## 2.3 PUBLIC HEALTH CONSIDERATIONS

The purpose of the chloramine conversion is to reduce the concentrations of carcinogenic disinfection byproducts in the delivered water. Hence, the chloramine conversion is expected overall to have a positive impact on public health.

There are two main threats to public health associated with chloramines. The first potential public health risk is to kidney dialysis patients – public notification requirements to avert this risk are described below in Section 2.4. The second major threat to public health is the potential loss of disinfectant residual due to nitrification. It is important to note that chloramines are less reactive than chlorine. Thus, in the absence of nitrification, chloramines may actually be more stable in the distribution system and decrease instances of low disinfectant residuals.

The focus of this report is to help EMID to manage its distribution system to lower the probability that nitrification will occur and to appropriately respond if nitrification does occur. However, below is a discussion of the possible public health implications of a loss of the residual due to nitrification.

The disinfectant residual plays several roles in the distribution system. Two of the most important are (1) to inactivate any microorganisms that enter the system through intrusion and (2) to control the growth of biofilms in the distribution system. A disinfectant residual may also play an important role in inactivating pathogens added to the system as part of a malevolent act.

Out of these concerns, the lack of protection from intrusion is probably the most significant. Intrusion may occur due to any type of cross-connection including the failure of a water main. If the failure is sufficiently great, the system may temporarily lose pressure and allow contaminated water or soil to enter the water distribution system through the main break. In addition, the low-pressure surge resulting from the break may lead to intrusion at other sites in the distribution system, where smaller breaks or leaks have gone undetected.

Other potential sources of pathogen intrusion are cross-connections and backflow. Cross-connections are connections between the clean drinking water supply and another pipeline that is not drinking water. Backflow occurs when water of lesser quality enters the distribution system through an existing connection. For example, water that has been contaminated by a tap may reenter the distribution system due to pressure transients. Most commercial connections have backflow prevention devices, whereas residential connections generally do not.

Biofilms are layers of bacteria and their associated 'slime' that grow on the surfaces of distribution system pipes. Bacterial biofilms are much more resistant to chlorine, as compared to dispersed bacteria. In addition, biofilms are very efficient at obtaining nutrients from the water, even when the nutrients are at very low concentrations (such is found in drinking water). Selected pathogens have been shown to be able to grow in biofilms under simulated distribution system conditions. However, there have been few instances when biofilm growth has been linked to human health impacts.

The presence of biofilms in all distribution systems is inevitable. However, the extent of biofilm growth can be partially controlled by maintaining a disinfectant residual. A loss in the disinfectant residual due to nitrification could allow increased growth of biofilms. The organisms growing in the biofilms may include the bacteria that cause nitrification, coliform bacteria (which may lead to violations of the Total Coliform Rule) and possibly even pathogens.

## 2.4 PUBLIC NOTIFICATION

The SFPUC is taking responsibility for much of the public notification requirements associated with the chloramine conversion. The SFPUC public education campaign materials are available on their website at better.sfwater.org under "Water Quality Improvements." The education campaign is focused on four major concerns associated with chloramine water, as follows:

- Kidney dialysis facilities – will have to treat the water to remove chloramines prior to use in their facilities.
- Tropical fish, reptile, and amphibian owners – will have to treat water to remove chloramines, for which there are commercial products available.
- Businesses using or requiring highly treated water – may have to treat water to remove chloramines.
- Degradation of household equipment – the chloraminated water may accelerate degradation of rubber parts on some household equipment and water heaters. Chloramine compatible parts are commercially available.

In particular, the SFPUC has taken the lead in contacting all kidney dialysis centers within their service area. In order to operate after the chloramine conversion, these centers must certify that they have installed appropriate treatment facilities to remove chloramines from their water.

The District indicated that the following steps to educate their customers about the chloramine conversion have already taken place or are in process:

- Have included information pamphlets with customers' water bills;
- Have included fact sheets in their monthly newsletter;
- Are currently working with the Chamber of Commerce to notify local businesses;
- Are currently updating the District's website with additional information on the conversion.
- Plan to confirm that local hardware stores are stocking chloramine compatible household equipment.

Public notification requirements under the Total Coliform Rule are included in the Coliform Episode Response Plan in Section 7.5.

# HYDRAULIC MODEL UPDATE

This chapter summarizes the update and calibration of the water distribution system computer hydraulic model for EMID. Controlling water age is one of the most important tools for managing a chloraminated distribution system. Computer hydraulic models are currently the best tools for calculating distribution system water age.

EMID's original model, developed by Metcalf and Eddy in H2ONet, was used as the starting point for this study. As part of this work, the model was updated to include major system changes that have occurred since the model was developed, as well as to include the proposed new reservoir. H2ONet models can be operated in two modes: under static conditions or extended period simulations (EPS). Operation under static conditions is often used in determinations of whether system pressures are sufficient under different scenarios. Use of EPS is required to determine water age in the distribution system. Updates to the model were required to run EPS, including correcting the controls for the pump station and reservoirs to mimic the actual system operation, correction of the diurnal demand curve, and elimination of a number of check valves that would not allow the model to run properly.

Calibration of the model was confirmed by comparing pressures in the model to those measured in the actual system under static and hydrant flow conditions. The model sufficiently mimicked the actual system without any further adjustments.

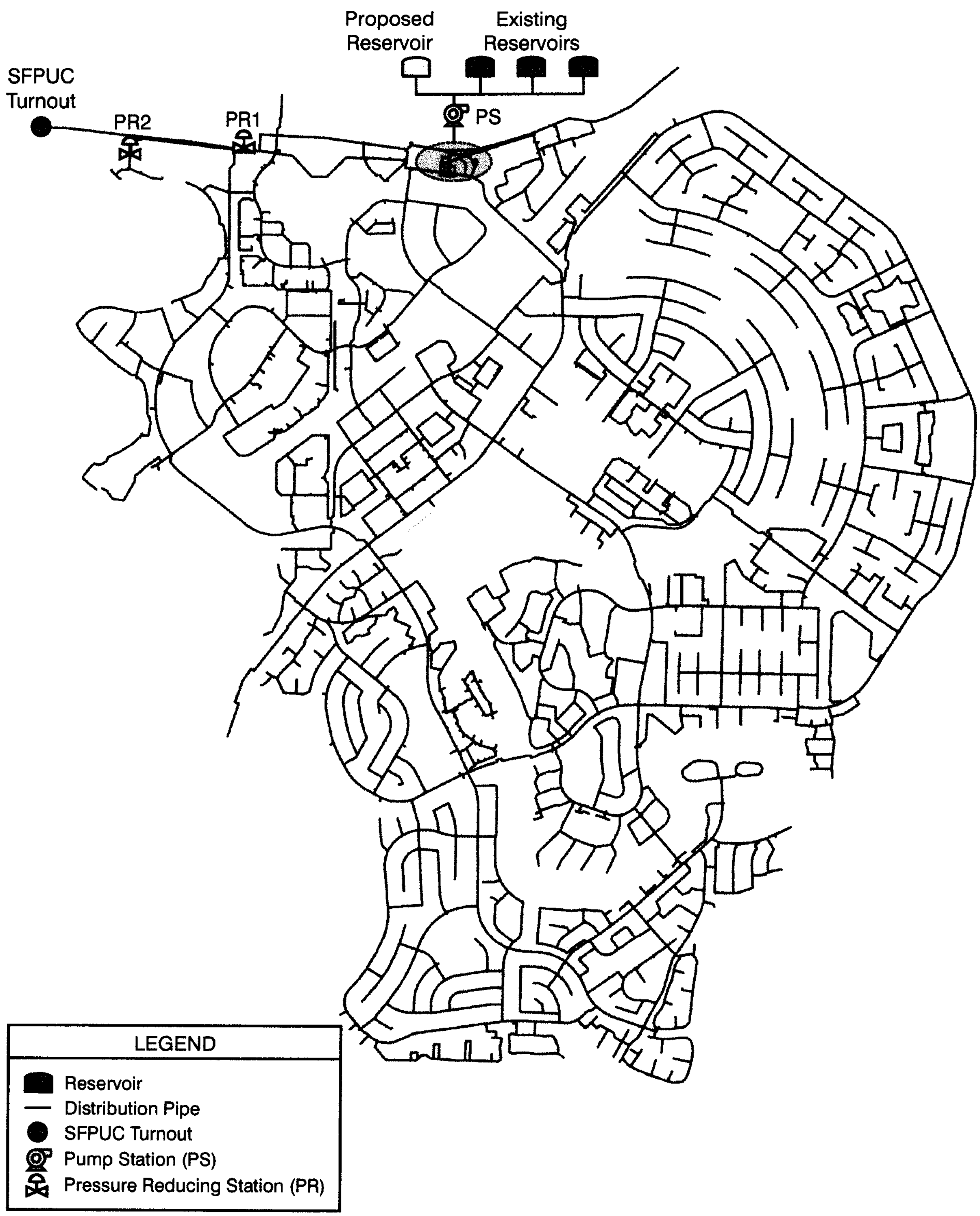
## 3.1 OVERVIEW OF THE MODEL

The model consists of a map with an accompanying database. Information contained in the database can be retrieved by selecting the desired object on the map. Alternately, the program has database functions that allow the user to view lists of data. Figure 3.1 presents the EMID hydraulic model.

The model is a simplification of the actual distribution system. For example, the original model only included pipes with a diameter of 6 inches or greater. Modeling at this level is sufficient to understand the conditions in the distribution system. Inclusion of all pipes would result in a cumbersome model that would provide little additional information.

The following is a brief description of each type of object included in the H2ONet model.

