goals are met. TOC removal is important for prevention of chlorinated disinfection byproducts and maintenance of a persistent disinfection residual in the distribution system.

2.1.11 Manganese

Recent well sampling data indicates that raw water manganese levels average at 0.004 mg/L and the maximum value did not exceed 0.008 mg/L. This is within the water quality goal of less than 0.02 mg/L and therefore manganese removal is not of concern in the treatment process.

2.1.12 Hydrogen Sulfide

Hydrogen sulfide (H_2S) levels in the raw water wells average 0.3 mg/L and range as high as 0.9 mg/L. This indicates that treatment will be required to lower the levels to the finished water target of less than 0.1 mg/L. Per the Florida Department of Environmental Protection (FDEP) Chapter 62, these H_2S levels are considered moderate to significant, and therefore require treatment beyond chlorine oxidation. Finished water H_2S data is not currently available, but it is recommended to use a robust H_2S technology such as forced draft aeration (aeration through design media with a high air-to-water ratio) to target H_2S in the future. This is further discussed in subsequent sections of the report.

2.1.13 LSI and CCPP

The Langelier Saturation Index (LSI) is a Calcium Carbonate Saturation Index. The variables needed to utilize the Langelier Index are: calcium concentration (as $CaCO_3$), total alkalinity (as $CaCO_3$), temperature, and dissolved solids. This index is the most accepted and misused index in the water field. The pH of calcium carbonate stabilization is calculated. This is the pH where the water has neither a tendency to dissolve or precipitate calcium carbonate. A positive value for the Langelier Index indicates that the water will precipitate calcium carbonate and a negative value indicates that the water will dissolve calcium carbonate and may cause corrosion problems in a distribution system. This method of analysis does not take into account ion pairs (such as $CaHCO_3^+$) and their effect on the calcium concentration. Other scales besides calcium carbonate have been shown to be protective against corrosion. In the presence of scale inhibitors this index is not appropriate. The Langelier index does not yield any information about the degree of scaling and corrosion.

The Calcium Carbonate Precipitation Potential (CCPP) is a quantitative index that calculates the quantity of calcium carbonate that will precipitate or be dissolved by a water of a known quality. Numerical iterations are needed for the calculation of this index which is the reason that most utilities utilize LSI. AWWA recommends maintaining a CCPP of 4-10 mg/L as $CaCO_3$. Average finished water CCPP at Fiveash WTP is estimated to be 17.5 which is high indicating possible calcium carbonate deposition in the distribution system. This can result in reduction of pipeline capacity and increased deposition in hot water heaters and dishwashers, reducing the useful life of this equipment.

2.1.14 Free Ammonia

A target finished water free ammonia level of 0.05 – 0.10 mg/L as N has been established to help prevent nitrification (bacterial conversion of ammonia to nitrite/nitrate) in the distribution system. Raw water levels appear to average approximately 1 mg/L as N. Since the plant uses a chloramine-based residual, the free ammonia levels should be controlled as long as chlorine and ammonia are added in the correct ratios. The average ammonia dose is approximately 1 mg/L. Dosing considerations are further discussed with respect to disinfection below. Any future disinfection strategies should carefully control and monitor chlorine, chloramine, and ammonia levels.

Ammonia dosing data are presented in Figures 2.19 and 2.20. The large dips in ammonia dosing likely represent days where free chlorine disinfection was used ('free chlorine burn') to help control nitrifying bacteria in the distribution system.

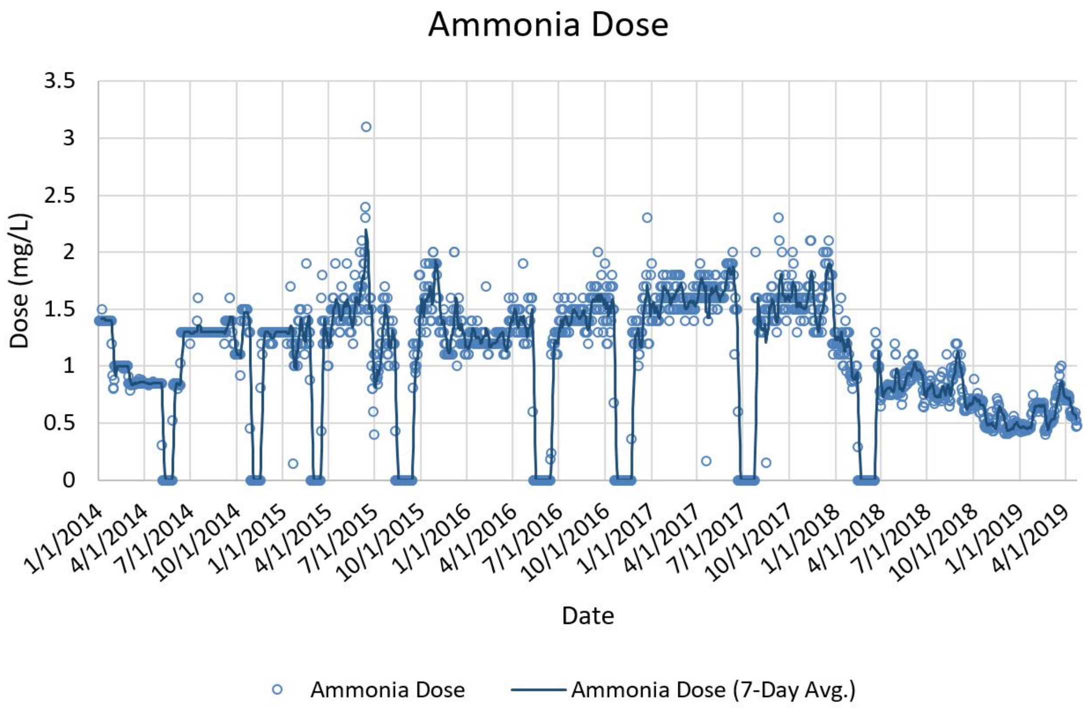

Figure 2.19 Ammonia Dosing Over Time

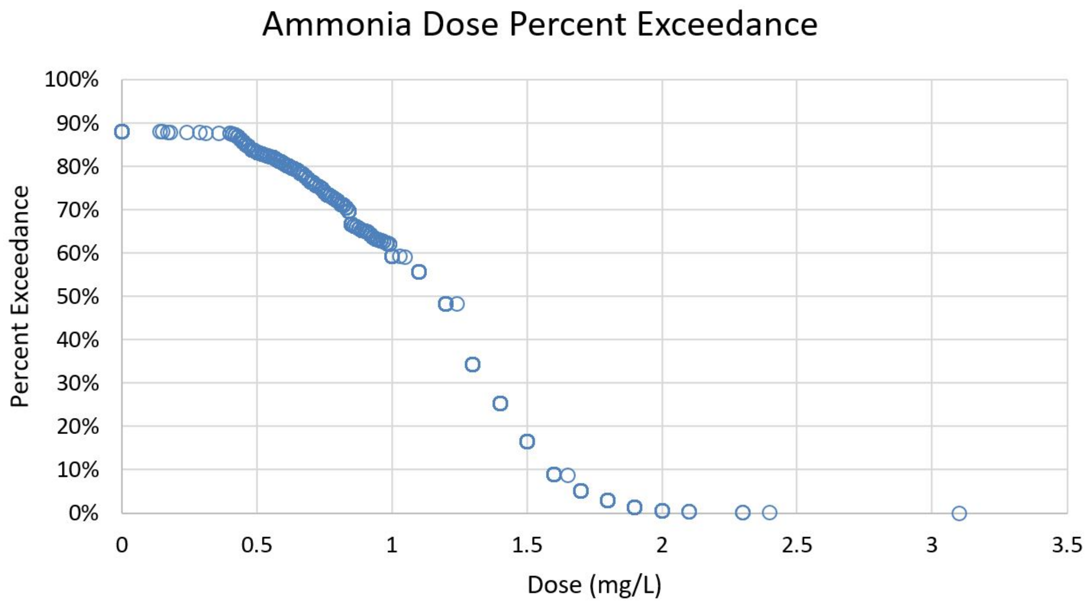

Figure 2.20 Ammonia Dose Percent Exceedance

2.1.15 Disinfection

2.1.15.1 Chlorination

In the United States, groundwater plants are not required to achieve any level of disinfection for viruses, bacteria, or protozoa, unless the aquifer is classified as *at risk*. In order to account for the possibility of being re-classified in the future, and because of possible additional future regulations, a goal has been established to achieve 4-log virus disinfection at the plant and to maintain a detectable disinfectant residual in the distribution system.

Any compound in the water that has the potential to be oxidized by chlorine will exert a chlorine demand and somewhat inhibit disinfection. These compounds include natural organic matter (NOM) (analogous to color, a major issue for Fiveash WTP), H_2S, iron, manganese, and other organics. Additionally, when NOM reacts with chlorine, there is a potential for disinfection byproduct (DBP) formation (discussed more in subsequent sections). Ammonia also exerts a chlorine demand as it combines with chlorine to form chloramines.

Chlorine is currently dosed at the influent box to the Hydrotreators (softeners) (approx. 2 mg/L) and the influent box to the recarbonators (approx. 7 – 7.5 mg/L). The average total chlorine dose is 9.64 mg/L (5th – 95th percentiles of 6.8 – 17.8 mg/L). The high 95th percentile value is likely skewed by free chlorine burns, where excess chlorine is added periodically to reduce the presence of nitrifying bacteria. Chlorine dosing and monitoring data are summarized in Figure 2.21.

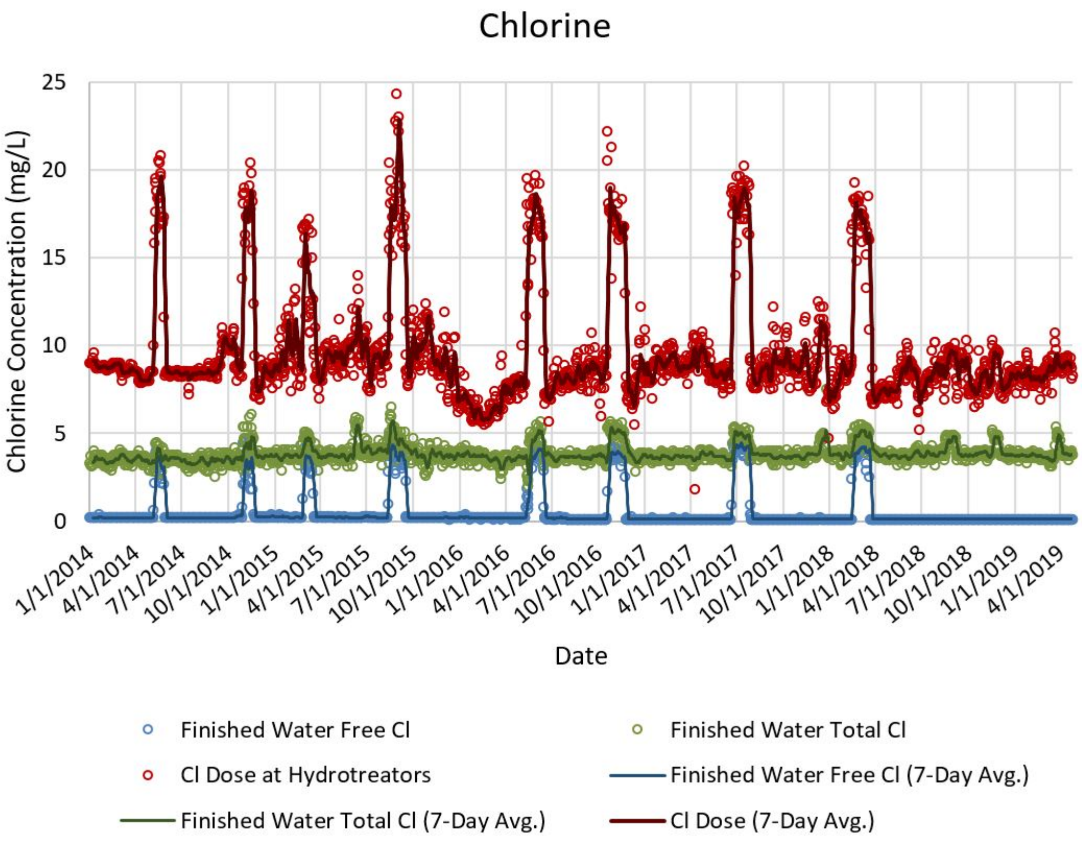

Figure 2.21 Chlorine Dose and Finished Water Concentration

As seen in Figure 2.21, average finished water total chlorine (free chlorine plus chloramines) is 3.8 mg/L and average finished water free chlorine is 0.6 mg/L. As previously mentioned, the discrepancy between dosed chlorine and finished water chlorine is due to combination with ammonia and chlorine demand from both organic and inorganic compounds.

2.1.15.2 Disinfection Byproducts

DBPs are formed primarily by the interaction between chlorine and NOM. Higher temperatures also increase DBP formation, and therefore present a significant concern for the warmer water temperatures encountered in South Florida. Chloramines tend to form less DBPs than chlorine, but chloramine-based disinfection requires additional cost and contact time to achieve the same microbial inactivation as free chlorine.

Approaches for controlling DBPs include the removal of NOM before chlorination, minimizing chlorine dose to achieve the minimum disinfection requirements, using chloramine disinfection, using free chlorine disinfection inside the plant and chloramine residual in the distribution system, or switching to a different disinfectant altogether, such as ultraviolet light (UV) or chlorine dioxide.

DBPs are USEPA regulated carcinogens in drinking water, per the Stage 2 DBP Rule. The sum of the concentrations of five primary haloacetic acids (HAAs) must be below 60 µg/L and the sum of trihalomethane (THM) concentrations must be below 80 µg/L. The City has set even more stringent goals of HAA5 < 40 µg/L and TTHM < 60 µg/L.

The only plant DBP data available comes from city Water Quality Reports, which combine analyses from both the Peele Dixie WTP and the Fiveash WTP (distribution system samples). Per these reports, average DBPs have been in compliance with the MCLs, with some of the maximum annual THM levels exceeding the MCL. THMs are base-catalyzed and therefore tend to form in higher amounts than HAAs in the high-pH finished water. DBP levels have regularly exceeded the established future goals of HAA5 < 40 µg/L and TTHM < 60 µg/L and therefore a new approach to DBP control is needed in the future.

The primary reasons for formation of DBPs at the WTP appear to be high NOM levels and dosing chlorine too early in the treatment train where NOM has not adequately been removed. The existing mechanism for controlling DBPs at the WTP appears to be the utilization of chloramine-based disinfection. Future DBP control can be accomplished in number of ways and the removal of DBP precursors are accomplished through the various color removal technologies discussed in subsequent sections.

2.1.15.3 Virus Inactivation

A 4-log virus inactivation goal has been established to protect public health and prepare for possible future regulations. The high temperatures of the water aid in disinfection while the high pH levels inhibit disinfection. Estimates for virus inactivation through the existing processes are as presented in Table 2.1.

Table 2.1 Virus Inactivation through the Existing WTP Process

Location	Dose	Virus inactivation
Chlorination at the Hydrotreators	2 mg/L as Cl_2	Assume no inactivation due to low dose, ammonia in the raw water, and extremely high NOM interference
Chloramination at the recarbonators	7.5 mg/L as Cl_2 (targeting 3.5 mg/L total residual in clearwells)	0.5-log(1)
Solids contact clarification and dual media filtration (mechanical disinfection)	NA	2-log
Total	**NA**	**2.5-log**

Notes:

(1) Estimated average contact times in recarbonation, filters, and clearwells are 6 min, 10 min, and 10 min, respectively. 3.5 mg/L x 26 min yields CT value of 91 min x mg/L. The required chloramine CT value at 25°C for 4-log virus is 497 min x mg/LA proportional awarding of log removal yields ~0.5-log, which may even be an overestimate as the baffling factors are low. Also note that contact time in the finished water storage tanks cannot be added to the CT calculation because some of the water is pumped directly from the clearwells to the distribution system.

As noted in Table 2.1, the current chloramination doses and filtration yield a 2.5-log virus inactivation, and therefore the plant is not currently meeting the future 4-log virus inactivation goal.

2.2 Additional Treatment Performance Considerations

2.2.1 Filter Performance

Unit Filter Run Volume (UFRV) is the average volume of water treated through a filter between backwashes per the filter area (measured in gallons per square foot). Average UFRV for the plant shows a clear decrease over the last 5 years, with a resulting increase in backwash waste percentage. This indicates decreased filter performance or a change in filter operations. This may be due to high settled water turbidity, calcium carbonate precipitation at the filters, poor bed expansion, or operational constraints placed on filter run time. UFRVs and backwash waste percentages are shown in Figure 2.22.

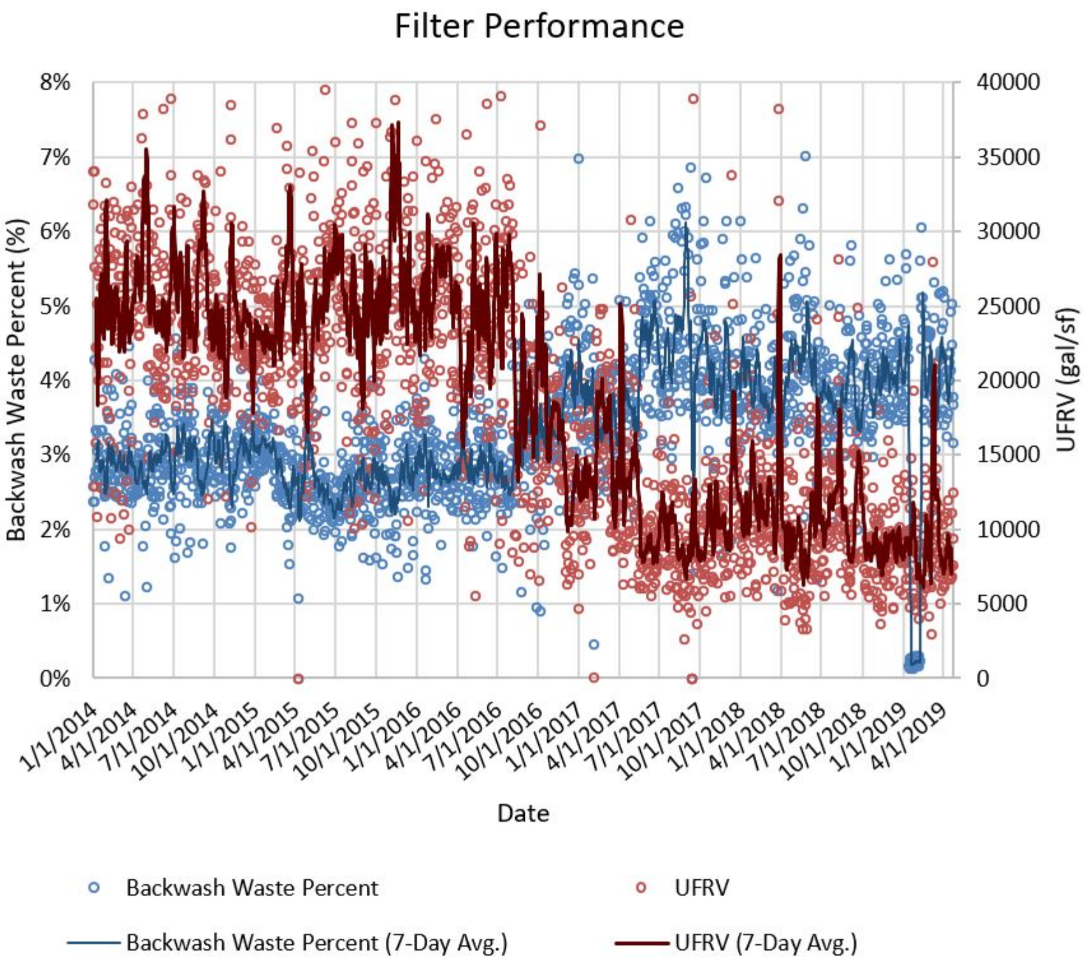

Figure 2.22 UFRV and Backwash Waste Percentage

2.2.2 Hydrotreator Performance

As indicated by the high settled water turbidity, the Hydrotreators are not adequately removing solids despite softening the raw water.

The existing Hydrotreators appear to have the following challenges:

- To function consistently with the equipment intent, the bottom of the Hydrotreators need to have approximately 2 feet of settled solids above the distributor outlet. This solids depth would result in an incredible amount of torque that the mechanical system was not designed for or cannot handle with age.
- There are a large number of influent flow outlets and lime flow outlets that plug over time. As the outlet's plug, flow distribution worsens and results in poorer clarifier performance.
- The mixing of lime and influent flow is poor. There is too much separation, and a significant number of the outlets do not have lime addition anywhere near the discharge of the influent water.

- The original design counts on the perfect accumulation of solids along the length of the distributor arms so that the depth of sludge is the same across the entire basin. This likely does not occur.

2.2.3 Recarbonator Performance

As mentioned previously, the recarbonators do not operate, leading to high pH through the filters (possible calcium precipitation) and high finished water pH.

2.2.4 Aeration Basin Performance

The primary goal of aeration is the removal of H_2S and free carbon dioxide from the raw water. There is not sufficient data to conclude whether or not H_2S or free carbon dioxide are being removed during this process.

2.3 Water Quality Performance Summary

A summary of current Fiveash WTP performance is shown in Table 2.2.

Table 2.2 Existing Plant Performance Summary

Parameter	Units	Raw Water	Settled Water	Finished Water	Finished Goal	Primary MCL	Secondary MCL
Color	CU	42 [32 – 70]	No data	16 [8 – 21]	< 12 (< 5)	NA	< 15
TOC	mg/L	14.4 [9.9 – 17.6]	No data	No data	NA	NA	NA
Alkalinity	mg/L as $CaCO_3$	215 [204 – 230]	110 [63 – 166]	81 [52 – 116]	40 – 100	NA	NA
Free ammonia	mg/L as N	No data	No data	No data	0.05 – 0.10	NA	NA
Total hardness	mg/L as $CaCO_3$	226 [218 – 238]	101 [72 – 140]	84 [66 – 116]	80 – 160	NA	NA
Iron	mg/L	0.44 [0.26 – 0.60]	No data	0.03 [0.02 – 0.05]	< 0.1	NA	< 0.3
Manganese	mg/L	0.004 [0.003 – 0.006]	No data	No data	< 0.02	NA	0.05
Sodium	mg/L	No data	No data	No data	< 50	< 160	NA
Total dissolved solids (TDS)	mg/L	~400	No data	No data	< 500	NA	< 500
Fluoride	mg/L	No data	No data	0.56 [0.47 – 0.66]	0.7	< 4.0	< 2.0
Sulfate	mg/L	~8	No data	No data	< 200	NA	< 250
Chloride	mg/L	59 [52 – 68]	No data	67 [59 – 80]	< 100	NA	< 250
Turbidity	NTU	0.8 [0.19 – 2.41]	8 [2 – 17]	0.16 [0.09 – 0.29]	< 1	NA	NA
H_2S	mg/L	0.185 [0.1 – 0.3]	No data	No data	< 0.1	NA	NA
pH	---	7.34 [7.10 – 7.60]	9.43 [8.48 – 10.06]	9.2 [8.6 – 9.6]	8.0 – 8.5	NA	6.5 – 8.5
TTHM	µg/L	NA	No data	71.7 [2.0 – 75.5]	< 60	< 80	NA
HAA5	µg/L	NA	No data	41.0 [4.5 – 54.4]	< 40	< 60	NA
Langelier Saturation Index (LSI)	---	0.98(1) [0.31 – 1.40]	0.66(2)	0.08(2)	> 0.2	NA	NA
Calcium Carbonate Precipitation Potential (CCPP)	mg/L as $CaCO_3$	13.5(2)	27.4(2)	14.4(2)	4 – 10	NA	NA
Virus inactivation	---	NA	NA	2.5-log	4-log	NA	NA

Notes:
(1) Calculated.
(2) Measured.

Section 3

COLOR CONTROL TECHNOLOGIES

3.1 Background

Color in untreated water is primarily caused by natural organic matter (NOM), especially humic substances such as humic and fulvic acids. There are two primary reasons to remove color from drinking water:

(1) Coloration presents an aesthetic consideration for the customers of the utility, as has been observed in complaints by City of Fort Lauderdale residents.
(2) From a public health and regulatory perspective, NOM exerts a chlorine demand that reduces the effectiveness of disinfection and acts as a disinfection byproduct (DBP) precursor, forming carcinogenic DBPs which are regulated by the USEPA Disinfection Byproduct Rule and the Florida Department of Environmental Protection (FDEP). Despite the link between color, NOM, and DBPs, color is not federally regulated with an MCL. However, the State of Florida has adopted the secondary drinking water standards into state law and therefore the SMCL of 15 CU is considered enforceable in this context.

There are several treatment technologies available for color removal/reduction, including ozone, granular activated carbon (GAC), nanofiltration (NF), reverse osmosis (RO), ion exchange (IX), enhanced lime softening, coagulation, and chlorination. Since the water at Fiveash WTP is highly colored, a combination of technologies will likely be selected. For the purposes of this study, GAC, lime softening, enhanced lime softening with additional chemicals, enhanced coagulation, IX, and NF have all been considered. Although ozone is commonly used for color oxidation, it was not considered for City of Fort Lauderdale due to the possibility of high bromide levels in source water and its documented poor performance in South Florida. At high levels, bromide interacts with ozone to form bromate, a regulated carcinogen.

Predicted performance and bench-scale results are presented below for various color control technologies. Bench-scale materials and methods are described in detail in Appendix A. Appendix B, Bench-Scale Testing Memorandum provides the results of the bench-scale testing activities.

3.2 Anion Exchange

3.2.1 Overview

Anion exchange resins, which exchange negatively charged molecules for chloride ions at the resin surface, are a well-established media for removal of NOM and color. In most waters, NOM functional groups have a tendency to be negatively charged and are therefore attracted to the positively charged anion exchange resins. There are two types of anion exchange resins: weak base (WBA) and strong base (SBA). WBA resins only exchange ions at pH < 6, whereas SBA exchange ions at pH levels from 3 to 13. SBA resins are therefore ideal for drinking water treatment applications.

The two primary types of vessels are fluidized bed reactors in combination with magnetic ion exchange resin, and fixed bed reactors. In a fluidized bed reactor, water enters a gently mixed vessel from the bottom, expanding a bed of ion exchange media before the magnetic properties take over at the top and the resin agglomerates and settles while the water flows out the top of the reactor. This upflow configuration tends to utilize small resin particles (~200 µm diameter), and due to the shear from mixing and pumping, resin will fracture and be lost over time. Since the fluidized bed reactor is completely mixed, it is not as efficient as a plug-flow fixed bed reactor. Fluidized bed reactors have lower power requirements than fixed bed reactors because the resin is fluidized and has minimal headloss as the water flows through the media. The fixed bed ion exchange vessel is a packed bed which has elevated headloss as the water flows through the packed resin media.

In a fixed bed reactor water flows from the top of the vessel down through a column of larger packed resins (~500 µm diameter) and then flows out through an underdrain that supports the resins. Fixed bed ion exchange is very efficient (in terms of anion removal) due to plug flow conditions. Fixed bed reactors have higher power requirements than fluidized bed reactors due to the headloss through the packed bed media.

For both processes, a regeneration cycle is needed in which a concentrated salt brine is exposed to the resins to replenish the exchange capacity. Regeneration in a fluidized bed reactor occurs outside of the reactor in a semi-continuous process using a regeneration system which looks and functions similar to a fixed bed ion exchange vessel. Regeneration in a fixed bed reactor occurs within the vessel periodically when IX capacity is exhausted.

Fluidized bed ion exchange is a proprietary process utilizing a resin called MIEX® (magnetic ion exchange), while fixed bed processes and resins are non-proprietary.

3.2.2 Predicted Color Removal Results

3.2.2.1 MIEX

Bench-scale testing of MIEX resin was performed at the Fiveash facility with a 1000 bed volume regeneration criteria (meaning the resin volume treated 1000 resin volumes of water before it was regenerated). The results of these tests indicated color reductions ranging from 56 percent to 75 percent. For the purposes of water quality analyses (presented in subsequent sections), 56 percent was used as a conservative estimated color removal for MIEX. Due to relatively low removals (especially compared to fixed bed IX), a MIEX system would require an additional treatment step to remove additional color. Bench-scale results are shown in Figure 3.1.

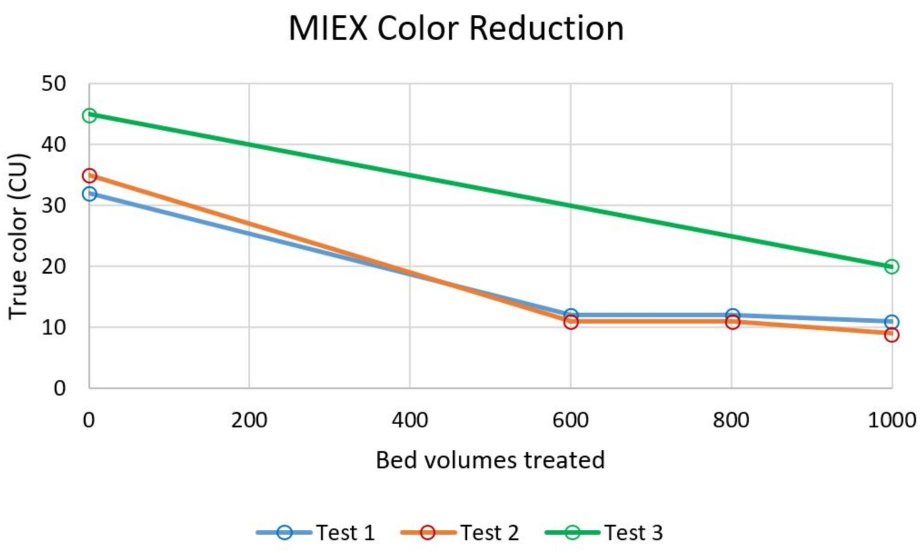

Figure 3.1 MIEX Color Removal: Bench-Scale Results

3.2.2.2 Fixed Bed IX

Fixed bed IX bench-scale results showed removal of nearly all true color for the first 500 bed volumes, with breakthrough above 5 CU occurring at greater than 800 BV and breakthrough above 12 CU occurring at greater than 2200 BV. Color removal for fully regenerated resin is therefore conservatively estimated to be 90 percent, but may be closer to 95-100 percent. These results indicate that fixed bed ion exchange significantly outperforms fluidized bed ion exchange in terms of amount of color removed. Bench-scale results are summarized in Figure 3.2.

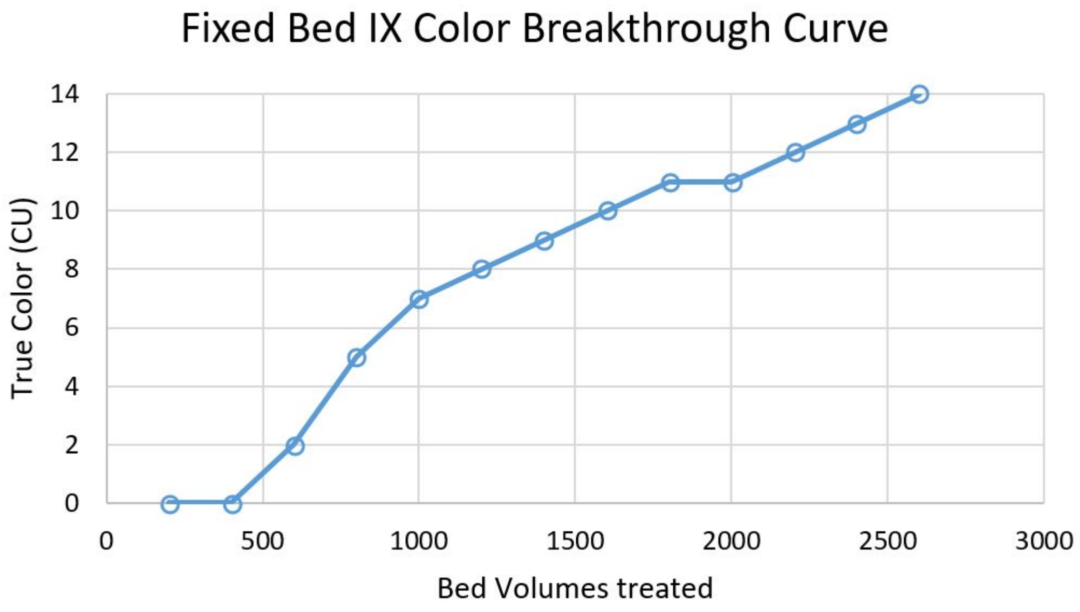

Figure 3.2 Fixed Bed IX Color Breakthrough: Bench-Scale Results

3.2.3 Reliability

3.2.3.1 MIEX

Fluidized bed IX is a technology that has previously been used in South Florida, and color removal results should be expected to be relatively consistent over time. However, as seen from bench-scale tests, treated water color may not meet the conservative goal of 5 CU or even the moderate goal of 12 CU, so even small fluctuations may be problematic with respect to meeting water quality goals. Because this technology would be placed first in the treatment train, another color removal technology could be placed downstream to mitigate fluctuations in fluidized bed ion exchange performance. One additional benefit of fluidized-bed ion exchange is that a small amount of free chlorine and iron in the raw water (as long as iron precipitation does not occur in the reactor) will not affect the process.

3.2.3.2 Fixed Bed IX

Fixed bed IX is a well-established technology that is commonly utilized in South Florida. The reliability exceeds that of fluidized bed in that changing influent conditions would likely not change finished water color, only breakthrough time. However, the placement of fixed bed ion exchange at the end of the treatment train means that performance may be influenced by the performance of upstream processes. The fixed bed ion exchange process cannot handle turbidity or solids so it is typically placed downstream of a filtration process. In addition, fixed bed ion exchange cannot tolerant as much free chlorine as MIEX resin. This is due to the fact that the MIEX resin is cross-linked and the fixed bed ion exchange resin is not. The proprietor of the MIEX process states that the resin can handle up to 1 mg/L of free chlorine and the fixed bed IX resin suppliers will only allow 0.4 mg/L (or less).

3.2.4 O&M Requirements

3.2.4.1 MIEX

Operation of a MIEX system involves three continuously running systems (although there would be multiple units for each): a reactor system, a regeneration system, and a brine system. In contrast to fixed bed ion exchange, which requires periodically stopping and starting of vessel operation for regeneration, resin regeneration in a fluidized bed system happens semi-continuously. MIEX also has low headloss compared to fixed bed ion exchange which minimizes additional pumping. A disadvantage of MIEX is that some resin is lost into the treated water over time, which can affect downstream processes and requires addition of new resin to the regeneration vessel. However, a side benefit of this is that resin never needs to be replaced in bulk. As with any ion exchange system, waste brine disposal may be a concern depending on the requirements of the local utility. Regular salt deliveries are also required to replenish the brine supply.

3.2.4.2 Fixed Bed IX

In contrast to fluidized bed IX, fixed bed IX will not result in any loss of resin over time, but requires replacement of IX media roughly every 10 years. Fixed bed ion exchange also requires pressurized vessels and a brine system, and is placed at the end of the treatment train instead of the beginning. This placement is due to an inability to handle particulate solids. Vessels have a large number of automated valves and extra control instrumentation is required. As with fluidized bed IX, water brine disposal may be a concern. Salt deliveries are required to replenish the brine supply. Typically the resin is backwashed prior to regeneration to eliminate any accumulated solids and to fluidize the media which may pack down during normal operation.

3.2.5 Footprint

(In this report the term *footprint* refers to the ground area (in square feet) required for a given technology or treatment alternative.)

3.2.5.1 MIEX

A MIEX system has a smaller footprint when compared to a fixed bed ion exchange system and can be installed as a high-rate system with rise rates of 8-10 gpm/sq ft or greater (for short periods of time because additional resin loss will occur). At 50 mgd, a fluidized bed system would require approximately 12,100 sq ft (taking into account space for ancillary equipment). This footprint is a scaled estimate based on previous MIEX installations.

3.2.5.2 Fixed Bed IX

Pressurized vessels are the conventional option for a fixed bed IX system. These vessels typically treat at rates up to approximately 8 gpm/sq ft, and when considering the footprint, space must account for necessary distances between vessels, walkways, valves, and piping. The total footprint at 50 mgd of a fixed bed system is estimated to be approximately 19,040 sq ft. This is larger than for fluidized bed, but smaller than softening-based color removal alternatives. This footprint is a scaled estimate based on previous fixed bed IX installations.

3.3 Softening and Coagulation

3.3.1 Overview

Conventional lime softening is a process of adding lime (CaO which is slaked to $Ca(OH)_2$) to a source water to precipitate calcium, and sometimes magnesium, to remove hardness. When lime is slaked using water, it is converted to calcium hydroxide under high temperature conditions, which, when added to the water raises the pH of the process. When the pH is raised to the point of calcium precipitation (approximately 9.4), calcium carbonate will begin to precipitate provided that there is enough alkalinity available to form carbonate solids.

Enhanced lime softening differs from conventional softening in that the lime dose is increased past the point of minimal calcium hardness for the purpose of removing NOM. In this case, NOM coprecipitates with and adsorbs to calcium and magnesium precipitates. This means that the amount of NOM removal achieved during the softening process depends primarily on two variables: the amount of precipitate available for coprecipitation and adsorption (represented by the ratio of Ca^{2+} and Mg^{+2} to DOC and the ratio of total hardness to DOC) and the affinity of the NOM for the precipitates. Calcium precipitates remove less organics than magnesium because calcium carbonate is crystalline with a low surface area and negative charge and magnesium hydroxide is gelatinous with a high surface area and a positive charge.

NOM aromaticity, hydrophobicity, specific UV absorbance (SUVA), and high-molecular-weight fraction are all positively correlated with increased NOM removal during enhanced softening. Additionally, higher initial pH levels and corresponding magnesium removal tends to increase NOM removal.

A previous enhanced lime softening study (which included samples from Ft. Lauderdale) showed an approximately 40 percent DOC removal when lime dose was increased to ~175 percent of conventional softening dose (dose required to reach the calcium removal pH). 15 percent NOM removal was achieved through the conventional lime dose and an additional 25 percent removal was achieved after the dose was increased. The slope of removal vs. lime dose tended to increase the most at 125 – 175 percent of conventional doses, the range in which magnesium precipitation occurred. This supports the premise that NOM has a higher affinity for magnesium precipitates than calcium precipitates. DBP concentrations both decreased with higher lime doses, likely due to lower levels of DBP precursors.

Using synthetic water batch tests, Kalscheur et al. (2006) found that a calcium to magnesium ratio in source water of 3:1 resulted in 72 percent removal of fulvic acids (component of color) vs. 35 percent removal with negligible magnesium levels. Russell et al. (2009) and Singer (1999) also describe significantly higher NOM removal with increased initial magnesium concentrations. However, precipitation of $Mg(OH)_2$ for NOM removal is often avoided at softening plants due to difficulty in settling and dewatering the large, low-density flocs that form. This is a challenge from both a process and financial perspective. Nevertheless, due to the color challenges at Fiveash WTP, supplemental magnesium addition in the form of $MgCl_2$ should be considered for enhanced NOM removal.

3.3.2 Predicted Color Removal Results

3.3.2.1 Conventional Lime Softening to $CaCO_3$ Precipitation pH

Bench-scale tests using lime softening without magnesium addition on Fiveash raw water showed moderate color removal. Figure 3.3 shows bench-scale results. It should be noted that this type of softening would only utilize a softening pH of 9.4 (the pH at which only $CaCO_3$ precipitates), and therefore the expected percent removal of color is only 29 percent according to the color reduction at this pH from the bench-scale results.

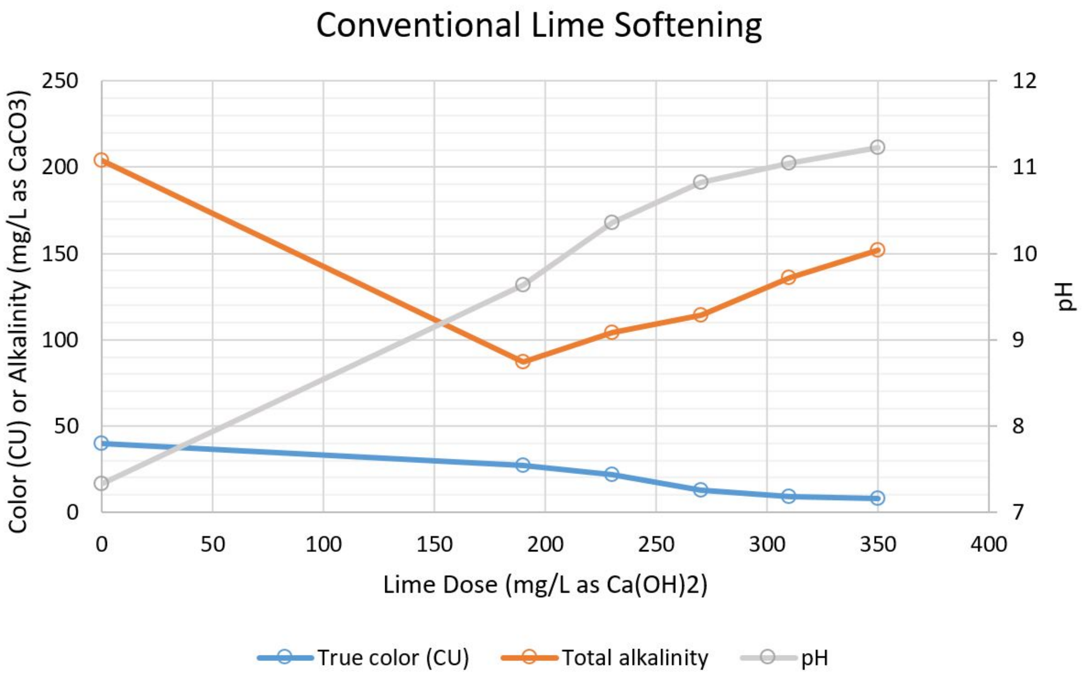

Figure 3.3 Conventional Lime Softening Bench-Scale Results

3.3.2.2 Enhanced Lime Softening with Magnesium Chloride Addition

In a bench-scale test, magnesium chloride ($MgCl_2$) was added at varying levels to Fiveash raw water with a varied lime dose and 0.2 mg/L of a bridging polymer. Results for true color are shown in Figure 3.4. With a lime dose of 430 mg/L, true color decreased as $MgCl_2$ doses increased, with minimum color averaging 8 CU at 60 mg/L $MgCl_2$. This represents a 70 percent removal on average. The series shown on the plot with lime dose of 310 mg/L as $CaCO_3$ represents an example where pH was not raised to the magnesium precipitation pH of 10.8. Based on these results, $MgCl_2$ supplementation will be effective if the lime dose is high enough to reach the magnesium precipitation pH.

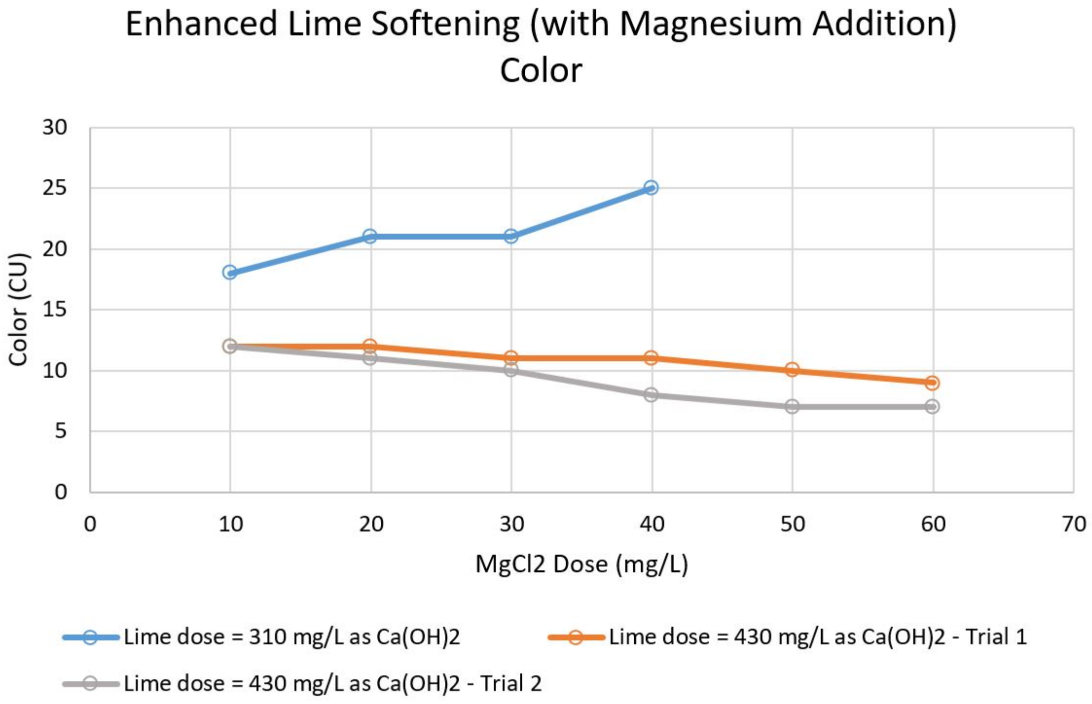

Figure 3.4 Enhanced Lime Softening with MgCl2 Addition: Bench-Scale Results

3.3.2.3 Lime Softening with Ferric Sulfate Addition

Ferric sulfate can also be added as an additional NOM removal chemical during the softening process (whether conventional or enhanced softening). Bench-scale tests, in which both lime and ferric sulfate were added to raw water (sequentially), show that the effect of lime dose on color removal was somewhat insignificant compared to the impact of ferric sulfate, as shown in Figure 3.5. Ferric doses above 40 mg/L consistently reduced color below 12 CU. The data collected show that doses above 200 mg/L reduced color below 5 CU. 80 mg/L of ferric sulfate without lime resulted in 81 percent color removal.

Since ferric sulfate lowers the pH of the water while lime raises the pH, ability to soften may be somewhat limited in this case, and management of the chemistry would be complex. Therefore, it is preferred to add lime (softening) and ferric sulfate (enhanced coagulation) in separate processes to achieve hardness and NOM removal, respectively. In this case enhanced coagulation would precede softening. An additional benefit of adding ferric sulfate is the lowered finished water CSMR (discussed in Section 2.1.9.1).

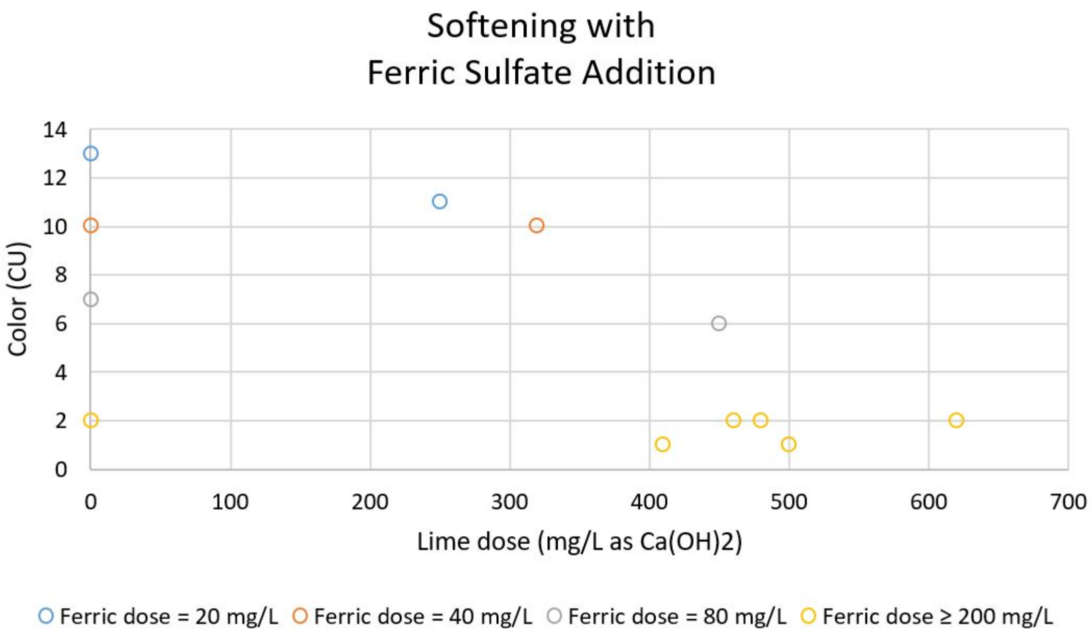

Figure 3.5 Lime Softening with Ferric Sulfate Addition: Bench-Scale Results

3.3.3 Reliability

3.3.3.1 Conventional Lime Softening to $CaCO_3$ Precipitation pH

Lime softening is a proven chemical technology for hardness and color removal. However, enhanced softening chemistry is complex and challenging to manage, and therefore changes in influent conditions or chemical dosing may have a negative impact on color removal levels. If this technology is to be used for color removal, conservative hardness and color targets should be set to account for variability in finished water color.

3.3.3.2 Enhanced Lime Softening with Magnesium Chloride Addition

Reliability considerations are similar to those of lime softening without additional chemicals, except that more color removal will occur with magnesium addition and therefore color targets would be easier to achieve. One concern with this type of softening is running out of alkalinity to precipitate solids, especially considering that Fiveash WTP's raw water is relatively low in alkalinity compared to hardness. This may necessitate the use of sodium hydroxide or soda ash instead of (or in addition) to lime.

3.3.3.3 Lime Softening with Ferric Sulfate Addition

Addition of Ferric Sulfate to Softening Process

Due to the complexity of the chemistry of adding pH-lowering and pH-raising chemicals into the same basin, this process would not be considered reliable, especially with varying influent water quality conditions. Ferric sulfate is also more effective at color/TOC removal at lower pH levels so combining the processes is considered to be much less efficient than separating them.

Enhanced Coagulation as a Separate Process

Ferric sulfate may be added in a separate enhanced coagulation process, including coagulation, flocculation, and sedimentation, in which the primary goal is NOM/TOC removal. This approach will provide additional reliability in that one process would consistently remove hardness and one process would consistently remove NOM. Adjustments to changing influent conditions would be more easily manageable and pH control would be relatively straightforward. This also affords the opportunity for a forced draft aeration process after the enhanced coagulation where the lowered pH will allow for better hydrogen sulfide removal. The aeration process will also remove free carbon dioxide which reduces the lime dose required in the softening process.

3.3.4 O&M Requirements

3.3.4.1 Conventional Lime Softening to $CaCO_3$ Precipitation pH

The operational requirements of a conventional softening system would not vary significantly from the existing softening process at the plant. Lime and polymer would be dosed to the softening system as they are now. As with any softening system, precipitation of solids on equipment is common and will present maintenance considerations.

3.3.4.2 Enhanced Lime Softening with Magnesium Chloride Addition

The O&M requirements of enhanced softening with magnesium are similar to that of softening without additional chemicals, but with additional chemical cost, storage, pumping, and solids disposal. Solids formed by magnesium are more difficult to dewater compared to solids formed by conventional lime softening. The chemistry will be more complex and will need to be carefully managed. Sodium hydroxide or soda ash may also need to be considered in this case due to the probability of running out of alkalinity to form solids.

3.3.4.3 Lime Softening with Ferric Sulfate Addition

Addition of Ferric Sulfate to Softening Process

The O&M requirements of enhanced softening with ferric sulfate are similar to that of softening without additional chemicals, but with additional chemical cost, storage, pumping, and solids disposal. Dosing ferric sulfate to the softening process will also consume alkalinity and lower pH, and therefore the chemistry of the process will require careful control and may require additional chemicals. To keep pH high for softening, it may be necessary to add sodium hydroxide or soda ash. Both of these chemicals will provide the carbonate necessary for a complete reaction and to achieve finished water hardness goals.

Enhanced Coagulation as a Separate Process

Adding ferric sulfate separately from the softening process allow separation of hardness and NOM removal, resulting in more easily manageable chemistry for each process. However, adding a flocculation/sedimentation process will require increased power, solids handling, and control of coagulation chemistry. With a groundwater source, the addition of a coagulant is only used for TOC removal and is not required for particulate removal, so the coagulant dose added will be solely based on desired TOC/color removal and the typical challenges associated with particle charge neutralization (getting the dose exactly right) will not be required.

3.3.5 Footprint

3.3.5.1 Conventional Lime Softening to $CaCO_3$ Precipitation pH

Conventional lime softening without additional chemicals requires a rise rate of less than or equal to 1.75 gpm/sq ft. At 50 mgd the total clarifier area required would be approximately 19,800 sq ft, similar to the land area occupied by the existing softening system. Taking into account the extra space around the clarifiers (concentric squares), the approximate footprint would be 25,200 sq ft.

3.3.5.2 Enhanced Lime Softening with Magnesium Chloride Addition

In contrast to softening without additional chemicals, the rise rate for a system with supplemental magnesium would need to stay below 1.25 gpm/sq ft. For a 50 mgd plant, approximately 32,000 sq ft of clarifier area would be required. Taking into account the extra space around the clarifiers, the approximate footprint would be 40,700 sq ft.

3.3.5.3 Enhanced Coagulation

If ferric sulfate is used as part of an enhanced coagulation system (preceding softening), a conventional flocculation/sedimentation system or a sand ballasted clarification will need to be installed. A conventional system would consist of a rapid mix step and flocculation step followed by sedimentation with plate settlers and hoseless sludge collectors. This system is estimated to have a footprint of approximately 25,000 sq ft for a 50 mgd treatment capacity. A sand ballasted flocculation and clarification system is another option, consisting of micro-sand flocculation and lamella tube settlers. This option is much more compact than a conventional system and would have a footprint of approximately 6,000 sq ft for 50 mgd of treatment.

3.4 Nanofiltration

3.4.1 Overview

Nanofiltration (NF) is a well-established pressure-driven membrane technology for removal of both color and hardness, and is therefore a candidate as a treatment technology for the Fiveash WTP. In most cases, NF can remove more than 95 percent of color. Membranes also have the added benefit of being more resistant to seasonal changes to raw water quality than media filtration.

Excessive solids, such as iron particles, fine sands, or debris will result in NF membrane fouling and may cause mechanical damage to the NF membrane element material. Sand separators and disposable cartridge filters are therefore provided as part of a packaged NF system as a final barrier to protect the NF membrane elements against fouling or damage from these particulates.

3.4.2 Predicted Color Removal Results

NF for color removal can utilize a low-pressure membrane specifically designed for color rejection, such as the Nitto HydraCoRe 50, which is expected to remove more than 99 percent of color. A three-stage modeled system using these membranes can also provide an approximately 75 percent reduction in hardness and a 68 percent reduction in TDS. This model utilizes an 85 percent flow recovery and predicted results are shown in Table 3.1.

Table 3.1 Nanofiltration Estimated Results (3-stage HydraCoRe 50)

Parameter	Change through Membrane Skid
Flow	- 15 %
Pressure	- 69.1 psi
Color	- 99%
Alkalinity	- 70%
Free ammonia	- 29%
Total hardness	- 72%
Iron	- 72%
Manganese	- 66%
Sodium	- 54%
Total dissolved solids (TDS)	- 68%
Fluoride	- 69%
Sulfate	- 99%
Chloride	- 57%
Turbidity	- 99%
pH	- 0.50
Silica	- 53%

3.4.3 Reliability

NF is a well-established technology for hardness and organics removal, and results are fairly easy to predict using modeling. Since color removal is near 100 percent, changing influent conditions should not have a large impact on the ability to meet color removal goals. No problematic constituents exceed their saturation levels so it is likely that fouling will not be a concern. Since saturation limits are not reached at an 85 percent flow recovery, the membranes could be reconfigured (4-stage system) to obtain an even higher percent recovery.

3.4.4 O&M Requirements

Operations and maintenance considerations for nanofiltration include power consumption (due to the pressure requirements of the membranes), membrane cleaning, replacement of cartridge filters, membrane replacement due to damage or age (typically 7-10 years), higher water requirements due to water loss in the concentrate stream, and disposal of the NF concentrate into a deep injection well.

3.4.5 Footprint

For a 50 mgd HydraCoRe system with cartridge filters, the total footprint is estimated to be approximately 15,040 sq ft. See Table 3.2 for NF footprint calculations. Note that in most cases, the NF treatment system will not need to have a 50 mgd capacity as it will have a bypass option that may be utilized up to 50 percent, depending on the treatment train. This is further discussed in subsequent sections.

Table 3.2 Nanofiltration Footprint Calculations

Description	Units	Value
Recovery	%	85
Permeate Flow Per Train	mgd	12.5
Permeate Flow Total	mgd	50
Number of Stages per Train	No.	3
1st Stage: Pressure Vessels per Train	No.	186
2nd Stage: Pressure Vessels per Train	No.	92
3rd Stage: Pressure Vessels per Train	No.	49
Elements per Pressure Vessel	No.	6
Total Elements	No.	7,848
Average ground area needed per vessel(1)	sq ft	11.5
Total ground footprint (50 mgd NF)	sq ft	15,040

Notes:

(1) Estimated from an existing membrane installation with 8-vessel-high stacking.

3.5 Granular Activated Carbon

3.5.1 Overview

Granular activated carbon (GAC) is a well-established technology for removal of NOM from drinking water. GAC's heterogeneity, high porosity, and high surface area allows it to effectively adsorb a variety of organic compounds. In general, GAC will remove nearly all of the NOM from a source water (depending on the non-adsorbable fraction of NOM) and then begin to increase when all adsorption sites have been filled. The empty bed contact time (EBCT) of a GAC vessel has a significant impact on the initial NOM removal level, with higher contact times (~20 min) leading to more sustained removal. Background water quality parameters also affect the effectiveness of GAC for NOM removal; lower influent NOM levels and higher pH levels tend to result in higher percent removals over time.

3.5.2 Predicted Color Removal Results

GAC will adsorb the vast majority of organics except for the non-adsorbable fraction (which is typically not composed of organics that cause color). The primary consideration with GAC is how long the removal will last; at some point the contaminant in question will begin to 'break through,' meaning that it will begin to increase in concentration above the desired treated water level. At this point the GAC needs to be replaced or regenerated. Breakthrough plots for bench-scale tests with influent color of 14 CU (filtered plant water) are shown in Figure 3.6. Filtered water is used because the GAC process would be placed downstream of the dual media filtration process. As shown in the figure, breakthrough above 5 CU and 12 CU in the treated water both occurred fairly quickly due to high TOC and color. Based on these results, the estimated time between GAC regeneration cycles or replacement is summarized in Table 3.3.

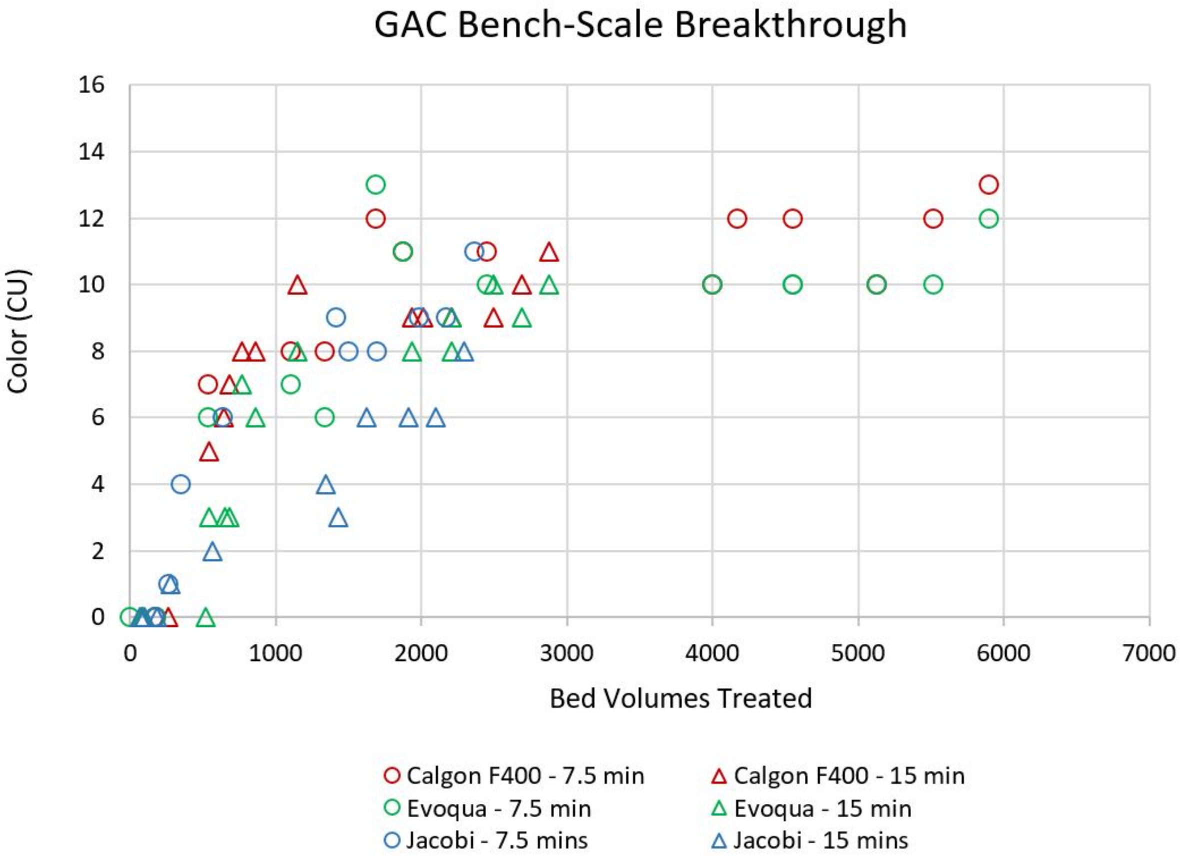

Figure 3.6 GAC Bench-Scale Breakthrough Results

Table 3.3 GAC Bench-Scale Breakthrough Time Summary

Carbon	EBCT (min)	Influent Color (CU)	Breakthrough Color (CU)	Bed Volumes to Breakthrough	Breakthrough Time (days)
Calgon F400	7.5	14	5	430	2.2
			12	No data	-
		28(1)	5	215	1.1
			12	Unknown	-
	15	14	5	545	5.7
			12	No data	-
		28(1)	5	272	2.8
			12	Unknown	-
Evoqua	7.5	14	5	500	2.6
			12	1,600	8.3
		28(1)	5	250	1.3
			12	800	4.2
	15	14	5	730	7.6
			12	1,800	18.8
		28(1)	5	365	3.8
			12	1,300	13.5
Jacobi	7.5	14	5	494	2.6
			12	Test ongoing	-
		28(1)	5	247	1.3
			12	Unknown	-
	15	14	5	Test ongoing	-
			12	Test ongoing	-
		28(1)	5	Unknown	-
			12	Unknown	-

Notes:

(1) Bed volumes and breakthrough time for 28 CU influent color are scaled estimates based on 14 CU influent data. 28 CU represents a maximum color that may appear in Fiveash filtered water at certain times of the year.

As shown in Table 3.3, the Evoqua GAC had the longest breakthrough times and therefore is considered the best-performing carbon for this application. Despite the performance exceeding the Calgon and Jacobi options, the breakthrough times are still very short due to high TOC levels. This significantly affects O&M and is discussed further in subsequent sections.

3.5.3 Reliability

Granular activated carbon is a well-established technology for adsorbing organic matter, and is able to remove NOM regardless of changing influent conditions. However, due to high influent color and TOC levels, breakthrough will occur very quickly, and therefore the reliability is only maintained if GAC is replaced at the appropriate frequency.

3.5.4 O&M Requirements

Granular activated carbon requires replacement or regeneration when all adsorption sites have been filled and contaminant breakthrough begins to occur. Typically breakthrough is on the order of a few months, but as was shown during Fiveash bench-scale testing with a 7.5 min EBCT influent color of 14 CU, color breakthrough above 5 CU occurred within 2.6 days and breakthrough above 12 CU occurred within 8.3 days (with the best-performing carbon). With a 15 minute EBCT, breakthroughs would occur at 7.6 and 18.8 days, respectively. These times may be shortened if influent color is higher than normal. Therefore GAC regeneration would need to occur every few days presenting a substantial O&M and cost issue. Frequent GAC regeneration would cause O&M costs to be one to two orders of magnitude higher than the other alternatives (likely greater than $100 million/year).

3.5.5 Footprint

A full-scale 50 mgd GAC system would require approximately 37,800 sq ft (15 min EBCT) or 19,600 sq ft (7.5 min EBCT) of land. Footprint calculations are summarized in Table 3.4.

Table 3.4 GAC Footprint for 50 mgd of Treatment

Parameter	Units	7.5 min EBCT	15 min EBCT
Weight of GAC required	tons	522	1045
Vessel capacity	lbs	40,000	
Number of vessels required (two extra for redundancy)	N/A	28	54
Vessel footprint (including buffer space)	sq ft	700	
Total land area required	sq ft	19,600	37,800

3.6 Chemical Oxidation

3.6.1 Chlorination

As part of future water plant design, chlorine and ammonia dosing will be tailored to achievement of 4-log virus removal. Chlorine has the added benefit of providing some color removal through oxidation, but should not be relied upon for meeting color requirements, due to limited reduction in color. Bench-scale chlorine data was limited but results suggest that chlorination would likely only result in an approximately 10 percent reduction in color. Adding larger amounts of chlorine is not recommended due to potential for increased regulated and unregulated DBP formation along with the additional complexity of dechlorination/rechlorination processes.

3.6.2 Ozonation

The use of ozone was not considered for Ft. Lauderdale due to the possibility of high bromide levels as previously stated.

3.7 Comparison of Color Control Technologies

A summarized comparison of color control technologies is presented in Table 3.5. Included are color removal estimates, other water quality considerations, estimated footprint at 50 mgd of treatment, water loss, reliability, O&M considerations, waste streams, and other advantages and disadvantages.

Table 3.5 Comparison of Color Control Technologies

	Fluidized-Bed IX (MIEX)	Fixed Bed IX	Conventional Softening	Enhanced Softening with MgCl2	Enhanced Coagulation	Nanofiltration	GAC
Color Removal	• 56%-70%. • Lower efficiency than fixed bed system due to CSTR configuration.	• 90-100%. • Higher efficiency than MIEX due to plug flow reactor configuration.	• 29%.	• 79%.	• 81%.	• 99%.	• 99%. • Breakthrough occurs quickly.
Other Water Quality Considerations	• Chloride to sulfate mass ratio increase. • May not de-sorb organics during regeneration (resin fouling). • If chlorine is needed pre-IX, there will be an increase in DBPs. • Removal of TOC helps optimize subsequent processes and prevent DBPs downstream. • Does not soften. • Allows independent control of color and hardness	• Chloride to sulfate mass ratio increase. • Removal of TOC does not help optimize other processes due to location in treatment train. • Does not soften. • Allows independent control of color and hardness	• Softens. • Does not affect chloride to sulfate mass ratio.	• Softens. • Does not affect chloride to sulfate mass ratio. • Other potential water quality benefits.	• Decreases chloride to sulfate ratio, inhibiting lead release, and reducing corrosion (effect is coagulant dependent). • Increases TDS. • Consumes some alkalinity. • Allows independent control of color and hardness. • Does not soften (additional softening process required).	• Ability to remove hardness and additional organics. • Removal of future regulatory contaminants. • Potential for over-softening. • Excessive mineral removal can result in less stabilized water in distribution System.	• Removes a wide range of other organics, CECs, T&O, SOCs. • Does not soften. • Does not affect chloride to sulfate mass ratio.
Footprint for 50 mgd of finished water	• 12,100 sq ft. • Not easily scalable for future expansion.	• 19,040 sq ft. • Easily scalable modular system.	• 25,200 sq ft.	• 40,700 sq ft.	• 25,000 sq ft.	• 15,040 sq ft.	• 37,800 sq ft (15 min EBCT). • 19,600 sq ft (7.5 min EBCT).
Loss of Flow (Water Recovery)	• Minimal.	• Minimal.	• Minimal.	• Minimal.	• Minimal.	• 10% - 25% loss (75% - 90% recovery) • Requires additional source water.	• Minimal.

Table 3.5 Comparison of Color Control Technologies (Continued)

	Fluidized-Bed IX (MIEX)	Fixed Bed IX	Conventional Softening	Enhanced Softening with MgCl2	Enhanced Coagulation	Nanofiltration	GAC
Reliability	• Used in South Florida. • Cannot be relied upon for color removal without pairing with a more effective technology. • Handles some free chlorine. • Iron does not affect process.	• Used in South Florida. • Extremely reliable for color removal. • Cannot handle free chlorine or particulates, fouling can occur.	• NOM removal may change significantly depending on water quality.	• Proven technology. • NOM removal may change significantly depending on water quality.	• NOM removal may change depending on water quality.	• Common in South Florida.	• Well-established, thoroughly researched technology for NOM removal. • Breakthrough time can change if influent water quality changes. • Potential for contaminant desorption.
O&M	• Low headloss. • Biological growth/fouling on resin can occur. • Loss of media, carryover into remaining unit processes. • No bulk replacement of media, continuous change-out instead. • Ongoing resin handling required. • Brine storage/salt delivery required. • Simple, highly automated process. • Continuous resin replacement is most significant recurring cost. • More labor intensive.	• No loss of media. • High number of automated valves. • Bulk media change-out every ~10 years, must be planned for. • Higher headloss. • . • Requires a backwash system. • Brine storage/salt delivery required. • Simple, highly automated process. • Less labor intensive.	• Similar to existing process. • Proven technology. • Low operational cost. • Chemistry can be complex. • Precipitation occurs on equipment surfaces. • More labor intensive.	• Similar to existing process. • Low operational cost. • Chemistry can be complex. • Precipitation occurs on equipment surfaces. • More labor intensive.	• Additional process adds complexity to plant. • Chemistry can be complex. • More labor intensive.	• Predictable process with simple operation. • Lower pressure than RO. • Power required for pressure loss through membranes. • Potential for fouling. • Membrane replacement. • Membrane cleaning/chemicals. • Cartridge filter replacement. • Less labor intensive.	• Flexible, simple operation. • Frequent media replacement. • Extremely high O&M costs for media replacement. • Fine particulates can migrate to GAC. • Deposition of calcium carbonate on media causes inefficient regeneration. • More labor intensive.
Waste Streams	• No solids disposal. • Brine disposal required.	• No solids disposal. • Brine disposal required.	• Solids disposal and processing.	• Solids disposal and processing. • Magnesium solids more difficult to handle and de-water than calcium solids.	• Solids disposal.	• Large amount of concentrate disposal.	• Backwash waste (minimal). • Spent GAC disposal/regeneration required.
Other Advantages	• Precedes other treatment processes – provides downstream benefits.	• Non-proprietary process.	• Non-proprietary process.	• Non-proprietary process.	• Non-proprietary process.	• Non-proprietary process.	• Non-proprietary process.
Other Disadvantages	• Proprietary resin and process.						

Section 4

TREATMENT PROCESS ALTERNATIVES

In this section several treatment process alternatives are presented, including a description of the treatment train, a process flow diagram, and a summary of advantages and disadvantages for each option. This section is used as a screening process from which a smaller number of viable alternatives are selected and discussed in greater detail in Section 5.

Due to the numerous locations where chlorine and ammonia injection can take place, along with the options and complexities of the dosing, these chemicals are considered a preliminary design item and not further evaluated within the treatment alternatives. For all alternatives, 4-log virus inactivation is feasible, and further consideration of chlorine and ammonia dosing locations and other means to achieve 4-log inactivation can be assessed during future design phases.

4.1 Alternative 1: Enhanced Lime Softening

This alternative includes forced draft aeration for H_2S and CO_2 removal (CO_2 exerts a lime demand and produces excess solids), enhanced softening in solids contact clarifiers for hardness, alkalinity, and color removal, recarbonation for stabilizing the settled water, and filtration for turbidity reduction. A bypass is provided around the softening process in case higher treated water hardness is desired. Magnesium chloride is added to the softening process to aid in NOM removal (co-precipitation with magnesium hydroxide). Ferric sulfate can be added in place of magnesium chloride, but the softening chemistry would be very complex and would potentially require a switch to sodium hydroxide instead of lime due to the alkalinity consumption of the ferric sulfate. A process flow diagram of Alternative 1 is presented in Figure 4.1. Advantages and disadvantages are discussed in Table 4.1.

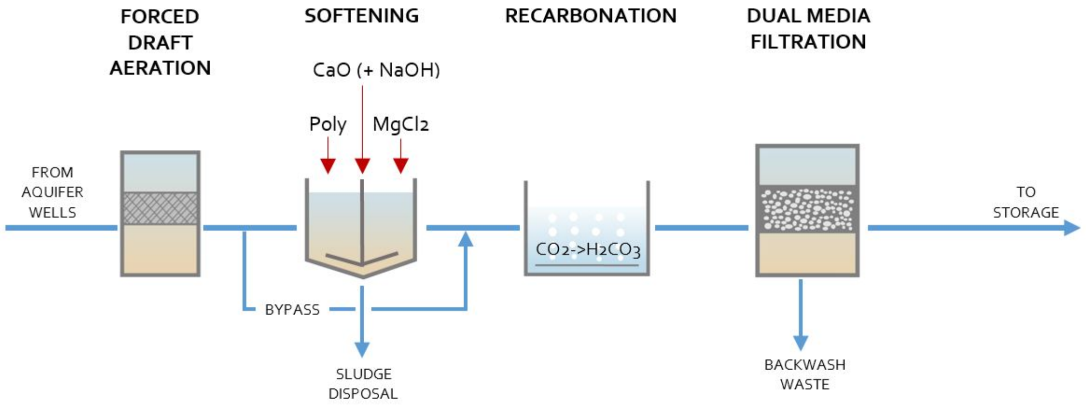

Figure 4.1 Alternative 1 Process Flow Diagram

Table 4.1 Alternative 1 Advantages and Disadvantages

Advantages	Disadvantages
• Few unit processes. • Ability to meet hardness and alkalinity requirements. • Aeration removes H_2S, VOCs, and free CO_2. • Enhanced softening removes inorganic metals such as iron, manganese, and arsenic. • Operation similar to the existing plant process, minimal operator training required. • Small footprint. • Low amount of wasted water (increased water allocation is not needed). • No proprietary technologies. • Not mechanically intensive. • High level of safety for public and employees. • Low power requirements. • Gravity flow through the plant.	• Finished water color and TOC will not meet project goals in most cases. • Enhanced softening chemistry can be complex and changes with influent conditions due to limited alkalinity. • SOCs and emerging contaminants are not removed. • Slaking lime and handling dry chemicals can be challenging. • Low flexibility in softening process (bypass is limited due to color goals). • Aeration of H_2S depends on raw water pH so performance is less predictable than other lower pH options. • Lime softening and gravity filtration rely on a high degree of manual operation. • Cost risk associated with solids disposal. • Magnesium solids handling more difficult and expensive than for calcium solids. • Clarifier footprint is larger than for calcium-only softening, due to lower rise rate required for magnesium precipitation. • Wide range of finished water hardness. • Increased solids production and handling.

4.2 Alternative 2: Lime Softening and Fixed Bed IX

This alternative is similar to Alternative 1 except that conventional lime softening is used instead of enhanced softening and a fixed bed IX process is added to the end of the treatment train. A bypass is included around the fixed bed IX vessels, which can be utilized to save on IX O&M costs as long as finished water color goals are still achieved.

Possible variations of this alternative include replacing conventional softening with pellet softening (similar softening process with a smaller footprint but no color removal), adding magnesium chloride to the conventional softening process to increase color removal (requires larger clarifier footprint), adding ferric sulfate to the softening process, or replacing the IX vessels with a gravity IX system (larger footprint but less power usage and valves/vessels to maintain). A process flow diagram of Alternative 2 is presented in Figure 4.2. Advantages and disadvantages are discussed in Table 4.2.

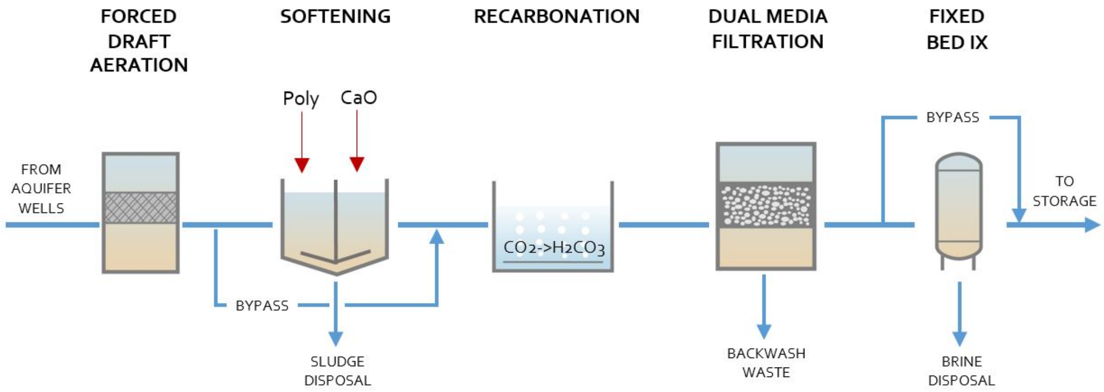

Figure 4.2 Title Alternative 2 Process Flow Diagram

Table 4.2 Alternative 2 Advantages and Disadvantages

Advantages	Disadvantages
• Good color and TOC removal. • Color removal flexibility using IX bypass. • Most color removal occurs in IX so there is flexibility to use the softening bypass as much as needed • Few unit processes. • Ability to meet hardness and alkalinity requirements. • Operation similar to existing plant process (except for IX), operator training minimal. • IX operation is mostly automated. • Aeration removes H_2S, VOCs, and free CO_2. • IX can remove other inorganic anions (perchlorate, chromate, and nitrate). • Operation similar to existing plant process. • Higher clarifier rise rate can be utilized due to calcium-only softening. • No proprietary technologies. • Not mechanically intensive. • Experience with fixed bed IX in South Florida. • Lower finished water sodium than other softening options.	• SOCs and emerging contaminants not removed. • Slaking lime and handling dry chemicals can be challenging. • Lime softening and gravity filtration rely on a high degree of manual operation. • Aeration of H_2S depends on raw water pH so performance is less predictable and other lower pH options. • Cost risk associated with $CaCO_3$ disposal. • Alternative requires a transfer pump station. • Potential requirement for deep well brine disposal if sewer disposal is not feasible. • Vessel IX requires a significant number of valve actuators to maintain (more maintenance).

4.3 Alternative 3: Enhanced Softening and MIEX

Alternative 3 is similar to Alternative 2, except MIEX is used instead of fixed bed IX (placed before the softening process instead of at the end of the treatment train), and enhanced softening is used instead of conventional softening. Magnesium chloride is added for enhanced color removal, and lime is supplemented with sodium hydroxide. This is due to the likelihood of running out of carbonate alkalinity when raising the pH with lime only. One possible variation of this alternative is to replace conventional softening with pellet softening (smaller footprint but no color removal). A process flow diagram of Alternative 3 is presented in Figure 4.3. Advantages and disadvantages are discussed in Table 4.3.

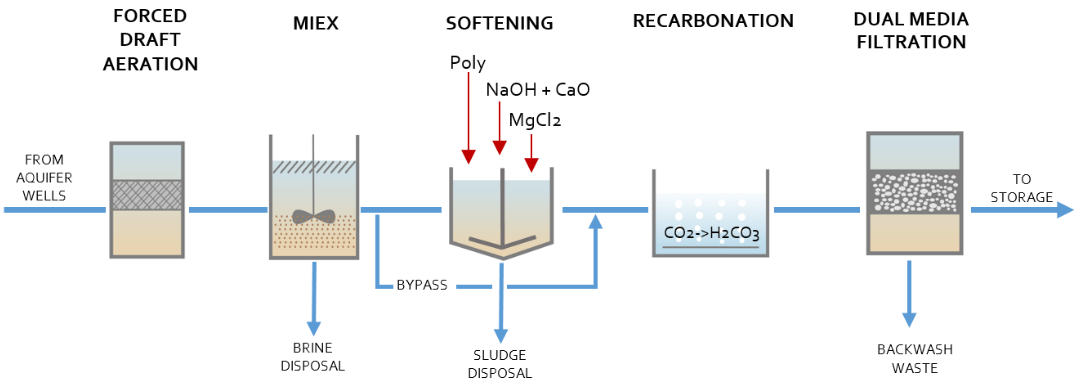

Figure 4.3 Alternative 3 Process Flow Diagram

Table 4.3 Alternative 3 Advantages and Disadvantages

Advantages	Disadvantages
• Few unit processes. • Ability to meet hardness and alkalinity requirements. • Aeration removes H_2S, VOCs, and free CO_2. • MIEX can remove other inorganic anions (perchlorate, chromate, and nitrate). • Operation similar to existing plant process (except for MIEX), minimal operator training required. • MIEX has smaller footprint than fixed bed IX. • Low power use compared to fixed bed IX. • Enhanced softening will remove radionuclides. • Potential chlorine reduction with MIEX if chlorine is added before filtration. • Experience with MIEX in South Florida. • Consistent finished water hardness. • Does not require the number of valve actuators of a fixed bed IX system.	• MIEX color removal is lower and less reliable than fixed bed IX. • Ability to utilize softening bypass is limited due to difficulty in meeting color goals. • Enhanced softening chemistry can be complex and changes with influent conditions • SOCs and emerging contaminants not removed. • Slaking lime and handling dry chemicals can be challenging. • Aeration of H_2S depends on raw water pH, so performance is less predictable than other lower pH options. • Softening and gravity filtration rely on a high degree of manual operation. • MIEX resin inventory tracking is operations-intensive. • Chemical dosing may rely on a certain degree of manual operation (as opposed to automated operation). • Cost risk associated with solids disposal. • Magnesium solids handling more difficult and expensive than for calcium solids. • Lower clarifier rise rate required for enhanced softening. • MIEX is proprietary, resin supply and equipment dependent on manufacturer. • More mechanically intensive than fixed bed IX. • Possible resin de-sorption of organics during regeneration due to resin fouling. • Deep well injection may be required if MIEX brine cannot be sent to sewer. • NaOH adds sodium to the finished water.

4.4 Alternative 4: Enhanced Lime Softening and GAC

This alternative is similar to Alternative 2, except enhanced softening is used instead of conventional softening and GAC is used instead of fixed bed IX. A bypass is included around the GAC, which can be utilized to save on O&M costs as long as color goals are still achieved. Considerations for the enhanced softening process and corresponding chemicals are the same as those of Alternative 3. One possible variation of this alternative is to replace the solids contact clarifiers with pellet reactors (smaller footprint), but no color removal will occur during the softening process in this case. A process flow diagram of Alternative 4 is shown in Figure 4.4. Advantages and disadvantages are discussed in Table 4.4.

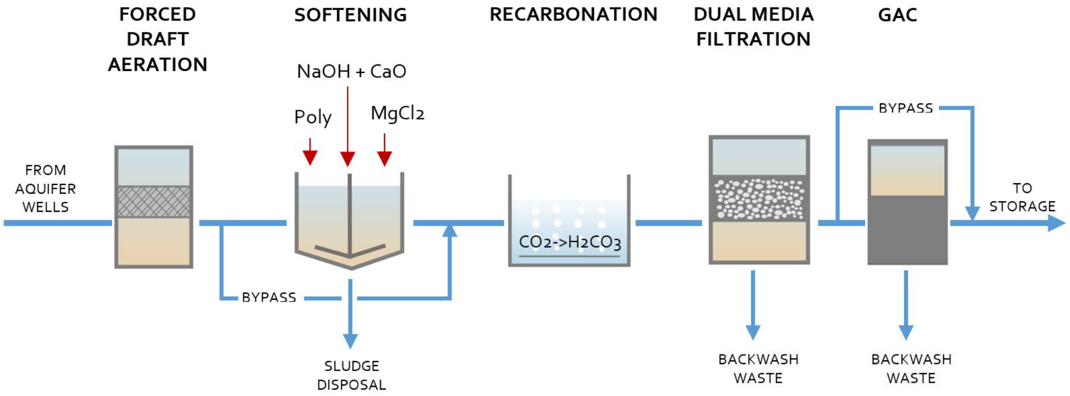

Figure 4.4 Alternative 4 Process Flow Diagram

Table 4.4 Alternative 4 Advantages and Disadvantages

Advantages	Disadvantages
• Excellent color and TOC removal. • Few unit processes. • Ability to meet hardness and alkalinity requirements. • Flexibility to utilize softening and GAC bypass. • Aeration removes H_2S, VOCs, and free CO_2. • Operation somewhat similar to existing plant process (except for GAC), less operator training required. • GAC operation is mostly automated or passive. • No proprietary technologies. • Not mechanically intensive. • High level of safety for public and employees. • Ability to meet future regulations. • GAC removes SOCs, CECs and other trace organics.	• Extremely high O&M costs for GAC. • GAC will require frequent regeneration/replacement, maintenance intensive (full-time crew replacing GAC). • Potential for calcium precipitation on GAC (if calcium carbonate precipitates on the GAC it cannot be regenerated). • Enhanced softening chemistry can be complex and changes with influent conditions due to limited alkalinity. • Slaking lime and handling dry chemicals can be challenging. • Aeration of H_2S depends on raw water pH, so performance is less predictable than other lower pH options. • Softening and gravity filtration rely on a high degree of manual operation. • Chemical dosing may rely on a certain degree of manual operation (as opposed to automated operation). • Cost risk associated with solids disposal. • Magnesium solids handling more difficult and expensive than for calcium solids. • Lower clarifier rise rate required for enhanced softening than conventional softening. • No experience with GAC in South Florida. • Requires re-pumping (although the required head is less than for fixed bed IX). • NaOH adds sodium to the finished water.

4.5 Alternative 5: Enhanced Lime Softening with MIEX and GAC

Alternative 5 is essentially the same as Alternative 3 but with the addition of a GAC color-polishing step. This provides more color removal reliability due to limited color removal by MIEX. A process flow diagram of Alternative 5 is presented in Figure 4.5. Advantages and disadvantages are discussed in Table 4.5.

