potentially increase the severity of deterioration compared to that caused by the hypochlorite anion.

However, it should be noted that Reiber's accelerated life cycle testing was conducted at elevated temperatures and concentrations. The accelerated life cycle testing was conducted at 100 degrees Fahrenheit, using concentrations of 300 mg/L of either hypochlorous acid, hypochlorite ion solution, dichloramine solution, or monochloramine solution. Based on Arrhenius principles (effects of temperature on reaction rate), the findings of Reiber's research may correspond to approximately 10 years (plus or minus 50 percent) of chemical exposure, (Reiber, 1999).

Though dramatic or rapid failure of elastomeric components is not anticipated, Table 5.3 below provides a summary of those parts of the District's distribution system where degradation rates may increase due to the change to chloramine disinfection. The factors considered in developing Table 5.3 include:

- The potential for continual water exposure versus exposure to stagnant ("dead") water.
- The added physical/mechanical action of valves opening/closing.
- The relative frequency of exposure.

5.3 SUMMARY OF DISTRIBUTION SYSTEMS MATERIAL RECOMMENDATIONS

Carollo does not anticipate that the District will experience rapidly increased failure rates of distribution system components. Rather there may be some moderately increased rate of degradation but, given the variability in elastomer formulations, water quality effects, and mechanical stresses, it is not possible to effectively identify any portion of the system that requires replacement prior to the conversion. The results of this investigation and recommendations are summarized below:

- Distribution system materials including ductile iron, cast iron, steel, asbestos cement, concrete, brass, and copper should not experience any significant increase in corrosion due to the conversion from chlorine to chloramines disinfection.
- Rapid (one year or less) elastomeric material degradation is not likely in the distribution system. Some components such as those made of natural rubber (used for gaskets, seats, and seals in older (greater than 20 years) components), and less expensive components such as residential toilet flapper valves may experience more rapid deterioration than experienced now with chlorinated water. The conversion may also cause some staining of household fixtures by releasing biofilms containing iron from pipe surfaces. Such impacts will be minimized by the recommended flushing programs.

**Table 5.3 Summary of Potential Problem Locations in the Distribution System
Chloramine Conversion Study
Estero Municipal Improvement District**

Component	Material Likely to be Present in Component	Potential for Increased Degradation
Flange Gaskets	Rubber(1)	Moderate to High
PVC Joints/Gaskets (Assume Flange)	Rubber(1)	Moderate to High
Hydrant Valves & Gaskets	Vulcanized SBR(2)	Moderate
DIP Push-On Joints	Rubber(1)	Moderate
Valve Seats (various)	Vulcanized SBR(2)	Low To Moderate
Mechanical Joints	Vulcanized SBR(2)	Low
Storage Tanks	Vulcanized SBR(2)	Low to Moderate
Toilet Tank flapper gaskets/float balls	SBR(2,3)	Moderate
Water heater valves	Celcon® or Delrin® (2,4)	Low to Moderate

DIP = Ductile iron pipe
PVC = polyvinyl chloride
SBR = styrene-butadiene rubber

Notes:

(1) Material specified in the District's Standard Specifications
(2) Typical materials provided by manufacturers
(3) Newer toilet tank flapper gaskets made with rubber manufactured with antidegradants that prolong the rubber life.
(4) Liners and valves may be manufactured with thermoplastics.

Ranking encompasses physical and/or operational considerations, in addition to the potential degradation from exposure to chlorine and chloramine. For hydrant valves and other valve seats, it is assumed that most of the time, exposure will be fairly static meaning little continual water flow will occur. However, because these components will incur stresses due to operational opening and closing, any potential degradation is increased by this physical action. In water storage tanks, any gasket(s) on the inlet or outlet will experience continual exposure.

- Any maintenance elastomer replacement programs should prioritize replacing those components that are 20 or more years old. Elastomers of this age are more likely to be made of natural rubber which is generally more sensitive to attack by chloramines than synthetic rubber elastomers.

- Monitor water losses in the distribution system by both visual methods (i.e. leaking hydrants or pump seals, wet pavement from underground leaks, etc.), and accounting methods (i.e. quantifying the amount of unaccounted-for water).

- Replace failed elastomers with chloramine-resistant components (as discussed above). When the amount of unaccounted for water shows an increase, or rises above a set value (10 percent) a detailed water audit or leak detection program may be warranted.

- Maintain an inventory of replacement elastomeric components that are made of more chloramine-resistant material than the original materials. The manufacturer of each component should be contacted to identify which of their available materials is both chloramine resistant and NSF-approved for potable water use.

CHLORAMINE CONVERSION PLAN

This chapter outlines the steps the District should take both prior to and during the conversion. These requirements are summarized in short form in Appendix C. System operation and maintenance recommendations following the conversion are outlined in Chapter 7.

6.1 OPERATIONS AND MAINTENANCE RECOMMENDATIONS PRIOR TO THE CONVERSION

6.1.1 Recommended Maintenance Actions

Keeping the distribution system in a clean condition will be critical for maintaining disinfectant residual levels and avoiding nitrification both during and after the chloramine conversion. The main maintenance activities for keeping the distribution system clean are distribution system flushing and reservoir cleaning.

6.1.1.1 Implement a Comprehensive Flushing Program

System-wide unidirectional flushing should be completed before the chloramine conversion. The District has indicated that they have an annual unidirectional flushing program in place, so no additional flushing should be needed. Descriptions of both unidirectional and conventional flushing, as well as flushing recommendations following the conversion, are included in Section 7.1.1.

6.1.1.2 Clean the Reservoirs Before Conversion

Prior to the chloramine conversion, we usually recommend cleaning the storage reservoirs to eliminate sediment and reduce the potential for nitrification. Sediment can provide nutrients for microorganisms, particularly the bacteria that take part in the nitrification process. In addition, when sediment is suspended in the tank during filling, it can shield microorganisms from the disinfectant. We understand that the District recently cleaned and recoated the tank interiors. Hence, the reservoirs do not need to be cleaned again prior to the conversion. Additional information on reservoir cleaning is included under Section 7.1.2.

6.1.2 Recommended Water Quality Monitoring

A water quality monitoring plan to be used following the conversion is included in Section 7.2. We recommend that this monitoring plan be initiated prior to the conversion for two reasons. First, the operators will gain familiarity with the sampling and testing procedures. Second, the data generated will aid the District in interpreting data collected following the chloramine conversion.

6.2 RECOMMENDED OPERATIONS ACTIONS DURING THE CONVERSION

The following is a plan for operating the District's system during the chloramine conversion. Prior to the conversion, the District may continue to operate the system as it has done so in the past. This plan is based on the assumption that the chloramine conversion will occur during the winter, as is currently planned by the SFPUC.

Immediately prior to the conversion, both the distribution system and the reservoirs will contain free chlorinated water. As chloraminated water enters the system from the turnout, it will mix with the free chlorinated water already in the system.

The immediate concern associated with the conversion is that the mixing of free chlorinated and chloraminated water will lead to the loss of an effective disinfectant residual. When chloramines and free chlorine are mixed, a chemical reaction can lead to the formation of chlorine compounds that are not effective disinfectants. The loss of the residual through this reaction will be encouraged if: (1) the free chlorine residuals are very high, or (2) a large amount of free chlorinated water is mixed with a small amount of chloraminated water.

We do not expect that the loss of a disinfectant residual over a short period (e.g., a couple days) would lead to a nitrification episode. The reasons why nitrification is not expected to occur are as follows:

- **Low Numbers of AOB.** For nitrification to occur, large numbers of AOB (the bacteria that cause nitrification) would have to be present in the distribution system. Prior to the conversion, numbers of AOB would be expected to be very low, as they require ammonia as a food source. AOB grow very slowly – they take around 7 days to reproduce. Hence, the numbers of AOB in the distribution system would not be expected to significantly increase over a period of a couple days.
- **Low Free Ammonia Concentration.** Any free ammonia present in the chloraminated water should be consumed by the free chlorine residual when the waters combine. Thus, there should be little ammonia available for the AOB.

Despite the lack of a nitrification threat, the lack of residual presents a potential public health concern. The main concern would be a lack of protection from pathogen intrusion of the distribution system. As the District has indicated that their unaccounted-for water percentage is low (< 10 percent), the system likely has a very limited amount of water main leaks. This condition mitigates, to some extent, the concern of potential intrusion during the conversion.

Unfortunately, there are far too many unknowns to accurately predict whether a loss of the disinfectant residual will occur. For example, it is not yet known what chlorine to ammonia ratio the SFPUC will use during the conversion, and we cannot predict what the free chlorine residual in the system will be at the time of the conversion. Hence, the basis for our recommended operations plan is to move the free chlorinated water out of the District's system as quickly as possible, and to minimize mixing free chlorinated water with chloraminated water in the reservoirs.

The greater the demand in the distribution system, the more quickly the free chlorinated water can be moved out of the system. To help avoid overwhelming the SFPUC water supply system, the total system demand during the conversion should be limited to the maximum summer demands. The maximum summer demands are approximately 6,000 gallons per minute (gpm), whereas the minimum winter demands are approximately 2,000 gpm. Assuming a flow rate from each hydrant of approximately 1,000 gpm, three or four hydrants should be continuously flushed during the conversion (an approximately 72-hour period).

The recommended hydrant locations are shown in Figure 6.1. Each of the chosen sites is at the intersection of two water mains. The locations were distributed along the perimeter of the distribution system to facilitate wasting free chlorinated water from all portions of the distribution system. This operation will reduce the amount of mixing that occurs between the chlorinated and chloraminated water. In addition, it will also reduce the amount of time that potentially low-disinfectant residual water resides in the system.

The following conversion plan is based on a number of assumptions. Based on District input, these assumptions and the resulting recommendations may be modified in later versions of this report. A simplified version of the conversion plan is also outlined in Appendix C.

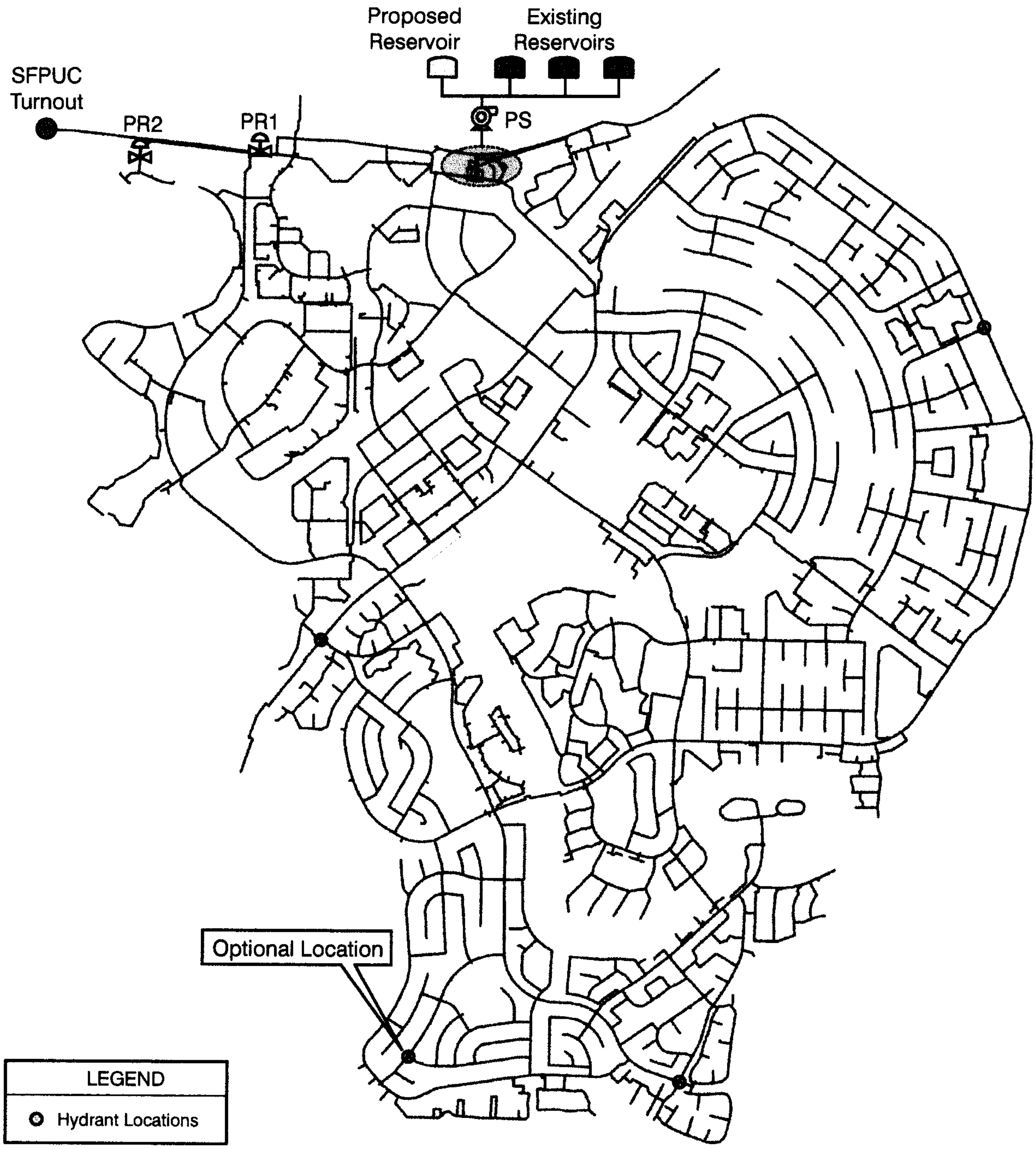
The conversion plan is presented in chronological order to aid implementation:

Immediately Prior to the Conversion:

- *Minimize Storage.* The storage in the reservoirs should be decreased to the minimum required storage (see Section 3.5). Assuming winter conditions, the required volume is approximately 7 MG. We recommend that the 7 MG be split between 2 of the existing 3 reservoirs. The water level in the 3rd reservoir should be lowered to its practical minimum, as determined by operations staff.

Day 1 of the Conversion:

- *Start Hydrant Flushing.* Flushing at the three or four recommended sites should be started. This flushing will continue over the duration of the chloramine conversion.
- *Monitor Turnout and Reservoir Water Quality.* Throughout the conversion, the operations staff should take total chlorine samples at the turnout every eight hours. If SFPUC is dosing chloramines at 1.5 mg-N/L, the total chlorine level received by



Note: Turnout, Reservoirs, Pressure Reducing Stations, and Pump Station represented pictorially and are not to scale.

Figure 6.1
RECOMMENDED HYDRANT FLUSHING DURING THE CONVERSION
CHLORAMINE CONVERSION STUDY
ESTERO MUNICIPAL IMPROVEMENT DISTRICT

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the District should be at least 0.5 mg/L. If the total chlorine level is much lower than 0.5 mg/L, the District should contact the SFPUC immediately. In addition, the operations staff should monitor the total chlorine levels at each of the reservoirs every eight hours. The purpose of this monitoring is to verify that the residual is being maintained, and that that breakpoint or total residual loss has not occurred before the water is delivered into the distribution system.

- *Fill the Empty Reservoir.* To maintain the minimum required storage, the empty reservoir must be filled before one of the other two reservoirs can be emptied of free chlorinated water. During this period, chloraminated water from the turnout will be filling the reservoir while meeting all system demands.
- *Empty One Free Chlorinated Reservoir.* Once the third reservoir has been filled with chloraminated water, one of the remaining two reservoirs should be drained by operating the pump station. To empty the reservoir as quickly as possible, the turnout should be turned off during this period. We estimate it will take approximately 15 hours to drain one tank of approximately 3.5 MG.
- *Open the Turnout.* During this period, no water should be entering or exiting the reservoirs. The turnout should be open and supplying all demands to the system.

Day 2 of the Conversion.

- *Continue Hydrant Flushing.* The hydrants should be continuously flushed throughout the conversion period.
- *Continue the Water Quality Monitoring.* See above.
- *Fill the Empty Reservoir.* See above.
- *Empty the Remaining Free Chlorinated Reservoir.* See above.
- *Open the Turnout.* See above.

At the end of Day 2 of the conversion, two of the reservoirs should be filled with chloraminated water, and the third reservoir should be virtually empty. At this point, the water levels in the three reservoirs can be equilibrated, and the system should be operated as recommended in Chapter 4. At this point, the District may also stop flushing at the hydrants.

The remaining task will be to verify that the chloraminated water has reached all portions of the distribution system. Operations staff should start by confirming that there is a reasonable disinfectant (total chlorine) residual at all water quality monitoring sites, including those sites recommended in Chapter 7, as well as regular Total Coliform Rule monitoring sites. If the SFPUC applies a chloramine concentration of 1.5 milligrams per liter (mg/L), a reasonable total chlorine residual would be approximately 0.5 mg/L. In regions with insufficient disinfectant residual levels, the local area should be flushed until the disinfectant residual is restored to a reasonable level.

