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May 10, 2004

Mr. Bruce E. Kennedy, P.E., Utilities Director  
Pasco County Utilities Department  
Public Works/Utilities Building, Suite 205  
7530 Little Road  
New Port Richey, Florida 34654

Re: FPSC Docket No. 020896-WS – Petition by customers of Aloha Utilities, Inc. for deletion of portion of territory in Seven Springs area in Pasco County.

Dear Mr. Kennedy:

Enclosed, at your request, is a copy of Phase II of Dr. Audrey Levine's report concerning the above-referenced utility, entitled "Technical Review of Production and Distribution of Drinking Water in the Seven Springs Water System."

On behalf of John Williams and myself, we thank you, Doug Bramlett, and Joseph Richards, for meeting with us on May 4, 2004. The meeting was very helpful to us.

Sincerely,

Rosanne Gervasi  
Senior Attorney

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Aloha Utilities

Seven Springs Water System

**Technical Review of Production and Distribution of Drinking  
Water in the Seven Springs Water System**

*Phase II*

*Analysis of well water, treated water, and distribution system water*

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February 2004

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## **Executive Summary**

The Seven Springs Water System, operated by Aloha Utilities, has been plagued by recurring occurrences of “black water” within residential plumbing systems since the mid 1990s. The purpose of this report is to evaluate water quality factors that impact the Seven Springs Water System and identify potential operational and treatment modifications that could be used to reduce the incidence of black water.

The report has been produced in two phases. Phase I includes extensive background information and a compilation of all available water quality and operations data on the Seven Springs system. Phase II of the report includes the results of supplemental testing conducted during October and November 2003.

The water supply for the Seven Springs Water System is derived from 8 wells located in southeast Pasco County. The water quality of the wells is typical for this region of Florida. The treatment system at each well consists of corrosion control using a polyphosphate corrosion inhibitor, followed by chlorination. Residual chlorine levels are monitored at each well and throughout the distribution system. The system has minimal capacity for storage of water.

The primary water quality concern associated with the Seven Springs Water System is control of hydrogen sulfide in the source water. Under the current treatment approach, the hydrogen sulfide is converted to elemental sulfur, iron sulfides, polysulfides, and sulfate by chlorination at each well. The various forms of sulfur can react biologically or chemically within the distribution system or residential plumbing to either re-form hydrogen sulfide or to react with dissolved metals to form insoluble particulates. These reactions are exacerbated by warm water temperatures and tend to occur more consistently in water lines that are used infrequently. Sulfate is naturally present in all groundwater and the levels of sulfate in the water from the Seven Springs System are relatively low. Removal of sulfate from water is not practical,

Point-of-use treatment systems can further complicate the situation by reducing the capacity to control microbial growth by removing disinfectant residuals in conjunction with removal of minerals that can provide a protective barrier within pipelines.

While the current treatment system is in compliance with Federal and State requirements for potable water systems, the water tends to react with metals in pipelines, faucets, and hot water tanks to form black insoluble particles. The use of alternative treatment approaches to control hydrogen sulfide may help to reduce the incidence of black water formation. In addition, upcoming modifications to convert the disinfection system from free chlorine to chloramines will impact the stability of sulfides within the distribution system.

The major findings from this Phase II report are:

1. The levels of hydrogen sulfide associated with each well are somewhat variable. Wells that have higher levels of hydrogen sulfide also tend to have higher levels of iron and ammonia.
2. Levels of hydrogen sulfide detected in the untreated water ranged from 0.6 to 3.95 mg/L. A trace amount of hydrogen sulfide was detected in the influent to the main plant (0.12 mg/L) during the November sampling.
3. Based on testing of the treatment at each well, chlorine is effective for converting the hydrogen sulfide to elemental sulfur, polysulfides, and sulfate.
4. For the two sets of samples that were collected for this project, there was no evidence of hydrogen sulfide in any of the treated water samples collected at the wells.
5. There was no evidence of chlorine in the untreated water from any of the wells.
6. The concentration of suspended solids in all of the water samples (untreated, treated, and distribution system) was below detection limits (< 1 mg/L)
7. The dominant elements in black water particles that are formed within residential plumbing include sulfur, iron, copper, phosphorus, manganese, calcium, and aluminum.

## Recommendations

Several alternatives should be considered to improve water quality within the Seven Springs system. The impacts of alternative treatment systems on the formation of black water should be tested on a pilot-scale system. While several treatment technologies may be effective for improving water quality, there are constraints due to the need for water conservation, the lack of capacity for discharge/disposal of byproducts or reject water, and economics. Prior to final selection of a treatment approach, it is important to assess the potential impacts of the treatment system on water corrosivity, copper release, disinfection effectiveness, disinfection byproduct formation, and the potential for production of "black water". Treatment options that warrant consideration are summarized below.

1. **Packed tower aeration.** *Packed tower aeration is a physical/chemical treatment system in which a chemical is added to the water to reduce the pH (carbon dioxide or a mineral acid) and the hydrogen sulfide is transferred from the water to air. This process needs to be coupled with a gas scrubber to control the release of odorous compounds into the air. In addition, due to the potential for the packing material to become clogged from biological growth, there is a need for frequent maintenance and/or filtration.*



2. **Alternative oxidants.** *Alternative oxidants can be used to improve the consistency of hydrogen sulfide conversion reactions. The most likely candidate oxidants are hydrogen peroxide or ozone. The presence of iron in the source water can serve as a catalyst for this process. Supplemental control of pH may be necessary to ensure that the hydrogen sulfide is converted to sulfate. Another advantage of using alternative oxidants is that the chlorine demand of the water will be reduced allowing for more effective use of chloramination. In addition, the supplemental oxygen in the treated water will improve the taste of the water and help to reduce the growth of anaerobic microorganisms within the distribution system.*
3. **Membrane technologies.** *Membrane technologies can be coupled with chemical oxidation to remove particulate forms of sulfur and to improve water quality. The use of membrane processes requires a reliable energy source and a means for treatment/disposal of the reject water.*

# **Technical Review of Production and Distribution of Drinking Water in the Seven Springs Water System: Phase II: Analysis of well water, treated water, and distribution system water**

## **Introduction**

Aloha Utilities, Inc. is a privately owned utility that has been providing potable water to a portion of unincorporated southwest Pasco County since the 1970s. One of the water systems that is owned and operated by Aloha Utilities is the Seven Springs Water System. The Seven Springs system consists of about 8,000 service connections that include single family homes, apartment and townhouse complexes, commercial areas, schools, and business parks in a primarily residential community southeast of New Port Richey. Over the past 8 years, there have recurring concerns by the residents of the Seven Springs service area about the quality of the potable water that is provided by Aloha Utilities. One of the major concerns is the occurrence of "black water" within residential plumbing systems. The purpose of this report is to assess the cause of these water quality complaints and provide recommendations to improve the quality of the treated water.

This report consists of two phases. Phase I is a comprehensive review of water quality and operations data for the Seven Springs Systems. Phase II is a summary of supplemental testing that was conducted during 2003.

## ***Objectives***

The objectives of this Phase II report are:

1. To evaluate characteristics of the untreated, treated, and distribution system water.
2. To identify potential causes of "black water" within residential plumbing.
3. To identify treatment alternatives appropriate for improving water quality within the Seven Springs Water System to reduce the incidence of black water,

## ***Approach***

A sampling and analysis protocol was developed to characterize water quality before and after treatment and within the distribution system. Site visits were made to the individual treatment facilities and to various areas of the distribution system. Samples were collected from each well before and after treatment and from 8 residential locations within the service area of the Seven Springs system. The testing program was coordinated with Aloha Utilities and parallel samples were obtained by Aloha Utilities from each sample location. The sites for the distribution system samples were selected by the Citizen's Advisory Committee (CAC). A representative from the CAC accompanied the sampling crew for each sample event.

## Methodology

Two sampling events were conducted during the fall of 2003. Each sample event involved collecting samples of the untreated and treated water from each well and collection of four samples from the distribution system. Wells 1, 2, 3, 6, 7, 8, and 9 were each sampled during both sampling events. Well 4 was only sampled during the November sampling event. A consistent protocol was used for sample collection. Field analyses were conducted for hydrogen sulfide, chlorine, pH, temperature, and conductivity. Supplemental samples were collected for further analysis.

### *Sample Collection*

The protocol for sample collection included flushing of the system, field tests, and collection of samples for laboratory analysis. The sequence of the sample collection was determined based on logistical considerations and was not pre-arranged prior to the sample event. Samples were collected between 9:30 am and 8 pm on each sampling day. The sampling team traveled in caravan formation to each sample site and included representatives from Aloha Utilities, Short Environmental Laboratories, and the CAC.

A sampling device, provided by Short Environmental Laboratories, was used to minimize the amount of sample aeration that occurred during sample collection. The sampling device consisted of a graduated cylinder with two ports that allowed for the water to flow into the bottom of the cylinder and overflow at the top, thus providing an ability to collect a sample without exposing the water to air. Photographs of the sampling device are shown in Figure 1.

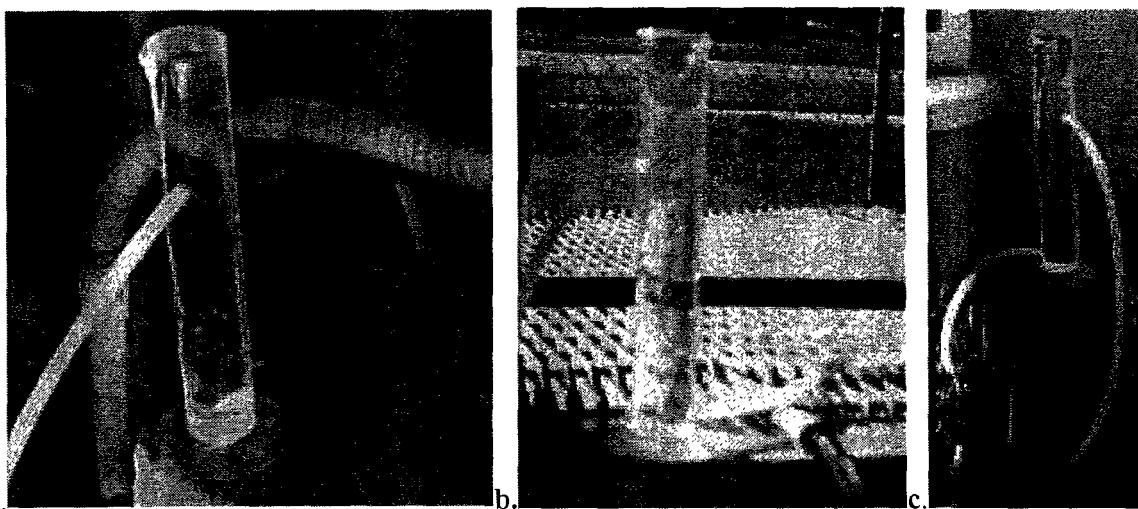


Figure 1. Sampling device used to collect water from the Seven Springs Service area in October and November 2003: a) sample of untreated water, b) sample from main plant, and c) sample from distribution system.

## **Well samples**

Upon arrival at each well, the sample hose and container were connected to the raw water sample tap, the tap was turned on, and the water was allowed to flow for a minimum of 2 minutes. Following the flushing period, samples were collected and tested immediately for hydrogen sulfide, chlorine, pH, conductivity, and temperature. Supplemental samples were collected in one-liter and 500 mL containers for laboratory testing. Parallel tests were conducted by Short Environmental Laboratories. Upon completion of sample collection of the raw water, the sampling device was connected to the finished water at each well site. The finished water was allowed to run for a minimum of 2 minutes prior to sample collection. After the two minute flushing period, samples were collected and tested immediately for hydrogen sulfide, total and free chlorine, pH, conductivity, and temperature. Supplemental samples of the finished water were collected for laboratory testing. At each well, the flowrate and the chlorine dosing rate in effect at the time of sampling were recorded to allow for calculation of the chlorine dose. Photographs were taken during the sample collection.

## **Distribution system samples**

In addition to samples collected from each well, four sites in the distribution system were sampled on each sampling date for a total of 8 distribution system samples. The sites were selected by the CAC. The CAC representative made preliminary contact with each of the homeowners and arranged for each site visit. Most of the residential samples were collected during the afternoon. At each residential site, the samples were collected either from an outside tap (prior to any point-of-use water treatment unit) or from the utility side of the water meter. For each site, the age of the home and the average water usage rate were logged to provide a basis for comparison of the samples. Prior to sample collection, the conductivity and chlorine residual of the water were tested to verify the absence of point-of-use treatment systems. After conducting preliminary tests, the sampling device was connected to the sample tap and the water was allowed to run for a minimum of 5 minutes. The flowrate was monitored during the flushing period. Following the flushing period, samples were collected and tested immediately for hydrogen sulfide, total and free chlorine, pH, conductivity, and temperature. Supplemental samples were collected for laboratory testing. At two of the locations, samples of "black water" were collected. One sample was obtained from a hot water tank (sample D-2b) and one was from the hot water faucet that serves a bathtub (sample D-7b).

## ***Sample Analysis***

The analytical methods that were used for the conduct of the tests are summarized in Table 1. The tests were selected to provide a basis for evaluating water quality changes that occur during treatment and distribution of the water. The water quality parameters were selected to allow for calculation/estimation of the fate of hydrogen sulfide in the system and to allow for calculation of corrosivity indices. Aloha Utilities collected parallel samples to allow for cross-comparison of results. A summary of the tests conducted by Aloha Utilities is given in Table 2.

**Table 1. Summary of analytical methods used for characterization of water samples.**

Test	Field or Laboratory	Method Reference Number (Standard Methods); Instrument	Detection Limit/sensitivity
Alkalinity	Lab	2320 B Titration /Bromocresol green/ methyl red	20 mg/L as CaCO <sub>3</sub>
Chlorine, total and free	Field	4500-Cl F DPD Colorimetric Method; Pocket Colorimeter II	0.01 mg/L as Cl <sub>2</sub>
Conductivity	Field and lab	HACH Conductivity Probe; Model 51975-03	20 µS/cm
Hydrogen Sulfide	Field	4500-S <sup>2-</sup> Iodometric titration	0.01 mg/L as S
pH	Field and lab	HACH Platinum pH Electrode, Model 51910; HACH Portable Multiparameter Meter Sension 156	0.01 pH units
Temperature	Field	HACH Platinum pH Electrode, Model 51910	0.01 °C
Turbidity	Lab	2130B Nephelometric Turbidity	0.01 NTU
Nitrogen			
Ammonia	Lab	HACH-8155	0.01 mg/L
Nitrate	Lab	HACH-8192	0.1 mg/L
Anions			
Chloride	Lab	4140 B. Capillary Electrophoresis with indirect UV detection	1 mg/L
Sulfate	Lab	4140 B. Capillary Electrophoresis with indirect UV detection	1 mg/L
Metals			
Calcium	Lab	3111 Metals by Flame Atomic Absorption Spectrometry	0.01 mg/L
Magnesium	Lab	3111 Metals by Flame Atomic Absorption Spectrometry	0.01 mg/L
Iron (total and dissolved)	Lab	3111 Metals by Flame Atomic Absorption Spectrometry	0.01 mg/L
Manganese	Lab	3111 Metals by Flame Atomic Absorption Spectrometry	0.01 mg/L
Copper (total)	Lab	3111 Metals by Flame Atomic Absorption Spectrometry	0.01 mg/L
Total Organic Carbon	Lab	5310C Persulfate-Ultraviolet Oxidation Method	0.05 mg/L
Particle characterization	Lab	Electron Microscopy/ Energy Dispersive Spectroscopy	0.5% (5000 ppm), 1 nm spot size

**Table 2. Summary of analytical methods used by Aloha Utilities for characterization of water samples..**

Test	Field or Laboratory	Method Reference Number (Standard Methods); Instrument	Detection Limit
pH	Field	Field probe	
Hydrogen Sulfide	Field	4500-S <sup>2</sup> D Methylene Blue Method	0.01 mg/L as S
Chlorine, total and free	Field	DPD Colorimetric Method	0.01 mg/L as Cl <sub>2</sub>
Conductivity	Field	Probe	
Dissolved Oxygen	Field	Probe	
Sulfate	Lab	EPA 375.4	1 mg/L
Temperature	Field	Probe	
Total Suspended Solids	Lab	EPA 160.2	1 mg/L
Iron (dissolved)	Lab	EPA 236.1	0.02 mg/L

Routine water quality parameters such as pH, alkalinity, hardness, conductivity, and ammonia were tested within one day of sample collection. Samples for elemental analysis (calcium, magnesium, iron, manganese, and copper) were preserved with nitric acid and analyzed within one week of sample collection. Tests for iron and copper were conducted on digested samples to provide information on the total quantity of each constituent. Tests for anions (chloride and sulfate) and total organic carbon were conducted within one week of sample collection. Turbidity measurements were used to identify samples with potentially higher concentrations of particles.

Samples for particle characterization were selected based on turbidity screening conducted the day after sample collection. Samples with relatively higher turbidity (>0.3 NTU) were processed for particle characterization. Each particle characterization sample was processed by centrifuging a 250 mL aliquot and suspending the centrifuged material in 10 mL of water (concentration factor of 25). Samples were preserved with glutaldehyde/formaldehyde, dehydrated with ethanol, dried, mounted on a filter or carbon tape, coated with carbon, and evaluated using a Phillips 515 scanning electron microscope with an EDAX Econ IV energy dispersive X-ray detector capable of semi-quantitative elemental analysis. The analyzer can detect elements with atomic weights higher than nitrogen. This method can be used to identify the dominant elements associated with a solid sample, but cannot be used to determine the exact elemental composition because it cannot discriminate between carbonates, hydroxides, and oxides. In this project it was used as a screening tool to provide improved characterization of particles isolated from selected sample points. Elements that are associated with particulates are in equilibrium with dissolved constituents and therefore the data can be used to identify the dominant contributors to particulate formation within the distribution system and residential plumbing.