**Pipes**. Pipes are defined in the model by their upstream and downstream nodes, and the pipe length and diameter. This information is used to determine the friction losses in the pipe, as well as the water volume (and hence the hydraulic retention time) in the pipe. The model also has the ability to designate pipes as closed, or to add a check valve that only allows flow in one direction. The EMID model originally had numerous check valves, some




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

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**Figure 3.1**
**DISTRIBUTION SYSTEM MODEL**
CHLORAMINE CONVERSION STUDY
ESTERO MUNICIPAL IMPROVEMENT DISTRICT

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of which prevented the model from running. The updated model contains 16 check valves, which appropriately control the direction of flow around the reservoirs and the pump station.

**Junctions**. Junctions are defined either where two or more pipes meet, or at the end of dead end pipes. The water demands in the model are distributed amongst the junctions. The model includes the information on the demand, location, and elevation of each junction. All junctions in the District's existing model are set at an elevation of 100 ft, which is not accurate, but it does not affect the accuracy of the calculated water ages.

**Reservoirs**. Both tanks and turnouts are modeled as reservoirs in H2ONet. The H2ONet software allows reservoirs to be modeled in several different ways. EMID's turnouts are modeled as constant head reservoirs, which supply an unlimited amount of water at a specified pressure. The system's tanks are not constant head because their water level varies. The model information for a tank includes the diameter and the bottom elevation of the tank, such that the model can accurately determine the water level in the tank based on the influent and effluent flows. The model also takes into account changes in hydraulic head due to the fluctuating tank levels.

**Valves**. There are several types of valves that can be used in H2ONet. Only two types of valves are used in the EMID model: pressure regulating valves (PRVs) and flow control valves (FCVs). PRVs maintain a constant pressure on the downstream side of the valve as long as the system can support that pressure. These valves are used at the PRV stations to reduce the pressure from the turnout down to normal system operating pressures. FCVs maintain the flow at a given rate, assuming there is sufficient head on the upstream end of the valve. These valves were used to represent the altitude valves at the intakes to each of the reservoirs.

The model allows controls to be applied to the valves, which allow them to be opened or closed while the model is running. For example, a valve could be opened eight hours into the simulation, and then closed for 2 hours before being opened again. Alternately, a valve can be opened and closed according to the water level in a reservoir or pressure at a junction. The valve controls in the EMID model were matched to the desired operational scenario. For example, under current operations, inlet valves to the reservoirs were set to open at 4:00 p.m. and close at 8:00 a.m.

**Pumps**. There are several ways to model pumps within H2ONet. In the EMID system, the pumps are modeled using their pump curves. These curves were entered in the original model. Similar to valves, controls can be applied to the pumps. For example, in the EMID model the pump station does not run constantly, but is manually turned on and off at certain times of the day.

## 3.2 UPDATE PROCESS

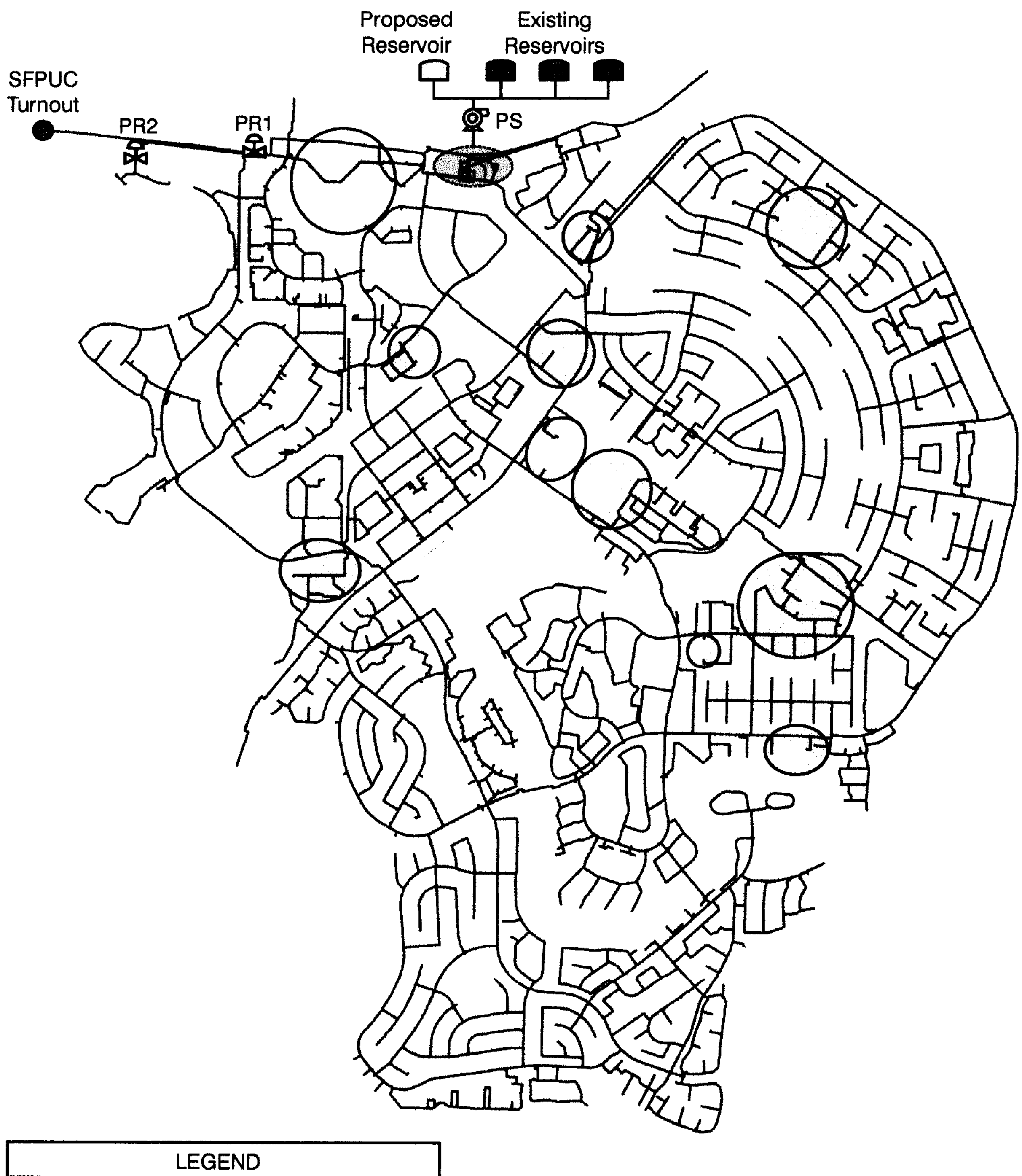
The following sections summarize the model updating activities conducted to date. The update activities included those required to allow for extended period simulations to determine water age. The existing model was not configured to allow for these simulations.

**Initial Update.** After all of the necessary files had been acquired, we updated the model to H2ONet Version 3.5. This effort required some alteration of the model parameters and some general cleanup work to remove residual model errors and to render it useful for this project. There were also some anomalies within the model, including pipe check valves that were oriented incorrectly and pipes that had been removed from the map interface of the model but had not been removed from the database. These anomalies prevented the model from performing extended period simulations, and so had to be corrected.

**Addition of New 16-inch Line.** Since development of the existing model, a 16-inch diameter main connecting the distribution system to EMID customer *Inktomi* has been added to EMID's system. The layout of the 16-inch pipeline was added to the model based on AutoCad map files provided by EMID. Length and material data for the pipeline were obtained from EMID's web-based GIS system. The base water demand for this customer was added to the end of the pipeline. The demand was calculated as the average water use measured between June 14, 2001 and October 14, 2002. The average demand was 7.2 gpm. No additional demands were added to this new line.

**Correction of Model Piping.** The existing hydraulic model was compared to the District's on-line GIS system to identify areas where the model does not reflect the piping in the actual system. Several discrepancies were found. The locations of these discrepancies are shown in Figure 3.2. In conjunction with the District, it was decided that most of the necessary corrections would be performed by the District while being trained to use the model. However, in two cases the piping was corrected prior to performing the water age analysis (see Figure 3.2). Data on pipe length, diameter, and material were obtained from the District's GIS system. None of the areas requiring changes were identified to have high water age (see Chapter 4).

**Addition of Proposed Reservoir.** The proposed new 8-million gallon (MG) reservoir was added to the model. The reservoir was modeled as a cylindrical tank with a diameter of 217 feet and a maximum water depth of 29 feet (the maximum depth matches that of the existing reservoirs). The reservoir operation was assumed to be the same as that of the existing reservoirs, whether under existing or proposed operational scenarios. This proposed reservoir was activated in the model only for future water age scenarios following its construction and commissioning.




| LEGEND |
| --- |
| O Changes Have Been Made |
| O Changes To Be Made By EMID Staff |

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

**Figure 3.2**
**REGIONS OF MODEL WITH MISSING AND/OR INCORRECT PIPES**
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## 3.3 SYSTEM DEMANDS

**Diurnal Curve.** Demands in the distribution system vary over the course of every day (e.g., there is a peak in water use in the morning and demand is typically lowest very late at night). This water demand variation is modeled using a diurnal curve, which consists of a series of factors (multiples of the average demand for the particular day being modeled) for each hour over a 24-hour period. EMID's existing model did have a diurnal curve entered into it. District staff indicated that the diurnal curve in the model was developed from flows at the turnout and did not take into account changes in the stored volume in the reservoirs. We attempted to develop a new diurnal curve based on turnout flows and water levels in the three tanks. The system demands at any hour were calculated as the total flows into the system from the turnout, less the amount stored (or plus the amount taken out of storage). We did not believe that the resulting curve was representative of system demands. For example, the total system demands dropped for the exact duration that the reservoirs were filling, which is unlikely to be due to coincidence. The exact cause of the problem is not known, however two problems were identified: (1) the reservoir diameters are so large that a small change in water depth represents a significant change in water volume, hence the calculations are very sensitive to water depth, and (2) the flow measurements provided may have been inaccurate.