6.3 RECOMMENDED CAPITAL IMPROVEMENTS

This section presents the recommended improvements needed to prepare the water distribution system for the pending chloramine conversion. This section also presents conceptual-level cost estimates of the recommended improvements. Developing cost estimates of recommended projects at this conceptual level will allow the District to budget for improvements to the water system. The cost estimates developed for each recommended improvement include the following costs in addition to the estimated construction cost:

- A construction contingency (30 percent) to account for uncertainty associated with the conceptual nature of the cost estimate.
- A project implementation multiplier (30 percent) that includes project related costs in addition to construction costs, such as planning, environmental design, and construction administration.

As many of the recommended improvements have not been defined in detail at this conceptual level, additional refinement will be necessary during additional planning, preliminary design, and final design efforts for each project. The anticipated level of accuracy is -30 percent to +50 percent. The level of accuracy is based on the scope of engineering provided at the conceptual level of project development.

The estimated capital costs are summarized in Table 6.1. The individual project descriptions follow the table.

6.3.1 Installation of Sample Taps at Reservoirs

Installing sample taps at the reservoirs will entail attaching fittings to the side of each tank to support a sample pipe that extends into the reservoir volume. Each of these pipes will penetrate the tank wall to the outside and terminate in a sample valve within reach of a sample taker standing at the base of the tank. Each tank will be equipped with three sample fittings, which will sample the reservoirs at three different water depths.

6.3.2 Installation of Distribution System Monitoring Taps

The recommended monitoring plan includes three new sampling sites in the distribution system. These sites were chosen to address areas identified to have high water age in the hydraulic model. The cost estimate presented above assumes three standard dedicated sampling fixtures, each located on public right-of-way.

6.3.3 Purchase of Water Quality Monitoring Kit

Analyzing the water quality will require new test equipment. We recommend the Hach DREL/2400 portable laboratory since it can be brought to any location, and it can analyze

Table 6.1 Recommended Capital Improvement Projects Chloramine Conversion Study Estero Municipal Improvement District			
Improvement	**Project Implementation Cost**	**Construction Cost**	**Total Project Cost**
A. Complete Prior to Conversion			
Reservoir Sample Taps	$9,000	$30,000	$39,000
Distribution System Sample Taps	$6,000	$20,000	$26,000
Water Quality Monitoring Kit	$0	$2,500	$2,500
Subtotal	**$15,000**	**$52,500**	**$67,500**
B. Include in Next CIP			
Automate Reservoir Controls	$39,000	$130,000	$169,000
Subtotal	**$39,000**	**$130,000**	**$169,000**
C. As Funds are Available			
Reservoir Flow Meter	$18,000	$59,000	$77,000
Chlorine Injectors for Reservoirs	$4,500	$15,000	$19,500
Mobile Chlorination Equipment	$0	$80,000	$80,000
On-line Water Quality Monitors	$20,000	$65,000	$85,000
Subtotal	**$42,500**	**$219,000**	**$261,500**
Total	**$96,500**	**$401,500**	**$498,000**

the water for the parameters of interest (free and total chlorine residual, total ammonia, and nitrite-N) when the system is converted to chloramine disinfection. The measurement of free ammonia is not possible with the recommended kit, nor with other available field kits. The recommended kit components are summarized in Table 6.2 and can be purchased directly from Hach on the internet at www.hach.com. We recommend the District purchase at least one of these kits.

6.3.4 Automate Reservoir Control

The control strategies recommended in this report require the District to operate the pump station and the inlet and outlet valves to the reservoirs based on the reservoir water level. Under the existing conditions, both the pump station and the reservoir valves are manually controlled. To allow for automated control the following is required:

- SCADA system improvements. The District indicated that they are planning on upgrading the existing pump station by replacing some of the existing engine-driven pumps with new electric pumps. The SCADA system improvements for pump

Table 6.2 Summary of Water Quality Monitoring Kit Components Chloramine Conversion Study Estero Municipal Improvement District				
	Item Number	**Cost**	**Number of Tests**	**Detection Limit (mg/L)**
DREL 2400 Spectrophotometer in "Do Your Own" Kit	2831800	$2,145.00	n/a	n/a
Total Chlorine – pillow packs	2105669	$16.55(1)	100	0.02 to 2.0
Free Chlorine – pillow packs	2105569	$16.30(1)	100	0.02 to 2.0
Total Ammonia – Test In Tube	2604545	$61.65(1)	50	0.02 to 2.50
Nitrite-N – pillow packs	2107169	$22.55(1)	100	0.002 to 0.300
Total Initial Cost (2)	-	**$2,262**	-	-

Notes:
(1) Cost is for initial purchase of reagent sets. Cost of ongoing purchase of reagents is included as O&M costs in Table 7.3.
(2) An estimated cost of $2,500 for these items is included in Table 6.1.

control should be included as part of that project. Since the pump station upgrade project is beyond the scope of this study, the cost to upgrade the pump controls is not presented here.

- Motorized Valves. The existing manually operated valves at the inlet and outlet to each reservoir should be replaced with motorized valves. The cost estimate presented above assumes that the valves will be tied into the District's SCADA system and that the operations staff will be able to monitor reservoir level and control the valve operation remotely from a computer terminal.

6.3.5 Reservoir Flow Meter

The estimated costs under this line item are for a single 24-inch flow meter to measure the combined flow from the reservoirs. Monitoring of reservoir flows would allow the District to refine the reservoir control strategy and would aid in the accurate determination of a diurnal demand curve. The cost estimate includes meter installation and connection to the District's SCADA system. The cost estimate does not include other improvements that may be needed such as a separate vault for the meter.

6.3.6 Chlorine Injectors for Reservoirs

The estimated costs under this line item are for chlorine injectors for each of the three existing reservoirs. These injectors would be used if the reservoirs needed to be breakpoint chlorinated. The reservoir would first be emptied to the greatest extent possible. Then, a concentrated chlorine solution would be injected into the influent stream as the reservoir is being filled, to help mix the chlorine solution with the reservoir water. The chlorine injectors would be located in the inlet piping and would be used with the mobile chlorination equipment.

It would also be possible to spray a chlorine solution over the surface of one of the reservoirs using the existing access ports near the tops of the reservoirs. This option would likely be used if the District were to hire a contractor to breakpoint the reservoirs. This option would not require further improvements to the reservoirs, but the influent ports may result in better chlorine mixing and more effective treatment of the reservoir.

6.3.7 Mobile Chlorination Equipment

The District must be able to breakpoint chlorinate its reservoirs, as well as sections of the distribution system, if necessary. The District may either hire a contractor to perform these services, or buy the necessary equipment to do the breakpoint chlorination in-house. The District does not need to purchase any mobile chlorination equipment if it intends to hire a contractor to perform any necessary breakpoint chlorination.

The second option requires the District to purchase equipment for breakpoint chlorination. The estimated cost given under this line item is based on the cost of a trailer-mounted calcium hypochlorite system, complete with a generator to power the electrical equipment on the trailer. Depending on the ultimate list of features and design details specified, this equipment may cost somewhat more or substantially less. More simple (and less costly) systems, and those using alternate forms of chlorine (e.g., sodium hypochlorite liquid or chlorine gas) could also be used, depending on District preferences. Performing the breakpoint chlorination in-house will also require training for the District operations staff in use of the equipment.

6.3.8 On-line Water Quality Monitors

The District may choose to install on-line water quality monitoring stations in the future to replace all or a portion of the nitrification monitoring program. The estimated cost is for a single monitoring station and assumes the following:

- ~ $30,000 for equipment.
- ~ $15,000 for a structure to house the equipment.
- ~ $15,000 for electrical and instrumentation upgrades.
- ~ $5,000 for miscellaneous expenses.
- ~ $20,000 for project implementation.

It is assumed that any on-line water quality monitoring equipment will be installed on District-owned property. As such, costs to acquire the property are not included. It is also assumed that the facilities are located near SCADA transmitters, electrical power, and sewer.

CHLORAMINATED SYSTEM OPERATION AND MONITORING

This chapter is focused on the operation and monitoring of the District's system after the chloramine conversion. Maintaining the distribution system in a clean condition will be critical for maintaining disinfectant residual levels and avoiding nitrification. Also, the system water quality will need to be more closely monitored so that the District's operations staff can respond appropriately and quickly to water quality changes that may signify the onset of nitrification.

7.1 RECOMMENDED OPERATIONS AND MAINTENANCE ACTIVITIES

System operation recommendations to control water age are presented in Chapter 4. In essence, the recommended operational procedures focus on maintaining the reservoir water age by operating the pumps to ensure adequate turnover. Regarding distribution system maintenance, it is critical that the pipes and reservoirs be kept clean. To maintain the distribution system Carollo recommends a comprehensive flushing program, and reservoir cleansing program.

7.1.1 Flushing

The District's water mains should be flushed annually. Dead end lines such as the ends of courts should be flushed twice a year, or more often as needed based on the water quality monitoring results. There are two main types of flushing: conventional and unidirectional. Each approach can be implemented on a comprehensive system-wide basis or on a narrower (spot) basis. Moreover, each approach has a specific use and can help to meet specific water quality goals. This largely depends on the configuration of the system within the area of interest and the water quality goals for that particular area.

Annual unidirectional flushing of the entire distribution system is recommended. The District indicated that an annual unidirectional flushing program is already in place. Unidirectional flushing consists of isolating a particular pipe section or loop, and exercising the hydrants in an organized, sequential manner. This is done moving from the turnout (cleanest water) and out into the system, always moving older water out ahead of clean water. This practice can help enhance water quality by cleaning the pipes and restoring a disinfectant residual to that area of the distribution system. This practice also aids in distribution system maintenance by exercising the isolation valves and identifying those that need repair. Flushing velocities may vary, according to the water quality objective in that area of pipe. Moving silts and sediment requires velocities equal to or greater than 3 feet per second. To promote scouring, velocities equal to or greater than 5 feet per second are recommended.

Conventional flushing consists of opening hydrants in a specific area of the distribution system until pre-selected water quality criteria are met. These criteria could include detectable disinfectant residual, reduction/elimination of color, reduction in turbidity, etc. It is important to note that valve isolation is not part of conventional flushing. Conventional flushing should be used to flush dead-ends twice a year, or at a greater frequency if required.

7.1.2 Reservoir Cleaning

In general, reservoirs should be cleaned every three to five years after the initial cleaning. Periodic cleansing of the reservoirs reduces the amount of sediment in the reservoir, which can provide nutrients to nitrifying microorganisms and shield the microbes from the disinfectant. Otherwise, the reservoirs should be inspected annually to assess the rate and level of sediment buildup and to provide a basis for the cleaning schedule. Reservoir cleaning may either be done with the reservoirs in service, or when they are taken off line. All of the waste fluid generated by the cleaning operation must be properly dechlorinated before being discharged to either the storm drain or the sewer as appropriate.

7.2 RECOMMENDED MONITORING PLAN

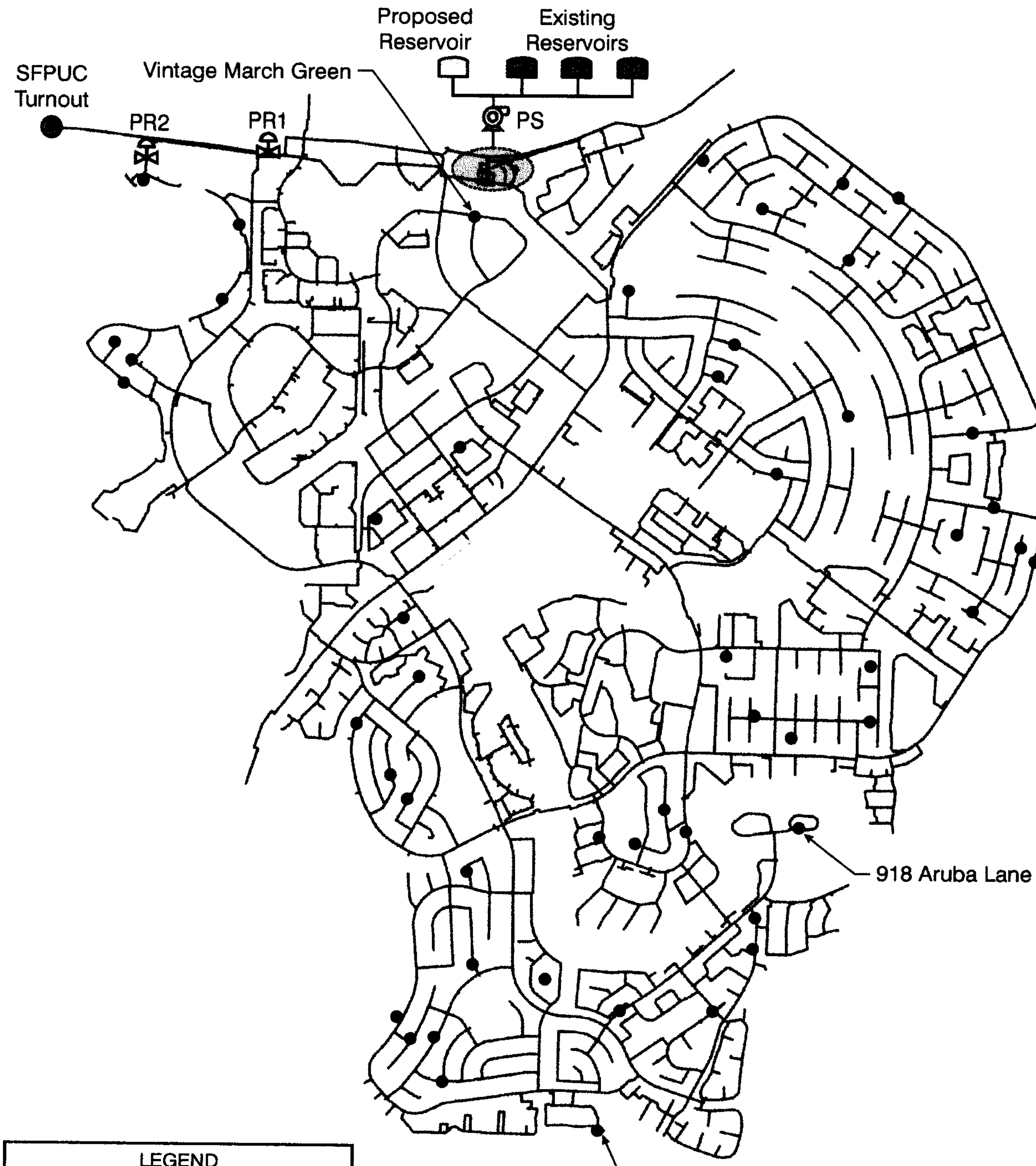
The District currently monitors for the following parameters: temperature, free chlorine residual, coliform, pH, alkalinity, turbidity, color, odor threshold, trihalomethanes (THMs), haloacetic acids (HAAs), and HPC. Temperature and chlorine residuals are measured in the field. SFPUC analyzes samples for THMs, HAAs, and HPC. The remaining parameters are analyzed by Scientific Environmental Laboratories Inc.

While these are excellent monitoring parameters for a system with chlorine residual, we recommend that the District supplement their regular monitoring with parameters that will help monitor for any degradation in the District's distribution system. These parameters should alert the District to potential problems in the distribution system before nitrification occurs. The following recommended monitoring plan should be performed in addition to the regular monitoring the District already performs. Data sheets for this monitoring program are presented in Appendix C.

7.2.1 Nitrification Monitoring Sites

The District currently has 50 distribution system sample sites, ten of which are sampled each week. Hence, distribution system sites are only sampled every fifth week. Additional samples are collected at the turnout and from each reservoir. The locations of the current sampling sites are shown in Figure 7.1.

The current sampling frequency is not sufficient for the early detection of nitrification. However, rather than sample all of the existing sites every week, we selected a subset of sample sites to be monitored each week for nitrification detection purposes. In addition to



LEGEND
● Sample Location

Note: Turnout, Reservoirs, Pressure Reducing Stations, and Pump Station represented pictorially and are not to scale.

Figure 7.1
CURRENT WATER QUALITY MONITORING SITES
CHLOROAMINE CONVERSION STUDY
ESTERO MUNICIPAL IMPROVEMENT DISTRICT

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these sites, the turnout and the reservoirs should be monitored on a weekly or more frequent basis.