## Source Water Quality

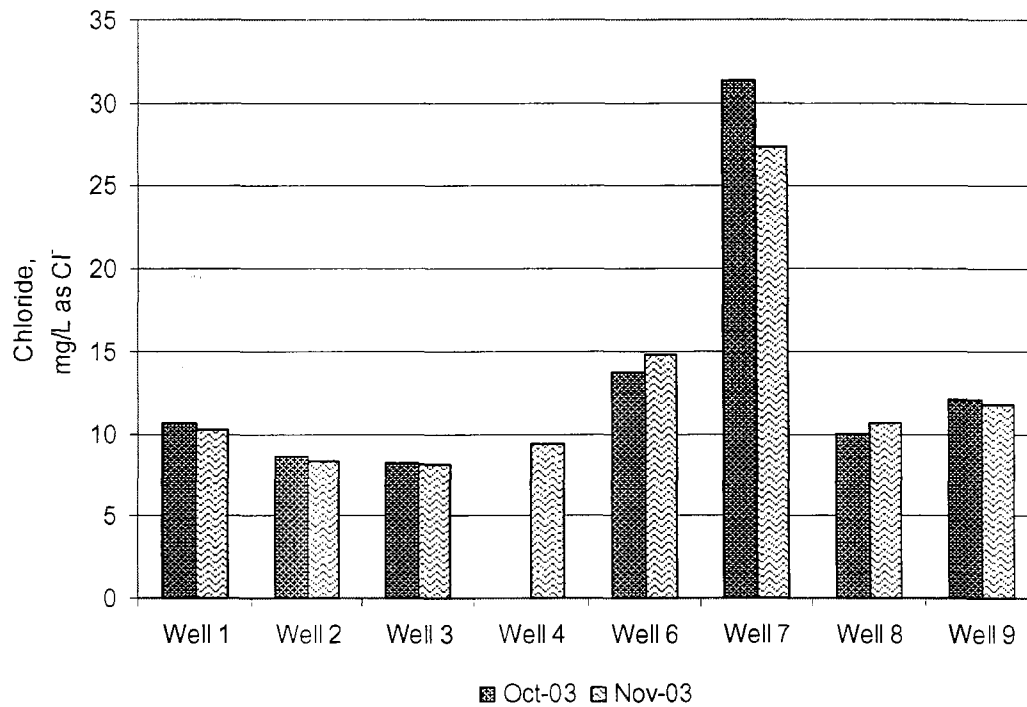
The wells that provide water for the Seven Springs Water system are open to the Floridian Aquifer. The wells range in depth from 280 to 500 ft. The eastern part of the service area is served by water from wells 1 and 2. Water from wells 3 and 4 is pumped directly to the storage tank (main plant) and then into the central and eastern part of the service area. Surplus water from wells 1 and 2 is also pumped to the ground storage tank, depending on water demand (Porter, 1997, 2002). Water from wells 6 through 9 serves the remaining service area and is pumped directly into the system.

Ground water derived from the Floridian Aquifer contains dissolved minerals such as calcium, magnesium, iron, and manganese; anions such as sulfate, chloride, and carbonates; dissolved gases such as carbon dioxide and hydrogen sulfide; and dissolved organic carbon. Trace levels of ammonia are also present in some well water. While all wells contain more or less the same constituents, the actual composition of the water varies among the wells due to localized geohydrological factors. In addition, seasonal variations such as rainfall, dry season, or drought conditions can influence the water quality for a given well. Drought conditions can cause an increase in the concentrations of dissolved constituents due to the lack of freshwater recharge. Changes in land use patterns can also impact water quality by diverting stormwater runoff from historic recharge zones. Thus water quality characteristics of the source water can vary seasonally.

During the Phase II testing, water from each well was tested for chloride, sulfate, sulfide, iron (total and dissolved), manganese, organic carbon, and ammonia. Routine water quality parameters such as alkalinity, turbidity, pH, and conductivity were also analyzed. Results are summarized below in comparison to historical data (where available).

### *Chloride levels*

A summary of chloride levels measured in each well for the two sample events is shown in Figure 2. As shown, chloride levels in wells 1,2,3,4, 8, and 9 were about 10 mg/L for both sample events. The chloride level in well 6 was around 15 mg/L and chloride levels in well 7 were between 25 and 30 mg/L. The levels reported for all wells are within the normal range associated with groundwater from the Floridian Aquifer and are consistent with historical data (see Phase I report).

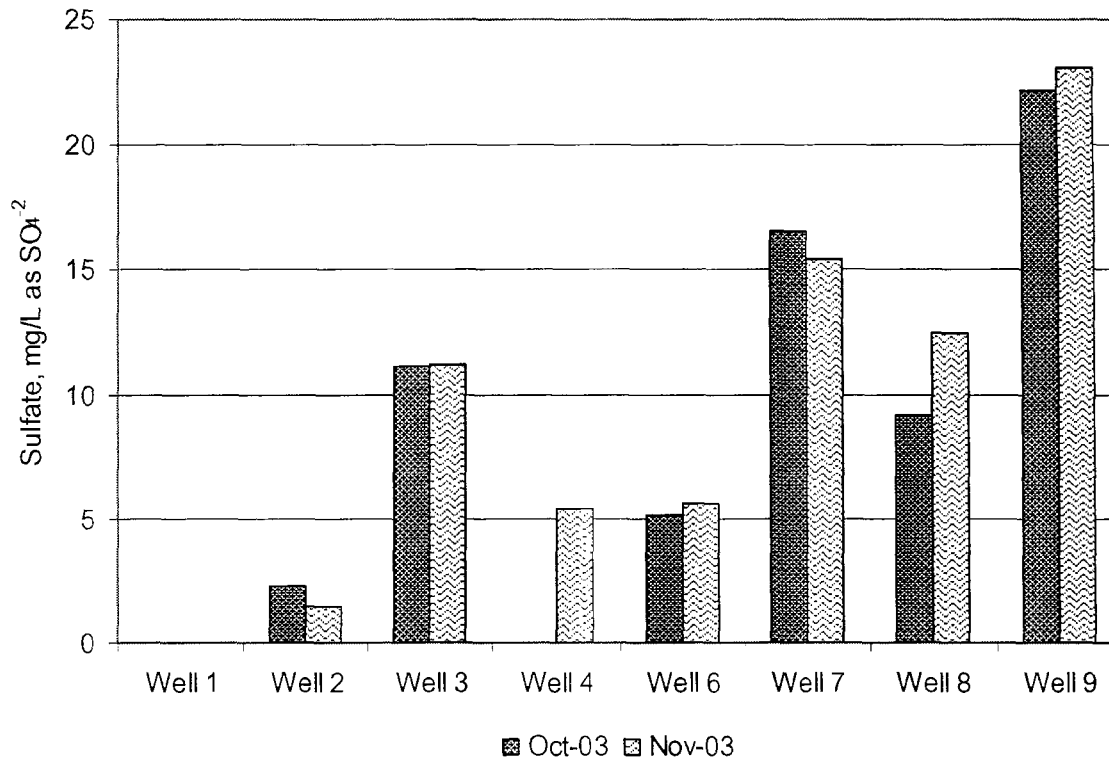


**Figure 2. Summary of chloride levels in untreated water sampled during October and November 2003.**

***Sulfate levels***

A comparison of sulfate levels in each well for the October and November sampling events is shown in Figure 3. As shown, the sulfate levels vary from below 2 mg/L (wells 1 and 2) to over 15 mg/L (wells 7 and 9). To put these values into perspective, levels of sulfate in other water systems in west central Florida range from about 2 to 200 mg/L. Thus, even though there is significant variation among the wells, the levels are within the “normal” range for potable water systems.





**Figure 3. Summary of sulfate levels in untreated water from the Seven Springs Water System from samples collected during October and November 2003.**

### ***Sulfide levels***

Hydrogen sulfide is a reduced dissolved gas that can be present in groundwater, depending on the local geohydrology. When water containing hydrogen sulfide is exposed to the atmosphere, some hydrogen sulfide can volatilize from water, generating odors. The level at which hydrogen sulfide odors can be detected in air is less than 0.1 parts per million (ppm). There are no specific regulations regarding the level of hydrogen sulfide that is permissible in drinking water. It is indirectly controlled through a secondary drinking water standard for odor.

A summary of the sulfide levels measured in the wells that serve the Seven Springs Water system is shown in Figure 4 and compared to historical data in Table 3. The lowest levels of hydrogen sulfide were associated with wells 1 and 7 and the highest levels were associated with well 9.

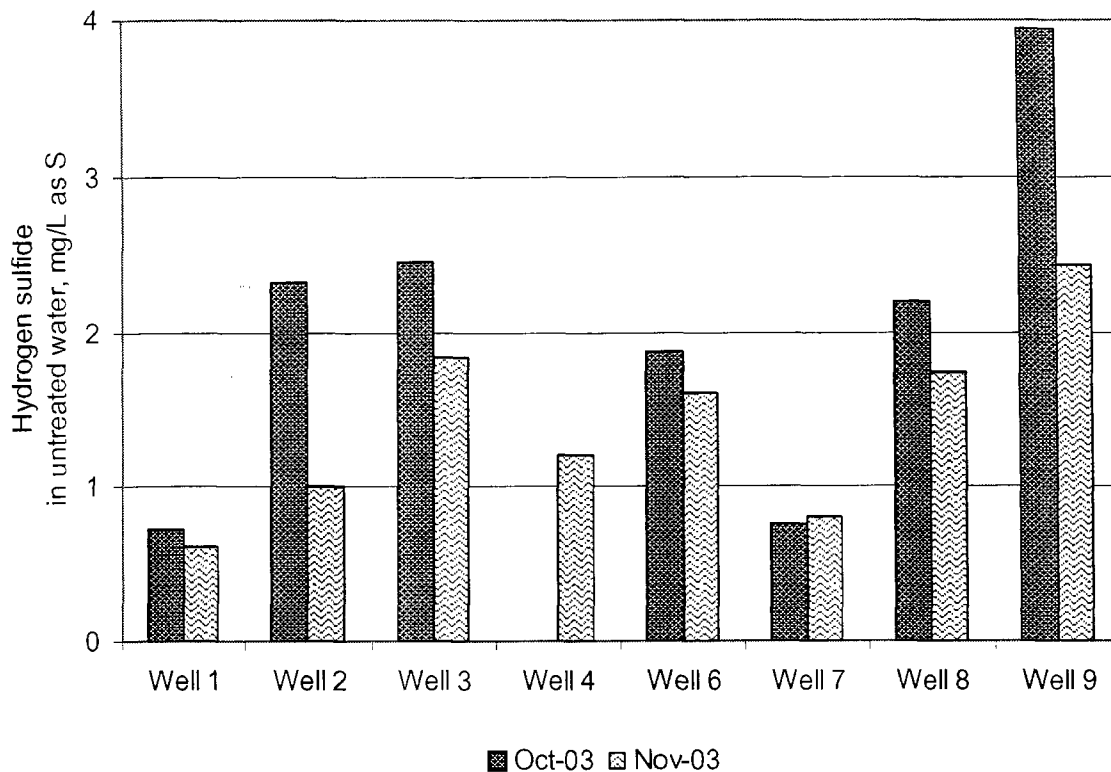


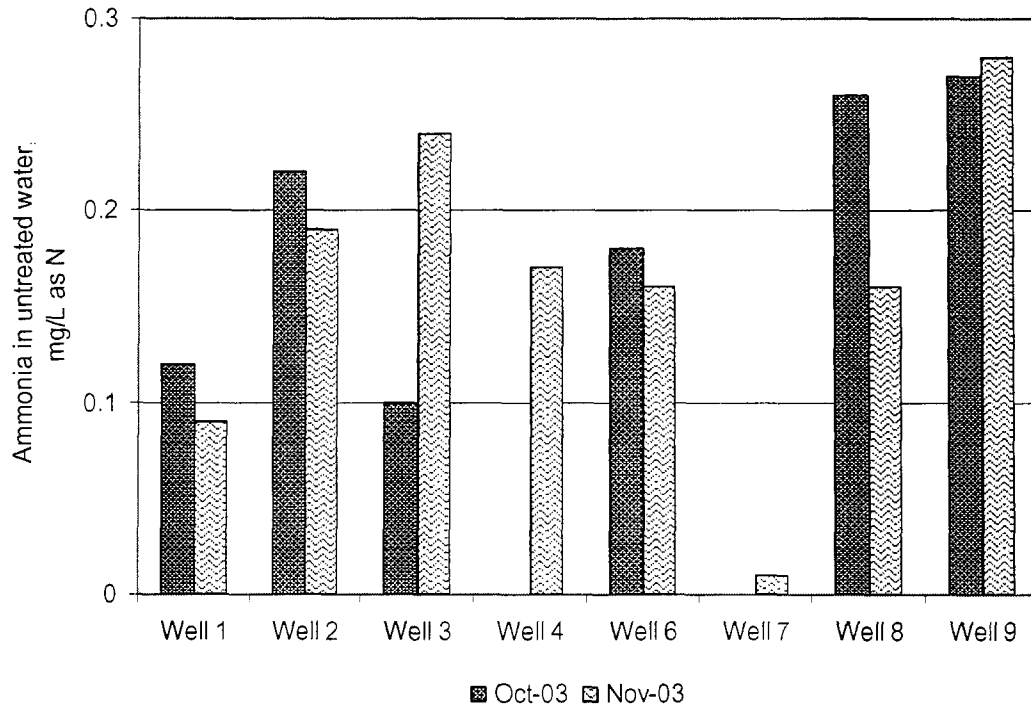
Figure 4. Summary of hydrogen sulfide concentrations in untreated well water from October and November 2003 sampling.

Table 3. Comparison of measured sulfide levels in untreated well water from wells that serve the Seven Springs Water system.

Well	November 1996	February 2001	October 2003	November 2003
	Hydrogen Sulfide, mg/L	Hydrogen Sulfide, mg/L	Hydrogen Sulfide, mg/L	Hydrogen Sulfide, mg/L
1		< 0.10	0.72	0.61
2		0.68	2.32	1.00
3		1.78	2.45	1.84
4		0.46	Not sampled	1.20
Main Plant Inflow			< 0.01	0.12
6		0.94	1.87	1.60
7		< 0.10	0.76	0.80
8	0.7	1.50	2.20	1.73
9	2.4	3.85	3.95	2.43

### *Ammonia, Iron, and Manganese levels*

As part of the Phase II sampling, the concentrations of ammonia, iron, and manganese were measured in each well to evaluate the potential chlorine demand associated with these constituents. A comparison of ammonia levels in each well is shown in Figure 5. Ammonia levels were all below 0.3 mg/L with the highest levels associated with well 9. These levels are typical for ground waters from the Floridian Aquifer.



**Figure 5. Summary of ammonia concentrations in untreated well water from October and November 2003 sampling.**

A summary of total iron levels in each well from the October and November samples is shown in Figure 6. The secondary drinking water standard for dissolved iron is 0.3 mg/L based on one sample every three years. This standard is based on aesthetic factors since iron can cause water discoloration. Iron can also react with sulfide to form black iron sulfide particles in water. Manganese data are shown in Figure 7. The secondary drinking water standard for manganese is 0.05 mg/L. Levels of iron and manganese measured during October and November 2003 are both within the potable water requirements.

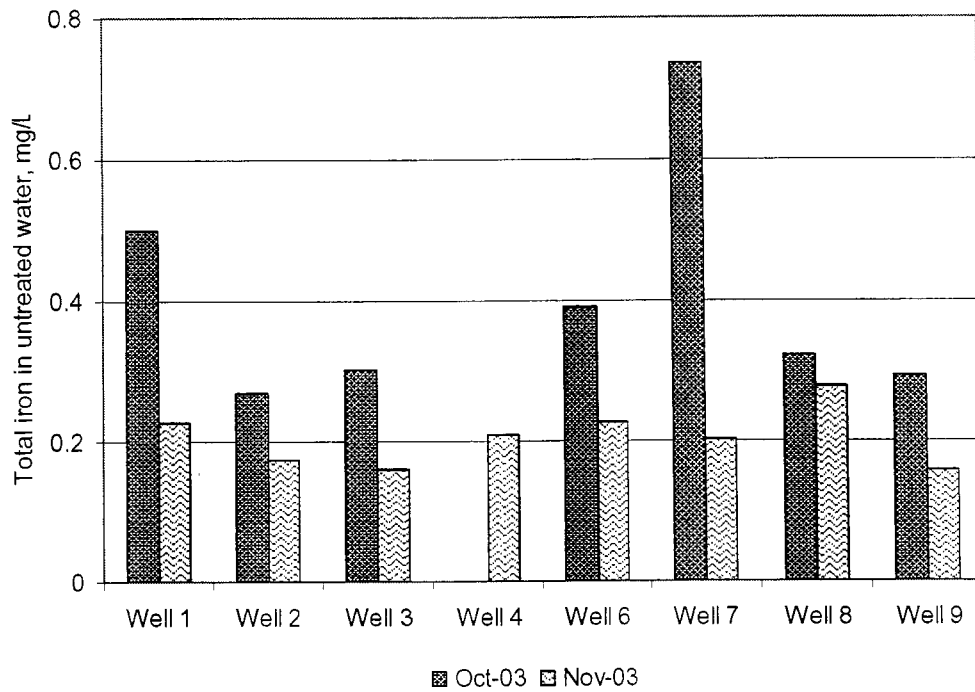


Figure 6. Summary of total iron concentrations in untreated well water from October and November 2003 sampling.

