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

PROJECT OVERVIEW

FINAL REDACTED | December 2019

CERTIFICATE OF AUTHORIZATION NO. 8571

CITY OF FORT LAUDERDALE

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Abbreviations

AC	acre
AACE	Association for the Advancement of Cost Engineering
AADD	Annual Average Daily Demand
AADF	Annual Average Day Flow
ARV	Automatic Recirculation Valve
ASCE	American Society of Civil Engineers
ASR	Aquifer Storage and Recovery
BFE	Base Flood Elevation
BW	backwash
$CaCO_3$	calcium carbonate
CaO	lime
CO_2	carbon dioxide
Carollo	Carollo Engineers, Inc.
CSMR	Chloride to Sulfate Mass Ratio
CSTR	continuous stirred-tank reactor
CU	Platinum-cobalt units
CUP	Consumption Use Permit
CUSMP	Comprehensive Utility Strategic Master Plan
DBP	disinfection by product
EBCT	empty bed contact time
FAC	Florida Administrative Code
FAS	Florida Aquifer System
FDOT	Florida Department of Transportation
FFE	Finished Floor Elevation
floc/sed	flocculation and sedimentation
G&A	general and administrative
GAC	granular activated carbon
gal	gallon
gfd	gallons per square foot per day
gpd	gallons per day
gpm	gallons per minute
GST	Ground Storage Tank
HAA_5	halogenated acetic acids
HMI	Human Machine Interface
HP	horsepower
H_2S	hydrogen sulfide

HSP	high service pump
I&C	Instrumentation and Control
IX	ion-exchange
Kgal	kilo gallons
Kw-hr	Kilo-watt hour
lb	pound
LEC	Lower East Coast
LSI	Langelier Saturation Index
M	million
MCC	motor control center
MCL	maximum contaminant levels
µg/L	micrograms per liter
MDD	maximum day demand
Mg	magnesium
MG	million gallons
$MgCl_2$	magnesium chloride
mgd	million gallons per day
mgm	million gallons per month
mgy	million gallons per year
mg/L	milligrams per liter
MIEX	magnetic ion exchange
MMDF	maximum month daily flow
MW	megawatts
N	nitrogen
NaOH	sodium hydroxide (caustic soda)
NF	nanofiltration
NFPA	National Fire Protection Agency
NM	Not Measured
NPV	net present value
NOM	natural organic matter
NS	No standard for groundwater systems
NTU	nephelometric turbidity units
O&M	Operation and Maintenance
OPCC	opinion of probable construction costs
OSHA	Occupational Safety and Health Administration
PFR	plug flow reactor
PLC	Programmable logic controller
psi	pounds per square inch

R&D	research and development
R&R	renewal and replacement
RO	reverse osmosis
RTU	remote telemetry unit
SBC	sand ballasted clarification
SCADA	supervisory control and data acquisition
SE	Southeast
SFMWD	South Florida Water Management District
sq ft	square feet
SMCL	secondary maximum contaminant level
SOC	synthetic organic compounds
T&O	taste and odor
TDS	total dissolved solids
TM	Technical Memorandum
TOC	total organic carbon
TTHM	total trihalomethanes
USEPA	US Environmental Protection Agency
UV	Ultraviolet
VFD	variable frequency drive
VOCs	volatile organic compounds
WTP	water treatment plant
WUP	water use permit
yr	year

Section 1

1.1 Project Background

The Utility Vision, as acknowledged in the 2017 Comprehensive utility Strategic Master Plan (CUSMP 2017), identifies goals and objectives of the City of Fort Lauderdale's (City's) potable water system. This vision encompasses the desire to have a progressive, state of the art, potable water treatment system to serve the existing Fiveash WTP service area. It is intended that this system shall provide for potable water treatment that delivers a product of the highest quality, is innovative, resilient, and conceived such that it achieves to the highest degree possible the City's desire for sustainability, energy conservation (reduced carbon footprint), and climate change, while providing for population growth. The facilities would be constructed in a manner which provides for maximum protection from natural disasters such as hurricanes and sea level rise.

In September of 2018 the City issued solicitation 12191-996, Granular Activated Carbon (GAC) Pilot and Plant Evaluation at the Fiveash Water Plant. The services requested in this solicitation included performing a small scale preliminary study to determine the feasibility of implementing a GAC system to address the potable water color issue, and an evaluation to identify options for long term water treatment for the Fiveash WTP. The City chose the Carollo Engineers, Inc. team to perform these efforts.

The negotiated project scope of work included the following technical tasks:

- Existing Facility Status Confirming Condition Assessment. The CUSMP 2017 noted that the Fiveash WTP would require extensive renewal, rehabilitation, and replacement to be a viable option for future potable water production. A high level, brief, general assessment to confirm the CUSMP 2017 findings was conducted.
- WTP Performance Goals Determination. Specific detailed water treatment facility goals associated with capacity, potable water quality, infrastructure requirements, and operation and maintenance activities were developed.
- Water Treatment Process Evaluation. Multiple tasks were performed as part of this treatment process evaluation effort including a desk-top technology review, bench-scale process testing at the existing facility, and GAC small scale testing at a remote laboratory.
- Alternate Facility Location Study. The feasibility of locating a treatment facility on property at the Prospect Wellfield locale was investigated. This investigation included an overview of existing zoning requirements and site conditions.
- Water Supply Investigation. The various water treatment technologies require different amounts of source water to generate the necessary amount of potable water. This evaluation consisted of a review and investigation into the current water supply sources, alternative water supply sources, water use allocations per the existing South Florida Water Management District (SFMWD) water use permit (WUP), and subsequent raw water needs based on identified treatment technologies.
- C-51 Reservoir Water Supply versus Florida Aquifer Water Supply Comparison. Water supply needs associated with future potable water requirements will likely need to be met from a source that is in addition to what is currently provided in the existing

SFWMD WUP. A "white paper" type effort to compare the options of obtaining water from the C-51 Reservoir System (C-51) versus water obtained from the Florida Aquifer was conducted.