We instead chose to apply a diurnal curve developed with data from Palo Alto, which has similar economic, land development, and weather conditions as Foster City. Figure 3.3 details the diurnal curve used in this current modeling work. However, we consider the existing diurnal curve data to be sufficient for the water age modeling.

**Demand Scenarios.** Water use data from the District's system were used to develop average and minimum day demand models. The minimum day model was developed to conservatively estimate water age during the winter (low demand) months, whereas the average day model was developed to conservatively estimate water age during the summer (high demand) months. The maximum day demands for the District's system were also calculated for the purpose of determining storage requirements, as discussed below in Section 3.5.

Water use data from January 1999 to November 2002 were analyzed to determine maximum, average, and minimum day demands. The unmodified daily-use data contained a number of anomalous points. To decrease the impact of these points, a running 16-day average demand was calculated, as shown in Figure 3.4. The 16-day average was used because it is approximately equivalent to the water age threshold of concern (400 hours). The overall average daily demand was calculated to be approximately 4,000 gpm.

The minimum day demand was estimated to be 2,000 gpm. The data provided included minimum demand periods for four separate years (1999 to 2002). Three of these years

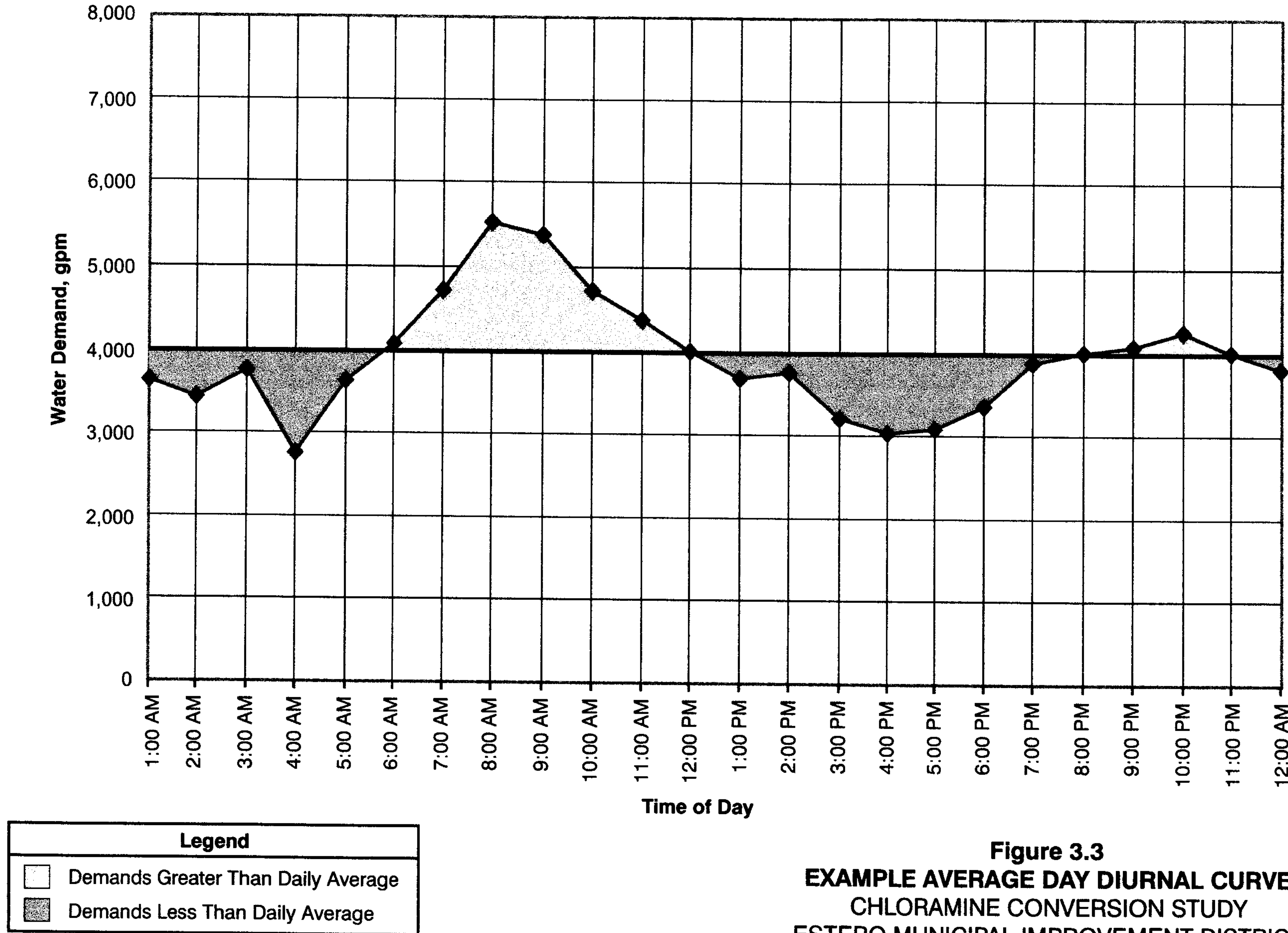


**Figure 3.3**
**EXAMPLE AVERAGE DAY DIURNAL CURVE**
CHLORAMINE CONVERSION STUDY
ESTERO MUNICIPAL IMPROVEMENT DISTRICT

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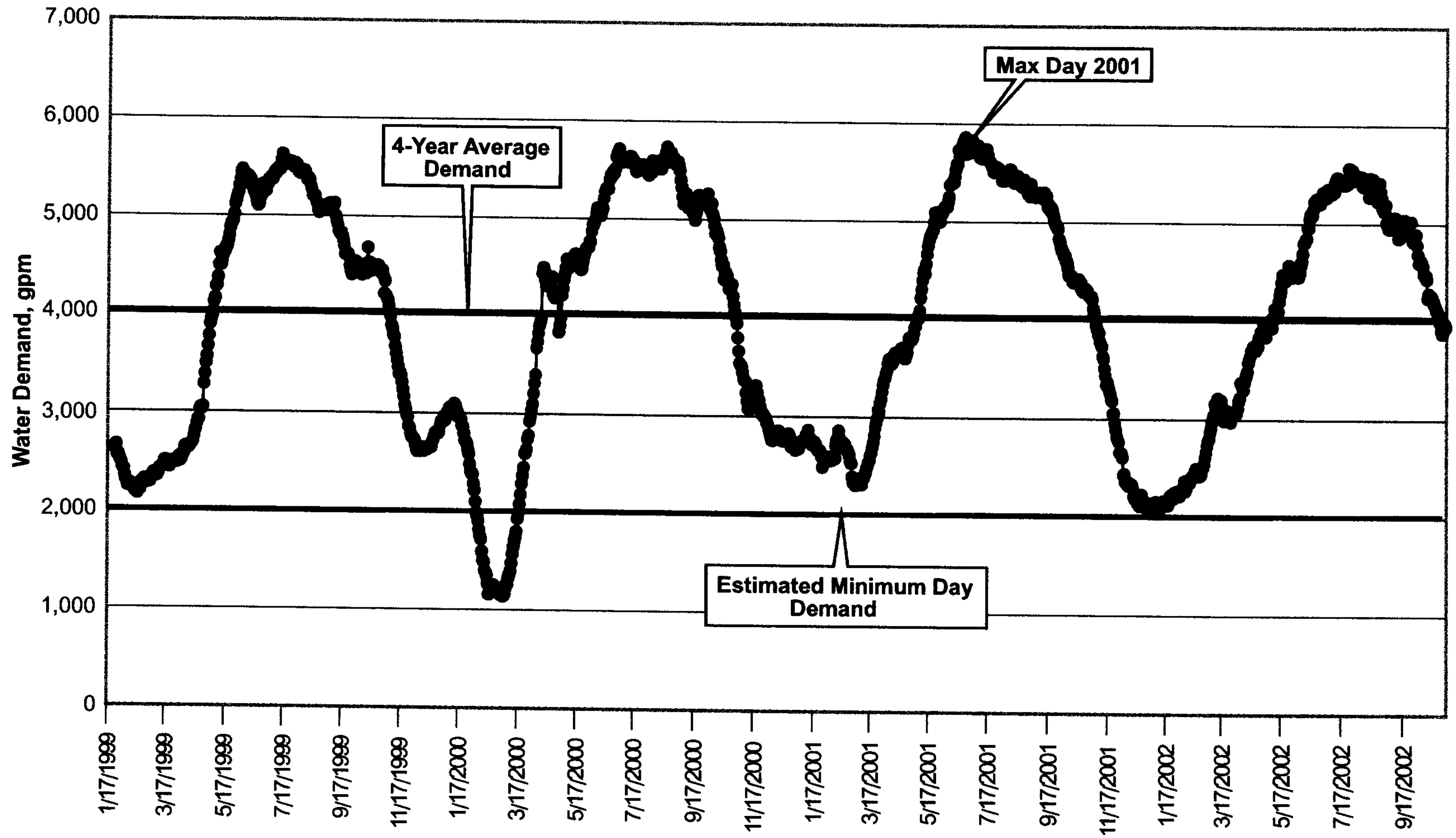


**Figure 3.4**
**RUNNING 400-HOUR AVERAGE DEMAND**
CHLORAMINE CONVERSION STUDY
ESTERO MUNICIPAL IMPROVEMENT DISTRICT

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(1999, 2001, and 2002) had similar minimum demands, just greater than 2,000 gpm, whereas the remaining year (2,000) had a much lower demand, just greater than 1,000 gpm. A demand of 2,000 gpm was selected for the minimum day model because it is conservative for three of the four years, but does not excessively skew the data towards the unusual fourth year.