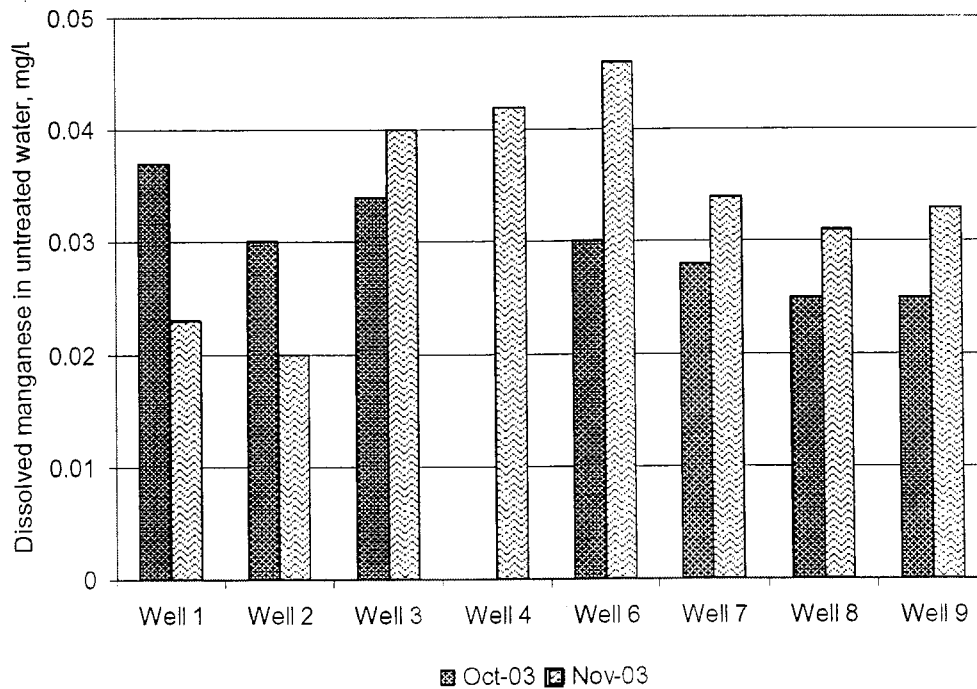


Figure 7. Summary of dissolved manganese concentrations in untreated well water from October and November 2003 sampling.

As shown in Figures 3,4,6, and 7, the levels of hydrogen sulfide, ammonia, iron, and manganese varied for each well for the two sampling events. The data were reviewed to determine if these parameters tend to co-vary. A comparison of hydrogen sulfide concentrations and the concentrations of ammonia and iron is shown in Figure 8. As shown, for these two sampling dates, increases in hydrogen sulfide are associated with slight increases in ammonia and total iron. While the ammonia and iron levels are relatively low (compared to hydrogen sulfide), the reducing environment prevalent in Florida groundwater, tends to result in increased mobilization of iron, ammonia, and other reduced compounds.

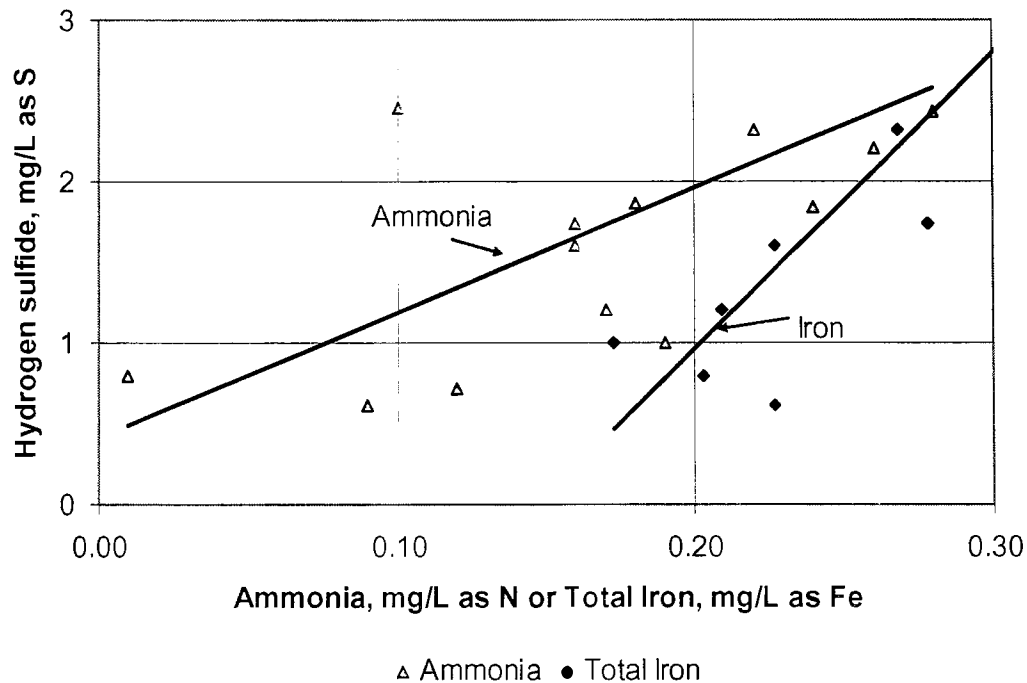
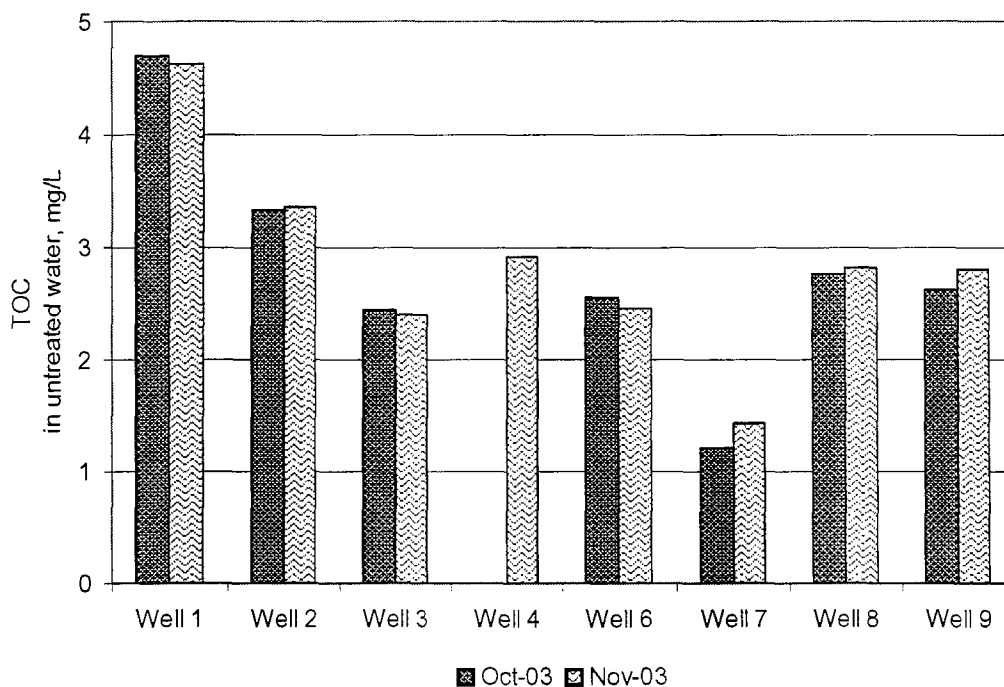


Figure 8. Comparison of total iron and ammonia concentrations with hydrogen sulfide concentrations in untreated well water from October and November 2003 sampling. Correlation coefficients ( $R^2$ ) are 0.45 for ammonia and hydrogen sulfide and 0.63 for iron and hydrogen sulfide.

### Organic Carbon

Total organic carbon (TOC) is a measure of dissolved organic matter in water. A summary of the TOC levels in untreated water from the Seven Springs system is shown in Figure 9. Levels of TOC in the untreated water ranged from about 1 to 4.5 mg/L. These levels are typical of ground water from the Floridian Aquifer. The highest TOC levels were associated with well 1 for these two sampling dates.



**Figure 9. Summary of Total Organic Carbon (TOC) concentrations in untreated well water from October and November 2003 sampling.**

***pH, Hardness, and Alkalinity***

As part of Phase II testing, the pH, hardness, and alkalinity of each well sample were also tested. A comparison of pH levels is shown in Figure 10. Variations in pH reflect variations in the levels of dissolved carbon dioxide and bicarbonate in the source water. Groundwater tends to be supersaturated with dissolved carbon dioxide. When the water contacts the atmosphere, carbon dioxide will tend to off-gas, resulting in an increase in pH. Thus, the temperature of the sample, the degree of sample agitation, and the time between sample collection and measurement can influence the pH measurement. For these samples, the pH ranged from about 6.4 to 7.9. With the exception of well 1, the majority of the samples had pH levels over 7, with the highest levels associated with wells 2, 3, 8, and 9. The pH levels are typical of water derived from the Floridian Aquifer.

Hardness levels associated with each well are shown in Figure 11. Hardness is a measure of the dissolved calcium and magnesium in water. These minerals dissolve in groundwater from limestone and other formations in the subsurface. The levels of hardness range from 150 to 200 mg/L as CaCO<sub>3</sub> and are consistent with levels associated with water from the Floridian Aquifer. Hardness in water can react with carbonates to form a protective coating on metal pipes.

Alkalinity levels associated with each well are shown in Figure 12. Alkalinity is a measure of the buffer capacity of a water. In general, alkalinity reflects the presence of carbonates in the water that act to mediate the impacts of acids on pH. Alkalinity reacts with hardness minerals (calcium) to form a protective coating on metal pipes that can help to control corrosion. The alkalinity levels reported for the Seven Springs Water System are between 150 to 200 mg/L as CaCO<sub>3</sub> with slightly lower alkalinity associated with well 7. The measured alkalinities (125-210 mg/L as CaCO<sub>3</sub>) are typical of ground water from this region.

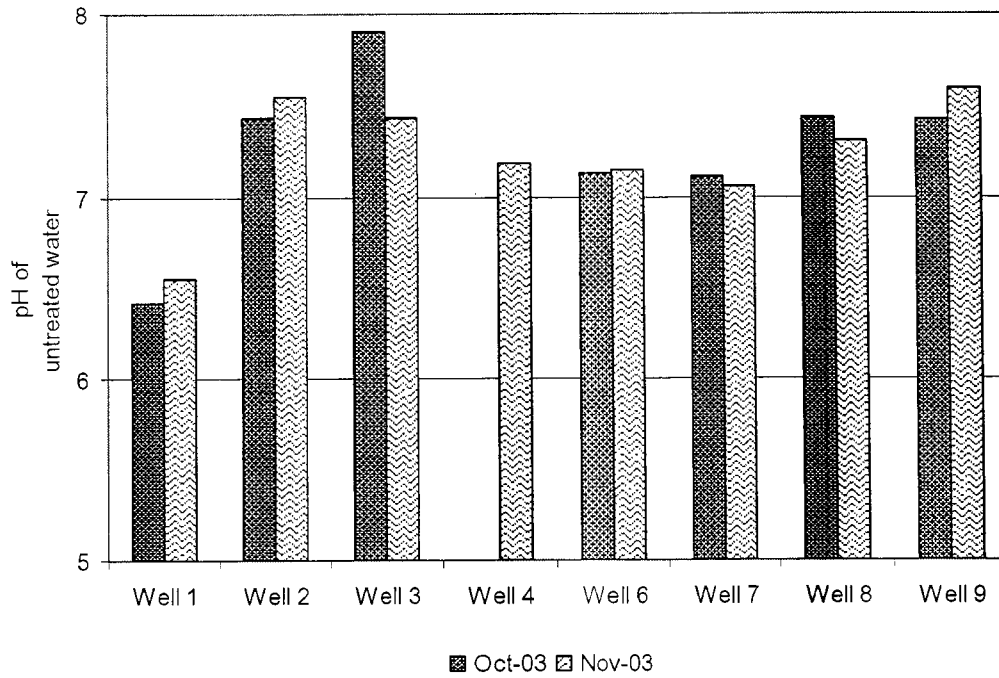


Figure 10. Summary of measured pH values for untreated water from the Seven Springs Water system.

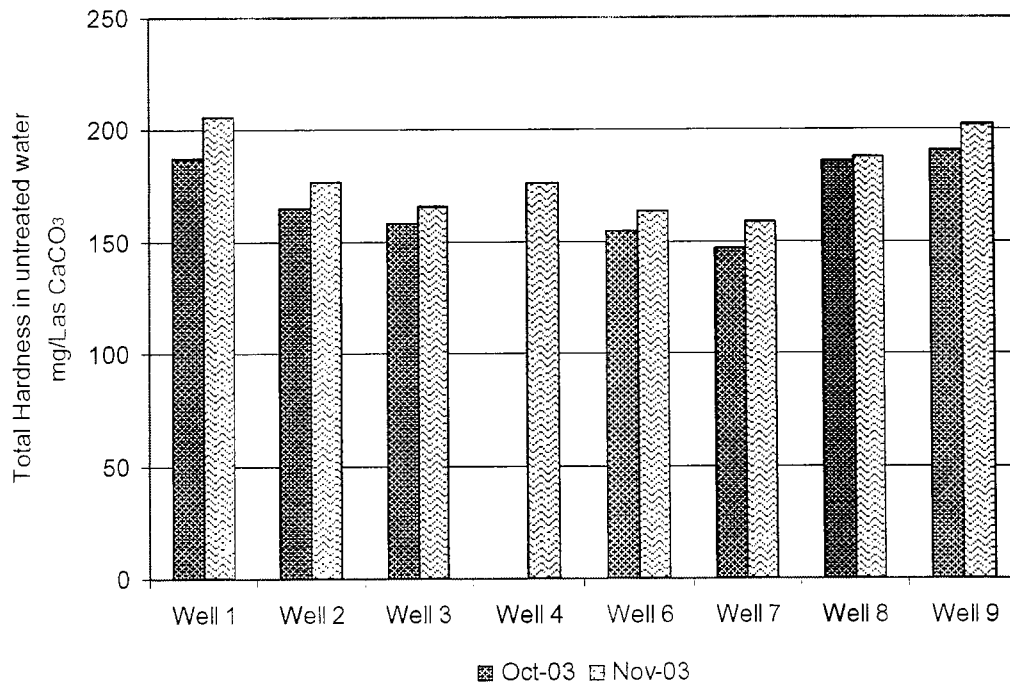
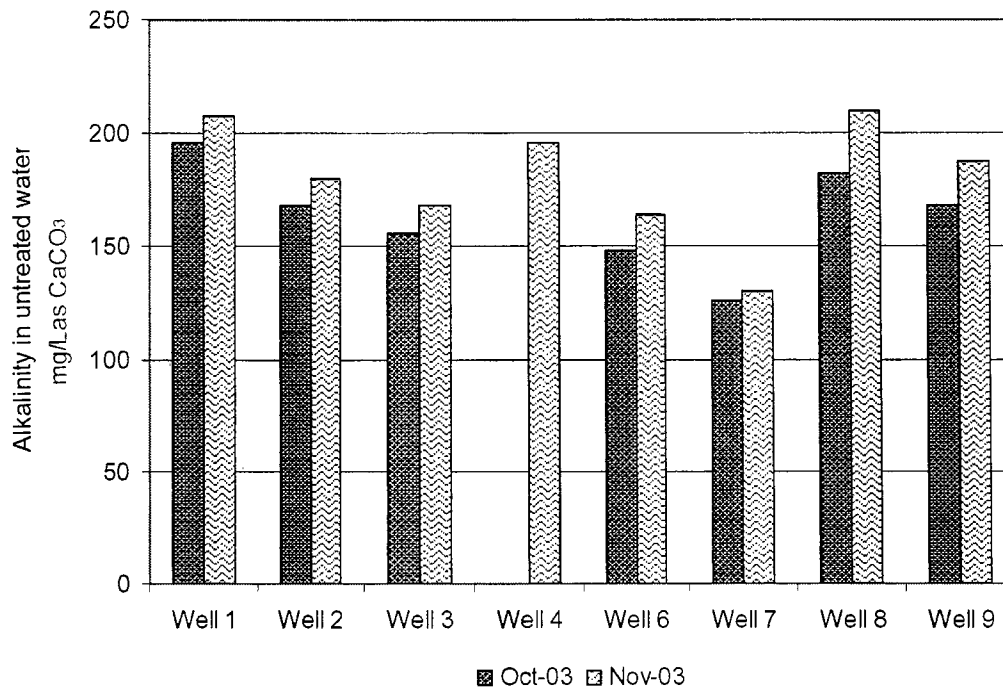


Figure 11. Summary of measured hardness levels for water from the Seven Springs Water system.



**Figure 12. Summary of measured alkalinity levels for water from the Seven Springs Water system.**

## **Production of Potable Water in the Seven Springs Water System**

The treatment process used to produce potable water in the Seven Springs Water System is a conventional groundwater treatment system consisting of chlorination and corrosion control. Each wellhead is equipped with pumps, chemical dosing equipment, chlorination equipment, and a reaction tank. The treatment sequence at each well is similar. Water is pumped from each well at a constant rate. Corrosion inhibitor chemicals are metered into the water using a chemical dosing pump operated at a constant rate. Following addition of the corrosion inhibitor, chlorine gas is injected into the water and the chlorinated water flows to a reaction tank (hydrotank). The chlorine dose is adjusted based on monitoring the residual chlorine in the treated water.

### ***Chlorination***

Chlorination serves a dual purpose in the Seven Springs Water System. When chlorine is added to water, it serves as an oxidizing chemical and reacts with reduced constituents in water, such as hydrogen sulfide, iron, manganese, and ammonia. The second role for chlorine is to disinfect the water by inactivating microorganisms that are potential pathogens, such as fecal coliform bacteria. At each well, chlorine is injected into the water using a wall mounted manually operated chlorinator. The chlorine dose is adjusted based on periodic monitoring of the chlorine residual in the treated water.



After injection of chlorine, the water flows into a reaction tank. The tanks for treatment of water from wells 1, 6, 7, 8, and 9 each have a capacity of 10,000 gallons, whereas the tanks for treatment of water from wells 2, 3, and 4 each hold 5,000 gallons. The tanks are designed to operate in a plug-flow mode. The reaction time available at each well depends on the pumping rate (see Phase I report).

