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Opflow®

Vol. 29, No. 1 January 2003

Distribution Systems

Corrosion Control Aids Residuals

by Y. Koby Cohen, Calvin G. Abernathy, and Christopher P. Hill

Unlined cast-iron and steel pipes, which are abundant in the Southern California Water Company–Southwest District distribution system, are known to have water quality problems because of higher disinfectant demands and higher biofilm density. Keeping ahead of the loss of disinfectant residual was labor intensive and costly, so the District conducted a pilot study to investigate alternatives.

Several bench-scale studies have documented that an effective corrosion control program may increase disinfectant residuals and improve water quality because fewer corrosion products are formed. So, over a three-year period, the District studied the long-term effect of corrosion inhibitors on disinfectant residuals, distribution system hydraulics, and water quality. The study proved that the use of polyphosphate-blend corrosion inhibitors is effective in maintaining residuals and will help limit water lost to and labor spent on flushing. The District is in the process of implementing the program systemwide.

District Disinfectant Demand

Unlined cast-iron and steel pipes, installed between 1930 and the late 1950s, comprise about 53 percent of the 410 miles of water distribution pipelines owned by the District. The remaining pipelines are ductile iron, polyvinyl chloride, and asbestos cement. The large number of unlined

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Corrosion Control Aids Residuals

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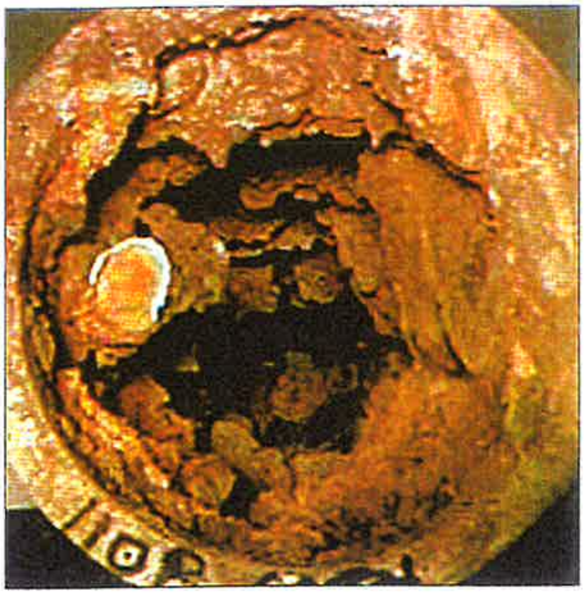

Corroded pipes comprise about 40 percent of the District's distribution system.

cast-iron and steel pipes promotes significant disinfectant demand in some sections of the distribution system. The demand can be divided into two major categories:

- the demand of the bulk fluid, and
- the demand of the pipe wall surface.

The disinfectant demand of the bulk fluid is exerted by reactions with organic, inorganic, and bacterial constituents of the water. Reactions with corrosion products, oxidation of dissolved iron originating from the pipe walls, biofilms that reside on the pipe surface, and the organic and inorganic constituents that accumulate within the corrosion product–biofilm matrix cause disinfectant demand.

Loss of disinfectant residual, especially in low-flow areas, increases biofilm accumulation, nitrification, and customer complaints about objectionable taste and odor, color, and particles in the water. To minimize these water quality problems and reduce consumer complaints, the District has a comprehensive flushing program that includes annual systemwide flushing, unidirectional flushing, dead-end flushing, and routine flushing of problem areas. These flushing programs use approximately 100 acre-ft (32.6 mil gal) of water per month and require three to four people to perform the flushing.

Polyphosphate-Blend Corrosion Inhibitors

Bench-scale studies done at the Montana State University–Biofilm Institute showed that polyphosphate-blend (approximately 77 percent polyphosphate and 23 percent orthophosphate) corrosion inhibitors produce corrosion products that are physically much softer and less cohesive than corrosion products formed with zinc orthophosphate-based corrosion inhibitors. Based on these studies, the District anticipated that use of this polyphosphate-blend would produce corrosion products that would be easier to remove by flushing. Because of the reduction in corrosion products, we expected an additional benefit of less disinfectant demand and a smoother and hydraulically superior pipe surface.

A short-term disadvantage of polyphosphate-blend corrosion inhibitors is that existing corrosion products on pipe wall surfaces are softened and removed shortly after adding the blend. The sloughing of these corrosion products may lead temporarily to increased disinfectant demand and increased microbial activity in the distribution system.

Study Description and Setup

The polyphosphate-blend-addition pilot study began in November 1998, in a less than 1 mi^2 isolated area of the distribution system. The District expanded the study in June 1999 to about a 3.6 mi^2 area. Pipes in the study area vary from 4 to 12 in. in diameter and are approximately 50 percent unlined cast iron, 25 percent cement-lined cast iron, and 25 percent asbestos–cement pipe. The study area, comprised of approximately 80 percent residential and 20 percent commercial and light industrial facilities, is representative of the rest of the distribution system.

Polyphosphate-blend solution

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was added at the effluent of five groundwater plants and at a treated surface water connection from Metropolitan Water District of Southern California. Each water source was disinfected using chloramines at a concentration of 2.5 to 4.0 mg/L total chlorine.

The polyphosphate-blend dose varied based on water quality parameters. It was dispensed at a rate of 1 mg/L per 1 mg/L of iron (Fe), manganese (Mn), and all divalent metals, plus 1 mg/L per 200 mg/L of hardness measured as calcium carbonate ($CaCO_3$) and 0.15–0.3 mg/L for polyphosphate-blend residual and corrosion control. In all cases, the polyphosphate-blend solution was injected after the chlorine and ammonia addition in the plant effluent line.

To evaluate changes in water quality, a number of parameters (Table 1) were measured regularly at five primary distribution system locations, each representing one of the plants. The same parameters were also monitored at each of the groundwater wells and 25 other locations within the distribution system. At each of the distribution system monitoring sites, orthophosphate was measured weekly, and heterotrophic plate counts (HPC) and total coliforms were monitored monthly to determine bacterial activity. Background data were collected three weeks prior to the startup of the pilot study at four of the five primary distribution system locations.

Results and Discussion

Water used in flushing activities. Prior to polyphosphate-blend addition, flushing typically required 20 to 30 acre-ft/month, and occasionally as much as 65 acre-ft/month. Following polyphosphate-blend addition that began June 1999, the required flushing volume dropped to 2 to 3 acre-ft; three years later, it has fallen as low as 0 to 1 acre-ft/month.

A crew of two to three people flushed the area as frequently as twice per week. In general, flushing was done until water quality goals were met.

Customer Complaints. One of the primary goals of the polyphosphate-blend addition was to reduce the number of customer complaints. During the summer of 1998, the number of complaints was as high as 35 per month. Because of its color-sequestering ability, the polyphosphate-blend addition had an immediate impact, reducing the number of complaints to fewer than five per month. The number of complaints has consistently remained fewer than five

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Constituent	Frequency	Importance
Total Chlorine	Daily/Weekly	Determine changes in disinfectant residual concentration
Total Ammonia	Weekly	Determine chlorine:ammonia ratio Nitrification indicator
Nitrite	Weekly	Nitrification indicator
Turbidity/Odor/Color	Weekly	Determine water quality and aesthetic properties
Orthophosphate	Weekly	Determine residual polyphosphate concentration
Manganese	Weekly	Determine effect on manganese solubility
Iron	Weekly	Determine effect on iron solubility
Larson Indexes	Monthly	Corrosion rate measurements
Total Coliforms	Weekly	Determine bacterial activity
HPC	Weekly	Determine bacterial activity
HPC using R2A media	Weekly	Determine bacterial activity
Customer Complaints	Ongoing	Indication of water quality
Orthophospate*	Weekly	Determine background orthophosphate level
Total Coliforms*	Monthly	Determine bacterial activity
HPC*	Monthly	Determine bacterial activity

Table 1. Water quality parameters measured in the distribution system or (*) at each source.

District Operator Profile

Name: Mike Cory **Age:** 38

Title: Quality Assurance Supervisor

Operator Certification Level: Water Treatment Operator Grade 2/Water Distribution Operator Grade 3

Education & Experience: Some college, presently working on a bachelor's degree in business administration. 19 years in water supply operations; four months in current position

How were you involved in the process described in the article? I was a water quality technician responsible for taking water quality samples from the distribution system and coordinating the flushing activities. I handled customer complaints, evaluated water quality data, and made recommendations for operational changes to improve water quality.

How does this process help make your job easier or more efficient? Since the introduction of polyphosphate-blend to the distribution system we have reduced the time spent on customer complaints, water loss to distribution system flushing, and unnecessary manpower spent resolving water quality problems.

Are there any changes or improvements you would make to the process? I would like to have the necessary resources for flushing the system during the first two weeks after the initial introduction of the polyphosphate blend.

Corrosion Control Aids Residuals

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per month, including a number of summer months in which zero complaints were received (Figure 1).

Total chlorine residuals. Total chlorine residual was monitored in the field, using pocket colorimeters

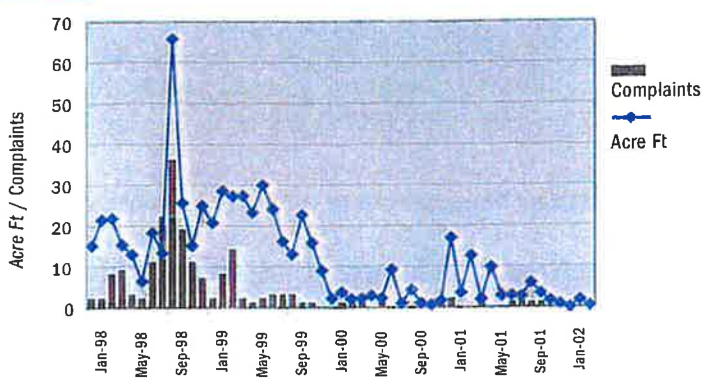

Figure 1. Flushing volume vs. complaints

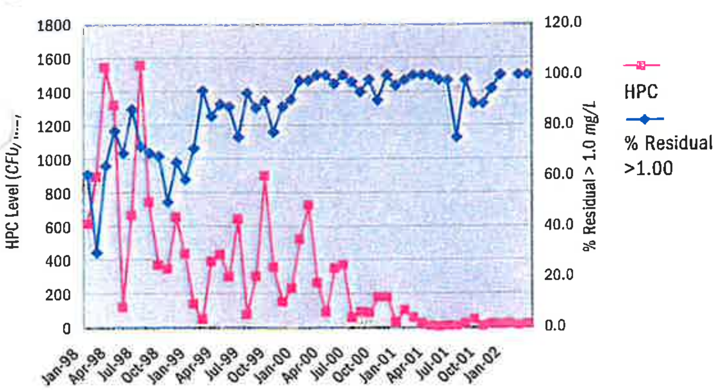

Figure 2. HPC vs. total chlorine residual level

with DPD-method procedures to determine if the District goal to maintain a total chlorine residual greater than 1.0 mg/L was being met. Prior to the addition of the polyphosphate blend, as few as 30 percent of monthly samples had a measured total chlorine residual greater than 1.0 mg/L. Approximately six months later, 90 to 100 percent of the residuals in the study area were greater than 1.0 mg/L. Also, less water was used in flushing to achieve the goal.

HPC bacteriological analyses. HPC levels, which are the main indicator of bacterial activity in the study area, also decreased significantly following the addition of polyphosphate blend. However, it took almost two years for the level to consistently remain below 100 colony forming units/mL, which is the District goal. We suspect that initially the polyphosphate-blend agent dissolves the corrosion product–biofilm matrix on the pipe wall, resulting in higher HPC levels. Throughout the study period, all bacteriological samples were absent of coliform bacteria.

For this system, a minimum of two years of polyphosphate-blend addition is required to establish low HPC levels. The length of time following polyphosphate-blend addition required to reduce HPC levels depends on the type and age of the water mains and characteristics of the biofilms and corrosion products. Newer systems, which may contain thinner biofilms or fewer corrosion by-products, may be able to reduce HPC concentrations in less time. Older systems that have unlined cast-iron and steel water mains with firmly established biofilms may require longer than two years (Figure 2).

Recommendations

Over the three-year study period, the results showed continual improvement in water quality (evidenced by frequent months in which no customer complaints were received), an ability to continuously maintain the desired total chlorine residual, and a reduction in HPC levels to below the District's goal. The District achieved these improvements while conducting limited flushing in the study area.

Conclusions and recommendations to utilities considering polyphosphate-blend addition include

- Polyphosphate-blend addition can soften and remove existing biofilm layers and corrosion tubercles. Implementation of a well-coordinated flushing program may minimize short-term water quality degradation associated with corrosion product and biofilm detachment events and speed up removal of biofilm layers.
- Short-term episodes of low disinfectant residuals and high HPC levels should be expected shortly after the implementation of polyphosphate blend as a result of sloughing of pipe biofilms and dissolution of corrosion products in the system. Therefore, it may be necessary to temporarily increase the plant effluent disinfectant residual.
- Immediate reduction in customer complaints can be achieved.
- Improvement in overall water quality may take as long as three years to achieve based on type and age of pipes.

Polyphosphates - The Solution To Distribution System Low Residuals, Biofilm and Pipe Corrosion

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Introduction

The Southern California Water Company – Southwest District (District) is located in the Southwest portion of Los Angeles County, serving the cities of Lawndale and Gardena, portions of the cities of Hawthorne, Inglewood, Compton and Carson, and the unincorporated area of Los Angeles County (Lennox, Athens, and Del Aire). The District sources of water supply include groundwater from 19 local wells and surface water treated by Metropolitan Water District of Southern California (MWDSC). Approximately 25 percent of the 44 million-gallon per day (mgd) water supply is obtained from the wells and the remaining supply is purchased from the MWDSC through 11 connections. Both water sources are disinfected with chloramines at an average dosage of 2.3 mg/L. There are 11 active storage reservoirs with a total storage capacity of approximately 13-MG and 11 booster stations delivering water between three pressure zones.

The distribution system consists of approximately 410 miles of water distribution pipelines. About 53 percent are unlined cast iron and steel pipes that were installed during the 1930's, 40's and 50's, while the remainder of the pipelines are ductile iron, polyvinylchloride and transite. Unlined cast iron and steel pipes are known to have higher disinfection demands, higher biofilm densities, and higher biofilm related water quality problems (LeChevallier, et al 1996; van der Wende and Characklis 1990; LeChevallier 1997; Delanoue, et al 1997; Chen, et al 1993; Camper, et al 1996; Ollos, et al 1997). Due to the large amount of unlined cast iron and steel pipe, there is a substantial residual disinfection demand in some sections of the distribution system. This demand results in low residual and routine customer complaints due to taste, odor and particles. The disinfection demand can be divided into two major categories: (a) disinfectant demand of the bulk fluid and, (b) the disinfectant demand of the pipes wall surface. The disinfectant demand of the bulk fluid is exerted by reactions with organic, inorganic and bacterial constituents of the water (Characklis and Marshall 1990; Abernathy 1998) while the disinfectant demand of the pipe surface is due to the reactions with corrosion products, oxidation of dissolved iron originating from the pipe walls, biofilm that reside on the pipe surface and the organic and inorganic constituents that accumulate within the corrosion product/biofilm matrix (van der Wende and Characklis 1990; Abernathy and Camper 1998).

The loss of disinfectant residual, especially in low flow areas, increases biofilm accumulation, nitrification, and customer complaints due to objectionable taste and odor, color, and particles in the water. To minimize these water quality problems and to reduce customer complaints, the District is implementing a comprehensive flushing program that includes annual system wide flushing, unidirectional flushing, dead-end flushing and routine flushing. The flushing programs use approximately 100 acre-ft (32.6 million gallons) of water per month and requires three to four people to perform the flushing.