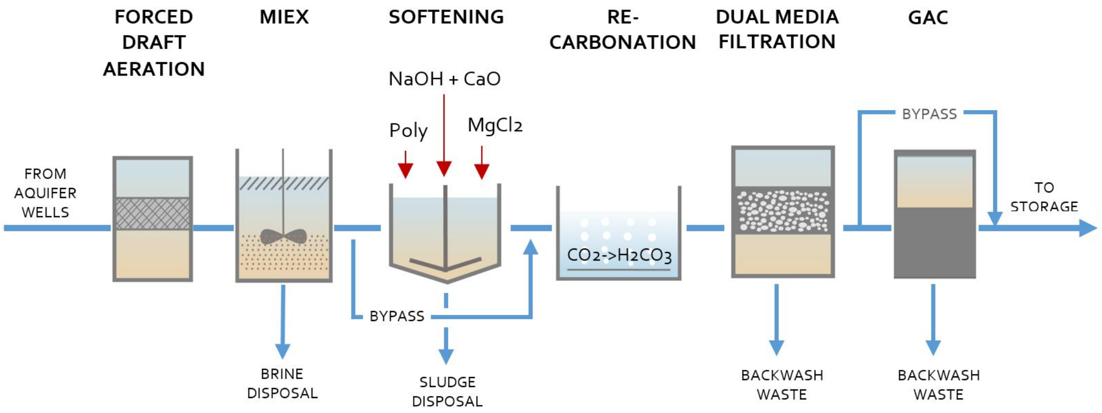

Figure 4.5 Alternative 5 Process Flow Diagram

Table 4.5 Alternative 5 Advantages and Disadvantages

Advantages	Disadvantages
• Excellent color and TOC removal, with flexibility using GAC bypass. • Ability to meet hardness and alkalinity requirements with flexibility using bypass. • Aeration removes H_2S, VOCs, and free CO_2. • Not mechanically intensive. • MIEX and GAC operations are mostly automated. • Ability to meet future regulations. • GAC removes CECs, SOCs, and other trace organics. • GAC functions as a polishing step rather than primary color removal step; possibility of longer time between regenerations.	• High O&M costs for GAC. • GAC will require frequent regeneration/replacement, maintenance intensive (full-time crew replacing GAC). • Potential for calcium precipitation on GAC (if calcium carbonate precipitates on the GAC it cannot be regenerated). • Two new processes are added, compared to the existing plant (MIEX and GAC), operator training required. • Enhanced softening chemistry can be complex and changes with influent conditions due to limited alkalinity. • Softening and gravity filtration rely on a high degree of manual operation. • MIEX resin inventory tracking is operations-intensive. • Slaking lime and handling dry chemicals reduces reliability. • Aeration of H_2S depends on raw water pH, so performance is less predictable than other lower pH options. • Cost risk associated with solids disposal. • Magnesium solids handling more difficult and expensive than for calcium solids. • Risk associated with IX brine disposal if sent to sewer. • Lower clarifier rise rate required for enhanced softening. • MIEX is proprietary, resin supply and equipment depends on manufacturer. • MIEX more mechanically intensive than fixed bed IX. • No experience with GAC in South Florida. • Possible resin de-sorption of organics during regeneration due to resin fouling. • Requires a significant amount of pumping (prior to MIEX and prior to GAC). • NaOH adds sodium to the finished water.

4.6 Alternative 6: Enhanced Coagulation and Caustic Softening

This alternative is similar to Alternative 1 (Enhanced Softening), but it includes a preliminary enhanced coagulation step, followed by flocculation and sedimentation (floc/sed), to improve color removal. Caustic softening is used instead of lime softening due to the reduced alkalinity in the water compared to treatment without enhanced coagulation.

One possible variation of this alternative is to replace the coagulation and floc/sed processes with a more compact sand-ballasted clarification (SBC) system, but this would involve significant energy consumption, increased operating costs, and increased maintenance. In contrast to some of the other softening alternatives, pellet reactors could not replace the solids contact clarifiers for Alternative 6 as the resulting finished water color would exceed project goals. A process flow diagram of Alternative 6 is shown in Figure 4.6. Advantages and disadvantages are discussed in Table 4.6.

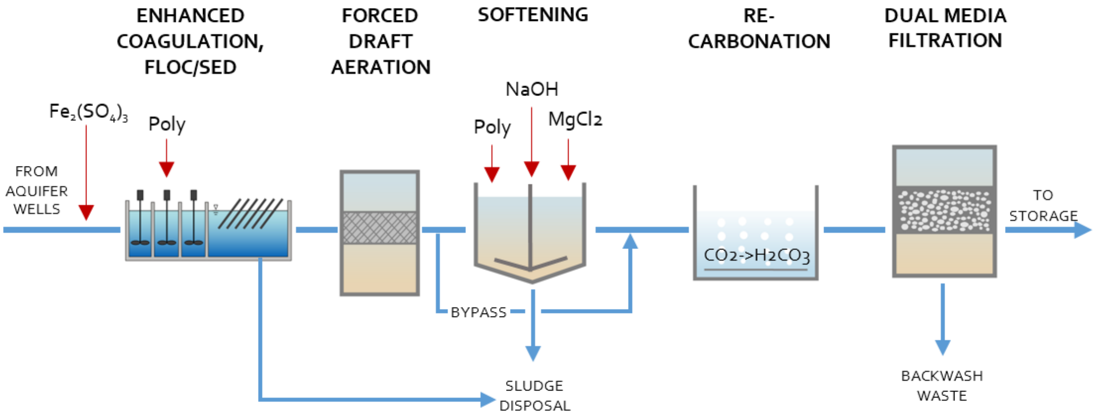

Figure 4.6 Alternative 6 Process Flow Diagram

Table 4.6 Alternative 6 Advantages and Disadvantages

Advantages	Disadvantages
• Good color and TOC removal. • NaOH softening can achieve lower hardness levels than lime softening as no additional calcium is being added. • Softening bypass provides a degree of flexibility. • Aeration removes H_2S, VOCs, and free CO_2. • Elimination of dry chemicals. • Relatively simple operation. • Operation somewhat similar to existing plant process (except for coagulation process), less operator training required. • No proprietary or unproven technologies. • Aeration is more effective at H_2S removal because of lowered influent pH. • No magnesium solids. • Caustic softening reduces solids generated (no calcium addition). • Consistent finished water hardness.	• NaOH can be expensive and the price is volatile. • Flocculation/sedimentation adds mechanical maintenance requirements. • Limited removal of CECs and trace organics. • Enhanced softening chemistry can be complex and changes with influent conditions due to limited alkalinity. • Softening and gravity filtration rely on a high degree of manual operation. • Cost risk associated with solids disposal. • Magnesium solids handling more difficult and expensive than for calcium solids. • Ability to utilize softening bypass is somewhat limited due to relying on enhanced softening for color removal. • Requires re-pumping (although the required head is less than for fixed bed IX). • NaOH adds sodium to the finished water.

4.7 Alternative 7: Enhanced Coagulation with Pellet Softening and Fixed Bed IX

This alternative is similar to Alternative 6 except pellet softening replaces solids contact clarifiers and fixed bed IX is provided at the end of the treatment train. Pellet softening has a smaller footprint than solids contact clarification but will not provide any color removal; this tradeoff is considered acceptable due to the high color removal provided by fixed bed IX. A bypass is provided around the softening and fixed bed IX processes.

If additional color removal is desired, the pellet softeners could be replaced by solids contact clarifiers, but this would result in a significantly larger footprint. A process flow diagram of Alternative 7 is presented in Figure 4.7. Advantages and disadvantages are discussed in Table 4.7.

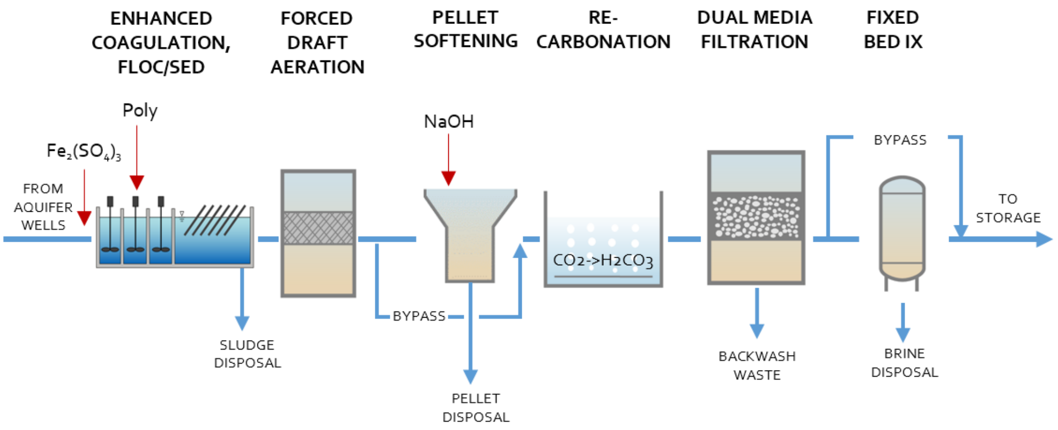

Figure 4.7 Alternative 7 Process Flow Diagram

Table 4.7 Alternative 7 Advantages and Disadvantages

Advantages	Disadvantages
• Excellent color and TOC removal with flexibility using IX bypass. • IX can remove other inorganic anions. • NaOH softening can achieve lower hardness levels than lime softening as no additional calcium is being added. • $CaCO_3$ precipitation occurs at lower pH than with solids contact clarifiers. • Pellet softener operation simpler than solids contact clarifier operation, largely automated. • IX operation is mostly automated. • Potential re-sale value of pellets. • Pellet softeners have small footprint. • Aeration removes H_2S, VOCs, and free CO_2. • No proprietary technologies. • Ability to meet future regulations. • Aeration is more effective because of lowered influent pH. • No magnesium solids. • Softening chemistry is relatively simple. • No dry chemicals. • Caustic softening reduces solids generated (not adding calcium). • No mechanical or lagoon/dry bed dewatering required for softening solids. • Softening bypass allows significant flexibility in finished water hardness levels (softening process not relied upon for color removal)	• NaOH can be expensive and the price is volatile. • Little to no color removal in softening process. • Few U.S. pellet softening installations, and no experience with pellet softening in South Florida. • Softening and gravity filtration rely on a high degree of manual operation. • Pellet softeners have a significant hydraulic impact because they are tall. • Flocculation/sedimentation adds mechanical maintenance requirements. • Limited removal of CECs and trace organics. • Higher power use due to IX pumping and pellet softening. • Potential requirement for deep well IX brine disposal if sewer disposal is not feasible. • Requires a significant amount of pumping (at a minimum, prior to aeration and prior to pellet softening). • NaOH adds sodium to the finished water.

4.8 Alternative 8: Enhanced Coagulation with Pellet Softening and MIEX

Alternative 8 is similar to Alternative 7 except that MIEX is used instead of fixed bed IX. This will provide less color removal but may result in O&M cost savings. A process flow diagram of Alternative 8 is presented in Figure 4.8. Advantages and disadvantages are discussed in Table 4.8.

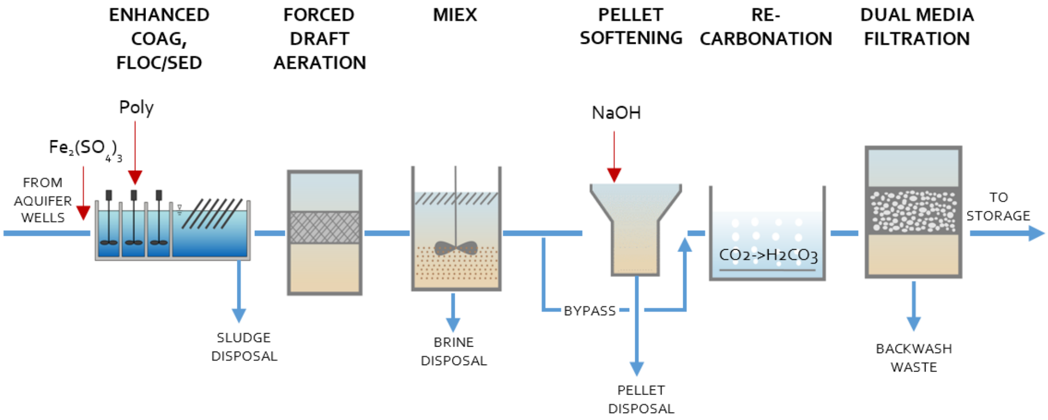

Figure 4.8 Alternative 8 Process Flow Diagram

Table 4.8 Alternative 8 Advantages and Disadvantages

Advantages	Disadvantages
• Good color and TOC removal. • IX can remove other inorganic anions. • NaOH softening can achieve lower hardness levels than lime softening. • $CaCO_3$ precipitation occurs at lower pH than with solids contact clarifiers. • Potential re-sale value of pellet. • Pellet softeners have small footprint. • Aeration removes H_2S, VOCs, and free CO_2. • Pellet softener operation simpler than solids contact clarifier operation, largely automated. • Ability to meet future regulations. • Aeration is more effective because of lowered influent pH. • No magnesium solids. • Pellets are very pure because iron and color have already been removed (better potential re-sale value). • Softening chemistry is relatively simple. • No dry chemicals. • Caustic softening reduces solids generated (not adding calcium). • Softening bypass allows significant flexibility in finished water hardness levels (softening process not relied upon for color removal). • No mechanical or lagoon/dry bed dewatering required for softening solids.	• NaOH can be expensive and the price is volatile. • Little to no color removal in softening process. • Few U.S. pellet softening installations and no experience in South Florida with pellet softening. • Pellet softeners have a significant hydraulic impact because they are tall. • Softening and gravity filtration rely on a high degree of manual operation. • MIEX resin inventory tracking is operations-intensive. • Floc/sed adds operational complexity and mechanical requirements. • Limited removal of CECs, SOCs, and trace organics. • MIEX resin is proprietary. • Requires a significant amount of pumping (at a minimum, prior to aeration and prior to pellet softening). • Hydraulic advantage of having MIEX at the front of the process is lost due to floc/sed – increased power usage. • MIEX more mechanically intensive than fixed bed IX. • Possible resin de-sorption of organics during regeneration due to resin fouling. • Potential requirement for deep well brine disposal if sewer disposal is not feasible. • NaOH adds sodium to the finished water.

4.9 Alternative 9: Enhanced Coagulation with Pellet Softening, MIEX, and GAC

Alternative 9 is similar to Alternative 8 except that GAC is added as a color polishing step at the end of the treatment train. As is the case with other coagulation and pellet softening alternatives, SBC could be used in place of the floc/sed system, and solids contact clarifiers could be used in place of pellet reactors. A process flow diagram of Alternative 9 is shown in Figure 4.9. Advantages and disadvantages are discussed in Table 4.9.

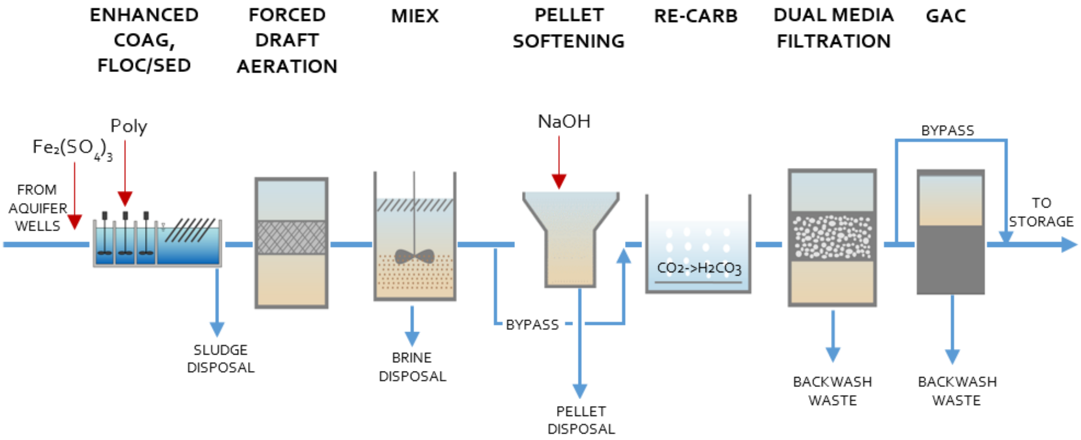

Figure 4.9 Alternative 9 Process Flow Diagram

Table 4.9 Alternative 9 Advantages and Disadvantages

Advantages	Disadvantages
• Excellent color and TOC removal with flexibility using GAC bypass. • MIEX can remove other inorganic anions. • $CaCO_3$ precipitation occurs at lower pH than with solids contact clarifiers. • Potential re-sale value of pellets. • Pellet softeners have small footprint. • Aeration removes H_2S, VOCs, and free CO_2. • Pellet softener operation simpler than solids contact clarifier operation, largely automated. • High flexibility to meet future regulations. • Aeration is more effective because of lowered influent pH. • No magnesium solids. • Pellets are very pure because iron and color have already been removed (better potential re-sale value). • GAC functions as color polishing step. • Softening chemistry is relatively simple. • No dry chemicals. • Caustic softening reduces solids generated (no calcium addition). • Softening bypass allows significant flexibility in finished water hardness (process not relied upon for color removal). • No mechanical or lagoon/dry bed dewatering required for softening solids. • Removal of CECs and trace organics.	• Many unit processes, complex operation. • No color removal in the softening process. • GAC has high O&M cost. • GAC replacement/regeneration will be maintenance intensive (full time crew replacing GAC). • Potential for calcium precipitation on GAC (if calcium carbonate precipitates on the GAC it cannot be regenerated). • Softening and gravity filtration rely on a high degree of manual operation. • MIEX resin inventory tracking is operations-intensive. • NaOH can be expensive and the price is volatile. • Few U.S. pellet softening installations and no experience in South Florida with pellet softening. • Pellet softeners have a significant hydraulic impact because they are tall. • Flocculation/sedimentation adds mechanical maintenance requirements. • MIEX resin is proprietary. • Hydraulic advantage of having MIEX at the front of the train is lost due to floc/sed – increased power usage. • MIEX more mechanically intensive than fixed bed IX. • Possible de-sorption of organics from resin during regeneration due to resin fouling. • Potential requirement for deep well brine disposal if sewer disposal is not feasible. • High pumping requirements (requires re-pumping before aeration, before pellet softening, and before GAC). • NaOH adds sodium to the finished water.

4.10 Alternative 10: Enhanced Coagulation with Pellet Softening and GAC

Alternative 10 is similar to Alternative 9 except that the MIEX process is removed. This simplifies operation but increases GAC regeneration costs due to higher color at the GAC influent. The possible process variations discussed for Alternative 9 also apply to Alternative 10. A process flow diagram of Alternative 10 is presented in Figure 4.10. Advantages and disadvantages are discussed in Table 4.10.

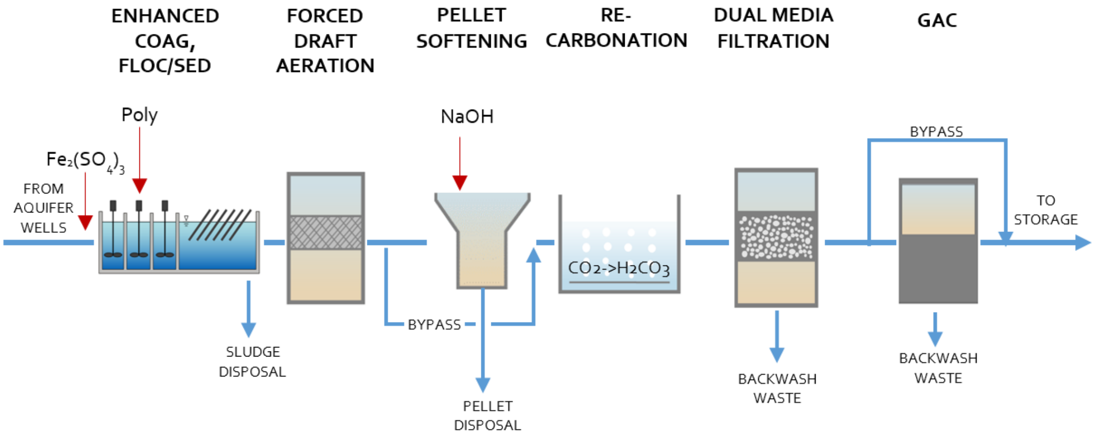

Figure 4.10 Alternative 10 Process Flow Diagram

Table 4.10 Title Alternative 10 Advantages and Disadvantages

Advantages	Disadvantages
• Excellent color and TOC removal with flexibility using bypass. • NaOH softening can achieve lower hardness levels than lime softening as no additional calcium is added. • $CaCO_3$ precipitation occurs at lower pH than with solids contact clarifiers. • Potential re-sale value of pellets. • Pellet softener operation simpler than solids contact clarifier operation, largely automated. • GAC operation is mostly automated. • Pellet softeners have small footprint. • Aeration removes H_2S, VOCs, and free CO_2. • No proprietary technologies. • Ability to meet future regulations. • Aeration is more effective because of lowered influent pH. • No magnesium solids. • Softening chemistry is relatively simple. • Excellent removal of CECs, SOCs, and trace organics. • No dry chemicals. • No mechanical dewatering required for softening solids. • Softening bypass allows significant flexibility in finished water hardness (process is not relied upon for color removal).	• Many unit processes. • GAC has high O&M cost. • GAC replacement/regeneration will be maintenance intensive (full time crew replacing GAC). • Potential for calcium precipitation on GAC (if calcium carbonate precipitates on the GAC it cannot be used for regeneration). • Softening and gravity filtration rely on a higher degree of manual operation. • NaOH can be expensive and the price is volatile. • No color removal in the softening process. • Few U.S. pellet softening installations. No experience in South Florida with pellet softening. • Pellet softeners have a significant hydraulic impact because they are tall. • Flocculation/sedimentation adds mechanical maintenance requirements. • No experience with GAC in South Florida. • High pumping requirements (requires re-pumping before aeration, before pellet softening, and before GAC). • NaOH adds sodium to the finished water.

4.11 Alternative 11: Nanofiltration with Fixed Bed IX Bypass

This alternative includes sand separation to reduce turbidity to the downstream processes, NF membranes (with cartridge filters preceding) for color and hardness reduction, forced draft aeration for H_2S removal and pH increase (CO_2 removal), and a bypass stream with forced draft aeration, dual media filtration, and fixed bed IX. The bypass stream is provided to reduce the amount of water that is disposed of as NF concentrate. Sulfuric acid is added to the NF influent for the purpose of lowering pH, which will reduce the membrane fouling potential. One possible technology variation is to replace the fixed bed IX vessels with a gravity IX system (increase in footprint but decrease in power use). A process flow diagram of Alternative 11 is shown in Figure 4.11. Advantages and disadvantages are discussed in Table 4.11.

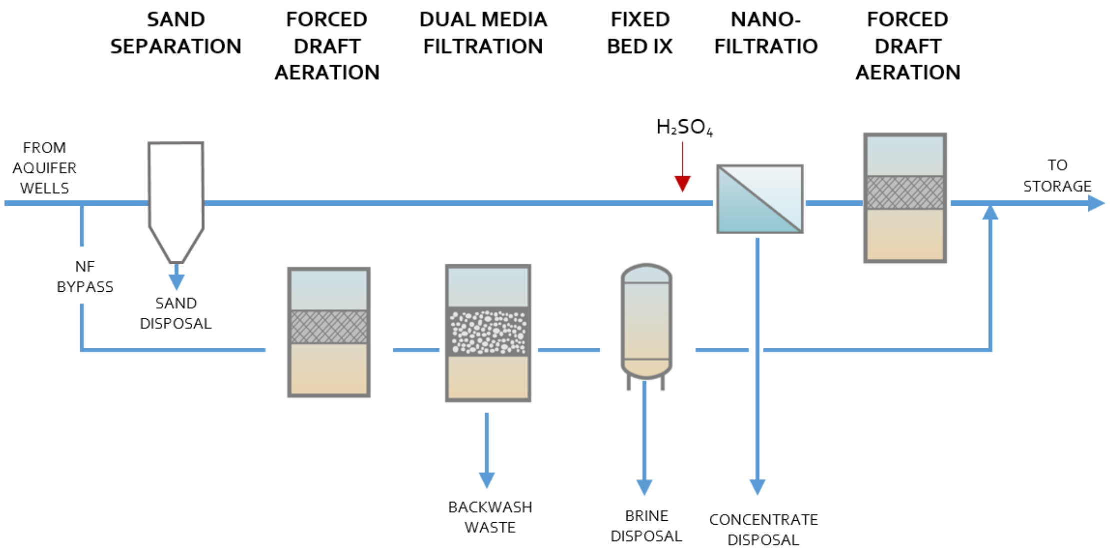

Figure 4.11 Alternative 11 Process Flow Diagram

Table 4.11 Alternative 11 Advantages and Disadvantages

Advantages	Disadvantages
• Excellent color and TOC removal, with precise control using bypass. • Simple, predictable operation (passive systems). • Few unit processes. • Aeration removes H_2S, VOCs, and free CO_2. • Relatively small footprint. • No proprietary technologies. • Process is highly automated (including bypass). • No complex softening chemistry. • Low chemical use. • No softening sludge disposal. • The NF concentrate deep well can also be used for brine disposal. • Less staffing requirements due to level of automation. • Post-NF aeration is highly effective due to lowered pH. • Experience with fixed bed IX and NF in South Florida.	• Low water recovery will require additional water supply allocation (5 to 10 additional mgd with allocation cost of $4.6 million/mgd). • Aeration of H_2S in bypass stream depends on raw water pH so performance is less predictable than other lower pH options. • Higher power use due to NF pumping. • Sulfuric acid adds chemical cost and requires additional safety protocols. • Differs from existing plant process, some operator training required. • Bypass percentage is limited by finished water hardness (the bypass stream does not provide softening). • NF requires membrane replacement. • Requires a deep injection well for concentrate disposal. • Finished water chloride to sulfate ratios are very high. • Bypass train requires re-pumping prior to fixed bed IX.

4.12 Alternative 12: Nanofiltration with MIEX Bypass

Alternative 12 is similar to Alternative 11 except that MIEX is used in the bypass stream instead of fixed bed IX. This provides less color removal in the bypass stream (resulting in less flexibility in bypass percentage) but has reduced power costs compared to fixed bed IX. A process flow diagram of Alternative 12 is presented in Figure 4.12. Advantages and disadvantages are discussed in Table 4.12.

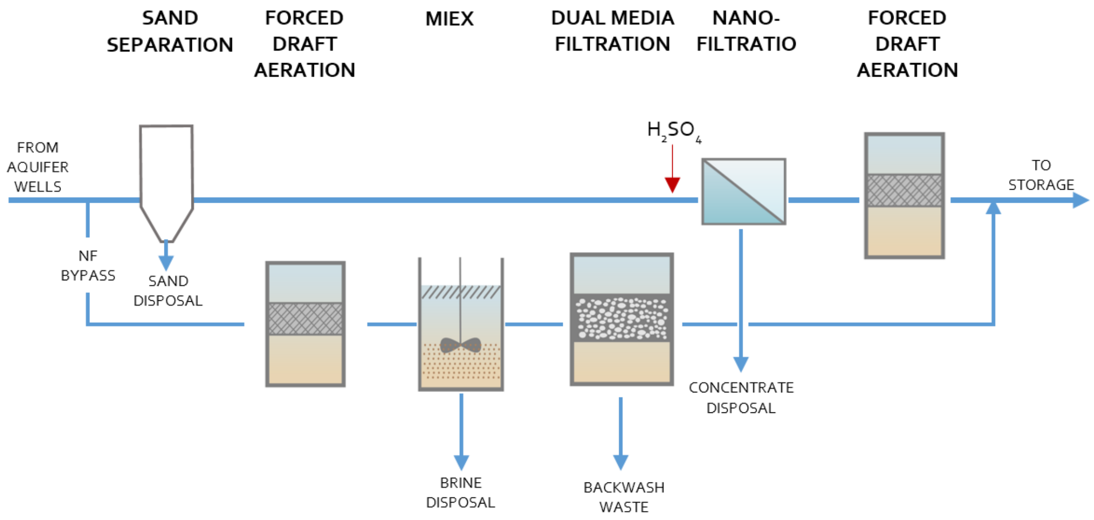

Figure 4.12 Alternative 12 Process Flow Diagram

Table 4.12 Alternative 12 Advantages and Disadvantages

Advantages	Disadvantages
• Excellent color and TOC removal, with precise control using bypass (but less flexible than with fixed bed IX). • Few unit processes. • Aeration removes H_2S, VOCs, and free CO_2. • Process is highly automated (except for MIEX resin management). • No complex softening chemistry. • Low chemical use. • No softening sludge disposal. • The NF concentrate deep well can also be used for brine disposal. • Less staffing requirements due to level of automation. • Post-NF aeration is highly effective due to lowered pH. • MIEX has smaller footprint than fixed bed IX. • Experience with MIEX and NF in South Florida.	• Low water recovery will require additional water supply allocation (5 to 10 additional mgd with allocation cost of $4.6 million/mgd). • Aeration of H_2S in bypass stream depends on raw water pH, so performance is less predictable than lower pH options. • Higher power use due to NF pumping. • Sulfuric acid adds chemical cost and requires additional safety protocols. • Bypass percentage is limited by finished water hardness (the bypass stream does not provide softening) and color (color is more limiting than Alternative 11 due to limitations of MIEX). • Operation differs from existing plant operation, training required. • NF requires membrane replacement. • Requires a deep injection well for concentrate disposal. • Post-NF aeration is highly effective due to lowered pH. • Operation differs from existing plant operation. • MIEX resin is proprietary and available from one supplier. • MIEX is more mechanically intensive the fixed bed IX. • Bypass train requires re-pumping after aeration (but not as much head required as fixed bed IX). • MIEX resin inventory tracking is operations-intensive.

4.13 Alternative 13: Nanofiltration with GAC Bypass

Alternative 13 is similar to Alternative 11, except that GAC is used in place of fixed bed IX. The ability to utilize the bypass train is more limited in this case due to the required GAC replacement frequency. A process flow diagram of Alternative 13 is presented in Figure 4.13. Advantages and disadvantages are discussed in Table 4.13.

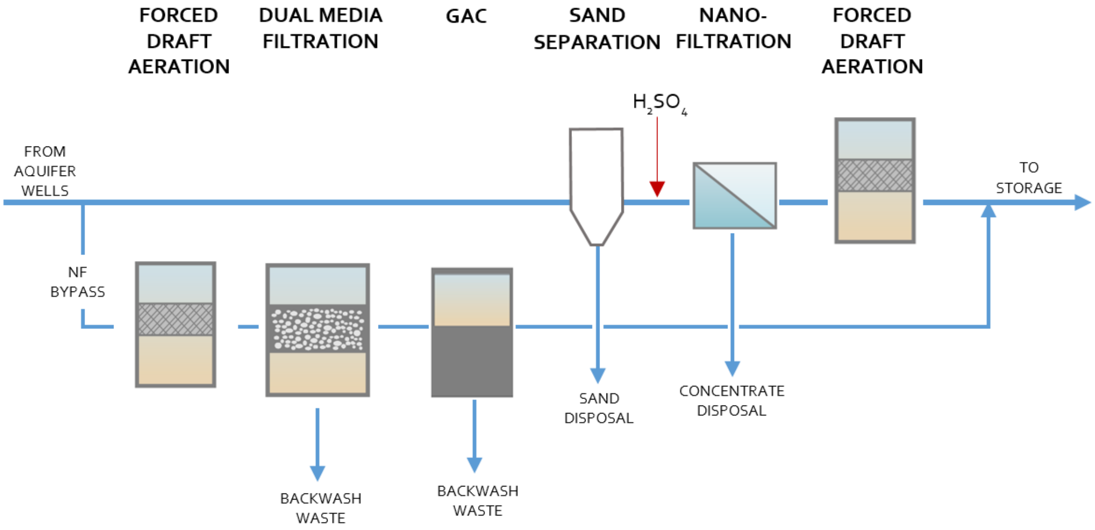

Figure 4.13 Alternative 13 Process Flow Diagram

Table 4.13 Alternative 13 Advantages and Disadvantages

Advantages	Disadvantages
• Simple, predictable operation. • Excellent color and TOC removal, with precise control using bypass. • Aeration removes H_2S, VOCs, and free CO_2. • Ability to meet future regulations. • No complex softening chemistry. • Process is highly automated. • Low chemical use. • No softening sludge disposal. • Deep well injection can be used for brine disposal (NF concentrate necessitates having a deep well). • Post-NF aeration is highly effective due to lowered pH. • No proprietary technologies. • Removal of CECs, SOCs, and trace organics in bypass train. • No dry chemicals. • Experience with NF in South Florida.	• GAC has high O&M costs. • GAC replacement/regeneration will be maintenance intensive. • High potential for calcium precipitation on GAC (if calcium carbonate precipitates on the GAC it cannot be used for regeneration). • Bypass train requires re-pumping (prior to GAC). • Bypass percentage is limited by finished water hardness (the bypass stream does not provide softening). • Frequent GAC regeneration required. • High potential for calcium precipitation on GAC, interferes with regeneration. • Operation different from existing plant operation, additional training required. • NF and GAC require additional power usage. • Sulfuric acid adds chemical cost and requires additional safety protocols. • Low water recovery will require additional water supply allocation (5 to 10 additional mgd with allocation cost of $4.6 million/mgd). • Aeration of H_2S in bypass stream depends on raw water pH, so performance is less predictable than lower pH options. • NF requires membrane replacement. • Requires a deep injection well for concentrate disposal. • No experience with GAC in South Florida.

4.14 Alternative 14: Nanofiltration with Enhanced Coagulation Bypass

Alternative 14 is similar to Alternatives 11, 12, and 13, except the bypass stream utilizes enhanced coagulation instead of IX or GAC. A process flow diagram for Alternative 14 is presented in Figure 4.14. Advantages and disadvantages are discussed in Table 4.14.

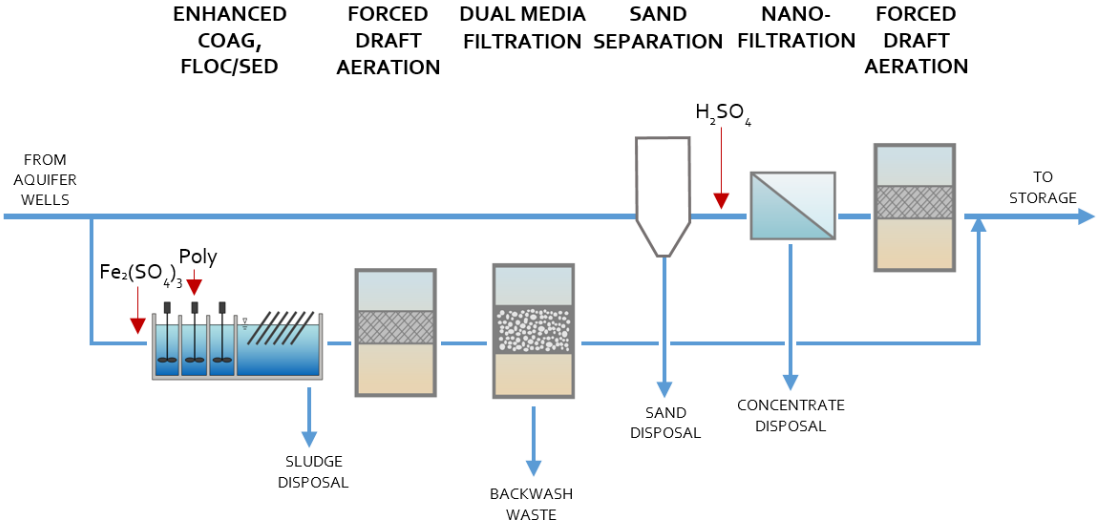

Figure 4.14 Alternative 14 Process Flow Diagram

Table 4.14 Alternative 14 Advantages and Disadvantages

Advantages	Disadvantages
• Excellent color and TOC removal, with precise control using bypass. • Aeration removes H_2S, VOCs, and free CO_2. • Process is mostly automated. • All aeration processes will have low influent pH, more effective H_2S removal. • No proprietary technologies. • No dry chemicals. • No complex softening chemistry. • Experience with NF in South Florida.	• Low water recovery will require additional water supply allocation (5 to 10 additional mgd with allocation cost of $4.6 million/mgd). • NF requires additional power usage. • Sulfuric acid adds chemical cost and requires additional safety protocols. • Floc/sed is mechanically intensive, chemistry can be complex. • Increased chemical use compared to IX and MIEX bypass options. • Operation differs from existing plant operation, training required. • Coagulant dosing may require a degree of manual operation (as opposed to automated operation). • Bypass percentage is limited by finished water hardness (the bypass stream does not provide softening) and color (coagulation will not remove as much color as fixed bed IX). • Operation differs from existing plant operation, training required. • NF requires membrane replacement. • Requires a deep injection well for concentrate disposal. • Flocculation/sedimentation adds operational complexity and mechanical requirements. • Limited removal of CECs, SOCs, and trace organics. • Bypass train requires re-pumping after floc/sed.

4.15 Alternative 15: Nanofiltration with Enhanced Coagulation/Softening Bypass

Alternative 15 is similar to Alternative 14 except that softening and re-carbonation occur after aeration. This increases color removal in the bypass train and may allow an increased bypass percentage by allowing more flexibility for hardness control in the finished water. Caustic softening is used instead of lime softening due to the reduced alkalinity in the water compared to treatment without enhanced coagulation. Pellet reactors could be used in place of the solids contact clarifiers. A process flow diagram of Alternative 15 is shown in Figure 4.15. Advantages and disadvantages are discussed in Table 4.15.

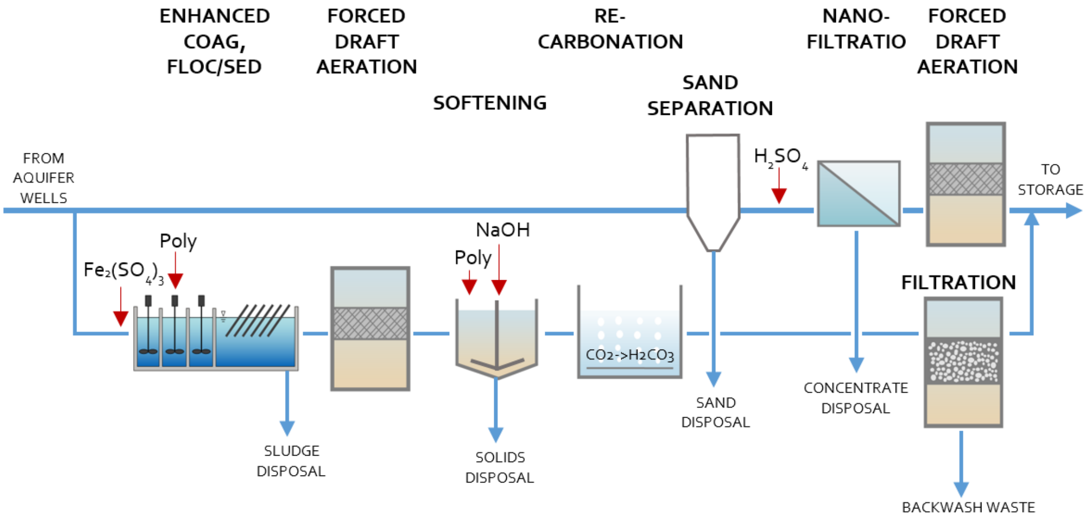

Figure 4.15 Alternative 15 Process Flow Diagram

Table 4.15 Alternative 15 Advantages and Disadvantages

Advantages	Disadvantages
• Excellent color and TOC removal, with precise control using bypass. • Increased control over hardness and alkalinity. • Aeration removes H_2S, VOCs, and free CO_2. • All aeration process will have low influent pH, more effective H_2S removal. • High clarifier rise rate can be utilized. • NaOH softening can achieve lower hardness levels than lime softening as no additional calcium is being added. • Elimination of dry chemicals. • No proprietary or unproven technologies. • Softening chemistry is relatively simple. • Caustic softening reduces solids generated (no calcium addition). • Experience with NF in South Florida.	• Low water recovery will require additional water supply allocation (5 to 10 additional mgd with allocation cost of $4.6 million/mgd). • Many unit processes. • Complex operation. • Process differs from existing plant, operator training required. • NF requires additional power usage. • Sulfuric acid adds chemical cost and requires additional safety protocols. • Softening and gravity filtration rely on a high degree of manual operation. • Coagulation and softening chemical dosing may require a degree of manual operation (as opposed to automated operation). • Floc/sed is mechanically intensive, chemistry can be complex. • Bypass train has increased chemical use compared to other NF bypass options. • Softening and sedimentation sludge disposal required. • Cost risk associated with $CaCO_3$ disposal. • Increased chemical use compared to IX bypass options. • NF requires membrane replacement. • Requires a deep injection well for concentrate disposal. • NaOH can be expensive and the price is volatile. • Bypass train requires re-pumping. • NaOH adds sodium to the finished water.

4.16 Alternative 16: Nanofiltration with EC, Softening, and IX Bypass

Alternative 16 is similar to Alternative 15 except that the bypass train ends with fixed bed IX, providing additional color removal. This alternative is an example of an 'all of the above approach' where there are many unit processes, each working incrementally to achieve water quality goals. The primary advantage of this system is operational flexibility, while the primary disadvantages are operational complexity and large footprint. A process flow diagram of Alternative 16 is shown in Figure 4.16. Advantages and disadvantages are discussed in Table 4.16.

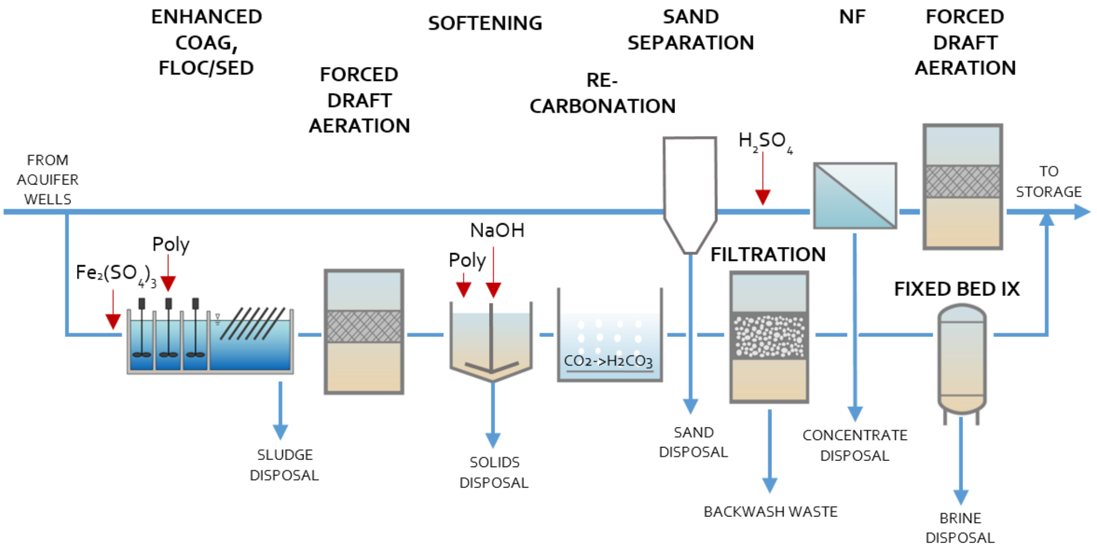

Figure 4.16 Alternative 16 Process Flow Diagram

Table 4.16 Alternative 16 Advantages and Disadvantages

Advantages	Disadvantages
• Excellent color and TOC removal, with precise control using bypass. • Highly flexible system. • Increased control over hardness and alkalinity. • Aeration removes H_2S, VOCs, and free CO_2. • High level of safety for public and employees. • All aeration process will have low influent pH, more effective H_2S removal. • High clarifier rise rate can be utilized. • No proprietary technologies. • NaOH softening can achieve lower hardness levels than lime softening as no additional calcium is being added. • Elimination of dry chemicals. • Softening chemistry is relatively simple. • Caustic softening reduces solids generated (not adding calcium). • Experience with NF and IX in South Florida.	• Low water recovery will require additional water supply allocation (5 to 10 additional mgd with allocation cost of $4.6 million/mgd). • Many unit processes, operationally complex. • Operation differs significantly from existing plant operation, extensive training required. • Floc/sed is mechanically intensive, chemistry can be complex. • Sulfuric acid adds chemical cost and requires additional safety protocols. • Softening and gravity filtration require a high degree of manual operation. • Increased chemical use compared to simpler NF train. • Softening and sedimentation sludge disposal required. • More operational complexity than simpler NF train. • Cost risk associated with $CaCO_3$ disposal. • IX brine disposal. • Operation different from existing plant operation. • NF and IX have high power costs due to headloss. • NF requires membrane replacement. • Requires a deep injection well for concentrate disposal. • NaOH can be expensive and the price is volatile. • Bypass requires pumping before aeration and before IX. • NaOH adds sodium to the finished water.

4.17 Alternative 17: Nanofiltration with Softening and MIEX Bypass

This alternative is similar to Alternative 12, except that a lime softening step is added to the bypass train. This provides hardness removal and additional color removal and therefore allows for more flexibility with bypass percentages. A process flow diagram of Alternative 17 is shown in Figure 4.17. Advantages and disadvantages are discussed in Table 4.17.

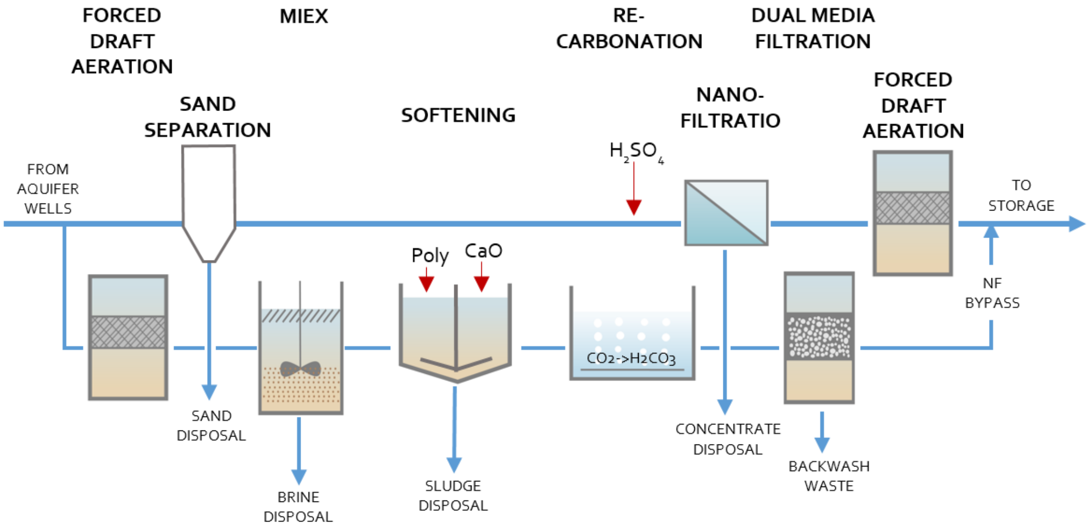

Figure 4.17 Alternative 17 Process Flow Diagram

Table 4.17 Alternative 17 Advantages and Disadvantages

Advantages	Disadvantages
• Excellent color and TOC removal, with precise control using bypass. • Bypass percentage is not limited by finished water hardness (both streams soften). • Aeration removes H_2S, VOCs, and free CO_2. • Process is mostly automated. • High clarifier rise rate can be utilized. • MIEX operation does not require additional pressure. • Deep well injection can be used for MIEX brine disposal (NF necessitates the use of deep well injection). • Post-NF aeration is highly effective due to lowered pH. • MIEX has smaller footprint than fixed bed IX. • Experience with MIEX and NF in South Florida. • Ability to meet hardness and alkalinity requirements. • MIEX can remove other inorganic anions. • Minimal re-pumping for bypass train.	• Low water recovery will require additional water supply allocation (5 to 10 additional mgd with allocation cost of $4.6 million/mgd). • Operationally complex, many unit processes. • Process differs from existing plant, operator training required. • Sulfuric acid adds chemical cost and requires additional safety protocols. • Aeration of H_2S in bypass train depends on raw water pH, so performance is less predictable than other lower pH options. • Lime softening and gravity filtration rely on a high degree of manual operation. • MIEX resin inventory tracking is operations-intensive. • Increased chemical use compared to simpler NF train. • Softening chemistry can be complex. • Softening sludge disposal required. • Softening chemistry can be complex and changes with influent conditions. • Slaking lime and handling dry chemicals reduces reliability. • Cost risk associated with $CaCO_3$ disposal. • High power use due to NF. • MIEX brine disposal. • MIEX resin is proprietary. • NF requires membrane replacement. • Requires a deep injection well for concentrate disposal. • MIEX more mechanically intensive than fixed bed IX.

4.18 Selection of Preferred Alternatives

In order to simplify the selection of desired treatment alternatives, a screening process was undertaken to differentiate between preferred alternatives and non-preferred alternatives. Screening considerations include ability to meet finished water color goals, ability to meet other water quality goals, operational complexity, anticipated O&M costs, and system flexibility. Table 4.18 summarizes the results of the screening process and primary reasons for selection or non-selection of an alternative. Detailed discussions of each selected alternative are presented in Section 5 of this report.

Table 4.18 Selection of Preferred Alternatives

Alternative	Title	Selection as a Preferred Alternative	Primary Reason(s) for Selection or Non-selection
1	Enhanced Lime Softening	x	Color removal not adequate.
2	Lime Softening and Fixed Bed IX	✓	Excellent color removal, flexible system.
3	Enhanced Lime Softening and MIEX	✓	Simple option for meeting moderate color goals.
4	Enhanced Lime Softening and GAC	x	GAC O&M costs are extremely high.
5	Enhanced Lime Softening with MIEX and GAC	x	GAC O&M costs are extremely high.
6	Enhanced Coagulation with Caustic Softening	✓	Good color removal, excellent hardness removal.
7	Enhanced Coagulation with Pellet Softening and Fixed Bed IX	✓	Excellent color removal, flexible system.
8	Enhanced Coagulation with Pellet Softening and MIEX	x	Limited color removal, low flexibility, extra unit processes.
9	Enhanced Coagulation with Pellet Softening, MIEX, and GAC	x	GAC O&M costs are high.
10	Enhanced Coagulation with Pellet Softening and GAC	x	GAC O&M costs are high.
11	Nanofiltration with Fixed Bed IX Bypass	✓	Excellent color removal, simple, predictable system, small footprint, flexible.
12	Nanofiltration with MIEX Bypass	✓	Excellent color removal, simple, predictable system, small footprint.
13	Nanofiltration with GAC Bypass	x	GAC O&M costs are high.
14	Nanofiltration with Enhanced Coagulation Bypass	x	Bypass train color removal is not as effective as other options.
15	Nanofiltration with Enhanced Coagulation/Softening Bypass	✓	Excellent color removal, flexible system, increased control over hardness and alkalinity.
16	Nanofiltration with Enhanced Coagulation, Softening, and Fixed Bed IX Bypass	x	System has too many unit processes, defeats the purpose of using a simpler nanofiltration system.
17	Nanofiltration with Softening and MIEX Bypass	x	System has too many unit processes, defeats the purpose of using a simpler nanofiltration system.

Section 5

COMPARISON OF SELECTED ALTERNATIVES

In this section detailed analyses of selected alternatives are presented, including modeled water quality results, system risks and reliability, flexibility, ability to meet future regulations, operational complexity, maintenance requirements, O&M costs, safety, footprint, and potential subalternatives.

Water quality (WQ) prediction ranges are generated using six different influent water quality conditions, which encompass a variety of average and extreme scenarios:

1. All influent WQ values are means.
2. Mean hardness, alkalinity, and pH, but all other WQ parameters are 95th percentile.
3. Low hardness, low alkalinity, high pH, and all other WQ parameters are means.
4. High hardness, high alkalinity, low pH, and all other parameters are means.
5. Low hardness, low alkalinity, high pH, and all other WQ parameters are 95th percentile.
6. High hardness, high alkalinity, low pH, and all other WQ parameters are 95th percentile.

Finished water quality predictions are estimated based on models, extensive calculations, prior research, and bench-scale testing.

5.1 Alternative 2: Lime Softening and Fixed Bed IX

See Section 4.2 for a general description of Alternative 2.

5.1.1 Process Flow Diagram

A process flow diagram of this alternative is shown in Figure 5.1.

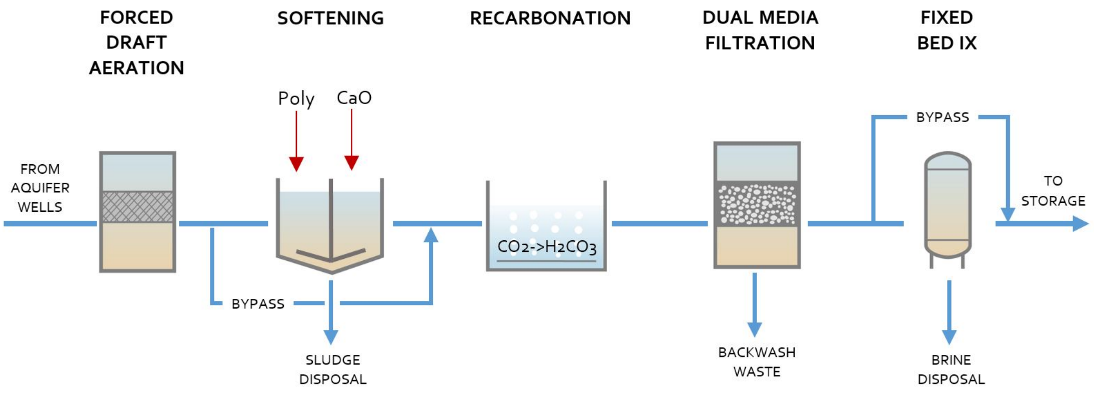

Figure 5.1 Alternative 2 Process Flow Diagram

5.1.2 Water Quality

5.1.2.1 Ability to Meet Water Quality Goals

Water quality predictions are summarized in Table 5.1. All percent removals through different processes use conservative estimates based on background research, models, calculations, and bench-scale data.

Table 5.1 Title Alternative 2 Water Quality Predictions

Parameter	Units	Value
Influent flow required for 50 mgd to distribution system	mgd	50.15
Softening bypass percent used in model	%	5(1)
IX bypass percent used in model	%	0(2)

Parameter	Units	Finished Water Goal	Finished Water Predicted Value		
			Average(3)	Minimum(4)	Maximum
Color	CU	< 5 (< 12)(6)	3.2	NA	5.4
Alkalinity	mg/L as $CaCO_3$	40 – 110	55	54	55
Free ammonia	mg/L as N	0.05 – 0.1	0.10	NA	0.10
Total hardness	mg/L as $CaCO_3$	80 – 160	82	81	84
Iron	mg/L	< 0.1	0.001	NA	0.002
Manganese	mg/L	< 0.02	0.004	NA	0.006
Sodium	mg/L	< 50	31	NA	37
Total dissolved solids (TDS)	mg/L	< 500	218	NA	263
Sulfate	mg/L	< 200	3.3	NA	3.6
Chloride	mg/L	< 100	103	NA	137
Turbidity	NTU	< 1.0	0.03	NA	0.03
H_2S	mg/L	< 0.1	0.04	NA	0.12
pH	---	8 – 8.5	8.5(5)	8.5(5)	8.5(5)
CSMR	---	< 0.5	31.2	NA	38.2

Notes:

(1) Softening bypass percentage is the optimal percentage to meet both finished water hardness and color goals.

(2) IX bypass was is not used in this model due to the possibility of exceeding color goals under high influent color scenarios.

(3) *Average* values were obtained using mean influent water quality conditions.

(4) Minimum values were only predicted for parameters where the finished water goal included a minimum value.

(5) pH was lowered to 8.5 during recarbonation in all water quality scenarios for this alternative, regardless of the influent water pH.

(6) A 5 CU color goal has been established but the City is also interested in exploring options that achieve between 5 and 12 CU.

Color

Under average influent color conditions, finished water color is predicted to achieve the conservative goal of less than 5 CU. With high influent color, finished water color is anticipated to be slightly above 5 CU but still meeting the moderate goal of 12 CU. Under average conditions there is flexibility to slightly increase the IX bypass percentage, resulting in reduced treatment and O&M costs.

It should also be noted that the removal of color through IX utilized a conservative percent removal estimate and finished water color would likely be lower than the model predictions.

Hardness

Total hardness is predicted to be within the goal range under all influent conditions. With low or average influent hardness, there is flexibility to increase the softening bypass percentage (thereby increasing finished water hardness) to reduce O&M costs.

Chloride

Under average influent water quality conditions, chloride is predicted to be 103 mg/L, slightly above the goal of 100 mg/L. This is due the addition of chlorides during the IX process. This can easily be remedied under mean influent conditions by slightly increasing the IX percentage. This will increase color but this can be controlled to not exceed 5 CU (or 12 CU if the moderate color goal is used).

If influent chlorides are high, finished water chloride is anticipated to be 137 mg/L, exceeding the goal of 100 mg/L. This can be remedied by increasing the IX bypass percentage if color is low enough to not exceed 5 CU (or 12 CU if the moderate color goal is used). This level of chlorides does not exceed the SMCL (250 mg/L). It should be noted that the chloride increase from IX is based on short-term bench-scale testing, and since a virgin IX resin was used, chloride increase may have been overestimated.

Chloride to Sulfate Mass Ratio

Finished water CSMR is predicted to be 31.2, exceeding the conventional CSMR target of 0.5 and the current plant CSMR of 8.2. Influent sulfate data is limited and concentrations may be higher than anticipated, potentially lowering the CSMR. Regardless, the high CSMR may need further consideration depending on the composition of the distribution system piping materials. If the CSMR is determined to be a concern, the ratio could be lowered by adding ferric sulfate during the softening process or preceding the softening process. The advantages to this approach include significantly reduced finished water CSMR and color, while the drawbacks include additional O&M costs, increased operational complexity, and larger overall footprint.

Hydrogen Sulfide

Predictive models for H_2S removal are limited, and therefore the only H_2S removal predicted in the process was accomplished through aeration, where 80 percent removal is used as a conservative estimate for the average influent pH of 7.34. Using these criteria, the finished water H_2S may be slightly above the goal for high influent H_2S conditions. This slightly higher value is not a concern due to the ability to remove the remaining H_2S through chlorination.

5.1.2.2 Other Water Quality Considerations

In addition to the water quality goals that were previously identified, there are other water parameters that are affected by the proposed treatment train. The following is a list of other parameters and how they are affected by the selected technologies:

- Volatile organic compounds – Aeration (specifically packed tower with forced draft and media) can remove a significant amount of volatile organic compounds. Packed tower aeration can effectively remove 70 – 95 percent of compounds such as dichloroethane, trichloroethane, trichloroethylene, tetrachlorethylene, vinyl chloride, and benzene.
- Free carbon dioxide – Carbon dioxide in excess of the concentration in equilibrium with the atmosphere will be removed with packed tower aeration. 97 percent removal of free carbon dioxide can be achieved. This is beneficial because free carbon dioxide has a lime demand and produces calcium carbonate, resulting in higher chemical costs and more residuals production.
- Inorganic chemicals – This includes constituents such as antimony, arsenic, asbestos, barium, cadmium, chromium, copper, lead, mercury, nitrate, nitrite, selenium, and fluoride. Enhanced softening is effective at removing many heavy metals (including many listed above). However, this alternative does not include enhanced softening and conventional softening is only marginally beneficial for these constituents. Arsenic, barium, cadmium, nitrite, and nitrate can be removed by IX.
- Synthetic organic compounds (SOCs) are typically only removed by GAC so none of these constituents would be removed by this treatment train.
- Radionuclides can only be removed by enhanced softening, so this treatment train would not remove these constituents.

5.1.3 Risks and Reliability

The following are discussion points regarding reliability and controlling risk for this treatment train:

- Meeting water quality goals – Vessel IX is one of the most effective methods for color reduction. The other technologies incorporated into this alternative are proven technologies with predictable performance from a water quality standpoint.
- Disposal of waste streams – Calcium carbonate residuals disposal is a concern for the future. Over time, disposal of these residuals has become more difficult and costly. Disposal of the brine waste from the IX system is a risk if discharged to the sewer because of potential regulations with respect to chlorides or TDS or due to the impact of these contaminants on water reuse. One approach to alleviate this risk is injection of the waste into a deep well (similar to what is done with NF and RO concentrate byproduct water).
- Technology – None of the technologies being utilized in this alternative are proprietary. All of the technologies proposed have a long track record of meeting the water quality goals established for the Fiveash WTP.
- This treatment train is not mechanically intensive so mechanical reliability is high.
- Aeration and fixed bed IX systems are passive, and therefore very reliable.
- Softening processes, and specifically lime softening (because of the requirements for slaking lime and handling dry chemicals), result in manageable reliability concerns.

5.1.4 Flexibility

The following are discussion points pertaining to the flexibility of the proposed treatment technologies:

- The softening process has high flexibility due to the softening bypass stream. Adjusting the bypass percentage allows careful control of finished water hardness and alkalinity.
- Aeration of H_2S is dependent on the raw water pH applied to the forced draft aerator. Aerator efficiency has limited flexibility to treat higher levels of H_2S.
- Due to the use of vessel IX and its capability to remove organics at a high level, the flexibility for TOC and color removal using the bypass is high.

5.1.5 Ability to Meet Future Regulations

The following water quality constituents are included in proposed regulations that are currently being examined by the USEPA. The potential for the proposed treatment alternative to address these constituents are as follows:

- Manganese – USEPA may change manganese from a secondary MCL to a primary MCL due to health effects (specifically brain development in children). The softening process removes manganese to very low levels and should have no problem addressing any future manganese regulations.
- Cyanotoxins – This potential regulation is applicable for surface water sources. The use of groundwater minimizes potential for future issues.
- Disinfection byproducts – The use of vessel IX and its ability to achieve high removals of NOM results in lower DBP formation than most other treatment technologies (except for membranes).
- Perfluoro-compounds – Although IX can be used to remove these contaminants, a specific resin would be required which is different than that proposed for color and TOC removal. IX expansion options can be incorporated into a facility design to address these constituents.
- Perchlorate – Anion exchange can be used to reduce perchlorate levels.

5.1.6 Operational Complexity

The operational complexity of this treatment train is similar to the existing plant, except for the addition of a fixed bed IX system. IX is a passive system and minimally increases operational complexity.

5.1.7 Maintenance Requirements

From a maintenance perspective, the biggest change compared to the existing facility would be maintenance of the transfer pump station which will be required to pump water through the IX system. In addition, the automated control valves associated with the IX system will require regular maintenance.

5.1.8 O&M Costs

Estimated O&M costs are presented in Table 5.2. These estimates are based on an average annual plant flow of 33 mgd and a 5 percent softening bypass (bypass percentage is discussed in Section 5.1.2.1). Items not included in estimates include aeration blower power (same for all treatment trains) and possible disposal costs for brine and concentrate. O&M costs for this alternative are considered to be lower than average when compared to other alternatives.

Table 5.2 Alternative 2 O&M Cost Estimates

Item	Average Annual Cost
Power	$1,089,400
Chemicals	$1,898,500
Solids Disposal	$927,300
IX Resin Replacement	$650,000
Total	**$4,565,200**

5.1.9 Safety

5.1.9.1 Public

The water treatment plant currently uses chlorine gas for disinfection. It is assumed that all treatment train alternatives would replace chlorine gas with bulk sodium hypochlorite

For this treatment train alternative the following chemicals may pose a level of safety concern to the public:

- Pebblelime.
- Polymer.
- Salt brine.
- Carbon dioxide.
- Chlorine.
- Ammonia.
- Fluoride.

This treatment train is very safe for the public because the chemicals used are not extremely dangerous; lime is the only chemical that is considered hazardous from a code perspective – corrosive and a Class 1 water reactive. In addition, all of these chemicals are concentrated, resulting in fewer truck deliveries, thereby reducing the potential risk to the public.

5.1.9.2 Facility Staff

Similar to public safety, employee safety risks are low for this alternative for similar reasons to those listed above. The main difference is that pebblelime requires slaking which generates heat and can pose an increased risk to employees. The slaking process occurs near the boiling point of water and does pose a burn risk to plant staff.

5.1.9.3 Hurricane Considerations

The power requirements for this treatment train are higher than some of the other options because intermediate pumping to transfer water to the IX vessels is required. This directly impacts the generator sizing necessary to treat water during a power outage.

As aforementioned, the majority of chemicals that are associated with this treatment train are concentrated, which limits delivery requirements and lends this treatment train to operate for longer periods of time without excessive capital expenditures associated with storage of more dilute chemicals.

Regarding hurricane hardening, all structures will be designed to meet or exceed the associated storm requirements, regardless of which alternative is selected.

5.1.10 Footprint

This treatment train has a large footprint compared to the other potential alternatives. The following are the assumptions utilized to estimate the required footprint:

- Only treatment associated facilities are considered in the footprint sizing. New administrative, storage, and maintenance buildings are not included.
- The solids contact clarifiers only need to remove calcium carbonate so their rise rate is higher than if magnesium was being removed with enhanced softening.

The estimated total footprint is calculated in Table 5.3. Note that only major unit processes are included in this table. The estimated footprint information is intended to be used for comparison of alternatives only, and does not include ancillary facilities that may be required for a complete WTP.

A hypothetical site plan for this alternative is shown on Figure 5.2.

Table 5.3 Alternative 2 Footprint Estimate

Component	Area (sq ft)
Forced draft aerators	3,000
Solids contact clarifiers	25,200
Dual media filters(1)	9,000
Ion exchange system	19,040
Transfer pump station	4,000
Total	**60,240**

Notes:
(1) 5 gpm/sf loading rate.

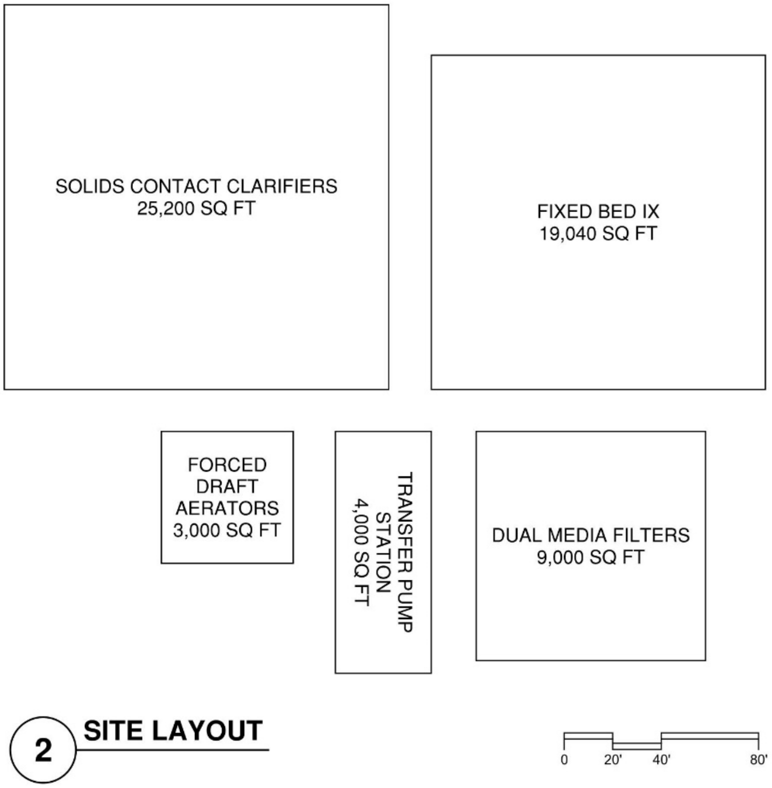

Figure 5.2 Alternative 2 Footprint

5.1.11 Technology Subalternatives

For each of the treatment alternatives there are a number of subalternatives that could be included to provide improved water quality, reduced capital and O&M costs, and improved operability. Each of these subalternatives has been included to provide options to the City to tailor the selected alternative to the needs of the facility. Each subalternative is discussed with respect to advantages and disadvantages, and changes to capital and O&M costs.

5.1.11.1 Pellet Softeners in Place of Solids Contact Clarifiers

Pellet softening is a technology that can achieve similar hardness removal to typical solids contact clarifiers. The technology utilizes an upflow reactor and starts with seed pellets which grow over time as calcium is removed. The following are the advantages and disadvantages of switching from conventional solids contact clarifiers to pellet softeners.

Advantages

- The pellet softening process produces a 100 percent calcium carbonate pellet that free drains and does not require dewatering. This results in cost savings because of reduced solids volume and no footprint requirements for dewatering.
- The pellet softening reactor operates at a hydraulic loading of 40 gpm/sq ft as compared to 1.75 gpm/sq ft for a conventional solids contact clarifier. This reduces the footprint of the reactors to a size that can easily be placed inside a building.
- The pellet softening process produces 0.9 mm pellets that have a potential re-sale value. They can be utilized to make drywall, masonry block, concrete, and livestock feed.

Disadvantages

- The reactors are taller than conventional solids contact clarifiers (~26 feet).
- The reactors can only be used for calcium removal. They will not remove mangnesium.
- The reactor will remove less organics and color than a conventional solids contact clarifier.
- Pellet softening has not been used extensively in the United States (Chino, CA has been running for 3 years and South Adams County Water and Sanitation District [CO] is currently building a 14 mgd facility). The technology has been used internationally since the 1980's.

5.1.11.2 Gravity IX System in Place of IX Vessels

One of the challenges with fixed bed IX is the economy of scale. For a 50 mgd installation, approximately 40 vessels would be required. A potential option would be to construct concrete IX boxes which would be similar to gravity filters (like the ones that Fiveash WTP currently has). This approach has been used in the United States at the 6 mgd Aliquippa Municipal Water Authority in Pennsylvania. This facility has plastic underdrains (manufactured by Leopold) and has not experienced problems with corrosion. The utility is pleased with the system and its operation. A photo of this system is shown in Figure 5.3.

It is anticipated that filter boxes with dimensions of approximately 15 ft by 45 ft would be necessary. At this size, there would be approximately 10 units for a 50 mgd facility. The loading rate of these units would be low to provide better hydraulic performance.

Figure 5.3 6 mgd Aliquippa Municipal Water Authority Concrete Filter Box Ion Exchange System

5.1.11.3 Adding Magnesium Chloride or Ferric Sulfate to Softening Process

Magnesium Chloride

From the bench-scale testing performed it has been determined that calcium-only softening does not remove large amounts of organics or color. To supplement organics removal, the addition of magnesium chloride could be combined with enhanced softening (at pH 11).

Advantages:

- Improved organics removal (and associated color removal).
- Ability to dial-in desired hardness.

- Enhanced removal of other constituents such as silica, barium, radionuclides, and other inorganic chemicals as discussed in section 5.1.2.2.
- Reduced loading of organics on the IX system resulting in longer runs between regeneration and lower salt use and brine discharge.

Disadvantages:

- Requires lower rise rate in solids contact clarifiers which would require a larger treatment unit (1.25 gpm/sq ft instead of 1.75 gpm/sq ft).
- Increased solids production.
- Increased chemical use. This option requires either caustic soda or soda ash to accommodate the precipitation of calcium carbonate. Without these chemicals the softening reaction runs out of carbonate alkalinity and the calcium hardness will be too high to achieve hardness goals.
- More challenging solids dewatering.

Ferric Sulfate

The use of ferric sulfate in the softening process was demonstrated to improve organics removal during bench-testing. Ferric sulfate would be added prior to the addition of softening chemicals (lime, caustic soda, soda ash) to maximize the organics removal.

Advantages:

- Improved organics removal (and associated color removal).
- Reduced loading of organics on the IX system resulting in longer runs between regeneration and lower salt use and brine discharge.
- No reduction in solids contact clarifier rise rate.
- Marginal increase in solids production and no degradation of the ability to dewater solids.
- Significantly improved CSMR.

Disadvantages:

- Increased chemical use. This option requires either caustic soda or soda ash to accommodate the precipitation of calcium carbonate (due to the consumption of alkalinity of the ferric sulfate). Without these chemicals the softening reaction runs out of carbonate alkalinity and the calcium hardness will be too high to achieve hardness goals.
- Adding ferric sulfate to a softening process will lower the pH of the solution, which can make softening more challenging, as raising the pH is an inherent part of the process.

5.1.11.4 Caustic Soda or Soda Ash

It should be noted that the use of caustic soda or soda ash can assist with achieving the hardness goals (especially if the City wants to be on the lower end of the hardness spectrum). If lime use is reduced and more caustic soda or soda ash is used, softening bypass percentages could be further increased. It should be noted that both caustic soda and soda ash are much more expensive and cost-volatile than lime.

5.2 Alternative 3: Enhanced Lime Softening and MIEX

See Section 4.3 for a general description of Alternative 3.

5.2.1 Process Flow Diagram

A process flow diagram of this alternative is shown in Figure 5.4.

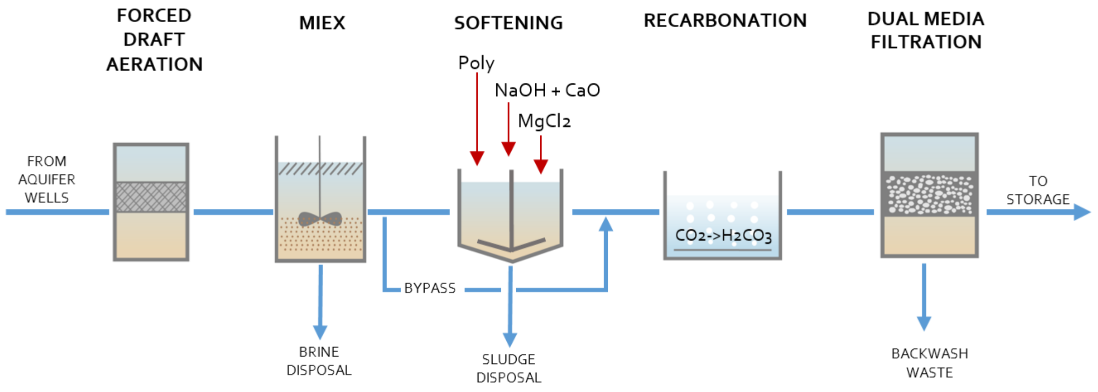

Figure 5.4 Alternative 3 Process Flow Diagram

5.2.2 Water Quality

5.2.2.1 Ability to Meet Water Quality Goals

Water quality predictions are summarized in Table 5.4. All percent removals through different processes use conservative estimates based on background research, models, calculations, and bench-scale data.

Table 5.4 Alternative 3 Water Quality Predictions

Parameter	Units	Value
Influent flow required for 50 mgd to distribution system	mgd	50.02
Softening bypass percent used in model	%	$3^{(1)}$

Parameter	Units	Finished Water Goal	Finished Water Predicted Value		
			Average$^{(2)}$	Minimum$^{(3)}$	Maximum
Color	CU	< 5 (< 12)$^{(5)}$	7.0	NA	11.9
Alkalinity	mg/L as $CaCO_3$	40 – 100	67	67	67
Free ammonia	mg/L as N	0.05 – 0.1	0.10	NA	0.10
Total hardness	mg/L as $CaCO_3$	80 – 160	60	60	60
Iron	mg/L	< 0.1	0.001	NA	0.002
Manganese	mg/L	< 0.02	0.004	NA	0.006
Sodium	mg/L	< 50	99	NA	106
Total dissolved solids (TDS)	mg/L	< 500	305	NA	339
Sulfate	mg/L	< 200	7.5	NA	8.1
Chloride	mg/L	< 100	115	NA	138
Turbidity	NTU	< 1.0	0.03	NA	0.03
H_2S	mg/L	< 0.1	0.04	NA	0.12
pH	---	8 – 8.5	8.5$^{(4)}$	8.5$^{(4)}$	8.5$^{(4)}$
CSMR	---	< 0.5	15.3	NA	17.0

Notes:

(1) Softening bypass percentage was limited by the ability to achieve the color goals. Under low or average color influent conditions, the bypass percentage could be increased.

(2) *Average* values were obtained using mean influent water quality conditions.

(3) Minimum values were only predicted for parameters where the finished water goal included a minimum value.

(4) pH was lowered to 8.5 during recarbonation in all water quality scenarios for this alternative, regardless of the influent water pH.

(5) A 5 CU color goal has been established but the City is also interested in exploring options that achieve between 5 and 12 CU.

Color

This alternative is anticipated to achieve the moderate color removal goal of 12 CU but not the conservative goal of 5 CU. Finished water color under average conditions is predicted to be 7.0 CU, and 11.9 CU under extreme conditions. If the influent color is low or average, the softening bypass percentage could be increased to better achieve hardness goals while still adhering to the moderate color goal. This alternative is a potential option that can provide good color removal while also providing power cost savings compared to the fixed bed IX alternative.

Hardness

With a 3 percent softening bypass, finished water hardness levels are expected to be 60 mg/L as $CaCO_3$, outside the target range of 80-160 mg/L as $CaCO_3$. The softening bypass would need to be increased to approximately 16 percent to reach 80 mg/L as $CaCO_3$ in the finished water for all influent scenarios. In conditions where the influent color is average, a 16 percent bypass would still put the color below the moderate goal of 12 CU.

Sodium and Chloride

Finished water sodium levels are predicted to be approximately 100 mg/L under all influent water quality scenarios, due to the addition of sodium hydroxide in the softening process. 100 mg/L exceeds the finished water goals but not the sodium MCL. It should be noted that the required sodium hydroxide dose is calculated through the softening chemistry and is particularly high because of the assumption of a magnesium chloride dose of 60 mg/L. On average, the magnesium dose may be lower and therefore sodium levels would be lower.

Chloride levels are predicted to exceed the 100 mg/L project goal but not to exceed the SMCL of 250 mg/L (115 and 138 mg/L average and maximum). Chlorides are released during the MIEX process and added during softening as magnesium chloride. As discussed above, the magnesium chloride dose could be reduced (as long as color goals are still achieved). Chloride release from the MIEX process could be overestimated for the same reasons described in Alternative 2.

Chloride to Sulfate Mass Ratio

CSMR is predicted to be approximately 15.3 for average influent conditions, above the target of 0.5. Bench-scale data show less sulfate removal in the MIEX process vs. the fixed bed IX process, and therefore the CSMR was lower than that of Alternative 2. However, influent sulfate levels are already very low and the bench-scale data may not be an accurate representation of sulfate percent removal through the anion exchange process. As was described for Alternative 2, ferric sulfate addition in the softening process or in a separate process could lower the CSMR if needed.

Hydrogen Sulfide

As previously noted, predictive models for H_2S removal are limited. Similar to Alternative 2. H_2S removal was only modeled through aeration with an assumed removal efficiency of 80 at the average raw water pH. Finished water H_2S may be slightly above the goal for high influent H_2S conditions, but this remaining H_2S can be removed through chlorination.

5.2.2.2 Other Water Quality Considerations

Other water parameters beyond those evaluated above could be affected by the proposed treatment train. The following is a list of other constituents and how they are affected by the selected technologies:

- Volatile organic compounds – As previously noted, forced draft aeration can effectively remove 70-95 percent of select VOCs.
- Free carbon dioxide – Packed tower aeration will also remove excess carbon dioxide, resulting more efficient operation as the result of lower lime demand and calcium carbonate production.
- Inorganic chemicals –Enhanced softening is effective at removing many heavy metals. Arsenic, barium, cadmium, nitrite, and nitrate can also be removed by MIEX. A selectivity diagram for the MIEX resin is shown in Figure 5.5. The higher the constituent on the list, the better it is removed by the resin.

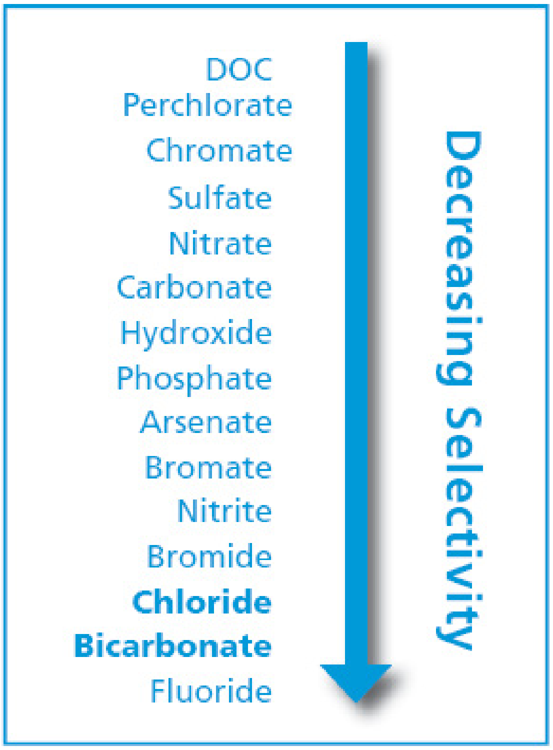

Figure 5.5 MIEX Selectivity Diagram

- Synthetic organics compounds are typically only removed by GAC, so the proposed treatment process would not remove these constituents.
- Radionuclides can be removed by enhanced softening.

5.2.3 Risks and Reliability

The following elements related to system reliability and risk control should be considered for this treatment train:

- Meeting water quality goals – Fluidized bed IX is moderately effective for color reduction, and the other technologies utilized are proven with predictable performance.
- Disposal of waste streams – As aforementioned, calcium carbonate residuals disposal has become more difficult and costly. Disposal of the brine waste from the MIEX process to the sewer may be subject to chloride of TDS regulations, or may otherwise impact

reuse potential. Waste injection into a deep well could be used to circumvent these issues.

- Technology – The MIEX resin is proprietary both from the resin and capital equipment perspectives. This could potentially be a risk for resin availability and cost. Unlike vessel IX media, MIEX resin must be continuously replaced.
- This treatment technology is more mechanically intensive than fixed bed IX. This system utilizes mixers and a mechanically intensive regeneration skid. From a mechanical standpoint the reliability is lower than the fixed bed option.
- The aeration system is a passive and has high reliability. Intermediate pumping will likely not be required for this option since the headloss through the fluidized bed IX system is low (2-3 feet).
- Lime slaking and dry chemical handling slightly reduce the reliability of this option.

5.2.4 Flexibility

The following are discussion points pertaining to the flexibility of the proposed treatment technologies:

- The fluidized bed IX system does not achieve the same color and TOC removal that the fixed bed IX does. Because of this the softening process is required to achieve more removal of these constituents and either enhanced softening or coagulant addition in the softening process is required. This makes the process more chemical-intensive, and either soda ash or caustic soda addition is required to achieve the hardness and alkalinity goals.
- Flexibility to treat higher levels of H_2S is limited because of its dependence on the raw water concentration and aeration pH.
- The softening bypass provides flexibility to reach various finished water hardness and color levels, and to save on solids disposal costs. However, when influent color levels are high, the ability to utilize the bypass is limited.

5.2.5 Ability to Meet Future Regulations

This alternative will have the following impacts on constituents which potentially could be regulated in the future:

- Manganese –The proposed softening process is very effective at removing manganese and can be used to meet future manganese regulations.
- Cyanotoxins – As previously noted, this potential regulation is primarily applicable for surface water sources and the use of groundwater minimizes potential for future regulatory issues.
- Disinfection byproducts – The use of fluidized bed IX and its ability to remove NOM results in lower DBP formation than some of the other treatment technologies (although not as well as fixed bed IX or membranes).
- Perfluoro-compounds – While MIEX can be used to remove these contaminants, a specific resin would be required which is different than the one which is proposed for color and TOC removal. IX expansion options can be incorporated into a facility design to address these constituents.
- Perchlorate – Anion exchange can be used to reduce perchlorate levels.

5.2.6 Operational Complexity

The operational complexity of this treatment train is greater than the existing facility due to the fluidized IX process. The MIEX system has continuous resin loss during operation. The resin inventory in the treatment basin must be maintained at the appropriate concentration to prevent excessive loss.

5.2.7 Maintenance requirements

The primary maintenance change compared to the existing plant would be maintenance of the fluidized-bed IX system which includes mixers, and the regeneration skid which incorporates a variety pumps, mixers, underdrains, and valves.

5.2.8 O&M Costs

Estimated O&M costs are presented in Table 5.5. These estimates are based on an average annual plant flow of 33 mgd and a 3 percent softening bypass (bypass percentage is discussed in Section 5.2.2.1). Items not included in estimates include aeration blower power (which is roughly the same for all alternatives) and possible disposal costs for brine. O&M costs for this alternative are considered to be high compared to other alternatives. The large cost difference between Alternative 3 and Alternative 2 is due to the sodium hydroxide and magnesium chloride required for the enhanced softening process.

Table 5.5 Alternative 3 O&M Cost Estimates

Item	Average Annual Cost
Power	$1,212,000
Chemicals	$10,227,000
Solids Disposal	$1,060,000
MIEX Resin	$625,400
Total	**$13,124,400**

5.2.9 Safety

5.2.9.1 Public

As aforementioned, it is assumed for all treatment alternatives presented herein that the existing chlorine gas system would be replaced with bulk sodium hypochlorite, thereby significantly decreasing the overall level of public safety concern for the facility.

For this treatment train alternative the following chemicals may pose a level of safety concern to the public:

- Pebblelime.
- Ferric sulfate.
- Caustic soda (sodium hydroxide).
- Magnesium chloride.
- Polymer.
- Salt brine.
- Carbon dioxide.

- Chlorine.
- Ammonia.
- Fluoride.

This treatment train has a slightly increased risk to the public due to the use of more hazardous chemicals such as caustic soda which is a considered corrosive and a Class 1 water reactive by code. In addition, the caustic soda and the magnesium chloride are not as concentrated, resulting in more frequent truck deliveries which slightly increases risk to the public.

5.2.9.2 Employee

Similar to public safety, employee safety risks are slightly higher for this treatment train for the reasons listed above. Caustic soda is corrosive and can be dangerous to employees, and pebblelime requires slaking which generates heat and can pose a burn risk to employees.

5.2.9.3 Hurricane Considerations

The power requirements for this treatment train are higher than some of the other options because of the fluidized-bed IX system, however the energy input is lower than that required for intermediate pumping to transfer water to the fixed bed IX vessels of Alternative 2.

The use of concentrated chemicals results in fewer chemical deliveries required and thereby allows many of the treatment processes associated with this alternative to operate for longer periods of time should the chemical supply chain be interrupted by a hurricane.

Although caustic soda and magnesium chloride are less concentrated, this treatment train would have the flexibility to not add caustic soda or magnesium chloride during an emergency situation (switching to conventional lime softening), which would result in still meeting hardness goals (however color goals may not be met under these conditions).

For all of the proposed alternatives, all structures will be designed to meet or exceed the associated storm requirements.

5.2.10 Footprint

This treatment train has a large footprint compared to the other potential alternatives. The following are the assumptions utilized to estimate the required footprint:

- As previously mentioned, only treatment associated facilities are considered in the footprint sizing. New administrative, storage, and maintenance buildings are not included.
- The solids contact clarifiers need to remove magnesium so their rise rate is lower than calcium-only options, increasing the required footprint.

The estimated total footprint is calculated in Table 5.6. A hypothetical site plan for this alternative is shown on Figure 5.6.

Table 5.6 Alternative 3 Footprint Estimate

Component	Area (sq ft)
Forced draft aerators	3,000
Solids contact clarifiers	40,700
Dual media filters(1)	9,000
Ion exchange system	12,100
Total	**64,800**

Notes:
(1) 5 gpm/sq ft loading rate.

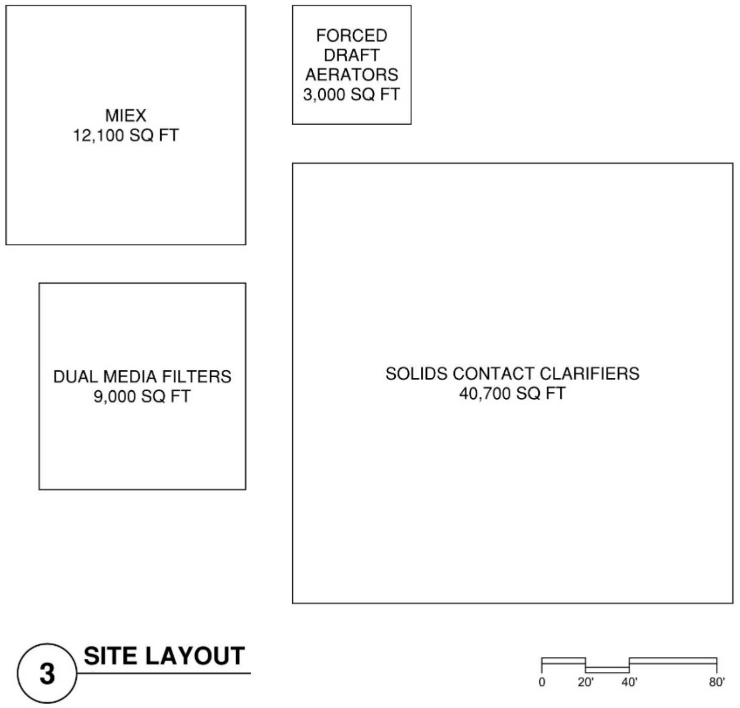

Figure 5.6 Alternative 3 Site Layout

5.2.11 Technology Subalternatives

Potential subalternatives that could be utilized with this option include adding pellet softeners in place of solids contact clarifiers and adding ferric sulfate to the softening process. See Section 5.1.11 for additional details on these technologies.

