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Arsenic and Antimony Removal from Drinking Water by Adsorptive Media U.S. EPA Demonstration Project at South Truckee Meadows General Improvement District (STMGID), NV Interim Evaluation Report

by

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FOREWORD

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Sally Gutierrez, Director
National Risk Management Research Laboratory

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The authors wish to extend their sincere appreciation to the staff of Washoe County Department of Water Resources (WCDWR) in Nevada. The WCDWR staff monitored the treatment system daily and collected samples from the treatment and distribution systems on a regular schedule throughout this reporting period. This performance evaluation would not have been possible without their efforts.

ABSTRACT

This report documents the activities performed during and the results obtained from the first 32 weeks of operation of an arsenic and antimony removal technology currently being demonstrated at the South Truckee Meadows General Improvement District (STMGID) in Washoe County, NV. The objectives of the project are to evaluate (1) the effectiveness of a granular ferric hydroxide (GFH) adsorptive media system in removing arsenic and antimony to meet the respective maximum contaminant levels (MCLs) of 10 and 6 µg/L, (2) the reliability of the treatment system, (3) the required system operation and maintenance (O&M) and operator's skills, and (4) the capital and O&M cost of the technology. The project also characterizes the water in the distribution system and process residuals produced by the treatment system.

The Siemens GFH system is a fixed-bed adsorption system that uses GFH, an iron-based media, to adsorb dissolved arsenic and antimony in drinking water supplies. When the media reaches its adsorption capacity, it will be removed from the vessels and replaced with new media. Spent media will be hauled away to a landfill after passing the Toxicity Characteristic Leaching Procedure (TCLP) test. GFH is produced by GEH Wasserchemie Gmbh and marketed by Siemens under an exclusive agreement. The GFH system for the STMGID site was designed to treat up to 350 gal/min (gpm) of water and consisted of three 66-in diameter, 72-in tall vertical carbon steel pressure tanks configured in parallel. Based on the design flow rate of 350 gpm and total media volume of 240 ft^3, the empty bed contact time (EBCT) in each tank (and the entire system) was 5.1 min and the hydraulic loading rate to each tank was 4.9 gpm/ft^2.

Between September 27, 2005 and May 3, 2006, the GFH system operated for a total of 943 hr. After it began normal daily operation on November 18, 2005, the system operated an average of 3.8 hr/day. The average flowrate during the 32-week study period was 275 gpm, which was 79% of the design flowrate. As a result, a longer average EBCT of 6.5 min was experienced by the media. During the 32-week study period, the volume of water processed was 15,567,000 gal or 8,677 bed volumes (BV) (one BV is equal to 240 ft^3 or 1,795 gal). There were no backwash events based on headloss buildup during this study period.

Breakthrough of arsenic at 10 µg/L from the GFH system occurred at approximately 7,200 BV. Breakthrough of antimony at 6 µg/L occurred at approximately 3,000 BV. The media run length for arsenic was much shorter than the vendor-projected working capacity of 38,000 BV. The unexpectedly short run length for arsenic was probably caused by the presence of competing anions, such as silica and phosphorous, at high levels in raw water. Silica concentrations in raw water ranged from 51.5 to 95.1 mg/L (as SiO_2) and averaged 72.6 mg/L (as SiO_2). Total phosphorous concentration in raw water ranged from 0.27 to 0.46 mg/L and averaged 0.35 mg/L (as PO_4) with some phosphorous existing as orthophosphate. Both silica and phosphorous were removed effectively by GFH, with silica reaching complete breakthrough about halfway through the 32-week study period and phosphorous never reaching complete breakthrough.

Treated water was blended with water from four other STMGID wells about one mile downstream of the GFH system. Water samples were collected at three locations in the distribution system, including one non-residential location prior to the blending point and two residences after the blending point, to evaluate the impact of the GFH system on water chemistry in the distribution system. As a combined result of treatment by the GFH system and blending with other source water, arsenic and antimony concentrations in the distribution system were significantly reduced to below the respective MCLs (except for one exceedance). There were no noticeable changes in lead or copper concentrations measured in the first draw samples from two residences. The lead concentrations remained low (i.e., 1.5 µg/L or less) in all samples; copper concentrations fluctuated from <1 to 176 µg/L, far below the action level of 1.3 mg/L.

The capital investment cost of $232,147 included $157,647 for equipment, $16,000 for site engineering, and $58,500 for installation. Using the system's rated capacity of 350 gpm (or 504,000 gpd), the capital cost was $663/gpm (or $0.46/gpd) of design capacity. O&M cost evaluated in this report included only the incremental costs associated with the GFH system, such as media replacement and disposal, electricity consumption, and labor. The media replacement and disposal did not take place during the first 32 weeks of operation; however, the cost to change out the media in all three adsorption tanks was estimated to be $70,550 by the vendor. The unit media replacement cost per 1,000 gal of water treated was developed as a function of the media run length to 10-μg/L arsenic or 6-μg/L antimony breakthrough in the combined effluent.

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FIGURES

TABLES

ABBREVIATIONS AND ACRONYMS

Δp	differential pressure
AAL	American Analytical Laboratories
Al	aluminum
AM	adsorptive media
As	arsenic
bgs	below ground surface
BV	bed volume(s)
Ca	calcium
Cl_2	chlorine
C/F	coagulation/filtration
CMU	concrete masonry unit
CRF	capital recovery factor
Cu	copper
DO	dissolved oxygen
EBCT	empty bed contact time
EPA	U.S. Environmental Protection Agency
F	fluoride
Fe	iron
GFH	granular ferric hydroxide
gpd	gallons per day
gpm	gallons per minute
HDPE	high-density polyethylene
hp	horsepower
ICP-MS	inductively coupled plasma-mass spectrometry
ID	identification
IX	ion exchange
kwh	kilowatt-hour(s)
LCR	(EPA) Lead and Copper Rule
MCL	maximum contaminant level
MDL	method detection limit
MDWCA	Mutual Domestic Water Consumers Association
Mg	magnesium
Mn	manganese
mV	millivolts
Na	sodium

NA	not available
NaOCl	sodium hypochlorite
ND	not detected
NRMRL	National Risk Management Research Laboratory
NTU	nephlemetric turbidity units
O&M	operation and maintenance
ORD	Office of Research and Development
ORP	oxidation-reduction potential
P&IDs	piping and instrumentation diagrams
Pb	lead
PE	professional engineer
PO_4	orthophosphate
PLC	programmable logic controller
PM	process modification
psi	pounds per square inch
psig	pounds per square inch (gauge)
PVC	polyvinyl chloride
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RPD	relative percent difference
RSSCT	rapid small-scale column test
Sb	antimony
SCADA	system control and data acquisition
SDWA	Safe Drinking Water Act
SiO_2	silica
SO_4	sulfate
STMGID	South Truckee Meadows General Improvement District
STS	Severn Trent Services
TCLP	Toxicity Characteristic Leaching Procedure
TOC	total organic carbon
WCDWR	Washoe County Department of Water Resources
WRWC	White Rock Water Company

1.0 INTRODUCTION

1.1 Background

The Safe Drinking Water Act (SDWA) mandates that the U.S. Environmental Protection Agency (EPA) identify and regulate drinking water contaminants that may have adverse human health effects and that are known or anticipated to occur in public water supply systems. In 1975 under the SDWA, EPA established a maximum contaminant level (MCL) for arsenic at 0.05 mg/L. Amended in 1996, the SDWA required that EPA develop an arsenic research strategy and publish a proposal to revise the arsenic MCL by January 2000. On January 18, 2001, EPA finalized the arsenic MCL at 0.01 mg/L (EPA, 2001). In order to clarify the implementation of the original rule, EPA revised the rule text on March 25, 2003, to express the MCL as 0.010 mg/L (10 µg/L) (EPA, 2003). The final rule requires all community and non-transient, non-community water systems to comply with the new standard by January 23, 2006.

In October 2001, EPA announced an initiative for additional research and development of cost-effective technologies to help small community water systems (<10,000 customers) meet the new arsenic standard, and to provide technical assistance to operators of small systems in order to reduce compliance costs. As part of this Arsenic Rule Implementation Research Program, EPA's Office of Research and Development (ORD) proposed a project to conduct a series of full-scale, on-site demonstrations of arsenic removal technologies, process modifications, and engineering approaches applicable to small systems. Shortly thereafter, an announcement was published in the *Federal Register* requesting water utilities interested in participating in the first round of this EPA-sponsored demonstration program to provide information on their water systems. In June 2002, EPA selected 17 sites from a list of 115 sites to be the host sites for the demonstration studies. The facility at South Truckee Meadows General Improvement District (STMGID) in Washoe County, NV was selected to participate in this demonstration project.

In September 2002, EPA solicited proposals from engineering firms and vendors for cost-effective arsenic removal treatment technologies for the 17 host sites. EPA received 70 technical proposals for the 17 host sites, with each site receiving from one to six proposals. In April 2003, an independent technical panel reviewed the proposals and provided its recommendations to EPA on the technologies that it determined were acceptable for demonstration at each site. Because of funding limitations and other technical reasons, only 12 of the 17 sites were selected for the Round 1 demonstration program. Using the information provided by the review panel, EPA, in cooperation with the host sites and the drinking water programs of the respective states, selected one technical proposal for each site. A granular ferric hydroxide (GFH) adsorptive media system proposed by Siemens (formerly known as USFilter) was selected for demonstration at the STMGID site for the removal of arsenic and antimony from drinking water supplies.