### **Oxidation reactions**

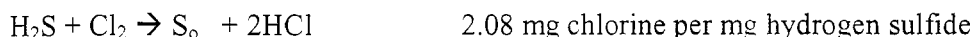
One of the functions of chlorination in the Seven Springs Water System is oxidation of reduced constituents. The primary constituents oxidized by chlorine include hydrogen sulfide, iron, manganese, ammonia, and organic matter. The amount of chlorine used to satisfy all of the oxidation reactions is termed the "chlorine demand" and it can be calculated by comparing the amount of chlorine applied and the amount of chlorine remaining (residual):

$$\text{Chlorine demand} = \text{Chlorine dose} - \text{Chlorine residual}$$

The chlorine demand is an indirect measure of the quantity of oxidizable constituents in the untreated water. Monitoring of the chlorine demand requires calculation of the chlorine dose based on the rate of chlorine use and the amount of water processed at a given well. As a result of the oxidation/disinfection reaction, chlorine is reduced to chloride. Evaluation of the change in chloride content can also be used to estimate the chlorine demand. As part of the Phase II testing, chlorine demand was estimated from assessment of the concentration of reduced species, changes in chloride content, and comparison of the chlorine dose and chlorine residual. To provide baseline data, the chlorine levels were checked in the untreated water. In all cases, there was no detectable chlorine in the water prior to treatment.

#### **Hydrogen sulfide oxidation**

When hydrogen sulfide is oxidized by chlorine, it is converted to elemental sulfur, polysulfides, and sulfate, depending on the pH. The forms of sulfur that might be produced from oxidation are discussed in the Phase I report. The amount of chlorine needed for production of elemental sulfur (oxidation state of zero) is described by the reaction below:



Elemental sulfur can be converted to polysulfides, sulfate, or remain as elemental sulfur, depending on the pH and the presence/absence of catalysts.

The amount of chlorine needed for production of sulfate is shown below:



These two reactions define the minimum and maximum amount of chlorine necessary to convert hydrogen sulfide to a more oxidized form. These reactions do not provide information on reaction rates. There are other water quality constraints that limit the end products of hydrogen sulfide conversion, such as pH, temperature, and the presence of metal catalysts. Thus, even if there is adequate oxidation capacity, the distribution of reaction products between elemental sulfur, polysulfides, and sulfate can vary widely. Typically, a combination of the two reactions occurs in drinking water systems (White, 1999). The combined effectiveness of all oxidation reactions is evaluated by the presence of a residual level of chlorine and by the absence of hydrogen sulfide.

It is difficult to measure the intermediate products from oxidation of hydrogen sulfide. Public water supplies have an additional constraint due to limitations on the amount of residual chlorine that can be present in the distribution system. To maintain the average chlorine concentration within the distribution system below 4 mg/L, it is not feasible to dose the chlorine at a level higher than the amount that can react between the point of chlorine application and the distribution system.

If the hydrogen sulfide is converted to sulfate, approximately 3 mg of sulfate are formed per mg of hydrogen sulfide that is oxidized. Since sulfate is usually present in groundwater, it is difficult to differentiate between the native sulfate and the sulfate formed through oxidation without sophisticated analyses. Qualitatively, if an increase in sulfate is observed following chlorination, the increase can be attributed to sulfide oxidation. However, because of the relatively low proportion of sulfur associated with hydrogen sulfide, differences in sulfate levels may be difficult to quantify due to limitations of the analytical method.

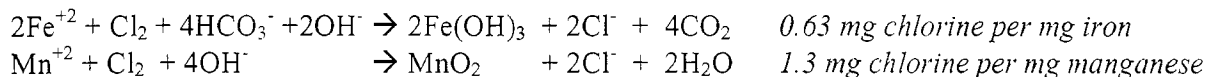
When elemental sulfur is produced, it forms colloidal particles ranging in size from about 0.01 µm to about 10 µm. Direct monitoring of elemental sulfur is not practical for drinking water systems due to the lack of standardized analytical methods.

Turbidity or suspended solids tests can be used as indirect measures of the presence of colloidal particles. However, the chemical composition of the particles cannot be determined from these measurements. In addition, particles smaller than about 1 µm are not readily detected by conventional turbidity measurements. Turbidity can also result from the presence of mineral precipitates such as iron, manganese, calcium, or magnesium. Currently, groundwater treatment systems are not required to monitor turbidity.

In practice, the effectiveness of hydrogen sulfide oxidation is monitored indirectly by assessment of the chlorine residual. Because hydrogen sulfide is a reduced gas, the presence of a measurable chlorine residual is associated with the absence of hydrogen sulfide. However, under routine operation, it is not possible to determine the distribution of oxidation endproducts (i.e. the distribution between sulfur and sulfate).

### **Iron and manganese oxidation**

The amount of chlorine needed to oxidize iron and manganese is shown in the equations below. For complete oxidation of reduced iron, 0.6 mg of chlorine is required per mg of iron. For manganese oxidation, 1.3 mg of chlorine are required per mg of manganese. The rates of these reactions depend on pH, temperature, and other competitive oxidation reactions.



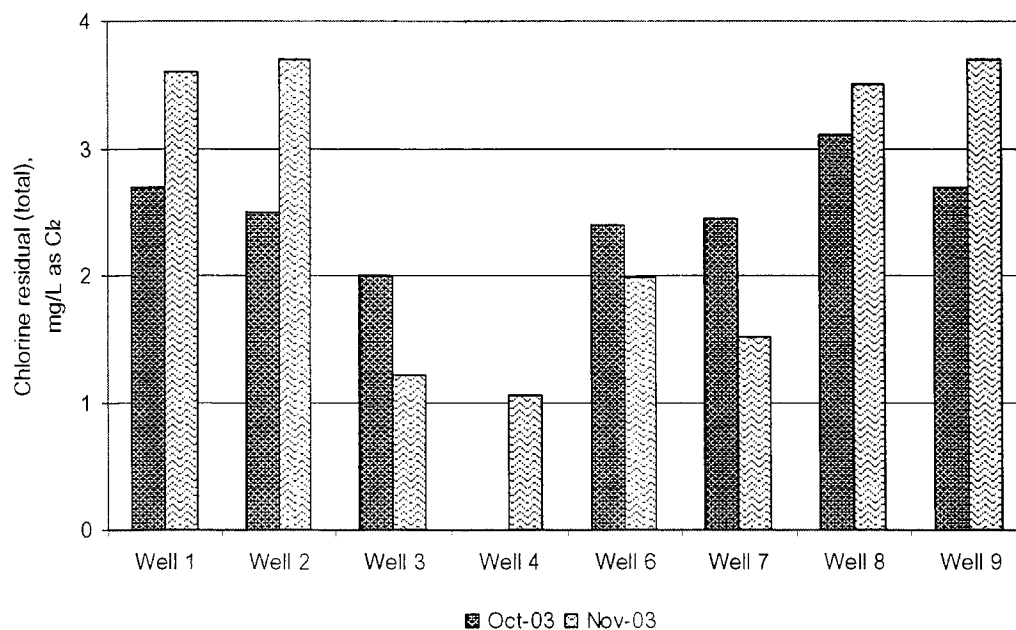
### **Chlorine dose analysis**

The amount of chlorine available at each well is related to the capacity of the chlorinator and the pump capacity. A comparison of the applied chlorine dose at each well for the two sampling events and the available chlorine dose is shown in Table 4 in comparison to the maximum available chlorine dose.

**Table 4. Comparison of the theoretical chlorine dose available at each well in the Seven Springs Water system with the estimated chlorine dose delivered on the two sampling dates.**

Well	Maximum available chlorine dose, mg/L	Chlorine dose 10-29-03	Chlorine dose, 11-12-03
1	8.3	6.9	6.5
2	20.8	13.5	7.6
3	41.7	15.3	16.6
4	41.7		8.3
Main plant: wells 1-4	27.8	4.9	12.7
6	18.5	15.3	13.9
7	18.5	6.0	4.3
8	25.0	18.4	18.9
9	25.0	24.6	23.8

The residual chlorine levels associated with each treated water sample are shown in Figure 13. As shown, there was adequate residual chlorine in each well implying that the hydrogen sulfide had been converted to a more oxidized form. In addition, there was no detectable hydrogen sulfide in the treated water measured at any of the wells on the two sample events.

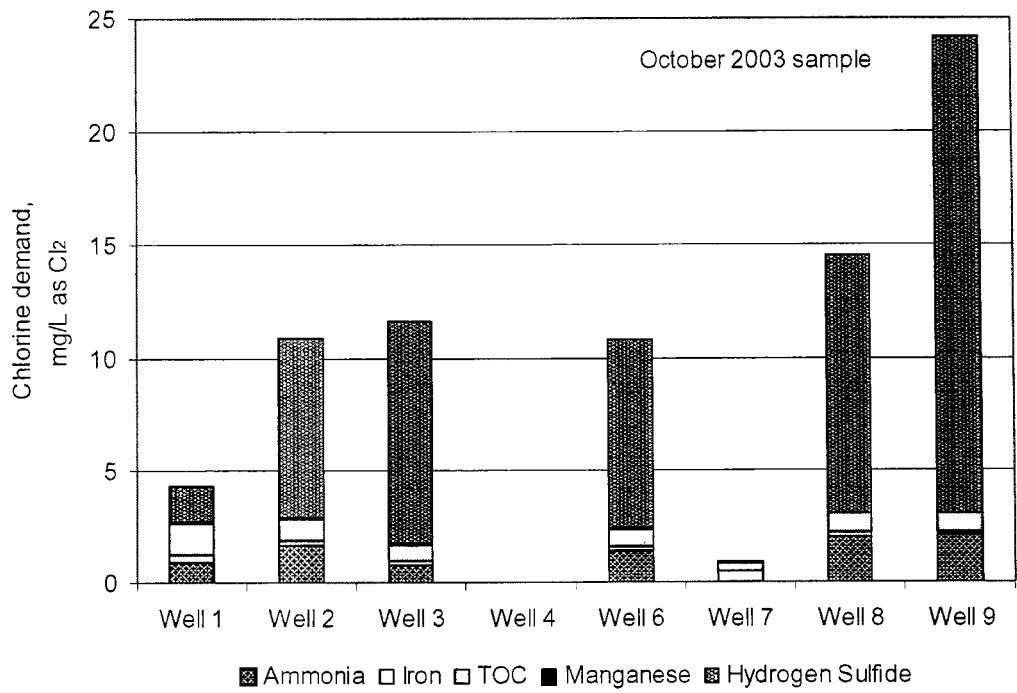


**Figure 13. Comparison of chlorine residuals in treated well water from the Seven Springs Water system sampled during October and November 2003.**

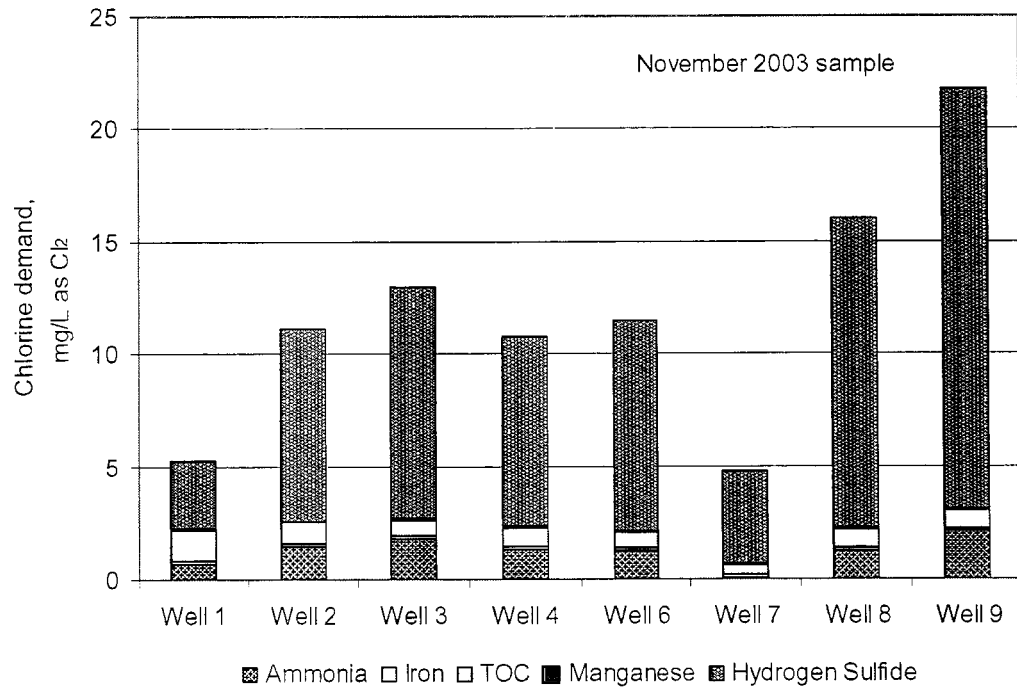
It is important to note that oxidation or precipitation of sulfide sequesters or converts odorous hydrogen sulfide to a less volatile form. However, oxidation reactions do not remove the sulfur and either form of sulfur (sulfate or sulfur) can revert back to hydrogen sulfide under conditions of low dissolved oxygen, low chlorine residual, the presence of metal catalysts, and/or when growth conditions are favorable for proliferation of sulfur reducing bacteria. The best approach for controlling the reversion to hydrogen sulfide is to maintain aerobic conditions and an adequate level of chlorine residual to inhibit growth of these microorganisms. Sulfate is naturally present in all groundwater and the levels of sulfate in the water from the Seven Springs System are relatively low. However, in parts of the system with long detention times (such as dead-ends), it is possible that conditions can become favorable for growth of sulfur reducing bacteria, particularly under summer conditions of high temperatures and lower water use. Thus, oxidation of hydrogen sulfide will eliminate odors but does not eliminate the potential for conversion to other forms of sulfur.

### **Chlorine demand analysis**

A comparison of the chlorine demand associated with each well for the October and November sampling is shown in Figure 14. In most cases, the dominant contributor to the chlorine demand was oxidation of hydrogen sulfide. For both sample events, water from well 9 had the highest chlorine demand.



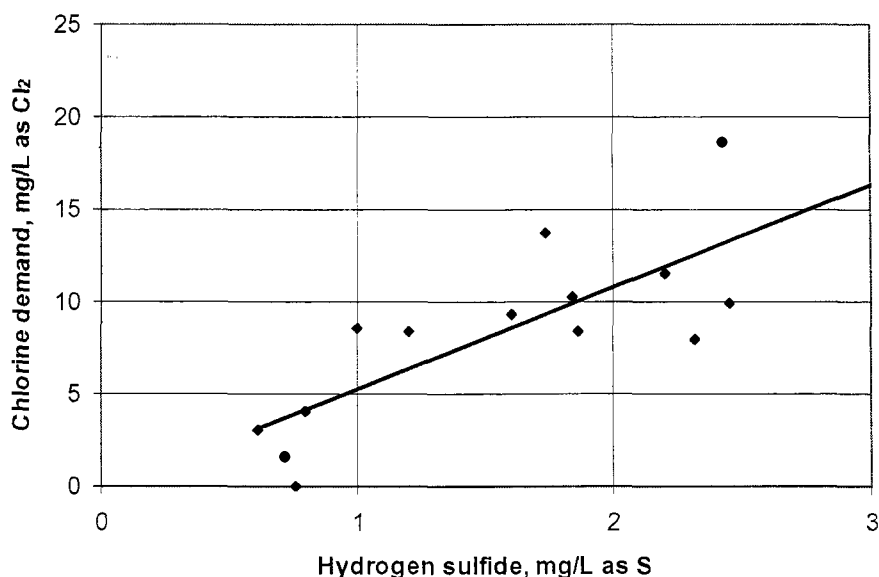
a. Comparison of chlorine demand for October 2003 water samples.



b. Comparison of chlorine demand for November 2003 water samples.

Figure 14. Summary of chlorine demand for water from the Seven Springs Water system.

The relationship between chlorine demand and hydrogen sulfide concentrations of the untreated water is shown in Figure 15. The chlorine demand was about 5.5 mg of chlorine per mg of hydrogen sulfide. This type of relationship has been reported previously (White, 1999) and is typical for oxidation of ground water. Typically, the transformation of hydrogen sulfide is not limited by the capacity of the chlorinators, but by the governing reaction rates and water quality variables (pH, temperature, alkalinity).



**Figure 15. Comparison of chlorine demand and hydrogen sulfide concentration for water from the Seven Springs Water system sampled during October and November 2003. The correlation coefficient,  $R^2$ , is 0.74.**

### *Water stability*

The stability of a water refers to the potential for the water to react with materials and form corrosion products. A variety of approaches are used to control water stability including modification of pH or alkalinity. Alternatively, a corrosion inhibitor can be added. In the Seven Springs Water System, a corrosion inhibitor has been used since 1996 for corrosion control. The chemical that is used is a poly-orthophosphate blend produced by Stiles Kem, (Aquadene Water Treatment Compound Series 7000, SK 7641). It is dosed into the water at each well at a concentration of about 1.5 mg/L as P and is monitored routinely. Polyphosphates form a passivating film on the pipe wall inhibiting the electrochemical processes that lead to corrosion (Cantor, 2000). The effectiveness of polyphosphates is related to the pH and the dissolved inorganic carbon concentration. Polyphosphates can also sequester metals such as iron and calcium.

A commonly used indicator of water stability is the Langelier Saturation Index (LSI). The LSI is computed from the pH, alkalinity, hardness, temperature, and total dissolved solids of each water sample. This index is a comparison of the saturation pH of water to the measured pH. A value of “zero” is considered neutral. A positive value for the LSI indicates that the water is scale forming and has the potential to form a scale on the inner surfaces of pipes, thereby mitigating the potential for corrosion. A negative value of the LSI indicates that the water has the potential to be corrosive.

In water that is treated by corrosion inhibitors, the LSI cannot be used to predict the water corrosivity due to the mechanism of action associated with the corrosion inhibitors. It can be used, however, as a basis for comparing water characteristics from different parts of the system. A comparison of the LSI for treated water from the Seven Springs system is shown in Figure 16. In general, the values are slightly negative and vary with sample location. The variations in LSI reflect the variations in water quality. To provide a reference point, the pH levels of the treated water are shown in Figure 17. As shown, higher values of pH correspond to higher values of LSI.

