State of Florida

Public Service Commission

CAPITAL CIRCLE OFFICE CENTER • 2540 SHUMARD OAK BOULEVARD
TALLAHASSEE, FLORIDA 32399-0850

-M-E-M-O-R-A-N-D-U-M-

DATE: March 26, 2008

TO: Ann Cole, Commission Clerk, Office of Commission Clerk

FROM: Jean Hartman, Senior Attorney, Office of General Counsel

RE: Docket Number 060606-WS

Please place the attached documents in the above-referenced docket file. Thank you.

JEH/tfw

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June 22, 2007

Chris de Comarmond
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Re: Aloha Utilities, Inc.; Contract with USF
Our File No. 26038.01

Dear Mr. de Comarmond:

I am an attorney representing Aloha Utilities, Inc. ("Aloha" or the "Utility"). I have been asked by Mr. Stephen Watford, President of Aloha Utilities, Inc., to provide a follow up letter to your June 1, 2007 email, and your subsequent conversation with Mr. Watford of June 18, 2007.

As you know, Aloha Utilities, Inc. contracted with the University of South Florida (USF) to provide Aloha with a study that would propose the best technology for treatment of hydrogen sulfide in raw water pumped by Aloha. The Utility also contracted with USF for the implementation of that selected technology. If you would refer to those two different contracts, you will see the specific tasks involved in each of them. As Mr. Watford explained to you, the Utility has not received the final reports from these projects, nor have they been provided with the services those contracts entailed.

As you know, the primary investigator on these projects coordinating both the research and the development of the resulting reports was Dr. Audrey Levine. As you are also no doubt aware, Dr. Levine left USF in December of 2006. Aloha's representatives have only sporadically been able to contact Dr. Levine in Washington D.C. and they are currently seeking assistance from her in finalizing the data, reports, and study results that were envisioned under these contracts. However, to date, Aloha does not have the reports detailing the conclusions of the study or any of the data that was produced during those lengthy and detailed studies. Therefore, the Utility basically has nothing that was envisioned to be provided to Aloha as a result of these two contracts.

The Utility's Consulting Engineer, David Porter, P.E., and Mr. Watford have spoken with

Dr. Levine on several occasions in the last six months about the project and most recently Dr. Levine promised to supply the above discussed materials and reports by Monday, June 18, 2007, then changed that to Friday, June 22, 2007, then today that was again changed to early next week. However, as of today's date, the Utility still has received nothing.

Aloha is willing to work with Dr. Levine and USF in bringing the contracted for studies, analysis, and reports to a swift conclusion. Time is of the essence, as not only Aloha, but also the Southwest Florida Management District, the DEP, and the Florida Public Service Commission, as well as other entities involved in overseeing the implementation of treatment for removal of hydrogen sulfide, have been eagerly awaiting these reports. Her reports are a prerequisite to the scheduling, analysis, planning, design, permitting and construction of such treatment implementation. We must obtain that information as quickly as possible, so that these contracts can be concluded and the Utility can progress to the next step of implementing the selected technology. Hopefully, by next week we will be provided with all of the needed data, information, and reports.

We will be glad to work with the University in any way we can. However, obtaining the data and the development of the needed conclusions and reports, is completely outside of our control.

If you have any questions in this regard, please let me know.

Sincerely,

ROSE, SUNDSTROM & BENTLEY, LLP

F. Marshall Deterding
For The Firm

FMD/tms
cc: Stephen G. Watford, President of Aloha Utilities, Inc.
David Porter, P.E.

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September 5, 2007

Michael Cooke, Esquire
General Counsel
Florida Public Service Commission
2540 Shumard Oak Boulevard
Tallahassee, Florida 32399-0850

RECEIVED
SEP - 6 2007
FLORIDA PUBLIC SERVICE COMMISSION
OFFICE OF THE GENERAL COUNSEL

Re: Aloha Utilities, Inc.; Contract with USF
Our File No. 26038.55

Dear Mr. Cooke:

As you are aware, Dr. Audrey Levine has been and remains an instrumental part of Aloha's team in the design and implementation of anion exchange, and was the scientist who envisioned, tested, and conceived of the treatment method which was ultimately accepted by consensus of the PSC, customer representatives, OPC, and Aloha, and the consultants of each.

In 2004, after Dr. Levine had already thoroughly familiarized herself with these issues as a consultant for OPC, and after Dr. Levine's expertise and credibility had been repeatedly lauded by OPC and customer representatives, Aloha contracted with the University of South Florida, under Dr. Levine's direction and control, to engage in a series of studies and to undertake a series of tests to determine how best to control hydrogen sulfide induced water quality issues at Aloha's Seven Springs water treatment facilities. The University, under Dr. Levine's direction and control, was and continues to be contractually obligated to assist Aloha in the development of design criteria for treatment systems at each well and to render assistance with process design, permitting, and implementation throughout the duration of the project.

On the last day of December 2006, Dr. Levine left the University of South Florida for a new job with the United States Environmental Protection Agency in Washington D.C. While Dr. Levine at times has been a source of frustration to Aloha and a source of delay in the process even before that move, since that time the situation has continued to worsen. Aloha has diligently and persistently attempted to obtain the information from Dr. Levine which it needs to go forward with the implementation of the anion exchange project. Her input, and the data and other information which form the basis of her conclusions, are absolutely essential in order for Aloha to proceed. Dr. Levine has failed to produce her underlying data and conclusions, and has thus impaired Aloha's ability to meet the time frames for the implementation of the project which was established by an Order of the Florida Public Service Commission. Aloha has done everything it could do, orally and in writing, to convince, cajole, persuade, and even threaten action against Dr. Levine or USF in an attempt to secure Dr. Levine's follow through on her promises to aid in the project. These promises continued even after the change to her new job at EPA. Dr. Levine has refused to prioritize the completion of this project, and even the enlistment of the help of administrators and attorneys for the University of South Florida has not yet yielded results.

Dr. Levine has made several representations to Aloha that her not-yet-completed work was near completion, even to the point where she informed Aloha several months ago that her final report was essentially complete. The most recent promise by Dr. Levine, as conveyed to Aloha by representatives of USF, was that Dr. Levine would complete the report, which was the critical step that must be completed before Aloha can move forward with any other aspect of the anion exchange treatment project, by the end of August 2007. While Aloha was and continues to be pained by this delay, it had no choice but to pursue this most recent avenue (use of representatives of USF) and allow that promise to play out. As of today, the second working day of September, 2007, it appears that once again Dr. Levine has failed to keep her promise to supply the reports.

Unfortunately, we have now reached a point where we must formally inform all of the parties to our Settlement Agreement that definite delays have resulted from the failure to receive Dr. Levine's reports and that the fault is squarely on Dr. Levine, and ultimately, USF. Dr. Levine's continued assistance is invaluable in seeing to it that this project is implemented in the most efficient and technically appropriate manner, and Aloha wishes to continue its relationship with Dr. Levine and USF. That is why Aloha has hesitated to raise the stakes in terms of the blame for these delays. However, Aloha simply has no choice but to now announce, formally, that our informal communications with OPC and Commission staff about our problems with Dr. Levine have come to fruition. While we continue to anticipate a finalized report from Dr. Levine in the next few weeks, we do not have unreserved confidence that the report will be produced in that time frame. However, as soon as that report is received, this project can proceed, once again, upon the contemplated time frames. All events which are in the control of Aloha have occurred when they should occur. In this case, it is the actions, or non-actions, of Dr. Levine and USF, which are not within the control of Aloha, which have caused any delays which result from the above.

Please call me if you have any additional questions regarding the above, and we will certainly have an update on our exact progress at the next quarterly meeting between OPC, Commission staff, customer representatives, and representatives of Aloha.

Thank you in advance for your attention to this matter.

Sincerely,

ROSE, SUNDSTROM & BENTLEY, LLP

John L. Wharton
For The Firm

JLW/tms
cc: Stephen C. Reilly, Esquire
Rosanne Gervasi, Esquire
Lorena Holley, Esquire

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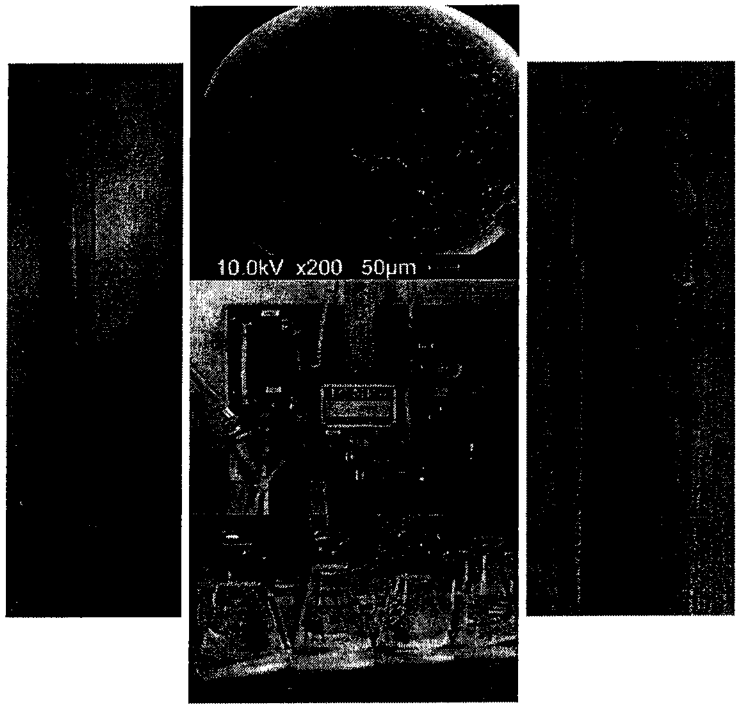
Pilot testing of packed-bed anion exchange for control of hydrogen sulfide from groundwater sources in the Seven Springs Service Area



Submitted to

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In accordance with provisions of a research contract granted to:

University of South Florida
Department of Civil and Environmental Engineering
4202 East Fowler Ave., ENB 118
Tampa, FL 33620

Report prepared by:
Dr. Audrey D. Levine, P.E., Camilo Romero Cotrino, and Panos Amitzoglou

October 2007

Pilot testing of packed-bed anion exchange for control of hydrogen sulfide from groundwater sources in the Seven Springs Service Area

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Pilot-testing of packed-bed anion exchange for control of hydrogen sulfide from groundwater sources in the Seven Springs Service Area

Aloha Utilities, Inc. is in the process of upgrading its water treatment facilities in the Seven Springs service area to improve water quality and to meet increasing water demands. The primary focus of the treatment upgrades is to incorporate hydrogen sulfide removal as an integral component of the treatment system. Five of the seven ground water treatment plants (Plants 2, Mitchell, 6, 8, and 9) will be upgraded to provide packed-bed anion exchange reactors for removal of sulfide, sulfate, organic carbon, and other anionic contaminants. The water produced through the anion exchange process will be disinfected using chlorine for primary disinfection and chloramines for secondary disinfection. The water will also be treated with a corrosion inhibitor prior to distribution. Water produced from the other two treatment plants (Plants 1 and 7) will be treated by disinfection (chlorine and chloramines) and corrosion control, but will not be treated by anion exchange because of the relatively lower levels of hydrogen sulfide in those water sources.

To develop design information related to the capacity of the anion exchange resins at each treatment facility and the overall process efficiency, pilot-scale testing of the treatment system was conducted during 2005 and 2006 by the University of South Florida (USF) through a research contract with AUI. Pilot-scale anion exchange reactors were provided by Tonka Equipment, MN. Under the USF research program, anion exchange process performance was evaluated under different conditions (flowrates, continuous versus intermittent operation, presence/absence of oxygen, temperature, etc.) to develop design information and optimize the regeneration process. Results from the pilot testing program and design recommendations are presented in this report.

OBJECTIVES

The purpose of this report is to provide design recommendations for implementation of anion exchange at water treatment facilities in AUI's Seven Springs service area. The objectives of this report are to:

1. Evaluate the influence of water quality on the capacity of anion exchange resin for removal of hydrogen sulfide, sulfate, and organic carbon from wells in the Seven Springs service area,

2. Provide design information for each treatment facility including reactor dimensions, regeneration frequency, and potential monitoring strategies,

3. Evaluate regeneration efficiency under different salt loading conditions,

4. Evaluate wastewater characteristics under different water demand scenarios, and

5. Evaluate impacts of wastewater generated by anion exchange on sodium and chloride levels in reclaimed water.

BACKGROUND

Background information on anion exchange technology and its application for treating ground water in the Seven Springs service area is presented in this section. General information on water quality and treatment capacity requirements is also provided.

Anion exchange technology

Anion exchange technology is a relatively mature technology with a long history in water purification applications (Owens 1995, Thompson and McGarvey 1953, Wachinski and Etzel 1997). Anion exchange technology can be applied for removal of negatively charged (anionic) dissolved and colloidal constituents from drinking water sources. Over the past ten years, spurred by increasingly stringent water quality requirements coupled with advances in resin production, the use of anion exchange technology has been adopted by many water utilities to remove negatively charged constituents from water. Anions that can be removed through anion exchange include hydrogen sulfide (HS^- or S^{-2}), organic carbon, nitrate (NO_3^-), Nitrite (NO_2^-), sulfate (SO_4^{-2}), carbonates (HCO_3^- and CO_3^{-2}), bromate (BrO_3^-), and phosphates ($H_2PO_4^-$, HPO_4^{-2}, and PO_4^{-3}). Other specialized applications include removal of perchlorate (ClO_4^-) or oxidized forms of arsenic (e.g. $HAsO4^{2-}$). Many types of microorganisms (viruses, bacteria, protozoa) also are amenable to removal through anion exchange due to surface characteristics which tend to be negatively charged in drinking water sources, depending on the pH and other water quality parameters. Through anion exchange, exchangeable anionic constituents in water react with anions that are associated with a porous matrix or resin. There are a variety of anion exchange resins commercially available that have been used in water treatment applications and have been approved by the National Sanitation Foundation (NSF).

The efficiency of anion exchange treatment of water depends on the resin characteristics (composition, particle size, selectivity, capacity) and water quality parameters (exchangeable anions, pH, temperature, oxidation potential, etc.). As anions from water are exchanged with resin anions, the anionic composition of the resin matrix changes as it equilibrates with the water. Once the resin-water anionic composition reaches equilibrium, there is no further exchange of anions. A regeneration process is used to restore the resin capacity by displacing the anions that were removed from the water with chloride, hydroxide, or other exchangeable anions. For most municipal water treatment anion-exchange applications, the exchangeable anion is chloride and the resin is regenerated using a brine solution containing either sodium or potassium chloride. Regeneration is an integral component of anion exchange treatment systems. The frequency of regeneration and the characteristics of the waste streams produced from anion exchange regeneration depend on interrelationships between resin characteristics, water quality, and process operation.

For removal of hydrogen sulfide from water, the use of anion exchange capitalizes on the fact that, under pH ranges typical of groundwater, the majority of the sulfur species are in an anionic form (HS^-, S^{-2}, polysulfides, thiosulfate, sulfite, sulfate). In addition to removing ionized hydrogen sulfide from water, additional benefits of anion exchange technology include removing other negatively charged constituents including sulfate, organic carbon, and turbidity. Removing sulfate has the advantage of reducing the total mass of sulfur introduced into the distribution system. The removal of organic carbon reduces the concentration of disinfection by-product precursors.

Reactor configuration options

Anion exchange systems can be designed to operate as packed-bed columns or as completely mixed reactors. The choice of reactor type depends on the specific application. The advantage of fixed-bed columns is that they can be operated without breaking suction between the well and the reactor, thus preventing the introduction of other contaminants and eliminating the need for repressurization. Completely-mixed systems and fluidized bed systems have also been developed for water treatment applications, such as MIEX™ systems. The effectiveness of MIEX™ resin for removal of hydrogen sulfide from the Seven Springs source water was demonstrated in 2001 (Porter 2002). Completely-mixed systems generate a continuous waste stream and require more space than fixed-bed columns. In addition, there is frequently a need for filtration to prevent resin carryover.

Packed-bed anion exchange systems consist of column-reactors that contain a fixed volume of anion-exchange resin. Operationally, packed-bed anion exchange reactors alternate between a service cycle for producing treated water and a regeneration period for restoring the resin capacity. During the service cycle, water flows through the resin and anions from the water are exchanged with anions (e.g. chloride) released from the resin. The resin bed also functions as a coarse granular medium filter and has the potential to entrap suspended particles within the media layer. The affinity of anionic exchange resins for negatively charged constituents may enhance removal of microorganisms due to the characteristically negative surface charge that is prevalent under neutral pH conditions. The length of the service cycle can vary from days to weeks, depending on the treatment objectives, resin characteristics, and water quality (exchangeable anions, pH, suspended solids, microbial concentration, etc.). As the service cycle progresses, exchangeable anions from the water saturate the resin matrix causing a decrease in removal efficiency. To restore treatment effectiveness, packed-bed reactors are taken off-line and regenerated using a salt solution (brine).

Anion Exchange Regeneration Process

The goal of resin-regeneration is to remove constituents that accumulate within the resin matrix during the service cycle and replenish the resin with exchangeable anions. Regeneration of the resin requires contacting the resin with a solution containing a high enough concentration of the exchangeable anion to promote diffusion into the resin matrix. The high ionic strength of the brine solution may also provide a mechanism for controlling microbial activity within the resin bed, depending on the salt concentration, exposure time, and regeneration frequency. The regenerant solution is applied as a brine and the waste produced by the process contains the spent regenerant and constituents that have been eluted from the resin matrix.

The regeneration process consists of 4 sequential steps: backwashing to flush the resin and remove particles and deposits that accumulated in the bed during the service cycle, introduction of a regenerant solution (brine) into the column, slow rinse to push the brine through the resin bed, and a fast rinse to remove excess salt from the reactor. The overall process requires a minimum of 80 minutes and can be conducted based on water quality monitoring or on a schedule that is coordinated with periods of low water demand. Following the fast-rinse, the reactor is placed back into service. Periodically, a supplemental regeneration step using caustic soda is used to remove accumulated minerals and organics from the resin. The regeneration steps are summarized in Table 1.

Table 1. Sequence of Regeneration Process

Step	Purpose	Water source
Backwash	Reverse flow through the packed-bed reactor to dislodge particulate material that has accumulated during the service cycle and fluidize the resin prior to regeneration	Water from treatment plant (untreated or treated water)
Brine	Apply brine solution to replenish resin matrix with exchangeable anions. The rate of replenishment is related to the relative concentration of chloride in the brine and within the resin matrix (diffusion control). The osmotic pressure of the brine solution may help to inactivate microbial cells.	Water from treatment plant (untreated or treated water) mixed with salt (either sodium chloride or potassium chloride)
Slow rinse	Allow brine solution to react with resin matrix	Water from treatment plant (untreated or treated water)
Fast rinse	Flush brine from the system and prepare for next service cycle	Water from treatment plant (treated water)

The characteristics of the anion exchange wastewater depend on the volume of water processed through each anion-exchange reactor, the regeneration frequency, the concentration and type of regenerant used, and operational variables.

Anion Exchange Resin

Based on previous studies conducted by USF at AUI well sites (Levine et al. 2005) a commercially available macroporous strong base anion exchange resin (Tulsion® A-72 MP (Cl-)) was selected for treating ground water at AUI's Plants 2, Mitchell, 6, 8, and 9. A summary of the resin characteristics is given in Table 2.

Table 2. Tulson® A-72 MP Resin Characteristics

Parameter	Characteristic or Value
Matrix Structure	Cross linked polystyrene
Physical form	Moist spherical beads
Particle size	0.3 to 1.2 mm
Moisture (approx.)	58%
Solubility	Insoluble in all common solvents
Backwash settled density	42 to 45 lbs/ft3 (670 to 720 g/l)
Temperature stability (max)	195°F (90°C)
pH range	0 to 14
Ionic form	Chloride
Functional group	Quaternary ammonium Type I
Total exchange capacity	1.0 meq/Ml
Swelling (approx.)	Cl- to OH- 21%

Adapted from Tulson® A-72 MP Brochure

Source Water Quality

The design of anion exchange systems is dependent on the characteristics of the source water. Key water quality parameters that impact resin capacity include the type and concentration of exchangeable anions, total dissolved solids, organic content, and the concentration suspended or colloidal solids. A summary of ground water quality associated with AUI's Seven Springs service area is given in Table 3. The values in this table correspond to the monitoring conducted by USF during 2005 and 2006.

Table 3. Summary of water quality associated with treatment Plants 2, 6, Mitchell, 8, and 9 in the Seven Springs service area (data from 2005 and 2006)

Parameter	Plant 2 Average (Range)	Mitchell* and Well 6 Average (Range)	Plant 8 Average (Range)	Plant 9 Average (Range)
Anions				
Sulfur Species				
Sulfide (mg/L as S^{2-})	0.94 (0.56 – 1.23)	1.07 (0.82 – 1.51)	1.64 (1.34 – 2.45)	2.64 (2.03- 3.23)
Sulfate (mg/L as SO_4^{2-})	1.1 (<0.1 – 3.2)	14.7 (0.7 - 79)	7.3 (<0.1 – 18.6)	37.4 (26.0 – 49.7)
Chloride (mg/L as Cl^-)	15 (8 - 22)	25 (10 – 47)	15 (10 - 28)	15 (10-28)
TOC (mg/L)	3.08 (2.79-3.35)	2.37 (1.49-2.61)	2.68 (1.73-3.46)	2.78 (1.5-6.87)
UV-254 Absorbance (cm^{-1})	0.10 (0.04-0.13)	0.12 (0.04-0.12)	0.08 (0.07-0.14)	0.09 (0.03-0.13)
Alkalinity (mg/L as $CaCO_3$)	148 (30 – 250)	180 (120 – 190)	180 (100 - 260)	164 (100 – 250)
Total Exchangeable Anions (meq/L)	3.99	3.88	4.59	5.56
Other Characteristics				
pH	7.44 (6.03 – 7.61)	7.38 (7.2 – 7.63)	7.35 (6.58 – 7.52)	7.39 (6.79 – 7.55)
Temperature (° C)	24.21 (12 – 27.7)	24.9 (23.1 – 26.80)	23.4 (11.1 – 28.30)	23.70 (11.7 – 27.1)
Conductivity (μS/cm)	377 (232 – 454)	384 (285 – 502)	427 (449 – 520)	464 (341 – 570)
Turbidity (NTU)	0.24 (0.07-1.25)	0.53 (0.10-3.12)	0.6 (0.07-4.03)	0.32 (0.07-1.51)
Cl_2 demand (mg/L)	10.8	10.4	14.2	17.1

*Water quality at the Mitchell Plant is assumed to be similar to Plant 6

Capacity requirements

An important design consideration is to ensure that each treatment facility is capable of delivering water to AUI's customers under a range of water usage conditions. Currently, the water use permit (WUP) for the Seven Springs service area allows for an annual average daily flow (AADF) of 2.04 million gallons per day (MGD). Under the high water usage rates that occur seasonally in west-central Florida, the anticipated average daily flow for the maximum (or peak) month (MMADF) is 2.9 MGD. The anticipated maximum day daily flow (MDDF) is 3.9 MGD. A summary of the capacities of each of the individual treatment plants in the Seven Springs service area and the amount of water that will be supplied by each plant under the current and anticipated flow conditions (average, maximum month, and maximum day) is given in Table 4. To meet increasing water demands in the Seven Springs service area, Pasco County has committed to supplying AUI with up to 2.4 MGD of bulk water in the near term and 3.1 MGD AADF in the future.

Table 4. Flowrates for each of the seven treatment plants in the Seven Springs Service Area under different water demand scenarios[1].

Plant location	Pumping rate,GPM	AADF, MGD	MMADF-1, MGD	MMADF-2, MGD	MDDF-1, MGD	MDDF-2, MGD	Maximum flow, MGD
Plant 1	1,000	0.449	0.614	1.000	0.826	1.440	1.440
Plant 2	500	0.288	0.407	0.490	0.548	0.580	0.720
Mitchell	500	0.289	0.430	0.390	0.578	0.580	0.720
Plant 6	500	0.239	0.357	0.400	0.480	0.580	0.720
Plant 7	500	0.284	0.409	0.620	0.549	0.720	0.720
Plant 8	500	0.259	0.370	off	0.497	off	0.720
Plant 9	500	0.232	0.313	off	0.422	off	0.720
Total	4,000	2.040	2.900	2.900	3.900	3.900	5.760

[1] The treatment plants that will be upgraded with anion exchange are shown in the shaded areas.
GPM: gallons per minute; MGD: Million gallons per day; AADF: Average Annual Daily Flow; MMADF: Maximum month average daily flow; MDDF: Maximum Day Daily Flow using different pumping scenarios

METHODOLOGY

To evaluate the effectiveness of using packed-bed anion exchange for treatment of ground water from the Seven Springs service area, bench-scale and pilot-scale tests were conducted. An overview of the components of this project is given in Table 5. The approach used for each component of the testing program is detailed in this section.

Table 5. Overview of testing program

Type of test	Purpose
Batch tests	Evaluate the relative rate of uptake for anions in ground water and determine if on-line monitoring can be used to predict resin saturation
Pilot-scale tests	Evaluate long-term performance of packed-bed anion exchange at individual treatment plant sites
Regeneration tests	Evaluate the salt requirements for resin regeneration

Batch tests

In design of packed-bed anion exchange systems, it is important that adequate contact time is available for ion exchange to occur before the water passes through the column. The contact time available is referred to as the EBCT (empty-bed contact time) and is based on the ratio between the resin volume and the flow-rate. This parameter influences the overall reactor size. Because cost is related to the resin size and the quantity of resin, it is important to design systems that can operate within an efficient EBCT. In addition, the resin capacity influences the characteristics of the waste stream.

The treatment systems for AUI's Seven Springs service area will be designed for removal of hydrogen sulfide. Concurrent removal of other anions such as sulfate and organic carbon (TOC) also occurs. As anions are removed by the resin, chloride ions are released. Bench-scale batch tests were conducted to evaluate the relative rate of uptake of anions. A secondary goal of the tests was to see if monitoring chloride concentrations or the conductivity of the solution corresponded to uptake of anions. For each test, a fixed volume of resin was pre-conditioned and placed into a batch reactor. A fixed volume of water was mixed with the resin and the concentrations of anions were monitored as a function of time until equilibrium was reached.

Prior to initiating the tests, the resin was conditioned using the steps outlined in Table 6. The purpose of the conditioning process was to remove impurities from the resin surface and to condition the resin with a brine solution and the test water.

Table 6. Overview of resin conditioning steps used in batch tests

Step	Details
1	~100 g of resin is placed into a pre-cleaned container
2	500 mL of Nanopure water is mixed with the resin
3	The mixture is stirred at a low-speed using a paddle-mixer for 30 minutes
4	Mixing is stopped and resin is allowed to settle
5	An aliquot of supernatant is removed and pH, conductivity, UV-254, chloride are measured
6	The remaining liquid is decanted
7	500 mL of "fresh" Nanopure water is added to the flask
8	Steps 3-7 are repeated a minimum of 5 times or until there is no change in conductivity or UV-254
9	A concentrated solution of salt is mixed with the resin for 24 hours to replenish the chloride ion concentrations
10	Resin is rinsed with Nanopure water and then soaked in test water
11	Steps 9 and 10 are repeated

A set of 8-10 100 mL Ehrlenmeyer flasks were set up for each batch test. Each flask was filled with 25 ml of pre-conditioned resin (see Table 2) and 75 ml of the test water amended with different concentrations of exchangeable anions (sulfide, sulfate, TOC) was mixed with the resin. In some cases, a chloride probe and/or a conductivity probe was used to provide direct monitoring of liquid characteristics. The reactors were gently mixed by swirling the reactor contents at 2-5 minute intervals. At approximately 5 minute intervals, the anion exchange reaction in individual flasks was stopped by filtering the reactor contents through a coarse filter. The liquid was analyzed to determine the concentrations of exchangeable anions. Tests involving sulfide were conducted at an elevated pH (~8.5) to reduce the potential for volatilization. Control flasks containing the solution without resin and the resin submerged in distilled water were used to account for potential reactions with the flask or volatilization.

A photograph of the batch reactors is shown in Figure 1. For tests with hydrogen sulfide, reactors were covered during the experimental procedure.

Figure 1. Batch reactors used for evaluating reaction rates

Pilot Scale Tests

Pilot scale tests were conducted using plexi-glass packed-bed columns that could be operated at hydraulic loading rates and EBCTs typical of full-scale operations. The reactors were provided by Tonka Equipment, MN. The characteristics of the reactors are given in Table 7 and a photograph is shown in Figure 2. For the first round of tests, one reactor was installed at each treatment facility (Plants 2,Mitchell, 6, 8, and 9). For regeneration tests, three reactors were operated in parallel at Plant 9. Over the time period of the study, the operation of the Mitchell Plant was modified and it was not possible to test for hydrogen sulfide removal. For the purposes of process design, water quality at the Mitchell Plant was assumed to be similar to that of Plant 6.

Table 7. Characteristics of pilot reactors used for testing packed-bed anion exchange at AUI's treatment facilities

Parameter	Value
Material	plexi-glass
Diameter, inches	2 inches
Bed Volume (BV)	0.065 ft^3 (0.5 gallons; 0.0018 m^3)
Bed-depth	3 ft (0.91 m)
Freeboard	18 inches (0.46 m)
Regeneration: brine solution	3- 10 lb/ft^3 (48.64 – 192.51 kg/m^3)
Flow rate:	2 – 8 gph
Empty Bed Contact Time (EBCT):	4-16 *min*
Surface Loading rate:	6 gpm/ft^2 (0.0041 m/s)
Volumetric loading:	2.0 gpm/ft^3 (0.0044 s^{-1})

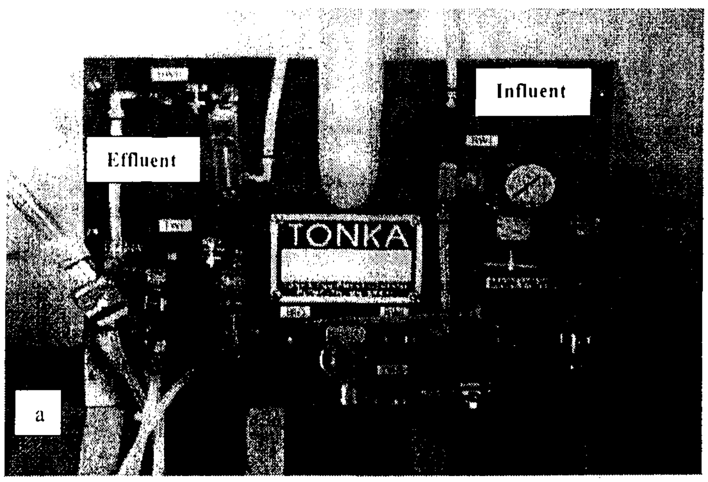

Figure 2. Anion Exchange Column Photographs. a) Control Panel Allows the Operation of all Anion Exchange Cycles; b) Anion Exchange Overall View

Anion exchange columns were operated at flowrates ranging from 2 to 8 gph (0.1 to 0.5 L/min) and at pressures ranging from 12 to 15 psi (82.73 kPa to 103.42 kPa). The columns were operated in consort with well pumps which turn on and off in response to pressure demand within the distribution system. The connection between the well pump and the AE column was made using a ½" garden hose (0.013 m). The capacity of the resin was defined based on the volume of water processed prior to sulfide breakthrough.

Specialized studies were conducted to evaluate the impacts of pre-aerating the water prior to anion exchange. For these studies, air was entrained into the water at the hose connection. Similar to the non-aerated studies, the capacity of the resin was defined based on the volume of water processed prior to sulfide breakthrough. The objective of these studies was to determine if air improved or impaired the removal efficiency. Dissolved oxygen levels ranged from about 0.2 to 2 mg/L, however, due to the reactor configuration and the need to maintain the system under pressure, it was not possible to accurately monitor or optimize the dissolved oxygen concentrations during these studies.

Columns were regenerated using a brine solution dose ranging from 3- 10 lb/ft^3 of salt (48.64 – 192.51 kg/m^3). The regeneration process consisted of four steps (see Table 1). An extended contact time (more than 12 hours) between the resin and the brine solution was allowed.

Regeneration analysis

To optimize the regeneration process, a testing program was conducted at the treatment plant with the highest concentrations of sulfide and sulfate (Plant 9). The goal of the testing program was to determine if the resin could perform at an equivalent capacity under different regeneration conditions as detailed in Table 8.

Table 8. Summary of regeneration parameters tested at Plant 9

Regeneration parameters	Range	Rationale
Salt concentration	2 to 15 lb/ft^3	Determine the feasibility of reducing salt usage and preventing high concentrations of salts in reclaimed water
Exposure time	30 minutes to >48 hours	Evaluate if exposure time impacts regeneration efficiency
Monitoring parameters	Conductivity, UV, hydrogen sulfide, chloride, sulfate, pH	Determine if on-line monitoring could be useful for predicting the end of the service cycle

For the regeneration studies, three pilot packed-bed columns were set up in parallel at Plant 9. This configuration provided a means for regeneration tests to be conducted in triplicate using a common source water quality. Ground water was applied to each reactor in parallel at similar loading rates and the reactors were operated until breakthrough of hydrogen sulfide was observed. The regeneration strategies that were tested included:

- Systematic comparison of salt loading rates
- Systematic comparison of salt contact time

The testing procedure involved operating the pilot-scale reactors, regenerating the reactors, and then evaluating the quantity of water that could be processed before breakthrough of hydrogen sulfide occurred after the regeneration. Following each regeneration cycle (backwashing, brine, slow rinse, fast rinse), each column was put back into service and the volume of water that could be treated prior to breakthrough of hydrogen sulfide was monitored. The success of each round of testing was evaluated based on the amount of water that could be processed after each regeneration. If the regeneration capacity of 1,000 gallons per cubic foot could be recovered, then the regeneration conditions were considered successful and the parameters were re-tested to verify the results. Conversely, if the regeneration capacity was not recovered then the test conditions were considered to be ineffective and either the salt concentration or contact time were changed for the next regeneration round.

