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TITLE: FLUORIDE BEST PRACTICES STUDY REPORT (WORKSHOP – 2:00 P.M.)

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CITY OF SACRAMENTO
DEPARTMENT OF UTILITIES
FLUORIDE BEST PRACTICES STUDY REPORT

FINAL REPORT

PREPARED BY: BLACK & VEATCH
Project Number: 172145

April 18, 2011

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ABBREVIATIONS AND ACRONYMS

The following abbreviations and acronyms are used in this report:

BMPs	best management practices
$CaCO_3$	calcium carbonate
CDC	Center for Disease Control
CIP	Capital Improvements Program
City	City of Sacramento
DDWEM	Division of Drinking Water & Environmental Management
F	fluorine
FRP	fiberglass reinforced plastic
FTE	full time equivalent
HFA	hydrofluosilicic acid
mgd	million gallons per day
mg/L	milligrams per liter

NaF	sodium fluoride
NSF	National Science Foundation
O&M	operations and maintenance
OPCC	opinion of probable construction cost
P&ID	process and instrumentation diagram
Pb	lead
PVC	polyvinyl chloride
U.S.	United States
WTP	water treatment plant

EXECUTIVE SUMMARY

The City of Sacramento (City) has been fluoridating their water supply since 2000. Over time, the City has experienced problems at some of their facilities and since the program began, operational costs have risen from $350,000 in 2000 to $957,000 in 2010. The average yearly increase on a percentage basis is approximately 10.5 percent.

The City has authorized Black & Veatch to review current fluoridation practices, develop and evaluate alternatives for the City's system, prepare opinions of probable costs, and recommend improvements to meet fluoridation best management practices (BMPs). This report presents the results of the Black & Veatch evaluation.

Preliminary Review of Fluoridation Practices

Many public water utilities add fluoride to their water to reduce the incidence of tooth decay. Three different types of fluoride compounds are commonly used by municipal water utilities to fluoridate water: hydrofluosilicic acid (HFA), sodium fluoride, and sodium silicofluoride. Hydrofluosilicic acid and sodium fluoride are both frequently used in water treatment and are potential options for the City. Sodium silicofluoride is not commonly used and is not considered a viable alternative.

Review of Fluoridation Practices at City Facilities and Other Utilities

The City currently distributes approximately 46 billion gallons of water annually to approximately 136,700 service connections through two water treatment plants (WTPs) and 27 groundwater wells. Their ongoing fluoridation costs equate to approximately $1.97 per person per year and approximately $0.58 per connection per month. The City provided Black & Veatch with a list of several issues associated with the existing fluoride systems at the wells and WTPs, including quality of the product, equipment failure and loss of production, safety, and higher than expected operation and maintenance (O&M) costs. A complete listing of the issues is presented in Appendix A.

Sacramento River Water Treatment Plant

The Sacramento River Water WTP HFA system was installed in 2000 in an outdoor location. A new chemical feed building was constructed in 2004. The equipment was replaced and installed in the new indoor location in 2007. The City's operation staff is not experiencing any particular issues with the fluoridation equipment, and improvements are not required at this time. However, regular equipment replacement is required throughout the 20-year planning horizon considered by this report.

E.A. Fairbairn Water Treatment Plant

The E.A. Fairbairn WTP HFA system was installed in 2000 in an outdoor location with only the chemical metering pumps enclosed within a building. The City has experienced maintenance issues with the bulk storage and chemical feed piping due to its exposure to the elements. The system components located outside are nearing the end of their useful life and need replacement. Three options were developed and evaluated, as described in the sections below.

Groundwater Wells

Fluoridation at the groundwater wells utilizes sodium fluoride. Issues experienced at some of the wells include clogging of equipment and piping, need for frequent cleaning, operational inconsistencies, and uncertainty in the quality of the delivered sodium fluoride product. These issues have resulted in increased O&M requirements on the City's staff. Four alternative options were developed and evaluated, as described below.

Fluoridation Facilities Alternatives Development, Evaluation, and Costs

Chapters 3 and 4, respectively, develop and evaluate fluoride handling options for each of the City's sites and present preliminary cost opinions.

Sacramento River Water Treatment Plant

The facilities at the Sacramento River WTP are in good working condition are are not due for replacement at this time. Replacement of certain components of the facilities should occur in years 2018, 2023, and 2028. Currently, operations and maintenance (O&M) activities utilize approximately 0.2 full-time equivalent (FTE) staff. There are no anticipated changes to this level of staffing over the next 20 years at this facility.

E.A. Fairbairn Water Treatment Plant

The following options are available for upgrading the fluoridation system at E.A. Fairbairn WTP:

- Option 1 – Replace the existing chemical piping, tanks, valves, and pumps in their existing location with no covering.
- Option 2 - Construct the new facility in the existing location and provide a canopy over new bulk storage and chemical metering facilities to minimize capital costs.
- Option 3 - Construct new bulk storage tanks and metering facility inside a chemical containment area, enclosed in a building structure.

Present value, future value, and annualized costs for the options are presented in Table ES-1.

TABLE ES-1: E.A. FAIRBAIRN WTP FLUORIDATION SYSTEM COSTS

	CAPITAL COST	2011 O&M COST	20-YEAR FUTURE VALUE COST	PRESENT VALUE COSTS	ANNUALIZED COSTS
(Option 1 – Replace Equipment in existing location)	$316,000	$241,800	**$11,176,000**	**$6,820,388**	**$437,508**
(Option 2 - Canopy Structure in existing location)	$408,000	$241,800	**$10,723,000**	**$6,543,935**	**$419,775**
(Option 3 - New Concrete Masonry Building in new location)	$893,000	$241,800	**$11,852,000**	**$7,232,931**	**$463,972**

Note: Chemical costs are based on the current target dose. The USEPA is currently considering a reduction in optimal fluoride levels to 0.7 mg/L; which may reduce annual chemical costs by approximately $65,000.

Currently, O&M activities utilize approximately 0.2 full-time FTE staff. There are no anticipated changes to this level of staffing over the next 20 years at this facility with the proposed improvements.

Groundwater Well Sites

Four options were identified to resolve issues and reduce the City's O&M requirements on the sodium fluoride systems:

- Option 1 – Upgrade Existing Dry Solid Sodium Fluoride System
- Option 2 – Convert Existing Sodium Fluoride System to Liquid HFA
- Option 3 – Convert to Liquid HFA and Hire Third Party Contractor for O&M Delivery
- Option 4 - Centralized Dry Solid Sodium Fluoride System

Under Option 1, improvements were identified to enhance the system and reduce O&M requirements. To minimize overall costs and confirm effectiveness, it is recommended that the City implement the recommendations below at a single well and evaluate its performance before implementing these measures across all the groundwater wells. Activities would include:

- Step 1: Check the water hardness and optimize existing water softening system.
- Step 2: Provide a new saturator with side facing dilution water distribution ports and float control (to maintain constant flow operation of water softener).
- Step 3: Replace existing metering pumps and provide new chemical piping.

Both Option 2 and Option 3 would involve converting to a liquid HFA system. The latter would include hiring a third party contractor to deliver the HFA and perform visual inspections of the equipment. Option 4 would involve construction of a sodium fluoride batching facility that would be

located at either of the City's two WTPs. However, due to significant disadvantages described in Section 3.3.5, Option 4 was eliminated from further consideration.

Present value, future value, and annualized costs for the viable options are presented in Table ES-2.

TABLE ES-2 WELL SITE 20-YEAR COST SUMMARY

	CAPITAL COST	2011 O&M COST	20-YEAR FUTURE VALUE COST	PRESENT VALUE COSTS	ANNUALIZED COSTS
OPTION 1 – Dry Sodium Fluoride, All Steps	$1,365,000	$429,000	**$21,057,000**	**$12,850,475**	**$824,321**
OPTION 2 – Liquid Hydrofluosilicic Acid w/ Standard Delivery	$2,846,000	$454,000	**$25,670,000**	**$15,665,655**	**$1,004,907**
OPTION 3 – Liquid Hydrofluosilicic Acid w/ Contract Delivery Service	$2,846,000	$470,000	**$26,824,000**	**$16,369,908**	**$1,050,083**

Note: Chemical costs are based on the current target dose. The USEPA is currently considering a reduction in optimal fluoride levels to 0.7 mg/L; which may reduce annual chemical costs by approximately $65,000.

The City did not increase staff when the fluoride systems were installed in 2000 and have been operating with a total of 8 staff assigned to the well system, plus supervisors and management. Additional staff are drawn upon for specialized repairs. These include Mechanical, Instrumentation & Electrical, and SCADA technicians. Table ES-3 summarizes the current staffing level requirements, and the anticipated staffing levels based on the proposed projects.

TABLE ES-3 WELL SITE STAFFING LEVEL SUMMARY

	Option	Total Labor Hours	Total Labor Days	Approximate FTE
	Dry Solid Sodium Fluoride (Current)	4,039	505	3.1
1	**Dry Solid Sodium Fluoride (Optimized)**	3,472	434	2.7
2	**Liquid Hydrofluosilicic Acid**	2,662	333	2.0
3	**Liquid Hydrofluosilicic Acid w/ Delivery Service**	2,171	271	1.7
* Full Time Equivalent (FTE) staff based on 163 effective labor days each year				

Recommendations and Project Implementation

Chapter 5 presents recommendations for the E.A. Fairbairn WTP and the groundwater wells and proposes an implementation plan for system improvements.

Recommendations for E.A. Fairbairn Water Treatment Plant

The costs associated with Option 1 (no canopy or enclosure) are lower than Option 2 (canopy) and Option 3 (building), however the level of protection for equipment achieved with a canopy is not comparable to the level of protection achieved with a building. The enclosed equipment will have a

longer service life due to the higher level of protection inside a building and the difference in life cycle costs is small. Therefore, Option 3 is recommended.

Total project costs are presented in Table ES-4.

TABLE ES-4: E.A. FAIRBAIRN WTP FLUORIDATION SYSTEM IMPLEMENTATION COSTS

TOTAL PROJECT COSTS – REPLACE LIQUID HFA SYSTEM INSIDE NEW BUILDING (OPTION 3)	
	COST
Total Probable Construction Cost	$893,000
Design Cost	$150,000
Construction Management Costs	$100,000
TOTAL PROJECT COST	**$1,143,000**

Recommendations for Groundwater Well Sites

The City has provided some hardness data which indicates that hardness may not be contributing significantly to the problems experienced at the well sites. However, data is required to rule out hardness completely as a contributing issue. Recommendations for additional testing are provided. If it is determined that the hardness is higher than 50 mg/L $CaCO_3$, it is recommended that the City implement Option 1, for upgrade of the existing dry solid sodium fluoride (NAF) system. However, it is noted that even with resolution of the current O&M issues on the sodium fluoride system, there is still concern regarding the quality of the foreign supplied sodium fluoride. If the City is not in alignment with accepting the risk associated with this product and the uncertainty associated with the level of remedy that the outlined steps in Option 1 may provide, then Option 2, is recommended for implementation. Similarly, if the City finds that the water hardness is not an issue, then it is recommended that the City move forward with the conversion of the well system to liquid HFA in Option 2. Conversion to liquid HFA at the well sites will not have a negative impact on water quality, in particular, pH levels in the groundwater. Preliminary modeling indicates that switching to liquid HFA at the well sites would only decrease the pH by 0.03 to 0.05 units. Total project costs are presented in Table ES-5 and ES-6.

TABLE ES-5: GROUNDWATER PRODUCTION WELLS FLUORIDATION SYSTEM IMPLEMENTATION COSTS

TOTAL PROJECT COSTS – IMPROVE DRY SOLID NAF SYSTEM (OPTION 1 ALL STEPS INCLUDED)	
	COST
Total Probable Construction Cost	$1,365,000
Design Cost	$150,000
Construction Management Costs	$100,000
TOTAL PROJECT COST	**$1,615,000**

TABLE ES-6: GROUNDWATER PRODUCTION WELLS FLUORIDATION SYSTEM IMPLEMENTATION COSTS

TOTAL PROJECT COSTS – CONVERT TO LIQUID HFA SYSTEM (OPTION 2)	
	COST
Total Probable Construction Cost	$2,846,000
Design Cost	$250,000
Construction Management Costs	$200,000
TOTAL PROJECT COST	**$3,296,000**

Section 4 provides the comparison of O&M requirements with the alternatives and standard requirements.

20-Year Fluoridation Cost Summary

The City has been meeting its fluoridation targets and has been operating within an acceptable range of costs. To continue fluoridating, the City will need to provide O&M expenditures and upgrade facilities to improve operations and replace aging equipment. This report outlines estimates for on-going O&M costs and makes recommendations regarding capital projects. Table ES-7 and ES-8 summarize the capital, O&M, 20-year future value, present value, and annualized costs of the combined recommended improvements.

TABLE ES-7 FLUORIDATION FACILITIES IMPROVEMENTS SUMMARY

	Base 2011 Costs					Total City Fluoridation Costs		
Description	2011 Capitol Projects	O&M Equipment Replacement	O&M Chemical	O&M Labor	Total 2011 O&M Costs	PW	Annualized	FW
Current System at Wells, EAF and Sac River		$19,756	$491,876	$445,305	$956,937			
Wells –Improve Dry Solid NAF System **EAF – Liquid HFA in New Building** **Sac River WTP Future Equipment Replacement**	$2,258,000	$18,000	$493,000	$399,000	$910,000	$26,289,000	$1,686,000	$43,077,000
Wells – Convert to Liquid HFA **EAF – Liquid HFA in New Building** **Sac River WTP Future Equipment Replacement**	$3,739,000	$29,000	$587,000	$318,000	$934,000	$29,104,000	$1,867,000	$47,690,000

Note: Chemical costs are based on the current target dose. The USEPA is currently considering a reduction in optimal fluoride levels to 0.7 mg/L; which may reduce annual chemical costs by approximately $65,000.

TABLE ES-8 SUMMARIZES THE FUTURE VALUE, PRESENT VALUE, AND ANNUALIZED COSTS FOR THE PRESENT AND FUTURE EQUIPMENT REPLACEMENT, AND THE TOTAL CITY FLUORIDATION COSTS MINUS THE EQUIPMENT REPLACEMENT COSTS.TABLE ES-8 FLUORIDATION FACILITIES IMPROVEMENTS SUMMARY

	Present and Future Equipment Replacement			Total City Fluoridation Costs less Equipment Costs		
Description	PW	Annualized	FW	PW	Annualized	FW
Wells –Improve Dry Solid NAF System **EAF – Liquid HFA in new Building** **Sac River WTP Future Equipment Replacement**	$6,065,000	$389,000	$9,938,000	$20,224,000	$1,297,000	$33,139,000
Wells – Convert to Liquid HFA **EAF – Liquid HFA in new Building** **Sac River WTP Future Equipment Replacement**	$8,073,000	$518,000	$13,228,000	$21,031,000	$1,349,000	$34,462,000

Note: Chemical costs are based on the current target dose. The USEPA is currently considering a reduction in optimal fluoride levels to 0.7 mg/L; which may reduce annual chemical costs by approximately $65,000.

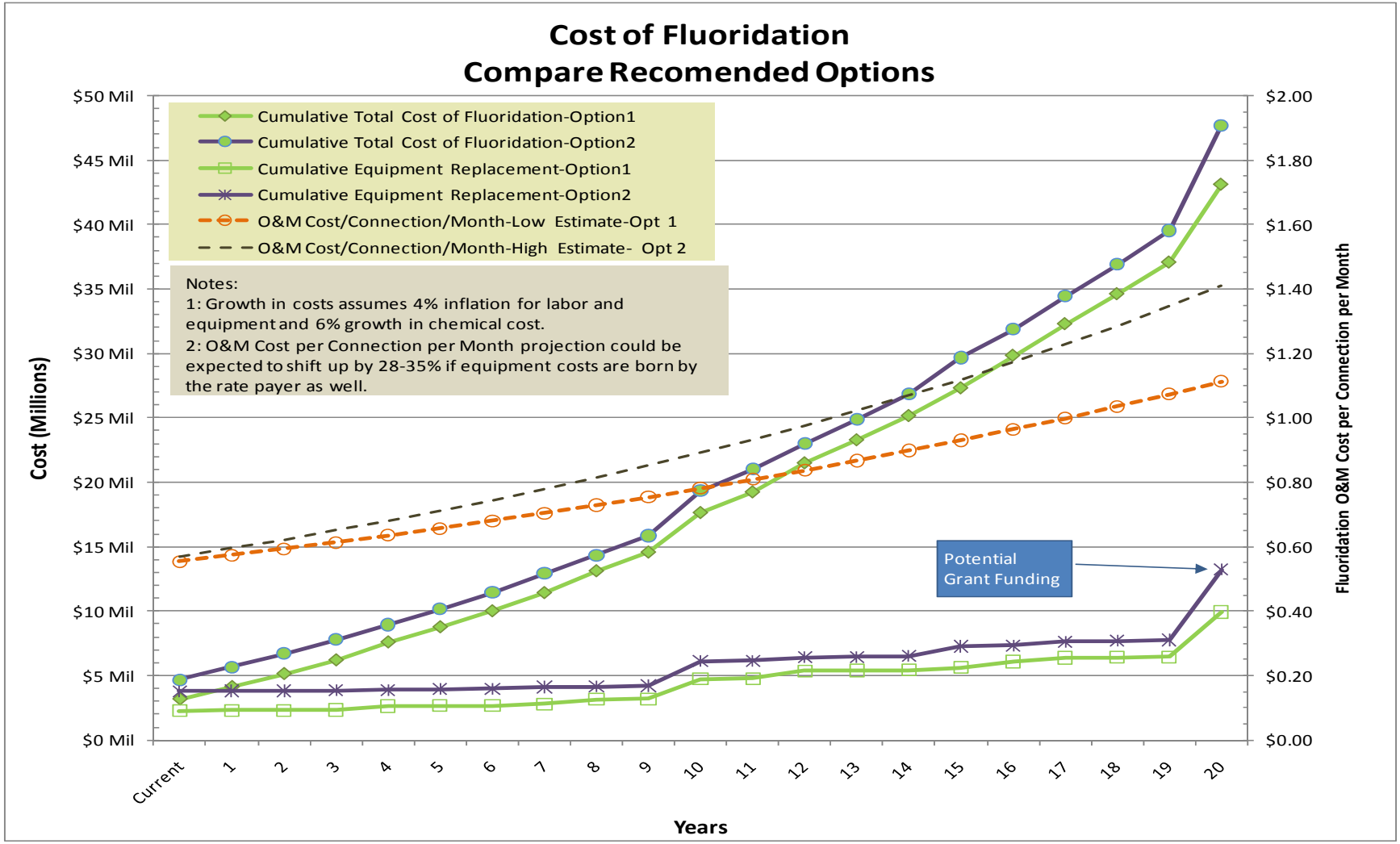

FIGURE ES-1: COST OF FLUORIDATION COMPARISON OF RECOMMENDED OPTIONS

1. BACKGROUND

The City of Sacramento (City) currently provides fluoridation at their 27 well sites, the E.A. Fairbairn Water Treatment Plant (WTP), and Sacramento River WTP. Sodium fluoride is used at the well sites and hydrofluosilicic acid (HFA) is used at the two WTPs. The City has been fluoridating their water supply since 2000 and is experiencing higher than expected operation and maintenance (O&M) costs with the well site systems. The City has retained Black & Veatch to review the existing fluoridation facilities and provide recommendations on the following:

- Identify best management practices (BMPs) for fluoridating the water supply.
- Identify and recommend upgrades needed to meet these BMPs.
- Identify opportunities to lower the total cost of providing fluoridation to the water supply.
- Develop cost estimates for capital improvements and ongoing O&M.

1.1. City of Sacramento Water System Overview

The City currently distributes approximately 46 billion gallons of water annually to approximately 136,700 service connections through two WTPs and groundwater wells. The City serves approximately 486,000 people (source: California Department of Finance, 1/1/2010), and their ongoing fluoridation costs break down to approximately $1.93 per person. If the total cost of service was averaged throughout all service connections on a monthly basis, the cost would be approximately $0.57 per connection per month. Operation data for average and maximum day demand over the past three years (2007-2010) at the two WTPs and from the City's groundwater wells are summarized in Table 1-1 and Table 1-2. The City's two WTPs account for majority of the total water supply while 11 to 15 percent is provided through the City's groundwater wells (see Figure 1-1). The majority of the City's groundwater wells each contribute less than 5 percent (typically in the range of 2 to 4 percent) of the total City water production.

TABLE 1-1: OPERATIONS SUMMARY (2007-2010)

	AVERAGE DAY (MGD)			MAXIMUM INSTANTANEOUS (MGD)[1]		
Plant	2007-2008	2008-2009	2009-2010	2007-2008	2008-2009	2009-2010
E.A. Fairbairn	57.1	55.1	50.8	110.5	102.2	94.9
Sacramento River	66.6	60.8	52.6	122.9	114.3	103.1
Groundwater Wells	18.6	17.3	17.1	23.8	21.9	20.5

1. **Maximum instantaneous flow at plants is maximum hourly. Maximum instantaneous flow at wells is maximum monthly.**

TABLE 1-2: WELL PRODUCTION DATA SUMMARY (2008-2010)

WELL #	AVERAGE FLOW (GPM)[1]	MAX FLOW (GPM)[1]	AVERAGE FEED RATE OF SODIUM FLUORIDE SOLUTION (GPD)
Well 083	406	455	58
Well 092	813	939	112
Well 093	415	590	62
Well 094	855	995	124
Well 107	635	798	98
Well 116	620	789	92
Well 120	550	800	91
Well 122	467	539	68
Well 124	572	726	86
Well 126	625	800	N/A
Well 127	535	631	66
Well 129	524	665	74
Well 131	424	800	66
Well 133	783	1003	115
Well 134	723	855	104
Well 137	535	619	78
Well 138	529	664	85
Well 142	970	1092	23
Well 143	397	442	52
Well 144	482	633	65
Well 153	1076	1259	152
Well 154	551	658	84
Well 155	825	1032	126
Well 156	472	1050	74
Well 158	754	862	121
Well 159	472	728	68
Well 164	847	1179	N/A

[1]Based on recorded SCADA Flow rates (gpm): 1/1/2008 to 11/19/2010

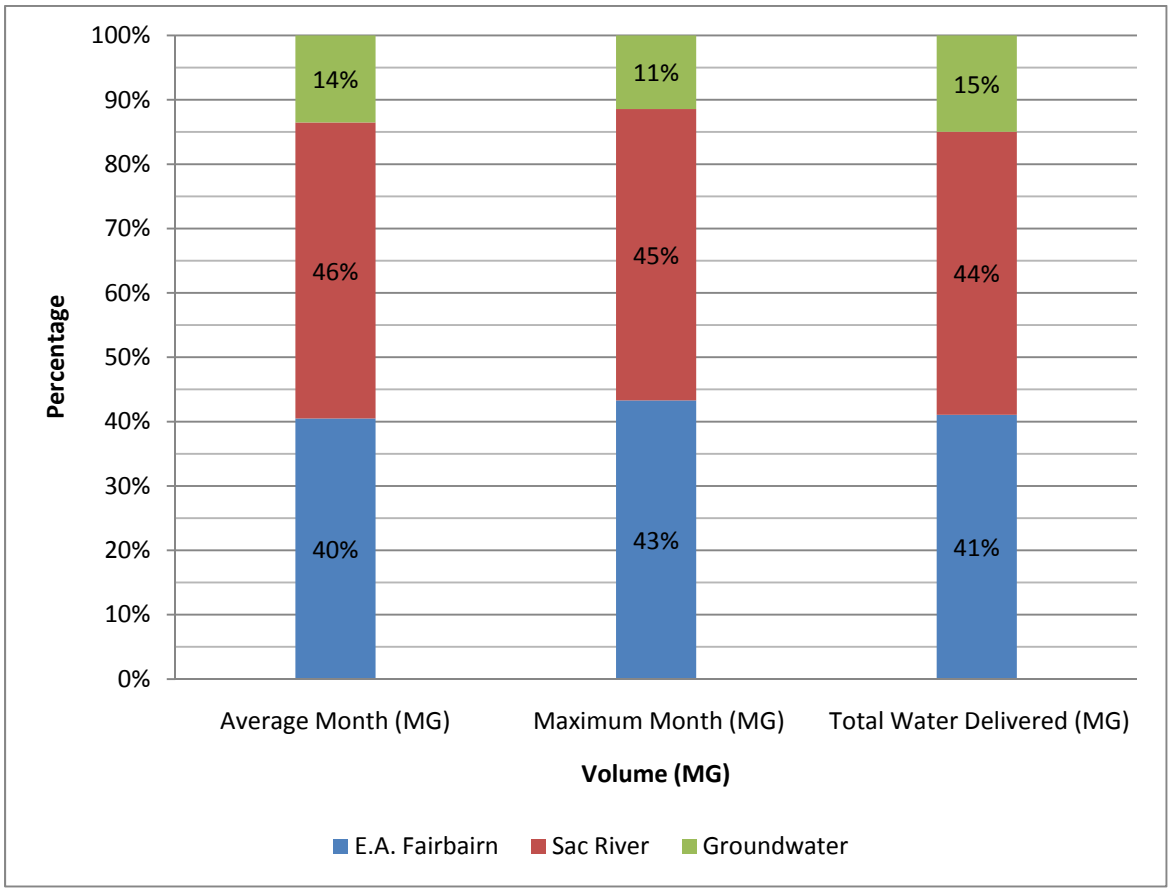

FIGURE 1-1: WATER SUPPLY CONTRIBUTION FROM WTPS AND GROUNDWATER SUPPLY (2007-2010)

1.2. City of Sacramento Fluoridation Facilities Overview

1.2.1. Fluoride Dosage Summary

The fluoride concentration in the water system is generally within the target range of 0.7 mg/L to 1.3 mg/L. Sampling data has been collected since the systems went on-line in the year 2000 to track the fluoride concentration. Table 1-3 summarizes the concentration at the two water treatment plants, the wells, and at various points in the distribution system and highlights the percent occurrence of given fluoride concentrations. It is noted that the USEPA is considering a reduction in the optimal fluoride levels which would potentially reduce the City's target to 0.7 mg/L.

TABLE 1-3 FLUORIDE CONCENTRATION SUMMARY

Variation in Fluoride Concentration (mg/l)[1]				
Percent Occurring	Injection Point			Distribution System
	EAFWTP	SRWTP	Wells	
0%	0.42	0.23	0.11	0.10
1%	0.70	0.67	0.62	0.60
5%	0.74	0.74	0.77	0.73
10%	0.76	0.76	0.82	0.75
20%	0.77	0.79	0.88	0.77
30%	0.79	0.82	0.91	0.79
40%	0.80	0.83	0.94	0.81
50%	0.81	0.84	0.96	0.82
60%	0.82	0.86	0.99	0.84
70%	0.84	0.88	1.02	0.85
80%	0.86	0.91	1.06	0.88
90%	0.89	0.95	1.11	0.93
95%	0.92	0.97	1.16	0.98
99%	1.00	1.02	1.27	1.10
100%	1.01	1.22	4.00	1.93
Average	0.82	0.85	0.96	0.83
St Dev	0.06	0.09	0.15	0.09
1: All results based on laboratory evaluated samples				
Recommended Range: 0.7 to 1.3 mg/l				
Sample Dates: 2000 to current				

The fluoride concentration is further summarized in Table 1-4 and highlights the percentage of samples within the recommended control range.

TABLE 1-4: FLUORIDE CONCENTRATION RANGE SUMMARY

Percentage of Fluoride Concentration Samples Within 0.7-1.3 mg/l Recommended Control Range	
EAFWTP	99.1%
SRWTP	97.5%
Wells	97.0%
Distribution System	96.9%
All results based on laboratory evaluated samples	
Sample Dates: 2000 to current	

1.2.2. E.A. Fairbairn Water Treatment Plant

The HFA system at the E.A. Fairbairn WTP consists of fiberglass reinforced plastic (FRP) storage tanks, diaphragm metering pumps, magnetic flow meters, and online fluoride analyzers.

The E.A. Fairbairn WTP liquid HFA system was installed in 2000 in an outdoor location adjacent to the filters. The storage tanks are located in an uncovered containment area, and the chemical feed pumps are in a fiberglass shelter adjacent to the storage tanks. Photos of the HFA system at E.A. Fairbairn WTP are provided in Figure 1-2.

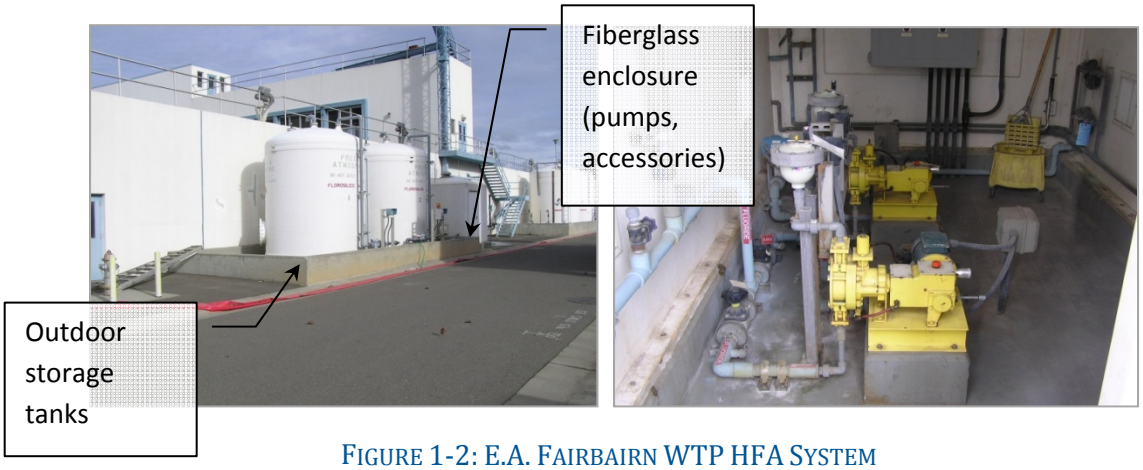

FIGURE 1-2: E.A. FAIRBAIRN WTP HFA SYSTEM

The City has experienced maintenance issues with the bulk storage and chemical feed piping located outdoors in an uncovered environment. During rain events, rain water collected inside the exposed containment area requires testing and manual pumping for disposal. This process increases the maintenance time associated with the system and exposes operators to a potentially hazardous situation.

The City also indicated that the equipment is over 10 years old and with continuous exposure to the elements may be due for replacement.

1.2.3. Sacramento River Water Treatment Plant

The Sacramento River WTPs liquid HFA system, with equipment that is similar to that at the E.A. Fairbairn WTP, was installed in 2000 in an outdoor location. However, during 2004, the Sacramento River WTP was expanded, and a new chemical feed building was constructed. The HFA system was replaced in 2007 and moved inside the new chemical storage building. Photos of the current HFA system, enclosed in the chemical feed building, are provided in Figure 1-3.

FIGURE 1-3: HFA SYSTEM AT SACRAMENTO RIVER WTP

The City's operation staff has indicated that they are not experiencing any particular issues with the Sacramento River WTP fluoridation equipment. Based on an installation year of 2007, the tanks, piping, and valves will likely need replacement in the next 10 to 15 years, whereas the metering pumps should last at least 20 years.

1.2.4. Well Sites

Fluoridation at the 27 well sites is carried out using dry solid sodium fluoride saturator systems. The fluoride chemical feed systems are housed in fabricated storage sheds or inside masonry buildings. In addition to the sodium fluoride system, gas chlorine feed systems and electrical and instrumentation equipment are installed inside the same enclosure. Each site consists of an upflow saturator, water softener assembly, solenoid type chemical metering pump, and accessories. The City noted that most of the well sites use a Digipulse type flow indicator that has small magnets that routinely need to be replaced. Photos of a typical well site sodium fluoride saturator are provided in Figure 1-4.

FIGURE 1-4: PHOTOS OF SODIUM FLUORIDE FEED SYSTEM AT WELLS (TYPICAL)

As indicated in Figure 1-4, the chemical feed systems are in fairly confined areas, and minimal room is available for expansion or rearrangement of existing equipment. The City indicated that a few sites are in masonry block buildings and there is more room for modifications in those buildings. However, the majority of the well sites are in installations similar to that depicted in Figure 1-4.

1.3. Fluoridation Operations and Maintenance Summary

The City provided a list of several issues associated with the existing sodium fluoride systems at the wells. The following subsection is an abbreviated list. The complete list is included in Appendix A. These issues are addressed in Section 2 and Section 3 of this report.

1.3.1. Quality of the Product

The City raised concerns about the quality of dry solid sodium fluoride produced in countries outside the US, the overall content of the material (i.e., 44% fluoride and 56% other content), and whether there are strategies to ensure a higher level of quality when specifying the chemical.

1.3.2. Equipment Failure and Loss of Production

The City is experiencing higher than anticipated O&M costs addressing pump malfunctions; clogged injectors and pipelines; failures of injectors, diaphragms, fittings, screens, flow indicators, floats, and diffusers; and troubleshooting the calculated well production rates and the chemical dosage and feed rates with measured data in order to maintain good records. Figure 1-5 presents photos of a new injector quill and used injector quill with evidence of clogging that builds up over time.

FIGURE 1-5: PHOTOS OF SODIUM FLUORIDE INJECTOR AT WELLS (NEW AND WITH CLOGGING)

1.3.3. Safety

The City raised concerns with safety and security with handling sodium fluoride, worker training, and potential impacts if the well systems were switched to HFA fluoridation systems.

1.3.4. Additional Costs and Issues

The City raised various other concerns that include cleaning the sodium fluoride equipment (saturators, water softeners), time required to document fluoride related activities and paperwork, and general funding issues for capital and O&M costs and adequate staffing.

2. FLUORIDATION SYSTEMS OVERVIEW

2.1. General Description

Fluorine (F) is a highly reactive halogen gas and is the most electronegative of all elements. Because of this, it is difficult, if not impossible, to oxidize it to a positive state. Thus, it is not found in a free state in nature and instead found in combination with other elements as fluoride compounds. When dissolved in water, these fluoride compounds dissociate into ions.

Fluoride is present in small but widely varying amounts in practically all soils, water supplies, plants, and animals, and thus is a normal constituent of all diets. The highest concentrations in mammals are found in the bones and teeth. All public water supplies in this country contain at least small amounts of natural fluoride.

2.2. Purpose of Fluoridation

Many public water utilities add fluoride to their water to reduce the incidence of tooth decay, which is the most prevalent chronic disease according to the Centers for Disease Control and Prevention (CDC). Three different types of fluoride compounds are commonly used by municipal water utilities to fluoridate water:

- Hydrofluosilicic acid
- Sodium fluoride
- Sodium silicofluoride

All three of these systems are considered viable options for the City of Sacramento. The fluoridation systems in consideration use chemicals in either the dry (granular or powder form) or liquid form. The fluoride chemicals that are manufactured and delivered in the dry form (sodium fluoride and sodium silicofluoride) are mixed into dilute solution on-site while chemicals delivered in liquid form (HFA) can be fed directly into the water system. It should be noted that the three fluoride compounds are aggressive and toxic chemical compounds that should be handled with extreme care. A brief discussion and comparison of these three fluoride addition systems are provided below.

2.3. Fluoride Addition Systems

2.3.1. Hydrofluosilicic Acid

HFA is delivered as a liquid solution that is 24 percent HFA and 76 percent water. Roughly 19 percent of the HFA solution is available as fluoride. HFA feed systems are relatively simple compared with dry, solid feed fluoride systems. HFA may impact the pH of the water if adequate alkalinity and buffer capacity is not present in the water

supply. Based on water quality modeling performed on the City's groundwater supply (average values of pH = 7.5, alkalinity = 133 mg/L as $CaCO_3$, and Hardness = 140 mg/L as $CaCO_3$), switching to HFA at the well sites would only decrease the pH by 0.03 to 0.05 units.

The HFA feed system typically consists of a bulk storage tank, transfer pumps, a day tank, and metering pumps which inject the acid into the water supply. Because the chemical is fed as delivered solution, carrier water is not needed and therefore water softening is not necessary. A day tank, with a volume much smaller than the bulk storage tank, is provided to reduce the potential for a large overfeed incident and is commonly mounted on a scale to monitor fluoride usage. Since day tanks are not currently used at the City's two WTPs, a waiver from the Department of Public Health's requirement of day tanks may be obtained for the well sites. A schematic of a typical HFA system is presented in Figure 2-1.

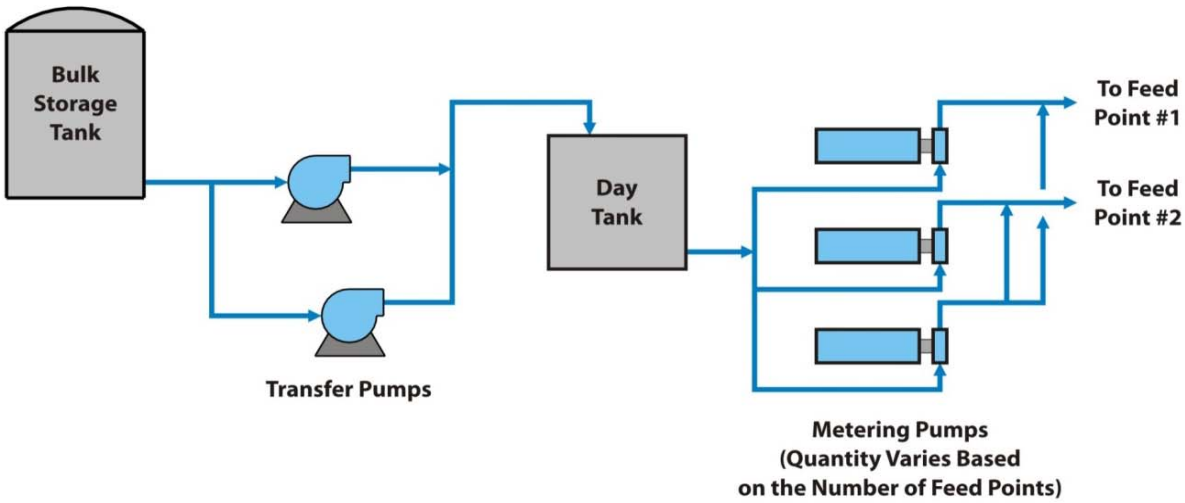

FIGURE 2-1: TYPICAL HFA SYSTEM PROCESS SCHEMATIC

Note: The City's well sites typically use one metering pump and one feed point.

HFA liquid and its vapor are extremely aggressive, and the highest level of safety must be taken to ensure no bodily harm to those working with this chemical. This includes wearing a protective suit and gloves as well as a splash resistant face shield when working with the system. However, under normal operations, minimal contact between the operations staff and the fluoride feed system is required since the bulk storage tank is filled directly from the chemical delivery truck. The bulk storage and day tank must be properly vented as the hydrogen fluoride fumes are corrosive to most metals and will frost glass. Because dry chemicals and dry feeders are not used with this system, O&M activities are generally less frequent then that required for dry chemical feed systems.

HFA is typically a 24 percent acid solution. Ground up phosphate rock and sulfuric acid are mixed to form a gas. The gas is then combined with water to form a dilute acid and then concentrated to the HFA product. Due to the high water content in HFA, shipping can be expensive. Thus, at this time it is only available from domestic sources.