5.3 Alternative 6: Enhanced Coagulation and Caustic Softening

See Section 4.6 for a general description of Alternative 6.

5.3.1 Process Flow Diagram

A process flow diagram of this alternative is shown in Figure 5.7.

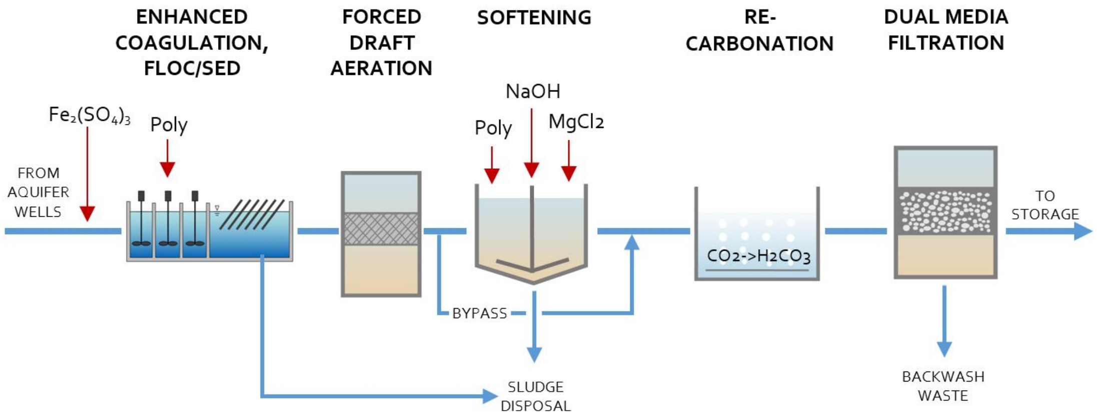

Figure 5.7 Alternative 6 Process Flow Diagram

5.3.2 Water Quality

5.3.2.1 Ability to Meet Water Quality Goals

Water quality predictions are summarized in Table 5.7 followed by a discussion of select parameters. All percent removals through different processes use conservative estimates based on background research, models, calculations, and bench-scale data.

Table 5.7 Alternative 6 Water Quality Predictions

Parameter	Units	Value
Influent flow required for 50 mgd to distribution system	mgd	50.00
Softening bypass percent used in model	%	9(1)

Parameter	Units	Finished Water Goal	Finished Water Predicted Value		
			Average(2)	Minimum(3)	Maximum
Color	CU	< 5 (< 12)(5)	3.4	NA	5.7
Alkalinity	mg/L as $CaCO_3$	40 – 100	70	70	71
Free ammonia	mg/L as N	0.05 – 0.1	0.10	NA	0.10
Total hardness	mg/L as $CaCO_3$	80 – 160	70	70	71
Iron	mg/L	< 0.1	0.000	NA	0.000
Manganese	mg/L	< 0.02	0.004	NA	0.006
Sodium	mg/L	< 50	154	NA	166
Total dissolved solids (TDS)	mg/L	< 500	314	NA	350
Sulfate	mg/L	< 200	65.2	NA	65.8
Chloride	mg/L	< 100	61	NA	82
Turbidity	NTU	< 1.0	0.03	NA	0.03
H2S	mg/L	< 0.1	0.01	NA	0.03
pH	---	8 – 8.5	8.5 (4)	8.5 (4)	8.5 (4)
CSMR	---	< 0.5	0.9	NA	1.2

Notes:

(1) The softening bypass percentage was chosen to balance the need to increase finished water hardness while still achieving adequate color removal.
(2) Average values refer to values obtained using mean influent water quality conditions.
(3) Minimum values were only predicted for parameters where the finished water goal included a minimum value.
(4) pH was lowered to 8.5 during recarbonation in all water quality scenarios for this alternative, regardless of the influent water pH.
(5) A 5 CU color goal has been established but the City is also interested in exploring options that achieve between 5 and 12 CU.

Color

Color removal under this alternative is predicted to achieve the conservative goal of 5 CU for most influent conditions, with a slight exceedance of this value (5.7 CU) when influent color is very high (influent = 75 CU). In this case, the softening bypass percentage could be decreased to improve color removal in the enhanced softening process, but the flexibility may be limited due to resulting low finished hardness levels.

Hardness

Finished water hardness is predicted to be slightly lower than desired at 70 mg/L as $CaCO_3$ (goal range is 80 – 160 mg/L as $CaCO_3$). This could be overcome by increasing the softening bypass percentage. Since the majority of color removal occurs during enhanced coagulation, increasing the bypass percentage during average color conditions should not have a significant impact on finished water color.

Chloride to Sulfate Mass Ratio

Because sulfates are added to the water during enhanced coagulation, this alterative has an improved chloride to sulfate mass ratio compared to the previous alternatives, averaging 0.9. This is also a significant improvement from the current plant CSMR of 8.2. However, 0.9 this still exceeds the conventional target of 0.5 and therefore the CSMR may need further consideration depending on the composition of the distribution system piping materials. Since this treatment train already includes a ferric sulfate process, a lower CSMR could be achieved by simply increasing the ferric sulfate dose.

5.3.2.2 Other Water Quality Considerations

The proposed process could provide additional treatment benefits with regards to other constituents than those evaluated above:

- Volatile Organic Compounds – As noted for other alternatives, packed tower aeration can remove 70-90 percent of select VOCs.
- Free carbon dioxide – Carbon dioxide will also be removed by packed tower aeration, thereby reducing the associated calcium carbonate production.
- Inorganic chemicals – Enhanced softening is effective at removing various heavy metals.
- Synthetic organics compounds - None of the treatment processes in this option would remove SOCs.
- Radionuclides can be removed by the enhanced softening process.

5.3.3 Risks and Reliability

The following are discussion points regarding reliability and control of risk for this treatment train:

- Meeting water quality goals – Enhanced coagulation and enhanced lime softening are effective for color reduction and the other technologies utilized are proven with predictable performance.
- Disposal of waste streams – Calcium carbonate and enhanced coagulation residuals disposal is a risk as this continues to become more difficult and costly.
- Technology – There is nothing proprietary about either the capital or O&M standpoint of this proposed treatment train.

- This treatment train is simple and less mechanically intensive than some of the other treatment trains. If space is limited and the enhanced coagulation train needs to be a sand ballasted sedimentation process in order to fit on site, the amount of mechanical equipment increases significantly and the reliability will be reduced unless redundancy is provided.
- The aeration system is a passive system which improves reliability, however intermediate pumping at the enhanced coagulation effluent will likely be required for this option.

5.3.4 Flexibility

The following are discussion points pertaining to the flexibility of the proposed technologies:

- The enhanced coagulation and softening system does not achieve the same level of color and TOC removal as some of the other treatment trains, such as fixed bed IX and NF. Due to the use of enhanced coagulation prior to the softening process, either soda ash or caustic soda will be required to achieve the hardness and alkalinity goals, increasing chemical expenses compared to lime-only softening.
- The removal of H_2S is dependent on the pH of the water applied to the forced draft aeration (lowered during the coagulation process) so flexibility to treat higher levels of H_2S is possible.
- Both the enhanced coagulation and softening processes can be designed with 'dials' that can be adjusted to improve color removal. These dials are:
  - Higher coagulant doses yield higher color removal.
  - Higher magnesium chloride doses yield higher color removal.

Both of these dials have chemical, capital and O&M cost, and residuals handling impacts.

5.3.5 Ability to Meet Future Regulations

Future regulatory changes would impact this treatment option as follows:

- Manganese – Softening can be used to achieve high levels of manganese removal and should have no problems addressing any future manganese regulations.
- Cyanotoxins – Because the source is groundwater, it is unlikely that any future cyanotoxin regulations will present a challenge for this system.
- Disinfection byproducts – This process can achieve high levels of TOC removal, resulting in lower DBP formation. However this removal is not as good as that of other technologies such as fixed bed IX.
- Perfluoro-compounds – These compounds will not be removed by this treatment process.
- Perchlorate – Perchlorate will not be removed by this treatment process.
- Strontium – Precipitative softening can be moderately effective for strontium removal.

5.3.6 Operational Complexity

This treatment train has one of the lowest operational complexities of any of the proposed treatment trains (although NF with fixed bed IX bypass has the lowest operational complexity). It is very similar to the existing treatment process except for the use of enhanced coagulation and replacement of diffused aeration with forced draft aeration. If the decision is made to utilize a high-rate enhanced coagulation process such as sand ballasted clarification (SBC), then the operational complexity will increase. SBC is further discussed in Section 5.3.11.

5.3.7 Maintenance Requirements

From a maintenance perspective, the differences between the existing plant and this treatment train would be the maintenance associated with the enhanced coagulation process and the blowers on the forced draft aerators. If the enhanced coagulation train is high-rate conventional (lamella plates) then the maintenance items are the flash mix system (pumps), flocculation equipment, and solids collection. If a higher-rate process like SBC is utilized then more energy is required for mixing, the hydrocyclones, and the residuals pumps for sand handling. With sand as the ballast there will be increased wear and tear on mechanical equipment. Each forced draft aerator will have blowers which will need to be maintained. These blowers will be easier to maintain than the current system because they operate at a lower head.

5.3.8 O&M Costs

Estimated O&M costs are presented in Table 5.8. The estimates are based on an average annual plant flow of 33 mgd and a 9 percent softening bypass (bypass percentage is discussed in Section 5.3.2.1). Aeration blower power is not included in the estimates as this will be the same across all the proposed alternatives. O&M costs for this alternative are considered to be high compared to other alternatives. The high cost is mainly due to sodium hydroxide, magnesium chloride, and ferric sulfate addition. It is possible that the magnesium chloride and sodium hydroxide doses could be slightly decreased, lowering chemical costs, but this could result in decreased color removal and difficulty meeting the 5 CU color goal.

Table 5.8 Alternative 6 O&M Cost Estimates

Item	Average Annual Cost
Power	$1,151,400
Chemicals	$13,100,100
Solids Disposal	$650,300
Total	**$14,901,800**

5.3.9 Safety

5.3.9.1 Public

Replacement of the existing chlorine gas system with either bulk sodium hypochlorite will improve public safety risk at the facility (this applies to all of the proposed alternatives).For this treatment train alternative the following chemicals may pose a level of safety concern to the public:

- Ferric sulfate.
- Caustic soda (sodium hydroxide).
- Magnesium chloride.
- Polymer.
- Carbon dioxide.
- Chlorine.
- Ammonia.

- Fluoride.

This treatment train has a slightly increased risk to the public due to the use of more hazardous chemicals such as caustic soda which is a considered corrosive and a Class 1 water reactive by code. In addition, the caustic soda and the magnesium chloride are not as concentrated, resulting in an increased number of truck deliveries which also increases risk to the public.

5.3.9.2 Employee

Employee safety risk is slightly higher for this treatment train for similar reasons outlined for public safety above. Caustic soda and ferric sulfate are both corrosive and can be dangerous for plant staff to handle.

5.3.9.3 Hurricane Considerations

The power requirements for this treatment train are lower than some of the other options because of the favorable hydraulics of the system. However, there still would be requirements for transfer pumping after the enhanced coagulation process.

The reduced frequency of deliveries by utilizing concentrated chemicals would allow certain processes to operate for extended periods of time in the event that chemical deliveries are interrupted because of a hurricane.

Caustic soda and magnesium chloride are less concentrated, however this treatment train would have the flexibility to not add caustic soda or magnesium chloride during an emergency situation (switching to conventional lime softening), which would result in still meeting hardness goals (but not necessarily color goals).

All structures will be designed to meet or exceed the associated storm requirements to withstand flooding and winds from hurricanes.

5.3.10 Footprint

This treatment train has a large footprint compared to the other potential alternatives. The following are the assumptions utilized to estimate the required footprint:

- Only treatment associated facilities are considered in the footprint sizing. New administrative, storage, and maintenance buildings are not included.
- The solids contact clarifiers need to remove magnesium so their rise rate is lower than calcium-only options, increasing the required footprint.
- The process includes an enhanced coagulation treatment train which further increases the footprint of the project. There would be significant differences between floc/sed with lamella plates and a higher-rate process like sand ballasted clarification; floc/sed with lamella plates requires 30 minutes of floc time and a sedimentation basin rise rate of 3-4 gpm/sq ft and sand ballasted clarification requires a few minutes of mixing followed by a sedimentation rise rate of 20-30 gpm/sq ft.

The estimated total footprint is calculated in Table 5.9. Note that only major unit processes are included in this table. The estimated footprint information is intended to be used for comparison of alternatives only, and does not include ancillary facilities that may be required for a complete WTP. A hypothetical layout of the existing site plan for this alternative is shown on Figure 5.8.

Table 5.9 Alternative 6 Footprint Estimate

Component	Area (sq ft)
Forced draft aerators	3,000
Solids contact clarifiers	40,700
Dual media filters(1)	9,000
Coag/Floc/Sed	25,000
Total	**77,700**

Notes:
(1) 5 gpm/sq ft loading rate.

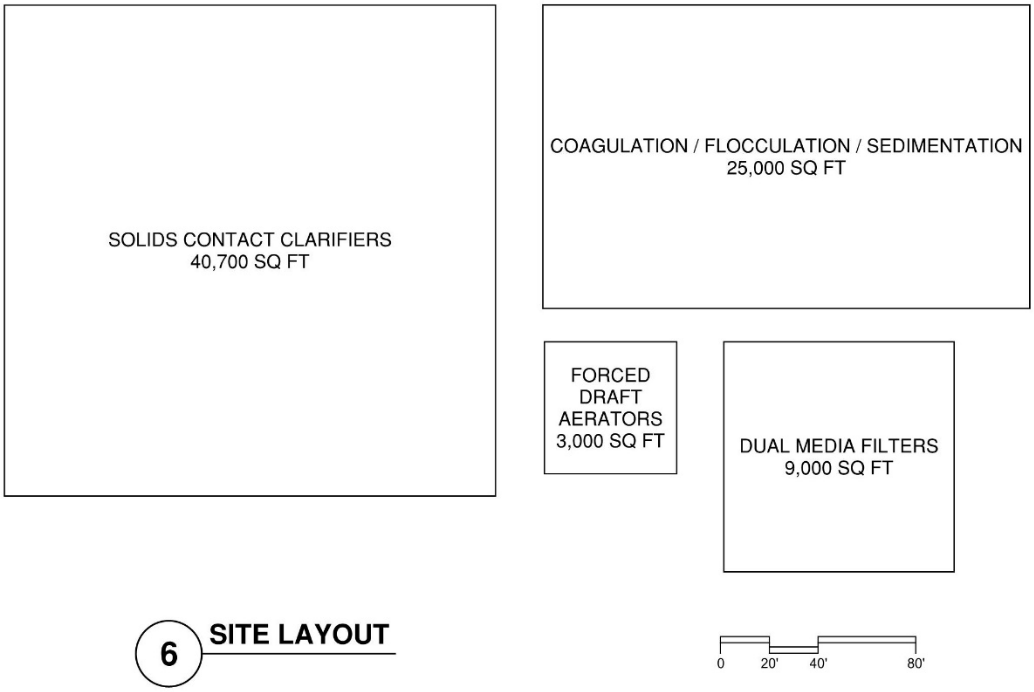

Figure 5.8 Alternative 6 Site Layout

5.3.11 Technology Subalternatives

5.3.11.1 Sand Ballasted Clarification in Place of Conventional Coag/Floc/Sed

Sand ballasted clarification (SBC) employs microsand as a means of enhancing flocculation and accelerating gravity sedimentation. Although high-rate, the process still requires chemical coagulation similar to conventional treatment. A bridging polymer attaches the flocculated particles to the sand and a high-energy mixer keeps the sand and floc solids suspended in the maturation basin in preparation for sedimentation. The sedimentation tank uses tube or plate settlers to hydraulically distribute water across of the tank and to enhance settling performance.

In the past this has been a proprietary system, but now there are two manufacturers that can supply and furnish the sand ballasted clarification process and equipment (RapiSand® by WesTech and Actilfo® by Kruger).

Specific challenges associated with sand ballasted sedimentation are as follows:

- High energy consumption.
- Large motors, pumps, and drives.
- Sand creates wear and tear on equipment, pumps, piping, etc.
- Sand carryover into sludge dewatering facilities.
- Equipment maintenance.
- Increased operating costs.
- Increased chemical usage and sludge production.

SBC systems are extremely high-rate with surface loading rates between 20 and 40 gpm/sf. Construction costs can also be lower because the hydraulic process basins require significantly less concrete than conventional basins. A schematic of the SBC process is shown in Figure 5.9.

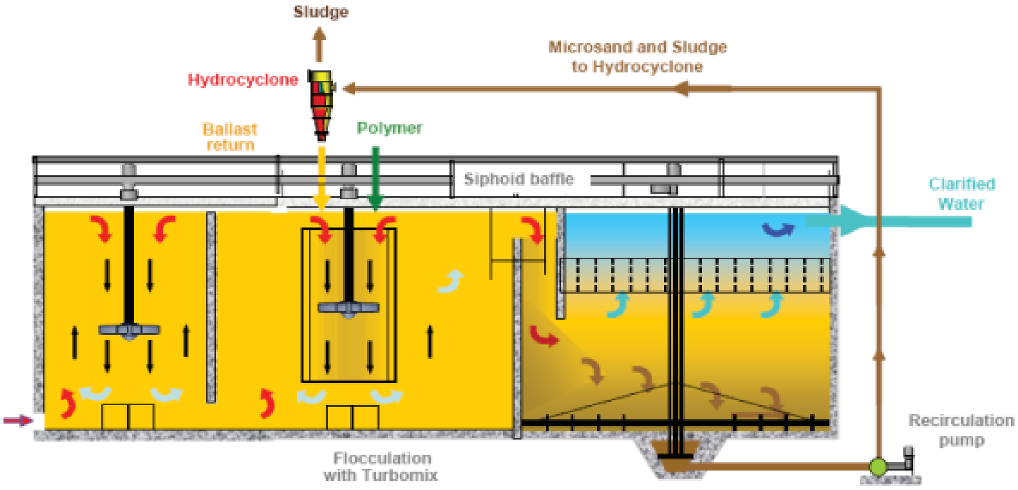

Figure 5.9 Sand Ballasted Clarification Process

5.4 Alternative 7: Enhanced Coagulation with Pellet Softening and Fixed Bed IX

See Section 4.7 for a general description of this alternative.

5.4.1 Process Flow Diagram

A process flow diagram of Alternative 7 is shown in Figure 5.10.

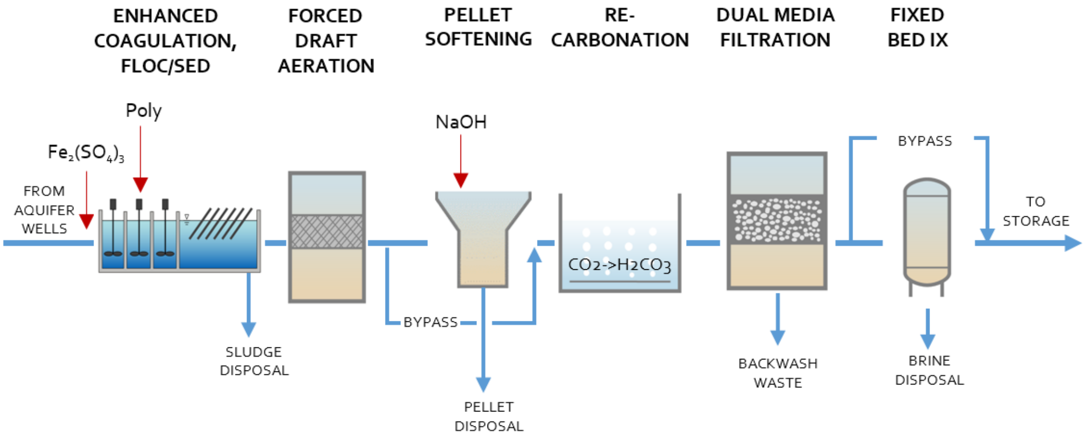

Figure 5.10 Alternative 7 Process Flow Diagram

5.4.2 Water Quality

5.4.2.1 Ability to Meet Water Quality Goals

Water quality predictions are summarized in Table 5.10. All percent removals through different processes use conservative estimates based on background research, models, calculations, and bench-scale data.

Table 5.10 Alternative 7 Water Quality Predictions

Parameter	Units	Value
Influent flow required for 50 mgd to distribution system	mgd	50.1
Softening bypass percent used in model	%	30(1)
IX bypass percent used in model	%	25(1)

Parameter	Units	Finished Water Goal	Finished Water Predicted Value		
			Average(2)	Minimum(3)	Maximum
Color	CU	< 5 (< 12)(5)	2.8	NA	4.6
Alkalinity	mg/L as $CaCO_3$	40 – 100	81	81	88
Free ammonia	mg/L as N	0.05 – 0.1	0.10	NA	0.10
Total hardness	mg/L as $CaCO_3$	80 – 160	110	110	115
Iron	mg/L	< 0.1	0.000	NA	0.000
Manganese	mg/L	< 0.02	0.004	NA	0.006
Sodium	mg/L	< 50	78.8	NA	88.4
Total dissolved solids (TDS)	mg/L	< 500	289	NA	339
Sulfate	mg/L	< 200	37.8	NA	38.2
Chloride	mg/L	< 100	92	NA	123
Turbidity	NTU	< 1.0	0.03	NA	0.03
H2S	mg/L	< 0.1	0.01	NA	0.03
pH	---	8 – 8.5	8.5 (4)	8.5 (4)	8.5 (4)
CSMR	---	< 0.5	2.4	NA	3.2

Notes:

(1) The softening bypass percentage was chosen as a means to achieve the finished water alkalinity and hardness goals. The IX bypass percentage was raised as high as possible while still meeting finished water color goals under all influent conditions.

(2) *Average* values refer to values obtained using mean influent water quality conditions.

(3) Minimum values were only predicted for parameters where the finished water goal included a minimum value.

(4) pH was lowered to 8.5 during recarbonation in all water quality scenarios for this alternative, regardless of the influent water pH.

(5) A 5 CU color goal has been established but the City is also interested in exploring options that achieve between 5 and 12 CU.

Color

Even with a 25 percent IX bypass, color results are predicted to meet the conservative target of 5 CU for all influent scenarios. Lowering the bypass percentage would result in even more color removal. The bypass percentage can be further increased if the City decides to target the moderate goal of 12 CU.

Hardness

Even with a 30 percent softening bypass, hardness goals are anticipated to be met under all influent conditions. Note that the softening bypass percentage has no effect on color removal for this alternative, and therefore there is more flexibility to target specific hardness and alkalinity goals.

Sodium

Finished water sodium is predicted to average 79 mg/L (maximum of 88 mg/L), exceeding the goal of 50 mg/L, but not exceeding the MCL of 160 mg/L. Excess sodium in the finished water comes from the pellet softening process, and therefore increasing the softening bypass percentage would reduce sodium levels. The maximum predicted value of 88 mg/L is not considered a public health risk.

Chloride

Chloride levels may exceed finished water goals (123 mg/L vs. 100 mg/L) when influent chlorides are high. This is due to the chlorides from the IX process. IX chloride release predictions are based on bench-scale testing and may have been overestimated due to using a virgin resin.

Chloride to Sulfate Mass Ratio

Finished water CSMR is predicted to be 2.4 on average and 3.2 maximum, a significant improvement for treatment alternatives without coagulation as well as compared to the existing finished water (~8.2), but still above the threshold of less than 0.5. The CSMR may need further consideration depending on the composition of the distribution system piping materials. If the CSMR is deemed to be a concern, the ferric sulfate dose could be increased to lower the CSMR below 0.5.

5.4.2.2 Other Water Quality Considerations

The following is a list of other constituents which could potentially be impacted this treatment process:

- Volatile Organic Compounds – As previously noted, packed tower aeration can effectively remove VOCs.
- Free carbon dioxide – Packed tower aeration will remove carbon dioxide, thereby reducing the associated calcium carbonate production.
- Inorganic chemicals – Arsenic, barium, cadmium, nitrite, and nitrate can be removed by IX.
- Synthetic organics compounds - SOCs would not be removed by any of the proposed treatment processes for this option.

5.4.3 Risks and Reliability

The following are discussion points regarding reliability and controlling risk for this treatment train:

- Meeting water quality goals – Vessel IX is one of the most effective treatment methods for color reduction, and the other technologies utilized are proven with predictable performance.
- Disposal of waste streams – Pellet softening helps address the risks previously described for calcium carbonate disposal because the process generates a 100 percent calcium carbonate pellet that is free draining. Ferric hydroxide solids will also need to be disposed from the sedimentation process, thereby increasing O&M costs. Disposal of the brine waste from the IX process is a concern if discharged to the sewer because of potential regulations with respect to chlorides and TDS, or due to the impact of these contaminants on reuse. One way to alleviate this concern is injection of the waste into a deep well (similar to what is done on nanofiltration/reverse osmosis plants).
- Technology – None of the technologies being utilized are proprietary. All of the technologies proposed have a long track record of meeting the water quality goals that they are being proposed for. Pellet softening has been used in the Netherlands since the 1980's, although currently its use in the US is limited.
- This treatment train is not a mechanically intensive so mechanical reliability is high.
- The aeration and fixed bed IX systems are passive systems which improve reliability, however intermediate pumping is required for this option.
- Pellet softening is more reliable than lime softening from the standpoint that it uses caustic soda (liquid chemical). Handling of pellets is also significantly easier than sludge.

5.4.4 Flexibility

The following are discussion points pertaining to the flexibility of the proposed treatment technologies:

- The softening process is not expected to remove TOC or color. Because of this hardness and alkalinity leaving the plant can be carefully and flexibly managed with a bypass to maintain a consistent water quality.
- The removal of H_2S is dependent on the pH of the water applied to the forced draft aeration. Because the pH is lowered though coagulation flexibility to treat higher levels of H_2S is possible.
- Due to the use of vessel IX and its capability to remove organics at a very high level, the flexibility for TOC and color removal using the bypass is very high.
- The ferric sulfate dose can be increased or decreased to increase or decrease color removal, respectively. This has chemical, capital and O&M cost, and residuals handling impacts, but allows flexibility for increased color removal.

5.4.5 Ability to Meet Future Regulations

This treatment train would have the following impacts on constituents which could potentially be regulated in the future:

- Manganese –The pellet softening process does not remove manganese, but influent manganese levels to the plant are already very low and therefore this parameter is not a major concern.
- Cyanotoxins – Cyanotoxins will not likely present any future regulatory challenges as this system has a ground water source.

- Disinfection byproducts – The use of vessel IX and its ability to remove NOM results in lower DBP formation than other treatment technologies. The use of enhanced coagulation at the front of process helps to further remove organic matter and reduces brine waste from the IX process.
- Perfluoro-compounds – Although IX is a technology used to remove these contaminants, this treatment train uses a specific IX resin so this process would have minimal impact on these constituents.
- Perchlorate – The anion IX process will reduce perchlorate levels.

5.4.6 Operational Complexity

The operational complexity of this treatment train is similar to the existing treatment train except for the addition of a fixed bed IX system and enhanced coagulation, which are passive systems that minimally increase operational complexity. Pellet softening is easier to operate than conventional lime softening, but overall this train would be similar to current plant operations. If the decision is made to utilize a higher-rate enhanced coagulation process (like sand ballasted sedimentation) then the operational complexity will increase.

5.4.7 Maintenance Requirements

From a maintenance perspective, the biggest change compared to the existing plant would be maintenance of the two transfer pump stations which will pump the water through the IX system, and from the forced draft aeration to the pellet softeners. One of the challenges associated with a vessel IX system is the number of vessels (33-50 vessels) and all of the automated valves associated with this system. If the enhanced coagulation train is high-rate conventional (lamella plates) then additional maintenance items will include the flash mix pumps, flocculation equipment, and solids collection system. If a higher-rate process like sand ballasted sedimentation is utilized then more energy is required for mixing, the hydrocyclones, and the residuals pumps for sand handling. With sand as the ballast there will be increased wear and tear on mechanical equipment. Each forced draft aerator will have blowers which will need to be maintained. These blowers will be easier to maintain than the current system because they operate at a lower head.

5.4.8 O&M Costs

Estimated O&M costs are presented in Table 5.11. The estimates are based on an average annual plant flow of 33 mgd, a 30 percent softening bypass, and a 25 percent IX bypass (bypass percentages are discussed in Section 5.4.2.1). Items not included in estimates include aeration blower power and disposal costs for brine. O&M costs for this alternative are considered to be average compared to other alternatives.

Table 5.11 Alternative 7 O&M Cost Estimates

Item	Average Annual Cost
Power	$1,239,700
Chemicals	$4,967,300
Solids Disposal	$157,700
IX Resin Replacement	$649,800
Total	**$7,014,500**

5.4.9 Safety

5.4.9.1 Public

Replacement of the existing chlorine gas system with sodium hypochlorite (bulk) will significantly improve public safety.

For this treatment train alternative the following chemicals pose a level of safety concern to the public:

- Ferric sulfate.
- Caustic soda.
- Polymer.
- Carbon dioxide.
- Chlorine.
- Ammonia.
- Fluoride.

This treatment train has a slightly increased risk to the public due to the use of more hazardous chemicals such as caustic soda which is a considered corrosive and a Class 1 water reactive by code. In addition, the caustic soda is not as concentrated, resulting in more frequent truck deliveries which slightly increases risk to the public.

5.4.9.2 Employee

Similar to public safety, employee safety risks are slightly higher for this treatment train for the reasons listed above. Caustic soda and ferric sulfate are is corrosive and can be dangerous for plant staff to handle.

5.4.9.3 Hurricane Considerations

The power requirements for this treatment train are higher than some of the other options because intermediate pumping to transfer water to the pellet softeners and to the IX vessels is required. This directly impacts the generator sizing necessary to treat water during a power outage.

As aforementioned, the majority of chemicals that are associated with this treatment train are concentrated, which limits delivery requirements and lends this treatment train to operate for longer periods of time without excessive capital expenditures associated with storage of more dilute chemicals.

Regarding hurricane hardening, all structures will be designed to meet or exceed the associated storm requirements.

5.4.10 Footprint

This treatment train has a large footprint compared to the other potential alternatives. The following are the assumptions utilized to estimate the required footprint:

- Only treatment associated facilities are considered in the footprint sizing. New administrative, storage, and maintenance buildings are not included.
- The pellet softeners have a much smaller footprint than solids contact clarifiers (40 gpm/sq ft versus 1.75 gpm/sq ft).

- The process includes an enhanced coagulation treatment train which increases the footprint required. There would be significant differences between flocculation/sedimentation with lamella plates and a higher-rate process like and ballasted sedimentation; flocculation/sedimentation with lamella plates requires 30 minutes of floc time and a sedimentation basin rise rate of 3-4 gpm/sq ft and sand ballasted clarification requires a few minutes of mixing followed by a sedimentation rise rate of 20-30 gpm/sq ft.
- The IX footprint is the same as that of Alternative 2.
- Two transfer pump stations are necessary for this alternative.

The estimated total footprint is calculated in Table 5.12. Note that only major unit processes are included in this table. The estimated footprint information is intended to be used for comparison of alternatives only, and does not include ancillary facilities that may be required for a complete WTP. A hypothetical layout of the existing site plan for this alternative is shown in Figure 5.11.

Table 5.12 Alternative 7 Footprint Estimate

Component	Area (sq ft)
Forced draft aerators	3,000
Pellet softeners	1,300
Dual media filters(1)	9,000
Coagulation/Flocculation/ Sedimentation	25,000
Ion exchange system	19,040
Transfer pump station 1	4,000
Transfer pump station 2	4,000
Total	**65,340**

Notes:
(1) 5 gpm/sq ft loading rate.

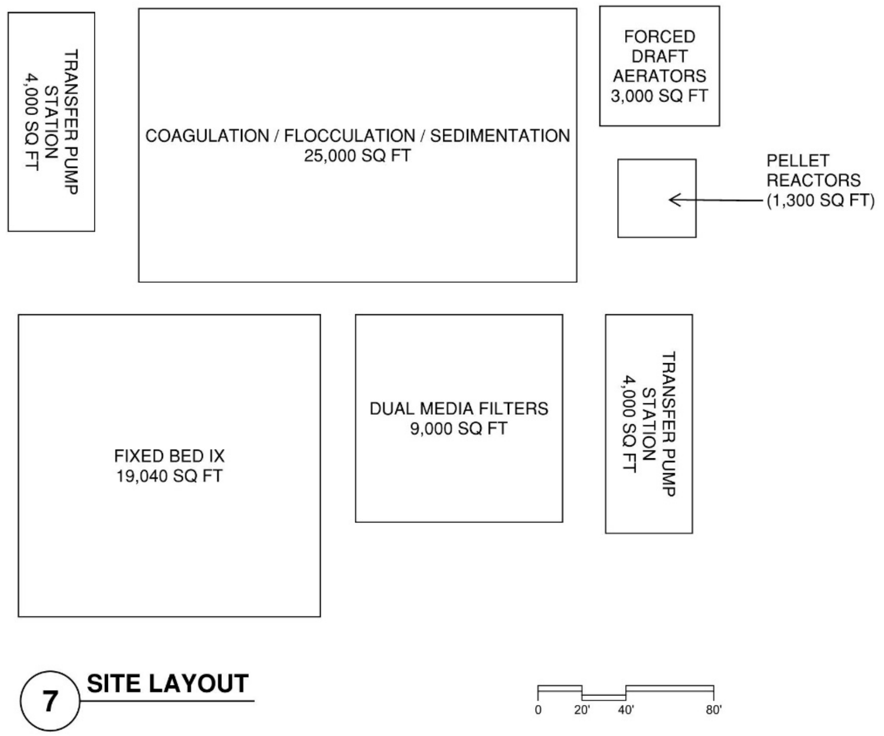

Figure 5.11 Alternative 7 Site Layout

5.4.11 Technology Subalternatives

Potential subalternatives which could be utilized with this option include sand ballasted clarification (see Section 5.3.11 for additional details), and gravity IX in place of fixed bed IX (see Section 5.1.11 for additional details). In addition, solids contact clarifiers could be used instead of pellet softeners. For details on how these technologies differ, refer to Section 5.1.11. The main advantage of solids contact clarifiers is that they provide additional NOM removal whereas pellet softening does not.

5.5 Alternative 11: Nanofiltration with Fixed Bed IX Bypass

See Section 4.11 for a general description of this alternative.

5.5.1 Process Flow Diagram

A process flow diagram of Alternative 11 is shown in Figure 5.12.

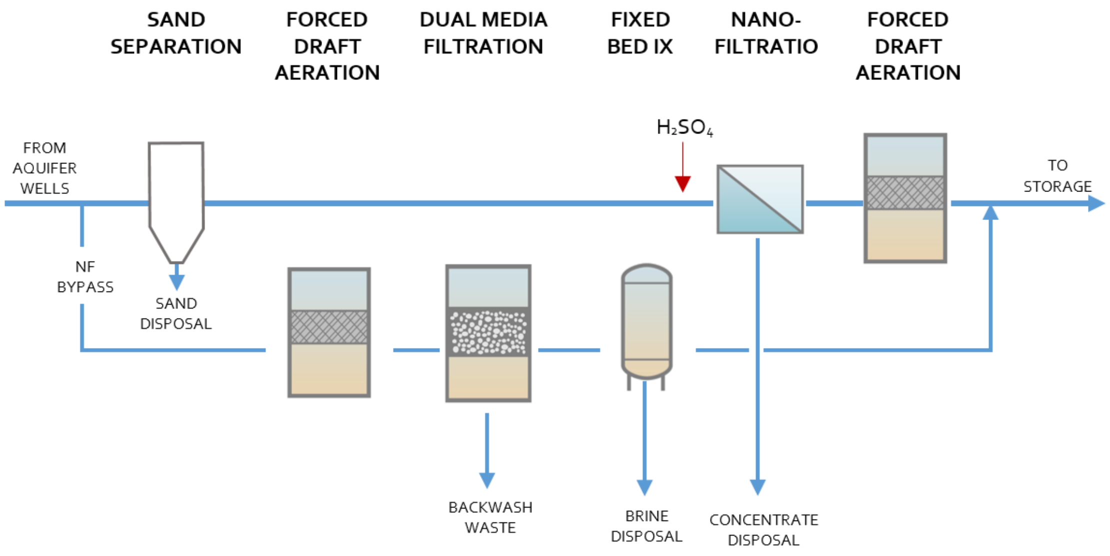

Figure 5.12 Alternative 11 Process Flow Diagram

5.5.2 Water Quality

5.5.2.1 Ability to Meet Water Quality Goals

Water quality predictions are summarized in Table 5.13. All percent removals through different processes use conservative estimates based on background research, models, calculations, and bench-scale data.

Table 5.13 Alternative 11 Water Quality Predictions

Parameter	Units	Value
Influent flow required for 50 mgd to distribution system	mgd	56.9
NF Recovery	%	85
Percent to Bypass Stream	%	20(1)

Parameter	Units	Finished Water Goal	Finished Water Predicted Value		
			Average(2)	Minimum(3)	Maximum
Color	CU	< 5 (< 12)(5)	1.4	NA	2.3
Alkalinity	mg/L as $CaCO_3$	40 – 100	61	58	66
Free ammonia	mg/L as N	0.05 – 0.1	0.07	NA	0.07
Total hardness	mg/L as $CaCO_3$	80 – 160	100	97	106
Iron	mg/L	< 0.1	0.101	NA	0.189
Manganese	mg/L	< 0.02	0.002	NA	0.003
Sodium	Mg/L	< 50	18.1	NA	21.6
Total dissolved solids (TDS)	mg/L	< 500	151	NA	176
Sulfate	mg/L	< 200	1.7	NA	1.8
Chloride	mg/L	< 100	44	NA	58
Turbidity	NTU	< 1.0	0.00	NA	0.01
H_2S	mg/L	< 0.1	0.02	NA	0.07
pH	---	8 – 8.5	8.0	8.0	8.0
CSMR	---	< 0.5	24.9	NA	32.4

Notes:

(1) The NF bypass percentage was chosen to minimize the influent flow while still maintaining adherence to finished water hardness goals.
(2) *Average* values refer to values obtained using mean influent water quality conditions.
(3) Minimum values were only predicted for parameters where the finished water goal included a minimum value.
(4) pH was raised to 8.0 during aeration in all models for this alternative, regardless of the influent water pH.
(5) A 5 CU color goal has been established but the City is also interested in exploring options that achieve between 5 and 12 CU.

Influent Flow

In order to accommodate the loss of flow associated with the nanofiltration treatment process recovery, maximum influent flow would need to be 56.9 mgd. This has significant cost implications, as additional water supply allocation will cost approximately $4.6 million/mgd. Therefore, the cost to increase the water allocation would total approximately $32 million (or higher if the average bypass percentage is decreased).

Color

This treatment process reduces color to extremely low levels (well below the 5 CU goal) even with a 20 percent nanofiltration bypass. As long as hardness and alkalinity remain controlled to meet water quality goals, the NF bypass percentage can be increased, resulting in source water savings.

Hardness

For this alternative, finished water hardness goals are predicted to be met under all influent conditions. Hardness concentration in the finished water can be controlled with bypass management.

Iron

If influent iron is higher than normal in the source water, there is a chance that finished water iron would be as high as 0.19 mg/L prior to disinfection, which exceeds the target goal of < 0.1 mg/L. However, the remaining iron would be oxidized with the addition of chlorine which is applied for disinfection, provided that the iron is not organically bound.

Chloride to Sulfate Mass Ratio

Finished water CSMR is predicted to be 25.1 on average, significantly exceeding the conventional CSMR target of 0.5. This is due to the decrease in sulfate through the NF process and an increase in chloride from the IX process. The high CSMR may need further consideration depending on distribution system piping materials.

5.5.2.2 Other Water Quality Considerations

The following constituents could also be impacted by this treatment process:

- Volatile Organic Compounds – As previously described for the other alternatives, packed tower aeration can remove VOCs. In addition, NF can remove most organics, thereby reducing DBP formation potential.
- Inorganic chemicals – Arsenic, barium, cadmium, nitrite, and nitrate can be removed effectively by NF, as well as IX.
- Synthetic organic compounds are typically removed by GAC so none of these constituents would be removed by this treatment technology unless the molecular weight of the compound is larger than the size exclusion of the selected membranes.
- Microorganisms – Due to the size exclusion of very small molecular weight compounds, NF can remove most pathogens from water as long as the integrity of the membranes is maintained.

5.5.3 Risks and Reliability

Risk and reliability factors to be taken into consideration for this alternative include:

- Meeting water quality goals – Membranes are one of the most robust treatment processes available for TOC and color removal. The only concern with respect to product water quality is the chloride-based corrosivity and its possible impacts on distribution system piping if additional stabilization procedures are not incorporated.
- Disposal of waste streams – The NF process produces a 10-15 percent waste stream which has high TDS and organic content.
- Disposal of the brine waste from the IX system is a concern if discharged to the sewer because of potential chloride and TDS regulations. As previously noted, this could be addressed by injection of the waste into a deep well along with the residual brine from the NF process.
- Technology – The proposed technologies for this option are all seasoned and well proven in the industry, and specifically in south Florida.
- This treatment process is simple and less operationally intensive than some of the other treatment trains, however it is mechanically intensive and includes a significant amount of instrumentation. Nevertheless, the space requirements are relatively small.
- One of the drawbacks associated with this option is the high energy input required.
- The aeration system is a passive system which has high reliability.
- The chemical addition requirements for this option are lower than those of other alternatives.

5.5.4 Flexibility

The following are discussion points pertaining to the flexibility of the proposed treatment technologies:

- The treatment train is very flexible in terms of achieving water quality goals. The IX bypass stream and membrane selection can effectively be utilized to achieve all treatment goals.
- The aeration of H_2S is dependent on raw water quality and the pH of the water applied to the forced draft aerator. The low pH of the membrane product water will allow for effective H_2S removal in the process.
- The high level of NOM removal achieved by utilizing vessel IX and membranes in conjunction with each other, allows for a high level of flexibility in the bypass control to balance hardness and alkalinity removal with TOC and color removal.

5.5.5 Ability to Meet Future Regulations

This treatment option could potentially be impacted by these constituents which may be regulated in the future:

- Manganese – The membrane process removes manganese to very low levels and should have no problems addressing any future manganese regulations. For the bypass train this would be more of a challenge, however the raw water manganese is currently very low.
- Cyanotoxins – This potential regulation is applicable for surface water sources and the use of groundwater minimizes potential for future issues, although NF would likely remove these compounds if encountered.
- Disinfection byproducts – The use of vessel IX and NF membranes results in significantly high levels of NOM removal, resulting in low DBP formation.

- Perfluoro-compounds – Membranes effectively remove perfluoro-compounds.
- Perchlorate – Perchlorate is removed with anion exchange resin. NF membranes also remove perchlorate.
- Strontium –NF membranes remove strontium by size exclusion.

5.5.6 Operational Complexity

Typically, these treatment processes have a high level of automation thereby making operation very user-friendly. The operational complexity of this treatment train is significantly lower than that of the existing treatment train because the flowrates, equipment settings, and chemical feed rates are constant for a particular flow rate even if water quality conditions change slightly.

5.5.7 Maintenance Requirements

From a maintenance perspective, the treatment processes are mechanically intensive, with multiple pumps, automatic valves, etc. Sophisticated equipment monitoring provides maintenance and operational problem notifications. Regular maintenance generally allows for reliable long-term operation. There could potentially be the following pumping associated with the membrane system:

- Wellfield booster pumps (to get the water through the sand separators and cartridge filters).
- Membrane booster pumps.
- Interstage booster pumps.
- CIP pumps
- Bypass booster pumps.
- Other miscellaneous smaller pumps (chemicals).

5.5.8 O&M Costs

Estimated O&M costs are presented in Table 40. The estimates are based on an average annual plant flow of 33 mgd, 85 percent NF recovery, and 20 percent bypass (bypass percentages are discussed in Section 5.5.2.1). Items not included in estimates include aeration blower power, disposal costs for brine and concentrate, and membrane cleaning chemicals. O&M costs for this alternative are considered to be low compared to other alternatives. This is mainly due to lower chemical costs. Power costs are higher than any of the previously presented alternatives due to the pumping associated with the use of membranes.

Table 5.14 Alternative 11 O&M Cost Estimates

Item	Average Annual Cost
Power	$1,610,300
Chemicals	$866,700(1)
Membrane and IX Resin Replacement	$456,700
Total	**$2,933,700**

Notes:
(1) Membrane cleaning chemicals not included in estimate.

5.5.9 Safety

5.5.9.1 Public

As is the case with all of the treatment alternatives, the existing chlorine gas system would be replaced with sodium hypochlorite, thereby reducing public safety risks.

For this treatment technology alternative the following chemicals may pose a level of safety concern to the public:

- Salt brine.
- Chlorine.
- Ammonia.
- Fluoride.
- Antiscalant.
- Sulfuric acid.
- Membrane cleaning chemicals.

Compared to previously discussed alternatives, the only chemical that poses additional safety risk for this alternative is sulfuric acid, which is corrosive and a Class 2 water-reactive. Safety protocols during deliveries and transport of sulfuric acid will need to be more stringent than for other chemicals.

5.5.9.2 Employee

Similar to public safety considerations, sulfuric acid is a potential hazard to plant staff if not properly handled. Increased chemical containment and safety protocols are required.

5.5.9.3 Hurricane Considerations

The power requirements for this treatment train are higher than any previously presented alternative due to the use of membranes. This directly impacts the generator size required to treat water during a power outage.

As noted for other alternatives, use of concentrated chemicals improves hurricane resiliency because many of the processes can operate for long periods of time without the risk of running out of chemicals should the supply train be interrupted.

Regarding hurricane hardening, all structures will be designed to meet or exceed the associated storm requirements.

5.5.10 Footprint

This treatment train is more compact than the other potential alternatives. The following are the assumptions utilized to estimate the required footprint:

- Only treatment associated facilities are considered in the footprint sizing. New administrative, storage, and maintenance buildings are not included.
- The footprints of the various technologies are sized so that the system can handle any NF bypass percentage between 0 percent and 50 percent.
- A transfer pump station is needed to supply the IX system.

The estimated total footprint is calculated in Table 5.15. Note that only major unit processes are included in this table. The estimated footprint information is intended to be used for comparison of alternatives only, and does not include ancillary facilities that may be required for a complete WTP.

A hypothetical layout of the existing site plan for this alternative is shown in Figure 5.13.

Table 5.15 Alternative 11 Footprint Estimate

Component	Area (sq ft)
Forced draft aerators	3,000
Dual media filters[1]	4,500
Membrane system	15,040
Ion exchange system	9,520
Transfer pump station	2,000
Total	**34,060**

Notes:

(1) 5 gpm/sq ft loading rate.

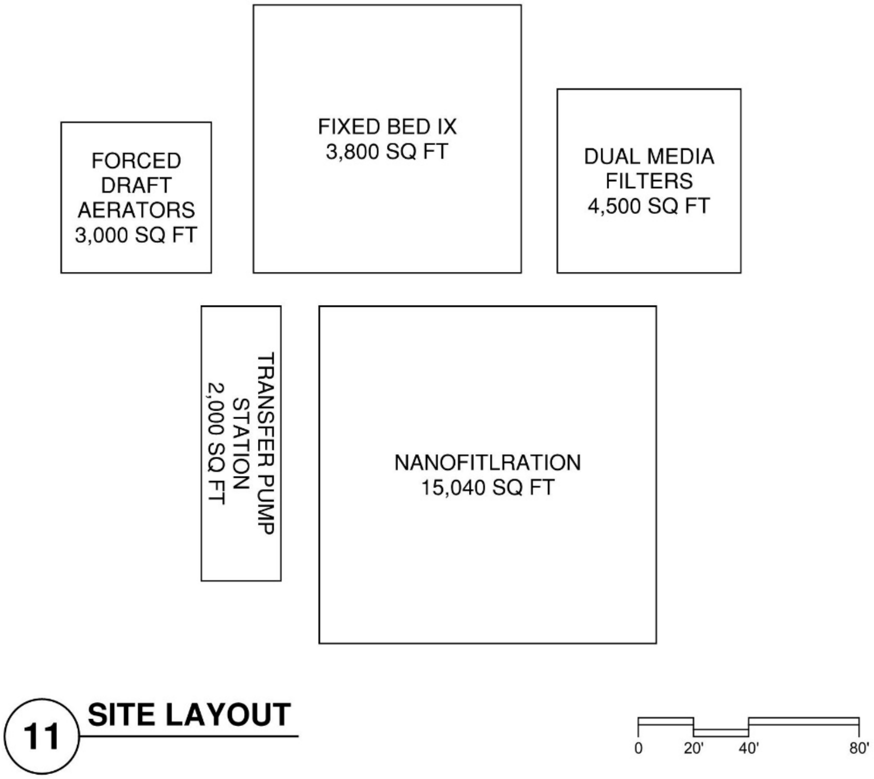

Figure 5.13 Alternative 11 Site Layout

5.5.11 Subalternatives

One potential subalternative which could be utilized with this alternative is using gravity bed IX on the bypass train rather than vessel IX. Additional details about this technology can be found in Section 5.1.11.

5.6 Alternative 12: Nanofiltration with MIEX Bypass

See Section 4.12 for a general description of this alternative.

5.6.1 Process Flow Diagram

A process flow diagram of Alternative 12 is shown in Figure 5.14.

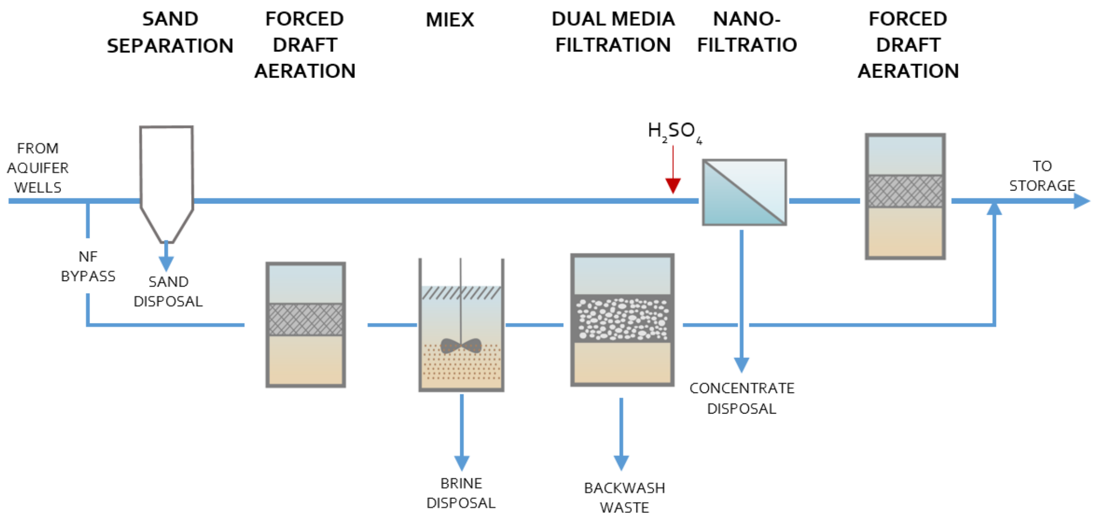

Figure 5.14 Alternative 12 Process Flow Diagram

5.6.2 Water Quality

5.6.2.1 Ability to Meet Water Quality Goals

Water quality predictions are summarized in Table 5.16. All percent removals through different processes use conservative estimates based on background research, models, extensive calculations, and bench-scale data.

Table 5.16 Alternative 12 Water Quality Predictions

Parameter	Units	Value
Influent flow required for 50 mgd to distribution system	mgd	57.8
NF Recovery	%	85
Percent to Bypass Stream	%	11(1)

Parameter	Units	Finished Water Goal	Finished Water Predicted Value		
			Average(2)	Minimum(3)	Maximum
Color	CU	< 5 (< 12)(4)	2.9	NA	4.8
Alkalinity	mg/L as $CaCO_3$	40 – 100	45	43	49
Free ammonia	mg/L as N	0.05 – 0.1	0.07	NA	0.07
Total hardness	mg/L as $CaCO_3$	80 – 160	84	81	88
Iron	mg/L	< 0.1	0.112	NA	0.208
Manganese	mg/L	< 0.02	0.002	NA	0.003
Sodium	mg/L	< 50	16	NA	20
Total dissolved solids (TDS)	mg/L	< 500	119	NA	139
Sulfate	mg/L	< 200	2.1	NA	2.2
Chloride	mg/L	< 100	32	NA	43
Turbidity	NTU	< 1.0	0.00	NA	0.01
H2S	mg/L	< 0.1	0.02	NA	0.07
pH	---	8 – 8.5	8.0	8.0	8.0
CSMR	---	< 0.5	15.4	NA	20.0

Notes:

(1) The NF bypass percentage was chosen to minimize the influent flow while still maintaining adherence to finished water conservative color goals.
(2) *Average* values refer to values obtained using mean influent water quality conditions.
(3) Minimum values were only predicted for parameters where the finished water goal included a minimum value.
(4) A 5 CU color goal has been established but the City is also interested in exploring options that achieve between 5 and 12 CU.

Influent flow

In order to accommodate the loss of flow associated with the nanofiltration treatment process recovery, the maximum influent flows would need to be 57.8 mgd. Bypass percentage could be increased for additional water savings, but in this case the 5 CU color goal may not be achieved under a high influent color scenario. The additional 7.8 mgd of source water allocation would cost approximately $36 million.

Color

This treatment process reduces color to low levels (below the 5 CU goal) for all influent conditions even with an 11 percent NF bypass.

Hardness

For this alternative, finished water hardness goals are predicted to be met under all influent conditions. Hardness can be increased if desired by increasing the NF bypass percentage or adding a softening bypass.

Iron

If influent iron is higher than normal in the source water, there is a chance that finished water iron would be as high as 0.21 mg/L prior to disinfection, which exceeds the target goal of 0.1 mg/L. However, the remaining iron would be oxidized with the addition of chlorine which is applied for disinfection, provided that the iron is not organically bound.

Chloride to Sulfate Mass Ratio

Finished water CSMR is predicted to be 15.5 on average, exceeding the conventional CSMR target of less than 0.5. This is due to the decrease in sulfate through the NF process and an increase in chloride from the IX process. The high predicted CSMR may need further consideration depending on the composition of the distribution system piping materials. As previously mentioned, the increase in chlorides due to IX may be slightly overestimated.

5.6.2.2 Other Water Quality Considerations

In addition to the water quality goals that were previously discussed, this treatment train could also impact the following contaminants:

- Volatile Organic Compounds – As previously noted, packed tower aeration can effectively remove VOCs, and NF can remove organic DBP precursor material.
- Inorganic chemicals – Arsenic, barium, cadmium, nitrite, and nitrate can be removed effectively by NF, as well as IX. The selectivity list for the MIEX resin is shown in section 5.2.2.2.
- Synthetic organics compounds could potentially be removed by NF if the molecular weight of a given compound is larger than the size exclusion of the selected membranes.
- Microorganisms – NF can remove most pathogens via size exclusion as long as the integrity of the membranes is maintained.

5.6.3 Risks and reliability

The following are discussion points regarding reliability and controlling risk for this treatment train:

- Meeting water quality goals – As noted above, the use of membranes for color and TOC removal is one of the most effective treatment processes available. Chloride-based corrosivity could potentially impact distribution system piping if proper stabilization is not implemented.
- Disposal of waste streams – The high rate of the NF waste stream may be problematic from a source water allocation standpoint as additional source water is required to supplement this loss.
- As previously discussed, IX brine waste is problematic because of high chlorides and TDS. Injection of the waste into a deep well along with the brine from the NF process is an alternative to discharging it to the sewer.
- There is nothing proprietary about the membranes from either the capital or O&M standpoint of this proposed treatment train. The membrane technology for this option is well proven in the industry and specifically in south Florida. The MIEX resin is proprietary both from the resin and capital equipment perspectives. This could potentially be a risk for resin availability if the manufacturer cannot keep up with resin demands. Unlike vessel IX, MIEX resin must be replaced on a continuous basis.
- This treatment train is simple and less operationally intensive than some of the other treatment trains, although it is mechanically intensive and includes a significant amount of instrumentation. The space requirements are relatively small.
- As is the case with all NF alternatives, one of the drawbacks associated with this option is the amount of energy required.
- The aeration system is a passive system which has high reliability.
- The chemical addition requirements for this option are lower than those of other alternatives.
- The MIEX process is more mechanically intensive than fixed bed IX due to the mixers and the regeneration skid, therefore from a mechanical standpoint the reliability is lower than the fixed bed options.

5.6.4 Flexibility

The following are discuss points pertaining to the flexibility of the proposed treatment technologies:

- The treatment train is flexible in terms of achieving water quality goals, but not as flexible as Alternative 11, due to limited color removal by MIEX. The IX bypass stream and membrane selection can effectively be utilized to achieve most treatment goals.
- The aeration of H_2S is dependent on raw water quality and the pH of the water applied to the forced draft aerator. The low pH of the membrane product water will allow for effective H_2S removal in the process.

5.6.5 Ability to Meet Future Regulations

This treatment train could be impacted by future regulation of the following constituents:

- Manganese – NF membranes are very effective at removing manganese and should have no problems addressing any future manganese regulations. The bypass train would not have effective manganese removal, however the raw water manganese is currently very low.

- Cyanotoxins – While unlikely to be encountered in a groundwater source, cyanotoxins would be effectively removed by NF membranes.
- Disinfection byproducts – The use of MIEX and NF membranes results in significantly high levels of NOM removal, resulting in low DBP formation.
- Perfluoro-compounds –Membranes remove perfluoro-compounds. IX systems can be used to remove these constituents, however this requires a specific resin. The MIEX process proposed for this alternative would have minimal impact on perfluoro-compounds.
- Perchlorate – Perchlorate is removed with anion exchange resin. NF membranes also remove perchlorate.
- Strontium – The NF membranes remove strontium by size exclusion.

5.6.6 Operational Complexity

The operational complexity of the NF treatment train is less than that of the existing treatment train. Despite the advantages of the NF system, the MIEX system increases the operational complexity of the overall system.

5.6.7 Maintenance requirements

As previously noted, the NF treatment process is mechanically intensive because it incorporates a number of pumps (see Section 5.5.7), automated valves, etc., and equipment monitoring tied to SCADA provides maintenance and operational problem notifications.

The fluidized-bed IX system increases the overall maintenance because it includes mixers, and the regeneration skid which incorporates a variety pumps, mixers, underdrains, and valves.

5.6.8 O&M Costs

Estimated O&M costs are presented in Table 5.17. The estimates are based on an average annual plant flow of 33 mgd, 85 percent NF recovery, and 11 percent bypass (bypass percentages are discussed in Section 5.6.2.1). Items not included in estimates include aeration blower power, disposal costs for brine and membrane concentrate, and membrane cleaning chemicals. O&M costs for this alternative are considered to be low compared to other alternatives. Power costs are higher than those for all non-membrane alternatives. Overall, costs for this option are very similar to the costs for Alternative 11

Table 5.17 Title Alternative 12 O&M Cost Estimates

Item	Average Annual Cost
Power	$1,663,600
Chemicals and MIEX Resin	$1,005,400(1)
Membrane Replacement	$349,200
Total	**$3,018,200**

Notes:
(1) Membrane cleaning costs not included in estimate.

5.6.9 Safety

5.6.9.1 Public

Replacement of the existing chlorine gas system with sodium hypochlorite (bulk) will significantly improve public safety.

For this treatment technology alternative the following chemicals may pose a level of safety concern to the public:

- Salt brine.
- Chlorine.
- Ammonia.
- Fluoride.
- Antiscalant.
- Sulfuric acid.
- Membrane cleaning chemicals.
- Sulfuric acid.

Public safety concerns regarding sulfuric acid are the same as those of Alternative 11.

5.6.9.2 Employee

Sulfuric acid is a Class 2 water reactive chemical, representing a safety consideration for employees. This will necessitate additional safety protocols and staff training.

5.6.9.3 Hurricane Considerations

The power requirements for this treatment train are high due to the use of membranes. This directly impacts the generator size required to treat water during a power outage.

Using concentrated chemicals improves hurricane resiliency because many of the processes can operate for long periods of time without the risk of running out of chemicals should the supply train be interrupted.

Regarding hurricane hardening, all structures will be designed to meet or exceed the associated storm requirements.

5.6.10 Footprint

This treatment train is more compact than the other potential alternatives. The following are the assumptions utilized to estimate the required footprint:

- Only treatment associated facilities are considered in the footprint sizing. Administrative, storage, and maintenance buildings are not included.
- The footprints of the various technologies are sized so that the system can handle any NF bypass percentage between 0 percent and 50 percent.
- No transfer pump station is needed for this alternative (the MIEX system does not have the pressure requirements of the fixed bed IX system).

The estimated total footprint is calculated in Table 5.18. Note that only major unit processes are included in this table. The estimated footprint information is intended to be used for comparison of alternatives only, and does not include ancillary facilities that may be required for a complete WTP. A hypothetical layout of the existing site plan for this alternative is shown on Figure 5.15.

Table 5.18 Alternative 12 Footprint Estimate

Component	Area (sq ft)
Forced draft aerators	3,000
Dual media filters(1)	4,500
Membrane system	15,040
MIEX system	6,050
Total	**28,590**

Notes:
(1) 5 gpm/sq ft loading rate.

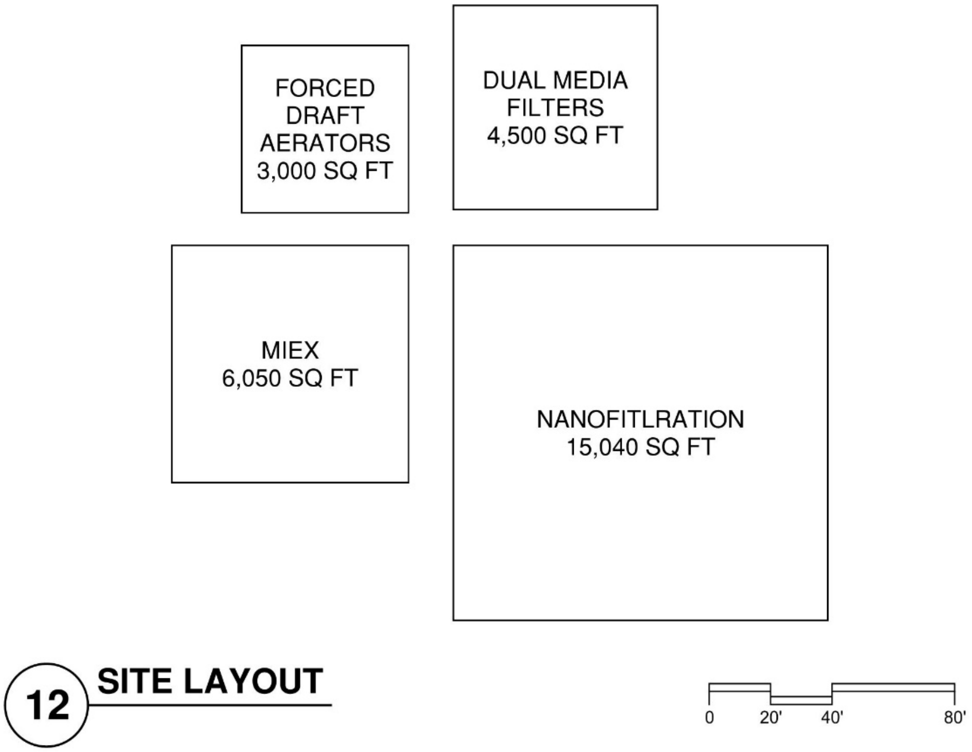

Figure 5.15 Alternative 12 Site Layout

5.7 Alternative 15: Nanofiltration with EC/Softening Bypass

See Section 4.15 for a general description of this alternative.

5.7.1 Process Flow Diagram

A process flow diagram of Alternative 15 is shown in Figure 5.16.

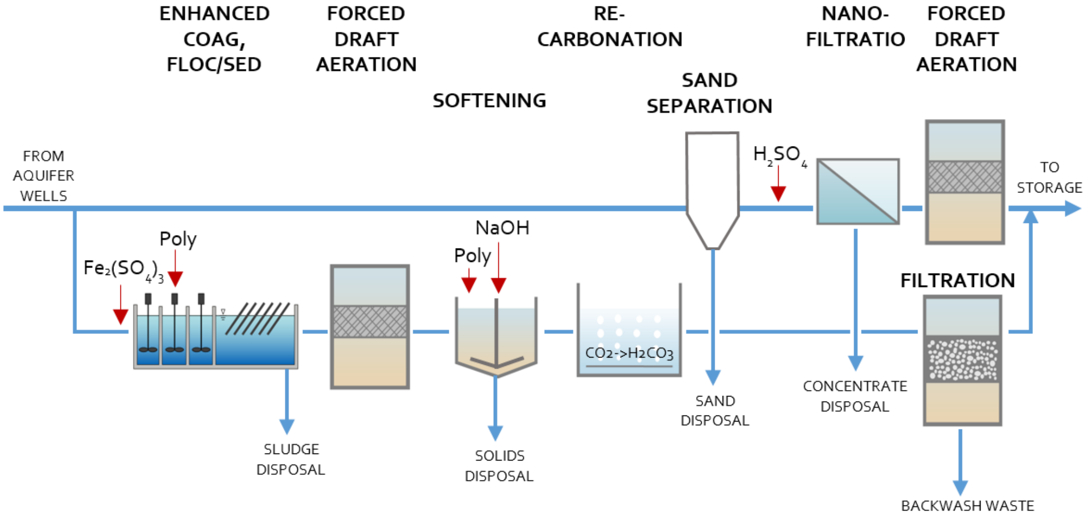

Figure 5.16 Alternative 15 Process Flow Diagram

5.7.2 Water Quality

5.7.2.1 Ability to Meet Water Quality Goals

Water quality predictions are summarized in Table 5.19. All percent removals through different processes use conservative estimates based on background research, models, extensive calculations, and bench-scale data.

Table 5.19 Alternative 15 Water Quality Predictions

Parameter	Units	Value
Influent flow required for 50 mgd to distribution system	mgd	56.4
NF Recovery	%	85
Percent to Bypass Stream	%	25(1)

Parameter	Units	Finished Water Goal	Finished Water Predicted Value		
			Average(2)	Minimum(3)	Maximum
Color	CU	< 5 (< 12)(4)	2.0	NA	3.4
Alkalinity	mg/L as $CaCO_3$	40 – 100	33	31	37
Free ammonia	mg/L as N	0.05 – 0.1	0.08	NA	0.08
Total hardness	mg/L as $CaCO_3$	80 – 160	63	61	65
Iron	mg/L	< 0.1	0.089	NA	0.167
Manganese	mg/L	< 0.02	0.002	NA	0.003
Sodium	mg/L	< 50	38	NA	43
Total dissolved solids (TDS)	mg/L	< 500	131	NA	153
Sulfate	mg/L	< 200	19.3	NA	19.5
Chloride	mg/L	< 100	36	NA	48
Turbidity	NTU	< 1.0	0.01	NA	0.01
H2S	mg/L	< 0.1	0.02	NA	0.08
pH	---	8 – 8.5	8.1	8.1	8.1
CSMR	---	< 0.5	1.9	NA	2.5

Notes:

(1) The NF bypass percentage was chosen to minimize the influent flow while still maintaining adherence to finished water hardness, alkalinity, and conservative color goals.

(2) *Average* values refer to values obtained using mean influent water quality conditions.

(3) Minimum values were only predicted for parameters where the finished water goal included a minimum value.

(4) A 5 CU color goal has been established but the City is also interested in exploring options that achieve between 5 and 12 CU.

Influent Flow

In order to accommodate the loss of flow associated with the nanofiltration treatment process recovery, the maximum influent flows would need to be 56.4 mgd. Increased bypass percentages would result in finished water alkalinity and hardness being too low. The additional 6.4 mgd of source water allocation would cost approximately $29 million.

Color

This treatment process reduces color to extremely low levels (well below the 5 CU goal) even with a 25 percent nanofiltration bypass.

Hardness and Alkali

For this alternative, predicted finished water hardness and alkalinity are slightly below the desired levels. This could be remedied by using a softening bypass.

Iron

If influent iron is higher than normal in the source water, there is a chance that finished water iron would be as high as 0.17 mg/L prior to disinfection, which exceeds the target goal of < 0.1 mg/L. However, the remaining iron would be oxidized with the addition of chlorine, provided that the iron is not organically bound.

Chloride to Sulfate Mass Ratio

CSMR is predicted to average 1.9 for this alternative, a significant improvement from the other NF alternatives due to sulfates being added in the enhanced coagulation process. It is also a significant improvement from the existing plant CSMR of 1.9. For this alternative, the higher the bypass, the better the CSMR. Nevertheless, the CSMR still may exceeds 0.5 and may need further consideration depending on the composition of the distribution system piping materials. As is the case for Alternatives 6 and 7, CSMR can be controlled fairly easily by increasing the ferric sulfate dose.

5.7.2.2 Other Water Quality Considerations

In addition to the water quality goals that were previously discussed, there are other water parameters that are affected by the proposed treatment technology. The following is a list of other parameters and how they are affected by the technology:

- Volatile Organic Compounds – Packed tower aeration can remove select VOCs. In addition NF can remove most organic DBP precursor material.
- Inorganic chemicals – Arsenic, barium, cadmium, nitrite, and nitrate can be removed effectively by NF.
- Synthetic organics compounds - As previously noted, SOCs could potentially be removed through the NF process if the molecular weight of a given compound is larger than the size exclusion of the membranes.
- Microorganisms – NF can remove most pathogens from the water as long as the integrity of the membrane system is maintained.
- NF is based on size exclusion so large molecular compounds are easily removed and smaller compounds such as ammonia, nitrate, and dissolved gases like carbon dioxide pass through the membranes.

5.7.3 Risks and Reliability

The following are discussion points regarding reliability and controlling risk for this treatment train:

- Meeting water quality goals – The use of membranes for color and TOC removal is one of the most robust treatment processes available. Because of the size exclusion nature of the membranes many other water quality considerations can be effectively managed.
- Disposal of waste streams – NF has a large challenge with respect to waste streams. The NF process produces a 10-15 percent waste stream with high TDS and organic levels. This is problematic from a water allocation standpoint (more water is necessary to produce the same amount of finished water) and the waste stream has limited disposal options (typically only deep well injection). Calcium carbonate and enhanced coagulation residuals disposal is a risk as disposal of these residuals has become more difficult and more costly.
- Technology – There is nothing proprietary about this treatment train from either the capital or O&M standpoint. The membrane and softening technologies for this option are well proven in the industry and specifically in South Florida.
- The membrane portion of the treatment train is simple and less operationally intensive, however it is mechanically intensive and includes a significant amount of instrumentation. The bypass treatment train would be similar in operational intensity to the current treatment process.
- One of the bigger challenges associated with this option is the high level of power required and providing adequate backup power.
- The aeration system is a passive system which improves reliability, however there is a considerable amount of pumping that will be required for this option.

5.7.4 Flexibility

The following are discussion points pertaining to the flexibility of the proposed treatment technologies:

- The treatment train is very flexible with respect to bypass treatment and membrane selection to achieve exact hardness and alkalinity goals.
- The aeration of H_2S is dependent on raw water quality and the pH of the water applied to the forced draft aerator. The low pH of the membrane product water will allow for effective H_2S removal in the process.
- This treatment train is more mechanically intensive than the other membrane bypass options.

5.7.5 Ability to Meet Future Regulations

Constituents which could potentially be regulated in the future would be impacted by the proposed treatment in the following ways:

- Manganese – As previously noted, NF membranes can remove manganese to very low levels and should have no problems addressing any future manganese regulations. For the bypass train this would be more of a challenge but the raw water manganese is currently very low.

- Cyanotoxins –NF would likely remove these compounds if encountered, however this is unlikely since this system uses a ground water source.
- Disinfection byproducts – The use of NF membranes and their associated ability to achieve high levels of TOC removal results in low DBP formation.
- Perfluoro-compounds – NF membranes remove perfluoro-compounds.
- Perchlorate – NF membranes remove perchlorate.
- Strontium – NF membranes remove strontium by size exclusion.

5.7.6 Operational Complexity

The operational complexity of this treatment train is higher than the existing treatment train because the City will be running a membrane system and a treatment train that is more complex than the current treatment process.

5.7.7 Maintenance Requirements

As noted for the previous two alternatives membrane filtration is mechanically intensive. The pumps required for this type of system are described in Section 5.5.7.

The main maintenance differences between the existing plant and the bypass treatment train would be the maintenance associated with the enhanced coagulation process and the blowers on the forced draft aerators. If the enhanced coagulation train is high-rate conventional (lamella plates) then the maintenance items are the flash mix system (pumps), flocculation equipment, and solids collection. If a higher-rate process like sand ballasted sedimentation® is utilized then more energy is required for mixing, the hydrocyclones, and the residuals pumps for sand handling. With sand as the ballast there will be increased wear and tear on mechanical equipment. Each forced draft aerator will have blowers which will need to be maintained. These blowers will be easier to maintain than the current system because they are operated at lower head.

5.7.8 O&M Costs

Estimated O&M costs are presented in Table 5.20. The estimates are based on an average annual plant flow of 33 mgd, 85 percent NF recovery, and 25 percent bypass (bypass percentages are discussed in Section 5.7.2.1). Items not included in estimates include aeration blower power, disposal costs for brine and concentrate, and membrane cleaning chemicals. O&M costs for this alternative are considered to be average/low compared to other alternatives.

Table 5.20 Alternative 15 O&M Cost Estimates

Item	Average Annual Cost
Power	$1,577,200
Chemicals	$2,355,700(1)
Sludge Disposal	$167,400
Membrane Replacement	$287,200
Total	**$4,387,500**

Notes:
(1) Membrane cleaning costs not included in estimate.

5.7.9 Safety

5.7.9.1 Public

Using bulk sodium hypochlorite in lieu of chlorine gas will mitigate some of the public safety risk associated with treatment.

For this treatment technology alternative the following chemicals may pose a level of safety concern to the public:

- Ferric sulfate.
- Caustic soda (sodium hydroxide).
- Polymer.
- Carbon dioxide.
- Chlorine.
- Ammonia.
- Fluoride.
- Antiscalant.
- Sulfuric acid.
- Membrane cleaning chemicals.

This treatment train has slightly more risk to the public due to the use of more hazardous chemicals such as caustic soda which is a considered a corrosive and a Class 1 water reactive and sulfuric acid which is a Class 2 water reactive. In addition, the caustic soda is not as concentrated resulting in more frequent truck deliveries which slightly increases risk to the public. Sulfuric acid is hazardous and requires strict safety protocols for transport and delivery.

5.7.9.2 Employee

Similar public safety, employee safety risks are slightly higher for this treatment train for the reasons listed above. Caustic soda, ferric sulfate, and sulfuric acid are corrosive and can be dangerous for plant staff to handle.

5.7.9.3 Hurricane Considerations

The power requirements for this treatment train are the higher than non-membrane alternatives. This directly impacts the generator size required to treat water during a power outage.

Ferric sulfate and caustic soda are more dilute than other chemicals and therefore may require more frequent deliveries than highly concentrated chemicals, which could pose a minor risk if the supply chain is interrupted.

All structures will be designed to meet or exceed the associated storm requirements. This applies for all alternatives presented herein.

5.7.10 Footprint

From a footprint standpoint, this treatment train is considered average compared to the other alternatives (larger than the other NF alternatives but smaller than the non-NF alternatives). The following are the assumptions utilized to estimate the required footprint:

- Only treatment associated facilities are considered in the footprint sizing. New administrative, storage, and maintenance buildings are not included.

- The footprints of the various technologies are sized so that the system can handle any NF bypass percentage between 0 percent and 50 percent.
- The solids contactor clarifier is only intended to remove calcium and therefore can be operated at the higher rate of 1.75 gpm/sq ft (reduced footprint compared to enhanced softening).
- A transfer pump station is required to recover the head lost through the coagulation system.

The estimated total footprint is calculated in Table 5.21. Note that only major unit processes are included in this table. The estimated footprint information is intended to be used for comparison of alternatives only, and does not include ancillary facilities that may be required for a complete WTP. A hypothetical layout of the site plan for this alternative is shown in Figure 62.

Table 5.21 Alternative 15 Footprint Estimate

Component	Area (sq ft)
Forced draft aerators	3,000
Dual media filters(1)	4,500
Membrane system	15,040
Coagulation/flocculation/ sedimentation	12,500
Solids contact clarifiers	12,600
Transfer pump station	2,000
Total	**49,640**

Notes:
(1) 5 gpm/sq ft loading rate.

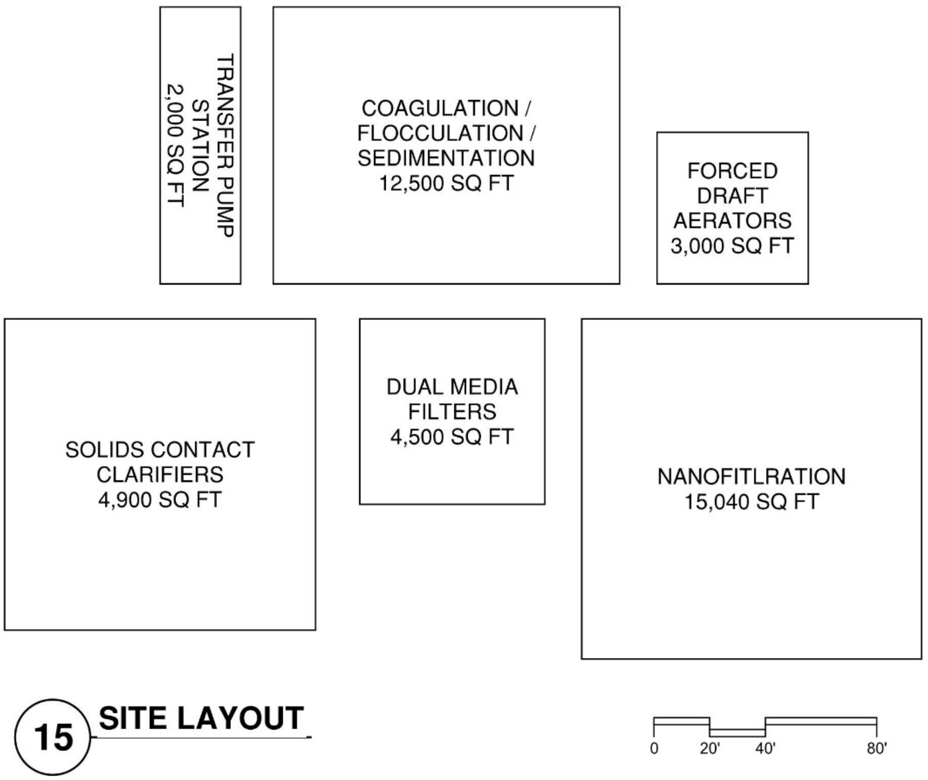

Figure 5.17 Alternative 15 Site Layout

5.7.11 Technology Subalternatives

Potential subalternatives which could be utilized with this option include using sand ballasted coagulation in lieu of conventional coagulation, flocculation, and sedimentation (see Section 5.3.11 for additional details on this technology), and using pellet softening instead of solids contact clarifiers (see Section 5.1.11 for additional details on this technology).

5.8 Comparison of Alternatives

A comparison matrix of the selected alternatives is presented in Table 5.22. This table can be used to select the best alternatives based on the specific needs of the City.

Table 5.22 Comparison of Selected Alternatives

Alternative	Description	Water Quality and Quantity Goals						O&M Considerations						
		Color	Hardness and Alkalinity	Sodium	Chloride to Sulfate Mass Ratio(1)	Future Regulations	Additional Source Water Allocation	Reliability	Flexibility	Operational Simplicity	Maintenance Requirements	Safety	O&M Costs	Footprint
2	Lime Softening and Fixed Bed IX	◒	●	●	○	●	●	●	●	●	●	●	◒	○
3	Enhanced Lime Softening and MIEX	○	◒	◒	○	◒	●	○	○	◒	◒	◒	○	○
6	Enhanced Coagulation and Caustic Softening	◒	◒	○	●	○	●	◒	○	◒	●	◒	○	○
7	Enhanced Coagulation with Pellet Softening and Fixed Bed IX	●	●	◒	●	●	●	●	●	●	●	◒	◒	○
11	Nanofiltration with Fixed Bed IX Bypass	●	●	●	○	●	○	●	●	●	●	◒	●	●
12	Nanofiltration with MIEX Bypass	●	●	●	○	●	○	◒	◒	◒	◒	◒	●	●
15	Nanofiltration with Enhanced Coagulation/Softening Bypass	●	◒	●	●	◒	○	◒	●	○	○	◒	◒	◒

Notes:

(1) For the purposes of this table, a CSMR significantly higher than the current plant finished water is indicated as 'less favorable' while a CSMR significantly lower than the current plant finished water is indicated as 'highly favorable'. General information regarding CSMR is dicussed in Section 2.1.9.1 and in each analysis in Section 5.

Legend:

● Highly favorable

◒ Moderately favorable

○ Less favorable

Section 6

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Appendix A

TEST PLAN

BENCH-SCALE EVALUATION CITY OF FORT LAUDERDALE – FIVEASH WATER TREATMENT PLANT

Section 1

INTRODUCTION

The City hired Carollo Engineers, Inc. for the evaluation of treatment options that would allow enhancing water production at the WTP while lowering color to a non-objectionable level. Carollo Engineers, Inc., proposed conducting bench-scale evaluations utilizing rapid small-scale column testing (RSSCT), jar testing for enhanced lime softening, and ion exchange to evaluate the possibility of lowering color in the finished water. This Test Plan is developed with the detailed bench-scale testing protocols for the evaluation of the candidate treatment processes.

The jar testing of conventional lime softening with coagulant addition, enhanced lime softening, and ion exchange testing will be conducted at the WTP. The RSSCTs will be performed at Carollo’s applied research center (i.e., Water ARC®).

1.1 RSSCT Evaluations

RSSCTs are bench-scale tests that simulate full-scale performance of granular activated carbon (GAC) for color removal. The RSSCT evaluations will be performed at Water ARC®, Boise, ID.

1.2 Objectives

The primary objectives of the RSSCT evaluations are:

1. Determine GAC adsorption characteristics and breakthrough patterns.
2. Determine the effects of EBCT on adsorption characteristics and breakthrough patterns.
3. Select the best performing GAC for developing project cost estimates.

1.3 Materials and Equipment

The following materials and equipment will be provided by Carollo for the RSSCT evaluations:

- Six RSSCT columns (1.1 cm outer diameter and 30 cm length)
- Three peristaltic pumps (Masterflex, Vernon Hills, IL)
- Beakers and disposable pipettes
- Spectrophotometer (Hach, Loveland, CO) with sampling vials for measuring color and UV254
- Kimwipes for cleaning the sampling vials
- Deionized (DI) water

1.4 RSSCT Evaluation Plan

1.4.1 Sample Water Collection

Filtered water will be collected from the WTP (at the sample point indicated in Figure 2) as the source water for the RSSCTs. The source water will be collected in 55-gal drums and shipped in a refrigerated truck to Carollo's Water ARC® laboratory in Boise, ID. The source water will be stored at 4 °C to prevent biological growth and changes in water quality. Small batches will be allowed to warm to room temperature prior to testing.

[redacted]

Figure A-1 Sample tap for collection of filtered water for RSSCTs.

Three 55-gallon drums will be filled with filtered water, and grab samples collected from each drum. Grab samplings will be analyzed for the following parameters: color (true), UV254, pH, alkalinity, total and calcium hardness, and total and free chlorine.

1.4.2 Preparing the RSSCT Columns

The following procedures will be followed for preparing the RSSCT columns:

1. Grind the GAC and sieve the ground media through 100 x 140 mesh size.
2. Thoroughly rinse the sieved media with distilled water (or deionized water) until the water is visibly clear of fines.
3. Rinse glass beads and glass wool with DI water.
4. Pack the RSSCT columns (refer to Figure 3):
    a. Pack the columns to achieve a bed depth of 3 cm glass wool over 3 cm glass beads.
    b. Fill the columns with DI water to maintain a standing water column of approximately 10 cm above the glass wool.

c. Slowly pour the rinsed media into the column, while gently tapping the column to prevent air entrapment in the bed. The packed media bed should be 18 cm in height.

d. On the top of the media bed, pack 3 cm glass beads over 3 cm of glass wool.

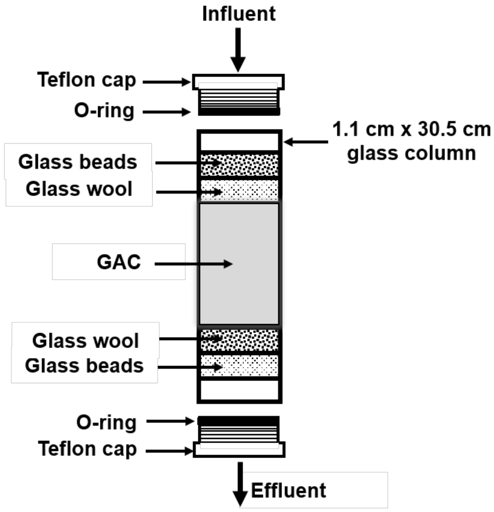

Figure A-2 Schematic representation of the RSSCT column

1.4.3 Test Protocol

RSSCT evaluations will be conducted on filtered water collected from the full-scale WTP with three set ups in parallel (Figure 4). Three types of GAC will be evaluated including Calgon F400, Jacobi Aquasorb 5010, and Evoqua UltraCarb 1240 . The three types of GAC were selected to represent different price points and manufacturers. Each set-up will have two columns in series, which will allow evaluating two EBCTs: 7.5 min and 15 min. Results from longer EBCTs were not tested as the performance for longer contact times can be extrapolated from the existing data.