Sampling and analytical tests

Anion exchange columns were operated until sulfide breakthrough was reached. Field tests included pH, conductivity, temperature, hydrogen sulfide, dissolved oxygen, chlorine demand, and oxidation reduction potential other samples were transported to the University of South Florida (USF) environmental engineering laboratory and analyzed for sulfate, chloride, alkalinity, UV-254 absorbance, and Total Organic Carbon (TOC).. A summary of analytical tests and method detection limits is given in Table 9.

Table 9. Summary of analytical methods used for characterization of water samples from bench-scale and pilot-scale testing.

Test	Field or Laboratory	Method Reference Number (Standard Methods); Instrument	Detection Limit/sensitivity
Alkalinity	Field and Lab	2320 B Titration /Bromocresol green/ methyl red	20 mg/L as $CaCO_3$
Chlorine, total and free	Field	4500-Cl F DPD Colorimetric Method; Pocket Colorimeter II	0.01 mg/L as Cl_2
Conductivity	Field and Lab	HACH Conductivity Probe; Model 51975-03	20 µS/cm
Hydrogen Sulfide	Field	4500-S^{-2} D Methylene Blue Method; Hach Field Spectrophometer Dr/2400	0.1 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	Field and 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	Field and Lab	4140 B. Capillary Electrophoresis with indirect UV detection; Beckman P/ACE 5000 CE or 4500 CL Argentometric titration or Nexsens Specific Chloride	1 mg/L
Sulfate	Field and Lab	4140 B. Capillary Electrophoresis with indirect UV detection; Beckman P/ACE 5000 CE or 4500 SO_4 turbidity method	1 mg/L
Metals			
Calcium	Lab	3111 Metals by Flame Atomic Absorption Spectrometry; Perkin Elmer Aanalyst 100	0.01 mg/L
Magnesium	Lab	3111 Metals by Flame Atomic Absorption Spectrometry; Perkin Elmer Aanalyst 100	0.01 mg/L
Iron (total and dissolved)	Lab	3111 Metals by Flame Atomic Absorption Spectrometry; Perkin Elmer Aanalyst 100	0.01 mg/L
Manganese	Lab	3111 Metals by Flame Atomic Absorption Spectrometry; Perkin Elmer Aanalyst 100	0.01 mg/L
Copper (total)	Lab	3111 Metals by Flame Atomic Absorption Spectrometry; Perkin Elmer Aanalyst 100	0.01 mg/L
Total Organic Carbon	Lab	5310C Persulfate-Ultraviolet Oxidation Method; Sievers TOC analyzer	0.05 mg/L
Particle characterization	Lab	Electron Microscopy/ Energy Dispersive Spectroscopy	0.5% (5000 ppm), 1 nm spot size

All sample containers were pre-cleaned by submerging in a 1% nitric acid bath at for at least 24 hours and rinsing with Nanopure™ water. Hydrogen sulfide samples were collected using a flowing sample device with a submerged sample port (see Figure 3. Glass bottles were used to transport samples for TOC and UV-254 absorbance tests. Other samples were transported in plastic bottles to the laboratory. Samples for Scanning Electron Microscopy (SEM) were preserved in a 2.5% glutaraldehyde solution for a minimum of 24 hours. Particulate matter was concentrated by filtration through a 47 mm nylon filter with a pore size of 0.1µm and dehydrated using a graded series of ethanol (30%, 50%, 70%, 95%, and 100%) and dried overnight at 50°C.

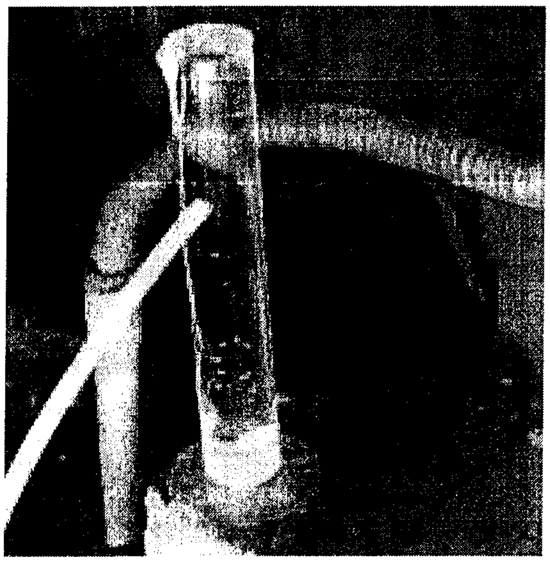

Figure 3. **Flow-through sampling device used for collecting samples for hydrogen sulfide analysis**

A chlorine demand test was conducted as an indirect measure of the concentration of oxidizable material available in the water source (Standard Methods, 1998). The test was conducted on untreated water from each plant on two different days. Chlorine was dosed into to the water at a concentration of 30 mg/L for untreated water and 10 mg/L as Cl_2 to the anion exchanger effluent. The contact time used to carry out this test was 30 minutes.

RESULTS

The results of the batch tests and the pilot-scale tests are presented in this section. In general, similar trends were observed in the batch and pilot-scale tests and the data were used to develop design information for the full-scale treatment facility

Reaction rates and monitoring options

The batch-tests were used to determine the reaction time needed for removal of hydrogen sulfide using Tulson® A-72 MP resin and to evaluate how the presence of other anions impacts the net removal of hydrogen sulfide. An example of a time series from batch testing of sulfate removal is shown in Figure 4. As shown, the highest rate of removal occurred in the first 3-5 minutes. Similar patterns were observed for sulfide and TOC and, in general, equilibrium was reached in less than 5 minutes.

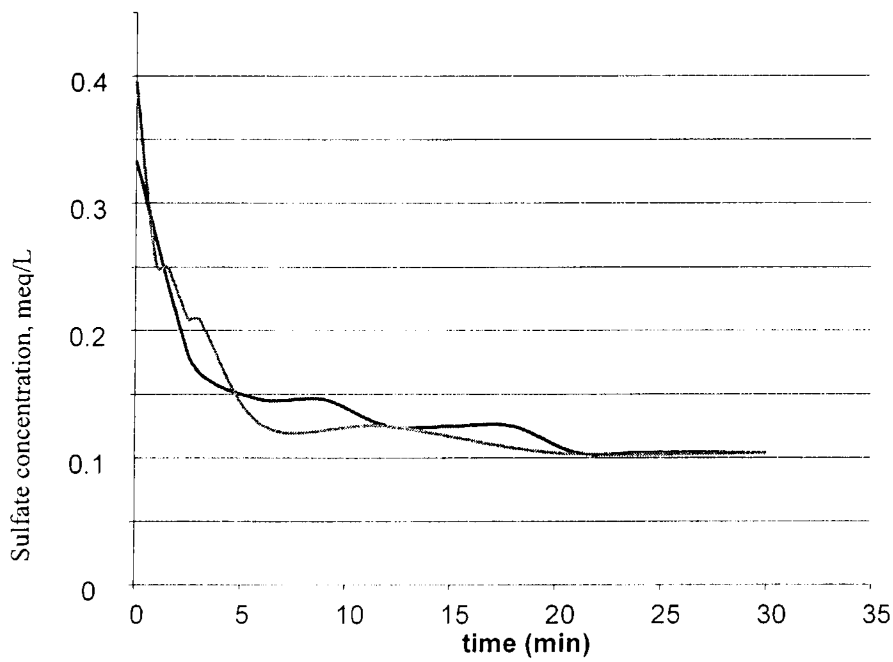

Figure 4. Anion exchange uptake of sulfate in batch tests conducted using Tulson® A-72 MP resin. The two lines represent two different batch tests.

Over the time period relevant for packed-bed anion exchange (4-16 minutes), the removal reactions could be approximated using a first-order reaction rate model where:

$$\frac{dC}{dt} = -kC$$

The overall rate of removal is related to the initial concentration and the reaction rate constant. For a batch reactor or plug flow reactor, this translates to:

$$C_t = C_o e^{-kt}$$

A comparison of the relative reaction rate constants is given in Table 10. As shown, the apparent rate constant for sulfate is approximately double the values observed for sulfide and TOC. It is important to note that, for water in some of the AUI plants, the mass of sulfate can be one to ten times the mass of sulfide or TOC.

Table 10. Apparent first order reaction rate constants for removal of sulfide, sulfate, and TOC based on batch tests using Tulsion anion exchange resin.

Parameter	Apparent first order reaction rate constant, min^{-1}
Sulfide	0.1
Sulfate	0.2
TOC	0.1

The use of on-line monitoring of chloride to identify equilibrium conditions was evaluated using an ion-specific chloride probe. An example output from chloride monitoring is shown in Figure 5. For the example that is shown, the concentration of chloride stabilized at about 700 seconds (~12 minutes) suggesting the system was at equilibrium. Specific ion electrodes are effective for laboratory monitoring, but may not be appropriate for full-scale testing. However, it is likely that similar trends could be developed using conductivity probes. The use of conductivity probes to detect equilibrium was not tested during this project.

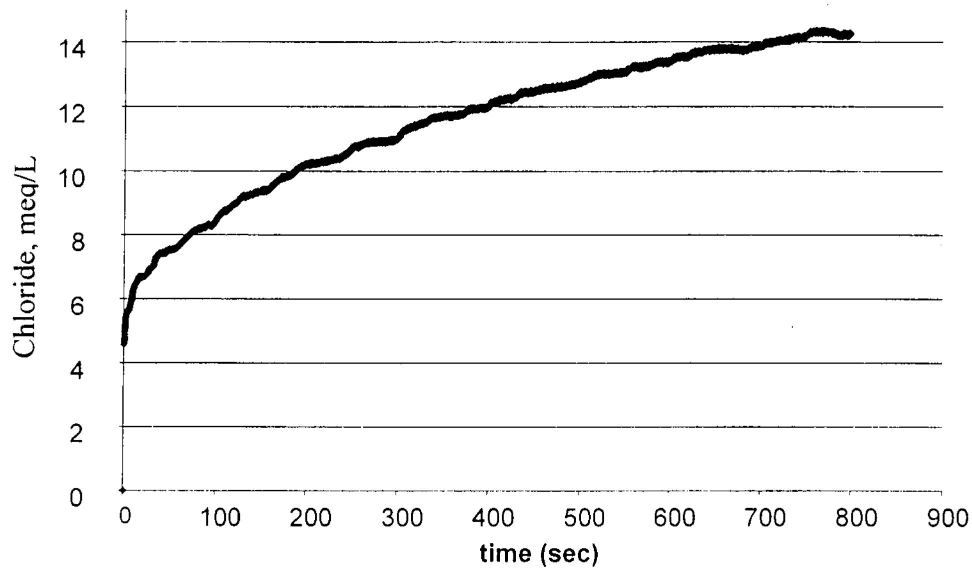

Figure 5. Example time series of chloride release during batch testing of anion exchange for uptake of hydrogen sulfide using Tulson® A-72 MP resin.

Pilot test results

The results of pilot testing were used to evaluate the resin capacity at each treatment facility. A comparison of the initial concentration of hydrogen sulfide and the breakthrough volume is shown in Figure 6 for four treatment facilities. In general, the resin capacity was related to the concentrations of hydrogen sulfide and sulfate in the untreated water. However, Plant 6 (C) did not follow the same trend as compared to Plant 8 (B). Differences in bed volumes for Plants 8 and 6 are most likely attributable to differences in sulfate concentration, where, for Plant 8, the average sulfate concentration was 7.27 mg/L while Plant 6 had about double the concentration of sulfate (14.75 mg/L as SO_4^{2-}) as compared to Plant 8 (see Table 3). In general, sulfate levels varied from 1 to over 30 mg/l as SO_4^{2-} among the treatment facilities and sulfate removal was typically over 90%. During the study period the average initial TOC concentrations for the four plants varied between 2.3 to 3.1 mg/L. About 80% of the TOC was removed by the anion exchange vessels.

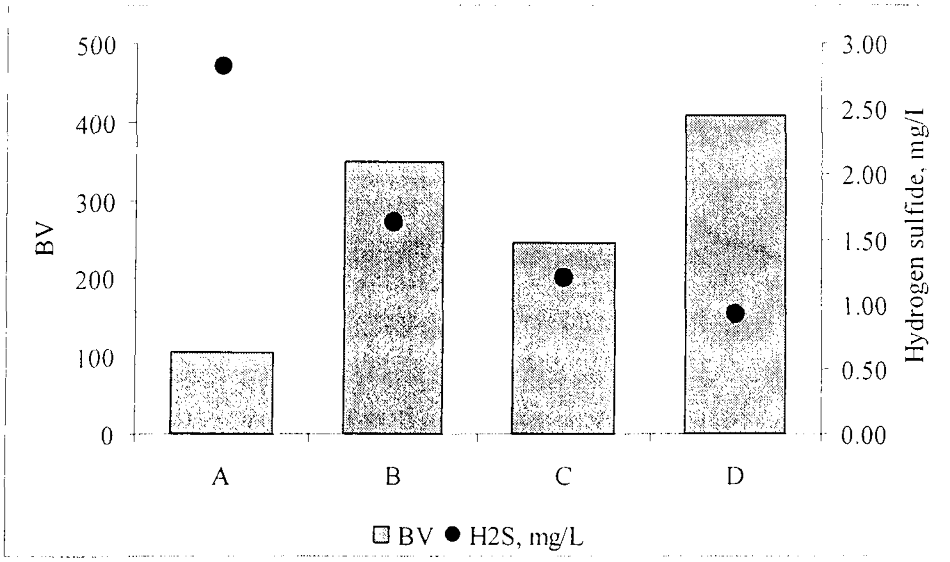

Figure 6. Comparison Between the Average Bed Volumes (volume of water/volume of resin) and the H_2S Concentration at four treatment facilities: A: Plant 9, B: Plant 8, C: Plant 6, and D: Plant 2

In parallel with evaluating removal of hydrogen sulfide and other anions, changes in chlorine demand were tested. A comparison of chlorine demand before and after anion exchange is shown in Figure 7 . Following anion exchange, the chlorine demand ranged from 2.0 to 3.23 mg/L. The major contributor to chlorine demand in the Seven Springs treatment facilities is hydrogen sulfide. A comparison of chlorine demand as a function of hydrogen sulfide concentration is shown in Figure 8. By removing the hydrogen sulfide through anion exchange, the concurrent reduction in chlorine demand will improve the effectiveness of disinfection and also the consistency of chloramination.

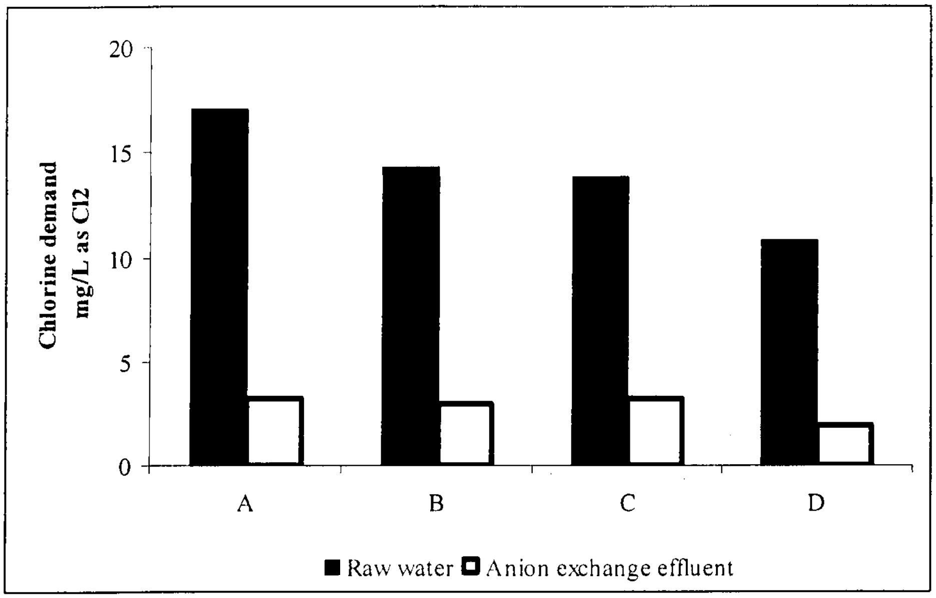

Figure 7. Comparison of Chlorine Demand in Water before and after Anion Exchange treatment at four treatment facilities: A: Plant 9, B: Plant 8, C: Plant 6, and D: Plant 2

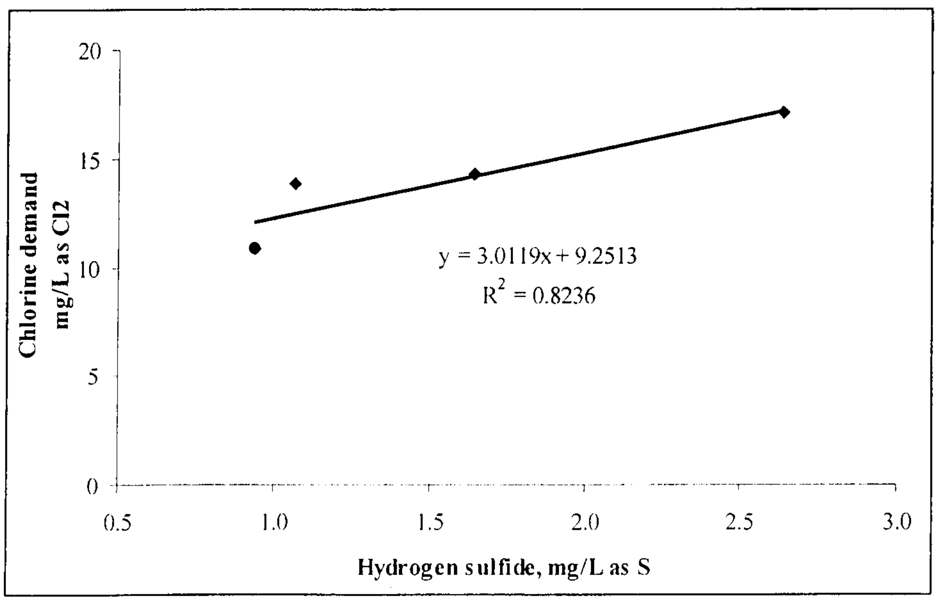

Figure 8. Chlorine Demand as Function of the Hydrogen Sulfide Concentration in untreated water from the Seven Spring service area.

Water discoloration potential

A major concern among customers in the Seven Springs service area is the potential for the water to become discolored due to reactions that occur in the distribution system. In some cases water discoloration occurs due to reactions between dissolved metals and hydrogen sulfide. To evaluate the impacts of anion exchange on the potential for water discoloration, an empirical test was developed. Water from Plant 9 was collected before and after anion exchange treatment in glass vials with Teflon lids that allowed for preserving the water without introduction of air. Dissolved copper (as copper chloride) was injected into each vial and the vials were allowed to react for 5-60 minutes. In some cases, the vials were stored for up to 2 weeks to simulate extreme copper-sulfide exposure conditions that might occur in pipes or tanks. For the purpose of these empirical tests, the concentrations of copper used ranged from 1 to 10 mg/L. It should be noted that the "Action Level" for copper is 1.3 mg/L and the concentrations of copper used in these empirical tests were designed to be high enough to allow for a visible reaction to occur and were not based on the "Action Level".

A visual comparison of the water before and after anion exchange treatment that was amended with a copper concentration of 6 mg/L and incubated at 20 C for 13 days in a dark environment is shown in Figure 9. As shown, the only vial that became discolored was untreated water amended with copper. No discoloration occurred in the untreated water that did not contain copper (left vial) or the two vials with water treated by anion exchange. The sulfide concentrations in the untreated water were between 1 and 2 mg/L.

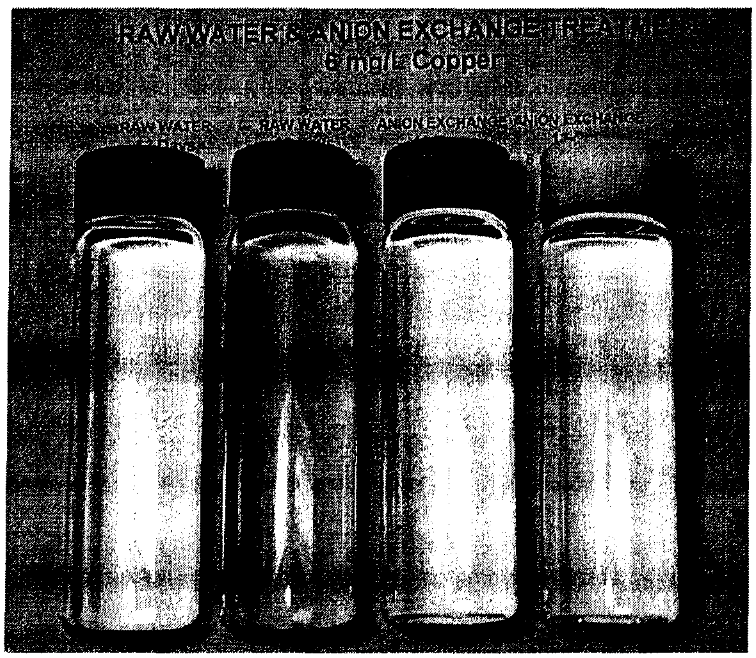

Figure 9. Visual comparison of water from Plant 9 before and after anion exchange treatment amended with 6 mg/L and incubated for 13 days at 20 C. The vial on the right contains untreated water that was not amended with copper, but incubated under the same conditions.

Impact of air in performance of anion exchange system

During the pilot-scale tests, it was observed that if air was introduced upstream of the anion exchange systems, it was possible to treat a larger volume of water before regeneration than in the absence of air. While these tests were not optimized, the resin capacity consistently increased when a small amount of air was induced. A comparison between average runs in Plants 9 and 8 is shown in Figure 10 . To evaluate this phenomenon in more detail, tests were conducted with and without air introduction. A linear relationship between the concentration of sulfide and sulfate (in meq/L) and the number of bed-volumes before breakthrough of hydrogen sulfide is shown in Figure 11. For the water sources tested in this project, the net exchangeable concentration of sulfide and sulfate appeared to control the service time (bed volumes) of each reactor. It should be noted that pattern displayed in Figure 11 is specific for the water sources tested in this project. Due to differences in water quality, further testing would be necessary to optimize this relationship for each treatment facility.

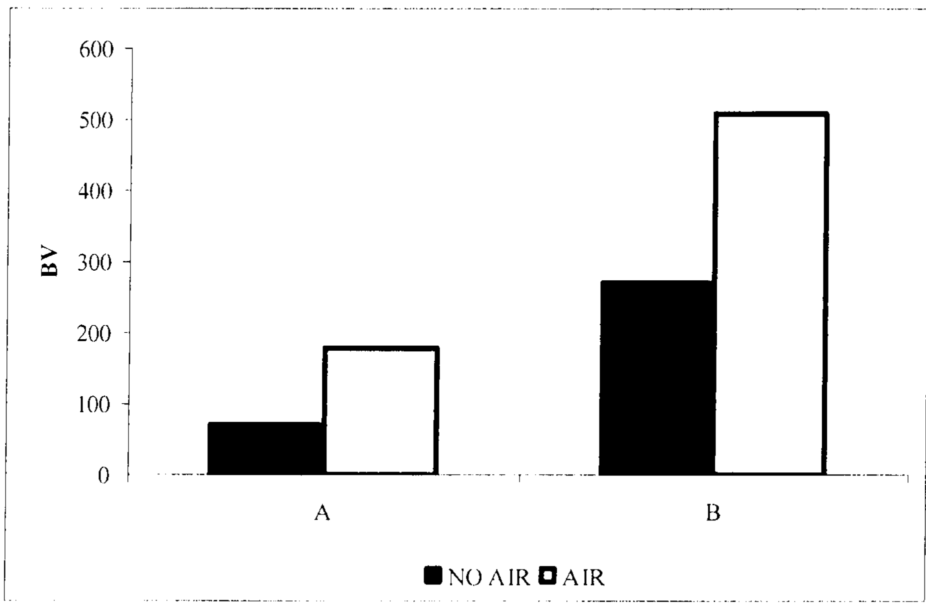

Figure 10. Comparison of the Average number of Bed Volumes for removal of hydrogen sulfide using Tulson® A-72 MP Resin in the presence or absence of Air at Plants 9 (A) and 8 (B).

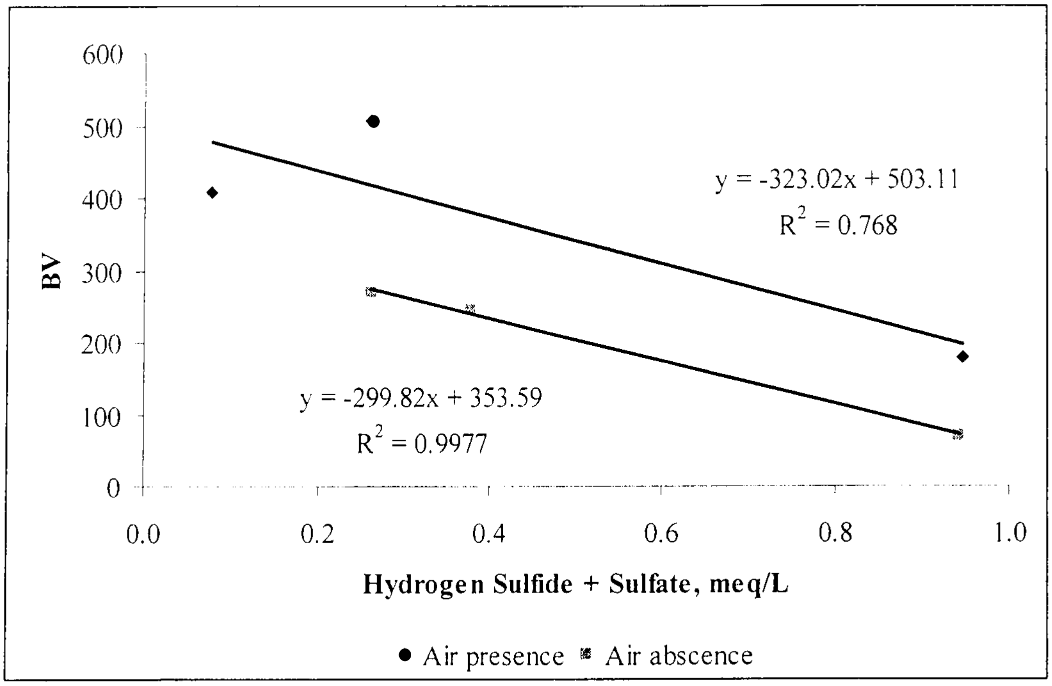

Figure 11. Relationship of the number of bed volumes for removal of hydrogen sulfide from Plants 2, 8, and 9 as a function of the concentration of exchangeable sulfur anions (sulfide and sulfate) in the presence or absence of upstream exposure to air.

Further investigation of the impacts of addition of air on process performance was conducted by evaluating samples of resin from the pilot-scale columns using Scanning Electron Microscopy (SEM) coupled with Energy Dispersive Spectroscopy (EDS) as shown in Figure 12. In general, there was evidence of bacterial growth on the resin surface. The growth of sulfur oxidizing bacteria is widely reported in aeration systems, thus the presence of these microorganisms in the anion exchange systems that were exposed to air is not surprising. Unlike aeration systems, the growth rates are controlled by the quantity of air introduced into the system and the regeneration step. The application of brine solutions for regeneration appears to control the overall accumulation of bacteria. Further study is needed to optimize the degree to which anion exchange can be enhanced through biological activity and to determine the factors that influence and control bacterial growth (e.g. temperature, dissolved oxygen concentrations, nutrients, salt loading rates, ionic strength, etc.).

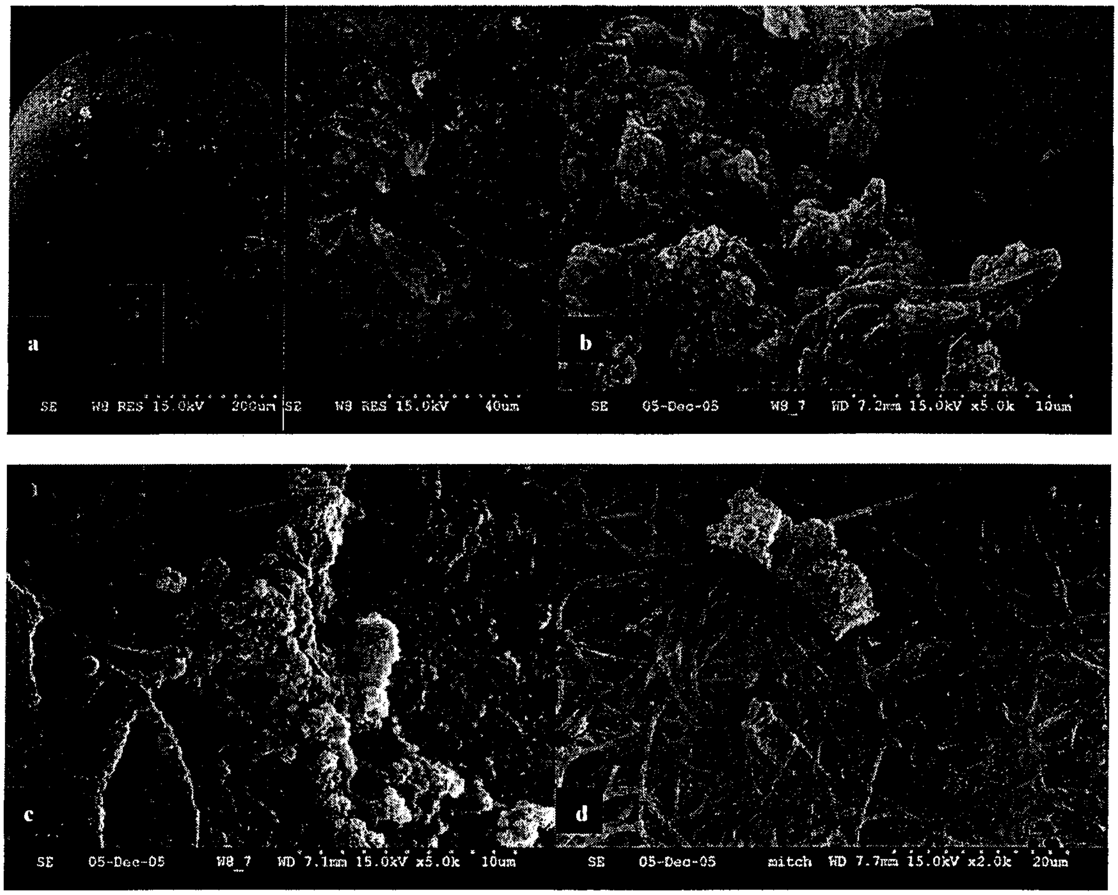

Figure 12. Scanning Electron Micrographs of Resin harvested from pilot scale operation of anion exchange systems at Plant 8 (a,b,c), and Plant 9 (d). The dotted line at the bottom right of each micrograph represents the size scale (10 to 200 microns)

DESIGN SUMMARY

Based on the results obtained through batch testing and pilot testing, a design capacity was calculated and preliminary design information was generated for each treatment facility. The overall design includes 3 reactors at each facility that will be operated in parallel. The reactor operation will be staggered to allow for regeneration of one reactor while the other two reactors are operational.

Reactor capacity at each treatment facility

A summary of the design information for each treatment plant is given in Table 11. The design capacity reflects the volume of water that can be processed per unit volume of resin prior to regeneration. Water quality factors, particularly sulfide and sulfate levels in the source waters (see Table 3) influence the design capacity. As shown in Table 3, the well that serves Plant 9 has the highest concentration of sulfide and sulfate, whereas Plant 2 has the lowest. These differences in water quality impact the volume of water that can be processed before regeneration is needed.

To compensate for differences in water quality, the diameter of the anion-exchange reactor vessels will be larger at Plants 6, 8, and 9 than at Plants 2 and Mitchell allowing for about 26% more resin. Even with the differences in the quantity of resin, the treatment system at Plant 2 should be able to process over two and a half times more water than the throughput at Plant 9 before the resin becomes saturated and regeneration is needed.

Table 11. Summary of packed-bed anion exchange design information for five treatment Plants in the Seven Springs service area.

Parameter	Plant 2	Mitchell	Plant 6	Plant 8	Plant 9
Design capacity, gal/ft^3	3500	2500	2500	1500	1000
Vessel Diameter, ft	8	8	9	9	9
Resin depth, ft	4	4	4	4	4
Resin volume ft^3	201	201	254	254	254
Number of vessels	3	3	3	3	3
Design flowrate per vessel, gpm	167	167	167	167	167
Hydraulic loading					
Volumetric, gpm/ft^3	0.8	0.8	0.7	0.7	0.7
Area, gpm/ft^2	3.3	3.3	2.6	2.6	2.6
Empty Bed Contact Time (EBCT), minutes	9.0	9.0	11.4	11.4	11.4
Volume of water processed before regeneration, gallons per vessel	703,717	502,655	636,173	381,704	254,469

Based on the testing program, it was possible to regenerate the resin at dosages ranging from 3 to 15 pounds of salt per cubic foot of resin. Regeneration at 2 pounds of salt per cubic foot was not effective. In addition, regeneration times of 30 minutes or less were not effective for the pilot-scale reactors. Due to the design of the pilot units and the manual operation of the regeneration process, it was not possible to optimize the contact times or to evaluate the impacts of mixing or brine recirculation on regeneration efficiency. However, longer contact times and recirculation of the brine solution through the resin bed appeared to enhance the regeneration process, particularly at lower dosages of salt.