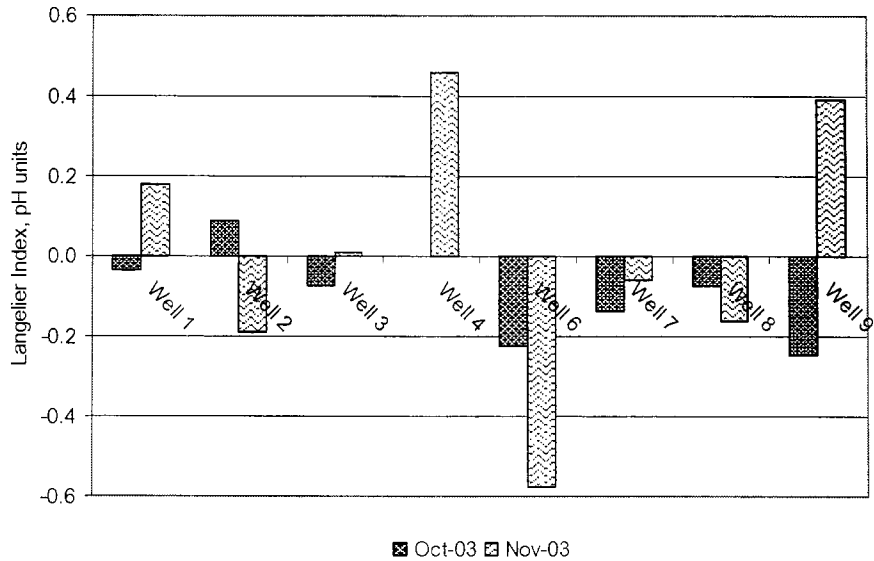


Figure 16. Comparison of the Langelier Saturation Index in treated well water from the Seven Springs Water system sampled during October and November 2003.

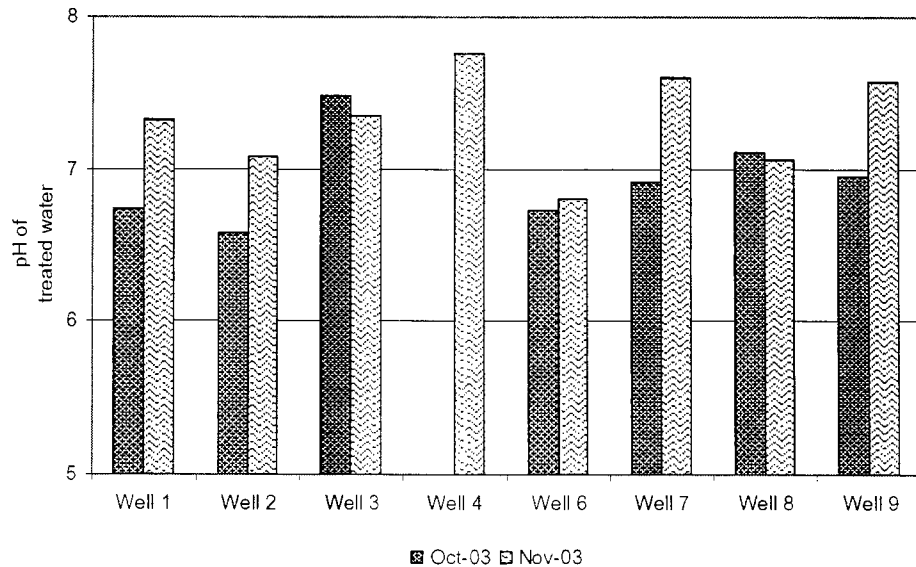


Figure 17. Comparison of the pH levels in treated well water from the Seven Springs Water system sampled during October and November 2003.

The LSI values for the main plant are shown in Figure 18 and for the distribution system samples are shown in Figure 19. The water entering the main plant is derived from a combination of wells 1-4 and the water quality characteristics reflect the combination of wells in service at any time. Water entering the main plant is rechlorinated before it re-enters the distribution system. Distribution system samples reflect the combination of wells in service at the time of sample collection. Water exiting from the Main Plant had positive LSI values for both sample events, whereas water from the distribution system was highly variable. Changes in pH and alkalinity that occur during water transmission impact the net stability of the water.

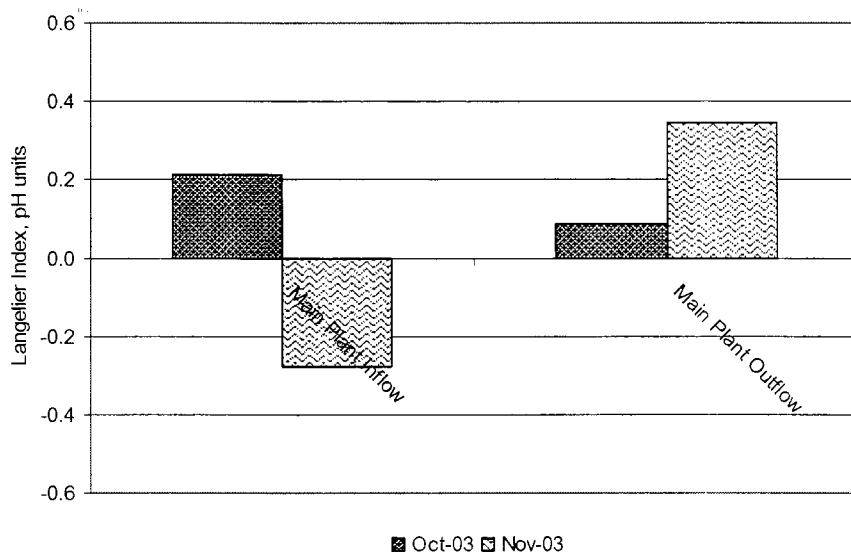


Figure 18. Comparison of the Langelier Saturation Index in the inflow and outflow from the Seven Springs Water System Main Plant sampled during October and November 2003.

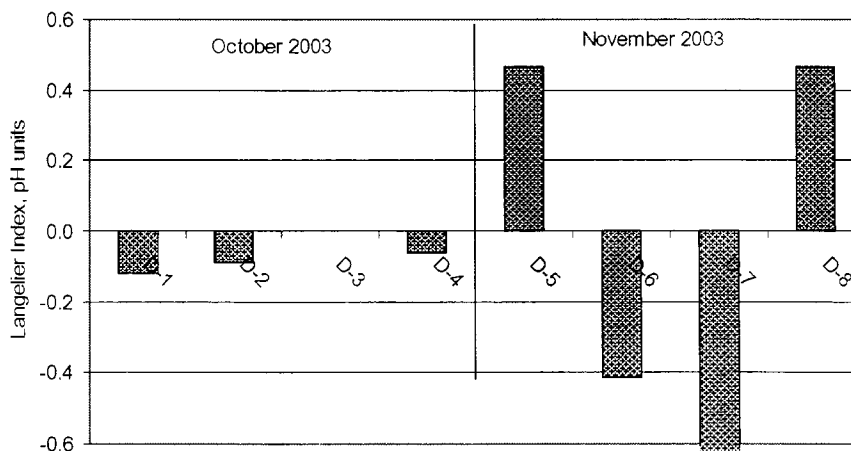


Figure 19. Comparison of the Langelier Saturation Index in distribution system samples collected from the Seven Springs Water system sampled during October and November 2003.



## Distribution System Analysis

Water quality characterization tests were conducted on samples from the distribution system in parallel with samples of untreated and treated water. In general, distribution system samples reflect the combination of wells in service at any given time. Water quality parameters for the distribution system samples were similar to values observed for the treated water. pH, alkalinity, and chlorine levels are shown in Figures 20, 21, and 22 for samples from the distribution system. As shown, these values are similar to the levels observed in the treated water (see Figures 10, 11, and 12). Chlorine levels tend to decrease with time due to reactions that occur within the transmission system. Chlorine levels in distribution samples collected during the October sampling ranged from 1.5 to 2.4 mg/L. During the November sampling, chlorine levels were between 1.1 and 1.7 mg/L.

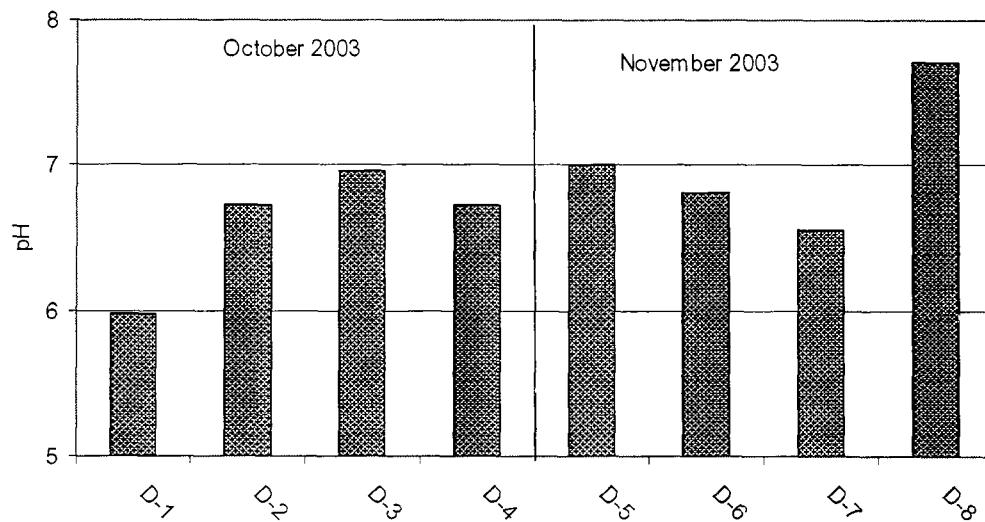


Figure 20. Comparison of the pH values in distribution system samples collected from the Seven Springs Water system sampled during October and November 2003.

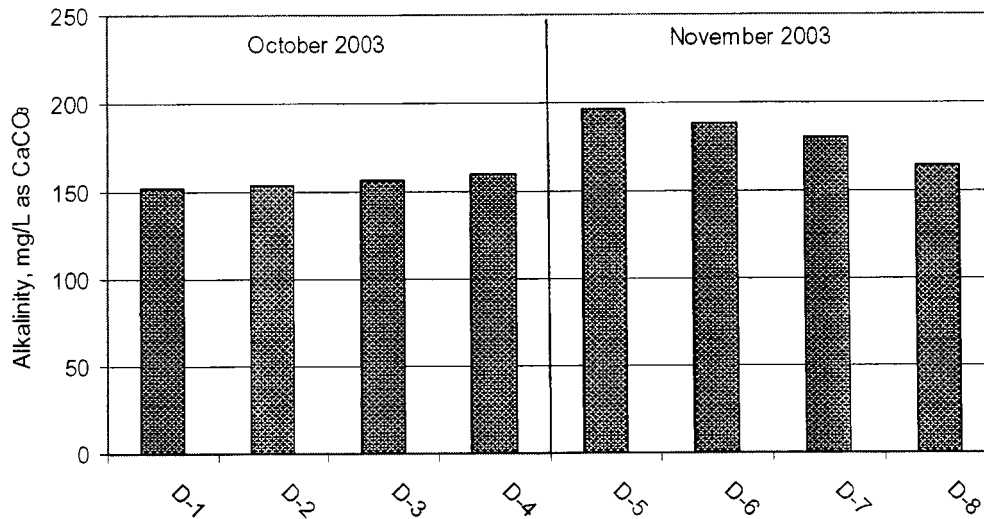


Figure 21. Comparison of the alkalinity values in distribution system samples collected from the Seven Springs Water system sampled during October and November 2003.

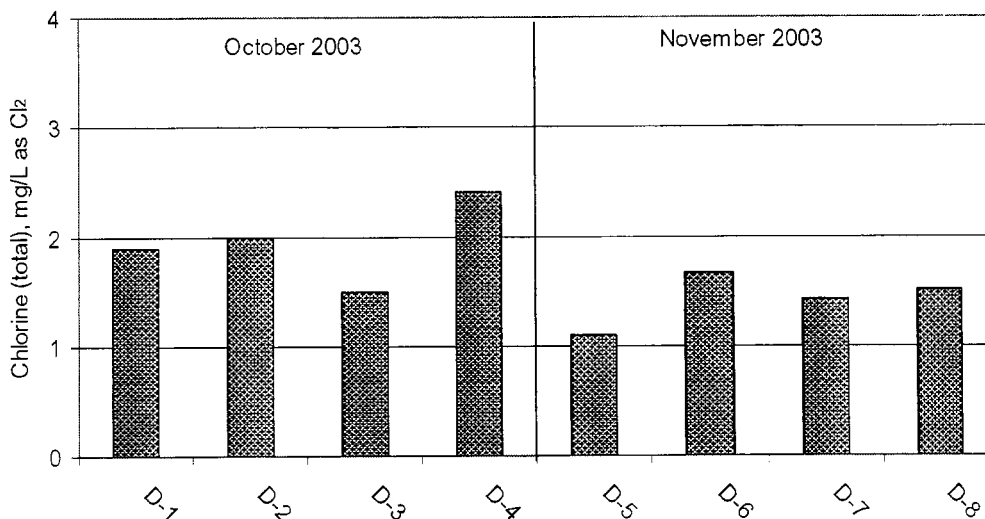


Figure 22. Comparison of the concentration of total chlorine in distribution system samples collected from the Seven Springs Water system sampled during October and November 2003.

A comparison of sulfate and chloride levels in each of the distribution system samples is shown in Figure 23. The variations observed in the levels of sulfate and chloride reflect differences in the combination of wells in service at the specific time and location of sampling. For this set of data, sulfate levels in wells 6, 7, 8, and 9 ranged from 5 to 22 mg/L with the highest levels associated with wells 7 and 9 for both sampling dates (see Figure 3). Distribution system samples that have sulfate levels over 15 mg/L most likely had a higher proportion of water from wells 7 and 9. Lower concentrations of sulfate reflect inputs from wells 6 and 8 and the main plant. Similar patterns can be observed for chloride, with the highest level of chloride associated with treated water from wells 7 and 9 (>30 mg/L), while the chloride levels in the wells 6 and 8 were above 25 mg/L and the other wells were below 20 mg/L (see Appendix). Based on this comparison, it is likely that the dominant source water for distribution system samples D-1, D-2, D-3, D-4, and D-8 was from a combination of wells 7 and 9 at the time of sampling. The dominant water sources in use when distribution samples D-5, D-6 and D-7 were collected most likely included the main plant and wells 6 through 9, whereas sample D-8 had a higher proportion of water from wells 7 and 9.

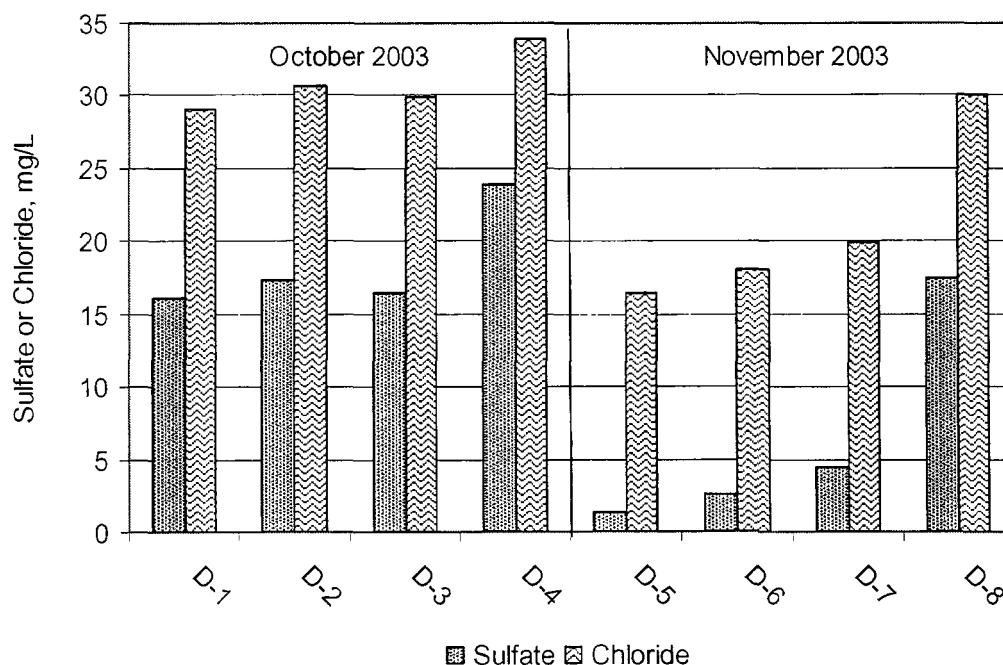


Figure 23. Comparison of the concentration of sulfate and chloride in distribution system samples collected from the Seven Springs Water system sampled during October and November 2003.

## Black Water Formation

Black water is a term used to describe water containing dark, suspended material. The occurrence of black water has been widely reported in the service area of the Seven Springs Water System. It is frequently associated with hot water lines, but has also been reported in cold water lines within residences. The black material causes staining of laundry and fixtures. As part of the Phase II testing, an effort was made to identify potential explanations for black water by characterizing particles present in the treated water from each well and in the distribution system samples. In addition, two samples of black water were obtained to provide a comparison between water entering the residence and black water.

### *Treated well water*

For each of the two sample events conducted for this study, the concentration of particles in the treated water was fairly low. There was no measureable hydrogen sulfide in any of the treated water samples and they all contained an adequate chlorine residual. The suspended solids concentration was below the detection limits of the test ( $< 1$  mg/L).

Particles from samples of treated well water were concentrated about 25 fold using centrifugation. The particles were resuspended in water, preserved with chemical fixative, dehydrated, collected on a filter with a pore size of  $0.01\ \mu\text{m}$ , coated, and analyzed using electron microscopy coupled with X-Ray analysis to determine the particle size and elemental composition of the particles. In most cases, the particle density was extremely low.

Examples of the particles isolated from treated water from well 8 are shown in Figure 24. The number of particles in all of the well samples was extremely low ( $< 100/\text{mL}$ ). The smaller, spherical particles ( $< 1\ \mu\text{m}$ ) were composed of iron, sulfur, and phosphate, whereas the larger particles ( $> 5\ \mu\text{m}$ ) contained a higher proportion of sulfur. The particle size of the sulfur-rich particles varied from  $0.1$  to over  $10\ \mu\text{m}$ . These particles are small enough to remain suspended in the water, but could accumulate in locations that have low velocities and a long residence time (dead-ends).