2.3.2. Sodium Fluoride

Sodium fluoride is available in a dry granular or powder form and is added to a saturator tank to be dissolved into a liquid solution. Powder sodium fluoride is not recommended because of the potential for plugging of the saturator and the higher dust levels it produces. In its dry, delivered chemical form, sodium fluoride is very pure; approximately 97 percent of the chemical is sodium fluoride, of which roughly 44 percent is available fluoride. One of the primary benefits of sodium fluoride is that it has a relatively constant solubility at normal operating temperatures, which means that it typically produces a 4 percent solution regardless of water temperature. Therefore, monitoring the amount of water added to the saturator is not necessary to ensure the proper solution concentration.

The granular sodium fluoride is added into a saturator tank so as to be dissolved into solution. Dry sodium fluoride is added to the saturator and settles to the bottom where dilution water is introduced into the tank using a distributor. As the water trickles up through the bed of sodium fluoride, the fluoride dissolves into solution to produce a 4 percent solution. If the dilution water is high in hardness, it would need to be softened to prevent fouling and plugging of the water inlet distributor located on the bottom of the saturator. A metering pump is used to accurately control the amount of fluoride solution fed to the water main. A schematic showing the general process of a sodium fluoride system is presented in Figure 2-2.

With sodium fluoride delivered and stored in a solid form, respirators must be worn when working with the dry chemical to avoid inhalation exposure. These respirators and additional safety gear are typically worn during sodium fluoride addition to the saturators and during some maintenance activities.

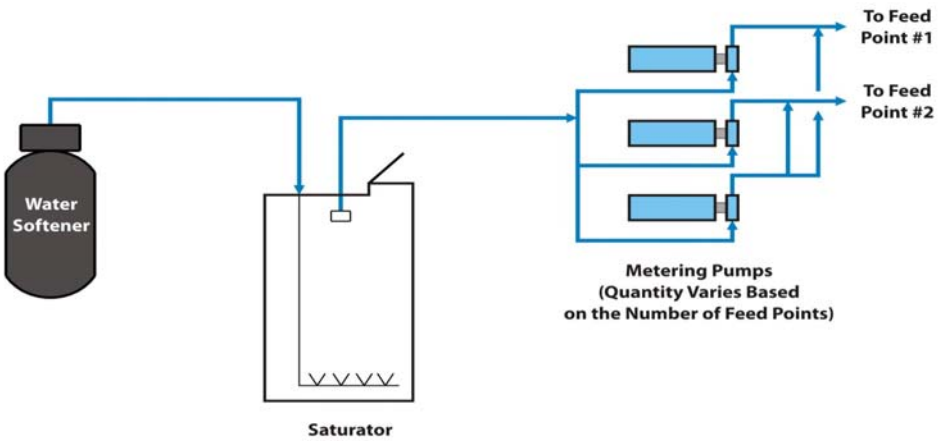

FIGURE 2-2: TYPICAL SODIUM FLUORIDE SYSTEM PROCESS SCHEMATIC

Note: The City's well sites typically use one metering pump and one feed point.

Over the past few years, domestic suppliers of sodium fluoride have removed themselves from the market due to low demand. The only exporter of sodium fluoride now is China. Typical chemical composition of the delivered sodium fluoride product is summarized in Table 2-1.

TABLE 2-1: SODIUM FLUORIDE COMPOSITION (TYPICAL)

=COMPONENT	CONCENTRATION
Sodium Fluoride	97%
Available fluoride	44%
Sodium	53%
Water insoluble	0.3%
Moisture (H_2O)	0.5%
Heavy Metal (Pb)	0.04%
Sodium silicofluoride (Na_2SiF_6)	1.5%
Free sodium carbonate ($NaCO_3$)	0.5%

The components and concentrations of foreign sodium fluoride are approximately the same as the discontinued domestic sodium fluoride. However, the City reports a decrease in the quality of the sodium fluoride product since it was no longer produced domestically. Impurities in the sodium fluoride solution have been observed (presence of third saturation layer in the saturator) and the delivered sodium fluoride bags have been damaged. The following issues should be noted for sodium fluoride:

- The amount of lead (Pb) in the sodium fluoride is below the National Science Foundation (NSF) limit (<1.5 parts per billion [ppb]). The maximum contaminant level (MCL) for lead is 15 ppb.

- Select sodium fluoride suppliers from China have earned the NSF-60 approval rating for drinking water chemicals. This rating is given upon inspection of the manufacturing plant and verified on an annual basis, the NSF-60 rating cannot fully guarantee the quality of the product.

- The amount of impurities present in the sodium fluoride solution should be confirmed by the City. If it does not meet NSF standards, then use of sodium fluoride should be discontinued. A summary of impurities, its analytical methods, NSF Single Product Allowable Concentration (SPAC), and Drinking Water Maximum Contaminant Limit (MCL)/Action Levels for these impurities are provided in Table 2-2.

TABLE 2-2: SUMMARY OF SODIUM FLUORIDE SOLUTION IMPURITIES AND LIMITS

CONSTITUENT	STANDARD METHOD	NSF SPAC, ppb	DRINKING WATER MCL/ ACTION LEVEL, ppb
Regulated Metals			
Antimony	3500-sb	0.6	6
Arsenic	3500-As	1	10
Barium	3500-Ba	200	2000
Beryllium	3500-Be	0.4	4
Cadmium	3500-Cd	0.5	5
Chromium	3500-Cr	10	100
Copper	3500-Cu	130	1300
Lead	3500-Pb	1.5	15
Mercury (inorganic)	3500-Hg	0.2	2
Selenium	3500-Se	5	50
Thallium	3500-Ti	0.2	2
Radionuclides			
Beta particle and photon activity	7110	0.4 mrem/yr	4 mrem/yr
Gross alpha particle activity	7110	1.5 pCi/L	15 pCi/L
Radium 226 and 228 (combined)	7500-Ra	0.5 pCi/L	5 pCi/L
Uranium	3500-U	3.0 ppb	30 ppb

- If it is not currently in the City's chemical procurement specifications, it is recommended that the City require either (1) an affidavit from the manufacturer or supplier that the sodium fluoride provided, according to the purchaser's document, complies with all applicable requirements ANSI/AWWA B701-06 and is NSF certified; or (2) certified analyses of the sodium fluoride, provided by the manufacturer or supplier, describing these items as required; or (3) both.

The alternative to sodium fluoride is liquid HFA, which is produced domestically and whose quality has been stable.

The City has also reported operational issues with their sodium fluoride systems. These issues include scaling of chemical lines, inconsistent sodium fluoride solution concentration, and frequent saturator cleaning. While these issues may be tied to the quality of sodium fluoride, high water hardness can also cause these problems. It is recommended that the City test the hardness of the water downstream of the water softener. Refer to Section 3 for a more detailed discussion of the issues resulting from hard water.

2.3.3. Sodium Silicofluoride

Sodium silicofluoride is delivered in a dry, solid form. Approximately 98-99+ percent of the chemical is sodium silicofluoride, and roughly 60 percent is available as fluoride. In a sodium silicofluoride system, the dry chemical (granular or powder form) is fed into a mixing tank by a volumetric or gravimetric feeder. The feeder meters the dry, delivered chemical from the storage hopper into the mixing tank at a variable rate that is flow-paced from the process water's flow rate. The volumetric feeder delivers the chemical on a volume per unit time basis while the gravimetric feeder supplies the chemical on a weight per unit time basis. Water is added to the mixing tank at a constant rate. Once in the mixing tank, the sodium silicofluoride is dissolved into solution and then injected into the water system with a constant speed pump. Thus, the dry feeder controls the amount of fluoride injected into the system.

Much like the sodium fluoride system, water hardness is of concern with the dilution water, and softening may be required. The solubility of sodium silicofluoride varies widely with water temperature; thus very dilute solutions are prepared to ensure the dry chemical dissolves in the mixing tank. A schematic showing the general process of a sodium silicofluoride system is presented in Figure 2-3.

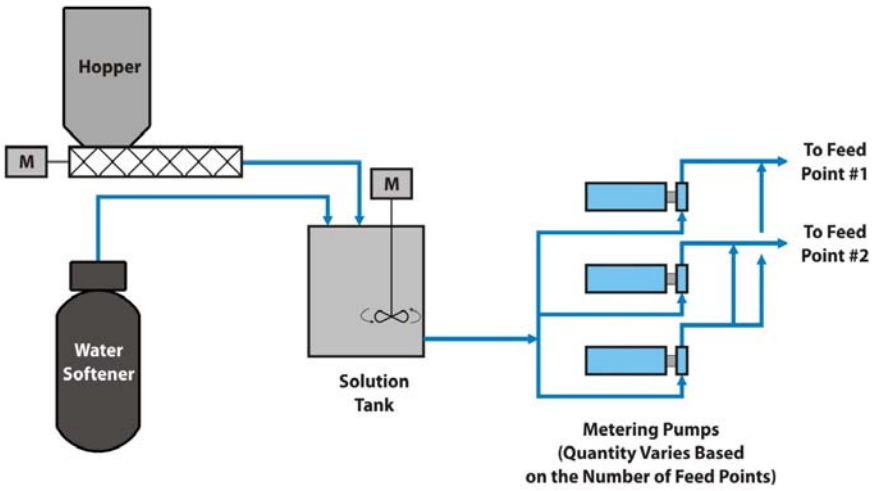

FIGURE 2-3: TYPICAL SODIUM SILICOFLUORIDE SYSTEM PROCESS SCHEMATIC

Note: The City's well sites typically use one metering pump and one feed point.

Sodium silicofluoride is delivered in a solid form, and respirators must be worn when working with the chemical to avoid inhalation exposure. These respirators and additional safety gear are typically worn during sodium silicofluoride addition to the storage hopper and feeder assembly and during some maintenance activities.

Sodium silicofluoride feed systems require the most equipment and the most O&M attention of the three fluoride feed systems discussed herein. Several factors may affect the accuracy, consistency, and reliability of the feed system. These factors include:

- Adequate mixing of the dry chemical with dilution water to ensure it goes into solution
- Operation and maintenance of dry feeders (e.g. plugging of dry feeders)
- Level of control needed to maintain low concentrations required to ensure consistency
- Dilution water temperature changes
- Consistent dilution water flow rate

2.3.4. Fluoride Feed System Comparison

A comparison of the three types of fluoride systems is provided in Table 2-3.

TABLE 2-3: FLUORIDE SYSTEM COMPARISON

CRITERIA	HFA	SODIUM FLUORIDE	SODIUM SILICOFLUORIDE
Chemical Type	Liquid	Dry Solid (batch mix, saturator)	Dry Solid (dry feed into mixing tank)
% Fluoride in Delivered Chemical	~19%	~44%	~60%
Solubility (% Solution, 32-77 °F)	Completely Miscible	4.0 - 4.1% (fairly constant)	0.44 – 0.76% (variable)
Industry Experience	Common (especially for large plants)	Common (esp. for smaller plants)	Minimal
Relative O&M Requirement	Low-Medium	Medium	High
Safety	Hazardous Liquid Acid and Vapors (Requires gloves, goggles, and aprons, etc.)	Respirators, gloves, and goggles	Respirators, gloves, and goggles
Water Quality Impacts	Medium-Low	Low	Low
Availability	High	Medium	Low
Ease of Delivering Constant Concentration	High	Medium	Low
Life Cycle Differences in Equipment	Metering Pumps Longer Life Cycle	Metering Pumps Shorter Life Cycle	Metering Pumps Shorter Life Cycle

The sodium silicofluoride system is used by very few utilities, it does not offer significant cost advantages over the other two systems, pumps are ten times larger than for sodium fluoride (because the chemical is less soluble), and the system is very operator intensive compared to the other two alternatives. Therefore, the sodium silicofluoride system is not recommended for further consideration. Sodium fluoride and HFA systems are much more common and have reduced O&M requirements, and thus were considered for further evaluation.

Best management practices (BMPs) for design and system selection for sodium fluoride and HFA systems are listed below.

- HFA Systems:
  - HFA systems are more common at large treatment plants because of the ability to store large quantities of the chemical on site without having to prepare batch solutions.
  - HFA systems should be considered if excessive sodium fluoride batching is required.
  - While sodium fluoride systems are more operation intensive, the HFA systems are dangerous and extreme care must be exercised when performing operational or maintenance activities to this type of system.

- Care must be taken when selecting the materials of construction for equipment and rooms, especially for HFA systems. Chemical compatibility and operating pressures must be considered.
- HFA tanks must be properly vented, as the acid and its fumes are very corrosive.

- Sodium Fluoride Systems:
  - Dry sodium fluoride may provide greater flexibility for remote, small systems since it could be supplied in 50-pound bags. The dry sodium fluoride could be directly added to a saturator, or a four percent sodium fluoride solution could be batched at a centralized location and transported to a tank at the well-site or WTP for direct injection.
  - Batching of sodium fluoride solution can be relatively time consuming and operator intensive, especially at larger facilities, but is commonly used at well sites and smaller plants.
  - Sodium fluoride dust released during bag unloading is a safety concern.
  - Routine cleaning of sodium fluoride saturator and distributor is required. If water hardness is less than 50 ppm, saturator cleaning is required every 6 to 12 months.
  - A water softener, and periodic regeneration, is required for sodium fluoride systems.

2.3.5. Staffing Requirements

Staffing requirements are dependent on the number of well-sites and WTPs in operation, the capacity at which they are operating, and the type of fluoride system used at the different locations. In general, the HFA system operates similar to other chemical feed systems where the chemical tanker truck delivers the liquid chemical on-site to re-fill the bulk storage tank. A chemical feed system technician needs to be present when the tank is being filled. In addition, the HFA day tank fill cycle must be started manually, either at the pump or at a central control station.

For the sodium fluoride system, the dry chemical is typically added to the saturator by the chemical feed system technician. If multiple bags of sodium fluoride are needed to meet daily demands, dedicated personnel may be required to load the dry chemicals and monitor the system.

It is noted that when the City began fluoridating in 2000, no adjustment in operation and maintenance staff was made. City staff indicate that as a result of O&M activities on the fluoride systems at the wells, other routine groundwater system O&M activities

have been deferred. The time associated with O&M of the City systems and recommendations are detailed in Section 4 and Section 5 of the report.

2.4. Comparable Fluoride Systems Overview

As part of the overall effort to optimize and enhance the City's fluoridation operations, surveys were conducted for fluoridation facilities using both HFA and sodium fluoride. The utilities surveyed and highlights of their fluoridation system are summarized in Table 2-4. The full questionnaire and utility responses are provided in Appendix B. The three utilities interviewed for this study are satisfied with their HFA system and its operation. The most significant issue with HFA was materials of construction and its compatibility with the chemical. The opinions of safety vary from utility to utility. For example, Long Beach Water Department felt the acid system was safer because their staff would not be required to directly handle dry chemical and its dust. On the other hand, Santa Monica felt that sodium fluoride was safer because it does not have the corrosive properties that HFA does. Santa Monica (sodium fluoride user) is reporting the highest maintenance costs, but the chemical cost of the HFA is higher. Overall, users of HFA and sodium fluoride are content with their systems.

TABLE 2-4: SUMMARY OF UTILITY SURVEY OF FLUORIDATION FACILITIES

UTILITY	TYPE OF FLUORIDE USED	TREATMENT SYSTEM	KEY HIGHLIGHTS
Metropolitan Water District of Southern California	HFA	Surface Water Treatment Plants	• Hydrofluosilicic acid was selected due to the large treatment capacities of the WTPs (>100 million gallons per day [mgd]) • Range of 478 to 1,630 gallons of delivered acid per day and on average, 14 days of storage is maintained • Majority of the O&M issues occurred at start-up and were tied to the corrosive nature of the HFA and material compatibility. • Generally happy with the system with the exception of the quality of the online analyzers (need to be checked daily by grab samples for accuracy)

Utility	Type of Fluoride Used	Treatment System	Key Highlights
Long Beach Water Department	HFA	Groundwater Treatment Plant	• HFA was selected at the Long Beach's 62.5 mgd groundwater treatment plant due to ease of operation and safety • 14,000 gallons is stored on-site and approximately 0.5 milligrams per liter (mg/L) of F is added, monitored through online analyzers, on average through metering pumps. • Generally happy with the system overall • Approximately 3 hours per day is spent on fluoride operations (including deliveries and lab analysis, every 4 hours to confirm online measurement)
City of Huntington Beach	HFA	Groundwater Wells	• Central storage facility is used to serve 10 well sites, each with a capacity of 2,700 gallons per minute (GPM) • Each well averages 18 gpd of fluoride added • City's operations staff is responsible for transport from bulk storage to each individual well site. A special chemical transport truck is required and must meet Department of Transportation requirements. • Approximately 1-2 hours per week is spent on fluoride system maintenance
City of Santa Monica	Sodium Fluoride	Groundwater Well Groundwater Treatment Plant	• Uses sodium fluoride for groundwater well and WTP. The groundwater well is approximately 240 gpm in capacity and the new WTP rated at 8.8 mgd. However, the WTP was just started up in December of 2010. • Sodium fluoride was selected over HFA due to safety in chemical handling and transport • Sodium fluoride is batched (using 50 pound bags) at central location and transported weekly to well site. Approximately 300 gpd is fed at the groundwater well • Have experienced varying bulk concentration of fluoride in saturator • Experienced issues with quality of sodium fluoride product from China with the primary issue being scaling and clogging of chemical feed pipes. • Approximately 10 hours per month is spent on O&M of sodium fluoride system serving a single, 240 gpm groundwater well.

3. FLUORIDATION SYSTEM OPTIONS FOR IMPROVEMENTS

This section of the report provides a discussion of the condition assessment of the City's existing fluoridation facilities and options for improvements at the City's Sacramento River WTP, E.A. Fairbairn WTP, and groundwater production wells. Costs are presented in Section 4, and recommendations and project implementation steps are in Section 5.

3.1. Sacramento River Water Treatment Plant

The Sacrament River WTP currently provides fluoridated treated water by adding liquid HFA to the final product water. The HFA system is designed for a current maximum month plant production flow of 80 mgd and maximum plant design capacity flow of 160 mgd (*City of Sacramento Fluoridation Preliminary Design Memorandum, 1999*). Existing bulk storage tanks and metering pumps are enclosed within a building and are in good working condition. The bulk storage tanks are sized for a full truckload.

In discussions with plant operation staff, during Black & Veatch's site visit (December 2010), the existing HFA system requires minimal troubleshooting and maintenance outside of routine checks. Table 3-1 represents design criteria for future replacement of the system.

TABLE 3-1: DESIGN CRITERIA FOR HFA SYSTEM AT SACRAMENTO RIVER WTP

CRITERIA	DESIGN VALUE
Chemical Information	
Delivered Chemical	24% HFA, 19% as fluoride, SG = 1.211
Fed Chemical	24% HFA, 19% as fluoride, SG = 1.211
Plant Flow, MGD	
Current Max Month	80
Maximum Plant Design	160
Chemical Dosage mg/L as 100% Fluoride	0.7
Chemical Feed Rate, gallons per day of 24% hydrofluosilicic acid	
Current Max Month	243
Maximum Plant Design	487
Bulk Chemical Storage Tank	
Type	Vertical cylindrical tank
Tank Material	Fiberglass Reinforced Plastic
Tank Number	Two (2)
Tank Volume, usable gallons	5,400
Diameter, feet	10
Straight side height, feet	11

Criteria	Design Value
Days of Storage	
Recommended Minimum	30 days at current max month conditions
Current Max Month	44
Maximum Plant Design	22
Level Measurement	Ultrasonic level transmitter Sight gauge
Metering Pumps	
Type	Motor driven diaphragm metering pumps
Quantity	Two (1 duty, 1 standby)
Pump Control	• Manual and automatic start-stop • Manual and automatic stroke speed adjustment • Manual and automatic stroke length adjustment

3.1.1. Condition Assessment of Existing Facility

The remaining useful life of the fluoridation equipment was evaluated at the Sacramento River WTP.

The City staff indicated that the fluoridation facilities were updated in 2007 and moved indoors. Table 3-2 indicates the typical service life of fluoridation equipment, and the age of the equipment at the Sacramento River WTP.

Table 3-2: Comparison of Fluoridation Facility Service Life (Sac River)

System Component	Typical Service Life Range		Sac River WTP Equipment Status
	Outdoors	Indoors	
FRP Storage Tanks	10 years	15+ years	4 years, indoors
Diaphragm Metering Pumps (Milroyal)	10+ years	20+ years	4 years, indoors
Polyvinyl Chloride (PVC) piping (w/protective coating)	10 years	10+ years	4 years, indoors
Accessories (valves, instrumentation)	5-10 years	10+ years	4 years, indoors

[1]Air surge from the unloading of chemicals from trucks to the storage tanks has a significant impact on the service life of the storage tanks. The vibration caused by the air surge can cause cracks in the inner lining which allows the fluoride to reach the fiberglass strands. Oversized tank vents (e.g., 6-inches or 8-inches diameter vent) will help to extend the life of a tank.

The fluoridation equipment is still fairly new, and should not need replacement for at least another 6 years. It is anticipated that the piping, valves, and instrumentation devices would need to be replaced first (2017 timeframe), followed by the tanks (2022) and the diaphragm metering pumps (2027). The typical service life can vary based on the particular service conditions, so the replacement dates should be monitored.

3.2. E.A. Fairbairn Water Treatment Plant

A condition assessment of the HFA system at the E.A. Fairbairn WTP and options for improvements are provided in this section.

3.2.1. Condition Assessment of Existing Facility

The fluoridation system at the E.A. Fairbairn WTP uses liquid HFA and is designed for a current maximum month flow of 75 mgd and maximum plant design capacity flow of 200 mgd (*City of Sacramento Fluoridation Preliminary Design Memorandum, 1999*). The two existing, 6,000 gallon, HFA storage tanks are located outside and not covered. Only the chemical metering pumps are enclosed within a building. This system was originally intended to be a temporary facility, but has now been in operation for about 10 years. During Black & Veatch's site visit (December 2010), the following deficiencies were noted based on visual observation and discussions with plant operating staff:

- Upon visual inspection and comparison with the enclosed HFA facility at the Sacramento River WTP, the bulk storage tanks and chemical feed pipes were degrading faster than those enclosed in a building.
- During rain events, operation staff has to confirm that rainwater collected in the containment is not from leaks or spills from the HFA system before it can be pumped and discharged. This has increased the testing and O&M requirements associated with maintaining the HFA system.

An assessment was conducted of the remaining useful life of the fluoridation facilities at the E.A. Fairbairn WTP and is summarized in Table 3-3.

TABLE 3-3: COMPARISON OF FLUORIDATION FACILITY SERVICE LIFE (EAF)

SYSTEM COMPONENT	TYPICAL SERVICE LIFE RANGE		E.A. FAIRBAIRN EQUIPMENT STATUS
	OUTDOORS	INDOORS	
FRP Storage Tanks	10 years	15+ years	10 years, outdoors
Diaphragm Metering Pumps (Milroyal)	10+ years	20+ years	10 years, indoors
Polyvinyl Chloride (PVC) piping (w/protective coating)	10 years	10+ years	10 years, outdoors
Accessories (valves, instrumentation)	5-10 years	10+ years	10 years, outdoors/indoors

[1]Air surge from the unloading of chemicals from trucks to the storage tanks has a significant impact on the service life of the storage tanks. The vibration caused by the air surge can cause cracks in the inner lining which allows the fluoride to reach the fiberglass strands. Oversized tank vents (e.g., 6-inches or 8-inches diameter vent) will help to extend the life of a tank.

The fluoride bulk storage tanks and chemical piping at E.A. Fairbairn WTP are located outside and are not covered. Thus, as the City's staff has indicated, the bulk storage tanks and chemical piping are near the end of their useful life. However, the chemical metering pumps and

chemical feed piping, from the chemical metering pumps to the injection point, are all located indoors and still have service life remaining.

3.2.2. Options for Modifications and Improvements

Because the equipment housed inside has remaining useful life, reuse of that equipment and construction of a building or canopy to cover the new tanks in the existing location was considered. However, the space available is not sufficient to properly construct a new canopy or building and therefore this option is not considered further. Three options are available for upgrading the fluoridation system at E.A. Fairbairn WTP:

- Option 1 – Replace the fluoridation equipment and reuse the existing space; no covering.
- Option 2 - Construct the new bulk storage tanks (each sized for a truckload) and metering facility and provide a canopy structure over the equipment.
- Option 3 - Construct new bulk storage tanks (each sized for a truckload) and metering facility inside a chemical containment area, enclosed in a building structure similar to the fluoridation facilities at the Sacramento River WTP.

The new facility could be constructed on the other side of the existing access road where the decommissioned lime storage silos are located (see Figure 3-1). This would allow the City to construct the new HFA facility and minimize interruptions to existing operations.

FIGURE 3-1: LOCATION OF NEW HFA FACILITY AT E.A. FAIRBAIRN WTP

Preliminary design criteria for a new HFA facility at E.A. Fairbairn WTP are provided in Table 3-4 and a Process and Instrumentation Diagram (P&ID) outlining the proposed HFA system at WTP is presented in Figures 6 and 7 in Appendix C.

Table 3-4: Design Criteria for New HFA System at E.A. Fairbairn WTP

Criteria	Design Value
Chemical Information	
Delivered Chemical	24% HFA, 19% as fluoride, SG = 1.211
Fed Chemical	24% HFA, 19% as fluoride, SG = 1.211
Plant Flow, MGD	
Current Max Month	75
Maximum Plant Design	200
Chemical Dosage mg/L as 100% Fluoride	0.7
Chemical Feed Rate, gallons per day of 24% hydrofluosilicic acid	
Current Max Month	228
Maximum Plant Design	609
Bulk Chemical Storage Tank	
Type	Vertical cylindrical tank
Tank Material	Fiberglass Reinforced Plastic
Tank Number	Two (2)
Tank Volume, usable gallons	6,000
Diameter, feet	10
Straight side height, feet	11
Days of Storage **Recommended** **Minimum** **Current Max Month** **Maximum Plant Design**	 30 days at current max month conditions 52 20
Level Measurement	Ultrasonic level transmitter Sight gauge
Metering Pumps	
Type	Motor driven diaphragm metering pumps
Quantity	Two (1 duty, 1 standby)
Pump Control	• Manual and automatic start-stop • Manual and automatic stroke speed adjustment • Manual and automatic stroke length adjustment

The three options are all anticipated to have similar O&M requirements. The City reported that with the storage tank area exposed, there is recurring maintenance to pump out rainwater, and also evaluate whether there is any chemical in the rainwater. Although this maintenance activity would be reduced if there is a canopy structure (Option 2), and virtually eliminated if the entire facility is in a masonry building (Option 3), both the canopy structure and masonry building would require maintenance on their coating systems and electrical and HVAC systems, offsetting the previously mentioned O&M reduction.

3.3. Groundwater Production Wells

The City currently owns and operates 27 groundwater production wells. Chlorine and fluoride are added prior to the groundwater being pumped into the distribution system. Fluoridation at the groundwater wells utilizes sodium fluoride. The sodium fluoride system consists of a water softener, Digipulse flow sensor, saturator, and dry 50 pound sodium fluoride bags added to the saturator. A condition assessment and options for improvements for fluoridation at the groundwater wells are provided in the subsections below.

3.3.1. Condition Assessment of Existing Groundwater Well Fluoridation System

Three groundwater wells (Well 158, Well 156, and Well 122) were visited by Black & Veatch during the December 2010 site visit in order to evaluate the fluoridation systems. These three wells were visited rather than visiting all well sites because the repair and configuration of the well system was sufficiently represented within the three sites. All equipment was installed at the same time.

The majority of the sodium fluoride systems for the groundwater wells were installed in 2000, and only the chemical metering pumps have been replaced or rebuilt periodically. Table 3-5 indicates the typical service life of the well fluoridation facilities.

TABLE 3-5: COMPARISON OF FLUORIDATION FACILITY SERVICE LIFE (WELLS)

SYSTEM COMPONENT	TYPICAL SERVICE LIFE RANGE		GROUNDWATER WELL EQUIPMENT STATUS
	OUTDOORS	INDOORS	
Polyethylene Saturator Tank	5 years	10 years	10 years, indoors
Solenoid Metering Pumps (LMI)[1]	2+ years	3-4 years	2-4 years, indoors
Polyvinyl Chloride (PVC) piping (w/protective coating)	10 years	10+ years	10 years, indoors
Accessories (valves, instrumentation)	5-10 years	10+ years	10 years, indoors

1. **Pumps can be rebuilt generally twice to prolong the service life.**

As indicated in the above table, the metering pumps require more frequent replacement than the rest of the equipment. All the fluoridation equipment at the wells is nearing the end of its useful life, and should be monitored closely.

The City indicated that majority of the groundwater wells are similar in size and layout to Well 158 (Figure 3-2), and about four wells are similar to Well 156 (Figure 3-3). Well 122 was selected for the visit since it was recently retrofitted with a Flowline chemical flow indicator (Figure 3-4) that may be more reliable than the current Digipulse sensor.

FIGURE 3-2: SODIUM FLUORIDE SYSTEM AT WELL 158

FIGURE 3-3: SODIUM FLUORIDE SYSTEM AT WELL 156

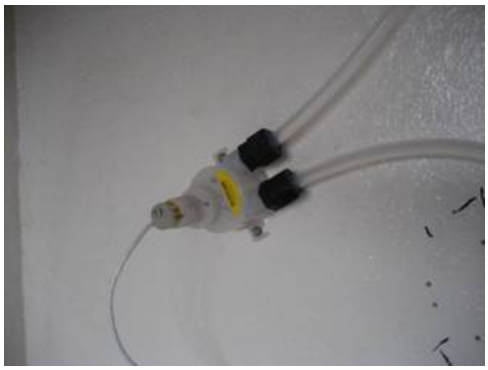

FIGURE 3-4: NEW FLOW INDICATOR AT WELL 122

The layout of the sodium fluoride and chlorine feed facilities at Well 158 is very compact with minimal space available in the storage shed for additions or improvements. Chemical facilities at Well 156 are configured in a similar manner as Well 158, but there is considerable room available within the chemical storage building for future improvements/additions. As noted by City staff during the Kick-off Meeting and Site visit, the existing sodium fluoride systems are experiencing multiple issues that force well shut-downs and require significant amounts of operator time to repair. A summary of these issues is listed below:

- Clogging of the sodium fluoride equipment and piping
- Sodium fluoride saturators require frequent cleaning
- Inconsistent sodium fluoride solution concentration in the saturator
- Inconsistent sodium fluoride residual as F, between field measurement and actual usage (estimated based on flow)
- Uncertainty in the quality of delivered sodium fluoride product (e.g. composition of other material that is not fluoride).

These issues related to chemical inconsistencies and equipment failures have resulted in increased O&M requirements on the City's well operation staff. On average, the City's well operation staff spends 20-30 minutes per well every two days for routine checks and fluoride measurements. However, the City reports that time spent on fixing and troubleshooting the sodium fluoride system can often vary from hours to a full day depending on the issue.

Four options have been identified to resolve these issues and reduce the City's O&M requirements on the sodium fluoride systems. These options are listed below and discussed in more detail in the following subsections.

- Option 1 – Upgrade Existing Sodium Fluoride System
- Option 2 – Convert Existing Sodium Fluoride System to HFA
- Option 3 – Convert to HFA and Hire 3rd Party Contractor for O&M
- Option 4 – Centralized Sodium Fluoride System

3.3.2. Option 1 – Upgrade Existing Dry Solid Sodium Fluoride System

After discussions with City operation staff and reviewing the design of the existing sodium fluoride systems, a list of improvements that may enhance and reduce O&M requirements was developed and is listed below. To minimize overall costs, the City could implement the recommendations below at a single well and evaluate the subsequent performance before implementing these recommendations across all the groundwater wells.

- Step 1: Review water hardness and optimize existing water softening system.
- Step 2: Provide a new saturator with side facing dilution water distribution ports and float control (to maintain constant flow operation of water softener).
- Step 3: Replace existing metering pumps and provide new chemical piping if scaling is suspected from past operations.

Step 1: Optimization of Existing Water Softening System: As City staff noted during Black & Veatch's site visit, the water softeners were designed based on criteria set in 2000 and have not been updated. In addition, the actual hardness of the water softener is not checked routinely to ensure it meets performance requirements during the media change out period. The water softening system is also flow paced with well production and varies throughout the day as the groundwater production wells are throttled to meet pressure demands in the distribution system. It is possible that the problems associated with equipment clogging, saturator cleaning frequency, and inconsistent sodium fluoride solution concentration are the result of hard water. The combination of sodium fluoride and hard water will form calcium fluoride, which precipitates out of solution and forms scale and may be causing many of the problems noted above.

Recommendations for optimizing the water softening system are listed below:

- Review design criteria of water softening system established in 2000 for inlet and outlet hardness for the water softening system.
- Test the hardness of the water downstream of the water softener. If the water hardness exceeds 50 mg/L of calcium carbonate ($CaCO_3$) the water hardness is too high. The media regeneration frequency would need to be revisited to meet this criterion. It is important that the water hardness of the make-up supply is verified at each well site right before media change out to ensure that the current replacement frequency is adequate to maintain the desired hardness levels in the make-up water.
- Check water softener design for minimum and maximum operating flow rate. If the feed water to the softeners is below the minimum flow rate, the water will channel through the resin and not be softened. Since the City is currently flow pacing the softened water flow rate to the saturator, the water flow may be too low for the softener, and this channel effect may be occurring. The best method to control the soft water flow to the saturator is to keep it constant and start and stop the flow based on liquid level in the saturator. The flow of the water should be set so that it is within the acceptable flow range of the water softener.
- Provide new water softening system should the existing system fail to meet performance and design criteria.

Step 2: New Sodium Fluoride Saturator: Once the water hardness has been confirmed and the water softener is operating correctly, operation of the sodium fluoride system should be improved. An additional step to further optimize the system is to install a new sodium fluoride saturator to improve consistency of saturated solution concentration. This step should only be implemented if City staff is satisfied that hardness was an issue and the modifications in step 1 made considerable improvement

to the system. Sufficient space is available in the existing structures to retrofit with a new saturator. As previously noted, the existing saturators are near the end of their useful life. The City may choose to assess the condition of the saturators and prioritize replacement based on condition.

A new dry sodium fluoride saturator with new dilution water distributor design and float controls, to control the softened make-up water feed into the saturator, could be provided to produce a 4% solution as sodium fluoride (or 1.8% as fluoride) in the sodium fluoride saturators. In addition, the new saturator will also have an overflow float available, similar to the one that the City currently has in the saturators, to prevent overflows of the saturated fluoride solution. The saturator tank can hold 300 pounds of sodium fluoride, it is constructed of polyethylene, and it has a water distributor with circular holes facing outwards at the bottom. The new saturator with different type of water distributer is recommended to prevent clogging issues by utilizing larger circular holes as compared to the smaller slotted type of distributer the City currently uses. Dry sodium fluoride is poured into the saturator on top of the water distributor. Water discharges from the distributor and flows through the bed of solid sodium fluoride to the top of the saturator. As the water flows through the solid sodium fluoride, it dissolves into solution. The saturated liquid solution stays on top of the solid sodium fluoride. As the solution level drops, a switch opens the water valve and more solution is made. This also improves operation of the water softening system to prevent flow pacing operations discussed previously where the make-up water flow is dependent on the well pump. Flow-pacing this valve is not necessary since the metering pump will control the sodium fluoride solution flow to the application point. The saturators operate best when:

- Periodic raking of the sodium fluoride in the saturator is performed to minimize channeling effects.
- The saturator is cleaned at least once per year, and the solid sodium fluoride level is above 100 pounds. It is noted that the City has a goal of cleaning the saturator every six months although this increased frequency over the once per year recommendation has proven difficult to accomplish and the current schedule is closer to once per year.
- A minimum solid sodium fluoride of 1-ft and maximum height of 1-ft and 1-inch. This is based on optimized saturator criteria at the City of Santa Monica for a 36-inch tall saturator.

Step 3: New Metering Pumps and Chemical Piping: This step should only be implemented when performance of Step 1 and 2 modifications are satisfactory to the City's operation staff and the City has decided to maintain the sodium fluoride system.

The metering pumps have a short useful life (2 to 4 years) and may be clogged due to operation under excessive hardness and useful life therefore may be diminished. One new diaphragm metering pump will be installed to feed sodium fluoride solution to each injection point. A shelf spare at each well location is recommended which can be installed in the event that the duty metering pump breaks or requires extended maintenance. New pumps are recommended because most of the pumps are near the end of their useful life and the clogging issues have most likely impacted performance of the existing pumps. Since the sodium fluoride solution is at the top of the saturator, the metering pump suction will be through the saturator cover. A magnetic type flow meter will be installed on the discharge of each metering pump to monitor the amount of sodium fluoride solution fed.

The sodium fluoride equipment design for each well site will be as listed in Table 3-6 and a P&ID outlining the proposed sodium fluoride system at the well sites is presented in Figures 4 and 5 in Appendix C.

TABLE 3-6: DESIGN CRITERIA OF NEW SODIUM FLUORIDE SYSTEM

CRITERIA	DESIGN VALUE
Chemical Information	
Delivered Chemical	98% sodium fluoride, 44% as fluoride
Fed Chemical	4% saturated sodium fluoride
Chemical Dosage mg/L as 100% Fluoride	0.7
Chemical Storage	
Type	50 pound bags
Saturator	
Type	50 gallon polyethylene tank with water distributor
Quantity	1
Capacity, pounds of sodium fluoride per saturator	300
Calendar Days of Storage per Well Station	44 to 119
Water Softener	
Quantity	One (1)
Metering Pumps	
Type	Solenoid operated diaphragm metering pumps
Quantity	Two (1 installed, 1 shelf spare per well site)
Pump Control	• Automatic start-stop • Manual and automatic stroke speed adjustment

Improving the well systems as described in Option 1 will resolve several of the issues the City is experiencing. The paragraphs below address a few of the remaining issues characteristic of the sodium fluoride system.

Consistency of Measured Dose versus Dosed Concentration: City operation staff have indicated that the field measured fluoride dose is not consistent with estimated dose based on chemical flow delivered. This could be due to the assumption that the saturated fluoride concentration is constant (4% as sodium fluoride [NaF] or approximately 1.8% as F) in the calculation based on flow delivered. The bulk concentration may actually vary anywhere between 1.0 and 1.8 percent as F since the make-up softened water fed into the saturator is flow paced with well production. City staff indicated that the well production rate could fluctuate throughout the day based on pressure demands in the distribution system. Other factors such as poor sodium fluoride distribution and blockage of make-up water distributor could also result in variation of the saturated concentration in the saturator. Thus, it is recommended that the operation of the softener be based on water levels in the saturator and that the operator check both the bulk concentration in the saturator as well as in the product water during routine checks.

Quality of Product: The final issue the City has been experiencing with the sodium fluoride system is the quality of the delivered sodium fluoride product. It is recommended that the City refuse to accept any sodium fluoride bags that are damaged upon delivery. The CDC recommends that 60 to 90 days of fluoride chemical be kept in storage. The City currently stores four pallets of sodium fluoride 50-pound sacks; when three pallets are empty, three fresh pallets are delivered. It is recommended that fresh pallets be delivered when two are empty. This will increase the frequency of deliveries, but it will give the City more time to refuse and replace a damaged pallet. The City can also require in their purchase specifications a current certificate of compliance with NSF and AWWA standards for sodium fluoride.