For design purposes, several factors need to be considered. The manufacturer's recommendation is 6 lbs of salt per cubic foot of resin. Using the 6 lb per cubic foot for design will allow for a robust system and ensure adequate storage capacity for the salt. Based on the pilot-testing results, resin regeneration using 4 pounds per cubic foot produced the same recovery efficiency (in terms of exchange capacity) as 6 pounds per cubic foot. Because the full-scale units will have more operational features, further refinement and optimization of backwashing, salt dosing approaches, salt loading, contact time, mixing, recirculation and the time and volume requirements for each step of regeneration should be conducted during the first year of full-scale operation.

Regeneration parameters

To evaluate the characteristics of wastewater generated by the regeneration process, salt requirements and wastewater properties were calculated based on using either 6 or 4 lbs of salt per cubic foot of resin. The salt quantity needed per regeneration is based on the salt loading and the volume of resin in each packed-bed reactor. The total salt quantity is based on the design capacity. The vessels in Plants 2 and Mitchell will be 8 ft in diameter with resin volumes of about 200 ft^3 while the reactors in Plants 6, 8, and 9 will be 9 ft in diameter with corresponding volumes of 254 ft^3. The quantity of salt required for regenerating individual treatment units at each treatment facility is given in Table 12. The frequency of regeneration and the total amount of salt needed varies among the treatment plants due to differences in flowrates (Table 4) and water quality (Table 3).

Table 12. Comparison of salt requirements per regeneration for each packed-bed anion exchange reactor under different salt application rates.

Parameter	Plant 2	Mitchell	Plant 6	Plant 8	Plant 9
Design capacity, gal/ft^3	3500	2500	2500	1500	1000
Resin volume ft^3	201	201	254	254	254
Salt requirements per regeneration, lb					
Loading rate					
6 lb salt per ft^3 of resin	1,206	1,206	1,527	1,527	1,527
4 lb salt per ft^3 of resin	804	804	1,018	1,018	1,018

Wastewater Characteristics

Development of appropriate approaches for managing wastewater generated by resin regeneration is a key component of the design of packed-bed anion exchange systems. Each regeneration step produces a waste stream and the characteristics of the waste streams differ in terms of salt content and other water quality parameters. The actual composition of wastewater from full-scale anion exchange treatment depends on the amount of salt applied and the volume of water used for each phase of the regeneration process. Preliminary data on waste stream characteristics was developed by testing the waste streams produced by the pilot scale ion exchange columns at Plant 9. A comparison of the relative concentrations of sodium, chloride, and sulfate in the pilot-scale regeneration streams is shown in Figure 13 (log-scale). The concentrations of dissolved solids in the brine and the slow-rinse waste streams are about two-orders of magnitude higher than the levels observed in the untreated water, backwash, or fast-rinse cycles. Data on other water quality parameters is provided in the Appendix.

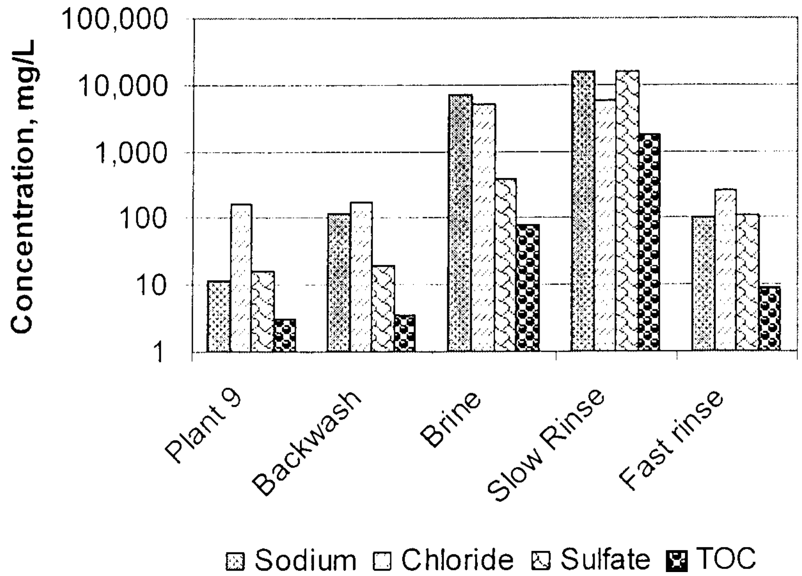

Figure 13. Comparison of the concentrations of sodium, chloride, sulfate, and organic carbon (TOC) in waste streams from pilot-scale anion exchange testing at Plant 9 (note log-scale)

Volume of wastewater

The volume of wastewater generated through each phase of regeneration depends on the flowrate and operating conditions. Typically the backwash is operated at a velocity high enough to fluidize the media, while the brine and rinse stages are operated at lower flow-rates to provide more contact time for the salts to diffuse into the resin matrix. The fast rinse is operated at the design flowrate for the system (167 gallons per minute). A summary of the volume of wastewater generated from each stage of regeneration is shown in Table 13 for each of the treatment plants. The highest volumes are associated with the backwash and fast-rinse cycles. The brine and slow-rinse wastewaters have the highest concentrations of dissolved solids and it is important to control the discharge from these waste streams to avoid introducing a shock load of salt to the sewer or wastewater plant. One option for managing the more saline waste streams is to store the spent regenerant on-site and blend it with the flow in the wastewater collection system. The volume needed to store wastewater from 3 regeneration cycles at each plant is also given in Table 13.

Table 13. Volume of wastewater generated by each stage of regeneration for packed-bed anion exchange at each treatment plant.

Regeneration stage	Flowrate[1], gpm	Minimum time[1], minutes	Wastewater volume, gallons per regeneration per vessel				
			Plant 2	Mitchell	Plant 6	Plant 8	Plant 9
Backwash	254	10	2,011	2,011	2,545	2,545	2,545
Brine	38	30	900	900	1,140	1,140	1,140
Slow-rinse	38	30	900	900	1,140	1,140	1,140
Fast-rinse	167	10	1,667	1,667	1,667	1,667	1,667
Total		80	5,478	5,478	6,492	6,492	6,492
On-site storage of waste streams from regeneration of 3 packed-bed reactors							
Brine and slow -rinse, gallons per 3 regeneration cycles			5,400	5,400	6,840	6,840	6,840
Backwash and fast-rinse, gallons per 3 regeneration cycles			11,034	11,034	12,636	12,636	12,636
Total waste generation, gallons per 3 regeneration cycles			16,434	16,434	19,476	19,476	19,476

[1]Flowrates and times provided by Tonka

The actual quantity of wastewater generated at each treatment plant depends on the amount of water produced at each treatment facility. A summary of the volume of wastewater projected to be produced at each treatment facility for each of the design flow scenarios (see Table 4) is given in Tables 14-18 for Plants 2, Mitchell, 6, 8, and 9 respectively.

Table 14. Number of hours of plant operation, regeneration frequency and the volume of wastewater generated per day for packed-bed anion exchange treatment at Plant 2.

Plant 2 Operating scenario*	Design flowrate, gallons per day	Hours of pump operation per day	Volume of water produced per anion exchange reactor per day, gallons**	Regeneration frequency per vessel, days	Average volume of wastewater generated per day, gallons
AADF	288,000	9.6	96,192	7.3	2,242
MMADF-1	407,409	13.6	136,075	5.2	3,171
MMADF-2	490,000	16.3	163,660	4.3	3,814
MDDF-1	547,895	18.3	182,997	3.9	4,264
MDDF-2	580,000	19.3	193,720	3.6	4,514

*AADF: Average Annual Daily Flow; MMADF: Maximum month average daily flow; MDDF: Maximum Day Daily Flow using different pumping scenarios

**There are three reactors per site

Table 15. Number of hours of plant operation, regeneration frequency and the volume of wastewater generated per day for packed-bed anion exchange treatment at the Mitchell Plant.

Mitchell Operating scenario*	Design flowrate, gallons per day	Hours per day	Volume of water produced per anion exchange reactor per day, gallons**	Regeneration frequency per vessel, days	Average volume of wastewater generated per day, gallons
AADF	289,000	9.6	96,526	5.2	3,149
MMADF-1	429,717	14.3	143,525	3.5	4,683
MMADF-2	390,000	13.0	130,260	3.9	4,250
MDDF-1	577,896	19.3	193,017	2.6	6,297
MDDF-2	580,000	19.3	193,720	2.6	6,320

*AADF: Average Annual Daily Flow; MMADF: Maximum month average daily flow; MDDF: Maximum Day Daily Flow using different pumping scenarios

**There are three reactors per site

Table 16. Number of hours of plant operation, regeneration frequency and the volume of waste per day is for packed-bed anion exchange treatment at Plant 6.

Plant 6 Operating scenario*	Design flowrate, gallons per day	Hours per day	Volume of water produced per anion exchange reactor per day, gallons**	Regeneration frequency per vessel, days	Average volume of wastewater generated per day, gallons
AADF	239,000	8.0	79,826	8.0	2,439
MMADF-1	356,923	11.9	119,212	5.3	3,642
MMADF-2	400,000	13.3	133,600	4.8	4,082
MDDF-1	480,000	16.0	160,320	4.0	4,898
MDDF-2	580,000	19.3	193,720	3.3	5,918

*AADF: Average Annual Daily Flow; MMADF: Maximum month average daily flow; MDDF: Maximum Day Daily Flow using different pumping scenarios
**There are three reactors per site

Table 17. Number of hours of plant operation, regeneration frequency and the volume of waste per day is for packed-bed anion exchange treatment at Plant 8.

Plant 8 Operating scenario*	Design flowrate, gallons per day	Hours per day	Volume of water produced per anion exchange reactor per day, gallons**	Regeneration frequency per vessel, days	Average volume of wastewater generated per day, gallons
AADF	259,000	8.6	86,506	4.4	4,405
MMADF-1	369,838	12.3	123,526	3.1	6,290
MMADF-2	0	0.0	0	0.0	0
MDDF-1	497,368	16.6	166,121	2.3	8,458
MDDF-2	0	0.0	0	0.0	0

*AADF: Average Annual Daily Flow; MMADF: Maximum month average daily flow; MDDF: Maximum Day Daily Flow using different pumping scenarios
**There are three reactors per site

Table 18. Number of hours of plant operation, regeneration frequency and the volume of waste per day is for packed-bed anion exchange treatment at Plant 9.

Plant 9 Operating scenario*	Design flowrate, gallons per day	Hours per day	Volume of water produced per anion exchange reactor per day, gallons**	Regeneration frequency per vessel, days	Average volume of wastewater generated per day, gallons
AADF	232,000	7.7	77,488	3.3	5,918
MMADF-1	313,482	10.4	104,703	2.4	7,997
MMADF-2	0	0.0	0	0.0	0
MDDF-1	421,579	14.1	140,807	1.8	10,754
MDDF-2	0	0.0	0	0.0	0

*AADF: Average Annual Daily Flow; MMADF: Maximum month average daily flow; MDDF: Maximum Day Daily Flow using different pumping scenarios
**There are three reactors per site

Quantity of salt

The amount of salt needed to supply the regeneration process depends on the salt loading and the frequency of regeneration. For the Seven Springs service area, the design concept is to store the salt at a single location where a concentrated solution of brine will be prepared. The brine will be distributed to the individual plant sites to allow for on-site storage of enough brine to regenerate all three anion exchange reactors. The salt storage area will be designed to accommodate a 7 day supply of salt. A summary of the salt requirements under different salt application rates (4 or 6 lb/ft^3) for different flowrates is given in Table 19. The maximum amount of salt needed is under MDDF, when higher flowrates from individual plants are needed to meet the maximum demand.

Table 19. Total quantity of salt needed for regeneration of anion exchange units at all treatment plants under different flow conditions for a 7 day period.

Flow rate	7 day salt supply for all treatment plants, dry tons	
	6 lb/ft^3	4 lb/ft^3
AADF	15	10
MMADF-1	21	14
MMADF-2	10	6
MDDF-1	28	19
MDDF-2	13	9

The amount of salt needed to regenerate all three anion exchange reactors at each site is summarized in Table 20. The salt will be prepared as a brine and delivered to each site as a 20% solution. The volume of brine needed to regenerate all three reactors at each site is also summarized in Table 20.

Table 20. Amount of salt and brine (20%) needed to regenerate three anion exchange vessels at each site

	Quantity of salt needed to regenerate 3 anion exchange reactors at each site, lb		Volume of 20% brine needed to regenerate 3 anion exchange reactors at each site, gallons	
Plant name	6 lb/ft^3	4 lb/ft^3	6 lb/ft^3	4 lb/ft^3
Plant 2	1,206	804	1,936	1,290
Mitchell	1,206	804	1,936	1,290
Plant 6	1,527	1,018	2,450	1,633
Plant 8	1,527	1,018	2,450	1,633
Plant 9	1,527	1,018	2,450	1,633

EVALUATION OF RECLAIMED WATER

Aloha Utilities, Inc. has an active water reuse program and has provided reclaimed water to its customers for public access reuse since February 2001. The reclaimed water supplies water for residential and commercial irrigation in the Seven Springs service area. The major users include a golf course, schools, and commercial and residential developments. To use reclaimed water for irrigation, it is important to ensure that the quality of the reclaimed water is compatible with the soil and landscape requirements. With the implementation of anion exchange technology at AUI's water treatment facilities, there will be some changes in the reclaimed water quality that will vary seasonally, depending on the water demand and the combination of treatment facilities that are in operation. From a water reuse perspective, the major constituents of concern are chloride and sodium.

Chloride

Sources of chloride in reclaimed water from AUI include baseline levels in the ground water, chlorine that is used for disinfection (water and wastewater), and chloride introduced from municipal and domestic wastewater, including discharges from point-of-use water softeners and other treatment devices. A summary of historical monitoring data on chloride concentrations in AUI's reclaimed water is shown in Figure 14. For the purposes of estimating the potential chloride levels in reclaimed water after implementation of anion exchange in the Seven Springs service area, a baseline level of 275 mg/L was assumed.

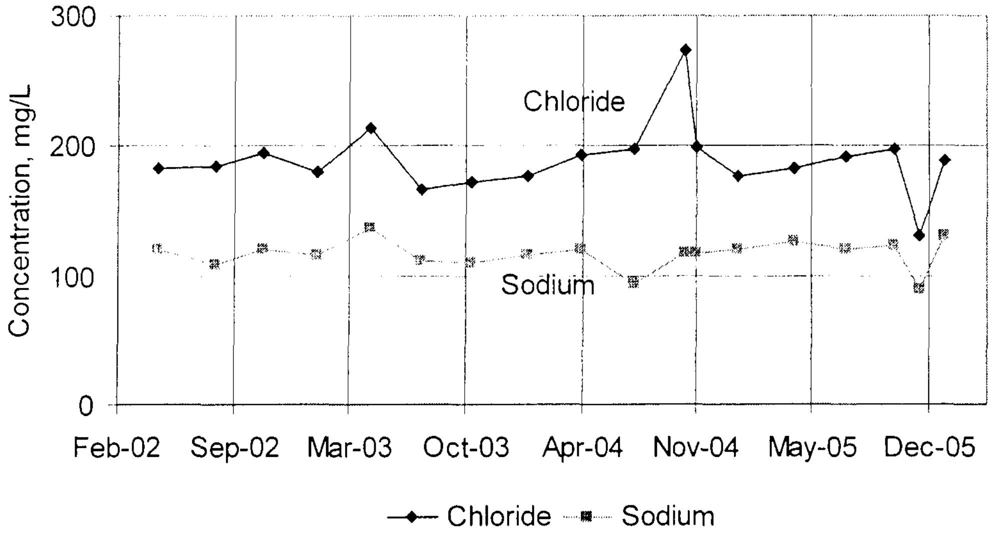

Figure 14. Summary of chloride and sodium concentrations in AUI's reclaimed water from 2002 through 2005 (Data from Short Environmental Laboratories).

Sodium

Sources of sodium in reclaimed water include baseline levels in the groundwater, sodium that is added to water through the use of sodium hypochlorite for disinfection (water and wastewater) and sodium in municipal and domestic wastewater discharges. A summary of monitoring data on sodium concentrations in AUI's reclaimed water is shown in Figure 14 in parallel with the chloride concentrations. For the purposes of estimating the potential sodium levels in reclaimed water after implementation of anion exchange in the Seven Springs service area, a baseline level of 150 mg/L was assumed.

Total Dissolved Solids

The total dissolved solids (TDS) concentration of reclaimed water provides an indication of water quality and ionic strength. A summary of TDS monitoring data from AUI is shown in Figure 15. About 60 percent of the TDS is contributed by chloride and sodium. When the regeneration waste streams are discharged to the reclaimed water treatment facility, TDS levels are likely to increase to over 800 mg/L and will still be dominated by sodium and chloride (>65%). The concentration of TDS and the extent to which the percentage of the TDS associated with sodium and chloride increases after implementation of anion exchange depends on how the treatment facilities are operated (combination of water sources and treatment plants in operation, pumping strategies, regeneration approaches, etc.).

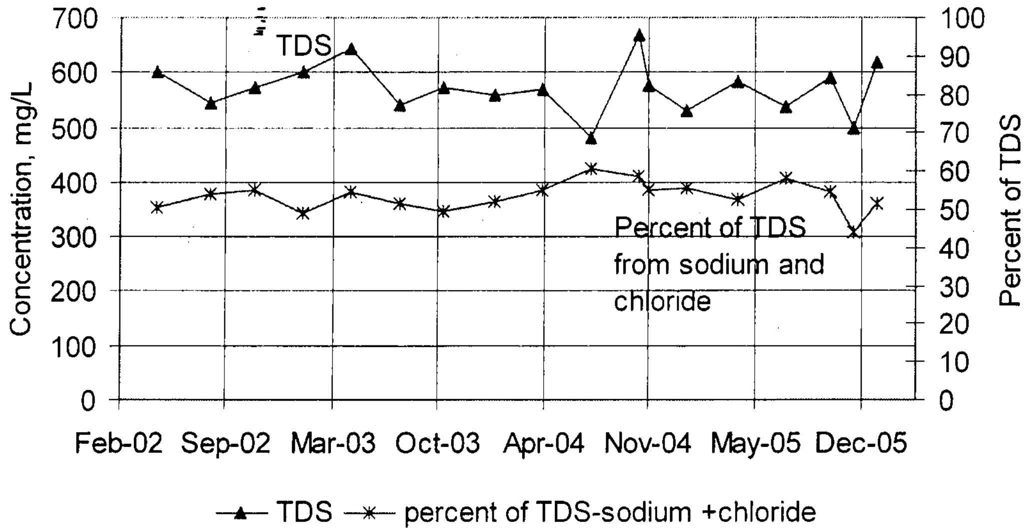

Figure 15. Summary of total dissolved solids concentrations in AUI's reclaimed water from 2002-2005 (Data from Short Environmental Laboratories).

AUI is in the process of upgrading its reclaimed water disinfection system from the use of gaseous chlorine to applying liquid chlorine in the form of sodium hypochlorite. A consequence of changing the form of disinfectant that is applied to the reclaimed water is the introduction of another source of sodium into the reclaimed water. The additional quantity of sodium depends on the disinfectant dose and the flowrate. The dosage of sodium hypochlorite (12.5%) to be used at the water reclamation facility will range from 360 to 672 gallons/day. An estimate of the incremental increase in sodium as a function of the water reclamation facility flowrate is shown in Figure 16.

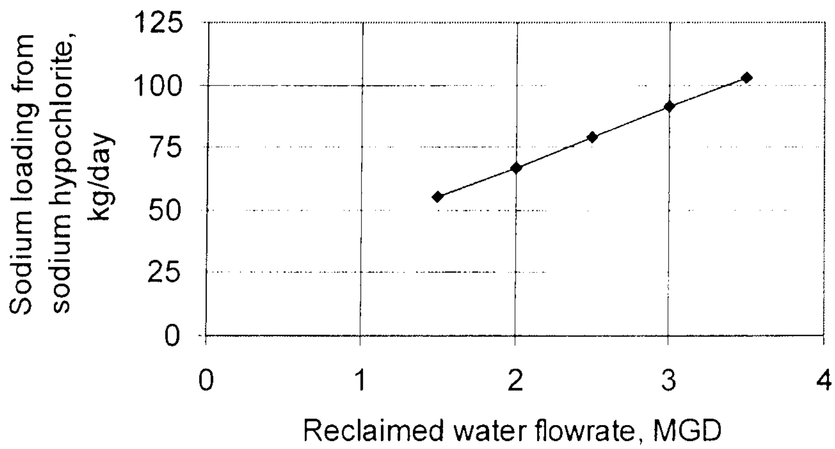

Figure 16. Estimate of the amount of sodium discharged per day (kg/day) as a function of the reclaimed water flowrate at AUI's treatment facility.

Estimate of reclaimed water quality

The net impacts of the wastewater from regeneration of packed-bed anion exchange columns on reclaimed water quality depend on the frequency of regeneration, the salt application rate, and the type of salt applied. The frequency of regeneration depends on the amount of water processed by each plant and the actual concentration in the reclaimed water depends on the salt application rate and the amount of reclaimed water that is produced. In general, wastewater treatment facilities are not designed to remove sodium or chloride, therefore the mass of salts that are introduced into the wastewater are likely to be carried over to the reclaimed water. Some dilution may occur during the rainy season and the concentrations may increase due to evaporation, depending on temperature.

A comparison of the estimated concentrations of sodium and chloride under average annual day (AADF) flow conditions is shown in Figure 17 as a function of the flowrate of reclaimed water for two different loadings of salt: 4 and 6 lb per cubic foot of resin. As shown, lower salt dosages and the higher reclaimed water flowrates yield lower concentrations of sodium and chloride in the reclaimed water. The concentrations of sodium and chloride projected for AUI's reclaimed water are within the range of values reported for other reclaimed water facilities (Food and Agriculture Organization of the United Nations 1992, Metcalf and Eddy 2003, National Research Council 1996).

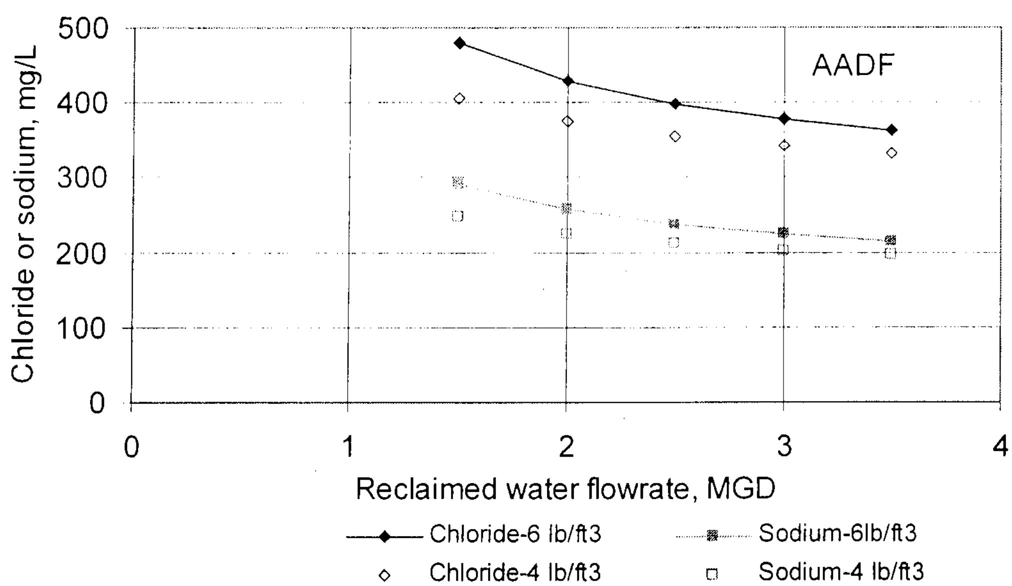

Figure 17. Estimated concentrations of chloride and sodium in reclaimed water under AADF operation of anion exchange reactors using either 4 or 6 lb of salt per cubic foot of resin.

Another parameter that is important in predicting the characteristics of reclaimed water relevant to public access irrigation systems is the ***Sodium Adsorption Ratio (SAR).*** The SAR provides an index of the amount of sodium in water in comparison to calcium and magnesium concentrations:

$$SAR = \frac{(Na^{+})}{\sqrt{((Ca^{+2}) + (Mg^{+2})) * 0.5}}$$

where the concentrations of sodium, calcium, and magnesium are in milli-equivalents per liter.

The presence of excess sodium in irrigation water can impact soil structure and reduce its permeability to water and air. Calcium and magnesium temper the effect of sodium. It is important to manage the reclaimed water application rates and drainage efficiency to prevent accumulation of salts. In addition, excess sodium can be toxic to some types of grasses and plants. Drainage systems that prevent salt accumulation in the root zone can help to prevent potential problems (Food and Agriculture Organization of the United Nations 1992, Metcalf and Eddy 2003, National Research Council 1996).

A comparison of estimated SAR levels that may be associated with reclaimed water produced from assimilating wastewater from anion exchange regeneration at the treatment facility is given in Figure 18 for two different flow scenarios: average annual daily flow (AADF) and maximum month average daily flow (MMADF-1). As shown, the SARs (and other water quality parameters) decrease with increasing flowrate. It is also interesting to note that using a salt dose of 4 pounds per cubic foot under MMADF-1 conditions yields approximately the same SAR as a 6 lb per cubic foot salt dose under AADF.

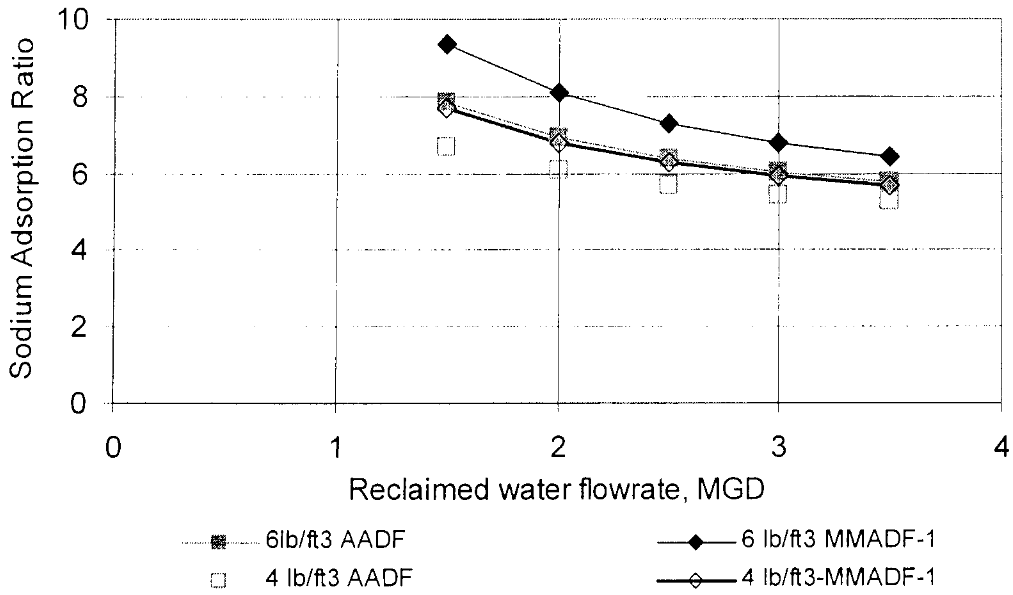

Figure 18. Comparison of Sodium Adsorption Ratios (SAR) projected in reclaimed water that receives wastewater from anion exchange regeneration under two flow conditions: Average Annual Daily Flow (AADF) 2.04 MGD and Maximum Month Daily Flow (MMDF-1) 2.9 MGD. The wastewater flowrate is assumed to be 1.5 MGD.

An estimate of the projected concentrations of sodium and chloride in the reclaimed water under different pumping scenarios is given in Table 21 for a salt application rate of 6 lb per cubic foot and in Table 22 for an application rate of 4 lb per cubic foot.

Table 21. Projected SAR and concentrations of sodium and chloride in reclaimed water receiving wastewater from regeneration of anion exchange treatment units under different pumping scenarios at a salt application rate of 6 lb/ft^3 and a reclaimed water flow of 1.5 MGD[1].

Flowrate scenario		Salt Application Rate: 6 lb salt per cubic foot of resin		
Design Condition[2]	Flowrate, MGD	Chloride, mg/L	Sodium, mg/L	SAR[3] estimate
AADF	2.04	479	292	7.9
MMADF-1	2.9	564	347	9.4
MMADF-2	2.9	408	246	6.6
MDDF-1	3.9	664	411	11.1
MDDF-2	3.9	459	279	7.5

[1]Reclaimed water flow is assumed to be 1.5 MGD [2]See Table 4 for definition of flow scenarios; [3]SAR: Sodium Adsorption Ratio.

Table 22. Projected SAR and concentrations of sodium and chloride in reclaimed water receiving wastewater from regeneration of anion exchange treatment units under different pumping scenarios at a salt application rate of 4 lb/ft^3 and a reclaimed water flow of 1.5 MGD[1].

Flowrate scenario		Salt Application Rate: 4 lb salt per cubic foot of resin		
Design Condition[2]	Flowrate, MGD	Chloride, mg/L	Sodium, mg/L	SAR[3] estimate
AADF	2.04	407	248	6.7
MMADF-1	2.9	462	284	6.5
MMADF-2	2.9	361	217	5.8
MDDF-1	3.9	527	328	8.8
MDDF-2	3.9	394	239	6.4

[1]Reclaimed water flowrate is assumed to be 1.5 MGD [2]See Table 4 for definitions of flow scenarios; [3]SAR: Sodium Adsorption Ratio

Substitution of potassium chloride at Plants 8 and 9

In some cases, particularly under high water demand conditions, the concentrations of sodium in the reclaimed water may exceed recommended levels for irrigation applications. There are several operational strategies that could be used to decrease the sodium concentrations such as varying the degree to which each plant is operated, using lower concentrations of salt for regeneration, introducing air into the reactors to decrease the regeneration frequency, or substituting potassium chloride for sodium chloride.

The use of potassium chloride as an alternative regeneration salt is approved by the National Sanitation Foundation (NSF). However, due to the higher costs of potassium chloride as compared to sodium chloride, it tends to be used only under situations where there are concerns about sodium levels in the regeneration waste streams. One option for AUI is to design the system to allow for the use of potassium chloride at the plants that have the highest regeneration frequency (Plants 8 and 9) and to use sodium chloride at the other facilities. The amount of salt needed if potassium chloride is used at Plants 8 and 9 instead of sodium chloride is shown in the Table 23. The salt requirements for using only sodium chloride (Table 19) are also shown in Table 23.

The impacts of substituting potassium chloride for sodium chloride at Plants 8 and 9 on the reclaimed water characteristics are shown in Table 24 for a salt loading rate of 6 lb/ft^3 and Table 25 for a salt loading rate of 4 lb/ft^3. As shown, the estimated concentrations of sodium can be reduced by using potassium chloride. The combined impacts of salt loading rates, introduction of air, and substitution of potassium chloride will need to be optimized under full-scale operating conditions.

Table 23. Total quantity of salt needed for regeneration of anion exchange units at all treatment plants under different flow conditions for a 7 day period.

Flow rate	7 day salt supply for all treatment plants, dry tons					
	Sodium chloride for plants 2, Mitchell, 6, 8, and 9		Sodium chloride for Plants 2, Mitchell, and 6		Potassium chloride for Plants 8 and 9	
	6 lb/ft^3	4 lb/ft^3	6 lb/ft^3	4 lb/ft^3	6 lb/ft^3	4 lb/ft^3
AADF	15	10	6	4	8	6
MMADF-1	21	14	9	6	12	8
MMADF-2	10	6	10	6	0	0
MDDF-1	28	19	12	8	16	11
MDDF-2	13	9	13	9	0	0

Table 24. Projected SAR and concentrations of sodium and chloride in reclaimed water receiving wastewater from regeneration of anion exchange treatment units under different pumping scenarios at a salt application rate of 6 lb/ft^3 and a reclaimed water flow of 1.5 MGD[1].

Well pumping scenario		Salt Application Rate: 6 lb salt per cubic foot of resin						
		Sodium Chloride: All plants			**Sodium Chloride:** Plants 2,6, Mitchell **Potassium Chloride**-Plants 8 and 9			
Design Condition[2]	Flowrate, MGD	Chloride, mg/L	Sodium, mg/L	SAR[3] estimate	Chloride, mg/L	Sodium, mg/L	Potassium, mg/L	SAR[3] estimate
AADF	2.04	479	292	7.9	435	215	274	5.8
MMADF-1	2.9	564	347	9.4	502	241	360	7.7
MMADF-2	2.9	408	246	6.6	408	246	50*	6.6
MDDF-1	3.9	664	411	11.1	580	269	467	7.3
MDDF-2	3.9	459	279	7.5	459	279	50*	7.5

[1]Reclaimed water flow is assumed to be 1.5 MGD [2]See Table 4 for definition of flow scenarios;
[3]SAR: Sodium Adsorption Ratio, * assumed concentration in reclaimed water.

Table 25. Projected SAR and concentrations of sodium and chloride in reclaimed water receiving wastewater from regeneration of anion exchange treatment units under different pumping scenarios at a salt application rate of 4 lb/ft^3 and a reclaimed water flow of 1.5 MGD[1].