Pilot Study Goals

In search of a less labor intensive and costly solution to the problem of losing disinfectant residual, the District implemented a pilot study to investigate the long-term effect of polyphosphate based corrosion inhibitors on disinfection residuals, hydraulics, and water quality. The use of polyphosphate based corrosion inhibitors are of interest because it has been documented in several studies that an effective corrosion control program may increase disinfectant residuals and improve water quality (LeChevallier, et al 1991; Geldreich 1996; Olson 1996). A recent bench and pilot-scale study at the Center for Biofilm Engineering at Montana State University demonstrated that the addition of a polyphosphate based corrosion inhibitors could result in lower corrosion product and biofilm densities if applied at the proper dose (Abernathy 1998). It is postulated that this is due to the reduction in corrosion product formation along with the type of corrosion product formed (Benjamin, et al 1990; Abernathy 1998; Abernathy and Camper 1998). Bench-scale studies found that polyphosphate corrosion inhibitors produced corrosion products that are much softer and less cohesive than corrosion products formed with zinc orthophosphate based corrosion inhibitors (Abernathy 1998). As a result of these properties, polyphosphate formed corrosion products are easier to remove by flushing and will have the added benefit of a smoother and hydraulically superior pipe surface. A possible short-term disadvantage of polyphosphate corrosion inhibitors is that existing corrosion products will be softened and removed shortly after implementing polyphosphate addition. The sloughing of these corrosion products may lead to increased disinfectant demands and increased microbial levels in the finished water (Geldreich

1996; Abernathy 1998), however, these are short-term consequences and not long-term results.

The objectives of this study were to:

- Determine the relationship between the application of polyphosphate and chlorine residual level
- Determine the effect of polyphosphate addition on biofilm accumulation within the distribution system
- Determine the effect of polyphosphates on unlined cast iron and steel pipe tubercles.
- Determine if the hydraulic capacity is increased after the addition of polyphosphates.
- Determine if customer complaints due to color are reduced after the addition of polyphosphates.
- Determine if customer complaints due to taste, odor and particles are reduced after the addition of polyphosphates.

Pilot Study Description and Setup

The polyphosphate addition started on November 6, 1998, in an isolated small area of the system and was expended on June 17, 1999, to approximately 3.6 mi^2 in size. Pipe sizes in this area vary from 4-12 inches in diameter and material composition is approximately 50% unlined cast iron, 25% cement lined cast iron and 25 % transite pipe. The study area is approximately 80% residential and 20% commercial and light industrial facilities.. affects the central and northern portions of the District's Lawndale-Gardena pressure zone.

Polyphosphate was initially added to one groundwater source, 157th Street Well, and than expended to five more groundwater sources and one surface water connection: Goldmedal Well, Southern Wells, 129th Street Well, and WB 25 (a MWDSC connection). See Figure 1 for location of sources within the study area. Each source was disinfected with a chloramine dose of 1.2 to 2.5 mg/L. The chloramines are formed by (a) combining free chlorine with natural ammonia in the well water, or (b) by adding a 19% strength ammonium hydroxide solution at a Cl_2 to NH_4-N ratio of 5:1 to chlorinated water.

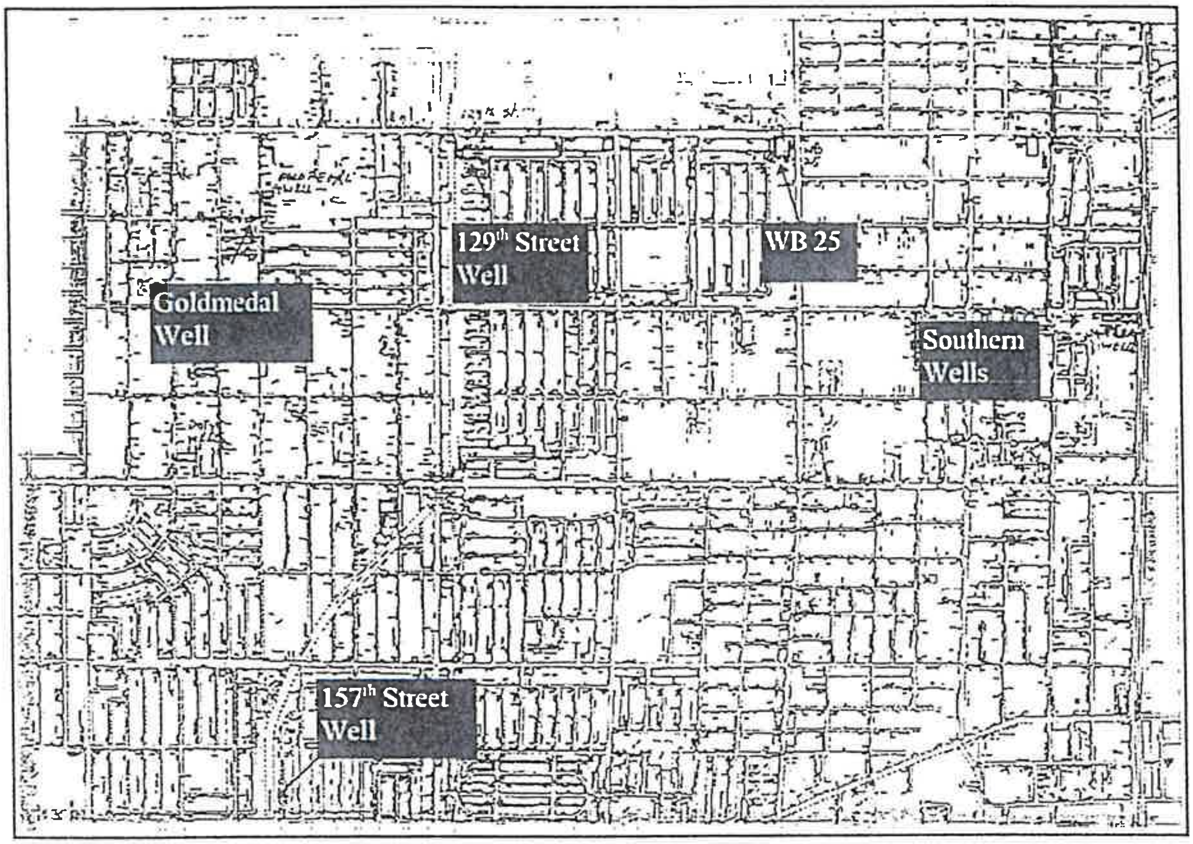

Figure No. 1: Study Area Map and Source Locations

Dosing of polyphosphate is set according to the following: 1 mg/L per 1 mg/L of iron and manganese plus all divalent metals, 1 mg/L per 200 mg/L of hardness measured as $CaCO_3$, plus 0.15-0.3 mg/L for residual and corrosion control. At all sites the polyphosphate solution is injected after the chlorine and/or ammonia addition at the plant effluent line. Table 1 illustrates the typical dosages applied at each site.

Plant Site	Type of Water	Max. Flow (gpm)	Hardness (mg/L of $CaCO_3$)	Fe, Mn and Divalent Metals	Typical Dosing Rate (gpd) (for 1.5 mg/L Residual)
Goldmedal Well	Groundwater	1,350	217	~0.1	6.5
Southern Plant - East	Groundwater	925	186	~0.2	4.5
Southern Plant - West	Groundwater	1,100	197	~0.2	5
129^{th} St. Well	Groundwater	450	138	~0.1	3

157th St. Well	Groundwater	250	205	~0.1	20
WB-25	Surface Water	4,000	260	~0.1	3

Table No. 1: Typical Dosing at Plant Sites

To evaluate the pilot study objectives, water quality constituents are collected at six distribution sites which are representative of the plant sites. In addition to the six primary locations, water quality samples were also collected from the wells and up to 25 other locations within the distribution system. Table 2 provides a list of the constituents that are collected from the distribution system and Table 3 provides a list of the constituents that are collected from the sources.

Constituent	Frequency	Importance
Total Chlorine	Daily/Weekly	Determine changes in disinfection residual level
Total Ammonia	Weekly	Determine chlorine/ammonia ratio. Nitrification indicator
Nitrite	Weekly	Nitrification indicator
Turbidity/Odor/ Color	Weekly	Determine water quality / esthetic
Orthophosphate	Weekly	Determine polyphosphate dosage
Manganese	Weekly	Determine effect on manganese solubility
Iron	Weekly	Determine effect on iron solubility
Larson Indexes	Monthly	Corrosion rate measurements
Total Coliforms	Weekly	Determine bacterial activity
HPC	Weekly	Determine bacterial activity
HPC Using R2A media	Weekly	Determine bacterial activity
Flow Test	Monthly	Determine effect on pipe walls tubercles
Customers Complaints	On-going	Indication of water quality

Table No. 2: Water Quality Parameters Collected From the Distribution System

Constituent	Frequency	Importance
Orthophosphate	Weekly	Determine background orthophosphate level
Total Coliforms	Monthly	Determine bacterial activity
HPC	Monthly	Determine bacterial activity

Table No. 3: Water Quality Parameters Collected From Sources

Background data were collected three weeks prior to the startup of the pilot study at four out of the six primary distribution system locations. A statistical analysis of the data collected was conducted using an analysis of variance (ANOVA) to determine if there were any statistical significant increases or decreases in water quality.

Results and Discussion

Chloramine Residuals. Residual monitoring was conducted in the field using a pocket colorimeters using the DPD method procedures equivalent to USEPA standard method 4500-CI G for drinking water.

The statistical analysis of disinfectant residuals before and after polyphosphate addition did not find any statistical increase or reduction ($p = 0.41$) in residual even though several low residual measurements were measured after polyphosphate addition. It is believed that these low residual measurements are the result of the softening and detachment of pre-existing corrosion tubercles within the study area. Detachment of these corrosion tubercles will lead to increased microbial populations and particulate matter in the bulk fluid and temporarily lower disinfectant residuals. The softening and detachment of corrosion tubercles could have short-term adverse impacts on water quality. However, in the long-term, disinfectant demands associated with the corrosion product/biofilm surface should decrease, leading to higher disinfection residuals and reduced biofilm. See Figure 2 for chloramine residual levels at the study area.

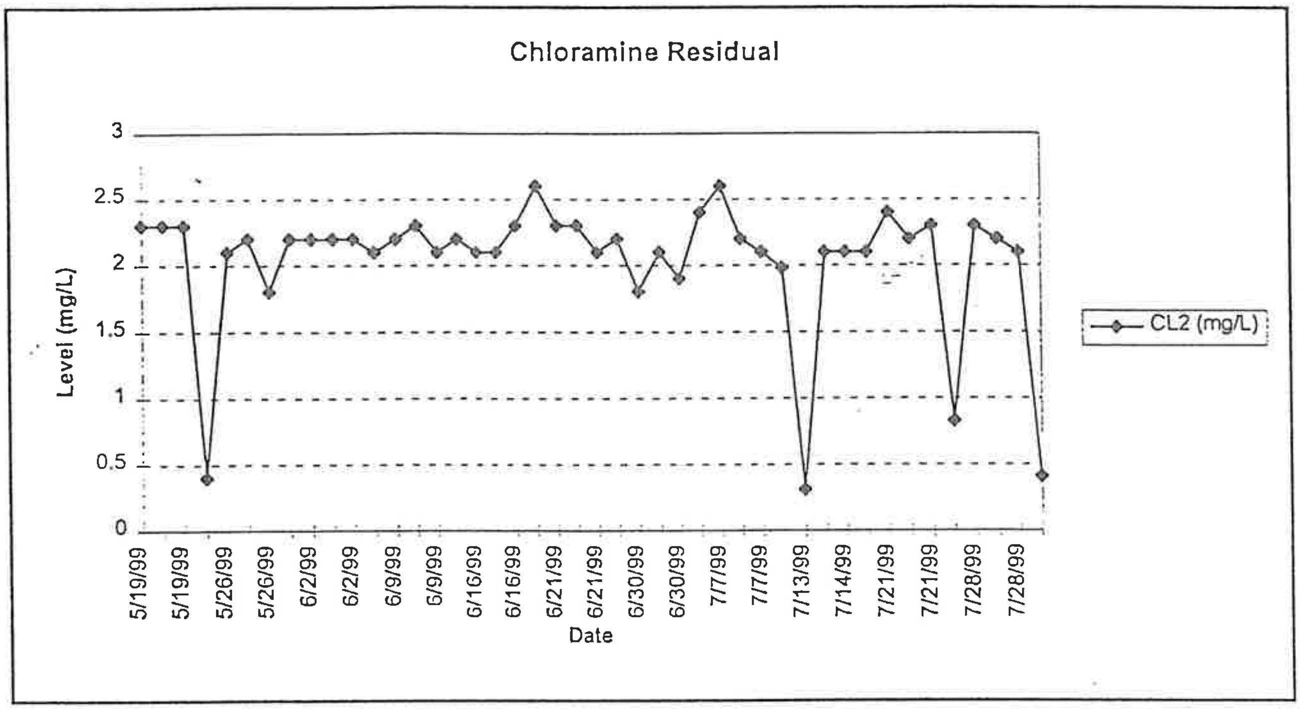

Figure No. 2: Chloramine Residuals at the Study Area (polyphosphate addition started on June 17, 1999)

HPC and R2A Bacteriological Analyses. Heterotrophic plate count (HPC) analysis was conducted according to the Pour Plate Method, standard method No. 9215 B and R2A-HPC analysis was conducted using the NWRI/R2A method No. 9215 D. Both methods are sited in the 18th edition of Standard Methods for the Examination of Water and Wastewater.

The HPC and R2A-HPC levels in the study area were found to follow the same trend as the disinfectant residuals (R2A-HPC results are shown in Figure 3). A statistical analysis of the bacterial populations did not show any significant increase or decrease in microbial populations even though there were several low and high data points after the addition of polyphosphate. This is due to the fact that the sequestering agent is dissolving the corrosion product/biofilm matrix from the pipe wall resulting in higher HPC levels. Please note that all bacteriological samples were absent for coliform bacteria.

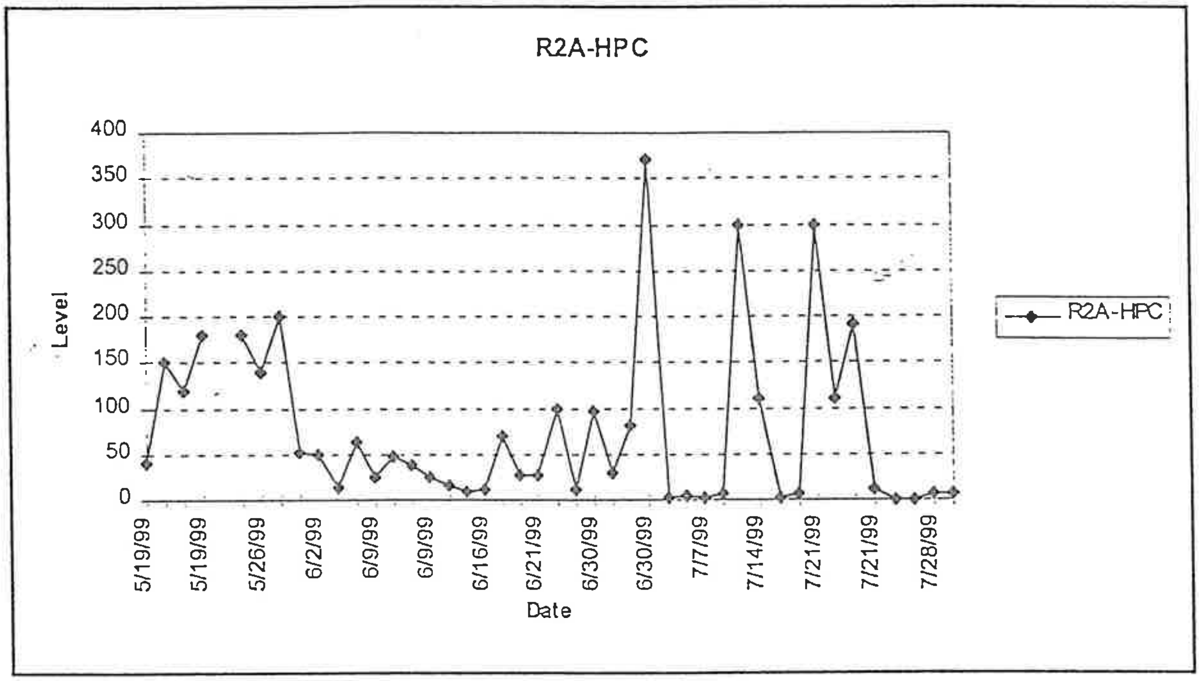

Figure No. 3: R2A HPC Level at the Study Area (polyphosphate addition started on June 17, 1999)

Fire Flows. Fire flow tests were done using two fire hydrants and two pressure gages. All flow tests were conducted during the same time of the day and with the same sources on line. Flow results conducted before and after the addition of the polyphosphate reagents show an increase in flows within the study area. The increase in flow supports the conclusion that the removal and sequestering of corrosion particles, mineral scale, biofilm and iron and manganese particles can result in reduced wall friction and increased hydraulic capacity shortly after the implementation of an effective dose of polyphosphate. Figure 4 presents fire flow data before and after polyphosphate addition within the isolated study area.