- WTP Facility Siting. Three of the water treatment process alternatives which were selected for further consideration had conceptual size requirements determined. These size requirements were overlaid on corresponding areas at the Fiveash and Prospect Wellfield sites to determine if adequate space was available for facility implementation.
- Conceptual Capital, Operations/Maintenance Costs, and Net Present Worth Determinations. Conceptual costs to construct, and operate and maintain were estimated. A net present value comparison was conducted for the three treatment process alternatives.

1.2 Existing Facility Status Confirming Condition Assessment

The Fiveash WTP is the City's largest WTP with a reported effective capacity of approximately 55 - 60 million gallons per day (mgd) and supplies potable water to approximately three quarters of the City's service area. The initial infrastructure associated with this facility was constructed in 1954. The CUSMP 2017 noted that although the WTP produces a safe reliable potable water much of the equipment associated with the facility's primary treatment process was at, or has exceeded, its projected useful life. The cost for the necessary repair and replacement to maintain current treatment performance was estimated to be "well over $100,000,000, with an additional $30,000,000 every 5-years through 2035".

In an effort to validate the findings of the CUSMP 2017, a team of engineers was formed to perform a cursory investigation into the existing facilities. In May of 2019 this team of engineers and City staff members conducted a site visit to evaluate the condition of the existing infrastructure at both the Prospect Wellfield and the Fiveash WTP. See Appendix A - TM04, Task 4 - Existing Facility Condition Assessment for investigation details.

The confirming assessment determined that in addition to old and antiquated equipment much of the infrastructure in terms of structures, basins, and other water treatment features are impacted from decades of continuous use. Some of the major treatment components are obsolete for which spare parts are not readily available. There are water containment features which are experiencing leakage and have unknown structural integrity. Systems exist which do not have sufficient redundancy to allow for optimum maintenance activities. The majority of electrical equipment is not conditioned from humidity, heat, nor corrosive atmosphere.

The conclusions of this validation/confirming assessment are consistent with the findings in the CUSMP 2017. Continuing re-investment of significant funds for the long-term use of this existing facility to maintain existing treatment performance while possible, may not be a prudent investment and is not recommended.

1.3 Water Treatment Plant (WTP) Performance Goals Determination

The City has a desire to develop a progressive, state of the art water treatment system which provides a high quality reliable product which is consistent with the City's overall infrastructure goals. The specific project goals developed for this project are outlined in Appendix B – TM01, Task 2 – Establishment of Project Goals, and include the following:

1.3.1 Facility Capacity Goal

The planning period associated with this project is through 2035, consistent with the CUSMP 2017. The projected system wide maximum day water demand for the entire City service area is 59.1 mgd. This demand must be satisfied by the Fiveash and Peele Dixie WTPs. Recognizing that the Peele Dixie WTP's official rated treatment capacity is 12 mgd, the remainder of 47.1 mgd needs to be provided by the Fiveash WTP. It was determined for the purpose of this effort that the 47.1 mgd would be rounded up to 50.0 mgd for conceptual planning purposes.

1.3.2 Water Quality Goals

The finished water goals identified in Table 1 (see below) from the 2017 Comprehensive Utility Strategic Master Plan (CUSMP) were evaluated and deliberated by the project team. It was agreed that the project finished water quality goals would remain as noted in the CUSMP 2017, with the following adjustments:

Additional Goal	Purpose of Goal
• Iron < 0.1 mg/L	Prevent red water staining
• Manganese < 0.02 mg/L	Prevent black water staining
• Alkalinity - 40 to 110 mg/L	Promote water stability in distribution system
• Total Hardness - 80 to 160 mg/L	Promote water stability in distribution system
• Free Ammonia - 0.05 to 0.10 mg/L	Minimize nitrification potential and promote water stability in distribution system
• Color - 5 to 12 Color Units, with a preference to be near 5	Eliminate color. At 5 Color Units visual color is eliminated (as it is not detectable by the human eye)

Table 1 WTP Effluent Quality from 2017 Comprehensive Utility Strategic Master Plan

Parameter	Units	Goal	Fiveash Effluent Water Quality (2014)	Primary Drinking Water Standard	Secondary Drinking Water Standard
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

Table 1 WTP Effluent Quality from 2017 Comprehensive Utility Strategic Master Plan (cont.)

Parameter	Units	Goal	Fiveash Effluent Water Quality (2014)	Primary Drinking Water Standard	Secondary Drinking Water Standard
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

1.3.3 Infrastructure Goals

The infrastructure goals shall meet or exceed the requirements outlined in Florida Administrative Code (FAC) 25-30.115 and 25-30.140. These goals are identified in Table 2.

Table 2 Average Service Life of Water Treatment System Components

Type	Time (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 shall be in accordance with applicable FAC and Florida Department of Environmental Protection (FDEP) requirements.