Well pumping scenario		Salt Application Rate: 4 lb salt per cubic foot of resin						
		Sodium Chloride: All plants			Sodium Chloride: Plants 2,6, Mitchell Potassium Chloride-Plants 8 and 9			
Design Condition[2]	Flowrate, MGD	Chloride, mg/L	Sodium, mg/L	SAR[3] estimate	Chloride, mg/L	Sodium, mg/L	Potassium, mg/L	SAR[3] estimate
AADF	2.04	407	248	6.7	381	197	199	5.3
MMADF-1	2.9	462	284	6.5	426	214	257	5.8
MMADF-2	2.9	361	217	5.8	361	217	50*	5.8
MDDF-1	3.9	527	328	8.8	478	233	328	6.3
MDDF-2	3.9	394	239	6.4	394	239	50*	6.4

[1]Reclaimed water flow is assumed to be 1.5 MGD [2]See Table 4 for definition of flow scenarios; [3]SAR: Sodium Adsorption Ratio, * assumed concentration in reclaimed water.

POTENTIAL IMPACTS ON WATER RECLAMATION FACILITY

The wastewater generated through the anion exchange process will be discharged to AUI's wastewater collection system for treatment. In general, chloride and sodium levels in the water reclamation facility's influent (and effluent) will increase due to the implementation of anion exchange for drinking water production (see Tables 21,22, 24,25). The increase in salt levels will result in about 1.7 to 2.6 fold higher concentrations of chloride and sodium than the current levels at AUI's treatment facility. The degree to which the increased salt concentrations may impact microbial activity in the wastewater treatment facility is difficult to predict from the existing data. In general, biological treatment systems are fairly robust and the microbial populations that comprise the biomass have a significant ability to adapt to changes in water quality, provided the changes are gradual. The sodium and chloride levels projected to be in the treatment plant effluent are within the range of values experienced by other treatment facilities, particularly in coastal environments.

Shock loadings of salt may inhibit some microbial activity, however, by using the existing equalization basin to provide a consistent loading to the biological treatment units and optimizing treatment process parameters (aeration, biomass concentrations, mean cell residence time, etc.) for removal of organics, the wastewater treatment facility should be capable of performing effectively. During the start-up phase, it will be important to ensure that the additional salt loading is gradually phased into the treatment plant to enable the biological treatment system to adapt appropriately.

SUMMARY AND CONCLUSIONS

The implementation of anion exchange technology at water treatment plants in the Seven Springs service area will improve water quality by reducing concentrations of hydrogen sulfide, sulfate, and organic carbon in drinking water. The benefits of the upgraded treatment system include more stable water quality, reduction in the potential for odor and water discoloration, and a decrease in the disinfection byproduct precursor concentrations.

An integral component of anion exchange technology is the need to periodically regenerate the resin. The characteristics of the wastewater generated through regeneration are related to the quantity of water treated, the frequency of regeneration, and the amount of salt used in the regeneration process. The major constituents of concern in regeneration wastewater are chloride and sodium. By optimizing the salt application rate and frequency of regeneration, the impacts of the additional salt loading on the wastewater treatment plant can be minimized. Because salts are not removed through wastewater treatment, the concentrations of chloride and sodium in the reclaimed water will increase in response to the implementation of anion exchange technology due to the regeneration wastewater.

Based on the data generated through this project, the following conclusions can be drawn:

1. The anion exchange resin capacity is related to the concentration of exchangeable anions, primarily hydrogen sulfide and sulfate for the treatment facilities in AUI's Seven Springs service area.
2. Supplemental benefits of anion exchange include removal of TOC, sulfate, and reduction of the chlorine demand. The reduction in chlorine demand will allow for more consistent chemical dosing for disinfection and chloramination.
3. The use of chloride or conductivity monitoring may be useful for evaluating the performance of the anion exchange system.
4. The introduction of air appears to increase the resin capacity through promoting the growth of aerobic bacteria and providing supplemental removal of hydrogen sulfide
5. The frequency of regeneration of the anion exchange systems impacts the quantity of wastewater generated and the net amount of salt that will be discharged to the wastewater treatment facility.
6. Regeneration of anion exchange resins can be achieved with salt dosages ranging from 3 to 15 lb/ft^3. Lower salt dosages result in lower salt loading to the wastewater treatment facility.

7. The major factors that impact the salt concentrations of reclaimed water produced after resin regeneration are:
    - Water demand
    - Combination of treatment plants used to produce drinking water.
    - Frequency of regeneration
    - Quantity of salt used for regeneration of anion exchange resins
    - Type of salt used for regeneration
8. The predicted concentrations of chloride and sodium in the wastewater and reclaimed water after implementation of anion exchange technology will be higher than current concentrations, depending on the combination of wells in service, the frequency of regeneration, the salt loading, and the type of salt used.
9. Under conditions of high water demand, a combination of approaches may be needed to control the sodium and chloride concentrations in the reclaimed water.

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ACKNOWLEDGEMENTS

The assistance from the staff at Aloha Utilities in constructing the pilot plant and helping with start-up and operation is appreciated. David Porter, P.E. provided technical assistance and facilitated the overall project execution. Mike McDonald provided valuable assistance with pilot-plant operation. Pam Yacobelli provided assistance with background information, data, and facilitating schedules for operation of the pilot plant. Several USF students participated in the project by providing supplemental field and laboratory assistance including Aaron Roberts, Francis, Eshun, Michael Keen, Kemi ; their assistance with this project is appreciated. Tom Davis and Amelia Jordan of Tonka Equipment and Chuck Hvalach of EnviroSales provided technical support for anion exchange testing. This project was conducted while Dr. Levine was a faculty member and Camilo Romero-Cotrino and Panos Amitzoglou were graduate students in the Department of Civil and Environmental Engineering at the University of South Florida (Tampa).

APPENDIX

Appendix

Appendix A: Pilot Column Design

Configuration

A/R. Air valve

BRI. Brine valve

BWE. Backwash effluent

BWI. Backwash influent

FRE. Fast rinse/ Brine effluent

ISO. Isolation valve

RWI. Raw water influent.

TWE. Treated water effluent

Appendix A: (Continued)

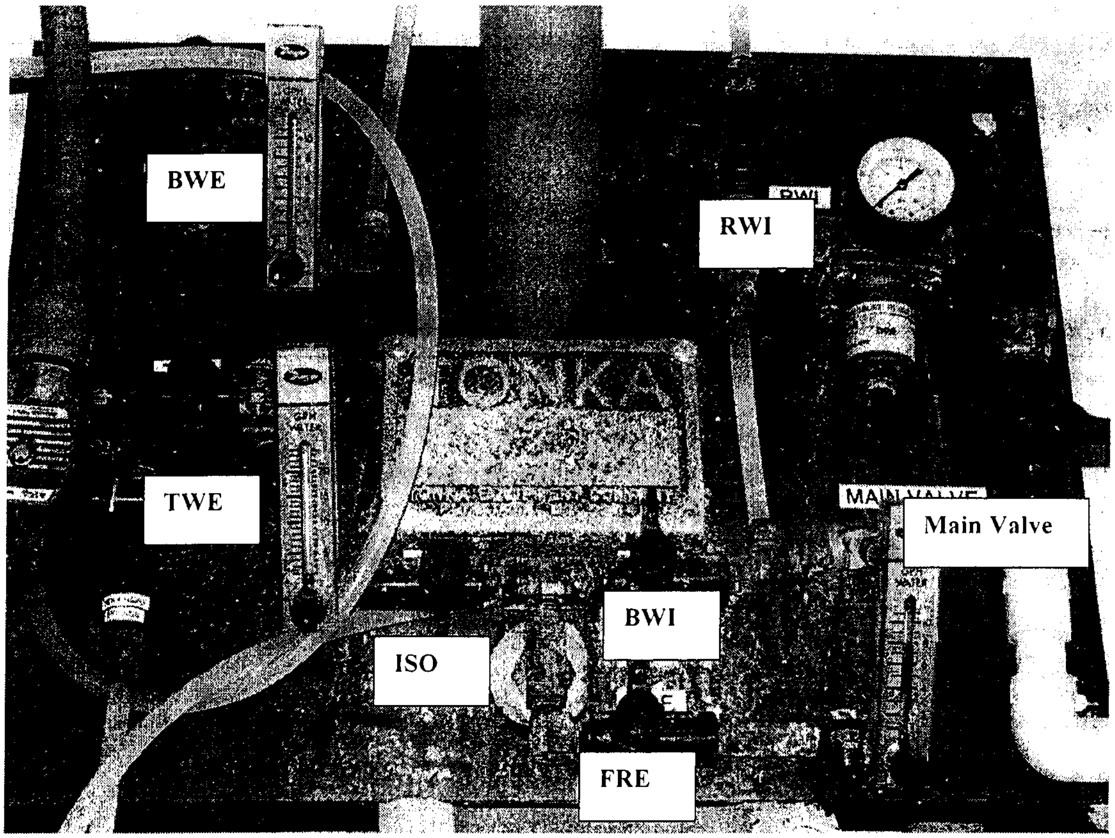

Figure 19.Anion Exchange Control Panel

Appendix A: (Continued)

Appendix

Operating and Regenerating Procedure

1. Service Mode

a) Open Main Valve

b) Set pressure reduced to 12 – 15 psi

c) Open RWI

d) Open ISO

e) Open TWE. Operate the column between 2 – 8 gph

f) Close all valves when the run is complete

2. Regeneration mode

a) Backwash

Close all valves

Set the pressure reduce to 12 – 15 psi

Open Main valve

Open BWI

Open BWE. Leave open for 10 minutes at 4 gph

Close BWI and BWE

b) Drain Down

Open FRE

Open A/R

Close FRE when the water level is 3" above the resin

c) Brine

Open BRI

Appendix A: (Continued)

Pour diluted brine solution into the funnel

Open FRE

Close FRE and leave the resin in contact with the resin for the ` chose contact time

Open FRE let the brine drain until brine level is 3" above the resin

Close BRI

d) Slow Rinse

Open RWI

Close A/R once the water come out

Open FRE. Leave open for 25 minutes at 2 gph

e) Fast Rinse

Change the flow rate of FRE to 8 gph for 10 minutes

Close FRE

Close RWI

Return to the operating mode

Appendix A: (Continued)

Brine Mixing Instructions

1. Add three pounds of non-iodized salt to 1 gallon of distilled water
2. Stir the solution
3. Measure 940 ml of solution in graduated cylinder in plastic recipient
4. Measure 940 ml of distilled water and add to brine solution
5. Shake the diluted solution
6. Pour the diluted solution into the anion exchanger funnel.

Appendix B: Summary of Water Quality before and after Anion Exchange

These data correspond to water before and after anion exchange treatment. The data were collected between September 1, 2005 and January 26, 2006.

Appendix

Table 26. Untreated Water Quality Summary from Plant 9

Parameter	Median	Mean	Minimum	Maximum	Std. Deviation	Sample variance	N
Sulfide (mg/L as S^-)	2.75	2.64	2.03	3.23	0.26	0.07	30
pH	7.41	7.39	6.79	7.55	0.15	0.02	31
Temperature (°C)	22.90	23.70	11.70	27.10	2.94	8.67	31
DO (mg/L as O_2)	1.50	1.49	0.01	6.20	1.77	3.12	10
ORP, (mV)	-202.0	-189.6	-244.0	-137.0	38.53	1484.7	9
Sulfate (mg/L as SO_4^{2-})	38.90	37.38	26.00	49.70	7.04	49.60	27
Chloride (mg/L as Cl^-)	17.80	19.72	10.09	44.77	8.26	68.19	28
Alkalinity (mg/L as $CaCO_3$)	200.00	163.50	100.00	250.00	53.99	2914.87	24
Conductivity (µS/cm)	491.00	463.71	341.00	570.00	54.55	2975.21	31
Turbidity (NTU)	0.31	0.32	0.07	1.51	0.33	0.11	31
Apparent Color (mg/L Pt.Co)	8.00	9.82	0.00	28.00	7.64	58.36	11
True Color (mg/L Pt.Co)	7.00	5.64	-2.00	14.00	5.01	25.05	11
TOC (mg/L)	2.66	2.78	1.54	6.87	0.84	0.71	29
UV-254 (cm^{-1})	0.09	0.13	0.03	1.06	0.19	0.03	30
Aluminum (mg/L)	0.00	0.00	0.00	0.00	0.00	0.00	5
Silica (mg/L)	10.50	0.67	7.50	9.98	1.50	2.26	5
Copper (mg/L)	-0.01	0.00	-0.03	0.07	0.04	0.00	6
Calcium (mg/L)	67.44	66.07	59.26	68.64	3.53	12.44	6
Magnesium (mg/L)	9.13	8.86	7.46	9.19	0.69	0.47	6
Sodium (mg/L)	7.67	0.10	7.27	7.57	0.23	0.05	5

Table 27. Untreated Water Quality Summary from Plant 8

Parameter	Median	Mean	Minimum	Maximum	Std. Deviation	Sample variance	N
Sulfide (mg/L as S^-)	1.61	1.64	1.34	2.45	0.22	0.05	27
pH	7.38	7.35	6.58	7.52	0.17	0.03	27
Temperature (°C)	25.10	24.11	11.10	28.30	3.26	10.65	27
DO (mg/L as O_2)	-209.50	-207.67	-241.00	-158.00	32.20	1036.67	6
ORP, (mV)	0.54	0.62	0.00	1.53	0.62	0.38	10
Sulfate (mg/L as SO_4^{2-})	8.15	7.27	-0.40	18.60	4.44	222.38	25
Chloride (mg/L as Cl^-)	13.94	14.67	10.09	28.44	4.29	18.38	28
Alkalinity (mg/L as $CaCO_3$)	200.00	180.30	100.00	260.00	52.11	2715.37	27
Conductivity (μS/cm)	449.00	427.33	323.00	520.00	52.83	2790.54	27
Turbidity (NTU)	0.20	0.60	0.07	4.03	0.89	0.79	27
Apparent Color (mg/L Pt.Co)	9.00	14.55	-1.00	51.00	15.27	233.07	11
True Color (mg/L Pt.Co)	7.00	8.00	-16.00	44.00	14.09	198.40	11
TOC (mg/L)	2.65	2.68	1.73	3.46	0.27	0.07	29
UV-254 (cm^{-1})	0.08	0.08	0.07	0.14	0.02	0.00	26
Aluminum (mg/L)	0.00	0.01	0.00	0.02	0.01	0.00	8
Silica (mg/L)	9.60	9.64	7.80	11.40	1.47	2.16	8
Copper (mg/L)	-0.03	-0.04	-0.13	0.02	0.05	0.00	7
Calcium (mg/L)	55.57	56.84	50.33	63.45	5.43	29.51	8
Magnesium (mg/L)	7.02	7.35	4.05	9.04	1.80	3.24	7
Sodium (mg/L)	6.76	0.07	6.71	6.81	0.13	0.02	3

Table 28. Untreated Water Quality Summary from Plant 6

Parameter	Median	Mean	Minimum	Maximum	Std. Deviation	Sample variance	N
Sulfide (mg/L as S^-)	1.02	1.07	0.82	1.51	0.20	0.04	13
pH	7.39	7.38	7.20	7.63	0.10	0.01	13
Temperature (°C)	25.30	24.90	23.10	26.80	1.14	1.29	13
DO (mg/L as O_2)	0.02	0.00	0.02	0.02			1
ORP, (mV)							
Sulfate (mg/L as SO_4^{2-})	6.40	14.75	0.70	79.00	21.68	470.03	13
Chloride (mg/L as Cl^-)	19.72	24.47	10.09	46.70	11.68	136.48	13
Alkalinity (mg/L as $CaCO_3$)	180.0	13.6	120.0	166.0		930.00	5
Conductivity (µS/cm)	397.50	384.58	285.00	502.00	54.85	3008.45	12
Turbidity (NTU)	0.17	0.53	0.10	3.12	0.89	0.79	11
Apparent Color (mg/L Pt.Co)	14.00	19.00	12.00	38.00	10.14	102.80	6
True Color (mg/L Pt.Co)	9.00	2.10	1.00	8.00		22.00	5
TOC (mg/L)	2.46	2.37	1.49	2.61	0.32	0.10	10
UV-254 (cm^{-1})	0.09	0.12	0.04	0.38	0.11	0.01	8
Aluminum (mg/L)	0.00	0.00	0.00	0.00		0.00	4
Silica (mg/L)	6.50	0.41	5.80	6.55		0.67	4
Copper (mg/L)	-0.07	0.02	-0.10	-0.05		0.00	5
Calcium (mg/L)	56.27	59.97	51.06	77.50	10.35	107.08	6
Magnesium (mg/L)	5.65	0.45	4.02	5.62		1.01	5
Sodium (mg/L)							

Table 29. Untreated Water Quality Summary from Plant 2

Parameter	Median	Mean	Minimum	Maximum	Std. Deviation	Sample variance	N
Sulfide (mg/L as S^-)	0.93	0.94	0.56	1.23	0.15	0.02	35
pH	7.49	7.44	6.03	7.61	0.26	0.07	33
Temperature (°C)	24.40	24.21	12.00	27.70	2.66	7.06	33
DO (mg/L as O_2)	1.39	3.76	0.80	24.90	6.87	47.15	12
ORP, (mV)	-150.50	-147.92	-232.00	-14.00	67.58	4567.72	12
Sulfate (mg/L as SO_4^{2-})	1.00	1.08	-0.60	3.20	0.75	0.56	32
Chloride (mg/L as Cl^-)	13.94	14.62	8.17	21.65	3.91	15.27	34
Alkalinity (mg/L as $CaCO_3$)	160.00	147.88	30.00	250.00	47.10	2218.82	32
Conductivity (µS/cm)	397.00	377.48	232.00	454.00	50.49	2548.76	33
Turbidity (NTU)	0.17	0.24	0.07	1.25	0.23	0.05	33
Apparent Color (mg/L Pt.Co)	12.00	12.44	5.00	22.00	6.11	37.28	9
True Color (mg/L Pt.Co)	9.00	10.38	2.00	19.00	5.18	26.84	8
TOC (mg/L)	3.08	3.08	2.79	3.35	0.14	0.02	32
UV-254 (cm^{-1})	0.10	0.10	0.04	0.13	0.02	0.00	31
Aluminum (mg/L)	0.01	0.00	0.00	0.00	0.00	0.00	3
Silica (mg/L)	7.00	1.41	6.10	7.93	2.44	5.94	3
Copper (mg/L)	-0.08	0.02	-0.09	-0.06	0.04	0.00	5
Calcium (mg/L)	76.39	7.45	48.17	66.45	16.66	277.66	5
Magnesium (mg/L)	5.60	0.32	4.08	5.35	0.72	0.51	5
Sodium (mg/L)							

Appendix

Table 30. Anion Exchange Data from Plant 9

Run	1	1	1	1	1
Date	10/28/05	10/28/05	10/28/05	10/28/05	10/28/05
Volume	1.68	1.75	2.625	1.56	1.56
Accumulate Volume (gal)	1.68	3.43	6.055	7.615	9.175
Flow rate (gph)	3.51	3.51	3.14	3.14	3.14
Sulfide (mg/L as S^-)	1.534	0.635	1.302	0.6	0.43
pH	6.54	6.5	6.45	6.46	6.42
Temperature (°C)	14.2	16.9	19	20.3	22.4
ORP (mV)					
DO (mg/L as O_2)					
Sulfate (mg/L as SO_4^{2-})	0.5	UDL	0.1	UDL	0.2
Chloride (mg/L as Cl^-)	187.34	197.25	177.98	235.78	255.05
Alkalinity (mg/L as $CaCO_3$)					
Conductivity (µS/cm)	529	573	583	629	636
Turbidity (NTU)	3.17	0.809	0.52	0.52	0.48
TOC (mg/L)	2.99	2.14	2.81	3.77	0.526
UV-254 (cm-1)	0.001	0.034	0.021	0.023	-0.004

UDL*, Under Detection Limit

Run	1	1	1	1	1
Date	10/28/05	10/28/05	10/28/05	10/28/05	10/28/05
Volume	1.56	3.12	3.12	3.12	3.12
Accumulate Volume (gal)	10.735	13.855	16.975	20.095	23.215
Flow rate (gph)	3.14	3.14	3.14	3.14	3.14
Sulfide (mg/L as S^-)	0.32	0.16	0.17	0.19	0.215
pH	6.43	6.43	6.46	6.54	6.61
Temperature (°C)	24	24.5	23.2	24	23.4
ORP (mV)					
DO (mg/L as O_2)					
Sulfate (mg/L as SO_4^{2-})	UDL	UDL	UDL	UDL	UDL
Chloride (mg/L as Cl^-)	216.51	274.31	139.45	235.78	235.78
Alkalinity (mg/L as $CaCO_3$)					
Conductivity (µS/cm)	655	701	635	634	614
Turbidity (NTU)	0.401	0.36	0.67	0.39	0.362
TOC (mg/L)	1.09	0.526		0.606	0.541
UV-254 (cm-1)	0.006	UDL*	0.005	0.017	0.016

UDL*, Under Detection Limit

Table 30. Continued

Run	2	2	2	2	2
Date	10/31/05	11/01/05	11/01/05	11/01/05	11/01/05
Volume	0	26.28	6.93	10.98	5.49
Accumulate Volume (gal)	0	26.28	33.21	44.19	49.68
Flow rate (gph)	2	5.46	5.46	5.46	5.46
Sulfide (mg/L as S^-)	0.445	0.185	0.27	0.495	0.74
pH	7.19	6.83	6.79		7.03
Temperature (°C)	24.1	19.4	21.5	22.9	23.5
ORP (mV)					
DO (mg/L as O_2)					
Sulfate (mg/L as SO_4^{2-})		0.6			
Chloride (mg/L as Cl^-)		235.78	197.25	120.18	123.76
Alkalinity (mg/L as $CaCO_3$)					
Conductivity (µS/cm)		574	583	584	580
Turbidity (NTU)		1.36	1.23	0.994	0.802
TOC (mg/L)	0.528	0.54	0.651	0.564	0.429
UV-254 (cm-1)	UDL*	UDL*	0.045	UDL*	UDL*

UDL*, Under Detection Limit

Run	2	2	3	3	3
Date	11/02/05	11/04/05	12/05/05	12/06/05	12/07/05
Volume	14.88	43.66	0	61.07	72.05
Accumulate Volume (gal)	64.56	119.51	0	61.07	133.12
Flow rate (gph)	5.46		3.82	6.65	6.89
Sulfide (mg/L as S^-)	1.095	1.905	0.205	0.39	0.66
pH	7.1	7.43	6.9	7.04	7.31
Temperature (°C)	20.7	22.8	19	21.2	21.9
ORP (mV)			140	-174	-192
DO (mg/L as O_2)		0.6	2.7	0.03	7.07
Sulfate (mg/L as SO_4^{2-})	2.4		6.5	0.5	3.8
Chloride (mg/L as Cl^-)	106.42	71.74	193.12	94.86	52.48
Alkalinity (mg/L as $CaCO_3$)			230.00	230.00	240.00
Conductivity (µS/cm)	389	524	657	552	506
Turbidity (NTU)	0.515	3	17.10	2.28	1.94
TOC (mg/L)		0.498	0.582	0.496	
UV-254 (cm-1)	UDL*	0.041	0.0036	0.0136	UDL*

UDL*, Under Detection Limit

Table 31. Anion Exchange Data from Plant 8

Run	1	1	1	1	1
Date	11/17/05	11/18/05	11/18/05	11/18/05	11/21/05
Volume	3.775	53.23	11.325	11.88	39
Accumulate Volume (gal)	3.775	57.005	68.33	80.21	119.21
Flow rate (gph)	7.55	7.92	7.92	7.92	7.32
Sulfide (mg/L as S^-)	0.376	0.029	0.063	0.147	0.842
pH	6.36		6.84	6.91	7.26
Temperature (°C)	25.4	21.5	21.7	23.1	24.8
ORP (mV)					-200
DO (mg/L as O_2)					
Sulfate (mg/L as SO_4^{2-})	0.3	0.3	0.1	1.2	4.8
Chloride (mg/L as Cl^-)	173.85	177.71	102.57	94.86	23.58
Alkalinity (mg/L as $CaCO_3$)	260	260	285	250	165
Conductivity (µS/cm)	669	524	520	526	511
Turbidity (NTU)	0.449	0.249	0.184	0.308	2.04
TOC (mg/L)	0.929	0.415	0.54	0.502	0.565
UV-254 (cm-1)	0.0146	0.0034	0.0096	0.0034	0.006

Run	2	2	2	2
Date	11/7/05	11/8/05	11/8/05	11/9/05
Volume		0.82	0.57	19.2
Accumulate Volume (gal)		0.82	1.39	20.59
Flow rate (gph)		1.37	1.73	5.9
Sulfide (mg/L as S^-)	0.188	0.8	0.995	0.075
pH		6.47	6.27	6.38
Temperature (°C)		29.3	28.2	24.1
ORP (mV)				
DO (mg/L as O_2)		0.53	0.03	0.05
Sulfate (mg/L as SO_4^{2-})		2.4	6.7	0.5
Chloride (mg/L as Cl^-)		166.15	171.93	162.29
Alkalinity (mg/L as $CaCO_3$)		150	140	160
Conductivity (µS/cm)		760	668	587
Turbidity (NTU)		7.97	2.49	0.087
TOC (mg/L)		1.92	0.488	0.462
UV-254 (cm-1)		0.0162	0.012	0.008

Appendix

Table 31. Continued

Run	2	2	2	2	2
Date	11/9/05	11/10/05	11/11/05	11/12/05	11/14/05
Volume	2.6	32.09	43.71	45	105.46
Accumulate Volume (gal)	23.19	55.28	98.99	143.99	249.45
Flow rate (gph)	1.57	2.37	3.28	3.47	3.28
Sulfide (mg/L as S^-)	0.074	0.145	0.074	0.046	0.149
pH	6.57	6.84	7	7.2	7.42
Temperature (°C)	23.5	21.9	22.1	23.2	22.8
ORP (mV)					
DO (mg/L as O_2)	0.04	0	0	0.16	0
Sulfate (mg/L as SO_4^{2-})		1		0.3	1.6
Chloride (mg/L as Cl^-)		158.44	69.82	60.18	21.65
Alkalinity (mg/L as $CaCO_3$)		150	135	100	225
Conductivity (μS/cm)	557	522	496	472	445
Turbidity (NTU)	0.185	0.212	0.157	0.542	0.57
TOC (mg/L)		0.496	0.422	0.477	0.52
UV-254 (cm-1)		0.0056	0.0108	0.0084	0.0096

UDL*, Under Detection Limit

Run	2	3	3	3
Date	11/16/05	9/30/05	10/3/05	10/5/05
Volume	141.09	30	123	206
Accumulate Volume (gal)	390.54	30	153	359
Flow rate (gph)	3.28		2.39	3.74
Sulfide (mg/L as S^-)	1.415	0.068	0.674	0.74
pH	7.31	7.16	6.72	6.91
Temperature (°C)	25.9	30.6	11.5	18.7
ORP (mV)				
DO (mg/L as O_2)				
Sulfate (mg/L as SO_4^{2-})	9.4	3.5	3.4	2.3
Chloride (mg/L as Cl^-)	21.65	56.33	21.65	21.65
Alkalinity (mg/L as $CaCO_3$)	250	84	106	116
Conductivity (μS/cm)	483	368	421	412
Turbidity (NTU)	0.457	0.516	0.23	0.378
TOC (mg/L)	0.681	0.691	0.564	3.46
UV-254 (cm-1)	0.0064	UDL*	0.017	0.012

UDL*, Under Detection Limit

Table 32. Anion Exchange Data from Plant 6

Run	1	1	1	1	1
Date	10/14/05	10/14/05	10/14/05	10/14/05	10/14/05
Volume (gal)	0				
Accumulate Volume (gal)	0	0.55	1.1	1.65	2.2
Flow rate (gph)	6.79	6.79	6.79	6.79	6.79
Sulfide (mg/L as S^-)	0.269	0.378	0.424	0.402	0.34
pH	6.21	6.26	6.31	6.32	6.28
Temperature (°C)					
ORP (mV)					
DO (mg/L as O_2)					
Sulfate (mg/L as SO_4^{2-})					
Chloride (mg/L as Cl^-)					
Alkalinity (mg/L as $CaCO_3$)					
Conductivity (µS/cm)					
Turbidity (NTU)					
TOC (mg/L)					
UV-254 (cm-1)					

Run	1	1	1	1	1
Date	10/14/05	10/14/05	10/14/05	10/14/05	10/28/05
Volume (gal)					
Accumulate Volume (gal)	2.75	3.3	4.4	6.6	6.6
Flow rate (gph)	6.79	6.79	6.79	6.79	7.09
Sulfide (mg/L as S^-)	0.348	0.318	0.261	0.152	0.379
pH	6.26	6.23	6.18	6.26	6.94
Temperature (°C)					23.9
ORP (mV)					
DO (mg/L as O_2)					
Sulfate (mg/L as SO_4^{2-})					1
Chloride (mg/L as Cl^-)					143.03
Alkalinity (mg/L as $CaCO_3$)					
Conductivity (µS/cm)					796
Turbidity (NTU)					0.107
TOC (mg/L)					0.771
UV-254 (cm-1)					0.038

Table 32. Continued

Run	1	1	1	1	1
Date	10/28/05	10/28/05	10/28/05	10/28/05	10/28/05
Volume (gal)	3.68	1.23	1.84	0.61	0.61
Accumulate Volume (gal)	10.28	11.51	13.35	13.96	17.03
Flow rate (gph)	7.09	7.09	7.09	7.09	7.09
Sulfide (mg/L as S^-)	0.372	0.248	0.151	0.108	0.073
pH	6.62	6.27	6.29	6.2	6.16
Temperature (°C)	22	22.9	22.5	22.9	23.5
ORP (mV)					
DO (mg/L as O_2)					
Sulfate (mg/L as SO_4^{2-})		15		14	54
Chloride (mg/L as Cl^-)		125.69		143.03	162.29
Alkalinity (mg/L as $CaCO_3$)					
Conductivity (µS/cm)	504	522	506	518	516
Turbidity (NTU)		0.186		0.125	0.139
TOC (mg/L)		0.632	0.559	0.494	
UV-254 (cm-1)		0.028	0.028	0.017	

Run	1	1	1	1	1
Date	10/28/05	10/28/05	10/28/05	10/28/05	10/28/05
Volume (gal)	1.80	2.45	2.45	3.07	3.07
Accumulate Volume (gal)	18.83	21.28	23.73	26.80	29.87
Flow rate (gph)	7.09	7.09	7.09	7.09	7.09
Sulfide (mg/L as S^-)	0.064	0.041	0.036	0.025	0.039
pH	6.19	6.2	6.3	6.36	6.45
Temperature (°C)	23	24.6	25	23.9	24.3
ORP (mV)					
DO (mg/L as O_2)					
Sulfate (mg/L as SO_4^{2-})		39	12	7	28
Chloride (mg/L as Cl^-)		121.83	148.81	135.32	133.39
Alkalinity (mg/L as $CaCO_3$)					
Conductivity (µS/cm)	524	536	533	522	522
Turbidity (NTU)		0.171	0.167	0.091	0.086
TOC (mg/L)			0.527		0.405
UV-254 (cm-1)			0.058		0.068

Table 32. Continued

Run	1	1	1	1	1
Date	10/28/05	10/28/05	10/28/05	10/28/05	10/29/05
Volume (gal)	3.07	3.07	4.02	4.91	110
Accumulate Volume (gal)	32.93	39.07	43.09	48.00	158.00
Flow rate (gph)	7.09	7.09	7.09	7.09	6.89
Sulfide (mg/L as S^-)	0.042	0.042	0.055	0.059	1.09
pH	6.53	6.79	7.02	7.02	7.35
Temperature (°C)	24.6	26	26	24.9	22
ORP (mV)					
DO (mg/L as O_2)					
Sulfate (mg/L as SO_4^{2-})	79	28	79	76	3
Chloride (mg/L as Cl^-)	125.69	129.54	110.27	98.72	37.06
Alkalinity (mg/L as $CaCO_3$)					
Conductivity (μS/cm)	519	525	518	501	410
Turbidity (NTU)	0.096	0.114	0.124	0.096	0.395
TOC (mg/L)	0.397	0.388	0.98	0.998	0.42
UV-254 (cm-1)	0.047	0.023	0.114	0.04	

UDL*, Under Detection Limit

Table 32. Continued

Run	2	2	2	2	2
Date	10/31/05	11/1/05	11/1/05	11/2/05	11/3/05
Volume (gal)	0	27.42	6.09	53.06	26.88
Accumulate Volume (gal)	0.00	27.42	33.51	86.57	113.45
Flow rate (gph)	2.61	2.40	6.09	2.38	2.49
Sulfide (mg/L as S^-)	0.023	0.027	0.07	0.365	0.365
pH	6.74	6.6		7.1	7.34
Temperature (°C)	24	23.9		24.4	21.4
ORP (mV)					
DO (mg/L as O_2)					
Sulfate (mg/L as SO_4^{2-})		35		1.3	20
Chloride (mg/L as Cl^-)		137.25		83.30	75.60
Alkalinity (mg/L as $CaCO_3$)					
Conductivity (μS/cm)		486		310	416
Turbidity (NTU)		0.259	0.453	0.284	0.069
TOC (mg/L)	0.556			0.498	1.97
UV-254 (cm-1)	UDL*			UDL*	UDL*

UDL*, Under Detection Limit

Table 32. Continued

Run	2
Date	11/4/05
Volume (gal)	53.47
Accumulate Volume (gal)	166.92
Flow rate (gph)	2.42
Sulfide (mg/L as S^{-})	0.574
pH	7.35
Temperature (°C)	21.5
ORP (mV)	
DO (mg/L as O_2)	UDL
Sulfate (mg/L as SO_4^{2-})	14
Chloride (mg/L as Cl^-)	37.06
Alkalinity (mg/L as $CaCO_3$)	
Conductivity (μS/cm)	392
Turbidity (NTU)	0.054
TOC (mg/L)	0.431
UV-254 (cm-1)	0.02