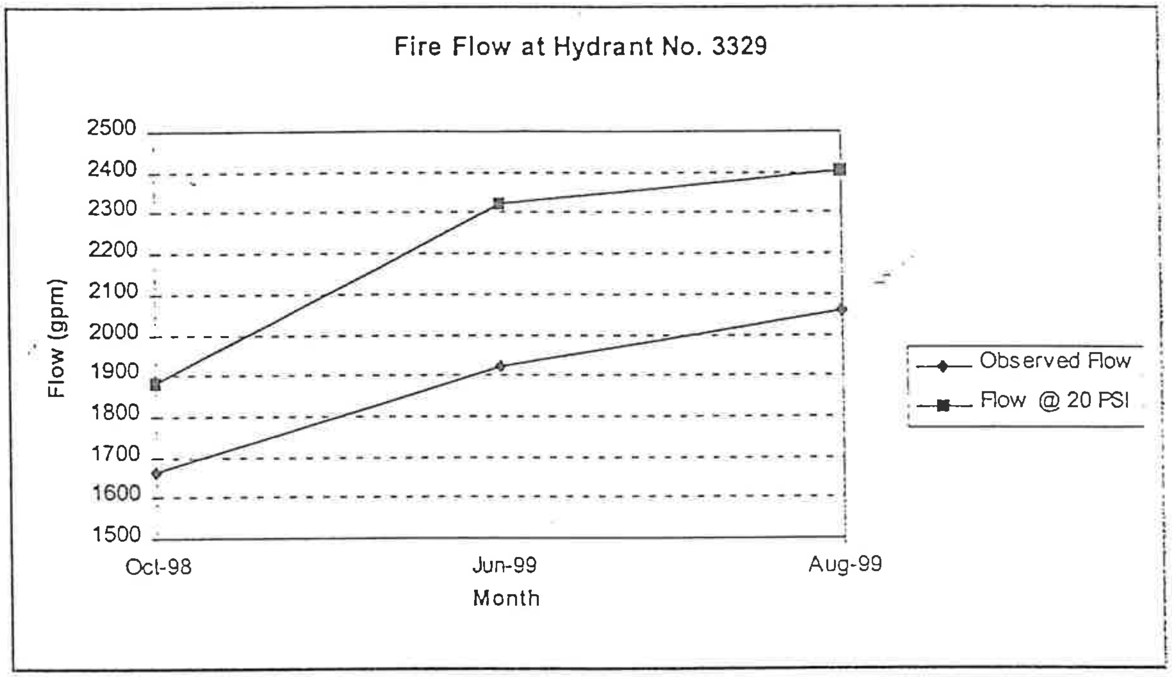

Figure No. 4: Fire Flow Data (polyphosphate addition started during November of 1998)

Customer Complaints. Within the study area there is an isolated area which is served by a well with elevated manganese level. In this area, the District used to receive customer complaints due to color on a regular basis. The data shows that the number of color complaints in that area was reduced to zero after the introduction of the polyphosphates in November of 1998. A reduction in customer color complaints is due to the iron and manganese sequestering effect of the polyphosphates. Statistical analysis of the customer complaints data did not show any significant increase or decrease in the number of taste, odor and particles complaints from the entire study area. Customer color complaints from the isolated area is shown in Figure 5.

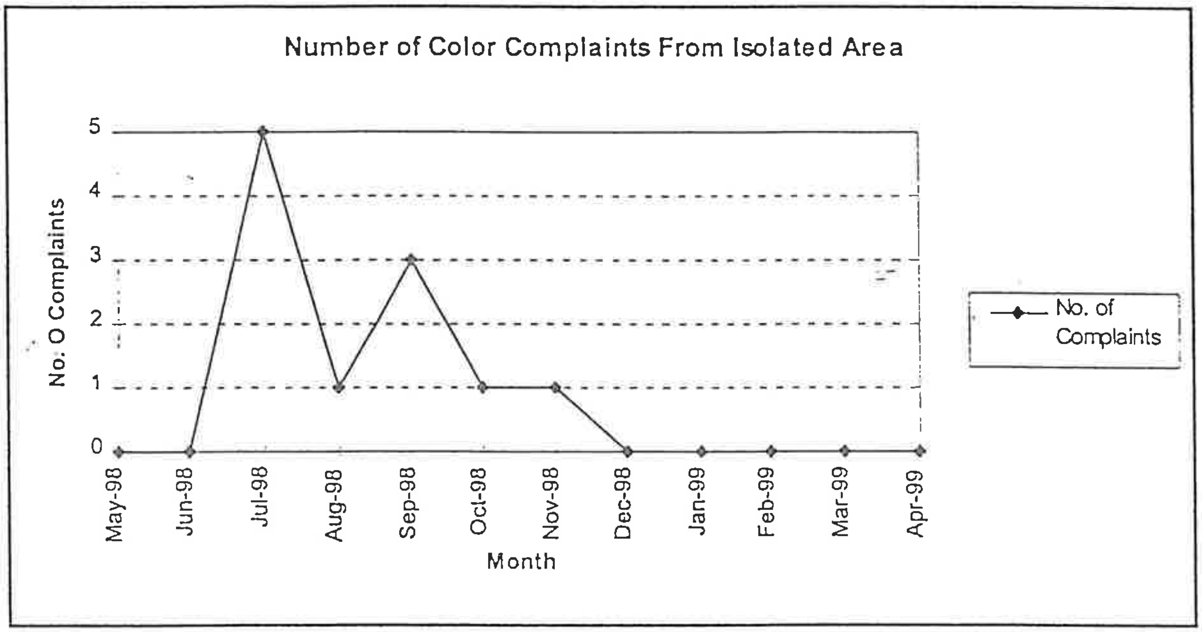

Figure No. 5: Customer Color Complaints (polyphosphate addition started during November of 1998)

Conclusions and Recommendations

To date, some of the observations that have been made support work done by other researchers. The corrosion products are softer and the detachment of corrosion products and biofilm is evident by the varying chlorine residual and periodic increase in R2A-HPC levels. Also, flow carrying capacity of the pipes has been increasing at a steady rate over a period of 10 months, which supports the hypothesis that a reduction in corrosion products on the pipe walls will result in increased hydraulic capacity of the distribution system. An increase in carrying capacity was also observed in areas in which cement coated pipes dominates. Customer complaints due to color from an isolated area of the study area were reduced to zero, however, there was no significant change in the number of other type of complaints.

An increase in chlorine residual and reduction in biofilm levels have not been statistically proven due to the limited data. Additional data are needed to establish statistically significant correlation and to determine the long term effect of the polyphosphate addition. It is anticipated that over the long term higher residual levels and lower R2A-HPC levels will be observed.

A comprehensive flushing program is and should be in effect until the goals of the study are achieved. Flushing is assisting in removing the softened corrosion products and biofilm as well as sediments and sand accumulation. Once a dynamic equilibrium is established between the polyphosphate and the pipe walls, it is anticipated that flushing can be reduced.

The following is a list of conclusions and recommendations to utilities that consider polyphosphate addition:

- Polyphosphate addition can soften and remove existing biofilm layers and corrosion tubercles. A flushing program will speed up the removal of these layers.
- Short-term episodes of low disinfectant residuals and high R2A-HPC levels should be expected shortly after the implementation of polyphosphate. Therefore, plant effluent chlorine residual should be increased if possible and system residuals closely monitored by qualified personnel.
- Implementation of a flushing program in conjunction with polyphosphate addition is a must. This program may minimize short-term water quality degradation associated with corrosion product and biofilm detachment events.
- The addition of an effective polyphosphate dose may lead to increased hydraulic capacity of existing water mains regardless of type.

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FAX TRANSMISSION SHEET

TO: All Sales Representatives
AT: Aqua Smart, Inc.
FAX NUMBER: ---------------
FROM: Jerry Grossblatt
DATE: 05/02/00

Number of Pages: 5 Including this transmission sheet

Please find attached a letter from Koby Cohen of Southern California Water Company confirming that the report submitted at the 1999 WTQC Conference in Tampa, Florida entitled Polyphosphates... resulted from their use of SeaQuest from Aqua Smart. You can add this document to your previous mailer date 1/3/00 which was a copy of Koby's presentation.

Additionally, we have attached more data from SCWC detailing further data through the end of December 1999 for chlorine residuals, HPC levels, and particularly number of complaints which have reduced dramatically since the start of SeaQuest use. Regarding the page on chlorine residuals, you will note the number 3.7 hand written in the middle of the page just under box 2. This number represents the current chlorine ppm readings as of March, 2000. This is almost a 400% increase in chlorine residual levels in distribution from the start of SeaQuest use--due strictly from distribution piping clean out and coating.

SOUTHERN CALIFORNIA WATER COMPANY

SOUTHWEST DISTRICT

Water Quality Department

17140 S. Avalon Blvd., Suite 100 • Carson, California 90746

Telephone (310) 767-8200 • Fax (310) 323-8257

April 13, 2000

Mr. Jerry Grossbaltt
Aqua Smart, Inc.
4445 Commerce Drive, Suite A4
Atlanta, GA 30336

Dear Mr. Grossbaltt:

This letter is to confirm that Southern California Water Company, Southwest System, has been using Aqua Smart, Seaquest product since June of 1999. The results and our experience with Seaquest have been documented in the paper submitted to the 1999 Water Quality Technology Conference, titled "Polyphosphate - The Solution to Distribution System Low Residual, Biofilm, and Pipe Corrosion." We will be happy to share our experience with you if needed.

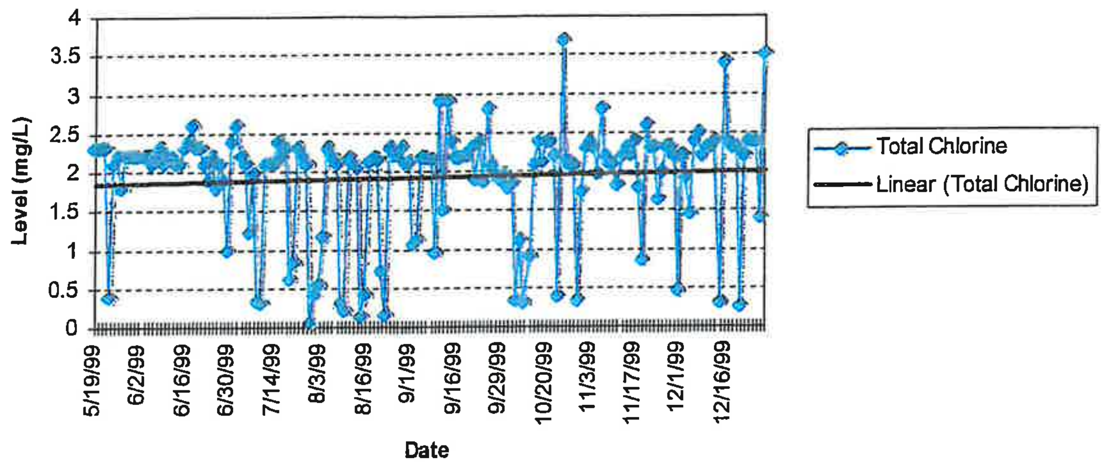
If you need more information or have any questions, please call me at (310) 767-8200, extension 503.