1.2 Treatment Technologies for Arsenic Removal

The technologies selected for the 12 Round 1 EPA arsenic removal demonstration host sites include nine adsorptive media systems, one ion exchange system, one coagulation/filtration system, and one process modification with iron addition. Table 1-1 summarizes the locations, technologies, vendors, and key source water quality parameters of the 12 demonstration sites. An overview of the technology selection and system design for the 12 demonstration sites and the associated capital cost is provided in two EPA reports (Wang et al., 2004; Chen et al., 2004), which are posted on the EPA website at http://www.epa.gov/ORD/NRMRL/wswrd/dw/arsenic/. As of April 2007, 11 of the 12 systems have been operational and the performance evaluations of eight systems have been completed.

Table 1-1. Summary of Round 1 Arsenic Removal Demonstration Sites

Demonstration Site	Technology (Media)	Vendor	Design Flowrate (gpm)	Source Water Quality		
				As (µg/L)	Fe (µg/L)	pH (S.U.)
WRWC (Bow), NH	AM (G2)	ADI	70[(a)]	39	<25	7.7
Rollinsford, NH	AM (E33)	AdEdge	100	36[(b)]	46	8.2
Queen Anne's County, MD	AM (E33)	STS	300	19[(b)]	270[(c)]	7.3
Brown City, MI	AM (E33)	STS	640	14[(b)]	127[(c)]	7.3
Climax, MN	C/F (Macrolite)	Kinetico	140	39[(b)]	546[(c)]	7.4
Lidgerwood, ND	PM	Kinetico	250	146[(b)]	1,325[(c)]	7.2
Desert Sands MDWCA, NM	AM (E33)	STS	320	23[(b)]	39	7.7
Nambe Pueblo Tribe, NM	AM (E33)	AdEdge	145	33	<25	8.5
Rimrock, AZ	AM (E33)	AdEdge	90[(d)]	50	170	7.2
Valley Vista, AZ	AM (AAFS50)	Kinetico	37	41	<25	7.8
Fruitland, ID	IX (A-300E)	Kinetico	250	44	<25	7.4
STMGID, NV	AM (GFH)	Siemens	350	39	<25	7.4

AM = adsorptive media; C/F = coagulation/filtration; IX = ion exchange;
PM = process modification; MDWCA = Mutual Domestic Water Consumers Association;
STMGID = South Truckee Meadows General Improvement District; WRWC = White Rock Water Company;
STS = Severn Trent Services

(a) System reconfigured from parallel to series operation due to reduced flowrate of 40 gpm.
(b) Arsenic existing mostly as As(III).
(c) Iron existing mostly as soluble Fe(II).
(d) System reconfigured from parallel to series operation due to reduced flowrate of 30 gpm.

1.3 Project Objectives

The objective of the Round 1 arsenic demonstration program is to conduct 12 full-scale arsenic removal technology demonstration studies on the removal of arsenic from drinking water supplies. The specific objectives of the demonstration study at STMGID are to:

- Evaluate the performance of the GFH arsenic and antimony removal technology for small systems such as STMGID.
- Determine the required system operation and maintenance (O&M) and operator skill levels.
- Characterize process residuals produced by the technology.
- Determine the capital and O&M cost of the technology.

This report summarizes the performance of Siemens's GFH system at STMGID in Washoe County, NV during the first 32 weeks of operation from September 27, 2005, through May 3, 2006. The types of data collected included system operation, water quality (both across the treatment train and in the distribution system), and capital and preliminary O&M cost.

2.0 SUMMARY AND CONCLUSIONS

Based on the information collected from the first 32 weeks system operation, the following conclusions were made relating to the overall objectives of the treatment technology demonstration study.

Performance of the arsenics and antimony removal technology for use on small systems:

- GFH media can remove arsenic and antimony to below their respective MCLs. The media run length for either contaminant is short, reaching only 7,200 bed volumes (BV) for arsenic and 3,000 BV for antimony. The unexpectedly short media life may have been caused by the presence of high concentrations of silica and phosphorous, which average 72.6 mg/L (as SiO_2) and 0.35 mg/L (as PO_4), respectively, in raw water.
- Results of a laboratory rapid small-scale column test (RSSCT) confirm the performance of the full-scale GFH system and difficulties of treating the STMGID water by adsorptive media.
- Significant reductions in pH (i.e., from 7.1 to < 4.5), alkalinity (i.e., from 92 to < 1.0 mg/L [as $CaCO_3$]), and chlorine residuals (i.e., from 0.8 to 0.2 mg/L [as Cl_2]) were observed in the system effluent during the first several days of system operation, indicating removal of bicarbonate ions and consumption of chlorine by the GFH media.

Required system operation and maintenance and operator skill levels:

- Under normal operating conditions, the system requires little attention from the operator. The daily demand on the operator is typically 30 min for routine activities including visual inspection of the system and recording of operational parameters..
- Operation of the GFH system does not require additional skills beyond those necessary to operate the existing water supply equipment. The system is operated by a State of Nevada certified Level 3 operator.

Process residuals produced by the technology:

- Residuals produced by the GFH system comprise spent media only, which should pass the Toxicity Characteristic Leaching Procedure (TCLP) test and can be disposed of at a landfill for non-hazardous wastes.
- Backwash is not required if the headloss buildup across the media bed is minimal.

Cost of the technology:

- Using the system's rated capacity of 350 gpm (or 504,000 gpd), the capital cost is \$663/gpm (or \$0.46/gpd).
- The cost of media replacement is the most significant add-on operational cost. The cost of replacing 240 ft^3 of GFH media in all three adsorption tanks is estimated to be \$70,550, equivalent to a unit cost of \$5.46/1,000 gal or \$13.10/1,000 gal if the changeout is governed by the 10-µg/L arsenic breakthrough or the 6-µg/L antimony breakthrough, respectively.

3.0 MATERIALS AND METHODS

3.1 General Project Approach

Following the predemonstration activities summarized in Table 3-1, the performance evaluation study of the GFH system began on September 27, 2005. Table 3-2 summarizes the types of data collected and considered as part of the technology evaluation process. The overall system performance was evaluated based on its ability to consistently remove arsenic and antimony (a co-contaminant) to below the respective target MCLs of 10 and 6 μg/L through the collection of weekly and monthly water samples across the treatment train. The reliability of the system was evaluated by tracking the unscheduled system downtime and frequency and extent of repairs and replacement. The unscheduled downtime and repair information were recorded by the plant operator on a Repair and Maintenance Log Sheet.

Table 3-1. Predemonstration Study Activities and Completion Dates

Activity	Date
Introductory Meeting Held	08/20/03
Request for Quotation Issued to Vendor	08/25/03
Draft Letter of Understanding Issued	09/03/03
Final Letter of Understanding Issued	09/19/03
Vendor Quotation Received by Battelle	10/01/03
Purchase Order Completed and Signed	05/13/04
Engineering Package Submitted to Washoe County Health Department	07/26/04
Final Study Plan Issued	09/09/04
Permit Issued by Washoe County Health Department	10/20/04
Building Permit Issued	11/19/04
Building Construction Initiated	11/22/04
Building Construction Completed	03/18/05
Siemens Equipment Shipped to Demonstration Site	03/21/05
Plumbing of Siemens GFH System Completed	04/18/05
Hydraulic Test Suspended due to High Wellhead Pressure that Exceeded Pressure Rating of Adsorption Tanks	04/25/05
Well Pump Reconfiguration Completed	09/06/05
Hydraulic Test and Media Loading Completed	09/14/05
Performance Evaluation Commenced	09/27/05

The O&M and operator skill requirements were evaluated based on a combination of quantitative data and qualitative considerations, including the need for pre- and/or post-treatment, level of system automation, extent of the preventive maintenance activities, frequency of chemical and/or media handling and inventory, and general knowledge needed for relevant chemical processes and related health and safety practices. The staffing requirements for the system operation were recorded on an Operator Labor Hour Log Sheet.

The cost of the system was evaluated based on the capital cost per gal/min (gpm) (or gal/day [gpd]) of design capacity and the O&M cost per 1,000 gal of water treated. This task required tracking of the

Table 3-2. Evaluation Objectives and Supporting Data Collection Activities

Evaluation Objectives	Data Collection
Performance	-Ability to consistently remove arsenic and antimony to below 10 and 6 μg/L, respectively, in treated water
Reliability	-Unscheduled system downtime -Frequency and extent of repairs including a description of problems encountered, materials and supplies needed, and labor and cost incurred
System O&M and Operator Skill Requirements	-Pre- and post-treatment requirements -Level of system automation for system operation and data collection -Staffing requirements including number of operators and laborers -Task analysis of preventative maintenance including number, frequency, and complexity of tasks -Chemical handling and inventory requirements -General knowledge needed of relevant chemical processes and health and safety practices
Residual Management	-Quantity and characteristics of aqueous and solid residuals generated by process
System Cost	-Capital cost for equipment, engineering, and installation -O&M cost for chemical and/or media usage, electricity, and labor

capital cost for equipment, engineering, and installation, as well as the O&M cost for media replacement and disposal, chemical usage, electricity consumption, and labor. The O&M cost was limited to electricity and labor because media replacement did not take place during the first 32 weeks of operation.

3.2 System O&M and Cost Data Collection

The plant operator performed daily, weekly, and monthly system O&M and data collection according to the instructions provided by the vendor and Battelle. On a daily basis, the plant operator recorded system operational data, such as pressure, flowrate, totalizer and hour meter readings on a Daily System Operation Log Sheet; checked the sodium hypochlorite (NaOCl) level; and conducted visual inspections to ensure normal system operations. If any problems occurred, the plant operator contacted the Battelle Study Lead, who determined if the vendor should be contacted for troubleshooting. The plant operator recorded all relevant information, including the problem encountered, course of actions taken, materials and supplies used, and associated cost and labor, on the Repair and Maintenance Log Sheet. On a weekly basis, the plant operator measured several water quality parameters on-site, including pH, temperature, dissolved oxygen (DO), oxidation-reduction potential (ORP), and residual chlorine, and recorded the data on a Weekly On-Site Water Quality Parameters Log Sheet.