The maximum day demand was estimated to be 6,000 gpm, based on the average of the maximum day demand from each of the four years.

The existing EMID model contained average, maximum, and peak day demand scenarios. To update the model, minimum and average day demands were updated to reflect current conditions. The existing water demand distribution (the proportion of the total demand drawn from each point in the system) was preserved. The demands were updated by multiplying the demands at each node by a single factor.

## 3.4 CURRENT SYSTEM OPERATION

Initially, the behavior of the turnout, the reservoirs, and the pump station in the existing model did not reflect current operating conditions. To correct this, the model was altered as follows:

**Turnout.** There is a single turnout in the District's system. This turnout is modeled as a constant head reservoir with a water depth of 277 ft (120 psi) above the distribution system.

The pressure from the turnout is regulated at two PRVs. The PRVs were simulated in the existing model as three parallel valves: two PRVs (set at 60 and 54 psi, respectively) and one throttle control valve. Two of the valves at each station were disabled, with a single PRV left operational. The settings on the operating PRVs in the updated model are 62 psi at both of the PRVs.

There is an additional PRV in the model that regulates flow to an isolated short dead-end region of the distribution system, immediately south of the turnout. From the District's GIS system, it was determined that this PRV leads to the Regional Water Quality Treatment Plant. In the existing model there were no demands assigned to this region of the system. No changes were made to update this portion of the model.

**Reservoir Operation.** There are currently three 4-MG reservoirs in the District's system. The reservoirs are passively filled by water pressure from the turnout via the distribution system. The reservoirs are emptied only when the pump station is activated. The District indicated their current system operation is to operate the pump station from 7:30 am until 3:30 pm daily. In the model, this was approximated as operation between 8:00 a.m. and 4:00 p.m. daily, as the model runs at one-hour intervals. Valves are set such that the pump station draws from a single reservoir each day. During the night, the valves between the reservoirs are opened such that the reservoirs completely fill, and water is free to pass between the reservoirs. The pumps are not currently operated on the weekend.

The three existing reservoirs are modeled as cylindrical tanks. In the existing model, each tank had a diameter of 155 feet and a maximum depth of 27 feet (total volume for each reservoir in the model was 3.81 MG). These values were corrected to a diameter of 153 feet (based on site plans provided by the District) and a maximum water depth of 29 ft (total reservoir volume of 4 MG). The model includes four pumps, however two of the pumps are disabled. The two remaining pumps are operated between 8:00 a.m. and 4:00 p.m. each day. The model controls do not reflect the fact that the pump station is not operated on weekends. However, the extra 48 hours of water age due to the weekends was included when considering the maximum allowable water age in the system.

## 3.5 SYSTEM STORAGE REQUIREMENTS

The distribution system reservoirs provide three functions for EMID. First, they provide water supply in case of a shutdown or other failure of the SFPUC supply. Second, they provide a nearby, high volume supply of water for fighting fires. Lastly, they provide a means of meeting peak daily demands, however these demands may also be met by peaking flows from the SFPUC turnout.

The emergency and fire components of storage must remain in storage until those events occur. Hence, these constitute the minimum volume of water that must be stored in the reservoirs at all times. Additional storage capacity is referred to as operational storage. This volume can be changed out on a regular basis to purge the reservoirs of older water and bring fresh water into storage. Cycling the reservoirs is a critical part of controlling the distribution system water age (i.e., if the water in the reservoirs is allowed to age excessively, the distribution system will be at greater risk of nitrification once that water is cycled out of the reservoirs).

**Emergency Storage.** The California Department of Health Services (DHS) recommends that each system have at least eight hours of maximum day demand stored and ready for use at any time. By comparison, Carollo typically recommends, and most Bay Area water utilities typically provide, at least one maximum day demand volume in case of supply failures. However, maintenance of less storage (i.e., 8-hours) may be necessary to control the water age or because sufficient storage is not available.

There is little redundancy to the EMID water supply. First, EMID has only one water source (SFPUC). Second, EMID has only one connection to that source (the single turnout). By comparison, the Mid-Peninsula Water District has two, Menlo Park has five, Palo Alto has five, and Mountain View has three. Third, the distribution system is connected to that supply by a fairly long single pipeline. As such, Carollo recommends that EMID should keep in storage at least one maximum demand day of water supply (8.65 MG) in the reservoirs at all times. Storage in excess of these minimum demands is desirable if the additional storage does not compromise water quality. Storage capacities for a number of local utilities are summarized in Table 3.1.

**Table 3.1 Summary of Storage Capacities of Neighboring Utilities**
**Chloramine Conversion Project**
**Estero Municipal Improvement District**

| | Number of Connections to SFPUC | Population Served | Storage Capacity (MG) |
|---|---|---|---|
| Estero Municipal Improvement District | 1 | 35,000 | 12.0 |
| Mid-Peninsula Water District | 2 | 28,000 | 8.9 |
| City of Menlo Park | 5 | 10,000 | 5.5 |
| City of Palo Alto(1) | 5 | 61,000 | 10.5 |
| City of Mountain View(1,2) | 2 | 72,000 | 7.0 |
| City of Hayward(1) | 2 | 145,000 | 25.0 |

Notes:
(1) Has groundwater wells.
(2) Has connection to Santa Clara Valley Water District.

**Fire Storage.** The fire storage requirement was calculated based on a flow rate of 5,000 gpm for 4 hours (1.2 MG). The fire storage component is based on our experience working for neighboring utilities. This estimate is reasonably conservative for these purposes, and was confirmed with the Fire Marshall, John Mapes, on April 4, 2003.

**Operational Storage.** The reservoir volume available for operational storage was calculated as the difference between the total reservoir volume (12.0 MG) and the storage requirements needed for fire and emergency storage.

The overall storage requirements are summarized below in Table 3.2.

**Table 3.2 Summary of Storage Requirements**
**Chloramine Conversion Project**
**Estero Municipal Improvement District**

| Type of Storage | Stored Volume |
|---|---|
| 8-hr Emergency Storage | |
| Emergency | 2.74 MG |
| Fire Flow | 1.20 MG |
| Total Minimum Storage | 3.94 MG |
| Available Operational Storage(1) | 8.06 MG |
| 24-hr Emergency Storage (Recommended) | |
| Emergency | 8.65 MG |
| Fire Flow | 1.20 MG |
| Total Minimum Storage | 9.85 MG |
| Available Operational Storage(1) | 2.15 MG |

Note:
(1) Equals 12.0 MG minus the total minimum storage (based on the three existing reservoirs with a total capacity of 12.0 MG).

## 3.6 MODEL CALIBRATION

The following is a summary of the effort involved in the calibration of the Estero Municipal Utility District H20Net Model.

The major modeling assumptions are as follows:

- Calibration involved the Average Day Demand Model (4,000 gpm)
- Two pumps operational during model calibration
- Three reservoirs operational during model calibration
- Hydrant test data provided by District Staff (2/24/03)
- Approximately overall +/- 5% difference between actual and modeled system pressures

Distribution system model calibration is typically achieved by comparing actual hydrant static and residual water pressures at a specific flow rate to modeled static and residual pressures at the same flow rate. Based on the percentage difference between actual system pressures and modeled system pressures, changes can be made to a distribution system model to more closely replicate system hydraulics. Changes in the model can include modification of node elevation, pipe roughness coefficients, pipe network improvements, and verification of actual system operation.

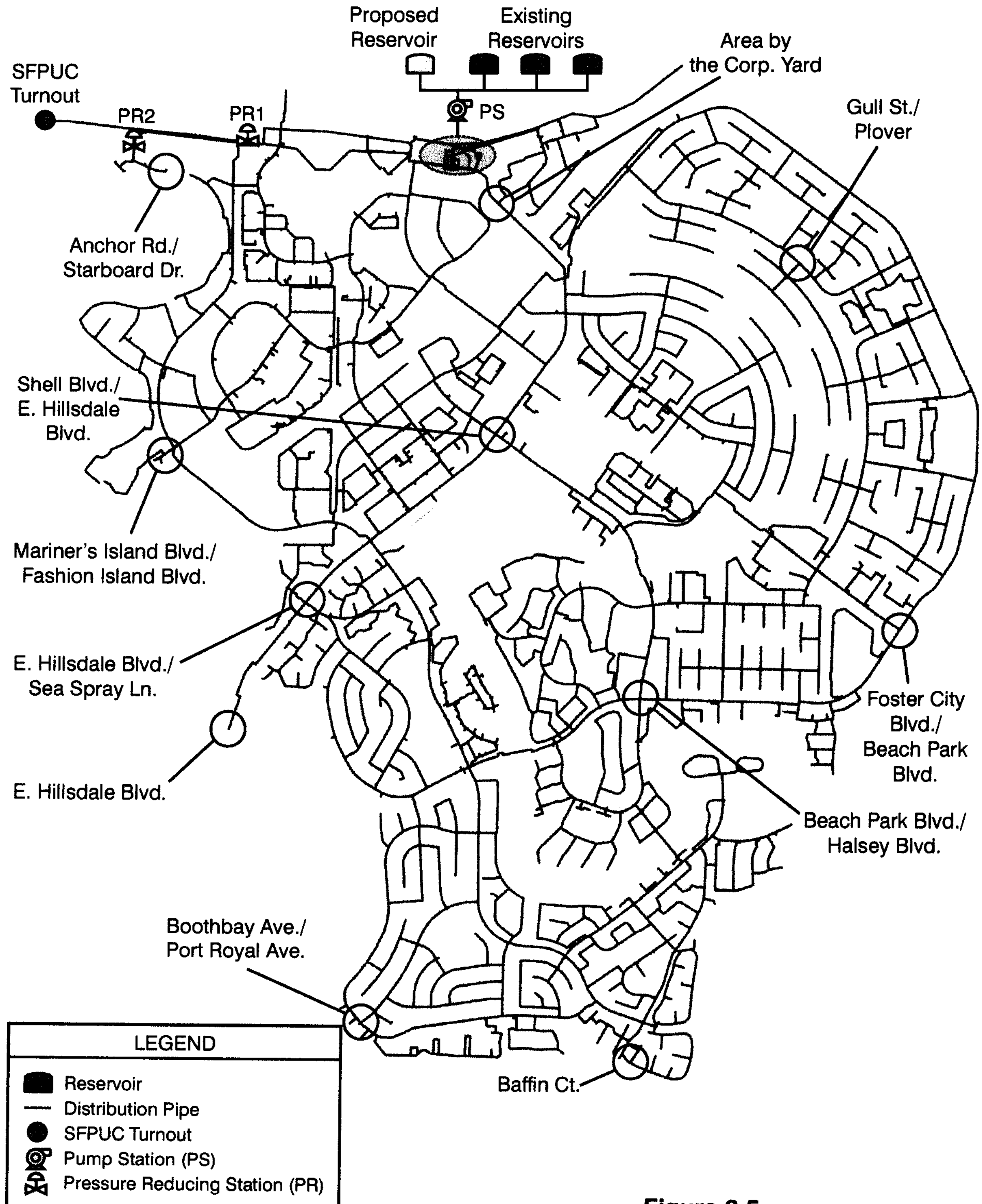
To perform the model calibration, eleven hydrant locations throughout the District were chosen for the hydrant tests. Hydrant locations represented both the outskirts and center of the distribution system. District Staff conducted the hydrant tests on February 24, 2003. Figure 3.5 illustrates the hydrant test locations.