1.3.4 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 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)

1.4 Water Treatment Process Evaluation

The Fiveash facility reliably provides potable water meeting applicable water quality standards in terms of primary requirements (maximum contaminant levels (MCLs)), but struggles to meet some of the secondary thresholds (secondary maximum contaminant levels (SMCLs)). 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. The 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.

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

1. From an aesthetic perspective color results in concerns and complaints by City 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 US Environmental Protection Agency (USEPA) Disinfection Byproduct Rule. While the Fiveash WTP typically meets the public health and regulatory aspects of color, 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, and therefore, is a key driver for more effective color removal.

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 a highly colored hard water, a combination of technologies will be necessary to meet color and other established water quality and project goals. For the purposes of this study the treatment processes considered include GAC, lime softening, enhanced lime softening with additional chemicals, enhanced coagulation, IX, and NF. Although ozone is commonly used for color oxidation, it was not considered for the City due to the possibility of high bromide levels in source water and concerns of excessive bromate formation and documented poor performance in South Florida at other WTPs. Biological filtration was also not considered due to the high amounts of NOM in the source water and the inability of the process to remove significant NOM. Table 4 identifies the treatment processes that were evaluated to achieve the color and other water quality goals. The evaluation process included detailed desk-top research and investigation, bench-scale testing of individual processes at the existing Fiveash WTP, and small scale testing of GAC at an off-site laboratory. A complete reporting of all activities and findings associated with this water treatment process evaluation can be found in Appendix C – TM02, Tasks 3 & 7 – Bench-Scale Testing Technical Memorandum.

Table 4 Identified Treatment Processes

Primary Alternatives	Subalternative	Infeasible Alternatives
• Fluidized Bed IX • Fixed Bed IX • Conventional Softening • Enhanced Softening • Enhanced Coagulation • Nanofiltration • GAC	• Pellet Softening • Suspended Ion Exchange (SIX) • Magnesium Addition	• Ozone • Flash Distillation • Super chlorination/air stripping • UV/advanced oxidation • Desalination

The attributes of the technologies which are pertinent to the goals of this evaluation effort are summarized in Table 5, Comparison of Technologies.

As noted previously, to efficiently achieve the established project goals a combination of treatment processes must be implemented. As part of this evaluation eighteen process alternatives were investigated and their ability to meet the project goals was established. Seventeen of the processes were combinations of the technologies identified herein and the eighteenth was seawater desalination (see seawater desalination conceptual evaluation in Appendix D – Conceptual Evaluation of Seawater Desalination). Of the 17 conventional alternatives considered, ten were eliminated due to failure to reliably achieve water quality goals, high cost, limited flexibility, and/or excess or redundant processes. Table 6 provides a summary of the alternatives.

A project team workshop was convened and the remaining seven alternatives were compared and debated. Table 7 provides comparison information of the seven shortlisted alternatives.

Table 5 Comparison of Technologies

	Fluidized-Bed IX (MIEX)	Fixed Bed IX	Conventional Softening	Enhanced Softening with $MgCl_2$	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 PFR configuration	• 29%	• 79%	• 81%	• 99%	• 99% • Breakthrough occurs quickly
Other Water Quality Considerations	• 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 • Chloride to sulfate mass ratio increase • 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 • Chloride to sulfate mass ratio increase • 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	• Decreases chloride to sulfate ratio, inhibiting lead release, and reducing corrosion (effect is coagulant dependent) • Increases TDS • 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 results 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
Reliability	• Used in South Florida • May not achieve color removal goal without pairing with an additional 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	• 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

Table 5 Comparison of Technologies (continued)

	Fluidized-Bed IX (MIEX)	Fixed Bed IX	Conventional Softening	Enhanced Softening with MgCl2	Enhanced Coagulation	Nanofiltration	GAC
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 • 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 • 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 • High O&M costs for media replacement • 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	• Significant solids disposal and processing	• Significant solids disposal and processing • Magnesium solids more difficult to handle and de-water	• Significant solids disposal	• Large amount of concentrate for disposal	• Backwash waste (minimal) • Spent GAC regeneration/disposal 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 components						

Table 6 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.

Table 7 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	●	◒	●	●	◒	○	◒	●	○	○	◒	◒	◒

Note:

(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 discussed in Section 2.1.9.1 and in each analysis in Section 5.

Legend:

(1) ● Highly favorable

(2) ◒ Moderately favorable

(3) ○ Less favorable

Utilizing this comparison information the project team further shortlisted the alternatives to three. The three alternatives shortlisted for further evaluation in terms of project siting/layout and cost determinations were:

- Treatment Scheme 2 – Lime Softening and Fixed Bed Ion Exchange (IX) (Figure 1)
- Treatment Scheme 7 – Enhanced Coagulation with Pellet Softening and Fixed Bed IX (Figure 2)
- Treatment Scheme 11 – Nanofiltration and Fixed Bed IX (Figure 3)