The selected nitrification sampling sites fall into one of three categories:

- Sites with historically low free chlorine residuals.
- Sites identified to have high water age.
- Additional sites to include underrepresented areas of the distribution system.

The process for selecting the sites is summarized in the below sections.

7.2.1.1 Identification of Sites with Historically Low Disinfectant Residuals

Historical water quality records for free chlorine residuals in the distribution system between December 3, 2001 and December 2, 2002 were analyzed. The purpose of the analysis was to identify sites with historically low chlorine residual levels, which may also have low disinfectant residual levels following SFPUC's conversion to chloramine. As discussed in Chapter 2, low chloramine residuals can contribute to nitrification events.

Analysis of the water quality data shows that 33 percent of the collected samples had free chlorine concentrations below 0.5 mg/L and 4 percent of the samples were below 0.2 mg/L. Residuals below 0.2 mg/L occurred at 15 of the 50 sites. Table 7.1 lists locations that exhibited residuals less than 0.2 mg/L during the sample period.

Three sites were found to have low free chlorine residuals, as follows:

- 918 Aruba Lane
- 44 Williams Lane
- Vintage & Marsh Green

Figure 7.2 summarizes the chlorine residuals from these three sites along with an average residual for the rest of the system. From the figure, it can be seen that the chlorine residuals at these sites were consistently lower than in the rest of the system.

One of the 3 sites (Vintage & Marsh Green) was selected as a nitrification monitoring location (see Figure 7.3). In addition, an existing monitoring site close to the Aruba Lane site (but further away from dead ends) was selected.

The Williams Lane site was not selected because it is situated at a dead end at the farthest reaches of the system. Decreased residuals at this site will likely occur regardless of flushing and reservoir operation and may only be indicative of water quality within a very small portion of the distribution system. Rather than selecting this worst-case scenario site, two other sites in the southern portion of the system were selected to monitor general water quality in this region.

Table 7.1 Distribution System Sites with Low Free Chlorine Residuals
Chloramine Conversion Study
Estero Municipal Improvement District

Distribution System Sample Site [1]	Number of Samples Less than 0.2 mg/L
Trader Lane & Bridgeport Green	1
1150 Chess Road	1
721 Baffin Street	1
117 Goldhunter Court	1
1404 Melbourne Street	1
771 Crane Avenue	1
900 Schooner Street	1
600 Bridgeport Lane	1
918 Aruba Lane	5
44 Williams Lane	3
2001 Chess Green	1
501 Coos Court	1
Vintage & Marsh Green	2
1935 Beach Park Blvd.	1
272 Boothbay Ave.	1

Note:
(1) This table includes the 15 monitoring sites that have regularly had low disinfectant residuals. The District will continue to monitor all 50 of their current monitoring sites as part of their regular monitoring program.

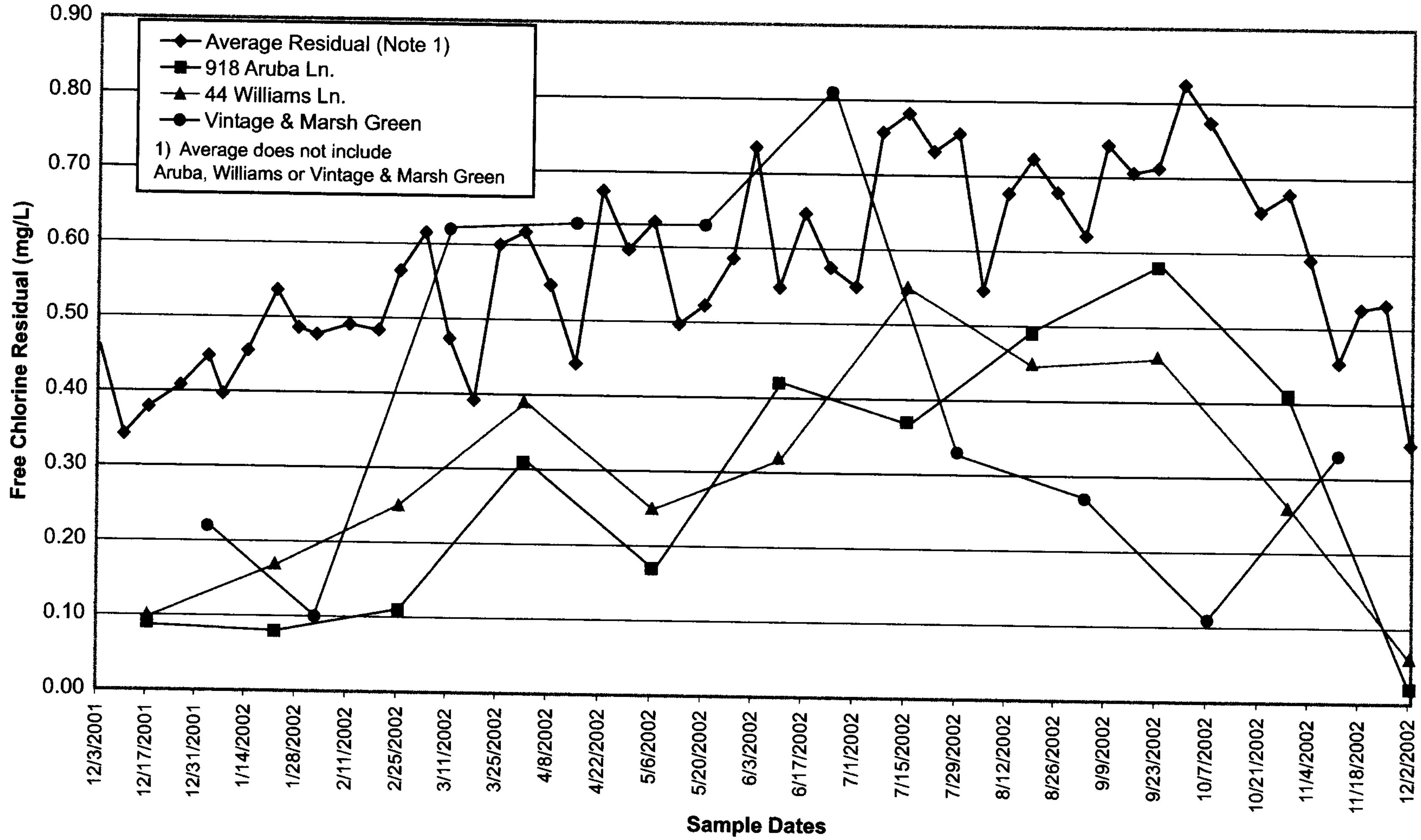

Figure 7.2
DISTRIBUTION SYSTEM CHLORINE RESIDUAL LEVELS
CHLORAMINE CONVERSION STUDY
ESTERO MUNICIPAL IMPROVEMENT DISTRICT

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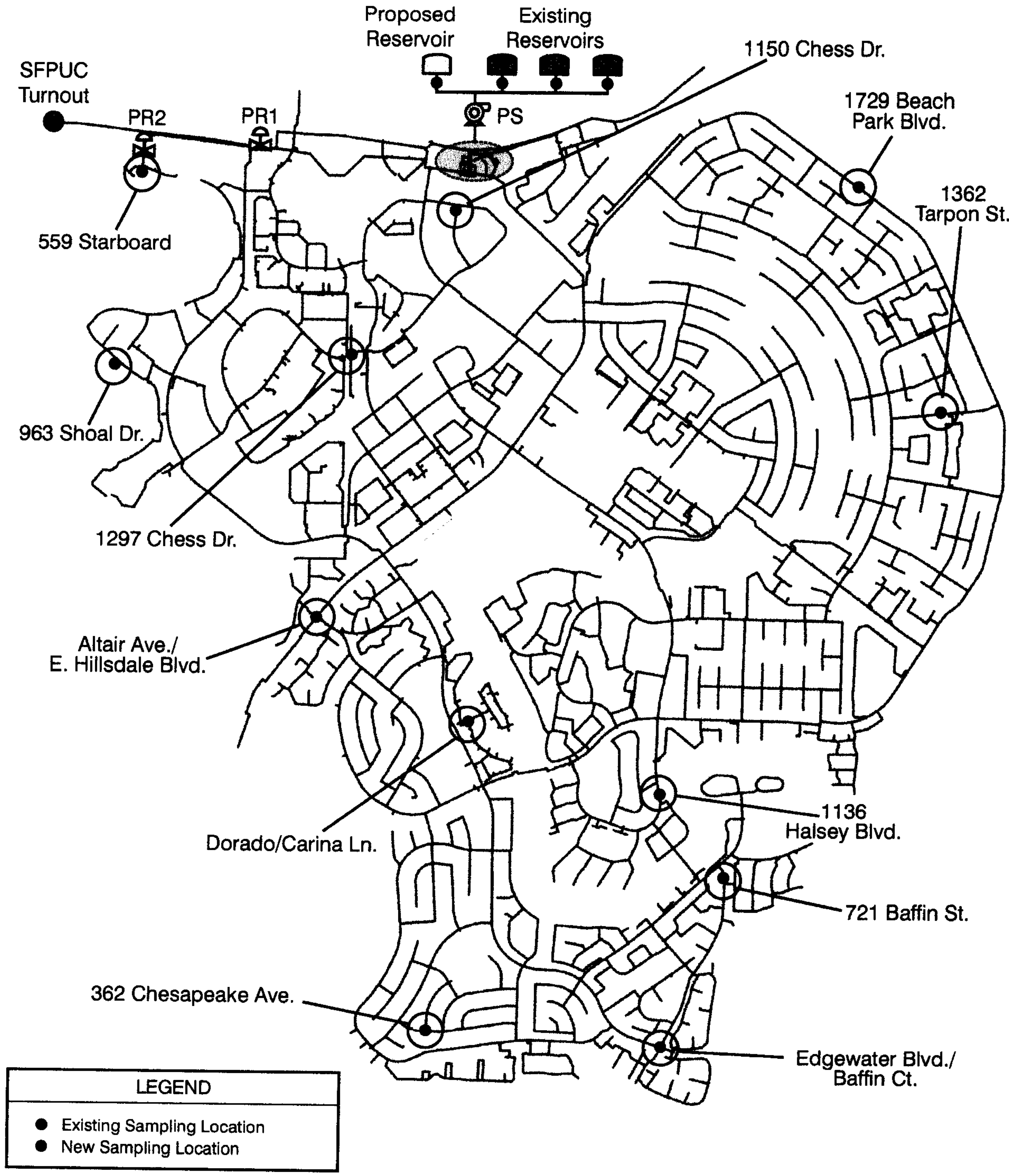

Note: Turnout, Reservoirs, Pressure Reducing Stations, and Pump Station represented pictorially and are not to scale.

Figure 7.3
RECOMMENDED NITRIFICATION MONITORING SITES
CHLOROAMINE CONVERSION STUDY
ESTERO MUNICIPAL IMPROVEMENT DISTRICT

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7.2.1.2 *Identification of Sites with High Water Age*

During the hydraulic modeling, 5 regions of high water age were identified, as shown in Figure 4.2. New sample sites were selected to monitor water age in 4 of these regions. These sites are shown in green in Figure 7.3. Monitoring in the vicinity of the remaining region, Region 5, was considered unnecessary, as the junction in question was at the end of a short dead end pipeline and was adjacent to regions of much lower water age.

The water quality monitoring sites selected in the remaining 4 regions were not located immediately at the junctions with high water age. Decreased residuals at these sites will likely occur regardless of regular flushing or reservoir operation and may only be indicative of water quality within a very small portion of the distribution system. Instead, the monitoring sites were located at nearby junctions, to monitor water quality within a larger area in the vicinity of the junctions of concern.

7.2.1.3 *Identification of Additional Monitoring Sites*

An additional six existing distribution system monitoring sites were chosen, such that all major areas of the distribution system are represented. We also recommend monitoring of the turnout and at each of the reservoirs. These additional sites are also shown in Figure 7.3.

7.2.2 Water Quality Parameters

There are a large number of water quality parameters that can be used to detect a nitrification episode. For example, Kirmeyer et al. (1995) recommended that a total of 16 parameters be measured at both reservoir and distribution system sites. Rather than testing for a large number of parameters, we recommend that the District focus on the few water quality parameters that are easy to interpret and have proven most useful to other utilities.

To understand the rationale for choosing these parameters, it is helpful to consider water quality changes in the distribution system as a nitrification event progresses (see Figure 7.4). Five water quality parameters are shown in the figure – the following is a summary of the behavior of each of the parameters:

- *Chloramine Residual.* A nitrification event is typically instigated by degradation of the chloramine residual, which leads to the release of ammonia. As the nitrification event proceeds, nitrite formed by ammonia-oxidizing bacteria (AOB) further degrades the disinfectant residual. Chloramine concentrations (measured as total chlorine residual) are easily interpreted, as they decrease throughout the progression of the nitrification episode. Hence, monitoring of total chlorine is very useful for detecting nitrification episodes.
- *Total Ammonia.* Total ammonia includes both free ammonia and the ammonia bound in chloramines. Hence, degradation of the disinfectant residual leads to the

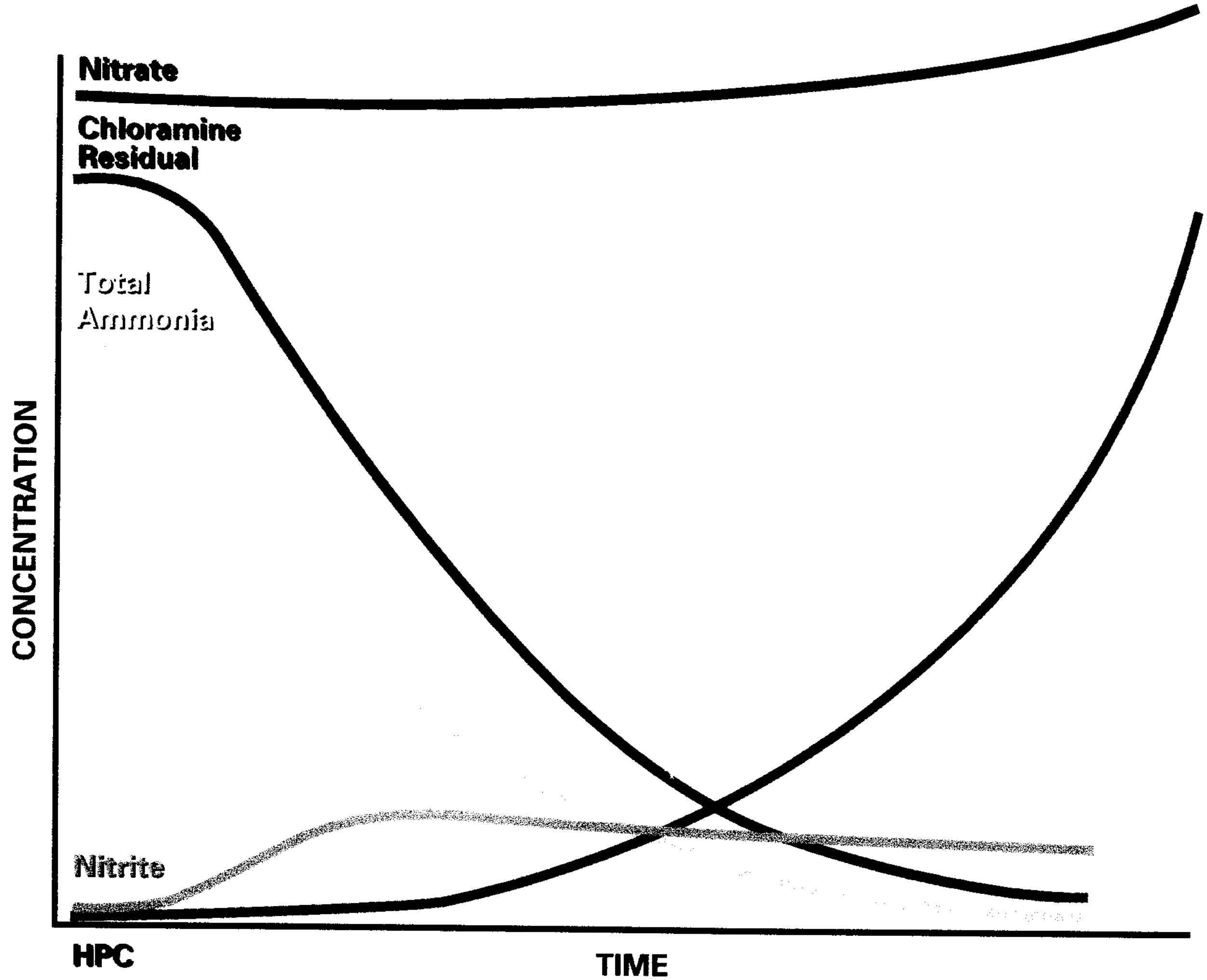

Figure 7.4
PROGRESSION OF A NITRIFICATION EPISODE
CHLORAMINE CONVERSION PROJECT
ESTERO MUNICIPAL IMPROVEMENT DISTRICT

Fc203g1-6627.cdr

release of free ammonia, but does not change the total ammonia concentration in the water. A decrease in the total ammonia concentration indicates that some of the ammonia has been removed from the system or converted to another nitrogen species (e.g., nitrite or nitrate). Total ammonia concentrations tend to decrease throughout a nitrification episode, hence they can be very useful for identifying nitrification episodes. In some systems, total ammonia concentrations have been seen to decrease before a decrease in the disinfectant residual is seen. However, this parameter has not proven useful in all systems.