The capital cost for the arsenic removal system consisted of the cost for equipment, site engineering, and system installation. The O&M cost consisted of the cost for the media replacement and spent media disposal, chemical usage, electricity consumption, and labor. Labor for various activities, such as the routine system O&M, troubleshooting and repair, and demonstration-related work, were tracked using an Operator Labor Hour Log Sheet. The routine system O&M included activities such as completing field logs, replenishing the NaOCl solution, ordering supplies, performing system inspections, and others as recommended by the vendor. The labor for demonstration-related work including activities such as performing field measurements, collecting and shipping samples, and communicating with the Battelle Study Lead and the vendor was recorded, but not used for the cost analysis.

3.3 Sample Collection Procedures and Schedules

To evaluate the system performance, samples were collected routinely by the opreator from the wellhead, across the treatment plant, and from the distribution system. Table 3-3 provides the sampling schedules and analytes measured during each sampling event. Specific sampling requirements for analytical methods, sample volumes, containers, preservation, and holding times are presented in Table 4-1 of the EPA-endorsed Quality Assurance Project Plan (QAPP) (Battelle, 2003). The procedure for arsenic speciation is described in Appendix A of the QAPP.

3.3.1 Source Water. During the initial site visit on August 20, 2003, one set of source water samples was collected and speciated using an arsenic speciation kit described in Section 3.4.1. The sample tap was flushed for several minutes before sampling; special care was taken to avoid agitation, which might cause unwanted oxidation. Analyses for the source water samples are listed in Table 3-3.

3.3.2 Treatment Plant Water. During the system performance evaluation study, samples were collected by the plant operator weekly, on a four-week cycle, for on- and off-site analyses. For the first week of each four-week cycle, samples taken at the wellhead (IN) and after Tanks A, B, and C combined (TT) were speciated on-site and analyzed for the analytes listed in Table 3-3 for monthly treatment plant water. For the next three weeks, samples were collected at four locations across the treatment train, including IN and after each adsorption tank (i.e., TA, TB, and TC) and analyzed for the analytes listed in Table 3-3 for the weekly treatment plant water. Note that orthophosphate was replaced with total P after January 10, 2006, due to difficulties of meeting the 48-hr holding time requirement for orthophosphate analysis. After four months, the sampling frequency for the monthly samples was reduced to a bimonthly basis and the weekly samples reduced to a biweekly basis. On-site measurements for pH, temperature, DO, and ORP were performed during each sampling event. Samples also were analyzed for free and total chlorine at the after prechlorination (AC) and the TT locations on a weekly basis. Figure 3-1 presents a flow diagram of the treatment system along with the analytes and schedules at each sampling location.

3.3.3 Backwash Water and Residual Solids. Because the system did not require backwash during the first 32-week period, no backwash water and backwash solid samples were collected. Additionally, because media replacement did not take place during this reporting period, there were no spent media samples collected.

3.3.4 Distribution System Water. Samples were collected from the distribution system to determine the impact of the arsenic treatment system on the water chemistry in the distribution system, specifically, the arsenic, antimony, lead, and copper levels. Prior to the system startup from June to September 2004, four sets of baseline distribution water samples were collected from three locations within the distribution system. Following system startup, distribution system sampling continued on a monthly basis at the same locations. The three sampling locations included two residences, which are part of the current STMGID Lead and Copper Rule (LCR) sampling locations, and one newly-installed sampling station, which is located 4,700 ft downstream from Well No. 9 and 500 ft upstream from a blending point where Well No. 9 water blends with water from other wells. The two LCR residences selected are located after the blending point. Figure 3-2 shows a distribution system map and the three distribution system sampling locations.

Home owners assisted by the Washoe County Department of Water Resources (WCDWR) staff collected samples following an instruction sheet developed according to the *Lead and Copper Rule Monitoring and Reporting Guidance for Public Water Systems* (EPA, 2002). First-draw samples were collected from cold-water faucets that had not been used for at least 6 hr to ensure that stagnant water was sampled. The sampler recorded the date and time of last water usage before sampling and the date and time of sample collection for calculation of the stagnation time. Arsenic speciation was not performed on these samples.

Table 3-3. Sampling Schedule and Analyses

Sample Type	Sample Locations(a)	No. of Samples	Frequency	Analytes	No. of Sampling Events
Source Water	At Wellhead (IN)	1	Once (during initial site visit)	Off-site: As (total and soluble), As(III), As(V), Sb (total and soluble), Fe (total and soluble), Mn (total and soluble), Al (total and soluble), V (total and soluble), Mo (total and soluble), Na, Ca, Mg, Cl, F, SO_4, SiO_2, PO_4, TOC, alkalinity, and pH	1
Treatment Plant Water	At Wellhead (IN), after Vessel A (TA), after Vessel B (TB), after Vessel C (TC)	4	Weekly(b)	On-Site: pH, temperature, DO, ORP, and chlorine(c) Off-Site: As (total), Sb (total), Fe (total), Mn (total), P (total), SiO_2, alkalinity, and turbidity	18
	At Wellhead (IN), after Vessels A, B, and C Combined (TT)	2	Monthly(b)	On-Site: pH, temperature, DO, ORP, and chlorine Off-Site: As (total and soluble), As(III), As(V), Sb (total and soluble), Fe (total and soluble), Mn (total and soluble), Ca, Mg, F, NO_3, SO_4, PO_4(e), P (total), SiO_2, alkalinity, and turbidity	6(d)
Distribution Water	Three LCR Locations	3	Monthly	Total As, Sb, Fe, Mn, Cu, and Pb, pH, and alkalinity	Baseline sampling(f): 4 Monthly sampling: 7
Backwash Water	Backwash Discharge Line	3	TBD	As (total and soluble), Sb (total and soluble), Fe (total and soluble), Mn (total and soluble) TDS, TSS, and pH	0
Residual Solids	Spent Media	3 from one vessel	Once	TCLP metals	TBD

(a) Abbreviations in parentheses corresponding to sample locations shown in Figure 3-1.
(b) Sampling frequency reduced to a biweekly/bimonthly basis since 01/31/06.
(c) Weekly at AC and TT only.
(d) Samples also collected at TA, TB, and TC locations.
(e) PO_4 replaced with P (total) analysis beginning January 10, 2006.
(f) Four baseline sampling events performed before system became operational.
TBD = to be determined