Appendix

Table 33. Anion Exchange Data from Plant 2

Run	1	1	1	1	1
Date	9/16/05	9/17/05	9/18/05	9/19/05	9/20/05
Volume (gal)		30	25.74	30.64	30.00
Accumulate Volume (gal)		30	55.74	86.38	116.38
Flow rate (gph)					
Sulfide (mg/L as S^-)	0.049	0.03	0.166	0.381	0.462
pH		6.51	6.79	7.02	7.23
Temperature (°C)		26.7	30.6	26.1	31
ORP (mV)					
DO (mg/L as O_2)					
Sulfate (mg/L as SO_4^{2-})		0.4	1		0.5
Chloride (mg/L as Cl^-)		123.76	102.57		58.26
Alkalinity (mg/L as $CaCO_3$)		50	70	50	70
Conductivity (μS/cm)		352	380	378	362
Turbidity (NTU)		0.062	0.131	0.117	0.159
A Color (mg/L Pt.Co)			6		1
T Color (mg/L Pt.Co)			2		
TOC (mg/L)		0.392	0.407	0.376	0.478
UV-254 (cm-1)		UDL*	0.014	UDL*	0.006

UDL*, Under Detection Limit

Table 34. Anion Exchange Data from Plant 2

Run	1	2	2	2	2
Date	9/21/05	10/13/05	10/14/05	10/15/05	10/17/05
Volume (gal)	29.36		150	150	328
Accumulate Volume (gal)	145.74		150	300	628
Flow rate (gph)			7.43	7.99	7.43
Sulfide (mg/L as S^-)	0.571	0.181	0.839	0.8225	0.842
pH		6.63	7.32	7.5	7.52
Temperature (°C)		32.4	27.7	24.1	24.5
ORP (mV)					
DO (mg/L as O_2)					
Sulfate (mg/L as SO_4^{2-})		1.4	0.4	3.8	UDL
Chloride (mg/L as Cl^-)		141.10	40.92	17.80	17.80
Alkalinity (mg/L as $CaCO_3$)		70	160	200	180
Conductivity (μS/cm)		415	469	405	410
Turbidity (NTU)		0.9	0.09	0.213	0.073
A Color (mg/L Pt.Co)					
T Color (mg/L Pt.Co)					
TOC (mg/L)		3.26	0.915	0.488	0.709
UV-254 (cm-1)		UDL*	UDL*	UDL*	0.04

UDL*, Under Detection Limit

Table 33. Continued

Run	3	3	3	3	3
Date	12/7/05	12/8/05	12/9/05	12/10/05	12/12/05
Volume (gal)	0	0	60.22	83.79	128.92
Accumulate Volume (gal)	0	0	60.22	144.01	272.93
Flow rate (gph)	3.14	5.23	5.22	5.03	5.11
Sulfide (mg/L as S^{-})	0	UDL	0.02	0.002	0.855
pH	7.14	6.74		7.19	7.55
Temperature (°C)	20.3	22.9	23.8	21.2	22
ORP (mV)	13.29	8.2	0.7	2.15	2.35
DO (mg/L as O_2)	2	97	137	4	-187
Sulfate (mg/L as SO_4^{2-})	0.7	0.5	1.1	1.6	0.7
Chloride (mg/L as Cl^{-})	135.32	131.47	110.27	52.48	15.87
Alkalinity (mg/L as $CaCO_3$)	200	220	180	160	30
Conductivity (μS/cm)	510	509	487	417	384
Turbidity (NTU)	0.095	0.079	0.088	0.063	0.071
A Color (mg/L Pt.Co)					
T Color (mg/L Pt.Co)					
TOC (mg/L)		0.699	0.434	0.434	
UV-254 (cm-1)	UDL*		0.009	UDL*	0.014

UDL*, Under Detection Limit

Table 33. Continued

Run	4	4	4	4	4
Date	1/17/06	1/18/06	1/19/06	1/20/06	1/23/06
Volume (gal)		64.13	63.55	74.14	244.91
Accumulate Volume (gal)		64.13	127.68	201.82	446.73
Flow rate (gph)	2.76	2.98	3.25	3.6	
Sulfide (mg/L as S^{-})	0.241	0.012	0.057	UDL	0.751
pH	6.55	6.43	7.05	7.36	7.43
Temperature (°C)	24.3	22.1	17.7	19.2	23.4
ORP (mV)	0.82	2.09	2.51	1.72	1.68
DO (mg/L as O_2)	-163	8	-8	114	-108
Sulfate (mg/L as SO_4^{2-})	UDL	UDL	2.1	0.9	1.6
Chloride (mg/L as Cl^{-})	225.87	114.13	133.39	131.47	15.87
Alkalinity (mg/L as $CaCO_3$)	150	55	90	105	170
Conductivity (μS/cm)	582	465	387	413	395
Turbidity (NTU)	0.129	0.137	0.124	0.133	0.187
A Color (mg/L Pt.Co)					
T Color (mg/L Pt.Co)					
TOC (mg/L)	0.838	0.426	0.427	0.428	0.514
UV-254 (cm-1)	0.0082	0.001	UDL*	UDL*	0.0018

UDL*, Under Detection Limit

Table 35. Chlorine Demand Test for Raw Water from Plant 9

Date	12/9/2005	12/11/2005
Sulfide (mg/L as S^-)	2.65	2.74
pH	7.43	7.46
Temperature (°C)	22.4	20.7
DO (mV)	0.60	1.53
ORP (mg/L as O_2)	-184	-202
Sulfate (mg/L as SO_4^{2-})	29.5	29.8
Chloride (mg/L as Cl^-)	15.87	12.02
Alkalinity (mg/L as $CaCO_3$)	110	200
Conductivity (μS/cm)	465	441
Turbidity (NTU)	0.754	0.198
TOC (mg/L)	2.59	2.68
UV-254 (cm^{-1})	0.134	0.115
Stock Concentration (mg/L as Cl_2)	5000	5100
Contact Time (min)	30	30
Chlorine Concentration (mg/L as Cl_2)	30	30
Volume added (mL)	1.76	1.76
Total Chlorine A (mg/L as Cl_2)	12.2	12.5
Total Chlorine B (mg/L as Cl_2)	13	14
Chlorine Demand A (mg/L as Cl_2)	17.8	17.5
Chlorine Demand B (mg/L as Cl_2)	17	16
Average Chlorine Demand (mg/L as Cl_2)	17.4	16.75

Table 36. Chlorine Demand Test for Anion Exchange Effluent from Plant 9

Date	12/9/2005	12/11/2005
Sulfide (mg/L as S^-)	0.149	0.027
pH	6.52	6.99
Temperature (°C)	22.4	18
DO (mV)	0.46	0.83
ORP (mg/L as O_2)	176	164
Sulfate (mg/L as SO_4^{2-})	0.3	1.9
Chloride (mg/L as Cl^-)	177.71	150.73
Alkalinity (mg/L as $CaCO_3$)	110	170
Conductivity (μS/cm)	623	500
Turbidity (NTU)	1.65	9.83
TOC (mg/L)	0.467	0.541
UV-254 (cm^{-1})	0.008	0.008
Stock Concentration (mg/L as Cl_2)	5000	5100
Contact Time (min)	30	30
Chlorine Concentration (mg/L as Cl_2)	10	10
Volume added (mL)	0.60	0.58
Total Chlorine A (mg/L as Cl_2)	6.2	7
Total Chlorine B (mg/L as Cl_2)	7.4	6.5
Chlorine Demand A (mg/L as Cl_2)	3.8	3
Chlorine Demand B (mg/L as Cl_2)	2.6	3.5
Average Chlorine Demand (mg/L as Cl_2)	3.2	3.25

Appendix

Table 37. Chlorine Demand Test for Raw Water from Plant 8

Date	12/11/2005	1/18/2006
Sulfide (mg/L as S^-)	1.675	1.475
pH	7.26	7.32
Temperature (°C)	18.5	21.8
DO (mV)	1.53	1.37
ORP (mg/L as O_2)	-187	-241
Sulfate (mg/L as SO_4^{2-})	6.9	6.7
Chloride (mg/L as Cl^-)	15.87	17.80
Alkalinity (mg/L as $CaCO_3$)	210	110
Conductivity (μS/cm)	409	460
Turbidity (NTU)	0.23	1.24
TOC (mg/L)	2.65	2.64
UV-254 (cm^{-1})	0.137	0.0914
Stock Concentration (mg/L as Cl_2)	5100	4200
Contact Time (min)	30	30
Chlorine Concentration (mg/L as Cl_2)	30	30
Volume added (mL)	1.76	2.11
Total Chlorine A (mg/L as Cl_2)	17.5	13
Total Chlorine B (mg/L as Cl_2)	17	15.5
Chlorine Demand A (mg/L as Cl_2)	12.5	17
Chlorine Demand B (mg/L as Cl_2)	13	14.5
Average Chlorine Demand (mg/L as Cl_2)	12.75	15.75

Appendix

Table 38. Chlorine Demand Test for Anion Exchange Effluent from Plant 8

Date	12/11/2005	1/18/2006
Sulfide (mg/L as S^-)	0.021	UDL*
pH	7.42	6.84
Temperature (°C)	16.4	19.7
DO (mV)	0.97	177
ORP (mg/L as O_2)	158	7.8
Sulfate (mg/L as SO_4^{2-})	1.9	UDL
Chloride (mg/L as Cl^-)	131.47	119.91
Alkalinity (mg/L as $CaCO_3$)	170	40
Conductivity (mS/cm)	494	518
Turbidity (NTU)	2.02	0.969
TOC (mg/L)	0.461	0.47
UV-254 (cm^{-1})	0.009	UDL*
Stock Concentration (mg/L as Cl_2)	5100	4200
Contact Time (min)	30	30
Chlorine Concentration (mg/L as Cl_2)	10	10
Volume added (mL)	0.58	0.7
Total Chlorine A (mg/L as Cl_2)	7	7.6
Total Chlorine B (mg/L as Cl_2)	7.5	6
Chlorine Demand A (mg/L as Cl_2)	3	2.4
Chlorine Demand B (mg/L as Cl_2)	2.5	4
Average Chlorine Demand (mg/L as Cl_2)	2.75	3.2

UDL*, Under Detection Limit

Appendix

Table 39. Chlorine Demand Test for Raw Water from Plant 2

Date	1/20/2006	1/26/2006
Sulfide (mg/L as S^{-})	0.995	1.08
pH	7.49	7.49
Temperature (°C)	22.7	21.6
DO (mV)	1.14	1.25
ORP (mg/L as O_2)	-112	-113
Sulfate (mg/L as SO_4^{2-})	0.3	1
Chloride (mg/L as Cl^-)	13.94	15.87
Alkalinity (mg/L as $CaCO_3$)	100	110
Conductivity (mS/cm)	394	380
Turbidity (NTU)	0.223	0.174
TOC (mg/L)	3.12	3.35
UV-254 (cm^{-1})	0.0974	0.086
Stock Concentration (mg/L as Cl_2)	4200	4200
Contact Time (min)	30	30
Chlorine Concentration (mg/L as Cl_2)	30	30
Volume added (mL)	2.11	2.11
Total Chlorine A (mg/L as Cl_2)	18.48	20.24
Total Chlorine B (mg/L as Cl_2)	17.8	20.28
Chlorine Demand A (mg/L as Cl_2)	11.52	9.76
Chlorine Demand B (mg/L as Cl_2)	12.2	9.72
Average Chlorine Demand (mg/L as Cl_2)	11.86	9.74

Appendix

Table 40. Chlorine Demand Test for Anion Exchange Effluent from Plant 2

Date	1/20/2006	1/26/2006
Sulfide (mg/L as S^-)	UDL*	0.065
pH	7.36	7.16
Temperature (°C)	19.2	17.5
DO (mV)	1.72	2
ORP (mg/L as O_2)	114	-6
Sulfate (mg/L as SO_4^{2-})	0.9	0.9
Chloride (mg/L as Cl^-)	131.47	73.67
Alkalinity (mg/L as $CaCO_3$)	105	55
Conductivity (μS/cm)	413	401
Turbidity (NTU)	0.133	0.065
TOC (mg/L)	0.428	0.405
UV-254 (cm^{-1})	UDL*	UDL*
Stock Concentration (mg/L as Cl_2)	4200	4200
Contact Time (min)	30	30
Chlorine Concentration (mg/L as Cl_2)	10	10
Volume added (mL)	0.7	0.7
Total Chlorine A (mg/L as Cl_2)	8.42	7.38
Total Chlorine B (mg/L as Cl_2)	8.44	7.9
Chlorine Demand A (mg/L as Cl_2)	1.58	2.62
Chlorine Demand B (mg/L as Cl_2)	1.56	2.1
Average Chlorine Demand (mg/L as Cl_2)	1.57	2.36

UDL*, Under Detection Limit

Appendix

Anion Exchange Batch Test Protocol

1. Materials
   - 82 mL of Anion Exchange Resin per amber bottle.
   - 125 mL amber HDPE bottles (8 bottles per group)
   - Non-ionized salt
   - Water from well 9
   - Parafilm

2. Methods

A. Amber Bottles.

Pre-rinse the amber bottles in nitric acid at 1% for at least 24 hours. Then rinse them using nanopure, and let them dry.

B. Resin.

Submerge 1400 mL (88 ml of excess) of SBR in nanopure in large recipient. Change the nanopure each 24 hours until the nanopure conductivity will be low. Drain the excess of nanopure from the recipient.

C. Brine Solution

Divided the SBR in two parts with equal amount of resin. Dissolved in 336 ml of nanopure 52.8 gr of salt (5 lbs/ft^3) per group of samples. Add 336 ml of nanopure to the prepared brine solution.

Allow 4-6 hours of contact time between pre-rinsed resin and brine solution for each group of samples. Drain the excess of brine solution. Fill each bottle with 82 ml of Anion Exchange resin, and cap each bottle. Transport the bottles to well 9.

3. Test.

Prepare two set of samples to be opened and tested at 2, 3, 4, 5, 8, 10, 15, and 20 minutes (8 bottles per set) after the raw addition.

Fill carefully each amber bottle with raw water to avoid loss of resin. Cover each bottle with piece of parafilm. Avoid air bubbles between the sample and the parafilm.
Test the following parameters for each sample: Hydrogen Sulfide, Sulfate, Chloride, pH, Conductivity, alkalinity, and TOC for each sample. Use 5 mL of sample for hydrogen sulfide, sulfate, chloride, and TOC, and 40 ml for alkalinity. Measure immediately H_2S, and for the other tests take immediately the correct amount of sample and put the respective cell for analysis.

Appendix

Pilot-scale anion exchange reactor characteristics

Material	plexi-glass
Diameter, inches	2
Bed volume	
ft3	0.065
gallons	0.5
m3	0.0018
Bed depth, ft	3
Freeboard, inches	18

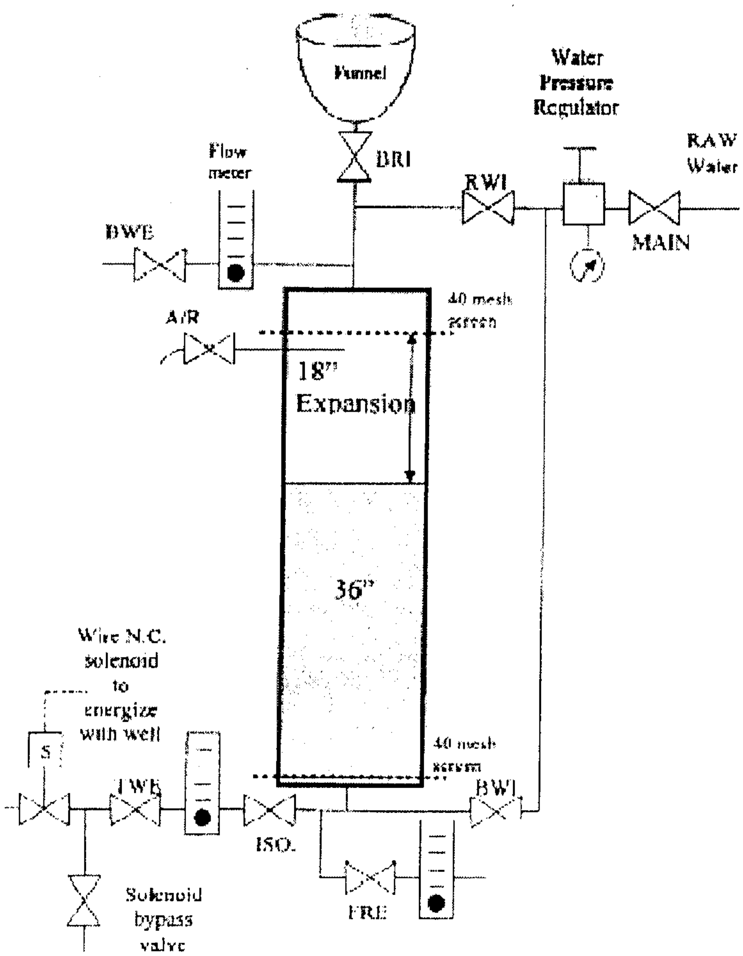

Diagram of pilot-scale anion exchange reactors provided by Tonka Equipment.

Appendix

Brine make-up procedure used for pilot testing of regeneration

1. Add three pounds of non-iodized salt to 1 gallon of make-up water (distilled water or well water)
2. Stir the solution to dissolve the salt and produce a concentrated brine
3. Calculate the salt concentration needed based on the volume of resin to be regenerated
4. Dilute concentrated brine to appropriate level (3-10 lb/ft^3)
5. Pour the diluted solution into the anion exchanger funnel.
6. Allow to react for specified time period

Table 41. Well 9 regeneration data

Parameter	Well 9 untreated 7/5/2006	Drain down 7/5/2006	Backwash 7/5/2006	Brine 7/5/2006	Slow Rinse 7/5/2006	Fast Rinse 7/5/2006
Flowrate, gph	7.60	1.20	4.00	8.00	1.20	8.00
time, minutes		15.00	15.00	15.00	25.00	10.00
Total volume, liters		4.5	15.1	30.3	7.6	20.2
Brine *concentration*, lb/ft^3				4		
BOD, mg/L				18	410	4.7
COD, mg/L				435	4560	
TDS, mg/L	602	486	362	8690	36800	708
TSS, mg/L				10	18	
TS, mg/L		474	358	8810	36700	676
NVSS, mg/L				8	14	
VSS, mg/L					4	
TNVS, mg/L		450	332	8480	35000	500
TVS, mg/L		24	26	330	1700	176
Alkalinity, mg/L as CaCO3	27	216	209	1710	2700	23
Chloride, mg/L	166	114	48		7310	188
Hardness	258	246	254	221	131	255
Sulfate, mg/L	35	31	37	4170	15300	95
Ammonia-n, mg/L	0.24	0.17	0.23	0.15	0.12	0.18
Nitrite-n, mg/L						
Nitrate-n, mg/L						
Total-n, mg/L				4.7	32.3	
Total-p, mg/L		0.08		12.4	5.91	
TKN, mg/L				4.68	32.3	
TOC, mg/L	3.2	1.9		123	1320	6.6
Cu, mg/L		0.523	0.577	0.062	0.048	
Fe, mg/L		0.139	0.152			
Na, mg/L	37.5	32.4	32.5	3300	16450	72.6

Appendix

Table 40 (continued) Well 9 regeneration data

Well 9 regeneration data	Well 9 untreated	Drain down	Backwash	Brine	Slow Rinse	Fast rinse
Sample Date	7/12/2006	7/12/2006	7/12/2006	7/12/2006	7/12/2006	7/12/2006
Flowrate, gph	7.60	1.20	4.00	8.00	1.20	8.00
time, minutes		15.00	15.00	15.00	25.00	10.00
Total volume, liters		4.5	15.1	30.3	7.6	20.2
Brine concentration, lb/ft^3				4		
BOD, mg/L			49	73	176	
COD, mg/L				792	3920	
TDS, mg/L	652		628	11400	36400	840
TSS, mg/L			6.6		4	
TS, mg/L			657	11624	37240	872
NVSS, mg/L			4.8		35426	664
VSS, mg/L						
TNVS, mg/L			437	11350		664
TVS, mg/L		244	220	274	1814	208
Alkalinity, mg/L as $CaCO_3$	14		148	844	2480	22
Chloride, mg/L	182	158	173	4940	5850	258
Hardness	254	254	254	179	150	246
Sulfate, mg/L	46	16	19	394	15500	112
Ammonia-n, mg/L	0.26	0.45	0.5	0.34	0.47	0.27
Nitrite-n, mg/L						
Nitrate-n, mg/L						
Total-n, mg/L			7.23	9.12	45.2	1.39
Total-p, mg/L			0.04	0.76	1.72	0.04
TKN, mg/L		5.65	7.23	9.12	45.2	1.39
TOC, mg/L	6.2	4.6	4.5	116	1270	11.6
Cu, mg/L		0.066	0.241	0.027	0.053	0.023
Fe, mg/L			0.12		0.021	
Na, mg/L	44.4	49.9	48.9	4080	12580	129

Table 40 (continued)

Well 9 regeneration data	Well 9 untreated	Drain down	Backwash	Brine	Slow Rinse	Fast rinse
Sample Date	7/18/2006	7/18/2006	7/18/2006	7/18/2006	7/18/2006	7/18/2006
Flowrate, gph	7.60	1.20	4.00	8.00	1.20	8.00
time, minutes		15.00	15.00	15.00	25.00	10.00
Total volume, liters		4.5	15.1	30.3	7.6	20.2
Brine concentration, lb/ft^3				4		
BOD, mg/L		4.9		15	279	
COD, mg/L				245	5120	
TDS, mg/L	528	292	430	6150	51500	714
TSS, mg/L						
TS, mg/L		290	449	6260	51900	714
NVSS, mg/L						
VSS, mg/L						
TNVS, mg/L		268		5800	50500	534
TVS, mg/L			448	460	1400	180
Alkalinity, mg/L as CaCO3		193	196	1390	4030	13
Chloride, mg/L	182	14	93	92	5440	254
Hardness	256	261	262	158	107	259
Sulfate, mg/L	48	48	43	3230	24400	76
Ammonia-n, mg/L	0.26	0.26	0.24	0.23	0.44	0.28
Nitrite-n, mg/L						
Nitrate-n, mg/L						
Total-n, mg/L		1.04		4.96	46.6	1.43
Total-p, mg/L		0.1	0.09	20.2	3.26	0.07
TKN, mg/L		1.04		4.96	46.6	1.43
TOC, mg/L	6.9	3.1	3.6	77.8	1720	8.6
Cu, mg/L		0.249	0.532	0.082	0.163	0.117
Fe, mg/L		0.172	0.122	0.059	0.122	0.052
Na, mg/L	48.2	11.5	116	6940	15600	99.6

Table 42. Anion Exchange Design Summary

Anion Exchange Design Summary
AADF

Plant name	Plant 9	Plant 8	Plant 6	Mitchell	Plant 2
Design capacity, gal/ft^3	1000	1500	2500	2500	3500
Volume processed before regen, vessel	254,469	381,704	636,173	502,655	703,717
Regeneration frequency per vessel, days	3.3	4.4	8.0	5.2	7.3
Design flowrate, AADF, gpd	232,000	259,000	239,000	289,000	288,000
Max hours of operation per day	7.7	8.6	8.0	9.6	9.6
gallons per vessel per day	77,488	86,506	79,826	96,526	96,192

WWTP flowrate, MGD	**1.5**	**2**	**2.5**	**3**	**3.5**
Chloride					
contribution from wastewater, kg/d assume 275 mg/L	1561	2082	2602	3123	3643
Sodium					
contribution from wastewater, kg/d assume 150 mg/L	852	1136	1419	1703	1987
contribution from sodium hypochlorite, kg/d	55	67	79	91	103
Estimated wastewater concentration					
Chloride					
mg/L (6 lb/ft^3)	479	428	397	377	362
mg/L (4 lb/ft^3)	407	374	354	341	332
Sodium					
mg/L (6 lb/ft^3)	292	258	237	224	214
mg/L (4 lb/ft^3)	248	225	211	202	195
If KCl is used for 8+9 instead of NaCl					
Chloride					
mg/L (6 lb/ft^3)	435	395	371	355	343
mg/L (4 lb/ft^3)	381	355	339	328	321
Sodium					
mg/L (6 lb/ft^3)	215	200	192	186	182
mg/L (4 lb/ft^3)	197	187	181	176	174
Potassium					
mg/L (6 lb/ft^3)	274	218	184	162	146
mg/L (4 lb/ft^3)	199	162	140	125	114

Table 41. Anion Exchange Design Summary (continued)

Anion Exchange Design Summary

MMADF-1

Plant name	Well 9	Well 8	Well 6	Mitchell	Well 2
Volume processed before regen, vessel	254,469	381,704	636,173	502,655	703,717
Regeneration frequency per vessel, days	2.4	3.1	5.3	3.5	5.2
Design flowrate, MMADF-1, gpd	313,482	369,838	356,923	429,717	407,409
Max hours of operation per day	10.4	12.3	11.9	14.3	13.6
gallons per vessel per day	104,703	123,526	119,212	143,525	136,075

WWTP flowrate, MGD	1.5	2	2.5	3	3.5
Chloride					
contribution from wastewater, kg/d assume 275 mg/L	1561	2082	2602	3123	3643
Sodium					
contribution from wastewater, kg/d assume 150 mg/L	852	1136	1419	1703	1987
contribution from sodium hypochlorite, kg/d	55	67	79	91	103
Estimated wastewater concentration					
Chloride					
mg/L (6 lb/ft^3)	564	492	448	419	399
mg/L (4 lb/ft^3)	462	415	387	369	355
Sodium					
mg/L (6 lb/ft^3)	347	299	271	252	238
mg/L (4 lb/ft^3)	284	252	233	220	211
If KCl is used for 8+9 instead of NaCl					
Chloride					
mg/L (6 lb/ft^3)	502	445	411	388	372
mg/L (4 lb/ft^3)	426	388	366	351	340
Sodium					
mg/L (6 lb/ft^3)	241	220	207	199	193
mg/L (4 lb/ft^3)	214	200	191	185	181
Potassium					
mg/L (6 lb/ft^3)	360	283	236	205	183
mg/L (4 lb/ft^3)	257	205	174	153	139

Table 41. Anion Exchange Design Summary (continued)

Aloha Utilities
Anion Exchange Design Summary
MMADF-2

Plant name	Well 9	Well 8	Well 6	Mitchell	Well 2
Volume processed before regen, vessel	254,469	381,704	636,173	502,655	703,717
Regeneration frequency per vessel, days	0.0	0.0	4.8	3.9	4.3
Design flowrate, MMADF-2, gpd	0	0	400,000	390,000	490,000
Max hours of operation per day	0.0	0.0	13.3	13.0	16.3
gallons per vessel per day	0	0	133,600	130,260	163,660

WWTP flowrate, MGD	1.5	2	2.5	3	3.5
Chloride					
contribution from wastewater, kg/d assume 275 mg/L	1561	2082	2602	3123	3643
Sodium					
contribution from wastewater, kg/d assume 150 mg/L	852	1136	1419	1703	1987
contribution from sodium hypochlorite, kg/d	55	67	79	91	103
Chloride					
mg/L (6 lb/ft^3)	408	375	355	341	332
mg/L (4 lb/ft^3)	361	340	327	318	312
Sodium					
mg/L (6 lb/ft^3)	246	223	210	201	195
mg/L (4 lb/ft^3)	217	202	193	187	182

Table 41. Anion Exchange Design Summary (continued)

Aloha Utilities
Anion Exchange Design Summary
MDDF-1

Plant name	Well 9	Well 8	Well 6	Mitchell	Well 2
Volume processed before regen, vessel	254,469	381,704	636,173	502,655	703,717
Regeneration frequency per vessel, days	1.8	2.3	4.0	2.6	3.9
Design flowrate, MDDF1, gpd	421,579	497,368	480,000	577,896	547,895
Max hours of operation per day	14.1	16.6	16.0	19.3	18.3
gallons per vessel per day	140,807	166,121	160,320	193,017	182,997

WWTP flowrate, MGD	1.5	2	2.5	3	3.5
Chloride					
contribution from wastewater, kg/d assume 275 mg/L	1561	2082	2602	3123	3643
Sodium					
contribution from wastewater, kg/d assume 150 mg/L	852	1136	1419	1703	1987
contribution from sodium hypochlorite, kg/d	55	67	79	91	103
Estimated wastewater concentration					
Chloride	664	566	508	469	442
mg/L (6 lb/ft^3)	527	464	426	401	383
mg/L (4 lb/ft^3)					
Sodium	411	348	309	284	266
mg/L (6 lb/ft^3)	328	285	259	242	230
mg/L (4 lb/ft^3)					
If KCl is used for 8+9 instead of NaCl					
Chloride					
mg/L (6 lb/ft^3)	580	504	458	427	406
mg/L (4 lb/ft^3)	478	427	397	377	362
Sodium					
mg/L (6 lb/ft^3)	269	241	224	213	205
mg/L (4 lb/ft^3)	233	214	202	195	189
Potassium					
mg/L (6 lb/ft^3)	467	363	300	259	229
mg/L (4 lb/ft^3)	328	259	217	189	169

Table 41. Anion Exchange Design Summary (continued)

Aloha Utilities
Anion Exchange Design Summary
MDDF-2

Plant name	**Well 9**	**Well 8**	**Well 6**	**Mitchell**	**Well 2**
Volume processed before regen, vessel	254,469	381,704	636,173	502,655	703,717
Regeneration frequency per vessel, days	0.0	0.0	3.3	2.6	3.6
Design flowrate, MDDF2, gpd (wells 8 and 9 off)	0	0	580,000	580,000	580,000
Max hours of operation per day	0.0	0.0	19.3	19.3	19.3
gallons per vessel per day	0	0	193,720	193,720	193,720

WWTP flowrate, MGD	**1.5**	**2**	**2.5**	**3**	**3.5**
Estimated wastewater concentration					
Chloride					
contribution from wastewater, kg/d assume 275 mg/L	1561	2082	2602	3123	3643
Sodium					
contribution from wastewater, kg/d assume 150 mg/L	852	1136	1419	1703	1987
contribution from sodium hypochlorite, kg/d	55	67	79	91	103
Estimated wastewater concentration					
Chloride					
mg/L (6 lb/ft^3)	459	413	385	367	354
mg/L (4 lb/ft^3)	394	364	346	334	326
Sodium					
mg/L (6 lb/ft^3)	279	248	230	217	209
mg/L (4 lb/ft^3)	239	218	206	198	192

Table 43. Projected SAR and concentrations of sodium and chloride in reclaimed water receiving wastewater from regeneration of anion exchange treatment units under different pumping scenarios at a salt application rate of 6 lb/ft^3 and a reclaimed water flow of 1.5 MGD[1].

Design Condition[2]	AADF			MMADF-1			MDDF-1		
Flowrate, MGD	2.04			2.9			3.9		
Plants in operation	9	8 and 9	2,6, Mitchell, 8, 9	9	8 and 9	2,6, Mitchell, 8, 9	9	8 and 9	2,6, Mitchell, 8, 9
Chloride, mg/L	343	393	479	366	438	564	398	495	664
Sodium, mg/L	204	236	292	219	265	347	239	302	411
SAR[3] estimate	5.5	6.4	7.9	5.9	7.2	9.4	6.4	8.1	11.1

[1]Reclaimed water flow is assumed to be 1.5 MGD [2]See Table 4 for definition of flow scenarios; [3]SAR: Sodium Adsorption Ratio.

Table 44. Projected SAR and concentrations of sodium and chloride in reclaimed water receiving wastewater from regeneration of anion exchange treatment units under different pumping scenarios at a salt application rate of 4 lb/ft^3 and a reclaimed water flow of 1.5 MGD[1].

Design Condition and Flowrate	Plants in operation	Chloride, mg/L	Sodium, mg/L	SAR[3] estimate
AADF, 2.04 MGD				
	9	319	189	5.1
	8 and 9	351	211	5.7
	2,6, Mitchell, 8, 9	407	248	6.7
MMADF-1, 2.9 MGD				
	9	334	199	5.3
	8 and 9	381	230	6.2
	2,6, Mitchell, 8, 9	462	284	6.5
MDDF-1, 3.9 MGD				
	9	355	213	5.7
	8 and 9	417	255	6.9
	2,6, Mitchell, 8, 9	527	328	8.8

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Date: October 14, 2007

Memo to: David W. Porter, P.E.

Re: Aloha Utilities Anion Exchange Project - Evaluation of the Effects on Plants, Soils, and Groundwater Quality from Adding Anion Exchange Wastewater to Reuse Water

Purpose. The purpose of this memo is to provide supplemental information for a permit application to modify the Seven Springs Wastewater Treatment Plant (WWTP). The modification is for the purpose of introducing anion exchange wastewater into the WWTP and ultimately into reclaimed water that is distributed and used for irrigation purposes.

This memo addresses hydrological issues raised in FDEP Rule 62-610.865 concerning blending of concentrate and treated wastewater. Specifically addressed here are the potential impacts identified in 62-610.865(13)(a)4, 5, and 6. These rule sections deal with, respectively, potential impacts to vegetation, the infiltration and percolation capacities of soils, and compliance with groundwater standards at the edge of the zone of discharge.

Summary. Average concentrations of sodium (Na) and chloride (Cl) in the reclaimed water will rise, after blending with anion exchange wastewater, from 121 to 292 mg/l for Na, and from 189 to 470 mg/l for Cl. Concentrations during times of maximum brine production will be higher still, but, if necessary, may be reduced by maximizing withdrawals from wells that do not produce brine.

During extended dry periods, the blend will stress some vegetation, producing wilting or yield reductions. This impact can be minimized by awareness to the potential problem, emphasizing drip irrigation for sensitive shrubbery, and hand-watering for especially delicate plants.