Safety Equipment: Proper safety equipment should be worn by the City's well operation staff when loading the sodium fluoride into the saturators including mask and cartridge or a self-contained breathing apparatus. Other protective equipment that should be worn includes; gloves, overalls, apron, boots, and dustproof goggles. Eyewashes should be installed near the chemical storage areas and be accessible without any obstructions.

3.3.3. Option 2 – Convert from Sodium Fluoride to Liquid Hydrofluosilic Acid System

A second option for the well site fluoridation system is to remove each sodium fluoride system and replace it with a liquid HFA system. The advantages of the HFA are listed below:

- HFA is produced in the United States, and there have not been any reports concerning chemical quality.

- HFA will be transferred by operators from delivered 55-gallon drums into tanks. The drums will be moved with a drum dolly. This eliminates lifting multiple 50-pound bags of sodium fluoride. No new vehicles are required as drums will be delivered to the site by the supplier.
- The freezing point of HFA is -4°F. Thus, crystallization of chemical in the pipes at cold temperatures should not be an issue.

Each HFA system will include the following pieces of equipment: one storage tank, one metering pump – installed, and one metering pump – shelf spare. The equipment would be installed in a new shed on-site.

HFA will be stored at a common site and delivered in 55-gallon drums by the City maintenance staff to each well site. HFA will be transferred from the drum into the storage tank via drum pump. The metering pump will pull HFA from the tank and deliver it to the designated fluoride feed point.

Storage: Each storage tank will be sized to hold 90 gallons of chemical so that the entire delivery drum can be transferred at once. Space will be allocated for storage of one delivery drum at each well site. To reduce the risk of a fluoride overfeed, the metering pump will pull suction from the top of the tank even though flooded suction is typically preferred. By pulling from the top of the tank, the tank cannot simply drain itself to the feed point. A vacuum breaker will be provided. The liquid level in the storage tank will be monitored with a scale.

An alternative to the storage tank is to pull chemical directly from the delivery drum. The advantage is eliminating the expense of the storage tank and the required transfer of chemical from the drum to the tank. Two drums will be connected to the metering pump suction so that fluoride feed can be continuous, and two scales will be required to monitor the liquid level of the drums.

Regardless of the storage type (drum or tank), modifications to each existing well station will be required. Due to the corrosive nature of HFA vapors and its incompatibility with chlorine, a separate storage enclosure is required for HFA in accordance with Chapter 27 of the 2009 International Fire Code (Section 2703.9.8 Separation of incompatible materials). A secondary containment curb is also recommended around all HFA storage and metering pumps. Sprinklers are required if an enclosure is provided for the on-site HFA storage at each well site. These improvements have been included in the cost estimates for these options in Section 4; however, each site would need to be visited to determine if space is available for the new enclosure.

Metering Pumps. One diaphragm metering pump will be installed to feed HFA to each injection point. A shelf spare will be provided which can be installed in the event that the duty metering pump breaks or requires extended maintenance. A magnetic type flow meter will be installed on the discharge of each of the metering pumps to monitor the amount of HFA fed.

The HFA equipment design for each well site is summarized in Table 3-7, and a P&ID outlining the proposed HFA system at the well sites is presented in Figures 8 and 9 in Appendix C.

Safety Equipment: Proper safety equipment should be worn by the City's well operation staff when working with HFA. Similar protection equipment provided at the City's two WTPs should be provided either on each of the well operator's trucks or at each well site. The protection equipment includes an eyewash station, mist respirator, acid-proof gloves and protective clothing, safety goggles, and full face shield. Additional hazardous material handling training will be required for the City's well operation staff to become familiar with handling and safety procedures for HFA.

TABLE 3-7: DESIGN CRITERIA FOR HFA SYSTEM AT THE GROUNDWATER WELLS

CRITERIA	DESIGN VALUE
Chemical Information	
Delivered Chemical	24% HFA, 19% as fluoride, SG = 1.211
Fed Chemical	24% HFA, 19% as fluoride, SG = 1.211
Chemical Dosage mg/L as 100% Fluoride	0.7
Bulk Chemical Storage Tank	
Type	Vertical cylindrical tank
Tank Material	Fiberglass Reinforced Plastic or HDPE
Tank Number	One (1)
Tank Volume, usable gallons	90
Diameter, inches	30
Straight side height, inches	36
Calendar Days of Storage per Well Station	39 to 95
Level Measurement	Tank scale Sight gauge
Metering Pumps	
Type	Solenoid drive diaphragm metering pumps
Quantity	Two (1 installed, 1 shelf spare per well site)
Pump Control	• Automatic start-stop • Manual and automatic stroke speed adjustment

3.3.4. Option 3 – Convert to Liquid HFA System and Contract Third Party O&M

Option 3 for improving fluoridation at the well sites is converting from the sodium fluoride system to an HFA system and hiring a third party contractor to deliver the HFA and perform visual inspections of the equipment. Required improvements and associated costs will be the same as Option 2 described above. A third party chemical delivery service is included to minimize the amount of operator involvement in the weekly chemical deliveries.

Sierra Chemical, a local distributor of chemicals for water treatment facilities, provides a similar service to Sacramento Suburban Water District. Sierra Chemical would be responsible for delivery of HFA to each well site at least once a week. City staff would not need to be present during deliveries. The delivery person would fill the chemical storage tank, and also perform a routine site inspection to see if there are any visible leaks, broken equipment, or security problems. The delivery person would contact City staff if there are any observed issues, as Sierra Chemical would not be responsible for making repairs to the chemical feed equipment. Costs for this service are described in Section 4 of the report.

3.3.5. Option 4 – Centralized Dry Solid Sodium Fluoride System

To reduce O&M requirements of the sodium fluoride saturators at each of the well sites, a centralized sodium fluoride saturator and storage system could be provided to replace the saturators at each well site. The centralized sodium fluoride saturator and storage system would be located at either of the City's two WTPs. Saturated sodium fluoride solution would be produced through two larger capacity saturators (one duty and one standby) at the centralized facility, stored in a bulk storage tank, and transferred to each well site on a weekly basis. A storage capacity of approximately 200 gallons is recommended at the well sites to provide 7 days of supply on average. The centralized saturators will use 2,000 pound supersacks, loaded to the saturator via a bulk bag loader. The centralized sodium fluoride saturators would need to be located within a building to control any sodium fluoride dust from transferring and loading of dry sodium fluoride into the saturators.

The benefits of having a centralized sodium fluoride saturator and bulk storage over individual saturators at each well site are listed below:

- Reduce saturator O&M requirements from 27 well saturators to 2 larger saturators at the centralized facility.
- Maintain better quality control of saturator condition to produce a more consistent saturated sodium fluoride solution.

- Eliminate lifting and loading of 50 pound sodium fluoride bags since the supersacks are loaded with a forklift or overhead crane.

However, one of the major drawbacks to having a centralized sodium fluoride facility is that minimal large-scale sodium fluoride saturators exist in the United States. Thus, minimal design and operation data is available for large-scale sodium fluoride saturators. Furthermore, the 200 gallon storage tank required at each well site would not fit in the existing enclosures, and capital upgrades, including a new enclosure, would be required. Due to these drawbacks, as well as the continuing concern over the quality of the sodium fluoride available, this option was eliminated from further consideration.

4. ENGINEER'S COST OPINION

This section presents an evaluation of the current O&M costs for the City's well sites and an opinion on the probable construction and O&M costs for modifications to the well sites and the E.A. Fairbairn WTP fluoridation system that are described in Section 3.

4.1. Assumptions and Approach

Conceptual construction costs presented below are based on B&V's past experience on chemical feed projects of similar scope and size. The annual O&M costs are based on a detailed and labor breakdown from the City that is used to establish the costs for the existing systems, and improvements described in Section 3 are based on the City's breakdown provided for their fluoridation facilities at their two water treatment plants, and B&V's past experience. The construction costs include the following:

- 10% allowance for general conditions (bonds, insurance, etc.)
- 25% construction contingency

The annual O&M costs include the following:

- Chemical, water softener (if necessary), and waste disposal costs verified with the City and Sierra Chemical
- Labor rates vary from approximately $70 per hour to $150 per hour based on Computer Maintenance Management System (CMMS) data provided by the City. Therefore, an average labor rate of $100 per hour has been used in this evaluation.
- Detailed labor breakdown from the City defines tasks associated with fluoridating the water, which includes permitting, sampling, troubleshooting activities, chemical delivery, maintenance, accounting, and management.
- Equipment replacement is included in present value and future value calculations based on the typical service life of equipment described in Section 3.
- City Internal Rate of Return: The City has provided an internal Rate of Return (ROR) of 2.5 percent on investments. This ROR is used to return future expenditures to a present worth value, should pre-funding of improvements occur.
- Inflation Factor: A value of 4 percent is used for inflation/escalation costs for labor and equipment based on historical Consumer Price Index and estimation of future market conditions. A value of 6 percent is used for inflation/escalation costs on chemicals due to recent average market performance.

- Chemical costs are based on the current target dose. The USEPA is currently considering a reduction in optimal fluoride levels to 0.7 mg/L; which may reduce annual chemical costs by approximately $65,000.

4.2. Current Fluoridation O&M Costs

4.2.1. Sacramento River WTP

Table 4-1 summarizes the current O&M costs at the Sacramento River WTP. The total labor hours are approximately 255, which equals approximately 0.2 full time equivalent (FTE) staff.

TABLE 4-1: CURRENT O&M COSTS FOR SACRAMENTO RIVER WTP

	CHEMICAL COST	LABOR ESTIMATE	EQUIPMENT REPLACEMENT	TOTAL
Hydrofluosilicic Acid	$212,100	$25,200	$500	**$237,800**

4.2.2. E.A. Fairbairn WTP

Table 4-2 summarizes the current O&M costs at the E.A. Fairbairn WTP. The total labor hours is approximately 251, which equals approximately 0.2 FTE staff.

TABLE 4-2: CURRENT O&M COSTS FOR E.A. FAIRBAIRN WTP

	CHEMICAL COST	LABOR ESTIMATE	EQUIPMENT REPLACEMENT	TOTAL
Sodium Fluoride (Current)	$215,000	$25,100	$500	**$240,600**

4.2.3. Well Site O&M Costs

When the City started fluoridating in 2000, O&M requirements for the system were anticipated to be low and additional O&M staff was not added at that time. O&M requirements, especially on the well systems, have been higher than anticipated and the City has concerns that groundwater O&M issues, outside of the fluoride system, are being deferred. Figure 4-1 and Figure 4-2 indicate the average annual O&M costs and labor days, respectively, from data provided by the City.

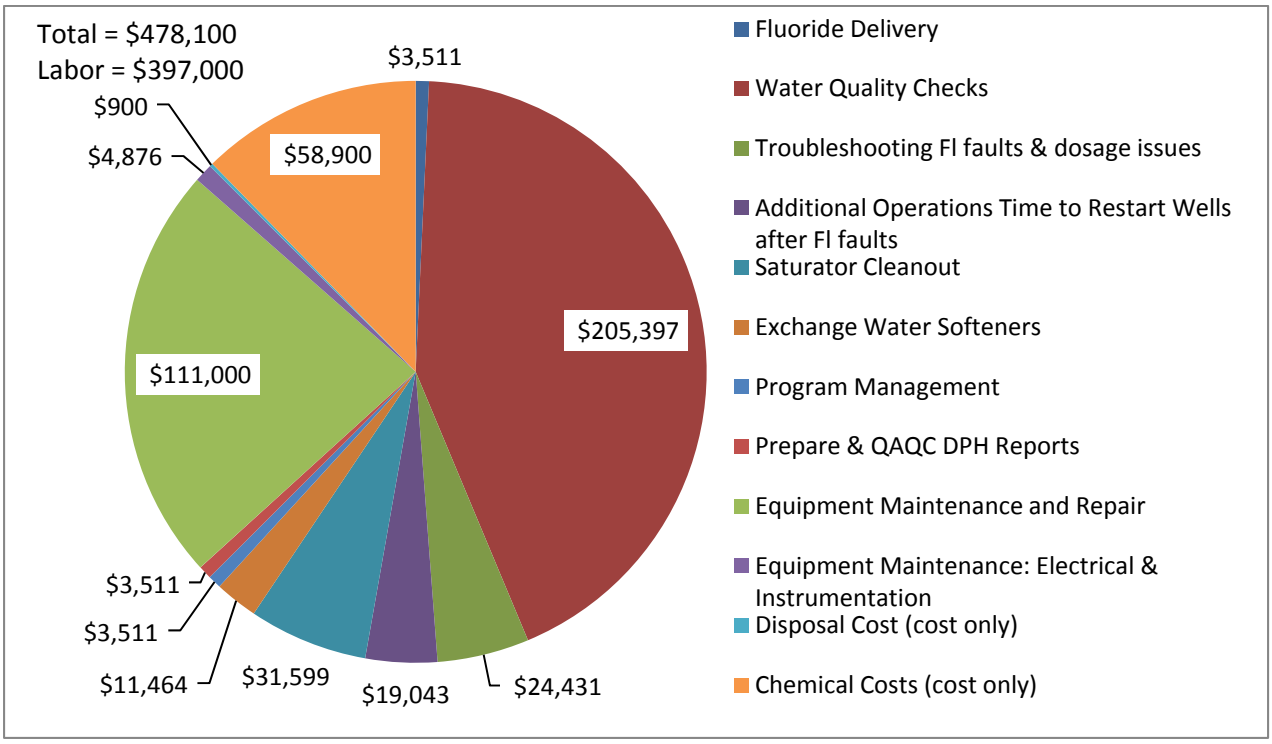

FIGURE 4-1: WELL SYSTEM ANNUAL O&M COSTS

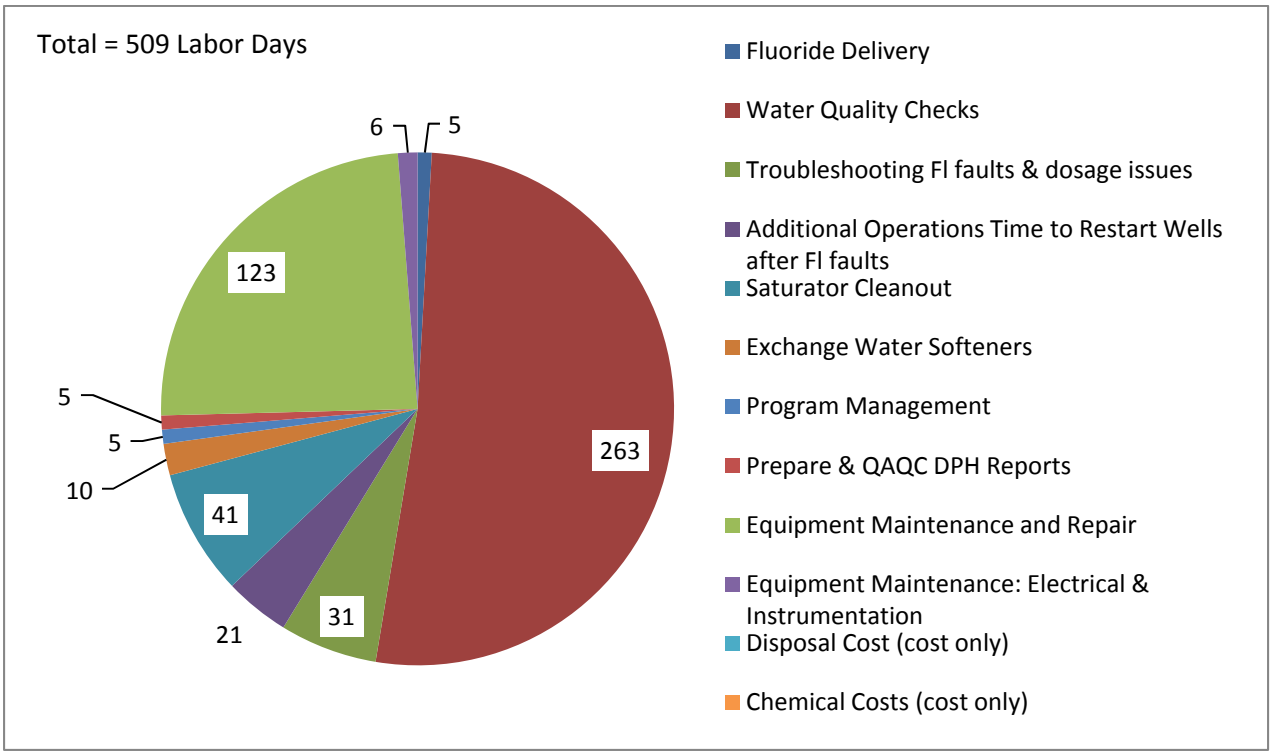

FIGURE 4-2: WELL SYSTEM ANNUAL O&M LABOR DAYS

Based on the breakdown in Figure 4-1 and Figure 4-2, the City is spending approximately 150 hours per well site, which equates to approximately $15,000 in labor costs per well site, annually. This equates to approximately 3.3 full-time equivalent (FTE) staff that are needed for fluoridation-related activities. The City currently has 8 FTEs dedicated to O&M on the well system, plus supervisors and management. Occasionally, additional staff, such as machinists and electricians, are drawn upon when more involved repairs are required.

The CMMS data indicates only approximately $4,400 in material costs recorded annually. The total hours required (approximately 1,200 for all 27 wells) annually are slightly more than ½ full time equivalent (FTE) for the combined 27 wells. This is on the lower side of typical for O&M of a sodium fluoride system of this size. However, the City notes that the CMMS does not necessarily provide an accurate record of the complete costs of maintaining the fluoridation system, because:

- Much of the O&M work related to fluoride is frequently combined with other preventative and corrective work and does not have a standalone work order. Extracting only fluoride-related work would be difficult in such instances.
- Many costs related to the operations and maintenance of the fluoridation systems have been absorbed by the division and are not reflected in CMMS

data. These costs would include trucks, tools, computer equipment, safety gear, permits, and fees

- The work order system does not include any work done by the Water Quality Laboratory, engineering, clerical, accounting, procurement and managerial staff, all of whom have duties related to fluoridation.

Table 4-3 summarizes the approximate current O&M costs for the well fluoridation facilities based on information provided by City staff to supplement the CMMS data.

TABLE 4-3: CURRENT O&M COSTS FOR WELL SYSTEM

	CHEMICAL COST	LABOR ESTIMATE	EQUIPMENT REPLACEMENT	TOTAL
Sodium Fluoride (Current)	$2,400	$14,700	$600	**$17,700**
Total O&M Costs (27 Well Sites)				**$478,100***
*** O&M costs simplified to generate standard well site costs that are multiplied by 27. Actual O&M at each well site varies. Reported total O&M costs by City is $478,144.**				

4.3. Fluoridation System Improvements

4.3.1. Sacramento River WTP Fluoridation System Improvements

The fluoride facilities at the Sacramento River WTP were replaced in 2007 and moved inside the chemical feed building. The equipment is in good work*i*ng condition and has a remaining life of approximately 7 to 12 years for the tanks, piping and valving, and approximately 17 years for the pumps. Table 4-4 presents the O&M and future value costs for this system.

TABLE 4-4: O&M, FUTURE, AND PRESENT VALUE COSTS FOR SACRAMENTO RIVER WTP

	CHEMICAL COST	LABOR ESTIMATE	EQUIPMENT REPLACEMENT	TOTAL O&M COSTS	20-YEAR FUTURE VALUE COSTS	PRESENT VALUE COSTS	ANNUALIZED COSTS
Hydrofluosilicic Acid System	**$212,100**	**$25,500**	**$1,000**	**$238,600**	**$10,168,000**	**$6,205,000**	**$398,000**

1. ENERGY COSTS NOT INCLUDED.
2. **Equipment Replacement included in Year 2018, 2023, and 2028.**
3. CHEMICAL COSTS ARE BASED ON THE CURRENT TARGET DOSE. THE USEPA IS CURRENTLY CONSIDERING A REDUCTION IN OPTIMAL FLUORIDE LEVELS TO 0.7 MG/L; WHICH MAY REDUCE ANNUAL CHEMICAL COSTS BY APPROXIMATELY $65,000.

4.3.2. E.A. Fairbairn WTP Fluoridation System Improvements

As noted in Section 3, all outdoor components at EAF are due for replacement.

A completely new HFA system would consist of two storage tanks, two diaphragm metering pumps, and new ancillary piping, valves, and flow meter. The new chemical feed system can be configured in the same space as the existing equipment with no covering (Option 1), under a simple fiberglass canopy structure (Option 2), or can be installed in a concrete masonry building (Option 3). Concrete masonry is recommended over a metal building due to the HFA fumes and potential damage to the metal structure. The existing lime storage silos would need to be demolished to make room for the new chemical feed system for Option 3, and those demolition costs are included in the evaluation.

A summary of the opinion of probable construction costs (OPCC) for each option at the E.A. Fairbairn WTP is summarized in

Table 4-5. The complete OPCC is presented in Appendix D.

TABLE 4-5: E.A. FAIRBAIRN WTP FLUORIDATION SYSTEM CONSTRUCTION COSTS

OPINION OF PROBABLE CONSTRUCTION COST SUMMARY		
		COST
E.A. Fairbairn HFA System Improvements		$219,000
(Option 1 – Replace Equipment Only)		
General Conditions (Bonds, Insurance, etc)	10%	$22,000
Contingency	25%	$60,000
Mid-Point of Construction (Rate = 5%, Time = 1.00 years)		$ 15,000
TOTAL PROBABLE CONSTRUCTION COST (OPTION 1 – NO CANOPY)		**$316,000**
E.A. Fairbairn HFA System Improvements		$283,000
(Option 2 – New Equipment and Canopy Structure in Existing Space)		
General Conditions (Bonds, Insurance, etc)	10%	$28,000
Contingency	25%	$78,000
Mid-Point of Construction (Rate = 5%, Time = 1.00 years)		$ 19,000
TOTAL PROBABLE CONSTRUCTION COST (OPTION 2 - CANOPY)		**$408,000**
E.A. Fairbairn HFA System Improvements		$618,000
(Option 3 - New Concrete Masonry Building in new location)		
General Conditions (Bonds, Insurance, etc)	10%	$62,000
Contingency	25%	$170,000
Mid-Point of Construction (Rate = 5%, Time = 1.00 years)		$43,000
TOTAL PROBABLE CONSTRUCTION COST (OPTION 3 - BUILDING)		**$893,000**

The O&M costs associated with any of the HFA optional projects at EAF are approximately the same and would not change dramatically from the existing O&M expenditures. These are presented in Table 4-6. There will likely be more general maintenance associated with the uncovered building versus the canopy or building

options. However, the canopy structure and masonry building would require their own maintenance.

TABLE 4-6: E.A. FAIRBAIRN WTP FLUORIDATION SYSTEM O&M COSTS

	CHEMICAL COST	LABOR ESTIMATE	EQUIPMENT REPLACEMENT	TOTAL
Hydrofluosilicic Acid System Upgrade	**$215,700**	**$25,100**	**$1,000**	**$241,800**
1. Electricity costs not included. Based on 2007-2008, energy usage was approximately $1.7m and for 2008-2009, energy usage was approximately $1.5m. **2. Plant operated 305 days in 2008-2009, and 312 days in 2009-2010.** **3. Chemical costs are based on the current target dose. The USEPA is currently considering a reduction in optimal fluoride levels to 0.7 mg/L; which may reduce annual chemical costs by approximately $65,000.**				

The 20-year future value costs associated with the upgraded HFA projects at E.A. Fairbairn WTP are summarized in Table 4-7.

TABLE 4-7: E.A. FAIRBAIRN WTP FLUORIDATION SYSTEM FUTURE AND PRESENT VALUE COSTS

	CAPITAL COST	2011 O&M COST	20-YEAR FUTURE VALUE COST	PRESENT VALUE COSTS	ANNUALIZED COSTS
(Option 1 – Replace Equipment in existing location)	$316,000	$241,800	**$11,176,000**	**$6,820,388**	**$437,508**
(Option 2 - Canopy Structure in existing location)	$408,000	$241,800	**$10,723,000**	**$6,543,935**	**$419,775**
(Option 3 - New Concrete Masonry Building in new location)	$893,000	$241,800	**$11,852,000**	**$7,232,931**	**$463,972**

Option 1 has the lowest initial capital cost, but will require more frequent equipment replacement, which increases the future value costs. Option 2 with the canopy shelter provides a greater level of protection than Option 1, so it is anticipated that the majority of the chemical feed equipment, including tanks, valves and piping can last slightly longer than a 10-year service life, so the equipment would not need to be changed out as frequent as Option 1, which lowers the future costs. Option 3 is the most expensive with the new masonry building but equipment has the longest service life. It is anticipated that the equipment will need replacement after approximately 10 (piping, valves, instruments), 15 (tanks), and 20 (pumps, piping, valves, instruments) years of service.

4.3.3. Well Site Modifications

The well system modifications are separated into three options. The first option includes a series of three steps, as described in Section 3 of the report, to optimize performance of the existing sodium fluoride system. The second and third options both include conversion of the well systems to a HFA system with the only difference being use of a third party contract service for delivery of HFA to the wells in Option 3.

The conceptual costs are based on a typical system that would be duplicated at each well site. Option 1 includes optimization of the water softening system, a new saturator system, and new solenoid metering pump (duty and shelf spare at each well). The costs are divided into the three implementation steps described previously in Section 3.

For Options 2 and 3, each well system consists of a new fiberglass shed, storage drum and transfer pump, day tank, solenoid metering pump (duty and spare on shelf), and new ancillary piping, valves, flow meter, and analytical instruments. New online analyzers were initially considered as part of the improvements to add remote monitoring capabilities. However, each analyzer would require a new drain line constructed and tied into a nearby sewer, and would add approximately $20,000 to the base construction cost per well site. In addition, the analyzers are fairly sensitive to hot weather, so installation inside the buildings at the well sites will likely lead to inaccurate readings during the afternoon hours. B&V does not anticipate a reduction in O&M with the addition of on-line analyzers. Based on these factors, it is not recommended that on-line analyzers be installed at the well sites as long as the City can maintain its current waiver.

The cost estimate for a contract chemical supplier includes access to the unattended well site, filling the chemical storage tanks, and also general site inspection to check for leaks, non-functioning equipment, alarms, and security. However, the contract chemical delivery service option would not allow for the chemical supplier to perform any maintenance, only inspection and notification to City staff.

The summary OPCC for the sodium fluoride (Option 1) and HFA system (Option 2 or Option 3) improvements at the well sites are summarized in Table 4-8 and Table 4-9, respectively, and the complete OPCCs are presented in Appendix D.

TABLE 4-8: OPINION PROBABLE CONSTRUCTION COST SUMMARY FOR OPTION 1 – SODIUM FLUORIDE SYSTEM

OPINION OF PROBABLE CONSTRUCTION COST SUMMARY		
		COST
Sodium Fluoride Improvements (unit cost per well site)		**$5,000**
(Step 1: Optimization of Existing Water Softener System)		
SUBTOTAL (27 WELL SITES)		***$135,000***
General Conditions (Bonds, Insurance, etc)	10%	$14,000
Contingency	25%	$37,000
Mid-Point of Construction (Rate = 5%, Time = 1.00 years)		$9,000
OPTION 1, STEP 1 TOTAL PROBABLE CONSTRUCTION COST		**$195,000**
Sodium Fluoride Improvements (unit cost per well site)		**$9,000**
(Step 2: New Sodium Fluoride Saturator)		
SUBTOTAL (27 WELL SITES)		***$243,000***
General Conditions (Bonds, Insurance, etc)	10%	$24,000
Contingency	25%	$67,000
Mid-Point of Construction (Rate = 5%, Time = 1.00 years)		$17,000
OPTION 1, STEP 2 TOTAL PROBABLE CONSTRUCTION COST		**$351,000**
Sodium Fluoride Improvements (unit cost per well site)		**$21,000**
(Step 3: New Metering Pumps and Chemical Piping)		
SUBTOTAL (27 WELL SITES)		***$567,000***
General Conditions (Bonds, Insurance, etc)	10%	$57,000
Contingency	25%	$156,000
Mid-Point of Construction (Rate = 5%, Time = 1.00 years)		$39,000
OPTION 1, STEP 3 TOTAL PROBABLE CONSTRUCTION COST		**$819,000**
OPTION 1 TOTAL ALL WELLS (STEPS 1-3)		**$1,365,000**

Table 4-9: Opinion Probable Construction Cost Summary for Option 2 and 3 – New HFA System

Opinion Of Probable Construction Cost Summary		
		Cost
Option 2 and Option 3 Hydrofluosilicic Acid Improvements (unit cost per well site)		**$73,000**
Subtotal (27 well sites)		**$1,971,000**
General Conditions (Bonds, Insurance, etc)	10%	**$197,000**
Contingency	25%	**$542,000**
Mid-Point of Construction (Rate = 5%, Time = 1.00 years)		**$136,000**
OPTION 2 OR OPTION 3, HFA SYSTEM TOTAL PROBABLE CONSTRUCTION COST		**$2,846,000***
* Costs increase to approximately **$3,626,000** if online analyzers are included		

The approximate annual O&M costs for the sodium fluoride and HFA system improvements at the well sites are summarized in Table 4-10.

Table 4-10: Well System Modifications O&M Costs

	Chemical Cost	Labor Estimate	Equipment Replacement	Total
Sodium Fluoride (Current)	$2,400	$14,700	$600	**$17,700**
Total O&M Costs (27 Well Sites)				**$478,100**
Sodium Fluoride (Option 1, Upgrade Steps 1-3)	$2,400	$12,900	$600	**$15,900**
Total O&M Costs (27 Well Sites)				**$429,000**
Hydrofluosilicic Acid (Option 2)	$5,900	$9,900	$1,000	**$16,800**
Total O&M Costs (27 Well Sites)				**$454,000**
Hydrofluosilicic Acid W/Delivery Service (Option 3)	$8,400	$8,000	$1,000	**$17,400**
Total O&M Costs (27 Well Sites)				**$470,000**
*** Electricity Costs not included. Based on 2007-2008, energy usage was approximately $723,000 and for 2008-2009, energy usage was approximately $683,000 for all lead well sites. Chemical costs are based on the current target dose. The USEPA is currently considering a reduction in optimal fluoride levels to 0.7 mg/L; which may reduce annual chemical costs by approximately $65,000.**				

The O&M costs indicated in Table 4-10 for sodium fluoride are less than the HFA systems, primarily due to the greater chemical costs, and more expensive equipment to maintain on the HFA system. There is

some reduction in labor with the HFA systems, but most of the labor activities (e.g., water quality checks, routine site visits) would still need to occur. Table 4-11 lists the 20-year future value costs for the well options.

TABLE 4-11 WELL SITE 20-YEAR CURRENT AND FUTURE COST SUMMARY

	2011 CAPITAL COST	2011 O&M COST	20-YEAR FUTURE VALUE COST	PRESENT VALUE COSTS	ANNUALIZED COSTS
Current System		$478,100	**$16,647,000**	**$10,159,180**	**$651,682**
OPTION 1 – Sodium Fluoride, All Steps	$1,365,000	$429,000	**$21,057,000**	**$12,850,475**	**$824,321**
OPTION 2 – Hydrofluosilicic Acid w/Standard Delivery	$2,846,000	$454,000	**$25,670,000**	**$15,665,655**	**$1,004,907**
OPTION 3 – Hydrofluosilicic Acid w/Contract Delivery Service	$2,846,000	$470,000	**$26,824,000**	**$16,369,908**	**$1,050,083**

Note: Future and present worth values include anticipated future capital projects not shown in the 2011 capital costs. Chemical costs are based on the current target dose. The USEPA is currently considering a reduction in optimal fluoride levels to 0.7 mg/L; which may reduce annual chemical costs by approximately $65,000.

5. RECOMMENDATIONS AND PROJECT IMPLEMENTATION

The purpose of this study was to conduct a review of the city's fluoridation practices and facilities, identify current issues and best management practices, evaluate costs and make recommendations to reduce costs and/or improve operations. The previous sections of this report provide information on the condition of the facilities, options for modifications, and costs. This section provides recommendations and implementation considerations.

5.1. Sacramento River Water Treatment Plant

The fluoride facilities at the Sacramento River WTP will not be due for replacement for several years. No improvement projects are recommended at this time. Table 5-1 summarizes the 20-year future value, present value, and annualized costs, which includes replacement of equipment in 7, 12, and 17 years from 2011.

TABLE 5-1: SACRAMENTO RIVER WTP FUTURE AND PRESENT VALUE AND ANNUALIZED COSTS

	20-YEAR FUTURE VALUE COSTS	PRESENT VALUE COSTS	ANNUALIZED COSTS
Hydrofluosilicic Acid System	**$10,168,000**	**$6,205,235**	**$398,048**

1. **Energy costs not included.**
2. **Equipment Replacement included in Year 2018, 2023, and 2028.**
3. **Chemical costs are based on the current target dose. The USEPA is currently considering a reduction in optimal fluoride levels to 0.7 mg/L; which may reduce annual chemical costs by approximately $65,000.**

5.2. E.A. Fairbairn Water Treatment Plant

The fluoride facilities at the E. A. Fairbairn WTP are nearing the end of their useful life (refer to Table 3-1 in Section 3). To maintain reliable operations and address the issues described under Section 3, three optional projects were developed and the costs were presented in Section 4. The costs associated with Option 1 (no covering) and Option 2 (canopy covering) are lower than Option 3 (building), however the level of protection for equipment achieved with a canopy is not comparable to the level of protection achieved with a building. The enclosed equipment will have a longer service life (approximately 5 to 10 years) due to the higher level of protection inside a building, and the difference in life cycle cost is low. Therefore Option 3 is recommended. Delaying replacement of equipment as it nears the end of its useful life will increase the risk associated with failure and leaks.

Implementation of this project, including design and construction, will take on the order of 17 to 20 months. B&V recommends that design of this project be started within 1 to 2 years, based on the remaining useful life of the facility. No additional permitting or training requirements have been identified for this project. Project implementation costs are presented in Table 5-2.

TABLE 5-2: E.A. FAIRBAIRN WTP FLUORIDATION SYSTEM IMPLEMENTATION COSTS

TOTAL PROJECT COSTS	
	COST
Total Probable Construction Cost	$893,000
Design Cost	$150,000
Construction Management Costs	$100,000
TOTAL PROJECT COST	**$1,143,000**

5.3. Groundwater Production Wells

The previous sections of this report identify the issues associated with the sodium fluoride systems at the groundwater production wells and provided costs for optional upgrade projects. The evaluation indicates the following recommendations:

1. It is recommended that the City test the hardness on the downstream side of the water softener. If the water hardness exceeds 50 mg/L of $CaCO_3$, the water hardness is too high. Hardness testing needs to be an on-going effort on each well. While recent data indicated hardness levels well below 50 mg/L, this data is not sufficient enough to rule out hardness as an issue. Tests should be completed, just prior to water softener changeout to determine if changeout frequency is suitable.

2. If it is determined that the hardness is higher than 50 mg/L $CaCO_3$, it is recommended that the City implement Option 1, for upgrade of the existing sodium fluoride system. However, it is noted that even with resolution of the current O&M issues on the sodium fluoride system, there is still concern regarding the quality of the foreign supplied sodium fluoride. If the City is not in alignment with accepting the risk associated with this product and the uncertainty associated with the level of remedy that the outlined steps in Option 1 may provide, then Option 2, is recommended for implementation. Similarly, if the City finds that the water hardness is not an issue, then it is recommended that the City move forward with the conversion of the well system to HFA in Option 2. Recommendations for additional provisions to be added to sodium fluoride procurement specifications are included in Section 2. The City may consider making upgrades to sodium fluoride system at one well to determine if improvements are suitable to continue the retrofit program.

3. If Option 2 is chosen for implementation, each site should be visited to confirm space available for the new structure.

4. The City could consider deferring modifications to the eight groundwater wells that are currently maintained in standby mode until a later date to defer costs. Upgrades at those wells could be completed in the future if the City determines that their continued use is required.
5. Eyewash stations should be installed at each of the well sites regardless of the project option selected.
6. On-line analyzers are typically required on fluoride systems. However, the existing system operates with an exemption from this requirement. It has been assumed for purposes of this evaluation that on-line analyzers will not be required on the upgraded systems. The City may consider installation of these units at some point in the future; however, the costs need to be considered. The units are approximately $10,000 each and a drain line to sewer would be required, bringing the total cost per well to approximately $20,000. B&V does not anticipate a reduction in O&M costs at the wells due solely to the addition of on-line analyzers.
7. The O&M data provided to B&V from the CMMS identifies a level of O&M on the wells sites that appears to be slightly higher than would be typical for a system such as this, but still within a reasonable range of acceptance. Refer to Table 5-3 for comparison between the City's expenditures and typical expenditures. Section 4 includes a breakdown of the City's O&M activities.

TABLE 5-3: O&M EXPENDITURE COMPARISON

	LABOR	EQUIPMENT REPLACEMENT	TOTAL
Typical System, per well	$12,000	$1,000	**$13,000**
City's Existing System, per well (from CMMS data)	$14,700	$600	**$15,300**

Implementation of Option 1, including design and construction, will take on the order of 15 to 17 months. B&V recommends that this project should be started immediately, to identify how hardness contributes to the experienced issues. No additional permitting or training requirements have been identified for this project. Project implementation costs are presented in Table 5-4.

TABLE 5-4: GROUNDWATER PRODUCTION WELLS FLUORIDATION SYSTEM IMPLEMENTATION COSTS

TOTAL PROJECT COSTS – OPTION 1 (ALL STEPS INCLUDED)	
	COST
Total Probable Construction Cost	$1,365,000
Design Cost	$150,000
Construction Management Costs	$100,000
TOTAL PROJECT COST	**$1,615,000**

If the City decides on implementation of Option 2, design and construction will take on the order of 17 to 20 months. B&V recommends that this project be started immediately to address the identified issues with the existing system. Additional hazardous material permitting will be required with the conversion to HFA and additional training for the operators on the new chemical will be required. Project implementation costs for Option 2 are presented in Table 5-5.

TABLE 5-5: GROUNDWATER PRODUCTION WELLS FLUORIDATION SYSTEM IMPLEMENTATION COSTS

TOTAL PROJECT COSTS – OPTION 2	
	COST
Total Probable Construction Cost	$2,846,000
Design Cost	$250,000
Construction Management Costs	$200,000
TOTAL PROJECT COST	**$3,296,000**

5.4. Project Management

The projects outlined above are of such a size that it is anticipated that the City could utilize in-house staff to provide project management services throughout the lifecycle of the projects. It is anticipated that project management duties will require a 15 to 25 percent full-time equivalent (FTE) commitment through the duration of each project.

5.5. Project Financing

Financing for the capital projects outlined herein will be contingent upon City Council direction. Projects will either be funded through the City's rate payer backed Capital Improvements Program (CIP) or through grant funding or bonding. Bond funding would most likely only be considered if the City decided to include one of these projects with another larger improvement project.

5.6. Total Fluoride System O&M Cost

Table 5-6 presents a summary of the total annual and 20-year present worth O&M expenditures anticipated for the City to continue fluoridating. Expenditures do not include energy costs or costs associated with capital improvement projects though it is assumed that the capital projects have been performed as recommended in this report.