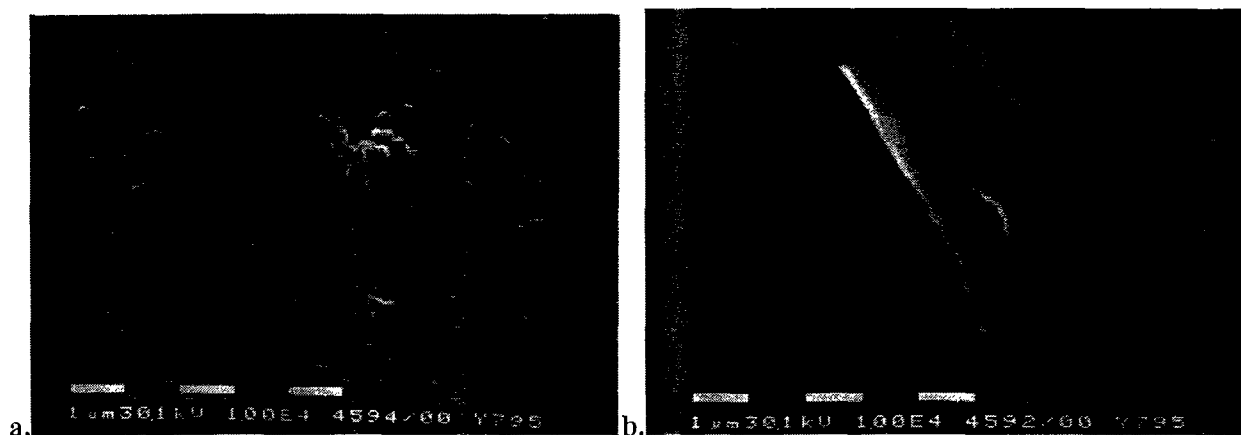
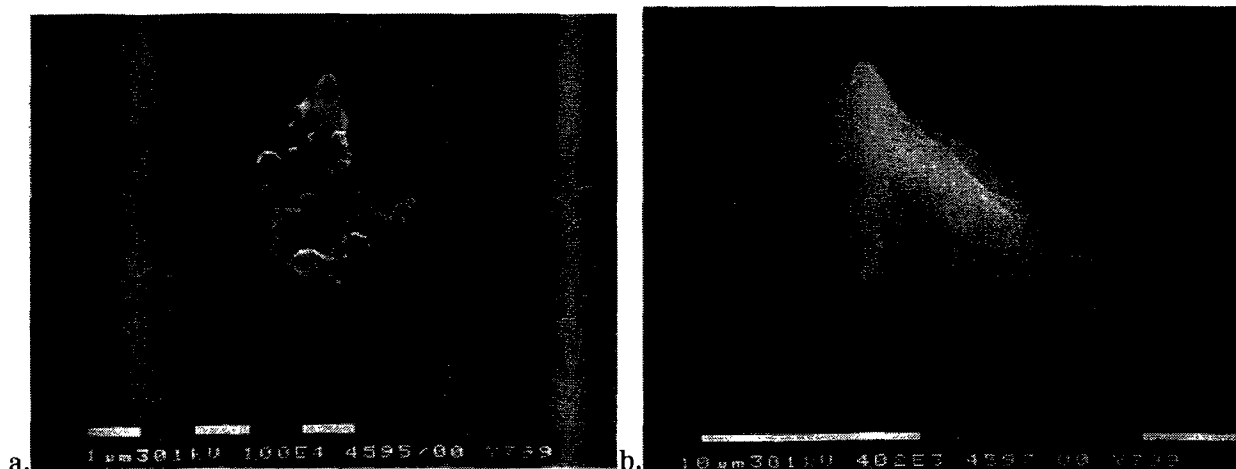


Figure 24. Comparison of electron micrographs of particles isolated from treated water from well 8. a) particles consisting of iron-phosphorus-sulfur; b) particles consisting of sulfur and organic material. The scale in the micrograph is depicted by the white bar ( $1\ \mu\text{m}$ ).

### *Distribution system samples*

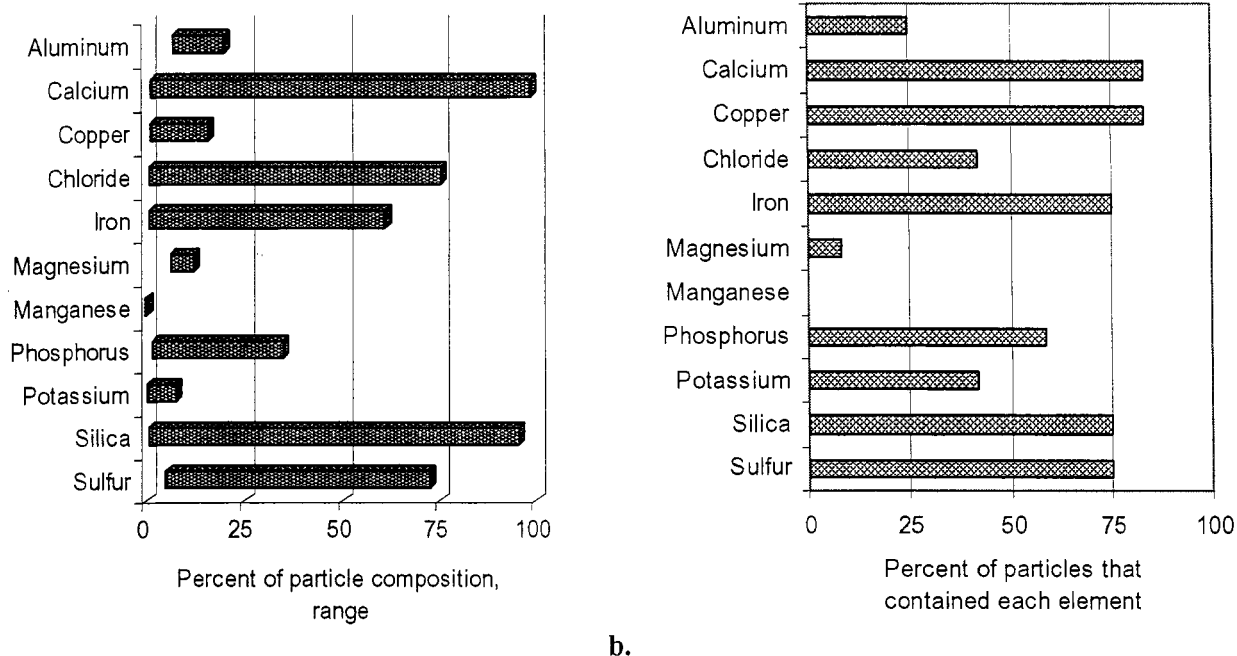
A comparison of particles isolated from the Main Plant inflow is shown in Figure 25. Again, the concentration of particles was fairly low and the composition of the particles was similar to that observed for samples from the treated well water. The smaller particles contained iron and sulfur with trace amounts of phosphorus, whereas the larger particles consisted of calcium-sulfur precipitates.



**Figure 25.** Comparison of electron micrographs of particles isolated from treated water from the main plant inflow. a) particles consisting of iron-phosphorus-sulfur; b) particles consisting of sulfur and calcium. The scale in the micrograph is depicted by the white bar (1  $\mu\text{m}$  for a and 10  $\mu\text{m}$  for b).

A comparison of the dominant elements identified in particles from the distribution system (treated well water, main plant, and distribution system samples) and the percent of particles that contained each element is shown in Figure 26. Calcium, silica, chloride, sulfur, and iron were the dominant constituents of the particles isolated from the distribution system. Calcium, copper, iron, silica, and sulfur were the most frequently detected elements. Aluminum, chloride, potassium, and magnesium were detected less frequently. All particles that contained phosphorus also contained calcium and copper and most contained iron. The presence of sulfur in a particle also corresponded to the presence of varying amounts of iron and calcium. All particles that contained copper also contained calcium, iron, sulfur, and silica.

The formation of particles in the distribution system results from chemical solubility reactions that occur within the pipeline and result in the formation of insoluble particles. Calcium, iron, and sulfur are all present in the untreated water. In this study, the concentration of silica was not measured, however its source is either from the wells or from exposure to concrete piping materials. The phosphorus is added to the water as a corrosion inhibitor and it functions as a complexing and sequestering agent for metals and minerals. The concentration of aluminum was not measured as part of this study, but it is probably associated with the source of silica. Trace levels of copper were detected in the distribution system samples and ranged from 0.04 to 0.14 mg/L. The source of the copper is either from the water pipes or from the fixtures in the home (Neff et al. 1987).



**Figure 26. Comparison of distribution of dominant elements in particles isolated from the distribution system (well water, main plant, distribution system samples). a) relative percent of particle composition, b) percent of particles that contained each element.**

***Black water samples from residential plumbing***

This study was focused on analysis of untreated water, treated water, and distribution system water. Therefore, analysis of black water samples was not a primary objective of the study. Preliminary information on black water characteristics was obtained from two sites. During the distribution system sampling, samples of black water were collected on an ad hoc basis from two residences (D-2 and D-7). In one case (D-2b) the sample was from the hot water tank, in the other case (D-7b), the sample was from a hot water faucet that serves the bathtub. The samples were characterized in parallel with the other distribution system samples and particles were examined to evaluate particle size and particle composition. In general, the chemical composition of the samples of black water was similar to the samples of water entering the residences with the exception of the quantity of iron and copper associated with the particles. A comparison of iron and copper levels in the water entering the residence and the black water samples is shown in Figure 27. As shown, in both cases, the black water contained significantly higher levels of copper and iron. In both cases, there was a slight increase in the sulfate concentration associated with the black water (~5 mg/L).

Very few particles were detected in the distribution system samples and the majority of the particles were similar in composition to the particles isolated from the treated well water and the main plant (see Figures 24 and 25). Examples of particles isolated from distribution samples D-2 and D-7 are shown in Figure 28. The particles from D-2 are composed of silica, aluminum, sulfur, iron, phosphorus, copper and calcium. Particles isolated from D-7 are composed of phosphorus, sulfur, calcium, and silica.

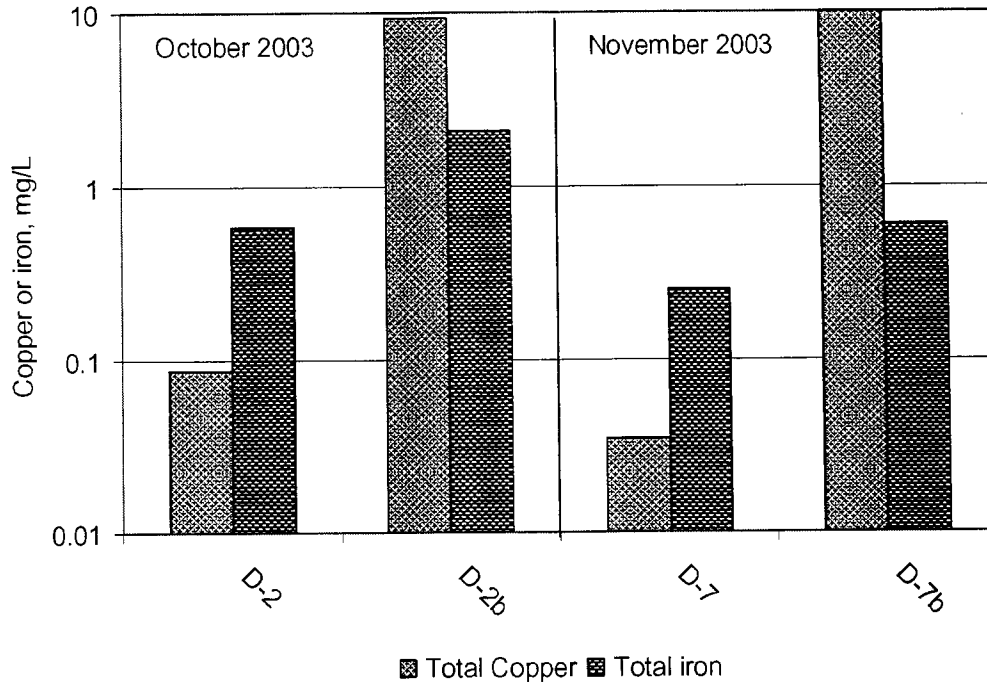


Figure 27. Comparison of total copper and total iron associated with distribution system water (D-2 and D-7) and black water from hot water tank(D-2b) and hot water faucet (D-7b).

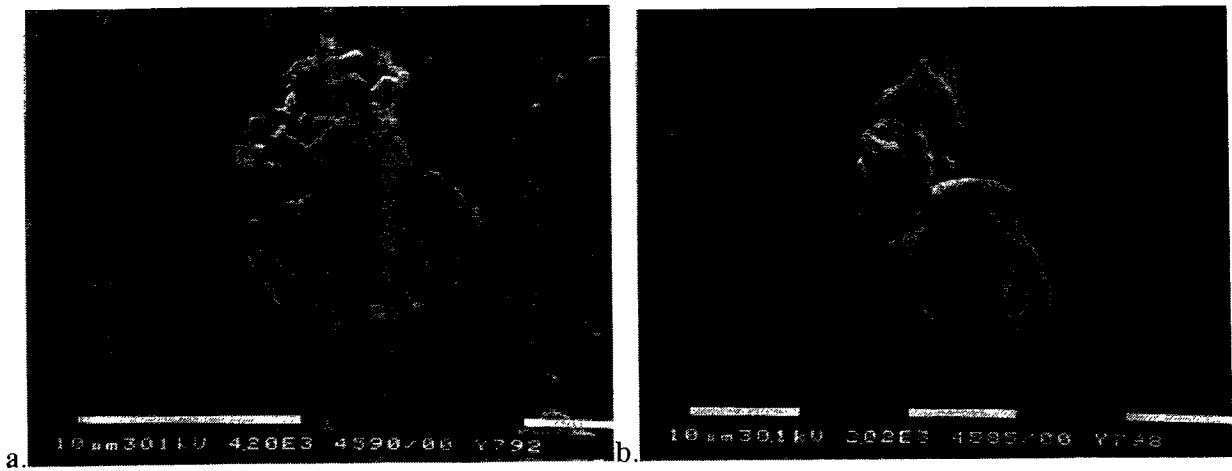
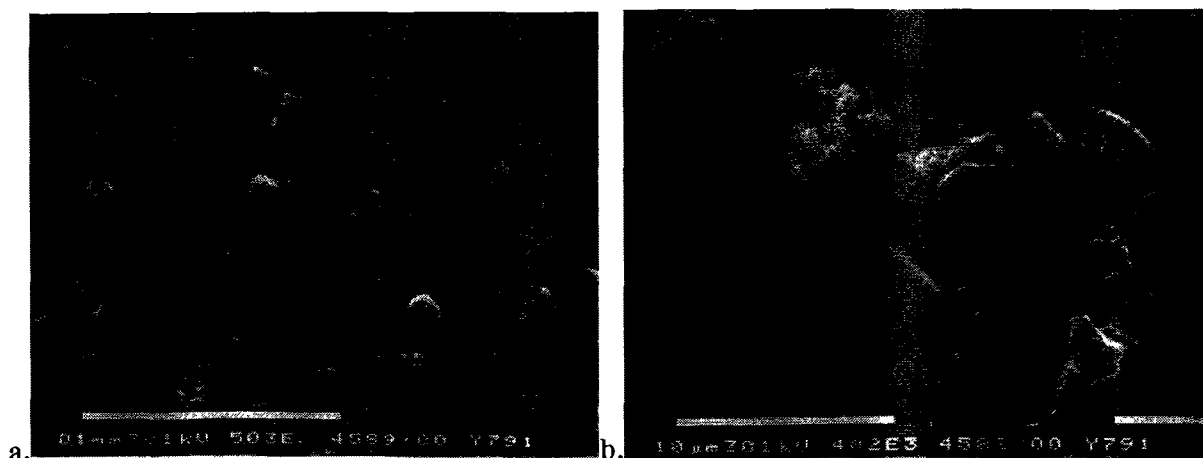
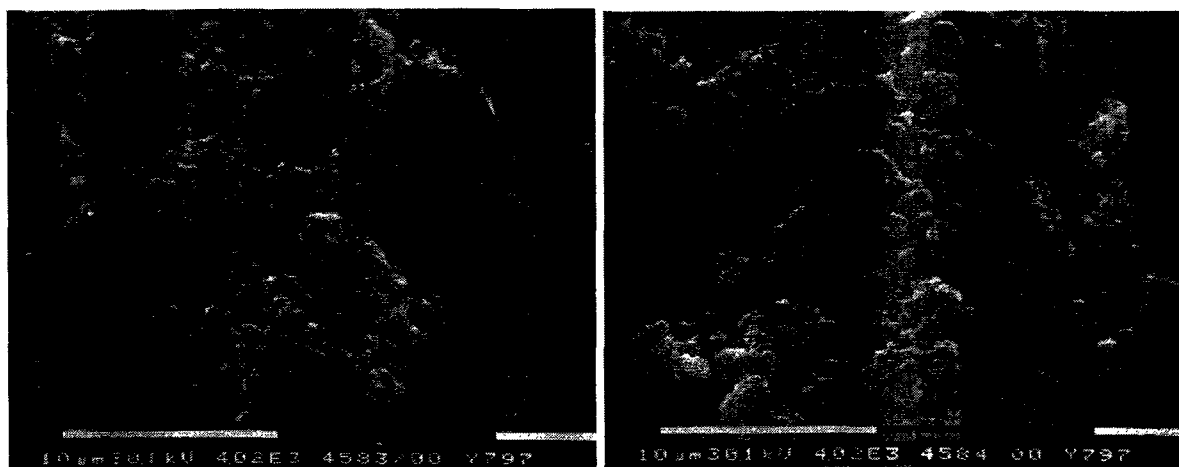


Figure 28. Comparison of electron micrographs of particles isolated from distribution system samples D-2 and D-7. a.) Particles isolated from D-2 consist of silica-aluminum-sulfur-iron-phosphorus-copper-calcium. b.) Particles isolated from D-7 consist of phosphorus- sulfur- -calcium-silica. The scale in the micrograph is depicted by the white bar (10  $\mu$ m).