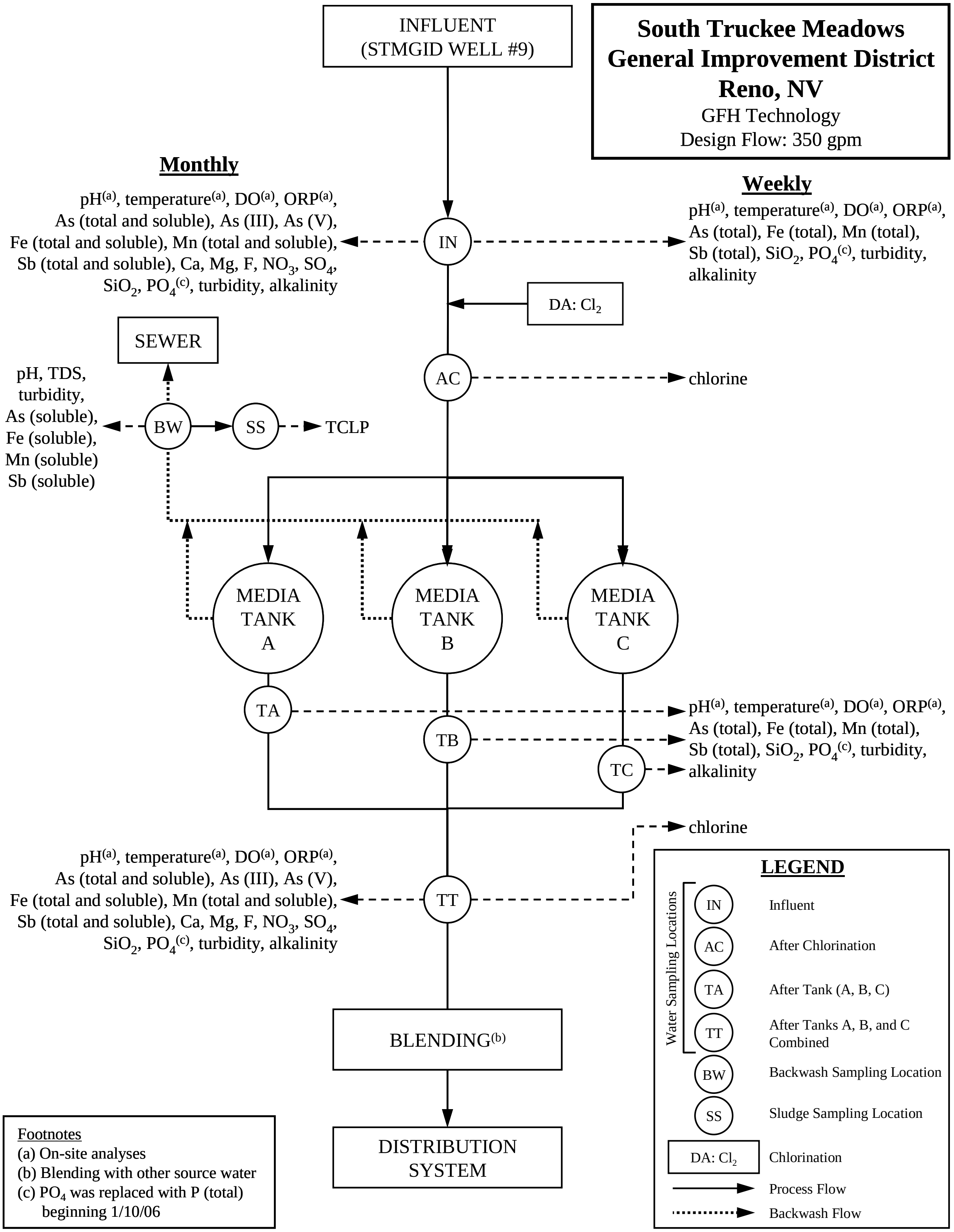
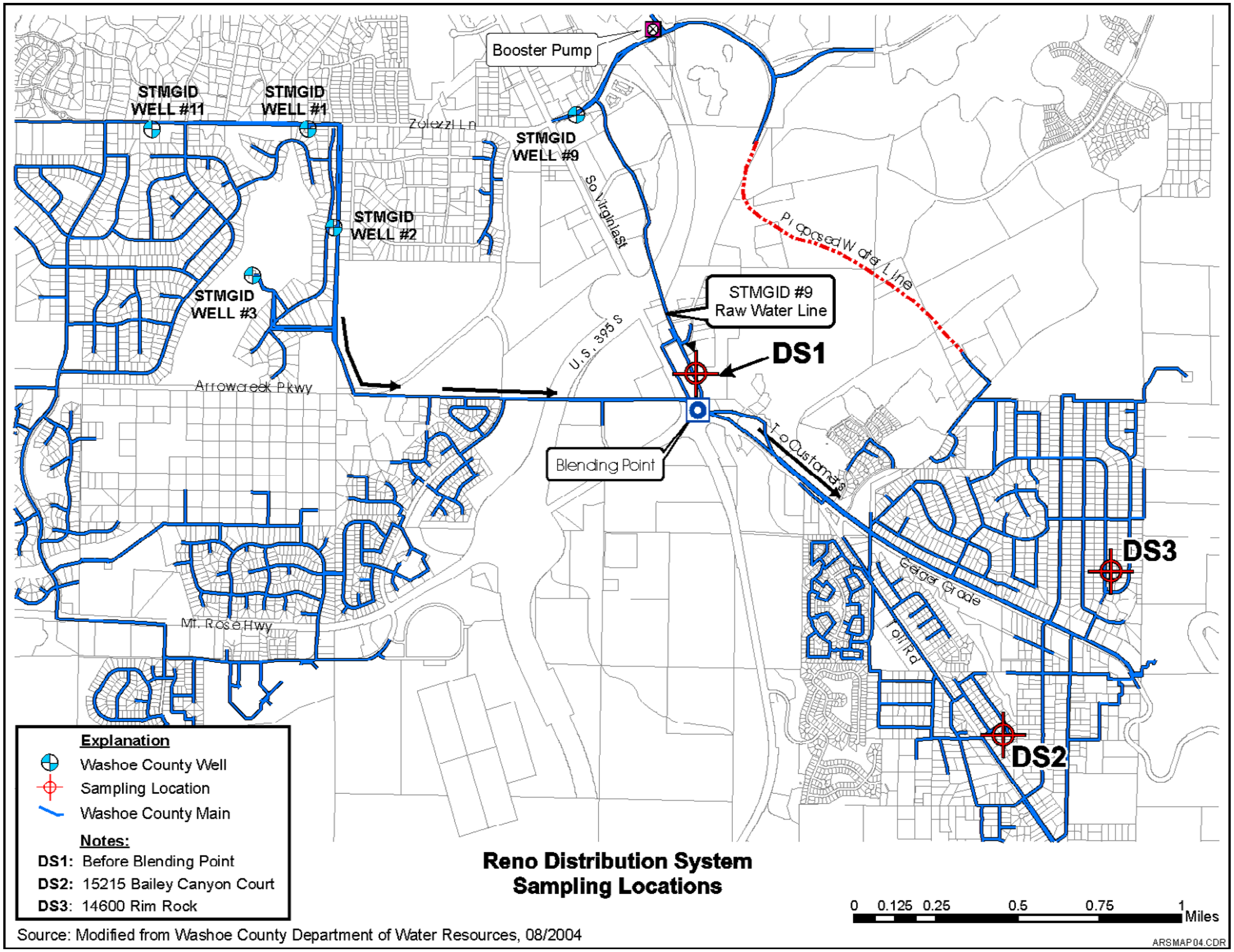


Figure 3-1. Process Flow Diagram and Sampling Locations



Source: Modified from Washoe County Department of Water Resources, 08/2004

Figure 3-2. Distribution Sampling Map (Source: WCDWR)

3.4 Sampling Logistics

All sampling logistics including arsenic speciation kit preparation, sample cooler preparation, and sample shipping and handling are discussed below.

3.4.1 Preparation of Arsenic Speciation Kits. The arsenic field speciation method uses an anion exchange resin column to separate the soluble arsenic species, As(V) and As(III) (Edwards et al., 1998). Resin columns were prepared in batches at Battelle laboratories according to the procedures detailed in Appendix A of the EPA-endorsed QAPP (Battelle, 2003).

3.4.2 Preparation of Sampling Coolers. For each sampling event, a sample cooler was prepared with the appropriate number and type of sample bottles, disc filters, and/or speciation kits. All sample bottles were new and contained appropriate preservatives. Each sample bottle was affixed with a pre-printed, colored-coded, waterproof label consisting of the sample identification (ID), date and time of sample collection, collector's name, site location, sample destination, analysis required, and preservative. The sample ID consisted of a two-letter code for the specific water facility, sampling date, a two-letter code for a specific sampling location, and a one-letter code for designating the arsenic speciation bottle (if necessary). The sampling locations at the treatment plant were color-coded for easy identification. For example, red, orange, yellow, green, and blue were used for IN, TA, TB, TC, and TT sampling locations. The labeled bottles for each sampling location were placed in a ziplock bag (each corresponding to a specific sample location) in the cooler. On a monthly basis, the sample cooler also included bottles for the distribution system sampling.

In addition, all sampling and shipping-related supplies, such as disposable gloves, sampling instructions, chain-of-custody forms, prepaid/pre-addressed FedEx air bills, and bubble wrap, were placed in each cooler. The chain-of-custody forms and air bills were completed except for the operator's signature and the sample date and time. After preparation, the sample cooler was sent to the site via FedEx for the following week's sampling event.

3.4.3 Sample Shipping and Handling. After sample collection, samples for off-site analyses were packed carefully in the original coolers with wet ice and shipped to Battelle. Upon receipt, the sample custodian verified that all samples indicated on the chain-of-custody forms were included and intact. Sample IDs were checked against the chain-of-custody forms, and the samples were logged into the laboratory sample receipt log. Discrepancies noted by the sample custodian were addressed with the plant operator by the Battelle Study Lead.

Samples for metal analyses were stored at Battelle's Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) Laboratory. Samples for other water quality analyses were packed in separate coolers and picked up by couriers from American Analytical Laboratories (AAL) in Columbus, OH and TCCI Laboratories in New Lexington, OH, both of which were under contract with Battelle for this demonstration study. The chain-of-custody forms remained with the samples from the time of preparation through analysis and final disposition. All samples were archived by the appropriate laboratories for the respective duration of the required hold time and disposed of properly thereafter.

3.5 Analytical Procedures

The analytical procedures described in Section 4.0 of the EPA-endorsed QAPP (Battelle, 2003) were followed by Battelle ICP-MS, AAL, and TCCI Laboratories. Laboratory quality assurance/quality control (QA/QC) of all methods followed the prescribed guidelines. Data quality in terms of precision, accuracy, method detection limits (MDL), and completeness met the criteria established in the QAPP (i.e., relative percent difference [RPD] of 20%, percent recovery of 80 to 120%, and completeness of 80%). The quality assurance (QA) data associated with each analyte will be presented and evaluated in a QA/QC Summary Report to be prepared under separate cover upon completion of the Arsenic Demonstration Project.

Field measurements of pH, temperature, DO, and ORP were conducted by the plant operator using a WTW Multi 340i handheld meter, which was calibrated for pH and DO prior to use following the procedures provided in the user's manual. The ORP probe also was checked for accuracy by measuring the ORP of a standard solution and comparing it to the expected value. The plant operator collected a water sample in a clean, plastic beaker and placed the WTW probe in the beaker until a stable value was obtained. The plant operator also performed free and total chlorine measurements using Hach chlorine test kits following the user's manual.

4.0 RESULTS AND DISCUSSION

4.1 Facility Description

STMGID was established in 1981 for the purpose of furnishing water, sanitary sewer, and storm drainage facilities for a portion of the South Truckee Meadows, which is located in southern Washoe County, NV. Currently, STMGID provides water to approximately 8,300 customers (see map of service area in Figure 3-2) via five wells that are operated by WCDWR. The Siemens GFH system is supplied by a 350-gpm well (i.e., Well No. 9) located on South Virginia Street and Damonte Parkway. Drilled in October 1994, Well No. 9 is constructed of 12-in-diameter casing with a 50-ft slotted screen to a total depth of 130 ft. The well pump is a Hays Model 400T-6GP 10-stage submersible pump with a 50-horsepower (hp) three-phase motor set at an approximate depth of 60 ft. Figure 4-1 shows Well No. 9 wellhead and pump house.