TABLE 5-6: 20-YEAR O&M COSTS FOR FLUORIDATION FACILITIES

FACILITIES	CHEMICAL COST	LABOR ESTIMATE	EQUIPMENT REPLACEMENT	TOTAL COSTS
Sacramento River WTP	$212,100	$25,500	$1,000	**$238,600**
E.A. Fairbairn WTP - Option 3	$215,700	$25,100	$1,000	**$241,800**
Groundwater Production Wells (27 wells) – Option 1	$64,800	$348,300	$16,200	**$429,300 (for 27 wells)**
Total Annual O&M Cost	$492,600	$398,900	$18,200	**$909,700**
Total O&M Cost – 20 Year Future Value Cost				**$33,722,000**
Total O&M Cost – 20 Year Future Value Cost, less equipment replacement				**$33,139,000**

1. Energy costs not included. Energy usage is considered negligible in comparison to the overall well site and water treatment plant operation.
2. Capital improvement projects not included.
3. Equipment replacement budget includes replacement of small items in the system on a routine basis including pumps, valves, piping, etc., and does not include replacement of the complete system on a pre-determined interval.
4. Chemical costs are based on the current target dose. The USEPA is currently considering a reduction in optimal fluoride levels to 0.7 mg/L; which may reduce annual chemical costs by approximately $65,000.

5.7. 20-Year Fluoridation Cost Summary

To continue fluoridating, the City will need to provide O&M expenditures and upgrade facilities to improve operations and replace aging equipment. This report has outlined estimates for on-going O&M costs and has made recommendations regarding capital projects. Table 5-7 and Table 5-8 summarize the capital, O&M, 20-year future value, present value, and annualized costs of the combined recommended improvements. Table 5-8 specifically summarizes the future value, present value, and annualized costs for the present and future equipment replacement, and the total City fluoridation costs minus the equipment replacement costs.

Figures 5-1, 5-2, and 5-3 provide a Cost of Fluoridation Summary in graphical format for Option 1, Option 2 and a comparison of both options.

TABLE 5-7 FLUORIDATION FACILITIES IMPROVEMENTS SUMMARY

	Base 2011 Costs					Total City Fluoridation Costs		
Description	2011 Capitol Projects	O&M Equipment Replacement	O&M Chemical	O&M Labor	Total 2011 O&M Costs	PW	Annualized	FW
Wells – Sodium Fluoride (Steps 1-3) **EAF – HFA in Building** **Sac River WTP Equipment Replacement**	$2,258,000	$18,000	$493,000	$399,000	$910,000	$26,289,000	$1,686,000	$43,077,000
Wells – HFA **EAF – HFA in Building** **Sac River WTP Equipment Replacement**	$3,739,000	$29,000	$587,000	$318,000	$934,000	$29,104,000	$1,867,000	$47,690,000

Note: Chemical costs are based on the current target dose. The USEPA is currently considering a reduction in optimal fluoride levels to 0.7 mg/L; which may reduce annual chemical costs by approximately $65,000.

TABLE 5-8 FLUORIDATION FACILITIES IMPROVEMENTS SUMMARY

	Present and Future Equipment Replacement			Total City Fluoridation Costs less Equipment Costs		
Description	PW	Annualized	FW	PW	Annualized	FW
Wells – Sodium Fluoride (Steps 1-3) **EAF – HFA in Building** **Sac River WTP Equipment Replacement**	$6,065,000	$389,000	$9,938,000	$20,224,000	$1,297,000	$33,139,000
Wells – HFA **EAF – HFA in Building** **Sac River WTP Equipment Replacement**	$8,073,000	$518,000	$13,228,000	$21,031,000	$1,349,000	$34,462,000

Note: Chemical costs are based on the current target dose. The USEPA is currently considering a reduction in optimal fluoride levels to 0.7 mg/L; which may reduce annual chemical costs by approximately $65,000.

FIGURE 5-5: PHOTOS OF SODIUM FLUORIDE INJECTOR AT WELLS (NEW AND WITH CLOGGING)

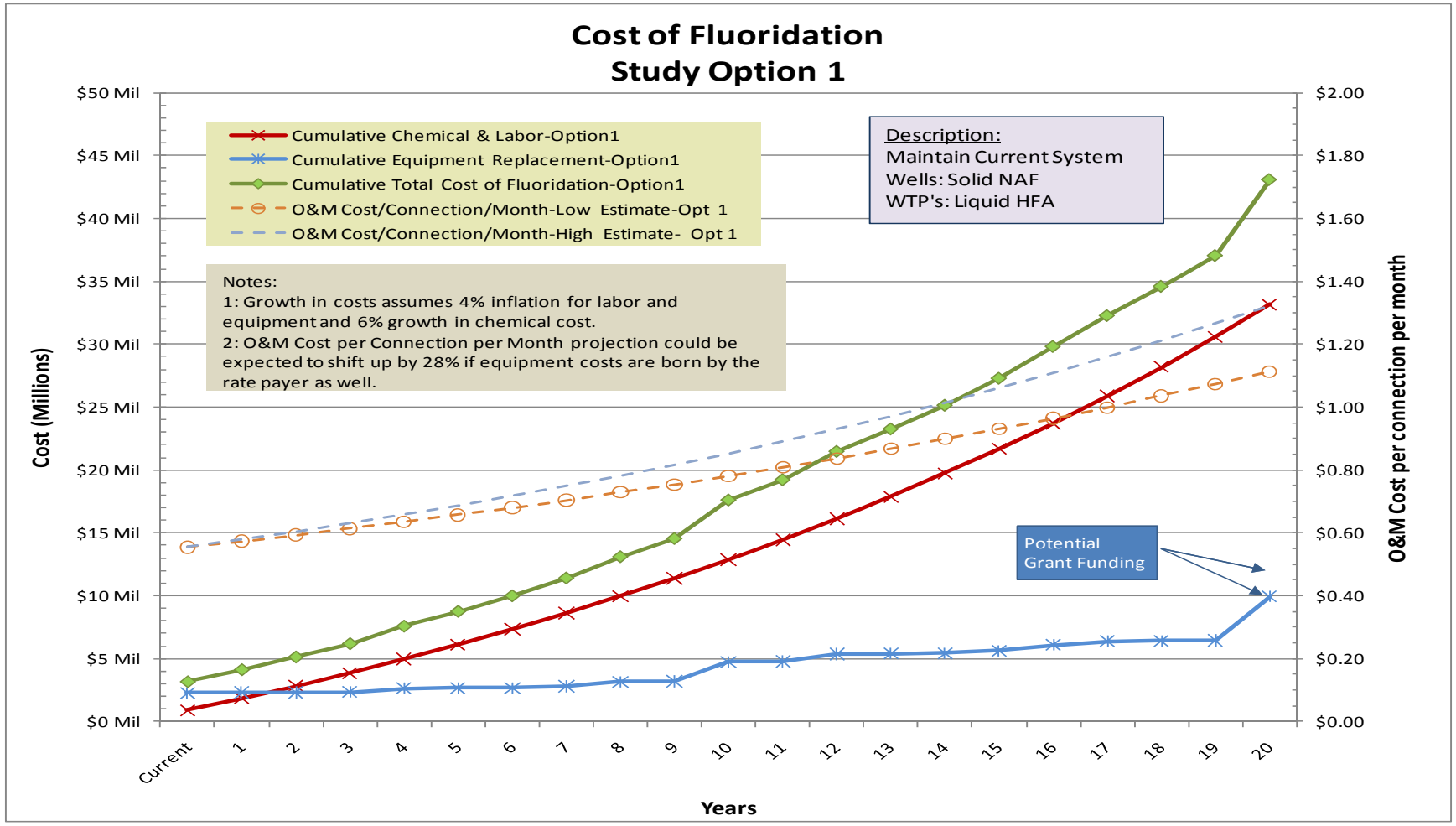

FIGURE 5-1: COST OF FLUORIDATION OPTION 1

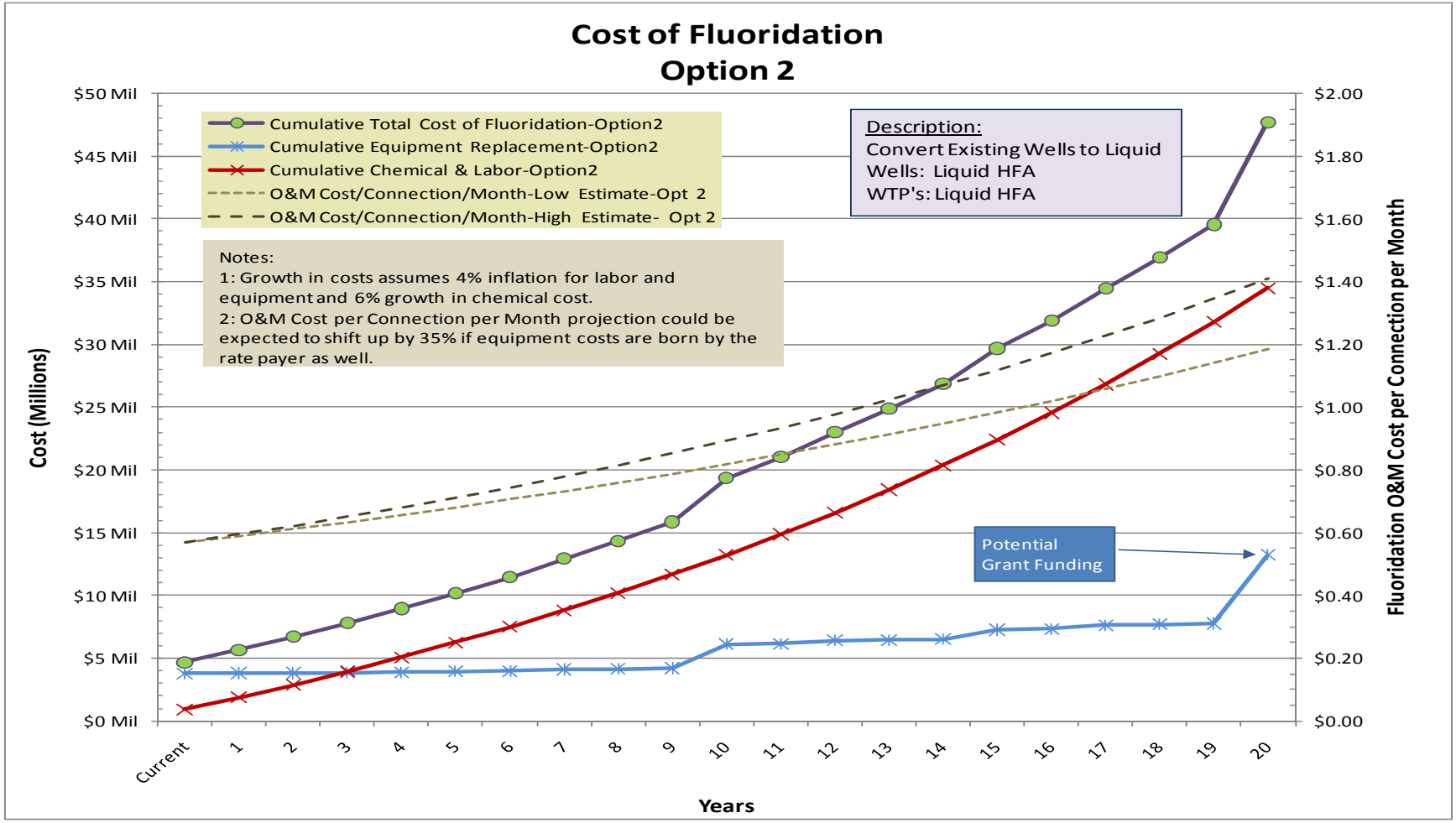

FIGURE 5-2: COST OF FLUORIDATION OPTION 2

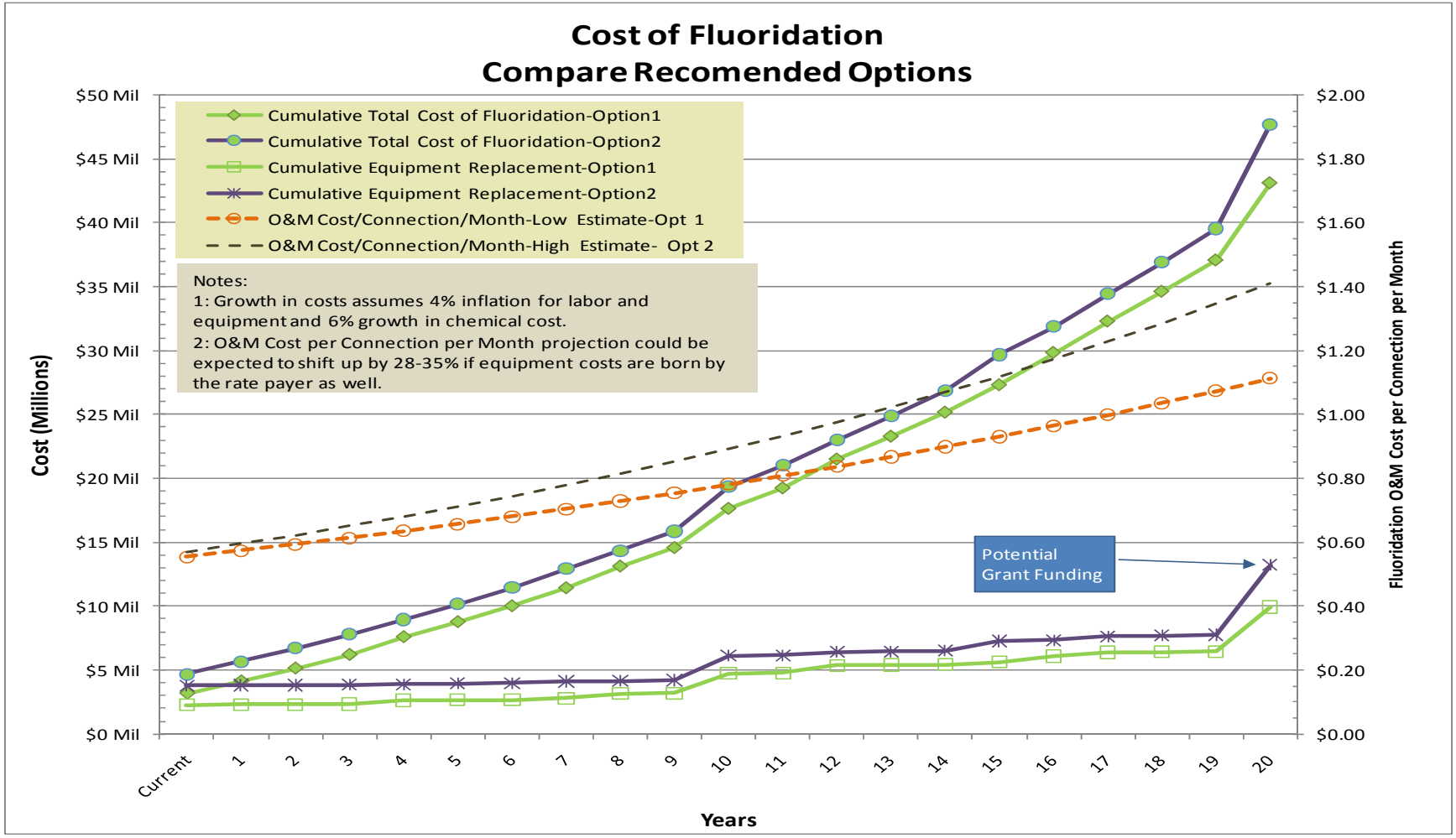

FIGURE 5-3: COST OF FLUORIDATION COMPARISON OF RECOMMENDED OPTIONS

APPENDIX A – LIST OF ISSUES FROM THE CITY

Current Issues with the Fluoride Delivery System-12/02/2010

<u>The Quality of Product</u>

1. The Center for Disease Control (CDC) recommends that only the US product be used due to quality control and efficient operation of the saturator, yet crystalline sodium fluoride is no longer produced in the USA. Availability is limited to import manufacturers in China, Japan, and Belgium.
2. Foreign product has a higher concentration of "inert" material, and produces more dust when handling, creating increased maintenance cost.
3. The quality of Japan and China manufactured supplies seem to exacerbate costly equipment problems and failures. Shipments of sodium fluoride often have damaged bags that are leaking product through punctures or failed seals as well.
4. One of the issues with sodium fluoride is the characteristic stratification that occurs with the current product and the impacts on equipment performance associated with characteristic. i.e. The product does not dissolve readily.
5. AWWA standards specify that sodium fluoride have 44% fluoride available. The study needs to identify what makes up the other 56% of the product. The study should also itemize what criteria sodium fluoride must meet to be NSF 60 certified. How is it determined there are no industrial or other wastes added into that 56% other material?
6. Should higher quality NAFL exist, what are the measurable parameters the City can utilize in a performance specification? I.e, the city needs to maintain competitive bidding, but needs the receive a particular level of quality.

<u>Equipment Failure and Loss of Production</u>

1. The movement of suppliers away from domestically produced sodium fluoride is adversely affecting the fluoridation feed equipment at the well sites, primarily due to clogged fluoride injector pumps. Clogging of flow indicators, chemical pump intake screens is also an issue.
2. Loss of production due to fluoride pump faults. Most of which are caused by plugging of the delivery system. Well shut downs also affect our ability to meet water pressure requirements, which are mandated in Title 22. Shortages of chemical supplies have also threatened interruption of service of wells.
3. Crystallization of lines in cold temperatures.
4. High rate of component failures such as pump injectors, diaphragms, fittings, screens, flow indicators, floats, and diffusers.

5. Operators must ensure that 3 attributes of fluoridation match in order to maintain well production. The chemical pump output (dose) must closely match the calculated dose which must closely match the measured residual dose. If they do not, the operator must troubleshoot equipment and run additional residual testing to determine why they don't match. The well must be taken out of service until the corrective measures can be implemented. The well can be out of service for several days depending on availability of maintenance staff to fix the problem.
6. The fluoridation infrastructure at the E.A. Fairbairn Water Treatment Plant is overdue for replacement and will be expensive to replace. Sacramento River Water Treatment Plant's fluoridation system will be due for replacement in 2014. When this system is installed, does it make financial sense to install new acid tank within a shelter
7. Sacramento Suburban Water District also identified the damages caused by the fumes emitted from the chemical tank vents. Control of these acid fumes should also be addressed in looking at an acid system for wells.
8. The existing chemical feed system for sodium fluoride is extremely vulnerable to any solid material (a spec of plastic the size of a straight pin head has fouled the digipulse on numerous occasions)and an increase in viscosity associated with the "fluff" level in the saturator reaching the pump intake. These vulnerabilities need recommended solutions.

Safety

1. The ergonomics of lifting the 50 pound bags of sodium fluoride to fill the saturator puts the workers in a position of increased risk of injury. Under the worker safety aspect, ergonomics of this activity should be addressed.
2. Addressing worker training is not a one-time thing. A training program that can be delivered to new staff needs to be identified. Comprehensive annual refresher training is required by State regulations.
3. There needs to be a detailed instructional manual developed to guide staff in proper operation and maintenance practices and procedures. What currently exists are scattered SOP's which are not cohesive.
4. Should we install acid system at the wells, how would material handling occur to minimize dangers? What is the risk to the public? How is site security impacted.

Additional Costs and Issues

1. Saturator cleaning is scheduled every 6 months rather than the recommended 12 month cycle. This increase in frequency is part of the City's effort to mitigate for clogging issues. This drives labor costs up.
2. There is added time/cost to condition fill water with water softeners for saturators.
3. Additional staff time required for the accounting of time spent specifically on fluoride related activities.

4. Discharge reporting requires 7 days prior notice. Discharge is restricted to 200 gallons per event. Samples must be sent to contract lab, and lab results must be reported within 14 days of sampling. The cost of additional sampling, as required by discharge permit agency, is the responsibility of City.
5. Additional cost for Hazardous Permits are a resultant of onsite storage and use of fluoride.
6. Additional cost to provide and maintain personal protective equipment required for handling of fluoride.
7. Troubleshooting fluoride related problems is very time consuming.
8. Grant funding is available for capital costs, but in order to take advantage of this grant, all the operations and maintenance costs must be covered by the city and ultimately the rate payers. Such a contract would also obligate the city to fluoridate its water supply for 20 years regardless of the economic condition or budgetary constraints. Developing a fluoride delivery system which minimizes operation and maintenance costs is a department goal.
9. There needs to be a table of comparative analysis between sodium fluoride saturator system costs and hydrofluorosillic acid system costs for well fluoridation.
10. Identify O&M work that is not being done <u>that is in support</u> of the existing fluoride system due to insufficient staff time. One example is the saturator's need to be pumped out and cleaned to remove insoluble waste and crystallized residues every 6 months. To date we have missed 4 cycled of this maintenance.
11. Specific to the Fluoridation system, what adequate staffing levels should be maintain now and after identified improvements?
12. In the chemical handling area there needs to be recommendations on how pallets that have product leaking from their containers are dealt with. If one bag out of 50 bundled together on a pallet is breached, how is the whole pallet to be treated? And if refusing the delivery is the action, what should the minimum quantity on hand be? (Our existing storage shed can only hold 4 pallets. We order 3 pallets when the 4th pallet starts to be used.)
13. In the analysis comparing the use of sodium fluoride and hydrofluorosillic acid there needs to be clear comparisons of product cost AND delivery. In conversation with Jim Arnez of Sac Suburban Water he indicated they pay dramatically higher prices (gallon per gallon) for fluoride acid than we do AND a premium for having delivery service to their wells AND the labor associated with each delivery.
14. What would the cost be to have the saturator pump-out waste disposed of as industrial waste if disposal to the sanitary sewer is prohibited?

15. The study needs to identify the additional cost associated with the extra travel required to accomplish all tasks associated with fluoridation. While Operators make a MWF site visit for chlorination system purposes anyway, it cannot be assumed there are no additional travel expenses related specifically to support of the fluoridation system. Example: The Operator encounters a problem that requires maintenance personnel. The Operator takes the system out-of-service until the repair can be made. There is additional travel for the maintenance staff to come and make the repair. The maintenance staff must have the Operator return to place the equipment back in service as required by State regulations. There is extra travel required of the Operator to return to the site AND extra travel for the Operator to return to whatever duties he was interrupted from. There is travel expense for the maintenance staff to return to their interrupted work as well. This example is a simple response involving only two staff. There are times where there are more staff required to be diverted.

APPENDIX B – QUESTIONNAIRES FROM OTHER UTILITIES USING FLUORIDE

Appendix B

Questions for Fluoride Users

NAME: Derrick Smith/ Jay Kleinheinz

AGENCY: Huntington Beach

DATE/ TIME: January 18, 2011; 10:40 AM Central Time

January 25, 2011; 5:30 PM Central Time

SUBJECT: Fluoride System

Question	Response
1. What kinds of facilities are operated? Plants, well sites, or both?	Ten well sites
2. How long have has fluoride been fed?	Since 1972
3. What kind of fluoride is used? Has that type of fluoride always been used?	Hydrofluosilicic acid – it has always been used.
4. Why was that fluoride type selected?	Don't know – it was selected too many years ago.
5. How much fluoride is fed? (gallons/day, pounds/day)	~18 gallons per day of acid per well station
6. If the utility has well sites, how many days of chemical storage are kept at each site?	Each well site uses 100 gallon tanks, which is about 10 days worth of storage.
7. If the utility has un-staffed well sites, what is the O&M requirement at each station?	Huntington Beach spent $6,000 in 2010 maintaining the fluoride systems at their well stations.
8. What kind of fluoride deliveries to are accepted? (drums/ totes/ bulk truck/ 50-pound bags/ super-sacks)	Bulk deliveries are made to a central storage tank. The Huntington Beach staff then takes the acid from the central storage and delivers it to the well stations via water trucks.
9. What equipment is used to feed the fluoride?	LMI solenoid metering pumps
10. What operations issues have been experienced? How were these issues solved?	Huntington Beach initially had some problems with their metering pumps. Now they specify Teflon seats, diaphragms, and ball checks, and these have proven to have good chemical compatibility.

Question	Response
11. Is the utility happy with their fluoride system? What changes could be made?	Yes; they consider it to be relatively easy to handle.
12. How much time is spent each month per fluoride system? Does that include chemical deliveries?	See the response to #7.
13. Have you ever identified the cost of the fluoride program or developed any cost ratios, such as cost/gallon produced or cost/ resident served? If so, can this be provided?	The total cost of the hydrofluosilicic acid systems for all well sites is $100,000. This includes operations, maintenance, chemical cost, and lab work.
14. Have you ever experienced problems with the fluoride product? What were they and were they ever resolved?	Huntington Beach has not had any problems with the hydrofluosilicic acid product.

Questions for Fluoride Users

NAME: Sun Liang

AGENCY: Metropolitan Water District (MWD)

DATE/ TIME: January 5, 2011; 2:10 PM CST

SUBJECT: Fluoride System

Question	Response
1. What kinds of facilities are operated? Plants, well sites, or both?	MWD operates 5 water treatment plants.
2. How long have has fluoride been fed?	Since October 2009
3. What kind of fluoride is used? Has that type of fluoride always been used?	Hydrofluosilicic acid is currently fed and has always been MWD's fluoride source.
4. Why was that fluoride type selected?	The WTP capacities are very large, making sodium fluoride too labor intensive.
5. How much fluoride is fed? (gallons/day, pounds/day)	WTP capacities range from 220 to 750 MGD each. This calculates to hydrofluosilicic acid 478 to 1,630 gallons of delivered acid per day.
6. If the utility has well sites, how many days of chemical storage are kept at each site?	Not applicable.
7. If the utility has un-staffed well sites, what is the O&M requirement at each station?	Not applicable.
8. What kind of fluoride deliveries to are accepted? (drums/ totes/ bulk truck/ 50-pound bags/ super-sacks)	Bulk delivery. MWD tries to keep 14 days of storage at each plant.
9. What equipment is used to feed the fluoride?	
10. What operations issues have been experienced? How were these issues solved?	Most of the issues occurred at start-up and were tied to the corrosive nature of the hydrofluosilicic acid and material compatibility. Now that these issues have been resolved, the system works fine.
11. Is the utility happy with their fluoride system? What changes could be made?	MWD is happy with the fluoride feed system. They are disappointed in the quality of fluoride analyzers, though. They tried using analyzers and found them to be unreliable. Now they test grab samples twice per day.

Question	Response
12. How much time is spent each month per fluoride system? Does that include chemical deliveries?	Now that the system is beyond start-up, O&M time is very low.

Questions for Fluoride Users

NAME: Tai Tseng

AGENCY: Long Beach Water Department

DATE/ TIME: December 17, 2010

SUBJECT: Fluoride System

Question	Response
1. What kinds of facilities are operated? Plants, well sites, or both?	Groundwater Treatment Plant
2. How long have has fluoride been fed?	1971
3. What kind of fluoride is used? Has that type of fluoride always been used?	Hydrofluosilicic Acid
4. Why was that fluoride type selected?	Ease and safety
5. How much fluoride is fed? (gallons/day, pounds/day)	On average, we add approximately 0.5 mg/L fluoride.
6. If the utility has well sites, how many days of chemical storage are kept at each site?	14,000 gallons at treatment plant
7. If the utility has un-staffed well sites, what is the O&M requirement at each station?	We use to feed it at an un-staff reservoir site. On-line fluoride monitoring and alarm system for automatic operations. Since MWD started fluoridating, we haven't had to feed fluoride at an un-staffed location.
8. What kind of fluoride deliveries to are accepted? (drums/ totes/ bulk truck/ 50-pound bags/ super-sacks)	Bulk
9. What equipment is used to feed the fluoride?	Metering pumps and on-line fluoride analyzer
10. What operations issues have been experienced? How were these issues solved?	Availability of on-line analyzers. Industry has improved. More products are now available.
11. Is the utility happy with their fluoride system? What changes could be made?	We are happy with existing system
12. How much time is spent each month per fluoride system? Does that include chemical deliveries?	Including deliveries and running lab analysis every 4 hours to confirm on-line instrument, about 3 hours per day.

Questions for Fluoride Users

NAME: Gary Richinick

AGENCY: City of Santa Monica

DATE/ TIME: January 19, 2011

SUBJECT: Fluoride System

Question	Response
1. What kind of facilities do you operate? Plants, well sites, or both?	Both One groundwater well @ 240 gpm Arcadia WTP = 8.8 mgd
2. How long have you been feeding fluoride?	3 years at the groundwater well, the facility at the WTP was just started up in December of 2010.
3. What kind of fluoride do you use? Have you always used that type of fluoride?	Sodium Fluoride.
4. Why was that fluoride type selected?	For safety of handling a lower concentration fluoride solution
5. How much fluoride do you feed? (gallons/day, pounds/day)	300 gpd of 4% NaF solution is fed at the well
6. If the utility has well sites, how many days of storage are kept at each site	9 days of storage is provided at the groundwater well site.
7. If the utility has un-staffed well sites, what is the O&M requirement at each station	The day tank at the well site is filled weekly.
8. What kind of fluoride deliveries to you accept? (drums/ totes/ bulk truck/ 50-pound bags/ super-sacks)	For the well site, 50 lb bags are used. At the Arcadia WTP, supersacks are used.
9. What equipment are you using to feed the fluoride?	Milton Roy Metering Pumps
10. What operations issues have you experienced? How did you solve these issues?	Low saturation sodium fluoride solution concentration Failure of online analyzers
11. Are you happy with your fluoride system? If not, what would you change?	Yes

Question	Response
12. How much time is spent each month per fluoride system? Does that include chemical deliveries	On average, 10 hours per month is spent on maintaining the sodium fluoride system at the single groundwater well (including chemical delivery). It is unknown at this time what the O&M requirement is for the sodium fluoride system at the Arcadia WTP since it was just started up recently.

APPENDIX C – PROCESS AND INSTRUMENTATION DIAGRAMS

SYSTEM CODE - DENOTES ASSOCIATED CHEMICAL SERVICE ABBREVIATION
FUNCTION CODE - DENOTES ASSOCIATED EQUIPMENT ABBREVIATION
SEQUENCE CODE - UNIQUE NUMERIC IDENTIFIER

SSS- FFF -9999

EQUIPMENT IDENTIFICATION DESCRIPTION

PIPE SIZE - INCHES UNLESS OTHERWISE NOTED
SYSTEM CODE - DENOTES ASSOCIATED PROCESS STREAM
MATERIAL CODE - DENOTES ASSOCIATED MATERIAL ABBREVIATION
PIPE SEQUENCE NUMBER (TO BE ADDED DURING FINAL DESIGN)

SSS - PPP - MAT - 999

PIPELINE IDENTIFICATION DESCRIPTION

PUMP & BLOWER SYMBOLS

DRUM PUMP

S — DIAPHRAGM METERING PUMP "S" INDICATES SOLENOID TYPE

LINE SYMBOLS

MAJOR PROCESS PIPING OR FLOW CHANNEL
SECONDARY PROCESS PIPING
MISCELLANEOUS PIPING
SCREENED LINE DENOTES EXISTING PIPE OR EQUIPMENT
DASHED LINE DENOTES FUTURE PIPE AND EQUIPMENT
ELECTRIC SIGNAL
HYDRAULIC SIGNAL
PNEUMATIC SIGNAL
SIGNAL CONNECTION POINT
SIGNAL LINK (SOFTWARE OR DATA LINK)
FF — FOUNDATION FIELDBUS
PB — PROFIBUS
PACKAGE BOUNDRY IDENTIFICATION

B PI-4 — SIGNAL LINE GOING TO ANOTHER SHEET
B PI-4 — SIGNAL LINE FROM ANOTHER SHEET (MATCH LETTERS)
FLOW ARROW FOR PROCESS PIPING
B PI-45 — PROCESS LINE GOING TO ANOTHER SHEET
MATCH SHEET NO. IDENTIFIER
MATCH LINE NO.
B PI-45 — PROCESS LINE COMING FROM ANOTHER SHEET
PROCESS LINES CROSSING (NOT CONNECTED)
BG AG — DENOTES TRANSITION OF PIPING FROM ABOVE GROUND TO BELOW GROUND

GENERAL NOTES

1. IN GENERAL, THE P &ID SYMBOLS AND DEVICE IDENTIFICATIONS ARE BASED ON INSTRUMENT SOCIETY OF AMERICA, STANDARD PRACTICE ISA-S5.1 (1988). SOME MODIFICATIONS, ADDITIONS, AND ALTERATIONS HAVE BEEN MADE AS NEEDED TO ACCOMMODATE THE PROJECT REQUIREMENTS.
2. SOME CONTROL AND INTERLOCK REQUIREMENTS WHICH CAN BE MORE CLEARLY ILLUSTRATED ON SCHEMATIC DRAWINGS HAVE BEEN OMITTED FROM THE P & ID DRAWINGS.
3. THIS IS A GENERAL LEGEND SHEET. SOME SYMBOLS AND ABBREVIATIONS MAY NOT BE UTILIZED ON THIS SPECIFIC PROJECT.
4. PIPING AND EQUIPMENT LEGEND APPLIES TO P & ID SHEETS ONLY AND MAY DIFFER FROM LEGENDS FOR OTHER SHEETS.

PRIMARY ELEMENT & FITTING SYMBOLS

DIAPHRAGM SEAL
PRIMARY FLOW ELEMENT: ORIFICE PLATE
PRIMARY FLOW ELEMENT: FLUME
PRIMARY FLOW ELEMENT: TURBINE OR PROPELLER-TYPE
PRIMARY FLOW ELEMENT: ELECTROMAGNETIC
THERMAL DISPERSION TYPE FLOW ELEMENT
PRIMARY FLOW ELEMENT: TRANSIT-TIME ULTRASONIC
TE 101 — TEMPERATURE ELEMENT WITH THERMOWELL
LE — ELECTRODE TYPE LEVEL SWITCH
ANNULAR TYPE DIAPHRAGM SEAL
PRIMARY FLOW ELEMENT: POSITIVE DISPLACEMENT
PRIMARY FLOW ELEMENT: VENTURI TUBE
PRIMARY FLOW ELEMENT: WEIR
PRIMARY FLOW ELEMENT: PITOT TUBE
PRIMARY FLOW ELEMENT: CORIOLIS
PRIMARY FLOW ELEMENT: DOPPLER TYPE ULTRASONIC
FE 100 — PRIMARY ELEMENT: ROTAMETER
LE 100 — ULTRASONIC LEVEL ELEMENT
REDUCER - CONCENTRIC
REDUCER - ECCENTRIC
FLANGE
D — DRAIN - BELL-UP
D — DRAIN - FUNNEL
FLEXIBLE CONNECTION
CAP
PLUG
T — TRAP
SURGE CHAMBER
FLAME ARRESTER
SEDIMENT TRAP
UNION
HOSE CONNECTION
STRAINER - Y TYPE
STRAINER - BASKET
Q — QUICK CONNECT
VENT
VENT - SCREENED
COUPLING
SIGHTGLASS
MOISTURE SEPARATOR
OVERFLOW LINE

VALVE & GATE SYMBOLS

GATE OR PENSTOCK
VALVE: GATE OR OTHER IN-LINE TYPE NOT OTHERWISE IDENTIFIED
VALVE: BALL
VALVE: GLOBE
VALVE: BUTTERFLY, DAMPER OR LOUVER
VALVE: PLUG
VALVE: THREE WAY
VALVE: FOUR WAY
VALVE: CHECK
VALVE: ANGLE
VALVE: SET STOP
VALVE: PINCH
VALVE: DIAPHRAGM
HYDRANT
VALVE: PRESSURE REDUCING
VALVE: PRESSURE SUSTAINING
VALVE: PRESSURE REDUCING (SELF ACTUATING TYPE)
VALVE: PRESSURE SUSTAINING (SELF ACTUATING TYPE)
VALVE: PILOT
VALVE: VACUUM RELIEF
VALVE: PRESSURE RELIEF
VALVE: PRESSURE/VACUUM RELIEF
STOP LOGS
EXPLOSION RELIEF
VALVE: AIR-VACUUM
VALVE: AIR RELEASE
VALVE: THERMAL SHUTOFF
VALVE: MUD
VALVE: SLEEVE
VALVE: KNIFE GATE
BACKFLOW PREVENTER
GATE: FLAP
VACUUM BREAKER
DIVERTER GATE

CHEMICAL FEED EQUIPMENT SYMBOLS

DIFFUSER: TANK
DIFFUSER: CHANNEL
INJECTOR
RUPTURE DISK
PULSATION DAMPNER
CHEMICAL INDUCTION UNIT
VAPOR SUPERHEATER
PRESSURE BUILDING COIL
CALIBRATION COLUMN
EXPANSION TANK OR FUNNEL
WEIGH SCALE
DRIP LEG HEATER
SCALE
TOTE — TOTE
AS — AUTOMATIC SWITCHOVER
GAS FEEDER
EVAPORATOR
DRY CHEMICAL FEEDER
POLYMER BLENDER FEEDER
POLYMER BLENDER FEEDER
POLYMER ACTIVATION CHAMBER — POLYMER ACTIVATION CHAMBER
DIFFUSER
POLYMER INJECTION RING
ACTIVATION CHAMBER
SPECTACLE BLIND
COMBINATION EYEWASH/SHOWER STATION

VALVE AND GATE ACTUATOR SYMBOLS

P — AIR CYLINDER
P/O — AIR-OIL CYLINDER
H — HYDRAULIC CYLINDER
E/H — ELECTRO HYDRAULIC
S — SOLENOID
M — STANDARD ELECTRIC
M P — PROGRAMMABLE ELECTRIC
M N — NETWORKED ELECTRIC
M SM — SMALL MOTOR ACTUATOR
P DA — PNEUMATIC ACTUATOR DOUBLE ACTING
P SC — PNEUMATIC ACTUATOR SPRING CLOSE
P SO — PNEUMATIC ACTUATOR SPRING OPEN
H HW — HANDWHEEL
H CW — CHAINWHEEL
H WN — WRENCH NUT
H L — LEVER
DIAPHRAGM VALVE

VALVE POSITION DESIGNATIONS

THE FOLLOWING ADDITIONAL DESIGNATIONS MAY BE UTILIZED ADJACENT TO SOME VALVE OR GATE SYMBOLS.