Sincerely,

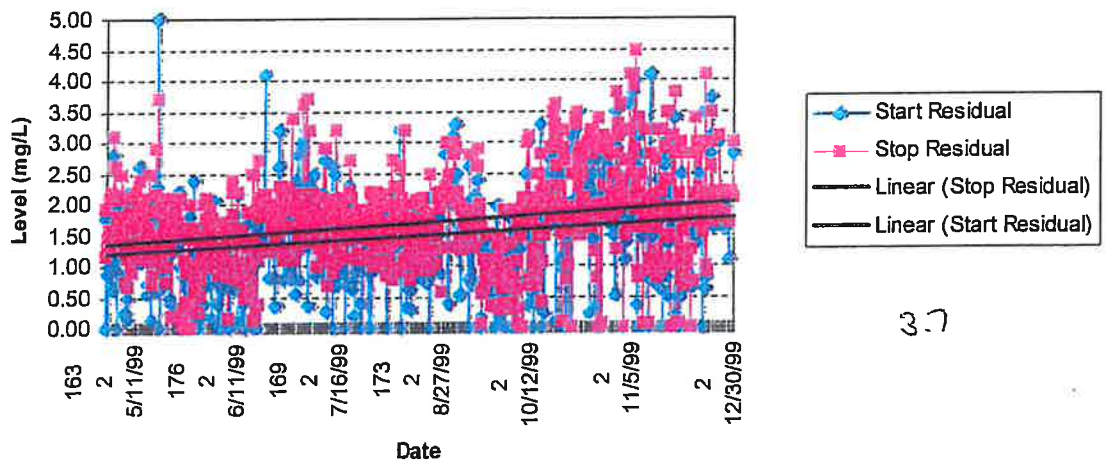
SOUTHERN CALIFORNIA WATER COMPANY

Y. Koby Cohen, P.E.
Water Quality Engineer

Study Area Total Chlorine Residual

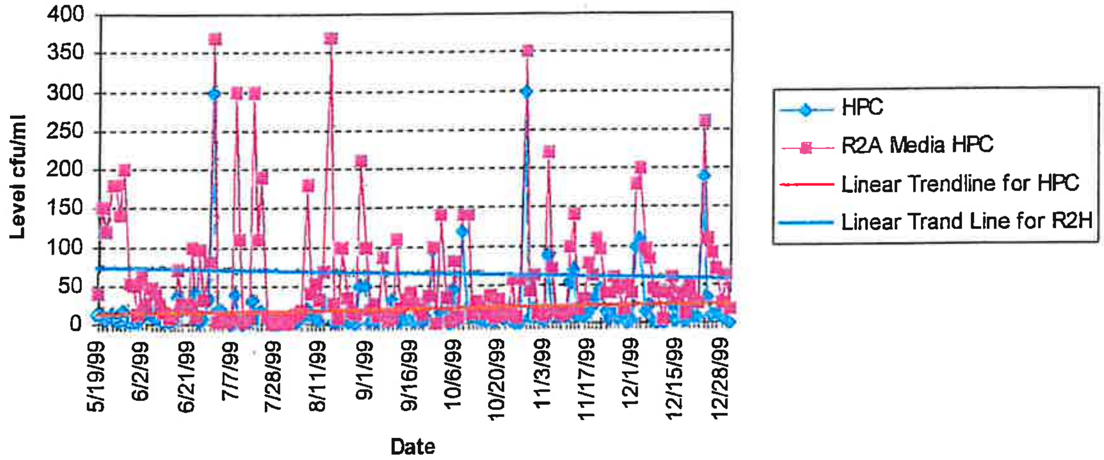


Study Area - Area 2 Only Residuals

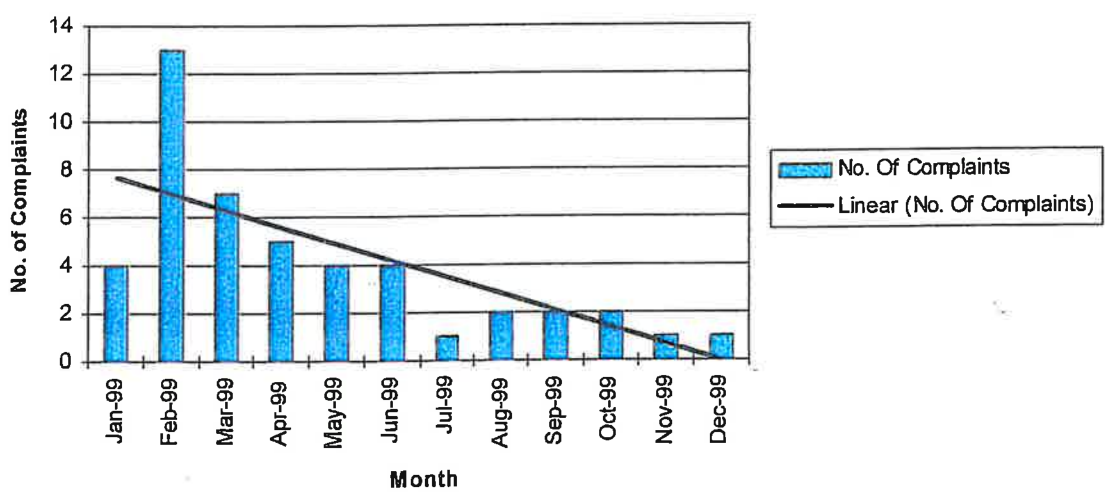


3.7

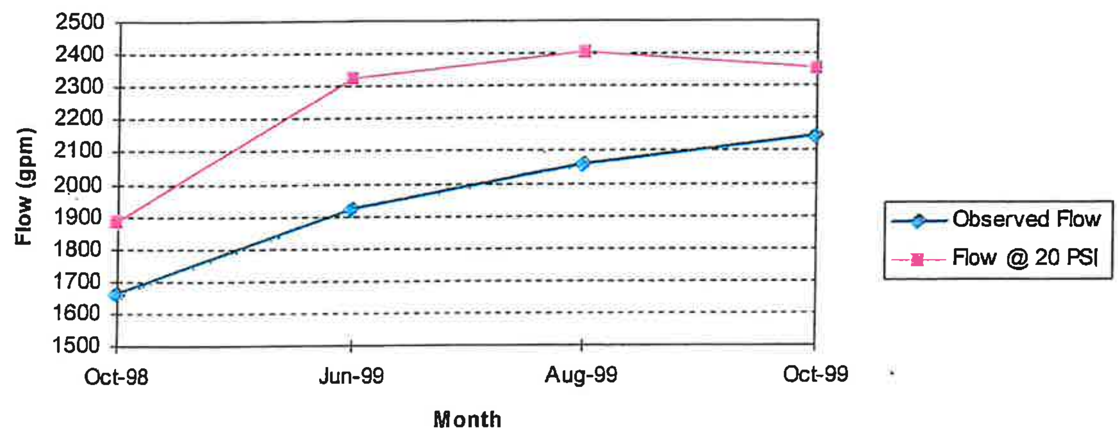
Study Area HPC and R2A Results



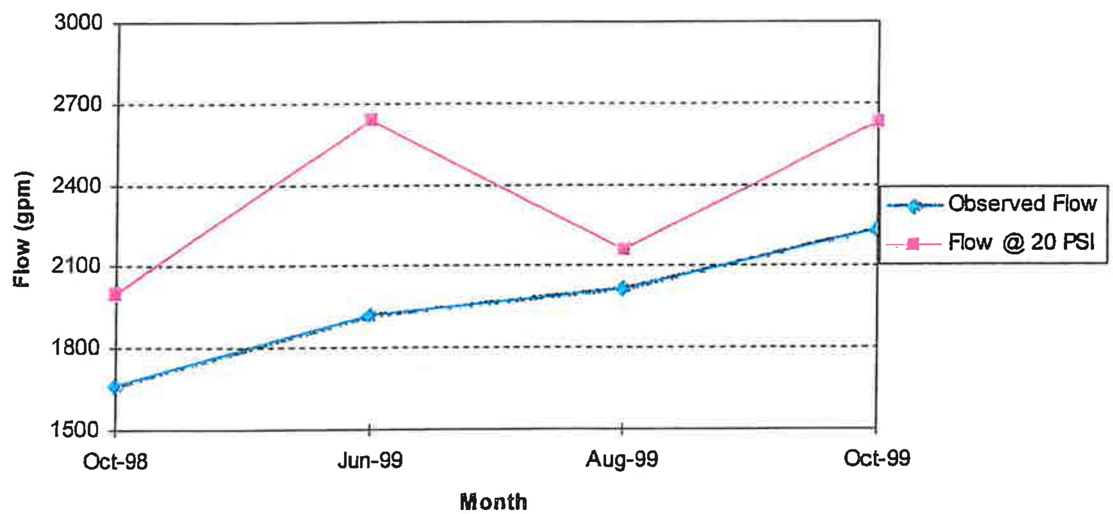
Complaints from Study Area

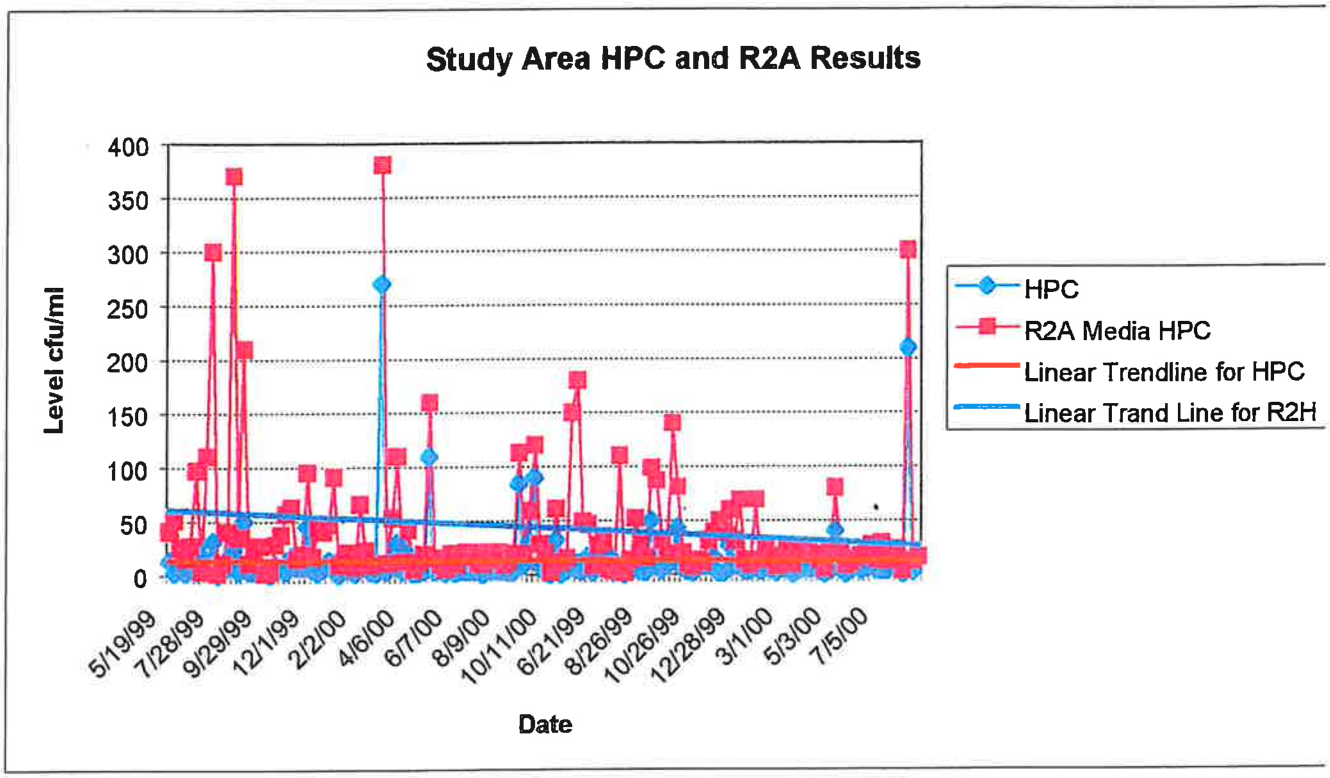


Fire Flow at Hydrant No. 3326



Flow at Hydrant No. 3370




Study Area HPC and R2A Results
Level cfu/ml
400
350
300
250
200
150
100
50
0
5/19/99
7/28/99
9/29/99
12/1/99
2/2/00
4/6/00
6/7/00
8/9/00
10/11/00
6/21/99
8/26/99
10/26/99
12/28/99
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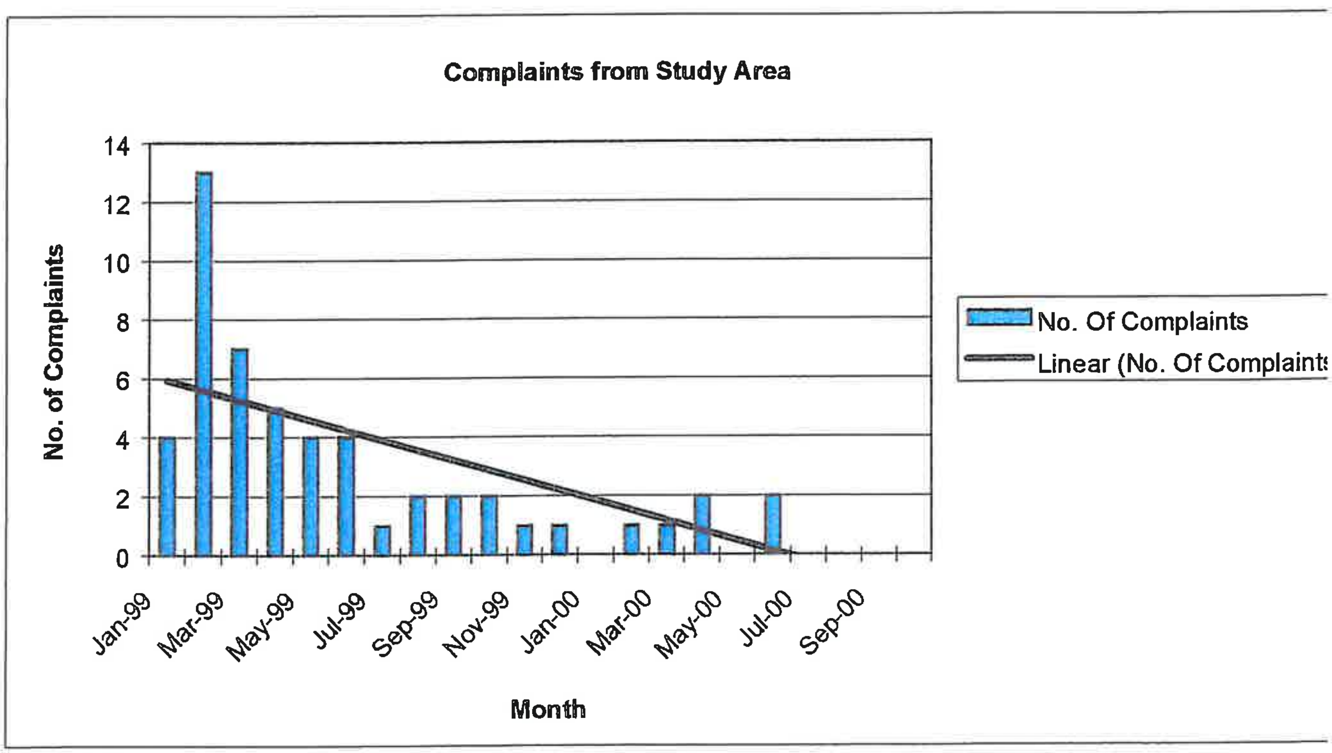
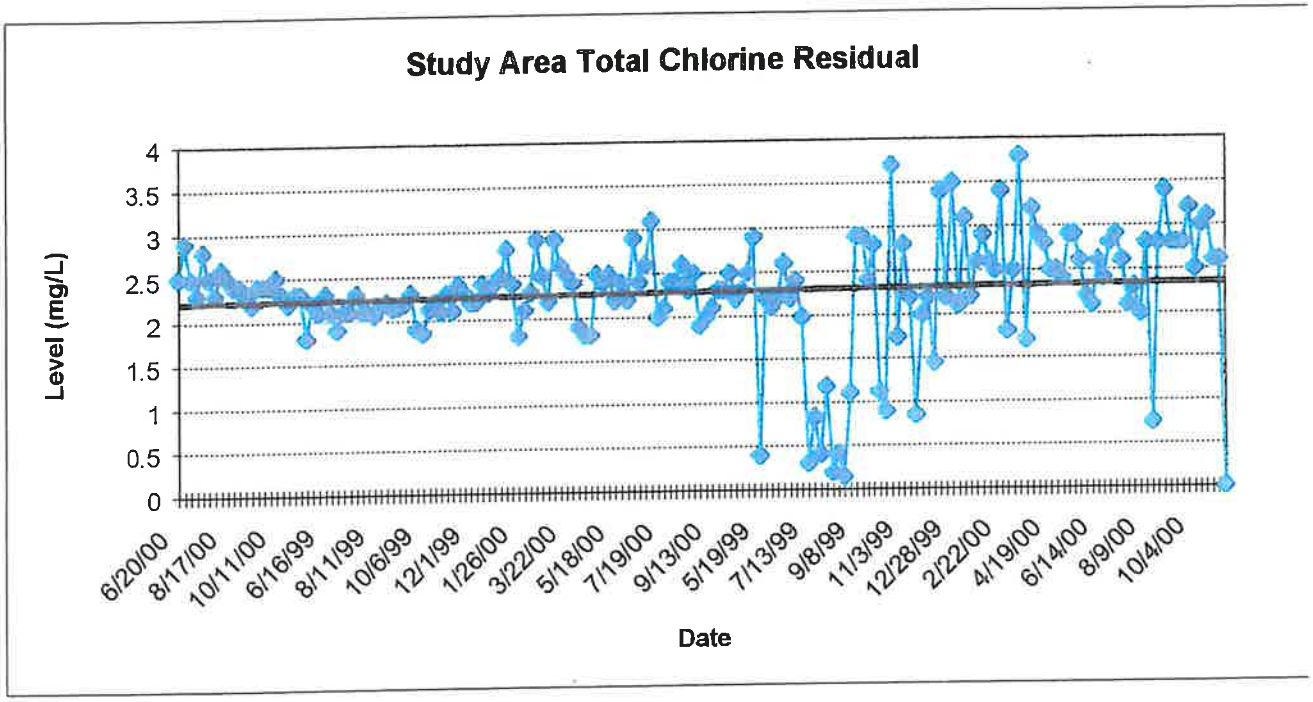
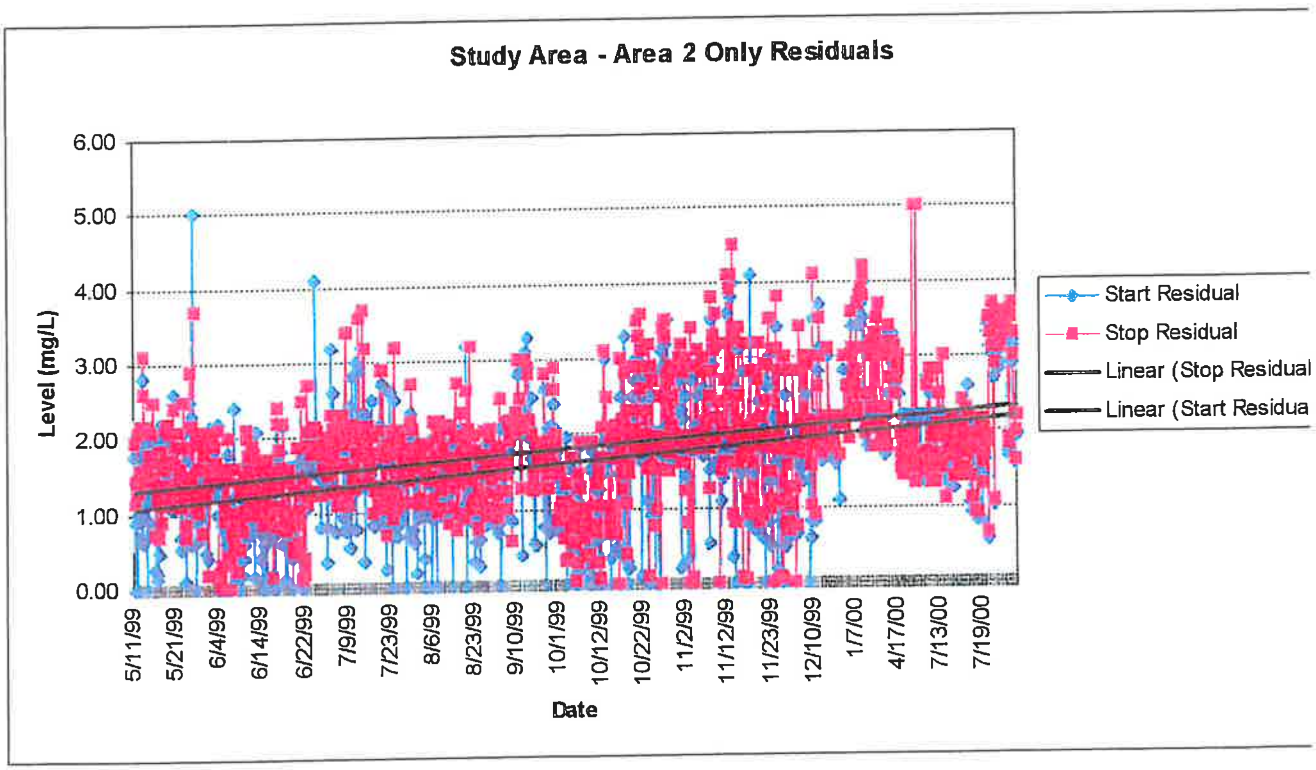
5/3/00
7/5/00
Date
HPC
R2A Media HPC
Linear Trendline for HPC
Linear Trand Line for R2H