- *Nitrite*. The AOB convert ammonia to nitrite, hence, as the AOB activity increases nitrite concentrations increase. However, there is a second group of bacteria that converts nitrite to nitrate. This second group of bacteria prevents the nitrite levels from increasing further. Typically, nitrite levels remain elevated throughout a nitrification episode. Hence, nitrite levels are easy to interpret and are useful for detecting nitrification episodes.
- *Nitrate*. As explained above, nitrite is converted to nitrate. Nitrate levels increase throughout the duration of a nitrification episode. However, ambient levels of nitrate are typically much greater than ambient levels of nitrite, hence the relatively small increases in nitrate levels tend to be difficult to detect. Thus, nitrate levels tend to be of limited use in detecting a nitrification episode.
- *HPC*. Heterotrophic plate counts tend to increase as a nitrification episode progresses. The HPC test does not actually detect AOB, however, the loss of residual and byproducts released by the AOB tend to increase the growth of other bacteria in the distribution system during a nitrification event. As the HPC tends to increase throughout a nitrification episode, this parameter is easily interpreted. However, an increase in HPC may not be noticeable until a nitrification episode is already well developed. Hence, HPC is a useful parameter for identifying a nitrification episode, but is often not the most appropriate for early detection.

Of these five water quality parameters, we recommend monitoring of the following four parameters:

- Total chlorine residual
- Ammonia-N
- Nitrite-N
- HPC (limited monitoring only)

Nitrite and ammonia are typically measured as ammonia-N and nitrite-N, respectively. The "-N" means that the concentration given is the concentration of nitrogen, rather than the concentration of the whole compound (ammonia or nitrite).

Total Chlorine, Ammonia-N, and Nitrite-N can be measured in the field using the test kit recommended in Chapter 6. HPC samples must be sent to an outside laboratory. HPC testing is available from the District's current lab, Scientific Environmental Laboratories. The District should request that the HPC testing be done on R2A agar with 7-days incubation at 25°C. Testing under these conditions is more sensitive than under conventional conditions (nutrient agar, 37°C, 1 or 2 days).

Using these four parameters, a nitrification event would generally be indicated by a decrease in total ammonia and total chlorine residual, accompanied by an increase in nitrite and HPC. Experiences of other utilities that have converted to a chloramine residual are summarized in Appendix A. The five utilities surveyed indicated which water quality parameters have been most useful in identifying nitrification episodes. All of the utilities cited one or more of chlorine residual, nitrite, and HPC as useful indicators. No other parameters were cited by any of the utilities.

7.2.3 Development of Action Levels

The most appropriate use of the water quality monitoring data is to establish normal levels of each of the parameters at the monitoring sites. That way, negative changes in the parameters can readily be detected. We recommend entering the water quality data into a spreadsheet program (such as Microsoft Excel™) and that graphs showing the trends at each site are maintained. Such graphs will aid in identifying negative changes in water quality (i.e., decreases in chloramine residual or total ammonia, or increases in HPC or nitrite).

However, the Nitrification Action Plan (see below) uses action levels for each of the four monitored water quality parameters to ease interpretation of the data. These action levels are generally developed specifically for each utility, as the ambient water quality at each utility will vary. However, we have provided preliminary levels based on those used at other California utilities. The District should revise these action levels in the future, based on the results of the monitoring program.

The preliminary action levels are summarized in the Table 7.2.

Table 7.2 Preliminary Action Levels for Nitrification Indicators
Chloramine Conversion Study
Estero Municipal Improvement District

	Action Level 1	Action Level 2
Total Chlorine (mg/L)	< 0.5	< 0.2
Total Ammonia-N (mg/L)	< 0.3	< 0.2
Nitrite-N (mg/L)	> 0.01	> 0.02
HPC (CFU/mL)	>50	>200

Total Chlorine. It is particularly difficult to establish action levels for total chlorine, as we can not be certain of the concentration that will initially be applied by the SFPUC. The following levels are based on the assumption that the SFPUC will add chloramines at a concentration of 1.5 mg/L. Our preliminary recommended Action Levels 1 and 2 are 0.5 and 0.2 mg/L, respectively. This should allow for some normal degradation of the residual in the absence of nitrification.

Historical water quality data in the reservoirs were reviewed as an indicator of residual disinfectant degradation under the current operation conditions. Historically, relatively low free chlorine residuals have been observed in the reservoirs (see Figure 7.5). From the figure it can be seen that between March and June 2002, free chlorine levels in the tanks were generally 0.1 mg/L or less, as compared to concentrations at the turnout averaging around 0.8 mg/L during this same period. This large decrease is likely due to the high water age in the tanks under the current operations strategy, particular during the winter and spring when there are low system demands. A much smaller decrease should be observed in the chloraminated system under the recommended operations strategies.

Total Ammonia-N. Similar to total chlorine, it is difficult to establish action levels for total ammonia, as we do not know the concentration of ammonia that will be added to the SFPUC water. The preliminary actions levels given are based on a review of levels used by 7 chloraminating utilities (see Appendix B). The preliminary Action Levels 1 and 2 chosen for the District are 0.3 mg/L and 0.2 mg/L, respectively.

Nitrite-N. The preliminary warning and action levels for nitrite are based on a review of levels used by 7 chloraminating utilities (see Appendix B). The Action Level 1 values for the 7 utilities ranged from 0.010 to 0.015 mg/L. The Action Level 2 values ranged from 0.020 to 0.080 mg/L. The values chosen for the District are on the conservative ends of these ranges.

HPC. The HPC warning and action levels were also based on a review of levels used by 7 chloraminating utilities. The Action Level 1 values for the 7 utilities ranged from 50 to 100 CFU/mL. The Action Level 2 values ranged from 200 to 500 CFU/L. Again, the values chosen for the District are on the conservative ends of these ranges.

7.2.4 Automatic (On-Line) Water Quality Monitoring

In most cases, the water quality parameters listed above for predicting the onset of nitrification may be measured by on-line analytical instruments. It is possible, therefore, that these instruments could be installed at each water quality sampling point (turnouts, reservoirs, distribution system monitoring sites) to record water quality data and transmit it to the District's SCADA system. The data could then be used for water quality recording and trending, and to alarm the operations staff of any issues that require action. This improvement, however, would require the following:

- A substantial capital investment. At up to $30,000 each, the analytical instruments are fairly expensive. One instrument would be required at each sample point. Also,

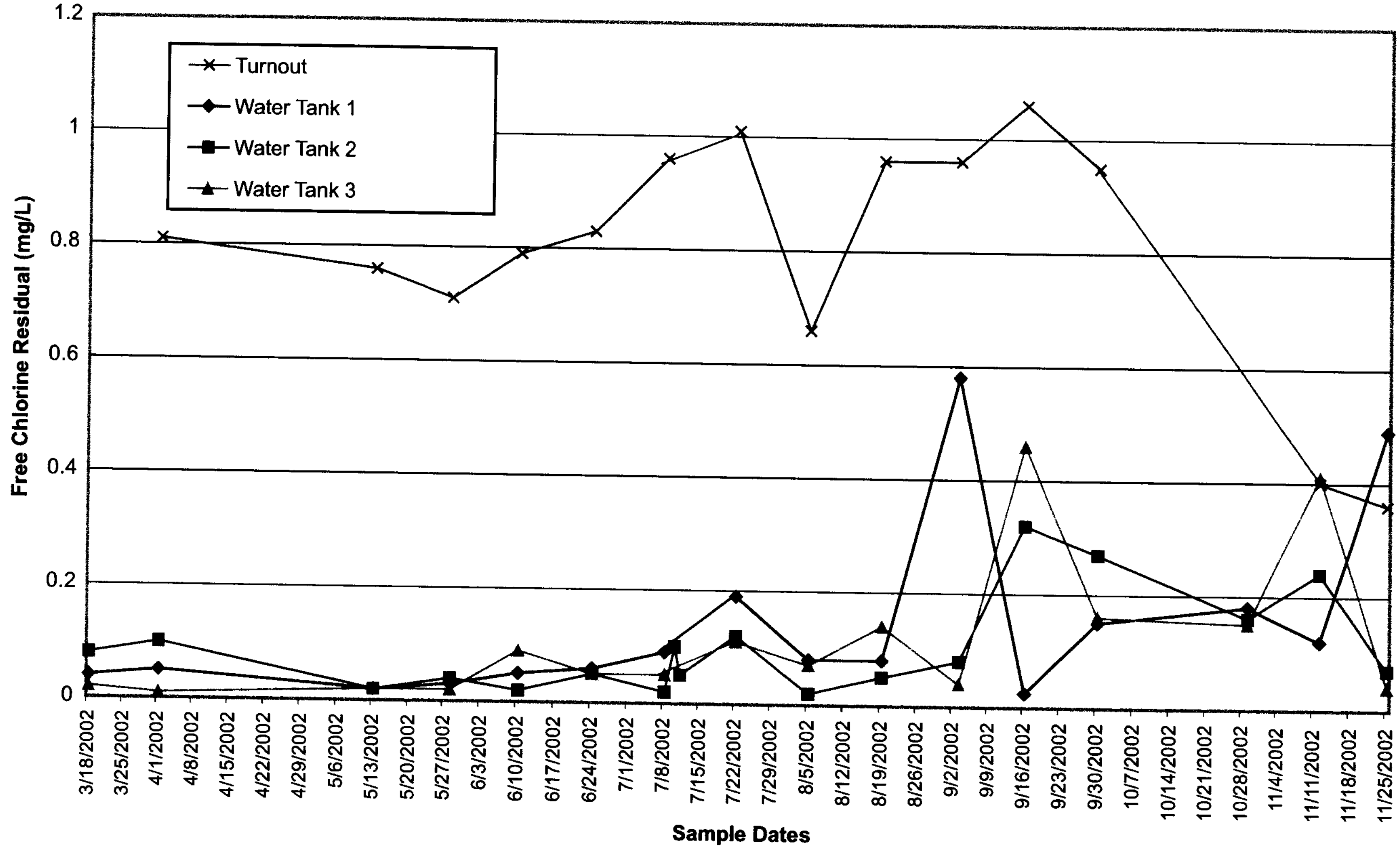

Figure 7.5
RESERVOIR CHLORINE RESIDUAL LEVELS
CHLORAMINE CONVERSION STUDY
ESTERO MUNICIPAL IMPROVEMENT DISTRICT

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since the equipment is sensitive and expensive, they will need to be housed within adequately protective structures.

- Potentially increased operator effort. All analytical instruments require regular calibration and maintenance. If the instruments are not calibrated, they will produce erroneous data that may either cause the District to react to a nitrification episode that has not happened, or miss the opportunity to prevent a potential nitrification episode.

The District may benefit, however, from installing a select number of instruments at a few critical locations, such as the turnout, the reservoirs, and key distribution system sampling sites. Such monitoring is not essential to operating the chloraminated system, but may be particularly useful if either the water quality coming from the turnouts is highly variable or if the reservoirs or other key points in the distribution system have frequent nitrification problems.

We recommend that the District wait until after the conversion to determine whether and where to implement on-line monitoring equipment. The District should be able to gauge the usefulness of on-line monitoring based on the results of the regular nitrification monitoring program. The District could start with one or two sites and then expand to additional sites if the program is successful.

7.3 NITRIFICATION ACTION PLAN – IDENTIFICATION AND RESPONSE

The purpose of the Nitrification Action Plan (NAP) is to provide guidelines to aid in the early detection and appropriate response to a nitrification episode. A simplified version of the NAP is provided in Appendix C. Nitrification is the biological conversion of ammonia to nitrate. This can lead to degradation of chloramine residuals and associated problems (see Section 2.1 for details). Nitrification occurs as the result of the activities of two groups of organisms - ammonia oxidizing bacteria (AOB) that convert ammonia to nitrite, and a second group of bacteria that oxidize nitrite to nitrate. The nitrite produced by AOB can also react directly with chloramine, resulting in further degradation of disinfectant residuals. Once initiated, nitrification is self-propagating and it may be difficult to stop. Thus, it is desirable to either prevent nitrification episodes, or alternately detect episodes early on before they have gained momentum.

There are a number of factors that contribute to nitrification. The most important factors over which the District has control are:

- **Controlling Water Age** – Controlling water age is very important to decrease the likelihood of a nitrification event occurring. A main component of the current project is to investigate operational changes to control water age in the distribution system. These operational recommendations are not included in the NAP, but are described above in Section 4.3.

- **Performing System Maintenance** – Keeping the distribution system "clean" (free from sediment and corrosion products) greatly decreases the probability of nitrification occurring. Recommendations for system maintenance are included in Section 7.1.

Controlling the above factors should greatly reduce the probability of a nitrification event. However, a nitrification event may still occur. The following sections outline methods to identify a nitrification event, as well as appropriate responses to identified nitrification problems.

Unfortunately, there is not a single water quality parameter that can be used to positively identify a nitrification event. However, as discussed in previous sections there are several water quality parameters that tend to be influenced by nitrification. We recommend that the District measure four of these parameters: total chlorine, total ammonia, nitrite, and HPC (limited monitoring only).

Figure 7.6 is a decision tree designed to aid the District in identifying and responding to potential nitrification events. Each box in the decision tree has been labeled with a letter, to facilitate discussion of the decision tree. The decision tree includes two types of boxes. Rectangular boxes are used for actions or endpoints. For example, the very first box (Box "A") is the regular monitoring program. After each rectangular box, continue down the decision tree to the next box (e.g., Box "B"). Diamond-shaped boxes are used for decisions. At each decision box there are two choices, depending on whether the answer to the decision is "Yes" or "No".

The following paragraphs describe the actions and decisions within the decision tree in further detail.

A. *Regular Monitoring Program* – The monitoring plan consists of weekly sampling of 17 sites (12 distribution system sites, the turnout, and 4 reservoirs) for total chlorine residual, total ammonia, and nitrite. Because HPC levels usually do not increase until a nitrification episode is relatively advanced, we are recommending HPC monitoring as part of the increased monitoring program only.

B. *Deterioration in at Least One Parameter* – A deterioration in one or more of the measured parameters (total chlorine, total ammonia, or nitrite) will initiate use of the decision tree. Deterioration is defined as a decrease in total chlorine or total ammonia, or an increase in nitrite.

C. *Action Level 1 Exceeded OR Greater than One Parameter Deteriorating* – Increased monitoring should be implemented if (1) one or more parameters has exceeded its Action Level 1 (see Table 7.2), or (2) more than one parameter is deteriorating (e.g., chlorine levels are going down and nitrite levels are going up).