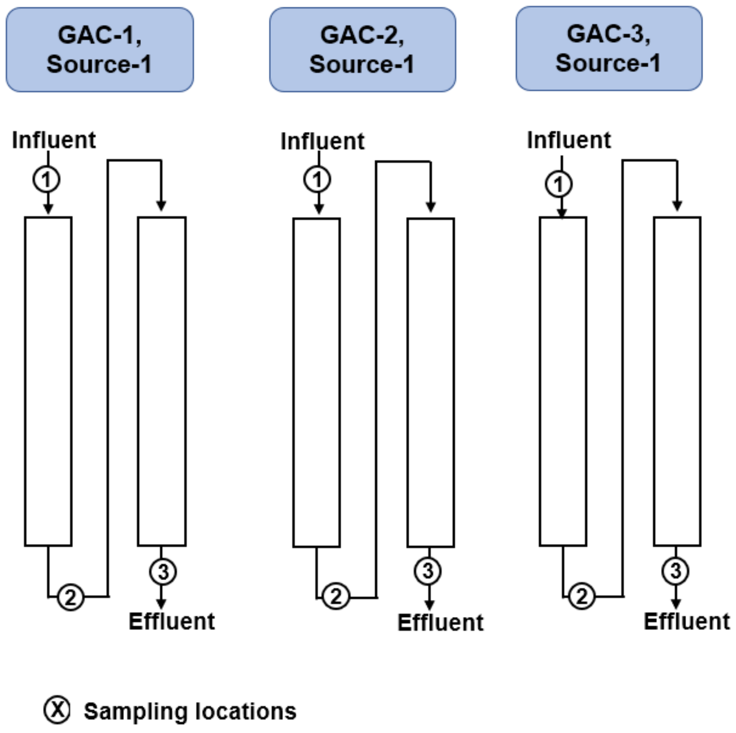

Figure A-3 RSSCT set-up

For the testing, the following procedures will be followed:

1. Homogenize the source water in a lined drum.
2. Set the peristaltic pumps to the required flow rate (e.g., 2.1 mL/min [1.3 gpm/ft^2] for Calgon and Evoqua carbons and 2.2 mL/min [1.4 gpm/ft^2] for Jacobi carbon).
3. Pump DI water with the adjusted flow rates through the columns for approximately 30 min to remove any residual fine particles and further compact the media bed. Re-check the media depth and add media if needed. Also, verify the flow rate by collecting the effluent in graduated cylinder for a specified time. If the actual flow rate is different from the flow rate set on the pump, adjust the pump flow rate.
4. Pump the source water into the RSSCT column in a down-flow mode with the pre-set flow rates.
5. Collect grab samples as listed in Table 1. Generate color breakthrough curves for each RSSCT set.

Table A-1 RSSCT Evaluations for Color Removal

Parameter	Sampling Locations	Frequency of Sampling	Laboratory Requirements
pH	Inf(1), Eff-1, Eff-2	2/week	Field
True Color(2)	Inf(1), Eff-1, Eff-2	2/week	Field
UV254(2)	Inf(1), Eff-1, Eff-2	2/week	Field
Total Sulfide	Inf(1), Eff-1, Eff-2	2/wk (Effluents), 1/wk (Inf)	Certified Lab

Notes:
(1) Influent sample collected from shared feed water container.
(2) 10 percent of the samples will be split and sent to a certified lab (Eurofins) for QA/QC.

Section 2

CONVENTIONAL AND ENHANCED LIME SOFTENING

Softening is a process in which calcium and magnesium species are removed through precipitation. For effective softening, pH should be raised, so that calcium carbonate and magnesium hydroxides are generated. Previously precipitated calcium and magnesium particles provide a surface for additional precipitation, which is enhanced when suspended particles are maintained at higher concentration.

Lime or caustic soda (sodium hydroxide) is typically used for the softening process. Conventional lime softening raises the pH to 9.5 to 9.8 and under this condition, only calcium precipitates. Enhanced softening with the removal of both calcium and magnesium can be achieved, if the pH is raised to 10.6 to 11.2. Enhanced softening may also result in the removal of organics (e.g., color); however, supplemental magnesium is required in magnesium limited waters.

Jar testing will be conducted to determine if conventional lime softening with coagulant addition or enhanced coagulation can achieve color removal to the desired color goal. The tests will be performed at the WTP.

2.1 Objectives

The primary objectives of jar testing lime softening processes is to quantify the level of color (TOC) removal from the source water under the following conditions:

- Adding coagulant (i.e., ferric sulfate) with the conventional lime softening process.
- Increasing the lime softening pH to between 10.6 and 11.2 (enhanced coagulation).
- Adding chemicals such as magnesium to provide additional color removal.

2.2 Materials and Equipment

The following materials and equipment will be utilized for the jar testing:

1. One standard jar testing apparatus with 2-L gator jars
2. Clarifloc A-3333P polymer (Note: a 1 g/L stock solution will be prepared in distilled water and allowed to age overnight prior to testing. A new stock solution will be prepared daily during testing.)
3. Hydrated lime ($Ca(OH)_2$)
4. Magnesium chloride ($MgCl_2$), anhydrous >98%
5. pH and temperature meter with electrode
6. pH calibration buffers
7. Titration apparatus for alkalinity including prepared acid solution
8. A stirrer plate with stir bars
9. Glassware
10. DI water
11. A 10-mL autopipette with tips
12. A 1000-µL autopipette with tips
13. 4L glass jars for collecting raw water
14. Spectrophotometer (Hach DR 5000, Loveland, CO) for measuring UV254 and color
15. Hach SL1000 portable parallel analyzer (Hach, Loveland, CO)
16. Digital titrator (Hach, Loveland, CO)
17. Vacuum pump, filtration apparatus, and 0.45 um filters
18. Cooler and sample bottles for sending samples to laboratory for TOC analysis, and split samples for color analysis

2.2.1 Source Water Collection

Source water will be raw water collected from the sampling port immediately upstream of the softening process at the WTP (i.e., upstream of the hydrotreater).

2.2.2 Jar Testing Equipment

A standard six jar paddle stirrer (Phipps and Bird, Richmond, VA) jar tester (Figure A-4) will be used for this testing. The system features six specially designed 2-liter square B-KER jars (Phipps and Bird, Richmond, VA), LED lamps for diffused sample illumination, and a stepper motor drive for speed control. The system utilizes four operator-programmable memory banks which may be programmed with paddle speeds from 5 to 300 rpm in 1 rpm increments and run times from 1 to 59 minutes in 1-second increments. Stainless steel 1” by 3” paddles are spaced six inches apart and are adjustable to a maximum depth of 9”). The specially designed “gator” jars have a sample tap located at a precise distance (10 cm) from the top of the water to allow the sampling of small quantities of settled water for turbidity measurements.

Figure 5 Phipps & Bird PB-950 Series Jar Tester

This equipment uses previously developed relationships that correlate mixing energy with stirrer speed and water temperature (that is, velocity gradient (G)) at the bench-scale level (Figure A-5).

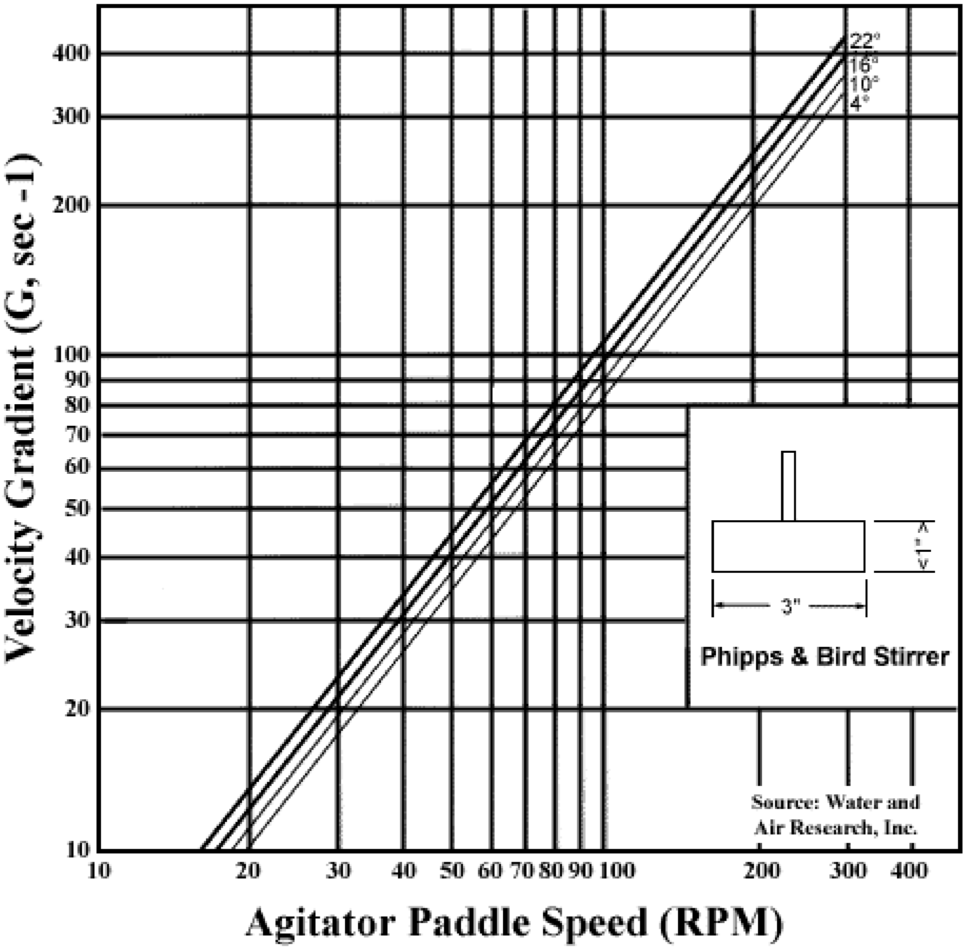

Figure 6 Velocity Gradient vs RPM for a 2-L Square Jars

Section 3

TEST PROTOCOL

The general jar test procedure for enhanced lime softening with and without $MgCl_2$ addition is outlined below:

1. Prepare the stock solutions as needed (e.g., polymer, $MgCl_2$).
2. Collect raw water upstream of the Hydrotreater and pour into the 2-L jars.
3. Collect grab samples for determination of water quality parameters including pH, true color, UV254, total alkalinity, calcium hardness, and total hardness.
4. Turn on the jar testing and set mixing speed to 100 rpm. Add a pre-determined dose of chemicals in this order: $MgCl_2$ (when desired), $Ca(OH)_2$, and 0.2 mg/L of polymer to the jars.
5. Mix at 100 rpm for 1 minute.
6. Turn down mixer speed to 25 rpm for 30 minutes.
7. Turn off the mixer and allow each jar to sample for 20 minutes
8. After 20 min of settling, collect grab samples for determination of pH, true color, UV 254, total alkalinity, calcium hardness, and total hardness. For all parameters except pH, filter samples through a 0.45 um filter before analysis.

Table A-2 Enhanced Lime Softening Jar Testing Plan

Jar	Chemical Doses(1)	Target Settled Water pH
1	190 mg/L $Ca(OH)_2$ 0.2 mg/L polymer	9.5
2	230 mg/L $Ca(OH)_2$ 0.2 mg/L polymer	10.0
3	270 mg/L $Ca(OH)_2$ 0.2 mg/L polymer	10.5
4	310 mg/L$Ca(OH)_2$ 0.2 mg/L polymer	11.0
5	350 mg/L $Ca(OH)_2$ 0.2 mg/L polymer	11.5

Notes:
(1) 1. Record $Ca(OH)_2$ dose. Settled water pH should be within +/- 0.3 S.U. of target.

Table A-3 Enhanced Lime Softening Jar Testing Plan with MgCl2 Addition

Jar	Chemical Doses	Target Settled Water pH$^{(1)}$
1	430 mg/L $Ca(OH)_2$ 0.2 mg/L polymer 10 mg/L Mg as $CaCO_3$	>11.0
2	430 mg/L $Ca(OH)_2$ 0.2 mg/L polymer 20 mg/L Mg as $CaCO_3$	>11.0
3	430 mg/L $Ca(OH)_2$ 0.2 mg/L polymer 30 mg/L Mg as $CaCO_3$	>11.0
4	430 mg/L $Ca(OH)_2$ 0.2 mg/L polymer 40 mg/L Mg as $CaCO_3$	>11.0
5	430 mg/L $Ca(OH)_2$ 0.2 mg/L polymer 50 mg/L Mg as $CaCO_3$	>11.0
6	430 mg/L $Ca(OH)_2$ 0.2 mg/L polymer 60 mg/L Mg as $CaCO_3$	>11.0

Notes:
(1) 1. Record $Ca(OH)_2$ dose. Settled water pH should be between 11.0 and 11.3.

The general jar test procedure for conventional lime softening with coagulant addition is outlined below:

1. Prepare the stock solutions as needed (e.g., $Ca(OH)_2$ and Ferric Sulfate).
2. Collect raw water upstream of the Hydrotreater and pour into the 2-L jars.
3. Collect grab samples for determination of water quality parameters including pH, true color, UV254, total alkalinity, calcium hardness, and total hardness.
4. Turn on the jar testing and set mixing speed to 100 rpm.
5. Add a pre-determined dose of chemicals in this order: $Ca(OH)_2$ and Ferric Sulfate
6. Mix at 100 rpm for 1 minute.
7. Turn down mixer speed to 25 rpm for 30 minutes.
8. Turn off the mixer and allow each jar to settle for 20 minutes
9. After 20 min of settling, collect grab samples for determination of pH, true color, UV 254, total alkalinity, calcium hardness, and total hardness. For all parameters except pH, filter samples through a 0.45 um filter before analysis.

Prior to jar testing, zeta potential evaluation will be utilized to better assess the floc characteristics and stability in the water. Zeta potential will be determined at Water ARC® using a ZetaSizer (Malvern, Cambridge, UK). Zeta potential reflects the charge on suspended particles and flocs with zeta potential closer to zero being the target. The impact of ferric sulfate dose on zeta potential in the source water will be determined by measuring zeta potential with different ferric sulfate doses. The results of these testing will be used to help determine the coagulant dose for jar testing, which will be performed at the WTP. The general zeta potential evaluation procedure is outlined below:

1. Rinse the cuvette with DI water using a syringe.

2. Fill the cuvette with the substandard solution of -42 mV. Calibrate the ZetaSizer.
3. Rinse the cuvette with DI water and fill the cuvette with raw water sample. Measure zeta potential.
4. Pour 500 mL water in a 1-L beaker. Add the desired ferric sulfate dose and mix on a magnetic stirrer plate.
5. Rinse the cuvette with DI water and load with the coagulant added water. Measure zeta potential.
6. Repeat steps 4 and 5 with the pre-determined ferric sulfate doses (i.e., 10 mg/L increments).
7. Plot zeta potential against ferric sulfate dose to determine the optimal coagulant dose.

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5. Rinse the cuvette with DI water and load with the coagulant added water. Measure zeta potential.
6. Repeat steps 4 and 5 with the pre-determined ferric sulfate doses (i.e., 10 mg/L increments).
7. Plot zeta potential against ferric sulfate dose to determine the optimal coagulant dose.

Section 4

FIXED BED ION EXCHANGE

4.1 Objectives

The primary objective of testing fixed bed ion exchange resin is to evaluate color removal from settled water at the WTP and determine the best operating conditions for a full-scale implementation. Specific objectives of the testing are to determine resin activity and optimal regeneration rate.

4.2 Materials and Equipment

The following materials and equipment will be utilized for the jar testing:

1. Peristaltic pump (Materflex, Vernon Hills, IL)
2. Hach SL1000 portable parallel analyzer (Hach, Loveland, CO)
3. 2-inch by 12-inch ion exchange column
4. pH and temperature meter with electrode
5. pH calibration buffers
6. Digital titrator (Hach, Loveland, CO) for alkalinity and hardness
7. Spectrophotometer (Hach DR 5000) for measuring color and UV254
8. 0.45 um filters and vacuum pump for sample preparation (e.g., for true color, UV254 analysis)
9. Coolers and sample bottles for laboratory analysis of water quality parameters
10. Jar test apparatus
11. Thermax ion exchange resin

4.2.1 Source Water Collection

Water will be collected from the settled water sampling port (pictured in Figure 2) at the WTP.

4.3 Test Protocol

The fixed bed ion exchange column will be fed filtered effluent at a flow rate of 0.17 gpm (~660 mL/min) (this equates to an application rate of 8 gpm/ft^2). The columns will be fed (downflow) by the use of a peristaltic feed pump (Masterflex, Vernon Hills, IL). Samples of filtered effluent (IX influent) and IX effluent will be collected and sampled for the parameters indicated in the following table. (Note: True color of the IX effluent should be measured at various times throughout sampling to develop a color breakthrough curve. The remaining parameters are measured after 120 and 180 minutes.)

Total and free chlorine residual of the filtered water used as the IX feed water will be measured and recorded. The total chlorine residual should be less than 4 mg/L Cl_2.

Before and during testing, flow rate of the peristaltic pump will be verified by timing the amount of time to fill a 1,000 mL graduated cylinder.

If breakthrough of color takes an extended period of time, jar testing will also be conducted to simulate the breakthrough of color through a fixed bed system. It should be noted that the jar testing conditions are CSTR while a fixed bed is plug flow; however, the data can be used to help set design criteria and estimate costs.

Table A-4 Water Quality Analysis for Fixed Bed Ion Exchange Testing

Parameter	Sampling Location/Frequency	Laboratory Requirements
Alkalinity	IX Influent, Effluent samples at 120 min and 180 min	Field
Chlorides1	IX Influent, Effluent samples at 120 min and 180 min	Certified Lab
Color (True)1	IX Influent, Effluent samples at 120 min and 180 min	Field2
Hardness (Ca)	IX Influent, Effluent samples at 120 min and 180 min	Field
Hardness (Total)	IX Influent, Effluent samples at 120 min and 180 min	Field
pH	IX Influent, Effluent samples at 120 min and 180 min	Field
Nitrate1	IX Influent, Effluent samples at 120 min and 180 min	Certified Lab
Sulfate1	IX Influent, Effluent samples at 120 min and 180 min	Certified Lab
TDS1	IX Influent, Effluent samples at 120 min and 180 min	Certified Lab
TOC	IX Influent, Effluent samples at 120 min and 180 min	Certified Lab
Temperature	IX Influent, Effluent samples at 120 min and 180 min	Field
Total chlorine	IX Influent, Effluent samples at 120 min and 180 min	Field
UV254	IX Influent, Effluent samples at 120 min and 180 min	Field

Notes:

(1) Color, nitrate, chloride, sulfate, and TDS analysis by Pace Analytical from a shared 1-L bottle.

(2) Select one 180-min effluent sample for split sample analysis at certified lab (Pace Analytical).

1. Measure out 10 mL of resin in a centrifuge tube or graduated cylinder.
2. Collect grab samples of raw water for determination of water quality parameters including pH, true color, UV254, total alkalinity, calcium hardness, and total hardness.
3. Add 2L of raw water to a jar after measuring for the parameters necessary.
4. Mix at 70 rpm for 60 minutes and collect samples at every 10 minutes to measure true color.
5. Use care to avoid losing any resin when sampling from jar.
6. Turn mixer off and allow resin to settle, about 30 seconds.
7. Measure color at the end of the 60 minutes.
8. Carefully add another 2L volume of raw water to resin and repeat Steps 4-6 until target number of bed volumes has been reached or color is no longer decreasing.

Section 5

FLUIDIZED BED ION EXCHANGE EVALUATION PLAN

Fluidized bed ion exchange is used as a slurry consisting of 150 to 180-micron beads with concentration ranging from 2 to 40 mg/L. With a 10 to 30 min contact time, ion exchange resins may effectively remove organic matters, irrespective of turbidity levels in the water. Due to magnetic properties, the resins form larger agglomerates and settle in the settling basin. Typically, 5 to 10 percent of the ion exchange resin requires regeneration, while the remaining resins are recycled back into the influent.

To evaluate whether fluidized bed ion exchange treatment will allow removing color and improving water quality at the WTP, jar testing will be performed.

5.1 Objectives

The primary objective of the jar testing with ion exchange resin is to evaluate color removal at the WTP and determine the best operating conditions for a full-scale implementation. Specific objectives of the testing are to determine resin activity and optimal regeneration rate.

5.2 Materials and Equipment

The following materials and equipment will be utilized for the jar testing:

1. One standard jar testing apparatus with 2-L gator jars
2. 4L glass jars for raw water collection
3. DI water
4. Glassware including volumetric flasks and beakers
5. A 10-mL autopipette with tips
6. A 1000-µL autopipette with tips
7. pH and temperature meter with electrode
8. pH calibration buffers
9. Titration apparatus for alkalinity and hardness
10. Spectrophotometer DR 5000 for measuring color and UV254
11. 0.45 um filters and vacuum pump for sample preparation (for true color and UV254 analysis)
12. Coolers and sample bottles for laboratory analysis of TOC and split samples for color
13. Regenerated ion exchange (MIEX) resin from the Boynton Beach East WTP

5.2.1 Source Water Collection

Source water will be collected in 5-gal buckets from the raw water sampling port (upstream of the softening process (i.e., hydrotreater) at the WTP.

5.3 Test Protocol

Regenerated resin from Boynton Beach East WTP will be used for this evaluation and the following tests will be conducted.

Treatment performance at a number of regeneration rates is determined by contacting a set volume of resin with different volumes of raw water. The volume of raw water treated divided by the volume of resin used to treat the water determines the bed volumes (BV) of raw water treated as calculated below:

Bed Volume (BV) = Volume Treated Water (L) / Volume Resin Used (L)

Bed Volumes for testing should include: 600, 800, and 1,000.

Procedure:

1. Measure out 10 mL of resin in a centrifuge tube or graduated cylinder.
2. Use DI (distilled water) to rinse resin down and allow the resin to settle at least 30 minutes to get a true volume.
3. Add 2L of raw water to a jar after measuring for the parameters indicated in the table below.
4. Using a magnet, hold the resin in place while decanting the DI off of the resin in the centrifuge tube or graduated cylinder (note: be careful not to lose any resin).
5. Using a disposable pipette, use the raw water from the 2L jar to add the 10 mL fresh resin (200 BV treatment rate per cycle).
6. Mix for 15 minutes at 150 rpm.
7. Turn mixer off and allow resin to settle, about 30 seconds.
8. Using great care decant treated water into collection vessel (i.e., a 5-gallon bucket) retaining resin in jar (placement of two magnets on either side of the pouring lip helps to create an additional trap for resin).
9. Measure UV254 and true color of sample in collection vessel using spectrophometer DR 5000. (Note: remove only the smallest volume of water needed to measure for these parameters.)
10. Carefully add another 2L volume of raw water to resin and repeat Steps 3-7 until target number of bed volumes has been reached (this takes 3, 4, or 5 total treatment repetitions for 600, 800, and 1,000 bed volumes).
11. After treating the target treatment rate, the collection vessel should contain the composite of all treatment cycles.
12. Measure water quality parameters from the composite water in the collection vessel as indicated in the table below. After, discard remaining water from the collection vessel and the used resin.
13. Repeat experiment for other bed volumes to be treated.

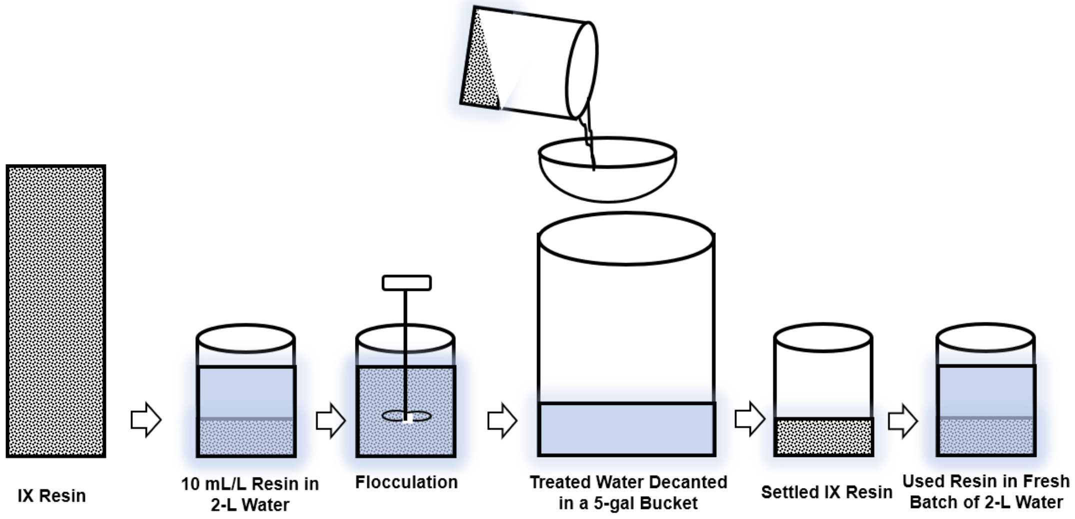

Figure A-6 Schematic of Fluidized Bed Ion Exchange Testing Protocol

Table A-5 Water Quality Analysis for Fluidized Bed Ion Exchange Testing

Parameter	Sampling Location/Frequency	Laboratory Requirements
Alkalinity (Total)	Raw water & 1,000 BV	Field
Chloride1	Raw water & 1,000 BV	Certified Lab
Color (True)1	Raw water 600, 800 & 1,000 BVs	Field2
Hardness (Ca)	Raw water & 1,000 BV	Field
Hardness (Total)	Raw water & 1,000 BV	Field
pH	Raw water 600, 800 & 1,000 BVs	Field
Nitrate1	Raw water & 1,000 BV	Certified Lab
Sulfate1	Raw water & 1,000 BV	Pace Lab
TDS1	Raw water & 1,000 BV	Certified Lab
TOC	Raw water & 1,000 BV	Certified Lab
Temperature	Raw water & 1,000 BV	Field
Total chlorine	Raw water & 1,000 BV	Field
UV254	Raw water 600, 800 & 1,000 BVs	Field

Notes:
(1) Color, nitrate, chloride, sulfate, and TDS analysis by Pace Analytical from a shared 1-L bottle.
(2) Split samples will be collected for raw water and 1,000 BV samples for analysis by Pace Analytical (certified laboratory).

5.4 Water Quality Analysis

Laboratory methods for water quality analysis are shown in the table below.

Table A-6 Analytical Methods

Parameter	Units	Analytical Method (1)
Chloride	mg/L	EPA Method 300.0
Chlorine residual	mg/L	Standard Method 4500-Cl
Color (true)	CU	Standard Method 2120
Hardness, total	mg/L as $CaCO_3$	Standard Method 2340B (field); EPA Method 200.7 (certified lab)
Hardness, calcium	mg/L as $CaCO_3$	Standard Method 2340B (field); EPA Method 200.7 (certified lab)
pH	SU	Standard Method 4500-H^+
Magnesium	mg/L	EPA 200.7
Nitrate	mg/L	EPA Method 353.2
Sulfate	mg/L	EPA Method 300.0
Temperature	deg. C	Standard Method 2550
Total dissolved solids	mg/L	Standard Method 2540C
Total alkalinity	mg/L as $CaCO_3$	Standard Method 2320
Total organic carbon	mg/L	Standard Method 5310B
Total sulfide	mg/L	Standard Method 4500-S^{2-}
UV254	1/cm	Standard Method 5910

Notes:
(1) Standard Method procedures in Standard Methods for the Examination of Water and Wastewater.

5.4.1 QA/QC

Standard quality assurance and control procedures will be practiced throughout implementation of this test plan. Analysis of water quality parameters will follow appropriate EPA and/or *Standard Methods for the Examination of Water and Wastewater*. Replicate sampling will be performed, as noted in the sampling plan, and will be evaluated for accuracy and precision.

Appendix B

BENCH-SCALE TESTING TECHNICAL MEMORANDUM

CITY OF FORT LAUDERDALE

City of Fort Lauderdale
Fiveash Water Treatment Plan

Technical Memorandum
BENCH-SCALE TESTING TECHNICAL MEMORANDUM

FINAL REDACTED| December 2019

carollo®

CERTIFICATE OF AUTHORIZATION NO. 8571

CITY OF FORT LAUDERDALE

City of Fort Lauderdale
Fiveash Water Treatment Plant

Technical Memorandum
BENCH-SCALE TESTING TECHNICAL MEMORANDUM

FINAL REDACTED | December 2019

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Abbreviations

AC	acre
AFY	acre-feet per year
ADD	average day demand
Carollo	Carollo Engineers, Inc.
cf	cubic feet
cfs	cubic feet per second
F	Fahrenheit
ft	feet
gpcd	gallons per capita day
gpd/ac	gallons per day per acre
MDD	maximum day demand
µg/L	micrograms per liter
MG	million gallons
mgd	million gallons per day
mg/L	milligrams per liter
MinDD	minimum day demand
MinMD	minimum month demand
MMD	maximum month demand
msl	mean sea level
PHD	peak hour demand
PS	pump station
psi	pounds per square inch
RO	reverse osmosis
SCADA	supervisory control and data acquisition
WRF	water reclamation facility
WWTP	wastewater treatment plant
WTP	water treatment plant

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Section 1

INTRODUCTION

The City of Fort Lauderdale (City) Fiveash Water Treatment Plant (WTP) (Figure 1.1) is the City's largest WTP, supplying approximately three quarters of all of the potable water provided to the City's service area. The facility was originally built with a capacity of 8 million gallons per day (mgd), which was expanded to 70 mgd overtime. However, its current daily production averages approximately 33 mgd due to several challenges, including aged equipment. While the facility meets all applicable water quality standards and reliably provides potable water, regular consumer complaints are received due to colored water.

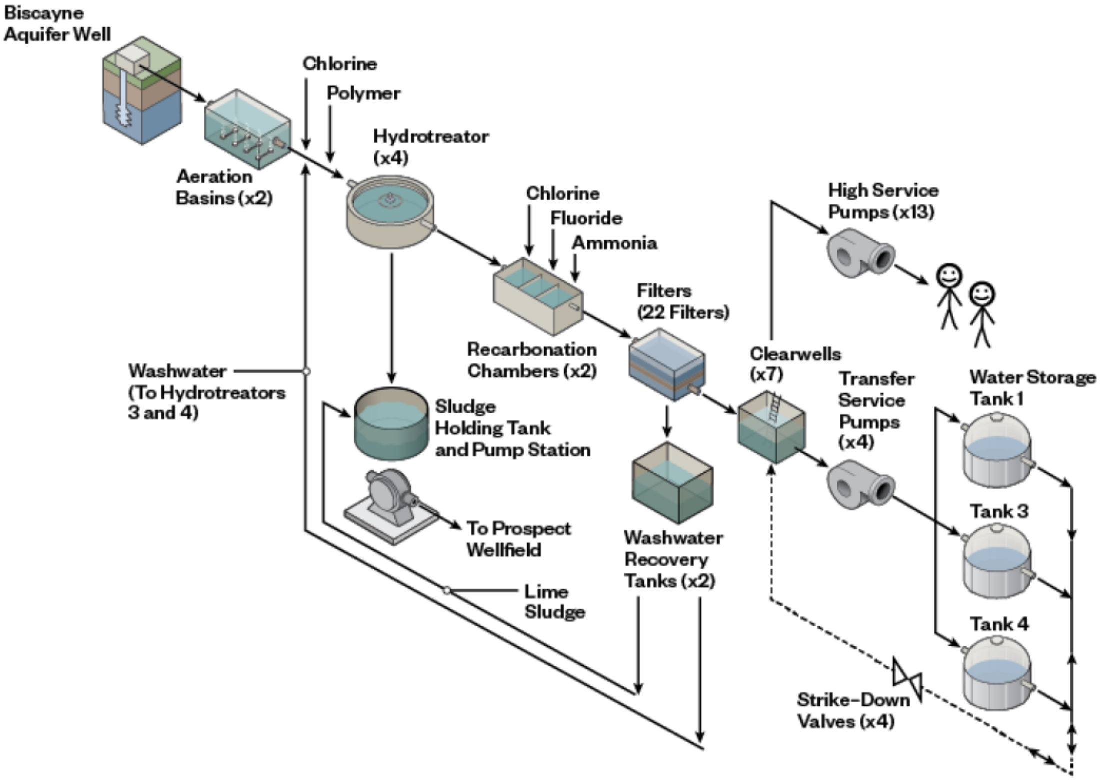


Figure 1.1 Treatment Train at the WTP

The City hired Carollo Engineers, Inc. (Carollo) for the evaluation of treatment options that would allow enhancing water production at the WTP while lowering color to a non-objectionable level. Carollo conducted bench-scale evaluations utilizing rapid small-scale column testing (RSSCT), jar testing for enhanced lime softening, and ion exchange to evaluate the possibility of lowering color in the finished water.

The jar testing of conventional lime softening with coagulant addition, enhanced lime softening, enhanced coagulation and ion exchange testing were conducted at the WTP. The RSSCTs were performed at Carollo's applied research center (i.e., Water ARC®).

1.1 RSSCT Evaluations

RSSCTs are bench-scale tests that simulate full-scale performance of granular activated carbon (GAC) for color removal. The RSSCT evaluations were performed at Water ARC®, Boise, ID.

1.1.1 Objectives

The primary objectives of the RSSCT evaluations are:

1. Determine GAC adsorption characteristics and breakthrough patterns
2. Determine the effects of EBCT on adsorption characteristics and breakthrough patterns
3. Select the best performing GAC for developing project cost estimates

1.1.2 Materials and Equipment

The following materials and equipment were provided by Carollo for the RSSCT evaluations:

- Six RSSCT columns (1.1 cm outer diameter and 30 cm length)
- Three peristaltic pumps (Masterflex, Vernon Hills, IL)
- Beakers and disposable pipettes
- Spectrophotometer (Hach, Loveland, CO) with sampling vials for measuring color and UV254
- Kimwipes for cleaning the sampling vials
- Deionized (DI) water

1.1.3 RSSCT Evaluation Plan

1.1.3.1 Sample Water Collection

Filtered water was collected from the WTP (at the sample point indicated in Figure 1.2) as the source water for the RSSCTs. The source water was collected in 55-gal drums and shipped to Carollo's Water ARC® laboratory in Boise, ID. Upon delivery, the source water was stored at 4 °C to prevent biological growth and changes in water quality. Small batches were allowed to warm to room temperature prior to testing. Water quality for the RSSCT was analyzed at collection and upon delivery at the laboratory to confirm chlorine residual was present.

[redacted]

Figure 1.2 Sample Tap for Collection of Filtered Water for RSSCTs

Three 55-gallon drums were filled with filtered water, and grab samples collected from each drum. Grab samplings were analyzed for the following parameters: color (true), UV254, pH, alkalinity, total and calcium hardness, and total and free chlorine.

1.1.3.2 Preparing the RSSCT Columns

The following procedures were followed for preparing the RSSCT columns:

1. Grind the GAC and sieve the ground media through 100 x 140 mesh size.
2. Thoroughly rinse the sieved media with distilled water (or deionized water) until the water is visibly clear of fines.
3. Rinse glass beads and glass wool with DI water.
4. Pack the RSSCT columns (refer to Figure 1.3):
    a. Pack the columns to achieve a bed depth of 3 cm glass wool over 3 cm glass beads.
    b. Fill the columns with DI water to maintain a standing water column of approximately 10 cm above the glass wool.
    c. Slowly pour the rinsed media into the column, while gently tapping the column to prevent air entrapment in the bed. The packed media bed should be 18 cm in height.
    d. On the top of the media bed, pack 3 cm glass beads over 3 cm of glass wool.

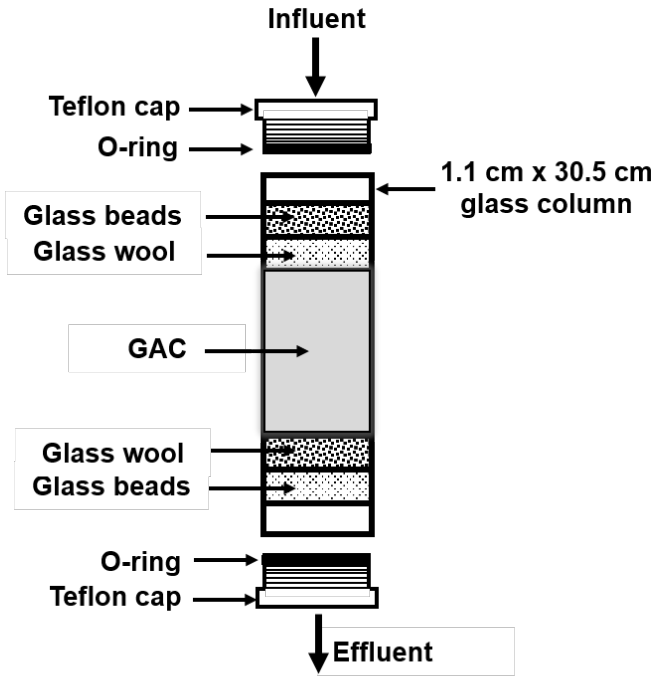


Figure 1.3 Schematic Representation of the RSSCT Column

1.1.3.3 Test Protocol

RSSCT evaluations were conducted on filtered water collected from the full-scale WTP with three set ups in parallel (Figure 1.4). Three types of GAC evaluated included Calgon F400, Jacobi Aquasorb 5010, and Evoqua UltraCarb 1240. The three types of GAC were selected to represent different price points and manufacturers. Each set-up will have two columns in series, which will allow evaluating two EBCTs: 7.5 min and 15 min. Results from longer EBCTs were not tested as the performance for longer contact times can be extrapolated from the existing data.

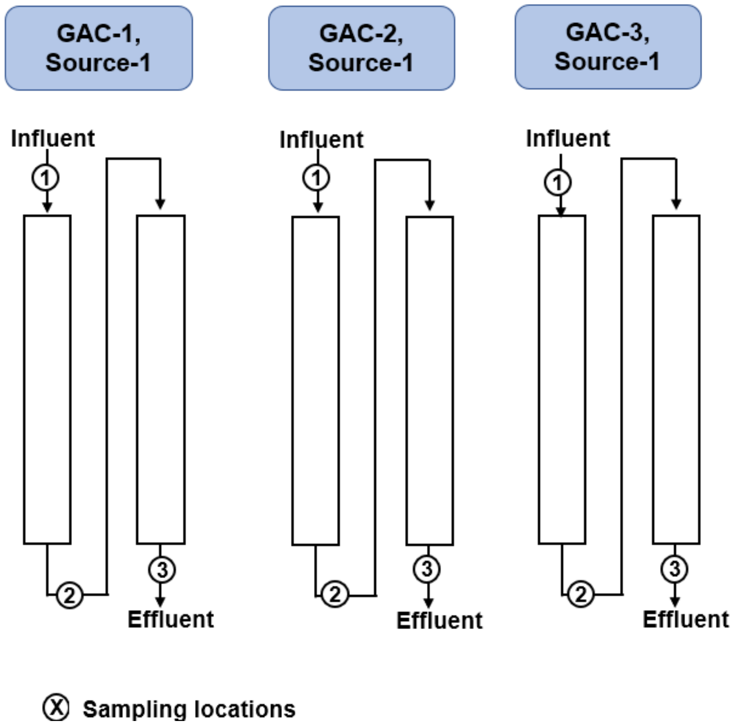


Figure 1.4 RSSCT Set-up

For the testing, the following procedures was followed:

1. Homogenize the source water in a lined drum.
2. Set the peristaltic pumps to the required flow rate (e.g., 2.1 mL/min [1.3 gpm/ft2] for Calgon and Evoqua carbons and 2.2 mL/min [1.4 gpm/ft2] for Jacobi carbon).
3. Pump DI water with the adjusted flow rates through the columns for approximately 30 min to remove any residual fine particles and further compact the media bed. Re-check the media depth and add media if needed. Also, verify the flow rate by collecting the effluent in graduated cylinder for a specified time. If the actual flow rate is different from the flow rate set on the pump, adjust the pump flow rate.
4. Pump the source water into the RSSCT column in a down-flow mode with the pre-set flow rates.
5. Collect grab samples as listed in Table 1.1. Generate color breakthrough curves for each RSSCT set.

Table 1.1 RSSCT Evaluations for Color Removal

Parameter	Sampling Locations	Frequency of Sampling	Laboratory Requirements
pH	Inf(1), Eff-1, Eff-2	2/week	Field
True Color(2)	Inf(1), Eff-1, Eff-2	2/week	Field
UV254(2)	Inf(1), Eff-1, Eff-2	2/week	Field
Total Sulfide	Inf(1), Eff-1, Eff-2	2/wk (Effluents), 1/wk (Inf)	Certified Lab

Notes:
(1) Influent sample collected from shared feed water container.
(2) 10% of the samples will be split and sent to a certified lab (Eurofins) for QA/QC.

1.1.3.4 Results

GAC will adsorb the vast majority of organics except for the non-adsorbable fraction (which is typically not composed of organics that cause color). The primary consideration with GAC is how long the removal will last; at some point the contaminant in question will begin to 'break through,' meaning that it will begin to increase in concentration above the desired treated water level. At this point the GAC needs to be replaced or regenerated. Breakthrough plots for bench-scale tests with influent color of 14 CU (filtered plant water) are shown in Figure 1.5. Filtered water is used because the GAC process would be placed downstream of the dual media filtration process. As shown in the figure, breakthrough above 5 CU and 12 CU in the treated water both occurred fairly quickly due to high TOC and color. Based on these results, the estimated time between GAC regeneration cycles or replacement is summarized in Table 1.2.

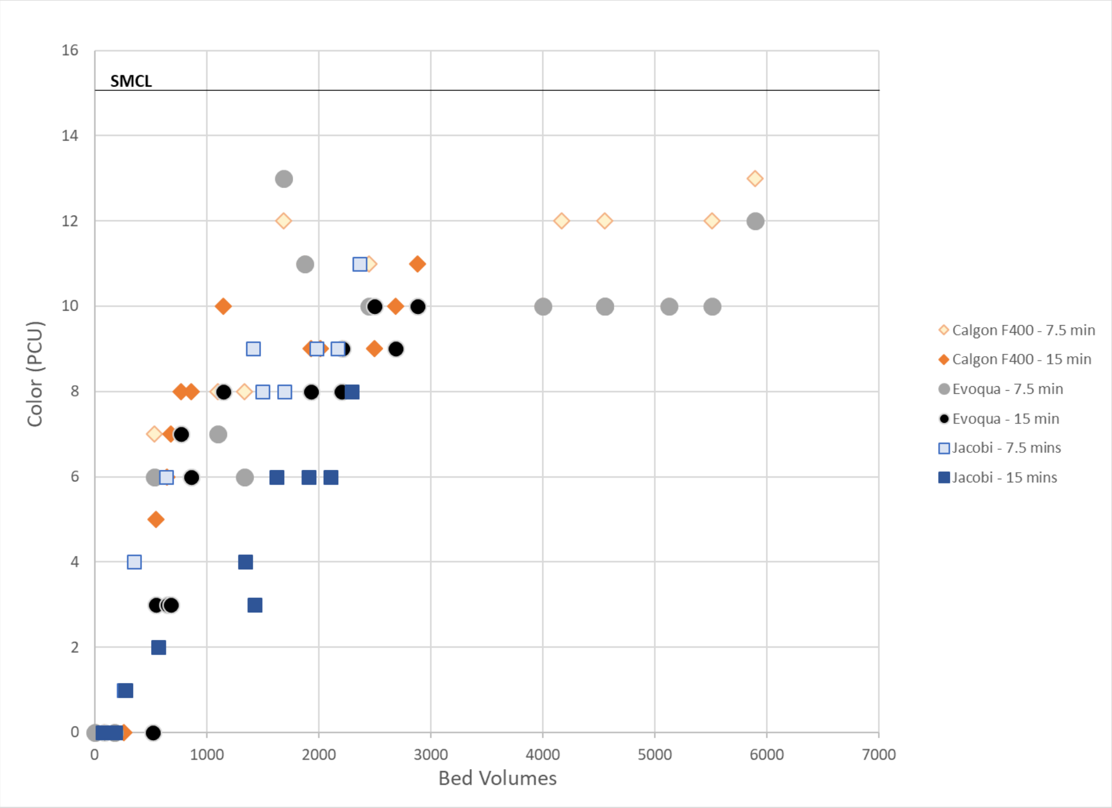


Figure 1.5 GAC Bench-Scale Breakthrough Results

Table 1.2 GAC Bench-Scale Breakthrough Time Summary

Carbon	EBCT (min)	Influent Color (CU)	Breakthrough Color (CU)	Bed Volumes to Breakthrough	Breakthrough Time (days)
Calgon F400	7.5	14	5	430	2.2
			12	No data	-
		28(1)	5	215	1.1
			12	Unknown	-
	15	14	5	545	5.7
			12	No data	-
		28(1)	5	272	2.8
			12	Unknown	-
Evoqua	7.5	14	5	500	2.6
			12	1,600	8.3
		28(1)	5	250	1.3
			12	800	4.2
	15	14	5	730	7.6
			12	1,800	18.8
		28(1)	5	365	3.8
			12	1,300	13.5
Jacobi	7.5	14	5	494	2.6
			12	Unknown	-
		28(1)	5	247	1.3
			12	Unknown	-
	15	14	5	1622	16.9
			12	Unknown	-
		28(1)	5	811	8.5
			12	Unknown	-

Notes:
(1) Bed volumes and breakthrough time for 28 CU influent color are scaled estimates based on 14 CU influent data. 28 CU represents a maximum color that may appear in Fiveash filtered water at certain times of the year.

As shown in Table 1.2, the Evoqua GAC had the longest breakthrough times at the 7.5 min EBCT and the Jacobi GAC had the longest breakthrough times at the 15 min EBCT. For all carbons, the breakthrough times are still very short due to high TOC levels. It should also be noted that the water quality used for this testing was an average color. A worse-case raw water color would have an even faster breakthrough curve (as estimated in the table - influent color of 28 CU). These results significantly affect O&M and are discussed further in the evaluation of treatment alternatives. A more detailed breakdown of data can be found in Appendix A. With an average GAC influent color of 14 CU and an EBCT of 15 min, the estimated GAC regeneration cost is $130,000,000 per year at 33 mgd average flow. If the average flow is raised to 40 mgd, the estimated GAC regeneration cost is $158,000,000 per year. Despite the higher number of bed volumes to breakthrough for the Jacobi GAC (at 15 min EBCT), annual costs are expected to be similar to the Calgon and Evoqua options due to the higher density of the Jacobi carbon.

1.2 Conventional and Enhanced Lime Softening

Softening is a process in which calcium and magnesium species are removed through precipitation. For effective softening, pH should be raised, so that calcium carbonate and magnesium hydroxides are generated. Previously precipitated calcium and magnesium particles provide a surface for additional precipitation, which is enhanced when suspended particles are maintained at higher concentration.

Lime or caustic soda (sodium hydroxide) is typically used for the softening process. Conventional lime softening raises the pH to 9.5 to 9.8 and under this condition, only calcium precipitates. Enhanced softening with the removal of both calcium and magnesium can be achieved, if the pH is raised to 10.6 to 11.2. Enhanced softening may also result in the removal of organics (e.g., color) due to the high surface area and positive charge of magnesium hydroxide; however, although not typically done in water treatment, supplemental magnesium was testing because the raw water ismagnesium limited waters.

Jar testing was conducted to determine if conventional lime softening with coagulant addition or enhanced coagulation can achieve color removal to the desired color goal. The tests was performed at the WTP.

1.2.1 Objectives

The primary objectives of jar testing lime softening processes is to quantify the level of color (TOC) removal from the source water under the following conditions:

- Adding coagulant (i.e., ferric sulfate) with the conventional lime softening process.
- Increasing the lime softening pH to between 10.6 and 11.2 (enhanced coagulation).
- Adding chemicals such as magnesium to provide additional color removal.

1.2.2 Materials and Equipment

The following materials and equipment will be utilized for the jar testing:

1. One standard jar testing apparatus with 2-L gator jars
2. Clarifloc A-3333P polymer (Note: a 1 g/L stock solution will be prepared in distilled water and allowed to age overnight prior to testing. A new stock solution will be prepared daily during testing.)
3. Hydrated lime ($Ca(OH)_2$)
4. Magnesium chloride ($MgCl_2$), anhydrous >98 percent
5. pH and temperature meter with electrode
6. pH calibration buffers
7. Titration apparatus for alkalinity including prepared acid solution
8. A stirrer plate with stir bars
9. Glassware
10. DI water
11. A 10-mL autopipette with tips
12. A 1000-µL autopipette with tips
13. 4L glass jars for collecting raw water
14. Spectrophotometer (Hach DR 5000, Loveland, CO) for measuring UV254 and color
15. Hach SL1000 portable parallel analyzer (Hach, Loveland, CO)
16. Digital titrator (Hach, Loveland, CO)

17. Vacuum pump, filtration apparatus, and 0.45 µm filters
18. Cooler and sample bottles for sending samples to laboratory for TOC analysis, and split samples for color analysis

1.2.2.1 Source Water Collection

Source water was raw water collected from the sampling port immediately upstream of the softening process at the WTP (i.e., upstream of the hydrotreater).

1.2.2.2 Jar Testing Equipment

A standard six jar paddle stirrer (Phipps and Bird, Richmond, VA) jar tester (Figure 1.6) was used for this testing. The system features six specially designed 2-liter square B-KER jars (Phipps and Bird, Richmond, VA), LED lamps for diffused sample illumination, and a stepper motor drive for speed control. The system utilizes four operator-programmable memory banks which may be programmed with paddle speeds from 5 to 300 rpm in 1 rpm increments and run times from 1 to 59 minutes in 1-second increments. Stainless steel 1-inch by 3-inch paddles are spaced six inches apart and are adjustable to a maximum depth of 9-inch). The specially designed "gator" jars have a sample tap located at a precise distance (10 cm) from the top of the water to allow the sampling of small quantities of settled water for turbidity and other water quality measurements.

Figure 1.6 Phipps & Bird PB-950 Series Jar Tester

This equipment uses previously developed relationships that correlate mixing energy with stirrer speed and water temperature (that is, velocity gradient (G)) at the bench-scale level (Figure 1.7).

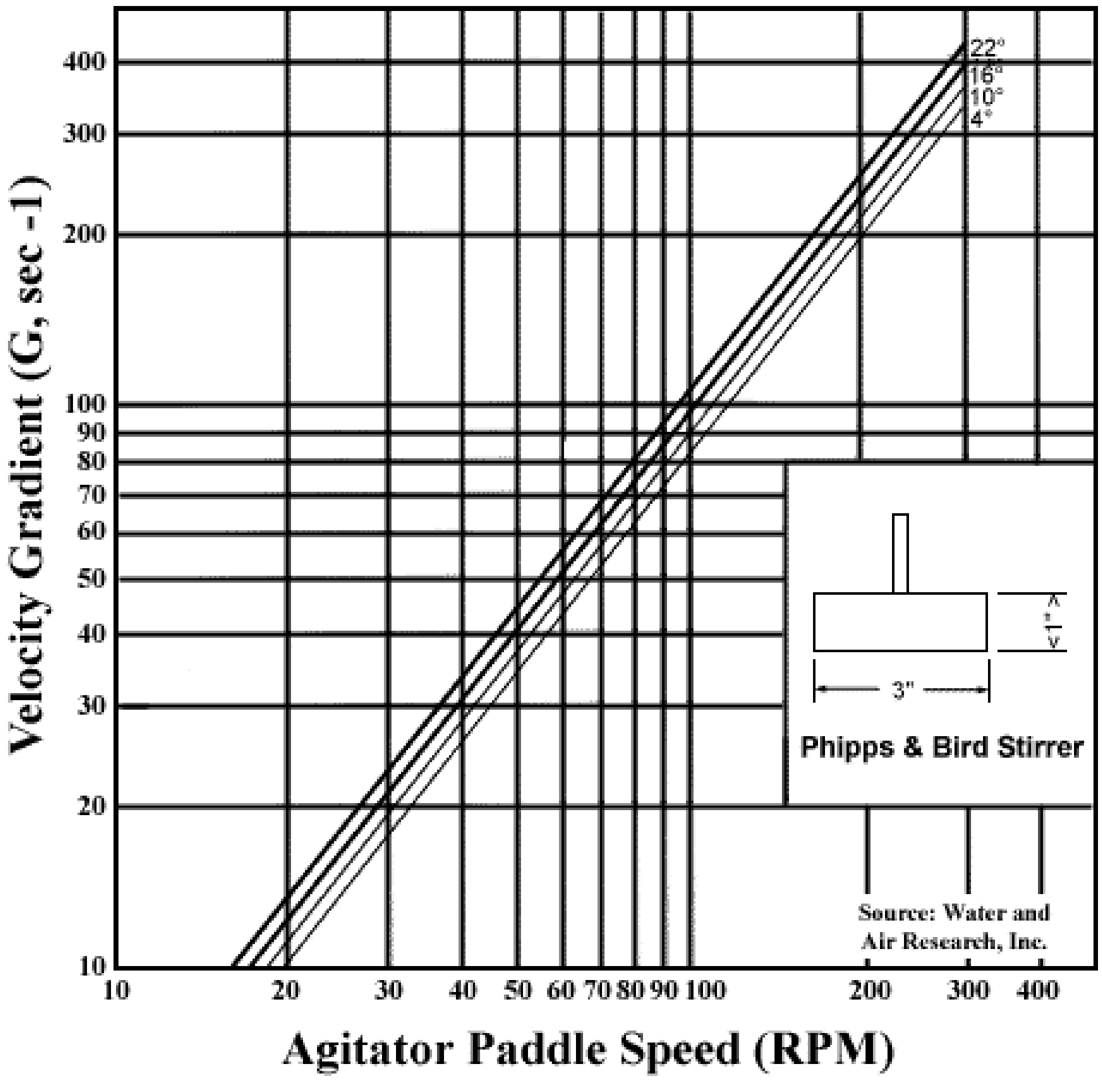


Figure 1.7 Velocity Gradient vs. RPM for a 2-L Square Jars

1.2.3 Test Protocol

The general jar test procedure for enhanced lime softening with and without $MgCl_2$ addition is outlined below:

1. Prepare the stock solutions as needed (e.g., polymer, $MgCl_2$).
2. Collect raw water upstream of the Hydrotreater and pour into the 2-L jars.
3. Collect grab samples for determination of water quality parameters including pH, true color, UV254, total alkalinity, calcium hardness, and total hardness.
4. Turn on the jar testing and set mixing speed to 100 rpm. Add a pre-determined dose of chemicals in this order: $MgCl_2$ (when desired), $Ca(OH)_2$, and 0.2 mg/L of polymer to the jars.
5. Mix at 100 rpm for 1 minute.

6. Turn down mixer speed to 25 rpm for 30 minutes.
7. Turn off the mixer and allow each jar to sample for 20 minutes
8. After 20 min of settling, collect grab samples for determination of pH, true color, UV 254, total alkalinity, calcium hardness, and total hardness. For all parameters except pH, filter samples through a 0.45 um filter before analysis.

Table 1.3 Enhanced Lime Softening Jar Testing Plan

Jar	Chemical Doses(1)	Target Settled Water pH
1	190 mg/L $Ca(OH)_2$ 0.2 mg/L polymer	9.5
2	230 mg/L $Ca(OH)_2$ 0.2 mg/L polymer	10.0
3	270 mg/L $Ca(OH)_2$ 0.2 mg/L polymer	10.5
4	310 mg/L $Ca(OH)_2$ 0.2 mg/L polymer	11.0
5	350 mg/L $Ca(OH)_2$ 0.2 mg/L polymer	11.5

Notes:
(1) Record $Ca(OH)_2$ dose. Settled water pH should be within +/- 0.3 S.U. of target.

Table 1.4 Enhanced Lime Softening Jar Testing Plan with $MgCl_2$ Addition

Jar	Chemical Doses(1)	Target Settled Water pH
1	430 mg/L $Ca(OH)_2$ 0.2 mg/L polymer 10 mg/L Mg as $CaCO_3$	>11.00
2	430 mg/L $Ca(OH)_2$ 0.2 mg/L polymer 20 mg/L Mg as $CaCO_3$	>11.00
3	430 mg/L $Ca(OH)_2$ 0.2 mg/L polymer 30 mg/L Mg as $CaCO_3$	>11.00
4	430 mg/L $Ca(OH)_2$ 0.2 mg/L polymer 40 mg/L Mg as $CaCO_3$	>11.00
5	430 mg/L $Ca(OH)_2$ 0.2 mg/L polymer 50 mg/L Mg as $CaCO_3$	>11.00
6	430 mg/L $Ca(OH)_2$ 0.2 mg/L polymer 60 mg/L Mg as $CaCO_3$	>11.00

Notes:
(1) Record $Ca(OH)_2$ dose. Settled water pH should be between 11.0 and 11.3.

The general jar test procedure for conventional lime softening with coagulant addition is outlined below:

1. Prepare the stock solutions as needed (e.g., $Ca(OH)_2$ and Ferric Sulfate).
2. Collect raw water upstream of the Hydrotreater and pour into the 2-L jars.
3. Collect grab samples for determination of water quality parameters including pH, true color, UV254, total alkalinity, calcium hardness, and total hardness.
4. Turn on the jar testing and set mixing speed to 100 rpm.
5. Add a pre-determined dose of chemicals in this order: $Ca(OH)_2$ and Ferric Sulfate
6. Mix at 100 rpm for 1 minute.
7. Turn down mixer speed to 25 rpm for 30 minutes.
8. Turn off the mixer and allow each jar to settle for 20 minutes
9. After 20 min of settling, collect grab samples for determination of pH, true color, UV 254, total alkalinity, calcium hardness, and total hardness. For all parameters except pH, filter samples through a 0.45 µm filter before analysis.

Prior to jar testing, zeta potential evaluation was used to better assess the floc characteristics and stability in the water. Zeta potential was determined at Water ARC® using a ZetaSizer (Malvern, Cambridge, UK). Zeta potential reflects the charge on suspended particles and flocs with zeta potential closer to zero being the target. The impact of ferric sulfate dose on zeta potential in the source water will be determined by measuring zeta potential with different ferric sulfate doses. The results of these testing will be used to help determine the coagulant dose for jar testing, which will be performed at the WTP. The general zeta potential evaluation procedure is outlined below:

1. Rinse the cuvette with DI water using a syringe.
2. Fill the cuvette with the substandard solution of -42 mV. Calibrate the ZetaSizer.
3. Rinse the cuvette with DI water and fill the cuvette with raw water sample. Measure zeta potential.
4. Pour 500 mL water in a 1-L beaker. Add the desired ferric sulfate dose and mix on a magnetic stirrer plate.
5. Rinse the cuvette with DI water and load with the coagulant added water. Measure zeta potential.
6. Repeat steps 4 and 5 with the pre-determined ferric sulfate doses (i.e., 10 mg/L increments).
7. Plot zeta potential against ferric sulfate dose to determine the optimal coagulant dose.

Prior to jar testing, zeta potential evaluation will be utilized to better assess the floc characteristics and stability in the water. Zeta potential was determined at Water ARC® using a ZetaSizer (Malvern, Cambridge, UK). Zeta potential reflects the charge on suspended particles and flocs with zeta potential closer to zero being the target. The impact of ferric sulfate dose on zeta potential in the source water was determined by measuring zeta potential with different ferric sulfate doses. Results

Conventional lime softening is a process of adding lime (CaO which is slaked to $Ca(OH)_2$) to a source water to precipitate calcium, and sometimes magnesium, to remove hardness. When lime is slaked using water, it is converted to calcium hydroxide under high temperature conditions, which, when added to the water raises the pH of the process. When the pH is raised to the point of calcium precipitation (approximately 9.4), calcium carbonate will begin to precipitate provided that there is enough alkalinity available to form carbonate solids. This softening approach has limited color removal because the calcium carbonate particles are crystalline with a small surface area and the calcium carbonate particles are negatively charged. This limits their ability to remove color.

Enhanced lime softening differs from conventional softening in that the lime dose is increased past the point of minimal calcium hardness for the purpose of removing NOM. In this case, NOM coprecipitates with and adsorbs to magnesium precipitates much more readily than calcium carbonate (because the magnesium has a high surface area and a positive charge). This means that the amount of NOM removal achieved during the softening process depends primarily on two variables: the amount of precipitate available for coprecipitation and adsorption (represented by the ratio of Ca^{2+} and Mg^{+2} to DOC and the ratio of total hardness to DOC) and the affinity of the NOM for the precipitates.

NOM aromaticity, hydrophobicity, specific UV absorbance (SUVA), and high-molecular-weight fraction are all positively correlated with increased NOM removal during enhanced softening. Additionally, higher initial pH levels and corresponding magnesium removal tends to increase NOM removal.

A previous enhanced lime softening study (which included samples from Ft. Lauderdale) showed an approximately 40 percent DOC removal when lime dose was increased to ~175 percent of conventional softening dose (dose required to reach the calcium removal pH). 15 percent NOM removal was achieved through the conventional lime dose and an additional 25 percent removal was achieved after the dose was increased. The slope of removal vs. lime dose tended to increase the most at 125 - 175 percent of conventional doses, the range in which magnesium precipitation occurred. This supports the premise that NOM has a higher affinity for magnesium precipitates than calcium precipitates. DBP concentrations decreased with higher lime doses, likely due to lower levels of DBP precursors.

Using synthetic water batch tests, Kalscheur et al. (2006) found that a calcium to magnesium ratio in source water of 3:1 resulted in 72 percent removal of fulvic acids (component of color) vs. 35 percent removal with negligible magnesium levels. Russell et al. (2009) and Singer (1999) also describe significantly higher NOM removal with increased initial magnesium concentrations. However, precipitation of $Mg(OH)_2$ for NOM removal is often avoided at softening plants due to difficulty in settling and dewatering the large, low-density flocs that form. This is a challenge from both a process and financial perspective. Nevertheless, due to the significant color challenges at Fiveash WTP, supplemental magnesium addition in the form of $MgCl_2$ (this is the only magnesium chemical that is NSF approved) was considered for enhanced NOM removal. It is also important to note that the supplemental magnesium must be in the dissolved form and then precipitated for the NOM removal affect to occur.

1.2.3.1 Zeta Potential Testing

As discussed above zeta potential testing was completed with ferric sulfate only in order to measure the charge requirements of the water prior to any treatment. This testing showed that in order to neutralize all of the raw water organics, a dose of approximately 340 mg/L of ferric sulfate would be required.

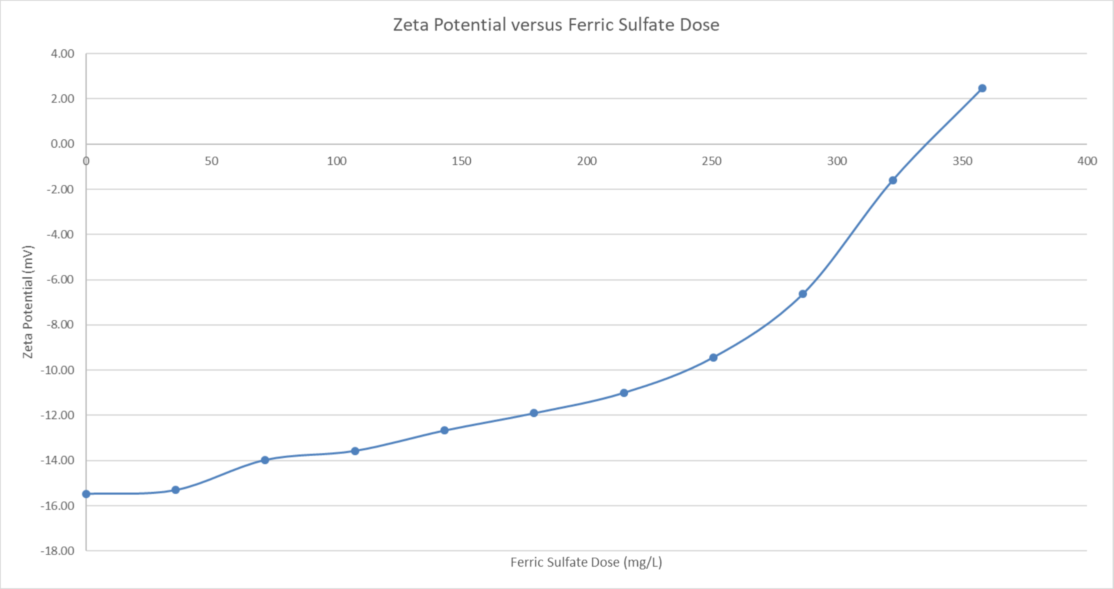


Figure 1.8 Zeta Potential Titration Curve of Raw Water (for Ferric Sulfate)

This demonstrates and verifies the high concentration of raw water NOM and its associated charge. It should be noted that the coagulation pH at a dose of 322 mg/L of ferric sulfate was 6.45. Testing of enhanced coagulation only occurred up to doses of 200 mg/L of ferric sulfate. Above this level alkalinity consumption was too high and softening would have been more complex and difficult to operate (it would have required caustic and soda ash).

1.2.3.2 Conventional Lime Softening to $CaCO_3$ Precipitation pH

Bench-scale tests using lime softening without magnesium addition on Fiveash raw water showed moderate color removal. Figure 1.8 shows bench-scale results. It should be noted that this type of softening would only utilize a softening pH of 9.4 (the pH at which only $CaCO_3$ precipitates), and therefore the expected percent removal of color is only 29 percent according to the color reduction at this pH from the bench-scale results.

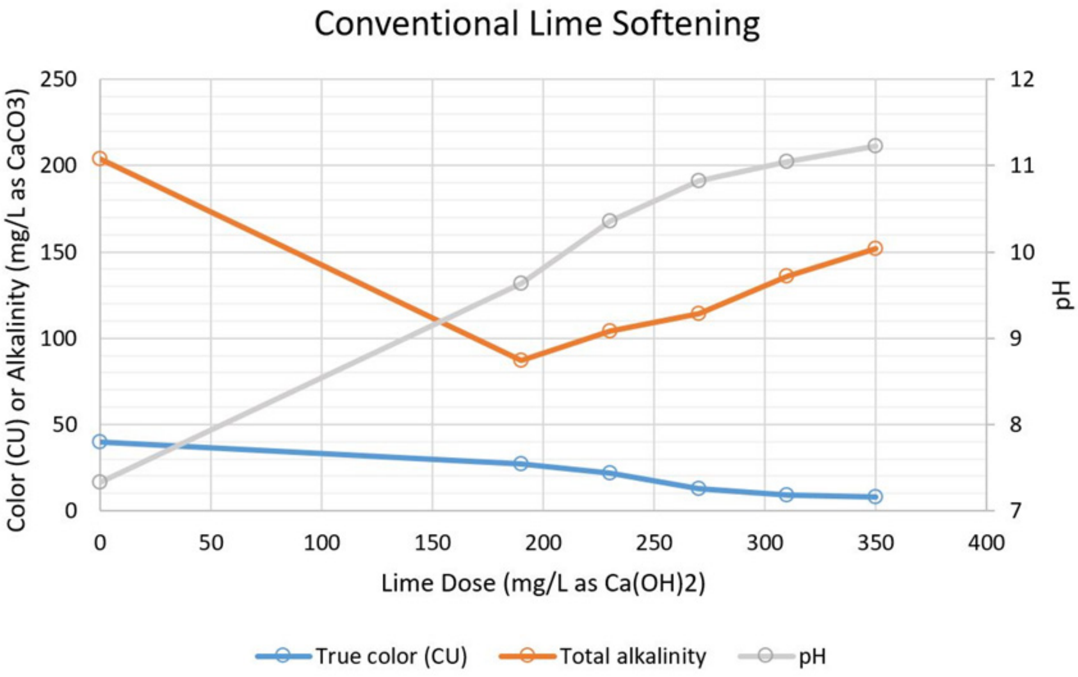


Figure 1.9 Conventional Lime Softening Bench-Scale Results

1.2.3.3 Enhanced Lime Softening with Magnesium Chloride Addition

Dissolved magnesium chloride ($MgCl_2$) was added at varying levels to Fiveash raw water with a varied lime dose and 0.2 mg/L of a bridging polymer (to assist with turbidity removal). Results for true color are shown in Figure 1.9. With a lime dose of 430 mg/L as $Ca(OH)_2$, true color decreased as $MgCl_2$ doses increased, with minimum color averaging 8 CU at 60 mg/L $MgCl_2$. This represents a 70 percent removal on average. The series shown on the plot with lime dose of 310 mg/L as $Ca(OH)_2$ represents an example where pH was not raised to the magnesium precipitation pH of 10.8. Based on these results, $MgCl_2$ supplementation will be effective if the lime dose is high enough to reach the magnesium precipitation pH.

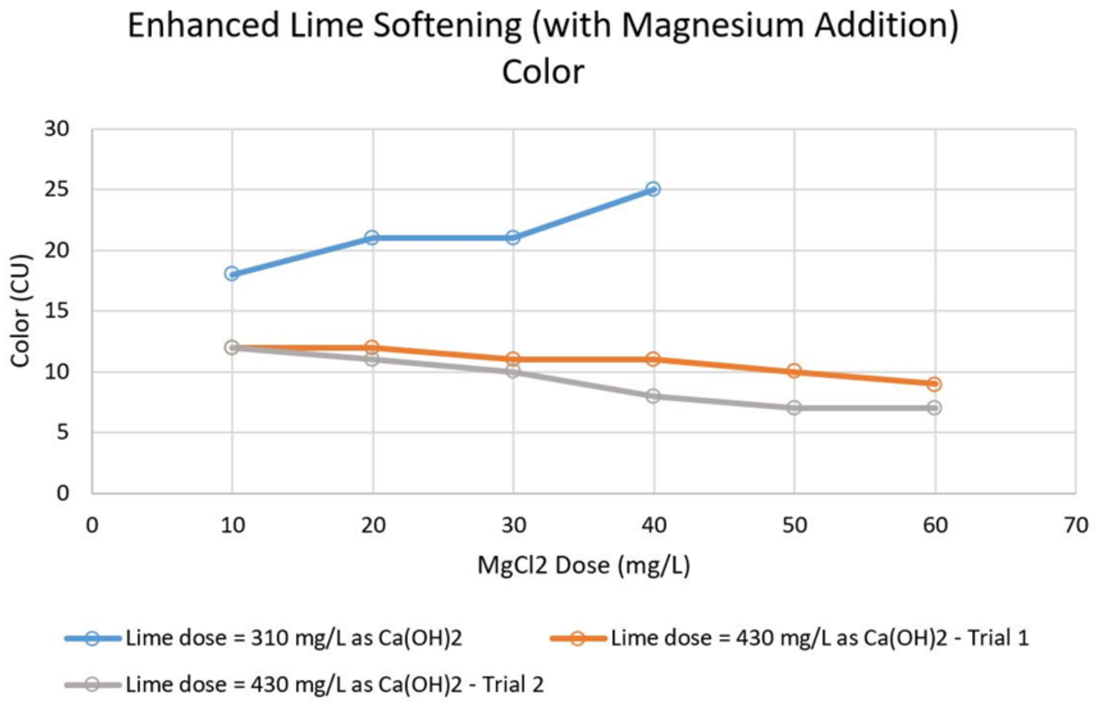


Figure 1.10 Enhanced Lime Softening with $MgCl_2$ Addition: Bench-Scale Results

1.2.3.4 Lime Softening with Ferric Sulfate Addition

Ferric sulfate was also added as an additional NOM removal chemical during the softening process (whether conventional or enhanced softening). Bench-scale tests, in which both lime and ferric sulfate were added to raw water (sequentially), show that the effect of lime dose on color removal was somewhat insignificant compared to the impact of ferric sulfate, as shown in Figure 1.10. Ferric doses above 40 mg/L consistently reduced color below 12 CU. The data collected show that doses above 200 mg/L reduced color below 5 CU. 80 mg/L of ferric sulfate without lime resulted in 81 percent color removal.

Since ferric sulfate lowers the pH (consumes alkalinity) and more NOM removal occurs at lower pHs, while lime raises the pH, ability to soften without running out of alkalinity may be somewhat limited in this case, and management of the chemistry would be complex and costly. Therefore, it is preferred to add lime (softening) and ferric sulfate (enhanced coagulation) in separate processes to achieve hardness and NOM removal, respectively. In this case enhanced coagulation would precede softening. An additional benefit of adding ferric sulfate is the lowered finished water CSMR which is discussed in the evaluation of treatment alternatives.

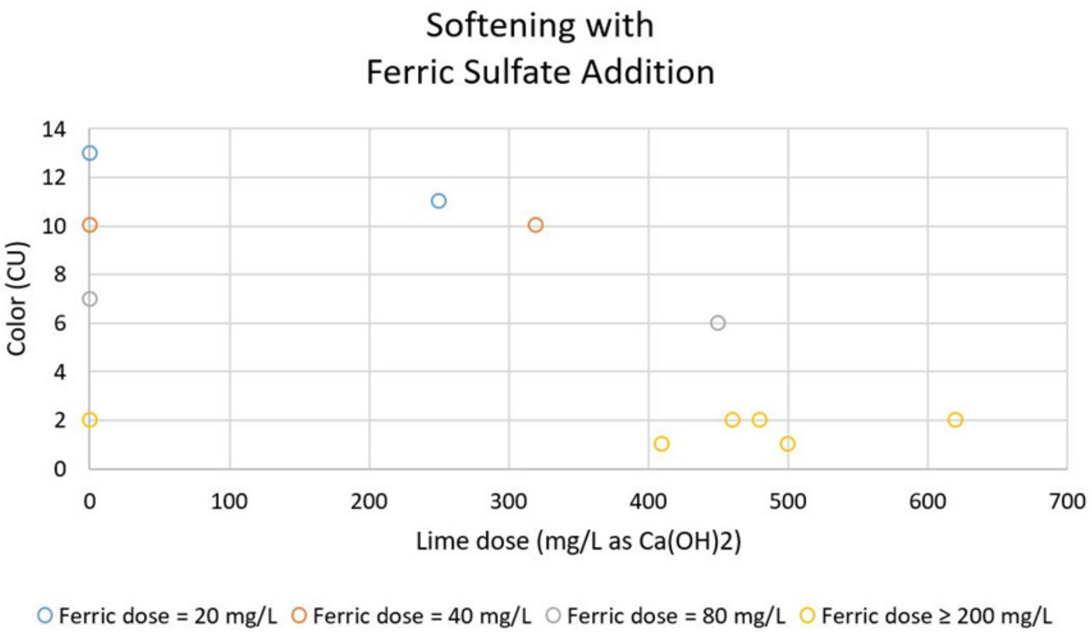


Figure 1.11 Lime Softening with Ferric Sulfate Addition and Enhanced Coagulation with only Ferric Sulfate

All of the data associated with softening, enhanced softening, coagulant addition to lime softening, and enhanced coagulation is provided in Appendix B.

1.3 Objectives

The primary objective of testing fixed-bed ion exchange resin was to evaluate color removal from filtered water at the WTP and determine the best operating conditions for a full-scale implementation. Specific objectives of the testing were to determine resin activity and optimal regeneration rate.

1.3.1 Materials and Equipment

The following materials and equipment were utilized for the jar testing:

1. Peristaltic pump (Materflex, Vernon Hills, IL)
2. Hach SL1000 portable parallel analyzer (Hach, Loveland, CO)
3. 2-inch by 12-inch ion exchange column
4. pH and temperature meter with electrode
5. pH calibration buffers
6. Digital titrator (Hach, Loveland, CO) for alkalinity and hardness
7. Spectrophotometer (Hach DR 5000) for measuring color and UV254
8. 0.45 um filters and vacuum pump for sample preparation (e.g., for true color, UV254 analysis)
9. Coolers and sample bottles for laboratory analysis of water quality parameters
10. Jar test apparatus
11. Thermax ion exchange resin

1.3.1.1 Source Water Collection

Water was collected from the filtered water sampling port (pictured in Figure 1.2) at the WTP.

1.3.2 Test Protocol

The fixed bed ion exchange column was fed filtered effluent at a flow rate of 0.17 gpm (~660 mL/min) (this equates to an application rate of 8 gpm/ft^2). The columns were fed (downflow) by the use of a peristaltic feed pump (Masterflex, Vernon Hills, IL). Samples of filtered effluent (IX influent) and IX effluent were collected and sampled for the parameters indicated in the following table. (Note: True color of the IX effluent was measured at various times throughout sampling to develop a color breakthrough curve. The remaining parameters were measured after 120 and 180 minutes.)

Total and free chlorine residual of the filtered water used as the IX feed water was measured and recorded. The total chlorine residual was less than 4 mg/L Cl_2.

Before and during testing, flow rate of the peristaltic pump was verified by timing the amount of time to fill a 1000 mL graduated cylinder.

Breakthrough of color took an extended period of time, so jar testing was also conducted to simulate the breakthrough of color through a fixed bed system. It should be noted that the jar testing conditions are CSTR while a fixed bed is plug flow; however, the data can be used to help set design criteria and estimate costs.

Table 1.5 Water Quality Analysis for Fixed Bed Ion Exchange Testing

Parameters	Sampling Location/Frequency	Laboratory Requirements
Alkalinity	IX Influent, Effluent samples at 120 min and 180 min	Field
Chlorides(1)	IX Influent, Effluent samples at 120 min and 180 min	Certified Lab
Color (True)(1)	IX Influent, Effluent samples at 120 min and 180 min	Field(2)
Hardness (Ca)	IX Influent, Effluent samples at 120 min and 180 min	Field
Hardness (Total)	IX Influent, Effluent samples at 120 min and 180 min	Field
pH	IX Influent, Effluent samples at 120 min and 180 min	Field
Nitrate(1)	IX Influent, Effluent samples at 120 min and 180 min	Certified Lab
Sulfate(1)	IX Influent, Effluent samples at 120 min and 180 min	Certified Lab
TDS(1)	IX Influent, Effluent samples at 120 min and 180 min	Certified Lab
TOC	IX Influent, Effluent samples at 120 min and 180 min	Certified Lab
Temperature	IX Influent, Effluent samples at 120 min and 180 min	Field
Total Chlorine	IX Influent, Effluent samples at 120 min and 180 min	Field
UV254	IX Influent, Effluent samples at 120 min and 180 min	Field

Notes:
(1) Color, nitrate, chloride, sulfate, and TDS analysis by Pace Analytical from a shared 1-L bottle.
(2) Select one 180-min effluent sample for split sample analysis at certified lab (Pace Analytical).

The general fixed bed IX jar test evaluation procedure is outlined below:

1. Measure out 10 mL of resin in a centrifuge tube or graduated cylinder.
2. Collect grab samples of raw water for determination of water quality parameters including pH, true color, UV254, total alkalinity, calcium hardness, and total hardness.
3. Add 2L of raw water to a jar after measuring for the parameters necessary.
4. Mix at 70 rpm for 60 minutes and collect samples at every 10 minutes to measure true color.
    a. Use care to avoid losing any resin when sampling from jar.
5. Turn mixer off and allow resin to settle, about 30 seconds.
6. Measure color at the end of the 60 minutes.
7. Carefully add another 2L volume of raw water to resin and repeat Steps 4-6 until target number of bed volumes has been reached or color is no longer decreasing.

1.3.3 Results

Fixed bed IX bench-scale results showed removal of nearly all true color for the first 500 bed volumes, with breakthrough above 5 CU occurring at greater than 800 BV and breakthrough above 12 CU occurring at greater than 2200 BV. Color removal for fully regenerated resin is therefore conservatively estimated to be 90 percent, but may be closer to 95-100 percent. Bench-scale results are summarized in Figure 1.12.

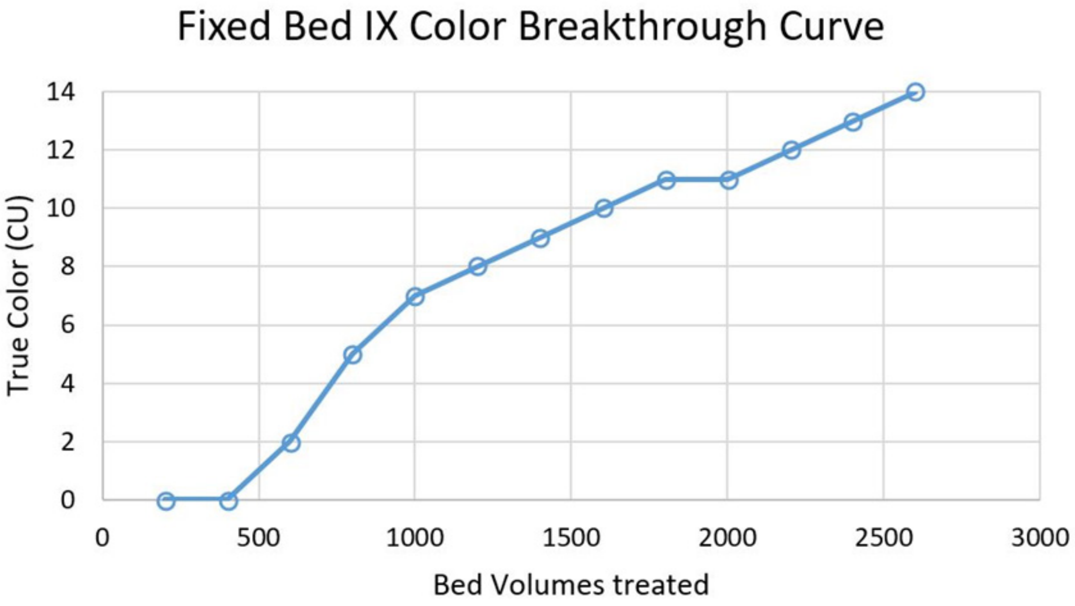


Figure 1.12 Fixed Bed IX Color Breakthrough: Bench-Scale Results

Fixed bed ion exchange data can be found in Appendix C.

1.4 Fluidized Bed Ion Exchange

Fluidized bed ion exchange was used as a slurry consisting of 150 to 180-micron magnetic beads with concentration ranging from 2 to 40 mL/L. With a 10 to 30 min contact time, ion exchange resins may effectively remove organic matters, irrespective of turbidity levels in the water. Due to magnetic properties, the resins form larger agglomerates and settle in the settling basin. Typically, 5 to 10 percent of the ion exchange resin requires regeneration, while the remaining resins are recycled back into the influent.

To evaluate whether fluidized bed ion exchange treatment will allow removing color and improving water quality at the WTP, jar testing was performed. It should be noted that fluidized bed ion exchange, because of its location in the treatment process, is exposed to higher levels of NOM (prior to softening).

1.4.1 Objectives

The primary objective of the jar testing with ion exchange resin was to evaluate color removal at the WTP and determine the best operating conditions for a full-scale implementation. Specific objectives of the testing were to determine resin activity and optimal regeneration rate.

1.4.2 Materials and Equipment

The following materials and equipment was utilized for the jar testing:

1. One standard jar testing apparatus with 2-L gator jars
2. 4L glass jars for raw water collection
3. DI water
4. Glassware including volumetric flasks and beakers
5. A 10-mL autopipette with tips
6. A 1000-µL autopipette with tips
7. pH and temperature meter with electrode
8. pH calibration buffers
9. Titration apparatus for alkalinity and hardness
10. Spectrophotometer DR 5000 for measuring color and UV254
11. 0.45 µm filters and vacuum pump for sample preparation (for true color and UV254 analysis)
12. Coolers and sample bottles for laboratory analysis of TOC and split samples for color
13. Regenerated ion exchange (MIEX) resin from the Boynton Beach East WTP. This was utilized because virgin resin removes more organics than an operating facility.

1.4.2.1 Source Water Collection

Source water was collected in 5-gal buckets from the raw water sampling port (upstream of the softening process (i.e., hydrotreater) at the WTP.

1.4.3 Test Protocol

Regenerated resin from Boynton Beach East WTP will be used for this evaluation and the following tests were conducted.

Treatment performance at a number of regeneration rates was determined by contacting a set volume of resin with different volumes of raw water. The volume of raw water treated divided by the volume of resin used to treat the water determines the bed volumes (BV) of raw water treated as calculated below:

Bed Volume (BV) = Volume Treated Water (L) / Volume Resin Used (L)

Bed volumes for testing included: 600, 800, and 1,000. Below 600 BVs requires very high regeneration rates and salt use and was not considered viable.

Procedure:

1. Measure out 10 mL of resin in a centrifuge tube or graduated cylinder.
2. Use DI (distilled water) to rinse resin down and allow the resin to settle at least 30 minutes to get a true volume.
3. Add 2L of raw water to a jar after measuring for the parameters indicated in the table below.
4. Using a magnet, hold the resin in place while decanting the DI off of the resin in the centrifuge tube or graduated cylinder (note: be careful not to lose any resin).
5. Using a disposable pipette, use the raw water from the 2L jar to add the 10 mL fresh resin (200 BV treatment rate per cycle).
6. Mix for 15 minutes at 150 rpm.
7. Turn mixer off and allow resin to settle, about 30 seconds.

8. Using great care decant treated water into collection vessel (i.e., a 5-gallon bucket) retaining resin in jar (placement of two magnets on either side of the pouring lip helps to create an additional trap for resin).
9. Measure UV254 and true color of sample in collection vessel using spectrophometer DR 5000. (Note: remove only the smallest volume of water needed to measure for these parameters.)
10. Carefully add another 2L volume of raw water to resin and repeat Steps 3-7 until target number of bed volumes has been reached (this takes 3, 4, or 5 total treatment repetitions for 600, 800, and 1,000 bed volumes).
11. After treating the target treatment rate, the collection vessel should contain the composite of all treatment cycles.
12. Measure water quality parameters from the composite water in the collection vessel as indicated in the table below. After, discard remaining water from the collection vessel and the used resin.
13. Repeat experiment for other bed volumes to be treated.

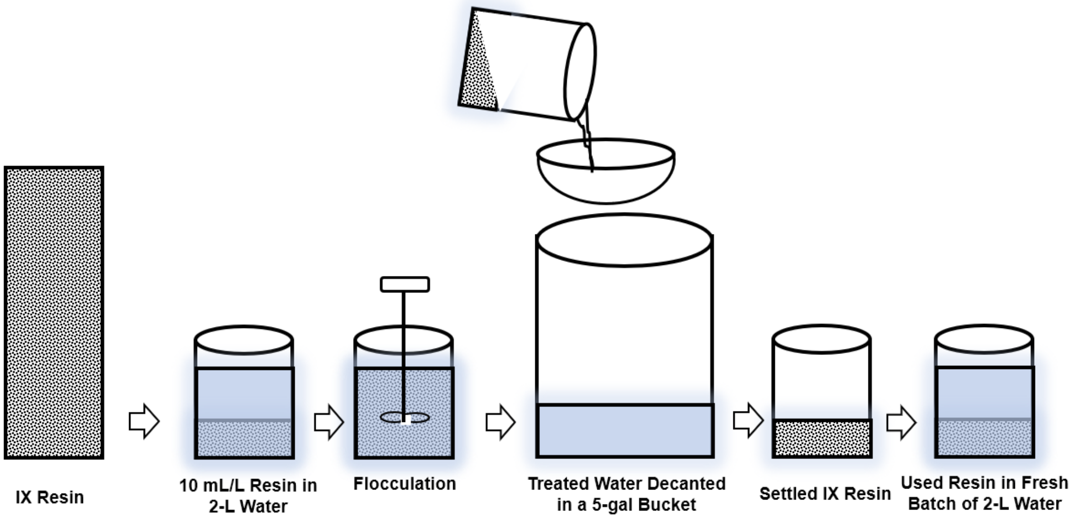


Figure 1.13 Schematic of Fluidized Bed Ion Exchange Testing Protocol

Table 1.6 Water Quality Analysis for Fluidized Bed Ion Exchange Testing

Parameters	Sampling Location/Frequency	Laboratory Requirements
Alkalinity	Raw water & 1,000 BV	Field
Chloride(1)	Raw water & 1,000 BV	Certified Lab
Color (True)(1)	Raw water 600, 800, & 1,000 BVs	Field(2)
Hardness (Ca)	Raw water & 1,000 BV	Field
Hardness (Total)	Raw water & 1,000 BV	Field
pH	Raw water 600, 800, & 1,000 BVs	Field
Nitrate(1)	Raw water & 1,000 BV	Certified Lab
Sulfate(1)	Raw water & 1,000 BV	Pace Lab
TDS(1)	Raw water & 1,000 BV	Certified Lab
TOC	Raw water & 1,000 BV	Certified Lab
Temperature	Raw water & 1,000 BV	Field
Total Chlorine	Raw water & 1,000 BV	Field
UV254	Raw water 600, 800, & 1,000 BVs	Field

Notes:

(1) Color, nitrate, chloride, sulfate, and TDS analysis by Pace Analytical from a shared 1-L bottle.