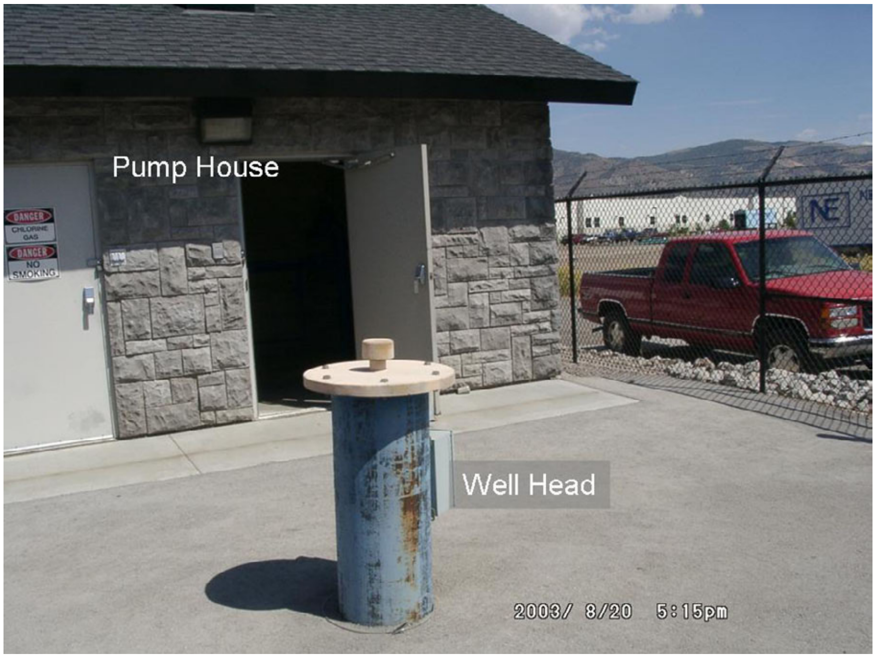


Figure 4-1. Preexisting Well No. 9 Pump House

Figure 4-2 shows the preexisting system housed within the pump house. Water treatment consisted of only chlorination using a gas feed system to reach a target free chlorine residual level of 1.0 mg/L (as Cl_2). Chlorine gas cylinders were kept in a room partitioned from the rest of the pump house for safety and connected to the system piping via underground conduit. The chlorine gas feed rate was regulated at 3.5 lb/day with a panel-mounted automatic switchover rotometer. A dual-cylinder scale was used to monitor the chlorine gas consumption. The chlorine gas was injected to a side stream where a Baldor 1¼-in centrifugal pump with a 2 hp motor was used to create a venturi effect to mix chlorine gas with carrier water. The chlorinated water then was blended with source water prior to entering a one-mile-long transmission main. After reaching the blending station, the treated water was blended with water from four other wells, i.e., Wells No. 11, 1, 2, and 3, before entering the distribution system.

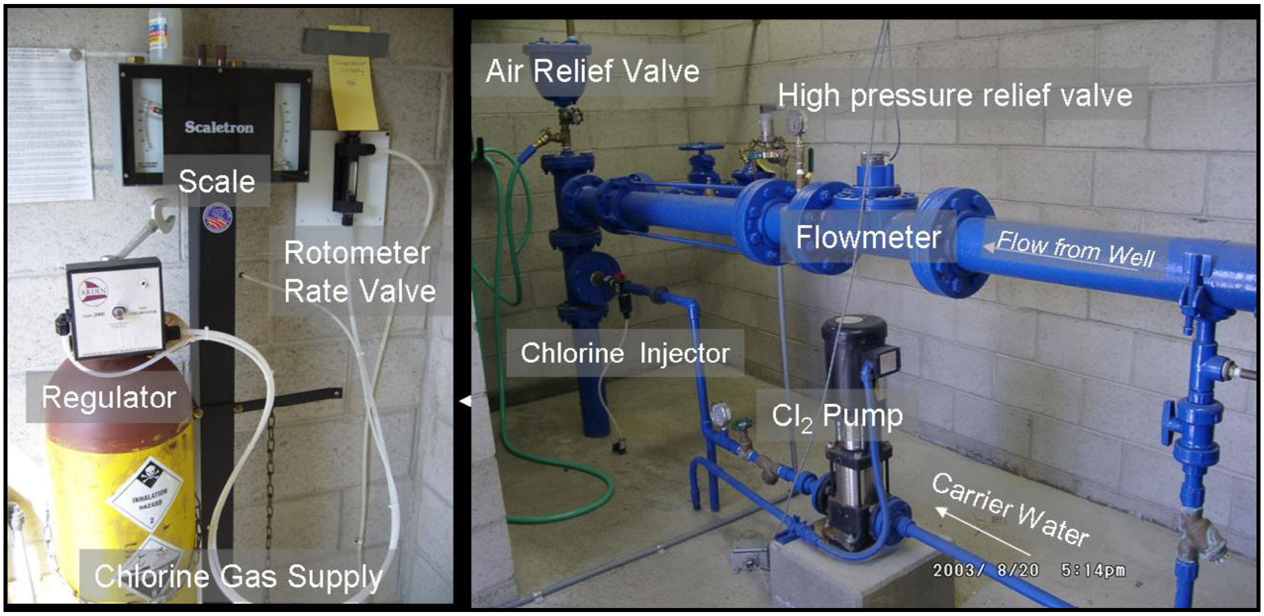


Figure 4-2. Preexisting Wellhead Chlorination System

4.1.1 Source Water Quality. Source water samples were collected at the wellhead of Well No. 9 on August 20, 2003, and analyzed for the analytes shown in Table 3-3. The analytical results, along with those provided by the facility to EPA for the demonstration site selection, obtained by EPA on October 3, 2002, and by the technology vendor in August 2003 in response to EPA's technology solicitation, are presented in Table 4-1. Additional historic source water quality data, including historical high and low results, for the parameters monitored by the facility between 1992 and 2003, are presented in Table 4-2.

Total arsenic and antimony concentrations of the samples obtained by Battelle on August 20, 2003 were 87.9 and 15.8 µg/L, respectively, which were close to the historic high concentrations of 93 and 18 µg/L for these elements. Based on the speciation results, arsenic existed almost entirely as As(V), with only a trace amount, i.e., 0.3 µg/L, existing as As(III). Antimony existed entirely in the soluble form. The data obtained/provided by the facility, EPA, and/or the vendor showed somewhat lower arsenic (ranging from 45 to 79 µg/L). The facility arsenic speciation data were in agreement with Battelle's data, with As (V) being the only species detected. Therefore, the purpose of prechlorination was only to provide chlorine residuals through the treatment train (to prevent biological growth) and to the distribution system.

pH values of source water ranged from 7.4 to 7.5 based on the samples provided/collected by the facility, EPA, the vendor, and Battelle for this demonstration study. The values fell within the range of the historic high and low values, i.e., 7.9 and 6.9, respectively. The GFH adsorptive media selected for this study adsorbs arsenic and, perhaps, antimony more effectively at the lower end of a pH range extending from 5.5 to 8.5. With source water pH values ranging from 6.9 to 7.9 historically and 7.4 to 7.5 within the last several years, no pH adjustment was used at this site.

Competing ions such as silica and phosphate in source water can be adsorbed onto the GFH media, thus reducing its arsenic and antimony removal capacities. Data obtained by Battelle showed 68.6 mg/L of silica (as SiO_2) and <0.1 mg/L of orthophosphate, comparable to the levels reported by all other parties. Silica concentrations were high and most likely would impact the arsenic and antimony adsorption. Published data have shown that silica reduced arsenic adsorptive capacity of ferric oxides/hydroxides and

Table 4-1. Well No. 9 Source Water Quality Data

Parameter	Unit	STMGID [(a)]	EPA	Siemens	Battelle
Sampling Date	–	Not specified	10/03/02	Aug. 2003	08/20/03
pH	–	7.4	NS	7.5	7.4
Total Alkalinity (as $CaCO_3$)	mg/L	85.0	96.0	NS	100.0
Total Hardness (as $CaCO_3$)	mg/L	32.0	23.0	20	17.1
Chloride	mg/L	5.0	9.4	14	10.0
Fluoride	mg/L	NS	NS	NS	0.1
Sulfate	mg/L	28.0	8.4	23	8.0
Silica (as SiO_2)	mg/L	NS	66.0	52.5	68.6
Orthophosphate (as PO_4)	mg/L	0.16[(b)]	NS	NS	<0.10
TOC	mg/L	NS	NS	NS	<1.0
As (total)	µg/L	45.0	79.0	>70	87.9
As (total soluble)	µg/L	NS	NS	NS	89.4
As (particulate)	µg/L	NS	NS	NS	<0.1
As(III)	µg/L	<2.0	NS	NS	0.3
As(V)	µg/L	45.0	NS	NS	89.1
Sb (total)	µg/L	NS	<25	NS	15.8
Sb (soluble)	µg/L	NS	NS	NS	15.8
Fe (total)	µg/L	20.0	5.0	6	<30
Fe (soluble)	µg/L	NS	NS	NS	<30
Al (total)	µg/L	NS	<25	NS	<10
Al (soluble)	µg/L	NS	NS	NS	<10
Mn (total)	µg/L	<10.0	<0.4	3	0.1
Mn (soluble)	µg/L	NS	NS	NS	< .1
V (total)	µg/L	NS	NS	NS	3.0
V (soluble)	µg/L	NS	NS	NS	3.0
Mo (total)	µg/L	NS	NS	NS	< .1
Mo (soluble)	µg/L	NS	NS	NS	< .1
Na (total)	mg/L	30.0	37.2	113	36.4
Ca (total)	mg/L	8.0	6.0	16	5.1
Mg (total)	mg/L	3.0	1.9	4	1.7

(a) Data to EPA for demonstration site selection.
(b) Data provided by EPA.
NS = not sampled.

activated alumina (Smith et al., 2005; Meng et al., 2000; Meng et al., 2002); the effect of silica was most noticeable at pH 8 or above. As such, the effect of silica was carefully monitored during this study.