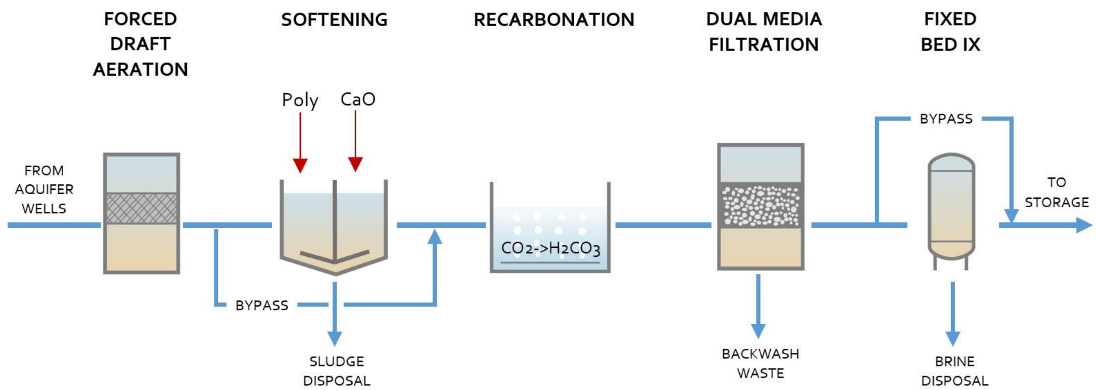

Figure 1 Treatment Scheme 2 Process Flow Diagram

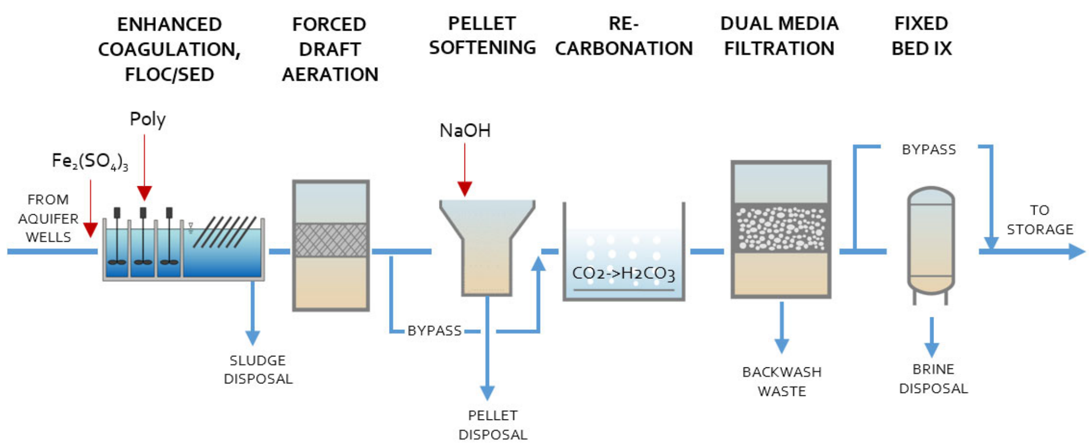

Figure 2 Treatment Scheme 7 Process Flow Diagram

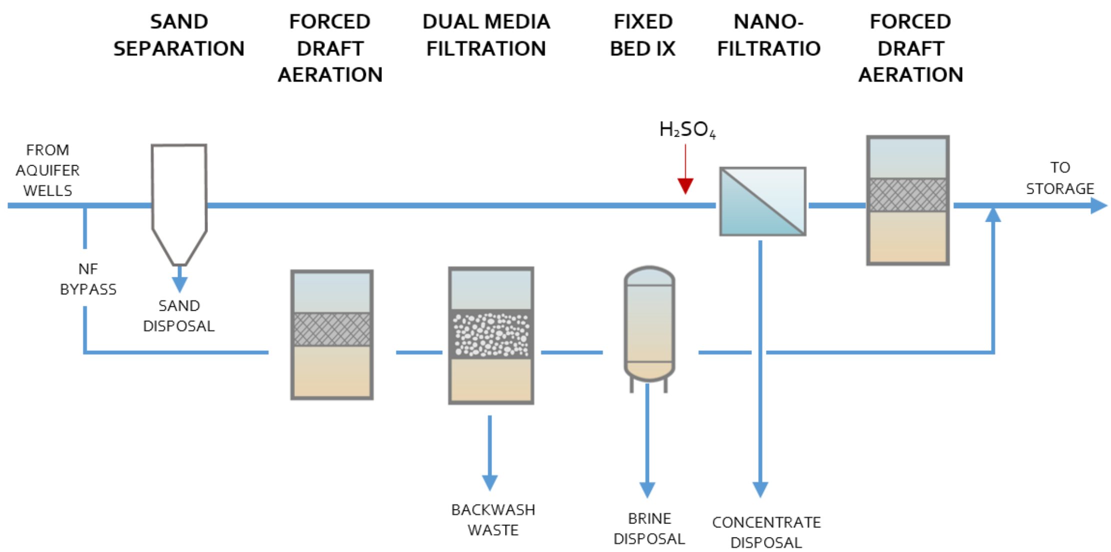

Figure 3 Treatment Scheme 11 Process Flow Diagram

1.5 Alternate Facility Location Study

In addition to the treatment facility and potable water storage tanks the current Fiveash WTP site supports multiple City functions. The site has little available space to incorporate additional water treatment features without area repurposing. Because of this, placing a replacement water treatment facility on City owned property at the Prospect wellfield was investigated. This conceptual investigation included accessing the following elements:

- Area zoning
- Site access
- Environmental factors including wetlands and protected species
- Existing utilities and infrastructure
- Requirements of the Federal Aviation Administration (FAA) and the Fort Lauderdale Executive Airport
- Considerations associated with adjacent properties

The project team performed site visits, researched existing as-built documents, obtained property and right-of-way information, inspected site boundaries and areas throughout the site, and compiled information from the Fort Lauderdale Executive Airport. The Technical Memorandum with the investigation details can be found in Appendix E – TM06, Task 6 – Alternative Fiveash Water Treatment Plant Location. Figure 4 depicts the boundaries of the Prospect Wellfield area.