D. *Increased Monitoring Frequency* – Under the increased monitoring frequency, the District should increase the frequency of total chlorine, total ammonia, and nitrite

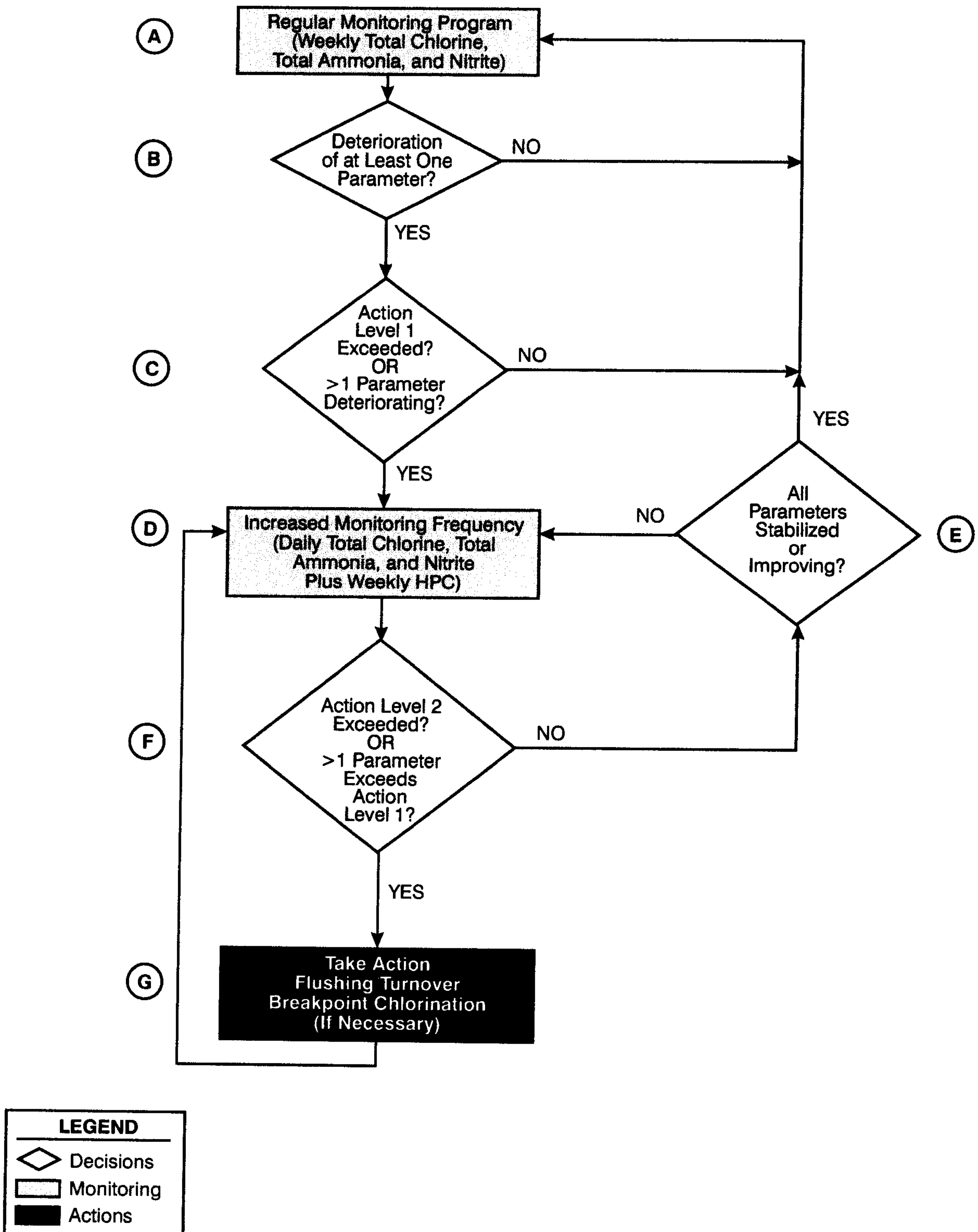

Figure 7.6
NITRIFICATION ACTION PLAN DECISION TREE
CHLORAMINE CONVERSION STUDY
ESTERO MUNICIPAL IMPROVEMENT DISTRICT

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measurements at the sampling sites of concern. In addition, the District should begin to collect *weekly* HPC samples at the sites of concern. Initially, we recommend that the increased monitoring of total chlorine, total ammonia, and nitrite consist of daily monitoring. However, as the District gains more comfort with the chloraminated system, the required increased monitoring frequency may be only 2 to 3 times per week. The increase monitoring need only be conducted at sites showing deterioration. Regular monitoring of total chlorine, total ammonia, and nitrite at other sampling sites may be continued on a weekly basis.

E. *Action Level 2 Exceeded OR Two Parameters Exceed Action Level 1* – Action should be taken is either (1) one of the parameters has exceeded its Action Level 2 value, or (2) two or more parameters have exceeded their Action Level 1 values.

F. *All Parameters Stabilized or Improving* – This decision will be reached if increased monitoring has been triggered, but the deterioration of the parameters is insufficient to warrant action. The increased sampling frequency should be continued until all parameters have stabilized or are improving.

G. *Take Action* – At this point, the monitoring data are suggesting that a nitrification event may be occurring. The immediate strategy is to replace the water in the nitrifying area with fresh water. If the nitrifying areas are in the distribution system, flushing should be used to bring fresh water to the region. If the nitrification is occurring in one of the reservoirs, the reservoir should be isolated and the water in the reservoir should be turned over by emptying the reservoir and refilling it with fresh water from the turnout. If more than one reservoir is nitrifying, one reservoir should be emptied and refilled at a time, to maintain minimum storage requirements. Monitoring should then continue at the increased frequency.

If the continued monitoring suggests that nitrification is still occurring, further flushing and/or turnover should be implemented. Strategies may be taken to increase the effectiveness of these operations. For example, flushing could be conducted for a longer period, or on a daily basis for a period of time, or additional hydrant taps or hydrants can be opened to increase the flow rate and better clean the offending piping. The water in a nitrifying reservoir could be cycled out more completely in an effort to overwhelm the established bacterial colonies.

If these actions are still unsuccessful at combating the nitrification, more drastic measures must be taken. The inability of fresh water to rid the area of nitrification indicates that a well-developed population of nitrifying bacteria is present. One method to kill the nitrifying bacteria is to breakpoint chlorinate the nitrifying area. For distribution piping, this is best accomplished by isolating the piping and feeding enough chlorine into the pipes to convert the water from a chloramines residual to a free chlorine residual. A similar approach can be used for a nitrifying reservoir. A second option for a reservoir would be to drain it and to thoroughly clean the reservoir walls.

If breakpoint chlorination is employed, care should be exercised in returning the facilities to normal operation. For the pipelines, it is best to flush the chlorinated water out of the piping with fresh chloraminated water taking care to dechlorinate the flushing water. Reservoirs containing free chlorine may be drained back into the system in a controlled fashion much like will be done when the system converts to chloramines disinfection. This can only be done, however, if the free chlorine levels are within regulatory limits.

7.4 COLIFORM EPISODE ACTION PLAN

The purpose of the Coliform Episode Action Plan is to provide guidelines to the District for the appropriate response to a violation of the Total Coliform Rule. This section is designed for limited use by District operations staff as a stand-alone document. However, to allow this section to be concise, the larger document is referenced to provide additional information where necessary.

7.4.1 Introduction

Coliform bacteria have served as indicators of the microbiological quality of drinking water for close to a century. The purpose of indicator organisms is to identify the presence of recent fecal contamination from warm-blooded animals in the water supply. Coliform bacteria observed in drinking water samples are used to warn utilities of a potential breakdown in the treatment process, or of potential contamination of the distribution system (e.g., through a main break or cross connection). It is important to note that though some coliform bacteria are human pathogens, the majority of coliform species are not. Hence, the presence of coliform bacteria does not *necessarily* indicate an immediate threat to public health.

Coliform bacteria are present in the intestines and feces of humans and other warm-blooded animals. Hence, their presence may indicate the presence of fecal contamination. However, there are two major weaknesses in the use of total coliform as indicators of fecal contamination:

- Fecal matter is not the only source of coliform bacteria – coliform bacteria are commonly found in both soil and natural aquatic environments
- Many coliform bacteria are able to multiply in distribution system biofilms. Hence, an increase in coliform bacteria may be due to the release of coliform bacteria from biofilms, rather than being an indicator of fecal contamination.

Fecal coliform bacteria are a much more specific indicator of fecal contamination, though not all fecal coliform bacteria are human pathogens. Fecal coliform are much less likely to have originated from an environmental (non-animal) source and tend to be less likely to multiply within the distribution system. As such, instances of fecal coliform are much more rare.

If breakpoint chlorination is employed, care should be exercised in returning the facilities to normal operation. For the pipelines, it is best to flush the chlorinated water out of the piping with fresh chloraminated water taking care to dechlorinate the flushing water. Reservoirs containing free chlorine may be drained back into the system in a controlled fashion much like will be done when the system converts to chloramines disinfection. This can only be done, however, if the free chlorine levels are within regulatory limits.

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7.4.2 Total Coliform Rule

The presence of coliform bacteria in the distribution system is regulated under the Total Coliform Rule (TCR). The TCR also requires the presence of a detectable disinfectant residual throughout the distribution system. A detectable chlorine residual is usually 0.05 mg/L or greater, but is dependent on the detection limit of the analytical method used. Appropriate response to loss of the disinfectant residual in the absence of coliform bacteria is included in the Nitrification Action Plan (see Section 7.4). Positive coliform samples may also lead the DHS to determine that a "Significant Increase in Bacterial Counts" has occurred (see Section 7.4.4).

To aid understanding of the requirements under the TCR, we have presented its requirements as a decision tree (see Figure 7.7). The following is a description of each component of the decision tree. Each description is labeled with a letter, which corresponds to letters shown on the Figure. The phrase "coliform-positive" refers to a sample that is positive for the presence of total coliform bacteria.

A. *Positive Total Coliform Sample* – A single positive total coliform sample should initiate use of the decision tree. The decision tree incorporates consideration of initial samples that are also positive for fecal coliform or *E. coli*. All samples that are positive for total coliform will be automatically analyzed for fecal coliform and *E. coli*.

B. *> 2 Positive Samples in Same Month* – The TCR specifies that a system is in violation if greater than 5 percent of collected samples are positive for total coliform in a given month. Thus the maximum number of allowable coliform positive samples per month is 2, based on collection of approximately 40 samples per month (10 samples per week). If the number of coliform-positive samples exceeds 5 percent, then the utility is in non-acute violation of the TCR (see description **G** below).

C. *Collect Set of 3 Repeat Samples* – The TCR requires that a set of at least 3 repeat coliform samples be collected within 24 hours of notification by the water quality laboratory that a previously collected sample was positive for total coliform. One of the samples must be collected at the same sample tap as the original coliform positive sample. The two additional samples must be collected within 5 service connections of the original positive sample, one upstream of the original site and one downstream.

D. *At Least One Repeat Sample is Total Coliform Positive* – If the repeat samples are all total coliform-negative, then no further additional testing is required. If at least one of the repeat samples is coliform positive, then an additional set of repeat samples must be collected within 24 hours of notification. Repeat sampling must be continued until no coliform are detected.

E. *Return to Regular Monitoring* – If no coliform are tested in a set of repeat samples, the District may return to its regular TCR monitoring program.

F. *Original or Repeat Sample Positive for Fecal Coliform or E. coli* – The District is in acute violation of the TCR (see description **H** below) if (1) at least one of the repeat

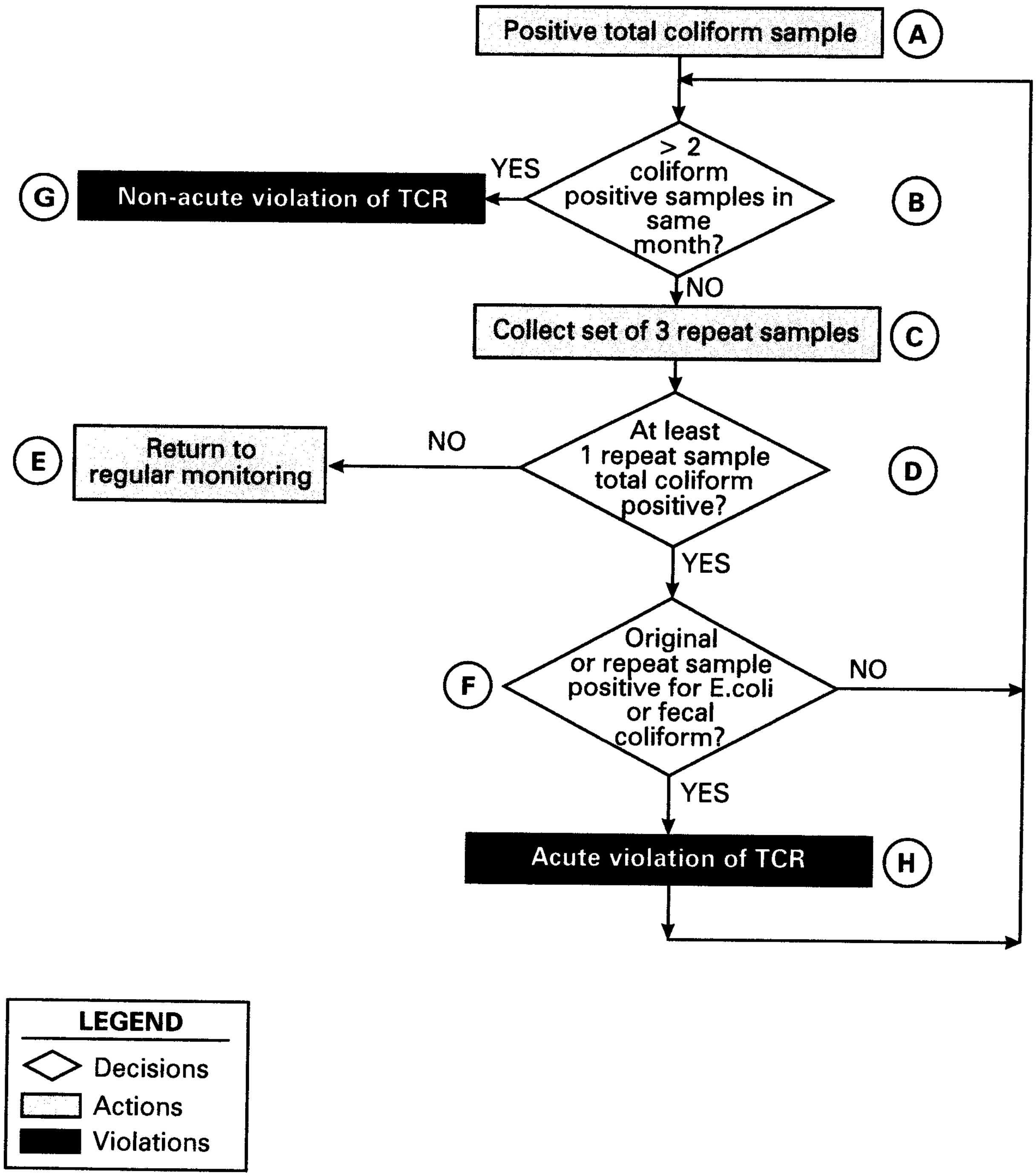


Figure 7.7
COLIFORM EPISODE ACTION PLAN DECISION TREE
CHLORAMINE CONVERSION STUDY
ESTERO MUNICIPAL IMPROVEMENT DISTRICT

Fc403f4-6627.cdr

samples is coliform positive and (2) either the original sample or one of the repeat samples is positive for *E. coli* or fecal coliform.

G. Violations and Required Notifications to the DHS

H. *Non-Acute Violation of the TCR* – A non-acute violation occurs as the result of the presence of coliform bacteria in greater than 5 percent of collected samples. Public notification requirements are described below under Section 7.4.3.1. The DHS must be contacted within 24-hours of the violation.

I. *Acute Violation of the TCR* – An acute violation of the TCR occurs as the result of either the original sample or one of the three repeat samples being positive for fecal coliform or *E. coli*. Public notification requirements are described below under Section 7.4.3.2. The DHS must be contacted within 24 hours of the violation.

7.4.3 Public Notification Requirements

7.4.3.1 Non-Acute Violation of the TCR

Non-acute violation requires notification under Sections 64464.1 and 64464.3 of the California Code of Regulations. These sections require that public notification be pursued through the following media:

- A notice shall be given once within 14 days after the violation or failure by publication in a daily newspaper of general circulation in the area served by the system.
- Notice by direct mail, with the water bill, or by hand delivery must be given within 45 days of the violation. Notification will be repeated by one method at least once every 3 months for as long as the violation or failure continues. The California Department of Health Services may waive the requirement if it determines that the violation has been corrected within 45 days.

The notices supplied by the water supplier will be a readily understandable explanation of the violation including the potential adverse health effects, the population at risk, and the steps being taken to correct the violation. The notice will also be conspicuous, include a telephone number of the water supplier, and if appropriate multilingual. The following language must be used in the notifications:

> *"The California Department of Health Services (Department) sets drinking water standards and has determined that the presence of total coliforms is a possible health concern. Total coliforms are common in the environment and are generally not harmful themselves. The presence of these bacteria in drinking water, however, generally is a result of a problem with water treatment or the pipes which distribute the water, and indicates that the water may be contaminated with organisms that can cause disease. Disease symptoms may include diarrhea, cramps, nausea, and possibly*

jaundice, and any associated headaches, and fatigue. These symptoms, however, are not just associated with disease-causing organisms in your drinking water, but also maybe caused by a number of factors other than your drinking water. The Department has set an enforceable drinking water standard for total coliforms to reduce the risk of these adverse health effects. Under this standard, no more than 5.0 percent of the samples collected during a month can contain these bacteria, except that systems collecting fewer than 40 samples/month that have one total coliform-positive sample per month are not violating the standard. Drinking water which meets this standard is usually not associated with a health risk from disease-causing bacteria and should be considered safe."