MANUAL VALVES:
NO NORMALLY OPEN FOR NORMAL OPERATION (DEFAULT CONDITION UNLESS NOTED OTHERWISE)
NC NORMALLY CLOSED FOR NORMAL POSITION

ACTUATED VALVES:
NO-FC NORMALLY OPEN FOR NORMAL OPERATION; FAILS CLOSED UPON LOSS OF CONTROL SIGNAL
NO-FO NORMALLY OPEN FOR NORMAL OPERATION; FAILS OPEN UPON LOSS OF CONTROL SIGNAL
NO-FIP NORMALLY OPEN FOR NORMAL OPERATION; FAILS IN LAST POSITION UPON LOSS OF CONTROL SIGNAL

FIGURE 1

CITY OF SACRAMENTO

BLACK & VEATCH
Black & Veatch Corporation
Sacramento, California

P&ID LEGEND
SHEET 1 OF 3

PLOTTED:
SAVED:
B5065FIG-L FB5000FIG-L

INSTRUMENT TAG NUMBERS

MEANINGS OF IDENTIFICATION LETTERS

LETTER	FIRST LETTER		SUCCEEDING LETTERS		
	MEASURED OR INITIATING VARIABLE	MODIFIER	READOUT OR PASSIVE FUNCTION	OUTPUT FUNCTION	MODIFIER
A	ANALYSIS		ALARM		
B	BURNER, COMBUSTION		USER'S CHOICE	USER'S CHOICE	USER'S CHOICE
C	CONDUCTIVITY (ELECTRICAL)			CONTROL	CLOSED
D	DENSITY (MASS) OR SPECIFIC GRAVITY	DIFFERENTIAL			
E	VOLTAGE (EMF)		PRIMARY ELEMENT		
F	FLOW RATE	RATIO (FRACTION)			
G	USER'S CHOICE		GLASS		
H	HAND (MANUALLY INITIATED)				HIGH
I	CURRENT (ELECTRICAL)		INDICATE		
J	POWER	SCAN			
K	TIME OR TIME-SCHEDULE	TIME RATE OF CHANGE		CONTROL STATION	
L	LEVEL		LIGHT (PILOT)		LOW
M	MOISTURE OR HUMIDITY	MOMENTARY			MIDDLE OR INTER-MEDIATE
N	USER'S CHOICE		USER'S CHOICE	USER'S CHOICE	USER'S CHOICE
O	USER'S CHOICE		ORIFICE (RESTRICTION)		OPEN
P	PRESSURE OR VACUUM		POINT (TEST CONNECTION)		
Q	QUANTITY	INTEGRATE OR TOTALIZE	INTEGRATE OR TOTALIZE		
R	RADIATION		RECORD OR PRINT		
S	SPEED OR FREQUENCY	SAFETY		SWITCH	
T	TEMPERATURE			TRANSMIT	
U	MULTIVARIABLE		MULTIFUNCTION	MULTIFUNCTION	MULTIFUNCTION
V	VIBRATION			VALVE, DAMPER, OR LOUVER	
W	WEIGHT OR FORCE		WELL		
X	UNCLASSIFIED		UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED
Y	EVENT, STATE, OR PRESENCE			RELAY OR COMPUTE	
Z	POSITION, DIMENSION			DRIVE, ACTUATOR OR UNCLASSIFIED FINAL CONTROL ELEMENT	

GENERAL INSTRUMENT SYMBOLS

FIELD MOUNTED INSTRUMENT

INSTRUMENT MOUNTED ON FACE OF PANEL

INSTRUMENT MOUNTED BEHIND OR INSIDE OF PANEL

INSTRUMENT MOUNTED ON FACE OF LOCAL PANEL

INSTRUMENT MOUNTED BEHIND OR INSIDE OF LOCAL PANEL

SINGLE INSTRUMENT HOUSING CONTAINING TWO (OR MORE) INSTRUMENTATION FUNCTIONS

I — CONTROL INTERLOCK FUNCTION, SEE SCHEMATICS AND SYSTEM SPECIFICATIONS FOR SPECIFIC FUNCTION

TAG NUMBERS AND ADDITIONAL DESIGNATIONS

TRC 12345

FIRST LETTER
SUCCEEDING LETTERS

LOOP DESIGNATION NUMBER. SEE SEQUENCE CODE RANGES ON SHEET PI-2003.

pH — SEE INSTRUMENT FUNCTIONAL DESIGNATIONS AND ABBREVIATIONS.

DIGITAL SYSTEMS INTERFACE SYMBOLS

NOTE: REFER TO DETAILED SYSTEM SPECIFICATIONS FOR FUNCTIONAL DESCRIPTION. ALSO SEE I/O SCHEDULES FOR COMPLETE INPUT AND OUTPUT LISTINGS.

COMPUTER, DISTRIBUTED CONTROL SYSTEM, OR DISPLAY FUNCTION BLOCK

LETTERS, TAG NUMBERS, ABBREVIATIONS AND OTHER ANNOTATIONS ARE SIMILAR TO THE GENERAL INSTRUMENT LEGEND

DIGITAL SIGNAL I/O INTERFACE DIRECTION OF ARROW DENOTES WHETHER INPUT OR OUTPUT

ANALOG SIGNAL I/O INTERFACE, DIRECTION OF ARROW DENOTES WHETHER INPUT OR OUTPUT

FUNCTION DESIGNATIONS AND ABBREVIATIONS

INSTRUMENT DESIGNATIONS

K	GAIN OR ATTENUATE (INPUT:OUTPUT)
-K	GAIN AND REVERSE
Σ	ADD OR SUM (ADD AND SUBTRACT)
Δ	SUBTRACT (DIFFERENCE)
√	EXTRACT SQUARE ROOT
÷	DIVIDE
F(X)	CHARACTERIZE SIGNAL
>	HIGH-SELECT
<	LOW-SELECT
×	MULTIPLY
∫	INTEGRATE (TIME INTEGRAL)
CH_4	METHANE
CL_2	CHLORINE RESIDUAL
CO_2	CARBON DIOXIDE
COND	CONDUCTIVITY
DO	DISSOLVED OXYGEN
HYD	HYDROCARBON
LEL	LOWER EXPLOSIVE LIMIT
MCC	MOTOR CONTROL CENTER
MLSS	MIXED LIQUOR SUSPENDED SOLIDS
O_2	OXYGEN (PURITY)
pH	pH CELL
SDI	SOLIDS DENSITY INDEX
TSS	TOTAL SUSPENDED SOLIDS
TURB	TURBIDITY

HAND SWITCH DESIGNATIONS

HOA	HAND-OFF-AUTO
LR	LOCAL REMOTE
OC	OPEN-CLOSE
OO	ON-OFF
LOR	LOCAL-OFF-REMOTE
OOA	ON-OFF-AUTO
OCR	OPEN-CLOSE-REMOTE
OOR	ON-OFF-REMOTE
FR	FORWARD-REVERSE
N-M	NORMAL-MAINTENANCE
JOG	MOMENTARY JOG
E-STOP	EMERGENCY STOP

TRANSDUCER & CONVERTER DESIGNATION

E	VOLTAGE
H	HYDRAULIC
I	CURRENT
P	PNEUMATIC PULSE
R	RESISTANCE (ELECTRICAL)

EXAMPLE: I/P = CURRENT TO PNEUMATIC TRANSDUCER

POWER SUPPLY ABBREVIATIONS

AS	AIR SUPPLY
ES	ELECTRIC SUPPLY
HS	HYDRAULIC SUPPLY
WS	WATER SUPPLY

AS >— POWER SUPPLY SOURCE LABEL. USED ONLY WHERE NECESSARY TO HELP CLARIFY AN INSTRUMENT OR SYSTEM FUNCTION.

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PIPELINE MATERIAL CODE ABBREVIATIONS

CPVC1	CHLORINATED POLYVINYL CHLORIDE PIPE
CS1	CARBON STEEL
CS2	OAL TAR EPOXY LINED CARBON STEEL
FRP1	FIBERGLASS REINFORCED PLASTIC PIPE RATED FOR __ BAR
FRP2	FIBERGLASS REINFORCED PLASTIC PIPE RATED FOR __ BAR
PE1	HIGH DENSITY POLYETHYLENE PIPE RATED FOR __ BAR
PE2	HIGH DENSITY POLYETHYLENE PIPE RATED FOR __ BAR
PVC1	POLYVINYL CHLORIDE PIPE
PVC2	POLYVINYL CHLORIDE PIPE
SS1	C316 STAINLESS STEEL
SS2	SUPER DUPLEX STAINLESS STEEL RATED FOR 73 BAR
SS3	SUPER DUPLEX STAINLESS STEEL RATED FOR 87 BAR
SS4	CARPENTER 20

FIGURE 2

CITY OF SACRAMENTO

BLACK & VEATCH

Black & Veatch Corporation
Sacramento, California

P&ID LEGEND
SHEET 2 OF 3

PLOTTED:
SAVED:
B5065FIG-L FB5000FIG-L

SYSTEM CODE ABBREVIATIONS

ACTIVATED CARBON - GRANULAR	GAC
AERATION AIR/PROCESS AIR	AIR
AERATION SYSTEM	AER
AIR WASH	ARW
ANTI-SCALANT	ATS
BACKWASH - MEMBRANE/FILTER	BWH
BALLASTED FLOCCULATION	BAL
BIOSOLIDS	BIO
BLENDED SLUDGE	BLS
BRINE	BRN
CARBON DIOXIDE	CO2
CENTRATE	CEN
CITRIC ACID	CA
CLEAN IN PLACE	CIP
COAGULATION	COA
COMPRESSED AIR - INSTRUMENT	CAI
COMPRESSED AIR - SERVICE	CMS
COPPER SULFATE	CUS
CORROSION INHIBITOR	CI
DETERGENT	DET
DEWATERING	DWT
DIESEL FUEL	FUE
DISSOLVED AIR FLOTATION	DAF
DRAINAGE	DRN
EFFLUENT PUMPING	EFP
ENERGY RECOVERY SYSTEM	ERS
ENGINE EXHAUST	EXH
EQUALIZATION BASIN	EQB
FERRIC CHLORIDE	FEC
FILTRATION	FLT
FLOCCULATION	FLC
GASEOUS OXYGEN	GOX
GASOLINE	GSL
GENERATOR	GEN
GREASE	GRS
HYDRAULIC FLUID	HFL
HYDROFLUOSILICIC ACID	HFA
INFLUENT PUMPING	INFP
INTAKE	INT
LAGOON STORAGE	LAG
LIQUID OXYGEN	LOX
LP GAS OR PROPANE GAS	LPG
MEMBRANE	MEM
MIXED LIQUOR	MXL
NATURAL GAS	NG
NITROGEN	NIT
ODOR CONTROL	ODC
OIL	OIL
OIL - FUEL	FO
PHOSPHATE	PPP
PHOSPHORIC ACID	PO4
PLANT EFFLUENT WASTEWATER	PEW
POLYMER	POLF
POWDERED ACTIVATE CARBON	PAC
RAW WATER PUMPING	RWP
RECIRCULATED SLUDGE	RCS
RECLAIMED WATER	RCW
RESIDUALS	RES
REVERSE OSMOSIS	ROS
SCREENINGS	SCR
SECONDARY CLARIFICATION	SCL
SECONDARY SCUM	SSC
SEPTAGE	SEP
SETTLED WATER	SET
SEWAGE	SEW
SODA ASH	NAC
SODIUM BISULPHITE	NHS
SODIUM FLUORIDE	NAF
SODIUM HYPOCHLORITE	NOCL
STORM WATER	STW
SULFURIC ACID	HSO4
THICKENING	THCK
TREATED WATER	TW
ULTRAVIOLET	UV
VACUUM	VAC
WASH WATER	WW
WASTE WASH WATER	WWW
WATER - COOLING	COLW
WATER - DISTILLED WATER	DW
WATER - FIRE	FW
WATER - IRRIGATION	IRW
WATER - SEAL	SWT
WATER - WATER HEATING	HW
WATER, NON-POTABLE	NPW
WATER, POTABLE	PW
WATER, RAW	RW
WATER, SERVICE	SVW
WATER, DISTRIBUTION SYSTEM	DSW

FUNCTION CODE ABBREVIATIONS

ACTIVATION CHAMBER	AC
ADJUSTABLE FREQUENCY DRIVE	AFD
AERATOR, COARSE BUBBLE DIFFUSED	ACD
AERATOR, FINE PORE DIFFUSED	AEFD
AFTERCOOLER	AFC
AIR DRYER	AD
AIR FILTER	FLT
AIR RECEIVER	AR
AIR SEPARATOR	AS
AIR STRIPPER	AST
BACKFLOW PREVENTER	BFP
BASIN	BSN
BASIN, AERATION	BSNA
BELT FILTER PRESS	BFPS
BIN (STORAGE - ALL TYPES)	BN
BIN ACTIVATOR	BA
BLOWER, CENTRIFUGAL	BLC
BLOWER, POSITIVE DISPLACEMENT	BL
BOILER	BLR
BUILDING SERVICES EQUIPMENT	EQPB
CALIBRATION COLUMN	CCLM
CENTRIFUGE	CFG
CHEMICAL FEEDER	CHF
CLARIFIER, PRIMARY	PCLR
CLARIFIER, SECONDARY	SCLR
CLEARWELL	CW
COMPRESSOR	CMR
COMPRESSOR, BASE MOUNTED	CP
COMPRESSOR, ROTARY SCREW	CMR
CONTAINER, PROCESS	CTR
CONVEYOR, BELT	CB
CONVEYOR, SCREW	COS
CRANE	CR
CRANE, GANTRY	CRG
CRANE, JIB	CRJ
CRANE, PORTABLE GANTRY	CRP
CRANE, TRAVELLING BRIDGE	CRT
DAY TANK	DT
DIAPHRAGM SEAL	DPS
DIFFUSER	DIF
DIFFUSER BANK	DFB
DISINFECTION UNIT, UV	DSUV
DISSOLVED AIR FLOTATION THICKENER	DAF
DUST COLLECTOR	DUC
ELECTRICAL EQUIPMENT, GENERAL	EQPE
EMERGENCY EYE WASH STATION	EMEW
EMERGENCY SHOWER	ES
EMERGENCY SHOWER & EYEWASH	ESE
ENGINE-GENERATOR	EG
EQUIPMENT, GENERAL OR UNSPECIFIED	EQPT
EVAPORATOR	EV
EXPANSION CHAMBER	EXC
FAN SUPPLY OR EXHAUST	FAN
FILTER SEPARATOR	FTSP
FILTER, CARTRIDGE TYPE	FLC
FILTER, GENERIC	FLT
FILTER, UNDERDRAINS AND MEDIA	FL
FILTER. SURFACE WASH EQUIPMENT	FL
FLOCCULATOR-MIXER	MXP
FLOOR DRAIN	FD
FLOW SPLITTER	FS
FLUME, PARSHALL	FE
FOAM SEPARATOR	FMSP
GATE, FLAP	GFL
GATE, SLIDE	GSD
GATE, SLUICE	GSC
GATE, WEIR	G
GENERATOR, ENGINE (BACKUP POWER)	GEN
GRAVITY THICKENER	GVT
HEAT EXCHANGER	HEX
HEATER, (TANK HEATER)	HTR
HOIST, CHAIN	HSC
INJECTOR, CHEMICAL	INJ
MEMBRANE, FILTER	MFM
MEMBRANE, MICROFILTRATION	MBMF
MEMBRANE, REVERSE OSMOSIS	MBRO
MIXER, FLOCCULATION - PADDLE	MXP
MIXER, IN-LINE	MXI
MIXER, RAPID	MXP
MIXER, STATIC	MXS
MIXER, SUBMERSIBLE PROPELLER	AG
MOTOR CONTROL CENTER	MCC
OIL MIST ELIMINATOR	OME
PENSTOCK	PS
POLYMER RING	PIR
POWER SUPPLY UNIT	PSU
PULSATION DAMPNER	PD
PUMP, AIR DIAPHRAGM	PAD
PUMP, CENTRIFUGAL	PCL
PUMP, DIAPHRAGM METERING	PDM
PUMP, HORIZONTAL END SUCTION	PCL
PUMP, HORIZONTAL SPLIT CASE	PCL
PUMP, PERISTALTIC	PP
PUMP, PROGRESSING CAVITY	PPC
PUMP, SUBMERSIBLE	PSM
PUMP, SUBMERSIBLE SUMP	PP
PUMP, SUMP	PP
PUMP, UNSPECIFIED TYPE	PP
PUMP, VERTICAL DIFFUSION VANE	PVE
REDUCED VOLTAGE SOFT STARTER	RVSS
RESERVOIR	RSV
RESIDUAL COLLECTOR	RCO
ROTAMETER	RM
RUPTURE DISK	RD
SAMPLER	SAMP
SCALE	SL
SCREEN, MECHANICALLY CLEANED BAR	SCRA
SCREEN, STEP	SCRS
SCREEN, TRAVELLING WATER	SCT
SCUM COLLECTOR	SMC
SCUM WEIR - ROTATING	SCW
SEPARATOR	SEP
SIGHT GLASS - TALL	SGT
SIGHTGLASS	SG
SILENCER	SIL
SLUDGE COLLECTOR, CIRCULAR	SLC
SLUDGE COLLECTOR, FLOCCULATING-CLARIFYING	SFC
SLUDGE COLLECTOR, SECONDARY CLARIFIERS	SCS
SLUDGE COLLECTOR, SOLIDS CONTACT	SSC
SLUDGE COLLECTOR, STRAIGHT LINE	SLCS
SLUDGE GRINDER	SLG
SOLIDS BLENDER-INLINE	SBL
STOP LOG	STLG
STRAINER	STR
STRAINER BASKET TYPE	STRB
STRAINER Y TYPE	STRY
SURGE CHAMBER	SRCH
TANK, ABOVE GROUND STORAGE	TNK
TANK, DOUBLE WALL	TNK
TANK, ELEVATED STORAGE	TNK
TANK, EXPANSION	TNK
TANK, FRP CHEMICAL STORAGE	TNK
TANK, GENERAL OR UNSPECIFIED	TNK
TANK, PE CHEMICAL STORAGE	TNK
TANK, STEEL CHEMICAL STORAGE	TNK
TANK, STEEL WATER STORAGE	TNK
TRAP, DRIP	TRP
TRAP, SEDIMENT	TRPS
UNINTERRUPTABLE POWER SUPPLY	UPS
VACUUM REGULATOR	VRG
VALVE, AIR RELEASE	ARV
VALVE, AIR-VACUUM	AVRV
VALVE, ANGLE	VAG
VALVE, BUTTERFLY	VBF
VALVE, BUTTERFLY, TYPE 1	VBF1
VALVE, BUTTERFLY, TYPE 2	VBF2
VALVE, BUTTERFLY, TYPE 3	VBF3
VALVE, BUTTERFLY, TYPE 4	VBF4
VALVE, BUTTERFLY, TYPE 5	VBF5
VALVE, BALL	VBM
VALVE, BALL, TYPE 1	VBM1
VALVE, BALL, TYPE 2	VBM2
VALVE, BALL, TYPE 3	VBM3
VALVE, BALL, TYPE 4	VBM4
VALVE, BALL, TYPE 5	VBM5
VALVE, CHECK	VCK
VALVE, CHECK, TYPE 1	VCK1
VALVE, CHECK, TYPE 2	VCK2
VALVE, CHECK, TYPE 3	VCK3
VALVE, CHECK, TYPE 4	VCK4
VALVE, CHECK, TYPE 5	VCK5
VALVE, CONE	VCN
VALVE, DIAPHRAGM OPERATED OPEN OR CLOSE	VDG
VALVE, DOUBLE DISC GATE	VGD
VALVE, ECCENTRIC PLUG	VPL
VALVE, ECCENTRIC PLUG, TYPE 1	VPL1
VALVE, ECCENTRIC PLUG, TYPE 2	VPL2
VALVE, ECCENTRIC PLUG, TYPE 3	VPL3
VALVE, EXPLOSION RELIEF	VER
VALVE, GATE	VG
VALVE, GENERAL OR UNSPECIFIED	V
VALVE, GLOBE	VGL
VALVE, INDUSTRIAL BUTTERFLY	VBI
VALVE, KNIFE GATE	VKG
VALVE, MATERIAL HANDLING ROTARY	VMR
VALVE, MUD	VMD
VALVE, PILOT	PTV
VALVE, PINCH	VPN
VALVE, PISTON OPERATED	VPO
VALVE, PLUG	VPG
VALVE, PLUG, TYPE 1	VPG1
VALVE, PLUG, TYPE 2	VPG2
VALVE, PLUG, TYPE 3	VPG3
VALVE, PLUG, TYPE 4	VPG4
VALVE, PRESSURE REDUCING	VPR
VALVE, PRESSURE REGULATING	VPC
VALVE, PRESSURE RELIEF	VSP
VALVE, PRESSURE/VACUUM RELIEF	VSPV
VALVE, SAFETY	VS
VALVE, SLEEVE	VSLV
VALVE, SOLENOID	VSL
VALVE, THREE WAY	VTW
VALVE, VACUUM BREAKER	VVB
VALVE, VACUUM RELIEF	VSV
VALVE, V-PORT BALL	VP
VAPORIZER	VAP
WEIR, CIPOLETTI	WC
WEIR, RECTANGULAR	WR
WEIR, V-NOTCH	WV
WELL, VERTICAL	WLV

FIGURE 3

CITY OF SACRAMENTO

BLACK & VEATCH

Black & Veatch Corporation
Sacramento, California

P&ID LEGEND
SHEET 3 OF 3

PLOTTED:
SAVED:
B5065FIG-L FB5000FIG-L

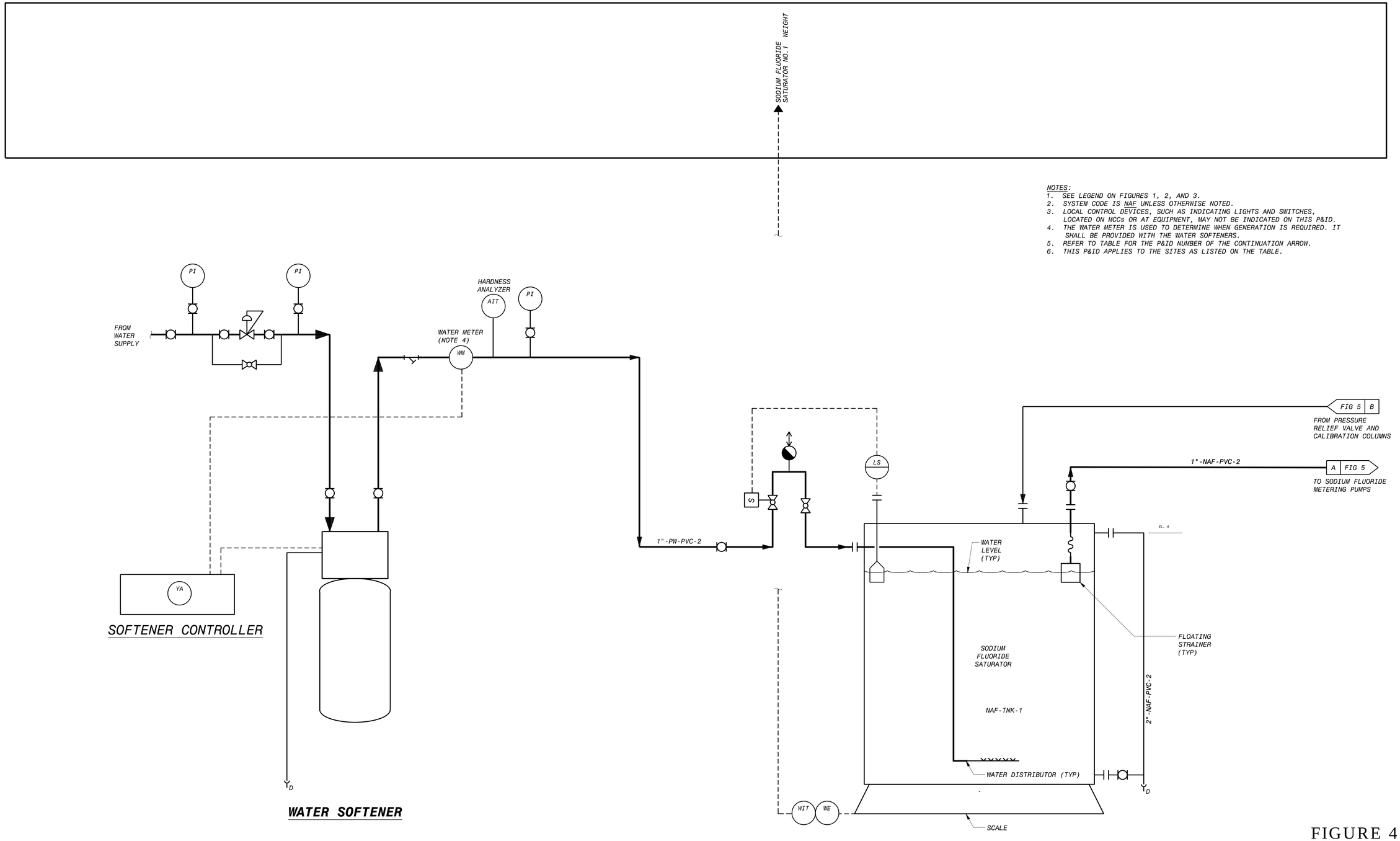


FIGURE 4

CITY OF SACRAMENTO

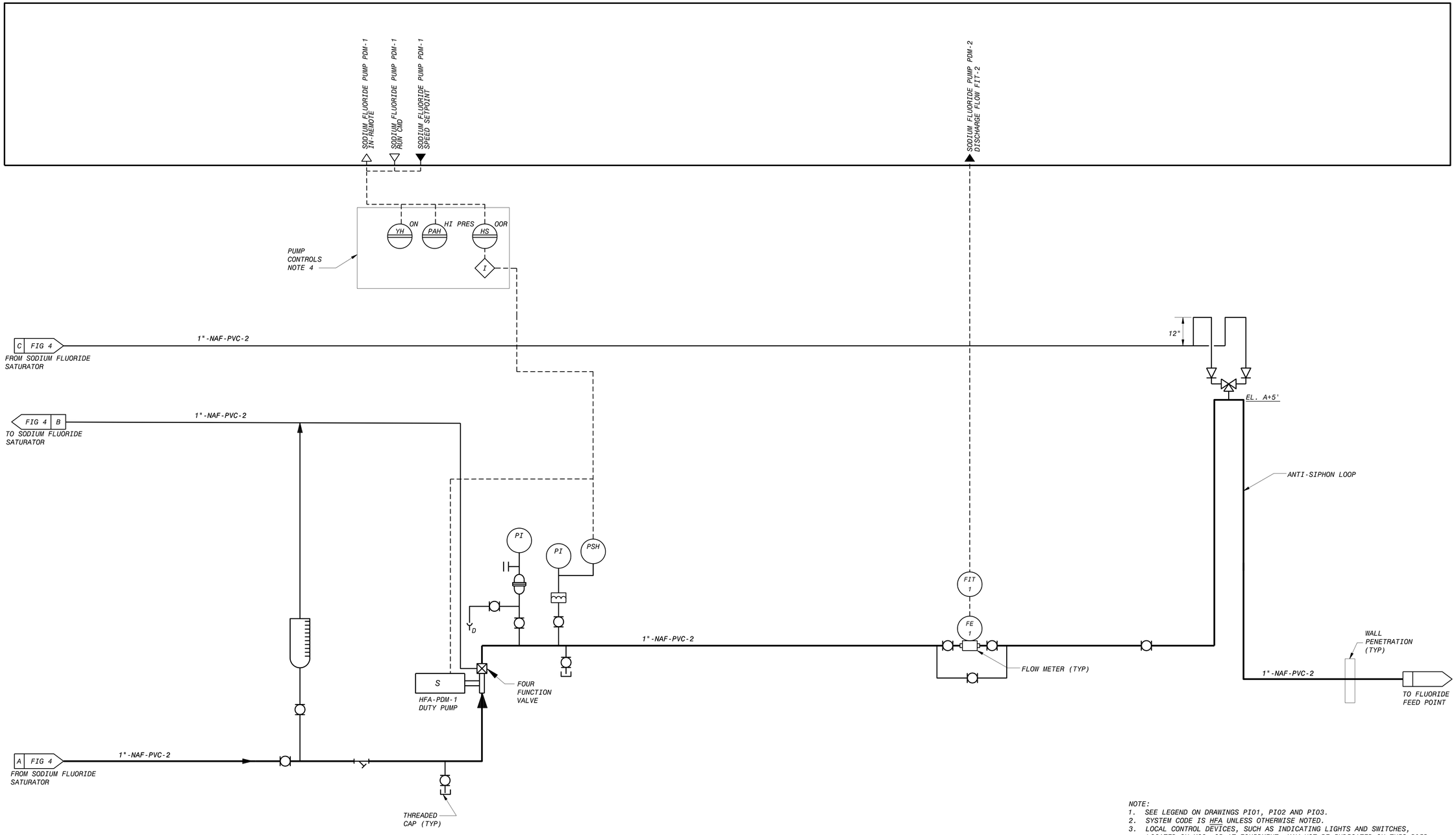
SODIUM FLUORIDE STORAGE SYSTEM - WELL SITES

BLACK & VEATCH

Black & Veatch Corporation
Sacramento, California

PLOTTED:
SAVED:
B5065FIG-L FB5000FIG-L

Date/Time, Plotted : 1/28/2011 10:12:41 AM



NOTE:
1. SEE LEGEND ON DRAWINGS PIO1, PIO2 AND PIO3.
2. SYSTEM CODE IS HFA UNLESS OTHERWISE NOTED.
3. LOCAL CONTROL DEVICES, SUCH AS INDICATING LIGHTS AND SWITCHES, LOCATED ON MCCs OR AT EQUIPMENT, MAY NOT BE INDICATED ON THIS P&ID.
4. CONTROLS ARE INTEGRAL TO THE METERING PUMP.

FIGURE 5

CITY OF SACRAMENTO

SODIUM FLUORIDE FEED SYSTEM - WELL SITES

BLACK & VEATCH

Black & Veatch Corporation
Sacramento, California

PLOTTED:
SAVED:
B5065FIG-L FB5000FIG-L

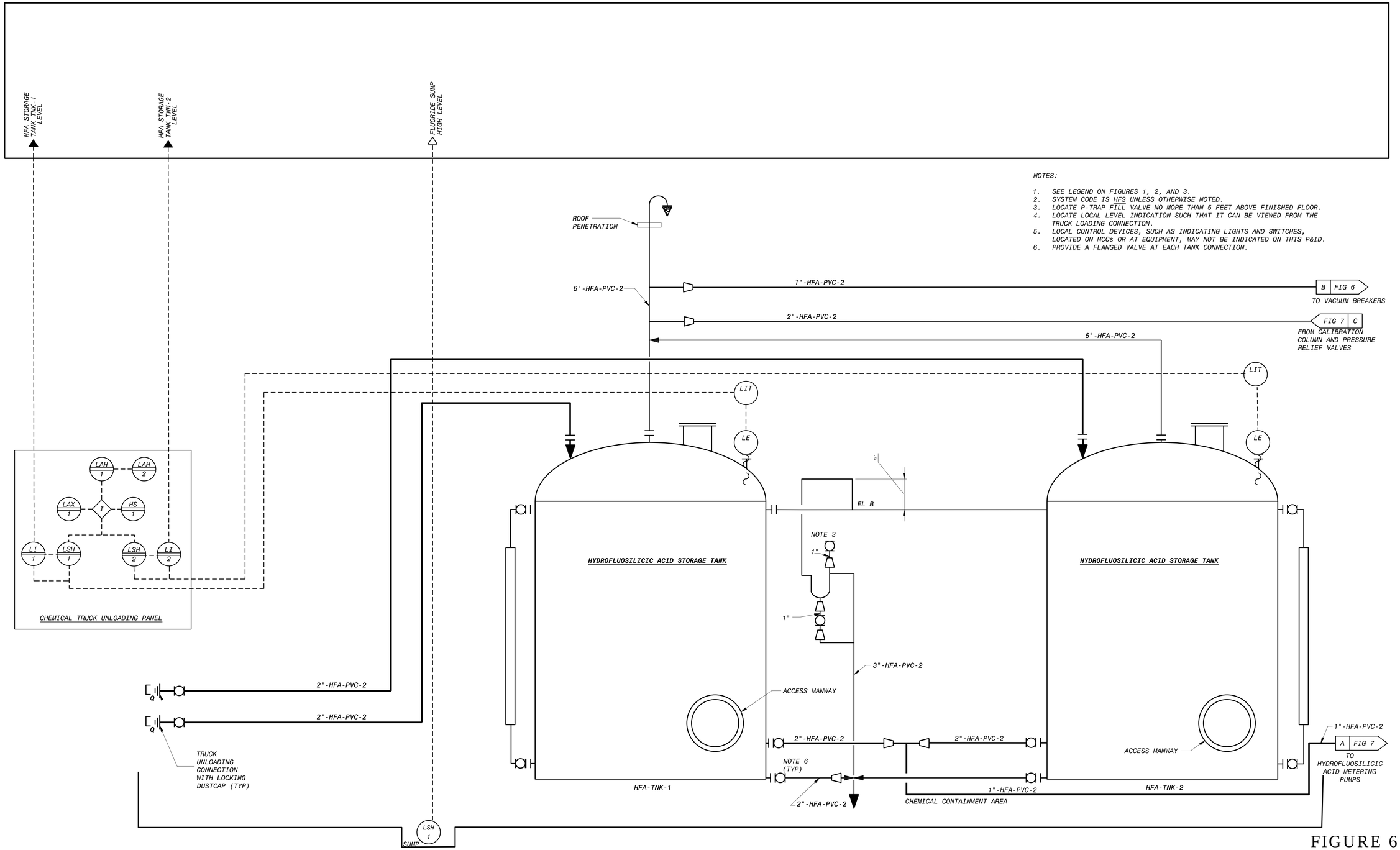


FIGURE 6

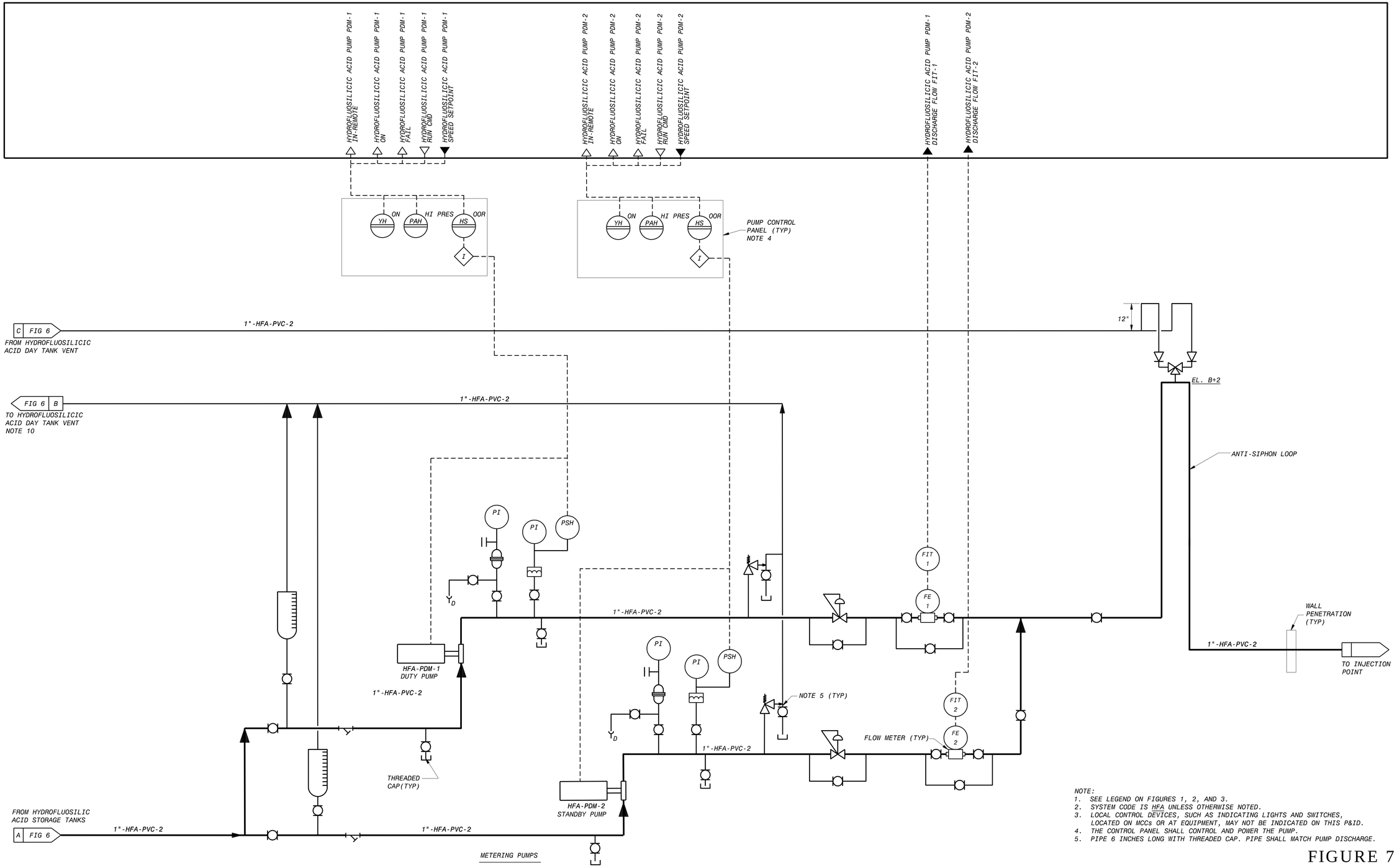
CITY OF SACRAMENTO

HYDROFLUOSILICIC ACID STORAGE SYSTEM - WTP

BLACK & VEATCH

Black & Veatch Corporation
Sacramento, California

PLOTTED:
SAVED:
B5065FIG-L FB5000FIG-L



NOTE:
1. SEE LEGEND ON FIGURES 1, 2, AND 3.
2. SYSTEM CODE IS HFA UNLESS OTHERWISE NOTED.
3. LOCAL CONTROL DEVICES, SUCH AS INDICATING LIGHTS AND SWITCHES, LOCATED ON MCCs OR AT EQUIPMENT, MAY NOT BE INDICATED ON THIS P&ID.
4. THE CONTROL PANEL SHALL CONTROL AND POWER THE PUMP.
5. PIPE 6 INCHES LONG WITH THREADED CAP. PIPE SHALL MATCH PUMP DISCHARGE.