Complaints from Study Area
No. of Complaints
14
12
10
8
6
4
2
0
Jan-99
Mar-99
May-99
Jul-99
Sep-99
Nov-99
Jan-00
Mar-00
May-00
Jul-00
Sep-00
Month
No. Of Complaints
Linear (No. Of Complaints

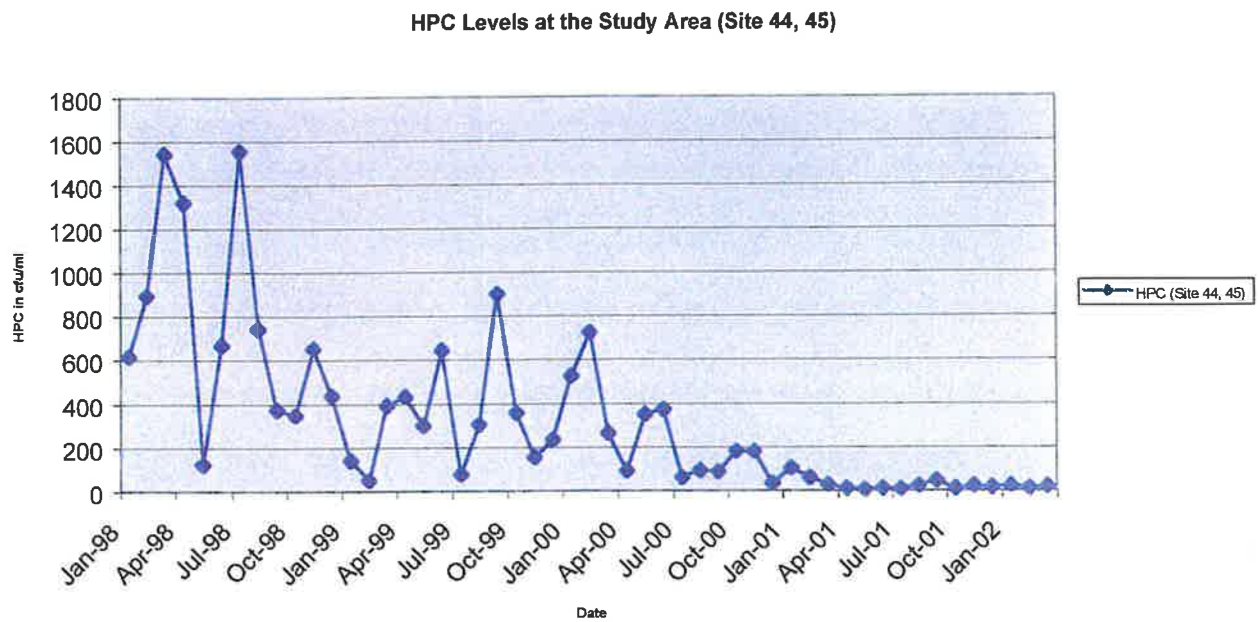


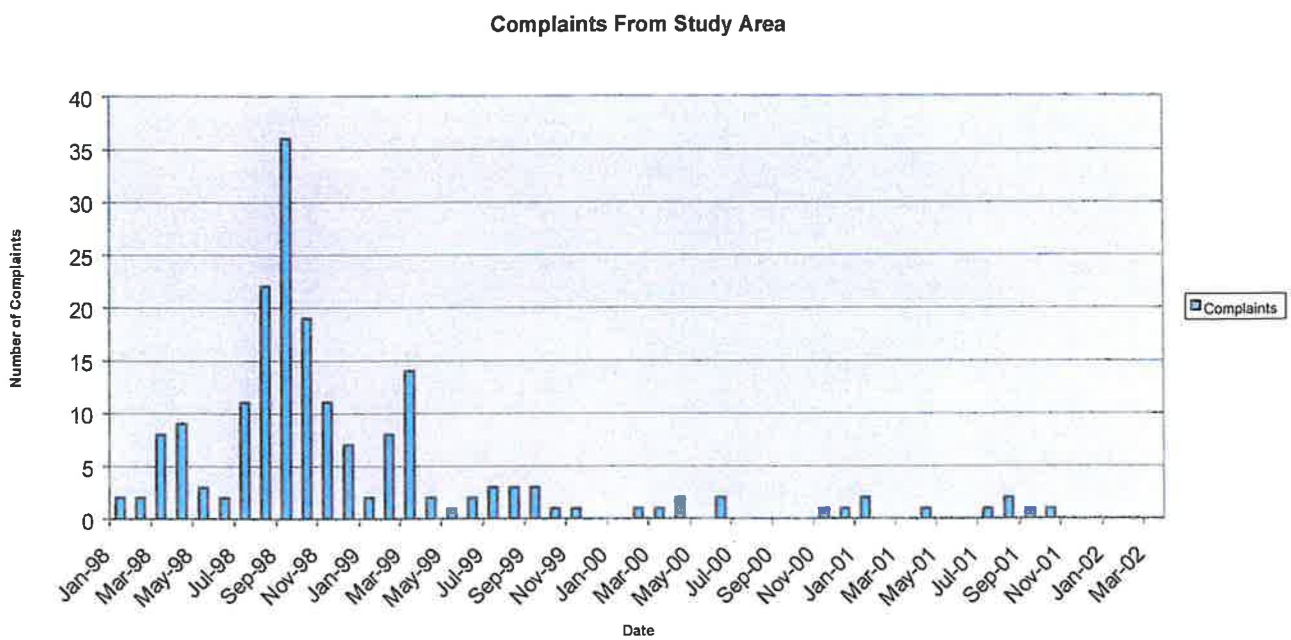
Study Area Total Chlorine Residual
Level (mg/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
6/20/00
8/17/00
10/11/00
6/16/99
8/11/99
10/6/99
12/1/99
1/26/00
3/22/00
5/18/00
7/19/00
9/13/00
5/19/99
7/13/99
9/8/99
11/3/99
12/28/99
2/22/00
4/19/00
6/14/00
8/9/00
10/4/00
Date



Study Area - Area 2 Only Residuals
Level (mg/L)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
5/11/99
5/21/99
6/4/99
6/14/99
6/22/99
7/9/99
7/23/99
8/6/99
8/23/99
9/10/99
10/1/99
10/12/99
10/22/99
11/2/99
11/12/99
11/23/99
12/10/99
1/7/00
4/17/00
7/13/00
7/19/00
Date
Start Residual
Stop Residual
Linear (Stop Residual
Linear (Start Residua

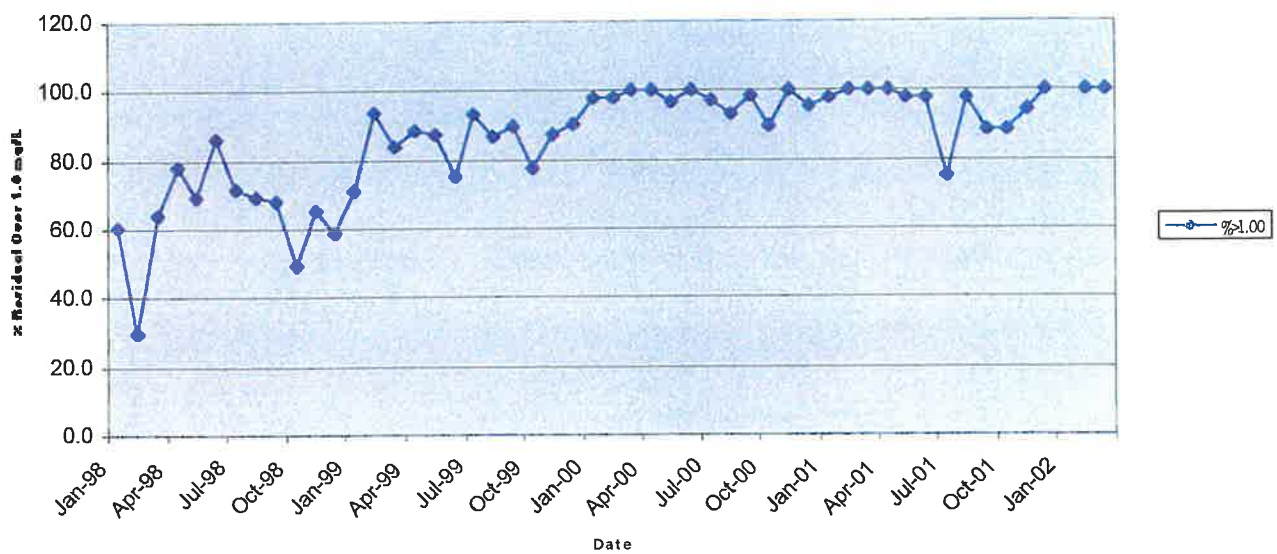
UPDATED CHARTS: CHLORINE RESIDUALS, HPC LEVELS, DISCOLORED WATER COMPLAINTS, & PSI/ WATER FLOW INCREASES FROM SOUTHERN CALIFORNIA WATER CO.



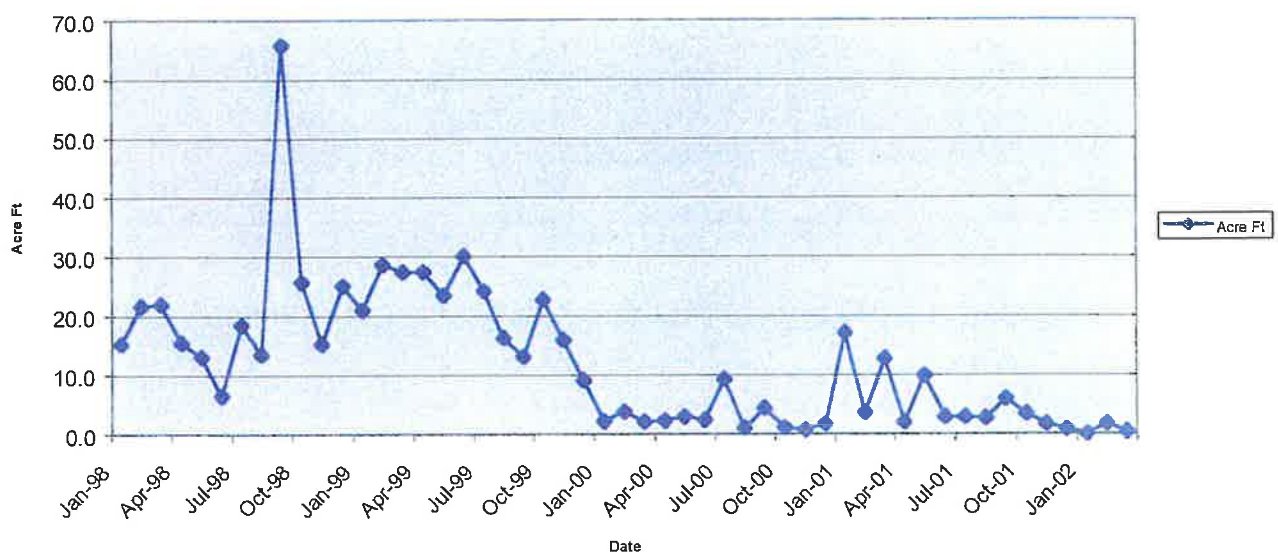


UPDATED CHARTS: CHLORINE RESIDUALS, HPC LEVELS, DISCOLORED WATER COMPLAINTS, & PSI/ WATER FLOW INCREASES FROM SOUTHERN CALIFORNIA WATER CO.

% of Total Chlorine Residual Over 1.0 mg/L



Water Use in Flushing Activites (Acre-ft of water)



SEAQUEST INCREASES CHLORINE RESIDUALS OVER 1.0 PPM BY 24% IN SOUTHERN CALIFORNIA WATER CO. WATER SYSTEM

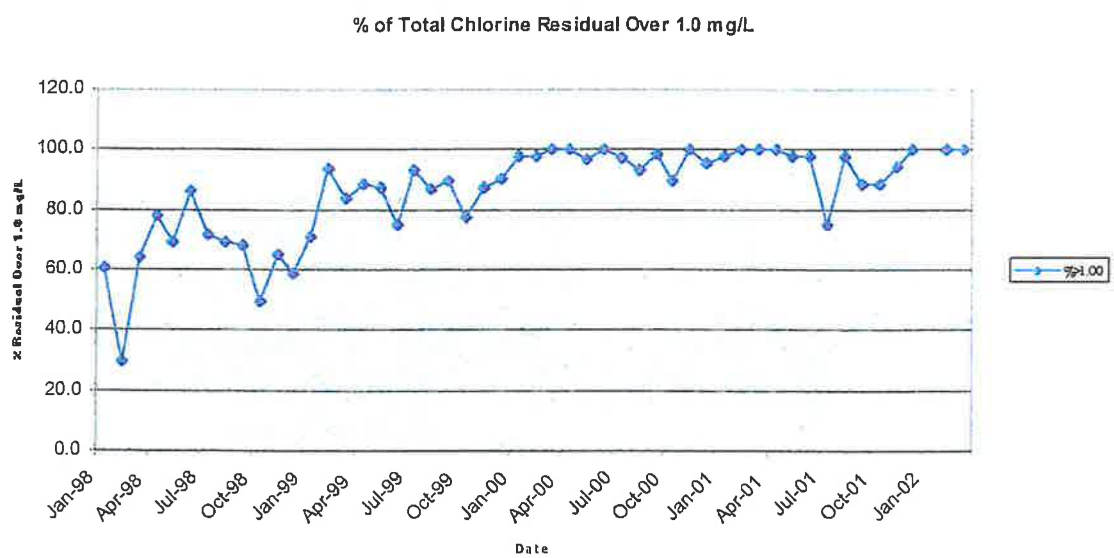
In November 1998, Southern California Water Company began testing SeaQuest in a small isolated area. During this time, SCWC continued original treatment in the remainder of the system. Then, in mid June 1999, SeaQuest treatment expanded to include many hundreds of miles of piping distribution. This Chart documents, on average, a 24% increase of Chlorine Residuals over 1.0 PPM with SeaQuest Treatment.

Prior to SeaQuest Treatment (January '98 – July '99)

Average Chlorine Residual Over 1.0 mg/L:
71.2 % of the Time

SeaQuest Treatment (1/'00 – 1/'02) Increases Chlorine Residuals By 24%

Average Chlorine Residual Over 1.0 mg/L:
95.2% of the Time



SeaQuest Reduces Chlorine Use by Increasing Residuals!
SeaQuest Lowers Chlorine Costs!