7.4.3.2 Acute Violation of the TCR

An acute violation of the TCR requires notification under Sections 64464.1 and 64465 of the California Code. These sections require that public notification be pursued through the following media:

- Notice shall be given to radio and television stations broadcasting in the area as soon as possible, but no later than 24 hours after direction from the Department of Health Services.
- In addition, a notice shall be given once within 14 days after the violation or failure by publication in a daily newspaper of general circulation in the area served by the system.
- Notice by direct mail, with the water bill, or by hand delivery will be given within 45 days of the violation. Notification will be repeated by one method at least once every 3 months for as long as the violation or failure continues.

The notices supplied by the water supplier will be a readily understandable explanation of the violation including the potential adverse health effects, the population at risk, and the steps being taken to correct the violation. The notice will also be conspicuous, include a telephone number of the water supplier, and if appropriate multilingual. The following language must be used in the notifications:

"The California Department of Health Services (Department) sets drinking water standards and has determined that the presence of fecal coliforms or E. Coli is a serious health concern. Fecal coliforms or E.Coli are generally not harmful themselves, but their presence in drinking water is serious because they usually are associated with sewage or animal wastes. The presence of these bacteria in drinking water is generally a result of a problem with water treatment or the pipes which distribute the water, and indicates that the water may be contaminated with organisms that can cause disease. Disease symptoms may include diarrhea, cramps, nausea, and possibly jaundice, and associated headaches and fatigue. These

symptoms, however, are not just associate with disease-causing organisms in drinking water but also may be caused by a number of factors other than your drinking water. The Department has set an enforceable drinking water standard for fecal coliforms and E.coli to reduce the risk of these adverse health effects. Under this standard all drinking water samples must be free of these bacteria. Drinking water which meets this standard is associated with little or none of this risk and should be considered safe. The Department recommends that consumers take the following precautions: (to be inserted by the water supplier according to instructions from the Department)"

7.4.4 Significant Rise in Bacterial Count

As the result of a TCR violation, or any sample that is positive for *E. coli* or fecal coliform, the DHS may determine that a Significant Rise in Bacterial Counts has occurred. The DHS may make this determination based on the following information: (1) current operating procedures that could be related to the increase in bacterial counts, (2) interruptions in the treatment process, (3) system pressure loss to less than 5 psi, (4) vandalism and/or unauthorized access to facilities, (4) physical evidence indicating bacterial contamination of the facilities, or (5) community illness suspected of being waterborne. Upon receiving notification from the DHS of a significant rise in bacterial counts, public notification according to the District's Emergency Response Plan is required. Additional instructions will be provided by the DHS.

7.4.5 Emergency Notification Plan

The District currently has a Water Quality Emergency Notification Plan that includes a list of designated personnel at the District and California Department of Health Services to implement the plan during a water quality emergency. Within the plan, notification of radio stations, television stations, and police/fire department is required within 25 minutes, which is within the required 24 hours to notify the public during an acute violation. Consideration of non-English speaking groups is also included within the plan. The plan could be improved with the inclusion of a procedure for non-acute and significant rise in bacterial count violations, which would include a list of local newspapers with contact information, a procedure for mailing of violation notices, and a time required to provide notice to the consumers.

7.5 ESTIMATED ADDITIONAL O&M COSTS

The estimated annual O&M costs associated with operational changes recommended for the chloraminated system are summarized in Table 7.3. In all cases the cost of labor was assumed to be $57/hour and the cost of water was assumed to be $1.05 per 100 cubic feet, as specified by the District. Each item is further described in the below sections.

Table 7.3 Estimated Additional O&M Costs Chloramine Conversion Study Estero Municipal Improvement District	Additional Water Volume Used (MG)	Required Labor (hours)	Direct Costs	Total Costs
A. Chloramine Conversion Costs				
Extra staffing	-	176	-	$10,030
Wasted Water	17.3	-	-	$24,280
Total	**17.3**	**176**	**-**	**$34,310**
B. Existing Costs				
Existing Water Quality Monitoring Program				
Labor	-	220	-	$12,540
Annual Unidirectional Flushing				
Labor	-	1,600	-	$91,200
Water Wasted Through Flushing	22.8	-	-	$32,000
Reservoir Cleaning	-	-	$6,000	$6,000
Total	**22.8**	**1,820**	**$6,000**	**$141,740**
C. New Costs				
Nitrification Monitoring				
Labor (8 hours per week)	-	416	-	$23,710
On-site Testing Reagents	-	-	$2,920	$2,920
HPC Tests	-	-	$1,050	$1,050
Bi-Annual Flush of Dead Ends				
Labor	-	160	-	$9,120
Wasted Water	2.3	-	-	$3,200
Increased Pumping				
Fuel	-	-	$6,490	$6,490
Labor	-	455	-	$25,940
Total	**2.3**	**1,031**	**$10,460**	**$72,430**

7.5.1 Chloramine Conversion Costs

The estimated costs under this line item are for expenses associated with the 3-day period of the conversion, based on the recommended conversion plan presented in Section 6.2. These costs are a one-time only event and will not occur annually.

There are two stages of the conversion that must be considered. In Phase 1, the reservoirs will be turned over and 3 or 4 hydrants will be flushed continuously. In Phase 2, operations staff will sample monitoring sites and dead ends, and flush the system as needed.

The following assumptions were made:

- Combined hydrant flow rate of 4,000 gpm during Phase 1.
- Flushing duration of 72 hours during Phase 1.
- Additional labor required during Phase 1 is two operators for 16-hours per day, to provide system oversight 24-hours per day.
- Total flushed volume during Phase 2 estimated to be 500,000 gallons.
- Total labor hours during Phase 2 assumed to be 80 hours based on 2 persons for five 8-hour workdays.

7.5.2 Existing Costs

7.5.2.1 Existing Water Quality Monitoring Program

The estimated labor hours specified under this line item are for the existing water quality monitoring program the District conducts to meet regulatory requirements. This monitoring program will be continued after the chloramine conversion and is separate from the additional nitrification monitoring recommended in this report.

The total hours assume:

- 4 hours per week for regular testing to meet the requirements of the total coliform rule.
- An additional 12 hours per year for quarterly collection of THM and HAA samples.

7.5.2.2 Annual Unidirectional Flushing Program

The estimates for the annual unidirectional flushing program are based on information provided by the District, as follows:

- Annual unidirectional flushing program requires the labor of 4 operators, 8-hours per day, 5 days per week, for 10 weeks (a total of 1,600 hours).
- The total flushed volume of 22.8 MG was based on the assumption of 1.382 hydrants flushed for 15 minutes each, at a flow rate of 1,100 gpm.

7.5.2.3 *Reservoir Cleaning*

The estimate for cleaning of the reservoirs assumes that the reservoirs will be cleaned once every 3 years (the recommended interval is every 3 to 5 years). The cost for cleaning each reservoir was estimated to be $6,000, based on District experience, for a total cost of $18,000 for all three reservoirs.

7.5.3 New Costs

7.5.3.1 *Nitrification Monitoring Program*

The estimated annual cost for the nitrification monitoring are based on the following:

- Approximately 8-hours per week will be required to collect and analyze the sample and enter the data into an appropriate spreadsheet.
- A total of 2,900 on-site tests will be conducted per year at an assumed reagent cost of $1 per sample. The number of samples is based on:
  - Testing is to be conducted at 17 samples sites (12 distribution sites, the turnout, and the four reservoirs).
  - There will be 3 onsite tests at each site (total chlorine, total ammonia, and nitrite).
  - An additional 10 percent was added to the cost to account for increased monitoring.
- An estimated total of 30 HPC tests per year at an estimated cost of $35/sample. This number is difficult to estimate, as testing is to be conducted only if increased monitoring is triggered.

7.5.3.2 *Bi-Annual Flush of Dead Ends*

It was assumed that one bi-annual flush of all dead ends would be included as part of the annual unidirectional flushing program. The wasted water and labor required for a second annual flush of the dead ends was calculated as 10 percent of the values used for the unidirectional flushing program.

7.5.3.3 *Additional Pumping Costs*

One of the recommendations of this report is that the District increase turnover in the reservoirs by pumping more each day. The current pumping regime is between 7:30 a.m. and 3:30 p.m. each day. The values provided in the table are for three reservoirs in service, and include the following assumptions:

- An estimated additional 4.5 hours would be needed in the winter, with no additional pumping during the summer.
- No pumping on weekends.
- Half of the year was assigned to "summer" conditions, and the other half to "winter" conditions.

- Only one operator would be required to attend to the motors during extended operation.
- Labor for one additional hour of pumping was assumed to be without cost, as operators are on duty for 9 hours per day.

The unit cost of energy per hour of pumping was calculated based on historical energy bills for the pump station for the period from 7/5/02 through 2/03/03. The unit cost was calculated to be $11.10 per hour (two pumps in operation), as follows:

- The total cost of power over this period was $13,588.
- The total pumping days (153 days) was assumed to be 5/7 of the total number of days in the period (214 days), to account for no pumping on the weekends.
- The total number of pumping hours (1,224 hours) was calculated based on operation of the pumps for 8 hours each day (7:30 a.m. to 3:30 p.m.).

The addition of the fourth reservoir would require an additional 2.5 hours of pumping in the summer. Under winter conditions, the pumping requirements are the same as for 3 reservoirs. This additional pumping would incur an estimated cost of $ 14,720/year ($11,120/year for labor and ~$3,600/year for fuel) based on the assumptions listed above.

APPENDIX A - EXPERIENCES OF OTHER UTILITIES CONVERTING TO CHLORAMINES

APPENDIX A - EXPERIENCES OF OTHER UTILITIES CONVERTING TO CHLORAMINES

Kirmeyer, et al. (1995) conducted a survey of utilities using chloramine that had experienced nitrification problems. Five of the utilities surveyed are listed below and are represented in Table 3.1 that is a summary of their respective experiences. The utilities included on Table 3.1 exercised control procedures after the onset of nitrification:

- Ann Arbor Utilities Department, Michigan.
- Metropolitan Water District of Southern California (MWD-SC).
- Los Angeles Department of Water and Power, California (LADWP).
- City of Fort Worth Water Department, Texas.
- City of Philadelphia Water Department, Pennsylvania

In addition, this section discusses the more recent experiences of a local utility, East Bay Municipal Utility District (EBMUD), that switched to chloramines in 1998.

EAST BAY MUNICIPAL UTILITY DISTRICT

In March 1998, East Bay Municipal Utility District (EBMUD) began implementing the conversion from free chlorine to chloramine. EBMUD's water sources include the Mokelumne River, the San Pablo Reservoir, and Upper Sobrante Lake Reservoir. The Mokelumne River is high quality water with low organic carbon; Lake Sobrante Reservoir water is also high quality, but has higher organic carbon and higher alkalinity. The Mokelumne River water is similar to the SFPUC reservoir water supplying San Francisco and the City.

From the Mokelumne River and Sobrante Lake Reservoir, water is distributed to 175 reservoirs servicing 122 pressure zones, and 4,000 miles of pipe. Due to topography and required fire protection, EBMUD has a high storage to demand ratio (2:1) and long detention times in the system. The reservoirs are 80 percent full all of the time. In some parts of the distribution system, 20 percent of the water resides in the system for more than 21 days (Wilczak et al. 1998).

Table A-1 Experiences of Other Utilities Using Chloramine
Chloramine Conversion Study
City of Mountain View

Utility	Nitrification Indicator	Cited Cause of Nitrification	Actions Taken to Control Nitrification	Interim Result	Final Operating Modifications to Reduce Nitrification
Ann Arbor	Decreased chloramine residual in distribution system. Increased HPC. Increased nitrite.	Excess ammonia in plant effluent. Discontinued Flushing. Change to GAC filtration.	Increased total chlorine. Low velocity flushing. Chlorinated Distribution System	Not effective. Nitrite eliminated, free chlorine increased, HPC concentrations lowered.	Use nitrite warning level = 0.025 mg/L. Use nitrite action level = 0.050 mg/L. $Cl_2 : NH_3$-N = 4.75:1. Free ammonia = 0.015 mg/L More flushing.
MWD-SC	Decreased chloramine residual. Increased nitrite. Increased HPC.	Low $Cl_2 : NH_3$-N ratio Long detention time in reservoirs.	Added water quality monitoring. Take reservoir off-line, breakpoint chlorinate. Maintain 1.2 mg/L Cl_2 residual for 3-4 weeks.	Nitrite reduced. HPC controlled.	$Cl_2 : NH_3$-N=5:1 Increase chloramine dose. Add sampling if nitrite detected. If nitrite>0.05 mg/L, breakpoint chlorinate.
LADWP	Decreased chloramine residual. Increased nitrite.	Blended water sources, and received pre-chloraminated water. Noticed loss of residual within the piping system.	Flushed mains. Breakpoint chlorinate at reservoir effluent.	Temporary improvements. Residual took 3-4 weeks to stabilize.	Still have to do periodic chlorination in problem spots. Will develop long term strategy.
City of Fort Worth	Increased HPC.	Long detention time in reservoirs.	Increased chloramine dose. Reduce reservoir detention time. Recirculation and rechlorination.	Reduction in nitrification. Found HPC best indicator.	Monitor HPC and all nitrogen species. Recirculation and rechlorination improvements.
City of Philadelphia	Decreased chloramine residual. Increased HPC. Increased nitrite.	Cross-connection at corrosion inhibitor in heating system C local pH 7.2. Increased temperatures.	Drained and filled standpipes. Increase reservoir turnover & maintain influent chloramine residual.	Chloramine residual restored. Long term reduction in nitrification potential.	Chloramine action level (<1 mg/L). Long term strategy: Improve storage design & add sampling points.

Source: Kirmeyer et al. 1995

EBMUD implemented a three stage monitoring approach; pre-conversion (1-month), conversion (2-3 months), and chloraminated system monitoring (long term) (Wilczak et al. 1998). The monitoring parameters for each stage were as follows:

Pre-conversion: Chlorine, ammonia, nitrite, nitrate, standard plate counts, R2A HPC plate counts, pH, iron, temperature, turbidity, color, and conductivity.

Conversion: Chlorine and ammonia.

Chloraminated System:Same as pre-conversion parameters.

During conversion and after, the operational experiences indicated problems with adjusting the ratios of sodium hypochlorite and ammonia in the clearwell effluent. Observations were that sodium hypochlorite instability could be eliminated through careful chlorine to ammonia ratio control by pacing the feed flow to accomplish this (Wilczak, 1998). Since the City will receive treated water, this will not be an issue.

Additional observations were that the distribution system should receive more attention. Changes to the distribution system operations were planned, including: reinstitution of a routine flushing program, routine reservoir cleaning, and progress towards decreasing water age in the system to include the following:

- Reduce reservoir storage volume by lowering minimum and maximum levels.
- Reduce age of water supplied to the reservoirs by utilizing the lowest age water source, and by synchronizing cascade pumping.
- Increase demand on reservoirs by returning flow to lower pressure zones, changing the preferred pumping plant, or through valve operations.
- Institute seasonal reservoir outages, removing one or more non-essential reservoirs from service.
- Size pipes carefully in lower demand areas (Wilczak, et al. 1998). EBMUD is currently flushing approximately 10 miles of distribution system mains every month (Mary Hicks, 1999).

EBMUD has experienced nitrification events at approximately 15 of their reservoirs due to long detention times (10 to 15 days) and chloramine residuals dropping below 1.5 mg/L (Song, et al. 1998). All these tanks were filled with water from the Upper Sobrante Lake Reservoir, the higher organic carbon source. Initially, the control action taken was to use free chlorine to arrest the nitrification process; this remedy only lasted one week, and nitrification began again. Finally, by taking the reservoirs off-line and replacing a bulk of the water with fresh water from the Mokelumne River, nitrification was halted (Song, et al. 1998).