[redacted]

Figure 4 Boundaries of Prospect Wellfield Area

The Prospect Wellfield site has four zoning designation including, Parks, Recreation & Open Spaces, Commerce Center District, Utility, and Residential Multi-Family. The extent of these zones are depicted in Figure 5.

[redacted]

Figure 5 Existing Zoning

Depending on the location of the proposed treatment facility within the property access would potentially be available from Northwest (NW) 31 Avenue, Prospect Road, or NW 62 Street. Construction of a new treatment facility would likely require roadway improvements 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 the Broward County Engineering and Highway Construction Division.

Large areas of the site contain heavy vegetation and water bodies. During design of the proposed facility the City will need to consider impacts to existing features including trees, wetlands, protected species, etc. Burrowing Owls were observed on the site. Permitting and mitigation requirements will need to be determined during the project development phase.

FAA considerations associated with the nearby Executive Airport will need to be considered. Initial review identified maximum building height requirements in the flight path. It is not anticipated that anticipated building heights will be in conflict with the requirements. Construction activities requiring cranes and other high profile equipment will need to be coordinated appropriately to ensure compliance.

The utilities in the area are predominately associated with wellfield infrastructure. Depending on the final facility location it will likely be necessary to relocate a few wells and raw water transmission mains.

Three proposed facility footprints are depicted in Figure 6. Alternatives 1 and 2 are located in the general vicinity of where the current Fiveash WTP stores its water treatment sludge for dewatering prior to ultimate hauling and disposal.

[redacted]

Figure 6 Locations of Three Alternatives for Water Treatment Plant

1.6 Water Supply Investigation

Available water supply, both quality and quantity, is crucial in determining what treatment alternative provides the greatest value in terms of meeting the City's potable water system goals for the future. The water supply alternatives available to the City were evaluated. For the complete evaluation of the water supply alternatives see Appendix F - TM05, Task 5 – Water Supply Alternative Investigation.

To determine the adequacy of the volume of water provided by the existing water use permit the maximum and average daily demands were identified. For the planning period of this study (through 2035) the maximum daily potable water demand (MDD) is established in the CUSMP 2017 to be 59.1 mgd, along with an average day demand (ADD) of 45.4 mgd. Accounting for the 12.0 mgd capacity of the Peele Dixie WTP, the required MDD amount to be provided by the Fiveash WTP is 47.1 mgd. For the purpose of this study the required MDD amount was rounded to 50 mgd. Utilizing the ADD to MDD factor of 1.3, the average daily requirement from the Fiveash WTP corresponding to a 50 mgd MDD is 38.5 mgd for the end of the planning period.

The water supply allocations are authorized by the SFWMD. These allocations are regulated per aquifer (Biscayne & Floridan Aquifer) and wellfield, as well as based on average annual day and maximum month flow basis. Table 8 provides the current Biscayne and Floridan Aquifer's allocations by wellfield.

Table 8 Biscayne and Floridan Aquifer Allocations by Wellfield

Description		Annual Allocation Million Gallons per Year (mgy)	Monthly Allocation Million Gallons per Month (mgm)	Annual Average Daily Allocation (mgd)
Biscayne Aquifer Annual		19,181	-	52.55
Biscayne Aquifer Maximum Month		-	1,857	-
Dixie Biscayne Wellfield		5475	465	15
Prospect Biscayne Wellfield		15,853	1,534.5	43.43
Florida Aquifer Annual Allocation (Total System)		3,153	-	8.64

The Biscayne Aquifer has been the 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. This high quality water from a reliable, prolific aquifer makes the Biscayne the aquifer of choice as a water source should the SFWMD water use permit allocation be sufficient.

If it is assumed that the treatment alternative selected for the future is the alternative which requires the most water supply (water recovery of 88 percent) the annual water use allocation would be calculated as follows:

(ADD / 0.88 (water recovery of treatment alternative) = Required Raw Water per day

Required Raw Water per Year = Raw Water per Day x 365 days = 15,969 mgy

The resultant amount of additional raw water required for meeting the year 2035 ADD would be approximately 0.7 percent more than the current water use permit allocation. For the purposes of this evaluation it is assumed that minor adjustments to the water treatment processes and/or the existing SFWMD water use permit will result in no additional Biscayne water being necessary to meet 2035 ADDs.

Regarding MDD flows, it was reported that these occur very infrequently, estimated to occur approximately once per year for a two to three day period. Due to this infrequent occurrence MDD flows will not violate the maximum monthly allocation provided for in the SFWMD water use permit.

1.7 C-51 Water Supply versus Floridan Aquifer Water Supply Comparison

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. The availability of water from the Biscayne aquifer is restricted due to existing water demands, source limitations, and issues related to saltwater intrusion, and environmental needs.

As identified in the Water Supply Investigation section, the existing water use permit has sufficient water allocation to meet the potable water capacity requirement of the Fiveash WTP through 2035. Additional source water needs past 2035 will need to be satisfied through the use of alternative water supplies or by acquiring additional Biscayne Aquifer water.

The Biscayne Aquifer is not available for additional raw water withdrawal to meet future demands beyond the allocation amount in the water use permit without mitigation offsets. Potential mitigation offsets can be achieved by providing recharge benefits to the aquifer.

One offset that is currently available to communities in southeast Florida is from the C-51 Reservoir System (C-51). 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.