Polyphosphates - The Solution To Distribution System Low Residuals, Biofilm and Pipe Corrosion

AWWA

1999 Water Quality Technology Conference

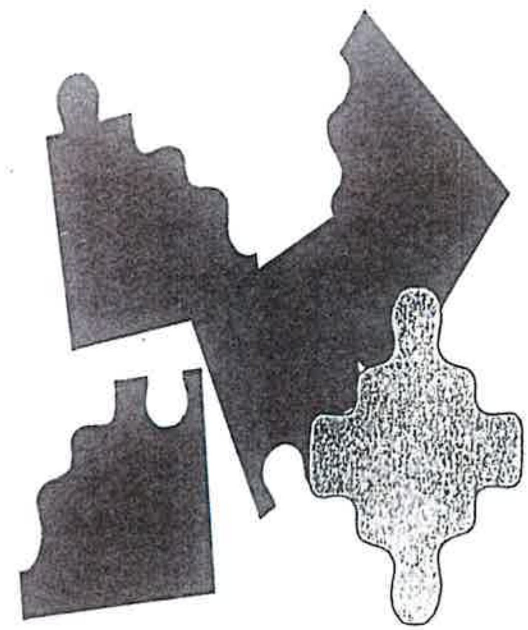
November 2, 1999

Koby Cohen

Southern California Water Company

Overview of Presentation

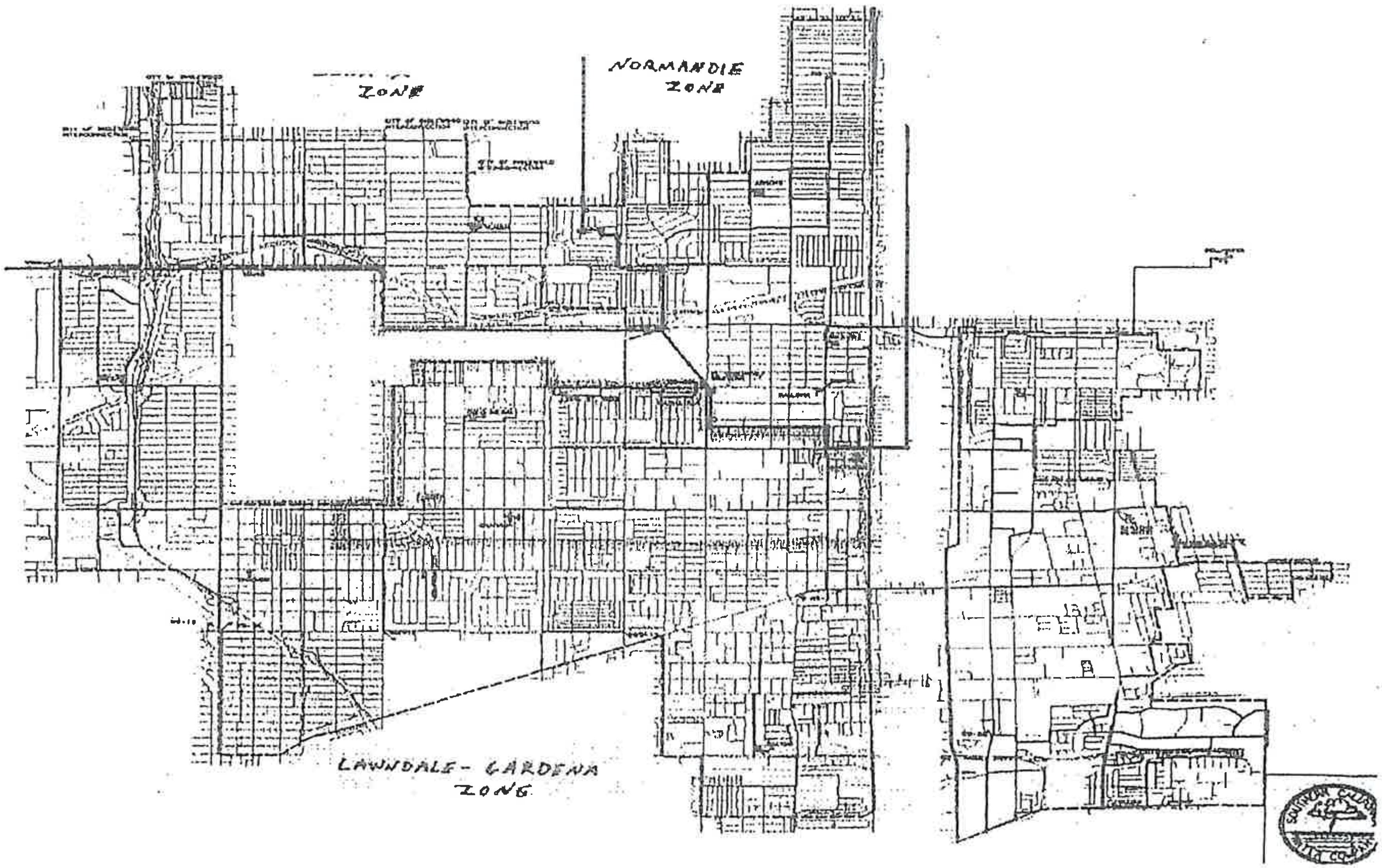
- Introduction
- Pilot Study Goals
- Pilot Study Setup
- Results and Discussion
- Conclusions & Recommendations
- Q&A



Introduction

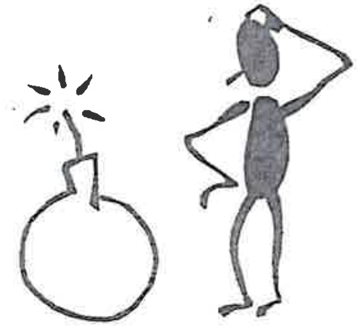
- Located in Southern California
- Serving approximately 150,000 people
- 80% purchased water 20% ground water
- Three Pressure Zones
- 19 wells, 11 tanks, 11 booster, 410 miles of pipes
- 4 Water Supply Techs, 2 Water Quality Techs and a Flushing Crew (3 people)

System Map

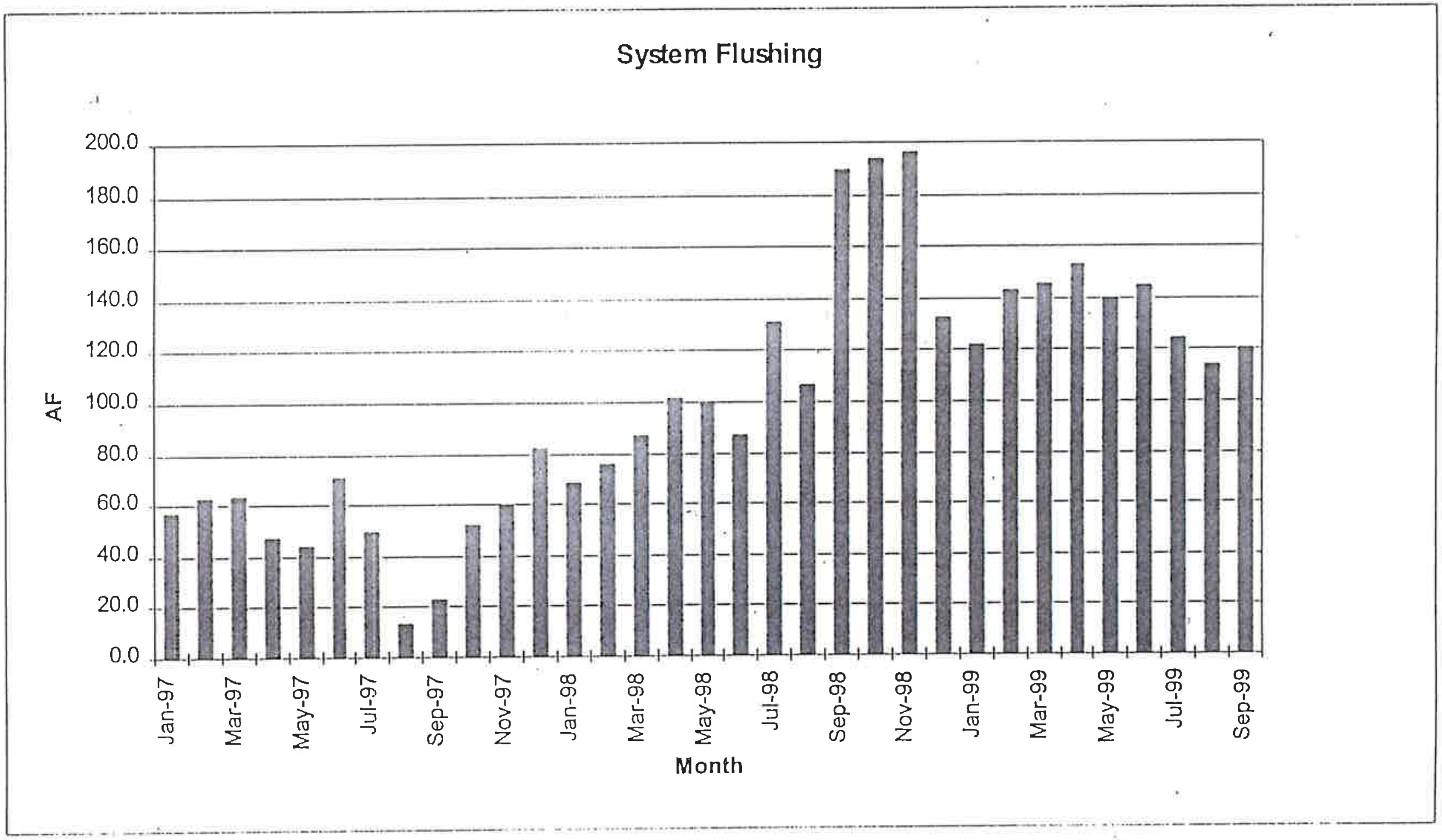


Introduction (cont.)

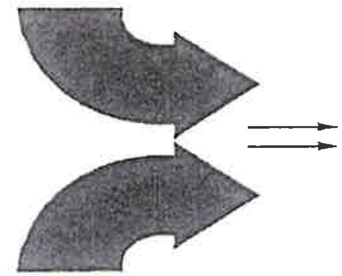
- ~ 53 % of pipes are unlined cast iron and steel pipes
- Loss of chloramine residual
  - Residual Demand Of Pipe Walls
  - Residual Demand Of Bulk Liquid
- Loss of residual results in:
  - Biofilm accumulation (HPC)
  - Nitrification
  - Customer complaints
- Mitigate by aggressive flushing (~100 AF/Month)



Flushing Data



Pilot Study Goals

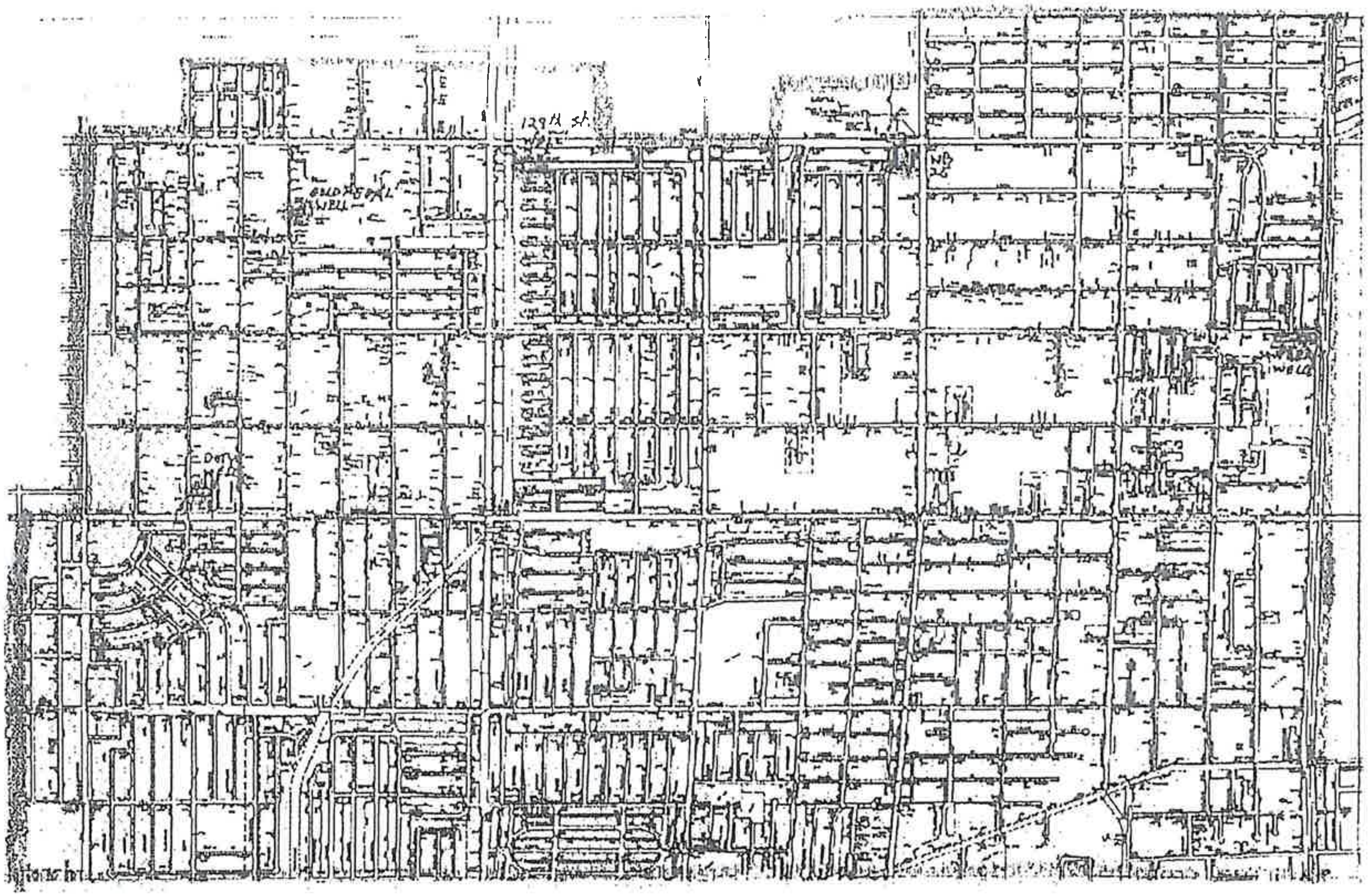


- Increase Secondary Disinfection Residuals (LeChevallier, et al 91; Geldreich 96; Olson 96)
- Improve Distribution System Hydraulics (Benjamin, et al 90; Abernathy 98; Abernathy and Camper 98)
- Improve Microbiological Quality (Abernathy 98)
- Reduce Customers Complaints

Pilot Study Setup

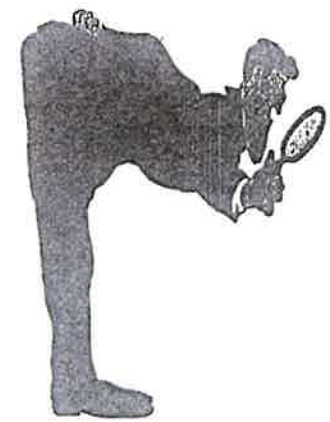
- Limited Study, 250 gpm- Started Nov. 6, 1998
- Expended to 8,075 gpm on June 17, 1999
- Apply ~ 1.5 mg/L of polyphosphate blend
  - 1 ppm per 1 ppm of Fe, Mn and all divalent metals
  - 1 ppm per 200 ppm of $CaCO_3$ hardness

Study Area Map

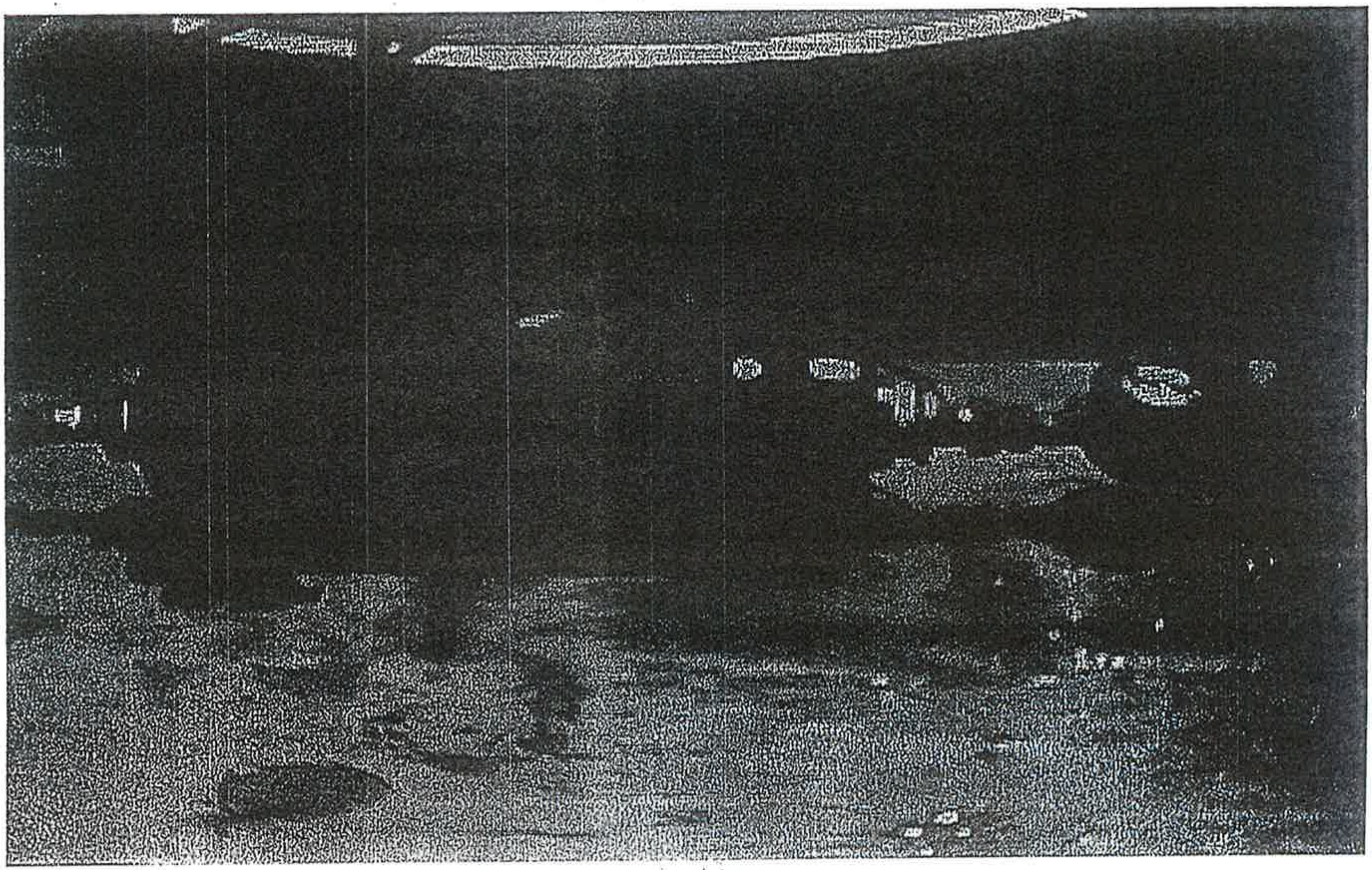


Pilot Study Setup (cont.)