For the most part, the sandy soils in the blended water application area are unlikely to be affected by irrigation. Selected areas such as depressions or swales where water ponds might experience soil clogging, but this impact can be reduced by awareness of the potential problem, and through the use of soil amendments such as gypsum.

Regarding compliance with Zone of Discharge Standards, one of two compliance wells at Fox Hollow golf course shows increasing trends of Na and Cl concentrations, in response to irrigation with reclaimed water. This trend will continue and probably accelerate when anion exchange wastewater is added to the reuse water. At times, concentrations of Na and Cl in the compliance well may exceed Maximum Contaminant Levels. To provide an early indication of possible water quality problems, additional monitoring should be considered, particularly in the area between the compliance well and where reclaimed water is applied.

Background. Raw water withdrawn from the Floridan aquifer by Aloha Utilities contains hydrogen sulfide concentrations typical of some groundwater in western Pasco County. An anion exchange process will be used to reduce these concentrations in potable water delivered by the utility to its service area customers. The process is similar in concept to that of a water softener, in that resin used to remove ions of concern will require periodic regeneration with ordinary salt (NaCl). The waste product of this process – termed anion exchange wastewater - will be salty water with a modest elevation in sulfates. This anion exchange wastewater will be routed to the Seven Springs WWTP and combined with domestic wastewater to produce what will be referred to here as a blend. After treatment to unrestricted access standards, the blend will be supplied to existing and new service area customers for irrigation use, as is currently being done with unblended reclaimed wastewater.

Users of reclaimed water within the Aloha service area include one golf course (Fox Hollow), a small portion of a second golf course (Heritage Springs), forty-four commercial and mixed-use customers (e.g. several schools, Trinity College, Suncoast YMCA, Wal-Mart, etc.) and about two thousand residential customers. Reclaimed water is supplied to these users at a very nominal rate ($0.31 per thousand gallons).

Reclaimed water loading rate. The loading or application rate of the reclaimed water blend is an important element in an evaluation of potential impacts to vegetation, soils, and groundwater quality. For a given concentration of brackish-water components (as is the case here), greater loading will have greater impact potential. A quite small application of slightly saline water, for example, will go unnoticed by plants, soils, and groundwater. A very large application with the same or even lower salinity, if that salinity exceeds the tolerance threshold of a particular plant, will have a deleterious effect. Current volumes of reclaimed water are in the range of 1.5 to 1.9 million gallons per day. The total volume of wastewater from the anion exchange process will add less than 20,000 gallons per day, or not much more than about a 1% volume increase. A very rough estimate of the average reclaimed water loading rate, with a supply of 1.7 MGD and a usage (Gomberg, 1998) based on 100 acres of irrigated turf at Fox Hollow, 230 acres of irrigated residential turf and landscaping (2000 DU's, 10,000 ft^2/DU, 50% coverage), and 84 acres of commercial and mixed-use irrigated turf and landscaping (est. avg. of 20% landscaping coverage for the mix of schools, shopping centers, hospitals, etc. currently receiving reclaimed water) is 1.06 inches/week.

This is a moderate and sustainable average rate that may decrease as additional commercial/mixed-use and up to 3000 additional DU's in the service area are developed. The actual and instantaneous loading rate for residential (and possibly commercial/mixed use) customers may be very different from the average rate. For example, users with a highly developed conservation ethic may landscape with xeriscape principles, and irrigate only as absolutely necessary. Other users may (and do) irrigate with less regard for conservation. In the case of irrigation with water of marginal quality, it may be that conservative users escape with no significant impacts while the vegetation of profligate users suffers.

Blend water quality. The quality of the reclaimed water blend is, along with the loading rate, the second of the two most important elements in a consideration of potential impacts to plants, soil, and groundwater. Information concerning the volume and quality of the brine has been furnished in a report prepared by Dr. Audrey Levine (A.D. Levine, et al., 2007). Based on her pilot plant studies, Dr. Levine has also been able to evaluate regeneration rates for the anion exchange facilities, and, from that, to calculate the additional loading of Chloride (Cl), Sodium (Na) and Sulfate (SO_4) that will be added to the reclaimed wastewater. That information is summarized in Table 1, for different water supply withdrawal scenarios (as described below). I have added to the data from the Levine report a calculation of Total Dissolved Solids. This is given in the last column of the table, by adding total combined milligrams/liter of Cl, Na, and SO_4 in the brine to the 5-yr. average TDS concentration of reclaimed water. Also included in Table 1, for comparison, are water quality data for other reuse systems in the Tampa Bay area. Those data were obtained from a recent search of FDEP files.

The first row of Table 1 shows the 5-year average concentrations for Cl, Na, SO_4 and TDS of unblended reclaimed water, based on the quarterly analyses that have been done in connection with regulatory monitoring. Row 2 gives the predicted average quality of the blend, from the Levine report.

Rows 3 and 4 show predicted blend quality during the month of maximum water demand (probably May or June), under two different well withdrawal scenarios. These scenarios derive from the fact that water from two of the eight public supply wells utilized by Aloha have low sulfide concentrations and thus will not require the anion exchange process. These two wells (#'s 1 & 7) will therefore not be associated with the production of the high Cl and Na brine. Under one scenario, these wells contribute water during the maximum demand month in the same proportion as they do during normal pumping. The quality of the blend under this scenario is presented in Row 3 of the Table, where it is termed MMADF-1 (MMADF=Maximum Month Average Daily Flow). Under the second scenario, pumpage from wells 1 & 7 is temporarily maximized (within the limits of the SWFMWD Water Use Permit) while wells 8 & 9, which have the highest sulfide concentrations and thus produce the most brine from the anion exchange process, are turned off. Predicted results are given in Row 4, where this scenario is termed MMADF-2.

The effect on the quality of the reclaimed water under these two scenarios is substantial. For example, by adopting scenario MMADF-2, chloride and sodium concentrations can be decreased by 28-29 %, from 564 to 408 mg/l for chloride, and from 347 to 246 mg/l for sodium. The decrease in TDS is somewhat less, because constituents other than Cl and Na are part of TDS, and these are not increased or decreased by the addition of brine. Scenario MMADF-2, while attractive from a water quality standpoint, apparently presents severe logistic and operational problems.

Rows 5 & 6 of Table 1 present the same two well withdrawal scenarios for conditions of maximum day pumpage (also likely to occur in May or June and predicted, under drought conditions, to last for several consecutive days). Row 5 shows blend quality under maximum day pumpage, with all wells pumping their long-term proportions. This is termed MDDF-1 (MDDF=Maximum Day Daily Flow). Row 6 shows predicted maximum day concentrations of Na and Cl with wells 8 & 9 turned off. As with the maximum month data, the decrease is substantial in Cl and Na concentrations, when withdrawals from wells 8 & 9 are curtailed. Chloride and sodium decrease by about 30%, and TDS decreases by about 26%.

Table 1. Predicted Reclaimed Water Blend Quality and Comparisons with Other Area Reclaimed Water Systems
(all values in mg/l)

		[Cl]	[Na]	[SO_4]	[TDS]
1	5-year avg. for unblended reclaimed water (with min & max values over 5 years)	189 (166-274)	121 (93-152)	29 (24-32)	603 (480-790)
2	blend quality during yearly average day pumpage (AADF)	479	292	46	966
3	blend quality during maximum month pumpage with no change in well withdrawal protocol (MMADF-1)	564	347	50	1110
4	blend quality during maximum month pumpage with wells 8 & 9 turned off (MMADF-2)	408	246	48	851
5	blend quality during maximum day pumpage with no change in well withdrawal protocol (MDDF-1)	664	411	56	1280
6	blend quality during maximum day pumpage with wells 8 & 9 turned off (MDDF-2)	459	279	53	940
7	Hillsborough Co. - Falkenburg Dec., 2005	133	110	155	667
8	City of Tampa Dec., 2006	260	240	190	900
9	Pinellas Co. So Cross Bayou 4th Qtr., 2006	332	220	160	1180±
10	Clearwater East August, 2006	190	130	69	550
11	Clearwater NE August, 2006	200	140	70	600
12	Clearwater Marshall St. August, 2006	330	190	97	860

The two scenarios discussed above and reflected in Table 1 are important because they show that, under adverse climatic conditions likely to produce impacts to plants, soils, or groundwater, Aloha may be able to ameliorate the quality of the blend and lessening the potential impacts relating to its irrigation use. Several other factors may also decrease potential impacts:

- The blend quality for all 3 conditions (avg day, max. month, max. day) is based on a salt requirement of 6 lbs. per regeneration of the anion exchange resin, in accordance with the equipment supplier's specifications for the system. Experimental work by Dr. Levine (as described in her referenced report) suggests that the actual salt requirement per regeneration may be somewhat less, and as low as 4 lbs. This would considerably reduce the salt concentration or volume of the brine, with a corresponding decrease of Na, Cl, and TDS in the reclaimed water blend.

- The maximum month and maximum day requirements for the Aloha wells should only be in place for about 1 to 1 ½ years. Pasco County will be supplementing Aloha's average-day withdrawals for 2008 and 2009. Starting in 2010, the County will also be supplying water to help meet maximum month and maximum day requirements. As a result, the wells will not have to be pumped as hard to meet those conditions, less regenerations will be required, and less salt will be delivered to be mixed with treated wastewater. However, impacts will not be eliminated.

- The maximum month and maximum day water supply requirements are based to a significant extent on climate, and rainfall in particular. While many water users in the Aloha service area irrigate with reclaimed water, others use potable water. Maximum month and maximum day demand will therefore be reduced if May and June are not extremely dry. A reduction in demand will cause a corresponding reduction in the addition of salt to the reclaimed water system, and better quality in the blend.

Potential impact on plants from using blended water for irrigation. Table 2 is a selected list of representative plants grouped by their tolerance to elevated TDS in irrigation water. It is a synthesis of a number of lists available in several of the cited references. The table is generalized in several respects. For ornamentals, for example, tolerance is commonly defined in terms of leaf wilt, which impacts foliage and can occur when saline irrigation water is applied via sprinkler. For some plants, switching to drip irrigation may reduce or eliminate this impact. Damage or impact to edible crops such as may be grown in residential gardens (e.g. tomatoes, cucumbers) is commonly defined in terms of yield reduction, rather than wilting or death. Stress to grasses, shrubs, and trees is often stated in terms of wilting or death.

Table 2 and similar tables available in the literature seldom specify soil conditions as a complicating factor. Plants grown in sandy soils are about twice as tolerant to saline water as plants grown in loamy soils, and nearly three times as tolerant as those grown in clayey soils. Table 2, compiled mostly from information concerning central and south Florida plants, is probably most applicable to loamy or sandy soils, with lower tolerances in clayey soils uncommonly found in coastal Florida. Rainfall is also not factored into available information, which often makes the tacit assumption that plants are grown almost entirely with irrigation water. For the Spring dry season in central Florida, this may not be far from accurate, though periodic frontal rains can diminish the impact of lower quality irrigation water.

A comparison of Tables 1 and 2 indicates that plants with a low salinity tolerance are at risk for adverse impact from the reclaimed water blend. With the less-restrictive groundwater withdrawal scenarios, the predicted TDS of the blend is 966 mg/l (avg. day), 1110 mg/l (max. month), and 1280 mg/l (max. day). These concentrations are not high enough to harm most landscaping plants, typical grasses planted in Pasco County, or most trees. As seen in Table 2, a few selected trees (e.g. avocado), a few ground cover plants (e.g caladium), and a few fruits and vegetables (e.g. lettuce, strawberries) are susceptible to wilting or stress from water with these TDS concentrations. Orchids, which can respond negatively to water with as low a TDS as

500 mg/l, are the most sensitive. Most orchids, however, are hand-watered, and not commonly with reclaimed water.

Table 2. Tolerances of Selected Florida Plants to Elevated TDS Concentrations

Tolerance Level	Trees & Palms	Common Landscaping Plants	Grasses and Ground Covers	Other
HIGH can tolerate TDS up to and greater than 3500	cabbage palm saw palmetto live oak sea grape was myrtle black olive carrotwood coconut palm	hibiscus lantana oleander plumbago vibirnum ixora pampas grass pittosporum	St. Augustine grass Paspalum gtass Bermuda grass Boston fern coontie creeping juniper dwarf pittosporum purslane	bougainvillea cape honeysuckle Confederate jasmine railroad vine geranium snapdragon kale spinach
MEDIUM can tolerate TDS up to about 2500	areca palm queen palm bottlebrush royal Poinciana ligustrum magnolia red cedar	queen sago copperleaf croton night blooming jasmine Surinam cherry bird of paradise	Bahia grass Zoisia	tomatoes cucumbers broccoli corn squash
LOW can tolerate TDS up to 1500-2000	citrus	roses	Bahia grass centipede grass	celery radishes
VERY LOW cannot tolerate TDS greater than 500-1000	avocado laurel oak jacaranda	azaleas	caladium verbena	lettuce beans carrots strawberries orchids

Independent of impacts related to elevated TDS, high concentrations of Sodium and Chloride can be specifically toxic to a select group of plants. These plants are mostly woody perennial shrubs and fruit trees. The toxicity is usually first expressed in mature plants as leaf burn and - for fruit trees - by leaf wilt and a reduction in yield. Sprinkler irrigation (as practiced almost universally in W. Pasco) decreases the toxicity threshold by encouraging direct salt uptake through leaves, compared with surface (i.e. drip or ditch) irrigation. Symptoms of toxicity are more likely to be observed during hot and dry weather conditions.

The City of St. Petersburg investigated the potential impact of elevated chlorides in reclaimed water on common landscaping plants in the Tampa Bay area. To protect sensitive landscaping from adverse effects, they recommended that chlorides in reclaimed water not exceed 400 mg/l. Table 1 shows that the average chloride concentration of the proposed reclaimed water blend will be 479 mg/l, with concentrations under the least restrictive pumping scenarios rising to 564 mg/l during the month of greatest water production, and up to 664 mg/l for maximum day production. Prolonged exposure to these salt concentrations, particularly the 564 mg/l maximum month concentration, coupled with application via overhead sprinkler, can be expected to produce stress to many woody ornamental landscaping plants and fruit trees. The impact may be short-lived if it occurs just prior to the summer rainy season, but will likely be more pronounced if it occurs during an extended drought in late Fall or Winter.

In some instances, the potential for damage to the plants most susceptible to impact from the reclaimed water blend can be reduced by switching from spray to drip irrigation. In other cases, selected plants might be protected from harm by temporary hand-watering with potable water. Plants can also be selected for their salinity tolerance. All of these steps may reduce impacts, but they all depend on knowledge by the users of the nature of reclaimed water and its potential toxicity to some vegetation. It might be helpful, therefore, to engage in an information program designed to increase community awareness.

Potential effect of blended water irrigation on soils. Irrigation water containing an elevated concentration of Sodium (Na) may have a deleterious effect on soil texture and structure. This is commonly manifested by disaggregation of fine-sized particles, soil clogging and loss of permeability, plus compactness and crusting when dry. Tilth, or the general suitability of the soil to support plant growth, is reduced.

Several factors dictate the likelihood of this impact. One is the length of time over which the high-Sodium water is applied. Soil clogging occurs after prolonged use, not after an application or two of poor quality water. Effects are more common in arid and semi-arid climates, where potential evapotranspiration exceeds rainfall, and salt build-up in the soil is more pronounced. The impact results directly from replacement in clay minerals of Calcium (Ca) and Magnesium (Mg) by Sodium. This causes swelling, which in turn leads to clogging. The availability of Ca and Mg in the irrigation water (and in the native soil) is thus another factor of relevance. Impacts are also less likely in soils with small amounts of clay. The process of loss of soil structure is reversible by the addition of soil amendments rich in Ca and Mg, such as gypsum.

An indication of the sandiness of soils in the Aloha service area and thus their likely resistance to soil clogging is summarized by Figure 1. This is from the Pasco County Soil Survey, and shows groupings of soil series in southwest Pasco County. The Aloha service area is outlined. Ninety to ninety-five percent of the service area consists of soil grouping #8 (light yellow), with the remainder in soil grouping #1 (green).

Group #8 are soils of flatwoods and depressions of the Smyrna-Sellars-Myakka series. These are described in the Soil Survey as follows:

Nearly level, poorly drained and very poorly drained soils that are sandy throughout; some have a dark-colored subsoil within a depth of 30 inches, and some have a thick dark-colored surface layer.

Group #1 are soils of the upland ridges of the Tavares-Adamsville-Narcoossee series. The Soil Survey describes the associated soils as:

Nearly level to gently sloping,, moderately well-drained and somewhat poorly drained soils that are sandy throughout; some have a dark-colored layer within a depth of 25 inches.

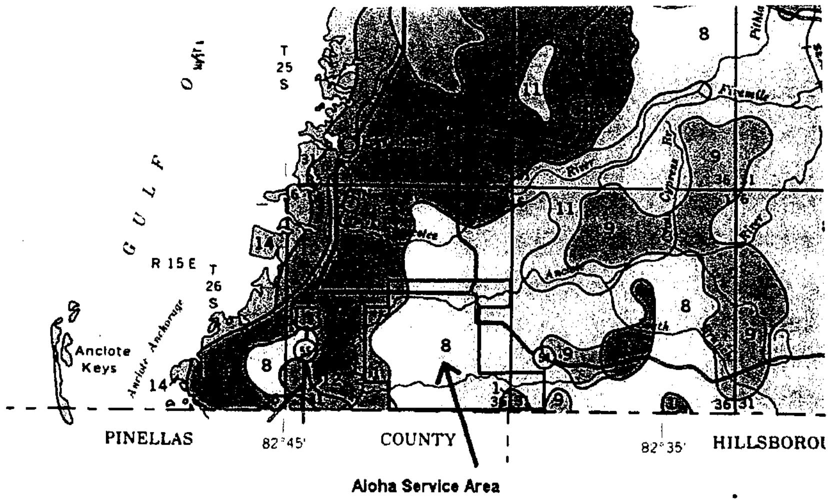


Figure 1. Soil Groupings in the Aloha Service Area

Further information regarding the low percentage of clay in the soils associated with these series is given in Table two, data from which also comes from the Pasco Co. soil survey. To a depth of at least 80 inches, all of the soils except one have a clay percentage in each of their horizons of no greater than 8%. Only Sellers mucky loamy fine sand has significant clay, at 12%. This soil is a depressional or wetland soil, flooded in the rainy season, and is an unlikely candidate for irrigation with reclaimed water.

Table 3. Clay Percentages of Soils in the Aloha Service Area (values are for the upper 80" of soil profile)

Soil	Max. clay %
Adamsville fine sand	8
Immokalee fine sand	7
Myakka fine sand	8
Narcoossee fine sand	6
Basinger fine sand	6
Pomona fine sand	5
Smyrna fine sand	4
Sellers mucky loamy fine sand	12

A somewhat more rigorous approach to evaluating the potential of irrigation water to impact soil structure is the Sodium Absorption Ratio (SAR):

$$SAR = \frac{[Na^+]}{\sqrt{1/2([Ca^{2+}]+[Mg^{2+}])}}$$

where Na, Ca, and Mg are , respectively, the concentration in milliequivalents/liter of Sodium, Calcium, and Magnesium in the irrigation water or in the water table. In general, higher values for SAR are more likely to impact soils than smaller SAR values. The impact occurs when sodium ions replace calcium and magnesium in clay minerals, causing swelling and loss of soil structure. In soils where clay minerals are absent or found in small amounts, this phenomenon may not occur or may be unremarkable.

Guidelines are available to indicate whether irrigation water having a particular SAR is suitable for use. These guidelines must be evaluated on a site or area-wide basis, such that SAR values in one location or for one soil type may cause impact, while the same values elsewhere will not. In addition to the amount and type of clay minerals present in the soil, other factors of particular importance are climate (especially rainfall), total salinity of the irrigation water, and water table drainage. Acceptable SAR values in the literature range from less than 3 to 40, depending on particular circumstances. In the sandy soils of west Pasco County, where rainfall averages about 50"/yr., acceptable SAR values may be on the order of 15 or greater, as suggested by the provision in FDEP Rule 62-610.865 (Blending of Demineralization Concentrate with Reclaimed Water) which uses this value as a threshold above which greater scrutiny and evaluation of potential soil impacts are required.

Table 3 gives SAR values for the various well withdrawal scenarios described above, using the predicted Na concentrations in the reclaimed water blend, and Ca and Mg values averaged over the last 4 quarterly analyses of the unblended reuse water. The table shows that SAR values do not approach 15 under any pumping scenario, ranging from 3.3 for the unblended reclaimed water to 11.1 for the scenario of maximum day withdrawals with utilization of all wells simultaneously.

Table 4. Predicted Sodium Absorption Ratios (SAR) of the Blended Reclaimed Water

SAR of unblended reclaimed water	3.3
blend SAR during yearly average day pumpage (AADF)	7.9
blend SAR during maximum month pumpage with no change in well withdrawal protocol (MMADF-1)	9.4
blend SAR during maximum month pumpage with wells 8 & 9 turned off (MMADF-2)	6.6
blend SAR during maximum day pumpage with no change in well withdrawal protocol (MDDF-1)	11.1
blend SAR during maximum day pumpage with wells 8 & 9 turned off (MDDF-2)	7.5

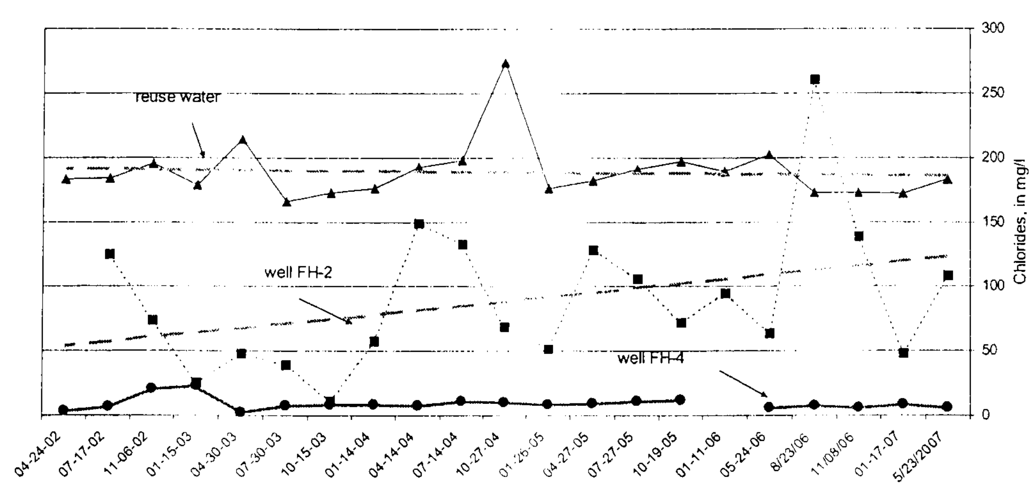
It should be noted that the SAR values in Table 3 are lower than the *effective* or *adjusted* SAR. This is because the reclaimed water (and the blend containing anion exchange wastewater) contains a significant amount of bicarbonate (HCO_3^-), which influences the available calcium concentration in the irrigation water. Removing calcium from availability by associating it with bicarbonate effectively lowers the denominator in the SAR equation, thereby increasing SAR. The magnitude of this effect is difficult to predict until the blend is actually in use for irrigation, because it depends on available calcium and other parameters in the water table.

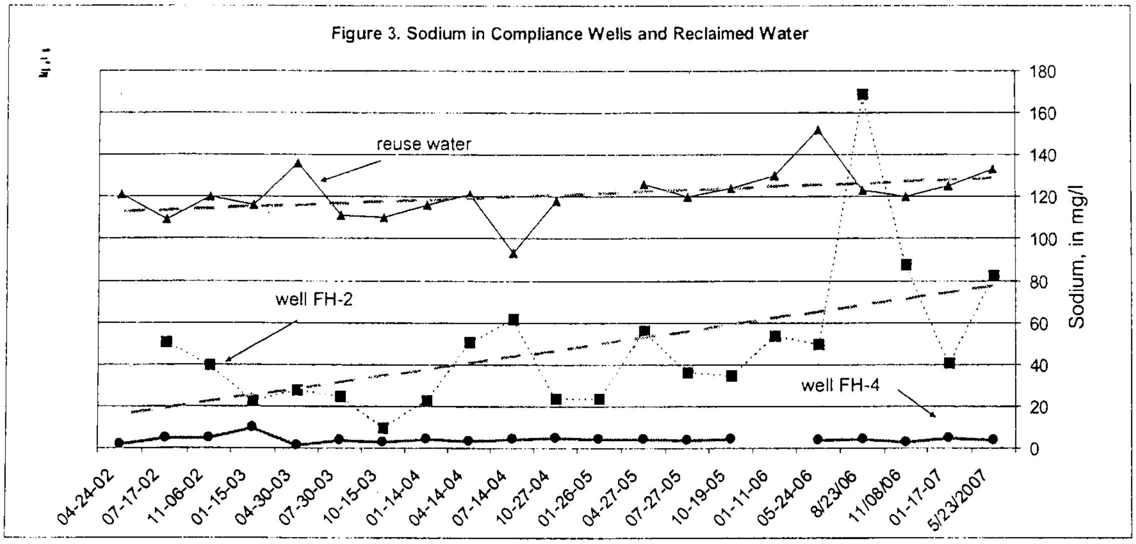
The moderate SAR values suggest that negative impacts to soils and permeability are unlikely to occur under normal climatic conditions and in the mostly well-drained, slightly elevated terrain common to residential and commercial lawns and landscaping. Grassy swales and small depressions where water may pond, particularly as might be associated with golf course fairways, may be susceptible to soil clogging impacts. It may be prudent to measure *in situ* SAR once irrigation with blended reclaimed water begins, to observe closely those depressional settings most susceptible to impacts, and, if need be, to consider soil amendments and implementing one of the withdrawal scenarios that can reduce the SAR.

Potential effect of irrigation with blended water on Zone of Discharge compliance. Existing monitoring data are perhaps the best predictor of ground water quality changes that may result from irrigation with the reclaimed water blend. Five years worth of quarterly monitoring data for compliance wells at Fox Hollow golf course and for reclaimed water can be used to track and assess changes in water quality. The data suggest that continuing increases in Cl and Na may be expected, and that, even with natural dilution from rainfall and native ground water, concentrations may periodically rise to levels greater than regulatory standards.

Figures 2 and 3 show, respectively, Cl and Na concentrations in Fox Hollow compliance wells FH-2 and FH-4, and in reclaimed water used there and elsewhere. Linear trendlines are also shown, for FH-2 and for the reclaimed water. The two graphs are very similar, and illustrate, for well FH-2, a trend of increasing concentrations that have about doubled over 5 years, from their early 2002 values. Currently, levels of Na and Cl in well FH-2 are about one-half the Maximum Contaminant Level (MCL), with Na at 83 mg/l in the most recent sample (vs. an MCL of 160 mg/l), and Cl at 109 mg/l (vs. a 250 mg/l MCL). Concentrations in Fox Hollow Compliance well FH-4 have not increased over the 5-year period, and remain, for both Na and Cl, at less than 10 mg/l.

Figure 2. Chlorides in Compliance Wells and Reclaimed Water





Because it is uncertain to what extent or at what rate Na and Cl may increase in compliance wells, additional monitoring should be considered. This might take the form of additional compliance wells at Fox Hollow or elsewhere, or perhaps more instructive, a monitoring well between the reclaimed water application area and well FH-2. For any new compliance well, an additional well half-way between it and the edge of the application area should also be considered.

Acknowledgments. I was fortunate to consult with two recognized experts in the Soil and Water Science Department of the University of Florida. Dr. Jerry Sartain, Professor of Soil Fertility and Turfgrass Nutrition, helped me understand how and why plants respond to stresses resulting from poor water quality, conditions that may enhance or reduce stress, and management strategies to control vegetative impacts. Dr. Willie Harris, Professor of Soil Mineralogy, helped me better understand soil responses to saline water and environmental factors that modify soil response. While they were extremely helpful to me, neither of these experts read this technical memo or shares any responsibility for my evaluation or conclusions.

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Evaluation of wastewater generated from packed-bed anion exchange treatment of groundwater sources in the Seven Springs Service Area

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September 2007

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Evaluation of wastewater generated from packed-bed anion exchange treatment of ground water sources in the Seven Springs Service Area

Packed-bed anion exchange is a water treatment technology that can be used for removal of negatively charged (anionic) dissolved and colloidal constituents from drinking water sources. Anions that can be removed through anion exchange include hydrogen sulfide (HS^- or S^{-2}), organic carbon, nitrate (NO_3^-), Nitrite (NO_2^-), sulfate (SO_4^{-2}), carbonates (HCO_3^- and CO_3^{-2}), bromate (BrO_3^-), and phosphates ($H_2PO_4^-$, HPO_4^{-2}, and PO_4^{-3}). Many types of microorganisms (viruses, bacteria, protozoa) also are amenable to removal through ion exchange due to surface characteristics which tend to be negatively charged in drinking water sources, depending on the pH and other water quality parameters. Through anion exchange, exchangeable anionic constituents in water react with anions that are associated with a porous matrix or resin. Typically, the types of anion exchange resins used for water treatment release chloride (Cl^-) and/or hydroxide (OH^-) anions in exchange for negatively charged dissolved and/or colloidal constituents present in the water source.

The efficiency of anion exchange treatment of water depends on the resin characteristics (composition, particle size, selectivity, capacity) and water quality parameters (exchangeable anions, pH, temperature, oxidation potential, etc.). As anions from water are exchanged with resin anions, the anionic composition of the resin matrix changes as it equilibrates with the water. Once the resin-water anionic composition reaches equilibrium, there is no further exchange of anions. A regeneration process is used to restore the resin capacity by displacing the anions that were removed from the water with chloride, hydroxide, or other exchangeable anions. For most municipal water treatment anion-exchange applications, the exchangeable anion is chloride and the resin is regenerated using a brine solution containing either sodium or potassium chloride. Regeneration is an integral component of anion exchange treatment systems. The frequency of regeneration and the characteristics of the waste streams produced from anion exchange regeneration depend on interrelationships between resin characteristics, water quality, and process operation.

Packed-bed anion exchange systems consist of column-reactors that contain a fixed volume of anion-exchange resin. Operationally, packed-bed anion exchange reactors alternate between a service cycle for producing treated water and a regeneration period for restoring the resin capacity. During the service cycle, water flows through the resin and anions from the water are exchanged with anions (e.g. chloride) released from the resin. The resin bed also functions as a coarse granular medium filter and can entrap suspended particles within the media. The affinity of anionic exchange resins for negatively charged constituents may enhance removal of microorganisms due to the characteristically negative surface charge that is prevalent under neutral pH conditions. The length of the service cycle can vary from days to weeks, depending on the treatment objectives, resin characteristics, and water quality (exchangeable anions, pH, suspended solids, microbial concentration, etc.). As the service cycle progresses, exchangeable anions from the water saturate the resin matrix causing a decrease in removal efficiency. To restore treatment effectiveness, packed-bed reactors are taken off-line and regenerated using a salt solution (brine).

Aloha Utilities, Inc. (AUI) is planning to adopt packed-bed anion exchange technology to upgrade five treatment facilities in the Seven Springs service area for removal of hydrogen sulfide, sulfate, and organic carbon from ground water. Three packed-bed column reactors will be operated in parallel at each of the five treatment plants (total of 15 reactors). The regeneration process will be staggered among the three reactors to allow for continuous production of water during regeneration. In each case, an individual reactor to be taken off-line for regeneration and the flow will be temporarily diverted to the other reactors. The waste streams generated from in situ resin regeneration will be discharged to AUI's water reclamation facility. The treatment provided at the water reclamation facility includes equalization, biological treatment, filtration, disinfection, and subsequent reuse.

The characteristics of the anion exchange wastewater depend on the volume of water processed through each anion-exchange reactor, the regeneration frequency, the concentration and type of regenerant used, and operational variables. Pilot testing of the treatment system was conducted during 2005 and 2006 by the University of South Florida (USF) under a research contract with AUI. Pilot-scale anion exchange reactors were provided by Tonka Equipment, MN. The USF research program was developed to evaluate process performance and optimize the regeneration process. The purpose of this report is to present information on the characteristics of the regeneration wastewater produced by the anion-exchange upgrades to AUI's treatment plants under different operating scenarios and evaluate potential impacts of the regenerant waste streams on sodium and chloride levels in the reclaimed water.

OBJECTIVES

The characteristics of wastewater that will be generated through implementation of anion exchange at five ground water treatment facilities in the Seven Springs service area are evaluated in this report. The specific objectives are:

1. Evaluate regeneration efficiency under different salt loading conditions

2. Evaluate wastewater characteristics under different water demand scenarios

3. Evaluate impacts of wastewater generated by anion exchange on sodium and chloride levels in reclaimed water.

BACKGROUND

Aloha Utilities, Inc. is in the process of upgrading its water treatment facilities in the Seven Springs service area to improve water quality and to meet increasing water demands. Five of the seven ground water treatment plants (plants 2, Mitchell, 6, 8, and 9) will be upgraded to provide packed-bed anion exchange reactors for removal of sulfide, sulfate, and organic carbon. The water produced through the anion exchange process will be disinfected using chlorine for primary disinfection and chloramines for secondary disinfection. The water will also be treated with a corrosion inhibitor prior to distribution. Water produced from the other two treatment plants (plants 1 and 7) will be treated by disinfection (chlorine and chloramines) and corrosion control, but will not be treated by anion exchange because of the relatively lower levels of hydrogen sulfide in those water sources.