APPENDIX B - COMPARISON OF NITRIFICATION ACTION LEVELS

METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

NITRIFICATION WORKSHOP

Comparison of Nitrification Action Levels

Agency	Parameter Monitored	Normal Range	Action Level 1	Action Level 2	Action Level Response
LADWP	Total Chlorine, mg/L				AL1: Increase monitoring and tank cycling (depth and frequency).
	a) Storage tanks/reserv.	1.0-2.5	0.5	0.2	AL2: Isolate tank, inspect and clean if needed; if cleaning is not needed, convert to free Cl_2.
	b) Distribution system (DS	1.7-2.8	1	0.3	AL1: Increase monitoring and check tank; AL2: Confirm if source is OK and flush mains.
	Nitrite, mg/L	0-0.01	>0.01	≥0.02 at two or more locations	AL1: Increase monitoring and check tank. AL2: Adjust Cl_2:NH_3 ratio, cycle tanks, possibly flush mains and/or convert DS to free Cl_2.
MWDSC Reservoir Effluent	Total Chlorine, mg/L	2.4-2.7	2.0-<2.4; >2.7-2.9	<2.0; >2.9	Maintain a 5:1 chlorine to ammonia ratio.
	Total Ammonia, mg/L	0.40-0.60	0.36-<0.40; >0.60	<0.36; >0.60	AL1: Check pretreatment residuals to ensure you are not over the curve
	Nitrite-Nitrogen, mg/L	0-0.010	>0.010-0.020	>0.020	AL1: Increase monitoring. AL2: Check chemical feed equipment for proper operation. Minimize free ammonia by optimizing the chloramine residual. Reduce detention time/improve circulation. Take reservoir out of service and breakpoint chlorinate.
	Turbidity, NTU	0-0.15	>0.15-0.25	>0.25	
		Normal Range	**Alert Level**	**Action Level**	
Glendale	Total Chlorine, mg/L	0.5-2.5	0.2-<0.5	<0.2	Varies based on elevation or pressure zones; Glendale has 7 pressure zones. Alert Level: Flush distribution system and chlorinate resevoirs/pump stations.
	Free Chlorine, mg/L	0.2-1.0		<0.2	Upper zones only
	Nitrite, mg/L		0.01-0.025	>0.025	Action Level: Trim chlorination or break to free chlorine depending on the ammonia and nitrite demand.
	Total Ammonia, mg/L				No action level, but used for calculating the chlorine amount when trimming or breaking.
	Free Ammonia, mg/L			>0.08	This test is not reliable. It is used as a secondary check and storage is chlorinated.
Long Beach Water Dept. Distribution System	Total Chlorine, mg/L	2.0 - 2.6	<1.0	<0.6	Alert Level: Increase monitoring.
	Nitrite, mg/L	0 - 0.03	>0.04	>0.08	Action Level: Flush at hydrants until CL_2 residuals increase and/or nitrite levels decrease.
	HPC, CFU/mL			>500	
So. Cal. WC Distribution System	Total Chlorine, mg/L	1.0-2.2	<1.0	<0.4	Alert Level: Increase monitoring (frequency and location).
	Total Ammonia, mg/L	0.35-0.5	<0.35	<0.2	
	Nitrite, mg/L	0.01-0.05	>0.05	>0.07	
	HPC, CFU/mL	0-50	>100	>200	
Sweetwater	Total Chlorine, mg/L	2.3-2.8	0.5	0.2	Alert Level: Increase monitoring frequency; implement deep cycling of problem tanks.
	Ammonia, mg/L	0.10-0.20	0.05	0.03	Action Level: Tank problem - take tank out of service, clean and disinfect
	Nitrite, mg/L	0.002-0.012	0.015	0.03	Distribution-wide problem - increase treatment plant chlorine levels; switch system to free chlorine.
	Turbidity, NTU	0.05-0.15			
	Coliforms, CFU/100 mL	<1	1	1	
	HPC, CFU/mL	<1 - 10	50	500	
Western MWD a) MWD Mills Water	Total Chlorine, mg/L	2.4-2.7	<2.0	<1.0	Alert Level: Problem with tank - increase cycling and monitoring. Problem with main - flush daily for a week.
	Total Ammonia, mg/L	0.48-0.50	<0.4	<0.3	
	Nitrite, mg/L	0.005-0.006	0.06	0.1	Action Level: Go to breakpoint chlorination only if necessary.; make sure all of the changes take place in the tank.
b) Riverside Well Water	Total Chlorine, mg/L	2.0-2.25	<2.0	<1.0	Carry a small residual of free chlorine to help maintain a clean system.
	Total Ammonia, mg/L	0.40-0.45	<0.4	<0.35	Increase chlorine if necessary.
	Nitrite, mg/L	0	0.015-0.020	<0.20	Cycle tanks or chlorinate and flush mains if problem persists.

APPENDIX C - SUMMARY OF OPERATIONS RECOMMENDATIONS

APPENDIX C - SUMMARY OF OPERATIONS RECOMMENDATIONS

Operational strategies presented in Table C.1 assume that the proposed reservoir is in service (total storage capacity of 20 MG). The summer and winter operational strategies both involve three phases. All three phases are cycled through each day. The three phases are as follows:

- Reservoir Drain: During this phase, the pump station will be activated and the reservoirs will be emptied from their maximum setpoint level to their minimum setpoint level. The maximum set point is the maximum point to which the reservoirs should be filled. For example, in the winter, it is recommended that the total volume of water stored be less than 11.5 MG at all times. In an automated system, controls for the inlet altitude valves would be set close when the maximum set point is reached.
- Reservoir Fill: During this phase, the pump station will be dormant and the reservoirs will be filled to their maximum setpoint with water from the turnout.
- Dormant: During this phase, the pump station will be dormant and the reservoirs will remain at their maximum setpoint.

Table C.1 Operational Strategies
Chloramine Conversion Project
Estero Municipal Improvement District

	Summer	Winter
3 Tanks in Service (Current System)		
Maximum Setpoint	12 MG (27 ft)	11.5 MG (25.9 ft)
Minimum Setpoint	10.5 MG (23.6 ft) (2)	10.0 MG (22.5 ft) (2)
Cycled Volume	1.5 MG	1.5 MG
Percent Cycled Per Day	12.5	13.0
4 Tanks in Service		
Maximum Setpoint	20 MG (27 ft)	11.5 MG (15.6ft)
Minimum Setpoint	17.5 MG (23.6 ft)(2)	10.0 MG (13.5 ft) (2)
Cycled Volume	2.5 MG	1.5 MG
Percent Cycled Per Day	12.5	13.0

Note:
(1) Strategies will result in local minimum water ages less than 400-hours at all points in the system except those discussed in Section 4.6.
(2) Minimum storage required is 9.41 MG year round.

It is difficult to estimate the number of hours of pumping that will be required to drain the recommended tank volumes. The maximum amount that can be drained from the tanks in a given period is dependent on the system demand over the same period (though some demands will be met from the turnout, even when the pump station is on). The demands are difficult to estimate, considering that: (1) demands can vary significantly from day to day and (2) we do not have an accurate diurnal curve for the District.

However, the current operation will likely be insufficient to provide the recommended turnover. The recommendations are based on the assumption that half of the daily demand can be supplied by the reservoirs (with the other half being supplied directly by the turnout). The current pump operation (between 7:30 a.m. and 4:30 p.m.) is unlikely to correspond to half of the demand, as (1) pumps are operated for only 8 hours per day and (2) the hours of operation are not hours typically of high demand. Also, the recommended strategies do not take into account non-operation of the pumps on weekends.

The recommended operational strategies do not include direction on the time of day during which the pumps should be operated. The times during which the pumping occurs will not affect the water quality in the tanks. The District may choose an appropriate time-of-day strategy based on other factors, such as operational constraints and peak-power costs.

REQUIRED OPERATIONS ACTIONS PRIOR TO AND DURING THE CONVERSION

Prior to the Conversion

1. Perform annual unidirectional flush.
2. Have new reservoir coatings inspected.
3. Start nitrification monitoring program 3 months prior to the conversion.

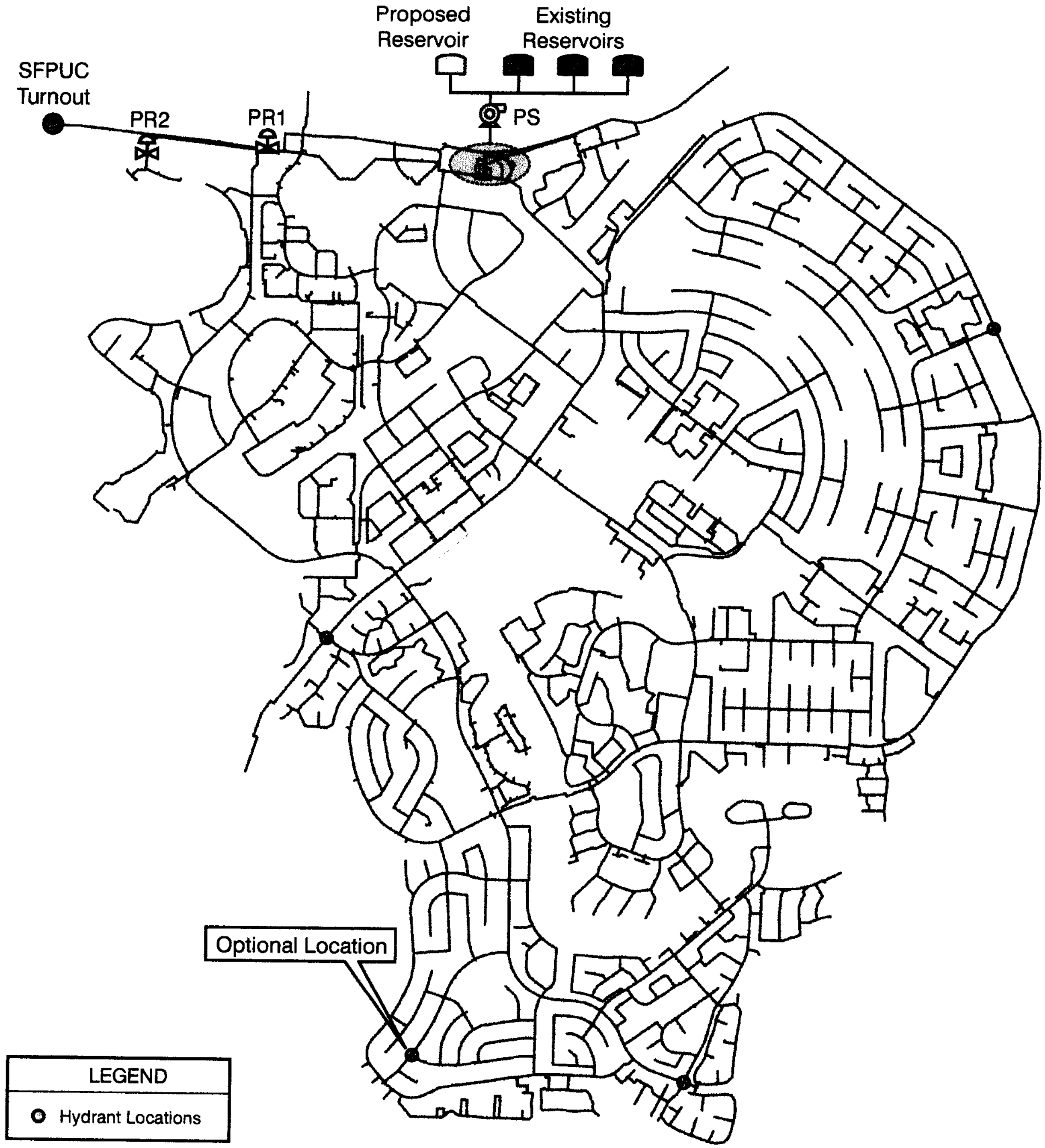
During the Conversion

Throughout the Conversion:

1. Continuous flushing of 3 or 4 hydrants, at the locations shown in Figure C-1.
2. Monitor total chlorine levels at the turnout and reservoir every 8 hours. If levels at the turnout drop below 0.5 mg/L, contact SFPUC. Once the reservoirs have been converted, the total chlorine levels should be within 0.5 mg/L of the concentration at the turnout.

Day 1 of the Conversion:

1. Start with 2 reservoirs full and the third near empty (should empty the one reservoir the day before, and not refill at night).
2. Fill the empty reservoir with chloraminated water from the turnout.
3. Empty one of the other two tanks filled with free chlorinated water.
4. Refill the tank with chloraminated water.



Note: Turnout, Reservoirs, Pressure Reducing Stations, and Pump Station represented pictorially and are not to scale.

Figure C.1
RECOMMENDED HYDRANT FLUSHING DURING THE CONVERSION
CHLOROAMINE CONVERSION STUDY
ESTERO MUNICIPAL IMPROVEMENT DISTRICT

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5. At the end of the day, should have two tanks filled with chloraminated water, and one remaining tank filled with free chlorinated water.

Day 2 of the Conversion:

1. Empty the remaining tank containing free chlorinated water.
2. Refill the tank with chloraminated water from the turnout.
3. At the end of Day 2, should have 3 tanks filled with chloraminated water.

Day 3 of the Conversion:

1. Cease hydrant flushing.
2. Return to regular reservoir operation.
3. Begin regular nitrification monitoring program.
4. Confirm that there is a reasonable total chlorine residual at all nitrification monitoring sites. If the residual is less than around 0.5 mg/L, should flush to bring fresh water to the area.
5. Start to sample dead ends throughout the system. If total chlorine residuals are below 0.5 mg/L, flush to bring fresh water into the local area.

Regions of High Water Age Requiring Flushing

The following identified regions will likely exhibit high water age and may be at risk for nitrification. These sites should be flushed on a bi-annual basis. Additional flushing should be conducted as needed, as indicated by water quality monitoring results.

Table C.2 High Water Age Areas Requiring Flushing
Chloramine Conversion Study
Estero Municipal Improvement District

Site Number	Location
Site 1	Corner of Baffin Court
Site 2	West end of East Hillsdale Blvd.
Site 3	End of Promontory Point Ln.
Site 4	End of pipeline at Black Angus Restaurant Close to intersection of State Route 92 and Vintage Park Dr.

Nitrification Action Plan

The following sections outline methods to identify a nitrification event, as well as appropriate responses to identified nitrification problems. Unfortunately, there is not a single water quality parameter that can be used to positively identify a nitrification event. However, as discussed in previous sections there are several water quality parameters that tend to be influenced by nitrification. We recommend that the District measure four of these parameters: total chlorine, total ammonia, nitrite, and HPC (limited monitoring only). Requirements are outlined in monitoring worksheets for both the regular monitoring and

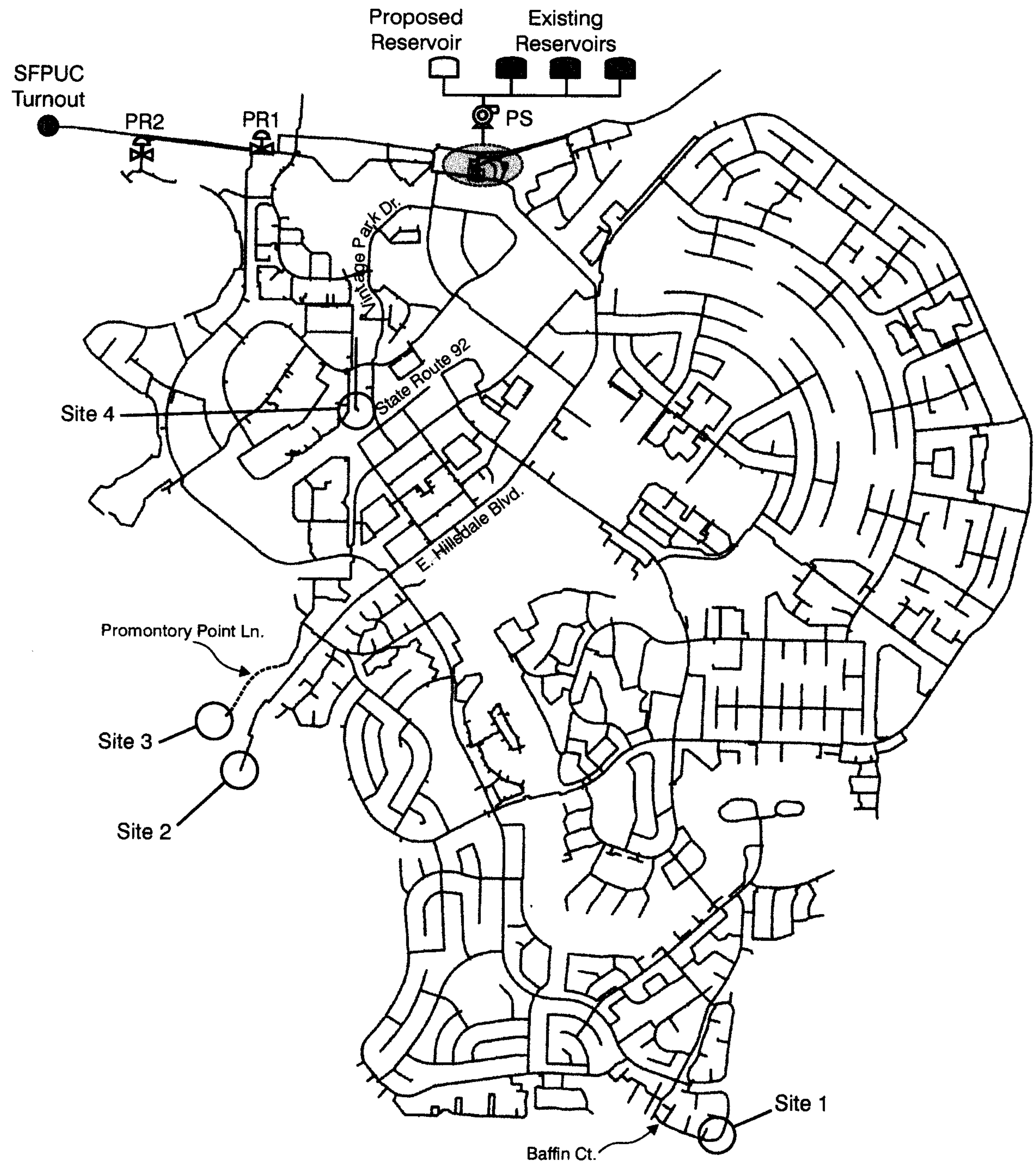

Figure C.2
RECOMMENDED FLUSHING SITES
CHLORAMINE CONVERSION STUDY
ESTERO MUNICIPAL IMPROVEMENT DISTRICT

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increased monitoring programs, which are attached following this section. A map showing the locations of the nitrification monitoring sites is also attached.