FIGURE 7

CITY OF SACRAMENTO

HYDROFLUOSILICIC ACID FEED SYSTEM - WTP

BLACK & VEATCH

Black & Veatch Corporation
Sacramento, California

PLOTTED:
SAVED:
B5065FIG-L FB5000FIG-L

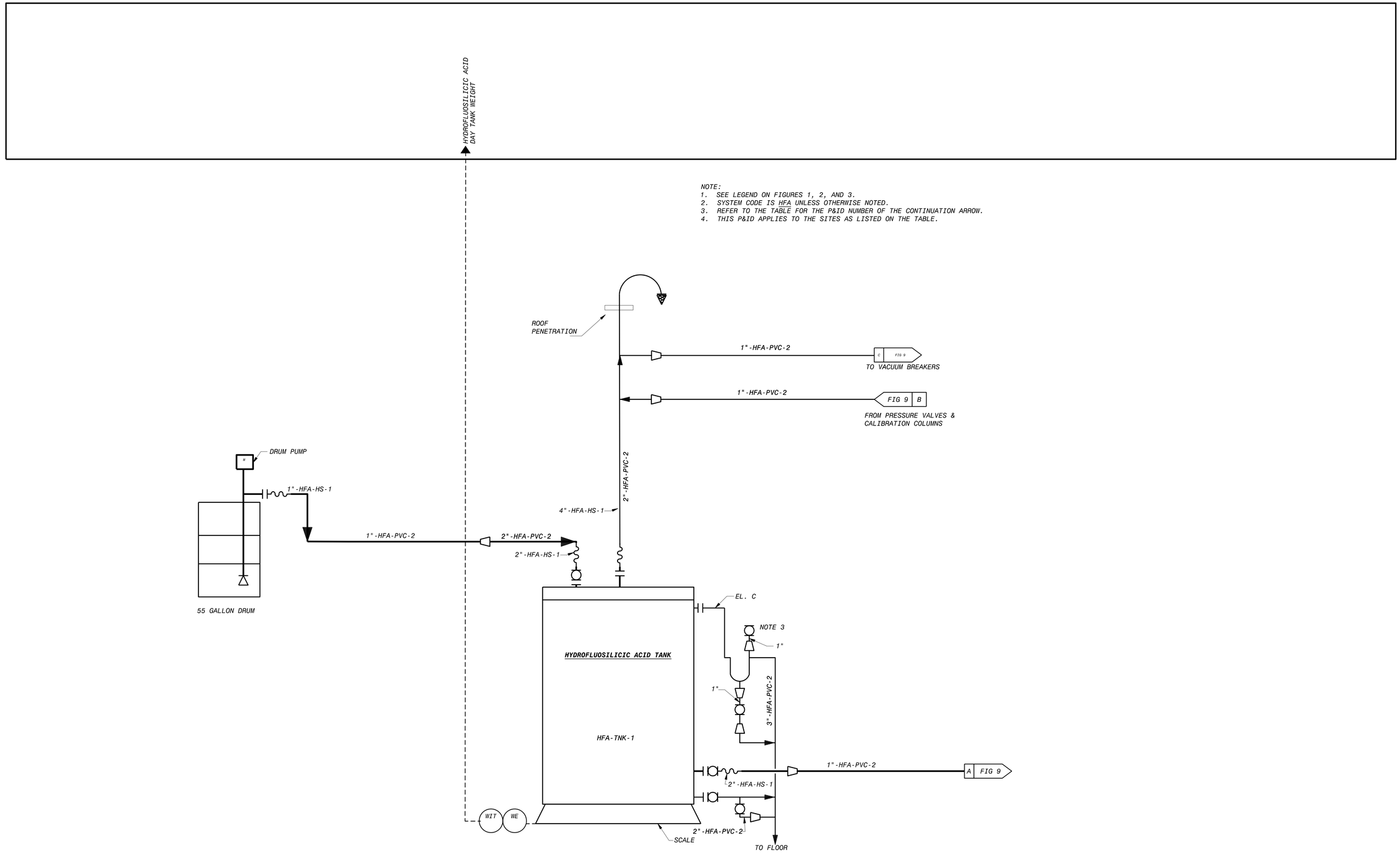


FIGURE 8

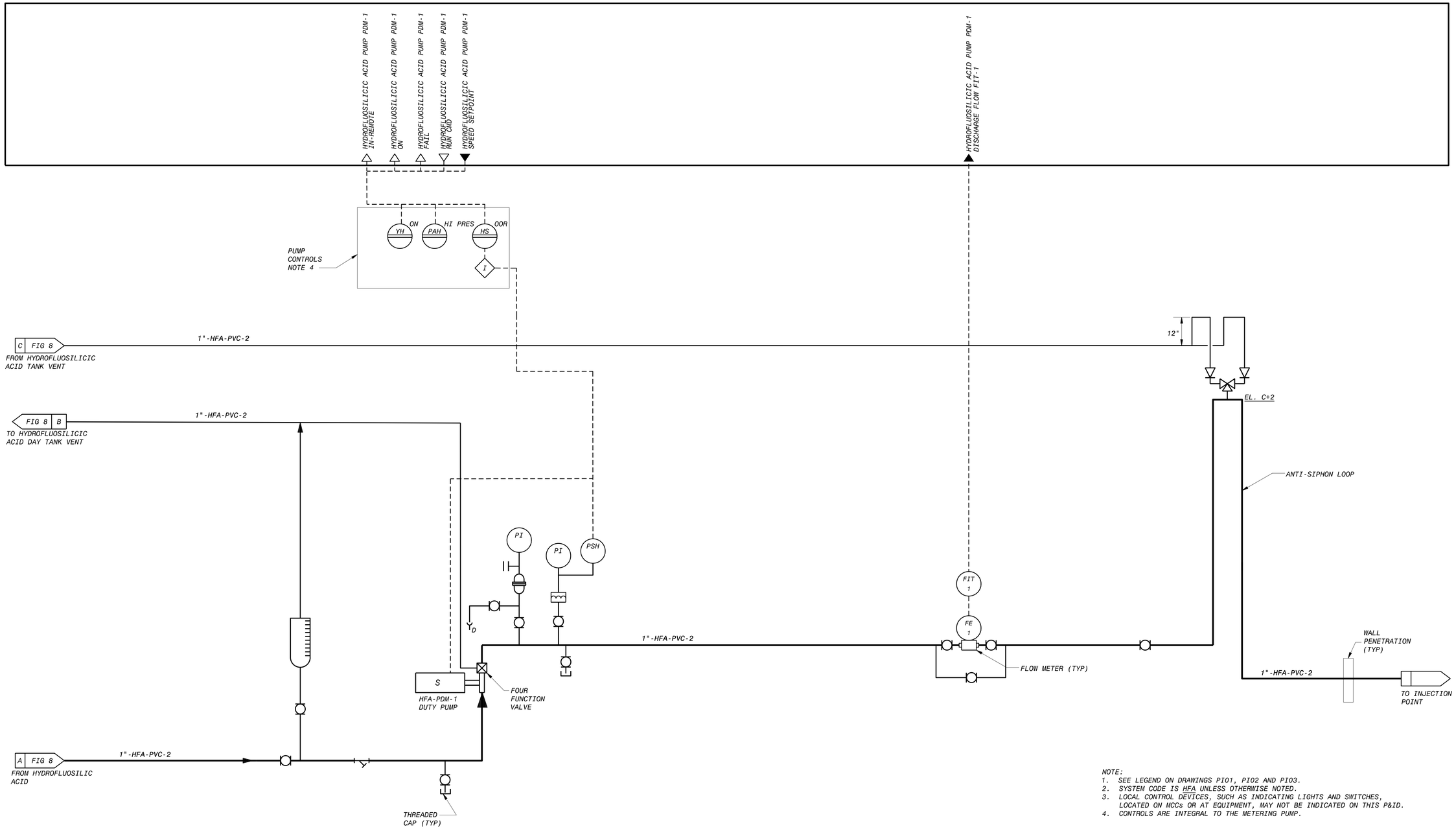
CITY OF SACRAMENTO

HYDDROFLUOSILICIC ACID STORAGE SYSTEM - WELL SITES

BLACK & VEATCH

Black & Veatch Corporation
Sacramento, California

PLOTTED:
SAVED:
FB5000FIG-L
B5065FIG-L



NOTE:
1. SEE LEGEND ON DRAWINGS PIO1, PIO2 AND PIO3.
2. SYSTEM CODE IS HFA UNLESS OTHERWISE NOTED.
3. LOCAL CONTROL DEVICES, SUCH AS INDICATING LIGHTS AND SWITCHES, LOCATED ON MCCs OR AT EQUIPMENT, MAY NOT BE INDICATED ON THIS P&ID.
4. CONTROLS ARE INTEGRAL TO THE METERING PUMP.

FIGURE 9

CITY OF SACRAMENTO

HYDROFLUOSILICIC ACID FEED SYSTEM - WELL SITES

BLACK & VEATCH

Black & Veatch Corporation
Sacramento, California

PLOTTED:
SAVED:
B5065FIG-L FB5000FIG-L

APPENDIX D – OPINION OF PROBABLE CONSTRUCTION COSTS

BLACK & VEATCH
Building a world of difference.

10995 Gold Center Drive Suite 100, Rancho Cordova, CA 95670

B&V Project 172145

PRELIMINARY DESIGN

CITY OF SACRAMENTO
SACRAMENTO, CA

FLUORIDATION STUDY

PRELIMINARY OPINION ON CAPITAL AND ANNUAL O & M COST
February 2011

SUMMARY			
		COST	
Sodium Fluoride Improvements (unit cost per well site)		$ 5,000	
(Step 1: Optimization of Existing Water Softener System)			
Subtotal (27 well sites)		$ 135,000	
General Conditions (Bonds, Insurance, etc)	10%	$ 14,000	
Contingency	25%	$ 37,000	
Mid-Point of Construction		$ 9,000	
Rate = % 5.0%			
Time = Years 1.00			$(S=P(1+i)^n)$
TOTAL PROBABLE CONSTRUCTION COST		**$ 195,000**	

SUMMARY			
		COST	
Sodium Fluoride Improvements (unit cost per well site)		$ 9,000	
(Step 2: New Sodium Fluoride Saturator)			
Subtotal (27 well sites)		$ 243,000	
General Conditions (Bonds, Insurance, etc)	10%	$ 24,000	
Contingency	25%	$ 67,000	
Mid-Point of Construction		$ 17,000	
Rate = % 5.0%			
Time = Years 1.00			
TOTAL PROBABLE CONSTRUCTION COST		**$ 351,000**	

SUMMARY			
		COST	
Sodium Fluoride Improvements (unit cost per well site)		$ 21,000	
(Step 3: New Metering Pumps and Chemical Piping)			
Subtotal (27 well sites)		$ 567,000	
General Conditions (Bonds, Insurance, etc)	10%	$ 57,000	
Contingency	25%	$ 156,000	
Mid-Point of Construction		$ 39,000	
Rate = % 5.0%			
Time = Years 1.00			
TOTAL PROBABLE CONSTRUCTION COST		**$ 819,000**	
Hydrofluosilicic Acid Improvements (unit cost per well site)		73,000	
Subtotal (27 well sites)		$ 1,971,000	
General Conditions (Bonds, Insurance, etc)	10%	$ 197,000	
Contingency	25%	$ 542,000	
Mid-Point of Construction		$ 136,000	
Rate = % 5.0%			
Time = Years 1.00			$(S=P(1+i)^n)$
TOTAL PROBABLE CONSTRUCTION COST		**$ 2,846,000**	

	Chemical Cost*	Labor Estimate	Equipment Replacement	Total
Sodium Fluoride (Current System)	$2,400	$15,000	$700	$18,100
TOTAL O&M COSTS (27 WELL SITES)				$488,700
Sodium Fluoride (Optimized Water Softener, New Equipment)	$2,400	$12,900	$600	$15,900
TOTAL O&M COSTS (27 WELL SITES)	$64,800	$348,300	$16,200	$429,300
Hydrofluosilicic Acid	$5,900	$9,900	$1,000	$16,800
TOTAL O&M COSTS (27 WELL SITES)	$159,300	$267,300	$27,000	$453,600
Hydrofluosilicic Acid w/Delivery Service	$8,400	$8,000	$1,000	$17,400
TOTAL O&M COSTS (27 WELL SITES)	$226,800	$216,000	$27,000	$469,800
* Chemical costs should decrease if the EPA reduces the fluoride target level to 0.7.				

BLACK & VEATCH

City of Sacramento
Fluoridation Study
Sacramento, California
Well Site Improvements Preliminary Opinion of Probable Construction Cost (OPCC)
February 2011

Item Description	Quantity	Unit	Unit Cost	Total Cost
WELL SITE SODIUM FLUORIDE FACILITY - OPTION 1, STEP 1, WATER SOFTENER IMPROVEMENTS				
Mobilization	7%	% of Total		$330
Lab Service, Culligan Water Consultation		LS		$1,000
Equipment				
Misc. Interior Piping / Devices	1	LS	$3,000	$3,000
Instrumentation and Control	10%	% of Total		$400
Electrical	8%	% of Total		$320
WELL SITE SODIUM FLUORIDE FACILITY TOTAL				$5,000

Item Description	Quantity	Unit	Unit Cost	Total Cost
WELL SITE SODIUM FLUORIDE FACILITY - OPTION 1, STEP 2, NEW SATURATOR				
Mobilization	7%	% of Total		$566
Equipment				
Saturator	1	EA	$2,000	$2,000
Scale	1	EA	$4,000	$4,000
Demolition	1	LS	$1,000	$1,000
Instrumentation and Control	10%	% of Total		$600
Electrical	8%	% of Total		$480
WELL SITE SODIUM FLUORIDE FACILITY TOTAL				$9,000

Item Description	Quantity	Unit	Unit Cost	Total Cost
WELL SITE SODIUM FLUORIDE FACILITY - OPTION 1, STEP 3, NEW PUMPS, FLOWMETER, REPLACE PIPING				
Mobilization	7%	% of Total		$1,392
Equipment				
Chemical Metering Pumps	2	EA	$2,000	$4,000
Chemical piping and accessories	100	LF	$30	$3,000
Chemical valves	10	EA	$100	$1,000
Flowmeter	2	EA	$4,000	$8,000
Demolition	1	LS	$1,000	$1,000
Instrumentation and Control	10%	% of Total		$1,600
Electrical	8%	% of Total		$1,280
WELL SITE SODIUM FLUORIDE FACILITY TOTAL				$21,000

Item Description	Quantity	Unit	Unit Cost	Total Cost
Well Site Hydrofluosilicic Acid Facility				
Mobilization	7%	% of Total		$4,759
Finishes				
Protective Coating on Equipment/Piping	1	LS	$5,000	$5,000
Equipment				
Chemical Metering Pumps	2	EA	$2,000	$4,000
Transfer Pumps	1	EA	$2,000	$2,000
Bulk Storage Tank (5200gallons)	0	EA	$20,800	$0
Day Tank (w/ scale)	1	EA	$4,500	$4,500
Truck Unloading Panel	0	EA	$5,000	$0
Chemical piping and accessories	100	LF	$30	$3,000
Chemical valves	20	EA	$100	$2,000
Static Mixer	1	EA	$11,200	$11,200
Sump Pump	0	EA	$6,000	$0
Emergency Shower and Eyewash	1	EA	$4,000	$4,000
Portable Fluoride Hand-Held Analyzer	1	EA	$4,000	$4,000
Flowmeter	1	EA	$4,000	$4,000
Misc. Interior Piping / Devices	1	LS	$3,000	$3,000
Special Construction				
Fiberglass Shed	100	SF	$100	$10,000
Demolition	1	LS	$1,000	$1,000
Instrumentation and Control	10%	% of Total		$5,670
Electrical	8%	% of Total		$4,616
WELL SITE HYDROFLUOSILICIC ACID FACILITY				$73,000

BLACK & VEATCH

Well Site
City of Sacramento
Sacramento, California
Well Site Operation and Maintenance Cost
February 2011

Sodium Fluoride

Current System	
ANNUAL O&M COSTS	
Chemical Costs	
Sodium Fluoride	
Cost of sodium fluoride, $/lb	$0.88
Sodium Fluoride usage - avg dose/max well capacity, lbs/d	7
Total sodium fluoride cost, $/year	$2,248
Water Softener Service/per year/per well	131
Total water softener cost, $/year	$131
Sodium Fluoride Disposal	
Sodium fluoride disposal costs, $ per pound	$1.50
Pounds of sodium fluoride disposed of per year	22
Total disposal cost, $/year	$33
Total Chemical Costs, $/year	$2,413
Labor	
Chemical Delivery	
Duration, hours	0.10
Frequency, per year	12.00
Total labor, per year, hours	1.20
Water Quality Checks	
Duration, hours	1.5
Frequency, per year	52
Total labor, per year, hours	78.0
Troubleshooting Fl faults & dosage issues	
Duration, hours	1.5
Frequency, per year	6
Total labor, per year, hours	9
Additional Operations Time to Restart Wells after Fl faults	
Duration, hours	1
Frequency, per year	6
Total labor, per year, hours	6
Saturator Cleanout	
Duration, hours	6.00
Frequency, per year	2.00
Total labor, per year, hours	12.00
Exchange Water Softeners	1
Duration, hours	0.5
Frequency, per year	6.0
Total labor, per year, hours	3.0
Program Management	
Duration, hours	0.1
Frequency, per year	12
Total labor, per year, hours	1.2

Transcribing Datasheets. Prepare & QAQC DPH Reports	
Duration, hours	0.1
Frequency, per year	12
Total labor, per year, hours	1.2
Equipment Maintenance and Repair	
Duration, hours	9.0
Frequency, per year	4.0
Total labor, per year, hours	36.0
Equipment Maintenance: Electrical & Instrumentation	
Duration, hours	2.0
Frequency, per year	1.0
Total labor, per year, hours	2.0
Overall Labor Costs	
Total number of hours of labor per year	150
Hourly rate, $/hr	$100.00
Total Labor cost per year	$14,960
Chemical Feed and Safety Equipment Replacement	
Number of equipment	1
Equipment install year	0
Replacement year	15
Cost of equipment replacement, $/year	$700
Total Annual O&M Cost per Well Site	***$18,073***

Sodium Fluoride

Option 1, 2, 3 - Optimized Sodium Fluoride System	
ANNUAL O&M COSTS	
Chemical Costs	
Sodium Fluoride	
Cost of sodium fluoride, $/lb	$0.88
Sodium Fluoride usage - avg dose/max well capacity, lbs/d	7
Total sodium fluoride cost, $/year	$2,248
Water Softener Service/per year/per well	131
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Pounds of sodium fluoride disposed of per year	22
Total disposal cost, $/year	$33
Total Chemical Costs, $/year	$2,413
Labor	
Chemical Delivery	
Duration, hours	0.10
Frequency, per year	12.00
Total labor, per year, hours	1.20
Water Quality Checks	
Duration, hours	1.5
Frequency, per year	52
Total labor, per year, hours	78.0
Troubleshooting Fl faults & dosage issues	
Duration, hours	1.0
Frequency, per year	6
Total labor, per year, hours	6
Additional Operations Time to Restart Wells after Fl faults	

Duration, hours	0
Frequency, per year	6
Total labor, per year, hours	0
Saturator Cleanout	
Duration, hours	6.00
Frequency, per year	2.00
Total labor, per year, hours	12.00
Exchange Water Softeners	
Duration, hours	0.5
Frequency, per year	6.0
Total labor, per year, hours	3.0
Program Management	
Duration, hours	0.1
Frequency, per year	12
Total labor, per year, hours	1.2
Transcribing Datasheets. Prepare & QAQC DPH Reports	
Duration, hours	0.1
Frequency, per year	12
Total labor, per year, hours	1.2
Equipment Maintenance and Repair	
Duration, hours	6.0
Frequency, per year	4.0
Total labor, per year, hours	24.0
Equipment Maintenance: Electrical & Instrumentation	
Duration, hours	2.0
Frequency, per year	1.0
Total labor, per year, hours	2.0
Overall Labor Costs	
Total number of hours of labor per year	129
Hourly rate, $/hr	$100.00
Total Labor cost per year	$12,860
Chemical Feed and Safety Equipment Replacement	
Number of equipment	1
Equipment install year	0
Replacement year	15
Cost of equipment replacement, $/year	$600
Total Annual O&M Cost per Well Site	***$15,873***

Hydrofluosilicic Acid

ANNUAL O&M COSTS	
Chemical	
Hydrofluosilicic Acid	
Delivery Amount	100
Cost of chemical, $/gal	$8.12
Chemical usage - avg dose/max well capacity, gpd	2.00
Chemical cost, $/year	$5,928
Total Chemical Cost per year, $/yr	$5,928
Labor	
Chemical Delivery	
Duration, hours	0.10
Frequency, per year	12.00
Total labor, per year, hours	1.20
Monthly Safety Inspections	
Duration, hours	0.5
Frequency, per year	12.0
Total labor, per year, hours	6.0
Water Quality Checks	
Duration, hours	1.5
Frequency, per year	52
Total labor, per year, hours	78.0
Troubleshooting Fl faults & dosage issues	
Duration, hours	0.5
Frequency, per year	2
Total labor, per year, hours	1
Program Management	
Duration, hours	0.1
Frequency, per year	12
Total labor, per year, hours	1.2
Transcribing Datasheets. Prepare & QAQC DPH Reports	
Duration, hours	0.1
Frequency, per year	12
Total labor, per year, hours	1.2
Equipment Maintenance and Repair	
Duration, hours	4.0
Frequency, per year	2.0
Total labor, per year, hours	8.0
Equipment Maintenance: Electrical & Instrumentation	
Duration, hours	2.0
Frequency, per year	1.0
Total labor, per year, hours	2.0
Overall Labor Costs	
Total number of hours of labor per year	99
Hourly rate, $/hr	$100.00
Total Labor cost per year	$9,860
Chemical Feed and Safety Equipment Replacement	
Number of equipment	1
Equipment install year	0
Replacement year	15
Cost of equipment replacement, $/year	$1,000
Total Annual O&M Cost	***$16,788***

Hydrofluosilicic Acid w/ Delivery Service

ANNUAL O&M COSTS	
Chemical	
Hydrofluosilicic Acid	
3rd Party Delivery Service, $/yr/well site	$8,369
Total Chemical cost per year, $/yr	$8,369
Labor	
Water Quality Checks	
Duration, hours	1.3
Frequency, per year	52
Total labor, per year, hours	65.0
Monthly Safety Inspections	
Duration, hours	0.5
Frequency, per year	12.0
Total labor, per year, hours	6.0
Troubleshooting Fl faults & dosage issues	
Duration, hours	0.5
Frequency, per year	2
Total labor, per year, hours	1
Program Management	
Duration, hours	0.1
Frequency, per year	12
Total labor, per year, hours	1.2
Transcribing Datasheets. Prepare & QAQC DPH Reports	
Duration, hours	0.1
Frequency, per year	12
Total labor, per year, hours	1.2
Equipment Maintenance and Repair	
Duration, hours	2.0
Frequency, per year	2.0
Total labor, per year, hours	4.0
Equipment Maintenance: Electrical & Instrumentation	
Duration, hours	2.0
Frequency, per year	1.0
Total labor, per year, hours	2.0
Overall Labor Costs	
Total number of hours of labor per year	80
Hourly rate, $/hr	$100.00
Total Labor cost per year	$8,040
Chemical Feed and Safety Equipment Replacement	
Number of equipment	1
Equipment install year	0
Replacement year	15
Cost of equipment replacement, $/year	$1,000
Total Annual O&M Cost	***$17,409***

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10995 Gold Center Drive Suite 100, Rancho Cordova, CA 95670

B&V Project 172145

PRELIMINARY DESIGN

CITY OF SACRAMENTO
SACRAMENTO, CA

FLUORIDATION STUDY

PRELIMINARY OPINION ON CAPITAL AND ANNUAL O & M COST
February 2011

SUMMARY			
E.A. Fairbairn Hydrofluosilicic Acid System Improvements		$ 219,000	
(No Shelter, Replace Equipment and Piping Only)			
General Conditions (Bonds, Insurance, etc)	10%	$ 22,000	
Contingency	25%	$ 60,000	
Mid-Point of Construction		$ 15,000	
Rate = % 5.0%			
Time = Years 1.00			$(S=P(1+i)^n)$
TOTAL PROBABLE CONSTRUCTION COST		**$ 316,000**	
E.A. Fairbairn Hydrofluosilicic Acid System Improvements		$ 283,000	
(New Canopy Structure at Existing Site, New Equipment and Piping)			
General Conditions (Bonds, Insurance, etc)	10%	$ 28,000	
Contingency	25%	$ 78,000	
Mid-Point of Construction		$ 19,000	
Rate = % 5.0%			
Time = Years 1.00			$(S=P(1+i)^n)$
TOTAL PROBABLE CONSTRUCTION COST		**$ 408,000**	
E.A. Fairbairn Hydrofluosilicic Acid System Improvements		618,000	
(New Concrete Masonry Structure Across the Street)			
General Conditions (Bonds, Insurance, etc)	10%	$ 62,000	
Contingency	25%	$ 170,000	
Mid-Point of Construction		$ 43,000	
Rate = % 5.0%			
Time = Years 1.00			$(S=P(1+i)^n)$
TOTAL PROBABLE CONSTRUCTION COST		**$ 893,000**	
Sacramento River WTP Fluoridation Improvements		143,000	
(Tank, Piping and Valve Replacement)			
General Conditions (Bonds, Insurance, etc)	10%	$ 14,000	
Contingency	25%	$ 39,000	
Mid-Point of Construction		$ 10,000	
Rate = % 5.0%			
Time = Years 1.00			$(S=P(1+i)^n)$
TOTAL PROBABLE CONSTRUCTION COST		**$ 206,000**	

	Chemical Cost*	Labor Estimate	Equipment Replacement	Total
Hydrofluosilicic Acid (E.A. Fairbairn)	$215,700	$25,100	$1,000	$241,800
Hydrofluosilicic Acid (Sac River)	$212,100	$25,500	$1,000	$238,600

* Chemical costs should decrease if the EPA reduces the fluoride target level to 0.7.

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City of Sacramento
Fluoridation Study
Sacramento, California
WTP Fluoridation Opinion of Probable Construction Cost (OPCC)
February 2011

				E.A. Fairbairn WTP			Sac River WTP
				Replace Equip Only	New Masonry Building	New Canopy Structure	Replace Tanks, Valves, Piping
Item Description	Quantity	Unit	Unit Cost	Total Cost	Total Cost	Total Cost	Total Cost
WTP Hydrofluosilicic Acid Facilities							
Mobilization	7%	% of Total		$13,431	$37,931	$17,396	$8,764
Special Construction							
Concrete Masonry Unit Building (includes HVAC system)	1,200	SF	$150	$0	$180,000		
Alternative Canopy Structure	1,200	SF	$40	$0		$48,000	$0
Concrete, cast in place							
Slab on grade	44	CY	$600	$0	$26,667	$0	$0
Walls	16	CY	$1,000	$0	$15,556	$0	$0
Equipment pads	7	CY	$800	$0	$5,926	$0	$0
Finishes							
Concrete Protective Coating on Containment Area	1,620	SF	$15	$24,300	$24,300	$24,300	$0
Protective Coating on Equipment/Piping	1	LS	$5,000	$5,000	$5,000	$5,000	$5,000
Metals							
Guardpost	4	EA	$840	$0	$3,360	$0	$0
FRP Grating	400	SF	$90	$0	$36,000	$0	$0
Miscellaneous Metals (Welding, Bolts, etc.)	1	LS	$4,000	$0	$4,000	$0	$0
Handrail	40	LF	$98	$0	$3,920	$0	$0
Equipment							
Chemical Metering Pumps	2	EA	$12,000	$24,000	$24,000	$24,000	$24,000
Bulk Storage Tank (6000gallons)	2	EA	$24,000	$48,000	$48,000	$48,000	$48,000
Truck Unloading Panel	1	EA	$5,000	$5,000	$5,000	$5,000	$0
Chemical piping and accessories	300	LF	$30	$9,000	$9,000	$9,000	$9,000
Chemical valves	20	EA	$100	$2,000	$2,000	$2,000	$2,000
Static Mixer	1	EA	$11,200	$11,200	$11,200	$11,200	$0
Sump Pump	1	EA	$6,000	$6,000	$6,000	$6,000	$6,000
Emergency Shower and Eyewash	2	EA	$4,000	$8,000	$8,000	$8,000	$0
Flowmeter	2	EA	$4,000	$8,000	$8,000	$8,000	$0
Misc. Interior Piping / Devices	1	LS	$3,000	$3,000	$3,000	$3,000	$3,000
Fluoride Analyzers (Hach CA610)	1	EA	$9,100	$9,100	$9,100	$9,100	$9,100
Demolition (outdoor lime storage silos)	1	LS	$25,000	$0	$25,000	$0	$0
Instrumentation and Control	10%	% of Total		$16,260	$43,803	$21,060	$10,610
Electrical	8%	% of Total		$13,008	$35,042	$16,848	$8,488
WTP Hydrofluosilicic Acid Facilities				$219,000	$618,000	$283,000	$143,000

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City of Sacramento
Fluoridation Study
Sacramento, California
WTP Fluoridation System Annual O&M Cost Opinion
February 2011

Hydrofluosilicic Acid E.A. Fairbairn WTP

ANNUAL O&M COSTS	
Chemical	
Hydrofluosilicic Acid	
Delivery Amount	12000
Cost of chemical, $/gal	$3.60
Chemical usage - avg dose/max well capacity, gpd	192
Chemical cost, $/year	$215,654
Total Chemical cost per year, $/yr	$215,654
Labor	
Chemical Delivery	
Duration, hours	2.00
Frequency, per year	6.00
Total labor, per year, hours	12.00
Monthly Safety Inspections	
Duration, hours	0.5
Frequency, per year	12.0
Total labor, per year, hours	6.0
Operations Labor and Sampling	
Duration, hours	0.5
Frequency, per year	365.0
Total labor, per year, hours	182.5
Equipment Maintenance and Repair	
Duration, hours	8.0
Frequency, per year	3.0
Total labor, per year, hours	24.0
Equipment Maintenance: Electrical & Instrumentation	
Duration, hours	2.0
Frequency, per year	7.0
Total labor, per year, hours	14.0
Program Management	
Duration, hours	1.0
Frequency, per year	12
Total labor, per year, hours	12.0
Total number of hours of labor per year	251
Hourly rate, $/hr	$100.00
Total Labor cost per year	$25,050
Equipment Replacement	
Number of equipment	1
Equipment install year	0
Replacement year	15
Cost of equipment replacement, $/year	$1,000
Total Annual O&M Cost	***$241,704***

Hydrofluosilicic Acid Sac River WTP

ANNUAL O&M COSTS	
Chemical	
Hydrofluosilicic Acid	
Delivery Amount	12000
Cost of chemical, $/gal	$3.30
Chemical usage - avg dose/max well capacity, gpd	206
Chemical cost, $/year	$212,098
Total Chemical cost per year, $/yr	$212,098
Labor	
Chemical Delivery	
Duration, hours	2.00
Frequency, per year	6.00
Total labor, per year, hours	12.00
Monthly Safety Inspections	
Duration, hours	0.5
Frequency, per year	12.0
Total labor, per year, hours	6.0
Operations Labor and Sampling	
Duration, hours	0.5
Frequency, per year	365.0
Total labor, per year, hours	182.5
Equipment Maintenance and Repair	
Duration, hours	8.0
Frequency, per year	3.0
Total labor, per year, hours	24.0
Equipment Maintenance: Electrical & Instrumentation	
Duration, hours	2.0
Frequency, per year	9.0
Total labor, per year, hours	18.0
Program Management	
Duration, hours	1.0
Frequency, per year	12
Total labor, per year, hours	12.0
Total number of hours of labor per year	255
Hourly rate, $/hr	$100.00
Total Labor cost per year	$25,450
Equipment Replacement	
Number of equipment	1
Equipment install year	0
Replacement year	15
Cost of equipment replacement, $/year	$1,000
Total Annual O&M Cost	***$238,548***

Staffing Level Evaluation

Well Site Staffing Level Summary

Option		Total Labor Hours	Total Labor Days	Approximate FTE
1	**Sodium Fluoride (Current)**	4,039	505	3.1
1	**Sodium Fluoride (Optimized)**	3,472	434	2.7
2	**Hydrofluosilicic Acid**	2,662	333	2.0
3	**Hydrofluosilicic Acid w/ Delivery Service**	2,171	271	1.7

* Full Time Equivalent (FTE) staff based on 163 effective labor days each year

Staff Efficiency Factor =	80%
	Days
Regular Days	260
Sick	-12
Vacation	-15
Holidays	-13
Daily Breaks	-14
Staff Meetings	-0.5
Overall Training	-0.8
Safety Meeting	-0.8
Gross Days	**204**
Effective Days (less efficiency factor)	163

Water Treatment Plant Staffing Summary

	Facility	Total Labor Hours	Total Labor Days	Approximate FTE
	E.A. Fairbairn WTP	251	31	0.2
	Sac River WTP	255	32	0.2

* Full Time Equivalent (FTE) staff based on 163 effective labor days each year

Staff Efficiency Factor =	80%
	Days
Regular Days	260
Sick	-12
Vacation	-15
Holidays	-13
Daily Breaks	-14
Staff Meetings	-0.5
Overall Training	-0.8
Safety Meeting	-0.8
Gross Days	**204**
Effective Days (less efficiency factor)	163

City's Pool A Rate	2.5%
ENR ROR	4.0%
Chemical Inflation	6.0%
Water Production Growth	0.3%

	Wells Current Costs					Wells Option 1					Wells Option 2A: City Provided HFA					Wells Option 2B: City Provided HFA-FL Analyzers				
Year	Major Equipment Replacement	Ongoing Equipment Replacement	Chemicals	Labor	Total	Major Equipment Replacement	Ongoing Equipment Replacement	Chemicals	Labor	Total	Major Equipment Replacement	Ongoing Equipment Replacement	Chemicals	Labor	Total	Major Equipment Replacement	Ongoing Equipment Replacement	Chemicals	Labor	Total
Current		$ 18,900	$ 65,141	$ 403,920	$ 487,961	$ 1,365,000	$ 16,200	$ 64,800	$ 348,300	$ 1,794,300	$ 2,846,000	$ 27,000	$ 159,300	$ 267,300	$ 3,299,600	$ 3,626,000	$ 27,000	$ 159,300	$ 267,300	$ 4,079,600
1		$ 19,656	$ 69,245	$ 421,289	$ 510,189		$ 16,848	$ 68,882	$ 362,232	$ 447,962		$ 28,080	$ 169,336	$ 277,992	$ 475,408		$ 28,080	$ 169,336	$ 277,992	$ 475,408
2		$ 20,442	$ 73,607	$ 439,404	$ 533,453		$ 17,522	$ 73,222	$ 376,721	$ 467,465		$ 29,203	$ 180,004	$ 289,112	$ 498,319		$ 29,203	$ 180,004	$ 289,112	$ 498,319
3		$ 21,260	$ 78,244	$ 458,298	$ 557,803		$ 18,223	$ 77,835	$ 391,790	$ 487,848		$ 30,371	$ 191,344	$ 300,676	$ 522,392		$ 30,371	$ 191,344	$ 300,676	$ 522,392
4		$ 22,110	$ 83,174	$ 478,005	$ 583,289	$ 273,747	$ 18,952	$ 82,739	$ 407,462	$ 782,899		$ 31,586	$ 203,399	$ 312,703	$ 547,688		$ 31,586	$ 203,399	$ 312,703	$ 547,688
5		$ 22,995	$ 88,414	$ 498,559	$ 609,968		$ 19,710	$ 87,951	$ 423,760	$ 531,421		$ 32,850	$ 216,213	$ 325,211	$ 574,274		$ 32,850	$ 216,213	$ 325,211	$ 574,274
6		$ 23,915	$ 93,984	$ 519,997	$ 637,896		$ 20,498	$ 93,492	$ 440,711	$ 554,701		$ 34,164	$ 229,835	$ 338,220	$ 602,218		$ 34,164	$ 229,835	$ 338,220	$ 602,218
7		$ 24,871	$ 99,905	$ 542,357	$ 667,133		$ 21,318	$ 99,382	$ 458,339	$ 579,039		$ 35,530	$ 244,314	$ 351,749	$ 631,593		$ 35,530	$ 244,314	$ 351,749	$ 631,593
8		$ 25,866	$ 106,199	$ 565,679	$ 697,743	$ 320,245	$ 22,171	$ 105,643	$ 476,673	$ 924,732		$ 36,951	$ 259,706	$ 365,819	$ 662,476		$ 36,951	$ 259,706	$ 365,819	$ 662,476
9		$ 26,901	$ 112,889	$ 590,003	$ 729,793		$ 23,058	$ 112,299	$ 495,740	$ 631,096		$ 38,429	$ 276,067	$ 380,451	$ 694,948		$ 38,429	$ 276,067	$ 380,451	$ 694,948
10		$ 27,977	$ 120,001	$ 615,373	$ 763,351	$ 1,386,989	$ 23,980	$ 119,373	$ 515,569	$ 2,045,911	$ 1,731,886	$ 39,967	$ 293,460	$ 395,669	$ 2,460,981	$ 1,731,886	$ 39,967	$ 293,460	$ 395,669	$ 2,460,981
11		$ 29,096	$ 127,561	$ 641,834	$ 798,491		$ 24,939	$ 126,894	$ 536,192	$ 688,025		$ 41,565	$ 311,948	$ 411,496	$ 765,009		$ 41,565	$ 311,948	$ 411,496	$ 765,009
12		$ 30,260	$ 135,598	$ 669,433	$ 835,290	$ 374,642	$ 25,937	$ 134,888	$ 557,640	$ 1,093,106		$ 43,228	$ 331,600	$ 427,956	$ 802,784		$ 43,228	$ 331,600	$ 427,956	$ 802,784
13		$ 31,470	$ 144,140	$ 698,219	$ 873,829		$ 26,974	$ 143,386	$ 579,945	$ 750,306		$ 44,957	$ 352,491	$ 445,074	$ 842,522		$ 44,957	$ 352,491	$ 445,074	$ 842,522
14		$ 32,729	$ 153,221	$ 728,242	$ 914,192		$ 28,053	$ 152,420	$ 603,143	$ 783,616		$ 46,755	$ 374,698	$ 462,877	$ 884,330		$ 46,755	$ 374,698	$ 462,877	$ 884,330
15		$ 34,038	$ 162,874	$ 759,556	$ 956,468		$ 29,175	$ 162,022	$ 627,269	$ 818,466	$ 563,695	$ 48,625	$ 398,304	$ 481,392	$ 1,492,017	$ 563,695	$ 48,625	$ 398,304	$ 481,392	$ 1,492,017
16		$ 35,399	$ 173,135	$ 792,217	$ 1,000,752	$ 438,278	$ 30,342	$ 172,229	$ 652,359	$ 1,293,209		$ 50,570	$ 423,397	$ 500,648	$ 974,616		$ 50,570	$ 423,397	$ 500,648	$ 974,616
17		$ 36,815	$ 184,043	$ 826,283	$ 1,047,141		$ 31,556	$ 183,080	$ 678,454	$ 893,090		$ 52,593	$ 450,071	$ 520,674	$ 1,023,338		$ 52,593	$ 450,071	$ 520,674	$ 1,023,338
18		$ 38,288	$ 195,637	$ 861,813	$ 1,095,738		$ 32,818	$ 194,614	$ 705,592	$ 933,024		$ 54,697	$ 478,426	$ 541,501	$ 1,074,624		$ 54,697	$ 478,426	$ 541,501	$ 1,074,624
19		$ 39,819	$ 207,963	$ 898,871	$ 1,146,653		$ 34,131	$ 206,875	$ 733,816	$ 974,821		$ 56,885	$ 508,567	$ 563,161	$ 1,128,612		$ 56,885	$ 508,567	$ 563,161	$ 1,128,612
20		$ 41,412	$ 221,064	$ 937,522	$ 1,199,999	$ 2,563,614	$ 35,496	$ 219,908	$ 763,168	$ 3,582,186	$ 4,526,860	$ 59,160	$ 540,606	$ 585,687	$ 5,712,314	$ 6,235,936	$ 59,160	$ 540,606	$ 585,687	$ 7,421,390
FV	$ -	$ 604,000	$ 2,696,000	$ 13,347,000	$ 16,647,000	$ 6,723,000	$ 518,000	$ 2,682,000	$ 11,135,000	$ 21,057,000	$ 9,668,000	$ 863,000	$ 6,593,000	$ 8,545,000	$ 25,670,000	$ 12,158,000	$ 863,000	$ 6,593,000	$ 8,545,000	$ 28,159,000
PV	$ -	$ 368,604	$ 1,645,290	$ 8,145,286	$ 10,159,180	$ 4,102,852	$ 316,120	$ 1,636,747	$ 6,795,367	$ 12,850,475	$ 5,900,099	$ 526,664	$ 4,023,516	$ 5,214,765	$ 15,665,655	$ 7,419,674	$ 526,664	$ 4,023,516	$ 5,214,765	$ 17,184,619
Annualized	$ -	$ 23,645	$ 105,541	$ 522,497	$ 651,682	$ 263,186	$ 20,278	$ 104,993	$ 435,903	$ 824,321	$ 378,474	$ 33,784	$ 258,097	$ 334,512	$ 1,004,907	$ 475,951	$ 33,784	$ 258,097	$ 334,512	$ 1,102,344

Equipment Replacement Detail (2011 Base Construction Costs)

Year 4 - $234,000 allowance for pump replacement
Year 8 - $234, 000 allowance for pump replacement
Year 10 - $937,000 allowance for tank, piping, valve access. Replacement
Year 12 - $234,000 allowance for pump replacement
Year 16 - $234,000 allowance for pump replacement
Year 20 - $1,170,000 allowance for pump, tank, piping… replacement

Equipment Replacement Detail (2011 Base Construction Costs)

Year 10 - $1,170,000 allowance for tank, piping, valve replacement
Year 15 - $313,000 allowance for pump replacement
Year 20 - $2,066,000 allowance for tank, piping, valve, instrument, access.