Capacity requirements

The treatment upgrades need to be capable of delivering water under a range of water usage conditions. Currently, the water use permit (WUP) for the Seven Springs service area allows for an annual average daily flow (AADF) of 2.04 million gallons per day (MGD). Under the high water usage rates that occur seasonally in west-central Florida, the anticipated average daily flow for the maximum (or peak) month (MMADF) is 2.9 MGD. The anticipated maximum day daily flow (MDDF) is 3.9 MGD. A summary of the capacities of each of the individual treatment plants in the Seven Springs service area and the amount of water that will be supplied by each plant under the current and anticipated flow conditions (average, maximum month, and maximum day) is given in Table 1. To meet increasing water demands in the Seven Springs service area, Pasco County has committed to supplying AUI with up to 2.4 MGD of bulk water.

Table 1. Flowrates for each of the seven treatment plants in the Seven Springs Service Area under different water demand scenarios[1].

Plant location	Pumping rate,GPM	AADF, MGD	MMADF-1, MGD	MMADF-2, MGD	MDDF-1, MGD	MDDF-2, MGD	Maximum flow, MGD
Plant 1	1,000	0.449	0.614	1.000	0.826	1.440	1.440
Plant 2	500	0.288	0.407	0.490	0.548	0.580	0.720
Mitchell	500	0.289	0.430	0.390	0.578	0.580	0.720
Plant 6	500	0.239	0.357	0.400	0.480	0.580	0.720
Plant 7	500	0.284	0.409	0.620	0.549	0.720	0.720
Plant 8	500	0.259	0.370	off	0.497	off	0.720
Plant 9	500	0.232	0.313	off	0.422	off	0.720
Total	4,000	2.040	2.900	2.900	3.900	3.900	5.760

[1] The treatment plants that will be upgraded with anion exchange are shown in the shaded areas.
GPM: gallons per minute; MGD: Million gallons per day; AADF: Average Annual Daily Flow;
MMADF: Maximum month average daily flow; MDDF: Maximum Day Daily Flow using different pumping scenarios

Source Water Quality

To develop design information for packed-bed anion exchange, extensive testing of ground water from the Seven Springs service area was conducted from 2004-2006. A summary of average water quality for plants 2, Mitchell, 6, 8, and 9 is given in Table 2. The most important parameters from the perspective of anion exchange are the anionic composition, turbidity, and pH. The anionic species that are removed by anion exchange include sulfide, sulfate, and organic carbon (TOC). As shown in Table 2, the sulfide and sulfate concentrations vary among the source waters, while there is less variability in TOC and turbidity. The use of anion exchange for source waters with higher levels of exchangeable anions requires more treatment capacity (resin volume) and/or more frequent regeneration. The frequency of regeneration influences the quantity of waste generated.

Table 2. Summary of water quality associated with treatment plants 2, 6, Mitchell, 8, and 9 in the Seven Springs service area (data from 2005 and 2006)

Parameter	Plant 2 Average (Range)	Mitchell* and Well 6 Average (Range)	Plant 8 Average (Range)	Plant 9 Average (Range)
Anions				
Sulfur Species				
Sulfide (mg/L as S^{2-})	0.94 (0.56 – 1.23)	1.07 (0.82 – 1.51)	1.64 (1.34 – 2.45)	2.64 (2.03- 3.23)
Sulfate (mg/L as SO_4^{2-})	1.1 (<0.1 – 3.2)	14.7 (0.7 - 79)	7.3 (<0.1 – 18.6)	37.4 (26.0 – 49.7)
Chloride (mg/L as Cl^-)	15 (8 - 22)	25 (10 – 47)	15 (10 - 28)	15 (10-28)
TOC (mg/L)	3.08 (2.79-3.35)	2.37 (1.49-2.61)	2.68 (1.73-3.46)	2.78 (1.5-6.87)
UV-254 Absorbance (cm^{-1})	0.10 (0.04-0.13)	0.12 (0.04-0.12)	0.08 (0.07-0.14)	0.09 (0.03-0.13)
Alkalinity (mg/L as $CaCO_3$)	148 (30 – 250)	180 (120 – 190)	180 (100 - 260)	164 (100 – 250)
Total Exchangeable Anions (meq/L)	3.99	3.88	4.59	5.56
Other Characteristics				
pH	7.44 (6.03 – 7.61)	7.38 (7.2 – 7.63)	7.35 (6.58 – 7.52)	7.39 (6.79 – 7.55)
Temperature (° C)	24.21 (12 – 27.7)	24.9 (23.1 – 26.80)	23.4 (11.1 – 28.30)	23.70 (11.7 – 27.1)
Conductivity (μS/cm)	377 (232 – 454)	384 (285 – 502)	427 (449 – 520)	464 (341 – 570)
Turbidity (NTU)	0.24 (0.07-1.25)	0.53 (0.10-3.12)	0.6 (0.07-4.03)	0.32 (0.07-1.51)
Cl_2 demand (mg/L)	10.8	10.4	14.2	17.1

Ion Exchange Resin

A commercially available macroporous strong base anion exchange resin (Tulsion® A-72 MP (Cl^-)) will be used for treating ground water at plants 2, Mitchell, 6, 8, and 9. A summary of the resin characteristics is given in Table 3. Pilot testing of this resin was conducted at each treatment plant site during 2006 to develop design information and evaluate long-term process performance under different conditions (flowrates, continuous versus intermittent operation, presence/absence of oxygen, temperature, regeneration efficiency, etc.).

Table 3. Tulson® A-72 MP Resin Characteristics

Parameter	Characteristic or Value
Matrix Structure	Cross linked polystyrene
Physical form	Moist spherical beads
Particle size	0.3 to 1.2 mm
Moisture (approx.)	58%
Solubility	Insoluble in all common solvents
Backwash settled density	42 to 45 lbs/ft3 (670 to 720 g/l)
Temperature stability (max)	195°F (90°C)
pH range	0 to 14
Ionic form	Chloride
Functional group	Quaternary ammonium Type I
Total exchange capacity	1.0 meq/Ml
Swelling (approx.)	Cl- to OH- 21%

Adapted from Tulson® A-72 MP Brochure

Design Summary

The design of the packed-bed anion exchange reactors for each facility consists of 3 reactors that will be operated in parallel. The reactor operation will be staggered to allow for regeneration of one reactor while the other two reactors are operational. A summary of the design information for each treatment plant is given in Table 4. The design capacity reflects the volume of water that can be processed per unit volume of resin prior to regeneration. Water quality factors, particularly sulfide and sulfate levels in the source waters (see Table 2) influence the design capacity. As shown in Table 2, the well that serves plant 9 has the highest concentration of sulfide and sulfate, whereas plant 2 has the lowest. These differences in water quality impact the volume of water that can be processed before regeneration is needed. To compensate for differences in water quality, the diameter of the anion-exchange reactor vessels will be larger at plants 6, 8, and 9 than at plants 2 and Mitchell allowing for about 26% more resin. Even with the differences in quantity of resin, the treatment system at plant 2 should be able to process over two and a half times more water than the throughput at plant 9 before the resin becomes saturated and regeneration is needed.

Table 4. Summary of packed-bed anion exchange design information for five treatment plants in the Seven Springs service area.

Parameter	Plant 2	Mitchell	Plant 6	Plant 8	Plant 9
Design capacity, gal/ft^3	3500	2500	2500	1500	1000
Vessel Diameter, ft	8	8	9	9	9
Resin depth, ft	4	4	4	4	4
Resin volume ft^3	201	201	254	254	254
Number of vessels	3	3	3	3	3
Design flowrate per vessel, gpm	167	167	167	167	167
Hydraulic loading					
Volumetric, gpm/ft^3	0.8	0.8	0.7	0.7	0.7
Area, gpm/ft^2	3.3	3.3	2.6	2.6	2.6
Empty Bed Contact Time (EBCT), minutes	9.0	9.0	11.4	11.4	11.4
Volume of water processed before regeneration, gallons per vessel	703,717	502,655	636,173	381,704	254,469

ANION EXCHANGE REGENERATION PROCESS

The goal of resin-regeneration is to remove constituents that accumulate within the resin matrix during the service cycle and replenish the resin with exchangeable anions. The exchangeable anion for the resin that will be used at the Seven Springs treatment facilities is chloride (see Table 3). Regeneration of the resin requires contacting the resin with a solution containing a high enough concentration of chloride to promote diffusion into the resin matrix. The high ionic strength of the brine solution may also provide a mechanism for controlling microbial activity within the resin bed, depending on the salt concentration and exposure time. Sources of chloride that are approved for use in drinking water treatment facilities include sodium chloride ($NaCl$) and potassium chloride (KCl). The regenerant solution is applied as a brine and the waste produced by the process contains the spent regenerant and constituents that have been eluted from the resin matrix.

The regeneration process consists of 4 sequential steps: backwashing to flush the resin and remove particles and deposits that accumulated in the bed during the service cycle, introduction of a regenerant solution (brine) into the column, slow rinse to push the brine through the resin bed, and a fast rinse to remove excess salt from the reactor. The overall process requires a minimum of 80 minutes and can be conducted on a schedule that is coordinated with periods of low water demand. Following the fast-rinse, the reactor is placed back into service. Periodically, a supplemental regeneration step using caustic soda is used to remove accumulated minerals and organics from the resin. The regeneration steps are summarized in Table 5.

Table 5. Sequence of Regeneration Process

Step	Purpose	Water source
Backwash	Reverse flow through the packed-bed reactor to dislodge particulate material that has accumulated during the service cycle and fluidize the resin prior to regeneration	Water from treatment plant (untreated or treated water)
Brine	Apply brine solution to replenish resin matrix with exchangeable anions. The rate of replenishment is related to the relative concentration of chloride in the brine and within the resin matrix (diffusion control). The osmotic pressure of the brine solution may help to inactivate microbial cells.	Water from treatment plant (untreated or treated water) mixed with salt (either sodium chloride or potassium chloride)
Slow rinse	Allow brine solution to react with resin matrix	Water from treatment plant (untreated or treated water)
Fast rinse	Flush brine from the system and prepare for next service cycle	Water from treatment plant (treated water)

Testing program

To optimize the regeneration process, a testing program was conducted at the treatment plant with the highest concentrations of sulfide and sulfate (plant 9). The resin design capacity for plant 9 is 1000 gallons per cubic foot (see Table 4). The goal of the testing program was to determine if the resin could perform at an equivalent capacity under different regeneration conditions. The parameters that were tested are summarized in Table 6. Three pilot packed-bed columns were set up in parallel to allow tests to be conducted in triplicate with the same salt loading rates or for parallel tests to be conducted under different salt loading conditions with a common source water quality. Following each regeneration cycle (backwashing, brine, slow rinsed, fast rinse) the column was put back into service and the volume of water that could be treated prior to breakthrough of hydrogen sulfide was monitored. If the regeneration capacity of 1,000 gallons per cubic foot could be recovered, then the regeneration was considered successful and the parameters were re-tested to verify the results. Conversely, if the regeneration capacity was not recovered then the test conditions were considered to be ineffective.

Table 6. Summary of regeneration parameters tested at plant 9

Regeneration parameters	Range	Rationale
Salt concentration	2 to 15 lb/ft^3	Determine the feasibility of reducing salt usage and preventing high concentrations of salts in reclaimed water
Exposure time	30 minutes to >48 hours	Evaluate if exposure time impacts regeneration efficiency
Monitoring parameters	Conductivity, UV, hydrogen sulfide, chloride, sulfate, pH	Determine if on-line monitoring could be useful for predicting the end of the service cycle

Based on the testing program, it was possible to regenerate the resin at a dosages ranging from 3 to 15 pounds of salt per cubic foot of resin. Regeneration at 2 pounds of salt per cubic foot was not effective. In addition, regeneration times of 30 minutes or less were not effective for the pilot-scale reactors. Due to the design of the pilot units and the manual operation of the regeneration process, it was not possible to optimize the contact times or to evaluate the impacts of mixing or brine recirculation on regeneration efficiency. However, longer contact times and recirculation of the brine solution through the resin bed appeared to enhance the regeneration process, particularly at lower dosages of salt.

To design a robust system and ensure adequate storage capacity for the salt, the design salt loading rate is 6 lbs per cubic foot. Based on the pilot-testing results, resin regeneration using 4 pounds per cubic foot produced the same recovery efficiency (in terms of exchange capacity) as 6 pounds per cubic foot. Because the full-scale units will have more operational features, further refinement and optimization of backwashing, salt dosing approaches, salt loading, contact time, mixing, recirculation and the time and volume requirements for each step of regeneration should be conducted during start-up.

Regeneration parameters

To evaluate the characteristics of wastewater generated by the regeneration process, salt requirements and wastewater properties were calculated based on using either 6 or 4 lbs of salt per cubic foot of resin. The salt quantity needed per regeneration is based on the salt loading and the volume of resin in each packed-bed reactor. The total salt quantity is based on the design capacity. The vessels in plants 2 and Mitchell will be 8 ft in diameter with resin volumes of about 200 ft^3 while the reactors in plants 6, 8, and 9 will be 9 ft in diameter with corresponding volumes of 254 ft^3. The quantity of salt required for regenerating individual treatment units at each treatment facility is given in Table 7. The frequency of regeneration and the total amount of salt needed varies among the treatment plants due to differences in flowrates (Table 1) and water quality (Table 2).

Table 7. Comparison of salt requirements per regeneration for each packed-bed anion exchange reactor under different salt application rates.

Parameter	Plant 2	Mitchell	Plant 6	Plant 8	Plant 9
Design capacity, gal/ft^3	3500	2500	2500	1500	1000
Resin volume ft^3	201	201	254	254	254
Salt requirements per regeneration, lb					
Loading rate					
6 lb salt per ft^3 of resin	1,206	1,206	1,527	1,527	1,527
4 lb salt per ft^3 of resin	804	804	1,018	1,018	1,018

WASTEWATER CHARACTERISTICS

Development of appropriate approaches for managing wastewater generated by resin regeneration is a key component of the design of packed-bed anion exchange systems. Each regeneration step produces a waste stream and the characteristics of the waste streams differ in terms of salt content and other water quality parameters. The actual composition of wastewater from full-scale anion exchange treatment depends on the amount of salt applied and the volume of water used for each phase of the regeneration process. Preliminary data on waste stream characteristics was developed by testing the waste streams produced by the pilot scale ion exchange columns at Plant 9. A comparison of the relative concentrations of sodium, chloride, and sulfate in the pilot-scale regeneration streams is shown in Figure 1 (log-scale). The concentrations of dissolved solids in the brine and the slow-rinse waste streams are about two-orders of magnitude higher than the levels observed in the untreated water, backwash, or fast-rinse cycles. Data on other water quality parameters is provided in the Appendix.

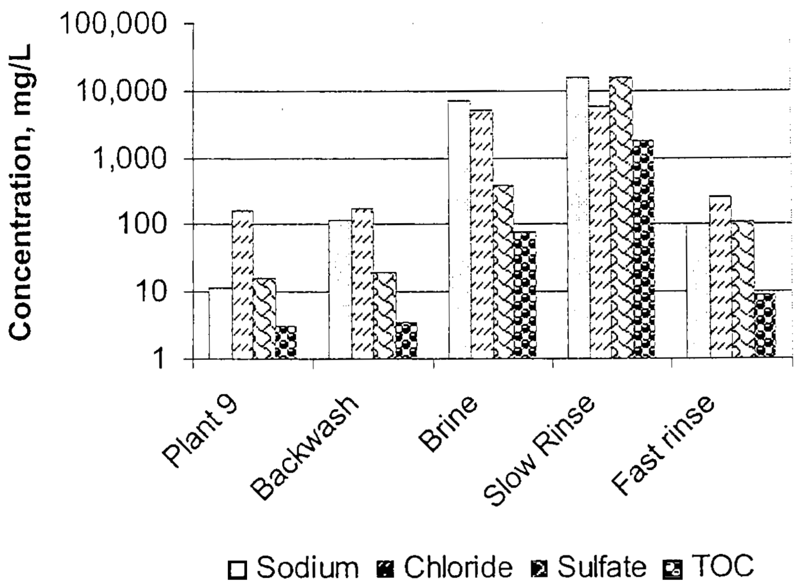

Figure 1. Comparison of the concentrations of sodium, chloride, sulfate, and organic carbon (TOC) in waste streams from pilot-scale anion exchange testing at Plant 9 (note log-scale)

Volume of wastewater

The volume of wastewater generated through each phase of regeneration depends on the flowrate and operating conditions. Typically the backwash is operated at a velocity high enough to fluidize the media, while the brine and rinse stages are operated at lower flow-rates to provide more contact time for the salts to diffuse into the resin matrix. The fast rinse is operated at the design flowrate for the system (167 gallons per minute). A summary of the volume of wastewater generated from each stage of regeneration is shown in Table 8 for each of the treatment plants. The highest volumes are associated with the backwash and fast-rinse cycles. The brine and slow-rinse wastewaters have the highest concentrations of dissolved solids and it is important to control the discharge from these waste streams to avoid introducing a shock load of salt to the sewer or wastewater plant. One option for managing the more saline waste streams is to store the spent regenerant on-site and blend it with the flow in the wastewater collection system. The volume needed to store wastewater from 3 regeneration cycles at each plant is also given in Table 8.

The actual quantity of wastewater generated at each treatment plant depends on the amount of water produced at each treatment facility. A summary of the volume of wastewater projected to be produced at each treatment facility for each of the design flow scenarios (see Table 1) is given in Tables 9- 13 for Plants 2, Mitchell, 6, 8, and 9 respectively.

Table 8. Volume of wastewater generated by each stage of regeneration for packed-bed anion exchange at each treatment plant.

Regeneration stage	Flowrate[1], gpm	Minimum time[1], minutes	Wastewater volume, gallons per regeneration per vessel				
			Plant 2	Mitchell	Plant 6	Plant 8	Plant 9
Backwash	254	10	2,011	2,011	2,545	2,545	2,545
Brine	38	30	900	900	1,140	1,140	1,140
Slow-rinse	38	30	900	900	1,140	1,140	1,140
Fast-rinse	167	10	1,667	1,667	1,667	1,667	1,667
Total		80	5,478	5,478	6,492	6,492	6,492
On-site storage of waste streams from regeneration of 3 packed-bed reactors							
Brine and slow -rinse, gallons per 3 regeneration cycles			5,400	5,400	6,840	6,840	6,840
Backwash and fast-rinse, gallons per 3 regeneration cycles			11,034	11,034	12,636	12,636	12,636
Total waste generation, gallons per 3 regeneration cycles			16,434	16,434	19,476	19,476	19,476

[1]Flowrates and times provided by Tonka

Table 9. Number of hours of plant operation, regeneration frequency and the volume of wastewater generated per day for packed-bed anion exchange treatment at Plant 2.

Plant 2 Operating scenario*	Design flowrate, gallons per day	Hours of pump operation per day	Volume of water produced per anion exchange reactor per day, gallons**	Regeneration frequency per vessel, days	Average volume of wastewater generated per day, gallons
AADF	288,000	9.6	96,192	7.3	2,242
MMADF-1	407,409	13.6	136,075	5.2	3,171
MMADF-2	490,000	16.3	163,660	4.3	3,814
MDDF-1	547,895	18.3	182,997	3.9	4,264
MDDF-2	580,000	19.3	193,720	3.6	4,514

*AADF: Average Annual Daily Flow; MMADF: Maximum month average daily flow; MDDF: Maximum Day Daily Flow using different pumping scenarios
**There are three reactors per site

Table 10. Number of hours of plant operation, regeneration frequency and the volume of wastewater generated per day for packed-bed anion exchange treatment at the Mitchell Plant.

Mitchell Operating scenario*	Design flowrate, gallons per day	Hours per day	Volume of water produced per anion exchange reactor per day, gallons**	Regeneration frequency per vessel, days	Average volume of wastewater generated per day, gallons
AADF	289,000	9.6	96,526	5.2	3,149
MMADF-1	429,717	14.3	143,525	3.5	4,683
MMADF-2	390,000	13.0	130,260	3.9	4,250
MDDF-1	577,896	19.3	193,017	2.6	6,297
MDDF-2	580,000	19.3	193,720	2.6	6,320

*AADF: Average Annual Daily Flow; MMADF: Maximum month average daily flow; MDDF: Maximum Day Daily Flow using different pumping scenarios
**There are three reactors per site

Table 11. Number of hours of plant operation, regeneration frequency and the volume of waste per day is for packed-bed anion exchange treatment at Plant 6.

Plant 6 Operating scenario*	Design flowrate, gallons per day	Hours per day	Volume of water produced per anion exchange reactor per day, gallons**	Regeneration frequency per vessel, days	Average volume of wastewater generated per day, gallons
AADF	239,000	8.0	79,826	8.0	2,439
MMADF-1	356,923	11.9	119,212	5.3	3,642
MMADF-2	400,000	13.3	133,600	4.8	4,082
MDDF-1	480,000	16.0	160,320	4.0	4,898
MDDF-2	580,000	19.3	193,720	3.3	5,918

*AADF: Average Annual Daily Flow; MMADF: Maximum month average daily flow; MDDF: Maximum Day Daily Flow using different pumping scenarios
**There are three reactors per site

Table 12. Number of hours of plant operation, regeneration frequency and the volume of waste per day is for packed-bed anion exchange treatment at Plant 8.

Plant 8 Operating scenario*	Design flowrate, gallons per day	Hours per day	Volume of water produced per anion exchange reactor per day, gallons**	Regeneration frequency per vessel, days	Average volume of wastewater generated per day, gallons
AADF	259,000	8.6	86,506	4.4	4,405
MMADF-1	369,838	12.3	123,526	3.1	6,290
MMADF-2	0	0.0	0	0.0	0
MDDF-1	497,368	16.6	166,121	2.3	8,458
MDDF-2	0	0.0	0	0.0	0

*AADF: Average Annual Daily Flow; MMADF: Maximum month average daily flow; MDDF: Maximum Day Daily Flow using different pumping scenarios

**There are three reactors per site

Table 13. Number of hours of plant operation, regeneration frequency and the volume of waste per day is for packed-bed anion exchange treatment at Plant 9.

Plant 9 Operating scenario*	Design flowrate, gallons per day	Hours per day	Volume of water produced per anion exchange reactor per day, gallons**	Regeneration frequency per vessel, days	Average volume of wastewater generated per day, gallons
AADF	232,000	7.7	77,488	3.3	5,918
MMADF-1	313,482	10.4	104,703	2.4	7,997
MMADF-2	0	0.0	0	0.0	0
MDDF-1	421,579	14.1	140,807	1.8	10,754
MDDF-2	0	0.0	0	0.0	0

*AADF: Average Annual Daily Flow; MMADF: Maximum month average daily flow; MDDF: Maximum Day Daily Flow using different pumping scenarios

**There are three reactors per site

Quantity of salt

The amount of salt needed to supply the regeneration process depends on the salt loading and the frequency of regeneration. For the Seven Springs service area, the salt will be stored at a single location where a concentrated solution of brine will be prepared. The brine will be distributed to the individual plant sites to allow for on-site storage of enough brine to regenerate all three anion exchange reactors. The salt storage area will be designed to accommodate a 7 day supply of salt. A summary of the salt requirements under different salt application rates (4 or 6 lb/ft^3) for different flowrates is given in Table 14. The maximum amount of salt needed is under MMDF, when higher flowrates from individual plants are needed to meet the maximum demand.

Table 14. Total quantity of salt needed for regeneration of anion exchange units at all treatment plants under different flow conditions for a 7 day period.

Flow rate	7 day salt supply for all treatment plants, dry tons	
	6 lb/ft^3	4 lb/ft^3
AADF	15	10
MMADF-1	21	14
MMADF-2	10	6
MDDF-1	28	19
MDDF-2	13	9

The amount of salt needed to regenerate all three anion exchange reactors at each site is summarized in Table 15. The salt will be prepared as a brine and delivered to each site as a 20% solution. The volume of brine needed to regenerate all three reactors at each site is also summarized in Table 15.

Table 15. Amount of salt and brine (20%) needed to regenerate three anion exchange vessels at each site

Plant name	Quantity of salt needed to regenerate 3 anion exchange reactors at each site, lb		Volume of 20% brine needed to regenerate 3 anion exchange reactors at each site, gallons	
	6 lb/ft^3	4 lb/ft^3	6 lb/ft^3	4 lb/ft^3
Plant 2	1,206	804	1,936	1,290
Mitchell	1,206	804	1,936	1,290
Plant 6	1,527	1,018	2,450	1,633
Plant 8	1,527	1,018	2,450	1,633
Plant 9	1,527	1,018	2,450	1,633

EVALUATION OF RECLAIMED WATER

Aloha Utilities, Inc. has an active water reuse program and has provided reclaimed water to its customers for public access reuse since February 2001. The reclaimed water supplies water for residential and commercial irrigation in the Seven Springs service area. The major users include a golf course, schools, and commercial and residential developments. To use reclaimed water for irrigation, it is important to ensure that the quality of the reclaimed water is compatible with the soil and landscape requirements. With the implementation of anion exchange technology at AUI's water treatment facilities, there will be some changes in the reclaimed water quality that will vary seasonally, depending on the water demand and the combination of treatment facilities that are in operation. From a water reuse perspective, the major constituents of concern are chloride and sodium.

Chloride

Sources of chloride in reclaimed water from AUI include baseline levels in the ground water, chlorine that is used for disinfection (water and wastewater), and chloride introduced from municipal and domestic wastewater, including discharges from point-of-use water softeners and other treatment devices. A summary of historical monitoring data on chloride concentrations in AUI's reclaimed water is shown in Figure 2. For the purposes of estimating the potential chloride levels in reclaimed water after implementation of anion exchange in the Seven Springs service area, a baseline level of 275 mg/L was assumed.

Sodium

Sources of sodium in reclaimed water include baseline levels in the groundwater, sodium that is added to water through the use of sodium hypochlorite for disinfection (water and wastewater) and sodium in municipal and domestic wastewater discharges. A summary of monitoring data on sodium concentrations in AUI's reclaimed water is shown in Figure 2. For the purposes of estimating the potential sodium levels in reclaimed water after implementation of anion exchange in the Seven Springs service area, a baseline level of 150 mg/L was assumed.

Total Dissolved Solids

The total dissolved solids (TDS) concentration of reclaimed water provides an indication of water quality and ionic strength. A summary of TDS monitoring data from AUI is shown in Figure 3. About 60 percent of the TDS is contributed by chloride and sodium. When the regeneration waste streams are discharged to the reclaimed water treatment facility, TDS levels are likely to increase to over 800 mg/L and will still be dominated by sodium and chloride (>65%). The concentration of TDS and the extent to which the percentage of the TDS associated with sodium and chloride increases after implementation of anion exchange depends on how the treatment facilities are operated (combination of water sources and treatment plants in operation, pumping strategies, regeneration approaches, etc.).

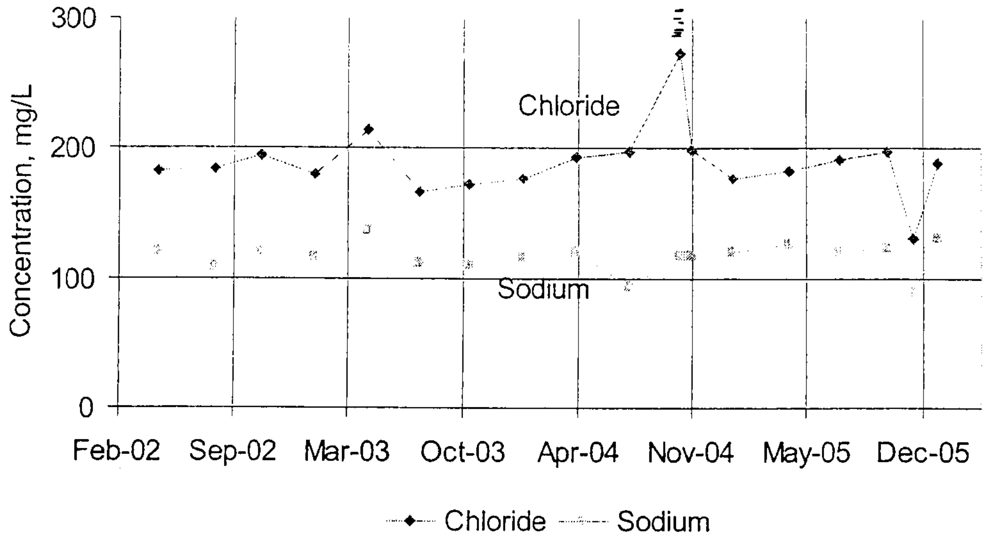

Figure 2. Summary of chloride and sodium concentrations in AUI's reclaimed water from 2002 through 2005 (Data from Short Environmental Laboratories).

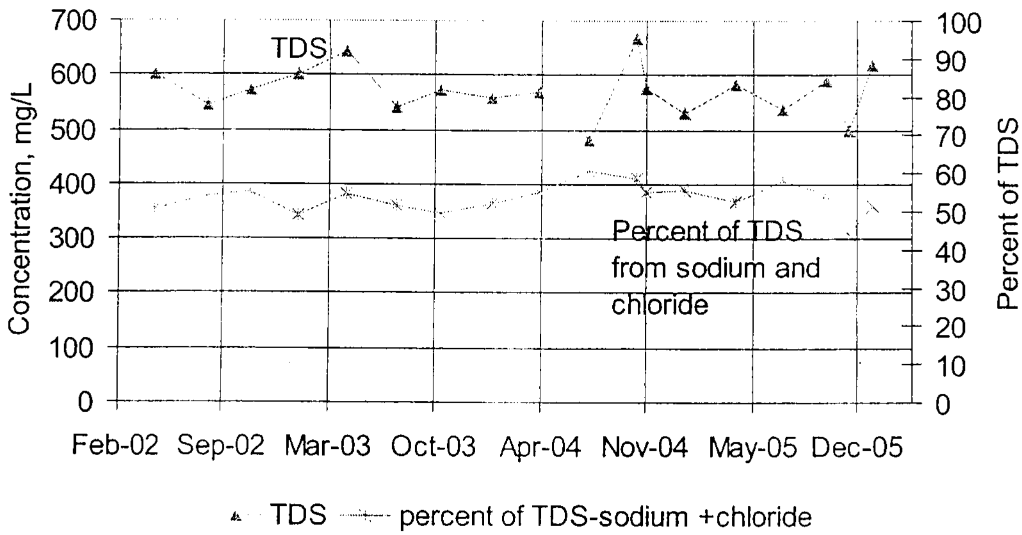

Figure 3. Summary of total dissolved solids concentrations in AUI's reclaimed water from 2002-2005 (Data from Short Environmental Laboratories).

AUI is in the process of upgrading its reclaimed water disinfection system from the use of gaseous chlorine to applying liquid chlorine in the form of sodium hypochlorite. A consequence of changing the form of disinfectant that is applied to the reclaimed water is the introduction of another source of sodium into the reclaimed water. The additional quantity of sodium depends on the disinfectant dose and the flowrate. The dosage of sodium hypochlorite (12.5%) to be used at the water reclamation facility will range from 360 to 672 gallons/day. An estimate of the incremental increase in sodium as a function of the water reclamation facility flowrate is shown in Figure 4.

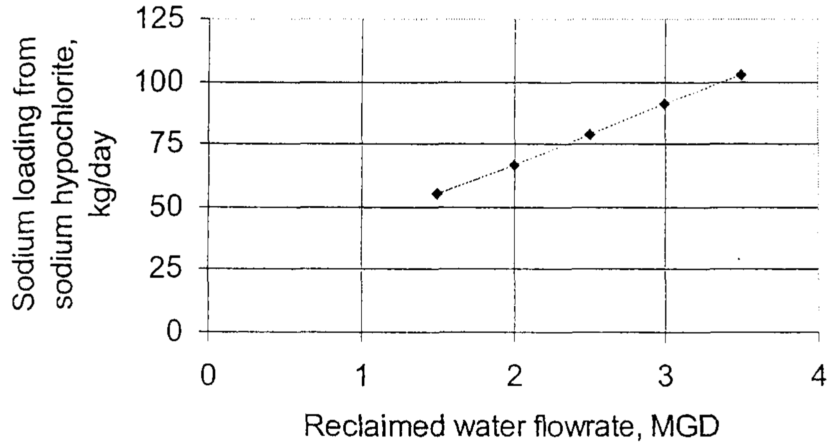

Figure 4. Estimate of the amount of sodium discharged per day (kg/day) as a function of the reclaimed water flowrate at AUI's treatment facility.

Estimate of reclaimed water quality

The net impacts of the wastewater from regeneration of packed-bed anion exchange columns on reclaimed water quality depend on the frequency of regeneration and the salt application rate. The frequency of regeneration depends on the amount of water processed by each plant and the actual concentration in the reclaimed water depends on the salt application rate and the amount of reclaimed water that is produced. In general, wastewater treatment facilities are not designed to remove sodium or chloride, therefore the mass of salts that are introduced into the wastewater are likely to be carried over to the reclaimed water. Some dilution may occur during the rainy season. Conversely, slight increases in concentrations may be observed due to evaporation, depending on temperature.

A comparison of the estimated concentrations of sodium and chloride under average annual day (AADF) flow conditions is shown in Figure 5 as a function of the flowrate of reclaimed water for two different loadings of salt: 4 and 6 lb per cubic foot of resin. As shown, lower salt dosages and the higher reclaimed water flowrates yield lower concentrations of sodium and chloride in the reclaimed water. The concentrations of sodium and chloride projected for AUI's reclaimed water are within the range of values reported for other reclaimed water facilities (Food and Agriculture Organization of the United Nations 1992, Metcalf and Eddy 2003, National Research Council 1996).