(2) Split samples will be collected for raw water and 1,000 BV samples for analysis by Pace Analytical (certified laboratory).

1.5 Results

Bench-scale testing of MIEX resin was performed at the Fiveash facility with a 1000 bed volume regeneration criteria (meaning the resin volume treated 1000 resin volumes of water before it was regenerated). The results of these tests indicated color reductions ranging from 56 percent to 75 percent. For the purposes of water quality analyses (presented in the treatment alternatives analysis), 56 percent was used as a conservative estimated color removal for MIEX. Due to relatively low removals (especially compared to fixed bed IX), a MIEX system would require an additional treatment step to remove additional color. Bench-scale results are shown in Figure 1.14.

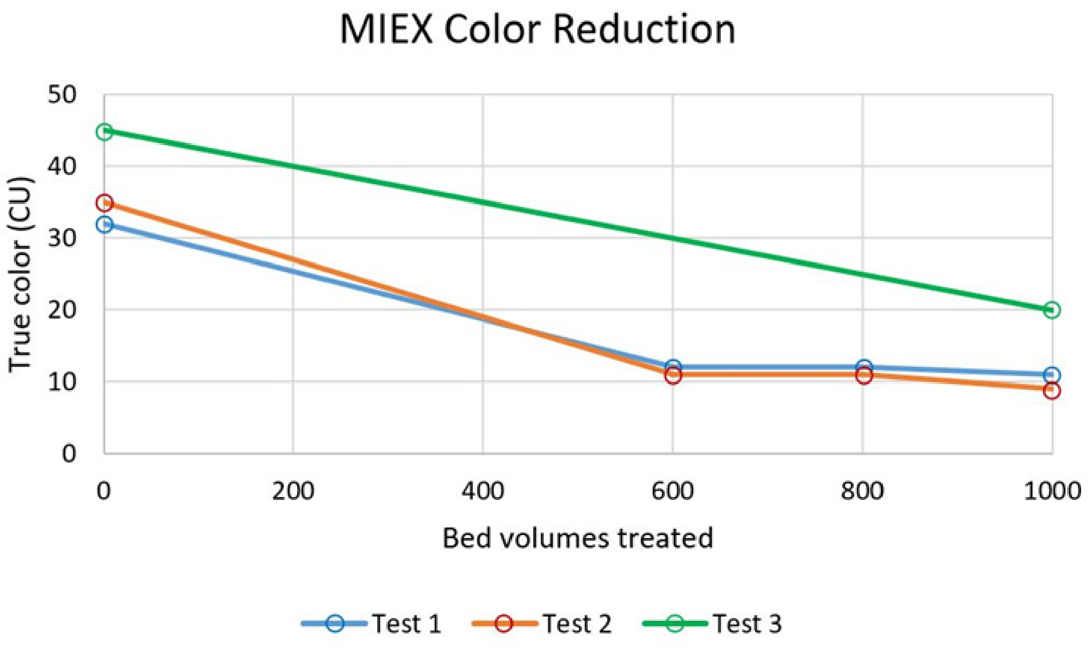


Figure 1.14 MIEX Color Removal: Bench-Scale Results

1.6 Color Reduction with Free Chlorine

Knowing that chlorine bleaching can be utilized to reduce color, some limited testing of chlorine addition was completed to measure potential reduction. Conventional softening experiments (pH 9.6) were tested to generate water for chlorination. Chlorine doses of approximately 4 mg/L were added to settled water and the corresponding color reduction with contact times of 1, 2, and 5 minutes were checked. Figure 1.15 shows the corresponding color after each of these timeframes. A dose of 4 mg/L of chlorine was added to limit the total chlorine added to 4 mg/L in order to not exceed the MCL for free or total chlorine.

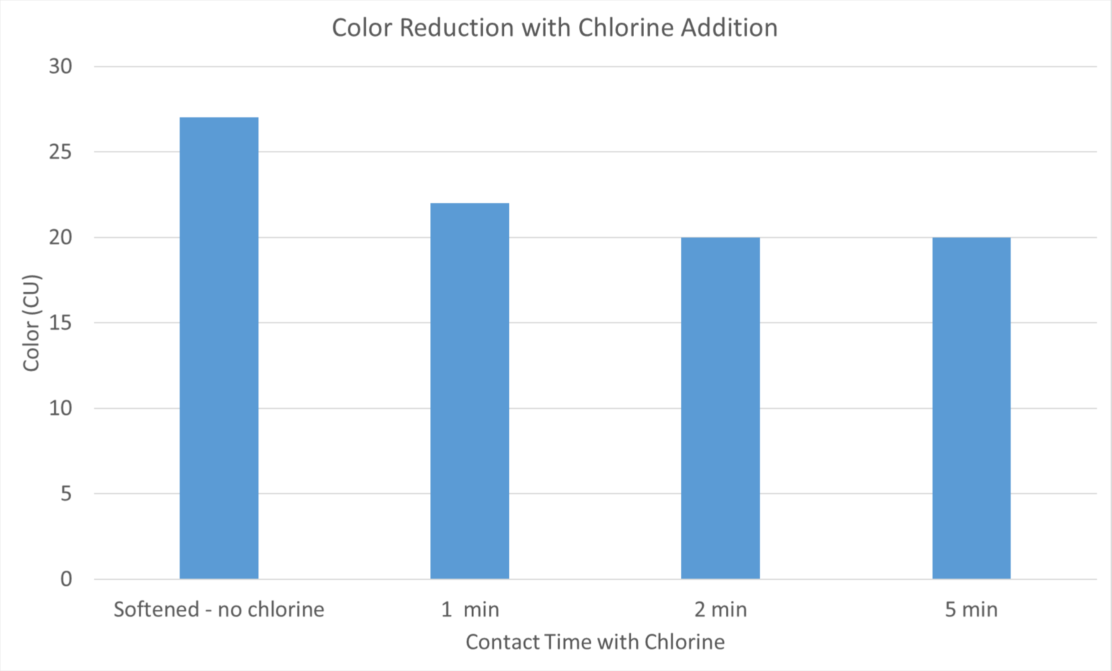


Figure 1.15 Softened Water Color Reduction with 4 mg/L of Chlorine Addition and Different Contract Times

In addition, disinfection by-products were measured. The five minute detention time samples resulted in THMs of 52.6 µg/L and HAA5 of 43.4 µg/L. The one minute detention time samples resulted in THMs of 23.9 µg/L and HAA5 of 23.8 µg/L. This demonstrates that color reduction using higher doses of chlorine or longer chlorine contact time would likely exceed the DBP regulations, require dichlorination, and the levels of HAA5 would not allow for air stripping of THMs only.

1.7 Water Quality Analysis

Laboratory methods for water quality analysis are shown in the table below.

Table 1.7 Analytical Methods

Parameter	Units	Analytical Method(1)
Chloride	mg/L	EPA Method 300.0
Chloride Residual	mg/L	Standard Method 4500-Cl
Color (True)	CU	Standard Method 2120
Hardness, Total	mg/L as $CaCO_3$	Standard Method 2340B (field); EPA Method 200.7 (certified lab)
Hardness, Calcium	mg/L as $CaCO_3$	Standard Method 2340B (field); EPA Method 200.7 (certified lab)
pH	SU	Standard Method 4500-H^+
Magnesium	mg/L	EPA 200.7
Nitrate	mg/L	EPA Method 353.2
Sulfate	mg/L	EPA Method 300.0
Temperature	deg. C	Standard Method 2550
Total Dissolved Solids	mg/L	Standard Method 2540C
Total Alkalinity	mg/L as $CaCO_3$	Standard Method 2320
Total Organic Carbon	mg/L	Standard Method 5310B
Total Sulfide	mg/L	Standard Method 4500-S^{2-}
UV254	1/cm	Standard Method 5910

Notes:
(1) Standard Method procedures in *Standard Methods for the Examination of Water and Wastewater.*

1.8 QA/QC

Standard quality assurance and control procedures were practiced throughout implementation of this test plan. Analysis of water quality parameters followed appropriate EPA and/or *Standard Methods for the Examination of Water and Wastewater*. Replicate sampling were performed, as noted in the sampling plan, and were evaluated for accuracy and precision. All of the QA/QC data can be found in the Appendix E of this technical memorandum. Baseline water quality is shown in Appendix F. All laboratory data completed by outside labs is located in Appendix G.

Appendix A

RSSCT DATA

Calgon F400

								UV254		Color	
Folderno		Sample Location (see sample naming convention tab)	Sampdate	Samptime	Sample Date/Time	Elapsed time (min)	Bed Volumes	Concentration	Units	Concentration	Units
Starte date/time	6/11/19 4:00 PM										
Stage 1 EBCT (min)	7.5										
Complete EBCT (min)	15										
	Raw Water	FTL-Raw-FW2-0612	6/12/2019	3:00 PM	6/12/19 3:00 PM	N/A		0.243	ABS	15	PtCo 50 mm
		FTL-Raw-FW2-0614	6/14/2019	12:00 PM	6/14/19 12:00 PM	N/A		0.245	ABS	13	PtCo 50 mm
		FTL-Raw-FW2-0617	6/17/2019	9:00 AM	6/17/19 9:00 AM	N/A		0.244	ABS	13	PtCo 50 mm
		FTL-Raw-FW2-0618	6/18/2019	3:30 PM	6/18/19 3:30 PM	N/A		0.246	ABS	14	PtCo 50 mm
		FTL-Raw-FW2-0621	6/21/2019	2:00 PM	6/21/19 2:00 PM	N/A		0.249	ABS	14	PtCo 50 mm
		FTL-Raw-FW2-0624	6/24/2019	12:00 PM	6/24/19 12:00 PM	N/A		0.249	ABS	15	PtCo 50 mm
		FTL-Raw-FW2-0628	6/28/2019	12:00 PM	6/28/19 12:00 PM	N/A		0.25	ABS		PtCo 50 mm
		FTL-Raw-FW3-0701	7/1/2019	12:00 PM	7/1/19 12:00 PM	N/A		0.249	ABS	15	PtCo 50 mm
		FTL-Raw-FW3-0703	7/3/2019	9:00 AM	7/3/19 9:00 AM	N/A		0.249	ABS	15	PtCo 50 mm
		FTL-Raw-FW3-0705	7/5/2019	9:00 AM	7/5/19 9:00 AM	N/A		0.2480	ABS	15	PtCo 50 mm
		FTL-Raw-FW3-0705	7/8/2019	9:00 AM	7/8/19 9:00 AM	N/A		0.2480	ABS	15	PtCo 50 mm
		FTL-Raw-FW3-0709	7/10/2019	9:00 AM	7/10/19 9:00 AM	N/A		0.2480	ABS	15	PtCo 50 mm
		FTL-Raw-FW3-0712	7/12/2019	8:50 AM	7/12/19 8:50 AM	N/A		0.2476	ABS	14	PtCo 50 mm
	Stage 1 Effluent	Cal-1-0612	6/12/2019	2:00 PM	6/12/19 2:00 PM	1320.00	176.00	0.0529	ABS	0	PtCo 50 mm
		Cal-1-0614	6/14/2019	10:20 AM	6/14/19 10:20 AM	3980.00	530.67	0.157	ABS	7	PtCo 50 mm
		Cal-1-0617	6/17/2019	9:25 AM	6/17/19 9:25 AM	8245.00	1099.33	0.189	ABS	8	PtCo 50 mm
		Cal-1-0618	6/18/2019	3:00 PM	6/18/19 3:00 PM	10020.00	1336.00	0.198	ABS	8	PtCo 50 mm
		Cal-1-0620	6/20/2019	11:00 AM	6/20/19 11:00 AM	12660.00	1688.00	0.197	ABS	12	PtCo 50 mm
		Cal-1-0621	6/21/2019	10:00 AM	6/21/19 10:00 AM	14040.00	1872.00	0.209	ABS	11	PtCo 50 mm
		Cal-1-0624	6/24/2019	10:00 AM	6/24/19 10:00 AM	18360.00	2448.00	0.216	ABS	11	PtCo 50 mm
		Cal-1-0626	6/26/2019	10:00 AM	6/26/19 10:00 AM	21240.00	2832.00	0.22	ABS		PtCo 50 mm
		Cal-1-0628	6/28/2019	10:00 AM	6/28/19 10:00 AM	24120.00	3216.00		ABS		PtCo 50 mm
		Cal-1-0702	7/2/2019	12:00 PM	7/2/19 12:00 PM	30000.00	4000.00	0.2296	ABS	10	PtCo 50 mm
		Cal-1-0703	7/3/2019	9:00 AM	7/3/19 9:00 AM	31260.00	4168.00	0.2268	ABS	12	PtCo 50 mm
		Cal-1-0705	7/5/2019	9:00 AM	7/5/19 9:00 AM	34140.00	4552.00	0.2168	ABS	12	PtCo 50 mm
		Cal-1-0708	7/8/2019	9:00 AM	7/8/19 9:00 AM	38460.00	5128.00	0.2208	ABS	10	PtCo 50 mm
		Cal-1-0710	7/10/2019	9:00 AM	7/10/19 9:00 AM	41340.00	5512.00	0.2234	ABS	12	PtCo 50 mm
		Cal-1-0712	7/12/2019	8:50 AM	7/12/19 8:50 AM	44210.00	5894.67	0.2444	ABS	13	PtCo 50 mm
							0.00			0	
	Stage 2 Effluent	Cal-2-0612	6/12/2019	12:30 PM	6/12/19 12:30 PM	1230.00	82.00	0.002	ABS	0	PtCo 50 mm
		Cal-2-0614	6/14/2019	9:10 AM	6/14/19 9:10 AM	3910.00	260.67	0.06	ABS	0	PtCo 50 mm
		Cal-2-0617	6/17/2019	8:15 AM	6/17/19 8:15 AM	8175.00	545.00	0.123	ABS	5	PtCo 50 mm
		Cal-2-0618	6/18/2019	8:30 AM	6/18/19 8:30 AM	9630.00	642.00	0.152	ABS	6	PtCo 50 mm
		Cal-2-0619	6/19/2019	11:00 AM	6/19/19 11:00 AM	10200.00	680.00	0.139	ABS	7	PtCo 50 mm
		Cal-2-0620	6/20/2019	9:00 AM	6/20/19 9:00 AM	11520.00	768.00	0.163	ABS	8	PtCo 50 mm
		Cal-2-0621	6/21/2019	8:30 AM	6/21/19 8:30 AM	12930.00	862.00	0.177	ABS	8	PtCo 50 mm
		Cal-2-0624	6/24/2019	8:30 AM	6/24/19 8:30 AM	17250.00	1150.00	0.182	ABS	10	PtCo 50 mm
		Cal-2-0626	6/26/2019	8:30 AM	6/26/19 8:30 AM	20130.00	1342.00	0.2	ABS		PtCo 50 mm
		Cal-2-0628	6/28/2019	8:30 AM	6/28/19 8:30 AM	23010.00	1534.00	0.19	ABS		PtCo 50 mm
		Cal-2-0702	7/2/2019	12:00 PM	7/2/19 12:00 PM	28980.00	1932.00	0.2022	ABS	9	PtCo 50 mm
		Cal-2-0703	7/3/2019	9:00 AM	7/3/19 9:00 AM	30240.00	2016.00	0.2066	ABS	9	PtCo 50 mm
		Cal-2-0705	7/5/2019	9:00 AM	7/5/19 9:00 AM	33120.00	2208.00	0.1972	ABS	9	PtCo 50 mm
		Cal-2-0708	7/8/2019	9:00 AM	7/8/19 9:00 AM	37440.00	2496.00	0.2052	ABS	9	PtCo 50 mm
		Cal-2-0710	7/10/2019	9:00 AM	7/10/19 9:00 AM	40320.00	2688.00	0.2064	ABS	10	PtCo 50 mm
		Cal-2-0712	7/12/2019	8:50 AM	7/12/19 8:50 AM	43190.00	2879.33	0.2114	ABS	11	PtCo 50 mm

Evoqua UltraCarb 1240

							UV254		Color	
		Sample Location	Sample date	Sample time	Elapsed time (min)	Bed Volumes	Value	Units	Value	Units
Start date/time	6/11/19 4:00 PM									
Stage 1 EBCT (min)	7.5									
Complete EBCT (min)	15.0									
	Raw Water	FTL-Raw-FW2-0612	6/12/2019	3:00 PM	N/A		0.243	ABS	15	PtCo 50 mm
		FTL-Raw-FW2-0614	6/14/2019	12:00 PM	N/A		0.245	ABS	13	PtCo 50 mm
		FTL-Raw-FW2-0617	6/17/2019	9:00 AM	N/A		0.244	ABS	13	PtCo 50 mm
		FTL-Raw-FW2-0618	6/18/2019	3:30 PM	N/A		0.246	ABS	14	PtCo 50 mm
		FTL-Raw-FW2-0621	6/21/2019	2:00 PM	N/A		0.249	ABS	14	PtCo 50 mm
		FTL-Raw-FW2-0624	6/24/2019	12:00 PM	N/A		0.249	ABS	15	PtCo 50 mm
		FTL-Raw-FW2-0628	6/28/2019	12:00 PM	N/A		0.25	ABS		PtCo 50 mm
		FTL-Raw-FW3-0701	7/1/2019	12:00 PM	N/A		0.249	ABS	15	PtCo 50 mm
		FTL-Raw-FW3-0703	7/3/2019	9:00 AM	N/A		0.249	ABS	15	PtCo 50 mm
		FTL-Raw-FW3-0705	7/5/2019	9:00 AM	N/A		0.2480	ABS	15	PtCo 50 mm
		FTL-Raw-FW3-0705	7/8/2019	9:00 AM	N/A		0.2480	ABS	15	PtCo 50 mm
		FTL-Raw-FW3-0709	7/10/2019	9:00 AM	N/A		0.2480	ABS	15	PtCo 50 mm
		FTL-Raw-FW3-0712	7/12/2019	8:50 AM	N/A		0.2476	ABS	14	PtCo 50 mm
	Stage 1 Effluent	Evo-1-0612	6/12/2019	2:00 PM	1320	176	0.052	ABS	0	PtCo 50 mm
		Evo-1-0614	6/14/2019	10:20 AM	3980	531	0.147	ABS	6	PtCo 50 mm
		Evo-1-0617	6/17/2019	9:25 AM	8245	1099	0.18	ABS	7	PtCo 50 mm
		Evo-1-0618	6/18/2019	3:00 PM	10020	1336	0.193	ABS	6	PtCo 50 mm
		Evo-1-0620	6/20/2019	11:00 AM	12660	1688	0.189	ABS	13	PtCo 50 mm
		Evo-1-0621	6/21/2019	10:00 AM	14040	1872	0.202	ABS	11	PtCo 50 mm
		Evo-1-0624	6/24/2019	10:00 AM	18360	2448	0.210	ABS	10	PtCo 50 mm
		Evo-1-0626	6/26/2019	10:00 AM	21240	2832	0.22	ABS		PtCo 50 mm
		Evo-1-0628	6/28/2019	10:00 AM	24120	3216	0.22	ABS		PtCo 50 mm
		Evo-1-0702	7/2/2019	12:00 PM	30000	4000	0.2096	ABS	10	PtCo 50 mm
		Evo-1-0703	7/5/2019	9:00 AM	34140	4552	0.2148	ABS	10	PtCo 50 mm
		Evo-1-0705	7/5/2019	9:00 AM	34140	4552	0.2178	ABS	10	PtCo 50 mm
		Evo-1-0708	7/8/2019	9:00 AM	38460	5128	0.2178	ABS	10	PtCo 50 mm
		Evo-1-0710	7/10/2019	9:00 AM	41340	5512	0.2236	ABS	10	PtCo 50 mm
		Evo-1-0712	7/12/2019	8:50 AM	44210	5895	0.2214	ABS	12	PtCo 50 mm
						0			0	
	Stage 2 Effluent	Evo-2-0612	6/12/2019	12:30 PM	1230	82	0.002	ABS	0	PtCo 50 mm
		Evo-2-0614	6/14/2019	9:10 AM	3910	521	0.069	ABS	0	PtCo 50 mm
		Evo-2-0617	6/17/2019	8:15 AM	8175	545	0.104	ABS	3	PtCo 50 mm
		Evo-2-0618	6/18/2019	11:30 AM	9810	654	0.132	ABS	3	PtCo 50 mm
		Evo-2-0619	6/19/2019	11:00 AM	10200	680	0.117	ABS	3	PtCo 50 mm
		Evo-2-0620	6/20/2019	9:00 AM	11520	768	0.149	ABS	7	PtCo 50 mm
		Evo-2-0621	6/21/2019	8:30 AM	12930	862	0.156	ABS	6	PtCo 50 mm
		Evo-2-0624	6/24/2019	8:30 AM	17250	1150	0.176	ABS	8	PtCo 50 mm
		Evo-2-0626	6/26/2019	8:30 AM	20130	1342	0.19	ABS		PtCo 50 mm
		Evo-2-0628	6/28/2019	8:30 AM	23010	1534	0.18	ABS		PtCo 50 mm
		Evo-2-0702	7/2/2019	12:00 PM	28980	1932	0.1882	ABS	8	PtCo 50 mm
		Evo-2-0703	7/5/2019	9:00 AM	33120	2208	0.1904	ABS	9	PtCo 50 mm
		Evo-2-0705	7/5/2019	8:30 AM	33090	2206	0.1944	ABS	8	PtCo 50 mm
		Evo-2-0708	7/8/2019	9:00 AM	37440	2496	0.1994	ABS	10	PtCo 50 mm
		Evo-2-0710	7/10/2019	9:00 AM	40320	2688	0.2048	ABS	9	PtCo 50 mm
		Evo-2-0712	7/12/2019	8:50 AM	43190	2879	0.2046	ABS	10	PtCo 50 mm

Jacobi Aquasorb 5010

								UV254		Color	
Folderno		Sample Location (see sample naming convention tab)	Sampdate	Samptime	Sample Date/Time	Elapsed time (min)	Bed Volumes	Concentration	Units	Concentration	Units
Starte date/time	6/17/19 6:30 PM										
Stage 1 EBCT (min)	7.5										
Complete EBCT (min)	15.0										
Flow rate was calibrated.	6/17/2019 9:00	FTL-Raw-FW2-0617	6/17/2019	9:00 AM	6/17/19 9:00 AM	N/A		0.244	Abs cm-1	13	PtCo 50 mm
	6/18/2019 3:30:00 PM	FTL-Raw-FW2-0618	6/18/2019	3:30 PM	6/18/19 3:30 PM	N/A		0.246	Abs cm-1	14	PtCo 50 mm
	6/21/2019 14:00	FTL-Raw-FW2-0621	6/21/2019	2:00 PM	6/21/19 2:00 PM	N/A		0.249	Abs cm-1	14	PtCo 50 mm
	6/24/2019 12:00:00 PM	FTL-Raw-FW2-0624	6/24/2019	12:00 PM	6/24/19 12:00 PM	N/A		0.249	Abs cm-1	15	PtCo 50 mm
	6/28/2019 12:00	FTL-Raw-FW2-0628	6/28/2019	12:00 PM	6/28/19 12:00 PM	N/A		0.25	Abs cm-1		PtCo 50 mm
	7/1/2019 12:00	FTL-Raw-FW3-0701	7/2/2019	9:00 AM	7/2/19 9:00 AM	N/A		0.249	Abs cm-1	15	PtCo 50 mm
	7/3/2019 9:00	FTL-Raw-FW3-0703	7/3/2019	9:00 AM	7/3/19 9:00 AM	N/A		0.249	Abs cm-1	15	PtCo 50 mm
	7/5/2019 9:00	FTL-Raw-FW3-0705	7/5/2019	9:00 AM	7/5/19 9:00 AM	N/A		0.248	Abs cm-1	15	PtCo 50 mm
	7/8/2019 9:00	FTL-Raw-FW3-0705	7/8/2019	9:00 AM	7/8/19 9:00 AM			0.248	Abs cm-1	15	PtCo 50 mm
	7/10/2019 9:00	FTL-Raw-FW3-0709	7/10/2019	9:00 AM	7/10/19 9:00 AM	N/A		0.248	Abs cm-1	15	PtCo 50 mm
	7/12/2019 8:50	FTL-Raw-FW3-0712	7/12/2019	8:50 AM	7/12/19 8:50 AM	N/A		0.2476	Abs cm-1	14	PtCo 50 mm
	6/18/2019 3:00:00 PM	Jac-1-0618	6/18/2019	3:00 PM	6/18/19 3:00 PM	1230.00	164.00	0.027	Abs cm-1	0	PtCo 50 mm
	6/20/2019 11:00:00 AM	Jac-1-0620	6/20/2019	11:00 AM	6/20/19 11:00 AM	3870.00	258.00	0.077	Abs cm-1	1	PtCo 50 mm
	6/21/2019 10:00:00 AM	Jac-1-0621	6/21/2019	10:00 AM	6/21/19 10:00 AM	5250.00	350.00	0.111	Abs cm-1	4	PtCo 50 mm
	6/24/2019 10:00	Jac-1-0624	6/24/2019	10:00 AM	6/24/19 10:00 AM	9570.00	638.00	0.162	Abs cm-1	6	PtCo 50 mm
	6/26/2019 11:30	Jac-1-0626	6/26/2019	10:00 AM	6/26/19 10:00 AM	12450.00	830.00	0.19	Abs cm-1		PtCo 50 mm
	6/28/2019 10:00	Jac-1-0628	6/28/2019	10:00 AM	6/28/19 10:00 AM	15330.00	1022.00	0.22	Abs cm-1		PtCo 50 mm
	7/2/2019 12:00	Jac-1-0702	7/2/2019	12:00 PM	7/2/19 12:00 PM	21210.00	1414.00	0.2028	Abs cm-1	9	PtCo 50 mm
	7/3/2019 9:00	Jac-1-0703	7/3/2019	9:00 AM	7/3/19 9:00 AM	22470.00	1498.00	0.2032	Abs cm-1	8	PtCo 50 mm
	7/5/2019 9:00	Jac-1-0705	7/5/2019	9:00 AM	7/5/19 9:00 AM	25350.00	1690.00	0.2082	Abs cm-1	8	PtCo 50 mm
	7/8/2019 9:00	Jac-1-0708	7/8/2019	9:00 AM	7/8/19 9:00 AM	29670.00	1978.00	0.2108	Abs cm-1	9	PtCo 50 mm
	7/10/2019 9:00	Jac-1-0710	7/10/2019	9:00 AM	7/10/19 9:00 AM	32550.00	2170.00	0.2176	Abs cm-1	9	PtCo 50 mm
	7/12/2019 8:50	Jac-1-0712	7/12/2019	8:50 AM	7/12/19 8:50 AM	35420.00	2361.33	0.218	Abs cm-1	11	PtCo 50 mm
							0.00			0	
	6/18/2019 8:30:00 AM	Jac-2-0618	6/18/2019	11:30 AM	6/18/19 11:30 AM	1020.00	68.00	0.003	Abs cm-1	0	PtCo 50 mm
Flow rate was calibrated (~2.2 ml/min; shared pump with Jac but different pump heads)		Jac-2-0619	6/19/2019	11:00 AM	6/19/19 11:00 AM	1410.00	94.00	0.002	Abs cm-1	0	PtCo 50 mm
	6/20/2019 9:00:00 AM	Jac-2-0620	6/20/2019	9:00 AM	6/20/19 9:00 AM	2730.00	182.00	0.04	Abs cm-1	0	PtCo 50 mm
	6/21/2019 8:30:00 AM	Jac-2-0621	6/21/2019	8:30 AM	6/21/19 8:30 AM	4140.00	276.00	0.059	Abs cm-1	1	PtCo 50 mm
	6/24/2019 8:30	Jac-2-0624	6/24/2019	8:30 AM	6/24/19 8:30 AM	8460.00	564.00	0.083	Abs cm-1	2	PtCo 50 mm
	6/26/2019 8:30	Jac-2-0626	6/26/2019	8:30 AM	6/26/19 8:30 AM	11340.00	756.00	0.1	Abs cm-1		PtCo 50 mm
	6/28/2019 8:30	Jac-2-0628	6/28/2019	8:30 AM	6/28/19 8:30 AM	14220.00	948.00	0.1	Abs cm-1		PtCo 50 mm
	7/2/2019 12:00	Jac-2-0702	7/2/2019	12:00 PM	7/2/19 12:00 PM	20190.00	1346.00	0.146	Abs cm-1	4	PtCo 50 mm
	7/3/2019 9:00	Jac-2-0703	7/3/2019	9:00 AM	7/3/19 9:00 AM	21450.00	1430.00	0.1476	Abs cm-1	3	PtCo 50 mm
	7/5/2019 9:00	Jac-2-0705	7/5/2019	9:00 AM	7/5/19 9:00 AM	24330.00	1622.00	0.1664	Abs cm-1	6	PtCo 50 mm
	7/8/2019 9:00	Jac-2-0708	7/8/2019	9:00 AM	7/8/19 9:00 AM	28650.00	1910.00	0.1776	Abs cm-1	6	PtCo 50 mm
	7/10/2019 9:00	Jac-2-0710	7/10/2019	9:00 AM	7/10/19 9:00 AM	31530.00	2102.00	0.1914	Abs cm-1	6	PtCo 50 mm
	7/12/2019 8:50	Jac-2-0712	7/12/2019	8:50 AM	7/12/19 8:50 AM	34400.00	2293.33	0.195	Abs cm-1	8	PtCo 50 mm

RSSCT Operational Parameters	
Media	Jacobi Aquasorb 5010
Full scale mean media diameter (mm)	0.6
Ground and sieved media size	100x140 mesh
Column diameter (mm)	7
Mean ground and sieved media diameter (mm)	0.127
Scaling factor* ($EBCT_{SC}/EBCT_{LC} = d_{SC}/d_{LC}$)	4.72
D_c/d_p (column diameter/particle	55.12
EBCT: Full Scale (min)	15.00
EBCT: Scaled RSSCT (min)	3.18
Media Depth (cm)	18.00
Bed volume (mL)	6.9
Flow Rate (mL/min)	2.18
Hyd Loading Rate	1.39
Number of column	2
Media height per column stage (cm)	9

RSSCT Operational Parameters	
Media	Calgon F400
Full scale mean media diameter (mm)	0.65
Ground and sieved media size	100x140 mesh
Column diameter (mm)	7
Mean ground and sieved media diameter (mm)	0.127
Scaling factor* ($EBCT_{SC}/EBCT_{LC} = d_{SC}/d_{LC}$)	5.12
D_c/d_p (column diameter/particle	55.12
EBCT: Full Scale (min)	15.00
EBCT: Scaled RSSCT (min)	2.93
Media Depth (cm)	16.00
Bed volume (mL)	6.2
Flow Rate (mL/min)	2.10
Hyd Loading Rate	1.34
Number of column	2
Media height per column stage (cm)	8

RSSCT Operational Parameters	
Media	Evoqua UltraCarb 1240
Full scale mean media diameter (mm)	0.65
Ground and sieved media size	100x140 mesh
Column diameter (mm)	7
Mean ground and sieved media diameter (mm)	0.127
Scaling factor* ($EBCT_{SC}/EBCT_{LC} = d_{SC}/d_{LC}$)	5.12
D_c/d_p (column diameter/particle	55.12
EBCT: Full Scale (min)	15.00
EBCT: Scaled RSSCT (min)	2.93
Media Depth (cm)	16.00
Bed volume (mL)	6.2
Flow Rate (mL/min)	2.10
Hyd Loading Rate	1.34
Number of column	2
Media height per column stage (cm)	8

Column Packing Parameters	
Layer 5	5 cm glass beads
Layer 4	3 cm glass wool (Soaked in DI water)
Layer 3	Media at specified height, in slurry form after being rinsed in DI water
Layer 2	3 cm glass wool (Soaked in DI water)
Layer 1	5 cm glass beads

Appendix B

SOFTENING AND COAGULATION DATA

		Raw water quality							Doses						Post-jar test water quality									Post-jar test, filtered		
Treatment	Water used	pH	True color (CU)	Appar-ent color (CU)	UV254	Total alk (mg/L as $CaCO_3$)	Total hardness (mg/L as $CaCO_3$)	Calcium hardness (mg/L as $CaCO_3$)	Lime dose (mg/L as $Ca(OH)2$)	Polymer dose (mg/L)	MgCl2 dose (mg/L)	Ferric sulfate dose (mg/L)	Total chlorine by NaOCl addition (mg/L)	Ammonia quench wait time (min)	pH	True color (CU)	Appar-ent color (CU)	UV254	Total alk (mg/L as $CaCO_3$)	Total hardness (mg/L as $CaCO_3$)	Calcium hardness (mg/L as CaCO3)	Total Cl2 (mg/L)	Free Cl2 (mg/L)	Filtered total alk (mg/L as $CaCO_3$)	Filtered total hardness (mg/L $CaCO_3$)	Filtered calcium hardness (mg/L $CaCO_3$)
Enhanced Lime Softening (ELS)	Plant raw water	7.33	40	44	0.4719	204			190	0	0	0			9.63	27	\	0.2844	87	86				77	89	
ELS	Plant raw water	7.33	40	44	0.4719	204			230	0	0	0			10.36	22	95	0.2741	104	94				83	95	
ELS	Plant raw water	7.33	40	44	0.4719	204			270	0	0	0			10.82	13	83	0.2312	114					104		
ELS	Plant raw water	7.33	40	44	0.4719	204			310	0	0	0			11.05	9	52	0.1976	136					124		
ELS	Plant raw water	7.33	40	44	0.4719	204			350	0	0	0			11.23	8	41	0.1799	152					130		
ELS with Mg Addition	Plant raw water	7.17	35	39	0.4043	204	238		310	0.2	10	0			10.88	18	72	0.222	128	128				128	130	
ELS with Mg Addition	Plant raw water	7.17	35	39	0.4043	204	238		310	0.2	20	0			10.72	21	71	0.2325	128	144				106	128	
ELS with Mg Addition	Plant raw water	7.17	35	39	0.4043	204	238		310	0.2	30	0			10.73	21	65	0.2346	172	160				132	144	
ELS with Mg Addition	Plant raw water	7.17	35	39	0.4043	204	238		310	0.2	40	0			10.18	25	38	0.2447	116	214				126	204	
ELS with Mg Addition	Plant raw water	7.22	30	36	0.3835	196	238		430	0.2	10	0			11.13	12	65	0.1498	172	168						
ELS with Mg Addition	Plant raw water	7.22	30	36	0.3835	196	238		430	0.2	20	0			11.11	12	70	0.1508	172							
ELS with Mg Addition	Plant raw water	7.22	30	36	0.3835	196	238		430	0.2	30	0			11.16	11	55	0.1435	168	200						
ELS with Mg Addition	Plant raw water	7.22	30	36	0.3835	196	238		430	0.2	40	0			11.22	11	41	0.1395	172	188						
ELS with Mg Addition	Plant raw water	7.22	30	36	0.3835	196	238		430	0.2	50	0			11.14	10	29	0.1362	204	152						
ELS with Mg Addition	Plant raw water	7.22	30	36	0.3835	196	238		430	0.2	60	0			11.2	9	17	0.1325	172	208						
ELS with Mg Addition	Plant raw water	7.24	32	37	0.3859	201	227	197	430	0.2	10	0			11.13	12	35	0.1476	172	168	152					
ELS with Mg Addition	Plant raw water	7.24	32	37	0.3859	201	227	197	430	0.2	20	0			11.11	11	28	0.1478	172	176	149					
ELS with Mg Addition	Plant raw water	7.24	32	37	0.3859	201	227	197	430	0.2	30	0			11.13	10	18	0.1417	142	170	143					
ELS with Mg Addition	Plant raw water	7.24	32	37	0.3859	201	227	197	430	0.2	40	0			11.09	8	13	0.1421	120	183	142					
ELS with Mg Addition	Plant raw water	7.24	32	37	0.3859	201	227	197	430	0.2	50	0			11.07	7	12	0.1331	115	182	137					
ELS with Mg Addition	Plant raw water	7.24	32	37	0.3859	201	227	197	430	0.2	60	0			11.06	7	15	0.1289	119	192	132					
ELS with FeSO4 Addition	Plant raw water	7.29	31	36					460	0	0	200			9.2	2		0.1716								
ELS with FeSO4 Addition	Plant raw water	7.29	31	36					500	0	0	400			8.9	1		0.0381								
ELS with FeSO4 Addition	Plant raw water	7.29	31	36					620	0	0	800			7.3	2		0.1113								
ELS with FeSO4 Addition	Plant raw water	7.29	31	36					410	0	0	200			8.07	1		0.111	127	307	300					
ELS with FeSO4 Addition	Plant raw water	7.29	31	36					480	0	0	800			6.28	2		0.021	86	414	396					
ELS with FeSO4 Addition	Plant raw water	7.29	31	36					0	0	0	200			6.33	2		0.011	79	227	198					
ELS with FeSO4 Addition	Plant raw water	7.39	37	39		207	217	201	250	0	0	20			9.42	11		0.2555						82	168	132
ELS with FeSO4 Addition	Plant raw water	7.39	37	39		207	217	201	320	0	0	40			9.4	10		0.2245						79	177	139
ELS with FeSO4 Addition	Plant raw water	7.39	37	39		207	217	201	450	0	0	80			9.73	6		0.1279						72	187	156
ELS with FeSO4 Addition	Plant raw water	7.39	37	39		207	217	201	0	0	0	20			7.34	13		0.3524						174	211	189
ELS with FeSO4 Addition	Plant raw water	7.39	37	39		207	217	201	0	0	0	40			7.13	10		0.2962						142	208	196
ELS with FeSO4 Addition	Plant raw water	7.39	37	39		207	217	201	0	0	0	80			6.91	7		0.2123						131	213	206

Appendix C

FIXED BED ION EXCHANGE DATA

IX Influent

Time Collected:	7:30 AM
pH	9.29
True Color	16
Apparent Color:	20
UV 254	0.2532
Total Alk.	65
Total Hardness:	
Calcium Hardness	
Temperature	79.5
Total Chlorine	3.67
Free Chlorine	0.02

Fixed Bed ion Exchange Column

				1h				2h				3h				4h
Time:	**15**	**30**	**45**	**60**	**75**	**90**	**105**	**120**	**135**	**150**	**165**	**180**	**195**	**210**	**225**	**240**
Color:	0	1	1	1	1	1	1	1		1		2	1	1		1
UV 254:	0.0255	0.0251	0.0234	0.0233	0.0229		0.225	0.0218		0.0225		0.0238	0.0232	0.0235		0.0233
Total Alk.				25			20	22				26		29		
Total Hardness:																
Calcium Hardness																
Temperature				79.6			79.7	79.6				79.4		79		
Total Chlorine				3.4			3.3	3.19				3.06		2.89		
Free Chlorine				<.02			<0.02	<0.02				<0.02				
pH				7.29			7.21	7.23				7.26		7.35		

Pace Laboratoy Analysis

	Influent	**120**	**180**
TDS	202	229	247
Chloride	61.2	109	97.7
Sulfate	5.7	2.5	2.5
Nitrate	0.067	0.025	0.025
UV 254:	0.24	0.023	0.023
pH	9.2	7.3	7.2
Color:	10	<5	<5
Mg	6.5	6.2	6.2
Total Alk.	74.3	16.8	29.6
Total Hardness:	84.8	79.4	81.5
Calcium Hardness	58.2	54.4	55.8
TOC	8.2	1.1	1.1

Fixed Bed ion Exchange Column

Volume Treated (L)		39.6	49.5	59.4	69.3	79.2	118.8	138.6	158.4	178.2	198	217.8	237.6	257.4	277.2	306.9	316.8	339.9	359.7	379.5
		1h				2h	3h		4h		5		6		7		8			
Time:	**45**	**60**	**75**	**90**	**105**	**120**	**180**	**210**	**240**	**270**	**300**	**330**	**360**	**390**	**420**	**465**	**480**	**515**	**545**	**575**
Color:	1	0	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
UV 254:	0.0297		0.0254	0.024		0.0234	0.0231	0.0337	0.0242	0.0253	0.0248	0.0259	0.0251	0.0249	0.0245	0.0253	0.0254	0.0337	0.0241	0.0248
Total Alk.	24			27		27	23	21	25		22				27		29			25
Total Hardness:																				
Calcium Hardness																				
Temperature	78.8	78.9		78.3		78.3	78.1	78.1	78.2	78.2	78.2	78.7	78.6	78.5	78.4	78.3	78.3	78.3	78.3	78.3
Total Chlorine	3.2			3.17		3.18	3.11			2.84	2.81									
Free Chlorine																				
pH	7.77	7.96		7.65		7.45	7.38	7.32	7.22	7.19	7.15	7.2	7.34		7.5	7.52		7.48		7.51

Jar test Using Thermax Resin Simulating FBIX

200 BV

Time (min)	10	20	30	40	50	60
Color	13	9	7	5	0	0

400 BV

Time (min)	10	20	30	40	50	60
Color	10	8	8	5	1	0

600 BV

Time (min)	10	20	30	40	50	60
Color	11	9	8	4	2	2

800 BV

Time (min)	10	20	30	40	50	60
Color	10	9	7	5	5	5

1000BV

Time (min)	10	20	30	40	50	60
Color	11	11	9	8	7	7

1200BV

Time (min)	10	20	30	40	50	60
Color	13	11	10	9	8	8

1400BV

Time (min)	10	20	30	40	50	60
Color	15	13	9	9	9	9

1600BV

Time (min)	10	20	30	40	50	60
Color	15	14	12	11	11	10

1800

Time (min)	10	20	30	40	50	60
Color	17	15	14	12	11	11

2000BV

Time (min)	10	20	30	40	50	60
Color	17	15	15	12	11	11

2200BV

Time (min)	10	20	30	40	50	60
Color	17	16	14	12	12	12

2400BV

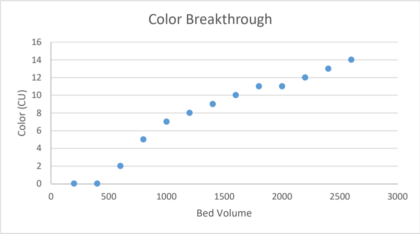
Time (min)	10	20	30	40	50	60
Color	17	15	15	14	13	13

2600BV

Time (min)	10	20	30	40	50	60
Color	17	16	16	15	14	14

Initial Color:	17
pH	9.31

BV	Color
200	0
400	0
600	2
800	5
1000	7
1200	8
1400	9
1600	10
1800	11
2000	11
2200	12
2400	13
2600	14



Procedure for Thermax Jar testing

1. Measure out 10 mL of resin in a centrifuge tube or graduated cylinder.
2. Measure parameters for raw water.
3. Add 2L of raw water to a jar after measuring for the parameters necessary.
4. Mix at 70 rpm for 60 minutes and collect samples at every 10 minutes to measure true color.
    a. Use care to avoid losing any resin when sampling from jar.
7. Turn mixer off and allow resin to settle, about 30 seconds.
8. Measure Color at then of the 60 minutes.
10. Carefully add another 2L volume of raw water to resin and repeat Steps 4-8 until target number of bed volumes has been reached or color is no longer decreasing.

Appendix D

FLUIDIZED BED ION EXCHANGE DATA

Fluidized Bed IX Testing

Date	Time	Test Type	Treatment	Raw water temp (°F)	Water used	Bed volumes	pH	True color (CU)	Percent removal	Apparent color (CU)	UV 254	Total alk (mg/L as $CaCO_3$)
6/4/2019	7:30 AM		MIEX	79.2	Raw water	0	7.24	32		37	0.3859	201
6/4/2019	7:30 AM		MIEX	79.2	Raw water	600	7.38	12			0.1963	
6/4/2019	7:30 AM		MIEX	79.2	Raw water	800	7.41	12			0.1966	
6/4/2019	7:30 AM		MIEX	79.2	Raw water	1000	7.46	11	0.65625		0.2101	
6/5/2019	7:50 AM		MIEX	79.4	Raw water	0	7.19	35		42	0.3844	202
6/5/2019	7:50 AM		MIEX	79.4	Raw water	600	7.62	11			0.1189	192
6/5/2019	7:50 AM		MIEX	79.4	Raw water	800	7.57	11			0.1247	226
6/5/2019	7:50 AM		MIEX	79.4	Raw water	1000	7.55	9	0.742857		0.1439	204
6/5/2019			MIEX	79.4	Raw water	0	6.7	45				
6/5/2019			MIEX	79.4	Raw water	1000		20	0.555556			

Appendix E

QA/QC STANDARD CHECKS

Parameter	Date Checked	Standard Value	Measurement 1	Standard Value	Measurement 2	Standard Value	Measurement 3	Instrument	Method	Lower Range of method	Upper Range of Method	Expiration Date	Kit Lot / Serial Number	Standard Lot Number	Standard Exp Date	Technologist initials	Notes
UV254 (ABS)	6/4/2019	Calibrated by HACH 5/1/19, PASSED self check						DR6000	Method 10054	None Listed		None	1700265	n/a	n/a	NB	
Total Chlorine (mg/L)	6/4/2019	1.9 +/- 0.2	2	3.4 +/- 0.3	3.6	6.2 +/- 0.6	6.7	DR6000	Method 8167	0.02	2	None	n/a	A8346	Dec-20	NB	ine; Secondary Sta
True Color (PtCo 50 mm)	6/4/2019	15	14					DR6000	Method 8025	3	200	None	n/a	A8005	22-Jan	NB	
TOC (mg/L)	6/7/2019	0	0.052	1	1.096	10	10.419	ach QbD12	EPA 415.3	0.4	100,000	None	1800SHG00406	9011804	7/30/2019	LX	Check every time.
pH	6/11/2019	7.01	6.97					Probe	Method 8156	2	14	None	172562568066	A8005	22-Jan	NB	
Turbidity	6/11/2019	10	9.66					TU5200	Method 10258	0	700	None	1561117	A8323	12/1/2019	NB	Check every time.
ORP (mV)	6/11/2019	228	226.8					Probe	Method 10228	-2000	2000	None	152243028001	9112	19-Oct	NB	
SL1000 SV (Abs)	6/11/2019	1	1.014					SL1000	n/a	0	0	None	180360103495	122020197	n/a	NB	
SL1000 CV (mg/L)	6/11/2019	2	2.01					SL1000				None	180360103495	112020196	n/a	NB	
TOC (mg/L)	6/11/2019	0	0.092	1	1.126	10	10.626	ach QbD12	EPA 415.3	0.4	100,000	None	1800SHG00406	9011804	7/30/2019	LX	Check every time.
Zeta potential analyzer	6/12/2019	-42 +/- 4.2	-39	-42 +/- 4.2	-38.8	-42 +/- 4.2	-40	Zeta Nano	phoretic Light Sc	-500 mV	+500 mV	n/a	MAL1130608	31901	20-Jan-20	LX	Check every time.
pH	6/14/2019	7.01	6.98					Probe	Method 8156	2	14	None	172562568066	A8005	22-Jan	LX	
pH	6/17/2019	7.01	6.99					Probe	Method 8156	2	14	None	172562568066	A8005	22-Jan	LX	
pH	6/18/2019	7.01	6.98					Probe	Method 8156	2	14	None	172562568066	A8005	22-Jan	LX	
pH	6/20/2019	7.01	6.98					Probe	Method 8156	2	14	None	172562568066	A8005	22-Jan	LX	
pH	6/21/2019	7.01	7					Probe	Method 8156	2	14	None	172562568066	A8005	22-Jan	LX	
pH	6/24/2019	7.01	6.99					Probe	Method 8156	2	14	None	172562568066	A8005	22-Jan	LX	
pH	7/8/2019	7.01	7.04					Probe	Method 8156	2	14	None	172562568066	A8005	22-Jan	LX	
pH	7/12/2019	7.01	7					Probe	Method 8156	2	14	None	172562568066	A8005	22-Jan	LX	
True Color (PtCo 50 mm)	7/12/2019	15	14					DR6000	Method 8025	3	200	None	n/a	A8005	22-Jan	LX	
pH	7/15/2019	7.01	6.96					Probe	Method 8156	2	14	None	172562568066	A8005	22-Jan	LX	
True Color (PtCo 50 mm)	7/15/2019	15	14					DR6000	Method 8025	3	200	None	n/a	A8005	22-Jan	LX	
pH	7/17/2019	7.01	7					Probe	Method 8156	2	14	None	172562568066	A8005	22-Jan	LX	
pH	7/19/2019	7.01	7					Probe	Method 8156	2	14	None	172562568066	A8005	22-Jan	LX	
True Color (PtCo 50 mm)	7/19/2019	15						DR6000	Method 8025	3	200	None	n/a	A8005	22-Jan	NB	
Turbidity	7/19/2019	10	10.09					TU5200	Method 10258	0	700	None	1561117	A8323	12/1/2019	NB	Check every time.
pH	7/22/2019	7.01	7					Probe	Method 8156	2	14	None	172562568066	A8005	22-Jan	LX	
TOC (mg/L)	7/23/2019	0	0.047	1	1.166	10	11.112	ach QbD12	EPA 415.3	0.4	100,000	None	1800SHG00406	9011804	7/30/2019	LX	Check every time.
pH	7/26/2019	7.01	7.05					Probe	Method 8156	2	14	None	172562568066	A8005	22-Jan	NB	
True Color (PtCo 50 mm)	7/26/2019	15	14					DR6000	Method 8025	3	200	None	n/a	A8005	22-Jan	LX	
pH	7/29/2019	7.01	6.98					Probe	Method 8156	2	14	None	172562568066	A8005	22-Jan	LX	
True Color (PtCo 50 mm)	7/29/2019	15	15					DR6000	Method 8025	3	200	None	n/a	A8005	22-Jan	LX	
pH	7/31/2019	7.01	6.98					Probe	Method 8156	2	14	None	172562568066	A8005	22-Jan	NB	
True Color (PtCo 50 mm)	7/31/2019	15	15					DR6000	Method 8025	3	200	None	n/a	A8005	22-Jan	NB	
pH	8/2/2019	7.01	7.01					Probe	Method 8156	2	14	None	172562568066	A8005	22-Jan	NB	
True Color (PtCo 50 mm)	8/2/2019	15	15					DR6000	Method 8025	3	200	None	n/a	A8005	22-Jan	NB	
pH	8/5/2019	7.01	6.98					Probe	Method 8156	2	14	None	172562568066	A8005	22-Jan	NB	
True Color (PtCo 50 mm)	8/5/2019	15	15					DR6000	Method 8025	3	200	None	n/a	A8005	22-Jan	NB	
pH	8/7/2019	7.01	6.98					Probe	Method 8156	2	14	None	172562568066	A8005	22-Jan	NB	
True Color (PtCo 50 mm)	8/7/2019	15	16					DR6000	Method 8025	3	200	None	n/a	A9193	Jul-23	NB	
pH	8/9/2019	7.01	7.05					Probe	Method 8156	2	14	None	172562568066	A8005	22-Jan	NB	
True Color (PtCo 50 mm)	8/9/2019	15	15					DR6000	Method 8025	3	200	None	n/a	A9193	Jul-23	NB	

Appendix F

BASELINE WATER QUALITY

Date Water Collected	5/30/2019
Date arrived in Water ARC™ Facility	6/4/2019
er upon arrival in Water ARC™ lab (deg C)	22
Target storage temperature (deg C)	4
Target Temperature for Testing (deg C)	Room Temperature

Lab ID	Drum Label	Date Water Collected	Arrival in Water ARC® Facility	Temp. Upon Arrival (oC)	Note
Drum 4 RW	FTL-RW-1	5/30/2019; 9:20 AM	6/4/2019; 8:30 AM	22	Not refrigerated
Drum 1 FW 1	FTL-FW-1	5/30/2019; 10:00 AM	6/4/2019; 8:30 AM	22	Not refrigerated
Drum 2 FW 2	FTL-FW-2	5/30/2019; 10:35 AM	6/4/2019; 8:30 AM	22	Not refrigerated
Drum 3 FW 3	FTL-FW-3	5/30/2019; 11:00 AM	6/4/2019; 8:30 AM	22	Not refrigerated
Carboy, FTL-RW-2	FTL-RW-2		6/11/2019; 10:30 AM	9.2	With ice and iced water

Water Sample	Lab ID	Date	Time	Parameter	Result	Units	Technologist Performing Test	Notes
Drum 1 FW 1		6/11/2019	14:00	Temperature	24.5	deg C	NB	
Drum 1 FW 1		6/11/2019	14:00	pH	8.81	SU	NB	
Drum 1 FW 1		6/11/2019	14:00	Alkalinity	59	mg/L $CaCO_3$	NB	
Drum 1 FW 1		6/11/2019	14:00	Turbidity	0.7335	NTU	NB	
Drum 1 FW 1		6/7/2019	11:13	TOC	10.356	mg/L	LX	
Drum 1 FW 1		6/11/2019	14:00	Total Hardness	85	mg/L $CaCO_3$	NB	
Drum 1 FW 1		6/11/2019	14:00	Conductivity	344	uS/cm	NB	
Drum 1 FW 1		6/11/2019	14:00	Calcium Hardness	58	mg/L $CaCO_3$	NB	
Drum 1 FW 1		6/11/2019	14:00	Dissolved Oxygen	9.21	mg/L	NB	
Drum 1 FW 1		6/4/2019	16:00	UV254	0.246	abs cm^{-1}	NB	1.228 / 50 mm cuvette
Drum 1 FW 1		6/11/2019	14:00	TSS	0.001	g/L	NB	
Drum 1 FW 1		6/11/2019	14:00	ORP	322	mV	NB	
Drum 1 FW 1		6/11/2019	14:00	Nitrite	0.02	mg/L - N	NB	
Drum 1 FW 1		6/11/2019	14:00	Free chlorine	0.27	mg/L Cl_2	NB	
Drum 1 FW 1		6/4/2019	16:00	Total chlorine	1.03	mg/L Cl_2	NB	LR
Drum 1 FW 1		6/11/2019	14:00	Free ammonia	0.16	NH_3 - N	NB	
Drum 1 FW 1		6/11/2019	14:00	Monochloramine	2.94	NH_2 Cl	NB	
Drum 1 FW 1		6/4/2019	16:00	True Color	13	PtCo 50 mm	NB	LR method
Drum 1 FW 1		6/12/2019	15:00	Total Sulfide	<0.024	mg/L	N/A	External Lab
Drum 2 FW 2		6/11/2019	14:30	Temperature	17.7	deg C	NB	
Drum 2 FW 2		6/11/2019	14:30	pH	8.75	SU	NB	
Drum 2 FW 2		6/11/2019	14:30	Alkalinity	69	mg/L $CaCO_3$	NB	
Drum 2 FW 2		6/7/2019	11:41	TOC	10.46	mg/L	LX	
Drum 2 FW 2		6/11/2019	14:30	Hardness	72	mg/L $CaCO_3$	NB	
Drum 2 FW 2		6/11/2019	14:30	Total Hardness	81	mg/L $CaCO_3$	NB	
Drum 2 FW 2		6/4/2019	16:00	UV254	0.248	abs cm^{-1}	NB	1.24 / 50 mm cuvette
Drum 2 FW 2		6/11/2019	14:30	Free chlorine	0.13	mg/L Cl_2	NB	
Drum 2 FW 2		6/4/2019	16:00	Total chlorine	1.09	mg/L Cl_2	NB	LR method
Drum 2 FW 2		6/4/2019	16:00	True Color	14	PtCo 50 mm	NB	LR method
Drum 2 FW 2		6/18/2019	15:00	Total Sulfide	<0.024	mg/L	N/A	External Lab
Drum 3 FW 3		6/11/2019	14:00	Temperature	22.3	deg C	NB	
Drum 3 FW 3		6/11/2019	14:00	pH	8.82	SU	NB	
Drum 3 FW 3		6/11/2019	14:00	Alkalinity	79	mg/L $CaCO_3$	NB	
Drum 3 FW 3		6/7/2019	12:08	TOC	10.43	mg/L	LX	
Drum 3 FW 3		6/11/2019	14:00	Hardness	59	mg/L $CaCO_3$	NB	
Drum 3 FW 3		6/11/2019	14:00	Total Hardness	80	mg/L $CaCO_3$	NB	
Drum 3 FW 3		6/4/2019	16:00	UV254	0.243	abs cm^{-1}	NB	1.213 / 50 mm cuvette
Drum 3 FW 3		6/11/2019	14:00	Free chlorine	0.18	mg/L Cl_2	NB	
Drum 3 FW 3		6/4/2019	16:00	Total chlorine	0.89	mg/L Cl_2	NB	LR method
Drum 3 FW 3		6/4/2019	16:00	True Color	13	PtCo 50 mm	NB	LR method
Drum 3 FW 3		6/27/2019		Total Sulfide	<0.024	mg/L	N/A	External Lab
Drum 4 RW		6/4/2019		Total chlorine	0.02	mg/L Cl_2	NB	LR method
Drum 4 RW		6/4/2019		True Color	32	PtCo 50 mm	NB	LR method
Carboy RW		6/11/2019	11:00	Temperature	16.8	deg C	NB	
Carboy RW		6/11/2019	11:00	pH	7.14	SU	NB	
Carboy RW		6/11/2019	11:00	Alkalinity	202	mg/L $CaCO_3$	NB	
Carboy RW		6/11/2019	11:00	Turbidity	0.7283	NTU	NB	
Carboy RW		6/11/2019	11:00	TOC	12.917	mg/L	LX	Another diluted sample: 1.388 ppm after 10 dilution.
Carboy RW		6/11/2019	11:00	Calcium Hardness	170	mg/L $CaCO_3$	NB	digital titrator
Carboy RW		6/11/2019	11:00	Total Hardness	237	mg/L $CaCO_3$	NB	
Carboy RW		6/11/2019	11:00	Conductivity	546	uS/cm	NB	
Carboy RW		6/11/2019	11:00	Dissolved Oxygen	8.27	mg/L	NB	
Carboy RW		6/11/2019	11:00	UV254	0.357	abs cm-1	NB	1.774 / 50 mm cuvette
Carboy RW		6/11/2019	11:00	TSS	0.001	g/L	NB	
Carboy RW		6/11/2019	11:00	ORP	210.2	mV	NB	
Carboy RW		6/11/2019	11:00	Nitrite	0.007	mg/L - N	NB	
Carboy RW		6/11/2019	11:00	Free chlorine	0.02	mg/L Cl2	NB	LR method
Carboy RW		6/11/2019	11:00	Total chlorine	0.01	mg/L Cl2	NB	LR method
Carboy RW		6/11/2019	11:00	Free ammonia	0.28	NH3 - N	NB	
Carboy RW		6/11/2019	11:00	Monochloramine	0	NH2 Cl	NB	
Carboy RW		6/11/2019	11:00	True Color	29	PtCo 50 mm	NB	

Appendix G

OUTSIDE LABORATORY DATA

Pace Analytical Services, LLC
8 East Tower Circle
Ormond Beach, FL 32174
(386)672-5668

July 09, 2019

Eduardo Torres
Carollo Engineers, Inc.
2056 Vista Parkway, Suite 400
West Palm Beach, FL 33411

RE: Project: Fort Lauderdale
Pace Project No.: 35477160

Dear Eduardo Torres:

Enclosed are the analytical results for sample(s) received by the laboratory on June 21, 2019. The results relate only to the samples included in this report. Results reported herein conform to the most current, applicable TNI/NELAC standards and the laboratory's Quality Assurance Manual, where applicable, unless otherwise noted in the body of the report.

Headspace is present in all VOC vials.

If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Lisa Harvey
lisa.harvey@pacelabs.com
(386) 672-5668
Project Manager

Enclosures

CERTIFICATIONS

Project:	Fort Lauderdale
Pace Project No.:	35477160

Ormond Beach Certification IDs

8 East Tower Circle, Ormond Beach, FL 32174
Alaska DEC- CS/UST/LUST
Alabama Certification #: 41320
Arizona Certification# AZ0819
Colorado Certification: FL NELAC Reciprocity
Connecticut Certification #: PH-0216
Delaware Certification: FL NELAC Reciprocity
Florida Certification #: E83079
Georgia Certification #: 955
Guam Certification: FL NELAC Reciprocity
Hawaii Certification: FL NELAC Reciprocity
Illinois Certification #: 200068
Indiana Certification: FL NELAC Reciprocity
Kansas Certification #: E-10383
Kentucky Certification #: 90050
Louisiana Certification #: FL NELAC Reciprocity
Louisiana Environmental Certificate #: 05007
Maryland Certification: #346
Michigan Certification #: 9911
Mississippi Certification: FL NELAC Reciprocity
Missouri Certification #: 236
Montana Certification #: Cert 0074
Nebraska Certification: NE-OS-28-14
New Hampshire Certification #: 2958
New Jersey Certification #: FL022
New York Certification #: 11608
North Carolina Environmental Certificate #: 667
North Carolina Certification #: 12710
North Dakota Certification #: R-216
Oklahoma Certification #: D9947
Pennsylvania Certification #: 68-00547
Puerto Rico Certification #: FL01264
South Carolina Certification: #96042001
Tennessee Certification #: TN02974
Texas Certification: FL NELAC Reciprocity
US Virgin Islands Certification: FL NELAC Reciprocity
Virginia Environmental Certification #: 460165
West Virginia Certification #: 9962C
Wisconsin Certification #: 399079670
Wyoming (EPA Region 8): FL NELAC Reciprocity

SAMPLE SUMMARY

Project: Fort Lauderdale
Pace Project No.: 35477160

Lab ID	Sample ID	Matrix	Date Collected	Date Received
35477160001	**JAR 1**	Water	06/20/19 14:00	06/21/19 10:25
35477160002	**JAR 2**	Water	06/20/19 14:00	06/21/19 10:25
35477160003	**JAR 3**	Water	06/20/19 14:00	06/21/19 10:25

SAMPLE ANALYTE COUNT

Project: Fort Lauderdale
Pace Project No.: 35477160

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
35477160001	**JAR 1**	EPA 552.3	MMB	7	PASI-O
		EPA 524.2	JLR	8	PASI-O
35477160002	**JAR 2**	EPA 552.3	MMB	7	PASI-O
		EPA 524.2	JLR	8	PASI-O
35477160003	**JAR 3**	EPA 552.3	MMB	7	PASI-O
		EPA 524.2	JLR	8	PASI-O

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35477160

Sample: JAR 1 **Lab ID: 35477160001** Collected: 06/20/19 14:00 Received: 06/21/19 10:25 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
552.3 Haloacetic Acids	Analytical Method: EPA 552.3 Preparation Method: EPA 552.3								
Dibromoacetic Acid	**0.43 U**	ug/L	1.0	0.43	1	07/05/19 22:20	07/07/19 01:01	631-64-1	Q
Dichloroacetic Acid	**12.4**	ug/L	1.0	0.24	1	07/05/19 22:20	07/07/19 01:01	79-43-6	Q
Haloacetic Acids (Total)	**23.8**	ug/L	1.0	0.90	1	07/05/19 22:20	07/07/19 01:01		
Monobromoacetic Acid	**0.29 U**	ug/L	1.0	0.29	1	07/05/19 22:20	07/07/19 01:01	79-08-3	Q
Monochloroacetic Acid	**2.8**	ug/L	1.0	0.90	1	07/05/19 22:20	07/07/19 01:01	79-11-8	Q
Trichloroacetic Acid	**8.7**	ug/L	1.0	0.26	1	07/05/19 22:20	07/07/19 01:01	76-03-9	J(L2),Q
Surrogates									
2,3-Dibromopropanoic Acid (S)	58	%	70-130		1	07/05/19 22:20	07/07/19 01:01	600-05-5	J(S0)
524.2 THM	Analytical Method: EPA 524.2								
Bromodichloromethane	**0.25 U**	ug/L	1.0	0.25	1		06/26/19 04:42	75-27-4	
Bromoform	**0.32 U**	ug/L	1.0	0.32	1		06/26/19 04:42	75-25-2	
Chloroform	**23.9**	ug/L	1.0	0.25	1		06/26/19 04:42	67-66-3	
Dibromochloromethane	**0.25 U**	ug/L	1.0	0.25	1		06/26/19 04:42	124-48-1	
Total Trihalomethanes (Calc.)	**23.9**	ug/L	1.0	0.32	1		06/26/19 04:42		
Surrogates									
4-Bromofluorobenzene (S)	92	%	70-130		1		06/26/19 04:42	460-00-4	J(HS)
1,2-Dichloroethane-d4 (S)	120	%	70-130		1		06/26/19 04:42	17060-07-0	
Toluene-d8 (S)	115	%	70-130		1		06/26/19 04:42	2037-26-5	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35477160

Sample: JAR 2 **Lab ID: 35477160002** Collected: 06/20/19 14:00 Received: 06/21/19 10:25 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
552.3 Haloacetic Acids	Analytical Method: EPA 552.3 Preparation Method: EPA 552.3								
Dibromoacetic Acid	**0.43 U**	ug/L	1.0	0.43	1	07/05/19 22:20	07/07/19 01:21	631-64-1	Q
Dichloroacetic Acid	**3.5**	ug/L	1.0	0.24	1	07/05/19 22:20	07/07/19 01:21	79-43-6	Q
Haloacetic Acids (Total)	**8.9**	ug/L	1.0	0.90	1	07/05/19 22:20	07/07/19 01:21		
Monobromoacetic Acid	**0.29 U**	ug/L	1.0	0.29	1	07/05/19 22:20	07/07/19 01:21	79-08-3	Q
Monochloroacetic Acid	**0.90 U**	ug/L	1.0	0.90	1	07/05/19 22:20	07/07/19 01:21	79-11-8	Q
Trichloroacetic Acid	**5.4**	ug/L	1.0	0.26	1	07/05/19 22:20	07/07/19 01:21	76-03-9	J(L2),Q
Surrogates									
2,3-Dibromopropanoic Acid (S)	60	%	70-130		1	07/05/19 22:20	07/07/19 01:21	600-05-5	J(S0)
524.2 THM	Analytical Method: EPA 524.2								
Bromodichloromethane	**0.25 U**	ug/L	1.0	0.25	1		06/26/19 05:07	75-27-4	
Bromoform	**0.32 U**	ug/L	1.0	0.32	1		06/26/19 05:07	75-25-2	
Chloroform	**7.8**	ug/L	1.0	0.25	1		06/26/19 05:07	67-66-3	
Dibromochloromethane	**0.25 U**	ug/L	1.0	0.25	1		06/26/19 05:07	124-48-1	
Total Trihalomethanes (Calc.)	**7.8**	ug/L	1.0	0.32	1		06/26/19 05:07		
Surrogates									
4-Bromofluorobenzene (S)	92	%	70-130		1		06/26/19 05:07	460-00-4	J(HS)
1,2-Dichloroethane-d4 (S)	122	%	70-130		1		06/26/19 05:07	17060-07-0	
Toluene-d8 (S)	116	%	70-130		1		06/26/19 05:07	2037-26-5	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35477160

Sample: JAR 3 **Lab ID: 35477160003** Collected: 06/20/19 14:00 Received: 06/21/19 10:25 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
552.3 Haloacetic Acids	Analytical Method: EPA 552.3 Preparation Method: EPA 552.3								
Dibromoacetic Acid	**0.92 I**	ug/L	1.0	0.43	1	07/05/19 22:20	07/07/19 01:42	631-64-1	Q
Dichloroacetic Acid	**23.3**	ug/L	1.0	0.24	1	07/05/19 22:20	07/07/19 01:42	79-43-6	Q
Haloacetic Acids (Total)	**43.4**	ug/L	1.0	0.90	1	07/05/19 22:20	07/07/19 01:42		
Monobromoacetic Acid	**0.29 U**	ug/L	1.0	0.29	1	07/05/19 22:20	07/07/19 01:42	79-08-3	Q
Monochloroacetic Acid	**3.9**	ug/L	1.0	0.90	1	07/05/19 22:20	07/07/19 01:42	79-11-8	Q
Trichloroacetic Acid	**15.2**	ug/L	1.0	0.26	1	07/05/19 22:20	07/07/19 01:42	76-03-9	J(L2),Q
Surrogates									
2,3-Dibromopropanoic Acid (S)	72	%	70-130		1	07/05/19 22:20	07/07/19 01:42	600-05-5	
524.2 THM	Analytical Method: EPA 524.2								
Bromodichloromethane	**5.1**	ug/L	1.0	0.25	1		06/28/19 16:16	75-27-4	
Bromoform	**0.32 U**	ug/L	1.0	0.32	1		06/28/19 16:16	75-25-2	
Chloroform	**47.5**	ug/L	1.0	0.25	1		06/28/19 16:16	67-66-3	
Dibromochloromethane	**0.25 U**	ug/L	1.0	0.25	1		06/28/19 16:16	124-48-1	
Total Trihalomethanes (Calc.)	**52.6**	ug/L	1.0	0.32	1		06/28/19 16:16		
Surrogates									
4-Bromofluorobenzene (S)	105	%	70-130		1		06/28/19 16:16	460-00-4	J(HS)
1,2-Dichloroethane-d4 (S)	103	%	70-130		1		06/28/19 16:16	17060-07-0	
Toluene-d8 (S)	100	%	70-130		1		06/28/19 16:16	2037-26-5	

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35477160

QC Batch: 549148
Analysis Method: EPA 524.2
QC Batch Method: EPA 524.2
Analysis Description: 524.2 THM MSV
Associated Lab Samples: 35477160001, 35477160002

METHOD BLANK: 2976884
Matrix: Water
Associated Lab Samples: 35477160001, 35477160002

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Bromodichloromethane	ug/L	0.25 U	1.0	0.25	06/25/19 20:58	
Bromoform	ug/L	0.32 U	1.0	0.32	06/25/19 20:58	
Chloroform	ug/L	0.25 U	1.0	0.25	06/25/19 20:58	
Dibromochloromethane	ug/L	0.25 U	1.0	0.25	06/25/19 20:58	
Total Trihalomethanes (Calc.)	ug/L	0.32 U	1.0	0.32	06/25/19 20:58	
1,2-Dichloroethane-d4 (S)	%	121	70-130		06/25/19 20:58	
4-Bromofluorobenzene (S)	%	91	70-130		06/25/19 20:58	
Toluene-d8 (S)	%	112	70-130		06/25/19 20:58	

LABORATORY CONTROL SAMPLE & LCSD: 2976885 2976886

Parameter	Units	Spike Conc.	LCS Result	LCSD Result	LCS % Rec	LCSD % Rec	% Rec Limits	RPD	Max RPD	Qualifiers
Bromodichloromethane	ug/L	40	45.1	46.4	113	116	70-130	3	20	
Bromoform	ug/L	40	36.3	35.5	91	89	70-130	2	20	
Chloroform	ug/L	40	42.3	43.2	106	108	70-130	2	20	
Dibromochloromethane	ug/L	40	41.2	40.3	103	101	70-130	2	20	
Total Trihalomethanes (Calc.)	ug/L	160	165	165	103	103	70-130	0	20	
1,2-Dichloroethane-d4 (S)	%				110	109	70-130			
4-Bromofluorobenzene (S)	%				90	88	70-130			
Toluene-d8 (S)	%				107	111	70-130			

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35477160

QC Batch: 550076
Analysis Method: EPA 524.2
QC Batch Method: EPA 524.2
Analysis Description: 524.2 THM MSV
Associated Lab Samples: 35477160003

METHOD BLANK: 2982477
Matrix: Water
Associated Lab Samples: 35477160003

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Bromodichloromethane	ug/L	0.25 U	1.0	0.25	06/28/19 10:21	
Bromoform	ug/L	0.32 U	1.0	0.32	06/28/19 10:21	
Chloroform	ug/L	0.25 U	1.0	0.25	06/28/19 10:21	
Dibromochloromethane	ug/L	0.25 U	1.0	0.25	06/28/19 10:21	
Total Trihalomethanes (Calc.)	ug/L	0.32 U	1.0	0.32	06/28/19 10:21	
1,2-Dichloroethane-d4 (S)	%	103	70-130		06/28/19 10:21	
4-Bromofluorobenzene (S)	%	103	70-130		06/28/19 10:21	
Toluene-d8 (S)	%	99	70-130		06/28/19 10:21	

LABORATORY CONTROL SAMPLE & LCSD: 2982478 2982479

Parameter	Units	Spike Conc.	LCS Result	LCSD Result	LCS % Rec	LCSD % Rec	% Rec Limits	RPD	Max RPD	Qualifiers
Bromodichloromethane	ug/L	40	42.3	41.3	106	103	70-130	2	20	
Bromoform	ug/L	40	35.8	36.0	90	90	70-130	1	20	
Chloroform	ug/L	40	40.6	40.2	102	100	70-130	1	20	
Dibromochloromethane	ug/L	40	36.6	37.1	92	93	70-130	1	20	
Total Trihalomethanes (Calc.)	ug/L	160	155	155	97	97	70-130	0	20	
1,2-Dichloroethane-d4 (S)	%				100	96	70-130			
4-Bromofluorobenzene (S)	%				104	105	70-130			
Toluene-d8 (S)	%				102	103	70-130			

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35477160

QC Batch: 551759
Analysis Method: EPA 552.3
QC Batch Method: EPA 552.3
Analysis Description: 5523 Haloacetic Acids
Associated Lab Samples: 35477160001, 35477160002, 35477160003

METHOD BLANK: 2992011
Matrix: Water
Associated Lab Samples: 35477160001, 35477160002, 35477160003

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Dibromoacetic Acid	ug/L	0.43 U	1.0	0.43	07/06/19 16:43	
Dichloroacetic Acid	ug/L	0.24 U	1.0	0.24	07/06/19 16:43	
Haloacetic Acids (Total)	ug/L	0.90 U	1.0	0.90	07/06/19 16:43	
Monobromoacetic Acid	ug/L	0.29 U	1.0	0.29	07/06/19 16:43	
Monochloroacetic Acid	ug/L	0.90 U	1.0	0.90	07/06/19 16:43	
Trichloroacetic Acid	ug/L	0.26 U	1.0	0.26	07/06/19 16:43	
2,3-Dibromopropanoic Acid (S)	%	99	70-130		07/06/19 16:43	

LABORATORY CONTROL SAMPLE: 2992012

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Dibromoacetic Acid	ug/L	10	8.2	82	70-130	
Dichloroacetic Acid	ug/L	10	7.2	72	70-130	
Haloacetic Acids (Total)	ug/L	50	37.6	75	70-130	
Monobromoacetic Acid	ug/L	10	8.0	80	70-130	
Monochloroacetic Acid	ug/L	10	7.8	78	70-130	
Trichloroacetic Acid	ug/L	10	6.5	65	70-130	J(L2)
2,3-Dibromopropanoic Acid (S)	%			84	70-130	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2992696 2992697

Parameter	Units	35477238001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Dibromoacetic Acid	ug/L	0.85 I	10	10	9.9	10.0	91	92	70-130	1	30	
Dichloroacetic Acid	ug/L	37.7	10	10	48.6	48.2	110	105	70-130	1	30	L
Haloacetic Acids (Total)	ug/L	48.7	50	50	105	104	112	110	70-130	1	30	
Monobromoacetic Acid	ug/L	<0.29	10	10	10.9	10.9	109	109	70-130	0	30	
Monochloroacetic Acid	ug/L	<0.90	10	10	15.1	14.2	151	142	70-130	7	30	J(M1)
Trichloroacetic Acid	ug/L	10.2	10	10	20.4	20.4	102	102	70-130	0	30	
2,3-Dibromopropanoic Acid (S)	%						88	86	70-130		30	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALIFIERS

Project:	Fort Lauderdale
Pace Project No.:	35477160

DEFINITIONS

DF - Dilution Factor, if reported, represents the factor applied to the reported data due to dilution of the sample aliquot.

ND - Not Detected at or above adjusted reporting limit.

TNTC - Too Numerous To Count

MDL - Adjusted Method Detection Limit.

PQL - Practical Quantitation Limit.

RL - Reporting Limit - The lowest concentration value that meets project requirements for quantitative data with known precision and bias for a specific analyte in a specific matrix.

S - Surrogate

1,2-Diphenylhydrazine decomposes to and cannot be separated from Azobenzene using Method 8270. The result for each analyte is a combined concentration.

Consistent with EPA guidelines, unrounded data are displayed and have been used to calculate % recovery and RPD values.

LCS(D) - Laboratory Control Sample (Duplicate)

MS(D) - Matrix Spike (Duplicate)

DUP - Sample Duplicate

RPD - Relative Percent Difference

NC - Not Calculable.

SG - Silica Gel - Clean-Up

U - Indicates the compound was analyzed for, but not detected.

N-Nitrosodiphenylamine decomposes and cannot be separated from Diphenylamine using Method 8270. The result reported for each analyte is a combined concentration.

Pace Analytical is TNI accredited. Contact your Pace PM for the current list of accredited analytes.

TNI - The NELAC Institute.

LABORATORIES

PASI-O	Pace Analytical Services - Ormond Beach

ANALYTE QUALIFIERS

I	The reported value is between the laboratory method detection limit and the laboratory practical quantitation limit.
U	Compound was analyzed for but not detected.
J(HS)	Estimated Value. Results are from sample aliquot taken from VOA vial with headspace (air bubble greater than 6 mm diameter).
J(L2)	Estimated Value. Analyte recovery in the laboratory control sample (LCS) was below QC limits. Results for this analyte in associated samples may be biased low.
J(M1)	Estimated Value. Matrix spike recovery exceeded QC limits. Batch accepted based on laboratory control sample (LCS) recovery.
J(S0)	Estimated Value. Surrogate recovery outside laboratory control limits.
L	Off-scale high. Actual value is known to be greater than value given.
Q	Sample held beyond the accepted holding time.

QUALITY CONTROL DATA CROSS REFERENCE TABLE

Project:	Fort Lauderdale
Pace Project No.:	35477160

Lab ID	Sample ID	QC Batch Method	QC Batch	Analytical Method	Analytical Batch
35477160001	**JAR 1**	EPA 552.3	551759	EPA 552.3	551910
35477160002	**JAR 2**	EPA 552.3	551759	EPA 552.3	551910
35477160003	**JAR 3**	EPA 552.3	551759	EPA 552.3	551910
35477160001	**JAR 1**	EPA 524.2	549148		
35477160002	**JAR 2**	EPA 524.2	549148		
35477160003	**JAR 3**	EPA 524.2	550076		

WO#: 35477160

35477160

Pace Analytical

CHAIN-OF-CUSTODY / Analytical Request Document

The Chain-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately.

Page : 1 Of

Section A
Required Client Information:

Company:	Carollo Engineering
Address:	20546 Vista Parkway
	Suite 400, West Palm Beach, FL 33411
Email To:	Eduardo Torres
Phone:	914-987-9494
Fax:	
Requested Due Date:	std

Section B
Required Project Information:

Report To:	Eduardo Torres
Copy To:	
Purchase Order #:	
Project Name:	Fort Lauderdale
Project #:	

Section C
Invoice Information:

Attention:	Accounts Payable
Company Name:	Carollo
Address:	
Pace Quote:	
Pace Project Manager:	Lisa Harvey
Pace Profile #:	11950-1 or 2 (see notes)

Regulatory Agency	FL
State / Location	FL

SAMPLE ID
One Character per box.
(A-Z, 0-9 / , -)
Sample Ids must be unique

MATRIX	CODE
Drinking Water	DW
Water	WT
Waste Water	WW
Product	P
Soil/Solid	SL
Oil	OL
Wipe	WP
Air	AR
Other	OT
Tissue	TS

ITEM #	SAMPLE ID	MATRIX CODE (see valid codes to left)	SAMPLE TYPE (G=GRAB C=COMP)	COLLECTED START DATE	COLLECTED START TIME	COLLECTED END DATE	COLLECTED END TIME	SAMPLE TEMP AT COLLECTION	# OF CONTAINERS	Preservatives: Unpreserved	H2SO4	HNO3	HCl	NaOH	Na2S2O3	Methanol	Other	Analyses Test Y/N	Requested Analysis Filtered (Y/N): sulfide	color	UV254	Cl, SO4	NO3	TDS	Alkalinity	Mg + hardness	Mg	TOC	THM	HAA	Residual Chlorine (Y/N)	
1	JAR 1																X												X	X		
2	JAR 2																X												X	X		
3	JAR 3																X												X	X		
4																																
5																																
6																																
7																																
8																																
9																																
10																																
11																																
12																																

ADDITIONAL COMMENTS	RELINQUISHED BY / AFFILIATION	DATE	TIME	ACCEPTED BY / AFFILIATION	DATE	TIME	SAMPLE CONDITIONS			
11950-line 1: includes hardness				/Pace	6/21/19	10:25				
11950-line 2: no hardness										
							TEMP in C	Received on Ice (Y/N)	Custody Sealed Cooler (Y/N)	Samples Intact (Y/N)

SAMPLER NAME AND SIGNATURE

PRINT Name of SAMPLER: EDUARDO TORRES

SIGNATURE of SAMPLER: Eduardo J Torres

DATE Signed: 06/20/19

Pace Analytical Florida Laboratory	Document Name: Sample Condition Upon Receipt Form	Document Revised: May 30, 2018
	Document No.: F-FL-C-007 rev. 13	Issuing Authority: Pace Florida Quality Office

Sample Condition Upon Receipt Form (SCUR)

Project # WO#: 35477160
Project Manager: PM: LMH Due Date: 07/08/19
Client: CLIENT: CARWESTPALM

Date and Initials of person:
Examining contents:
Label:
Deliver:
pH:

Thermometer Used: T337 Date: 6/21/19 Time: 1135 Initials: BBB

State of Origin:

☐ For WV projects, all containers verified to ≤6 °C

Cooler #1 Temp.°C 3.0 **(Visual)** +.3 **(Correction Factor)** 3.3 **(Actual)** ☐ Samples on ice, cooling process has begun
Cooler #2 Temp.°C____ **(Visual)** ____ **(Correction Factor)** ____ **(Actual)** ☐ Samples on ice, cooling process has begun
Cooler #3 Temp.°C____ **(Visual)** ____ **(Correction Factor)** ____ **(Actual)** ☐ Samples on ice, cooling process has begun
Cooler #4 Temp.°C____ **(Visual)** ____ **(Correction Factor)** ____ **(Actual)** ☐ Samples on ice, cooling process has begun
Cooler #5 Temp.°C____ **(Visual)** ____ **(Correction Factor)** ____ **(Actual)** ☐ Samples on ice, cooling process has begun
Cooler #6 Temp.°C____ **(Visual)** ____ **(Correction Factor)** ____ **(Actual)** ☐ Samples on ice, cooling process has begun

Courier: ☐ Fed Ex ☑ UPS ☐ USPS ☐ Client ☐ Commercial ☐ Pace ☐ Other

Shipping Method: ☐ First Overnight ☐ Priority Overnight ☐ Standard Overnight ☐ Ground ☐ International Priority ☑ Other Next Day Air

Billing: ☐ Recipient ☐ Sender ☐ Third Party ☐ Credit Card ☑ Unknown

Tracking #

Custody Seal on Cooler/Box Present: ☐ Yes ☑ No **Seals intact:** ☐ Yes ☐ No **Ice:** [✓ Wet] Blue Dry None

Packing Material: ☐ Bubble Wrap ☑ Bubble Bags ☐ None ☐ Other

Samples shorted to lab (If Yes, complete) Shorted Date: Shorted Time: Qty:

		Comments:
Chain of Custody Present	☑ Yes ☐ No ☐ N/A	
Chain of Custody Filled Out	☐ Yes ☑ No ☐ N/A	No # of containers /
Relinquished Signature & Sampler Name COC	☐ Yes ☑ No ☐ N/A	No relinquish sign.
Samples Arrived within Hold Time	☑ Yes ☐ No ☐ N/A	
Rush TAT requested on COC	☐ Yes ☑ No ☐ N/A	
Sufficient Volume	☑ Yes ☐ No ☐ N/A	
Correct Containers Used	☑ Yes ☐ No ☐ N/A	
Containers Intact	☑ Yes ☐ No ☐ N/A	
Sample Labels match COC (sample IDs & date/time of collection)	☐ Yes ☑ No ☐ N/A	No collected time on COC
All containers needing acid/base preservation have been checked.	☐ Yes ☐ No ☑ N/A	Preservation Information: Preservative: Lot #/Trace #: Date: Time: Initials:
All Containers needing preservation are found to be in compliance with EPA recommendation: Exceptions: VOA, Coliform, TOC, O&G, Carbamates	☐ Yes ☐ No ☑ N/A	
Headspace in VOA Vials? (>6mm):	☑ Yes ☐ No ☐ N/A	*Large amount of HS*
Trip Blank Present:	☐ Yes ☑ No ☐ N/A	

Client Notification/ Resolution:
Person Contacted: Date/Time:

Comments/ Resolution (use back for additional comments): Profile does not exist.

Project Manager Review: Date:

Pace Analytical Services, LLC
8 East Tower Circle
Ormond Beach, FL 32174
(386)672-5668

June 20, 2019

Eduardo Torres
Carollo Engineers, Inc.
2056 Vista Parkway, Suite 400
West Palm Beach, FL 33411

RE: Project: Fort Lauderdale
Pace Project No.: 35473138

Dear Eduardo Torres:

Enclosed are the analytical results for sample(s) received by the laboratory on June 06, 2019. The results relate only to the samples included in this report. Results reported herein conform to the most current, applicable TNI/NELAC standards and the laboratory's Quality Assurance Manual, where applicable, unless otherwise noted in the body of the report.