On the following page is a decision tree designed to aid the District in identifying and responding to potential nitrification events. Each box in the decision tree has been labeled with a letter, to facilitate discussion of the decision tree. The decision tree includes two types of boxes. Rectangular boxes are used for actions or endpoints. For example, the very first box (Box "A") is the regular monitoring program. After each rectangular box, continue down the decision tree to the next box (e.g., Box "B"). Diamond-shaped boxes are used for decisions. At each decision box there are two choices, depending on whether the answer to the decision is "Yes" or "No".

The following paragraphs describe the actions and decisions within the decision tree in further detail.

A. *Regular Monitoring Program* – The monitoring plan consists of weekly sampling of 17 sites (12 distribution system sites, the turnout, and 4 reservoirs) for total chlorine residual, total ammonia, and nitrite. Because HPC levels usually do not increase until a nitrification episode is relatively advanced, we are recommending HPC monitoring as part of the increased monitoring program only.

B. *Deterioration in at Least One Parameter* – A deterioration in one or more of the measured parameters (total chlorine, total ammonia, or nitrite) will initiate use of the decision tree. Deterioration is defined as a decrease in total chlorine or total ammonia, or an increase in nitrite.

C. *Action Level 1 Exceeded OR Greater than One Parameter Deteriorating* – Increased monitoring should be implemented if (1) one or more parameters has exceeded its Action Level 1 (see Table 7.2), or (2) more than one parameter is deteriorating (e.g., chlorine levels are going down and nitrite levels are going up).

D. *Increased Monitoring Frequency* – Under the increased monitoring frequency, the District should increase the frequency of total chlorine, total ammonia, and nitrite measurements at the sampling sites of concern. In addition, the District should begin to collect *weekly* HPC samples at the sites of concern. Initially, we recommend that the increased monitoring of total chlorine, total ammonia, and nitrite consist of daily monitoring. However, as the District gains more comfort with the chloraminated system, the required increased monitoring frequency may be only 2 to 3 times per week. The increase monitoring need only be conducted at sites showing deterioration. Regular monitoring of total chlorine, total ammonia, and nitrite at other sampling sites may be continued on a weekly basis.

E. *Action Level 2 Exceeded OR Two Parameters Exceed Action Level 1* – Action should be taken is either (1) one of the parameters has exceeded its Action Level 2 value, or (2) two or more parameters have exceeded their Action Level 1 values.

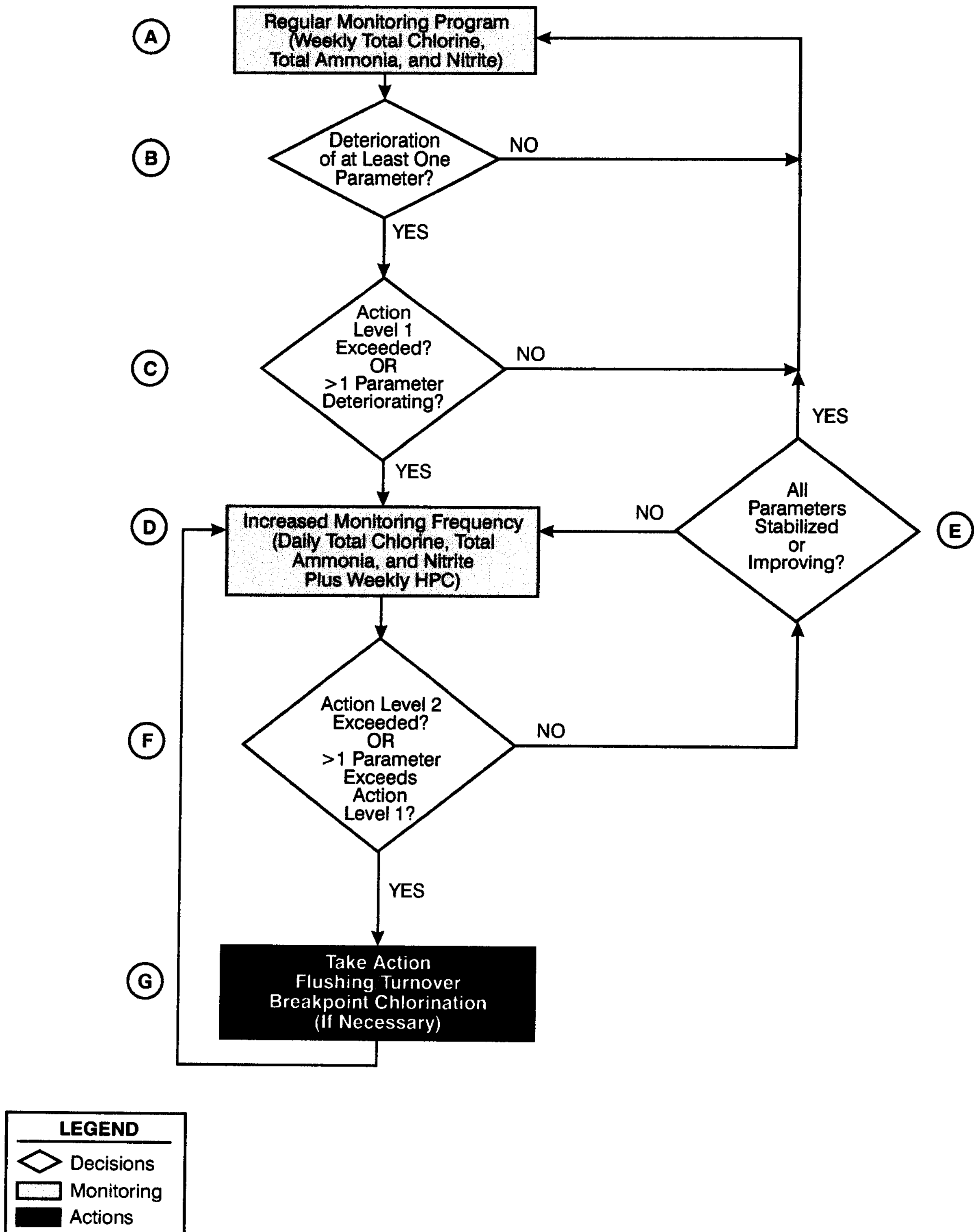

Figure C.3
NITRIFICATION ACTION PLAN DECISION TREE
CHLORAMINE CONVERSION STUDY
ESTERO MUNICIPAL IMPROVEMENT DISTRICT

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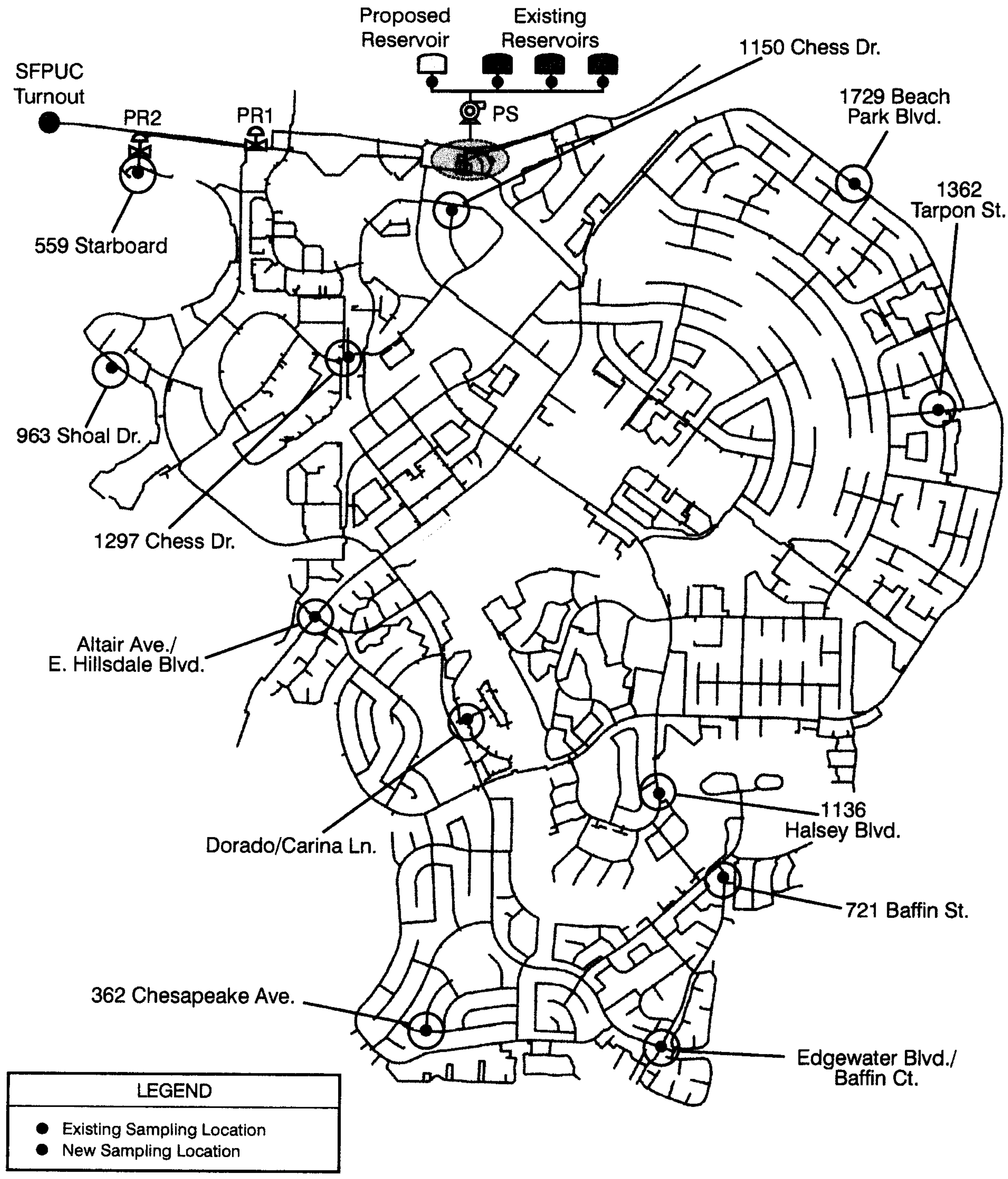
F. *All Parameters Stabilized or Improving* – This decision will be reached if increased monitoring has been triggered, but the deterioration of the parameters is insufficient to warrant action. The increased sampling frequency should be continued until all parameters have stabilized or are improving.

G. *Take Action* – At this point, the monitoring data are suggesting that a nitrification event may be occurring. The immediate strategy is to replace the water in the nitrifying area with fresh water. If the nitrifying areas are in the distribution system, flushing should be used to bring fresh water to the region. If the nitrification is occurring in one of the reservoirs, the reservoir should be isolated and the water in the reservoir should be turned over by emptying the reservoir and refilling it with fresh water from the turnout. If more than one reservoir is nitrifying, one reservoir should be emptied and refilled at a time, to maintain minimum storage requirements. Monitoring should then continue at the increased frequency.

H. If the continued monitoring suggests that nitrification is still occurring, further flushing and/or turnover should be implemented. Strategies may be taken to increase the effectiveness of these operations. For example, flushing could be conducted for a longer period, or on a daily basis for a period of time, or additional hydrant taps or hydrants can be opened to increase the flow rate and better clean the offending piping. The water in a nitrifying reservoir could be cycled out more completely in an effort to overwhelm the established bacterial colonies.

I. If these actions are still unsuccessful at combating the nitrification, more drastic measures must be taken. The inability of fresh water to rid the area of nitrification indicates that a well-developed population of nitrifying bacteria is present. One method to kill the nitrifying bacteria is to breakpoint chlorinate the nitrifying area. For distribution piping, this is best accomplished by isolating the piping and feeding enough chlorine into the pipes to convert the water from a chloramines residual to a free chlorine residual. A similar approach can be used for a nitrifying reservoir. A second option for a reservoir would be to drain it and to thoroughly clean the reservoir walls.

J. If breakpoint chlorination is employed, care should be exercised in returning the facilities to normal operation. For the pipelines, it is best to flush the chlorinated water out of the piping with fresh chloraminated water taking care to dechlorinate the flushing water. Reservoirs containing free chlorine may be drained back into the system in a controlled fashion much like will be done when the system converts to chloramines disinfection. This can only be done, however, if the free chlorine levels are within regulatory limits.



Note: Turnout, Reservoirs, Pressure Reducing Stations, and Pump Station represented pictorially and are not to scale.

Figure C.4
RECOMMENDED NITRIFICATION MONITORING SITES
CHLORAMINE CONVERSION STUDY
ESTERO MUNICIPAL IMPROVEMENT DISTRICT

carollo engineers

fc403f6-6627.cdr

Nitrification Monitoring Plan
Regular Weekly Sampling Schedule
Estero Municipal Improvement District

	Site	Week ____			Week ____		
		Total Chlorine (mg/L)	**Total Ammonia (mg/L)**	**Nitrite –N (mg/L)**	**Total Chlorine (mg/L)**	**Total Ammonia (mg/L)**	**Nitrite –N (mg/L)**
	Preliminary Action Level 1	< 0.5	< 0.3	> 0.01	< 0.5	< 0.3	> 0.01
	Preliminary Action Level 2	< 0.2	< 0.2	> 0.02	< 0.2	< 0.2	> 0.02
	Deteriorating if…	Decreasing	Decreasing	Increasing	Decreasing	Decreasing	Increasing
1	Reservoir 1						
2	Reservoir 2						
3	Reservoir 3						
4	Reservoir 4						
5	SFPUC Turnout						
6	559 Starboard						
7	1150 Chess Dr.						
8	1297 Chess Dr.						
9	963 Shoal Dr.						
10	Altair Ave./E. Hillsdale Blvd.						
11	Dorado/Carina Ln.						
12	362 Chesapeake Ave.						
13	Edgewater Blvd./Baffin Ct.						
14	721 Baffin St.						
15	1136 Halsey Blvd.						
16	1362 Tarpon St.						
17	1729 Beach Park Blvd.						

Increased monitoring should be conducted if at a given site:
(1) One parameter has exceeded the Action Level 1, OR
(2) Two parameters are deteriorating.

Nitrification Monitoring Plan
Increased Sampling Schedule
Estero Municipal Improvement District

Sample Site Requiring Increased Monitoring ____________

	Total Chlorine				Total Ammonia				Nitrite–N				Heterotrophic Plate Count (HPC)			
	mg/L	Getting Worse? (Decreasing)	Less than Action Level 1?	Less than Action Level 2?	mg/L	Getting Worse? (Decreasing)	Less than Action Level 1?	Less than Action Level 2?	mg/L	Getting Worse? (Decreasing)	Less than Action Level 1?	Less than Action Level 2?	CFU/mL	Getting Worse? (Decreasing)	Less than Action Level 1?	Less than Action Level 2?
Action Level 1	< 0.5				< 0.3				>0.01				> 50			
Action Level 2	< 0.2				< 0.2				>0.02				>200			
Day 1																
Day 2																
Day 3																
Day 4																
Day 5																
Day 6																
Day 7																

Action should be taken if at a given site if:
(1) One parameter has exceeded the Action Level 2, OR
(2) Two parameters have exceeded Action Level 1.
The site can be returned to regular (weekly) monitoring if all parameters have stabilized or are improving after one week of increased monitoring.