Samples of black water were processed for examination by electron microscopy. Examples of particles isolated from sample D-2b are shown in Figure 29. This sample was dominated by the presence of aluminum. The spherical particles are composed of aluminum, copper, phosphorus, and iron. Examples of particles isolated from sample D-7b are shown in Figure 30. There was no evidence of aluminum in the particles from sample D-7b and the dominant elements in the particles were copper, sulfur, and phosphorus.



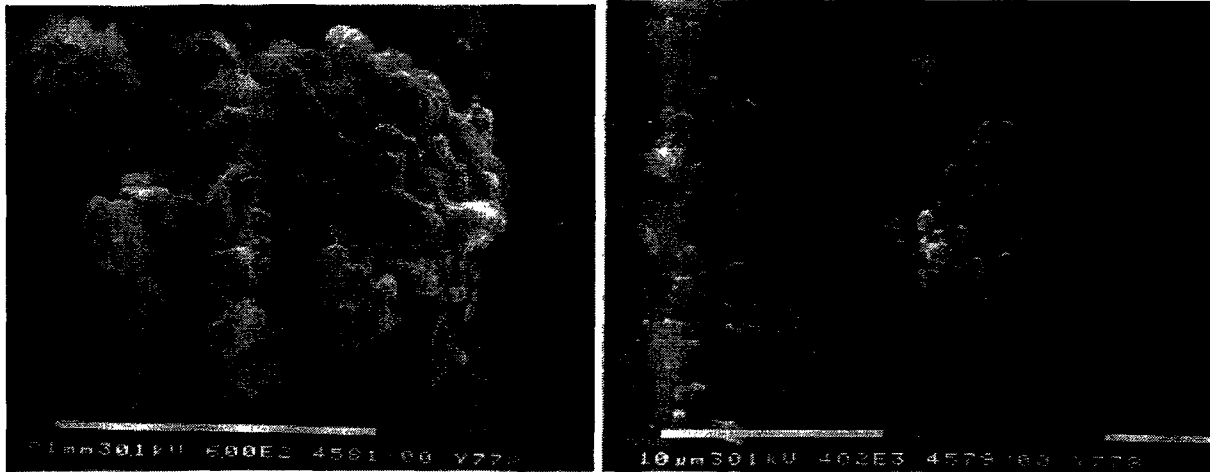
**Figure 29. Comparison of electron micrographs of particles isolated from sample D-2b. Particles consist of aluminum-copper-sulfur-iron-phosphorus-calcium. The smaller particles are predominantly aluminum-phosphorus. The scale in the micrographs is depicted by the white bar (100  $\mu\text{m}$  or 10  $\mu\text{m}$ ).**



**Figure 30. Comparison of electron micrographs of particles isolated from sample D-7b. Particles consist of copper-sulfur-phosphorus with some calcium and iron present. The scale in the micrographs is depicted by the white bar (10  $\mu\text{m}$ ).**

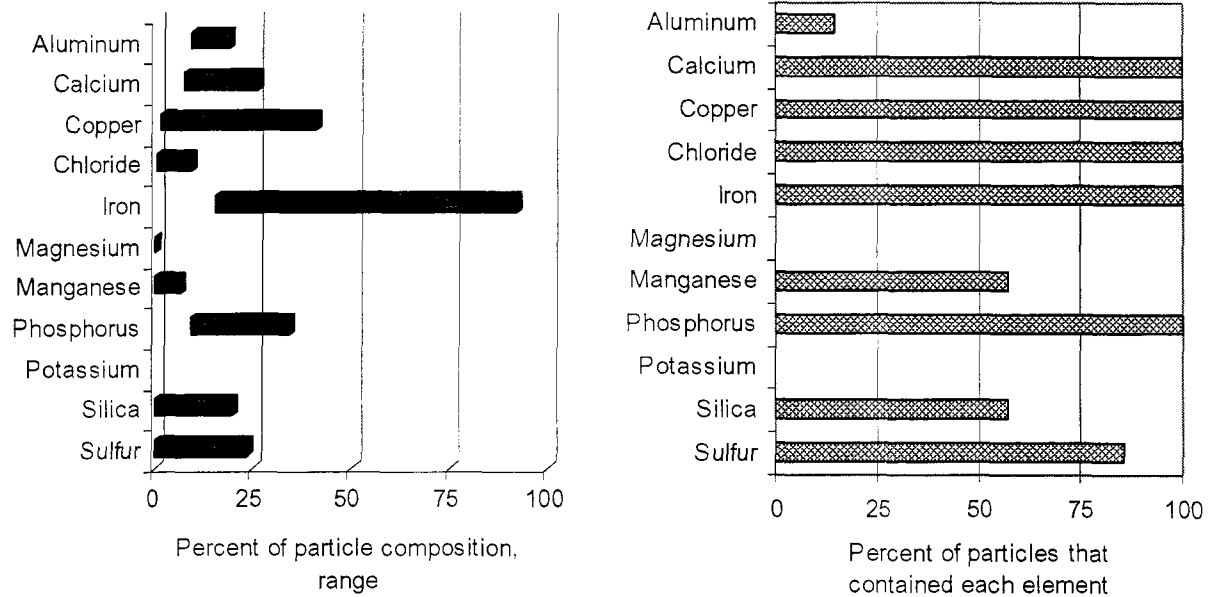
An additional analysis was conducted on particles isolated from a whole house water filter obtained from a residence in the Seven Springs service area. The particles were removed from the filter and processed for electron microscopy. Examples of the particles isolated from the filter are shown in Figure 31. The dominant elements in the particles were iron, phosphorus, calcium, and sulfur.





**Figure 31. Comparison of electron micrographs of particles isolated from a household water filter that is used to filter water entering the house. Particles consist of iron-phosphorus-calcium or iron-sulfur with trace amounts of copper. The scale in the micrographs is depicted by the white bar (100  $\mu\text{m}$  or 10  $\mu\text{m}$ ).**

A comparison of the elemental composition of particles isolated from the filter is shown in Figure 32. The dominant element in the particles was iron. Calcium, copper, chloride, iron, and phosphorus were identified in all of the particles.



**Figure 32. Comparison of distribution of dominant elements in particles isolated from a water filter installed on the inflow to a residence a) relative percent of particle composition, b) percent of particles that contained each element.**

## Discussion

This report is an effort to understand the problem of black water formation within the Seven Springs Water System. The data collected and compiled for this report provide comprehensive water quality information on the untreated and treated water that serves the Seven Springs Water System. In general, water quality associated with the Seven Springs Water System does not differ dramatically from other water sources derived from the Floridian Aquifer. The variations of pH, alkalinity, hardness, sulfate, chloride, hydrogen sulfide, iron, ammonia, and organic carbon are all within typical ranges associated with water from this region of Florida.

The existing treatment process is effective for converting hydrogen sulfide to more oxidized forms such as elemental sulfur, polysulfides, and sulfates. However, iron and manganese in the water can complex with sulfur or phosphorus and form particulate matter. As the water travels through the distribution system, the potential to form particles is related to the presence of dissolved metals and the availability of sulfur and phosphate to complex with those metals. Once the water contacts copper pipes, copper can be solubilized. The extent of copper solubilization depends on the water temperature, contact time within the pipeline, and the effectiveness of corrosion control measures. The reactions with copper pipes are either due to chemical or biological mechanisms and result in the release of copper that can complex with sulfur or phosphate. The current corrosion control practice of adding polyphosphate appears to satisfy the requirements of the lead and copper rule (see Phase I report), however there is some evidence that the phosphates added as corrosion inhibitors complex with aluminum, iron, or copper to form particulate matter. The source of the aluminum is unknown but it could be solubilized from components of hot water tanks or from impurities in water conduits.

Several potential options are available to modify the existing treatment system. Removal of hydrogen sulfide can be accomplished using packed tower aeration. However, the use of packed tower aeration can promote biological growth in the aeration system and lead to release of microorganisms and elemental sulfur into the distribution system (Duranceau, 2003; Levine, 2004). Another approach is to use an alternative oxidant such as hydrogen peroxide or ozone to oxidize the hydrogen sulfide and other reduced constituents. The use of an alternative oxidant would decrease the chlorine demand and provide for more efficient disinfection using chloramination. However, there is no guarantee that the use of either packed tower aeration or alternative disinfection can completely alleviate the black water problem.

## Conclusions

The purpose of this report was to assess available information on the Seven Springs Water System and collect supplemental water quality data. The Seven Springs Water System, as it is currently operated, meets all relevant water quality regulations for potable water systems imposed by the USEPA and the Florida DEP. However, there is a need to reduce the recurrence of black water problems within the system.

The major conclusions from this Phase II report are:

1. The levels of hydrogen sulfide associated with each well are somewhat variable. Wells that have higher levels of hydrogen sulfide also tend to have higher levels of iron and ammonia.
2. Levels of hydrogen sulfide detected in the untreated water ranged from 0.6 to 3.95 mg/L. A trace amount of hydrogen sulfide was detected in the influent to the main plant (0.12 mg/L) during the November sampling.
3. Based on testing of the treatment at each well, chlorine is effective for converting the hydrogen sulfide to elemental sulfur, polysulfides, and sulfate.
4. For the two sets of samples that were collected for this project, there was no evidence of hydrogen sulfide in any of the treated water samples collected at the wells.
5. There was no evidence of chlorine in the untreated water from any of the wells.
6. The concentration of suspended solids in all of the water samples (untreated, treated, and distribution system) was below detection limits ( $< 1$  mg/L)
7. The black water particles that are formed within residential plumbing consist of sulfur, iron, copper, phosphorus, manganese, calcium, and aluminum.

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**APPENDIX:**  
**SUMMARY OF DATA FROM FIELD SAMPLE COLLECTION**

*A: Samples collected on 10-29-03*

**Water Quality Analyses**  
**Aloha Utilities; Seven Springs Water System**

<b>Collection Date:10/29/2003</b>	<b>Well 1 Inflow</b>	<b>Well 1 Outflow</b>	<b>Well 2 Inflow</b>	<b>Well 2 Outflow</b>	<b>Well 3 Inflow</b>	<b>Well 3 Outflow</b>
Sample Time	11:30	11:55	10:50	11:15	19:10	19:30
Flow Rate, gpm	960		400		152	
Alkalinity, mg/L as CaCO <sub>3</sub>	196	164	168	150	156	138
pH field	6.42	6.74	7.43	6.58	7.90	7.48
pH lab	7.31	7.30	7.72	7.46	7.59	7.37
Temperature, ° C	25.1	24.6	25.9	25.1	21.2	23.7
Chlorine, mg/L as Cl <sub>2</sub>						
Free, mg/L as Cl <sub>2</sub>		>2.2		2.1		>2.2
Total, mg/L as Cl <sub>2</sub>	<0.01	>2.2	<0.01	>2.2	<0.01	> 2.2
Hydrogen sulfide, mg/L as S	0.72	<0.01	2.32	<0.01	2.45	<0.01
Conductivity, µS/cm	454	466	390	400	383	397
Nitrogen						
Ammonia, mg/L NH <sub>3</sub> - N	0.12	<0.01	0.22	<0.01	0.10	<0.01
Nitrate, mg/L NO <sub>3</sub> - N	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Anions						
Chloride, mg/L	10.65	14.92	8.56	19.44	8.18	19.80
Sulfate, mg/L	<0.1	<0.1	2.26	3.12	11.12	11.35
Cations						
Calcium, mg/L	62.11	57.02	56.34	57.02	51.79	53.43
Magnesium, mg/L	7.64	7.58	5.73	5.68	6.85	6.91
Manganese, mg/L	0.04	0.05	0.03	0.02	0.03	0.03
Copper (total), mg/L	0.03	0.04	0.03	0.05	0.05	not measured
Iron, mg/L						
Dissolved						not measured
Total	0.50	0.44	0.27	0.44	0.30	measured
Total Hardness, mg/L as CaCO <sub>3</sub>	187	174	165	166	158	162
TOC, filtered, mg/L	4.70	4.67	3.33	3.43	2.45	2.41

**Data from Short Environmental Laboratories**

<b>Collection date: 10-29-03</b>	<b>Well 1 Inflow</b>	<b>Well 1 Outflow</b>	<b>Well 2 Inflow</b>	<b>Well 2 Outflow</b>	<b>Well 3 Inflow</b>	<b>Well 3 Outflow</b>
pH (field)	6.62	6.88	6.87	6.85	7.43	7.16
Temperature, ° C	23.8	23.8	24.9	25.0	24.7	24.7
Dissolved Oxygen, mg/L	0.25	1.23	0.37	0.86	0.28	1.84
Free, mg/L as Cl <sub>2</sub>	<0.01	2.10	<0.01	2.20	<0.01	2.00
Total, mg/L as Cl <sub>2</sub>	<0.01	2.70	<0.01	2.50	<0.01	2.00
Hydrogen sulfide, mg/L as S	0.05	<0.01	1.14	<0.01	2.08	<0.01
Conductivity (µS/cm)	478	480	406	416	400	412
Sulfate (mg/L)	<1	<1	<1	<1	11	13
Iron, dissolved mg/L	0.18	0.17	0.04	0.22	0.03	0.03
Total Suspended Solids, mg/L	<1	<1	<1	<1	<1	<1

**Water Quality Analyses**  
**Aloha Utilities; Seven Springs Water System**

<b>Collection Date:10/29/2003</b>	<b>Well 6 Inflow</b>	<b>Well 6 Outflow</b>	<b>Well 7 Inflow</b>	<b>Well 7 Outflow</b>
Sample Time	13:40	14:10	12:50	13:10
Flow Rate, gpm	425		290	
Alkalinity, mg/L as CaCO <sub>3</sub>	148	148	126	120
pH field	7.13	6.73	7.11	6.91
pH lab	7.59	7.15	7.67	7.36
Temperature, ° C	25.2	24.4	24	24.6
Chlorine, mg/L as Cl <sub>2</sub>				
Free, mg/L as Cl <sub>2</sub>		>2.2		>2.2
Total, mg/L as Cl <sub>2</sub>	<0.01	>2.2	<0.01	>2.2
Hydrogen sulfide, mg/L as S	1.87	<0.01	0.76	<0.01
Conductivity, µS/cm	388	392	420	422
Nitrogen				
Ammonia, mg/L NH <sub>3</sub> - N	0.18	<0.01	<0.01	<0.01
Nitrate, mg/L NO <sub>3</sub> - N	<0.1	<0.1	1.41	1.30
Anions				
Chloride, mg/L	13.77	24.58	31.35	31.23
Sulfate, mg/L	5.14	7.11	16.54	14.58
Cations				
Calcium, mg/L	55.74	57.03	53.41	53.20
Magnesium, mg/L	3.75	3.65	3.32	3.26
Manganese, mg/L	0.03	0.02	0.03	0.03
Copper (total), mg/L	0.07	0.06	0.05	0.06
Iron, mg/L				
Dissolved				
Total	0.39	0.37	0.74	0.83
Total Hardness, mg/L as CaCO <sub>3</sub>	155	158	147	147
TOC, filtered, mg/L	2.55	2.53	1.21	1.30

**Data from Short Environmental Laboratories**

<b>Collection Date: 10/29/2003</b>	<b>Well 6 Inflow</b>	<b>Well 6 Outflow</b>	<b>Well 7 Inflow</b>	<b>Well 7 Outflow</b>
pH (field)	7.30	6.96	7.20	7.19
Temperature, ° C	24.2	24.2	24.3	28.4
Dissolved Oxygen, mg/L	0.17	0.67	0.34	0.80
Free, mg/L as Cl <sub>2</sub>	<0.01	2.00	<0.01	2.45
Total, mg/L as Cl <sub>2</sub>	<0.01	2.40	<0.01	2.45
Hydrogen sulfide, mg/L as S	1.46	<0.01	0.08	<0.01
Conductivity (µS/cm)	400	410	437	451
Sulfate (mg/L)	6.1	9.8	17	10
Iron, dissolved mg/L	0.08	0.09	0.04	0.05
Total Suspended Solids, mg/L	<1	<1	<1	<1

**Water Quality Analyses  
Aloha Utilities; Seven Springs Water System**

<b>Collection Date:10/29/2003</b>	<b>Well 8 Inflow</b>	<b>Well 8 Outflow</b>	<b>Well 9 Inflow</b>	<b>Well 9 Outflow</b>
Sample Time	17:35	17:55	18:15	18:40
Flow Rate, gpm	544		355	
Alkalinity, mg/L as CaCO <sub>3</sub>	182	162	168	149
pH field	7.43	7.11	7.42	6.95
pH lab	7.57	7.24	7.63	7.09
Temperature, ° C	24.6	23.9	24.3	24
Chlorine, mg/L as Cl <sub>2</sub>				
Free, mg/L as Cl <sub>2</sub>		>2.2		>2.2
Total, mg/L as Cl <sub>2</sub>	<0.01	>2.2	<0.01	>2.2
Hydrogen sulfide, mg/L as S	2.20	<0.01	3.95	<0.01
Conductivity, µS/cm	445	467	473	498
Nitrogen				
Ammonia, mg/L NH <sub>3</sub> - N	0.26	<0.01	0.27	<0.01
Nitrate, mg/L NO <sub>3</sub> - N	<0.1	<0.1	<0.1	<0.1
Anions				
Chloride, mg/L	9.97	24.53	12.10	36.28
Sulfate, mg/L	9.12	11.27	22.19	24.82
Cations				
Calcium, mg/L	62.73	62.02	63.86	64.79
Magnesium, mg/L	7.02	6.98	7.35	7.31
Manganese, mg/L	0.03	0.03	0.03	0.02
Copper (total), mg/L	0.03	0.09	0.04	0.06
Iron, mg/L				
Dissolved				
Total	0.32	0.65	0.29	0.46
Total Hardness, mg/L as CaCO <sub>3</sub>	186	184	190	192
TOC, filtered, mg/L	2.77	2.81	2.63	2.69