District Staff provided the following information for the calibration effort:

- Hydrant Location
- System Static Pressure (psi)
- Flow Rate (gpm)
- System Residual Pressure (psi)
- Diameter of pipe connected to hydrant (inches)

To mimic the hydrant test within the model, fire flow demands equal to hydrant test flow rates were applied at specific model nodes. The selected model nodes most closely represent actual system location of the tested hydrants. Surrounding pipe diameters were verified based on the provided District hydrant test information.

The calibration was conducted assuming an extended period simulation (EPS). The EPS was used to replicate actual system operation including pumped flow from the three reservoirs. The model was run for 96 hours (seven days), and the various fire flows were applied at hour 36:00.




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

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**Figure 3.5**
**LOCATIONS OF HYDRANTS USED FOR MODEL CALIBRATION**
CHLORAMINE CONVERSION STUDY
ESTERO MUNICIPAL IMPROVEMENT DISTRICT

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In general, the model replicated static and residual pressures measured in the distribution system. The goal of calibration was to achieve an overall ± 5 percent accuracy. As indicated in Table 3.3, static pressures were within ± 4 percent, and residual pressures were within + 10 percent to - 7 percent. After accounting for the error both with hydrant test data collection (± 5 percent) and the model itself, the overall model results are acceptable. The hydraulic model output indicates that the model is calibrated and accurate to conduct both water quality analyses and hydraulic analyses. No further modification to the hydraulic model was necessary.

**Table 3.3 Hydraulic Model Calibration – February 24, 2003 Hydrant Flow Test Data**
**Chloramine Conversion Project**
**Estero Municipal Utility District**

| Hydrant Test | Model Node | Street Intersection | Pipe Diameter of (inches) | Flow Rate (gpm) | Static Pressure (psi) | Residual Pressure (psi) | Model Static Pressure | Model Residual Pressure | Percent Difference Static Pressure | Percent Difference Residual Pressure |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3500 | Gull St./Plover | 6 | 1,090 | 65 | 55 | 62.5 | 58.3 | 4% | -6% |
| 2 | 7320 | Shell Blvd./E. Hillsdale | 18 | 1,090 | 65 | 55 | 62.8 | 60.9 | 3% | -11% |
| 3 | 7600 | Mariner's Isl. Blvd./ Fashion Island Blvd. | 12 | 1,110 | 65 | 60 | 62.8 | 60.9 | 3% | -2% |
| 4 | 13350 | E. Hillsdale Blvd. | 12 | 1,125 | 65 | 60 | 62.6 | 55.8 | 4% | 7% |
| 5 | 11230 | Foster City Blvd/Beach Park Blvd | 12 | 1,090 | 62 | 55 | 62.4 | 60.1 | -1% | -9% |
| 6 | 12540 | Beach Park Blvd./Halsey Blvd. | 16 | 1,090 | 65 | 56 | 62.4 | 60.2 | 4% | -8% |
| 7 | 16400 | Boothbay Ave/ Port Royal Ave. | 14 | 1,110 | 62 | 55 | 62.4 | 59.8 | -1% | -9% |
| 8 | 16700 | Baffin Court | 8 | 1,090 | 62 | 55 | 62.3 | 58.7 | 0% | -7% |
| 9 | 1560 | Anchor Road/ Starboard Dr. | 10 | 1,090 | 62 | 58 | 63.1 | 55.3 | -2% | 5% |
| 10 | 3180 | Area by the Corp Yard | 10 | 1,090 | 62 | 58 | 63.1 | 62.3 | -2% | -7% |
| 11 | 10770 | East Hillsdale Blvd./ Sea Spray | 14 | 1,090 | 65 | 55 | 62.6 | 60.4 | 4% | -10% |

# WATER AGE ANALYSIS

Controlling water age is one of the most important factors in decreasing the probability of nitrification occurrences in the distribution system. The maximum water age goal throughout the system was set at 16 days (or 400 hours). This corresponds to about half the age (30 days) at which the chloramine residual may decay significantly, as determined by SFPUC lab tests. The SFPUC tests were conducted at the bench scale in clean glass bottles. Significantly greater residual degradation would be expected in the actual distribution system. Hence, the 400-hour goal was chosen to provide EMID with a factor of safety to account for conditions not studied in the lab tests. The water entering EMID's system was assumed to have an age of two days (48 hours) based on information provided by the SFPUC, hence 48 hours have been added to all water ages calculated by the hydraulic water distribution system computer model.

Conventional distribution system modeling to determine system capacity is performed using maximum day demand. However, the most conservative estimation of water age is determined by running the model using the minimum day demand. In this study, we also considered the water age at average day demand, to determine whether high water age is only a concern during low-flow (winter) months, or also during higher flow (summer) months.

The water modeling was divided into several sections. First, we determined whether water age in the system is satisfactory using the current operational strategy (pumps on at 7:30 a.m. and off at 3:30 p.m.) under both summer and winter conditions. Second, we evaluated the impact of the proposed new reservoir under both summer and winter conditions. Finally, we developed a recommended operational strategy to maintain water quality with either the 3 existing reservoirs or all 4 reservoirs (including the proposed 8 MG reservoir in service) under both summer and winter conditions.

## 4.1 RESULTS – EXISTING OPERATIONS

The following results were generated assuming the current operational strategy specified by the District (pumps on at 7:30 a.m. and off at 3:30 p.m., approximated in the model as operation between 8:00 a.m. and 4:00 p.m.). It was assumed that all three reservoirs were in operation.

### 4.1.1 Summer Conditions (Existing Operations, 3 Tanks In Service)

Summer conditions were modeled using the average day hydraulic model. The average day demands are a conservative estimate of the lowest demands experienced during the summer months. Under these conditions, the water ages in the reservoirs and throughout the distribution system were satisfactory, with the exception of a single dead-end pipe section.

The water ages at junctions throughout the distribution system cycle between local maximum and minimum values. The local maximum occurs when most of the water is being received from the reservoirs (when the pump station is in operation), whereas the local minimum water age occurs when the water is being received primarily from the turnout (when the pump station is off). This phenomenon is illustrated in Figure 4.1, which shows the water age at a single junction near the center of the District over a 24-hour period. The figure shows that the water age at the junction is high between 10:00 a.m. and 7:00 p.m., which corresponds to the time at which the pump station is on (8:00 a.m. to 4:00 p.m.), taking into account the time required for the water to travel from the pump station to the junction. During the remainder of the 24-hour period, the water age is generally low, as the water is received primarily from the turnout.

To be considered a successful model run, every node must have at least a minimum local water age that is less than 400 hours. If the node periodically receives water from the reservoirs that exceeds 400 hours, it is believed that the potential for nitrification to occur will be controlled by the periodic "flushing" with fresher (lower water age) water from the turnouts.

The calculated water ages in the three tanks were approximately 185 hours. The local maximum water ages throughout the distribution system generally ranged from zero up to 333 hours. Taking into account aging over the weekend when the pumps are off (48 hours), the actual ages would range up to around 381 hours. This is within the 400-hour water age goal. In addition, the local minimum ages at many of these sites were often significantly lower than the local maximum ages. For example, at one junction the local maximum age was 322 hours, whereas the local minimum age was only 123 hours.

The single exception was the age at the end of a long dead-end pipe (Pipe #662) with low demand (see Figure 4.2). The local maximum and minimum ages at three nodes located at the end of this pipe were approximately 650 hours. Because this problem is highly localized, it would be more appropriate to address this area with looping or flushing, rather than attempt to address it through reservoir operation. Appropriate actions for this location are discussed below.

### 4.1.2 Winter Conditions (Existing Operations, 3 Tanks In Service)

Winter conditions were modeled using the minimum day hydraulic model. The minimum day demands are a conservative estimate of the lowest demands experienced during the winter months. Under winter conditions, using the current pump station and reservoir operation practices, the water ages in all reservoirs and in several locations in the distribution system exceeded the 400-hour goal. Hence, new operational strategies to decrease the water age are needed.