A task was incorporated into this project to conceptually evaluate whether it would be more cost effective to purchase water from the C-51 and treat it similar to existing Biscayne Aquifer practices or to obtain source water from the Floridan Aquifer and treat it utilizing reverse osmosis (RO) treatment. A "white paper" was prepared summarizing this evaluation. This can be found in Appendix G - TM08, Task 8 – "White Paper" C-51 Reservoir® Water versus Floridan Aquifer Usage.

At the time of this analysis potable water need projections past 2035 were not available. It was determined that for the purposes of this analysis a water production capacity of 10 mgd (20 percent of currently identified Fiveash capacity requirement) would be used as the basis of this comparison.

For comparative evaluation of the use of C-51 reservoir water source versus the use of Floridan Aquifer water source several assumptions were utilized. These 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. The increase in demand over 50 year period is assumed to be 20 percent of the projected MDD of 50 mgd at the Fiveash WTP.

- 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 (NF). 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 percent for NF and 75 percent for reverse osmosis (RO) treatment.

Comparative conceptual capital, and operation and maintenance costs were developed for both scenarios based on the assumptions noted above. A Net Present Worth (NPW) comparison was also developed. Table 9 provides a summary of comparative costs between the two source options.

Table 9 Comparative Costs Between Two Source Water Options

	51 Reservoir Water	Floridan Aquifer Water
Treated Flow (GPD)	10,000,000	10,000,000
Total Capital Cost	$119,280,000	$98,000,000
Total O&M Cost/Kgal	$7,738,000	$10,950,000
PV of Operating Costs (20 yr, 3.5% discount)	$122,860,000	$173,858,000
NPW	$242,140,000	$271,858,000

1.8 WTP Facility Siting

The Water Treatment Evaluation identified three treatment alternatives that can effectively achieve the established project goals. The treatment schemes associated with these alternatives were further evaluated in terms of facility physical size requirements and construction sequencing that may be required if selected for implementation. The two potential sites under consideration for the new WTP are the existing Fiveash WTP site and the area of the Prospect Wellfield. Appendix H - TM09, Task 9 – Alternative Development – WTP Siting and Construction Sequencing provides a full reporting of this evaluation.

1.8.1 Fiveash Site

In addition to the Fiveash WTP, there is the Public Services Administration building on the site, as well as parking areas that are utilized for City vehicle staging. The area where the Administration building and parking lots are located would need to be utilized for future water treatment facilities. The area utilized by the existing WTP would not be available due to the requirement that the facility would need to remain in service and fully functional until a new treatment facility was commissioned and placed into full time service.

The components of each of the three shortlisted treatment schemes were evaluated in terms of physical size and space requirements. Utilizing this sizing information the processes which make up the treatment alternatives were arranged on the Fiveash WTP site. Travel routes and corridors for process piping, drainage, etc. are provided for in space between the unit processes.

As illustrated in Figures 7 and 8, Treatment Schemes 2 and 7 do not fit on the existing Fiveash site as land beyond the current property boundaries would be required (which is unlikely to be feasible to obtain because the railroad and interstate highway is adjacent to the site).

[redacted]

Figure 7 Treatment Scheme 2 Fiveash Location

[redacted]

Figure 8 Treatment Scheme 7 Fiveash Location

Treatment Scheme 11 can potentially fit on the Fiveash site with the Administration building remaining, although the area currently occupied by City of Oakland Park's dog park would need to be utilized. See Figure 9 for the conceptual siting of Treatment Scheme 11.

Travel routes for chemical deliveries, operation and maintenance activities, and employee parking would be less than optimal. Complications associated with facility construction in such a constrained area would pose many challenges and would likely result in additional costs. Emergency vehicle travel considerations will also need to be further evaluated during the design phase. The area currently occupied by the existing WTP would become available after facility decommissioning.

1.8.2 Prospect Wellfield Area

The Prospect Wellfield is located just north of Prospect Road adjacent to the Florida Turnpike and State Road 441. The wellfield site area consists primarily of open space, drainage lakes, Fiveash WTP sludge storage and drying areas, and miscellaneous vegetation. Some residential is located in the northeast corner of the site and a Florida Department of Transportation (FDOT) facility exists in the north-central area. The wells which serve the Fiveash WTP are scattered throughout the site.

The site has ample space available for all of the treatment alternatives. The area which conceptually appears most appropriate for a new treatment facility is in the Southeast (SE) quadrant. Figure 10 illustrates a conceptual layout of the most area intensive treatment alternative (Treatment Scheme 7).

[redacted]

Figure 9 Treatment Scheme 11 Fiveash Location

[redacted]

Figure 10 Treatment Scheme 7 Prospect Wellfield Location

1.9 Conceptual Capital, Operations/Maintenance Costs, and Net Present Value Determinations

It has been determined that rehabilitating the existing Fiveash WTP is not an option that fits with the City's Utility Vision or the specific goals and objectives of the Fiveash water treatment system. As such, a replacement facility will be necessary to achieve the elements of the Utility Vision and these established goals. For the short-listed proposed treatment alternatives conceptual capital and O&M costs were developed. Utilizing these costs a net present worth analysis was conducted to compare the alternatives. A complete reporting of the cost estimating can be found in Appendix I – TM10, Task 10 - Opinion of Probable Construction Cost and Net Present Worth Evaluation.