If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Lisa Harvey
lisa.harvey@pacelabs.com
(386) 672-5668
Project Manager

Enclosures

CERTIFICATIONS

Project: Fort Lauderdale
Pace Project No.: 35473138

Ormond Beach Certification IDs

8 East Tower Circle, Ormond Beach, FL 32174
Alaska DEC- CS/UST/LUST
Alabama Certification #: 41320
Arizona Certification# AZ0819
Colorado Certification: FL NELAC Reciprocity
Connecticut Certification #: PH-0216
Delaware Certification: FL NELAC Reciprocity
Florida Certification #: E83079
Georgia Certification #: 955
Guam Certification: FL NELAC Reciprocity
Hawaii Certification: FL NELAC Reciprocity
Illinois Certification #: 200068
Indiana Certification: FL NELAC Reciprocity
Kansas Certification #: E-10383
Kentucky Certification #: 90050
Louisiana Certification #: FL NELAC Reciprocity
Louisiana Environmental Certificate #: 05007
Maryland Certification: #346
Michigan Certification #: 9911
Mississippi Certification: FL NELAC Reciprocity
Missouri Certification #: 236
Montana Certification #: Cert 0074
Nebraska Certification: NE-OS-28-14
New Hampshire Certification #: 2958
New Jersey Certification #: FL022
New York Certification #: 11608
North Carolina Environmental Certificate #: 667
North Carolina Certification #: 12710
North Dakota Certification #: R-216
Oklahoma Certification #: D9947
Pennsylvania Certification #: 68-00547
Puerto Rico Certification #: FL01264
South Carolina Certification: #96042001
Tennessee Certification #: TN02974
Texas Certification: FL NELAC Reciprocity
US Virgin Islands Certification: FL NELAC Reciprocity
Virginia Environmental Certification #: 460165
West Virginia Certification #: 9962C
Wisconsin Certification #: 399079670
Wyoming (EPA Region 8): FL NELAC Reciprocity

SAMPLE SUMMARY

Project: Fort Lauderdale
Pace Project No.: 35473138

Lab ID	Sample ID	Matrix	Date Collected	Date Received
35473138001	**MIEX RAW 1**	Water	06/05/19 13:00	06/06/19 09:30
35473138002	**MIEX RAW 2**	Water	06/05/19 13:00	06/06/19 09:30
35473138003	**MIEX SETTLED 1**	Water	06/05/19 13:00	06/06/19 09:30
35473138004	**MIEX SETTLED 2**	Water	06/05/19 13:00	06/06/19 09:30
35473138006	**MIEX SETTLED 3**	Water	06/05/19 13:00	06/06/19 09:30
35473138007	**MIEX SETTLED 4**	Water	06/05/19 13:00	06/06/19 09:30
35473138008	**MIEX RAW 3**	Water	06/05/19 13:00	06/06/19 09:30
35473138009	**MIEX RAW 4**	Water	06/05/19 13:00	06/06/19 09:30

SAMPLE ANALYTE COUNT

Project: Fort Lauderdale
Pace Project No.: 35473138

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
35473138001	**MIEX RAW 1**	SM 2320B	AGS	1	PASI-O
35473138002	**MIEX RAW 2**	SM2120B-01	AGS	2	PASI-O
		SM 2540C	MRS	1	PASI-O
		EPA 300.0	JDM	2	PASI-O
		EPA 353.2	CLL	1	PASI-O
35473138003	**MIEX SETTLED 1**	SM2120B-01	AGS	2	PASI-O
		SM 2540C	MRS	1	PASI-O
		EPA 300.0	JDM	2	PASI-O
		EPA 353.2	CLL	1	PASI-O
35473138004	**MIEX SETTLED 2**	SM 2320B	AGS	1	PASI-O
35473138006	**MIEX SETTLED 3**	EPA 200.7	JWP	4	PASI-O
35473138007	**MIEX SETTLED 4**	SM 5310B	SA1	1	PASI-O
35473138008	**MIEX RAW 3**	EPA 200.7	JWP	4	PASI-O
35473138009	**MIEX RAW 4**	SM 5310B	SA1	1	PASI-O

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35473138

Sample: MIEX RAW 1 **Lab ID: 35473138001** Collected: 06/05/19 13:00 Received: 06/06/19 09:30 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity, Total as CaCO3	**220**	mg/L	5.0	5.0	1		06/18/19 11:21		

REPORT OF LABORATORY ANALYSIS

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35473138

Sample: MIEX RAW 2 **Lab ID: 35473138002** Collected: 06/05/19 13:00 Received: 06/06/19 09:30 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
2120B Apparent Color	Analytical Method: SM2120B-01								
Apparent Color	**45.0**	units	5.0	5.0	1		06/07/19 09:47		
pH	**6.7**	units			1		06/07/19 09:47		
2540C Total Dissolved Solids	Analytical Method: SM 2540C								
Total Dissolved Solids	**323**	mg/L	5.0	5.0	1		06/11/19 14:18		
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Chloride	**53.6**	mg/L	5.0	2.5	1		06/19/19 13:02	16887-00-6	J(M1)
Sulfate	**5.5**	mg/L	5.0	2.5	1		06/19/19 13:02	14808-79-8	
353.2 Nitrogen, NO2/NO3 unpres	Analytical Method: EPA 353.2								
Nitrogen, Nitrate	**0.025 U**	mg/L	0.050	0.025	1		06/07/19 09:32	14797-55-8	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35473138

Sample: MIEX SETTLED 1 **Lab ID: 35473138003** Collected: 06/05/19 13:00 Received: 06/06/19 09:30 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
2120B Apparent Color	Analytical Method: SM2120B-01								
Apparent Color	**20.0**	units	5.0	5.0	1		06/07/19 09:47		
pH	**6.8**	units			1		06/07/19 09:47		
2540C Total Dissolved Solids	Analytical Method: SM 2540C								
Total Dissolved Solids	**340**	mg/L	5.0	5.0	1		06/11/19 14:18		
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Chloride	**62.1**	mg/L	5.0	2.5	1		06/19/19 14:09	16887-00-6	
Sulfate	**5.0**	mg/L	5.0	2.5	1		06/19/19 14:09	14808-79-8	
353.2 Nitrogen, NO2/NO3 unpres	Analytical Method: EPA 353.2								
Nitrogen, Nitrate	**0.025 U**	mg/L	0.050	0.025	1		06/07/19 09:33	14797-55-8	

ANALYTICAL RESULTS

Project:	Fort Lauderdale
Pace Project No.:	35473138

Sample: MIEX SETTLED 2 **Lab ID: 35473138004** Collected: 06/05/19 13:00 Received: 06/06/19 09:30 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity, Total as CaCO3	**217**	mg/L	5.0	5.0	1		06/18/19 11:26		

ANALYTICAL RESULTS

Project:	Fort Lauderdale
Pace Project No.:	35473138

Sample: MIEX SETTLED 3 **Lab ID: 35473138006** Collected: 06/05/19 13:00 Received: 06/06/19 09:30 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Ca Hardness as CaCO3 (SM 2340B	**195**	mg/L	1.2	0.16	1	06/07/19 03:22	06/09/19 18:58		
Mg Hardness as CaCO3 (SM 2340B	**30.6**	mg/L	2.1	0.35	1	06/07/19 03:22	06/09/19 18:58		
Magnesium	**7.4**	mg/L	0.50	0.084	1	06/07/19 03:22	06/09/19 18:58	7439-95-4	
Tot Hardness asCaCO3 (SM 2340B	**226**	mg/L	3.3	0.51	1	06/07/19 03:22	06/09/19 18:58		

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35473138

Sample: MIEX SETTLED 4 **Lab ID: 35473138007** Collected: 06/05/19 13:00 Received: 06/06/19 09:30 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**5.7**	mg/L	1.0	0.50	1		06/19/19 08:18	7440-44-0	

ANALYTICAL RESULTS

Project:	Fort Lauderdale
Pace Project No.:	35473138

Sample: MIEX RAW 3 **Lab ID: 35473138008** Collected: 06/05/19 13:00 Received: 06/06/19 09:30 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Ca Hardness as CaCO3 (SM 2340B	**195**	mg/L	1.2	0.16	1	06/07/19 03:22	06/09/19 19:02		
Mg Hardness as CaCO3 (SM 2340B	**30.5**	mg/L	2.1	0.35	1	06/07/19 03:22	06/09/19 19:02		
Magnesium	**7.4**	mg/L	0.50	0.084	1	06/07/19 03:22	06/09/19 19:02	7439-95-4	
Tot Hardness asCaCO3 (SM 2340B	**226**	mg/L	3.3	0.51	1	06/07/19 03:22	06/09/19 19:02		

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35473138

Sample: MIEX RAW 4 **Lab ID: 35473138009** Collected: 06/05/19 13:00 Received: 06/06/19 09:30 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**10.3**	mg/L	1.0	0.50	1		06/19/19 09:00	7440-44-0	

QUALITY CONTROL DATA

Project:	Fort Lauderdale
Pace Project No.:	35473138

QC Batch:	544516	Analysis Method:	EPA 200.7
QC Batch Method:	EPA 200.7	Analysis Description:	200.7 MET

Associated Lab Samples: 35473138006, 35473138008

METHOD BLANK: 2949997 Matrix: Water

Associated Lab Samples: 35473138006, 35473138008

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Ca Hardness as CaCO3 (SM 2340B	mg/L	0.16 U	1.2	0.16	06/09/19 17:19	
Magnesium	mg/L	0.084 U	0.50	0.084	06/09/19 17:19	
Mg Hardness as CaCO3 (SM 2340B	mg/L	0.35 U	2.1	0.35	06/09/19 17:19	
Tot Hardness asCaCO3 (SM 2340B	mg/L	0.51 U	3.3	0.51	06/09/19 17:19	

LABORATORY CONTROL SAMPLE: 2949998

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Ca Hardness as CaCO3 (SM 2340B	mg/L	31.2	31.7	102	85-115	
Magnesium	mg/L	12.5	12.6	101	85-115	
Mg Hardness as CaCO3 (SM 2340B	mg/L	51.5	51.8	101	85-115	
Tot Hardness asCaCO3 (SM 2340B	mg/L	82.7	83.5	101	85-115	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2949999 2950000

Parameter	Units	35472919001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Ca Hardness as CaCO3 (SM 2340B	mg/L	63.7	31.2	31.2	88.4	87.1	79	75	70-130	1	20	
Magnesium	mg/L	16.2	12.5	12.5	21.7	21.4	44	42	70-130	1	20	J(M1)
Mg Hardness as CaCO3 (SM 2340B	mg/L	66.6	51.5	51.5	89.4	88.3	44	42	70-130	1	20	
Tot Hardness asCaCO3 (SM 2340B	mg/L	130	82.7	82.7	178	175	57	54	70-130	1	20	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2950001 2950002

Parameter	Units	35472921002 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Ca Hardness as CaCO3 (SM 2340B	mg/L	152000 ug/L	31.2	31.2	177	178	81	85	70-130	1	20	
Magnesium	mg/L	10600 ug/L	12.5	12.5	23.1	23.4	100	103	70-130	1	20	
Mg Hardness as CaCO3 (SM 2340B	mg/L	43500 ug/L	51.5	51.5	95.0	96.4	100	103	70-130	1	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35473138

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2950001 2950002

Parameter	Units	35472921002 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Tot Hardness asCaCO3 (SM 2340B	mg/L	195000 ug/L	82.7	82.7	272	275	93	96	70-130	1	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35473138

QC Batch: 544520
Analysis Method: SM2120B-01
QC Batch Method: SM2120B-01
Analysis Description: 2120B Color
Associated Lab Samples: 35473138002, 35473138003

METHOD BLANK: 2950016
Matrix: Water
Associated Lab Samples: 35473138002, 35473138003

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Apparent Color	units	5.0 U	5.0	5.0	06/07/19 09:46	
pH	units	5.5			06/07/19 09:46	

SAMPLE DUPLICATE: 2950017

Parameter	Units	35472840001 Result	Dup Result	RPD	Max RPD	Qualifiers
Apparent Color	units	15.0	15.0	0	20	Q
pH	units	7.3	7.3	0		Q

SAMPLE DUPLICATE: 2950018

Parameter	Units	35473138003 Result	Dup Result	RPD	Max RPD	Qualifiers
Apparent Color	units	20.0	20.0	0	20	
pH	units	6.8	6.8	0		

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35473138

QC Batch: 547313 Analysis Method: SM 2320B
QC Batch Method: SM 2320B Analysis Description: 2320B Alkalinity
Associated Lab Samples: 35473138001, 35473138004

METHOD BLANK: 2965954 Matrix: Water
Associated Lab Samples: 35473138001, 35473138004

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Alkalinity, Total as CaCO3	mg/L	5.0 U	5.0	5.0	06/18/19 10:31	

LABORATORY CONTROL SAMPLE: 2965955

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Alkalinity, Total as CaCO3	mg/L	252	257	102	90-110	

SAMPLE DUPLICATE: 2965956

Parameter	Units	35473102003 Result	Dup Result	RPD	Max RPD	Qualifiers
Alkalinity, Total as CaCO3	mg/L	185	184	1	20	

SAMPLE DUPLICATE: 2965957

Parameter	Units	35474130004 Result	Dup Result	RPD	Max RPD	Qualifiers
Alkalinity, Total as CaCO3	mg/L	416	427	3	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35473138

QC Batch: 545376 Analysis Method: SM 2540C
QC Batch Method: SM 2540C Analysis Description: 2540C Total Dissolved Solids
Associated Lab Samples: 35473138002, 35473138003

METHOD BLANK: 2954618 Matrix: Water
Associated Lab Samples: 35473138002, 35473138003

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Total Dissolved Solids	mg/L	5.0 U	5.0	5.0	06/11/19 14:14	

LABORATORY CONTROL SAMPLE: 2954619

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Total Dissolved Solids	mg/L	300	301	100	90-110	

SAMPLE DUPLICATE: 2954620

Parameter	Units	35472563003 Result	Dup Result	RPD	Max RPD	Qualifiers
Total Dissolved Solids	mg/L	2000	2060	3	5	

SAMPLE DUPLICATE: 2954621

Parameter	Units	35473434001 Result	Dup Result	RPD	Max RPD	Qualifiers
Total Dissolved Solids	mg/L	15900	16600	4	5	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35473138

QC Batch: 547454
Analysis Method: EPA 300.0
QC Batch Method: EPA 300.0
Analysis Description: 300.0 IC Anions
Associated Lab Samples: 35473138002, 35473138003

METHOD BLANK: 2966826
Matrix: Water
Associated Lab Samples: 35473138002, 35473138003

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Chloride	mg/L	2.5 U	5.0	2.5	06/19/19 12:17	
Sulfate	mg/L	2.5 U	5.0	2.5	06/19/19 12:17	

LABORATORY CONTROL SAMPLE: 2966827

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Chloride	mg/L	50	50.8	102	90-110	
Sulfate	mg/L	50	50.0	100	90-110	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2970304 2970305

Parameter	Units	35473138002 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Chloride	mg/L	53.6	50	50	111	111	115	115	90-110	0	20	J(M1), L
Sulfate	mg/L	5.5	50	50	56.5	56.1	102	101	90-110	1	20	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2970306 2970307

Parameter	Units	35474086008 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Chloride	mg/L	26.4	50	50	81.0	83.0	109	113	90-110	2	20	J(M1)
Sulfate	mg/L	8.2	50	50	58.1	60.3	100	104	90-110	4	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35473138

QC Batch: 544521
Analysis Method: EPA 353.2
QC Batch Method: EPA 353.2
Analysis Description: 353.2 Nitrate + Nitrite, Unpres.
Associated Lab Samples: 35473138002, 35473138003

METHOD BLANK: 2950020
Matrix: Water
Associated Lab Samples: 35473138002, 35473138003

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Nitrogen, Nitrate	mg/L	0.025 U	0.050	0.025	06/07/19 08:56	

SAMPLE DUPLICATE: 2950022

Parameter	Units	35473102001 Result	Dup Result	RPD	Max RPD	Qualifiers
Nitrogen, Nitrate	mg/L	0.058	0.057	0	20	

SAMPLE DUPLICATE: 2950024

Parameter	Units	35472894004 Result	Dup Result	RPD	Max RPD	Qualifiers
Nitrogen, Nitrate	mg/L	0.61	0.62	1	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35473138

QC Batch: 547277
Analysis Method: SM 5310B
QC Batch Method: SM 5310B
Analysis Description: 5310B TOC
Associated Lab Samples: 35473138007, 35473138009

METHOD BLANK: 2965781
Matrix: Water
Associated Lab Samples: 35473138007, 35473138009

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Total Organic Carbon	mg/L	0.50 U	1.0	0.50	06/19/19 07:37	

LABORATORY CONTROL SAMPLE: 2965782

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Total Organic Carbon	mg/L	20	18.8	94	90-110	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2965785 2965786

Parameter	Units	35474130004 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Total Organic Carbon	mg/L	14.2	20	20	33.4	34.4	96	101	80-120	3	20	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2966213 2966214

Parameter	Units	35473138007 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Total Organic Carbon	mg/L	5.7	20	20	25.3	25.2	98	97	80-120	1	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALIFIERS

Project:	Fort Lauderdale
Pace Project No.:	35473138

DEFINITIONS

DF - Dilution Factor, if reported, represents the factor applied to the reported data due to dilution of the sample aliquot.

ND - Not Detected at or above adjusted reporting limit.

TNTC - Too Numerous To Count

MDL - Adjusted Method Detection Limit.

PQL - Practical Quantitation Limit.

RL - Reporting Limit - The lowest concentration value that meets project requirements for quantitative data with known precision and bias for a specific analyte in a specific matrix.

S - Surrogate

1,2-Diphenylhydrazine decomposes to and cannot be separated from Azobenzene using Method 8270. The result for each analyte is a combined concentration.

Consistent with EPA guidelines, unrounded data are displayed and have been used to calculate % recovery and RPD values.

LCS(D) - Laboratory Control Sample (Duplicate)

MS(D) - Matrix Spike (Duplicate)

DUP - Sample Duplicate

RPD - Relative Percent Difference

NC - Not Calculable.

SG - Silica Gel - Clean-Up

U - Indicates the compound was analyzed for, but not detected.

N-Nitrosodiphenylamine decomposes and cannot be separated from Diphenylamine using Method 8270. The result reported for each analyte is a combined concentration.

Pace Analytical is TNI accredited. Contact your Pace PM for the current list of accredited analytes.

TNI - The NELAC Institute.

LABORATORIES

PASI-O	Pace Analytical Services - Ormond Beach

ANALYTE QUALIFIERS

U	Compound was analyzed for but not detected.
J(M1)	Estimated Value. Matrix spike recovery exceeded QC limits. Batch accepted based on laboratory control sample (LCS) recovery.
L	Off-scale high. Actual value is known to be greater than value given.
Q	Sample held beyond the accepted holding time. Sample was received outside EPA method holding time.

QUALITY CONTROL DATA CROSS REFERENCE TABLE

Project:	Fort Lauderdale
Pace Project No.:	35473138

Lab ID	Sample ID	QC Batch Method	QC Batch	Analytical Method	Analytical Batch
35473138006	**MIEX SETTLED 3**	EPA 200.7	544516	EPA 200.7	544529
35473138008	**MIEX RAW 3**	EPA 200.7	544516	EPA 200.7	544529
35473138002	**MIEX RAW 2**	SM2120B-01	544520		
35473138003	**MIEX SETTLED 1**	SM2120B-01	544520		
35473138001	**MIEX RAW 1**	SM 2320B	547313		
35473138004	**MIEX SETTLED 2**	SM 2320B	547313		
35473138002	**MIEX RAW 2**	SM 2540C	545376		
35473138003	**MIEX SETTLED 1**	SM 2540C	545376		
35473138002	**MIEX RAW 2**	EPA 300.0	547454		
35473138003	**MIEX SETTLED 1**	EPA 300.0	547454		
35473138002	**MIEX RAW 2**	EPA 353.2	544521		
35473138003	**MIEX SETTLED 1**	EPA 353.2	544521		
35473138007	**MIEX SETTLED 4**	SM 5310B	547277		
35473138009	**MIEX RAW 4**	SM 5310B	547277		

WO#: 35473138

35473138

Pace Analytical
www.pacelabs.com

CHAIN-OF-CUSTODY / Analytical Request Document

The Chain-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately.

Page : 1 **Of** 1

Section A
Required Client Information:

Company: Carollo Engineers
Address: 2056 Vista Parkway, Suite 400
West Palm Beach, FL 33411
Email: etorres@carollo.com
Phone: 914-987-9494 Fax:
Requested Due Date:

Section B
Required Project Information:

Report To: Torres, Eduardo
Copy To:
Purchase Order #:
Project Name: Fort Lauderdale
Project #: 11484800 - 700

Section C
Invoice Information:

Attention:
Company Name:
Address:
Pace Quote:
Pace Project Manager: lisa.harvey@pacelabs.com,
Pace Profile #: 11950

Regulatory Agency

State / Location
FL

SAMPLE ID
One Character per box.
(A-Z, 0-9 / , -)
Sample Ids must be unique

MATRIX	CODE
Drinking Water	DW
Water	WT
Waste Water	WW
Product	P
Soil/Solid	SL
Oil	OL
Wipe	WP
Air	AR
Other	OT
Tissue	TS

ITEM #	SAMPLE ID	MATRIX CODE (see valid codes to left)	SAMPLE TYPE (G=GRAB C=COMP)	COLLECTED START DATE	COLLECTED START TIME	COLLECTED END DATE	COLLECTED END TIME	SAMPLE TEMP AT COLLECTION	# OF CONTAINERS	Preservatives: Unpreserved	H2SO4	HNO3	HCl	NaOH	Na2S2O3	Methanol	Other	Analyses Test Y/N	Requested Analysis Filtered (Y/N): Sulfide	Alkalinity	UV254	Mg and hardness-200.7	Mg-200.7	color,NO3,Cl,SO4,TDS	TOC	1L plastic for field use					Residual Chlorine (Y/N)	
1	[redacted]	WT																	[redacted]	[redacted]	[redacted]	[redacted]										[redacted]
2	[redacted]	WT																	X	[redacted]	[redacted]	[redacted]										[redacted]
3	MIEX RAW 1	WT	G			6/5/19	1300													X												
4	MIEX RAW 2	WT	G																					X								
5	MIEX SETTLED 1	WT	G																					X								
6	MIEX SETTLED 2	WT	G																	X												
7	MIEX FILTERED	WT	G																							X						
8	MIEX SETTLED 3	WT	G									X										X										
9	[illegible]EX SETTLED 4	WT	G										X												X							
10	MIEX RAW 3	WT	G									X										X										
11	MIEX RAW 4	WT	G										X												X							
12	RAW FILTERED	WT	C																							X						

ADDITIONAL COMMENTS	RELINQUISHED BY / AFFILIATION	DATE	TIME	ACCEPTED BY / AFFILIATION	DATE	TIME	SAMPLE CONDITIONS			
				TCH/PACE	6-6-19	09:39	11.0	Y	N	Y
							TEMP in C	Received on Ice (Y/N)	Custody Sealed Cooler (Y/N)	Samples Intact (Y/N)

SAMPLER NAME AND SIGNATURE

PRINT Name of SAMPLER: EDUARDO TORRES
SIGNATURE of SAMPLER: Eduardo Torres **DATE Signed:** 06/5/19

Date/time = 6/5/19 @ 1300 per bottles
— lmh 6/7/19

Pace Analytical Florida Laboratory	Document Name: Sample Condition Upon Receipt Form	Document Revised: May 30, 2018
	Document No.: F-FL-C-007 rev. 13	Issuing Authority: Pace Florida Quality Office

rm (SCUR)

WO#: 35473138
PM: LMH Due Date: 06/20/19
CLIENT: CARENG

Projec
Project Manag
Clien

Date and Initials of person:
Examining contents:
Label:
Deliver: TC7
pH:

Thermometer Used: T-357 Date: 6.6.19 Time: 1110 Initials: I.R.

State of Origin: ☐ For WV projects, all containers verified to ≤6 °C

Cooler #1 Temp.°C 10.9 **(Visual)** +.1 **(Correction Factor)** 11.0 **(Actual)** ☐ Samples on ice, cooling process has begun
Cooler #2 Temp.°C ____ **(Visual)** ____ **(Correction Factor)** ____ **(Actual)** ☐ Samples on ice, cooling process has begun
Cooler #3 Temp.°C ____ **(Visual)** ____ **(Correction Factor)** ____ **(Actual)** ☐ Samples on ice, cooling process has begun
Cooler #4 Temp.°C ____ **(Visual)** ____ **(Correction Factor)** ____ **(Actual)** ☐ Samples on ice, cooling process has begun
Cooler #5 Temp.°C ____ **(Visual)** ____ **(Correction Factor)** ____ **(Actual)** ☐ Samples on ice, cooling process has begun
Cooler #6 Temp.°C ____ **(Visual)** ____ **(Correction Factor)** ____ **(Actual)** ☐ Samples on ice, cooling process has begun

Courier: ☐ Fed Ex ☐ UPS ☑ USPS ☐ Client ☐ Commercial ☐ Pace ☐ Other

Shipping Method: ☐ First Overnight ☐ Priority Overnight ☐ Standard Overnight ☐ Ground ☐ International Priority ☐ Other

Billing: ☐ Recipient ☐ Sender ☐ Third Party ☐ Credit Card ☐ Unknown

Tracking # [illegible]

Custody Seal on Cooler/Box Present: ☐ Yes ☒ No **Seals intact:** ☐ Yes ☐ No **Ice:** [✓ Wet] Blue Dry None

Packing Material: ☐ Bubble Wrap ☑ Bubble Bags ☐ None ☐ Other

Samples shorted to lab (If Yes, complete) Shorted Date: Shorted Time: Qty:

		Comments:
Chain of Custody Present	☑ Yes ☐ No ☐ N/A	
Chain of Custody Filled Out	☐ Yes ☑ No ☐ N/A	Missing Dates/time
Relinquished Signature & Sampler Name COC	☐ Yes ☑ No ☐ N/A	
Samples Arrived within Hold Time	☑ Yes ☐ No ☐ N/A	
Rush TAT requested on COC	☐ Yes ☑ No ☐ N/A	
Sufficient Volume	☑ Yes ☐ No ☐ N/A	
Correct Containers Used	☑ Yes ☐ No ☐ N/A	
Containers Intact	☑ Yes ☐ No ☐ N/A	
Sample Labels match COC (sample IDs & date/time of collection)	☑ Yes ☐ No ☐ N/A	
All containers needing acid/base preservation have been checked.	☑ Yes ☐ No ☐ N/A	Preservation Information:
All Containers needing preservation are found to be in compliance with EPA recommendation: Exceptions: VOA, Coliform, TOC, O&G, Carbamates	☑ Yes ☐ No ☐ N/A	Preservative: Lot #/Trace #: Date: Time: Initials:
Headspace in VOA Vials? (>6mm):	☐ Yes ☐ No ☑ N/A	
Trip Blank Present:	☐ Yes ☐ No ☑ N/A	

Client Notification/ Resolution:
Person Contacted: Date/Time:

Comments/ Resolution (use back for additional comments): Got OK to run per P.M.
6/5/19 @ 1300 per bottles. -Lmh
Client notified of Rcpt temp 6/6/19 - LMH

Project Manager Review: Date:

Pace Analytical Services, LLC
8 East Tower Circle
Ormond Beach, FL 32174
(386)672-5668

June 24, 2019

Eduardo Torres
Carollo Engineers, Inc.
2056 Vista Parkway, Suite 400
West Palm Beach, FL 33411

RE: Project: Fort Lauderdale
Pace Project No.: 35473267

Dear Eduardo Torres:

Enclosed are the analytical results for sample(s) received by the laboratory on June 07, 2019. The results relate only to the samples included in this report. Results reported herein conform to the most current, applicable TNI/NELAC standards and the laboratory's Quality Assurance Manual, where applicable, unless otherwise noted in the body of the report.

If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Lisa Harvey
lisa.harvey@pacelabs.com
(386) 672-5668
Project Manager

Enclosures

CERTIFICATIONS

Project: Fort Lauderdale
Pace Project No.: 35473267

Ormond Beach Certification IDs

8 East Tower Circle, Ormond Beach, FL 32174
Alaska DEC- CS/UST/LUST
Alabama Certification #: 41320
Arizona Certification# AZ0819
Colorado Certification: FL NELAC Reciprocity
Connecticut Certification #: PH-0216
Delaware Certification: FL NELAC Reciprocity
Florida Certification #: E83079
Georgia Certification #: 955
Guam Certification: FL NELAC Reciprocity
Hawaii Certification: FL NELAC Reciprocity
Illinois Certification #: 200068
Indiana Certification: FL NELAC Reciprocity
Kansas Certification #: E-10383
Kentucky Certification #: 90050
Louisiana Certification #: FL NELAC Reciprocity
Louisiana Environmental Certificate #: 05007
Maryland Certification: #346
Michigan Certification #: 9911
Mississippi Certification: FL NELAC Reciprocity
Missouri Certification #: 236
Montana Certification #: Cert 0074
Nebraska Certification: NE-OS-28-14
New Hampshire Certification #: 2958
New Jersey Certification #: FL022
New York Certification #: 11608
North Carolina Environmental Certificate #: 667
North Carolina Certification #: 12710
North Dakota Certification #: R-216
Oklahoma Certification #: D9947
Pennsylvania Certification #: 68-00547
Puerto Rico Certification #: FL01264
South Carolina Certification: #96042001
Tennessee Certification #: TN02974
Texas Certification: FL NELAC Reciprocity
US Virgin Islands Certification: FL NELAC Reciprocity
Virginia Environmental Certification #: 460165
West Virginia Certification #: 9962C
Wisconsin Certification #: 399079670
Wyoming (EPA Region 8): FL NELAC Reciprocity

SAMPLE SUMMARY

Project:	Fort Lauderdale
Pace Project No.:	35473267

Lab ID	Sample ID	Matrix	Date Collected	Date Received
35473267001	**IX INFLUENT 1**	Water	06/06/19 12:00	06/07/19 10:35
35473267002	**IX 120-1**	Water	06/06/19 12:00	06/07/19 10:35
35473267003	**IX 180-1**	Water	06/06/19 12:00	06/07/19 10:35
35473267004	**IX INFLUENT 2**	Water	06/06/19 12:00	06/07/19 10:35
35473267005	**IX 120-2**	Water	06/06/19 12:00	06/07/19 10:35
35473267006	**IX 180-2**	Water	06/06/19 12:00	06/07/19 10:35
35473267007	**IX INFLUENT 3**	Water	06/06/19 12:00	06/07/19 10:35
35473267008	**IX 120-3**	Water	06/06/19 12:00	06/07/19 10:35
35473267009	**IX 180-3**	Water	06/06/19 12:00	06/07/19 10:35
35473267010	**IX INFLUENT 4**	Water	06/06/19 12:00	06/07/19 10:35
35473267011	**IX 120-4**	Water	06/06/19 12:00	06/07/19 10:35
35473267012	**IX 180-4**	Water	06/06/19 12:00	06/07/19 10:35
35473267013	**IX INFLUENT 5**	Water	06/06/19 12:00	06/07/19 10:35
35473267014	**IX 120-5**	Water	06/06/19 12:00	06/07/19 10:35
35473267015	**IX 180-5**	Water	06/06/19 12:00	06/07/19 10:35
35473267016	**IX INFLUENT 6**	Water	06/06/19 12:00	06/07/19 10:35
35473267017	**IX 120-6**	Water	06/06/19 12:00	06/07/19 10:35
35473267018	**IX 180-6**	Water	06/06/19 12:00	06/07/19 10:35
35473267019	**IX INFLUENT 7**	Water	06/06/19 12:00	06/07/19 10:35
35473267020	**IX 120-7**	Water	06/06/19 12:00	06/07/19 10:35
35473267021	**IX 180-7**	Water	06/06/19 12:00	06/07/19 10:35

SAMPLE ANALYTE COUNT

Project: Fort Lauderdale
Pace Project No.: 35473267

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
35473267001	**IX INFLUENT 1**	SM 2540C	MRS	1	PASI-O
		EPA 300.0	JDM	2	PASI-O
		EPA 353.2	AMP	1	PASI-O
35473267002	**IX 120-1**	SM 2540C	MRS	1	PASI-O
		EPA 300.0	JDM	2	PASI-O
		EPA 353.2	AMP	1	PASI-O
35473267003	**IX 180-1**	SM 2540C	MRS	1	PASI-O
		EPA 300.0	JDM	2	PASI-O
		EPA 353.2	AMP	1	PASI-O
35473267004	**IX INFLUENT 2**	SM 5910	JDW	1	PASI-O
35473267005	**IX 120-2**	SM 5910	JDW	1	PASI-O
35473267006	**IX 180-2**	SM 5910	JDW	1	PASI-O
35473267007	**IX INFLUENT 3**	SM2120B-01	AMP	2	PASI-O
35473267008	**IX 120-3**	SM2120B-01	AMP	2	PASI-O
35473267009	**IX 180-3**	SM2120B-01	AMP	2	PASI-O
35473267010	**IX INFLUENT 4**	EPA 200.7	JWP	1	PASI-O
35473267011	**IX 120-4**	EPA 200.7	JWP	1	PASI-O
35473267012	**IX 180-4**	EPA 200.7	JWP	1	PASI-O
35473267013	**IX INFLUENT 5**	EPA 200.7	JWP	4	PASI-O
35473267014	**IX 120-5**	EPA 200.7	JWP	4	PASI-O
35473267015	**IX 180-5**	EPA 200.7	JWP	4	PASI-O
35473267016	**IX INFLUENT 6**	SM 2320B	AGS	1	PASI-O
35473267017	**IX 120-6**	SM 2320B	AGS	1	PASI-O
35473267018	**IX 180-6**	SM 2320B	AGS	1	PASI-O
35473267019	**IX INFLUENT 7**	SM 5310B	SA1	1	PASI-O
35473267020	**IX 120-7**	SM 5310B	SA1	1	PASI-O
35473267021	**IX 180-7**	SM 5310B	SA1	1	PASI-O

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35473267

Sample: IX INFLUENT 1 **Lab ID: 35473267001** Collected: 06/06/19 12:00 Received: 06/07/19 10:35 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
2540C Total Dissolved Solids	Analytical Method: SM 2540C								
Total Dissolved Solids	**202**	mg/L	5.0	5.0	1		06/11/19 15:54		
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Chloride	**61.2**	mg/L	5.0	2.5	1		06/21/19 20:49	16887-00-6	
Sulfate	**5.7**	mg/L	5.0	2.5	1		06/21/19 20:49	14808-79-8	
353.2 Nitrogen, NO2/NO3 unpres	Analytical Method: EPA 353.2								
Nitrogen, Nitrate	**0.067**	mg/L	0.050	0.025	1		06/07/19 17:31	14797-55-8	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35473267

Sample: IX 120-1 **Lab ID: 35473267002** Collected: 06/06/19 12:00 Received: 06/07/19 10:35 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
2540C Total Dissolved Solids	Analytical Method: SM 2540C								
Total Dissolved Solids	**229**	mg/L	5.0	5.0	1		06/11/19 15:54		
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Chloride	**109**	mg/L	10.0	5.0	2		06/22/19 06:25	16887-00-6	
Sulfate	**2.5 U**	mg/L	5.0	2.5	1		06/21/19 21:11	14808-79-8	
353.2 Nitrogen, NO2/NO3 unpres	Analytical Method: EPA 353.2								
Nitrogen, Nitrate	**0.025 U**	mg/L	0.050	0.025	1		06/07/19 17:33	14797-55-8	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35473267

Sample: IX 180-1 **Lab ID: 35473267003** Collected: 06/06/19 12:00 Received: 06/07/19 10:35 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
2540C Total Dissolved Solids	Analytical Method: SM 2540C								
Total Dissolved Solids	**247**	mg/L	5.0	5.0	1		06/11/19 15:54		
300.0 IC Anions 28 Days	Analytical Method: EPA 300.0								
Chloride	**97.7**	mg/L	10.0	5.0	2		06/22/19 06:48	16887-00-6	
Sulfate	**2.5 U**	mg/L	5.0	2.5	1		06/21/19 21:33	14808-79-8	
353.2 Nitrogen, NO2/NO3 unpres	Analytical Method: EPA 353.2								
Nitrogen, Nitrate	**0.025 U**	mg/L	0.050	0.025	1		06/07/19 17:36	14797-55-8	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35473267

Sample: IX INFLUENT 2 **Lab ID: 35473267004** Collected: 06/06/19 12:00 Received: 06/07/19 10:35 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
UV254	Analytical Method: SM 5910								
U254 UV Absorbing Organic	**0.24**	cm-1	0.0050	0.0016	1		06/08/19 11:21		

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35473267

Sample: IX 120-2 **Lab ID: 35473267005** Collected: 06/06/19 12:00 Received: 06/07/19 10:35 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
UV254	Analytical Method: SM 5910								
U254 UV Absorbing Organic	**0.023**	cm-1	0.0050	0.0016	1		06/08/19 11:21		

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35473267

Sample: IX 180-2 **Lab ID: 35473267006** Collected: 06/06/19 12:00 Received: 06/07/19 10:35 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
UV254	Analytical Method: SM 5910								
U254 UV Absorbing Organic	**0.023**	cm-1	0.0050	0.0016	1		06/08/19 11:21		

REPORT OF LABORATORY ANALYSIS

ANALYTICAL RESULTS

Project:	Fort Lauderdale
Pace Project No.:	35473267

Sample: IX INFLUENT 3 **Lab ID: 35473267007** Collected: 06/06/19 12:00 Received: 06/07/19 10:35 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
2120B Apparent Color	Analytical Method: SM2120B-01								
Apparent Color	**10.0**	units	5.0	5.0	1		06/07/19 18:43		
pH	**9.2**	units			1		06/07/19 18:43		

ANALYTICAL RESULTS

Project:	Fort Lauderdale
Pace Project No.:	35473267

Sample: IX 120-3 **Lab ID: 35473267008** Collected: 06/06/19 12:00 Received: 06/07/19 10:35 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
2120B Apparent Color	Analytical Method: SM2120B-01								
Apparent Color	**5.0 U**	units	5.0	5.0	1		06/07/19 18:43		
pH	**7.3**	units			1		06/07/19 18:43		

ANALYTICAL RESULTS

Project:	Fort Lauderdale
Pace Project No.:	35473267

Sample: IX 180-3 **Lab ID: 35473267009** Collected: 06/06/19 12:00 Received: 06/07/19 10:35 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
2120B Apparent Color	Analytical Method: SM2120B-01								
Apparent Color	**5.0 U**	units	5.0	5.0	1		06/07/19 18:43		
pH	**7.4**	units			1		06/07/19 18:43		

ANALYTICAL RESULTS

Project:	Fort Lauderdale
Pace Project No.:	35473267

Sample: IX INFLUENT 4 **Lab ID: 35473267010** Collected: 06/06/19 12:00 Received: 06/07/19 10:35 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Magnesium	**6.5**	mg/L	0.50	0.084	1	06/08/19 06:18	06/09/19 19:26	7439-95-4	

ANALYTICAL RESULTS

Project:	Fort Lauderdale
Pace Project No.:	35473267

Sample: IX 120-4 **Lab ID: 35473267011** Collected: 06/06/19 12:00 Received: 06/07/19 10:35 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Magnesium	**6.2**	mg/L	0.50	0.084	1	06/08/19 06:18	06/09/19 19:39	7439-95-4	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35473267

Sample: IX 180-4 **Lab ID: 35473267012** Collected: 06/06/19 12:00 Received: 06/07/19 10:35 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Magnesium	**6.2**	mg/L	0.50	0.084	1	06/08/19 06:18	06/09/19 19:43	7439-95-4	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35473267

Sample: IX INFLUENT 5 **Lab ID: 35473267013** Collected: 06/06/19 12:00 Received: 06/07/19 10:35 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Ca Hardness as CaCO3 (SM 2340B	**58.2**	mg/L	1.2	0.16	1	06/08/19 06:18	06/09/19 19:47		
Mg Hardness as CaCO3 (SM 2340B	**26.6**	mg/L	2.1	0.35	1	06/08/19 06:18	06/09/19 19:47		
Magnesium	**6.5**	mg/L	0.50	0.084	1	06/08/19 06:18	06/09/19 19:47	7439-95-4	
Tot Hardness asCaCO3 (SM 2340B	**84.8**	mg/L	3.3	0.51	1	06/08/19 06:18	06/09/19 19:47		

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35473267

Sample: IX 120-5 **Lab ID: 35473267014** Collected: 06/06/19 12:00 Received: 06/07/19 10:35 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Ca Hardness as CaCO3 (SM 2340B	**54.2**	mg/L	1.2	0.16	1	06/08/19 06:18	06/09/19 19:51		
Mg Hardness as CaCO3 (SM 2340B	**25.2**	mg/L	2.1	0.35	1	06/08/19 06:18	06/09/19 19:51		
Magnesium	**6.1**	mg/L	0.50	0.084	1	06/08/19 06:18	06/09/19 19:51	7439-95-4	
Tot Hardness asCaCO3 (SM 2340B	**79.4**	mg/L	3.3	0.51	1	06/08/19 06:18	06/09/19 19:51		

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35473267

Sample: IX 180-5 **Lab ID: 35473267015** Collected: 06/06/19 12:00 Received: 06/07/19 10:35 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Ca Hardness as CaCO3 (SM 2340B	**55.8**	mg/L	1.2	0.16	1	06/08/19 06:18	06/09/19 19:55		
Mg Hardness as CaCO3 (SM 2340B	**25.7**	mg/L	2.1	0.35	1	06/08/19 06:18	06/09/19 19:55		
Magnesium	**6.2**	mg/L	0.50	0.084	1	06/08/19 06:18	06/09/19 19:55	7439-95-4	
Tot Hardness asCaCO3 (SM 2340B	**81.5**	mg/L	3.3	0.51	1	06/08/19 06:18	06/09/19 19:55		

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35473267

Sample: IX INFLUENT 6 **Lab ID: 35473267016** Collected: 06/06/19 12:00 Received: 06/07/19 10:35 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity, Total as CaCO3	**74.3**	mg/L	5.0	5.0	1		06/19/19 16:02		

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35473267

Sample: IX 120-6 **Lab ID: 35473267017** Collected: 06/06/19 12:00 Received: 06/07/19 10:35 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity, Total as CaCO3	**16.8**	mg/L	5.0	5.0	1		06/19/19 16:13		

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35473267

Sample: IX 180-6 **Lab ID: 35473267018** Collected: 06/06/19 12:00 Received: 06/07/19 10:35 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
2320B Alkalinity	Analytical Method: SM 2320B								
Alkalinity, Total as CaCO3	**29.6**	mg/L	5.0	5.0	1		06/19/19 16:18		

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35473267

Sample: IX INFLUENT 7 **Lab ID: 35473267019** Collected: 06/06/19 12:00 Received: 06/07/19 10:35 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**8.2**	mg/L	1.0	0.50	1		06/19/19 21:52	7440-44-0	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35473267

Sample: IX 120-7 **Lab ID: 35473267020** Collected: 06/06/19 12:00 Received: 06/07/19 10:35 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**1.1**	mg/L	1.0	0.50	1		06/19/19 22:04	7440-44-0	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35473267

Sample: IX 180-7 **Lab ID: 35473267021** Collected: 06/06/19 12:00 Received: 06/07/19 10:35 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**1.1**	mg/L	1.0	0.50	1		06/19/19 22:19	7440-44-0	

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35473267

QC Batch: 544862
Analysis Method: EPA 200.7
QC Batch Method: EPA 200.7
Analysis Description: 200.7 MET
Associated Lab Samples: 35473267010, 35473267011, 35473267012, 35473267013, 35473267014, 35473267015

METHOD BLANK: 2952224
Matrix: Water
Associated Lab Samples: 35473267010, 35473267011, 35473267012, 35473267013, 35473267014, 35473267015

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Ca Hardness as CaCO3 (SM 2340B	mg/L	0.16 U	1.2	0.16	06/09/19 19:18	
Magnesium	mg/L	0.084 U	0.50	0.084	06/09/19 19:18	
Mg Hardness as CaCO3 (SM 2340B	mg/L	0.35 U	2.1	0.35	06/09/19 19:18	
Tot Hardness asCaCO3 (SM 2340B	mg/L	0.51 U	3.3	0.51	06/09/19 19:18	

LABORATORY CONTROL SAMPLE: 2952225

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Ca Hardness as CaCO3 (SM 2340B	mg/L	31.2	31.4	100	85-115	
Magnesium	mg/L	12.5	12.5	100	85-115	
Mg Hardness as CaCO3 (SM 2340B	mg/L	51.5	51.5	100	85-115	
Tot Hardness asCaCO3 (SM 2340B	mg/L	82.7	82.9	100	85-115	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2952226 2952227

Parameter	Units	35473267010 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Ca Hardness as CaCO3 (SM 2340B	mg/L	58.7	31.2	31.2	89.5	89.8	99	100	70-130	0	20	
Magnesium	mg/L	6.5	12.5	12.5	19.1	19.1	101	101	70-130	0	20	
Mg Hardness as CaCO3 (SM 2340B	mg/L	26.7	51.5	51.5	78.6	78.7	101	101	70-130	0	20	
Tot Hardness asCaCO3 (SM 2340B	mg/L	85.3	82.7	82.7	168	168	100	101	70-130	0	20	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2952228 2952229

Parameter	Units	35473323004 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Ca Hardness as CaCO3 (SM 2340B	mg/L	723000 ug/L	31.2	31.2	752	748	93	80	70-130	1	20	
Magnesium	mg/L		12.5	12.5	252	252	90	83	70-130	0	20	L
Mg Hardness as CaCO3 (SM 2340B	mg/L	993000 ug/L	51.5	51.5	1040	1040	90	83	70-130	0	20	
Tot Hardness asCaCO3 (SM 2340B	mg/L	1720000 ug/L	82.7	82.7	1790	1780	91	82	70-130	0	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35473267

QC Batch: 544765
Analysis Method: SM2120B-01
QC Batch Method: SM2120B-01
Analysis Description: 2120B Color
Associated Lab Samples: 35473267007, 35473267008, 35473267009

METHOD BLANK: 2951349
Matrix: Water
Associated Lab Samples: 35473267007, 35473267008, 35473267009

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Apparent Color	units	5.0 U	5.0	5.0	06/07/19 18:43	
pH	units	6.1			06/07/19 18:43	

SAMPLE DUPLICATE: 2951350

Parameter	Units	35473267007 Result	Dup Result	RPD	Max RPD	Qualifiers
Apparent Color	units	10.0	10.0	0	20	
pH	units	9.2	9.2	0		

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35473267

QC Batch: 547624
Analysis Method: SM 2320B
QC Batch Method: SM 2320B
Analysis Description: 2320B Alkalinity
Associated Lab Samples: 35473267016, 35473267017, 35473267018

METHOD BLANK: 2967878
Matrix: Water
Associated Lab Samples: 35473267016, 35473267017, 35473267018

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Alkalinity, Total as CaCO3	mg/L	5.0 U	5.0	5.0	06/19/19 14:27	

LABORATORY CONTROL SAMPLE: 2967879

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Alkalinity, Total as CaCO3	mg/L	252	262	104	90-110	

SAMPLE DUPLICATE: 2967880

Parameter	Units	35474543002 Result	Dup Result	RPD	Max RPD	Qualifiers
Alkalinity, Total as CaCO3	mg/L	241	242	1	20	

SAMPLE DUPLICATE: 2967881

Parameter	Units	35473267016 Result	Dup Result	RPD	Max RPD	Qualifiers
Alkalinity, Total as CaCO3	mg/L	74.3	73.0	2	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35473267

QC Batch: 545493
Analysis Method: SM 2540C
QC Batch Method: SM 2540C
Analysis Description: 2540C Total Dissolved Solids
Associated Lab Samples: 35473267001, 35473267002, 35473267003

METHOD BLANK: 2955189
Matrix: Water
Associated Lab Samples: 35473267001, 35473267002, 35473267003

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Total Dissolved Solids	mg/L	5.0 U	5.0	5.0	06/11/19 15:54	

LABORATORY CONTROL SAMPLE: 2955190

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Total Dissolved Solids	mg/L	300	300	100	90-110	

SAMPLE DUPLICATE: 2955191

Parameter	Units	35473267001 Result	Dup Result	RPD	Max RPD	Qualifiers
Total Dissolved Solids	mg/L	202	204	1	5	

SAMPLE DUPLICATE: 2955192

Parameter	Units	35473435003 Result	Dup Result	RPD	Max RPD	Qualifiers
Total Dissolved Solids	mg/L	830	814	2	5	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35473267

QC Batch: 544699 Analysis Method: SM 5910
QC Batch Method: SM 5910 Analysis Description: UV254 UV Absorbing Organics
Associated Lab Samples: 35473267004, 35473267005, 35473267006

METHOD BLANK: 2950741 Matrix: Water
Associated Lab Samples: 35473267004, 35473267005, 35473267006

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
U254 UV Absorbing Organic	cm-1	0.0016 U	0.0050	0.0016	06/08/19 11:21	

LABORATORY CONTROL SAMPLE: 2950742

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
U254 UV Absorbing Organic	cm-1	0.009	0.0074	82	75-125	

SAMPLE DUPLICATE: 2950743

Parameter	Units	35473267004 Result	Dup Result	RPD	Max RPD	Qualifiers
U254 UV Absorbing Organic	cm-1	0.24	0.24	1	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35473267

QC Batch: 548157
QC Batch Method: EPA 300.0
Analysis Method: EPA 300.0
Analysis Description: 300.0 IC Anions
Associated Lab Samples: 35473267001, 35473267002, 35473267003

METHOD BLANK: 2970844 Matrix: Water
Associated Lab Samples: 35473267001, 35473267002, 35473267003

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Chloride	mg/L	2.5 U	5.0	2.5	06/21/19 18:58	
Sulfate	mg/L	2.5 U	5.0	2.5	06/21/19 18:58	

LABORATORY CONTROL SAMPLE: 2970845

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Chloride	mg/L	50	51.4	103	90-110	
Sulfate	mg/L	50	50.1	100	90-110	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2973997 2973998

Parameter	Units	92432828001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Chloride	mg/L	7.6	50	50	57.3	59.7	99	104	90-110	4	20	
Sulfate	mg/L	10.6	50	50	59.0	61.4	97	102	90-110	4	20	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2973999 2974000

Parameter	Units	35473416001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Chloride	mg/L	7.3	50	50	55.5	62.8	96	111	90-110	12	20	J(M1)
Sulfate	mg/L	14.6	50	50	62.5	69.8	96	110	90-110	11	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project:	Fort Lauderdale
Pace Project No.:	35473267

QC Batch: 544763 Analysis Method: EPA 353.2

QC Batch Method: EPA 353.2 Analysis Description: 353.2 Nitrate + Nitrite, Unpres.

Associated Lab Samples: 35473267001, 35473267002, 35473267003

METHOD BLANK: 2951340 Matrix: Water

Associated Lab Samples: 35473267001, 35473267002, 35473267003

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Nitrogen, Nitrate	mg/L	0.025 U	0.050	0.025	06/07/19 17:21	

SAMPLE DUPLICATE: 2951342

Parameter	Units	35473049001 Result	Dup Result	RPD	Max RPD	Qualifiers
Nitrogen, Nitrate	mg/L	3.7	3.7	1	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35473267

QC Batch: 547565
Analysis Method: SM 5310B
QC Batch Method: SM 5310B
Analysis Description: 5310B TOC
Associated Lab Samples: 35473267019, 35473267020, 35473267021

METHOD BLANK: 2967673
Matrix: Water
Associated Lab Samples: 35473267019, 35473267020, 35473267021

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Total Organic Carbon	mg/L	0.50 U	1.0	0.50	06/19/19 15:44	

LABORATORY CONTROL SAMPLE: 2967674

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Total Organic Carbon	mg/L	20	18.7	94	90-110	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2967675 2967676

Parameter	Units	35474130007 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Total Organic Carbon	mg/L	12.6	20	20	31.4	31.7	94	95	80-120	1	20	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2967677 2967678

Parameter	Units	20106451002 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Total Organic Carbon	mg/L	1.3	20	20	18.5	18.6	86	86	80-120	0	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALIFIERS

Project:	Fort Lauderdale
Pace Project No.:	35473267

DEFINITIONS

DF - Dilution Factor, if reported, represents the factor applied to the reported data due to dilution of the sample aliquot.

ND - Not Detected at or above adjusted reporting limit.

TNTC - Too Numerous To Count

MDL - Adjusted Method Detection Limit.

PQL - Practical Quantitation Limit.

RL - Reporting Limit - The lowest concentration value that meets project requirements for quantitative data with known precision and bias for a specific analyte in a specific matrix.

S - Surrogate

1,2-Diphenylhydrazine decomposes to and cannot be separated from Azobenzene using Method 8270. The result for each analyte is a combined concentration.

Consistent with EPA guidelines, unrounded data are displayed and have been used to calculate % recovery and RPD values.

LCS(D) - Laboratory Control Sample (Duplicate)

MS(D) - Matrix Spike (Duplicate)

DUP - Sample Duplicate

RPD - Relative Percent Difference

NC - Not Calculable.

SG - Silica Gel - Clean-Up

U - Indicates the compound was analyzed for, but not detected.

N-Nitrosodiphenylamine decomposes and cannot be separated from Diphenylamine using Method 8270. The result reported for each analyte is a combined concentration.

Pace Analytical is TNI accredited. Contact your Pace PM for the current list of accredited analytes.

TNI - The NELAC Institute.

LABORATORIES

PASI-O	Pace Analytical Services - Ormond Beach

ANALYTE QUALIFIERS

I	The reported value is between the laboratory method detection limit and the laboratory practical quantitation limit.
U	Compound was analyzed for but not detected.
J(M1)	Estimated Value. Matrix spike recovery exceeded QC limits. Batch accepted based on laboratory control sample (LCS) recovery.
L	Off-scale high. Actual value is known to be greater than value given.

QUALITY CONTROL DATA CROSS REFERENCE TABLE

Project: Fort Lauderdale
Pace Project No.: 35473267

Lab ID	Sample ID	QC Batch Method	QC Batch	Analytical Method	Analytical Batch
35473267010	**IX INFLUENT 4**	EPA 200.7	544862	EPA 200.7	544866
35473267011	**IX 120-4**	EPA 200.7	544862	EPA 200.7	544866
35473267012	**IX 180-4**	EPA 200.7	544862	EPA 200.7	544866
35473267013	**IX INFLUENT 5**	EPA 200.7	544862	EPA 200.7	544866
35473267014	**IX 120-5**	EPA 200.7	544862	EPA 200.7	544866
35473267015	**IX 180-5**	EPA 200.7	544862	EPA 200.7	544866
35473267007	**IX INFLUENT 3**	SM2120B-01	544765		
35473267008	**IX 120-3**	SM2120B-01	544765		
35473267009	**IX 180-3**	SM2120B-01	544765		
35473267016	**IX INFLUENT 6**	SM 2320B	547624		
35473267017	**IX 120-6**	SM 2320B	547624		
35473267018	**IX 180-6**	SM 2320B	547624		
35473267001	**IX INFLUENT 1**	SM 2540C	545493		
35473267002	**IX 120-1**	SM 2540C	545493		
35473267003	**IX 180-1**	SM 2540C	545493		
35473267004	**IX INFLUENT 2**	SM 5910	544699		
35473267005	**IX 120-2**	SM 5910	544699		
35473267006	**IX 180-2**	SM 5910	544699		
35473267001	**IX INFLUENT 1**	EPA 300.0	548157		
35473267002	**IX 120-1**	EPA 300.0	548157		
35473267003	**IX 180-1**	EPA 300.0	548157		
35473267001	**IX INFLUENT 1**	EPA 353.2	544763		
35473267002	**IX 120-1**	EPA 353.2	544763		
35473267003	**IX 180-1**	EPA 353.2	544763		
35473267019	**IX INFLUENT 7**	SM 5310B	547565		
35473267020	**IX 120-7**	SM 5310B	547565		
35473267021	**IX 180-7**	SM 5310B	547565		

WO#: 35473267

35473267

Pace Analytical
www.pacelabs.com

-OF-CUSTODY / Analytical Request Document

-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately.

Page : 1 Of 2

Section A
Required Client Information:

Company:	Carollo Engineering
Address:	20546 Vista Parkway
	Suite 400, West Palm Beach, FL 33411
Email To:	Eduardo Torres
Phone:	914-987-9494 Fax:
Requested Due Date:	std

Section B
Required Project Information:

Report To:	Eduardo Torres
Copy To:	
Purchase Order #:	
Project Name:	Fort Lauderdale
Project #:	

Section C
Invoice Information:

Attention:	Accounts Payable
Company Name:	Carollo
Address:	
Pace Quote:	
Pace Project Manager:	Lisa Harvey
Pace Profile #:	11950-1 or 2 (see notes)

Regulatory Agency
FL
State / Location
FL

MATRIX / CODE
Drinking Water DW
Water WT
Waste Water WW
Product P
Soil/Solid SL
Oil OL
Wipe WP
Air AR
Other OT
Tissue TS

Requested Analysis Filtered (Y/N)

ITEM #	SAMPLE ID One Character per box. (A-Z, 0-9 / , -) Sample Ids must be unique	MATRIX CODE (see valid codes to left)	SAMPLE TYPE (G=GRAB C=COMP)	COLLECTED START DATE	COLLECTED START TIME	COLLECTED END DATE	COLLECTED END TIME	SAMPLE TEMP AT COLLECTION	# OF CONTAINERS	Preservatives Unpreserved	H2SO4	HNO3	HCl	NaOH	Na2S2O3	Methanol	Other	Y/N Analyses Test	sulfide	color	UV254	Cl, SO4	NO3	TDS	Alkalinity	Mg + hardness	Mg	TOC			Residual Chlorine (Y/N)	
1	IX INFLUENT 1	WT		6/6	9AM	6/6	12:00			X											1	1	1	1								
2	IX 120-1	WT		6/6	9AM	6/6	12			X												1	1	1								
3	IX 180-1	WT		6/6	9AM	6/6	12			X												1	1	1								
4	IX INFLUENT 2	WT		6/6	9	6/6	12			X											1											
5	IX 120-2	WT		6-6	9	6/6	12			X											1											
6	IX 180-2	WT		6/6	9	6/6	12			X											1											
7	IX INFLUENT 3	WT		6/6	9	6/6	12			X										1												
8	IX 120-3	WT		6/6	9	6/6	12			X										1												
9	IX 180-3	WT		6/6	9	6/6	12			X										1												
10	IX INFLUENT 4	WT		6/6	9	6/6	12					X															1					
11	IX 120-4	WT		6/6	9	6/6	12					X															1					
12	IX 180 4	WT		6/6	9	6/6	12					X															1					

ADDITIONAL COMMENTS	RELINQUISHED BY / AFFILIATION	DATE	TIME	ACCEPTED BY / AFFILIATION	DATE	TIME	SAMPLE CONDITIONS			
11950-line 1: includes hardness										
11950-line 2: no hardness										
							TEMP in C	Received on Ice (Y/N)	Custody Sealed Cooler (Y/N)	Samples Intact (Y/N)

SAMPLER NAME AND SIGNATURE

PRINT Name of SAMPLER: EDUARDO TORRES

SIGNATURE of SAMPLER: Eduardo Torres

DATE Signed: 6/6/2019

Pace Analytical

CHAIN-OF-CUSTODY / Analytical Request Document

The Chain-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately.

Page : ~~1~~ 2 **Of** 2

Section A
Required Client Information:

Company:	Carollo Engineering
Address:	20546 Vista Parkway
	Suite 400, West Palm Beach, FL 33411
Email To:	Eduardo Torres
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Requested Due Date:	std

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Required Project Information:

Report To:	Eduardo Torres
Copy To:	
Purchase Order #:	
Project Name:	Fort Lauderdale
Project #:	

Section C
Invoice Information:

Attention:	Accounts Payable
Company Name:	Carollo
Address:	
Pace Quote:	
Pace Project Manager:	Lisa Harvey
Pace Profile #:	11950-1 or 2 (see notes)

Regulatory Agency	FL
State / Location	FL

SAMPLE ID
One Character per box.
(A-Z, 0-9 / , -)
Sample Ids must be unique

MATRIX	CODE
Drinking Water	DW
Water	WT
Waste Water	WW
Product	P
Soil/Solid	SL
Oil	OL
Wipe	WP
Air	AR
Other	OT
Tissue	TS

Requested Analysis Filtered (Y/N)

ITEM #	SAMPLE ID	MATRIX CODE (see valid codes to left)	SAMPLE TYPE (G=GRAB C=COMP)	COLLECTED START DATE	COLLECTED START TIME	COLLECTED END DATE	COLLECTED END TIME	SAMPLE TEMP AT COLLECTION	# OF CONTAINERS	Unpreserved	H2SO4	HNO3	HCl	NaOH	Na2S2O3	Methanol	Other	Analyses Test Y/N	sulfide	color	UV254	Cl, SO4	NO3	TDS	Alkalinity	Mg + hardness	Mg	TOC	Residual Chlorine (Y/N)
1	IX INFLUENT 5	WT		6/6	9AM	6/6	12					X														1			
2	IX 120-5	WT		6/6	9	6/6	12					X														1			
3	IX 180-5	WT		6/6	9	6/6	12					X														1			
4	IX INFLUENT 6	WT		6/6	9	6/6	12			X															1				
5	IX 120-6	WT		6/6	9	6/6	12			X															1				
6	IX 180-6	WT		6/6	9	6/6	12			X															1				
7	IX INFLUENT 7	WT		6/6	9	6/6	12						X															2	
8	IX 120-7	WT		6/6	9	6/6	12						X															2	
9	IX 180-7	WT		6/6	9	6/6	12						X															2	
10																													
11																													
12																													

ADDITIONAL COMMENTS	RELINQUISHED BY / AFFILIATION	DATE	TIME	ACCEPTED BY / AFFILIATION	DATE	TIME	SAMPLE CONDITIONS
11950-line 1: includes hardness					6/7/19	1035	
11950-line 2: no hardness					19.7 -3.53		

SAMPLER NAME AND SIGNATURE

PRINT Name of SAMPLER: EDUARDO TORRES

SIGNATURE of SAMPLER: Eduardo Torres

DATE Signed: 6/6/2019

TEMP in C	Received on Ice (Y/N)	Custody Sealed Cooler (Y/N)	Samples Intact (Y/N)

Pace Analytical Florida Laboratory	Document Name: Sample Condition Upon Receipt Form Document No.: F-FL-C-007 rev. 13	Document Revised: May 30, 2018 Issuing Authority: Pace Florida Quality Office

WO#:35473267

n (SCUR)

Project # PM: LMH Due Date: 06/21/19

Project Manager CLIENT: CARENG

Client:

Date and Initials of person:

Examining contents:

Label:

Deliver:

pH:

Thermometer Used: T-353 Date: 6/7/19 Time: 1045 Initials: JW

State of Origin:

☐ For WV projects, all containers verified to ≤6 °C

Cooler #1 Temp.°C 19.6 **(Visual)** +0.1 **(Correction Factor)** 19.7 **(Actual)** ☐ Samples on ice, cooling process has begun

Cooler #2 Temp.°C____ **(Visual)** ____ **(Correction Factor)** ____ **(Actual)** ☐ Samples on ice, cooling process has begun

Cooler #3 Temp.°C____ **(Visual)** ____ **(Correction Factor)** ____ **(Actual)** ☐ Samples on ice, cooling process has begun

Cooler #4 Temp.°C____ **(Visual)** ____ **(Correction Factor)** ____ **(Actual)** ☐ Samples on ice, cooling process has begun

Cooler #5 Temp.°C____ **(Visual)** ____ **(Correction Factor)** ____ **(Actual)** ☐ Samples on ice, cooling process has begun

Cooler #6 Temp.°C____ **(Visual)** ____ **(Correction Factor)** ____ **(Actual)** ☐ Samples on ice, cooling process has begun

Courier: ☐ Fed Ex ☒ UPS ☐ USPS ☐ Client ☐ Commercial ☐ Pace ☐ Other____

Shipping Method: ☐ First Overnight ☐ Priority Overnight ☐ Standard Overnight ☒ Ground ☐ International Priority

☐ Other____

Billing: ☐ Recipient ☐ Sender ☐ Third Party ☐ Credit Card ☐ Unknown

Tracking # 12 8R8 E81 9510 4811

Custody Seal on Cooler/Box Present: ☐ Yes ☒ No **Seals intact:** ☐ Yes ☐ No **Ice:** [✓ Wet] Blue Dry None

Packing Material: ☐ Bubble Wrap ☒ Bubble Bags ☐ None ☐ Other____

Samples shorted to lab (If Yes, complete) Shorted Date:____ Shorted Time:____ Qty:____

		Comments:
Chain of Custody Present	☒ Yes ☐ No ☐ N/A	
Chain of Custody Filled Out	☒ Yes ☐ No ☐ N/A	
Relinquished Signature & Sampler Name COC	☒ Yes ☐ No ☐ N/A	
Samples Arrived within Hold Time	☒ Yes ☐ No ☐ N/A	
Rush TAT requested on COC	☐ Yes ☐ No ☒ N/A	
Sufficient Volume	☒ Yes ☐ No ☐ N/A	
Correct Containers Used	☒ Yes ☐ No ☐ N/A	
Containers Intact	☒ Yes ☐ No ☐ N/A	
Sample Labels match COC (sample IDs & date/time of collection)	☒ Yes ☐ No ☐ N/A	
All containers needing acid/base preservation have been checked.	☒ Yes ☐ No ☐ N/A	Preservation Information: Preservative:____ Lot #/Trace #:____ Date:____ Time:____ Initials:____
All Containers needing preservation are found to be in compliance with EPA recommendation: Exceptions: VOA, Coliform, TOC, O&G, Carbamates	☒ Yes ☐ No ☐ N/A	
Headspace in VOA Vials? (>6mm):	☐ Yes ☐ No ☒ N/A	
Trip Blank Present:	☐ Yes ☐ No ☒ N/A	

Client Notification/ Resolution:

Person Contacted:____ Date/Time:____

Comments/ Resolution (use back for additional comments): Arrived OOT

Project Manager Review:____ Date:____

Pace Analytical Services, LLC
8 East Tower Circle
Ormond Beach, FL 32174
(386)672-5668

July 05, 2019

Eduardo Torres
Carollo Engineers, Inc.
2056 Vista Parkway, Suite 400
West Palm Beach, FL 33411

RE: Project: Fort Lauderdale
Pace Project No.: 35478062

Dear Eduardo Torres:

Enclosed are the analytical results for sample(s) received by the laboratory on June 27, 2019. The results relate only to the samples included in this report. Results reported herein conform to the most current, applicable TNI/NELAC standards and the laboratory's Quality Assurance Manual, where applicable, unless otherwise noted in the body of the report.

If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Lisa Harvey
lisa.harvey@pacelabs.com
(386) 672-5668
Project Manager

Enclosures

CERTIFICATIONS

Project: Fort Lauderdale
Pace Project No.: 35478062

Ormond Beach Certification IDs

8 East Tower Circle, Ormond Beach, FL 32174
Alaska DEC- CS/UST/LUST
Alabama Certification #: 41320
Arizona Certification# AZ0819
Colorado Certification: FL NELAC Reciprocity
Connecticut Certification #: PH-0216
Delaware Certification: FL NELAC Reciprocity
Florida Certification #: E83079
Georgia Certification #: 955
Guam Certification: FL NELAC Reciprocity
Hawaii Certification: FL NELAC Reciprocity
Illinois Certification #: 200068
Indiana Certification: FL NELAC Reciprocity
Kansas Certification #: E-10383
Kentucky Certification #: 90050
Louisiana Certification #: FL NELAC Reciprocity
Louisiana Environmental Certificate #: 05007
Maryland Certification: #346
Michigan Certification #: 9911
Mississippi Certification: FL NELAC Reciprocity
Missouri Certification #: 236
Montana Certification #: Cert 0074
Nebraska Certification: NE-OS-28-14
New Hampshire Certification #: 2958
New Jersey Certification #: FL022
New York Certification #: 11608
North Carolina Environmental Certificate #: 667
North Carolina Certification #: 12710
North Dakota Certification #: R-216
Oklahoma Certification #: D9947
Pennsylvania Certification #: 68-00547
Puerto Rico Certification #: FL01264
South Carolina Certification: #96042001
Tennessee Certification #: TN02974
Texas Certification: FL NELAC Reciprocity
US Virgin Islands Certification: FL NELAC Reciprocity
Virginia Environmental Certification #: 460165
West Virginia Certification #: 9962C
Wisconsin Certification #: 399079670
Wyoming (EPA Region 8): FL NELAC Reciprocity

SAMPLE SUMMARY

Project: Fort Lauderdale
Pace Project No.: 35478062

Lab ID	Sample ID	Matrix	Date Collected	Date Received
35478062001	**Well 25**	Water	06/26/19 15:00	06/27/19 10:15
35478062002	**Well 28**	Water	06/26/19 15:00	06/27/19 10:15
35478062003	**Well 37**	Water	06/26/19 15:00	06/27/19 10:15
35478062004	**Well 32**	Water	06/26/19 15:00	06/27/19 10:15
35478062005	**Well 33**	Water	06/26/19 15:00	06/27/19 10:15
35478062006	**Well 34**	Water	06/26/19 15:00	06/27/19 10:15
35478062007	**Well 35**	Water	06/26/19 15:00	06/27/19 10:15
35478062008	**Well 47**	Water	06/26/19 15:00	06/27/19 10:15
35478062009	**Well 53**	Water	06/26/19 15:00	06/27/19 10:15
35478062010	**Well 54**	Water	06/26/19 15:00	06/27/19 10:15

SAMPLE ANALYTE COUNT

Project: Fort Lauderdale
Pace Project No.: 35478062

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
35478062001	**Well 25**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478062002	**Well 28**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478062003	**Well 37**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478062004	**Well 32**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478062005	**Well 33**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478062006	**Well 34**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478062007	**Well 35**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478062008	**Well 47**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478062009	**Well 53**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478062010	**Well 54**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478062

Sample: Well 25 **Lab ID: 35478062001** Collected: 06/26/19 15:00 Received: 06/27/19 10:15 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0033 I**	mg/L	0.0050	0.00042	1	07/03/19 08:58	07/03/19 22:28	7439-96-5	
Silica	**8.3**	mg/L	0.21	0.098	1	07/03/19 08:58	07/03/19 22:28	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**12.6**	mg/L	1.0	0.50	1		07/03/19 04:34	7440-44-0	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478062

Sample: Well 28 **Lab ID: 35478062002** Collected: 06/26/19 15:00 Received: 06/27/19 10:15 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0023 I**	mg/L	0.0050	0.00042	1	07/03/19 08:58	07/03/19 22:41	7439-96-5	
Silica	**7.1**	mg/L	0.21	0.098	1	07/03/19 08:58	07/03/19 22:41	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**17.2**	mg/L	1.0	0.50	1		07/03/19 04:48	7440-44-0	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478062

Sample: Well 37 **Lab ID: 35478062003** Collected: 06/26/19 15:00 Received: 06/27/19 10:15 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0041 I**	mg/L	0.0050	0.00042	1	07/03/19 08:58	07/03/19 22:46	7439-96-5	
Silica	**7.2**	mg/L	0.21	0.098	1	07/03/19 08:58	07/03/19 22:46	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**15.7**	mg/L	1.0	0.50	1		07/03/19 05:03	7440-44-0	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478062

Sample: Well 32 **Lab ID: 35478062004** Collected: 06/26/19 15:00 Received: 06/27/19 10:15 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0064**	mg/L	0.0050	0.00042	1	07/03/19 08:58	07/03/19 22:51	7439-96-5	
Silica	**8.2**	mg/L	0.21	0.098	1	07/03/19 08:58	07/03/19 22:51	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**11.4**	mg/L	1.0	0.50	1		07/03/19 05:17	7440-44-0	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478062

Sample: Well 33 **Lab ID: 35478062005** Collected: 06/26/19 15:00 Received: 06/27/19 10:15 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0027 I**	mg/L	0.0050	0.00042	1	07/03/19 08:58	07/03/19 22:55	7439-96-5	
Silica	**8.2**	mg/L	0.21	0.098	1	07/03/19 08:58	07/03/19 22:55	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**12.1**	mg/L	1.0	0.50	1		07/03/19 05:32	7440-44-0	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478062

Sample: Well 34 **Lab ID: 35478062006** Collected: 06/26/19 15:00 Received: 06/27/19 10:15 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0036 I**	mg/L	0.0050	0.00042	1	07/03/19 08:58	07/03/19 23:09	7439-96-5	
Silica	**8.2**	mg/L	0.21	0.098	1	07/03/19 08:58	07/03/19 23:09	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**10.6**	mg/L	1.0	0.50	1		07/03/19 05:47	7440-44-0	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478062

Sample: Well 35 **Lab ID: 35478062007** Collected: 06/26/19 15:00 Received: 06/27/19 10:15 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0034 I**	mg/L	0.0050	0.00042	1	07/03/19 08:58	07/03/19 23:14	7439-96-5	
Silica	**7.8**	mg/L	0.21	0.098	1	07/03/19 08:58	07/03/19 23:14	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**9.9**	mg/L	1.0	0.50	1		07/03/19 06:01	7440-44-0	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478062

Sample: Well 47 **Lab ID: 35478062008** Collected: 06/26/19 15:00 Received: 06/27/19 10:15 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0040 I**	mg/L	0.0050	0.00042	1	07/03/19 08:58	07/03/19 23:18	7439-96-5	
Silica	**7.7**	mg/L	0.21	0.098	1	07/03/19 08:58	07/03/19 23:18	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**16.7**	mg/L	1.0	0.50	1		07/03/19 06:55	7440-44-0	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478062

Sample: Well 53 **Lab ID: 35478062009** Collected: 06/26/19 15:00 Received: 06/27/19 10:15 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0055**	mg/L	0.0050	0.00042	1	07/03/19 08:58	07/03/19 23:23	7439-96-5	
Silica	**9.8**	mg/L	0.21	0.098	1	07/03/19 08:58	07/03/19 23:23	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**15.6**	mg/L	1.0	0.50	1		07/03/19 07:10	7440-44-0	

REPORT OF LABORATORY ANALYSIS

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478062

Sample: Well 54 **Lab ID: 35478062010** Collected: 06/26/19 15:00 Received: 06/27/19 10:15 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0076**	mg/L	0.0050	0.00042	1	07/03/19 08:58	07/03/19 23:28	7439-96-5	
Silica	**10.7**	mg/L	0.21	0.098	1	07/03/19 08:58	07/03/19 23:28	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**14.5**	mg/L	1.0	0.50	1		07/03/19 07:53	7440-44-0	

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35478062

QC Batch: 551167 Analysis Method: EPA 200.7
QC Batch Method: EPA 200.7 Analysis Description: 200.7 MET
Associated Lab Samples: 35478062001, 35478062002, 35478062003, 35478062004, 35478062005, 35478062006, 35478062007, 35478062008, 35478062009, 35478062010

METHOD BLANK: 2988959 Matrix: Water
Associated Lab Samples: 35478062001, 35478062002, 35478062003, 35478062004, 35478062005, 35478062006, 35478062007, 35478062008, 35478062009, 35478062010

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Manganese	mg/L	0.00042 U	0.0050	0.00042	07/03/19 22:19	
Silica	mg/L	0.098 U	0.21	0.098	07/03/19 22:19	

LABORATORY CONTROL SAMPLE: 2988962

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Manganese	mg/L	0.25	0.24	95	85-115	
Silica	mg/L	5.3	5.2	97	85-115	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2988963 2988964

Parameter	Units	35478062001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Manganese	mg/L	0.0033 I	0.25	0.25	0.24	0.24	96	94	70-130	2	20	
Silica	mg/L	8.3	5.3	5.3	13.5	13.4	97	96	70-130	1	20	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2988965 2988966

Parameter	Units	35479210002 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Manganese	mg/L	0.0016 I	0.25	0.25	0.24	0.23	95	93	70-130	2	20	
Silica	mg/L	6460 ug/L	5.3	5.3	11.3	11.4	91	93	70-130	1	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35478062

QC Batch: 550865
Analysis Method: SM 5310B
QC Batch Method: SM 5310B
Analysis Description: 5310B TOC
Associated Lab Samples: 35478062001, 35478062002, 35478062003, 35478062004, 35478062005, 35478062006, 35478062007, 35478062008, 35478062009

METHOD BLANK: 2987107
Matrix: Water
Associated Lab Samples: 35478062001, 35478062002, 35478062003, 35478062004, 35478062005, 35478062006, 35478062007, 35478062008, 35478062009

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Total Organic Carbon	mg/L	0.50 U	1.0	0.50	07/02/19 23:19	

LABORATORY CONTROL SAMPLE: 2987108

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Total Organic Carbon	mg/L	20	18.4	92	90-110	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2987109 2987110

Parameter	Units	20109298002 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Total Organic Carbon	mg/L	2.4	20	20	20.3	20.2	90	89	80-120	1	20	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2987111 2987112

Parameter	Units	35477980003 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Total Organic Carbon	mg/L	13.2	20	20	31.0	31.4	89	91	80-120	1	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35478062

QC Batch: 550868
QC Batch Method: SM 5310B
Analysis Method: SM 5310B
Analysis Description: 5310B TOC
Associated Lab Samples: 35478062010

METHOD BLANK: 2987113
Matrix: Water
Associated Lab Samples: 35478062010

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Total Organic Carbon	mg/L	0.50 U	1.0	0.50	07/03/19 07:22	

LABORATORY CONTROL SAMPLE: 2987114

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Total Organic Carbon	mg/L	20	18.5	93	90-110	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2987115 2987116

Parameter	Units	35478062010 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Total Organic Carbon	mg/L	14.5	20	20	32.3	32.1	89	88	80-120	1	20	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2987117 2987118

Parameter	Units	35478502009 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Total Organic Carbon	mg/L	11.5	20	20	29.6	29.8	90	91	80-120	1	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALIFIERS

Project:	Fort Lauderdale
Pace Project No.:	35478062

DEFINITIONS

DF - Dilution Factor, if reported, represents the factor applied to the reported data due to dilution of the sample aliquot.

ND - Not Detected at or above adjusted reporting limit.

TNTC - Too Numerous To Count

MDL - Adjusted Method Detection Limit.

PQL - Practical Quantitation Limit.

RL - Reporting Limit - The lowest concentration value that meets project requirements for quantitative data with known precision and bias for a specific analyte in a specific matrix.

S - Surrogate

1,2-Diphenylhydrazine decomposes to and cannot be separated from Azobenzene using Method 8270. The result for each analyte is a combined concentration.

Consistent with EPA guidelines, unrounded data are displayed and have been used to calculate % recovery and RPD values.

LCS(D) - Laboratory Control Sample (Duplicate)

MS(D) - Matrix Spike (Duplicate)

DUP - Sample Duplicate

RPD - Relative Percent Difference

NC - Not Calculable.

SG - Silica Gel - Clean-Up

U - Indicates the compound was analyzed for, but not detected.

N-Nitrosodiphenylamine decomposes and cannot be separated from Diphenylamine using Method 8270. The result reported for each analyte is a combined concentration.

Pace Analytical is TNI accredited. Contact your Pace PM for the current list of accredited analytes.

TNI - The NELAC Institute.

LABORATORIES

PASI-O	Pace Analytical Services - Ormond Beach

ANALYTE QUALIFIERS

I	The reported value is between the laboratory method detection limit and the laboratory practical quantitation limit.
U	Compound was analyzed for but not detected.

QUALITY CONTROL DATA CROSS REFERENCE TABLE

Project:	Fort Lauderdale
Pace Project No.:	35478062

Lab ID	Sample ID	QC Batch Method	QC Batch	Analytical Method	Analytical Batch
35478062001	**Well 25**	EPA 200.7	551167	EPA 200.7	551264
35478062002	**Well 28**	EPA 200.7	551167	EPA 200.7	551264
35478062003	**Well 37**	EPA 200.7	551167	EPA 200.7	551264
35478062004	**Well 32**	EPA 200.7	551167	EPA 200.7	551264
35478062005	**Well 33**	EPA 200.7	551167	EPA 200.7	551264
35478062006	**Well 34**	EPA 200.7	551167	EPA 200.7	551264
35478062007	**Well 35**	EPA 200.7	551167	EPA 200.7	551264
35478062008	**Well 47**	EPA 200.7	551167	EPA 200.7	551264
35478062009	**Well 53**	EPA 200.7	551167	EPA 200.7	551264
35478062010	**Well 54**	EPA 200.7	551167	EPA 200.7	551264
35478062001	**Well 25**	SM 5310B	550865		
35478062002	**Well 28**	SM 5310B	550865		
35478062003	**Well 37**	SM 5310B	550865		
35478062004	**Well 32**	SM 5310B	550865		
35478062005	**Well 33**	SM 5310B	550865		
35478062006	**Well 34**	SM 5310B	550865		
35478062007	**Well 35**	SM 5310B	550865		
35478062008	**Well 47**	SM 5310B	550865		
35478062009	**Well 53**	SM 5310B	550865		
35478062010	**Well 54**	SM 5310B	550868		

WO#: 35478062

35478062

Pace Analytical
www.pacelabs.com

CHAIN-OF-CUSTODY / Analytical Request Document

The Chain-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately.

Page : 1 Of

Section A
Required Client Information:

Company: Carollo Engineering
Address: 20546 Vista Parkway
Suite 400, West Palm Beach, FL 33411
Email To: Eduardo Torres
Phone: 914-987-9494 Fax
Requested Due Date: std

Section B
Required Project Information:

Report To: Eduardo Torres
Copy To:
Purchase Order #:
Project Name: Fort Lauderdale
Project #:

Section C
Invoice Information:

Attention: Accounts Payable
Company Name: Carollo
Address:
Pace Quote:
Pace Project Manager: Lisa Harvey
Pace Profile #: 12021-5

Regulatory Agency: FL
State / Location: FL

MATRIX / CODE: Drinking Water DW, Water WT, Waste Water WW, Product P, Soil/Solid SL, Oil OL, Wipe WP, Air AR, Other OT, Tissue TS

SAMPLE ID: One Character per box. (A-Z, 0-9 / , -) Sample Ids must be unique

ITEM #	SAMPLE ID	MATRIX CODE (see valid codes to left)	SAMPLE TYPE (G=GRAB C=COMP)	COLLECTED START DATE	COLLECTED START TIME	COLLECTED END DATE	COLLECTED END TIME	SAMPLE TEMP AT COLLECTION	# OF CONTAINERS	Preservatives: Unpreserved	H2SO4	HNO3	HCl	NaOH	Na2S2O3	Methanol	Other	Y/N Analyses Test	TOC	Mn, Si	Residual Chlorine (Y/N)
1	WELL 25	WT	G	6/26	9 PM							1	2						2	1	
2	WELL 28	WT	G									1	2						2	1	
3	WELL 31											1	2						2	1	
4	WELL 32											1	2						2	1	
5	WELL 33											1	2						2	1	
6	WELL 34											1	2						2	1	
7	WELL 35											1	2						2	1	
8	WELL 47											1	2						2	1	
9	WELL 53											1	1						2	1	
10	WELL 54											1	2						2	1	
11																					
12																					

Requested Analysis Filtered (Y/N)

ADDITIONAL COMMENTS	RELINQUISHED BY / AFFILIATION	DATE	TIME	ACCEPTED BY / AFFILIATION	DATE	TIME	SAMPLE CONDITIONS			
				AS/Pace	6/27/19	1015		4	N	Y
					2-T-35					
							TEMP in C	Received on Ice (Y/N)	Custody Sealed Cooler (Y/N)	Samples Intact (Y/N)

SAMPLER NAME AND SIGNATURE

PRINT Name of SAMPLER: EDUARDO TORRES
SIGNATURE of SAMPLER: Eduardo Torres
DATE Signed: 06/26/19

Pace Analytical Florida Laboratory	Document Name: Sample Condition Upon Receipt Form	Document Revised: May 30, 2018
	Document No.: F-FL-C-007 rev. 13	Issuing Authority: Pace Florida Quality Office

m (SCUR)

WO#:35478062
PM: LMH Due Date: 07/12/19
CLIENT: CARWESTPALM

Project
Project Manager
Client:

Date and Initials of person:
Examining contents:
Label:
Deliver:
pH:

Thermometer Used: T353 Date: 6/27/19 Time: 1024 Initials: BBB

State of Origin: ____ ☐ For WV projects, all containers verified to ≤6 °C

Cooler #1 Temp.°C 2.6 **(Visual)** +.1 **(Correction Factor)** 2.7 **(Actual)** ☐ Samples on ice, cooling process has begun
Cooler #2 Temp.°C ____ **(Visual)** ____ **(Correction Factor)** ____ **(Actual)** ☐ Samples on ice, cooling process has begun
Cooler #3 Temp.°C ____ **(Visual)** ____ **(Correction Factor)** ____ **(Actual)** ☐ Samples on ice, cooling process has begun
Cooler #4 Temp.°C ____ **(Visual)** ____ **(Correction Factor)** ____ **(Actual)** ☐ Samples on ice, cooling process has begun
Cooler #5 Temp.°C ____ **(Visual)** ____ **(Correction Factor)** ____ **(Actual)** ☐ Samples on ice, cooling process has begun
Cooler #6 Temp.°C ____ **(Visual)** ____ **(Correction Factor)** ____ **(Actual)** ☐ Samples on ice, cooling process has begun

Courier: ☐ Fed Ex ☑ UPS ☐ USPS ☐ Client ☐ Commercial ☐ Pace ☐ Other ____

Shipping Method: ☐ First Overnight ☐ Priority Overnight ☐ Standard Overnight ☐ Ground ☐ International Priority
☐ Other NPA

Billing: ☐ Recipient ☐ Sender ☐ Third Party ☐ Credit Card ☐ Unknown

Tracking # 1Z 8R8 158 01 0094 9050

Custody Seal on Cooler/Box Present: ☐ Yes ☑ No **Seals intact:** ☐ Yes ☐ No **Ice:** [✓ Wet] Blue Dry None

Packing Material: ☑ Bubble Wrap ☐ Bubble Bags ☐ None ☐ Other ____

Samples shorted to lab (If Yes, complete) Shorted Date: ____ Shorted Time: ____ Qty: ____

		Comments:
Chain of Custody Present	☑ Yes ☐ No ☐ N/A	
Chain of Custody Filled Out	☑ Yes ☐ No ☐ N/A	
Relinquished Signature & Sampler Name COC	☑ Yes ☐ No ☐ N/A	
Samples Arrived within Hold Time	☑ Yes ☐ No ☐ N/A	
Rush TAT requested on COC	☐ Yes ☐ No ☑ N/A	
Sufficient Volume	☑ Yes ☐ No ☐ N/A	
Correct Containers Used	☑ Yes ☐ No ☐ N/A	
Containers Intact	☑ Yes ☐ No ☐ N/A	
Sample Labels match COC (sample IDs & date/time of collection)	☑ Yes ☐ No ☐ N/A	
All containers needing acid/base preservation have been checked.	☑ Yes ☐ No ☐ N/A	Preservation Information: Preservative: ____ Lot #/Trace #: ____ Date: ____ Time: ____ Initials: ____
All Containers needing preservation are found to be in compliance with EPA recommendation: Exceptions: VOA, Coliform, TOC, O&G, Carbamates	☑ Yes ☐ No ☐ N/A	
Headspace in VOA Vials? (>6mm):	☐ Yes ☐ No ☑ N/A	
Trip Blank Present:	☐ Yes ☐ No ☑ N/A	

Client Notification/ Resolution:
Person Contacted: ____ Date/Time: ____

Comments/ Resolution (use back for additional comments): ____

Project Manager Review: ____ Date: ____

Pace Analytical Services, LLC
8 East Tower Circle
Ormond Beach, FL 32174
(386)672-5668

July 05, 2019

Eduardo Torres
Carollo Engineers, Inc.
2056 Vista Parkway, Suite 400
West Palm Beach, FL 33411

RE: Project: Fort Lauderdale
Pace Project No.: 35478502

Dear Eduardo Torres:

Enclosed are the analytical results for sample(s) received by the laboratory on June 28, 2019. The results relate only to the samples included in this report. Results reported herein conform to the most current, applicable TNI/NELAC standards and the laboratory's Quality Assurance Manual, where applicable, unless otherwise noted in the body of the report.