The local maximum water ages throughout the distribution system generally ranged from zero up to 640 hours, with a few dead ends exhibiting exceptionally high water age.

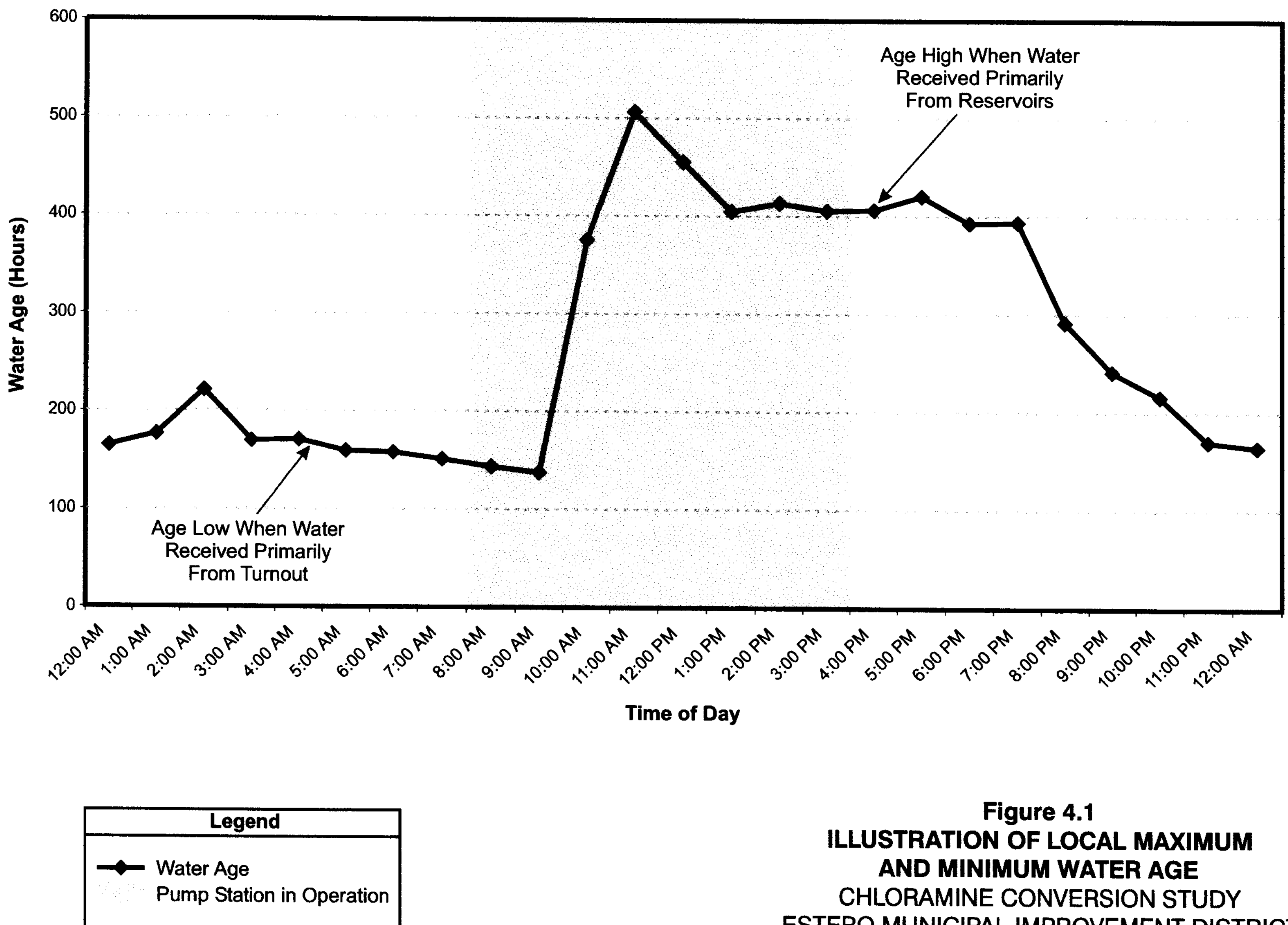
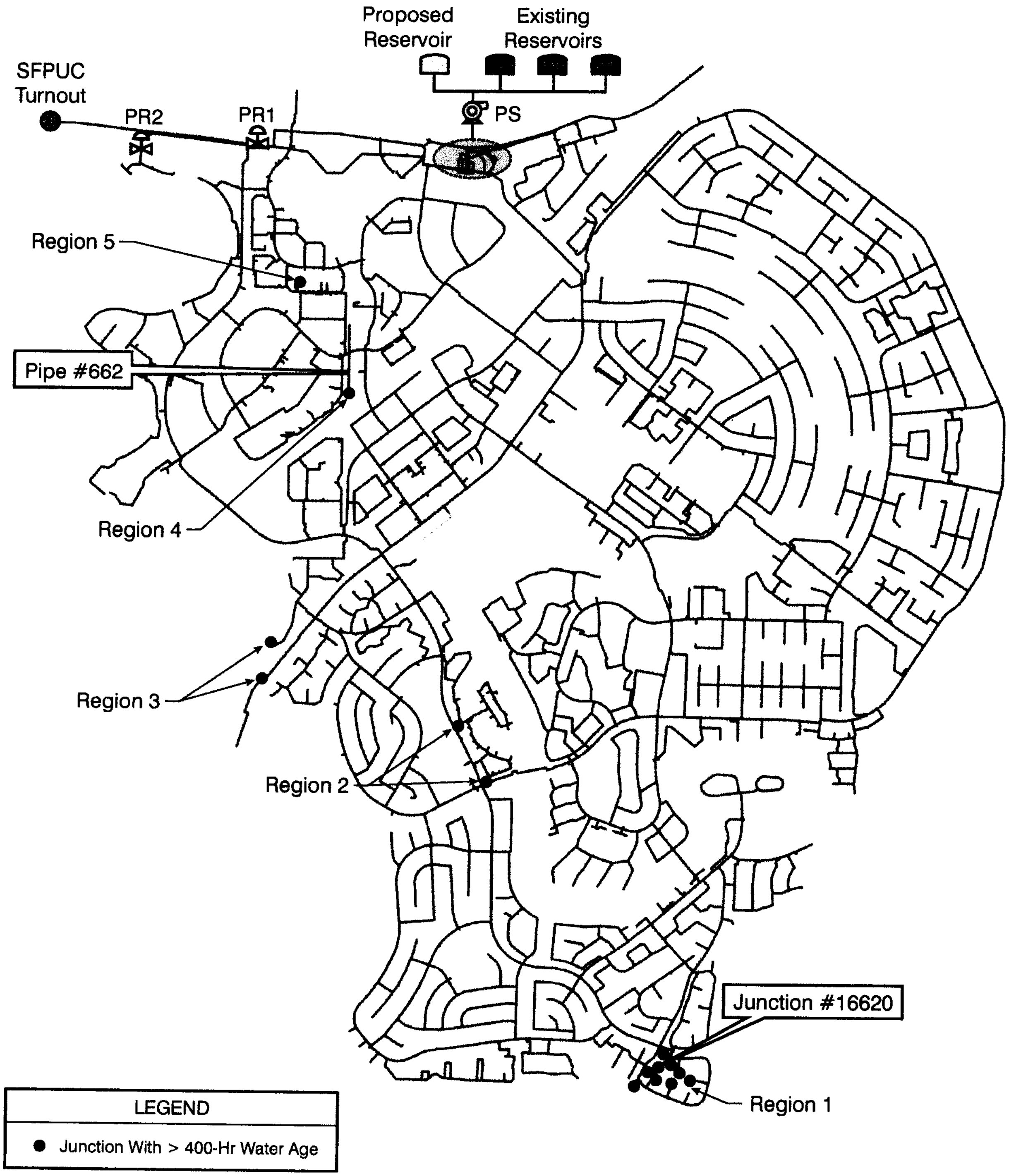



**Figure 4.1**
**ILLUSTRATION OF LOCAL MAXIMUM AND MINIMUM WATER AGE**
CHLORAMINE CONVERSION STUDY
ESTERO MUNICIPAL IMPROVEMENT DISTRICT

fc403g1-6627.cdr




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

**Figure 4.2**
**REGIONS OF HIGH WATER AGE**
CHLORAMINE CONVERSION STUDY
ESTERO MUNICIPAL IMPROVEMENT DISTRICT

carollo engineers

fc203f5-6627.cdr

Fortunately, many of the junctions with high local maximum water ages had minimum local water ages within the 400-hour goal.

However, the local minimum water ages exceeded the 400-hour goal at 15 junctions. These junctions are shown in Figure 4.2. Almost all of these junctions are dead ends or are located very close to dead ends. The water ages at these sites can not be controlled through reservoir operation, and must be controlled locally through flushing or looping. Candidates for looping are discussed further in Section 7.6. However, it is evident that under these conditions the water age in the far south-east corner of the distribution system is unacceptably high. Water age in this region may be reduced through improved reservoir operation. Recommended operational changes are discussed in Section 4.3.

## 4.2 RESULTS – ADDITION OF PROPOSED RESERVOIR

Under this scenario, the three existing reservoirs and the proposed additional reservoir were operated under the current operational strategy (pumping from 7:30 a.m. to 3:30 p.m., approximated in model as operation between 8:00 a.m. and 4:00 p.m.).

### 4.2.1 Summer Conditions (Existing Operations, 4 Tanks In Service)

Summer conditions were modeled using the average day hydraulic model and the current pump station operation strategy. Under summer conditions, the water ages in the reservoirs exceeded the 400-hour goal, whereas the minimum local water ages throughout the distribution system were satisfactory with some isolated exceptions.