1.9.1 Capital Costs

Capital costs were developed for the option of locating Treatment Alternative 11 at the existing Fiveash WTP site, and the option of locating Treatment Alternatives 2, 7, and 11 at the Prospect Wellfield site. Two capital cost estimates were developed for each option. The two cost estimates differ only in how much of the existing treatment system infrastructure is utilized, and 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 the existing raw water transmission main which transfers raw water from the Prospect Wellfield to the Fiveash WTP into a finished water line feeding the distribution system pumps. Due to the Fiveash service area distribution system piping commencing at the Fiveash facility location it is essential that the potable water from a future facility is delivered to this same origination point to eliminate the requirement of distribution system modifications. For capital cost option 1 the existing piping from the Prospect site to the Fiveash site will be utilized.
- **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.

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.

2. The currently planned reliability upgrade project at the Fiveash WTP may likely not proceed, therefore new disinfection system is planned for.
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 with the following project elements included:

1. A new 5 MG ground storage tank (GST) at the Fiveash WTP.
2. The existing high service pumps at Fiveash WTP will be replaced with new pumps and variable frequency drives (VFDs) for Alternative 3 (new WTP at the existing Fiveash site).
3. Two new GSTs, including a 5 MG and 7 MG onsite GSTs are included for Alternative 4 (replacement treatment facility at the Prospect Wellfield site).
4. High Service pumps, VFDs, associated electrical equipment, and 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 included 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.

The capital cost for Treatment Scheme 11 at the existing Fiveash site, is outlined in Table 10 below.

Table 10 Conceptual Opinion of Probable Construction Cost for Fiveash Site, 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**
Additional 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.

The capital costs for Treatment Schemes 2, 7, and 11, where the replacement WTP will be located at the existing Prospect Wellfield site, are outlined in Tables 11 - 13 below.

Table 11 Conceptual Opinion of Probable Construction Cost for Prospect Site, 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**
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**
Additional Capital Cost for Elements Associated with Estimate 2	*$83,700,000*
Concept Level Capital Cost Estimate 2 Total	***$393,720,000***

Table 12 Conceptual Opinion of Probable Construction Cost for Prospect Site, 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**
Additional Capital Cost for Elements Associated with Estimate 2	*$83,700,000*
Concept Level Capital Cost Estimate 2 Total	***$427,610,000***

Table 13 Conceptual Opinion of Probable Construction Cost for Prospect Site, 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**
Additional Capital Cost for Elements Associated with Estimate 2	*$83,700,000*
Concept Level Capital Cost Estimate 2 Total	***$432,260,000***

1.9.2 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 14.
- 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 at a level consistent with current staffing.

- Equipment maintenance and spare parts cost was computed as 1 percent 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.

Table 14 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 15 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 15 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

1.9.3 Net Present Worth

NPW 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 NPW 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 bringing the cost to present value.

The duration for NPW 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 16 shows the Net Present Worth for each alternative and treatment scheme under consideration with the concept level Capital Cost Estimate 1.

Table 16 Net Present Worth Comparison

	Capital Cost 1	Annual O&M Cost	Net Present Worth(1)
Fiveash WTP Site, Scheme 11	$315,120,000	$16,700,000	$616,400,000
Prospective Wellfield Site, Scheme 2	$310,020,000	$14,740,000	$564,200,000
Prospective Wellfield Site, Scheme 7	$343,910,000	$16,960,000	$624,370,000
Prospective Wellfield Site, 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 17 shows the Net Present Worth for each alternative and treatment scheme under consideration with the concept level Capital Cost Estimate 2.

Table 17 Net Present Worth Comparison with Incremental Capital Cost

	Capital Cost 2	Annual O&M Cost	Net Present Worth(1)
Fiveash WTP Site, Scheme 11	$348,470,000	$16,700,000	$649,750,000
Prospective Wellfield Site, Scheme 2	$393,720,000	$14,740,000	$647,900,000
Prospective Wellfield Site, Scheme 7	$427,610,000	$16,960,000	$708,070,000
Prospective Wellfield Site, 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.

1.10 Conclusions

The tasks which comprised this project included goal setting and information gathering activities, as well as evaluation efforts to determine the path forward for the Fiveash Water Treatment System. The results of the goal setting and informational activities are summarized the previous sections herein. For the remaining tasks the following conclusions pertain:

1.10.1 Existing Facility Status Confirming Condition Assessment

The confirming assessment performed substantiates the findings of the CUSMP 2017 in regard to the conclusions that the existing Fiveash WTP will require very substantial renewal and replacement (R&R) expenditures over the next several years to achieve status quo potable water treatment performance. The initial treatment features of the WTP are approaching 60 years old and utilize treatment technologies that are antiquated and are unable to effectively perform as originally intended. Many of the processes at the facility operate below optimum conditions due to several factors, including equipment being at or beyond it normal useful life expectancy.

Maintaining status quo performance does not achieve the stated goals for the Fiveash water treatment system.

1.10.2 Water Treatment Process, Site, and Cost Evaluation

The water treatment evaluation process included detailed analysis of multiple treatment processes and combination of processes to achieve the goals for the Fiveash water treatment system. Eighteen treatment alternatives were developed and analyzed. The results of these efforts, and the input from the City project team, resulted in three treatment alternatives that would most effectively meet the project goals being short-listed. The three nominated alternatives are:

- 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 and Fixed Bed IX

These three alternatives were further evaluated to determine physical site requirements and whether or not they can be accommodated at the Fiveash and/or Prospect Wellfield site. It was determined that Alternatives 2 and 7 cannot fit on the Fiveash site, and although Alternative 11 can fit, the full implications to City operations would need to be further investigated in subsequent project phases. Table 18 notes pros and cons of the two site locations

Table 18 Comparison of WTP Locations

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 construction staging.
		Challenges associated with unknown site conditions and relocation of existing utilities will increase construction costs
		Construction will impact the operations and maintenance of the existing facility from an accessibility standpoint and shutdowns for tie-ins.
		Can only accommodate Treatment Alternative 11.
		Requires likely purchase of adjacent parcel owned by City of Oakland Park for Alternative 11.