- Established Representative Sample Locations, collected background data
- 15 primary distribution locations, all sources, pipe coupon setup, and over 500 other distribution locations
- Collected over 10 different parameters, daily, weekly and monthly
- Main Parameters:
  - Chloramine Residual
  - HPC and R2A
  - Flow Test Program
  - Customer Complaints

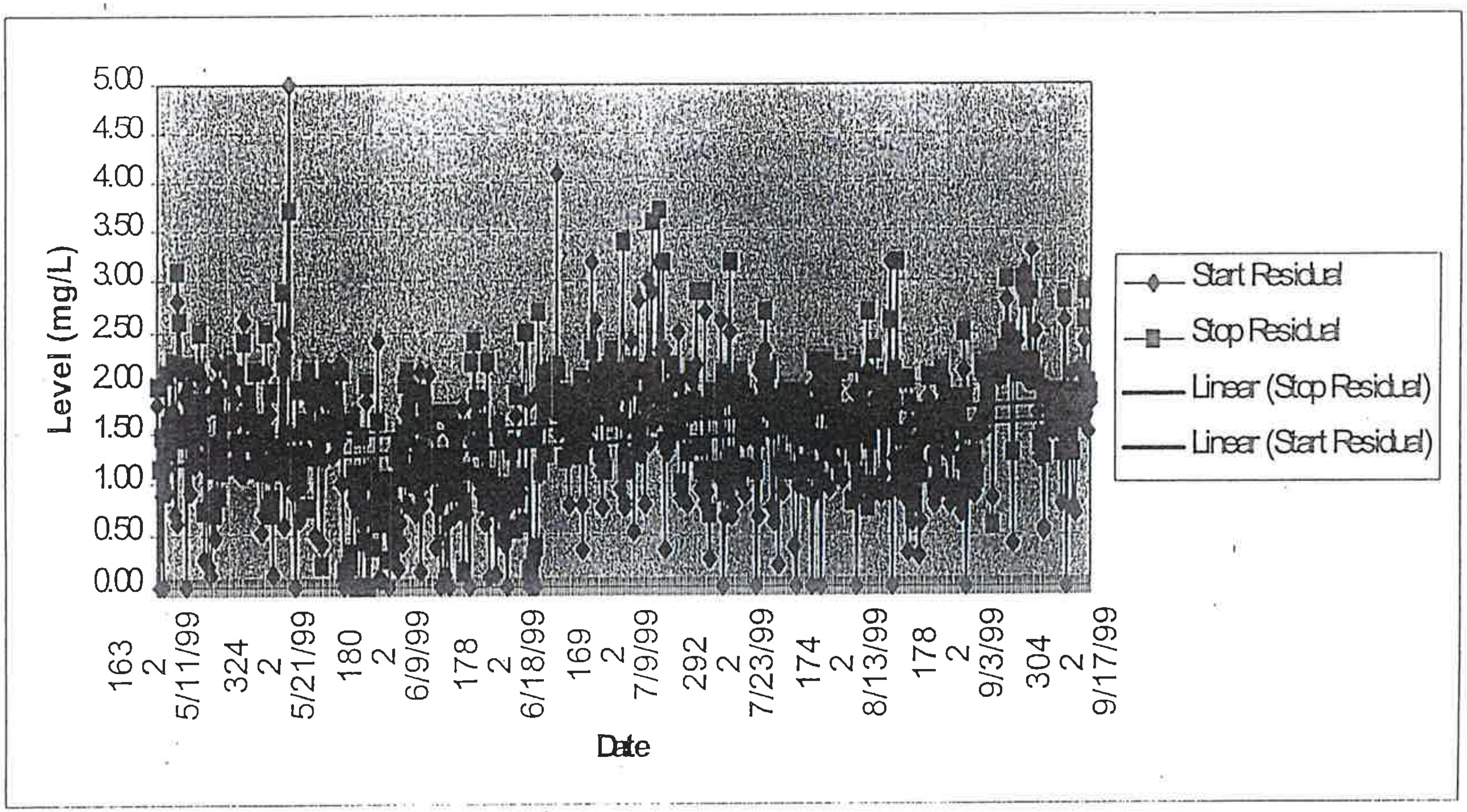


Pipe Coupon Setup



Results and Discussion

- Chloramine Residual (taken during flushing)



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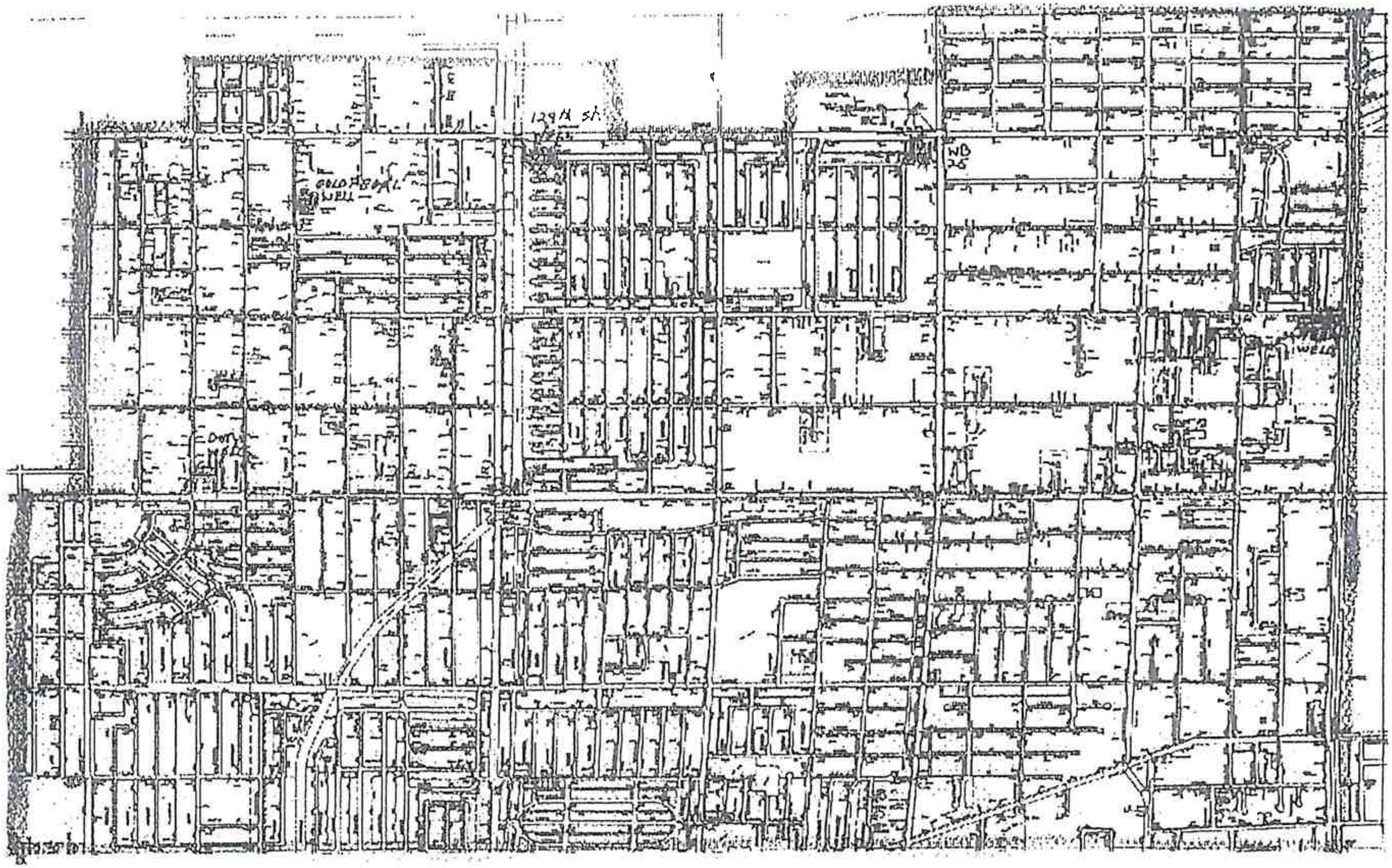
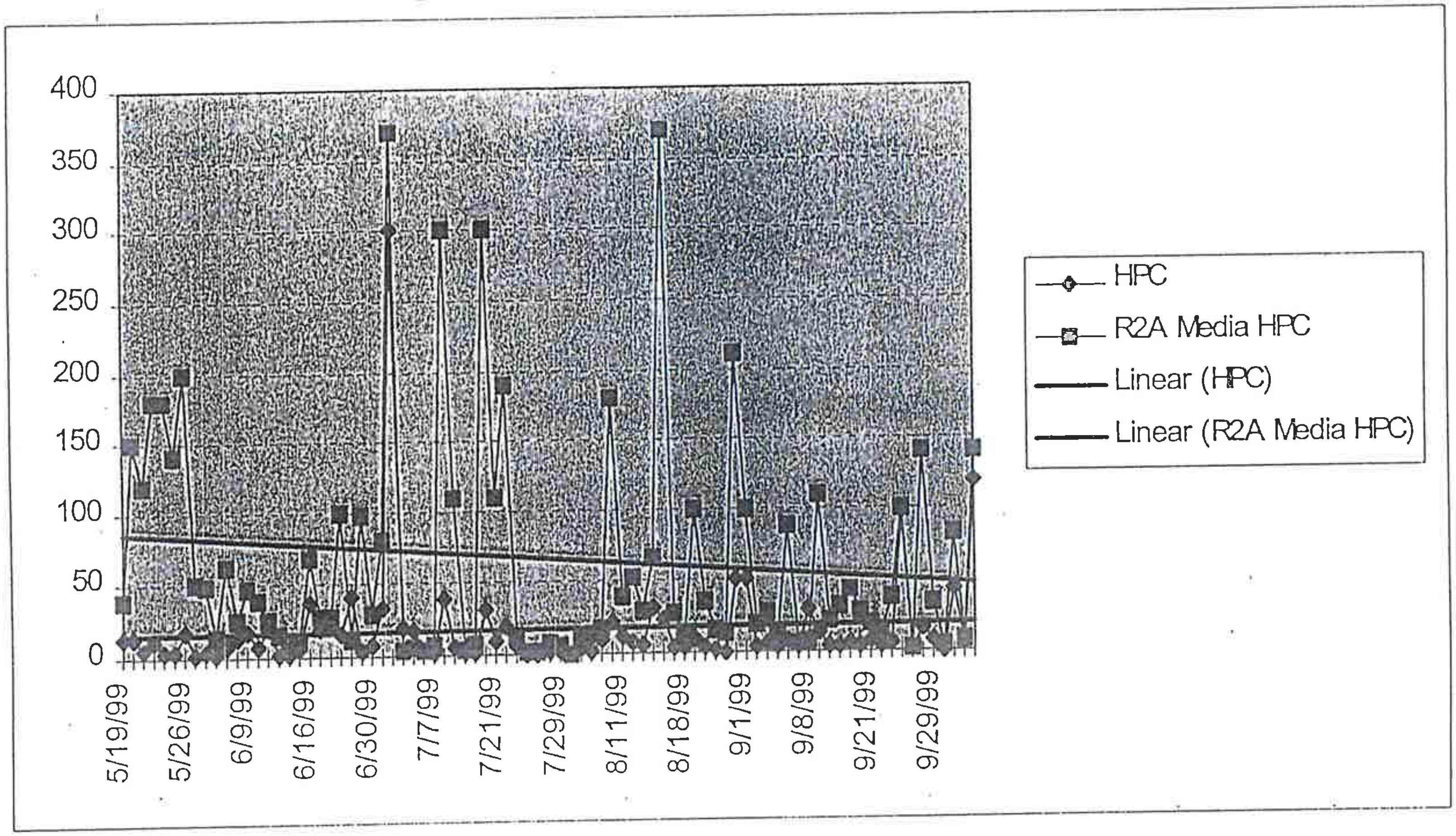


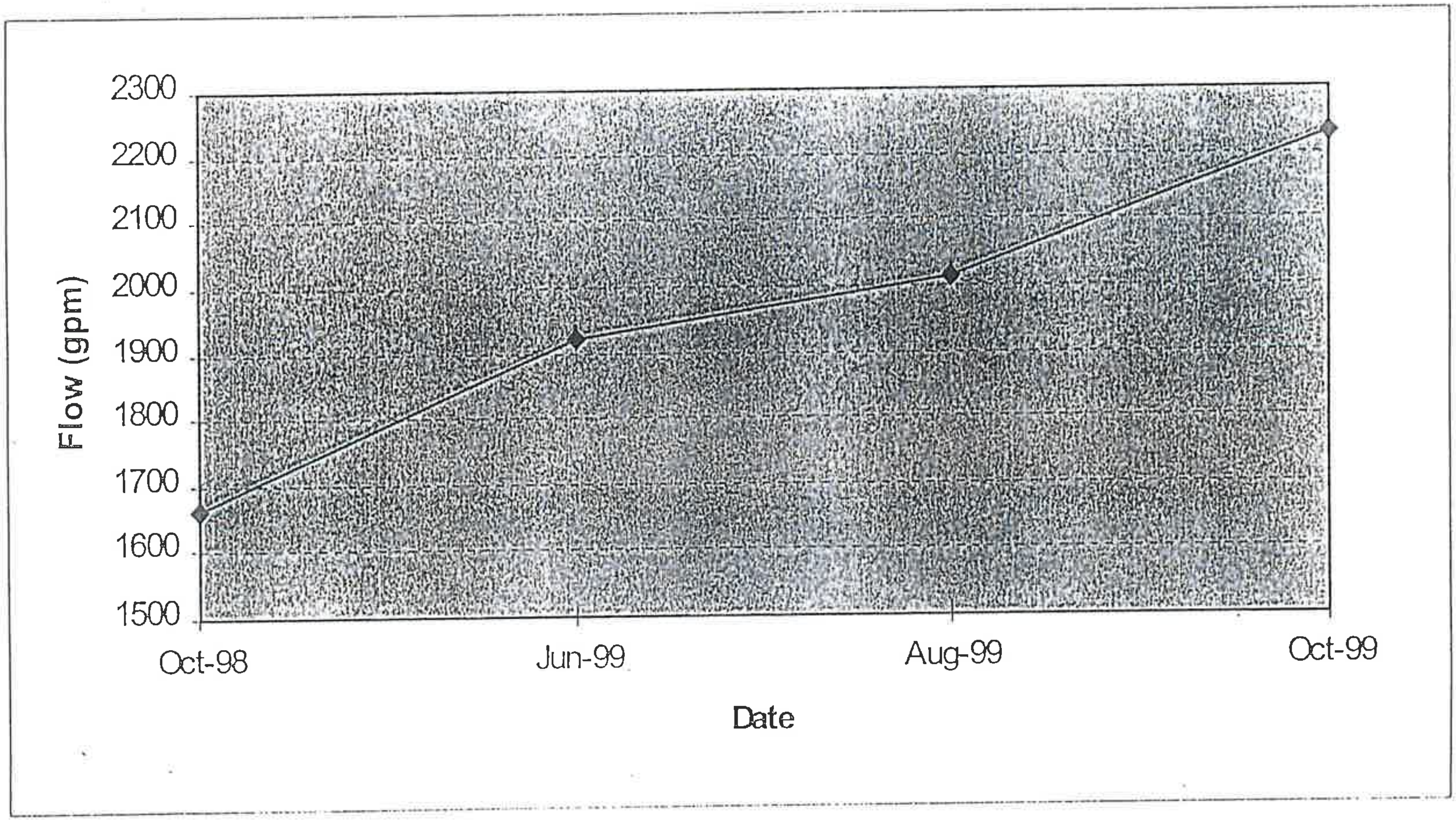
Results and Discussion (cont.)