The average water age in the reservoirs was 396 hours. Taking into account aging over the weekend when the pumps are off (48 hours), the actual age reaches 444 hours. This is in excess of the 400-hour goal by approximately 10 percent. In addition, two junctions directly upstream of the pump station that only receive water from the reservoirs had higher than acceptable age. Decreasing water age under these conditions was addressed using alternate operational strategies.

Similar to the results with only three reservoirs on-line, the junctions at the end of dead-end Pipe #662 had local maximum (~ 620 hours) and minimum (~ 590 hours) water ages greater than 400 hours. Again, these high ages are best addressed locally, and would not be appropriately addressed through altering reservoir operation. The local minimum water ages at all other locations in the distribution system were less than 400 hours. The greatest local minimum water age was 304 hours.

### 4.2.2 Winter Conditions (Existing Operations, 4 Tanks In Service)

Winter demands were modeled using the minimum day hydraulic model. Under winter conditions, the water ages in the reservoirs and in numerous locations in the distribution system were in excess of the 400-hour goal.

The average age in the reservoirs was 774 hours. Hence, the local maximum water ages were greater than 400-hours at the majority of the junctions. The local minimum water ages generally ranged up to 860 hours, with 16 of the junctions having an age exceeding 400-hours. Interestingly, the additional reservoir had very little effect on the minimum water ages. For example, in the case of one junction located in the southeast corner of the system (#16620), the local minimum water age with 3 reservoirs operational was 278 hours, whereas with four reservoirs it was 315 hours (an increase of only 37 hours). This is reasonable, because the local minimum water age occurs when the majority of the demand is being supplied by the turnout. The implication of this result is that water age in the distribution system and in the reservoirs can virtually be controlled separately. This idea has been incorporated into the alternate operational strategies discussed below.

The results from the four scenarios are summarized below in Table 4.1.

**Table 4.1 Summary of Modeling Results Under Current Operations
Chloramine Conversion Study
Estero Municipal Improvement District**

| | Water Age | | | Number of Areas to Flush[(2)] |
|---|---|---|---|---|
| **Scenario** | **Reservoirs** | **Local Maxima[(1)]** | **Local Minima[(1)]** | |
| 3 Tanks – Summer | < 200 Hours | < 400 hours | << 400 hours[(1)] | 1 |
| 3 Tanks – Winter | > 400 hours | Many sites > 400 hours | < 400 hours[(1)] | 4 |
| 4 Tanks – Summer | Slightly > 400 hours | Many sites > 400 hours | < 400 hours[(1)] | 1 |
| 4 Tanks – Winter | >> 400 hours | Most sites > 400 hours | < 400 hours[(1)] | 4 |

Notes:
(1) Excludes sites requiring flushing.
(2) The number of junctions identified to have local minimum water ages greater than 400 hours is greater than the number of areas requiring flushing because a single flushing location may address high age at multiple junctions.

## 4.3 RECOMMENDED PUMP STATION AND RESERVOIR OPERATIONAL STRATEGY

Alternate operational strategies for summer and winter conditions were developed based on the following observations and assumptions:

- The water age at each junction cycles between a local maximum and minimum age. The minimum age occurs when the majority of the demand is supplied by the turnout (the pump station is off), whereas the maximum age occurs when the majority of the demand is supplied by the reservoirs (the pump station is on).

- Maintenance of a local minimum water age less than 400 hours should be sufficient to help prevent nitrification, even if the maximum local water age is greater than 400 hours. This assumes that fresh low-age water from the turnout is supplied to the system with sufficient frequency. For the purposes of developing an operational strategy, it was assumed that it is desirable to "flush" the system from the turnout (i.e., turn off the pump station and refill the reservoirs) once per day.

- The proposed reservoir provides additional storage capacity that is needed to maintain a good level of system reliability in case of water supply emergencies or fires, while allowing the District's operations staff to change out the old water to maintain the high water quality level throughout the service area.

- Sites with local minimum water ages greater than 400-hours must be addressed locally through looping or flushing. Alternate reservoir operations will have little impact on the minimum water ages at these points.

- Maintenance of a sufficiently low water age in the reservoirs is of great importance, as nitrification occurring in the reservoirs may "seed" nitrifying bacteria throughout the distribution system. For the purposes of developing an operational strategy, a water age goal of 200 hours in the reservoirs was assumed (i.e., 12.5 percent of the reservoir volume must be cycled out per day).

- Minimum storage requirements outlined in Section 3.5 must be met at all times. Maintenance of storage in excess of the minimum requirements is desirable.

- Recommended operational strategies should maximize available storage while maintaining sufficiently low water age.

- The amount of water cycled out of the reservoirs each day is limited to the demand in the system. For the purposes of developing an operational strategy, it was assumed that half of the daily demand would be supplied directly from the turnout, with the remaining half supplied from the reservoirs. As there is little flow through the turnout when the pump station is on, this assumption is reasonable. The maximum cycled volume is 2.88 MGD during summer conditions and 1.44 MGD during winter conditions.

Operational strategies presented below assume that the proposed reservoir is in service (total storage capacity of 20 MG). The recommended strategies will result in a water age of 200 hours in the reservoirs. The maximum local water ages in the distribution system will still be greater than 400 hours at many junctions. However, the minimum water ages at all junctions (with the exception of those junctions discussed below in Section 4.6) will be less than 400 hours. The daily "flushing" of these points by fresh water from the turnout should be sufficient to prevent the establishment of nitrifying bacteria.

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.

Capital improvements required for the recommended operational strategies are outlined in Section 7.4. The operational strategies are summarized in Table 4.2 and are also outlined in Appendix C.

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.

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.

The recommended strategies do not take into account non-operation of the pumps on weekends, which will add two days to the water age in the reservoirs. As the targeted water age in the reservoirs (200 hours) is conservative, not pumping on the weekends will likely not cause a problem. However, we recommend that the water quality in the reservoirs be

**Table 4.2 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.

closely monitored and that the water age be reduced if deterioration in water quality is observed (see Section 4.5).

## 4.4 AVAILABILITY OF EMERGENCY STORAGE

The minimum amount of water in storage under the recommended operational strategies is lower in the winter than in the summer. However, as the demands are lower in the winter, the emergency storage requirements will be lower. To compare the available storage under the two scenarios, the number of days of emergency storage was determined under summer and winter conditions. From Table 4.3, it can be seen that the relative amount of emergency storage in the winter (3.1 days) is greater than the relative amount of emergency storage in the summer (1.9 days). Hence, the decreased storage in the winter recommended to improve water quality does not adversely impact the level of risk protection provided by the reservoirs.

Given the design of the system (i.e., single source of supply, single connection to the source, long supply pipeline) Carollo recommends providing two days of emergency

| Table 4.3 Emergency Storage Available Under Summer and Winter Conditions<br>Chloramine Conversion Study<br>Estero Municipal Improvement District | | |
|---|---|---|
| | **Summer** | **Winter** |
| Minimum Stored Volume | 17.5 MG | 10.0 MG |
| Fire Flow Storage | 1.2 MG | 1.2 MG |
| Available Emergency Storage (1) | 16.3 MG | 8.8 MG |
| System Demands | 8.65 MG (2) | 2.88 MG (3) |
| Days of Emergency Storage (4) | 1.9 days | 3.1 days |

Notes:
(1) Available Emergency Storage is the Minimum Stored Volume minus the Fire Flow Storage.
(2) Maximum Day Demand.
(3) Minimum Day Demand.
(4) Days of Emergency Storage is the Available Emergency Storage divided by the System Demands.

storage at all times. As is shown in Table 4.3, this recommendation is essentially met with the proposed new reservoir.

## 4.5 MODIFICATION OF RECOMMENDED OPERATIONAL STRATEGIES

The recommended control strategies are based on a number of assumptions. These assumptions are generally conservative. For example, the 400-hour water age target is half the age identified to be of concern in SFPUC tests. This age was further cut in half when developing the strategies to control water age in the reservoirs. The reason for this assumption was that despite daily "flushing" of the system with water from the turnout, allowing very high water ages when the water is coming from the reservoirs was considered undesirable. Hence, the recommended strategies should be treated as conservative guidelines for operation. The District may prefer to operate the reservoirs such that they have a higher water age due to operational constraints or because a greater amount of minimum storage is desired. Increasing the water age will not necessarily lead to nitrification. However, the risk of nitrification will be increased.

If the reservoirs are operated to allow higher water age, we recommend daily monitoring of the total chlorine residuals in the reservoirs. This frequency may be decreased as the District gains a comfort level with the expected behavior of the reservoirs. If a significant decrease in total chlorine residuals is routinely observed in the reservoirs, the water age in the reservoirs must be reduced. The water age may be reduced in one of two ways:

- **Increase the Turnover.** To increase the turnover, the amount of water pumped out of the tanks each day must be increased. This can be accomplished by increasing the number of hours the pump is operational or by dumping a portion of the water.
- **Decrease the Average Amount of Water in Storage.** The easiest way to decrease the average amount of water in storage is to decrease the maximum water level in the reservoirs.