Source water from Well No. 9 had low or less than detectable concentrations of iron, manganese, aluminum, vanadium, molybdenum, sodium, calcium, magnesium, chloride, fluoride, sulfate, and total organic carbon (TOC).

4.1.2 Distribution System. As shown on the distribution map in Figure 3-2, the distribution system at the eastern half of the STMGID site is supplied by five wells, including Wells No. 1, 2, 3, 9, and 11. (Note that there are five other independently-operated wells, i.e., Well No. 4, 5, 6, 7, and 8, in the western half of STMGID) Water feeding the GFH system was supplied by Well No. 9 only. Water from Well No. 9 is transported through a 6-in diameter, 5,000-ft long polyvinyl chloride (PVC) transmission line to a blending point where it is blended with water from the other four

Table 4-2. Summary of Historic Well No. 9 Water Quality Data

Constitute	Unit	Year 2003	Historic High (1992–2003)	Historic Low (1992–2003)
Primary Standards				
Antimony	μg/L	17	18	6
Arsenic	μg/L	80	93	18
Barium	mg/L	0.05	0.06	0.01
Beryllium	μg/L	<1	<1	<1
Cadmium	μg/L	<1	<1	<1
Chromium	μg/L	1	2	<1
Cyanide	μg/L	<5	<5	<5
Fluoride	mg/L	0.04	0.17	0.02
Mercury	μg/L	<0.5	<0.5	<0.5
Nickel	μg/L	<1	<1	<1
Nitrate (as N)	mg/L	0.9	2.3	0.6
Nitrite (as N)	mg/L	<0.01	<0.01	<0.01
Selenium	μg/L	<1	<1	<1
Thallium	μg/L	<0.5	<0.5	<0.5
Secondary Standards				
Chloride	mg/L	8	9	3
Color	–	3	5	3
Copper	mg/L	0	0.04	<0.01
Fluoride	mg/L	0.04	0.17	0.02
Iron	mg/L	0.02	0.07	<0.01
Magnesium	mg/L	2	3	0
Manganese	mg/L	<0.01	<0.01	<0.01
pH	–	7.2	7.9	6.9
Sulfate	mg/L	8	9	6
Zinc	mg/L	0.01	0.03	<0.01
TDS	mg/L	177	195	160
Additional Constituents				
Lead	μg/L	<5	<5	<5
Hardness	mg/L	37	37	21
Calcium	mg/L	10	10	5
Potassium	mg/L	5	6	2
Sodium	mg/L	27	45	26
Silica	mg/L	70	81	65

Data Source: Washoe County Department of Water Resources

wells (i.e., Wells No. 11, 1, 2, and 3) at a combined flowrate of approximately 1,400 to 1,500 gpm. Due to elevated arsenic and antimony concentrations, Well No. 9 was operated under a bilateral compliance agreement with local regulators. According to the agreement, WCDWR must collect water quality samples from the wellhead for arsenic and antimony analyses weekly when the well is in operation. Prior to the demonstration study, to save analytical and data reporting costs, the well was not operated during periods of low demand, which normally extended from the beginning of November through the end of February the following year.

After the blending point, water flows through a 16-in ductile iron transmission main to connect to the distribution system and then to one 500,000- and one 750,000-gal storage tank. The distribution system consists of 8- to 12-in ductile iron, PVC, and asbestos cement pipe. The residential service lines are constructed of ¾-in high-density polyethylene (HDPE) with some commercial and irrigation service lines using 1- to 2-in copper pipe.

4.2 Treatment Process Description

The Siemens adsorption system uses GFH, a granular ferric hydroxide media, for arsenic and antimony removal from drinking water supplies. Produced by GEH Wasserchemie Gmbh, the media is imported from Germany and marketed by Siemens under an exclusive marketing agreement. It can remove both As(V) and As(III), but the capacity for As(III) is much less than that for As(V). It also can remove other oxyanions, such as antimony, chromium, phosphate, selenium, and vanadium. The media life for arsenic and antimony removal relies on factors, such arsenic and antimony concentrations, raw water pH value, and the presence of other competing anions. GFH has a pH operating range of 5.5 to 8.5 with the removal capacity increasing with decreasing pH. Competing ions such as silica and phosphate are known to adsorb onto the GFH media and reduce the arsenic removal capacity of the media (Meng et al., 2000; Meng et al., 2002). Once exhausted, the media is removed from the vessel and replaced with new media. The spend media can be disposed of as a non-hazardous waste after passing the TCLP test. This single use media approach eliminates the needs for on-site storage of regeneration chemicals and any issues related to the handling, storage, and disposal of concentrated regeneration wastes. The GFH media has received NSF International Standard 61 listing for use in drinking water applications. The physical and chemical properties of the media are presented in Table 4-3. Figure 4-3 is a photograph of the media.

Table 4-3. Physical and Chemical Properties of GFH Adsorptive Media

Physical Properties	
Parameter	**Value**
Matrix	β-ferric oxyhydroxide and ferric hydroxide
Physical Form	Granular
Color	Dark-brown to black
Bulk Density (kg/L)	1.15
Bulk Density (lb/ft^3)	71.8
Moisture Content (%)	47
Grain Size (mm)	0.3–2.0
Adsorption Density (g/kg)	>8 based on wet weight
Chemical Properties	
Constituent	**Typical Value**
Fe (%)	61
As (mg/kg)	<10
Cd (mg/kg)	<5
Pb (mg/kg)	<10
Cu (mg/kg)	30
Cr (mg/kg)	100
Ni (mg/kg)	100
Zn (mg/kg)	100
Mn (mg/kg)	1,500

Source: Siemens

A standard GFH system consists of two or more vertical pressure vessels with factory installed internals for distribution and collection of effluent and backwash flows. The media vessels can be placed in either parallel or series configuration. According to the vendor, if a consistent 90% reduction is needed across the system, the series design is used. The parallel design is typically used if the percent reduction needed

Source: Siemens

Figure 4-3. A Photograph of GFH Media

is less than 90%. The treatment system at the STMGID site consists of three vertical pressure vessels configured in parallel with each vessel treating approximately one-third of the incoming flow.

The site-specific design features of the GFH arsenic removal system are summarized in Table 4-4. A generalized flow chart for the treatment process and sampling locations is shown in Figure 3-1. Key process steps and major system components are discussed as follows:

- **Intake**. Raw water pumped from Well No. 9 was prechlorinated before being fed into the GFH arsenic removal system. The peak flow rate was estimated to be 350 gpm. The existing wellhead pressure was approximately 180 pounds per square inch (psi), which was higher than the 100-psi pressure rating of the adsorption tanks. Therefore, the well pump had to be reconfigured to produce a pressure of less than 100 psi at the filter inlet. The well pump reconfiguration is further discussed in Section 4.3.3.

- **Prechlorination**. Prechlorination with chlorine gas was used to provide chlorine residuals through the treatment train (to prevent biological growth) and in the distribution system. Figure 4-2 presents photographs of the pre-chlorination system, which was located in the preexisting pump house. The chlorine gas feed rate was 3.5 lb/day and controlled by a panel-mounted automatic switchover rotometer. A dual-cylinder scale was used to monitor the chlorine gas consumption. The chlorine gas was injected to a side stream where it was mixed with carrier water prior to being drawn into the main line. The chlorinated water was then flown to the adsorption vessels in a nearby building constructed to house the treatment system. A sample tap was installed (“AC”) on a common feed line to the adsorption tanks to collect chlorinated water prior to treatment by the GFH system.

- **Adsorption System**. The GFH system was a fixed bed down-flow adsorption system consisting of three 66-in-diameter by 72-in straight-side-height vertical pressure vessels fabricated of carbon steel (Figure 4-4). Each vessel contained 80 ft^3 of GFH media supported by a 2 to 3 mm (with a 1.6 uniformity coefficient) underbedding gravel. The skid-mounted filter vessels were operated in parallel and rated for 100 psi of working pressure. A 20-hp booster pump was installed to boost the effluent pressure back to the preexisting levels of approximately 180 psi (Figure 4-5). The system includes a header lateral underdrain with media retaining strainers, front piping, fittings, valves, and meters.

Table 4-4. Design Specifications of GFH System

Parameter	Value	Remarks
Pretreatment		
Chlorine Dosage (lb/day as Cl_2)	3.5	Prechlorination with chlorine gas for target free chlorine residual of 1.0 mg/L (as Cl_2)
Adsorbers		
Number of Vessels	3	
Configuration	Parallel	
Vessel Size (in)	66 D × 72 H	Vessel height at straight side shell
Type of Media	GFH	
Quantity of Media (ft^3/vessel)	80	240 ft^3 total
Media Depth (in)	40	
Backwash		
Backwash Flowrate through Each Vessel (gpm)	285	
Backwash Hydraulic Loading Rate (gpm/ft^2)	12	
Backwash Duration (min)	15–20	
Backwash Frequency (times/month)	1–2	
Adsorption System		
Peak Flowrate (gpm)	350	
Flowrate through Each Vessel (gpm)	117	
EBCT (min/vessel)	5.1	Based on peak flow
Average Use Rate (gpd)	336,000	Based on 16 hr of daily operation at 350 gpm
Daily Throughput (BV/day)	187	1 BV = 240 ft^3 = 1,795 gal
Estimated Working Capacity (BV)	38,000	
Estimated Volume to Breakthrough (gal × 10^6)	68.2	Based on 10-µg/L As breakthrough
Estimated Media Life (day)	203	Estimated frequency of changeout at 75% utilization

- **Backwash.** The adsorption vessels are taken off line one at a time for upflow backwash using treated water to remove particulates and media fines and prevent media compaction. Backwashing can be initiated manually, semi-automatically, and automatically. The system at the STMGID, NV site is operated in the semi-automatic mode: the PLC sounds an alarm when it receives a high differential pressure signal across the adsorption tanks or a time elapsed signal from the adjustable clock and the operator acknowledges the alarm and initiates the backwash cycle. During a backwash event, the effluent from the two vessels in the service mode is used to backwash the third. All vessels are backwashed sequentially using treated water from the storage tank. The backwash water produced is discharged to the sanitary sewer (Figure 4-6). A backwash flowrate and a loss of head gauges are installed in the front piping. The backwash flowrate gauge is provided with a 6 in diameter standard weight pipe flange and installed to the end of the GFH system backwash waste header piping with standard flange gasket and mounting bolts.