- Microbiological Quality (from primary sites)



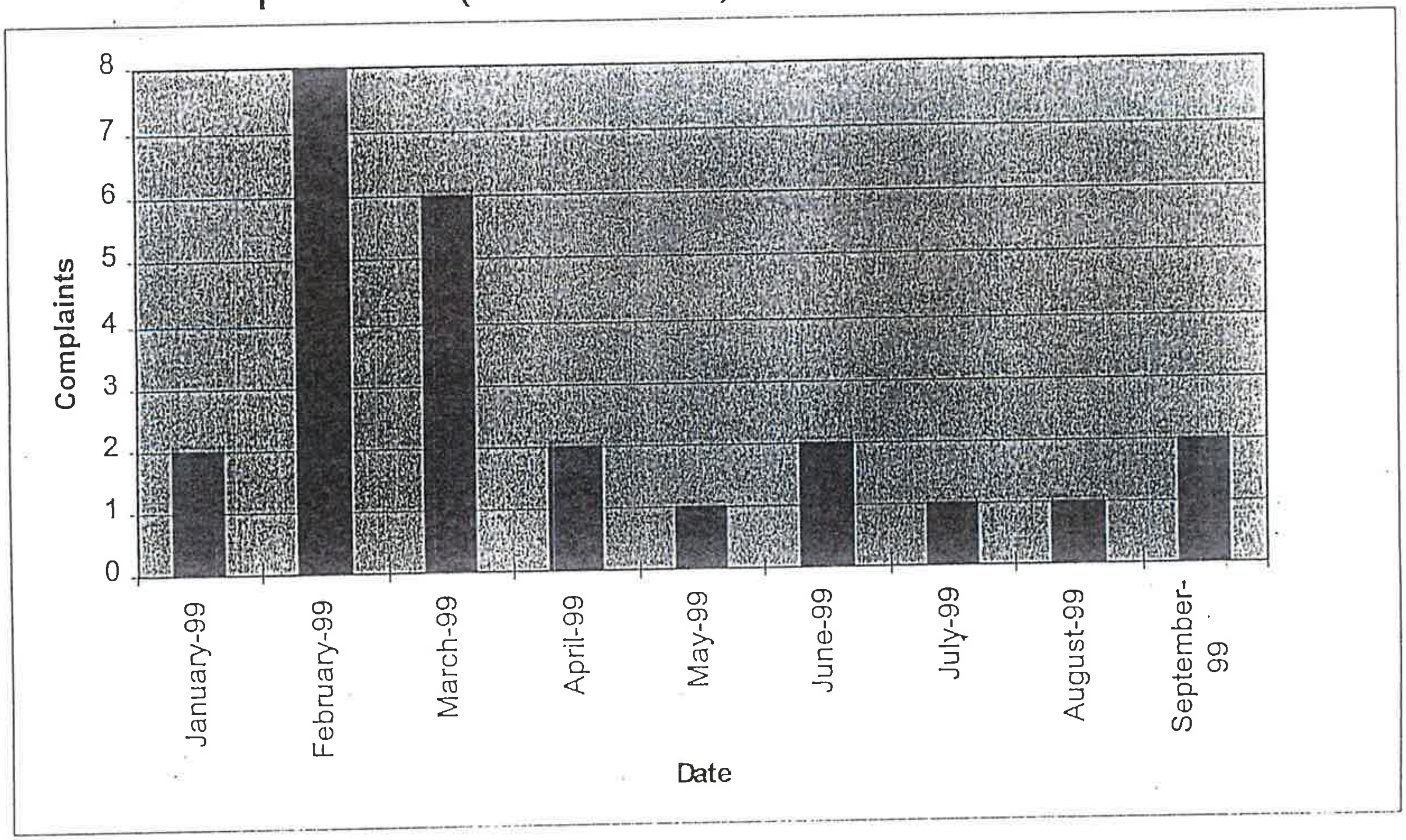
Results and Discussion (cont.)

- Flow Tests (one hydrant)



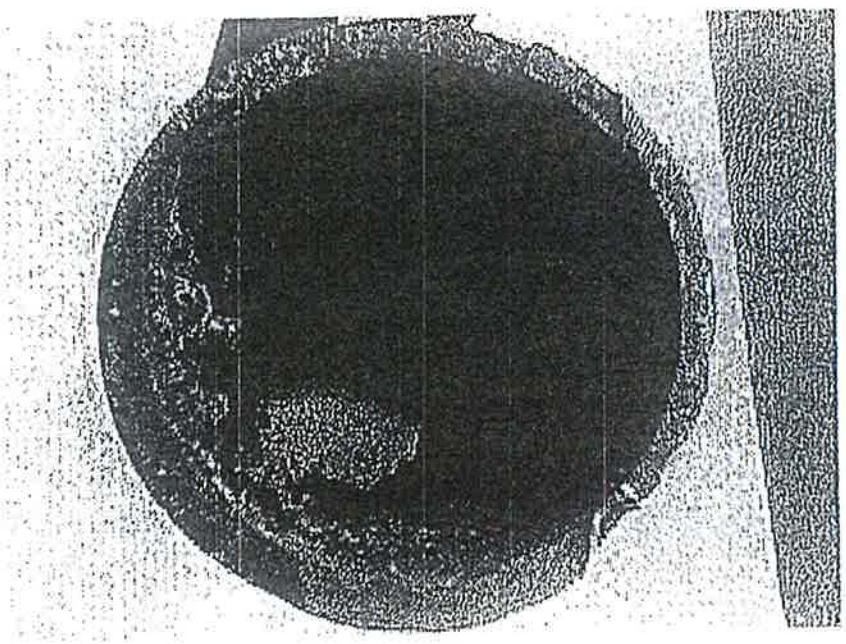
Results and Discussion (cont.)

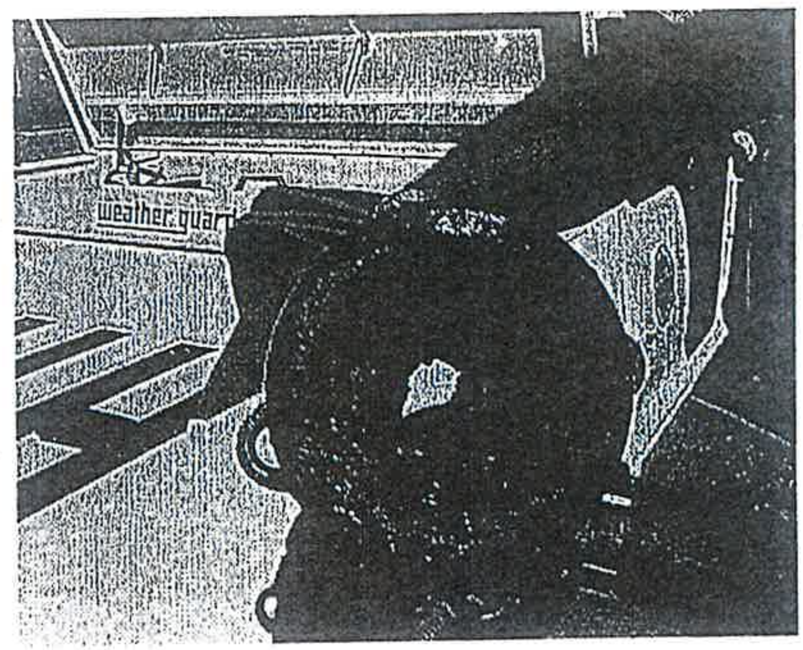
- Complaints (one area)



Results and Discussion (cont.)

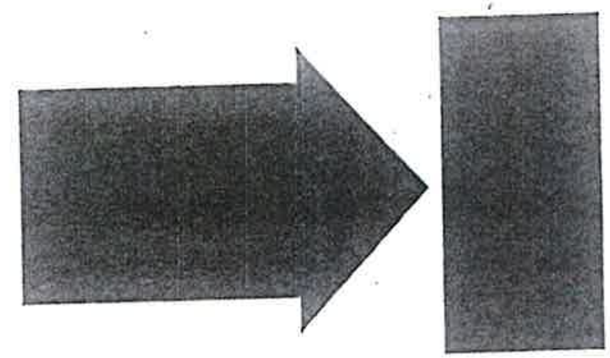
- Pipe Coupon





Conclusions and Recommendations

- Polyphosphate addition can soften and remove existing biofilm layers and corrosion tubercles. A flushing program will speed up the removal of these layers.



Conclusions and Recommendations (Cont.)

- Short-term episodes of low disinfectant residuals and high R2A-HPC levels should be expected shortly after the implementation of polyphosphate. Therefore, plant effluent chlorine residual should be increased if possible and system residuals closely monitored by qualified personnel.

Conclusions and Recommendations (Cont.)

- Implementation of a flushing program in conjunction with polyphosphate addition is a must. This program may minimize short-term water quality degradation associated with corrosion product and biofilm detachment events.

Conclusions and Recommendations (Cont.)

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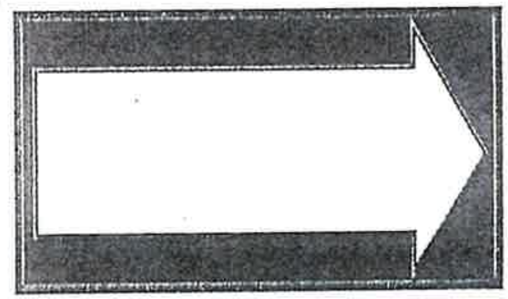

Acknowledgments

- Southern California Water Company
- Calvin Abernathy
- Anne Camper
- Southwest District Personnel:

  John Jones

  Mike Cory

  Ed Galven

  Jun Carpio

  Lorrie Bolen

Contact Information

- You may reach me at:

Phone: 310-767-8212
Fax: 310-323-8257
E-mail: Kcohen@SCWATER. Com

Polyphosphates - The Solution To Distribution System Low Residuals, Biofilm and Pipe Corrosion

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1

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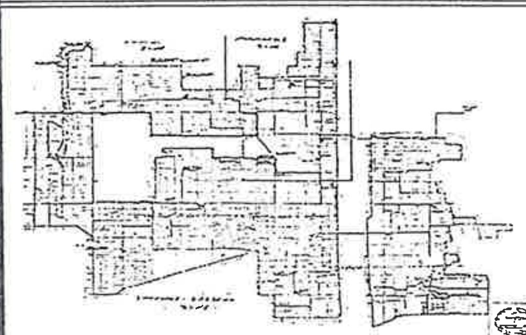

4

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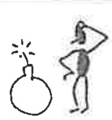
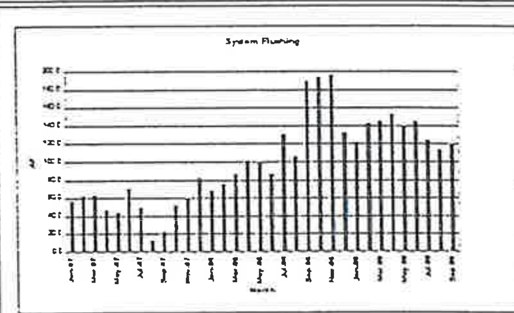


5

Flushing Data



6

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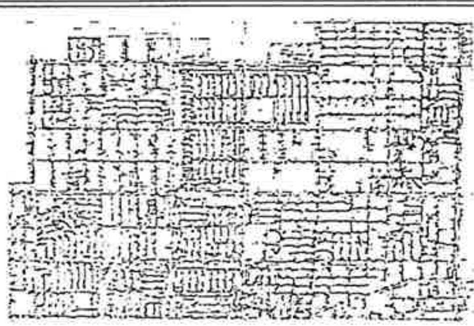

9

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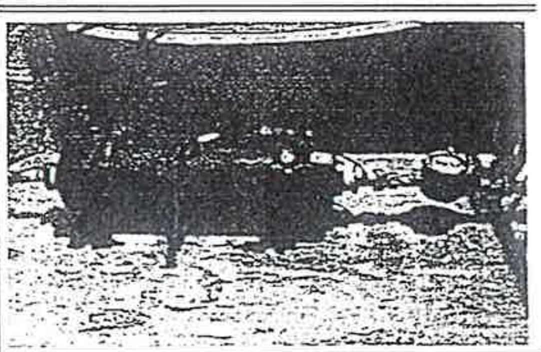
10

Pipe Coupon Setup



11

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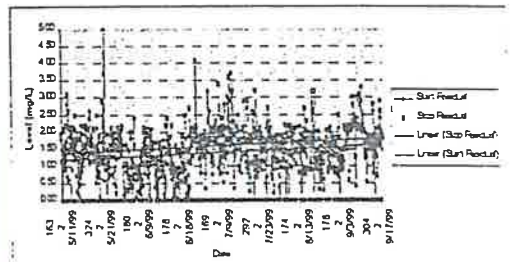

12

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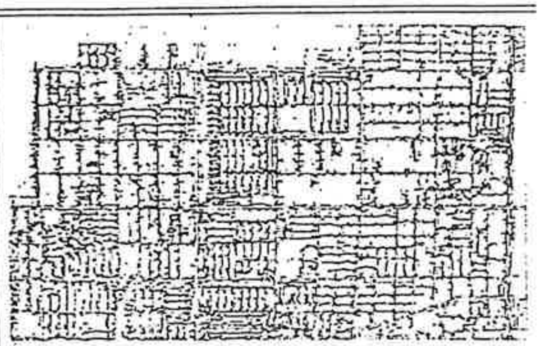

13

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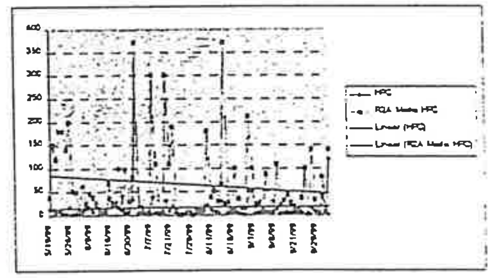

14

Results and Discussion (cont.)

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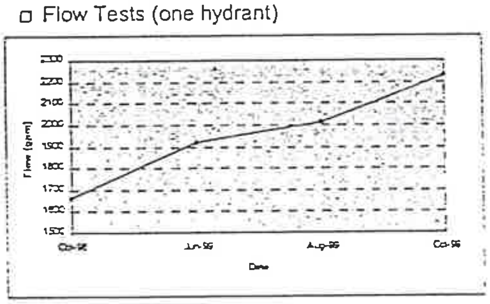
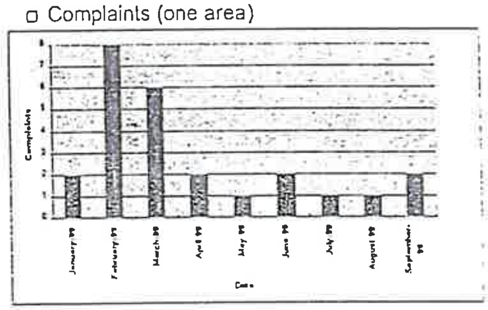


15

Results and Discussion (cont.)

- Complaints (one area)



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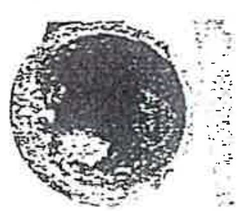
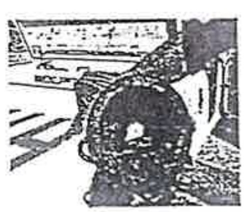
Results and Discussion (cont.)

- Pipe Coupon





17

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Contact Information

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Phone: 310-767-8212
Fax: 310-323-8257
E-mail: Kcohen@SCWATER. Com