## 4.6 RECOMMENDED STRATEGIES FOR ADDRESSING HIGH WATER AGE REGIONS IN THE DISTRIBUTION SYSTEM

As aforementioned, there are a number of junctions in the distribution system that are expected to have a water age greater than 400 hours regardless of whether the above changes are made to the reservoir operational strategy. These junctions have been divided into five regional groups, as shown on Figure 4.2. The recommended strategies for these groups are as follows:

- **Region 1**. The high water age in this region of the distribution system is reasonable, as it is distant from both the reservoirs and the turnout. Though the junctions with particularly high water age are located at dead-ends, water ages at nearby junctions are also very high. Hence, looping would likely not improve the water quality in this region. The only way to decrease water age in this region is to increase the demand (i.e., flush). Flushing at a single hydrant at the far reach of this region should be sufficient to bring fresh water into the area (flushing of individual dead ends should not be necessary). We recommend that the water quality in this region be monitored. Flushing should be implemented if a decrease in the disinfectant residual is observed. An initial flushing frequency of once per month should be implemented until baseline water quality data can be established.
- **Region 2**. The two junctions with high water age in this region are both located at the ends of short dead-end pipes. We do not expect these short dead-ends to be a problem and do not recommend monitoring at these junctions.
- **Region 3**. The two junctions with high water age in this region are both located at the ends of long dead-end pipes. From the District's GIS system, there is some piping located between these two lines. The District indicated that these lines are not usually functioning. Regardless, as there is high water age in both pipes, looping would not likely have a significant impact on the high water age. Similar to Region 1, we recommended that one of the pipelines be monitored, and that both pipelines be regularly flushed as necessary.
- **Region 4.** There are three junctions at the end of a long dead-end pipeline in this region. As the pipeline is located parallel to a nearby pipeline with sufficiently low water age, looping to the adjacent pipeline may aid in maintaining water quality in

this region. Alternately, this dead-end may similarly be monitored and flushed as needed.

- **Region 5.** There is a single junction with high water age in this region, which is located at the end of a short dead-end pipeline. Similarly to Region 2, we do not recommend any actions to address this region.

The recommended regions requiring flushing are summarized in Appendix C.

# MATERIALS EVALUATION

## 5.1 BACKGROUND ON MATERIALS DEGRADATION BY CHLORAMINES

This section presents the major concerns related to potential chloramines degradation of piping materials and on elastomers. Where possible, materials degradation rates of chlorinated and chloraminated systems are compared.

### 5.1.1 Chloramine Effects on Pipeline Materials

Distribution system piping materials include cast iron (CIP), asbestos cement (ACP), ductile iron pipe (DIP), concrete (CCP), polyvinyl chloride (PVC), polyethylene (PE), wrapped steel, and, in small diameter piping and tubing, copper and brass. Distribution system valves and fittings are constructed of cast iron, bronze, stainless steel, brass, and other similar materials. Inconclusive results (Reiber, 1993) have shown that copper and brass may be more susceptible to chloramines attack than chlorine attack. However, the other pipeline materials mentioned above have not shown evidence that chloramines corrodes them any quicker than chlorine.

Piping material should not be affected nor should the District experience any increased piping failure following the conversion. Therefore, piping material degradation is not discussed further. Because available research literature indicates the primary concern is elastomer degradation, the remainder of this evaluation focuses on the elastomers.

### 5.1.2 Chloramine Effects on Elastomers

This section of report discusses the potential for increased elastomer degradation from chloramines in the water. Elastomer type and uses are first described, followed by a description of the mechanism for elastomer failure.

#### 5.1.2.1 Elastomer Types and Common Uses in Distribution Systems

The elastomer types commonly used in water distribution systems are presented in Table 5.1. The information contained in this table is based on industry-standard uses for the various elastomers.

#### 5.1.2.2 Elastomer Surface Deterioration

Elastomer surface deterioration has been found to be accelerated by chloramine exposure (Reiber, 1993). Table 5.2 provides a relative ranking of elastomer exposure degradation. The ranking is based on Reiber's research (1993). The scale of the rankings range from

| Table 5.1 Typical Uses of Elastomer in the Distribution System<br>Chloramine Conversion Study<br>Estero Municipal Improvement District | |
|---|---|
| **Polymer Type** | **Usage** |
| Natural Rubber (NR) | Flapper valves, large pipeline gaskets |
| Synthetic Rubber (SBR) | Gasket material |
| Butyl Rubber (IIR) | Pumping impellers, valves seats, chemical feed pumps, piping gaskets |
| Neoprene (CR) | O-rings, valve seats, flat gaskets |
| Ethylene-propylene-diene (EPDM) | O-rings, valve seats, pump impellers, check balls, service clamp and saddle seals |
| Silastic (SI) | High temperature applications |
| Source: Rieber, S., 1993<br>Note: Letters in parenthesis after polymer type represent rubber industry abbreviations. | |

0 (least susceptible) to 10 (most susceptible) and are based on the five physical effects (located below) noted during exposure to chloramines:

- Surface Cracking: Ranked from no cracking to destructive cracking (50 percent depth).
- Hardness (embrittlement): Ranked from minor to extreme.
- Permanent Surface Distortion: Ranked from minor to extreme.
- Surface Tack (caused by plasticizer leaching): Ranked from minor to extreme.
- Loss of Filler Material: Ranked from minor to extreme.

From the information presented in Table 5.2, it is clear from these results that elastomers vary in their susceptibility to both free chlorine and chloramine.

### 5.1.3 Experiences of Other Utilities

Several utilities or water companies having long term experience, or that have switched from chlorination to chloramination over the last 5 to 10 years have been interviewed related to their experiences with elastomer failure. A summary of those interviews follows.

- **Skagit Public Utility District (PUD)**, Washington (Peterka, 1999). Skagit PUD reported they are not aware of any problems to date. This utility uses chloraminated water for their plant process water (e.g., chemical feed systems), and to date have not experienced any component failures.

**Table 5.2 Elastomer Surface Characterization [1]**
**Chloramine Conversion Study**
**Estero Municipal Improvement District**

| | Free Chlorine (300 mg/L) pH 8.5 | Chloramines (300 mg/L) pH 8.5 |
|---|---|---|
| NBR[2] (acrylonitrile-butadiene) Sulfur cure | 2 | 6 |
| NBR-PO[2] Peroxide cure | 0 | 4 |
| NBR-PO2[2] Peroxide cure | 0 | 4 |
| NBR (commercial sheetstock) Sulfur cure | 2 | 1 |
| EPDM[2] (ethylene-propylene-diene) Peroxide cure | 1 | 1 |
| EPDM[2] Sulfur cure | 1 | 4 |
| EPDM (commercial sheetstock) Sulfur cure | 5 | 8 |
| Natural Rubber[2] | 4 | 7 |
| Gum Rubber (commercial sheetstock) | 2 | 8 |
| Neoprene[2] | 6 | 5 |
| Neoprene (commercial sheetstock) | 2 | 3 |
| SBR[2] (styrene-butadiene) | 2 | 4 |
| SBR (commercial sheetstock) | 2 | 5 |
| Vinyl-methyl-silicone[2] (VMQ) | 0 | 0 |
| Fluorocarbon[2] (FKM) (Viton)[7] | 0 | 1 |
| XIIR[2] (Isobutylene-isoprene) | 0 | 3 |

Notes:
(1) Source: Reiber, 1993. Ranking adapted for purposes of this report. See explanation in text.
(2) No antidegradants.

Ranking from 0 to 10, with 0 being least susceptible to degradation and 10 being most susceptible to degradation.

- **East Bay Municipal Utility District (EBMUD)**, California (Wilczak, 1999). EBMUD reported no acute failures throughout the distribution system, but have received some reports of toilet tank flapper valve degradation. In response, the utility issued a general notification to plumbing suppliers and manufacturers regarding the possible correlation between chloramine exposure and increased degradation of these products.

- **American Water Works Service Company (AWWSC)**, New Jersey (LeChevallier, 1999). AWWSC noted no distribution system problems, and also stated they made no particular provisions for material replacement in their systems upon changing disinfectants. They too report incidences of toilet tank flapper valve degradation. LeChevallier (1999) noted that because the amount of elastomer material exposed in distribution system components is so minimal, that acute effects are not likely to be noticed yet.

- **Portland Bureau of Water Works (WW)** (Knudson, 1999). The City of Portland has reportedly been using chloramine disinfection for approximately 50 years, and have not experienced any particular problems in the distribution system. Given the ages of their system it is likely that the majority of their elastomeric water distribution system components are constructed of natural rubber. They have had no customer complaints regarding toilet flapper gaskets or water heater valves and liners.
- **Metropolitan Water District of Southern California (MWD-SC)** (Mofidi, 1999). MWD-SC reported no particular problems with elastomers in the distribution system. They have not received complaints regarding toilet tank appurtenances.

None of those interviewed reported significant problems aside from sporadic degradation of domestic appurtenances such as toilet tank flapper valves.

Other anecdotal information provided through our interview with the Skagit PUD reflects the opinions of Specification Rubber in Birmingham, Alabama. This rubber manufacturer indicated they do not believe standard gasket deterioration occurs in waters where chloramine levels are maintained below 5 mg/L. Considering that the Disinfectants/ Disinfection By-Product Rule has established a Maximum Residual Disinfectant Level (MRDL) of 4 mg/L for chloramines, the 5 mg/L threshold cited by Specification Rubber is not likely to occur in the District's system. Further, standard gasket material for the last 15-20 years has been synthetic rubber (like SBR), not natural rubber. Although SBR can be sensitive to chloramine degradation, it is less susceptible than natural rubber (shown previously in Table 5.2).

## 5.2 SPECIFIC CONSIDERATIONS OF THE DISTRICT'S ELASTOMERIC COMPONENTS

The average pH of SFPUC water is about 9. Based on this pH, it is likely that the free chlorine presently in the District's system is in the hypochlorite anion form. Upon changing over to chloramine disinfection, assuming the chlorine to ammonia-nitrogen ratio is less than or equal to 5:1 and the pH is 9, it is likely the chlorine will occur as monochloramine, as desired. In Reiber's (1993) work, the conclusion was made that the severity of attack and degradation from both chlorine and chloramine followed the order:

dichloramine>>monochloramine>hypochlorous acid>hypochlorite anion

Therefore, the change to chloramine will perhaps increase the rate of degradation. According to the ranking on Table 5.2, the switch to monochloramine at a pH of 9 could