Figure 4-4. Siemens GFH Arsenic/Antimony Removal System

Figure 4-5. A New Booster Pump Station

Figure 4-6. Backwash Discharge

- **Programmable Logic Controller.** A control panel was provided for automated system control (Figure 4-7). This panel was interfaced with the local system control and data acquisition (SCADA) enclosure as a means for remote communication. The filter system can be operated locally from the operator interface terminal. Each adsorption vessel has two electronically actuated butterfly valves and one manual butterfly valve with handwheel actuator for the process flow control. The electronically actuated valves are the influent valve and the backwash waste valve. The manual valve is the effluent valve, which remains open. Pressure gauges were used to monitor the system pressure and pressure drop across each vessel and the treatment train. In addition, a flowmeter/totalizer was installed in the effluent line of each adsorption vessel to monitor the flowrate and track the volume throughput through each vessel (Figure 4-8).

- **Media Replacement**. When the adsorptive capacity of the GFH media is exhausted, the spent media will be taken out of the vessels for disposal and replaced with virgin media. According to Siemens, the media changeout was estimated to take place once every 203 days based on the water analysis and a 75% water usage rate. The actual run length of the media was determined based on the results of the performance evaluation study as discussed in Section 4.5.

Figure 4-7. Programmable Logic Controller

Figure 4-8. Third Pressure Vessel and Associated Plumbing and Monitoring Components

4.3 Permitting and System Installation

The following summarizes permitting, building construction, and system installation, shakedown, and startup activities.

4.3.1 Permitting. WCDWR prepared engineering plans and permit submittals for the project using input from Siemens, such as system specifications and process and instrumentation diagrams (P&IDs). The plans included site engineering drawings, equipment tie-ins, and site plans. The submittals were certified by a State of Nevada-registered professional engineer (PE) and sent to the Washoe County Department of Health for review and approval. The approval was submitted on July 26, 2004, and granted by Washoe County Department of Health on October 20, 2004.

4.3.2 Building Construction. A building was constructed by STMGID to house the GFH system. A photograph of the treatment building and pump house is shown in Figure 4-9. The construction bid for the building was awarded on September 28, 2004. Construction of the building was delayed because the building contractor did not submit the adequate bonding paperwork for building permit application. Siemens stored the equipment at its Ames, IA facility until the construction was completed and delivery of the equipment could be scheduled. Upon payment of building permit fees on October 25, 2004, the building permit was granted. Building construction began on November 22, 2004, and was completed the week of March 14, 2005. The free-standing building constructed of concrete masonry unit (CMU) blocks measured 32 ft × 18 ft, with an interior wall height of 14 ft and a 3 tab asphalt shingle roof. Due to the close proximity to a commercial shopping center, the pump house and treatment building had stone/stucco exterior and/or a stone water table to match the architecture style of the neighborhood. The building had one walk-through door and an 8-ft × 12-ft rollup door.

Figure 4-9. New Treatment Building and Preexisting Well Pump House

4.3.3 Installation, Shakedown, and Startup. The equipment for the GFH system arrived at the site on March 21, 2005, and installation began immediately after the system off-loading (Figure 4-10). The well riser pipe and the system inlet piping did not match; therefore, a custom piece had to be constructed to connect the system and the well. Plumbing of the GFH system was completed on April 18, 2005, by Siemens's subcontractor, Christman Construction. The system was originally scheduled for hydraulic testing before the media loading; however, the hydraulic testing and media loading had to be put off because it was discovered that the wellhead pressure exceeded the 100-psi pressure rating of the adsorption vessels. As a result, the wellhead pressure had to be reduced before the adsorption vessels could be hydraulically tested and subsequently operated. Meanwhile, Siemens collected one gal of the media that had been stored at the site since October 2004 for precautionary testing and determined that the moisture content of the media was not impacted due to the long term storage.

Figure 4-10. Delivery of One Adsorption Vessel

Reduction of wellhead pressure was achieved by well pump reconfiguration, which was undertaken by WCDWR with partial funding provided by EPA. From April to July 2005, WCDWR pursued required funding and contractors to perform the well pump modification. The well pump reconfiguration work extended from August 29, 2005, through September 6, 2005. The work included removing the existing submersible well pump and motor and associated piping and electrical wiring from the well casing, removing four stages from the pump, trimming one or more impellers to achieve a new pump design operating point of 285 ft total dynamic head at 305 gpm, and reinstalling the pump and appurtenances into the well. The reconfigured well pump produced a maximum pressure of 100 psig. A Goulds 4-in booster pump with a Baldor 20-hp motor and a check valve was installed on the filter discharge piping to boost the pressure back to 180 psi. The booster pump and associated electrical work was completed by September 6, 2005. The existing SCADA system was modified to control the well and booster pump. In addition to the initial engineering design, WCDWR also performed final construction inspections.

Following the modification, Siemens's subcontractor returned to the site on September 12, 2005, to perform hydraulic testing and media loading. The hydraulic testing was conducted by initiating the flow through each vessel, partially closing the discharge valve, adjusting the flow to approximately 100 gpm, and measuring the inlet, outlet, and differential pressure across each vessel and the system. The results of the hydraulic testing on the empty vessels indicated minimal pressure drop across each vessel and the system at a combined flowrate of 300 gpm, and an evenly balanced flow across each of the three vessels.

The media was loaded following the hydraulic testing. The support media was first installed to a depth of 12 in. Water was added to the vessel to a depth of approximately 3 ft above the top of the support media and the GFH media was then loaded to a depth of about 40 in. Due to lack of a roof hatch, the media loading was conducted manually and took three days to complete. The media loading was followed by initial backwash that was performed at half of the normal backwash flowrate for 30 to 45 min. The loading of gravel and GFH media was completed on September 14, 2005. The system was subsequently disinfected with a 5.25% NaOCl solution on September 15, 2005, and bacterial samples were collected on September 16, 2005. The bacterial results passed; however, the PLC did not function properly so the system could not be put into service. The Siemens technician returned to the site on September 19, 2005, to complete the startup and perform O&M training. The technician reprogrammed the PLC to interface with the SCADA system so that the well pump, treatment system, and booster pump might work together in the service mode.

Battelle made a site visit on September 23, 2005, to conduct system inspections and operator training for sampling and data collection. Further, upon careful inspections of the system, a punch list was developed and summarized as follows:

- Revise PLC program to enable automatic backwash.
- Replace six 0-100 psig pressure gauges with 0-150 psig gauges to enable measurements of the system pressure, which was slightly above 100 psig.
- Adjust the PLC totalizer screen to display throughput readings properly.
- Increase the pressure set point for automatic backwash from 3 psi to 7 psi.

The Siemens technician returned to the site the week of September 26, 2005. The first set of water samples was collected on September 27, 2005, indicating the commencement of the performance evaluation study at the STMGID site. The items on the punch list were addressed during a site visit by the Siemens technician on October 11 to 12, 2005. One exception was that the backwash totalizer did not display properly on the PLC screen. The backwash totalizers were connected to the PLC by the Siemens technician during a later site visit, which took place on December 22, 2005.

4.4 System Operation

4.4.1 Operational Parameters. The system operational parameters are tabulated and attached as Appendix A. Key parameters are summarized in Table 4-5. From September 27, 2005, through May 3, 2006, the treatment system operated for approximately 943 hr based on hour meter readings of the well pump. The system operating schedule varied during this 32-week study period. In the first three weeks, the system ran for 18 days, with daily operating hours ranging from 4.0 to 22.1 hr/day and averaging 13.8 hr/day. The system was operated for longer periods of time during startup, but the daily operating time was decreased following a decrease in water demand. During the following four and a half weeks, the system ran for 16 days, with daily operating hours ranging from 1.2 to 6.8 hr/day and averaging 3.6 hr/day. Starting from November 18, 2005 (except for the three-week duration from December 17, 2005, through January 6, 2006, when the system was shut down to make repairs as described in Section 4.4.4), the system began operating daily (including weekends), with daily operating hours ranging from 1.7 to 9.7 hr/day and averaging 3.8 hr/day.

The total system throughput during this 32-week period was 15,567,000 gal, equivalent to 8,677 BV of water processed through the entire system. Note that BV for the system was calculated based on a total of 240 ft^3 (or 1,795 gal) of media in the three adsorption vessels. The total flow processed through the system was based on the sum of the throughputs through each of the three vessels measured with individual totalizers. Individually, the number of BV processed through each vessel was slightly different (i.e., 9,033, 8,390, and 8,609 BV for Vessels A, B, and C, respectively) due to uneven flow distributed through each vessel. The total system throughput thus obtained was only 1.2% lower than that from the master totalizer at the wellhead.