	Wells Option 3: HFA Deliverer					Wells Option 3B: HFA Deliverer w/ FL Analyzers					EAF Option 1: No Shelter				
Year	Major Equipment Replacement	Ongoing Equipment Replacement	Chemicals	Labor	Total	Major Equipment Replacement	Ongoing Equipment Replacement	Chemicals	Labor	Total	Major Equipment Replacement	Ongoing Equipment Replacement	Chemicals	Labor	Total
Current	$ 2,846,000	$ 27,000	$ 226,800	$ 216,000	$ 3,315,800	$ 3,626,000	$ 27,000	$ 226,800	$ 216,000	$ 4,095,800	$ 316,000	$ 1,000	$ 215,700	$ 25,100	$ 557,800
1		$ 28,080	$ 241,088	$ 224,640	$ 493,808		$ 28,080	$ 241,088	$ 224,640	$ 493,808		$ 1,040	$ 229,289	$ 26,104	$ 256,433
2		$ 29,203	$ 256,277	$ 233,626	$ 519,106		$ 29,203	$ 256,277	$ 233,626	$ 519,106		$ 1,082	$ 243,734	$ 27,148	$ 271,964
3		$ 30,371	$ 272,422	$ 242,971	$ 545,764		$ 30,371	$ 272,422	$ 242,971	$ 545,764		$ 1,125	$ 259,090	$ 28,234	$ 288,449
4		$ 31,586	$ 289,585	$ 252,689	$ 573,861		$ 31,586	$ 289,585	$ 252,689	$ 573,861		$ 1,170	$ 275,412	$ 29,363	$ 305,946
5		$ 32,850	$ 307,829	$ 262,797	$ 603,476		$ 32,850	$ 307,829	$ 262,797	$ 603,476		$ 1,217	$ 292,763	$ 30,538	$ 324,518
6		$ 34,164	$ 327,222	$ 273,309	$ 634,695		$ 34,164	$ 327,222	$ 273,309	$ 634,695		$ 1,265	$ 311,207	$ 31,760	$ 344,232
7		$ 35,530	$ 347,837	$ 284,241	$ 667,609		$ 35,530	$ 347,837	$ 284,241	$ 667,609		$ 1,316	$ 330,813	$ 33,030	$ 365,159
8		$ 36,951	$ 369,751	$ 295,611	$ 702,313		$ 36,951	$ 369,751	$ 295,611	$ 702,313		$ 1,369	$ 351,655	$ 34,351	$ 387,374
9		$ 38,429	$ 393,045	$ 307,435	$ 738,910		$ 38,429	$ 393,045	$ 307,435	$ 738,910		$ 1,423	$ 373,809	$ 35,725	$ 410,957
10	$ 1,731,886	$ 39,967	$ 417,807	$ 319,733	$ 2,509,392	$ 1,731,886	$ 39,967	$ 417,807	$ 319,733	$ 2,509,392	$ 405,587	$ 1,480	$ 397,359	$ 37,154	$ 841,580
11		$ 41,565	$ 444,129	$ 332,522	$ 818,216		$ 41,565	$ 444,129	$ 332,522	$ 818,216		$ 1,539	$ 422,392	$ 38,640	$ 462,572
12		$ 43,228	$ 472,109	$ 345,823	$ 861,160		$ 43,228	$ 472,109	$ 345,823	$ 861,160		$ 1,601	$ 449,003	$ 40,186	$ 490,790
13		$ 44,957	$ 501,852	$ 359,656	$ 906,465		$ 44,957	$ 501,852	$ 359,656	$ 906,465		$ 1,665	$ 477,290	$ 41,793	$ 520,749
14		$ 46,755	$ 533,468	$ 374,042	$ 954,266		$ 46,755	$ 533,468	$ 374,042	$ 954,266		$ 1,732	$ 507,360	$ 43,465	$ 552,556
15	$ 563,695	$ 48,625	$ 567,077	$ 389,004	$ 1,568,402	$ 563,695	$ 48,625	$ 567,077	$ 389,004	$ 1,568,402		$ 1,801	$ 539,323	$ 45,204	$ 586,328
16		$ 50,570	$ 602,803	$ 404,564	$ 1,057,937		$ 50,570	$ 602,803	$ 404,564	$ 1,057,937		$ 1,873	$ 573,301	$ 47,012	$ 622,185
17		$ 52,593	$ 640,779	$ 420,747	$ 1,114,119		$ 52,593	$ 640,779	$ 420,747	$ 1,114,119		$ 1,948	$ 609,419	$ 48,892	$ 660,259
18		$ 54,697	$ 681,149	$ 437,576	$ 1,173,422		$ 54,697	$ 681,149	$ 437,576	$ 1,173,422		$ 2,026	$ 647,812	$ 50,848	$ 700,686
19		$ 56,885	$ 724,061	$ 455,079	$ 1,236,025		$ 56,885	$ 724,061	$ 455,079	$ 1,236,025		$ 2,107	$ 688,624	$ 52,882	$ 743,613
20	$ 4,526,860	$ 59,160	$ 769,677	$ 473,283	$ 5,828,980	$ 6,235,936	$ 59,160	$ 769,677	$ 473,283	$ 7,538,056	$ 692,395	$ 2,191	$ 732,007	$ 54,997	$ 1,481,591
FV	$ 9,668,000	$ 863,000	$ 9,387,000	$ 6,905,000	$ 26,824,000	$ 12,158,000	$ 863,000	$ 9,387,000	$ 6,905,000	$ 29,313,000	$ 1,414,000	$ 32,000	$ 8,927,000	$ 802,000	$ 11,176,000
PV	$ 5,900,099	$ 526,664	$ 5,728,613	$ 4,213,921	$ 16,369,908	$ 7,419,674	$ 526,664	$ 5,728,613	$ 4,213,921	$ 17,888,872	$ 862,923	$ 19,529	$ 5,447,889	$ 489,437	$ 6,820,388
Annualized	$ 378,474	$ 33,784	$ 367,474	$ 270,311	$ 1,050,083	$ 475,951	$ 33,784	$ 367,474	$ 270,311	$ 1,147,520	$ 55,354	$ 1,253	$ 349,466	$ 31,396	$ 437,508

Equipment Replacement Detail (2011 Base Construction Costs)

Year 10 - $1,170,000 allowance for tank, piping, valve replacement
Year 15 - $313,000 allowance for pump replacement
Year 20 - $2,066,000 allowance for tank, piping, valve, instrument, access.

Equipment Replacement Detail (2011 Base Construction Costs)

Year 10 - $274,000 allowance for pumps, tank, piping, valve replacement
Year 20 - $316,000 allowance for pumps, tank, piping, valve, instr, access.

	EAF Option 2: Shade Structure					EAF Option 3: Masonary Building					SRWTP				
Year	Major Equipment Replacement	Ongoing Equipment Replacement	Chemicals	Labor	Total	Major Equipment Replacement	Ongoing Equipment Replacement	Chemicals	Labor	Total	Major Equipment Replacement	Ongoing Equipment Replacement	Chemicals	Labor	Total
Current	$ 408,000	$ 1,000	$ 215,700	$ 25,100	$ 649,800	$ 893,000	$ 1,000	$ 215,700	$ 25,100	$ 1,134,800		$ 1,000	$ 212,100	$ 25,500	$ 238,600
1		$ 1,040	$ 229,289	$ 26,104	$ 256,433		$ 1,040	$ 229,289	$ 26,104	$ 256,433		$ 1,040	$ 225,462	$ 26,520	$ 253,022
2		$ 1,082	$ 243,734	$ 27,148	$ 271,964		$ 1,082	$ 243,734	$ 27,148	$ 271,964		$ 1,082	$ 239,666	$ 27,581	$ 268,329
3		$ 1,125	$ 259,090	$ 28,234	$ 288,449		$ 1,125	$ 259,090	$ 28,234	$ 288,449		$ 1,125	$ 254,765	$ 28,684	$ 284,574
4		$ 1,170	$ 275,412	$ 29,363	$ 305,946		$ 1,170	$ 275,412	$ 29,363	$ 305,946		$ 1,170	$ 270,816	$ 29,831	$ 301,817
5		$ 1,217	$ 292,763	$ 30,538	$ 324,518		$ 1,217	$ 292,763	$ 30,538	$ 324,518		$ 1,217	$ 287,877	$ 31,025	$ 320,118
6		$ 1,265	$ 311,207	$ 31,760	$ 344,232		$ 1,265	$ 311,207	$ 31,760	$ 344,232		$ 1,265	$ 306,013	$ 32,266	$ 339,544
7		$ 1,316	$ 330,813	$ 33,030	$ 365,159		$ 1,316	$ 330,813	$ 33,030	$ 365,159	$ 107,906	$ 1,316	$ 325,292	$ 33,556	$ 468,071
8		$ 1,369	$ 351,655	$ 34,351	$ 387,374		$ 1,369	$ 351,655	$ 34,351	$ 387,374		$ 1,369	$ 345,786	$ 34,899	$ 382,053
9		$ 1,423	$ 373,809	$ 35,725	$ 410,957		$ 1,423	$ 373,809	$ 35,725	$ 410,957		$ 1,423	$ 367,570	$ 36,294	$ 405,288
10		$ 1,480	$ 397,359	$ 37,154	$ 435,993	$ 149,505	$ 1,480	$ 397,359	$ 37,154	$ 585,498		$ 1,480	$ 390,727	$ 37,746	$ 429,953
11		$ 1,539	$ 422,392	$ 38,640	$ 462,572		$ 1,539	$ 422,392	$ 38,640	$ 462,572		$ 1,539	$ 415,343	$ 39,256	$ 456,138
12		$ 1,601	$ 449,003	$ 40,186	$ 490,790		$ 1,601	$ 449,003	$ 40,186	$ 490,790	$ 186,511	$ 1,601	$ 441,509	$ 40,826	$ 670,447
13	$ 552,804	$ 1,665	$ 477,290	$ 41,793	$ 1,073,553		$ 1,665	$ 477,290	$ 41,793	$ 520,749		$ 1,665	$ 469,324	$ 42,459	$ 513,449
14		$ 1,732	$ 507,360	$ 43,465	$ 552,556		$ 1,732	$ 507,360	$ 43,465	$ 552,556		$ 1,732	$ 498,892	$ 44,158	$ 544,781
15		$ 1,801	$ 539,323	$ 45,204	$ 586,328	$ 162,085	$ 1,801	$ 539,323	$ 45,204	$ 748,413		$ 1,801	$ 530,322	$ 45,924	$ 578,047
16		$ 1,873	$ 573,301	$ 47,012	$ 622,185		$ 1,873	$ 573,301	$ 47,012	$ 622,185		$ 1,873	$ 563,732	$ 47,761	$ 613,366
17		$ 1,948	$ 609,419	$ 48,892	$ 660,259		$ 1,948	$ 609,419	$ 48,892	$ 660,259	$ 248,530	$ 1,948	$ 599,247	$ 49,671	$ 899,397
18		$ 2,026	$ 647,812	$ 50,848	$ 700,686		$ 2,026	$ 647,812	$ 50,848	$ 700,686		$ 2,026	$ 637,000	$ 51,658	$ 690,684
19		$ 2,107	$ 688,624	$ 52,882	$ 743,613		$ 2,107	$ 688,624	$ 52,882	$ 743,613		$ 2,107	$ 677,131	$ 53,725	$ 732,962
20		$ 2,191	$ 732,007	$ 54,997	$ 789,196	$ 885,214	$ 2,191	$ 732,007	$ 54,997	$ 1,674,409		$ 2,191	$ 719,790	$ 55,874	$ 777,855
FV	$ 961,000	$ 32,000	$ 8,927,000	$ 802,000	$ 10,723,000	$ 2,090,000	$ 32,000	$ 8,927,000	$ 802,000	$ 11,852,000	$ 543,000	$ 32,000	$ 8,778,000	$ 815,000	$ 10,168,000
PV	$ 586,470	$ 19,529	$ 5,447,889	$ 489,437	$ 6,543,935	$ 1,275,466	$ 19,529	$ 5,447,889	$ 489,437	$ 7,232,931	$ 331,377	$ 19,529	$ 5,356,958	$ 497,371	$ 6,205,235
Annualized	$ 37,620	$ 1,253	$ 349,466	$ 31,396	$ 419,775	$ 81,817	$ 1,253	$ 349,466	$ 31,396	$ 463,972	$ 21,257	$ 1,253	$ 343,633	$ 31,905	$ 398,048

Equipment Replacement Detail (2011 Base Construction Costs)

Year 13 - $332,000 allowance for pumps, tank, piping, valve replacement

(Not Included)

Year 23 - $332,000 allowance for pumps, tank, piping, valve replacement

Equipment Replacement Detail (2011 Base Construction Costs)

Year 10 - $101,000 allowance for piping, valve replacement

Year 15 - $90,000 allowance for tank replacement

Year 20 - $404,000 for pumps, tank, piping, valve replacement

Equipment Replacement Detail (2011 Base Construction Costs)

Year 7 - $82,000 allowance for piping, valve replacement

Year 12 - $126,000 allowance for tank replacement

Year 17 - $138,000 for pumps, piping, valve replacement

		2011 Cost of Fluoridation					Total City Fluoridation Costs			Present and Future Equipment Replacement			Total City Fluoridation Costs less Equipment Costs		
Goal	Description	2011 Capitol Project	O&M Equipment Costs	O&M Chemical Costs	O&M Labor Costs	Total 2011 O&M Costs	PW	Annuallized	FW	PW	Annuallized	FW	PW	Annuallized	FW
	Current System Costs	$ -	$ 19,756	$ 491,876	$ 445,305	$ 956,937	NA	NA	NA	NA	NA	NA			
B&V Recommendation 1. Optimize the wells. Protect EAF Equipment	Scenario 1: NAF @ Wells + EAF in Bldg+ SRWTP	$2,258,000	$18,000	$493,000	$399,000	$910,000	$26,289,000	$1,686,000	$43,077,000	$6,065,000	$389,000	$9,938,000	$20,224,000	$1,297,000	$33,139,000
B&V Recommendation 2. Change Wells to HFA. Protect EAF Equipment.	Scenario 2: HFA @ Wells + EAF in Bldg + SRWTP	$3,739,000	$29,000	$587,000	$318,000	$934,000	$29,104,000	$1,867,000	$47,690,000	$8,073,000	$518,000	$13,228,000	$21,031,000	$1,349,000	$34,462,000
Provide for minimimal Total Costs, but lower employee exposure to HFA	Scenario 3: Delivered HFA @ Wells + EAF in Bldg + SRWTP	$ 3,739,000	$ 29,000	$ 655,000	$ 267,000	$ 951,000	$ 29,808,000	$ 1,912,000	$ 48,844,000	$ 8,073,000	$ 518,000	$ 13,228,000	$ 21,735,000	$ 1,394,000	$ 35,616,000
Minimize initial capital costs	Scenario 4: NAF @ Wells + EAF Outdoors + SRWTP	$ 1,681,000	$ 18,000	$ 493,000	$ 399,000	$ 910,000	$ 28,691,000	$ 1,840,000	$ 47,014,000	$ 7,660,000	$ 491,000	$ 12,552,000	$ 21,031,000	$ 1,349,000	$ 34,462,000
Minimize long term costs	Scenario 5: NAF @ Wells + EAF in Canopy + SRWTP	$ 1,773,000	$ 18,000	$ 493,000	$ 399,000	$ 910,000	$ 25,600,000	$ 1,642,000	$ 40,152,000	$ 5,376,000	$ 345,000	$ 8,809,000	$ 20,224,000	$ 1,297,000	$ 31,343,000

O&M Cost	$	956,937	
Less Fraction of Chemical Cost to Fluoridate Wholseale Water	$	(19,718)	
City Only O&M Portion	$	937,219	
Population	$	486,189	Source: Cal Dep of Finance, 1/1/2010 Estimate
Current Cost Ratio of Fluoridation	$	1.93	$/person

APPENDIX E – ANSI/AWWA B701-06

ANSI/AWWA B701-06
(Revision of ANSI/AWWA B701-99)

American Water Works Association

The Authoritative Resource on Safe Water℠

AWWA Standard

Sodium Fluoride

ANSI American National Standards Institute

Effective date: March 1, 2006.
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Sections

AWWA Standard

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Marion E. Casto, *Vice-Chair*
Paul B. Maasen, *Secretary*

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Foreword

This Foreword is for information only and is not a part of ANSI/AWWA B701.

I. Introduction.

I.A. *Background.* Sodium fluoride (NaF) is one of several fluoride compounds presently being added to drinking water to reduce the incidence of dental caries. Since the first fluoridation installation in 1945, studies have shown that dental decay can be reduced by 20 to 40 percent among children who have consumed fluoridated water since birth.

Sodium fluoride is a white, odorless material available as a coarse crystalline material, as free-flowing crystals, or a combination of both. It is stable at temperatures up to and beyond its melting point (990°C), is nonflammable, and does not react with air or moisture. Its formula weight is 42.00; its specific gravity is 2.79; and its solubility is practically constant at 4 g/100 mL of water at the temperatures generally encountered in water treatment plants. The pure material produces solutions with pH values close to 7.0.

Sodium fluoride is generally produced by neutralizing hydrofluoric acid with caustic soda or soda ash. The various particle sizes are obtained by grinding and screening the dried crystals.

Sodium fluoride is proportionally added to the water being treated as a dry, coarse crystalline material or as a solution of varying strength. Its constant solubility is particularly valuable in producing, automatically and continuously, a saturated solution in a tank specially designed for this purpose. This tank does require a water meter to measure the amount of water that is used to make up a solution of known strength.

Refer to AWWA Manual M4, *Water Fluoridation Principles and Practices,*[*] for additional technical information concerning the use of sodium fluoride.

I.B. *History.* The AWWA Standard for Sodium Fluoride was tentatively approved by the AWWA Board of Directors on July 21, 1950. Subsequent revisions to ANSI/AWWA B701were approved by the AWWA Board of Directors on May 15, 1960; Jan. 24, 1971; Jan. 28, 1978; Jan. 30, 1984; Jan. 29, 1989; Jan. 30, 1994; and

*AWWA Manual M4, *Water Fluoridation Principles and Practices,* AWWA, Denver, Colo.

June 20, 1999. This ninth edition was prepared by the AWWA Standards Committee on Fluorides and was approved on Feb. 12, 2006.

I.C. *Acceptance.* In May 1985, the US Environmental Protection Agency (USEPA) entered into a cooperative agreement with a consortium led by NSF International (NSF) to develop voluntary third-party consensus standards and a certification program for direct and indirect drinking water additives. Other members of the original consortium included the American Water Works Association Research Foundation (AwwaRF) and the Conference of State Health and Environmental Managers (COSHEM). The American Water Works Association (AWWA) and the Association of State Drinking Water Administrators (ASDWA) joined later.

In the United States, authority to regulate products for use in, or in contact with, drinking water rests with individual states.* Local agencies may choose to impose requirements more stringent than those required by the state. To evaluate the health effects of products and drinking water additives from these products, state and local agencies may use various references, including two standards developed under the direction of NSF, NSF†/ANSI‡ 60, Drinking Water Treatment Chemicals—Health Effects, and NSF/ANSI 61, Drinking Water System Components—Health Effects.

Various certification organizations may be involved in certifying products in accordance with NSF/ANSI 60. Individual states or local agencies have authority to accept or accredit certification organizations within their jurisdiction. Accreditation of certification organizations may vary from jurisdiction to jurisdiction.

Annex A, "Toxicology Review and Evaluation Procedures," to NSF/ANSI 60 does not stipulate single product allowable concentration (SPAC) values of a contaminant for substances not regulated by a USEPA final maximum contaminant level (MCL). The SPACs of an unspecified list of "unregulated contaminants" are based on toxicity testing guidelines (noncarcinogens) and risk characterization methodology (carcinogens). Use of Annex A procedures may not always be identical, depending on the certifier.

ANSI/AWWA B701 addresses additives requirements in Sec. 4.3 of the standard. The transfer of contaminants from chemicals to processed water or the residual solids is becoming a problem of greater concern. The language in Sec. 4.3.3 is a

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*Persons outside the United States should contact the appropriate authority having jurisdiction.

†NSF International, 789 N. Dixboro Road, Ann Arbor, MI 48105.

‡American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

recommendation only for direct additives used in the treatment of potable water to be certified by an accredited certification organization in accordance with NSF/ANSI 60, Drinking Water Treatment Chemicals—Health Effects. However, users of the standard may opt to make this certification a requirement for the product. Users of this standard should consult the appropriate state or local agency having jurisdiction in order to

1. Determine additives requirements, including applicable standards.
2. Determine the status of certifications by all parties offering to certify products for contact with or treatment of drinking water.
3. Determine current information on product certification.

II. Special Issues.

II.A. *Storage and Handling Precautions.* Sodium fluoride chemicals must be stored in a clean, dry location that is well ventilated. Sodium fluoride has a tendency to compact or cake when exposed to moisture, when bags are stacked too high, or during long periods of storage. Bags of sodium fluoride should be stored on pallets in stacks not more than six bags high.

Sodium fluoride is hazardous if swallowed or inhaled in large amounts. Ingestion of 4 to 5 g of fluoride ion (F^-) per 150 lb (69 kg) body weight may be fatal. The inhalation of sodium fluoride dust should be avoided. Protective safety gear should be worn when handling sodium fluoride. The following protective clothing and equipment should be the minimum available:

1. A National Institute for Occupational Safety and Health/Mine Safety Health Administration (NIOSH/MSHA) approved, high-efficiency dust respirator (chemical mask) with a soft rubber face-to-mask seal and replaceable cartridges.*
2. Gauntlet neoprene gloves (12-in. [300-mm] minimum glove length).
3. Heavy-duty neoprene aprons.

Spills should be cleaned up immediately. Personnel should wash thoroughly after handling fluoride chemicals. For additional safety aspects, refer to material safety data sheets (MSDS) available from the chemical supplier or manufacturer.

*NIOSH/MSHA approval is given to various masks. Each brand is evaluated by NIOSH/MSHA for the proposed use and conditions. Available from the National Institute of Occupational Safety and Health, 4676 Columbia Parkway, Cincinnati, OH 45226; or Mine Safety Health Administration, 4015 Wilson Boulevard, Arlington, VA 22203.

III. Use of This Standard. It is the responsibility of the user of an AWWA standard to determine that the products described in that standard are suitable for use in the particular application being considered.

III.A. *Purchaser Options and Alternatives.* The following items should be provided by the purchaser:

1. Standard used—that is, ANSI/AWWA B701, Standard for Sodium Fluoride, of latest revision.

2. Whether the recommended compliance with NSF/ANSI 60, Drinking Water Treatment Chemicals—Health Effects, is required.

3. Quantity required.

4. Additional impurity limits if required. If additional impurity limits are required by the purchaser, the purchaser must state the test procedures to be used to determine compliance with the limits (Sec. I.C and Sec. 4.3.4).

5. Physical form desired—coarse crystalline—and required mesh sizes (Sec. 4.1).

6. If an analysis by a referee laboratory is required, the assignment of testing costs should be addressed (Sec. 5.2.9.1).

7. Form of shipment—bulk or package (type and size) (Sec. 6.2).

8. Affidavit of compliance or certified analyses if required (Sec. 6.3).

III.B. *Modification to Standard.* Any modification to the provisions, definitions, or terminology in this standard must be specified by the purchaser.

IV. Major Revisions. Major changes made to the standard in this revision include the following:

1. Impurity requirements have been tied to the SPACs listed in NSF/ANSI 60 (Sec. 4.3.3).

2. Turbidity requirements have been added (Sec. 4.3.5).

3. Test procedures for impurities have been defined and referenced (Sec. 5.2.7 and Table 1).

4. A test procedure for turbidity has been added (Sec. 5.2.8).

5. A table showing SPACs for impurities regulated under NSF/ANSI 60 has been added as an appendix (Appendix A).

V. Comments. If you have any comments or questions about this standard, please call the AWWA Volunteer & Technical Support group, 303.794.7711, FAX 303.795.7603, write to the group at 6666 West Quincy Avenue, Denver, CO 80235-3098, or e-mail at standards@awwa.org.

American Water Works Association

ANSI/AWWA B701-06
(Revision of ANSI/AWWA B701-99)

AWWA Standard

Sodium Fluoride

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard describes sodium fluoride (NaF), coarse crystalline grade, for water supply service application.

Sec. 1.2 Purpose

The purpose of this standard is to provide the minimum requirements for sodium fluoride, including physical, chemical, packaging, shipping, and testing requirements.

Sec. 1.3 Application

This standard can be referenced in specifications for purchasing and receiving sodium fluoride and can be used as a guide for testing the physical and chemical properties of sodium fluoride samples. The stipulations of this standard apply when this document has been referenced and only to sodium fluoride used in water supply service applications.

SECTION 2: REFERENCES

This standard references the following documents. In their latest edition, they form a part of this standard to the extent specified in this standard. In any case of conflict, the requirements of this standard shall prevail.

ASTM* E11—Standard Specification for Wire Cloth and Sieves for Testing Purposes.

NSF†/ANSI‡ 60, Drinking Water Treatment Chemicals—Health Effects.

Standard Methods for the Examination of Water and Wastewater. APHA,§ AWWA, and WEF.**

SECTION 3: DEFINITIONS

The following definitions shall apply to this standard:

1. *Day:* A day is defined as a 24-hr period.
2. *Manufacturer:* The party that manufactures, fabricates, or produces materials or products.
3. *Purchaser:* The person, company, or organization that purchases any materials or work to be performed.
4. *Supplier:* The party that supplies materials or services. A supplier may or may not be the manufacturer.

SECTION 4: REQUIREMENTS

Sec. 4.1 Physical Requirements

The sodium fluoride supplied according to this standard shall be a dry, coarse crystalline material containing no lumps. Particle-size distribution for the coarse

*ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

†NSF International, 789 N. Dixboro Road, Ann Arbor, MI 48105.

‡American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

§American Public Health Association, 800 I Street NW, Washington, DC 20001.

**Water Environment Federation, 601 Wythe Street, Alexandria, VA 22314.

crystalline grade of sodium fluoride shall comply with the following mesh size requirements.*

4.1.1 *Coarse crystalline grade.*

1. At least 98 percent shall pass through US Standard Sieve Series No. 20 (850 μm).

2. At least 50 percent shall be retained on US Standard Sieve Series No. 100 (150 μm).

Sec. 4.2 Chemical Requirements

The chemical composition shall be determined by the test methods provided in Sec. 5.2.

4.2.1 *Sodium fluoride content.* The sodium fluoride supplied according to this standard shall have a minimum of 97 percent (dry basis) sodium fluoride, corresponding to approximately 44 percent fluoride ion.

4.2.2 *Moisture.* Moisture shall not exceed 0.5 percent by weight.

Sec. 4.3 Impurities†

4.3.1 *General impurities.* The sodium fluoride supplied according to this standard shall contain no soluble materials or organic substances in quantities capable of producing deleterious or injurious effects on the health of those consuming water that has been treated properly with the sodium fluoride.

4.3.2 *Insoluble matter.* Insoluble matter shall not exceed 0.6 percent by weight.

4.3.3 *Product certifications.* Sodium fluoride is a direct additive used in the treatment of potable water. This material should be certified as suitable for contact with or treatment of drinking water by an accredited certification organization in accordance with NSF/ANSI 60, Drinking Water Treatment Chemicals—Health Effects. Evaluation shall be accomplished in accordance with requirements that are no less restrictive than those listed in NSF/ANSI 60. Certification shall be accomplished by a certification organization accredited by the American National Standards Institute.

The sodium fluoride impurities regulated under NSF/ANSI 60, their drinking water regulatory levels, and their single product allowable concentration (SPAC)

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*All Sieve numbers referred to in this standard are US Standard Sieve Series numbers, as specified in the American Society for Testing and Materials (ASTM) Standard Designation E11, Specification for Wire-Cloth Sieves for Testing Purposes, available from ASTM, 1916 Race St., Philadelphia, PA 19103.

†See Sec. I.C of the Foreword.

values are as provided in Appendix A. The SPAC values are to be compared to the concentration's values resulting from an applied sodium fluoride dose that results in a concentration of 1.2 mg/L fluoride in the treated water.

4.3.4 *Additional impurity limits.* Additional impurity limits may be specified by the purchaser to ensure that the material supplied is suitable for water treatment. If additional impurity limits are specified, the purchaser must state the test methodology to be used to determine compliance with the additional limits.

4.3.5 *Saturated solution turbidity.* Turbidity of saturated sodium fluoride solutions shall be no more than 10 ntu, 5 min after preparation.

SECTION 5: VERIFICATION

Sec. 5.1 Sampling

Sampling shall be conducted in accordance with this section of the standard. Each sample container shall be labeled to identify it and shall be signed by the sampler. A chain-of-custody form shall accompany all samples and shall be properly completed by the individuals collecting samples.

5.1.1 *Sampling point.* Samples shall be taken at the point of destination.

5.1.2 *Sampling device.* Sodium fluoride may be sampled by means of a sampling tube that is at least 3/4 in. (19 mm) in diameter. If the sodium fluoride is handled by conveyor or elevator, a mechanical sampling procedure may be used. The procedure must provide representative sampling of the entire shipment that is being handled.

5.1.3 *Amount of shipment to be sampled.* If the sodium fluoride is packaged, 5 percent of the packages shall be sampled. No sample for testing shall be taken from a broken package. Samples from individual packages shall be combined to form a composite sample.

5.1.4 *Sample size and handling.* A composite sample weighing at least 16 lb (7.3 kg) shall be taken. The composite sample shall be mixed thoroughly and divided in the following manner:

1. Divide into four 4-lb (1.8-kg) sections.
2. Select alternate quarters.
3. Re-divide each to provide eight 1-lb (0.5-kg) sections.
4. Select six 1-lb (0.5-kg) samples.

5.1.5 *Sample storage.* The 1-lb (0.5-kg) samples shall be sealed in airtight, moisture-proof plastic or glass containers, each identified by a label signed by the sampler. Two samples shall be for use by the purchaser for the tests specified in Sec. 5.2. The other four shall be retained for at least 30 days after the date of receipt to be used for retesting, as provided in Sec. 5.2.9.

Sec. 5.2 Test Procedures

Testing of sodium fluoride shall be conducted in accordance with the procedures presented in this standard. Alternate test procedures may be used only with written approval from the purchaser. In any case of conflict, the test procedures in this standard shall prevail.

5.2.1 *Test samples.* Test samples shall be obtained from the 1-lb (0.5-kg) samples taken in accordance with Sec. 5.1. Samples shall be stored in an airtight container and unsealed only when it is necessary to remove quantities of material for testing. Removal of material shall be performed as rapidly as possible to avoid changes in moisture content, and the sample container shall be resealed for future reference.

5.2.2 *Test procedure for size.* Rapidly weigh approximately 100 g of sample to the nearest 0.1 g and screen until a constant weight is achieved on the appropriate US Standard Sieve Series to determine compliance with the size requirements of Sec. 4.1. Weigh to the nearest 0.1 g the amounts of material passing through the sieve or being retained on the sieve. Report each portion of material passing through the sieve or retained on the sieve as a percent of the total initial sample. The entire process should be performed in a dry atmosphere and as quickly as possible.

5.2.3 *Test procedure for insoluble matter.*

5.2.3.1 Procedure.

1. Weigh 5 g of sample that has been dried at 105°C to a constant weight and transfer to a 500-mL beaker. (As the sample is granular, grind to powder with a mortar and pestle.) Dissolve in about 400 mL of hot deionized water. Digest with constant stirring at a temperature of about 90°C for 4 hr, maintaining the original water level by frequent additions of hot deionized water.

2. Filter through a tared Gooch crucible or a tared fritted-glass filter of medium porosity. Wash with at least six separate 25-mL portions of boiling deionized water, allowing the crucible or filter to drain between washings. Dry the crucible or filter at 105°C to a constant weight.

5.2.3.2 Calculation. Calculate the percent of insoluble matter:

$$\frac{\text{weight of residue}}{\text{weight of sample}} \times 100 = \text{percent insoluble matter} \qquad \text{(Eq 1)}$$

5.2.4 *Test procedure for moisture content.*

1. Weigh 5 g of the sample into a broad weighing bottle and heat in an oven at 105°C to constant weight. Cool in desiccator and reweigh.

2. Calculate the percent of moisture:

$$\frac{\text{loss in weight}}{\text{weight of sample}} \times 100 = \text{percent of moisture} \qquad \text{(Eq 2)}$$

5.2.5 *Test procedure for fluoride content—fluoride electrode method.*

NOTE: Sec. 5.2.5 and Sec. 5.2.6 contain references for two analytical procedures to determine fluoride content. Should a referee method be needed, the fluoride electrode method shall be considered the preferred procedure.

5.2.5.1 Reagents.

1. Lanthanum nitrate (0.3*N*). Dissolve 43.3 g of lanthanum nitrate [$La(NO_3)_3 \cdot 6H_2O$] in deionized water in a 1,000-mL volumetric flask. Fill to the mark with deionized water and mix. Filter if necessary. To standardize lanthanum nitrate, (1) pipette 25 mL of 0.1*N* fluoride standard and 50 mL of water into a 100-mL plastic beaker and begin stirring; (2) immerse calibrated fluoride electrode; (3) set meter to "mV EX"; (4) titrate with 0.3*N* lanthanum nitrate, using a 10-mL microburette, to a reading of 90 ±2 mV. Repeat step 4 with two more 25-mL portions of the same 0.1*N* fluoride standard and 50 mL of water. Use the average of the three determinations in the calculation. NOTE: The lanthanum nitrate solution should be standardized monthly. The following equation can be used to calculate the normality of lanthanum nitrate:

$$\frac{0.5954 \times (A/100) \times (B)}{\text{mL } La(NO_3)_3} = N \text{ of } La(NO_3)_3 \qquad \text{(Eq 3)}$$

Where:

A = percent purity of fluoride (from bottle label) used to prepare the 0.1*N* fluoride standard

B = weight of sodium fluoride, in grams, used to prepare the 0.1*N* fluoride standard

2. Sodium fluoride, American Chemical Society (ACS)* reagent grade.

*American Chemical Society, 1155 Sixteenth Street NW, Washington, DC 20036.

3. Fluoride standard (0.1*N*). Dry a sample of ACS reagent-grade sodium fluoride at 105°C to constant weight. Cool in a desiccator. Weigh out 4.2 g to the nearest 0.0001 g. Transfer quantitatively to a 1,000-mL volumetric flask. Add 400 mL of deionized water and mix until dissolved. Fill to the mark with deionized water and mix.

4. Fluoride standard (0.05*N*). Pipette 500 mL of the fluoride standard prepared in step 3 into a 1,000-mL volumetric flask. Fill to the mark with total ionic strength adjuster buffer (TISAB) and mix.

5. Fluoride standard (0.005*N*). Pipette 50 mL of the fluoride standard prepared in step 3 into a 1,000-mL volumetric flask. Add 500 mL of TISAB, fill to the mark with deionized water, and mix.

6. Fluoride standard (0.0005*N*). Pipette 5 mL of the fluoride standard into a 1,000-mL volumetric flask. Add 500 mL of TISAB, fill to the mark with deionized water, and mix.

7. Hydrochloric acid (0.1*N*).

5.2.5.2 Special equipment.

1. A pH meter, with expanded millivolt (mV) scale.
2. Fluoride-specific ion electrode.

5.2.5.3 Calibration of fluoride electrode.*

NOTE: The electrode should be calibrated daily.

1. Set up the meter and electrode per instructions supplied by the manufacturer.

2. Transfer 50 mL of the 0.05*N*, 0.005*N*, and 0.0005*N* fluoride standards into three separate 100-mL plastic beakers and label them solution 1, solution 2, and solution 3, respectively.

3. Immerse the electrode into solution 2 and turn on stirrer. Turn the Function knob to "mV EX" and the Operate switch to "USE." Allow reading to stabilize. If necessary, use the Standardization knob to adjust reading to 0.0 mV ±0.1 mV. The reading should be stable for 1 min. Put the meter in "STBY" mode, remove the electrode from the solution, and pat dry.

4. Immerse the electrode in solution 1 and turn on stirrer. Turn the Operate switch to "USE." Allow the reading to stabilize. Record the mV reading. (It should

*The pH meters with expanded mV scales commonly have control markings consistent with the calibration procedure provided. Consult with manufacturers of specific pH meters if control markings differ from those listed in this section.

be –56 mV ±2 mV.) Put the meter in "STBY" mode, remove the electrode from the solution, and pat dry.

5. Repeat step 4 with solution 2 using the Standardization knob to readjust to zero if necessary.

6. Repeat step 4 with solution 3 and record the mV reading. It should be +56 mV ±2 mV.

7. Repeat step 4 with solution 2, readjusting to zero if necessary.

5.2.5.4 Sodium fluoride assay procedure and calculation.

1. Grind a sample of the sodium fluoride to be assayed in a mortar and pestle to pass a US 100 sieve.

2. Dry the sample at 105°C to constant weight. Cool in a desiccator.

3. Weigh out 4.2 g of the sample to the nearest 0.0001 g.

4. Transfer the sample quantitatively to a 1,000-mL volumetric flask, add 400 mL of water, and shake to dissolve. Fill to the mark with water and mix.

5. Pipette 25 mL of the sample solution and 50 mL of water into a 100-mL plastic beaker and begin stirring.

6. Immerse the electrode into the solution and titrate with 0.3*N* lanthanum nitrate, using a 10-mL microburette, until a reading of 90 mV ±2 mV is obtained. Record the amount of lanthanum nitrate used to the nearest 0.01 mL.

7. Calculation*

$$\frac{[\text{mL of La}(NO_3)_3] \times [N \text{ of La}(NO_3)_3] \times 1.68 \times 100}{\text{weight of sample, in grams}} = \text{percent NaF} \qquad \text{(Eq 4)}$$

$$\text{percent NaF} \times 0.4524 = \text{percent F}$$

5.2.6 *Test procedure for fluoride content—titration method.*

NOTE: Sec. 5.2.5 and 5.2.6 contain references for two analytical procedures to determine fluoride content. Should a referee method be needed, the fluoride electrode method shall be considered the preferred procedure. See Sec. 5.2.5 for the preferred procedure. Required reagents and the procedure for the titration method are as follows:

5.2.6.1 Reagents.

1. Alcoholic potassium chloride—dissolve 60 g of potassium chloride in 400 mL of freshly boiled and cooled deionized water and add 400 mL of neutral 95 percent ethyl alcohol.

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*Based on the chemical equation:

$3NaF + La(NO_3)_3 \rightarrow LaF_3 + 3NaNO_3$.

2. Standard sodium hydroxide solution, 0.2*N*.
3. Powdered silica gel.
4. Concentrated hydrochloric acid.
5. Methyl orange indicator, 0.5 percent.
6. Phenolphthalein indicator, 1 percent.
7. Potassium chloride crystals.
8. Ethyl alcohol, neutral.