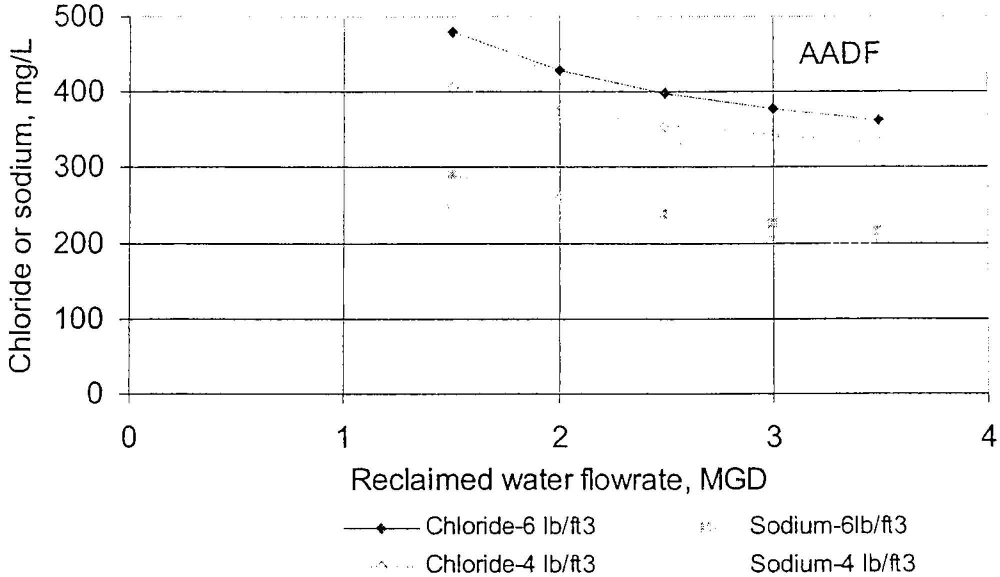

Figure 5. Estimated concentrations of chloride and sodium in reclaimed water under AADF operation of anion exchange reactors using either 4 or 6 lb of salt per cubic foot of resin.

Another parameter that is important in predicting the characteristics of reclaimed water relevant to public access irrigation systems is the ***Sodium Adsorption Ratio (SAR).*** The SAR provides an index of the amount of sodium in water in comparison to calcium and magnesium concentrations:

$$SAR = \frac{(Na^{+})}{\sqrt{((Ca^{+2}) + (Mg^{+2})) * 0.5}}$$

where the concentrations of sodium, calcium, and magnesium are in milli-equivalents per liter.

The presence of excess sodium in irrigation water can impact soil structure and reduce its permeability to water and air. Calcium and magnesium temper the effect of sodium. It is important to manage the reclaimed water application rates and drainage efficiency to prevent accumulation of salts. In addition, excess sodium can be toxic to some types of grasses and plants. Drainage systems that prevent salt accumulation in the root zone can help to prevent potential problems (Food and Agriculture Organization of the United Nations 1992, Metcalf and Eddy 2003, National Research Council 1996).

A comparison of estimated SAR levels that may be associated with reclaimed water produced from assimilating wastewater from anion exchange regeneration at the treatment facility is given in Figure 7 for two different flow scenarios: average annual daily flow (AADF) and maximum month average daily flow (MMADF-1). As shown, the SARs (and other water quality parameters) decrease with increasing flowrate. It is also interesting to note that using a salt dose of 4 pounds per cubic foot under MMADF-1 conditions yields approximately the same SAR as a 6 lb per cubic foot salt dose under AADF.

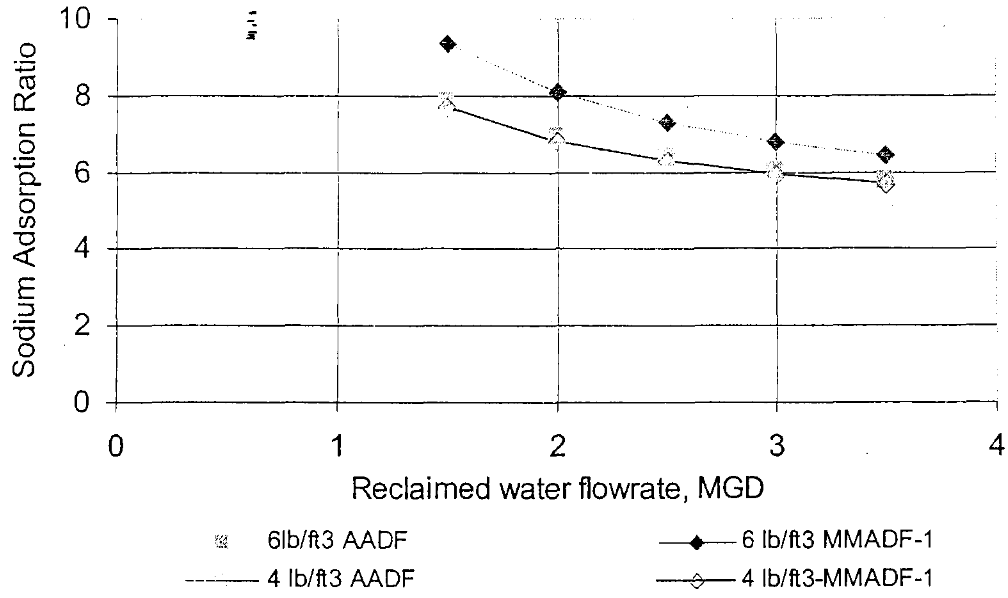

Figure 6. Comparison of Sodium Adsorption Ratios (SAR) projected in reclaimed water that receives wastewater from anion exchange regeneration under two flow conditions: Average Annual Daily Flow (AADF) 2.04 MGD and Maximum Month Daily Flow (MMDF-1) 2.9 MGD. The wastewater flowrate is assumed to be 1.5 MGD.

An estimate of the projected concentrations of sodium and chloride in the reclaimed water under different pumping scenarios is given in Table 16 for a salt application rate of 6 lb per cubic foot and in Table 17 for an application rate of 4 lb per cubic foot.

Table 16. Projected SAR and concentrations of sodium and chloride in reclaimed water receiving wastewater from regeneration of anion exchange treatment units under different pumping scenarios at a salt application rate of 6 lb/ft^3 and a reclaimed water flow of 1.5 MGD[1].

Flowrate scenario		Salt Application Rate: 6 lb salt per cubic foot of resin		
Design Condition[2]	Flowrate, MGD	Chloride, mg/L	Sodium, mg/L	SAR[3] estimate
AADF	2.04	479	292	7.9
MMADF-1	2.9	564	347	9.4
MMADF-2	2.9	408	246	6.6
MDDF-1	3.9	664	411	11.1
MDDF-2	3.9	459	279	7.5

[1]Reclaimed water flow is assumed to be 1.5 MGD [2]See Table 1 for definition of flow scenarios; [3]SAR: Sodium Adsorption Ratio.

Table 17. Projected SAR and concentrations of sodium and chloride in reclaimed water receiving wastewater from regeneration of anion exchange treatment units under different pumping scenarios at a salt application rate of 4 lb/ft^3 and a reclaimed water flow of 1.5 MGD[1].

Flowrate scenario		Salt Application Rate: 4 lb salt per cubic foot of resin		
Design Condition[2]	Flowrate, MGD	Chloride, mg/L	Sodium, mg/L	SAR[3] estimate
AADF	2.04	407	248	6.7
MMADF-1	2.9	462	284	6.5
MMADF-2	2.9	361	217	5.8
MDDF-1	3.9	527	328	8.8
MDDF-2	3.9	394	239	6.4

[1]Reclaimed water flowrate is assumed to be 1.5 MGD [2]See Table 1 for definitions of flow scenarios; [3]SAR: Sodium Adsorption Ratio

POTENTIAL IMPACTS ON TREATMENT FACILITY

The wastewater generated through the anion exchange process will be discharged to AUI's wastewater collection system for treatment. As shown in Tables 16 and 17, chloride and sodium levels in the water reclamation facility's influent (and effluent) will increase due to the implementation of anion exchange for drinking water production. The increase in salt levels will result in about 1.7 to 2.6 fold higher concentrations of chloride and sodium than the current levels at AUI's treatment facility. The degree to which the increased salt concentrations may impact microbial activity in the wastewater treatment facility is hard to predict from the existing data. In general, biological treatment systems are fairly robust and the microbial populations that comprise the biomass have a significant ability to adapt to changes in water quality, provided the changes are gradual. The sodium and chloride levels projected to be in the treatment plant effluent are within the range of values experienced by other treatment facilities, particularly in coastal environments.

Shock loadings of salt may inhibit some microbial activity, however, by using the existing equalization basin to provide a consistent loading to the biological treatment units and optimizing treatment process parameters (aeration, biomass concentrations, mean cell residence time, etc.) for removal of organics, the wastewater treatment facility should be capable of performing effectively. During the start-up phase, it will be important to ensure that the additional salt loading is gradually phased into the treatment plant to enable the biological treatment system to adapt appropriately.

SUMMARY AND CONCLUSIONS

The implementation of anion exchange technology at water treatment plants in the Seven Springs service area will improve water quality by reducing concentrations of hydrogen sulfide, sulfate, and organic carbon in drinking water. The benefits of the upgraded treatment system include more stable water quality, reduction in the potential for odor and water discoloration, and a decrease in the disinfection byproduct precursor concentrations. An integral component of anion exchange technology is the need to periodically regenerate the resin. The characteristics of the wastewater generated through regeneration are related to the quantity of water treated, the frequency of regeneration, and the amount of salt used in the regeneration process. The major constituents of concern in regeneration wastewater are chloride and sodium. By optimizing the salt application rate and frequency of regeneration, the impacts of the additional salt loading on the wastewater treatment plant can be minimized. Because salts are not removed through wastewater treatment, the concentrations of chloride and sodium in the reclaimed water will increase in response to the implementation of anion exchange technology due to the regeneration wastewater. The major conclusions from this project are:

1. The use of anion exchange in the Seven Springs service area will generate wastewater that contains high concentrations of chloride and sodium.
2. The frequency of regeneration of the anion exchange systems impacts the quantity of wastewater generated and the net amount of salt that will be discharged to the wastewater treatment facility.
3. Regeneration of anion exchange resins can be achieved with salt dosages ranging from 3 to 15 lb/ft^3. Lower salt dosages result in lower salt loading to the wastewater treatment facility.
4. The major factors that impact the salt concentrations of reclaimed water produced after resin regeneration are:
    - Water demand
    - Combination of treatment plants used to produce drinking water.
    - Frequency of regeneration
    - Quantity of salt used for regeneration of anion exchange resins
5. The predicted concentrations of chloride and sodium in the wastewater and reclaimed water after implementation of anion exchange technology will be higher than current concentrations, but within the range of concentrations observed at other water reclamation facilities, particularly in coastal areas.
6. Under conditions of high water demand, a combination of approaches may be needed to minimize the sodium and chloride concentrations in the reclaimed water.

REFERENCES

Food and Agriculture Organization of the United Nations (1992), Wastewater treatment and use in agriculture, FAO Irrigation and Drainage Paper 47 by M.B. Pescod, FAO, Italy (ISBN 92-5103135-5).

Metcalf and Eddy (2003), Wastewater Engineering: Treatment and Reuse, 4th Edition revised by G.Tchobanoglous, F. L. Burton, and H.D. Stensel, McGraw Hill, New York.

National Research Council (1996), Use of Reclaimed Water and Sludge in Food Crop Production, National Academy Press.

ACKNOWLEDGEMENTS

The assistance from the staff at Aloha Utilities in constructing the pilot plant and helping with start-up and operation is appreciated. Mike McDonald provided valuable assistance with pilot-plant operation. Pam Yacobelli provided assistance with background information, data, and facilitating schedules for operation of the pilot plant. Mr. David Porter, P.E. provided technical assistance throughout the project. Several USF students participated in the project by providing supplemental field and laboratory assistance. Tom Davis and Amelia Jordan of Tonka Equipment and Chuck Hlvalach of EnviroSales provided technical support for anion exchange testing.

APPENDIX

Pilot-scale anion exchange reactor characteristics

Material	plexi-glass
Diameter, inches	2
Bed volume	
ft3	0.065
gallons	0.5
m3	0.0018
Bed depth, ft	3
Freeboard, inches	18

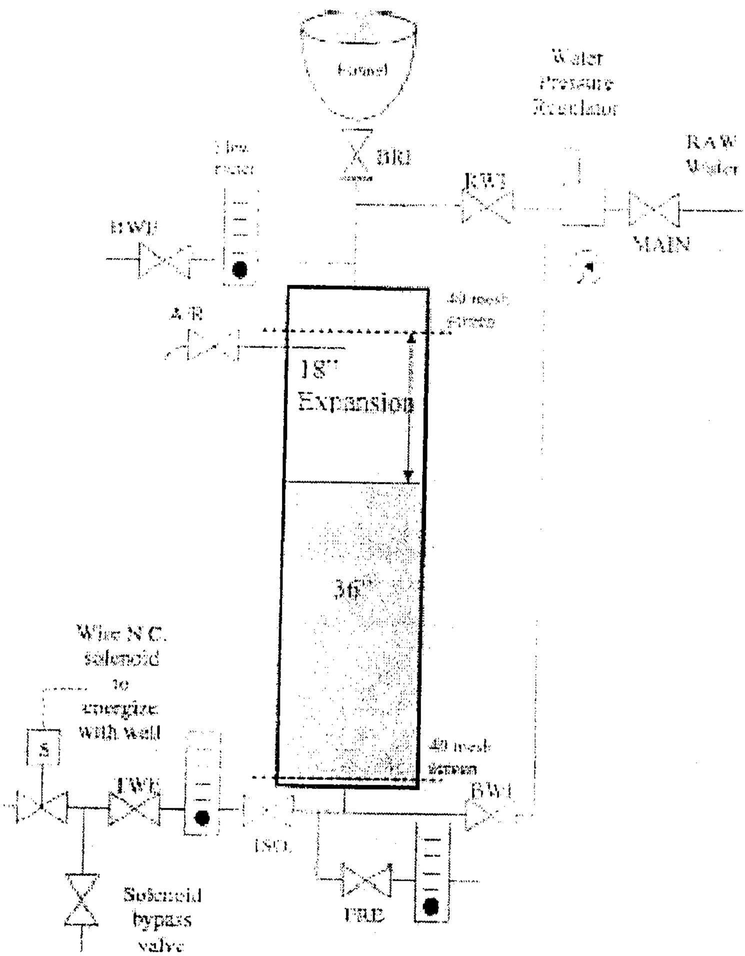

Diagram of pilot-scale anion exchange reactors provided by Tonka Equipment.

Brine make-up procedure used for pilot testing of regeneration

1. Add three pounds of non-iodized salt to 1 gallon of make-up water (distilled water or well water)
2. Stir the solution to dissolve the salt and produce a concentrated brine
3. Calculate the salt concentration needed based on the volume of resin to be regenerated
4. Dilute concentrated brine to appropriate level (3-10 lb/ft^3)
5. Pour the diluted solution into the anion exchanger funnel.
6. Allow to react for specified time period

Well 9 regeneration data

Parameter	Well 9 untreated 7/5/2006	Drain down 7/5/2006	Backwash 7/5/2006	Brine 7/5/2006	Slow Rinse 7/5/2006	Fast rinse 7/5/2006
Flowrate, gph	7.60	1.20	4.00	8.00	1.20	8.00
time, minutes		15.00	15.00	15.00	25.00	10.00
Total volume, liters		4.5	15.1	30.3	7.6	20.2
Brine concentration, lb/ft^3				4		
BOD, mg/L				18	410	4.7
COD, mg/L				435	4560	
TDS, mg/L	602	486	362	8690	36800	708
TSS, mg/L				10	18	
TS, mg/L		474	358	8810	36700	676
NVSS, mg/L				8	14	
VSS, mg/L					4	
TNVS, mg/L		450	332	8480	35000	500
TVS, mg/L		24	26	330	1700	176
Alkalinity, mg/L as CaCO3	27	216	209	1710	2700	23
Chloride, mg/L	166	114	48		7310	188
Hardness	258	246	254	221	131	255
Sulfate, mg/L	35	31	37	4170	15300	95
Ammonia-n, mg/L	0.24	0.17	0.23	0.15	0.12	0.18
Nitrite-n, mg/L						
Nitrate-n, mg/L						
Total-n, mg/L				4.7	32.3	
Total-p, mg/L		0.08		12.4	5.91	
TKN, mg/L				4.68	32.3	
TOC, mg/L	3.2	1.9		123	1320	6.6
Cu, mg/L		0.523	0.577	0.062	0.048	
Fe, mg/L		0.139	0.152			
Na, mg/L	37.5	32.4	32.5	3300	16450	72.6

Well 9 regeneration data	Well 9 untreated	Drain down	Backwash	Brine	Slow Rinse	Fast rinse
Sample Date	7/12/2006	7/12/2006	7/12/2006	7/12/2006	7/12/2006	7/12/2006
Flowrate, gph	7.60	1.20	4.00	8.00	1.20	8.00
time, minutes		15.00	15.00	15.00	25.00	10.00
Total volume, liters		4.5	15.1	30.3	7.6	20.2
Brine concentration, lb/ft^3				4		
BOD, mg/L			49	73	176	
COD, mg/L				792	3920	
TDS, mg/L	652		628	11400	36400	840
TSS, mg/L			6.6		4	
TS, mg/L			657	11624	37240	872
NVSS, mg/L			4.8		35426	664
VSS, mg/L						
TNVS, mg/L			437	11350		664
TVS, mg/L		244	220	274	1814	208
Alkalinity, mg/L as CaCO3	14		148	844	2480	22
Chloride, mg/L	182	158	173	4940	5850	258
Hardness	254	254	254	179	150	246
Sulfate, mg/L	46	16	19	394	15500	112
Ammonia-n, mg/L	0.26	0.45	0.5	0.34	0.47	0.27
Nitrite-n, mg/L						
Nitrate-n, mg/L						
Total-n, mg/L			7.23	9.12	45.2	1.39
Total-p, mg/L			0.04	0.76	1.72	0.04
TKN, mg/L		5.65	7.23	9.12	45.2	1.39
TOC, mg/L	6.2	4.6	4.5	116	1270	11.6
Cu, mg/L		0.066	0.241	0.027	0.053	0.023
Fe, mg/L			0.12		0.021	
Na, mg/L	44.4	49.9	48.9	4080	12580	129

Well 9 regeneration data	Well 9 untreated	Drain down	Backwash	Brine	Slow Rinse	Fast rinse
Sample Date	7/18/2006	7/18/2006	7/18/2006	7/18/2006	7/18/2006	7/18/2006
Flowrate, gph	7.60	1.20	4.00	8.00	1.20	8.00
time, minutes		15.00	15.00	15.00	25.00	10.00
Total volume, liters		4.5	15.1	30.3	7.6	20.2
Brine concentration, lb/ft^3				4		
BOD, mg/L		4.9		15	279	
COD, mg/L				245	5120	
TDS, mg/L	528	292	430	6150	51500	714
TSS, mg/L						
TS, mg/L		290	449	6260	51900	714
NVSS, mg/L						
VSS, mg/L						
TNVS, mg/L		268		5800	50500	534
TVS, mg/L			448	460	1400	180
Alkalinity, mg/L as CaCO3		193	196	1390	4030	13
Chloride, mg/L	182	14	93	92	5440	254
Hardness	256	261	262	158	107	259
Sulfate, mg/L	48	48	43	3230	24400	76
Ammonia-n, mg/L	0.26	0.26	0.24	0.23	0.44	0.28
Nitrite-n, mg/L						
Nitrate-n, mg/L						
Total-n, mg/L		1.04		4.96	46.6	1.43
Total-p, mg/L		0.1	0.09	20.2	3.26	0.07
TKN, mg/L		1.04		4.96	46.6	1.43
TOC, mg/L	6.9	3.1	3.6	77.8	1720	8.6
Cu, mg/L		0.249	0.532	0.082	0.163	0.117
Fe, mg/L		0.172	0.122	0.059	0.122	0.052
Na, mg/L	48.2	11.5	116	6940	15600	99.6

Anion Exchange Design Summary

Anion Exchange Design Summary

AADF

Plant name	Plant 9	Plant 8	Plant 6	Mitchell	Plant 2
Design capacity, gal/ft^3	1000	1500	2500	2500	3500
Volume processed before regen, vessel	254,469	381,704	636,173	502,655	703,717
Regeneration frequency per vessel, days	3.3	4.4	8.0	5.2	7.3
Design flowrate, AADF, gpd	232,000	259,000	239,000	289,000	288,000
Max hours of operation per day	7.7	8.6	8.0	9.6	9.6
gallons per vessel per day	77,488	86,506	79,826	96,526	96,192

WWTP flowrate, MGD	1.5	2	2.5	3	3.5
Chloride					
contribution from wastewater, kg/d assume 275 mg/L	1561	2082	2602	3123	3643
Sodium					
contribution from wastewater, kg/d assume 150 mg/L	852	1136	1419	1703	1987
contribution from sodium hypochlorite, kg/d	55	67	79	91	103
Estimated wastewater concentration					
Chloride					
mg/L (6 lb/ft^3)	479	428	397	377	362
mg/L (4 lb/ft^3)	407	374	354	341	332
Sodium					
mg/L (6 lb/ft^3)	292	258	237	224	214
mg/L (4 lb/ft^3)	248	225	211	202	195
If KCl is used for 8+9 instead of NaCl					
Chloride					
mg/L (6 lb/ft^3)	435	395	371	355	343
mg/L (4 lb/ft^3)	381	355	339	328	321
Sodium					
mg/L (6 lb/ft^3)	215	200	192	186	182
mg/L (4 lb/ft^3)	197	187	181	176	174
Potassium					
mg/L (6 lb/ft^3)	274	218	184	162	146
mg/L (4 lb/ft^3)	199	162	140	125	114

Anion Exchange Design Summary
MMADF-1

Plant name	Well 9	Well 8	Well 6	Mitchell	Well 2
Volume processed before regen, vessel	254,469	381,704	636,173	502,655	703,717
Regeneration frequency per vessel, days	2.4	3.1	5.3	3.5	5.2
Design flowrate, MMADF-1, gpd	313,482	369,838	356,923	429,717	407,409
Max hours of operation per day	10.4	12.3	11.9	14.3	13.6
gallons per vessel per day	104,703	123,526	119,212	143,525	136,075

WWTP flowrate, MGD	**1.5**	**2**	**2.5**	**3**	**3.5**
Chloride					
contribution from wastewater, kg/d assume 275 mg/L	1561	2082	2602	3123	3643
Sodium					
contribution from wastewater, kg/d assume 150 mg/L	852	1136	1419	1703	1987
contribution from sodium hypochlorite, kg/d	55	67	79	91	103
Estimated wastewater concentration					
Chloride					
mg/L (6 lb/ft^3)	564	492	448	419	399
mg/L (4 lb/ft^3)	462	415	387	369	355
Sodium					
mg/L (6 lb/ft^3)	347	299	271	252	238
mg/L (4 lb/ft^3)	284	252	233	220	211
If KCl is used for 8+9 instead of NaCl					
Chloride					
mg/L (6 lb/ft^3)	502	445	411	388	372
mg/L (4 lb/ft^3)	426	388	366	351	340
Sodium					
mg/L (6 lb/ft^3)	241	220	207	199	193
mg/L (4 lb/ft^3)	214	200	191	185	181
Potassium					
mg/L (6 lb/ft^3)	360	283	236	205	183
mg/L (4 lb/ft^3)	257	205	174	153	139

Aloha Utilities
Anion Exchange Design Summary
MMADF-2

Plant name	**Well 9**	**Well 8**	**Well 6**	**Mitchell**	**Well 2**
Volume processed before regen, vessel	254,469	381,704	636,173	502,655	703,717
Regeneration frequency per vessel, days	0.0	0.0	4.8	3.9	4.3
Design flowrate, MMADF-2, gpd	0	0	400,000	390,000	490,000
Max hours of operation per day	0.0	0.0	13.3	13.0	16.3
gallons per vessel per day	0	0	133,600	130,260	163,660

WWTP flowrate, MGD	**1.5**	**2**	**2.5**	**3**	**3.5**
Chloride					
contribution from wastewater, kg/d assume 275 mg/L	1561	2082	2602	3123	3643
Sodium					
contribution from wastewater, kg/d assume 150 mg/L	852	1136	1419	1703	1987
contribution from sodium hypochlorite, kg/d	55	67	79	91	103
Chloride					
mg/L (6 lb/ft^3)	408	375	355	341	332
mg/L (4 lb/ft^3)	361	340	327	318	312
Sodium					
mg/L (6 lb/ft^3)	246	223	210	201	195
mg/L (4 lb/ft^3)	217	202	193	187	182

Aloha Utilities
Anion Exchange Design Summary
MDDF-1

Plant name	Well 9	Well 8	Well 6	Mitchell	Well 2
Volume processed before regen, vessel	254,469	381,704	636,173	502,655	703,717
Regeneration frequency per vessel, days	1.8	2.3	4.0	2.6	3.9
Design flowrate, MDDF1, gpd	421,579	497,368	480,000	577,896	547,895
Max hours of operation per day	14.1	16.6	16.0	19.3	18.3
gallons per vessel per day	140,807	166,121	160,320	193,017	182,997

WWTP flowrate, MGD	**1.5**	**2**	**2.5**	**3**	**3.5**
Chloride					
contribution from wastewater, kg/d assume 275 mg/L	1561	2082	2602	3123	3643
Sodium					
contribution from wastewater, kg/d assume 150 mg/L	852	1136	1419	1703	1987
contribution from sodium hypochlorite, kg/d	55	67	79	91	103
Estimated wastewater concentration					
Chloride	664	566	508	469	442
mg/L (6 lb/ft^3)	527	464	426	401	383
mg/L (4 lb/ft^3)					
Sodium	411	348	309	284	266
mg/L (6 lb/ft^3)	328	285	259	242	230
mg/L (4 lb/ft^3)					
If KCl is used for 8+9 instead of NaCl					
Chloride					
mg/L (6 lb/ft^3)	580	504	458	427	406
mg/L (4 lb/ft^3)	478	427	397	377	362
Sodium					
mg/L (6 lb/ft^3)	269	241	224	213	205
mg/L (4 lb/ft^3)	233	214	202	195	189
Potassium					
mg/L (6 lb/ft^3)	467	363	300	259	229
mg/L (4 lb/ft^3)	328	259	217	189	169

Aloha Utilities
Anion Exchange Design Summary
MDDF-2

Plant name	**Well 9**	**Well 8**	**Well 6**	**Mitchell**	**Well 2**
Volume processed before regen, vessel	254,469	381,704	636,173	502,655	703,717
Regeneration frequency per vessel, days	0.0	0.0	3.3	2.6	3.6
Design flowrate, MDDF2, gpd (wells 8 and 9 off)	0	0	580,000	580,000	580,000
Max hours of operation per day	0.0	0.0	19.3	19.3	19.3
gallons per vessel per day	0	0	193,720	193,720	193,720

WWTP flowrate, MGD	**1.5**	**2**	**2.5**	**3**	**3.5**
Estimated wastewater concentration					
Chloride					
contribution from wastewater, kg/d assume 275 mg/L	1561	2082	2602	3123	3643
Sodium					
contribution from wastewater, kg/d assume 150 mg/L	852	1136	1419	1703	1987
contribution from sodium hypochlorite, kg/d	55	67	79	91	103
Estimated wastewater concentration					
Chloride					
mg/L (6 lb/ft^3)	459	413	385	367	354
mg/L (4 lb/ft^3)	394	364	346	334	326
Sodium					
mg/L (6 lb/ft^3)	279	248	230	217	209
mg/L (4 lb/ft^3)	239	218	206	198	192

Marshall Willis

From: John Wharton [johnw@RSBattorneys.com]
Sent: Friday, March 07, 2008 11:44 AM
To: Bart Fletcher
Cc: Cheryl Bulecza-Banks; Jean Hartman; Marshall Willis; Tim Devlin
Subject: RE: Revised Construction Schedule for Anion Exchange Project
Attachments: Schedule.doc

Bart, we expedited the preparation of this schedule as you requested. Attached is our best estimate given the short time frame we had to work it up.

John L. Wharton, Esq.
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(850) 877-6555 - telephone
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From: Bart Fletcher [mailto:BFletche@PSC.STATE.FL.US]
Sent: Wednesday, March 05, 2008 5:36 PM
To: John Wharton
Cc: Cheryl Bulecza-Banks; Jean Hartman; Marshall Willis; Tim Devlin
Subject: RE: Revised Construction Schedule for Anion Exchange Project

Good afternoon, John.

The requested timeline would be a useful tool for the Commission in its role to monitor the implementation of the anion exchange project pursuant to the stipulation. The Commission has a direct interest in on staying on top of this to help keep this project on track.

Thanks.

Bart Fletcher
Public Utilities Supervisor
Florida Public Service Commission
Division of Economic Regulation
2540 Shumard Oak Blvd.
Tallahassee, FL 32399-0850
(850) 413-7017 (voice)
(850) 413-7018 (fax)
bart.fletcher@psc.state.fl.us

From: John Wharton [mailto:johnw@RSBattorneys.com]
Sent: Wednesday, March 05, 2008 11:35 AM
To: Bart Fletcher
Cc: Cheryl Bulecza-Banks; Jean Hartman; Marshall Willis; Tim Devlin
Subject: RE: Revised Construction Schedule for Anion Exchange Project

Bart,

I have received your e-mail. I am not sure we can have the response to you by Friday as you request, but we will respond as soon as we reasonably can.

Can you help us understand the purpose of this exercise and why you have requested this on such a short time frame ?

John L. Wharton. Esq.
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From: Bart Fletcher [mailto:BFletche@PSC.STATE.FL.US]
Sent: Tuesday, March 04, 2008 5:07 PM
To: John Wharton
Cc: Cheryl Bulecza-Banks; Jean Hartman; Marshall Willis; Tim Devlin
Subject: Revised Construction Schedule for Anion Exchange Project
Importance: High

Good morning, John.

With the assumption that the brine waste disposal issue would be resolved by July 1, 2008, please provide a revised timeline the anion exchange project tasks by noon Friday, March 7, 2008.

Anion Exchange Project Tasks	Phase	Per Utility's 7/2/2007 Timeline	Aloha's Revised Timeline	Individual(s) Responsible
Receive Pasco County Bulk water Data	Design	4/11/2007	4/11/2007	
Redefine WTP Treatment Requirements	Design	5/14/2007		
Redefine Project Design Parameters	Design	5/14/2007		
Update Tasks List and Schedule	Design	7/2/2007	3/7/2008	
Submit Updated Schedule to PSC	Design	7/2/2007	3/7/2008	
Prepare WWTP Permit Modification Application	Permitting	8/21/2007		
Submit WWTP Permit Application Review and Approval	Permitting	8/21/2007		
FDEP Permit Application Review and Approval	Permitting	9/21/2007		
Complete Updates to AE Permit Level Design Docs.	Permitting	9/30/2007		
Complete FDEP AE Permit Application	Permitting	9/30/2007		
Submit AE Permit Application Review and Approval	Permitting	9/30/2007		
FDEP AE Permit Application Review and Approval	Permitting	10/21/2007		
Preparation of Bid Packages	Bidding	11/21/2007		
Preparation of Bid and Award Construction Contracts	Bidding/K Award	1/7/2008		
Obtain DRD and Building Permits from Pasco County	Construction	2/14/2008		
AE Construction and Start-up	Construction	2/18/2009		
All AE Plants On-line		2/18/2009		

Thanks,

Bart Fletcher
Public Utilities Supervisor
Florida Public Service Commission
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Estimated Schedule as of March 7, 2008

Anion Exchange Project Tasks	Phase	Per Utility's 7/2/2007 Timeline	Aloha's Revised Timeline	Individual(s) Responsible
Receive Pasco County Bulk water Data	Design	4/11/2007	4/11/2007	A/D/E/L/R
Redefine WTP Treatment Requirements	Design	5/14/2007	7/1/08*	A/D/E/L/R/V
Redefine Project Design Parameters	Design	5/14/2007	7/1/08*	A/D/E/L/V
Update Tasks List and Schedule	Design	7/2/2007	3/7/2008*	A/D/E/L
Submit Updated Schedule to PSC	Design	7/2/2007	3/7/2008*	A/D/E/L
Prepare WWTP Permit Modification Application	Permitting	8/21/2007	7/31/08*	A/D/E/L
Submit WWTP Permit Application Review and Approval	Permitting	8/21/2007	7/31/08*	A/D/E/L/R/V
FDEP Permit Application Review and Approval	Permitting	9/21/2007	9/1/08*	R
Complete Updates to AE Permit Level Design Docs.	Permitting	9/30/2007	9/15/08*	A/D/E/L/V
Complete FDEP AE Permit Application	Permitting	9/30/2007	9/15/08*	A/D/E/L/V
Submit AE Permit Application Review and Approval	Permitting	9/30/2007	9/15/08*	A/D/E/L/V
FDEP AE Permit Application Review and Approval	Permitting	10/21/2007	10/20/08*	R
Preparation of Bid Packages	Bidding	11/21/2007	11/21/08*	A/D/E/L
Award Construction Contracts	Bidding/Award	1/7/2008	1/7/09*	A/D/E/L/V
Obtain DRD and Building Permits from Pasco County	Construction	2/14/2008	2/16/09*	A/D/E/L/R
AE Construction and Start-up	Construction	2/18/2009	2/22/10*	A/D/E/L/V/R
All AE Plants On-line		2/18/2009	2/22/10*	A/D/E/L/V/R

Notes:

1. Updated schedule dates shown herein assume (as directed by PSC staff) that all AE waste disposal issues will be resolved on or before July 1, 2008. *The estimated schedule dates shown will change if this assumption is not correct.

2. Updated schedule assumes that previous project concept, design objectives and implementation assumptions continue to be correct and no major deviations will be necessary. *The estimated schedule dates shown will change if these assumptions are not correct.

3. A = Aloha staff and management; D = David W. Porter, P.E., E = Other engineering services; C = Contractors, R = Regulatory Agencies; E = Equipment Vendors, L = Legal Support