If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Lisa Harvey
lisa.harvey@pacelabs.com
(386) 672-5668
Project Manager

Enclosures

CERTIFICATIONS

Project: Fort Lauderdale
Pace Project No.: 35478502

Ormond Beach Certification IDs

8 East Tower Circle, Ormond Beach, FL 32174
Alaska DEC- CS/UST/LUST
Alabama Certification #: 41320
Arizona Certification# AZ0819
Colorado Certification: FL NELAC Reciprocity
Connecticut Certification #: PH-0216
Delaware Certification: FL NELAC Reciprocity
Florida Certification #: E83079
Georgia Certification #: 955
Guam Certification: FL NELAC Reciprocity
Hawaii Certification: FL NELAC Reciprocity
Illinois Certification #: 200068
Indiana Certification: FL NELAC Reciprocity
Kansas Certification #: E-10383
Kentucky Certification #: 90050
Louisiana Certification #: FL NELAC Reciprocity
Louisiana Environmental Certificate #: 05007
Maryland Certification: #346
Michigan Certification #: 9911
Mississippi Certification: FL NELAC Reciprocity
Missouri Certification #: 236
Montana Certification #: Cert 0074
Nebraska Certification: NE-OS-28-14
New Hampshire Certification #: 2958
New Jersey Certification #: FL022
New York Certification #: 11608
North Carolina Environmental Certificate #: 667
North Carolina Certification #: 12710
North Dakota Certification #: R-216
Oklahoma Certification #: D9947
Pennsylvania Certification #: 68-00547
Puerto Rico Certification #: FL01264
South Carolina Certification: #96042001
Tennessee Certification #: TN02974
Texas Certification: FL NELAC Reciprocity
US Virgin Islands Certification: FL NELAC Reciprocity
Virginia Environmental Certification #: 460165
West Virginia Certification #: 9962C
Wisconsin Certification #: 399079670
Wyoming (EPA Region 8): FL NELAC Reciprocity

SAMPLE SUMMARY

Project: Fort Lauderdale
Pace Project No.: 35478502

Lab ID	Sample ID	Matrix	Date Collected	Date Received
35478502001	**Well 27**	Water	06/27/19 12:00	06/28/19 09:20
35478502002	**Well 30**	Water	06/27/19 12:00	06/28/19 09:20
35478502003	**Well 37**	Water	06/27/19 12:00	06/28/19 09:20
35478502004	**Well 38**	Water	06/27/19 12:00	06/28/19 09:20
35478502005	**Well 39**	Water	06/27/19 12:00	06/28/19 09:20
35478502006	**Well 42**	Water	06/27/19 12:00	06/28/19 09:20
35478502007	**Well 43**	Water	06/27/19 12:00	06/28/19 09:20
35478502008	**Well 44**	Water	06/27/19 12:00	06/28/19 09:20
35478502009	**Well 45**	Water	06/27/19 12:00	06/28/19 09:20
35478502010	**Well 46**	Water	06/27/19 12:00	06/28/19 09:20
35478502011	**Well 47**	Water	06/27/19 12:00	06/28/19 09:20
35478502012	**Well 48**	Water	06/27/19 12:00	06/28/19 09:20
35478502013	**Well 49**	Water	06/27/19 12:00	06/28/19 09:20
35478502014	**Well 50**	Water	06/27/19 12:00	06/28/19 09:20
35478502015	**Well 51**	Water	06/27/19 12:00	06/28/19 09:20
35478502016	**Well 52**	Water	06/27/19 12:00	06/28/19 09:20

SAMPLE ANALYTE COUNT

Project: Fort Lauderdale
Pace Project No.: 35478502

Lab ID	Sample ID	Method	Analysts	Analytes Reported	Laboratory
35478502001	**Well 27**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478502002	**Well 30**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478502003	**Well 37**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478502004	**Well 38**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478502005	**Well 39**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478502006	**Well 42**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478502007	**Well 43**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478502008	**Well 44**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478502009	**Well 45**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478502010	**Well 46**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478502011	**Well 47**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478502012	**Well 48**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478502013	**Well 49**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478502014	**Well 50**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478502015	**Well 51**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O
35478502016	**Well 52**	EPA 200.7	LEC	2	PASI-O
		SM 5310B	SA1	1	PASI-O

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478502

Sample: Well 27 **Lab ID: 35478502001** Collected: 06/27/19 12:00 Received: 06/28/19 09:20 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0035 I**	mg/L	0.0050	0.00042	1	07/01/19 13:15	07/02/19 19:46	7439-96-5	
Silica	**8.5**	mg/L	0.21	0.098	1	07/01/19 13:15	07/02/19 19:46	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**16.6**	mg/L	1.0	0.50	1		07/03/19 09:07	7440-44-0	

ANALYTICAL RESULTS

Project:	Fort Lauderdale
Pace Project No.:	35478502

Sample: Well 30 **Lab ID: 35478502002** Collected: 06/27/19 12:00 Received: 06/28/19 09:20 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0032 I**	mg/L	0.0050	0.00042	1	07/01/19 13:15	07/02/19 19:59	7439-96-5	
Silica	**8.2**	mg/L	0.21	0.098	1	07/01/19 13:15	07/02/19 19:59	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**16.9**	mg/L	1.0	0.50	1		07/03/19 09:58	7440-44-0	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478502

Sample: Well 37 **Lab ID: 35478502003** Collected: 06/27/19 12:00 Received: 06/28/19 09:20 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0044 I**	mg/L	0.0050	0.00042	1	07/01/19 13:15	07/02/19 20:04	7439-96-5	
Silica	**8.9**	mg/L	0.21	0.098	1	07/01/19 13:15	07/02/19 20:04	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**11.3**	mg/L	1.0	0.50	1		07/03/19 10:13	7440-44-0	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478502

Sample: Well 38 **Lab ID: 35478502004** Collected: 06/27/19 12:00 Received: 06/28/19 09:20 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0037 I**	mg/L	0.0050	0.00042	1	07/01/19 13:15	07/02/19 20:09	7439-96-5	
Silica	**8.9**	mg/L	0.21	0.098	1	07/01/19 13:15	07/02/19 20:09	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**11.9**	mg/L	1.0	0.50	1		07/03/19 10:27	7440-44-0	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478502

Sample: Well 39 **Lab ID: 35478502005** Collected: 06/27/19 12:00 Received: 06/28/19 09:20 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0046 I**	mg/L	0.0050	0.00042	1	07/01/19 13:15	07/02/19 20:13	7439-96-5	
Silica	**6.8**	mg/L	0.21	0.098	1	07/01/19 13:15	07/02/19 20:13	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**14.9**	mg/L	1.0	0.50	1		07/03/19 10:42	7440-44-0	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478502

Sample: Well 42 **Lab ID: 35478502006** Collected: 06/27/19 12:00 Received: 06/28/19 09:20 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0028 I**	mg/L	0.0050	0.00042	1	07/01/19 13:15	07/02/19 20:18	7439-96-5	
Silica	**7.6**	mg/L	0.21	0.098	1	07/01/19 13:15	07/02/19 20:18	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**17.6**	mg/L	1.0	0.50	1		07/03/19 10:57	7440-44-0	

ANALYTICAL RESULTS

Project:	Fort Lauderdale
Pace Project No.:	35478502

Sample: Well 43 **Lab ID: 35478502007** Collected: 06/27/19 12:00 Received: 06/28/19 09:20 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0059**	mg/L	0.0050	0.00042	1	07/01/19 13:15	07/02/19 20:22	7439-96-5	
Silica	**9.4**	mg/L	0.21	0.098	1	07/01/19 13:15	07/02/19 20:22	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**11.2**	mg/L	1.0	0.50	1		07/03/19 11:12	7440-44-0	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478502

Sample: Well 44 **Lab ID: 35478502008** Collected: 06/27/19 12:00 Received: 06/28/19 09:20 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0028 I**	mg/L	0.0050	0.00042	1	07/01/19 13:15	07/02/19 20:36	7439-96-5	
Silica	**7.4**	mg/L	0.21	0.098	1	07/01/19 13:15	07/02/19 20:36	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**16.4**	mg/L	1.0	0.50	1		07/03/19 11:26	7440-44-0	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478502

Sample: Well 45 **Lab ID: 35478502009** Collected: 06/27/19 12:00 Received: 06/28/19 09:20 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0041 I**	mg/L	0.0050	0.00042	1	07/01/19 13:15	07/02/19 20:41	7439-96-5	
Silica	**9.0**	mg/L	0.21	0.098	1	07/01/19 13:15	07/02/19 20:41	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**11.5**	mg/L	1.0	0.50	1		07/03/19 11:41	7440-44-0	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478502

Sample: Well 46 **Lab ID: 35478502010** Collected: 06/27/19 12:00 Received: 06/28/19 09:20 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0049 I**	mg/L	0.0050	0.00042	1	07/01/19 13:15	07/02/19 20:46	7439-96-5	
Silica	**8.5**	mg/L	0.21	0.098	1	07/01/19 13:15	07/02/19 20:46	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**12.0**	mg/L	1.0	0.50	1		07/03/19 13:07	7440-44-0	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478502

Sample: Well 47 **Lab ID: 35478502011** Collected: 06/27/19 12:00 Received: 06/28/19 09:20 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0043 I**	mg/L	0.0050	0.00042	1	07/01/19 13:15	07/02/19 20:50	7439-96-5	
Silica	**7.2**	mg/L	0.21	0.098	1	07/01/19 13:15	07/02/19 20:50	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**14.8**	mg/L	1.0	0.50	1		07/03/19 17:48	7440-44-0	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478502

Sample: Well 48 **Lab ID: 35478502012** Collected: 06/27/19 12:00 Received: 06/28/19 09:20 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0049 I**	mg/L	0.0050	0.00042	1	07/01/19 13:15	07/02/19 20:55	7439-96-5	
Silica	**7.3**	mg/L	0.21	0.098	1	07/01/19 13:15	07/02/19 20:55	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**16.8**	mg/L	1.0	0.50	1		07/03/19 18:03	7440-44-0	

ANALYTICAL RESULTS

Project:	Fort Lauderdale
Pace Project No.:	35478502

Sample: Well 49 **Lab ID: 35478502013** Collected: 06/27/19 12:00 Received: 06/28/19 09:20 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0038 I**	mg/L	0.0050	0.00042	1	07/01/19 13:15	07/02/19 20:59	7439-96-5	
Silica	**7.2**	mg/L	0.21	0.098	1	07/01/19 13:15	07/02/19 20:59	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**17.3**	mg/L	1.0	0.50	1		07/03/19 18:58	7440-44-0	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478502

Sample: Well 50 **Lab ID: 35478502014** Collected: 06/27/19 12:00 Received: 06/28/19 09:20 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0031 I**	mg/L	0.0050	0.00042	1	07/01/19 13:15	07/02/19 21:04	7439-96-5	
Silica	**8.0**	mg/L	0.21	0.098	1	07/01/19 13:15	07/02/19 21:04	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**16.8**	mg/L	1.0	0.50	1		07/03/19 19:14	7440-44-0	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478502

Sample: Well 51 **Lab ID: 35478502015** Collected: 06/27/19 12:00 Received: 06/28/19 09:20 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0044 I**	mg/L	0.0050	0.00042	1	07/01/19 13:15	07/02/19 21:09	7439-96-5	
Silica	**7.1**	mg/L	0.21	0.098	1	07/01/19 13:15	07/02/19 21:09	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**16.0**	mg/L	1.0	0.50	1		07/03/19 19:29	7440-44-0	

ANALYTICAL RESULTS

Project: Fort Lauderdale
Pace Project No.: 35478502

Sample: Well 52 **Lab ID: 35478502016** Collected: 06/27/19 12:00 Received: 06/28/19 09:20 Matrix: Water

Parameters	Results	Units	PQL	MDL	DF	Prepared	Analyzed	CAS No.	Qual
200.7 MET ICP	Analytical Method: EPA 200.7 Preparation Method: EPA 200.7								
Manganese	**0.0056**	mg/L	0.0050	0.00042	1	07/01/19 13:15	07/02/19 21:13	7439-96-5	
Silica	**8.2**	mg/L	0.21	0.098	1	07/01/19 13:15	07/02/19 21:13	7631-86-9	
5310B TOC	Analytical Method: SM 5310B								
Total Organic Carbon	**15.9**	mg/L	1.0	0.50	1		07/03/19 20:15	7440-44-0	

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35478502

QC Batch: 550602 Analysis Method: EPA 200.7
QC Batch Method: EPA 200.7 Analysis Description: 200.7 MET
Associated Lab Samples: 35478502001, 35478502002, 35478502003, 35478502004, 35478502005, 35478502006, 35478502007, 35478502008, 35478502009, 35478502010, 35478502011, 35478502012, 35478502013, 35478502014, 35478502015, 35478502016

METHOD BLANK: 2985680 Matrix: Water
Associated Lab Samples: 35478502001, 35478502002, 35478502003, 35478502004, 35478502005, 35478502006, 35478502007, 35478502008, 35478502009, 35478502010, 35478502011, 35478502012, 35478502013, 35478502014, 35478502015, 35478502016

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Manganese	mg/L	0.00042 U	0.0050	0.00042	07/03/19 13:31	
Silica	mg/L	0.098 U	0.21	0.098	07/03/19 13:31	

LABORATORY CONTROL SAMPLE: 2985681

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Manganese	mg/L	0.25	0.24	96	85-115	
Silica	mg/L	5.3	4.7	89	85-115	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2985684 2985685

Parameter	Units	35478497002 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Manganese	mg/L	0.42 U ug/L	0.25	0.25	0.25	0.27	99	108	70-130	9	20	
Silica	mg/L	97.8 U ug/L	5.3	5.3	4.9	5.6	91	105	70-130	14	20	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2985749 2985750

Parameter	Units	35478502001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Manganese	mg/L	0.0035 I	0.25	0.25	0.27	0.28	107	109	70-130	2	20	
Silica	mg/L	8.5	5.3	5.3	13.8	14.1	100	106	70-130	2	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35478502

QC Batch: 550868 Analysis Method: SM 5310B
QC Batch Method: SM 5310B Analysis Description: 5310B TOC
Associated Lab Samples: 35478502001, 35478502002, 35478502003, 35478502004, 35478502005, 35478502006, 35478502007, 35478502008, 35478502009, 35478502010

METHOD BLANK: 2987113 Matrix: Water
Associated Lab Samples: 35478502001, 35478502002, 35478502003, 35478502004, 35478502005, 35478502006, 35478502007, 35478502008, 35478502009, 35478502010

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Total Organic Carbon	mg/L	0.50 U	1.0	0.50	07/03/19 07:22	

LABORATORY CONTROL SAMPLE: 2987114

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Total Organic Carbon	mg/L	20	18.5	93	90-110	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2987115 2987116

Parameter	Units	35478062010 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Total Organic Carbon	mg/L	14.5	20	20	32.3	32.1	89	88	80-120	1	20	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2987117 2987118

Parameter	Units	35478502009 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Total Organic Carbon	mg/L	11.5	20	20	29.6	29.8	90	91	80-120	1	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALITY CONTROL DATA

Project: Fort Lauderdale
Pace Project No.: 35478502

QC Batch: 551104
Analysis Method: SM 5310B
QC Batch Method: SM 5310B
Analysis Description: 5310B TOC
Associated Lab Samples: 35478502011, 35478502012, 35478502013, 35478502014, 35478502015, 35478502016

METHOD BLANK: 2988667
Matrix: Water
Associated Lab Samples: 35478502011, 35478502012, 35478502013, 35478502014, 35478502015, 35478502016

Parameter	Units	Blank Result	Reporting Limit	MDL	Analyzed	Qualifiers
Total Organic Carbon	mg/L	0.50 U	1.0	0.50	07/03/19 15:25	

LABORATORY CONTROL SAMPLE: 2988668

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Qualifiers
Total Organic Carbon	mg/L	20	19.2	96	90-110	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2988669 2988670

Parameter	Units	35479012001 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Total Organic Carbon	mg/L	1.6	20	20	20.6	20.8	95	96	80-120	1	20	

MATRIX SPIKE & MATRIX SPIKE DUPLICATE: 2988671 2988672

Parameter	Units	35478502015 Result	MS Spike Conc.	MSD Spike Conc.	MS Result	MSD Result	MS % Rec	MSD % Rec	% Rec Limits	RPD	Max RPD	Qual
Total Organic Carbon	mg/L	16.0	20	20	35.3	35.6	96	98	80-120	1	20	

Results presented on this page are in the units indicated by the "Units" column except where an alternate unit is presented to the right of the result.

QUALIFIERS

Project: Fort Lauderdale
Pace Project No.: 35478502

DEFINITIONS

DF - Dilution Factor, if reported, represents the factor applied to the reported data due to dilution of the sample aliquot.

ND - Not Detected at or above adjusted reporting limit.

TNTC - Too Numerous To Count

MDL - Adjusted Method Detection Limit.

PQL - Practical Quantitation Limit.

RL - Reporting Limit - The lowest concentration value that meets project requirements for quantitative data with known precision and bias for a specific analyte in a specific matrix.

S - Surrogate

1,2-Diphenylhydrazine decomposes to and cannot be separated from Azobenzene using Method 8270. The result for each analyte is a combined concentration.

Consistent with EPA guidelines, unrounded data are displayed and have been used to calculate % recovery and RPD values.

LCS(D) - Laboratory Control Sample (Duplicate)

MS(D) - Matrix Spike (Duplicate)

DUP - Sample Duplicate

RPD - Relative Percent Difference

NC - Not Calculable.

SG - Silica Gel - Clean-Up

U - Indicates the compound was analyzed for, but not detected.

N-Nitrosodiphenylamine decomposes and cannot be separated from Diphenylamine using Method 8270. The result reported for each analyte is a combined concentration.

Pace Analytical is TNI accredited. Contact your Pace PM for the current list of accredited analytes.

TNI - The NELAC Institute.

LABORATORIES

PASI-O	Pace Analytical Services - Ormond Beach

ANALYTE QUALIFIERS

I	The reported value is between the laboratory method detection limit and the laboratory practical quantitation limit.
U	Compound was analyzed for but not detected.

QUALITY CONTROL DATA CROSS REFERENCE TABLE

Project: Fort Lauderdale
Pace Project No.: 35478502

Lab ID	Sample ID	QC Batch Method	QC Batch	Analytical Method	Analytical Batch
35478502001	**Well 27**	EPA 200.7	550602	EPA 200.7	550686
35478502002	**Well 30**	EPA 200.7	550602	EPA 200.7	550686
35478502003	**Well 37**	EPA 200.7	550602	EPA 200.7	550686
35478502004	**Well 38**	EPA 200.7	550602	EPA 200.7	550686
35478502005	**Well 39**	EPA 200.7	550602	EPA 200.7	550686
35478502006	**Well 42**	EPA 200.7	550602	EPA 200.7	550686
35478502007	**Well 43**	EPA 200.7	550602	EPA 200.7	550686
35478502008	**Well 44**	EPA 200.7	550602	EPA 200.7	550686
35478502009	**Well 45**	EPA 200.7	550602	EPA 200.7	550686
35478502010	**Well 46**	EPA 200.7	550602	EPA 200.7	550686
35478502011	**Well 47**	EPA 200.7	550602	EPA 200.7	550686
35478502012	**Well 48**	EPA 200.7	550602	EPA 200.7	550686
35478502013	**Well 49**	EPA 200.7	550602	EPA 200.7	550686
35478502014	**Well 50**	EPA 200.7	550602	EPA 200.7	550686
35478502015	**Well 51**	EPA 200.7	550602	EPA 200.7	550686
35478502016	**Well 52**	EPA 200.7	550602	EPA 200.7	550686
35478502001	**Well 27**	SM 5310B	550868		
35478502002	**Well 30**	SM 5310B	550868		
35478502003	**Well 37**	SM 5310B	550868		
35478502004	**Well 38**	SM 5310B	550868		
35478502005	**Well 39**	SM 5310B	550868		
35478502006	**Well 42**	SM 5310B	550868		
35478502007	**Well 43**	SM 5310B	550868		
35478502008	**Well 44**	SM 5310B	550868		
35478502009	**Well 45**	SM 5310B	550868		
35478502010	**Well 46**	SM 5310B	550868		
35478502011	**Well 47**	SM 5310B	551104		
35478502012	**Well 48**	SM 5310B	551104		
35478502013	**Well 49**	SM 5310B	551104		
35478502014	**Well 50**	SM 5310B	551104		
35478502015	**Well 51**	SM 5310B	551104		
35478502016	**Well 52**	SM 5310B	551104		

WO#: 35478502

35478502

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CH ocument

The C st be completed accurately.

Page : 1 **Of** 2

Section A **Required Client Information:**		**Section B** **Required Project Information:**		**Section C** ...Information:	
Company:	Carollo Engineering	Report To:	Eduardo Torres	Attention:	Accounts Payable
Address:	20546 Vista Parkway	Copy To:		Company Name:	Carollo
	Suite 400, West Palm Beach, FL 33411			Address:	
Email To:	Eduardo Torres	Purchase Order #:		Pace Quote:	
Phone:	914-987-9494 Fax:	Project Name:	Fort Lauderdale	Pace Project Manager:	Lisa Harvey
Requested Due Date:	std	Project #:		Pace Profile #:	12021-5

Regulatory Agency
FL
State / Location
FL

SAMPLE ID
One Character per box.
(A-Z, 0-9 / , -)
Sample Ids must be unique

MATRIX	CODE
Drinking Water	DW
Water	WT
Waste Water	WW
Product	P
Soil/Solid	SL
Oil	OL
Wipe	WP
Air	AR
Other	OT
Tissue	TS

Requested Analysis Filtered (Y/N)

ITEM #	SAMPLE ID	MATRIX CODE (see valid codes to left)	SAMPLE TYPE (G=GRAB C=COMP)	COLLECTED START DATE	COLLECTED START TIME	COLLECTED END DATE	COLLECTED END TIME	SAMPLE TEMP AT COLLECTION	# OF CONTAINERS	Unpreserved	H2SO4	HNO3	HCl	NaOH	Na2S2O3	Methanol	Other	Analyses Test Y/N	TOC	Mn, Si	Residual Chlorine (Y/N)
1	WELL 27	WT	G	6/27	12pm	12pm	6/27					1	2						2	1	
2	WELL 30											1	2						2	1	
3	WELL 37											1	2						2	1	
4	WELL 38											1	2						2	1	
5	WELL 39											1	2						2	1	
6	WELL 42											1	2						2	1	
7	WELL 43											1	2						2	1	
8	WELL 44											1	2						2	1	
9	WELL 45											1	2						2	1	
10	WELL 46											1	2						2	1	
11	WELL 47											1	2						2	1	
12	WELL 48											1	2						2	1	

ADDITIONAL COMMENTS	RELINQUISHED BY / AFFILIATION	DATE	TIME	ACCEPTED BY / AFFILIATION	DATE	TIME	TEMP in C	Received on Ice (Y/N)	Custody Sealed Cooler (Y/N)	Samples Intact (Y/N)
				AS / [illegible]	6/28/19	0920		Y	N	Y
					[illegible]	[illegible]				

SAMPLE CONDITIONS

SAMPLER NAME AND SIGNATURE

PRINT Name of SAMPLER: EDUARDO TORRES

SIGNATURE of SAMPLER: Eduardo S [illegible]

DATE Signed: 6/27/2019

Pace Analytical

CHAIN-OF-CUSTODY / Analytical Request Document

The Chain-of-Custody is a LEGAL DOCUMENT. All relevant fields must be completed accurately.

Page : 2 Of 2

Section A
Required Client Information:

Company: Carollo Engineering
Address: 20546 Vista Parkway
Suite 400, West Palm Beach, FL 33411
Email To: Eduardo Torres
Phone: 914-987-9494 Fax:
Requested Due Date: std

Section B
Required Project Information:

Report To: Eduardo Torres
Copy To:
Purchase Order #:
Project Name: Fort Lauderdale
Project #:

Section C
Invoice Information:

Attention: Accounts Payable
Company Name: Carollo
Address:
Pace Quote:
Pace Project Manager: Lisa Harvey
Pace Profile #: 12021-5

Regulatory Agency
FL
State / Location
FL

MATRIX	CODE
Drinking Water	DW
Water	WT
Waste Water	WW
Product	P
Soil/Solid	SL
Oil	OL
Wipe	WP
Air	AR
Other	OT
Tissue	TS

SAMPLE ID
One Character per box.
(A-Z, 0-9 / , -)
Sample Ids must be unique

Requested Analysis Filtered (Y/N)

ITEM #	SAMPLE ID	MATRIX CODE (see valid codes to left)	SAMPLE TYPE (G=GRAB C=COMP)	COLLECTED START DATE	COLLECTED START TIME	COLLECTED END DATE	COLLECTED END TIME	SAMPLE TEMP AT COLLECTION	# OF CONTAINERS	Preservatives: Unpreserved	H2SO4	HNO3	HCl	NaOH	Na2S2O3	Methanol	Other	Y/N Analyses Test	TOC	Mn, Si	Residual Chlorine (Y/N)
1	WELL 49	WT	G	6/27	12PM	6/27	12P					1	2						2	1	
2	WELL 50	"	"	"	"	"	"					1	2						2	1	
3	WELL 51	"	"	"	"	"	"					1	2						2	1	
4	WELL 52	"	"	"		"						1	2						2	1	
5																					
6																					
7																					
8																					
9																					
10																					
11																					
12																					

ADDITIONAL COMMENTS	RELINQUISHED BY / AFFILIATION	DATE	TIME	ACCEPTED BY / AFFILIATION	DATE	TIME	SAMPLE CONDITIONS
				AS / Pace	6/28	1400	

SAMPLER NAME AND SIGNATURE

PRINT Name of SAMPLER: EDUARDO TORRES
SIGNATURE of SAMPLER: Eduardo J Torres
DATE Signed: 6/27/2019

TEMP in C	Received on Ice (Y/N)	Custody Sealed Cooler (Y/N)	Samples Intact (Y/N)

Pace Analytical Florida Laboratory	Document Name: Sample Condition Upon Receipt Form Document No.: F-FL-C-007 rev. 13	Document Revised: May 30, 2018 Issuing Authority: Pace Florida Quality Office

WO#:35478502

PM: LMH Due Date: 07/15/19
CLIENT: CARWESTPALM

m (SCUR)

Project
Project Manage
Client:

Date and Initials of person:
Examining contents:
Label:
Deliver:
pH:

Thermometer Used: T337 Date: 6.28.19 Time: 1259 Initials: 1.R.7.

State of Origin: ______ ☐ For WV projects, all containers verified to ≤6 °C

Cooler #1 Temp.°C 16.6 **(Visual)** +0.3 **(Correction Factor)** 17.7 **(Actual)** ☐ Samples on ice, cooling process has begun
Cooler #2 Temp.°C ______ **(Visual)** ______ **(Correction Factor)** ______ **(Actual)** ☐ Samples on ice, cooling process has begun
Cooler #3 Temp.°C ______ **(Visual)** ______ **(Correction Factor)** ______ **(Actual)** ☐ Samples on ice, cooling process has begun
Cooler #4 Temp.°C ______ **(Visual)** ______ **(Correction Factor)** ______ **(Actual)** ☐ Samples on ice, cooling process has begun
Cooler #5 Temp.°C ______ **(Visual)** ______ **(Correction Factor)** ______ **(Actual)** ☐ Samples on ice, cooling process has begun
Cooler #6 Temp.°C ______ **(Visual)** ______ **(Correction Factor)** ______ **(Actual)** ☐ Samples on ice, cooling process has begun

Courier: ☐ Fed Ex ☑ UPS ☐ USPS ☐ Client ☐ Commercial ☐ Pace ☐ Other______

Shipping Method: ☐ First Overnight ☐ Priority Overnight ☐ Standard Overnight ☐ Ground ☐ International Priority
☐ Other______

~~**Billing:** ☐ Recipient ☐ Sender ☐ Third Party ☐ Credit Card ☐ Unknown~~

Tracking # 12 8R8 E81 01 9531 2873

Custody Seal on Cooler/Box Present: ☐Yes ☑No **Seals intact:** ☐ Yes ☐ No **Ice:** [✓ Wet] Blue Dry None

Packing Material: ☐Bubble Wrap ☑ Bubble Bags ☐None ☐Other______

Samples shorted to lab (If Yes, complete) Shorted Date: ______ Shorted Time: ______ Qty: ______

		Comments:
Chain of Custody Present	☑Yes ☐ No ☐N/A	
Chain of Custody Filled Out	☑Yes ☐ No ☐N/A	
Relinquished Signature & Sampler Name COC	☑Yes ☐ No ☐N/A	
Samples Arrived within Hold Time	☑Yes ☐ No ☐N/A	
Rush TAT requested on COC	☐Yes ☐ No ☑N/A	
Sufficient Volume	☑Yes ☐ No ☐N/A	
Correct Containers Used	☑Yes ☐ No ☐N/A	
Containers Intact	☐Yes ☑ No ☐N/A	
Sample Labels match COC (sample IDs & date/time of collection)	☑Yes ☐ No ☐N/A	
All containers needing acid/base preservation have been checked. All Containers needing preservation are found to be in compliance with EPA recommendation: Exceptions: VOA, Coliform, TOC, O&G, Carbamates	☑Yes ☐ No ☐N/A ☑Yes ☐ No ☐N/A	Preservation Information: Preservative:______ Lot #/Trace #:______ Date:______ Time:______ Initials:______
Headspace in VOA Vials? (>6mm):	☐Yes ☐ No ☑N/A	
Trip Blank Present:	☐Yes ☐ No ☑N/A	

Client Notification/ Resolution:
Person Contacted: ______ Date/Time: ______

Comments/ Resolution (use back for additional comments): COT
1 of 2 VOC vials received broken for sample well52
and well 44

Project Manager Review: ______ Date: ______

Pace Container Order #511372

Order By :

Company Carollo Engineers
Contact Torres, Eduardo
Email etorres@carollo.com
Address 2056 Vista Parkway, Suite 400
Address 2
City West Palm Beach
State FL Zip 33411
Phone 914-987-9494

Ship To :

Company Carollo Engineers
Contact Torres, Eduardo
Email etorres@carollo.com
Address 2056 Vista Parkway, Suite 400
Address 2
City West Palm Beach
State FL Zip 33411
Phone 914-987-9494

Return To:

Company Pace Analytical Ormond Beach
Contact Harvey, Lisa
Email lisa.harvey@pacelabs.com
Address 8 East Tower Circle
Address 2
City Ormond Beach
State FL Zip 32174
Phone (386) 672-5668

Info

Project Name Fort Lauderdale
Due Date 06/25/2019
Profile 12021-5
Quote
Project Harvey, Lisa
Return
Carrier Pace Courier
Locatio FL

Trip Blanks

☐ Include Trip Blanks

Bottle Labels

☐ Blank
☒ Pre-Printed No Sample IDs
☐ Pre-Printed With Sample IDs

Bottles

☐ Boxed Cases
☒ Individually Wrapped
☐ Grouped By Sample

Return Shipping Labels

☐ No Shipper
☐ With Shipper

Misc

☐ Sampling Instructions
☒ Custody Seal
☒ Temp. Blanks
☐ Coolers
☐ Syringes
☐ Extra Bubble Wrap
☐ Short Hold/Rush
☐ DI Liter(s)
☐ USDA Regulated Soils

COC Options

☐ Number of Blanks
☒ Pre-Printed attchd

# of Samples	Matrix	Test	Container	Total	# of	Lot #	Notes
30	WT	TOC	2-40ml amber vials with HCl	60	0		
30	WT	Mn, Silica	1-250ml plastic, HNO3	30	0		

RETURN WITH COC

Hazard Shipping Placard In Place : NO

*Sample receiving hours are Mon-Fri 8:00am-6:00pm and Sat 10:00am-6:00pm unless special arrangements are made with your project manager.
*Pace Analytical reserves the right to return hazardous, toxic, or radioactive samples to you.
*Pace Analytical reserves the right to charge for unused bottles, as well as cost associated with sample
*Payment term are net 30 days
*Please include the proposal number on the chain of custody to insure proper billing

LAB USE:
Ship Date :
Prepared By:
Verified By:

Sample

CLIENT USE (Optional):
Date Rec'd:
Received By:
Verified By:

Appendix D

CONCEPTUAL EVALUATION OF SEAWATER DESALINATION

City of Fort Lauderdale
Fiveash Water Treatment Plant Evaluation

CONCEPTUAL EVALUATION OF SEAWATER DESALINATION

FINAL REDACTED | December 2019

CERTIFICATE OF AUTHORIZATION NO. 8571

City of Fort Lauderdale
Fiveash Water Treatment Plant Evaluation

CONCEPTUAL EVALUATION OF SEAWATER DESALINATION

FINAL REDACTED | December 2019

Lyle D. Munce
FL PE# 55097

Carollo Engineers, Inc.
CA 8571
2056 Vista Parkway, Suite 400
West Palm Beach, FL 33411
Ph: 561-868-6400
Fax: 561-868-6401

Printed copies of this document are not considered signed and sealed and the signature must be verified on any electronic copies

Contents

Tables

Figures

Abbreviations

BW	backwash
$Ca(OH)_2$	calcium hydroxide
Carollo	Carollo Engineers, Inc.
$CaCO_3$	calcium carbonate
Cl_2	chlorine
CO_2	carbon dioxide
CSMR	chloride to sulfate mass ratio
CU	color units (cobalt units)
DBPs	disinfection byproducts
$FeCl_3$	ferric chloride
floc/sed	flocculation and sedimentation
gfd	gallons per square foot per day
H_2S	hydrogen sulfide
µg/L	micrograms per liter
MG	million gallons
mgd	million gallons per day
mg/L	milligrams per liter
MW	megawatts
N	nitrogen
NaOCl	sodium hypochlorite
NH_3	ammonia
NTU	nephelometric turbidity unit
O&M	operations and maintenance
PFD	process flow diagram
psi	pounds per square inch
RO	reverse osmosis
SCADA	supervisory control and data acquisition
SOCs	synthetic organic compounds
TDS	total dissolved solids
TOC	total organic carbon
VOCs	volatile organic compounds
WTP	water treatment plant

1.0 Executive Summary

Background

Over the last few decades, advances in seawater desalination technology have made it a viable option for addressing some of the water challenges facing utilities across the United States. These advancements allow for potable water to be produced that meets the acceptable water quality standards at a lesser cost than before.

The City of Fort Lauderdale's (City) Fiveash Water Treatment Plant has issues with meeting the secondary water quality standard of finished water color. Wanting to address these issues, the City explored several alternatives, one of which involved sourcing seawater and building a desalination facility using reverse osmosis (RO).

To assess the viability of implementing a seawater desalination facility for the City, Carollo completed a conceptual assessment that involved comparing similar facilities recently implemented in the United States. Carollo limited its assessment to this comparison because the seawater desalination facility would be in an urban area, which presents several challenges that have not yet been investigated.

The facility in question would have a capacity of 50 million gallons per day (mgd), which is the capacity required to replace the water produced from the Fiveash Water Treatment Plant (WTP). Thus, the main facility used for this comparison was the 50-mgd Claude “Bud” Lewis Carlsbad Desalination Plant in Carlsbad, California.

Seawater Treatment System

The seawater desalination facility would have four major components: a seawater intake, a power plant, a reverse osmosis treatment facility, and waste discharge. Information about each component and the potential challenges associated with it are summarized below.

Seawater Intake. To produce 50 mgd of potable water, the facility would need approximately 110+ mgd of seawater, since the seawater RO process converts roughly 45 percent of the seawater taken into the process to potable water. For seawater intake, an offshore submerged open intake system could be used that collects water and transmits it to a facility on land via pipelines and intake structures. Another option for seawater intake is a system of beach wells that collect saline water from vertical, horizontal, or slant wells.

Both approaches carry considerable cost and come with many engineering and environmental challenges that must be addressed before regulatory approval is granted to construct. If the treatment facility is located near the seawater intake, the challenges associated with transferring the water from the ocean could be minimized. If real estate is not available, the seawater would need to be pumped through a pipeline system to the treatment facility.

Power Plant. A seawater desalination treatment system is energy intensive. Due to the transmission considerations and the higher level of power reliability required, a power plant adjacent to the desalination facility would be recommended. A power plant for a 50-mgd desalination facility would need to be sized to provide approximately 40 megawatts (MW) of power.

Reverse Osmosis Treatment Facility. Recent seawater desalination WTPs have used RO for treatment because it doesn't carry substantial cost. With an RO process, pressurized seawater is applied to the outside surface of a semipermeable membrane. A portion of the feed water then permeates the membrane and is collected on the other side as desalinated freshwater. The separated salts remain on the feed side of the membrane and are removed from the system in a brine flow stream.

An RO treatment system that receives seawater from an open submerged offshore intake will need to be preceded by a pretreatment system designed to remove suspended material and other impurities that could foul the RO membranes. Such a system would need to be designed to maintain a long and sustainable membrane life. These pretreatment schemes typically include chemical treatment followed by media or micro- or ultrafiltration filtration systems, and the solids removed from the water require subsequent disposal, typically to a landfill.

Waste Discharge. The seawater desalination treatment system creates a liquid waste from the RO membrane system and a solid waste from the pretreatment system. As noted under the above intake discussion, only approximately 45 percent of the seawater taken into the system is converted to potable water. The remaining water is concentrated to a high salinity, high density brine flow stream that needs to be returned to the ocean.

Brine disposal has several environmental concerns. The higher density flow stream must be sufficiently mixed with ocean water so it does not sink to the ocean floor and harm plants, fish, or other marine life. This disposal system, however, can lead to complex discharge diffuser systems that can contribute greatly to the overall project cost.

The solid waste from the pretreatment system can be trucked offsite to an approved disposal location such as a landfill.

Cost Considerations

The capital costs associated with constructing a seawater desalination facility depend on many factors, such as the following:

- Location of treatment facility relative to the ocean.
- Availability of sufficient real estate.
- Size, type, and location of the seawater intake facilities.
- Water quality and required pretreatment systems.
- Proximity to and reliability of power plant/power supply and transmission.
- RO brine disposal facilities.
- Vulnerability of plant site, intake, and outfall facilities to coastal hazards (e.g., hurricanes, erosion, storm surge, sea level rise, etc.).
- Proximity to the potable water distribution system.

Capital costs of a similarly sized seawater desalination facility in Carlsbad, California, were reportedly between $700 million and $1 billion, not including the cost for a new power plant to support the desalination facility. The cost does, however, include preliminary development, engineering, permitting, and construction costs.

For comparable projects, typical annualized costs reported for seawater desalination facilities, including the cost for both debt service and operating costs, are between $5 to 10 per 1000 gallons of potable water produced.[1] The 2017 cost of water from the 50-mgd desalination plant in Carlsbad reportedly ranges from $6.52 to $7.26 per 1000 gallons, while Santa Barbara's much smaller 3-mgd desalination plant produces water at a cost of $9.20 per 1000 gallons.

1.1 Background

The City of Fort Lauderdale is considering ways to improve treatment at its Fiveash Water Treatment Plant (WTP). Although the WTP provides potable water that meets primary water quality standards, it has difficulty meeting the secondary water quality standard for finished water color.

The City reviewed an evaluation of treatment alternatives, where each alternative was assessed for its ability to reduce color below visual thresholds and to meet all applicable water quality goals. All of the previously evaluated alternatives used groundwater from the Biscayne Aquifer as a source water. However, as an additional alternative, the City would like to consider sourcing seawater and building a desalination facility.

This report evaluates the efficacy of seawater desalination with respect to meeting water quality goals, additional source water allocation, reliability, risk, flexibility, operations and maintenance (O&M) requirements, footprint, capital costs, and O&M costs.

1.2 Process Flow

The seawater desalination treatment process consists of the following components:

1. Seawater intake.
2. Natural gas-fired power plant that provides power to the reverse osmosis (RO) system.
    a. Note: Because seawater desalination requires substaintial capacity and has high power needs, and the water supply must be reliable and unable to be interrupted, a dedicated power plant would need to be built.
3. RO desalination.
4. Brine discharge to ocean.

A process flow diagram of the desalination system is shown in Figure 1.

---

[1] Water Reuse Association. 2012. White Paper: Seawater Desalination Costs.

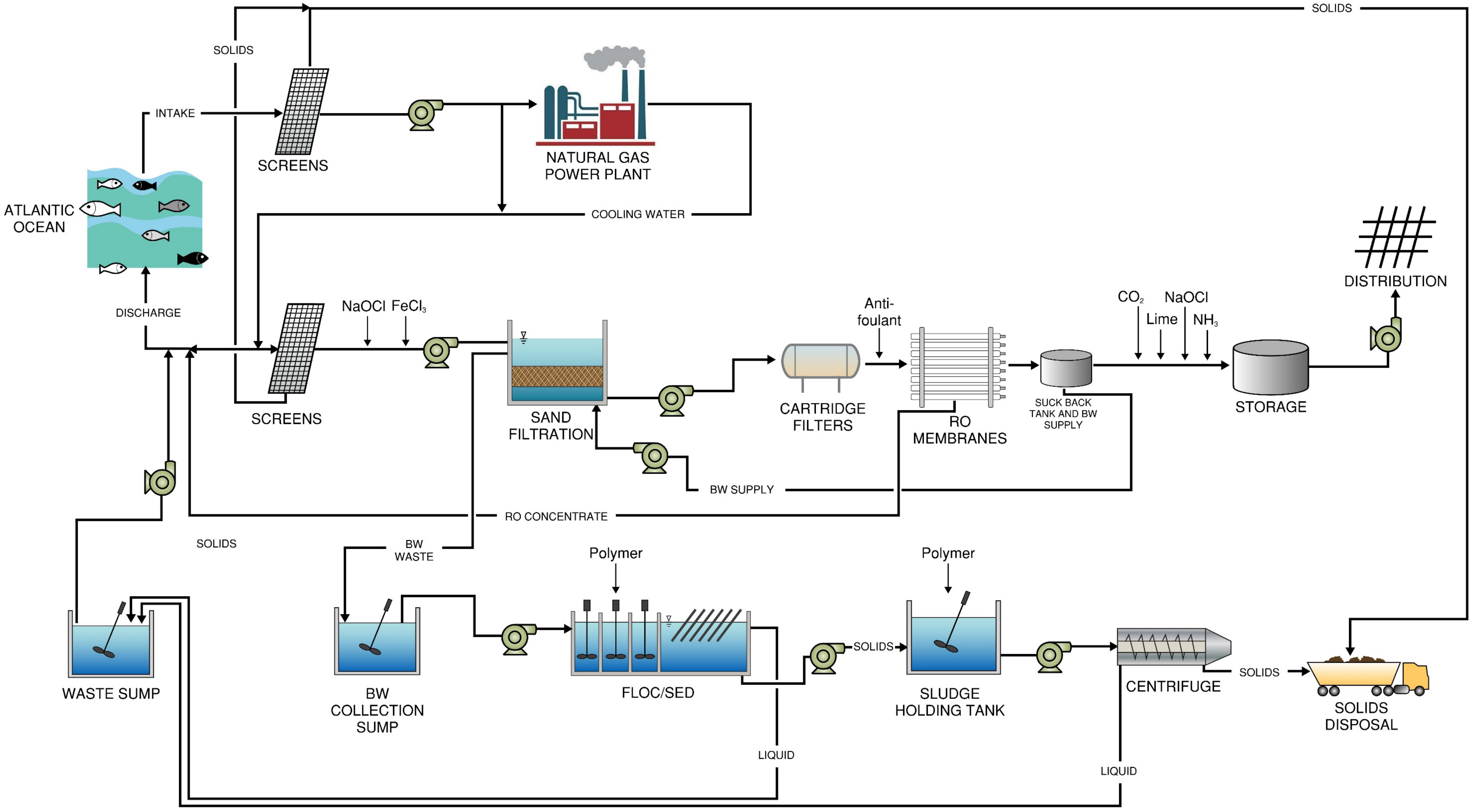


Figure 1 Seawater Desalination Process Flow Diagram

1.3 Flow Summary

Projected plant flows are summarized in Table 1.

Table 1 Plant Flow Summary

Parameter	Units	Value	
		Average Production	Maximum Production
Ocean Intake Flow$^{(1)}$	mgd	104.1	130.2
Water through Power Plant	mgd	7.5	9.4
Sand Filter Backwash Waste Percent	%	8	
Sand Filter Influent Flow	mgd	96.6	120.8
Sand Filter Average Backwash Flow	mgd	7.7	9.7
Sand Filter Effluent Flow (net)	mgd	88.9	111.1
RO System Recovery	%	45	
RO Permeate Flow	mgd	40.0	50.0
RO Concentrate Flow	mgd	48.9	61.1
Ocean Discharge Flow$^{(1)}$	mgd	64.1	80.2

Notes:

(1) Intake and discharge flows shown in this table assume that a discharge diffuser will be used to distribute the high salinity brine and avoid discharge toxicity. If a diffuser is not used, the discharge flow total dissolved solids (TDS) should be diluted to 40,000 milligrams per liter (mg/L) or less. This would necessitate adding a dilution pipe from the seawater intake directly to the discharge, carrying an additional 270 mgd (average) to 337 mgd (maximum).

1.4 Seawater Intake

Because an intake flow of approximately 105 - 130 mgd is needed to produce 50 mgd of potable water, a screened open ocean intake would be required. Beach wells cannot be used for the following reasons:

- The beach well's capacity would be limited by proven well technology type and low pumping rates that don't affect area groundwater.
- The beach well's limited production capacity would likely mean that more than 50 wells would be needed, spaced out over many miles.
- The multiple well facilities would each need to be fortified against coastal hazards, including hurricanes, storm surge, beach erosion, and sea level rise.

Per the Clean Water Act Section 316(b), because a gas-fired power plant needs a water supply, the best available screening technology would be required, namely a cylindrical wedge wire screen located offshore. The screens would require periodic maintenance, would need to be located away from shipping traffic, and would require a siting study that includes an evaluation of marine life impacts.

Generally, a desalination plant's intake screens should be located at a depth of at least 40 feet below mean sea level to avoid the additional treatment required to remove algae, which would otherwise limit plant capacity and require the RO membranes to be cleaned. This would likely require locating the intake over 1 mile from shore.

Cylindrical wedge wire intake screens – Santa Barbara, California

1.5 RO System Design Parameters

Design parameters for the RO system are listed in Table 2.

Table 2 RO Desalination System Design Parameters

Parameter	Units	Value	
		Average Production	Maximum Production
Number of Trains	---	4	
Number of Stages	---	1	
Number of Vessels	---	580	
Elements per Vessel	---	6	
System Recovery	%	45	
Total Feed Flow	mgd	88.9	111.1
Total Permeate Flow	mgd	40.0	50.0
Total Concentrate Flow	mgd	48.9	61.1
Feed Flow per Train	mgd	22.2	27.8
Permeate Flow per Train	mgd	10.0	12.5
Concentrate Flow per Train	mgd	12.2	15.3
1st Pass Average Flux	gfd	7.2	9.0
Feed Pressure	psi	758	802
Concentrate Pressure	psi	748	789

1.6 Water Quality Analysis

1.6.1 Ability to Meet Water Quality Goals

Seawater RO systems are a proven technology that can be designed to meet the City's water quality goals. Key water quality objectives are discussed further in the following subsections.

1.6.1.1 Color

Raw seawater is lighter in color than water produced by the Biscayne Aquifer. As a result, the RO-treated water would meet color goals under all conditions as long as the system is regularly cleaned and maintained.

1.6.1.2 Hardness and Alkalinity

As shown in Figure 1, lime and CO_2 are added after RO treatment to control hardness and alkalinity in the finished water. For the City's desalination plant, hardness and alkalinity concentrations could be adjusted by adding lime and CO_2 as well to meet the City’s goals.

1.6.2 Other Water Quality Considerations

- Volatile organic compounds (VOCs) – The RO process generally doesn't remove VOCs, meaning source water protection and monitoring would be required. If an oil spill occurs near the intake, or if source water monitoring indicates oil exposure, the desalination facilities would either need to be shut off temporarily, or additional treatment such as dissolved air floatation would be required.
- Inorganic chemicals – Arsenic, barium, cadmium, nitrite, and nitrate can be effectively removed by RO.
- Synthetic organic compounds (SOCs) – The RO process removes most SOCs to the same levels as the salts.
- Disinfection – With proper monitoring, the RO system may provide up to 4-log virus removal, meeting the plant's disinfection goals. However, chlorine dosing is still required at the finished water to form a distribution system residual.

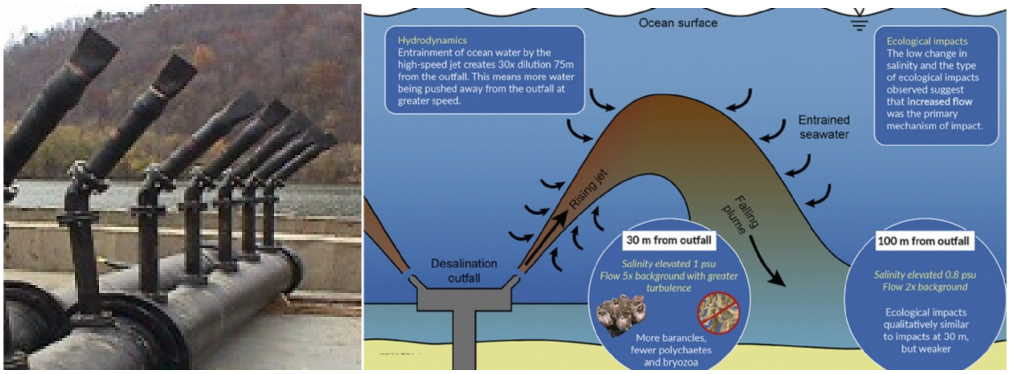
1.6.3 Ability to Meet Future Regulations

- Manganese – RO membranes can reduce manganese to very low concentrations. As a result, this alternative should have no problem meeting future manganese regulations.
- Cyanotoxins – The RO system would remove cyanotoxins.
- Disinfection byproducts (DBP) – Seawater total organic carbon (TOC) levels are already fairly low, and the RO membranes would remove most of the remaining TOC, resulting in very little DBP formation.
- Perfluorinated compounds – RO membranes remove perfluorinated compounds.

1.7 Ocean Outfall

Desalination plant brine has twice the salinity concentration of seawater. As a result, the discharge will be dense, and, without properly engineered mixing, the brine will settle to the ocean floor where it would be toxic to bottom-dwelling marine life.

Thus, an ocean outfall would be required to create a specially designed diffuser system that sends the brine discharge upward at a high velocity to improve mixing. A siting study would be required as well to locate the outfall where it does not affect the intake and shipping traffic, and only minimally affects marine life.



Brine Outfall Diffusers

1.8 Estimated Conceptual Capital and O&M Costs

The conceptual capital and O&M costs for a 50-mgd seawater desalination plant shown in Table 3 are based on existing desalination plants in the United States, such as the Claude "Bud" Lewis Carlsbad Desalination Plant (Carlsbad, CA) and the Charles E. Meyer Desalination Plant (Santa Barbara, CA).

Table 3 Conceptual Capital and O&M Cost Estimates

Component	Parameter	Units	Low Value	High Value
Water Treatment Plant	Capital Cost	$M	750	1,000
	O&M Costs (Averaging 40 mgd)	$M/yr	43.8	58.4
Natural Gas Power Plant	Production Capacity	MW	38	40
	Capital Cost	$M	20	40
Totals	**Capital Cost**	**$M**	**770**	**1,040**
	O&M Cost	**$M/yr**	**43.8**	**58.4**

1.9 O&M Requirements

This treatment alternative would have the following O&M considerations:

- RO process:
  - Operations – An RO membrane system is a relatively automated process. However, sophisticated equipment monitoring would be required to regularly identify operational problems.
  - Maintenance – The RO process is mechanically intensive with many pumps and automated valves that need to be regularly maintained. The RO membranes need regular cleanings as well.
  - Safety – Unlike most RO systems treating groundwater in Southeast Florida, a seawater RO system operates at extremely high pressures, often in excess of 800 psi. Thus, piping systems and equipment must be carefully designed and assembled. Extreme care and special safety procedures are required to prevent accidental release of high-pressure water, which may result in death.
- Power plant – A 24-hour operations staff would be needed at the power plant. This staff would regularly coordinate with the treatment plant to maintain flows, temperatures, and energy usage. All power plant equipment would require regular maintenance.
- Screens – A marine contractor would need to periodically clean offshore cylindrical wedge wire intake screens. Onshore screens would produce solids primarily associated with the biological growth of material inside the intake pipeline. These solids would need to be regularly removed from the screens and hauled by trucks for disposal.
- Sand filtration – The filters would require regular monitoring to maintain proper flow rates, loading rates, and headloss. The backwash system, however, can be automated.
- Solids processing – The flocculation and sedimentation equipment would require regular maintenance and cleaning. Due to the quality of the raw water, flocculator speeds will likely be fairly consistent. All solids treatment processes require maintenance and operational monitoring.
- Brine discharge – The brine discharge will require monitoring for eco-toxicity, and a marine contractor will need to periodically inspect and/or repair any offshore diffusers.
- Chemicals – Several chemicals would need to be stored on-site, including sodium hypochlorite, ferric chloride, RO anti-scalant, pressurized CO_2, lime, and ammonia.
  - Specific lime O&M requirements include delivery of dry chemical, filling silos, slaking, and slurry tank mixing. Lime is the only chemical that would be delivered in dry form.
  - Other chemicals (with the exception of CO_2) would be delivered as liquids and would require regular tank and pump maintenance, along with ancillary dilution systems for hypochlorite storage and delivery.

- Pumping – The pumps listed below would be required for this process. (Major process flows are listed in Table 1.) In most cases, specialty pumps are needed to handle the water's high salt content. All pumps require monitoring and regular maintenance.
  - Primary process:
    - Seawater intake pumps.
    - Transfer pumps between power plant and sand filters.
    - RO feed pumps.
    - Distribution system pumps.
  - Ancillary:
    - BW supply pumps.
    - Various solids processing pumps.
    - Seawater discharge pumps.
    - Chemical feed pumps.
    - Other ancillary pumps (recirculation, etc.).
  - Power plant:
    - Numerous pumps will be required within the power plant building to circulate cooling water.

1.10 Risks, Challenges, and Reliability

Developing a new water supply can pose many challenges that affect both the project costs and the time required to implement the supply. Depending on several factors, the cost and schedule can be unpredictable, as demonstrated by the following examples:

- Tampa, Florida (25 mgd): 12 years from planning to operation of functioning facility; project costs increased by 50 percent over the original estimate.
- Carlsbad, California (50 mgd): 14 years from planning to operation; project costs increased by 150 percent over original estimate.
- Huntington Beach, California (50 mgd): 19 years and counting since planning started; project costs have increased by more than 150 percent over the original estimate.

The following are risk factors for increased costs and schedule:

- Brine disposal – Disposing the desalination process brine to the ocean is a feasible option; however, due to the large volumes of brine (up to 61.1 mgd), there are environmental concerns. Concentrated brine can create toxicity for aquatic wildlife, and the concentrate stream will have elevated temperatures from combining with the power plant cooling waste. As a result, permitting for ocean withdrawal and brine disposal would require a special siting study and permits.
- Energy consumption – Because desalination plants consume large amounts of energy, a dedicated 38-40 MW natural gas power plant would have to be built. This would require extensive permitting and construction of a natural gas pipeline.

- Plant siting – Desalination plants are typically located directly adjacent to the ocean/sea. The 50-mgd Carlsbad desalination plant is located on a 6-acre parcel, but the power plant co-located with it occupies nearly 90 acres. Thus, space limitations and objections from residents who don't want to be able to see the facility may make plant siting challenging. Environmental challenges associated with coastal hazards, including hurricanes, storm surge, coastal erosion and sea level rise, can make project facilities less viable, both on land and off-shore.
- Permitting challenges – Permit applications for this plant could be rejected, meaning the plant cannot be built. If the power plant permit was rejected, power would need to be secured from a nearby power grid. Environmental mitigation may also be required to address the impacts of the project facilities, which can increase costs unpredictably.

For these reasons, to secure a new water supply within the timeframe required and at an affordable cost, most public agencies that consider seawater desalination as a water supply alternative often pursue multiple supply alternatives in parallel. These other supply alternatives may include fresh surface water, groundwater treatment (if available), or even potable reuse.

1.10.1 Facility Staff

The treatment process and chemicals involved are generally safe for treatment plant staff. However, chemical deliveries and storage require strict adherence to standard safety protocols.

Power plant staff will encounter risks associated with combustible materials. The power plant's proximity to the water treatment plant may pose an additional safety risk for treatment plant staff if the sites are combined.

1.10.2 Environmental Considerations

Because this treatment plant would be located directly adjacent to the ocean, hurricane protection and storm surge considerations are critical. All structures would need to be designed to meet or exceed storm and sea level rise requirements.

1.11 Flexibility

- Treatment process – The desalination treatment process has little flexibility with respect to finished water quality. If a second pass of RO membranes was added with a modulating bypass option, this would offer flexibility in terms of total salt rejection. The source water quality is expected to be relatively consistent year-round, with slight temperature variation. As a result, the plant's operating parameters for water quality are expected to be relatively consistent through the year. Making each process modular using multiple trains per process will ensure that a variety of flow rates could be treated.
- Supply flow – Depending on the nature of the permit for withdrawing seawater, this option will likely have more flexibility than groundwater-based alternatives.
- Drought resilience – One advantage of desalination is that neither drought nor inconsistencies in freshwater supplies would affect the plant's production capacity.

1.12 Footprint

The facility's footprint would be moderate to large. Although membrane-driven processes are fairly compact, the power plant and associated pump stations would require a large land area.

The following components would contribute to the footprint of this facility:

- Natural gas power plant.
- Intake pump station.
- Transfer pumps (power plant to sand filtration).
- RO pumps, cartridge filters, and membranes.
- Suck back and backwash supply tank.
- Finished water storage tank.
- Finished water pump station.
- Backwash collection sump.
- Solids flocculation/sedimentation system.
- Sludge holding tank.
- Centrifuges.
- Waste sump.
- Chemical storage facility.

Appendix E

TASK 6 – ALTERNATIVE FIVEASH WATER TREATMENT PLANT LOCATION

CITY OF FORT LAUDERDALE

City of Fort Lauderdale
Granular Activated Carbon Pilot and Plant
Evaluation at the Fiveash Water Plant

Technical Memorandum 6
TASK 6– ALTERNATIVE FIVEASH WATER TREATMENT PLANT LOCATION

FINAL REDACTED | December 2019

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CERTIFICATE OF AUTHORIZATION NO. 8571

CITY OF FORT LAUDERDALE

City of Fort Lauderdale
Granular Activated Carbon Pilot and Plant Evaluation at the Fiveash Water Plant

Technical Memorandum 6

TASK 6 – ALTERNATIVE FIVEASH WATER TREATMENT PLANT LOCATION

FINAL REDACTED | December 2019

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TASK 6 – ALTERNATIVE FIVEASH WATER TREATMENT PLANT LOCATION

6.1 Background

The Fiveash Water Treatment Plant (WTP) was constructed in the 1950's and has infrastructure and equipment that is aging, antiquated, and at the end of its useful life. The existing infrastructure at the WTP also poses various operational and maintenance challenges. Alternatives are being considered to make improvements to the existing plant in the short and long term, as well as to consider a site location for a new plant. This Technical Memorandum (TM) describes the siting evaluation for the only available land parcel owned by the City within the Prospect Wellfield site. The TM provides an overview of location, existing zoning, summary of cursory site investigations, and facility siting alternatives within the Prospect Wellfield site.

The general location for the new plant will be within the City of Fort Lauderdale's property were the existing WTP wells are located (Prospect Wellfield). As shown in Figure 6.1, the property is bound by Prospect Road to the south, State Road 441 and Florida's Turnpike to the west, NW 62nd Street and Palm Aire Village to the north, and NW 31st Avenue to the east.

[redacted]

Figure 6.1 General Location for New WTP

The existing prospect wellfield site has four zoning designations including: parks, recreation and open spaces; commerce center district; utility; and residential multi-family. The location of each zone is shown in Figure 6.2.

[redacted]

Figure 6.2 Existing Zoning

6.2 Site Considerations

To determine an appropriate site for a new WTP within the Prospect Wellfield area, the following criteria were considered:

- Existing Fiveash site area and current facility size (for conceptual purposes it is assumed that a future facility would likely be of similar size to the existing)
- Site access and potential entrances
- Environmental factors, including wetlands and protected species
- Existing utilities and infrastructure
- Requirements of the Federal Aviation Administration (FAA) and the Fort Lauderdale Executive Airport
- Wellfield protection ordinance constraints
- Considerations associated with adjacent properties, restrictions, and available property

Chen Moore performed site visits, researched existing as-builts, obtained property and right-of-way information, inspected the site boundaries and the surface water areas, coordinated with City staff and compiled information from the Fort Lauderdale Executive Airport which was provided by the City. The findings in this report are general in nature and it is recommended that for a more detailed siting analysis the City meet with agencies with jurisdiction over this area, including Broward County, Florida Department of Environmental Protection (FDEP), FAA, City of Fort Lauderdale Planning and Zoning and the Florida Department of Transportation (FDOT). A summary of the selection criteria for the new WTP site preliminary evaluation is as follows:

6.2.1 Site Area

The current Fiveash WTP is located immediately west of I-95 just south of Prospect Road and north of NW 38th Street. The WTP site footprint is approximately 18 acres and includes the treatment facility, public works building, administration building, storage tanks, parking lots, access driveways and stormwater retention ponds. For purposes of determining the size of the new WTP, the Fiveash footprint of the existing 70 mgd conventional lime softening treatment plant was considered. A minimum area of 12 acres was determined to encompass the treatment plant which excludes the PW building, parking lots and administration structures. The estimated 12 acres is considered adequate considering modern treatment process generally occupy much lesser space, therefore a 12 acre site was used for the facility siting evaluation.

6.2.2 Site Access

[redacted] Depending on the location of the site, the new WTP could be accessed from NW 31st Avenue, Prospect Road, or NW 62nd Street, all of which are Broward County Roads. Construction of the new facility may require improvements to the existing roads such as turn lanes, signals and access driveways. Final determination of the necessary improvements and access location will be determined during Site Plan processing and permitting through Broward County Engineering and Highway Construction Division.

6.2.3 Environmental Considerations

Portions of the property contain heavy vegetation and surface water bodies. Prior to finalizing the selection of the WTP site location, the City must consider the impact to the existing features including trees, water bodies, wetlands and protected species. Borrowing owls, a protected species, were observed on-site. Further investigation is required to determine the mitigation and permitting requirements of local and State jurisdictional agencies.

Setback requirements for wellfield protection was reviewed based on criteria set in FAC 62-532. Well field protection zone requirement was reviewed from Broward County Chapter 27. Landscape and parking in the vicinity of the wellfield can be planned for and constructed. The alternative layouts presented further in this TM indicates that the proposed sites do not interfere with the existing wells.

Contaminated land areas in the vicinity is of concern and need to be addressed in the planning phase. As indicated in Figure 6.3, a Broward County contaminated site is located at the northeast intersection of NW 62nd Street and NW 31st Avenue. The property contains petroleum pollutants and it is registered as DEP facility 069063935.

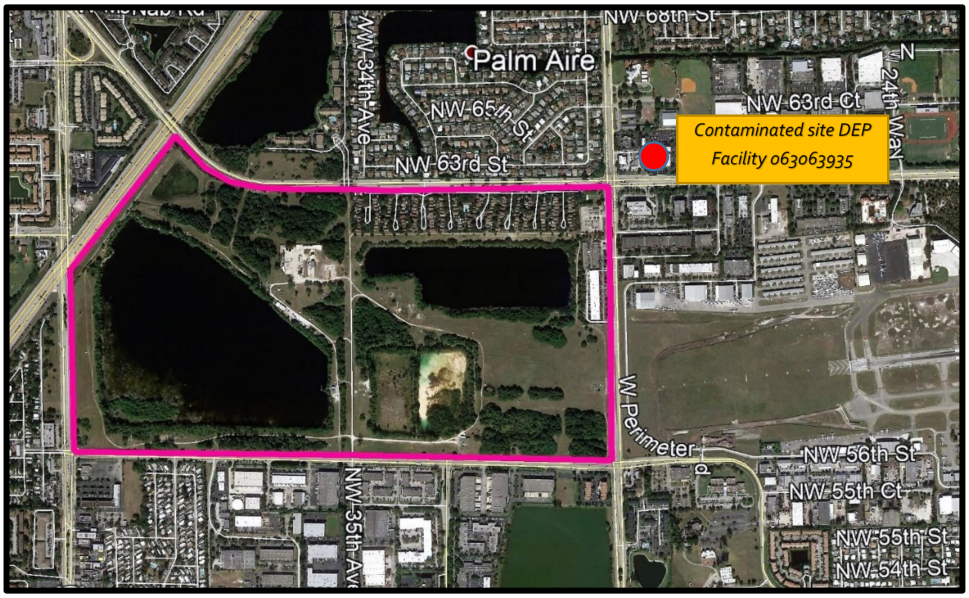

Figure 6.3 Contaminated Sites

Section 27-353(b), Broward County Code, states that "No construction or other intrusive activities shall be initiated, proceeded or continued at any site, location or property where it is known or discovered that such site, location or property overlies or contains contaminants unless it can be demonstrated that the construction will not result in the enhancement or spread of the contaminants."

Section 27-353(i), Broward County Code, states that "Dewatering operations at or within a one-quarter-mile radius of a contaminated site shall not be conducted without EPD approval."

The contaminated site is more than one quarter mile from any of the proposed locations (shown later in this TM) for the new water treatment facility; therefore, construction activities and dewatering during construction would likely not affect the construction of a new WTP.

6.2.4 Federal Aviation Administration (FAA) Considerations

The site will be located just west, and within the flight path, of the City of Fort Lauderdale Executive Airport. Consideration to make sure all FAA requirements are met during construction and operation of the plant will be necessary. Criteria provided by the Airport include the maximum permissible height for structures encroaching into the flight path. The maximum height cannot be exceeded by the new WTP, or by equipment during construction of the WTP. Meetings with FAA and the airport will be required to determine additional criteria, and elevation reference. Figures 6.4 provides the proposed site location and its proximity to the airport, and Figure 6.5 indicates the height restriction information provided by the City staff for the Prospect Wellfield site.

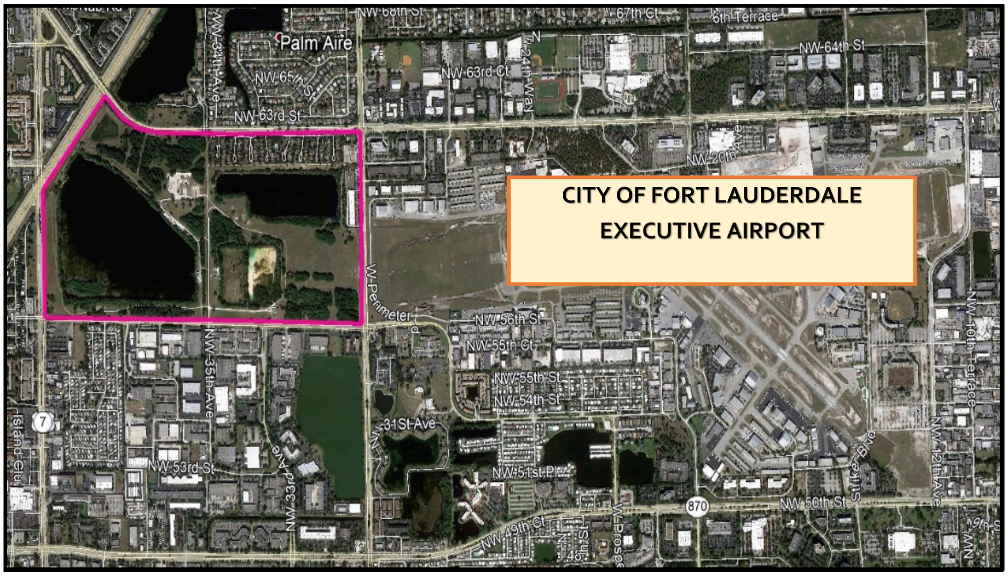

Figure 6.4 Location of Site – West of City of Fort-Lauderdale Executive Airport

Figure 6.5 Maximum Allowable Height for Structures within the Flight Path

6.2.5 Existing Utilities

The existing utilities in the area were investigated. Due to area and space limitations, the relocation of some of the raw watermains may be necessary to obtain the adequate area to accommodate the new WTP. Other existing site features and utilities may require relocation to obtain the necessary footprint for the new WTP. Figure 4.6 presents the locations of existing wells and the connecting raw water lines.

6.3 Proposed WTP Sites

[redacted]

[redacted]

[redacted]

6.4 Conclusion

It appears that there is adequate space at the prospect wellfield site for a new plant. Based on the size, location and orientation of the potential site some utilities as well as wetlands and protected species may need to be relocated. Upon selection of water treatment process, an additional study is recommended to be initiated to understand the Development Review Committee (DRC) process with the City, meet with Federal Aviation Administration (FAA) and determine the relocation need for wetland, utility and/or protected species.

[redacted]

Figure 6.6 Existing Wells and Raw Water Lines

[redacted]

Figure 6.7 Locations of Three Alternatives for Water Treatment Plant

[redacted]

Figure 6.8 Site Location of Alternative 1

[redacted]

Figure 6.9 Site Location of Alternative 2

[redacted]

Figure 6.10 Site Location of Alternative 3

[redacted]

Figure 6.11 Maximum Allowable Height for Structure within the Flight Path – with Alternatives

Appendix F

TASK 5 – WATER SUPPLY ALTERNATIVE INVESTIGATION

CITY OF FORT LAUDERDALE

City of Fort Lauderdale
Granular Activated Carbon Pilot and Plant
Evaluation at the Fiveash Water Treatment Plant

Technical Memorandum 5
TASK 5 –WATER SUPPLY ALTERNATIVE INVESTIGATION

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CITY OF FORT LAUDERDALE

City of Fort Lauderdale
Granular Activated Carbon Pilot and Plant Evaluation at the Fiveash Water Treatment Plant

Technical Memorandum 5
TASK 5 –WATER SUPPLY ALTERNATIVE INVESTIGATION

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WATER SUPPLY ALTERNATIVE INVESTIGATION

5.1 Background

The City of Fort Lauderdale (City) has initiated an evaluation to determine how to best address the current and future needs at the Fiveash Water Treatment Plant (WTP). This evaluation consisted of a review and investigation into the current water supply sources, alternative water supply sources, water use allocation per consumptive use permit (CUP), and relevant planning documents. This Technical Memorandum (TM) provides a summary of existing water supply allocation, alternative water supply sources, and evaluates incremental finished water needs and subsequent raw water needs based on recommended treatment technologies.

5.2 Existing Water Supply Allocation

A review of CUP, Lower East Coast Plan Update 2017, and the Comprehensive Utility Strategic Master Plan (CUSMP) 2017 was performed. The City currently has two Biscayne aquifer wellfields, Prospect wellfield supplying water to the Fiveash WTP, and Peele Dixie wellfield supplying water to the Peele Dixie WTP. Additionally, there are two existing Floridan Aquifer test wells, and a proposed Floridan Aquifer wellfield at a location near the Peele Dixie surficial aquifer wellfield.

The water supply allocations are authorized by the South Florida Water Management District (SFWMD). These allocations are regulated per aquifer and wellfield, as well as based on average annual day and maximum month flow basis. Table 5.1 indicates the Biscayne and Floridan Aquifer allocations for the City by wellfield. It is important to note that each Biscayne wellfield has annual average day (AAD) demand allocation such that the total of each individual wellfield (43.43 mgd + 15 mgd = 58.43 mgd) is greater than the total permitted withdrawal rate (52.55 mgd). This is usually the case for utilities with more than one wellfield, where SFWMD CUP considers providing some level of operational flexibility at individual wellfield level to allow for maintenance.

Table 5.1 Biscayne and Floridan Aquifer Allocations for the City by Wellfield

Description	Annual Allocation MGY	Monthly Allocation MGM	Annual Average Daily Allocation MGD
Biscayne Aquifer Annual	19,181	-	52.55
Biscayne Aquifer Maximum Month	-	1,857	-
Dixie Biscayne Wellfield	5,475	465	15
Prospect Biscayne Wellfield	15,853	1,534.5	43.43
Floridan Aquifer Annual Allocation	3,153	-	8.64

5.3 Alternative Water Supply Sources

This section presents the potential alternative water supply sources from the conventional Biscayne Aquifer source for impact offset, alternative Floridan Aquifer source, C-51 reservoir as water supply source, Aquifer Storage and Recovery (ASR), and seawater as a supply source considering the proximity of the City to the ocean. The following subsections describe the source, availability, treatment technologies needed to treat the source water, and future challenges associated with the source.

5.3.1 Biscayne Aquifer

The Biscayne Aquifer has been a traditional water supply source in Florida's Lower East Coast (LEC). The Biscayne aquifer produces high-quality fresh water from relatively shallow wells in most of the Tri-County area. This is the most productive aquifer in Florida.

Utility infrastructure has been historically designed to treat the water from the Biscayne Aquifer. Since the SFWMD enacted the Water Supply Availability Rule in 2007, there is a limit to the use of the Biscayne Aquifer as a water source. Based on the CUP, the City is limited to 52.55 mgd of raw water withdrawals from the Biscayne Aquifer through its exiting water supply facilities between the Prospect and Peele Dixie wellfields.

The availability of water from the Biscayne aquifer is restricted due to existing water demands, source limitation, and issues such as saltwater intrusion, and environmental needs. The Biscayne Aquifer is not available for additional raw water withdrawal to meet future demands beyond the allocation amount in the CUP without mitigation offsets. Potential mitigation offsets can be achieved by providing recharge benefits to the aquifer.

5.3.1.1 Impact Offset

Increased withdrawals from the Biscayne Aquifer are limited due to potential impacts on the SFWMDs regional system, wetlands, existing legal water users, and due to the potential for saltwater intrusion. Additional raw water allocation from the Biscayne Aquifer can be obtained if mitigation offsets are demonstrated using ground water models. Mitigation offsets can be obtained in various ways such as groundwater recharge using reclaimed or excess surface water as an impact offset or substitution credit.

Example of surface water recharge benefits would be Prospect Lake recharge which is further explained below or the C-51 Reservoir project. For information on the C-51 Reservoir system please see TM 8.

The City has the various canals within the local governmental area, these canals are utilized to discharge excess surface water flows to tide. One potential option for surface water recharge is to consider a network of drainage wells which pump stormwater into the aquifer which help prevent the saltwater from moving further inland. This option can potentially provide the benefit of keeping the wellfields safe from saltwater intrusion, and it could potentially result in impact offset benefit to the City, and potentially providing the City with additional Biscayne allocation. An example of such project is the C-12/C-13 project. This project has been discussed in the CUSMP 2017. The City has decided not to move forward with this project.

Broward County has developed a model associated with this type of recharge system and may have the capability of performing such modeling for the City to demonstrate the benefit of saltwater intrusion mitigation and impact offset for the City. Further discussions on this matter between the City and County is recommended.

A similar project to obtain impact offset credit using excess surface water was developed by the City between late 1990s and early 2000s. This project 'C-14 Canal Recharge to Prospect Lake' is described in detail below.

5.3.1.2 C-14 Canal Recharge to Prospect Lake

In 1997, as part of the SFWMD LEC Water Supply Plan, the City and Stantec (Montgomery Watson Harza) developed an alternative water supply project that redirects C-13 Canal flow, which otherwise would be discharged to tide, to recharge the Prospect Wellfield lakes and indirectly the Biscayne aquifer. Montgomery Watson Harza carried out a water source feasibility study, a preliminary design report and subsequent facilities design, followed by construction assistance. The feasibility study identified two sources of water (i.e. south portion of C-13 and north portion of C-14) as possible means to recharge the Prospect Wellfield lakes and surrounding aquifer. The study concluded that the C-14 Canal, which is located 1.5 miles north of the wellfield, was a better than C-13 canal source of recharge water for Prospect and Gator Lakes. In 1998 the City, in a joint effort with the SFWMD, initiated a project to recharge the Prospect Wellfield with water from the regional canal system into the Prospect lake and Gator lake from the adjacent Palm Aire Canal.

The C-14 canal project was to provide an additional source of recharge to the Prospect Wellfield area lakes and aquifer. Recharge water from the C-14 to the lakes is conveyed through the Palm Aire Canal and 2,600 feet of new pipeline between the Palm Aire Canal and by connecting the lakes. Based on the TM 'Prospect Lake Recharge Water Demand Analysis' prepared in April, 1999, the maximum recharge to the aquifer through the pipeline while filling the lakes is expected to be 21 mgd on a maximum day basis and 11 mgd during average day conditions.

Due to the unusual aspects of the project that includes impact offset to the regional system using surface water for indirect aquifer recharge, the permitting process was extensive and required over 2 years of effort to attain Federal, State, County, and SFWMD approval. One pivotal approval condition needed was to reclassify the lakes from a Class I to Class III water body based on FAC 62-302.400 so that water could be accepted from the Class III Palm Aire and C-14 Canals. This approval was granted in June 2000, and construction of this important alternative water supply project was completed in August 2000.

The existing CUP states that, "… the City has completed modeling efforts regarding stormwater capture near the Proposed Wellfield. The City has started to develop a Stormwater Master Plan. Excess water in the C-14 is discharged to tide via the S-37A Structure. Structures are gated spillways. Excess stormwater released at S-37A is captured and routed directly to the Prospect Lake as wellfield recharge. When conditions are favorable (when excess canal water is available), up to 35 cubic feet per second of water is diverted into Prospect Lake and the Prospect Wellfield through interconnects with the C-14 Canal. Additional interconnects with the C-13 and C-12 could result in more stormwater capture. The City has stated that surface modeling indicates the 11 million gallons per day was available for capture in three recent 1-in-10 dry-season events. While the infrastructure does not exist yet to capture all of that flow, the construction of additional conveyance connections could utilize some level of that seasonal water discharged to tide. The City anticipates a stormwater capture project of at least 4.0 million gallons per day going into service by 2023."

A meeting with Broward County occurred on September 18, 2019 to discuss the status of C-14 canal project. Broward County provided an Environmental Review Permit staff review summary. It was concluded during this meeting that next step would be to confirm the base condition in CUP with SFWMD.

Further discussions with SFWMD were held to determine if the full benefit of mitigation offsets for C-14 recharge has been realized by the City. Based on input from the SFWMD, the base condition model incorporated the recharge to the two lakes. Upon review of the response to request for information during the CUP application, it does not appear that full benefit as proposed in the response was granted to the City. It also appears that by performing operational modifications to the downstream structures and additional surface water/groundwater modeling, the City may be able to obtain additional allocation in the range of 1 to 4 mgd.

5.3.1.3 Treatment Technologies

The Biscayne Aquifer source water has been traditionally treated using two predominant technologies, namely lime softening and nano filtration. Over the last decade, side streams using the ion exchange process to conserve minerals in the finished water is being implemented at plants. The lime softening process has a recovery rate of 97 percent (i.e. amount of raw water converted to potable water) while the nanofiltration (NF) process has a recovery rate of 85 percent. Different recovery rates for each treatment technology dictate the need for raw water amount. A 50 mgd maximum day capacity lime softening plant needs 51.5 mgd of raw Biscayne Aquifer source water, while a 50 mgd maximum day capacity nanofiltration plant needs 59 mgd of raw source water.

5.3.1.4 Challenge

An influx of saltwater into the Biscayne Aquifer is a significant water supply challenge. The Biscayne Aquifer is being monitored for inward movement of saltwater interface over several decades. According to the LEC Water Supply Plan Update 2018, only minor movement of the saltwater interface has occurred in northern and central Broward County; however, steady inland movement has been observed in the aquifer around Dania Beach and along the North New River. The North Miami and Homestead areas show the most inland movement of the saltwater interface in Miami-Dade County.

The CUSMP 2017 states the City has 10 saltwater monitoring wells where data suggests the "toe" of the saline wedge may exist beneath the Peele Dixie wellfield which indicates a vulnerability to saline intrusion depending on future operations and conditions. The eastern most well at the Prospect Wellfield is approximately two miles away from the 2014 saline interface map presented in the CUSMP 2017.

5.3.2 Floridan Aquifer

The Floridan aquifer system (FAS) in the LEC is shallowest in the northwestern part of Palm Beach County and deepens to the south and east. The top of the FAS is approximately 800 to 1,100 feet below land surface and is under artesian pressure in the tri-County area. The FAS provides brackish ground water as supply source.

The LEC Water Supply Plan Update 2018 states that by 2016 there were 15 treatment plants constructed which utilize the Floridan aquifer as source water with combined treatment capacity of 102 mgd in the tri-County area. There are 22 utilities with Floridan aquifer allocations of 184 mgd.

Based on the CUP, the City has 8.64 mgd of raw water withdrawals allocation from the FAS. The City has two Floridan wells installed at the Dixie Wellfield with plans for transmission and treatment in the future at the Peele Dixie WTP.

5.3.2.1 Treatment Technologies

Reverse osmosis (RO) treatment is required to remove excess salinity and reach acceptable drinking water quality of Floridan Aquifer source water. The recovery rates for brackish water RO facility is generally around 75 percent.

5.3.2.2 Challenges

There are several utilities planning to develop Floridan wells that are in close proximity to each other. In the future, the Floridan Aquifer may have sustainability issues caused by water quality degradation due to excess withdrawal by utilities and their neighboring utilities. The LEC Plan Update 2018 states that there are several Floridan aquifer wellfields in the tri-County area that have experienced some water quality degradation.

The City of Sunrise recently constructed two Floridan wells in the Sawgrass International Corporate Parkway area. The Total dissolved solids is in the range of 7,000 mg/L at these wells which is generally considered towards the high end considering that Floridan Aquifer water quality degradation is expected over time. The City of Sunrise is planning to use these as combination ASR and Floridan production wells. The City of Sunrise also has a Floridan test well in the Melaleuca location along SR 595 where the total dissolved solids concentration is approximately 8,000 mg/L. This well has been placed on standby and there are no future plans to develop the well.

Broward County system 1A has two test wells where the total dissolved solids concentration was approximately 7,000 mg/L and it was recommended against further development due to the fact that the amount of total dissolved solids is considered to be high to start off with and would only degrade further over time resulting in requiring seawater desalination level of membranes.

The East Coast Floridan Model simulations and analyses conducted for LEC plan update 2018 identified potential issues related to water quality and draw down impacts that may require further evaluation to help understand sustainability and long-term use and reliability of this aquifer. The following FAS-related actions are suggested by LEC:

- Utilities should use an incremental approach to install and test production wells due to geologic variability within the Floridan aquifer. Wellfields should be designed and monitored to prevent over-stressing production zones and to minimize changes in water quality.
- Utilities developing Floridan aquifer sources are encouraged to share water quality, water level, and hydrologic data to increase understanding of the aquifer and improve regional groundwater models.
- Floridan aquifer users and SFWMD staff should evaluate the effects of water quality degradation and coordinate on related permitting, modeling, and planning strategies to maintain the viability of the Floridan aquifer as a water supply source.

5.3.3 C-51 Reservoir

The C-51 Reservoir project is a public-private partnership (P3) being developed by participating utilities and water supply authorities for use as an alternative water supply source in southeastern Florida. The C-51 Reservoir was conceptualized in the 1992 Everglades Restoration Plan (Restudy) intended to capture excess stormwater discharged to the Lake Worth Lagoon via the C-51 Canal at the SFWMD S-155 structure. The location of this reservoir is adjacent to the SFWMD's existing L-8 Reservoir in Palm Beach County and has been shown to consist of impermeable geologic formation that provides for significant storage capacity with reduced construction requirements. This unique feature allows for significant, and cost-effective wet season stormwater storage options with subsequent water supply deliveries throughout the dry season. The capture of excess stormwater proposed in the C-51 Reservoir is considered an alternative water supply project and the storage of water that can be permitted as a water supply allocation which would directly benefit utilities in southern Palm Beach and Broward Counties.

After several joint task force meetings between Palm Beach and Broward County in 2011, a final plan was coordinated with the U.S. Environmental Protection Agency (EPA) to ensure water quality protections as required in the Federal Everglades Settlement Agreement, with a revised permit issued by the FL Department of Environmental Protection in 2012. In 2013, a phased construction approach was developed as an option for potential end users to provide 35 million gallons per day (mgd) in water supply at an estimated cost of $150M.

The C-51 Reservoir Public Private Partnership (P3) would facilitate the development of the C-51 Reservoir (the "Reservoir") as an alternative water supply project for South Florida. The parties involved in the P3 would be the SFWMD and Palm Beach Aggregates, LLC (PBA) until completion, at which time Phase 1 would be transferred to a new not-for-profit special purpose entity (NFP Reservoir Entity). Under this arrangement:

- PBA would design, permit, finance construction, construct and deliver the completed Reservoir in pre-determined phases.
- NFP Reservoir Entity would own the Reservoir upon completion and transfer of each phase.
- SFWMD would operate and maintain the Reservoir and provide for the conveyance systems to and from the Reservoir.

Participating utilities would commit to water storage capacity in the Reservoir. The participating utilities have executed agreements with the property owners to purchase capacity as part of total reservoir storage. As of fall 2018, four PWS utilities (Broward County, Sunrise, Dania Beach, and Hallandale Beach) have entered into capacity allocation agreements for a total of 13 mgd of the available 35 mgd in Phase 1. The utilities have received or are processing modifications to their water use permits to reflect this AWS source as a means for meeting future demands.

The C-51 reservoir source water alternative would allow the City to continue the use of Biscayne aquifer for additional allocation. A white paper outlining a comparison of C-51 supply option to the option of using the Floridan aquifer as supply source is prepared as part of this project and submitted as TM 8 to the City.

5.3.3.1 Treatment Technologies

The Biscayne aquifer source water would be treated using previously described technologies described under section 1.3.1 Biscayne Aquifer.

5.3.3.2 Challenges

The risk using C-51 Reservoir supply for additional Biscayne Aquifer allocation is similar to that described in section 1.3.1 Biscayne Aquifer. Participating in C-51 Reservoir project requires long-term planning and commitment.

5.3.4 Aquifer Storage and Recovery

Storage of water is an essential component of any supply system that experiences a significant wet season followed by a significant dry season, which is relevant to South Florida. Without sufficient storage capacity, much of this water discharges to the ocean through the canal networks and drainage. Aquifer Storage and Recovery (ASR) offers such potential storage options.

ASR can be used for storing fresh groundwater, treated finished water, surface water, stormwater, and reclaimed water and recovering the water for later use. The injected water is treated to appropriate standards depending on the water quality of the receiving aquifer and then pumped into the aquifer well (stored). The water is recovered later during high demand periods and treated for use to meet the system demands.

The City has an ASR well system at Fiveash WTP constructed in 1998 to store raw Biscayne aquifer water from prospect wellfield during low demand periods. Water would be recovered to meet the high demand during dry season. There have been seven recharge/recovery cycles so far and results indicated poor recovery rates. The CUSMP 2017 states that it was concluded that the well as constructed was not viable for routine operations as an ASR facility in context of operational costs and poor recovery.

The City of Sunrise has constructed dual purpose wells that can be used as Floridan supply and as raw water ASR wells. During the wet season, excess raw water from Biscayne wells would be stored in the ASR wells for recovery at a later time of higher demands. The City of Sunrise has constructed two wells and are in process of installing raw water main between the wells and their treatment plant. This raw water main will be capable of carrying the flow bi-directionally (to store and to recover and transfer to the plant). This approach to ASR wells could augment the annual average day raw water demand.

Considering the C-12, C-13 and C-14 canals within the City limits, surface water ASRs could also be a potential alternative supply source. The water stored in a surface water ASR well requires pre-treatment to remove organics (UV disinfection) prior to storage, as well as treatment after recovery.

5.3.4.1 Treatment Technologies

The treatment technologies for ASR wells vary based on the type and purpose of the ASR well. Reverse Osmosis treatment is needed if the City plans to convert the existing ASR well to a Floridan well. For dual purpose, Floridan and raw water ASR wells, NF/RO treatment process is needed. For surface water ASRs, pre-treatment such as UV disinfection prior to storage and NF treatment process post recovery is suitable.

5.3.4.2 Challenges

ASR wells typically provide relief during peak demands and can provide a peak flow management solution. ASR wellfields with multiple storage and recovery wells spaced adequately far apart can provide a way to augment the annual average day demand.