5.2.6.2 Procedure.

1. Weigh and transfer to a 250-mL beaker 0.5 g of sample that has been dried at 105°C to a constant weight. (As the sample is granular, grind to powder with a mortar and pestle.) Add 20 to 25 mL of deionized water. Add 0.5 g of silica gel, a few drops of methyl orange indicator, and concentrated hydrochloric acid, dropwise, to a permanent pink color and then 0.5 mL in excess.

2. Bring the solution just to the boiling point, cool to room temperature, add 4 g of potassium chloride, and stir until dissolved or place it on a shaking machine for at least 30 min. Add 25 mL of neutral ethyl alcohol and allow to stand for 1 hr.

3. Filter with a Buchner funnel or filter crucible with suction and wash with alcoholic potassium chloride solution until one washing does not destroy the color made by one drop of 0.2*N* sodium hydroxide solution and phenolphthalein indicator.

4. Transfer the filter paper and contents to a 400-mL beaker. Add 200 mL of recently boiled deionized water and 1 to 2 mL of 1 percent phenolphthalein indicator, heat to 70–90°C, and titrate with 0.2*N* sodium hydroxide to first pink color. Finish titration with the solution boiling actively.

5.2.6.3 Calculation.*

$$\frac{\text{mL NaOH} \times N \times 0.0630}{\text{weight of sample, in grams}} \times 100 = \text{percent NaF} \qquad \text{(Eq 5)}$$

$$\text{percent NaF} \times 0.4524 = \text{percent F}$$

5.2.7 *Test procedure for impurities.* When testing for impurities, the analytic methods provided for in *Standard Methods for the Examination of Water and*

*Based on the following chemical equations:

$6NaF + SiO_2 + 4HCl \rightarrow Na_2SiF_6 + 4NaCl + 2H_2O$

$Na_2SiF_6 + 2KCl \rightarrow K_2SiF_6 + 2NaCl$

$K_2SiF_6 + 4NaOH \rightarrow 2KF + 4NaF + SiO_2 + 2H_2O$

Table 1 Impurity analytic methods

Impurity	*Standard Methods*[*] Part	Aggregate Methodologies[†]
Regulated Metals		
Antimony	3500-Sb	AAS, ICP, ICP/MS
Arsenic	3500-As	AAS, ICP, ICP/MS
Barium	3500-Ba	AAS, ICP, ICP/MS
Beryllium	3500-Be	AAS, ICP, ICP/MS
Cadmium	3500-Cd	AAS, ICP, ICP/MS
Copper	3500-Cu	AAS, ICP, ICP/MS
Lead	3500-Pb	AAS, ICP, ICP/MS
Mercury (inorganic)	3500-Hg	AAS
Selenium	3500-Se	AAS, ICP, ICP/MS
Thallium	3500-Tl	AAS, ICP, ICP/MS
Radionuclides		
Beta particle and photon activity	7110	—
Gross alpha particle activity	7110	—
Radium 226 and 228 (combined)	7500-Ra	—
Uranium	3500-U	ICP/MS

[*] *Standard Methods for the Examination of Water and Wastewater.* American Public Health Association, American Water Works Association, and Water Environment Federation, Washington, D.C.

[†] Aggregate Methodologies

AAS—Atomic Absorption Spectrometry

ICP—Inductively Coupled Plasma (with spectrometer)

ICP/MS—Inductively Coupled Plasma/Mass Spectrometer

Wastewater shall be employed. Impurity-specific methods and additional methodologies that provide for automation and for multiple analyses to be determined at the same time are provided in Table 1. The aggregate methodologies are often more economical when the full spectrum of impurities are to be determined, and are recommended. Producers are encouraged to maintain a database of impurity concentrations based on quarterly analysis of normal production product.

5.2.8 *Test procedure for turbidity of saturated sodium fluoride solution.*

1. Weigh 1.00 g of sodium fluoride and add to 25.0 mL of distilled water in a stoppered bottle.
2. Cap and shake vigorously for 5 sec. Let stand for 5 min.
3. Transfer supernatant to turbidity vial. Measure turbidity immediately.

5.2.9 *Rejection.*

5.2.9.1 Notice of nonconformance. If the sodium fluoride delivered does not meet the requirements of this standard, a notice of nonconformance shall be provided by the purchaser to the supplier within 10 days after receipt of the shipment at the point of destination. The results of the purchaser's tests shall prevail, unless the supplier notifies the purchaser within five days after receipt of the notice of nonconformance that a retest is desired. On receipt of the request for a retest, the purchaser shall forward to the supplier one of the sealed samples taken in accordance with Sec. 5.1 of this standard. In the event that the results obtained by the supplier on retesting do not agree with the results obtained by the purchaser, the remaining sealed sample shall be forwarded, unopened, for analysis to a referee laboratory agreed on by both parties. The results of the referee analysis shall be accepted as final.

5.2.9.2 Material originating outside of North America. On request of the purchaser, the supplier shall inform the purchaser of the origin of the sodium fluoride to be provided. The purchaser may request from the supplier a written statement presenting the steps the supplier will take to ensure that the material to be supplied conforms to the requirements of this standard and NSF/ANSI 60.

5.2.9.3 Torn bags. Ripped or torn bags are not acceptable.

SECTION 6: DELIVERY*

Sec. 6.1 Marking

6.1.1 *Required.* Each package and container shall be legibly marked with the name of the compound, the net weight of the contents, the minimum percent (dry basis) of sodium fluoride (see Sec. 4.2.1), the name of the manufacturer, the lot number, and the brand name (if any). Each package shall bear other markings as are required by the US Department of Transportation (USDOT) and other applicable laws. When shipped in bulk, this information shall accompany the bill of lading.

6.1.2 *Optional.* Packages may also bear the statement "This material meets the requirements of ANSI/AWWA B701 Standard for Sodium Fluoride," provided

*Governmental marking, packaging, and shipping references reflect US requirements. Users of ANSI/AWWA B701 outside the United States should verify applicable local and national regulatory requirements.

that the requirements of this document are met and the material is not of a different quality, in a separate agreement between the supplier and the purchaser.

Sec. 6.2 Packaging and Shipping*

6.2.1 *Packaging.* Bags, drums, and any other nonbulk containers used for packaging sodium fluoride shall comply with all applicable paragraphs of HM-181, part 178 (specifications for packaging) of CFR 49.† Sodium fluoride may be shipped in multiwall paper bags, fiber drums, super sacks, bulk, or other USDOT-approved containers as specified by the purchaser. Where feasible, bags should be constructed with vapor barrier liners.

6.2.2 *Net weight.* The net weight of packages shall not deviate from the recorded weight by more than ±2.5 percent. If exception is taken to the weight of the material received, it shall be based on a certified unit weight of not less than 10 percent of the packages shipped, selected at random from the entire shipment.

6.2.3 *Shipping regulations.* The shipping of sodium fluoride shall conform to all applicable federal, state, local, and provincial regulations.

Sec. 6.3 Affidavit of Compliance or Certified Analyses

The purchaser may require either (1) an affidavit from the manufacturer or supplier that the sodium fluoride provided according to the purchaser's documents complies with all applicable requirements of this standard; or (2) certified analyses of the sodium fluoride, provided by the manufacturer or supplier, describing these items as required; or (3) both.

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*Because of frequent changes in these regulations, all parties should remain informed of possible revisions. Provisions of the purchaser's documents should not preclude compliance with applicable regulators.

† *Code of Federal Regulations,* Title 49, part 178 (Transportation). Superintendent of Documents, US Government Printing Office, Washington, DC 20402.

APPENDIX A

Sodium Fluoride—Contaminants

This appendix is for information only and is not a part of ANSI/AWWA B701.

Table A1 Sodium fluoride—contaminants

Contaminant*	Regulation	Drinking Water Maximum Contaminant Level/Maximum Allowable Concentration (MCL/MAC) *mg/L*	Single Product Allowable Concentration (SPAC) *mg/L*
Antimony	(40 CFR § 141.60, § 141.62)	0.006	0.0006
Arsenic	(effective date: 01/23/06)	0.010	0.001
Barium	(40 CFR § 141.60, § 141.62)	2	0.2
Beryllium	(40 CFR § 141.60, § 141.62)	0.004	0.0004
Cadmium	(40 CFR § 141.60, § 141.62)	0.005	0.0005
Copper (at tap)	(40 CFR § 141.80, 65 FR 1950)	TT† (action level 1.3 mg/L)	0.13
Lead (at tap)	(40 CFR § 141.80, 65 FR 1950)	TT† (action level 0.015 mg/L)	0.0015
Mercury (inorganic)	(40 CFR § 141.60, § 141.62)	0.002	0.0002
Selenium	(40 CFR § 141.60, § 141.62)	0.05	0.005
Thallium	(40 CFR § 141.60, § 141.62)	0.002	0.0002
Radionuclides			
Beta particle and photon activity	(40 CFR § 141.16)	4 mrem/y	0.4 mrem/y
Gross alpha particle activity	(40 CFR § 141.15)	15 pCi/L	1.5 pCi/L
Radium 226 and 228 (combined)	(40 CFR § 141.15)	5 pCi/L	0.5 pCi/L
Uranium	(40 CFR § 141.66)	30 µg/L	3.0 µg/L

*The references for criteria based on US primary drinking water regulations are from the US Code of Federal Regulations, Title 40 (Protection of Environment), revised as of July 1, 1999. This document is available online at www.access.gpo.gov/cgi-bin/cfrassemble.cgi. Issue dates are given for criteria based on Health Canada guidelines. Additional information on the guidelines for these chemicals is available at www.hc-sc.gc.ca/water quality.

†TT—Treatment technique

ANSI/AWWA B703-06
(Revision of ANSI/AWWA B703-00)

American Water Works Association

The Authoritative Resource on Safe Water℠

AWWA Standard

Fluorosilicic Acid

ANSI American National Standards Institute

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Sections

AWWA Standard

This document is an American Water Works Association (AWWA) standard. It is not a specification. AWWA standards describe minimum requirements and do not contain all of the engineering and administrative information normally contained in specifications. The AWWA standards usually contain options that must be evaluated by the user of the standard. Until each optional feature is specified by the user, the product or service is not fully defined. AWWA publication of a standard does not constitute endorsement of any product or product type, nor does AWWA test, certify, or approve any product. The use of AWWA standards is entirely voluntary. AWWA standards are intended to represent a consensus of the water supply industry that the product described will provide satisfactory service. When AWWA revises or withdraws this standard, an official notice of action will be placed on the first page of the classified advertising section of *Journal AWWA*. The action becomes effective on the first day of the month following the month of *Journal AWWA* publication of the official notice.

American National Standard

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Foreword

This Foreword is for information only and is not a part of ANSI/AWWA B703.

I. Introduction.

I.A. *Background.* Fluorosilicic acid (H_2SiF_6) is one of several fluoride compounds presently being added to drinking water to reduce the incidence of dental caries. Since the first fluoridation installation during 1945, studies have shown that dental decay can be reduced by 20 to 40 percent among children who have consumed fluoridated water since birth.

Fluorosilicic acid is an aqueous solution of H_2SiF_6—water white to straw yellow in color. It is a corrosive acid, irritating to the skin, and has a pungent odor. It is not known to exist in any anhydrous form. The boiling point increases with increasing acid content. At a typical commercial strength of 25 percent acid content, the boiling point is 105.8°C (222.5°F), and the freezing point is approximately –15.5°C (4°F). A 25 percent solution has a pH of 1.2 and weighs 10.1 lb/gal (1.20 kg/L). The molecular weight of H_2SiF_6 is 144.08.

Fluorosilicic acid is produced as a co-product in the manufacture of wet-process phosphoric acid and other phosphate fertilizers. The raw material, phosphate rock, contains fluoride and silica and is treated with sulfuric acid, which evolves the gases silicon tetrafluoride (SiF_4) and hydrogen fluoride (HF). These gases are passed through scrubbers and react with water to form fluorosilicic acid. This acid is the principal raw material in the production of all silicofluoride salts. It is also used in the ceramic, brewing, paint, and metallurgical industries.

Fluorosilicic acid is added to water using various liquid-feeding devices and metering pumps. It is normally fed directly into the water to produce the optimal fluoride concentration. Dilution of the acid before feeding is not recommended. If the acid is too concentrated for the solution feeder to control, solutions of other compounds are generally indicated, for example, solutions of sodium fluoride or sodium fluorosilicate. If the acid must be diluted, dilutions in the range of 10 to 1 and 20 to 1 (parts water to parts acid) should be avoided, because they often result in the formation of an insoluble silica precipitate that can clog feeders, orifices, and other equipment. The use of softened or distilled water has no effect on the formation of this precipitate. However, the precipitate can be avoided by using dilutions outside the critical range (dilutions in the range of 200:1 to 100:1 are

known to work well), or by using acid that has been fortified with hydrogen fluoride (HF).

Refer to AWWA Manual M4, *Water Fluoridation Principles and Practices*,* for additional technical information concerning the application and use of fluorosilicic acid.

I.B. *History.* This standard was first published in the November 1954 issue of *Journal AWWA* as tentative, having been approved on July 30, 1954, by the AWWA Board of Directors. Subsequent revisions to ANSI/AWWA B703 were approved by the AWWA Board of Directors on May 15, 1960; June 18, 1971; Jan. 30, 1984; Jan. 29, 1989; Jan. 30, 1994; and Jan. 23, 2000. This eighth edition was prepared by the AWWA Standards Committee on Fluorides and approved by the AWWA Board of Directors on Feb. 12, 2006.

I.C. *Acceptance.* In May 1985, the US Environmental Protection Agency (USEPA) entered into a cooperative agreement with a consortium led by NSF International (NSF) to develop voluntary third-party consensus standards and a certification program for direct and indirect drinking water additives. Other members of the original consortium included the American Water Works Association Research Foundation (AwwaRF) and the Conference of State Health and Environmental Managers (COSHEM). The American Water Works Association (AWWA) and the Association of State Drinking Water Administrators (ASDWA) joined later.

In the United States, authority to regulate products for use in, or in contact with, drinking water rests with individual states.† Local agencies may choose to impose requirements more stringent than those required by the state. To evaluate the health effects of products and drinking water additives from such products, state and local agencies may use various references, including two standards developed under the direction of NSF, NSF‡/ANSI§ 60, Drinking Water Treatment Chemicals—Health Effects, and NSF/ANSI 61, Drinking Water System Components—Health Effects.

Various certification organizations may be involved in certifying products in accordance with NSF/ANSI 60. Individual states or local agencies have authority to

*AWWA Manual M4, *Water Fluoridation Principles and Practices*, AWWA, Denver, Colo.

†Persons outside of the United States should contact the appropriate authority having jurisdiction.

‡NSF International, 789 N. Dixboro Road, Ann Arbor, MI 48105.

§American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

accept or accredit certification organizations within their jurisdiction. Accreditation of certification organizations may vary from jurisdiction to jurisdiction.

Annex A, "Toxicology Review and Evaluation Procedures," to NSF/ANSI 60 does not stipulate a single product allowable concentration (SPAC) value of a contaminant for substances not regulated by a USEPA final maximum contaminant level (MCL). The SPAC values of an unspecified list of "unregulated contaminants" are based on toxicity testing guidelines (noncarcinogens) and risk characterization methodology (carcinogens). Use of Annex A procedures may not always be identical, depending on the certifier.

ANSI/AWWA B703 addresses additives requirements in Sec. 4.3 of the standard. The transfer of contaminants from chemicals to processed water or the residual solids is becoming a problem of greater concern. The language in Sec. 4.3.3 is a recommendation only for direct additives used in the treatment of potable water to be certified by an accredited certification organization in accordance with NSF/ANSI 60, Drinking Water Treatment Chemicals—Health Effects. However, users of the standard may opt to make this certification a requirement for the product. Users of this standard should consult the appropriate state or local agency having jurisdiction in order to

1. Determine additives requirements, including applicable standards.
2. Determine the status of certifications by all parties offering to certify products for contact with, or treatment of, drinking water.
3. Determine current information on product certification.

II. **Special Issues.**

II.A. *Storage, Handling, and Safety Precautions.* Fluorosilicic acid must be handled carefully because it is corrosive. If the acid comes in contact with skin, the affected parts should be immediately rinsed thoroughly with water. For information on safety, refer to the material safety data sheets (MSDS) available from the chemical supplier or manufacturer. Protective safety gear should be worn when handling fluorosilicic acid. The following protective clothing and equipment should be the minimum available:

1. Gauntlet neoprene gloves (12-in. [300-mm] minimum glove length).
2. Full 8-in. (200-mm) face shield or acid-proof-type safety goggles.
3. Heavy-duty, acid-proof-type neoprene aprons.
4. Safety shower and eyewash in an easily accessible location.

Materials such as glass, ceramics, steel, concrete, and wood are not suitable for fluorosilicic acid containers and other equipment because they are attacked by the hydrofluoric acid (HF) and silicon tetrafluoride (SiF_4) formed at the surface of the fluorosilicic acid. Bulk storage tanks and other containers can be made of polyethylene, rubber-lined steel, or other appropriate materials. The polyethylene should be manufactured from high-density, cross-linked material (cross-linking provides strength). The polyethylene should contain a minimum of 0.25 percent ultraviolet stabilizer to protect against sunlight. Steel tanks must always be lined. The linings are commonly made of natural rubber, neoprene, butyl rubber, or equivalent and should be at least 2.4-mm (3/32-in.) thick. Structural carbon, Hastelloy C, Durimet 20, or equivalent materials can be used for hardware. The rooms where the acid is stored and used should be thoroughly ventilated with a vent located near the ceiling because acid fumes are lighter than air. Closed tanks should be vented to the outside. Additional information on materials compatibility appears in Appendix A.

III. Use of This Standard. It is the responsibility of the user of an AWWA standard to determine that the products described in that standard are suitable for use in the particular application being considered.

III.A. *Purchaser Options and Alternatives.* The following items should be provided by the purchaser:

1. Standard used—that is, ANSI/AWWA B703, Standard for Fluorosilicic Acid, of latest revision.

2. Whether compliance with NSF/ANSI 60, Drinking Water Treatment Chemicals—Health Effects, is required.

3. Quantity required.

4. If an analysis by a referee laboratory is required, the assignment of testing costs should be addressed.

5. Concentration (strength of acid desired) (Sec. 4.2). The acid shall contain between 20 and 30 percent H_2SiF_6 by weight. Where variations in acid strength are acceptable, arrangements should be made between the purchaser and the supplier as to the method of payment, based on the aggregated acid content.

6. Form of shipment—bulk or package (type) (Sec. 6.2.2).

7. Affidavit of compliance or certified analyses, or both, if required (Sec. 6.3).

III.B. *Modification to Standard.* Any modification to the provisions, definitions, or terminology in this standard must be specified by the purchaser.

IV. **Major Revisions.** Major changes made in this revision of the standard include the following:

1. Impurity requirements have been tied to the SPACs listed in NSF/ANSI 60, Drinking Water Treatment Chemical—Health Effects (Sec. 4.3.3).

2. Test procedures for impurities have been defined and referenced (Sec. 5.2.5 and Table 1).

3. A table showing SPACs for impurities regulated under NSF/ANSI 60, Drinking Water Treatment Chemical—Health Effects, has been added as an appendix (Appendix B).

V. **Comments.** If you have any comments or questions about this standard, please call the AWWA Volunteer & Technical Support group, 303.794.7711, FAX 303.795.7603, write to the group at 6666 West Quincy Avenue, Denver, CO 80235-3098, or e-mail at standards@awwa.org.

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American Water Works Association

ANSI/AWWA B703-06
(Revision of ANSI/AWWA B703-00)

AWWA Standard

Fluorosilicic Acid

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard describes fluorosilicic acid (H_2SiF_6) for water supply service application.

Sec. 1.2 Purpose

The purpose of this standard is to provide the minimum requirements for fluorosilicic acid, including physical, chemical, packaging, shipping, and testing requirements.

Sec. 1.3 Application

This standard can be referenced in specifications for purchasing and receiving fluorosilicic acid and can be used as a guide for testing the physical and chemical properties of fluorosilicic acid samples. The stipulations of this standard apply when this document has been referenced and only to fluorosilicic acid used in water supply service application.

SECTION 2: REFERENCES

This standard references the following documents. In their latest edition, they form a part of this standard to the extent specified in this standard. In any case of conflict, the requirements of this standard shall prevail.

NSF*/ANSI† 60, Drinking Water Treatment Chemicals—Health Effects.

Standard Methods for the Examination of Water and Wastewater. APHA,‡ AWWA, and WEF.§

SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

1. *Day:* A day is defined as a 24-hr period.

2. *Manufacturer:* The party that manufactures, fabricates, or produces materials or products.

3. *Purchaser:* The person, company, or organization that purchases any materials or work to be performed.

4. *Supplier:* The party that supplies materials or services. A supplier may or may not be the manufacturer.

SECTION 4: REQUIREMENTS

Sec. 4.1 Physical Requirements

4.1.1 *Suspended matter.* The fluorosilicic acid supplied according to this standard shall be clean and free of visible suspended matter.

4.1.2 *Color.* The fluorosilicic acid supplied according to this standard shall be white to straw yellow. Straw yellow shall be determined as material with a

*NSF International, 789 N. Dixboro Road, Ann Arbor, MI 48105.

†American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

‡American Public Health Association, 800 I Street NW, Washington, DC 20001.

§Water Environment Federation, 601 Wythe Street, Alexandria, VA 22314.

maximum of 100 units in accordance with method 2120B, visual comparison method.*

Sec. 4.2 Chemical Requirements

The fluorosilicic acid shall contain between 20 and 30 percent fluorosilicic acid by weight unless specified otherwise by the purchaser.

Sec. 4.3 Impurities†

4.3.1 *General.* The fluorosilicic acid supplied according to this standard shall contain no mineral or organic substances in quantities capable of producing deleterious or injurious effects on the health of those consuming water that has been properly treated with fluorosilicic acid.

4.3.2 *Free acid content.* The fluorosilicic acid supplied according to this standard shall contain a maximum of 1 percent free acids (other than fluorosilicic acid), expressed as HF (hydrofluoric acid).

4.3.3 *Product certifications.* Fluorosilicic acid is a direct additive used in the treatment of potable water. This material should be certified as suitable for contact with or treatment of drinking water by an accredited certification organization in accordance with NSF/ANSI 60, Drinking Water Treatment Chemicals—Health Effects. Evaluation shall be accomplished in accordance with requirements that are no less restrictive than those listed in NSF/ANSI 60. Certification shall be accomplished by a certification organization accredited by the American National Standards Institute.

The fluorosilicic acid impurities regulated under NSF/ANSI 60, their drinking water regulatory levels, and their single product allowable concentration (SPAC) value are as provided in Appendix B. The SPAC values are to be compared to the concentration's values resulting from an applied fluorosilicic acid dose that results in a concentration of 1.2 mg/L fluoride in the treated water.

4.3.4 *Additional impurity limits.* Additional impurity limits may be specified by the purchaser to ensure that the material supplied is suitable for water treatment. If additional impurity limits are specified, the purchaser must state the test methodology to be used to determine compliance with the additional limits.

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* *Standard Methods for the Examination of Water and Wastewater.*

† See Sec. I.C of the Foreword.

SECTION 5: VERIFICATION

Sec. 5.1 Sampling and Laboratory Examination

Sampling shall be conducted in accordance with this section of the standard. The laboratory examination of the samples shall be completed within the following time limitations:

1. Bulk shipments—before unloading, unless the shipment is accompanied by a certified analysis from the manufacturer or supplier.
2. Drum shipments—within five days after receipt of the shipment.

5.1.1 *Sampling point.* Samples shall be taken at the point of destination.

5.1.2 *Amount of shipment to be sampled.* If the acid is supplied in drums, the number of drums sampled will be left to the discretion of the purchaser. In the case of bulk shipments, a composite sample should be taken from the tank truck or tank car.

5.1.3 *Sampling container.* Samples shall be collected in a clean, plastic or rubber container. Containers lined with acid-resistant plastic, wax, or rubber may also be used.

5.1.4 *Sampling method for drums.* When sampling from drums, the fluorosilicic acid in the containers to be sampled shall first be mixed by rolling or other suitable means. A portion shall be taken from each container to be sampled so that the total gross sample consists of at least 2 L.

5.1.5 *Sampling method for bulk material.* When sampling from a tank truck or tank car, at least five different 500-mL portions shall be taken from different places in the container (top, middle, and bottom) and combined to form a composite sample that is representative of the entire container.

5.1.6 *Sample handling.* After mixing of the gross sample, three 500-mL samples shall be sealed in airtight, moisture-proof, plastic or rubber containers. Each sample container shall be labeled to identify it, and the label shall be signed by the sampler.

5.1.7 *Sample retention.* Samples shall be held for 30 days before disposal.

Sec. 5.2 Test Procedures

Testing of fluorosilicic acid shall be conducted in accordance with the procedures presented in the following sections. Alternate procedures can be used only

on the written approval of the purchaser. In any case of conflict, the methods of this standard shall prevail.

5.2.1 *Test samples.* Test samples shall be obtained from the sealed material samples (Sec. 5.1.6) delivered to the laboratory. Material samples shall be unsealed only when it is necessary to remove quantities of the material for testing. Removal of material shall be performed quickly, and the material samples shall then be resealed for future reference.

5.2.2 *Determining fluorosilicic acid content.* Two methods are presented for determining the percentage of fluorosilicic acid content. The specific-gravity method will provide only a very rough approximation and should not be used for determining the exact amount of acid. If facilities are available, the hydrogen titration method is the preferred method for determining fluorosilicic acid content.

5.2.2.1 Hydrogen titration method.

1. Principle. Titration of ionizable hydrogen in a chilled solution from which the fluorosilicate ions have been precipitated as potassium fluorosilicate.

2. Reagents.

a. Deionized ice.

b. Potassium nitrate-saturated solution.

c. Standard sodium hydroxide solution, 0.5*N*.

d. Bromothymol blue, 0.2 percent solution.

3. Procedure.

a. Using a pipette bulb, pipette 25 mL of sample into a 500-mL volumetric flask. Dilute with deionized water to the mark and mix. If this suggested dilution produces a precipitate (Sec. I.A of the Foreword), pipette a smaller sample volume (in 5-mL increments) until no precipitate forms.

b. Place 100 to 150 mL of clean deionized ice into a 400-mL beaker, add 25 mL of potassium nitrate solution, and using a pipette bulb, pipette a 25-mL aliquot of the diluted sample solution into the beaker. Wash down the sides of the beaker with deionized water.

c. Stirring constantly, promptly titrate with standard sodium hydroxide, using bromothymol blue as the end-point indicator. The end point has been reached when the blue color persists for at least 30 sec. On standing longer, the indicator will turn yellow.

4. Calculation.*

$$\text{volume of sample taken, in milliliters } (D)\ C \times \frac{A}{B} \qquad \text{(Eq 1)}$$

$$\text{weight of sample, in grams} = D \times \text{specific gravity (at room temperature)} \qquad \text{(Eq 2)}$$

$$\text{percent } H_2SiF_6 = \frac{\text{mL NaOH} \times N \times 0.072 \times 100}{\text{weight of sample, in grams}} \qquad \text{(Eq 3)}$$

Where:

A = original sample volume, in milliliters (step 1)

B = diluted sample volume, in milliliters (generally 500 mL)

C = aliquot volume, in milliliters (step 2)

5.2.3 *Determining free acid.*

5.2.3.1 Procedure. The preceding method will include any free acid other than fluorosilicic acid that may be present. If it is necessary to distinguish between fluorosilicic acid and other acids, place the beaker, the contents of which have been titrated as above, on a hot plate and bring to a boil. Titrate the hot solution with standard sodium hydroxide to the neutral point of the bromothymol blue. This titration breaks down the fluorosilicate radical of the potassium fluorosilicate:

$$K_2SiF_6 + 4NaOH \rightarrow 2KF + 4NaF + SiO_2 + 2H_2O \qquad \text{(Eq 4)}$$

If the fluorosilicic acid is 100 percent pure, the milliliters of NaOH used in the cold titration will equal exactly half the milliliters of NaOH used in the hot titration. If free acid other than fluorosilicic is present, the cold titer will exceed half the hot titer. If the fluorosilicate salts are present, half the hot titer will exceed the cold titer.

*Based on the following chemical equations:

$H_2Si_6 + 2KNO_3 \rightarrow K_2SiF_6 + 2HNO_3$

$HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$

5.2.3.2 Calculation.

$$\frac{\left(\text{mL NaOH}^{*} - \frac{\text{mL NaOH}^{\dagger}}{2}\right) \times N \times 0.02 \times 100}{\text{weight of sample, in grams}}$$

= percent free acid other than H_2SiF_6, expressed as HF (Eq 5)

$$\frac{\frac{\text{mL NaOH}^{\dagger}}{2} \times N \times 0.072 \times 100}{\text{weight of sample, in grams}} = \text{percent } H_2SiF_6 \quad \text{(Eq 6)}$$

5.2.4 *Specific-gravity method.*

5.2.4.1 Apparatus.

1. Acid-resistant plastic or glass cylinder or dish with sufficient depth to float a hydrometer.

2. Glass hydrometer (long stem) capable of being read to three significant figures. (If the density of the solution varies over a wide range, a set of three or more hydrometers should be available to cover the range.)

5.2.4.2 Procedure.

1. Carefully transfer the fluorosilicic acid from the sample container to the cylinder and adjust the temperature to 17.5°C (63.5°F). Insert the hydrometer and measure the specific gravity.

2. Do not keep the hydrometer and other glassware in contact with the fluorosilicic acid solution longer than is necessary. Thoroughly rinse the hydrometer and other glassware in clear, cool, running water immediately after using.

3. Determine the approximate percentage of fluorosilicic acid from a table‡ or graph that has been prepared from the analyses of a number of shipments from which both specific gravity and actual fluoride content have been determined.

5.2.5 *Test procedure for impurities.* When testing for impurities, the analytic methods provided for in *Standard Methods for the Examination of Water and Wastewater* shall be employed. Impurity-specific methods and additional methodologies that provide for automation and for multiple analyses to be determined at the same time are provided in Table 1. The aggregate methodologies are often more economical when the

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*Cold titer.

†Hot titer.

‡The use of a standard table from a handbook is not recommended. Because these tables are prepared from dilutions of cp-grade acid, distilled water may introduce errors of more than 10 percent. Experience in the field has shown that the specific gravity of commercial grades of fluorosilicic acid in concentrations from 20 to 30 percent varies considerably between different manufacturers (5 to 14 percent less than that given in the standard table).

Table 1 Impurity analytic methods

Impurity	*Standard Methods*[*] Part	Aggregate Methodologies[†]
Regulated Metals		
Antimony	3500-Sb	AAS, ICP, ICP/MS
Arsenic	3500-As	AAS, ICP, ICP/MS
Barium	3500-Ba	AAS, ICP, ICP/MS
Beryllium	3500-Be	AAS, ICP, ICP/MS
Cadmium	3500-Cd	AAS, ICP, ICP/MS
Copper	3500-Cu	AAS, ICP, ICP/MS
Lead	3500-Pb	AAS, ICP, ICP/MS
Mercury (inorganic)	3500-Hg	AAS
Selenium	3500-Se	AAS, ICP, ICP/MS
Thallium	3500-Tl	AAS, ICP, ICP/MS
Radionuclides		
Beta particle and photon activity	7110	—
Gross alpha particle activity	7110	—
Radium 226 and 228 (combined)	7500-Ra	—
Uranium	3500-U	ICP/MS

[*] *Standard Methods for the Examination of Water and Wastewater.*

[†] Aggregate Methodologies

AAS—Atomic Absorption Spectrometry

ICP—Inductively Coupled Plasma (with spectrometer)

ICP/MS—Inductively Coupled Plasma/Mass Spectrometer

full spectrum of impurities are to be determined and are recommended. Producers are encouraged to maintain a database of impurity concentrations based on quarterly analysis of normal production product.

5.2.6 *Rejection.*

5.2.6.1 Notice of nonconformance. If the fluorosilicic acid delivered does not meet the requirements of this standard, a notice of nonconformance shall be provided by the purchaser to the supplier within 10 days after receipt of the shipment at the point of destination. The results of the purchaser's test shall prevail, unless the supplier notifies the purchaser within five days after receipt of the notice of

nonconformance that a retest is desired. On receipt of the request for a retest, the purchaser shall forward to the supplier one of the sealed samples taken in accordance with Sec. 5.1 of this standard. In the event that the results obtained by the supplier on retesting do not agree with the results obtained by the purchaser, the other sealed sample shall be forwarded, unopened, for analysis to a referee laboratory agreed on by both parties. The results of the referee analysis shall be accepted as final.

5.2.6.2 Material originating outside of North America. On request of the purchaser, the supplier shall inform the purchaser of the origin of the fluorosilicic acid to be provided. The purchaser may request from the supplier a written statement presenting the steps the supplier will take to ensure that the material to be supplied conforms to the requirements of this standard and NSF/ANSI 60.

SECTION 6: DELIVERY*

Sec. 6.1 Marking

6.1.1 *Required.*

6.1.1.1 Drum shipment labels. Each shipment shall contain clear identification of the material and a warning of potential danger in handling. Each drum shall have marked legibly on it the name of the acid, the net weight or volume of the contents, the percent strength of the acid, the name and address of the supplier or manufacturer, the lot number, and the brand name if any, and shall bear other markings as are required by applicable laws. The warning label should include suggestions for immediately rinsing away all acid coming in contact with the skin and the thorough dilution of acid accidentally spilled, including neutralization of the acid with lime.

6.1.1.2 Bulk shipment labels. On rail tank cars and tank truck shipments, the information listed under Sec. 6.1.1.1 shall accompany the bill of lading.

6.1.2 *Optional.* Packages may also bear the statement, "This material meets the requirements of ANSI/AWWA B703, Standard for Fluorosilicic Acid," provided that the requirements of this standard are met and the material is not of a different quality or strength by separate agreement between the supplier and purchaser.

*Governmental marking, packaging, and shipping references reflect US requirements. Users of ANSI/AWWA B703 outside the United States should verify applicable local and national regulatory requirements.

Sec. 6.2 Packaging and Shipping*

6.2.1 *Packaging.* Drums and any other nonbulk container used to package fluorosilicic acid shall comply to all applicable paragraphs of HM-181, part 178 of CFR 49.†

6.2.2 *Containers.*

6.2.2.1 General. Containers shall be rubber-lined steel, cross-linked polyethylene, or other structures suitably lined to prevent corrosion by the fluorosilicic acid. US Department of Transportation (USDOT) regulations should be consulted for additional options.

6.2.2.2 Structure. The container must be structurally sound and designed to withstand all hydrostatic pressures and other forces encountered. The specific gravity of fluorosilicic acid at 30 percent solution is 1.27.

6.2.3 *Net weight.* The net weight or net volume of the containers shall not be less than the recorded weight or volume, or more than 10 percent greater. If exception is taken to the weight or volume of the material received, it shall be based on the certified weight or volume of not less than 10 percent of the containers, selected at random from the entire shipment. Tank truck shipments shall be accompanied by certified weight tickets.

6.2.4 *Shipping regulations.* Packaging and shipping of all fluorosilicic acid solutions shall conform to all applicable local, state, provincial, and federal regulations (including USDOT regulations and applicable interstate regulations).

Sec. 6.3 Affidavit of Compliance or Certified Analyses

The purchaser may require (1) an affidavit from the manufacturer or supplier that the fluorosilicic acid provided in the purchaser's documents complies with all applicable requirements of this standard; (2) certified analyses of the fluorosilicic acid, provided by the manufacturer or supplier, covering items as required; or (3) both.

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*Because of the frequent changes in these regulations, all parties should remain informed of possible revisions. Provisions of the purchaser's documents should not preclude compliance with applicable regulations.

† *Code of Federal Regulations,* Title 49, part 178 (Transportation). Superintendent of Documents, US Government Printing Office, Washington, DC 20402.

APPENDIX A

Materials Compatibility

This appendix is for information only and is not a part of ANSI/AWWA B703.

All tanks and containers must be manufactured from or lined with materials that are highly resistant to fluorosilicic acid. General materials in use include the following:

1. Fiberglass coated with resistant resin.
2. Polyethylene manufactured from high-density, cross-linked material that contains a minimum of 0.25 percent ultraviolet stabilizer.
3. Steel tanks lined with a minimum 2.4-mm (3/32-in.) thickness of natural rubber, butyl rubber, or neoprene and secured to the metal surface with proper adhesive.

References to specific materials commonly in use include, but are not limited to, the following: polyvinyl chloride (PVC), type 1, grade 1; polyvinylidene fluoride (PVDF); ethylene propylene dienemonomer (EPDM); ethylene chlorotrifluoroethylene (E-CTFE); Saran; Vinyl; Hypalon; Carpenter 20; and Hastelloy C.

When purchasing storage tanks or other appurtenances used to handle fluorosilicic acid, the purchaser may request certification from the materials manufacturer verifying the tested resistance of the particular material for use in contact with fluorosilicic acid. Bulk storage tanks should be provided with a certification plate containing (at minimum) the following:

1. Name of tank manufacturer.
2. Date of manufacture.
3. Chemical (chemicals) to be stored.
4. Mechanical properties of the structure.*
5. Mechanical properties of the lining.†

*For example, high-density, cross-linked polyethylene.

†For example, 2.4-mm (3/32-in.) thick butyl rubber.

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APPENDIX B

Fluorosilicic Acid—Contaminants

This appendix is for information only and is not a part of ANSI/AWWA B703.

Table B.1 Fluorosilicic acid—contaminants

Contaminant*	Regulation	Drinking Water Maximum Contaminant Level/Maximum Allowable Concentration (MCL/MAC) *mg/L*	Single Product Allowable Concentration (SPAC) *mg/L*
Antimony	(40 CFR § 141.60, § 141.62)	0.006	0.0006
Arsenic	(effective date: 01/23/06)	0.010	0.001
Barium	(40 CFR § 141.60, § 141.62)	2	0.2
Beryllium	(40 CFR § 141.60, § 141.62)	0.004	0.0004
Cadmium	(40 CFR § 141.60, § 141.62)	0.005	0.0005
Copper (at tap)	(40 CFR § 141.80, 65 FR 1950)	TT† (action level 1.3 mg/L)	0.13
Lead (at tap)	(40 CFR § 141.80, 65 FR 1950)	TT† (action level 0.015 mg/L)	0.0015
Mercury (inorganic)	(40 CFR § 141.60, § 141.62)	0.002	0.0002
Selenium	(40 CFR § 141.60, § 141.62)	0.05	0.005
Thallium	(40 CFR § 141.60, § 141.62)	0.002	0.0002
Radionuclides			
Beta particle and photon activity	(40 CFR § 141.16)	4 mrem/y	0.4 mrem/y
Gross alpha particle activity	(40 CFR § 141.15)	15 pCi/L	1.5 pCi/L
Radium 226 and 228 (combined)	(40 CFR § 141.15)	5 pCi/L	0.5 pCi/L
Uranium	(40 CFR § 141.66)	30 µg/L	3.0 µg/L

*The references for criteria based on US primary drinking water regulations are from the US Code of Federal Regulations, Title 40 (Protection of Environment), revised as of July 1, 1999. This document is available online at www.access.gpo.gov/cgi-bin/cfrassemble.cgi. Issue dates are given for criteria based on Health Canada guidelines. Additional information on the guidelines for these chemicals is available at www.hc-sc.gc.ca/water quality.

†TT—Treatment technique