**Data from Short Environmental Laboratories**

<b>Collection Date:10/29/2003</b>	<b>Well 8 Inflow</b>	<b>Well 8 Outflow</b>	<b>Well 9 Inflow</b>	<b>Well 9 Outflow</b>
pH (field)	7.27	7.15	7.36	7.08
Temperature, ° C	24.6	24.5	24.9	24.8
Dissolved Oxygen, mg/L	0.49	0.75	0.26	1.39
Free, mg/L as Cl <sub>2</sub>	<0.01	2.50	<0.01	2.35
Total, mg/L as Cl <sub>2</sub>	<0.01	3.10	<0.01	2.70
Hydrogen sulfide, mg/L as S	2.11	<0.01	3.84	0.04
Conductivity (µS/cm)	465	480	494	512
Sulfate (mg/L)	10	6.4	22	25
Iron, dissolved mg/L	0.05	0.06	0.03	0.03
Total Suspended Solids, mg/L	<1	<1	<1	<1



**Water Quality Analyses**  
**Aloha Utilities; Seven Springs Water System**

<b>Collection Date:10/29/2003</b>	<b>Main Plant Inflow</b>	<b>Main Plant Outflow</b>	<b>D-1</b>	<b>D-2</b>	<b>D-2b</b>	<b>D-3</b>	<b>D-4</b>
Sample Time	19:50	20:00	16:05	15:40	15:40	16:45	15:00
Flow Rate, gpm	340.7		9.375	12			12
Alkalinity, mg/L as CaCO <sub>3</sub>	168	178	152	154	166	156	160
pH field	7.29	7.32	5.97	6.73	not measured	6.96	6.73
pH lab	7.51	7.37	7.17	7.20	7.53	7.26	7.20
Temperature, ° C	24	23	27	26.5	not measured	26.5	27.5
Chlorine, mg/L as Cl <sub>2</sub>							
Free, mg/L as Cl <sub>2</sub>			4.3	1.7	not measured	3.1	2.5
Total, mg/L as Cl <sub>2</sub>			5.0	2.0	not measured	3.7	3.0
Hydrogen sulfide, mg/L as S	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Conductivity, µS/cm	443	437	478	476	402	480	476
Nitrogen							
Ammonia, mg/L NH <sub>3</sub> - N	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate, mg/L NO <sub>3</sub> - N	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Anions							
Chloride, mg/L	17.83	21.43	29.12	30.73	37	29.91	33.83
Sulfate, mg/L	4.14	5.18	16.09	17.31	24	16.44	23.92
Cations							
Calcium, mg/L	61.46	61.62	63.79	63.86	58	67.24	63.43
Magnesium, mg/L	7.47	7.19	7.00	7.02	7.48	7.08	7.09
Manganese, mg/L	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Copper (total), mg/L	0.05	0.07	0.09	0.09	9.33	0.14	0.06
Iron, mg/L							
Dissolved							
Total	0.43	0.47	0.40	0.59	2.21	0.34	0.47
Total Hardness, mg/L as CaCO <sub>3</sub>	185	184	189	189	177	198	188
TOC, filtered, mg/L	2.47	3.72	2.71	2.73	not measured	2.69	2.95

**Data from Short Environmental  
Laboratories**

<b>Collection date: 10-29-03</b>	<b>Main Plant Inflow</b>	<b>Main Plant Outflow</b>	<b>D-1</b>	<b>D-2</b>	<b>D-3</b>	<b>D-4</b>
pH (field)	7.11	7.11	7.00	6.99	6.92	6.89
Temperature, ° C	24.8	25.0	26.1	26.7	26.5	27.2
Dissolved Oxygen, mg/L	1.65	1.94	1.06	0.75	1.76	1.34
Free, mg/L as Cl <sub>2</sub>	1.85	2.80	1.85	1.60	1.40	1.90
Total, mg/L as Cl <sub>2</sub>	1.85	3.00	1.90	1.80	1.50	2.40
Hydrogen sulfide, mg/L as S	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Conductivity (µS/cm)	448	454	494	495	495	491
Sulfate (mg/L)	<1	4.4	18	17	17	15
Iron, dissolved mg/L	0.11	0.10	0.04	0.05	0.04	0.04
Total Suspended Solids, mg/L	<1	<1	<1	<1	<1	<1

*B: Samples collected on 11-12-03*

**Water Quality Analyses  
Aloha Utilities; Seven Springs Water System**

<b>Collection Date:11/12/2003</b>	<b>Well 1 Inflow</b>	<b>Well 1 Outflow</b>	<b>Well 2 Inflow</b>	<b>Well 2 Outflow</b>	<b>Well 3 Inflow</b>	<b>Well 3 Outflow</b>
Sample Time	18:05	18:20	17:30	17:45	11:20	11:40
Flow Rate, gpm	1050		875		140	
Alkalinity, mg/L as CaCO <sub>3</sub>	208	220	180	172	168	148
pH (field)	6.55	7.32	7.55	7.08	7.43	7.35
pH (lab)	7.20	7.15	7.46	7.22	7.42	7.24
Temperature, ° C	23.6	23.6	25.2	24.6	27.5	25.5
Chlorine, mg/L as Cl <sub>2</sub>						
Free, mg/L as Cl <sub>2</sub>		2.80		3.15		0.60
Total, mg/L as Cl <sub>2</sub>	<0.01	3.60	not measured	3.70	not measured	1.22
Hydrogen Sulfide, mg/L as S	0.61	<0.01	1.00	<0.01	1.84	<0.01
Conductivity, µS/cm	449	446	394	391	375	343
Nitrogen						
Ammonia, mg/L NH <sub>3</sub> - N	0.09	<0.01	0.19	<0.01	0.24	0.04
Nitrate, mg/L NO <sub>3</sub> - N	0.24	<0.1	0.35	0.38	0.07	0.29
Anions						
Chloride, mg/L	10.2	15.5	8.3	19.5	8.1	21.1
Sulfate, mg/L	<0.1	<0.1	1.5	3.3	11.2	12.7
Cations						
Calcium, mg/L	69.59	68.51	60.79	61.60	54.00	58.23
Magnesium, mg/L	7.57	7.77	6.01	5.91	7.29	7.01
Manganese, mg/L	0.02	0.04	0.02	0.04	0.04	0.04
Copper (total), mg/L	0.02	0.05	0.04	0.07	0.06	0.06
Iron, mg/L						
Dissolved	0.20	0.21	0.12	0.14	0.12	0.12
Total	0.23	0.28	0.17	0.31	0.16	0.19
Total Hardness, mg/L as CaCO <sub>3</sub>	205	204	177	179	165	175
TOC, filtered, mg/L	4.63	4.73	3.36	3.32	2.40	2.53
UV 254, cm <sup>-1</sup>	0.14	0.10	0.19	0.10	0.08	0.14

**Data from Short  
Environmental Laboratories**

<b>Collection Date:11/12/2003</b>	<b>Well 1 Inflow</b>	<b>Well 1 Outflow</b>	<b>Well 2 Inflow</b>	<b>Well 2 Outflow</b>	<b>Well 3 Inflow</b>	<b>Well 3 Outflow</b>
pH (field)	7.25	7.02	7.54	7.09	7.31	6.99
Temperature, ° C	23.7	23.7	24.9	24.9	24.7	24.8
Dissolved Oxygen, mg/L	4.46	4.73	4.36	4.64	3.62	4.14
Free, mg/L as Cl <sub>2</sub>	<0.01	2.40	<0.01	2.50	<0.01	0.70
Total, mg/L as Cl <sub>2</sub>	<0.01	2.80	<0.01	2.75	<0.01	1.20
Hydrogen sulfide, mg/L as S	0.05	0.03	1.31	<0.01	2.19	<0.01
Conductivity (µS/cm)	476	479	409	416	401	412
Sulfate (mg/L)	<1	<1	2	<1	13	13
Iron, dissolved mg/L	0.18	0.19	0.05	0.08	0.03	<0.02
Total Suspended Solids, mg/L	<1	<1	<1	<1	<1	<1

**Water Quality Analyses  
Aloha Utilities; Seven Springs Water  
System**

<b>Collection Date:11/12/2003</b>	<b>Well 4 Inflow</b>	<b>Well 4 Outflow</b>	<b>Well 6 Inflow</b>	<b>Well 6 Outflow</b>	<b>Well 7 Inflow</b>	<b>Well 7 Outflow</b>
Sample Time	12:00	12:15	19:30	19:40	19:00	19:10
Flow Rate, gpm	240		430		390	
Alkalinity, mg/L as CaCO <sub>3</sub>	196	168	164	142	130	130
pH (field)	7.18	7.76	7.15	6.80	7.06	
pH (lab)	7.39	7.27	7.43	7.11	7.43	7.24
Temperature, ° C	26.3	25.5	24.0	24.0	24.2	23.1
Chlorine, mg/L as Cl <sub>2</sub>						
Free, mg/L as Cl <sub>2</sub>		0.92		1.59		1.39
Total, mg/L as Cl <sub>2</sub>	not measured	1.06	<0.01	1.99	not measured	1.52
Hydrogen Sulfide, mg/L as S	1.20	<0.01	1.60	<0.01	0.80	<0.01
Conductivity, µS/cm	402	413	387	391	409	409
Nitrogen						
Ammonia, mg/L NH <sub>3</sub> - N	0.17	0.01	0.16	<0.01	0.01	0.06
Nitrate, mg/L NO <sub>3</sub> - N	0.31	0.34	0.32	<0.1	1.46	1.38
Anions						
Chloride, mg/L	9.4	20.1	14.8	26.2	27.3	32.1
Sulfate, mg/L	5.4	6.5	5.6	7.6	15.5	15.5
Cations						
Calcium, mg/L	58.35	57.58	58.62	59.74	57.00	55.67
Magnesium, mg/L	7.28	7.52	4.13	4.12	3.90	3.82
Manganese, mg/L	0.04	0.05	0.05	0.05	0.03	0.03
Copper (total), mg/L	0.07	0.07	0.07	0.06	0.07	0.08
Iron, mg/L						
Dissolved	0.19	0.20	0.18	0.18	0.15	0.15
Total	0.21	0.41	0.23	0.25	0.20	0.35
Total Hardness, mg/L as CaCO <sub>3</sub>	176	175	164	167	159	155
TOC, filtered, mg/L	2.92	2.75	2.46	2.53	1.43	1.40
UV 254, cm <sup>-1</sup>	0.16	0.07	0.11	0.06	0.05	0.03

**Data from Short Environmental  
Laboratories**

<b>Collection Date:11/12/2003</b>	<b>Well 4 Inflow</b>	<b>Well 4 Outflow</b>	<b>Well 6 Inflow</b>	<b>Well 6 Outflow</b>	<b>Well 7 Inflow</b>	<b>Well 7 Outflow</b>
pH (field)	7.32	7.07	7.39	7.01	7.63	7.40
Temperature, ° C	24.4	24.5	24.2	24.2	24.4	24.4
Dissolved Oxygen, mg/L	4.04	4.20	4.45	4.35	4.25	4.36
Free, mg/L as Cl <sub>2</sub>	<0.01	0.80	<0.01	1.80	<0.01	1.20
Total, mg/L as Cl <sub>2</sub>	<0.01	1.30	<0.01	2.95	<0.01	1.60
Hydrogen sulfide, mg/L as S	1.38	0.04	2.13	0.01	0.17	<0.01
Conductivity (µS/cm)	424	433	400	410	423	428
Sulfate (mg/L)	6	<1	6	7	15	15
Iron, dissolved mg/L	0.04	0.09	0.09	0.10	0.04	0.04
Total Suspended Solids, mg/L	<1	<1	<1	<1	<1	<1

**Water Quality Analyses**  
**Aloha Utilities; Seven Springs Water System**

<b>Collection Date: 11/12/2003</b>	<b>Well 8 Inflow</b>	<b>Well 8 Outflow</b>	<b>Well 9 Inflow</b>	<b>Well 9 Outflow</b>
Sample Time	13:10	13:25	13:55	14:15
Flow Rate, gpm	530		451	
Alkalinity, mg/L as CaCO <sub>3</sub>	210	178	188	184
pH (field)	7.31	7.06	7.59	7.57
pH (lab)	7.39	7.11	7.36	6.98
Temperature, ° C	25.6	25.5	25.6	25.3
Chlorine, mg/L as Cl <sub>2</sub>				
Free, mg/L as Cl <sub>2</sub>		3.00		3.20
Total, mg/L as Cl <sub>2</sub>	<0.01	3.50	<0.01	3.70
Hydrogen Sulfide, mg/L as S	1.73	<0.01	2.43	<0.01
Conductivity, µS/cm	475	not measured	464	445
Nitrogen				
Ammonia, mg/L NH <sub>3</sub> - N	0.16	<0.01	0.28	<0.01
Nitrate, mg/L NO <sub>3</sub> - N	0.13	0.57	0.49	0.92
Anions				
Chloride, mg/L	10.6	26.6	11.8	33.6
Sulfate, mg/L	12.5	12.0	23.0	20.5
Cations				
Calcium, mg/L	63.31	66.68	68.76	71.18
Magnesium, mg/L	7.15	7.08	7.33	7.38
Manganese, mg/L	0.03	0.03	0.03	0.04
Copper (total), mg/L	0.05	0.07	0.08	0.08
Iron, mg/L				
Dissolved	0.19	0.20	0.15	0.18
Total	0.28	0.26	0.16	0.20
Total Hardness, mg/L as CaCO <sub>3</sub>	188	196	202	209
TOC, filtered, mg/L	2.82	2.79	2.80	2.95
UV 254, cm <sup>-1</sup>	0.10	0.06	0.16	0.15



**Data from Short Environmental  
Laboratories**

<b>Collection Date:11/12/2003</b>	<b>Well 8 Inflow</b>	<b>Well 8 Outflow</b>	<b>Well 9 Inflow</b>	<b>Well 9 Outflow</b>
pH (field)	7.33	6.93	7.43	6.79
Temperature, ° C	24.6	24.8	24.8	24.9
Dissolved Oxygen, mg/L	4.24	4.61	4.31	4.96
Free, mg/L as Cl <sub>2</sub>	<0.01	2.40	<0.01	2.30
Total, mg/L as Cl <sub>2</sub>	<0.01	2.60	<0.01	2.70
Hydrogen sulfide, mg/L as S	2.06	0.02	3.06	<0.01
Conductivity (µS/cm)	463	479	482	503
Sulfate (mg/L)	11	13	22	23
Iron, dissolved mg/L	0.07	0.07	0.05	0.06
Total Suspended Solids, mg/L	<1	<1	<1	<1

**Water Quality Analyses**  
**Aloha Utilities; Seven Springs Water System**

<b>Collection Date: 11/12/2003</b>	<b>Main Plant Inflow</b>	<b>Main Plant Outflow</b>	<b>D-5</b>	<b>D-6</b>	<b>D-7</b>	<b>D-7b</b>	<b>D-8</b>
Sample Time	9:55	10:45	16:10	17:00	15:15	15:15	14:40
Flow Rate, gpm	196		8	10	14		12
Alkalinity, mg/L as CaCO <sub>3</sub>	156	212	196	188	180	188	164
pH (field)	7.05	7.51	7.00	6.81	6.55	not measured	7.71
pH (lab)	7.16	7.15	7.16	7.17	7.16	7.16	7.16
Temperature, ° C	26.0	25.5	27.6	26.3	28.6	not measured	27.6
Chlorine, mg/L as Cl <sub>2</sub>							
Free, mg/L as Cl <sub>2</sub>	1.31	2.20	0.89	1.49	1.26	not measured	1.17
Total, mg/L as Cl <sub>2</sub>	1.53	2.90	1.09	1.67	1.43	not measured	1.51
Hydrogen Sulfide, mg/L as S	0.12	<0.01	<0.01	<0.01	<0.01	not measured	<0.01
Conductivity, µS/cm	465	417	441	476	427	not measured	476
Nitrogen							
Ammonia, mg/L NH <sub>3</sub> - N	<0.01	<0.01	<0.01	0.02	<0.01	0.02	<0.01
Nitrate, mg/L NO <sub>3</sub> - N	0.22	0.40	0.17	0.28	0.25	0.19	0.22
Anions							
Chloride, mg/L	19.3	17.9	16.4	18.1	19.9	19.4	30.1
Sulfate, mg/L	10.9	4.3	1.3	2.6	4.4	9.5	17.4
Cations							
Calcium, mg/L	58.20	62.30	63.73	60.93	64.61	65.24	66.09
Magnesium, mg/L	6.95	7.37	6.95	6.26	7.30	7.22	7.48
Manganese, mg/L	0.04	0.04	0.03	0.03	0.02	0.04	0.04
Copper (total), mg/L	0.04	0.06	0.07	0.09	0.04	10.09	0.10
Iron, mg/L							
Dissolved	0.15	0.23	0.22	0.19	0.21	0.37	0.21
Total	0.17	0.22	0.23	0.24	0.25	0.60	0.21
Total Hardness, mg/L as CaCO <sub>3</sub>	174	186	188	178	192	193	196
TOC, filtered, mg/L	2.88	3.79	4.27	3.58	3.64		2.90
UV 254, cm <sup>-1</sup>	0.07	0.08	0.09	0.06	0.15	0.24	0.06

**Data from Short  
Environmental Laboratories**

<b>Collection Date:11/12/2003</b>	Main Plant Inflow	Main Plant Outflow	D-5	D-6	D-7	D-8
pH (field)	7.04	6.94	7.23	7.14	7.15	6.86
Temperature, ° C	24.6	24.6	26.5	24.8	26.9	26.6
Dissolved Oxygen, mg/L	1.75	4.14	4.79	4.87	4.85	4.90
Free, mg/L as Cl <sub>2</sub>	0.57	1.62	0.8	1.5	1.05	0.85
Total, mg/L as Cl <sub>2</sub>	1.15	1.95	1.41	1.8	1.45	1
Hydrogen sulfide, mg/L as S	<0.01	<0.01	<0.01	<0.01	0.03	<0.01
Conductivity (µS/cm)	450	459	463	435	458	495
Sulfate (mg/L)	1.10	2.70	<1	<1	5	19
Iron, dissolved mg/L	0.11	0.10	0.10	0.07	0.09	0.05
Total Suspended Solids, mg/L	<1	<1	<1	<1	<1	<1