The water recovery is a function of storage time, subsurface condition, and water quality. The water availability is a function of aquifer characteristics, variability of supply and demand, well yield, well construction, and use type. Extensive cycle testing may be needed to address various variability associated with subsurface condition and water quality. As a result of the variability, this alternative results in longer permitting durations compared to other alternatives.

5.3.5 Seawater

Considering the City is a coastal community in close proximity to the ocean, sea water desalination deserves consideration as an alternative water source. The SFWMD does not require water use permits for seawater. There is an abundant source of ocean water, however, desalination is required before seawater can be used for water supply purposes. There are three power plants that use seawater, these are FPL Riviera Beach Next Generation Clean Energy Center, FPL Port Everglades Next Generation Clean Energy Center, and FPL Dania Beach Energy Center. There are two RO seawater desalination facilities in the LEC Planning Area. Both plants are in Monroe County (Stock Island and Marathon) and operated by the Florida Keys Aqueduct Authority for emergencies. They have a combined supply capacity of 3 mgd to the lower Florida Keys.

5.3.5.1 Treatment Technologies

More prevalent desalination treatment technologies include distillation, RO, and electrodialysis reversal. RO is the most common desalination technology in the LEC Planning Area. Over the last decade, there have been major advances in seawater desalination treatment, but the cost of standalone seawater desalination facilities remains significantly higher than brackish water desalination. The seawater desalination treatment capital cost is 100 percent greater than the brackish ground water from Floridan aquifer and if the intake, discharge and conveyance components are removed, the annualized cost is 50 percent greater for the seawater desalination process compared to the brackish water desalination process based on data presented in the *Seawater Desalination Costs White Paper, WateReuse Association, 2012*.

5.3.5.2 Challenges

Seawater desalination process is highly energy intensive compared to brackish water treatment using membranes. The recovery rates for seawater desalination is around 50 percent. The remaining reject needs to be disposed as brine, a super saturation of saltwater. Most desalination plants pump this brine back into the ocean, which presents an environmental drawback. Ocean species are not equipped to adjust to the immediate change in salinity caused by the release of brine into the area. The super-saturated salt-water also decreases oxygen levels in the water affecting biological life. In an age where energy is becoming increasingly precious, desalination plants have the disadvantage of requiring large amounts of power. Other water sources under prior consideration are comparatively more cost effective and energy efficient.

5.4 Finished Water Projections

The CUSMP 2017 shows systemwide finished water projections for the City. The expected buildout in CUSMP 2017 is shown in year 2035 with systemwide finished water AAD demand is 45.4 mgd and systemwide finished water maximum day demand (MDD) is 59 mgd. The systemwide finished water demand is supplied by the two WTPs, Fiveash WTP and Peele Dixie WTP. Based on direction from the City, the Fiveash WTP would provide 50 mgd of MDD and the Peele Dixie WTP would provide 9 mgd of the finished water MDD.

5.5 Raw Water Projections

Raw water need is computed based on the finished water projections for the year of 2035. The raw water needs for ADD and for a scenario of MDD is calculated in this sub section.

5.5.1.1 Annual Average Day Flow Scenario

Withdrawals for each wellfield are computed for AAD scenario, this is converted to finished water for each wellfield-treatment plant pair based on the treatment system recovery process. Using this data, the additional treated water needs to meet 2035 finished water and subsequent raw water AAD demand is calculated.

As shown in Table 1 in the beginning of the TM, the Biscayne aquifer raw water withdrawal is limited to 52.55 mgd on an AAD demand by the CUP. The Citywide system generally operates by maximizing withdrawals from Prospect wellfield to minimize systemwide treatment losses and supplementing additional raw water needs in the system from Dixie wellfield. Therefore, 43.43 mgd from Prospect wellfield and 9 mgd from Dixie wellfield is assumed.

Water balance for the raw and treated water for AAD demand scenario is as follows:

1. Raw water from Dixie wellfield = 9 mgd
2. Treatment Recovery Rate from Peele Dixie WTP = 85 percent
3. Finished water from Peele Dixie WTP = 9 mgd x 0.85 = 7.65 mgd
4. Raw water from Prospect wellfield = 43.43 mgd
5. Assuming a conservative future treatment process of nanofiltration (NF) at Fiveash WTP
6. Treatment Recovery Rate from Fiveash WTP (future 100 percent NF process) = 85 percent
7. Finished water from Fiveash WTP = 43.43 mgd x 0.85 = 36.91 mgd
8. Systemwide finished water available based on CUP = 44.56 mgd (7.65 mgd + 36.91 mgd)
9. Total Systemwide forecasted AADF_{2035} demand = 45.4 mgd

Therefore, the additional finished water need =

Total Systemwide forecasted AADF_{2035} demand of 45.4 mgd – Systemwide finished water available based on CUP of 44.56 mgd = 0.84 mgd

There is an additional finished water need of 0.84 mgd, which translates to 1 mgd of raw water deficit considering the lowest recovery treatment process, NF.

5.5.1.2 Maximum Day Flow Scenario

The CUP has a raw water Maximum Month withdrawal limit of 1,857 million gallons per month (MGM) from Biscayne aquifer. The CUP does not limit maximum day raw water withdrawals by the City from any source. A hypothetical scenario was developed for MDD where water balance is shown below:

Assuming Raw Maximum Month Daily Flow (MMDF) of 59.9 mgd,

- Finished water at Peele Dixie plant is limited by its treatment capacity of 12 mgd
- Treatment Recovery Rate from Peele Dixie WTP = 85 percent
- Raw water from Dixie Wellfield = 12 mgd / 0.85 = 14.1 mgd
- Total Systemwide forecasted Finished MDDF_{2035} demand = 59.07 mgd
- Finished MMDF from Fiveash WTP = 59.07 mgd – 12 mgd = 47.07 mgd
- Assuming a conservative future treatment process of nanofiltration (NF) at Fiveash WTP

- Treatment Recovery Rate from Fiveash WTP (future 100 percent NF process) = 85 percent
- Raw MDDF from Prospect Wellfield = 47.07 mgd / 0.85 = 55.37 mgd

Therefore, total Biscayne Aquifer MDD allocation needed = 14.1 mgd + 55.37 mgd = 69.47 mgd

Based on information from the operations staff, the maximum day demand is usually observed for three consecutive days. Considering there is no maximum day withdrawal limit from Biscayne wellfield, this demand can be met based on current allocation.

5.6 Potential Water Supply Alternatives for Further Considerations

The additional finished water needs of 0.84 mgd would translate to 1 mgd of raw water deficit considering the lowest recovery treatment process which is the most conservative treatment process to meet the average day finished water demand by 2035 based on projections from CUSMP 2017. This additional raw water need can be achieved by implementing water conservation, converting existing ASR well to Floridan well or seeking impact offset credit using surface water recharge.

Viable water supply alternatives include following future consideration if demand projections change drastically are following:

- Impact offset allocation from Biscayne aquifer
  - Drainage wells to limit effect of saltwater intrusion on wellfields
  - Prospect lake recharge using C-14 water
- Floridan aquifer
- Participation in C-51 Reservoir

5.7 Recommendation

The alternative water supply needs based on CUSMP 2017 amounts to 1 mgd of additional raw water in year 2035 considering 50 mgd Maximum Day Finished water flow using a conservative nanofiltration treatment technology. This can be achieved by in-house conservation efforts or a combination of the different strategies noted in the previous section. For longer range planning, it is recommended that the City should consider and implement diverse sources of water supply ranging from Biscayne aquifer, Floridan aquifer, impact offset credits as well as regional projects such as C-51.

Appendix G

TASK 8 – “WHITE PAPER” C-51 RESERVOIR® WATER VERSUS FLORIDAN AQUIFER USAGE

CITY OF FORT LAUDERDALE

City of Fort Lauderdale
Granular Activated Carbon Pilot and Plant
Evaluation at the Fiveash Water Plant

Technical Memorandum
TASK 8 – "WHITE PAPER" C-51 RESERVOIR WATER VERSUS FLORIDAN AQUIFER USAGE

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"WHITE PAPER" C-51 RESERVOIR® WATER VERSUS FLORIDAN AQUIFER USAGE

8.1 Background

A study is underway to identify an appropriate means to address the water treatment challenges that exist at the City's Fiveash Water Treatment Plant (WTP). Included in this study is an investigation into which water treatment processes will best accomplish the established water quality and production goals.

Currently the City has a water use permit from the South Florida Water Management District (SFWMD) which allows the systemwide facilities to obtain 52.52 mgd of source water for treatment from the Biscayne Aquifer to meet the annual average daily potable water demands. The treatment processes being considered have water recovery rates which range from 75 – 98 percent recovery of the source water. Due to these recovery rates and the limited amount of Biscayne Aquifer water available, some treatment processes will require that the City obtain additional source water for treatment. This White Paper compares the feasibility and practicality of using water from the C-51 Reservoir System (C-51) versus water from the Floridan Aquifer.

The C-51 is a Public-Private Partnership under development by Palm Beach Aggregates, LLC, (PBA) and local utilities. The concept of this endeavor is to capture and store stormwater in the regional system during wet periods, and then allow utilities to harvest this water in form of additional Biscayne Aquifer withdrawals during dry periods.

This technical memorandum provides an overview of the C-51, status of the participation from utilities, its potential relevance to the City of Fort Lauderdale, and its comparison to utilization of the Floridan Aquifer from a technical and fiscal perspective.

8.2 Overview of C-51 Reservoir Project

PBA is currently constructing the C-51 reservoir near the 20 Mile Bend in Western Palm Beach County. The concept is to store water that is historically lost to tide, and subsequently release it into the regional system during dry periods of the year. The water released from the reservoir will be moved south to the participating utilities through the Lake Worth Drainage District (LWDD) canal system to recharge the Biscayne Aquifer in Southern Palm Beach and Broward County. This supplemental water would provide offsets for potential impacts to the Lower East Coast waterbodies and benefit the project participants (water users that enter into an agreement with the PBA). The water from the reservoir would provide a water "lift" to the regional system commensurate with, or exceeding, additional surficial aquifer withdrawals granted to utilities. The concept is that during a 1-in-10 year drought the regional system would not be negatively impacted by the additional withdrawals granted to the utilities since the canal elevations would be maintained at a sufficient elevation to recharge the aquifer and retard seepage from the water conservation areas.

The C-51 project was originally comprised of three phases and which was later reduced to two phases. Phase I is intended to have storage capacity of approximately 14,000 acre-feet which translates into a water supply of 35 mgd annual average day for participating utilities. Phase II is planned to have a capacity of 46,000 acre-feet, and an associated distribution of 120 mgd annual average day, based on feasibility work performed in 2009 where water supply capacity of Phase II was finalized.

The SFWMD canals would serve as a source of stormwater inflow and discharge routing once the reservoir is constructed and put in operation. It is intended that PBA enter into an operation and maintenance agreement with the SFWMD, and develop an operating plan for the project. PBA has entered into a conveyance agreement with the LWDD where LWDD will facilitate the conveyance of water.

What follows is a timeline of activities that has occurred with the C-51:

- May 2012 - PBA entered into a Memorandum of Understanding with the SFWMD for a cooperative environment for the operation and maintenance of the reservoir.
- June of 2012, PBA released its Preliminary Design and Construction Report (PDR) that outlined the three reservoir construction phases (the third phase was subsequently removed), 7-year plan for development of the 75,000 acre reservoir (total for all three phases), and preliminary cost estimates. This PDR was updated in 2013.
- May 2013 - Broward and Palm Beach counties formed a joint task force, the C-51 Governance and Finance Work Group, to evaluate the financial feasibility and governance model for long term management.
- PBA applied for Environmental Resource Permit (ERP) with Florida Department of Environmental Protection (FDEP), which was issued to PBA in April 2014.
- July 2014 – Independent Cost Estimate and Financial Analysis was performed by MWH (Montgomery Watson Harza)
- December 2015 - surface water Consumptive Use Permit (CUP) was issued to C-51 Phase 1 Reservoir project. This is a fifty (50) year permit with an annual average day allocation of 13.39 mgd.
- PBA is working on the design and permitting of the phase I of the reservoir. The construction is anticipated to commence by late 2019. The duration is expected to be 24 months and final completion is anticipated in January 2022.

Initial utility participants are Broward County, City of Sunrise, Hallandale Beach and Dania Beach, with potential participation by Miami-Dade County. Table 8.1 shows the participants, wellfields, and allocation amounts by participants.

Table 8.1 Wellfield and Allocation Amounts by Participants

Participants	Wellfield	Allocation
Broward County	South Regional Wellfield District 1 Wellfield	6 mgd
City of Sunrise	Springtree Wellfield	5 mgd(1)
City of Dania Beach	Broward County South Regional Wellfield through Large User Agreement	1 mgd
City of Hallandale Beach	Broward County South Regional Wellfield through Large User Agreement	1 mgd
	Total	13 mgd
	Remaining	22 mgd

Notes:
(1) Source: C51 Reservoir Draft Operating Plan March 2019

In addition to the above participants, Miami Dade Water and Sewer is in process of evaluating the feasibility of participating in the C-51 project. This planning effort is expected to be completed by Fall 2019.

8.3 Comparative Evaluation

The C-51 Reservoir project has a CUP allocation for 50 years. Broward County has received a separate CUP for C-51 with a duration of 50 year allocation and the City of Sunrise is in process of responding to request for information on their CUP application for C-51, which also includes demand projections for 50 years. For the purpose of the comparative evaluation between use of C-51 reservoir source and use of Floridan aquifer the projected demand is considered over a period of 50 years.

8.3.1 Evaluation Assumptions

For comparative evaluation of the use of C-51 reservoir water source versus the use of Floridan aquifer water source, several assumptions were made and are listed below:

- The CUP for C-51 allocation can be obtained for 50 year duration, and the corresponding City system demands are estimated to identify allocation over a similar timeframe. Currently, population and subsequent demand projections are available for 20 years, and 50 year population projections and demand projections are not available. The increase in demand over 50 years period is assumed to be 20 percent of the projected maximum day demand of 50 mgd at the Fiveash WTP.A duration of 50 years was used to determine additional allocation needs.
- The potential C-51 water allocation will be associated with the Biscayne aquifer at the Prospect wellfield.
- There are sufficient Biscayne aquifer raw water production wells for the additional C-51 allocation and no new wells are needed.
- The treatment process utilized to determine the amount of C-51 source water allocation that will be needed in the future is nanofiltration. It is intended that this represents a “worse case” source water need scenario from treatment recovery and cost perspective
- The treatment process recovery rate is estimated to be 85% for nanofiltration (NF) and 75 percent for reverse osmosis (RO) filtration.

8.3.2 C-51 Reservoir Source Water Option

Utilization of C-51 Reservoir water would allow use of the Biscayne aquifer for additional future source water needs at the Fiveash WTP. This additional water can be obtained by using existing raw water production and transmission system infrastructure.

The amount of C-51 water needed is estimated utilizing the 85 percent nanofiltration treatment recovery and the required facility maximum day production rate of 50 mgd, minus the current CUP allocation. This identified volume will need to be potentially purchased from PBA.

8.3.3 Floridan Aquifer Source Water Option

The Floridan Aquifer source water option would draw water from Floridan aquifer which is approximately 1,000 feet +/- below land surface. New Floridan production wells and raw water transmission line would be required for this option. The treatment process for this water would be reverse osmosis (RO). The associated water recovery rate of this process is estimated to be 75 percent.

8.3.4 Comparison

New infrastructure needs for both source water options were evaluated and compared for capacity, capital cost, operation and maintenance (O&M) cost and net present value. The infrastructure consists of raw water production well and transmission lines for Floridan aquifer supply option, and pre-treatment, membrane treatment, post-treatment, and disposal for both options. Due to a lower water recovery in the case of the RO process, a greater amount of raw water along with associated additional pre-treatment chemicals and system pumping is needed. Both treatment processes have similar clearwell, transfer pumps, storage tank and high service pump needs. Both options consider a hypothetical finished water requirement of 10 mgd (which represents 20 percent of the identified planned capacity of the Fiveash WTP). Treatment process equipment and infrastructure for nanofiltration technology is similar to reverse osmosis technology. Table 8.2 below shows the comparative process capacity needs for the two processes.

Table 8.2 Comparative Capacity Needs for Production Well and Treatment Process

	C-51 Reservoir (using Nano Filtration)	Floridan Aquifer (using Reverse Osmosis)
Pre-Treatment	1	1.1
Feed and Booster Pumps	1	1.1
Skids and Membranes	1	1.1
Chemical System	1	1
Post Treatment	1	1

Notes:
(1) For comparative purpose if the capacity of NF is 1, a comparative capacity of RO pre-treatment, pumps and membranes would be 10 percent greater to account for RO requirements necessary to produce same amount of finished water.

The above table indicates that the use of Floridan Aquifer as a supply source requires 10 percent additional pretreatment, pumping and membrane equipment and infrastructure when compared to the use of C-51 reservoir as a supply source.

8.3.5 Capital Cost

The capital cost for each option represents upfront investment in the infrastructure, or water purchase commitment in the case of the C-51 option. The C-51 Reservoir supply option has two types of capital cost, a cost attributed to the C-51 reservoir water purchase, and a cost for treatment plant infrastructure. A unit rate of $4.60/gal of capital cost has been provided by the PBA for the water purchase. A unit rate for treatment, storage, and disposal utilizing the nanofiltration process of $6.5/gal of capital cost was determined based on best available information.

The Floridan aquifer supply option considers capital cost for raw water supply, treatment and disposal at a unit rate of $9.8/gal. This unit cost is based on the best available information.

8.3.6 Operation and Maintenance Cost

The operations and maintenance (O&M) cost for each option represents recurring costs related to the operateration of the planned infrastructure such as chemicals and power and furnishing labor to operate and maintain the facility. For this evaluation, the C-51 Reservoir supply option has two types of O&M costs, a cost attributed to operating the C-51 reservoir and subsequent flow through the SFWMD and LWDD canals, and a cost to operate and maintain a nanofiltration or RO plant infrastructure. A unit rate of $0.12/1,000 gal of O&M cost has been provided by the PBA for the reservoir and canal operation. A unit rate for operating and maintaining nanofiltration process and disposal well of $2.0/ 1,000 gal was used based on the data provided from the Peele Dixie nanofiltration facility (an additional cost associated with labor was included).

A unit rate for operation and maintenance of reverse osmosis treatment and disposal of $3.0/1,000 gal was calculated. This information is based on the best available information.

8.3.7 Quantitative Comparison

Based on the capital and O&M unit rates and an infrastructure capacity of 10 mgd finished water, a quantitative comparison for C-51 reservoir source water option and Floridan aquifer source water option was performed.

8.3.8 Capital Cost Comparison

The capital cost for the C-51 reservoir source water option includes cost to participate in the C-51 reservoir project at $54M, and nanofiltration treatment and disposal cost to produce finished water at $65M. The capital cost for the Floridan aquifer source water option of $98M includes cost to construct production wells, transmission lines, treatment, and disposal costs. The C-51 reservoir source water option is greater by $21M in capital cost compared to the Floridan aquifer source water option. An assumption of 6 percent interest rate and 3.5% discount rate over 30 year period was used to compute the cost differential on a comparative basis. The annual debt service on capital for the 30 years loan period is approximately $8.6M for C-51 reservoir source option and $7M for Floridan aquifer source water option.

8.3.9 O & M Cost Comparison

The O&M cost to treat C-51 reservoir source water includes the cost to operate and maintain the C-51 project at $438,000 per year, and the cost of power, chemicals and labor to operate the nanofiltration facility at $7.3M per year. The O&M cost to treat Floridan aquifer source water of approximately $10.95M includes cost of power, chemicals and labor to operate the reverse osmosis facility. Total annual O&M cost for C-51 reservoir source water option is approximately three quarters of the Floridan aquifer source water option. Total O&M cost was calculated over the 30-year loan period considering 3.5% annual discount rate at approximately $399M for C-51 reservoir source option and $565M for Floridan aquifer source water option. The resulting annualized O&M cost is $13M for C-51 reservoir source option and $19M for Floridan aquifer source water option.

8.3.10 Comparative Cost Contrast

The sum of annual debt service on capital (considering principal and interest) and annualized O&M cost prorated over 30 years of borrowing period results in cost differential of approximately $119M between the Floridan aquifer source water option compared to the C-51 reservoir source water option for a 10 mgd finished water infrastructure. Table 8.3 provides a summary of costs between the two source water options.

Table 8.3 Summary of Comparative Costs between the Two Source Water Options

	C-51 Reservoir (using Nano Filtration)		Floridan Aquifer (using Reverse Osmosis)	
	Unit Cost	Cost	Unit Cost	Cost
Treated Flow (GPD)		10,000,000		10,000,000
Annual Flow (365 days)		3,650,000,000		3,650,000,000
Capital Cost				
Treatment Facilities (10 MGD finished)	$6.5/gal	$65,000,000	$9.80/gal	$98,000,000
C-51 Reservoir (11.8 MGD raw)	$4.6/gal	$54,280,000		
Total Capital Cost		**$119,280,000**		**$98,000,000**
Annual O&M Costs				
Water Treatment	$2.0/Kgal	$7,300,000	$3.0/Kgal	$10,950,000
C-51 Reservoir O&M	$0.12/Kgal	$438,000		
Total O&M Cost/Kgal		$ 7,738,000		$10,585,000
PV of Operating Costs (20 yr, 3.5% discount)		$122,860,000		$173,858,000
Net Present Value (NPV)		**$242,140,000**		**$271,858,000**

Table 8.3 Summary of Comparative Costs between the Two Source Water Options (continued)

	C-51 Reservoir (using Nano Filtration)		Floridan Aquifer (using Reverse Osmosis)	
	Unit Cost	Cost	Unit Cost	Cost
Comparative Evaluation Considering Debt Service				
Interest Rate	6%			
Discount Rate for Costs	3.5%			
Debt Period	30			
Capital Expense		$119,280,000		$98,000,000
Annual Debt Service on Capital (P&I)		$8,665,600		$7,119,600
Daily cost of Capital Ex (365/yr)		$23,741		$19,506
Total Capital Outlay over period w/ finance		$259,968,800		$213,588,000
Total O&M Cost over 30 years		$399,456,300		$565,268,400
Annualized O&M Cost		$13,315,300		$18,842,300
Annual cost (P&I) and O&M		$21,980,900		$25,961,900
Total Comparative Cost over duration		$659,427,000		$778,857,000
C-51 Reservoir Total savings over duration		$119,430,000		

8.3.11 Qualitative Comparison

A qualitative comparison of the C-51 reservoir source option and Floridan aquifer source option was performed with criteria ranging from practical implementation, consumptive use permit, sustainability, and reliability perspective. These comparisons are listed in Table 8.4.

Table 8.4 Qualitative Comparison of Options

	C-51 Reservoir (using Nano Filtration)	Floridan Aquifer (using Reverse Osmosis)
Practical Implementation	The C-51 reservoir project is underway and commitments have been made by four utilities for a total of 13 mgd only.	Floridan Aquifer Treatment plants exists at many locations in Florida therefore implementation issues are known.
Consumptive Use Permit (CUP)	This option will require a new CUP application which will be separate from the existing CUP. The duration of the C-51 related CUP will be granted for 50 year duration.	Since the CUP for C-51 duration is 50 years, a comparative period of comparison for additional Floridan aquifer would be over 50 year duration. The City has an existing Floridan aquifer allocation of 8.6 mgd. This option would require an additional allocation of 5 mgd over a 50 year duration.
Reliability	Biscayne aquifer has proven to be historically reliable.	Floridan Aquifer's future in terms of quantity and quality is unknown and expected to change due to significant predicted usage throughout the area. It should also be noted that this potential degradation has been identified in several areas within the South Florida area.
Sustainability	Since the C-51's water availability comes from southeast Florida's natural hydrogeologic/ hydrogeology cycle it is sustainable	Floridan aquifer is recharged in central Florida and areas north, and has many users. The waters from Central Florida takes years to recharge and reach south Florida. Excessive use of the resource has been known to cause capacity and quality issues. This option uses power intensive treatment technology
Diversification of Source	C-51 reservoir offers the City an additional source of water. This option allows continuing use of existing City infrastructure.	The Floridan Aquifer option is an existing planned source of water.

8.3.11.1 C-51 Participation Logistics

The process of participation in the C-51 reservoir project was explained by PBA where, if the City chooses to participate in this option, a letter of interest from the City would need to be submitted to the PBA. Subsequent to the letter of interest, CUP modifications would need to be initiated to demonstrate future water need over 50-year duration. The CUP modification would include groundwater modeling to determine the mitigation offset impact to demonstrate future allowable withdrawals as a result of 10 mgd participation in C-51 reservoir project. Upon receiving the CUP allocation, capacity needs would be finalized, and capacity allocation agreement would be formulated between the City and the PBA. Upon construction completion of the C-51 reservoir project by PBA, the project will be transferred from the P3 entity to the participating utility operating group known as C-51 Reservoir Inc. The accounting of incremental additional water will be managed by SFWMD, and the operations of the canals will be performed by the SFWMD, the 298 District, and LWDD.

8.4 Results

The comparative evaluation of C-51 reservoir source water versus Floridan aquifer source water options indicates that the Floridan aquifer source water option requires additional production wells and transmission lines. The process treatment requirements for each options are very similar, but the reverse osmosis technology to treat Floridan water necessitates 10 percent greater capacity for pre-treatment, pumps and membranes. The comparative capital cost differential is $21M greater for C-51 reservoir source water option for additional 10 mgd finished water. The comparative annual O&M cost differential is approximately $3M greater for Floridan aquifer source water option. The total differential cost over a 30 year borrowing period is $119M between Floridan aquifer and C-51 reservoir option. In addition, there are qualitative benefits of the C-51 Reservoir option such as allocation commitment by SFWMD through CUP for 50 years, reliability of source water, and diversification of source water.

8.5 Recommendations

Based on the qualitative and quantitative information contained herein the use of C-51 reservoir source water option is a favorable option over the Floridan aquifer source water option. It should be noted that the C-51 reservoir source water option can be considered in conjunction with Floridan aquifer option to maximize the diversification of the City’s source water supply.

Appendix H

TASK 9 – ALTERNATIVE DEVELOPMENT – WTP SITING AND CONSTRUCTION SEQUENCING

CITY OF FORT LAUDERDALE

City of Fort Lauderdale
Granular Activated Carbon Pilot and Plant
Evaluation at the Fiveash Water Plant

Technical Memorandum 9
TASK 9 – ALTERNATIVE DEVELOPMENT – WTP SITING AND CONSTRUCTION SEQUENCING

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TASK 9 – ALTERNATIVE DEVELOPMENT – WTP SITING AND CONSTRUCTION SEQUENCING

9.1 Background

A study is underway to identify an appropriate means to address the water treatment challenges that exist at the City's Fiveash Water Treatment Plant (WTP). The existing infrastructure at the WTP poses operational and maintenance challenges, and struggles with the ability to meet the water quality goal of color. Alternatives are being considered to determine the most appropriate water treatment process, and water supply source. An alternative site location for a new plant is also being considered. Several treatment schemes considering different treatment options were analyzed and developed and are reported in Technical Memorandum - Evaluation of Treatment Alternatives. From this analysis three treatment schemes were selected and recommended for further development.

The City requested four options be investigated. These options are level of service driven alternatives and include the following:

- Base level of service being repair and rehabilitation of existing Fiveash WTP,
- Next level of service includes the incorporation of a color removal process at existing Fiveash WTP,
- The ultimate level of service includes replacement of the existing WTP at the Fiveash site, or
- A replacement facility at an alternative location of the Prospect wellfield site (Prospect site).

This TM further develops the shortlisted treatment schemes from TM 3 to identify process capacities, along with general facility sizes to determine space requirements and siting at the existing Fiveash and at the Prospect site.

This TM describes the level of service and the three shortlisted treatment processes/schemes for each alternative. Conceptual level process capacities and site layouts are presented to determine if adequate space is available at each site. Potential phasing of infrastructure needs as well as space adequate for future expansion is considered in each alternative evaluated.

9.2 Alternative 1 – Existing WTP Repair and Rehabilitation

Existing facility condition assessment for Prospect wellfield (wellfield) and Fiveash Water Treatment Plant (WTP) was performed as part of the Comprehensive Utility Strategic Master Plan (CUSMP) 2017, followed by a high-level confirming assessment of the wellfield and WTP as part of this evaluation effort under TM 4- Existing Facility Condition Assessment. Both the CUSMP 2017 and confirming assessment noted that the existing facility was in a challenging condition to be considered for long term potable water production service. The assessments identified that the original WTP and wellfield facility infrastructure is from 1950's. Multiple facility expansions over the years have occurred since that time. Much of the existing wellfield has wells and well equipment is at the end of the predicted useful life, with primary and backup electrical systems old and vulnerable to future failure. The primary WTP processes have also exceeded the predicted useful life. Much of the WTP equipment is old and antiquated technology, including the electrical equipment.

There are several additional major operational and maintenance issues at the WTP such as leaking aeration and filtration structures; single point of failure due to lack of isolation, insufficient interconnectivity and redundancy; lack of access for maintenance; lack of spare part access due to outdated/antiquated equipment and so forth. A quantification in terms of correction is difficult to assess. It was determined that continuing re-investment of significant funds for the long-term use of existing facility originally constructed in 1950's, while possible, is not be prudent nor recommended. This alternative was not investigated further.

9.3 Alternative 2 - Color Removal Systems at Existing Facility

The ability to add color control treatment processes at the existing facility was investigated. At the facility the water is treated by a series of processes including aeration, softening, filtration and disinfection. These process systems are closely situated in an overall facility footprint that has no available space for color removal treatment units. Because of this, color removal treatment units would need to be located remote from the current primary flow path of the facility. Modifications necessary to intercept the flow of water and transmit it to an adjacent location on the site would be required. The current WTP configuration does not allow for a reasonable connection strategy. Any connection approach would require significant demolition and replacement of portions of the existing facility. This demolition and reconstruction would likely require that the WTP be taken out of service for extended periods of time. Therefore, demolition and replacement of portions of the 60+ year old facility is not recommended. This alternative was not investigated further.

9.4 Alternative 3 - WTP Replacement at the Existing WTP Site

Treatment alternatives at the Fiveash WTP for future production of potable water were evaluated based on their ability to meet production requirements and all applicable water quality goals established. Based on desk top analysis and bench scale testing, seven treatment schemes were initially short listed from original eighteen treatment schemes considered. These seven were further condensed to three final schemes which were recommended for further development based on the criteria in the technical memorandum Evaluation of Treatment Alternatives (Task3). These three treatment schemes are as follows:

- Treatment Scheme 2 – Lime Softening and Fixed Bed Ion Exchange (IX)
- Treatment Scheme 7 – Enhanced Coagulation with Pellet Softening and Fixed Bed IX
- Treatment Scheme 11 – Nanofiltration (NF) and Fixed Bed IX

All three treatment schemes were considered for the Existing WTP site. Several necessary assumptions were made to perform concept level siting. These are as listed below:

- The existing plant equipment and processes will remain operational while the new processes are constructed, commissioned, tested and placed into service.
- One new 5 Million Gallon (MG) Ground Storage Tank (GST) at the location of existing GST 1 is planned for if space is available based on treatment scheme selected.

- A new WTP control building is proposed for new treatment processes while existing WTP control building will continue to operate the current plant during construction of the new plant processes.
- The existing administration building will remain and is not planned to be replaced.
- The dog park to the south which is owned by City of Oakland Park, will be utilized.
- Utilize the future sodium hypochlorite, fluoride and carbon dioxide storage and feed facilities, and generator building which are being installed under the Disinfection and Reliability Upgrades project.
- It should be noted that contractor staging areas will be very limited and will likely need to be located offsite. There is a Broward County Park on the south side of the roadway that may be able to be temporarily utilized for a staging area.
- The existing parking lot in the administration building area will be utilized by the new WTP, a new multistory parking lot, or similar, will likely be needed to provide parking for vehicles in the future.

9.4.1 Treatment Scheme 2 - Lime Softening and Fixed Bed IX

9.4.1.1 Process Overview

Treatment scheme 2 includes lime softening, filtration and ion exchange as the primary processes to produce 50 mgd of finished water to meet maximum day demand (MDD). Table 9.1 presents major process overview with capacities for average day and maximum day flow rates for the plant, and Figure 9.1 depicts the process flow diagram of Treatment Scheme 2. It should be noted that the process flow diagram depicts the bypass of the softening process and ion exchange process. Table 9.2 shows that the process bypass rates are different for average day and maximum day flow conditions.

Table 9.1 Major Process Capacity for Lime Softening and Fixed Bed IX

Flow Stream	Average Flow (mgd)	Maximum Design Flow (mgd)
Forced draft aeration	40	50
Softening	38	50
Softening Bypass	2	25
Recarbonation	40	50
Dual Media filtration	40	50
IX	40	50
IX Bypass	0	25

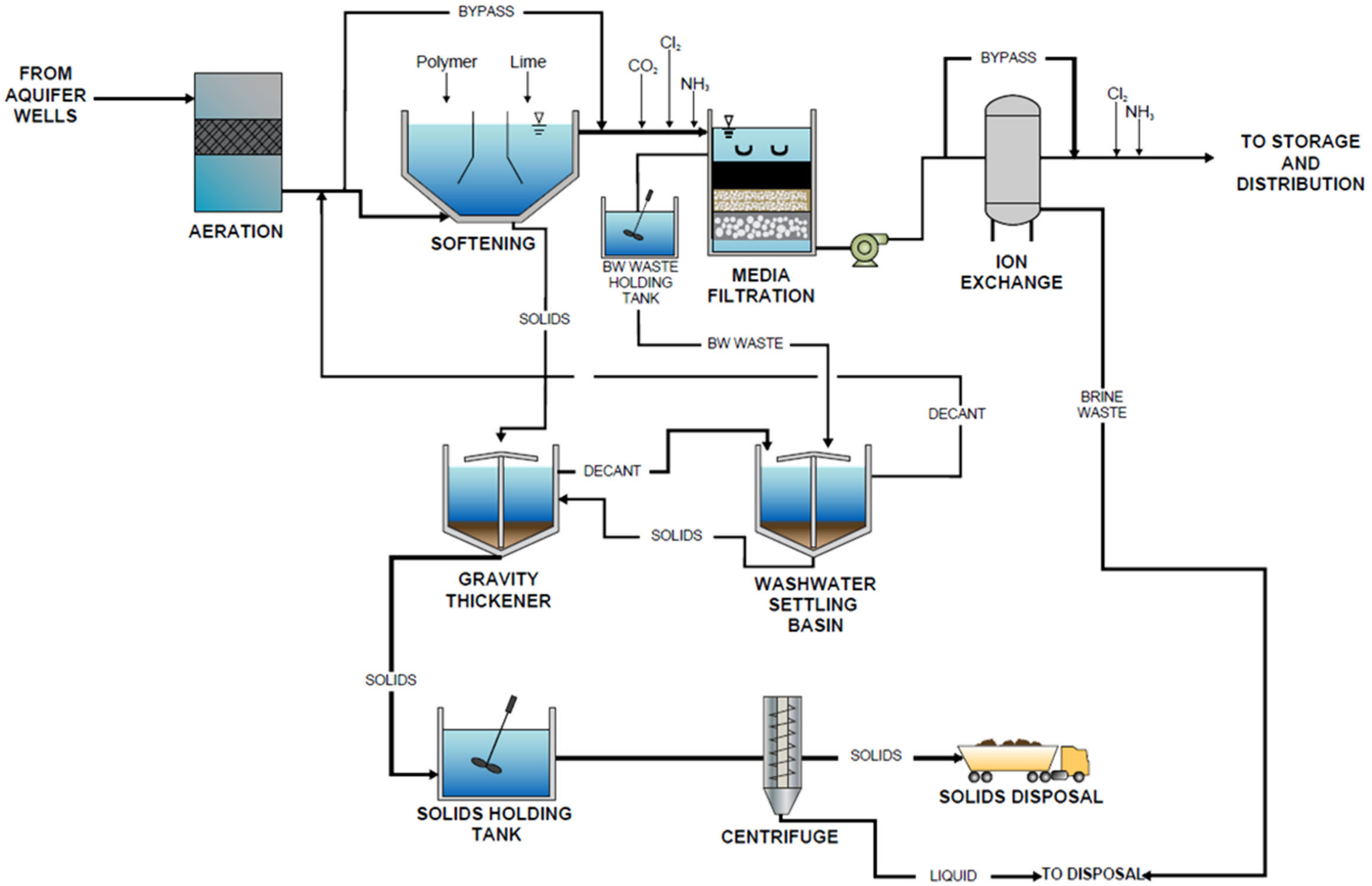

Figure 9.1 Treatment Scheme 2 – Lime Softening and Fixed Bed IX

Table 9.2 Major Process Information for Treatment Scheme 2

Process	Parameter	Quantity	Units
Pre-treatment (Forced Draft Aeration)	Aerators	20	each
	Towers/Columns	1,740	gpm
	Blowers (cfm)	34,740	cfm
Softener Units	Solids contact clarifiers	4	each
	Solids contact clarifier diameter	92	ft
Polymer Storage and Feed	Softening polymer totes	2	each
	Polymer tote volume	275	gal
	Polymer pumps	5	each
Lime Storage and Feed	Total lime silo capacity needed (by weight)	565	tons as CaO
	Silos	4	each
	Lime slurry tanks	4	each
	Lime metering pumps	5	each
Filters	Filters	10	each
	Backwash pumps	2	each
Recarbonation	CO2 Tanks	2	each
Ion Exchange	Pre-IX pumps	7	each
	Vessels	35	each
	Brine supply tanks	4	each
Washwater System	Backwash holding tanks	2	each
	Washwater settling basins	2	each
Lime Sludge Dewatering and Thickening	Lime solids production rate (max)	3	lbs dry solids /lb
	Gravity thickeners	2	each
	Solids holding tanks	2	each
	Centrifuges	3	each
Disinfection	Sodium Hypochlorite Bulk tanks	10	each
	Transfer Pumps	4	each
	Sodium Hypochlorite Day tanks	4	each
	Metering pumps	3	Each
	Ammonia Tanks	2	each
	Ammonia Pumps	3	each
Clearwell	Chlorine Contact Tank	1	each
Transfer Pumps	Vertical Turbine Pumps	8	each

9.4.1.2 Conceptual Layout

The existing Fiveash WTP processes are located on the northern portion of the site. There is limited infrastructure that can be retired prior to construction and operation of the new WTP.

Therefore, use of the northern portion of the site is not practical to partially locate new process in the area (even with the removal of the ground storage tank (GST) 1 which was constructed in 1958 and is in poor condition). The south portion of the site has administration building, parking lot, fuel filling station and fleet parking. The south portion of the site is considered appropriate to locate the proposed treatment processes. A conceptual layout for Alternative 3, Treatment Scheme 2, is presented in Figure 9.2. This conceptual layout considers areas for the processes identified in Table 9.2, as well as a new controls building, new electrical building consisting of switchgears, emergency generators, fuel storage, and a new storage building.

The Treatment Scheme 2 layout does not fit on the Fiveash site even after considering the use of the area of GST 1, the existing administration building, parking lot, fuel filling station, fleet parking and the adjacent dog park area (which is owned by the City of Oakland Park). This alternative does not appear feasible at the Fiveash site for a new 50 mgd facility.

[redacted]

Figure 9.2 Alternative 2 Treatment Scheme 2 Conceptual Plant Layout

9.4.2 Treatment Scheme 7 - Enhanced Coagulation with Pellet Softening and Fixed Bed IX

9.4.2.1 Process Overview

This treatment scheme includes coagulation/flocculation/sedimentation, pellet softening, filtration, and ion exchange as main processes to produce 50 mgd of MDD finished water. Table 9.3 presents major process overview with capacities for average day and maximum day flow rates for the plant, and Figure 9.3 depicts the process flow diagram of Treatment Scheme 7. It should be noted that the process flow diagram depicts the bypass of the softening process and ion exchange process. Table 9.3 shows that the process bypass rates are different for average day and maximum day flow conditions.

Table 9.3 Major Process Capacity for Enhanced Coagulation with Pellet Softening and Fixed Bed IX

Flow Stream	Average Flow (mgd)	Maximum Design Flow (mgd)
Coagulation/flocculation /sedimentation	40	50
Forced draft aeration	40	50
Softening	28	50
Softening bypass	12	25
Recarbonation	40	50
Dual Media filtration	40	50
IX	30	50
IX bypass	10	25

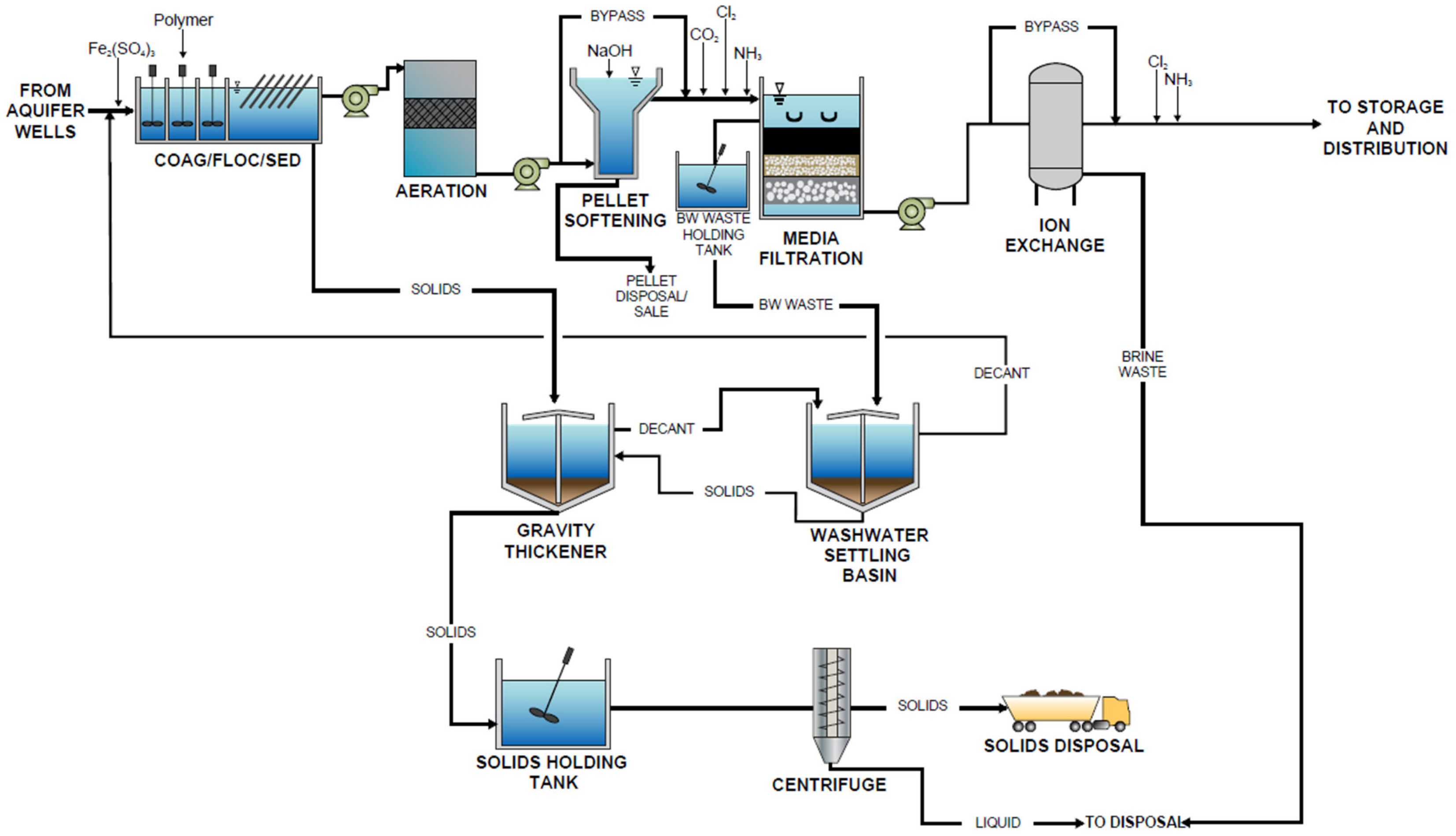

Figure 9.3 Treatment Scheme 7 – Enhanced Coagulation with Pellet Softening and Fixed Bed IX

Table 9.4 Major Process Information for Treatment Scheme 7

Process	Parameter	Quantity	Units
Pre-treatment (Forced Draft Aeration)	Number of aerators	20	each
	Towers/Columns	1737	gpm
	Blowers (cfm)	34740	cfm
	Number influent pumps	5	each
Enhanced Coag-Floc General Info	Basin area	24000	sq ft
	Flocculator operating hp	1, 0.5, 0.25	hp
	Number of settling plates per train	4,515	each
	Number of hoseless sludge collectors per train	4	each
Enhanced Coag-Floc Ferric Sulfate system	Number of Bulk Tanks	8	each
	Transfer pumps	2	each
	Metering pumps	2	each
Enhanced Coag-Floc polymer system	Totes	2	each
	Transfer pumps	2	each
	Metering pumps	3	each
Enhanced Coag-Floc Solids handling	Number of settled sludge holding tanks (before sending to gravity thickeners)	2	each
	Individual sludge collector flow rate	175	gpm
	Sludge holding tank individual volume	3000	gal
	Sludge pumps per sludge tank	2	each
Pellet Softening	Number of pellet reactors	6	each
	Number of pellet process influent pumps	6	each
	Sodium hydroxide tanks	6	each
	Sodium hydroxide transfer pumps	2	each
	Sodium hydroxide metering pumps	7	each
Sludge Management	Backwash holding tanks	2	
	Number of washwater settling basins	2	each
	Dry solids produced (max)	36000	dry lbs/day
	Gravity thickeners	2	each
	Solids holding tanks	2	each
	Centrifuges	3	each
	Drying bed size	12	lb/yr/sq.ft
Recarbonation	Carbon Dioxide Tanks	2	each

Table 9.4 Major Process Information for Treatment Scheme 7 (cont.)

Process	Parameter	Quantity	Units
Filters	Filters	10	each
	Backwash pumps	2	each
Ion Exchange (Alt 2, 7, 11)	Pre-IX pumps	7	each
	Vessels	35	each
	Brine supply tanks	4	each
Disinfection	Sodium Hypochlorite Bulk storage tanks	10	each
	Transfer Pumps	4	each
	Sodium Hypochlorite Day tanks	4	each
	Number of metering pumps	3	each
	Ammonia Tanks	2	each
	Ammonia Pumps	3	each
Clearwell	Chlorine Contact Tank	1	each
Transfer Pumps	Vertical Turbine Pumps	8	each

9.4.2.2 Conceptual Layout

A conceptual layout for Alternative 3, Treatment Scheme 7 is presented in Figure 9.4. The site constraints and availability is the same for Treatment Scheme 2 where use of the area on south portion of the site that has administration building, parking lot, fuel filling station and fleet parking needs to be considered.

The layout considers process areas for processes shown in Table 9.4, a new controls building, new electrical building consisting of switchgears, emergency generators, fuel storage, and a new storage building.

Treatment Scheme 7 conceptual space requirements are similar to that of Scheme 2. It does not fit on the Fiveash site even after considering the use of the area of GST 1, the existing administration building, parking lot, fuel filling station, fleet parking as well as the adjacent dog park area. This alternative is not appear feasible for the Fiveash site for a new 50 mgd facility.

[redacted]

Figure 9.4 Alternative 3 Treatment Scheme 7 Conceptual Plant Layout

9.4.3 Treatment Scheme 11 – Nanofiltration and Fixed Bed IX

9.4.3.1 Process Overview

This treatment scheme includes Nanofiltration and a side stream of filtration and ion exchange as the primary processes to produce 50 mgd of MDD finished water. Table 9.5 presents major process overview with capacities for average day and maximum day flow rates for the plant, and Figure 9.5 presents the process flow diagram of Treatment Scheme 11.

Table 9.5 Major Process Capacity for Nanofiltration and Fixed Bed IX

Flow Stream	Average Flow (mgd)	Maximum Design Flow (mgd)
Sand separators	33.8	42.3
Forced draft aeration (post-NF)	28.8	36
Forced draft aeration (bypass stream)	11.3	14.1
Dual Media filtration	11.3	14.1
IX	11.3	14.1

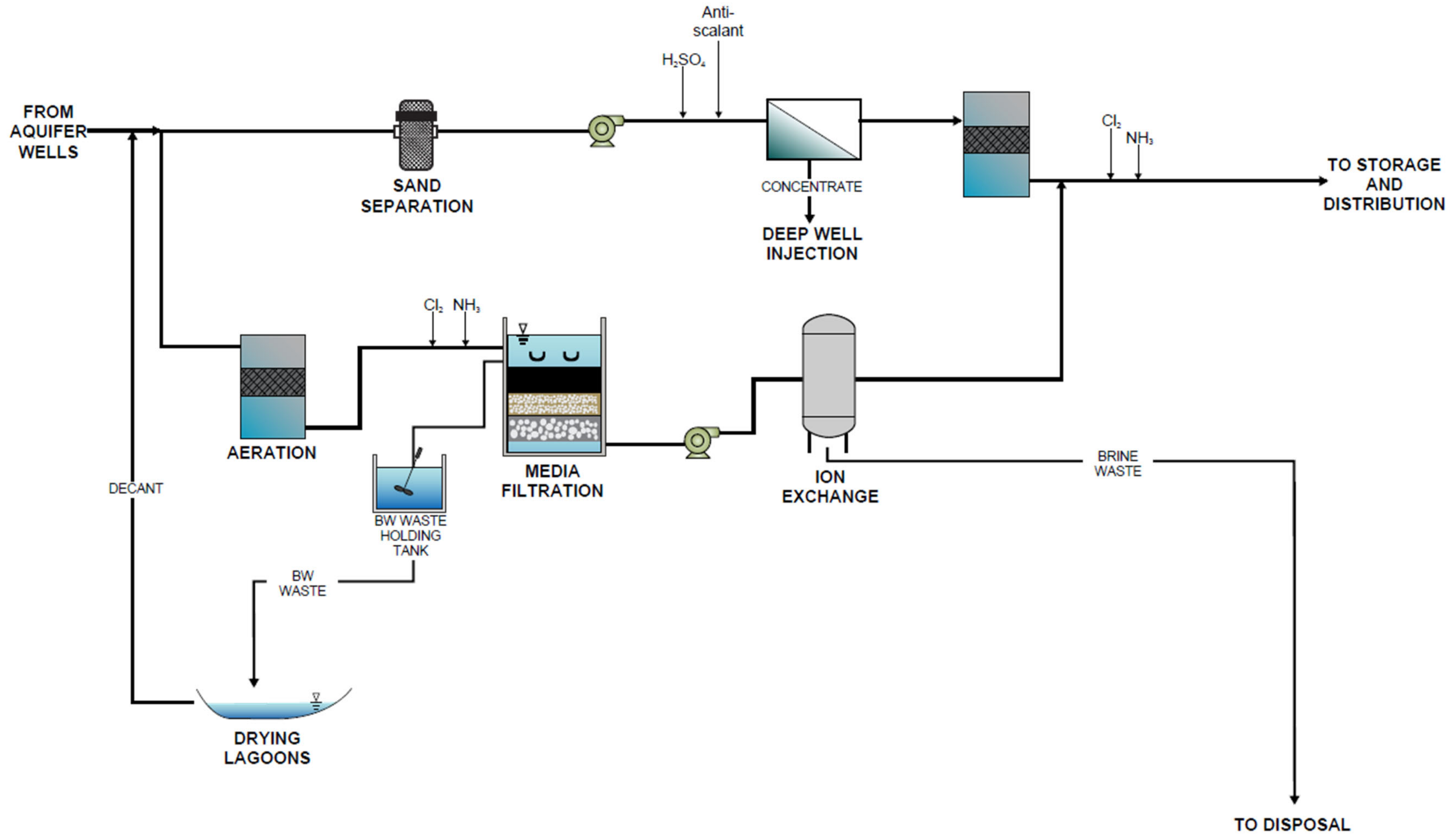

Figure 9.5 Treatment Scheme 11 – Nanofiltration and Fixed Bed IX

Table 9.6 Major Process Information for Treatment Scheme 11

Process	Parameter	Quantity	Units
Sand Separators	Strainers	6	each
	Strainer flow capacity	7,000	gpm
Pre-treatment (Forced Draft Aeration)	Aerators	6	each
	Towers/Columns	1,744	gpm
	Blowers (cfm)	8,715	cfm
Sulfuric Acid Pretreatment (NF)	Bulk Tanks	5	each
	Transfer pumps	2	each
	Day Tanks	2	each
	Metering pumps	2	each
Antiscalant (NF)	Bulk Tanks	2	each
	Transfer pumps	2	each
	Metering pumps	2	each
Nanofiltration	Number of pre-NF pumps	5	each
	Number of Trains	4	each
	Elements/vessel	6	each
Sludge Management	Number of backwash holding tanks	2	each
	Backwash holding tank volume	250,926	gal/tank
	Dry solids produced (max)	123	dry lbs/day
	Drying bed size	3,728	sq ft
Filters	Filter design flow	13.5	mgd
	Filters	4	each
	Number of backwash pumps	2	each
Ion Exchange	Pre-IX pumps	2	each
	IX vessels	11	each
	Brine tank capacity, each	15	tons salt
Post-treatment (Forced Draft Aeration)	Aerators	15	each
	Towers/Columns	1,744	gpm
	Blowers (cfm)	8,715	cfm
Disinfection	Sodium Hypochlorite Bulk storage tanks	10	each
	Transfer Pumps	4	each
	Sodium Hypochlorite Day tanks	4	each
	Metering pumps	3	each
	Ammonia Tanks	2	each
	Ammonia Pumps	3	each

Table 9.6 Major Process Information for Treatment Scheme 11 (cont.)

Process	Parameter	Quantity	Units
Clearwell	Chlorine Contact Tank	1	each
Transfer Pumps	Vertical Turbine Pumps	8	each
Concentrate Disposal	Deep Injection Wells	2	each
	Concentrate Flow Rate	7.5	mgd

9.4.3.2 Conceptual Layout of Alternatives

A conceptual layout for Alternative 3, Treatment Scheme 11 is presented in Figure 9.6. The use of south portion of the site with administration building, parking lot, fuel filling station and fleet parking is considered for this treatment scheme.

The layout considers process areas for processes shown in Table 9.6, a new controls building, new electrical building consisting of switchgears, emergency generators, fuel storage, and a new storage building.

Treatment Scheme 11 layout fits on the Fiveash site when including the use of the space consisting of existing parking lot, fuel filling station, fleet parking and adjacent parcel owned by the City of Oakland Park. It should be noted that there is very limited room for expansion beyond the 50 mgd facility.

Based on the site layouts presented in Figure 9.2, 9.4 and 9.6, Treatment Schemes 2 and 7 do not fit within the existing available space. While Treatment Scheme 11 fits within the existing site, it requires demolition of the existing fueling station and parking lot, as well as purchase of adjacent parcel from the City of Oakland Park. The administration building may be able stay, but with most parking and contractor staging and laydown areas offsite.

[redacted]

Figure 9.6 Alternative 3 Treatment Scheme 11 Conceptual Plant Layout

9.4.4 Phasing and Sequencing

In order to provide continuous service to customers it is important to carefully consider construction phasing and sequencing. The following should be considered as it pertains to phasing and sequencing of Treatment Scheme 11:

- During construction a pre-fabricated connection with a tee and plug can be considered to limit the downtime of the raw water line while connecting to the new facility. Similar connections to the existing storage tanks would need to be considered.
- Due to limited available space on site, replacement of High Service Pumps, generators, and ground storage tank would be need to be planned with upgraded equipment at the same location.

9.5 Alternative 4 - WTP Replacement at Prospect Site

Alternative 4 considers a new treatment plant at the Prospect Site. This site consists of mostly open areas which currently includes raw water wells, raw water supply lines, sludge drying beds and sludge delivery line. The three treatment schemes considered are the same as those considered for location at the existing Fiveash WTP site. Assumptions for this evaluation include the following:

- The existing plant equipment and processes will be operational while the new processes are constructed, commissioned, tested and placed into service.
- A new 5 MG and 7 MG Storage tank has been considered for this alternative for different treatment schemes.
- A new High Service Pump Station has been considered for this alternative.
- A new operations building will be needed at the Prospect Site.
- No improvements will be performed on existing Fiveash administration building and the new site will not require an administration building.
- The raw water supply lines will need cleaning and reconfiguration to deliver water to the head of the new WTP.
- The existing raw water transmission lines will be repurposed as finished water delivery lines serving the high service pumping facilities at the Fiveash site. New flow meters will be added to record the treated flow transmission.
- There will be a need for a new FPL substation

9.5.1 Treatment Scheme 2 – Lime Softening and Fixed Bex IX

9.5.1.1 Process Overview

This treatment process is the same as that described in section 9.4.1.1.

9.5.1.2 Conceptual Layout

A conceptual layout for Alternative 4, Treatment Scheme 2 is presented in Figure 9.7. The Prospect Site has sufficient space for future expansions. A few minor modifications such as re-piping of the raw water header pipe to head of the new WTP, relocation of sludge line, excavation and new fill for the east sludge cell will be needed.

9.5.2 Treatment Scheme 7 – Enhanced Coagulation with Pallet Softening and Fixed Bed IX

9.5.2.1 Process Overview

This treatment process is same as that described in section 9.4.2.1.

9.5.2.2 Conceptual Layout

A conceptual layout for Alternative 4, Treatment Scheme 7 is presented in Figure 9.8. The Prospect Site has sufficient space for future expansions. Similar to Treatment Scheme 2 a few minor modifications such as re-piping of the raw water header pipe to head of the process trains, relocation of sludge line and two production wells, excavation and new fill for the east sludge cell is needed for the new WTP.

9.5.3 Treatment Scheme 11 – Nanofiltration and Fixed Bed IX

9.5.3.1 Process Overview

This treatment process is same as that described in section 9.4.3.1.

9.5.3.2 Conceptual Layout

A conceptual layout for Alternative 4, Treatment Scheme 11 is presented in Figure 9.9. Consistent with the Schemes 2 and 7 the Prospect Site has sufficient space for future expansions. Re-piping of the raw water header pipe to head of the process trains, relocation of sludge line, excavation and new fill for the east sludge cell is needed for the new WTP. Two new Deep Injection Wells are required and are located to the West of the new WTP parcel.

[redacted]

Figure 9.7 Alternative 3 Treatment Scheme 11 Conceptual Plant Layout

[redacted]

Figure 9.8 Alternative 3 Treatment Scheme 11 Conceptual Plant Layout

[redacted]

Figure 9.9 Alternative 3 Treatment Scheme 11 Conceptual Plant Layout

[redacted]

Figure 9.10 Alternative 4 Treatment Scheme 11 Conceptual Plant Layout

9.6 Pros and Cons of Fiveash Site versus Prospect Site

This section summarizes advantages and disadvantages of using each site as shown in Table 9.7.

Table 9.7 Advantages and Disadvantages of Using Fiveash Site and Prospect Site

	Pros	Cons
Fiveash Site	Raw water piping and finished water distribution system infrastructure and piping are utilized.	Significant impact to City operations and need to find offsite location for housing the staff, vehicles, and storage.
		Congested site with limited areas for staging.
		Will increase construction costs and challenges associated with unknowns and relocation of existing utilities
		Construction will impact the operations and maintenance of the existing facility from an accessibility standpoint and shutdowns for tie-ins.
		Limited to Treatment Scheme 11 only.
		Requires likely purchase of adjacent parcel owned by City of Oakland Park for Scheme 11.
Prospect Site	There is sufficient space for all 3 alternatives to easily fit. Sufficient area exists for all construction contractor's activities.	Only possible impact may be the ability to utilize cranes for construction, this will need to be coordinated with the airport, but should be feasible with prior coordination and approval.
	Has sufficient space for future expansions.	Requires repurposing the existing 42-inch raw water pipelines to transfer the finished water to the Fiveash site for distribution in the system.
	Allows the city to incorporate security and protection into the new facility.	
	After construction of new facilities, a large portion of the Fiveash site can be repurposed for other City activities.	
	Efficient site access due to location relative to major thoroughfares.	
	Site can be developed to be consistent with area demographics.	

9.7 Results and Recommendations

The Fiveash site is space challenged, with limited area which will accommodate only Treatment Scheme 11. The site presents significant construction complications due to the limited space and the need to maintain the existing facility in operation until after the new WTP is constructed and placed into service. Existing City activities which are currently performed at the site will need to be moved to other locations. Additionally, there is no ability for future expansions. Constructing a new facility at the Fiveash site will allow for simpler utilization of some of the existing infrastructure.

The Prospect Site has sufficient space for all three of the short listed treatment alternatives. It can be incorporated into the area with minor impact to existing surrounding activities, and has sufficient available land to easily fit future capacity expansions. To utilize the underground distribution system from Fiveash facility the existing raw water transmission main will need to be refurbished and repurposed for potable water service.

As noted in Section 9.6, pros and cons exist for both location alternatives. Based solely on the site sizes and the construction logistics associated with constructing a new treatment facility, the Prospect Site is recommended for further detailed analysis.

Appendix I

TASK 10 - OPINION OF PROBABLE CONSTRUCTION & NET PRESENT WORTH EVALUATION

CITY OF FORT LAUDERDALE

City of Fort Lauderdale
Granular Activated Carbon Pilot and Plant
Evaluation at the Fiveash Water Plant

Technical Memorandum 10
TASK 10 – OPINION OF PROBABLE CONSTRUCTION COST AND NET PRESENT WORTH EVALUATION

FINAL REDACTED | December 2019

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CITY OF FORT LAUDERDALE

City of Fort Lauderdale
Granular Activated Carbon Pilot and Plant Evaluation at the Fiveash Water Plant

Technical Memorandum 10
TASK 10 – OPINION OF PROBABLE CONSTRUCTION COST AND NET PRESENT WORTH EVALUATION

FINAL REDACTED | December 2019

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TASK 10 – OPINION OF PROBABLE CONSTRUCTION COST AND NET PRESENT WORTH EVALUATION

10.1 Background

A study is underway to evaluate and address the water treatment challenges that exist at the City of Fort Lauderdale's Fiveash Water Treatment Plant (WTP). Treatment alternatives to meet the future potable water capacity, along with water quality and infrastructure goals, have been evaluated and shortlisted. Three treatment schemes from the initial schemes were shortlisted for further evaluation in Technical Memorandum (TM) - Evaluation of Treatment Alternatives.

There were originally eighteen treatment schemes under consideration. These were narrowed down using a desk top analysis and bench scale testing to seven treatment schemes under Task 7. These seven were further condensed to three final schemes which were recommended for further development based on the criteria in the technical memorandum Evaluation of Treatment Alternatives. These three treatment schemes are as follows:

- Treatment Scheme 2 – Lime Softening and Fixed Bed Ion Exchange (IX)
- Treatment Scheme 7 – Enhanced Coagulation with Pellet Softening and Fixed Bed IX
- Treatment Scheme 11 – Nano Filtration (NF) and Fixed Bed IX

A conceptual-level siting evaluation for an alternate site, in addition to the existing Fiveash WTP site, was performed under Task 6, where the alternate site of the Prospect wellfield was determined to be feasible for the location of a new water treatment facility. Layout of the shortlisted treatment schemes at the two sites was performed based on process information for the treatment schemes. Only one of the three selected treatment schemes fit at the Fiveash WTP site due to the fact that the existing facility has to remain in service until after the replacement facility is complete. The alternate location at the Prospect Wellfield site has sufficient area available to accommodate all three of the treatment schemes.

At the inception of the project the City requested four levels of service driven alternatives to be investigated. These include:

- Alternative 1 - Base level of service being repair and rehabilitation of existing Fiveash WTP,
- Alternative 2 -Next level of service includes the incorporation of a color removal process at existing Fiveash WTP,
- Alternative 3 -The ultimate level of service includes replacement of the existing WTP at the Fiveash site, or
- Alternative 4 -A replacement facility at an alternative location of the Prospect wellfield site (Prospect site).

Upon evaluation included in Task 4, it was determined that the existing primary WTP processes have exceeded the useful life, and where the technology and equipment is antiquated. Additionally there are major operational and maintenance issues such as leaking tanks, single point of failure due to lack of isolation, insufficient interconnectivity and redundancy, lack of access for maintenance and so forth. It was determined that continuing re-investment of significant funds for the long-term use of existing facility originally constructed in 1950's, while possible, is not prudent nor recommended. Therefore, alternative one was not investigated further.

The next level of service to incorporate color removal process at the existing WTP was investigated. The processes at the plant are closely located and do not offer available space for the color removal treatment units and would require the location of the color removal treatment units remote from the flow path. This would require extensive modifications to intercept the flow of water and transmit it to an adjacent location, but the existing plant configuration does not allow for a reasonable connection strategy without demolition, reconstruction, and requiring the plant to be out of service for an extended duration of time. Demolition and reconstruction of the old WTP facility is not recommended there this alternative was not investigated any further.

Alternatives three and four consists of the ultimate level of service to include replacement of the existing WTP. Only treatment scheme 11 is feasible at the existing WTP under Alternative three while all three treatment schemes 2, 7 and 11 are feasible at the Prospect site. This determination was made under Task 9. The feasible schemes under alternative three and four are further analyzed and capital and operation and maintenance (O&M) costs as well as net present worth was developed as part of this TM.

10.2 Purpose

The purpose of this effort is to develop capital cost estimates, operation and maintenance (O&M) cost estimates and perform a net present worth evaluation for the three treatment schemes under consideration. The following sections present these costs along with a net present worth comparison.

10.3 Capital Costs

Concept level Capital costs in this report are developed for treatment schemes under consideration for alternatives 3 and 4. Two concept level capital cost estimates were developed for each treatment scheme. These two capital cost estimates differ in the extent of use of existing treatment system infrastructure as are defined as follows:

Concept Level Capital Cost Estimate 1 – This estimate represents the cost of the proposed full treatment system but relies on using existing Fiveash WTP infrastructure of storage tanks, high service pumps, and auxiliary power generators associated with pumps and retrofitting raw water transmission main which transfers raw water from the Prospect Wellfield to the Fiveash WTP into a finished water line feeding the distribution pumps.

Concept Level Capital Cost Estimate 2 – This estimate represents the cost of the proposed full treatment system as well as two new storage tanks, high service pumps, auxiliary power generators for the pumps, and a new 54 inch potable water pipeline from Prospect site to Fiveash site.

The opinion of probable construction costs (OPCCs) are developed based on conceptual level information using an integrated approach across all disciplines and does not represent absolute cost at an individual line item level. The majority of the equipment costs are derived from database of vendor equipment quotes and/or purchase records. Because of the limited project scope development at this stage of the project the estimates are an order of magnitude estimates. The capital cost is based on Association for the Advancement of Cost Engineering (AACE) International Class 5 guidelines, which is defined as follows:

AACE International Class 5 Cost Estimate – Class 5 estimates are generally prepared based on very limited information, and subsequently have wide accuracy ranges. Typically, engineering is from 2% to 10% complete. They are often prepared for strategic planning purposes, market studies, assessment of viability, project location studies, and long-range capital planning. Virtually all Class 5 estimates use stochastic estimating methods such as cost curves, capacity factors, and other parametric techniques. Expected accuracy ranges are from –20% to –50% on the low side and +30% to 100% on the high side, depending on technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.

As noted above and given the fact that future market conditions cannot be defined, the actual project cost may vary from this estimate. The following givens/assumptions are utilized in the development of the capital construction cost estimate:

1. Raw water supply wells at the Prospect wellfield will continue being used for all alternatives and treatment schemes except for two wells and raw water supply line relocation for Alternative 4
2. Reliability upgrade project may likely not proceed, therefore new disinfection system is planned for under alternative 3.
3. Estimates include a 30 percent project contingency;
4. The following allocations are included:
    a. Electrical and instrumentation & control costs = 20 percent of facility component costs;
    b. Site work and yard piping costs = 7 percent of facility component costs;
    c. Contract General Conditions = 15 percent
5. Costs have been rounded to the nearest thousand dollars;
6. Financing costs are not included.

Concept Level Capital Cost Estimate 2 was prepared for each alternative for following project elements:

1. A new 5 MG ground storage tank (GST) is considered for Fiveash WTP.
2. The existing high service pumps at Fiveash WTP will be replaced with new pumps and variable frequency drive (VFD)s for Alternative 3.
3. Two new 5 MG and 7 MG onsite GSTs are considered for Alternative 4.
4. High Service pumps, VFDs, associated electrical equipment, stand by power to be housed in new electrical building for Alternative 4.
5. A new 54 inch transmission line from Prospect site to Fiveash site is considered under Alternative 4.

Several clarifications are listed below that were also utilized to develop the OPCCs.

1. Outdoor equipment slab dimensions were established from sketching basic layout of the known equipment items and including an allowance for piping & accessibility.
2. Slab and building costs were established by utilizing an anticipated finished square foot cost based on the geometry and complexity involved with the structure.
3. Each line cost includes cost of process equipment, installation and labor, as well as costs for subcontractor-level burdens and general contractor bonds, insurances, general and administrative (G&A), and profit.
4. Due to lack of geotechnical information, deep foundations or over-excavation has not been included.
5. Estimate is based upon a standard bid/build delivery method and excludes any alternative project delivery and P3 costs.
6. Estimate does not include consideration of bid participation with less than three qualified bidders.
7. Dual independent power feeds from outside the site are not considered in the estimates and power facilities (i.e. substations) are assumed to be provided by Florida Power and Light.

10.4 Alternative 3 – WTP Replacement at the Existing Fiveash WTP Site

Alternative 3 considered replacement of the existing plant with a new treatment scheme at the existing Fiveash WTP location. All three treatment schemes were considered under Alternative 3 for determining the layout fit and site constraints under Task 9. It was determined that the Fiveash site is space challenged with limited area and can accommodate only Treatment Scheme 11 with no ability for any future expansion. Under this section the estimates are prepared for Treatment Scheme 11 only.

10.4.1 Treatment Scheme 11 – Nano Filtration and Fixed Bed IX

As noted previously Treatment Scheme 11 consists of nano filtration and ion exchange as the primary treatment processes. The conceptual capital costs estimate 1 are broken down by process components consisting of the following:

- Pre-Treatment – Strainers, aeration columns and blowers,
- Nano filtration – Cartridge filters, feed pumps, membrane skids, booster pumps, cleaning system and building
- Post Treatment – Aeration columns and blowers
- Filtration – Filters, backwash and transfer pumps, blowers
- Ion Exchange – Vessels, brine system, regeneration tanks
- Chemical system - sulfuric acid, antiscalant, Sodium hypochlorite, and ammonia systems
- Sludge Management – Backwash holding tanks, transfer pumps, drying beds
- Clearwell and transfer pumps
- Buildings – Operations, electrical, storage
- Deep injection wells and monitoring well
- Raw water, finished water and concentrate disposal piping and connections

The OPCC for this alternative assumes the following:

- The existing generators will be replaced within the existing building and no new building will be needed to house the future generators.

Table 10.1 shows the Conceptual Opinion of Probable Construction Cost Estimate 1 for Alternative 3, Treatment Scheme 11. A conceptual layout for Alternative 3, Treatment Scheme 11 is presented in Figure 10.1.

For Concept Level Capital Cost Estimate 2, the existing GST 1 on the north of the property will be replaced with new 5 MG GST and the existing high service pumps will be replaced with new pumps and VFDs at the same location. This is estimated at$33,350,000.

[redacted]

Figure 10.1 Alternative 3 Treatment Scheme 11 Conceptual Plant Layout

Table 10.1 Conceptual Opinion of Probable Construction Cost for Alternative 3, Scheme 11

Process Components	Estimated Cost
Pre-Treatment	$4,183,000
Nanofiltration	$41,543,000
Solids Handling	$1,964,000
Filtration	$6,196,000
Ion Exchange	$10,240,000
Post-Treatment	$7,390,000
Chemicals	$7,290,000
Clearwell and Transfer Pumps	$4,273,000
Buildings (Operations, Electrical, Storage)	$12,124,000
Supply Well Relocation, Raw Water Main Lining, Onsite Piping Connections (Raw, Finished, Disposal)	$16,107,000
Deep Injection Well	$20,000,000
Subtotal	**$131,310,000**
Electrical and I&C (20%)	$26,262,000
Site work & Yard Piping (7%)	$9,191,700
General Conditions (15%)	$19,696,500
Sub-Total	**$186,460,000**
Contingency (30%)	$55,938,000
Opinion of Probable Construction Cost	**$242,398,000**
Engineering, Permitting and Administration (30%)	$72,719,400
Concept Level Capital Cost Estimate 1 Total	**$315,120,000**
Capital Cost for Elements Associated with Estimate 2	$33,350,000
Concept Level Capital Cost Estimate 2 Total	**$348,470,000**

It must be noted that due to the fact the only scheme that fits at Fiveash site is Scheme 11, there are elements that are not quantifiable from a cost perspective at this stage of the study. These include items associated with current City activities such as the cost of impact to current City operations on the site, impact to site functionality due to an extremely congested site, lack of adequate parking for staff, relocation of existing utilities, and accessibility for routine operation and maintenance.

10.5 Alternative 4 - WTP Replacement at Alternate Site

Alternative 4 considers a new treatment plant at the Prospect Wellfield Site. It was determined in Task 9, Alternative Development – WTP Siting and Construction Sequencing, that the site has sufficient space for all three treatment schemes. The following subsections describe the major components within each treatment scheme as well as the conceptual OPCC cost for each treatment scheme.

10.5.1 Treatment Scheme 2 - Lime Softening and Fixed Bed IX

Treatment Scheme 2 consists of lime softening and ion exchange as the primary treatment processes. The conceptual Capital Cost Estimate 1 are broken down by process components consisting of the following:

- Pre-Treatment – aeration columns and blowers
- Lime Softening – clarifiers, wash water system, waste sludge pumps
- Filtration – filters, backwash and transfer pumps, blowers
- Ion Exchange – vessels, brine system, regeneration tanks
- Solids Handling – thickeners, sludge pumps, holding tanks, centrifuges, transfer pumps
- Chemical system – polymer system, lime feed system, recarbonation, disinfection system
- Clearwell and transfer pumps
- Buildings – operations, electrical, storage
- Supply well relocation, raw water, finished water and sludge transfer onsite piping and connections as well as lining of one 42 inch raw water main.

Table 2 shows the Conceptual Opinion of Probable Construction Cost Estimate 1 for Alternative 4, Treatment Scheme 2. A conceptual layout for Alternative 4, Treatment Scheme 2 is presented in Figure 10.2.

For Concept Level Capital Cost Estimate 2, two new 5 MG and 7 MG onsite GSTs, high service pumps, VFDs, associated electrical equipment, stand by power to be housed in new electrical building, and a new 54 inch transmission line from Prospect site to Fiveash site is considered under Alternative 4. This is estimated at$83,700,000.

Table 10.2 Conceptual Opinion of Probable Construction Cost for Alternative 4, Scheme 2

Process Components	Estimated Cost
Pre-Treatment	$9,405,000
Softening	$10,490,000
Chemical Systems	$18,767,000
Solids Handling	$7,025,000
Filtration	$17,172,000
Ion Exchange	$28,797,000
Clearwell and Transfer Pumps	$4,273,000
Buildings (Operations, Electrical, Storage)	$16,898,000
Supply Well Relocation, Raw Water Main Lining, Onsite Piping Connections (Raw and Finished)	$16,357,000
Subtotal	**$129,184,000**
Electrical and I&C (20%)	$25,837,000
Site work & Yard Piping (7%)	$9,043,000
General Conditions (15%)	$19,378,000
Sub-Total	**$183,442,000**

Table 10.2 Conceptual Opinion of Probable Construction Cost for Alternative 4, Scheme 2 (cont.)

Process Components	Estimated Cost
Contingency (30%)	$55,033,000
Opinion of Probable Construction Cost	**$238,475,000**
Engineering, Permitting and Administration (30%)	$71,543,000
Concept Level Capital Cost Estimate 1 Total	**$310,020,000**
Capital Cost for Elements Associated with Estimate 2	$83,700,000
Concept Level Capital Cost Estimate 2 Total	**$393,720,000**

[redacted]

Figure 10.2 Alternative 4 Treatment Scheme 2 Conceptual Plant Layout

10.5.2 Treatment Scheme 7 - Enhanced Coagulation with Pellet Softening and Fixed Bed IX

The primary treatment processes which comprise Treatment Scheme 7 are enhanced coagulation-flocculation, pellet softening, and ion exchange. The Conceptual Capital Cost Estimate 1 are broken down by process components consisting of the following:

- Enhanced coagulation flocculation – basins, flocculators, mixers, transfer pumps
- Pre-Treatment – aeration columns and blowers
- Pellet Softening – reactors, influent pumps, waste pumps
- Filtration – filters, backwash and transfer pumps, blowers
- Ion Exchange – vessels, brine system, regeneration tanks
- Solids Handling – thickeners, sludge pumps, holding tanks, centrifuges, transfer pumps
- Chemical system – polymer system, ferric sulfate system, caustic feed system, recarbonation, disinfection system
- Clearwell and transfer pumps
- Buildings – operations, electrical, storage
- Supply well relocation, raw water, finished water and sludge transfer onsite piping and connections as well as lining of one 42 inch raw water main.

Table 10.3 shows the Conceptual Opinion of Probable Construction Cost Estimate 1 for Alternative 4, Treatment Scheme 7. A conceptual layout for Alternative 4, Treatment Scheme 7 is presented in Figure 10.3.

For Concept Level Capital Cost Estimate 2, two new 5 MG and 7 MG onsite GSTs, high service pumps, VFDs, associated electrical equipment, stand by power to be housed in new electrical building, and a new 54 inch transmission line from Prospect site to Fiveash site is considered under Alternative 4. This is estimated at$83,700,000.

[redacted]

Figure 10.3 Alternative 4 Treatment Scheme 7 Conceptual Plant Layout

Table 10.3 Conceptual Opinion of Probable Construction Cost for Alternative 4, Scheme 7

Process Components	Estimated Cost
Pre-Treatment	$11,215,000
Enhanced Coagulation-Flocculation	$8,195,000
Pallet Softening	$19,937,000
Solids Handling	$12,090,000
Filtration	$17,017,000
Ion Exchange	$28,797,000
Chemicals	$8,527,000
Clearwell and Transfer Pumps	$4,273,000
Buildings (Operations, Electrical, Storage)	$16,898,000
Supply Well Relocation, Raw Water Main Lining, Onsite Piping Connections (Raw and Finished)	$16,357,000
Subtotal	**$143,306,000**
Electrical and I&C (20%)	$28,662,000
Site work & Yard Piping (7%)	$10,031,400
General Conditions (15%)	$21,496,000
Sub-Total	**$203,496,000**
Contingency (30%)	$ 61,049,000
Opinion of Probable Construction Cost	**$264,545,000**
Engineering, Permitting and Administration (30%)	$79,364,000
Concept Level Capital Cost Estimate 1 Total	**$343,910,000**
Capital Cost for Elements Associated with Estimate 2	$83,700,000
Concept Level Capital Cost Estimate 2 Total	**$427,610,000**

10.5.3 Treatment Scheme 11 - Nano Filtration and Fixed Bed IX

Treatment Scheme 11 consists of nano filtration and ion exchange as the major treatment processes. The Conceptual Capital Cost Estimate 1 are broken down by process components consisting of the following:

- Pre-Treatment – strainers, aeration columns and blowers,
- Nanofiltration – cartridge filters, feed pumps, membrane skids, booster pumps, cleaning system and building
- Post Treatment – aeration columns and blowers
- Filtration – filters, backwash and transfer pumps, blowers
- Ion Exchange – vessels, brine system, regeneration tanks
- Chemical system – sulfuric acid, antiscalant, polymer, recarbonation, and disinfection systems
- Sludge Management – backwash holding tanks, transfer pumps, drying beds
- Clearwell and transfer pumps
- Buildings – operations, electrical, storage
- Supply well relocation, raw water, finished water and sludge transfer onsite piping and connections as well as lining of one 42 inch raw water main.
- Deep injection wells and monitoring well

Table 10.4 shows the Conceptual Opinion of Probable Construction Cost estimate 1 for Alternative4, Treatment Scheme 11. A conceptual layout for Alternative 4, Treatment Scheme 11 is presented in Figure 10.4 and Figure 10.5.

For Concept Level Capital Cost Estimate 2, two new 5 MG and 7 MG onsite GSTs, high service pumps, VFDs, associated electrical equipment, stand by power to be housed in new electrical building, and a new 54 inch transmission line from Prospect site to Fiveash site is considered under Alternative 4. This is estimated at$83,700,000.

Table 10.4 Conceptual Opinion of Probable Construction Cost for Alternative 4, Scheme 11

Process Components	Estimated Cost
Pre-Treatment	$4,183,000
Nanofiltration	$41,543,000
Solids Handling	$1,964,000
Filtration	$6,196,000
Ion Exchange	$10,240,000
Post-Treatment	$7,390,000
Chemicals	$7,290,000
Clearwell and Transfer Pumps	$4,273,000
Buildings (Operations, Electrical, Storage)	$20,552,000
Supply Well Relocation, Raw Water Main Lining, Onsite Piping Connections (Raw, Finished, Disposal)	$21,614,000
Deep Injection Well	$20,000,000
Subtotal	**$145,245,000**
Electrical and I&C (20%)	$29,049,000
Site work & Yard Piping (7%)	$10,167,200
General Conditions (15%)	$21,786,800
Sub-Total	**$206,248,000**
Contingency (30%)	$61,874,400
Opinion of Probable Construction Cost	**$268,123,000**
Engineering, Permitting and Administration (30%)	$80,437,000
Concept Level Capital Cost Estimate 1 Total	**$348,560,000**
Capital Cost for Elements Associated with Estimate 2	$83,700,000
Concept Level Capital Cost Estimate 2 Total	**$432,260,000**

Incremental capital cost was prepared for Alternative 3 and for all treatment schemes under Alternative 4. These costs consider following:

1. Alternative 3 - A new 5 MG ground storage tank (GST) and replacement of existing high service pumps at Fiveash WTP with new pumps and VFDs. Total estimated project cost for these incremental components is$33,350,000.
2. Alternative 4 - Two new 5 MG and 7 MG onsite GSTs, new high service pumps, associated electrical equipment and stand by power to be housed in a new electrical building. A new 54- inch transmission line from Prospect site to Fiveash site. Total estimated project cost for these incremental components is$83,700,000.

[redacted]

Figure 10.4 Alternative 4 Treatment Scheme 11 Conceptual Plant Layout

[redacted]

Figure 10.5 Alternative 4 Treatment Scheme 11 Conceptual Overall Layout

10.6 Operation and Maintenance Costs

The conceptual estimate of O&M costs consists of the chemicals, power, and labor used to operate the processes, equipment, and overall WTP. The following forms the basis of O&M estimates:

- The unit costs of chemicals come from the existing City of Fort Lauderdale Fiveash WTP and Peele Dixie WTP. These chemical costs are shown in Table 10.5.
- A unit cost of$0.08 per Kilo-watt hour (Kw-hr) was used for power cost based on the existing City rate. This is the actual current cost of electricity at the City of Fort Lauderdale WTPs.
- Operator hours are in compliance with FDEP 62-699. Three shifts of operators including supervisors, mechanics, electrician, technicians, process control specialists, plant SCADA and I&C specialist. Additional regulatory and compliance staff has been considered within the labor cost.
- Equipment maintenance and spare parts cost was computed as 1% of the total construction cost based on maintenance costs. This estimate metric was taken from the reference "Special Publication SJ2008-SP10, St. Johns River Water Management District".
- Annual deposit to a renewal and replacement (R&R) fund is equal to 10 percent of the equivalent annual capital cost. This estimate metric was taken from the reference 'Water Supply Cost Estimation Study, South Florida Water Management District".

Table 10.5 Unit Cost of Chemicals

Chemical	Unit Price
Polymer	$1.14/lb
Ferric Sulfate	$1.60/gal
Sodium Hydroxide	$2.76/gal
Sulfuric Acid	$200 /ton
Antiscalant	$1.52/lb
CO2	$225/ton
Salt	$120 /ton
Sodium Hypochlorite 10 percent	$0.50/gal
Ammonia	$0.79/lb

The conceptual annual O&M cost was computed based on average daily use of chemicals, equipment, and processes. These are presented in Table 10.6 for the three treatment schemes. It should be noted that the annual O&M cost for Scheme 11 is same for both Fiveash and Prospect site.

Table 10.6 Conceptual Operation and Maintenance Costs

	Scheme 2	Scheme 7	Scheme 11
Chemicals	$3,890,000	$5,040,000	$4,100,000
Power	$2,150,000	$2,490,000	$3,480,000
Manpower	$3,000,000	$3,000,000	$3,000,000
Equipment Maintenance	$2,392,650	$2,689,000	$2,820,000
Equipment Replacement	$3,716,438	$4,036,242	$4,080,606
Sludge Hauling	$373,538	$489,602	N/A
Conceptual Annual O&M	$15,530,000	$17,750,000	$17,490,000

10.7 Net Present Worth Comparison

Net Present Value is the value of all cash flows over a duration of an investment discounted to the present time period. In other words, it accounts for the time value of money. The NPV applies to a series of cash flows occurring at different times, and in this case used for determining the value of the project as it relates to different treatment schemes under consideration. The cost of operation in some cases can dwarf the original capital cost of the equipment over the operating life of the process equipment. Therefore, an NPV calculation is an effective tool to evaluate and compare projects by bring the cost to present value.

The duration for NPV calculation was established to be 20 years. Based on FAC 25-30.115 and 25-30.140, the major process equipment has a useful life of 22 years while structures are expected to last longer. Since the treatment schemes under consideration consists of different types of process equipment with varying life expectancy, a more conservative period of 20 years was used for the equipment useful life which is reasonable for a comparison of options. Additionally, the following non-annual operation costs were considered:

- Ion exchange media replacement once every 10 years
- Mechanical Integrity Test for deep injection well once every 5 years
- Cartridge filter replacement 2 to 3 times a year
- Membrane element replacement once every 10 years

Table 10.7 shows the Net Present Worth for each alternative and treatment scheme under consideration with the Concept Level Capital Cost Estimate 1.

Table 10.7 Net Present Worth Comparison

	Capital Cost(1)	Annual O&M Cost	Net Present Worth
Alternative 3, Scheme 11	$315,120,000	$16,700,000	$616,400,000
Alternative 4, Scheme 2	$310,020,000	$14,740,000	$564,200,000
Alternative 4, Scheme 7	$343,910,000	$16,960,000	$624,370,000
Alternative 4, Scheme 11	$348,560,000	$16,700,000	$649,840,000

Note:
(1) Assumes interest rate of 3.5 percent. This does not account for debt service for capital.

Table 10.8 shows the Net Present Worth for each alternative and treatment scheme under consideration with the Concept Level Capital Cost Estimate 2.

Table 10.8 Net Present Worth Comparison with Incremental Capital Cost

	Capital Cost(1)	Annual O&M Cost	Net Present Worth
Alternative 3, Scheme 11	$348,470,000	$16,700,000	$649,750,000
Alternative 4, Scheme 2	$393,720,000	$14,740,000	$647,900,000
Alternative 4, Scheme 7	$427,610,000	$16,960,000	$708,070,000
Alternative 4, Scheme 11	$432,260,000	$16,700,000	$733,540,000

Note:

(1) Assumes interest rate of 3.5 percent. This does not account for debt service for capital.