Table 18 Comparison of WTP Locations (cont.)

Site	Pros	Cons
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" raw water pipelines to transfer the finished water to the Fiveash site to use the existing ground storage tanks (GSTs) and high service pumps (HSPs).
	Allows the city to incorporate property set-backs and security 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.	

The associated conceptual capital and O&M costs were developed for each alternative. These costs were utilized for a 20 year net present value comparison.

A comparison of the qualitative primary features and the capital costs of the alternatives was developed. These comparisons are summarized in Table 19.

Table 19 Comparison of WTP Alternatives

Evaluation Criteria	Treatment Scheme 2 Lime Softening + Ion Exchange	Treatment Scheme 7 Enhanced Coagulation with Pellet Softening + Ion Exchange	Treatment Scheme 11 Nanofiltration + Ion Exchange
Capital Cost			Fiveash Site:
Capital Cost 1	$310.02 M	$343.91 M	$315.12 M
Capital Cost 2	$393.72 M	$427.61 M	$348.47 M
			Prospect Site:
Capital Cost 1			$348.56 M
Capital Cost 2			$432.26 M
Meets Water Quality Goals	Yes	Yes	Yes
Proven Technology at this scale	Yes	Yes	Yes
Color and Organics Removal	Good	Excellent	Superior
Effectiveness for potential future regulated contaminants	Limited	Limited	Very good
Size of footprint	Large; will not fit on Fiveash site	Smaller than Alt 2; but will not fit on Fiveash site	Smaller than Alts 2 and 7, and will fit on Fiveash site
Operations	Similar to existing Fiveash WTP; high degree of manual operation	High degree of manual operation	Highly automated; minimal manual operation; less operational staff required
Water recovery	High water recovery > 97%	High water recovery > 97%	Lower water recovery than Alts 2 & 7 – approx. 85 – 88%
Byproduct Disposal	Significant solids to dispose of; future disposal alternatives unknown	Less solids than Alt 2; but still significant solids to dispose of – future disposal alternatives unknown	No solids disposal; Injection wells required for disposal of liquid byproduct
Chemical usage	Similar to current Fiveash WTP operation	Less than current operation; no dry chemicals to handle	Similar to Peele Dixie WTP per mgd
Energy requirements	Similar to current Fiveash WTP operation	Similar to current Fiveash WTP operation	Significantly more than current Fiveash; similar to Peele Dixie WTP per mgd

As noted the capital costs for a replacement facility ranges from approximately $310 million (M) to $349 M for option Capital Cost 1, and from $348 M to $432 M for option Capital Cost 2. This represents a cost variability between treatment facilities of approximately 12 percent for option Capital Cost 1, and 24 percent for option Capital Cost 2 scenarios.

All three of the shortlisted processes technologies are capable of meeting desired water quality goals and are a proven reliable technology at the 50 mgd capacity. Treatment Scheme 11 is the most suitable for addressing potential future regulated contaminants. Treatment Scheme 11 also eliminates the unknowns associated with treatment system byproducts disposal, as disposal would be accomplished utilizing on-site injection wells.

Treatment Schemes 2 and 7 require a higher degree of operator attention but have approximate 10 percent higher water recovery. All schemes require multiple chemical systems. Scheme 11 is more energy intensive.

In summary, all the treatments schemes are effective at achieving project goals associated with capacity, water quality, and infrastructure sustainability. The level of each technology to meet the operation and maintenance goals varies due to chemical and power usage, labor requirement, and byproducts disposal.

A key objective of the Utility Vision as noted in the CUSMP 2017 is for "..., all of our water treatment facilities will be state of the art by 2035, ...". State of the art implies the most recent stage in development of a product incorporating the newest ideas, etc. Of the three short-listed technologies the most state of the art technologies are included in Scheme 11. These technologies of nanofiltration and ion exchange are tried and true over decades of utilization. In addition to a solid performance track record, the industry continues to support significant research and development (R&D) to address existing and potential future challenges. Treatment Scheme 11 best meets the project goals and the Utility Vision with a potential conceptual cost differential less than the capital cost contingency estimated.

1.10.3 Recommendation

Based on the analysis and evaluation described herein, it is recommended that the City proceed with design and construction of a new state-of-the-art water treatment facility at the Prospect Wellfield site with a proposed treatment process consisting of a combination of nanofiltration and ion exchange (Treatment Scheme 11). The City could minimize capital costs in the short term by utilizing existing infrastructure at Fiveash Water Treatment Plant (WTP) including the high service pump station, generators, storage tanks, etc. as defined in "Capital Cost Estimate 1." The conceptual cost estimate for this alternative is approximately $350 million.

This recommended alternative utilizes a technology of which the City is familiar, along with an additional technology that results in a robust treatment system. These technologies are highly automated requiring less manual operation and best meet the City's desire for color elimination and other specific project goals. Further, this recommended alternative is best suited to minimize the potential impacts of future uncertainties including future regulated contaminants and treatment system byproduct disposal.