The average flowrates measured by individual flowmeters installed on Vessels A, B, and C were 95, 89, and 91 gpm, respectively. These values were comparable to calculated average flowrates (i.e., 96, 88, and 90 gpm) from readings generated by the individual totalizers and well-pump hour meter. Thus, the flowmeters/totalizers installed on the adsorption vessels appeared to be calibrated accurately. The range of flowrates through the entire system was 205 to 333 gpm, with an average of 275 gpm (compared to the design flowrate of 350 gpm). This resulted in an EBCT range between 5.4 to 8.7 min with an average of 6.5 min (compared to the design EBCT of 5.1 min). Based on the average flowrate and average daily operating time, the average volume of water treated each day under normal system operations was 62,700 gpd (Table 4-5).

Table 4-5. Summary of Siemens GFH System Operations

Operational Parameter	Value
Total Operating Time (hr) – from 09/27/05 to 05/03/06	943
Average Daily Operating Time (hr/day)(a)	3.8
Throughput Based on Master Flow Totalizer (gal)	15,753,000
Throughput Based on Individual Totalizers (gal)	15,567,000
Throughput (BV)(b)	8,677
Range of Flowrate (gpm)	205–333
Average Flowrate (gpm)	275
Range of Daily Use Rate (gpd)(a)	46,740-75,924
Average Daily Use Rate (gpd)(a)	62,700
Range of EBCT (min)(b)	5.4–8.7
Average EBCT (min)(b)	6.5

(a) Calculated based on operational data collected during normal system operations starting from November 18, 2005 (except for a three-week duration when system was shut down for repairs).

(b) Calculated based on combined throughput from individual totalizers and 240 ft^3 (or 1,795 gal) of media in three vessels.

The pressure loss across each tank ranged from 0 to 1.9 psi. The average influent pressure reading at the head of the system was 102.8 psi, and the average pressure reading at the combined effluent was 100.8 psi. Thus, the total pressure loss across the system averaged 2.0 psi.

4.4.2 Backwash. Siemens recommended that the GFH arsenic treatment system be backwashed, either manually or automatically, approximately once every 2 to 6 weeks. Automatic backwash could be initiated either by timer or by differential pressure across the vessels. The timer set point was set at the maximum time allowable, which was 630 hr. Due to the steady pressure in the vessels, the system was backwashed only once to test the automatic backwash system about one month after the system startup with only 219 hr of operating time.

4.4.3 Residuals Management. The only residuals produced by the operation of the GFH treatment system would be backwash wastewater and spent media. The backwash wastewater is discharged to the sewer directly. The media was not replaced during the first 32 weeks of operation.

4.4.4 System Operation, Reliability and Simplicity. In general, operation of the GFH system did not require additional skills beyond those necessary to operate the existing water system. However, several problems related to the PLC and system components arose during this 32-week study period. Additional discussions regarding system operation and operator skill requirement follow:

Pre- and Post-Treatment Requirements. The majority of arsenic at this site existed as As(V), therefore, a preoxidation step was not required. However, prechlorination was provided to prevent biological growth in the treatment system and maintain chlorine residuals in the disinfection system.

System Controls. The Siemens GFH system is fitted with automated controls to allow for automatic backwash. During system startup, the system was tested but failed to perform automatic backwash because the PLC did not interface with the SCADA system properly. When the system initiated a backwash cycle, the backwash valves would completely close for 5 to 10 sec as the system attempted to backwash the next vessel in line. The closed valves caused the system pressure to spike, which, in turn, caused the well pump to shut off, resulting in an aborted backwash. The SCADA design included a high pressure well shutoff when a pressure of 125 psi is maintained for more than 5 sec. The PLC program was revised to eliminate the time delay between valves closing and opening in order to prevent the spike in the system pressure. The vendor instructed the facility operator to exercise the valves on a routine basis to prevent sticking. A subsequent site visit also was required to ensure the backwash totalizer reading would be displayed on the PLC screen during backwash.

Another problem encountered was that the pneumatic butterfly valves associated with the backwash discharge line were not resting properly, causing the vessels to bleed off pressure as they sat idle. The existing chlorine gas system has a check valve that is held closed by the pressure in the inlet piping to the vessels. When the pressure was lost, the check valve opened, allowing water to enter the chlorine gas lines. The system was turned off for three weeks during December 17, 2005, through January 6, 2006, while Siemens serviced the butterfly valves and replaced the chlorine gas lines.

Operator Skill Requirements. The State of Nevada has an operator certification program that applies to all persons who operate community or non-transient, non-community public water systems and to persons who operate transient non-community systems that utilize surface water as a source. Grade levels of operator certification start at a minimum grade of 1 and progress to grade 4. The grade level required is determined by the complexity of the system, such as the population served, type of source water, disinfection method, treatment for contaminants, and other factors.

Prior to the treatment system being installed, the preexisting plant required a Grade 2 distribution system operator (i.e., D-2). The Siemens GFH system was operated by a Grade 3 operator in both treatment and distribution systems (i.e., D-3 and T-3). A Grade 3 operator requires several postsecondary courses of instruction, such as successful completion of 36 hr college level courses related to drinking water. Under normal operating conditions, no additional skills were required beyond those necessary to operate the existing water supply equipment. However, as described above, some initial adjustments to the PLC made by the Siemens technician were required to achieve the desired interface with the SCADA and correct readings on the display screen.

Preventative Maintenance Activities. The only regularly scheduled preventative maintenance activity recommended by the vendor was to exercise the backwash valves occasionally so that they might function properly in case backwash was needed. The treatment system operator visited the site about five times per week and stayed for about 30 min each time to check the system for leaks, and record flow, volume, and pressure readings.

4.5 System Performance

The system performance was evaluated based on analyses of samples collected from the treatment and distribution systems.

4.5.1 Treatment Plant. Table 4-6 summarizes the results of arsenic, antimony, and three competing anions for samples collected across the treatment train. Table 4-7 summarizes the results of other water quality parameters. Appendix B contains a complete set of analytical results through the 32-week operation. The results of the treatment plant sampling are discussed as follows.

Arsenic. The key parameter for evaluating the effectiveness of the GFH adsorption system was the concentration of arsenic in the treated water. The treatment plant water was sampled on 25 occasions during the first 32 weeks of system operation (including one event with duplicate samples taken), with field speciation performed on six occasions.

As shown on Table 4-6, total As concentrations in raw water ranged from 35.0 to 88.0 µg/L and averaged 67.2 µg/L. Arsenic existed primarily as As(V), with trace amounts, i.e., 0.3 and 1.2 µg/L, present as As(III) and particulate, respectively (see Figure 4-11 for detailed arsenic speciation results). Figure 4-12 shows the influent (IN) total arsenic concentrations plotted against the number of bed volumes of water processed through each vessel and the entire system at the time of sampling. (Note that one BV equals to the combined volume of three parallel adsorptive media beds at 240 ft^3 or 1,795 gal.) The influent arsenic concentrations measured during this period showed a steadily increasing trend, rising from 35.0 µg/L at the system startup to 88.0 µg/L by the end of this study period. The highest arsenic concentration observed was close to the historic high concentration of 93 µg/L. It is not clear why the arsenic concentrations continued to rise as observed.

Figure 4-12 also plots the total arsenic concentration measured after each vessel at TA, TB, and TC and after the entire system at TT. WCDWR took TT samples for arsenic analysis by Sierra Environmental Monitoring Laboratory (Reno, NV) and the results also are presented in the graph. In general, WCDWR's data matched closely with Battelle's data, except for two high data points observed just before and after the 2,000-BV mark. As shown in the figure, all three adsorption vessels initially removed arsenic to <0.5 µg/L and the effluent from the individual vessels and entire system remained less than 10 µg/L until the system had processed approximately 7,200 BV of water, which was significantly less than the estimated capacity of 38,000 BV. The short run length observed was believed to be the result of competitive adsorption by competing anions, such as silica and phosphorous. The effects of these anions are further discussed in the following sections.

Arsenic speciation results for samples taken on three occasions at TA, TB, and TC and six occasions at TT are presented in four bar charts shown in Figure 4-11. Except for a few cases, As(V) was the predominating species in the treated water. As(III) in raw water remained essentially untreated, with 0.3 µg/L (on average) entering the system and 0.2 to 0.3 µg/L coming out of the system.

Table 4-6. Summary of Analytical Results for Arsenic, Antimony, and Three Competing Anions

Parameter	Sampling Location	Unit	Number of Samples	Concentration			Standard Deviation[(a)]
				Minimum	Maximum	Average[(a)]	
As (total)	IN	µg/L	25	35.0	88.0	67.2	13.0
	TA	µg/L	25	0.2	25.1	-	-
	TB	µg/L	25	0.1	20.0	-	-
	TC	µg/L	25	<0.1	19.8	-	-
	TT	µg/L	10	0.2	21.6	-	-
As (soluble)	IN	µg/L	6	29.5	79.7	60.0	17.4
	TA	µg/L	3	0.7	1.4	-	-
	TB	µg/L	3	0.2	0.7	-	-
	TC	µg/L	3	0.3	0.8	-	-
	TT	µg/L	6	0.1	8.4	-	-
As (particulate)	IN	µg/L	6	<0.1	5.5	1.2	2.2
	TA	µg/L	3	<0.1	1.1	-	-
	TB	µg/L	3	<0.1	0.9	-	-
	TC	µg/L	3	0.2	1.1	-	-
	TT	µg/L	6	<0.1	0.5	-	-
As (III)	IN	µg/L	6	0.2	0.4	0.3	0.1
	TA	µg/L	3	0.2	0.3	-	-
	TB	µg/L	3	0.2	0.3	-	-
	TC	µg/L	3	<0.1	0.3	-	-
	TT	µg/L	6	<0.1	0.3	-	-
As (V)	IN	µg/L	6	29.1	79.4	59.7	17.4
	TA	µg/L	3	0.3	1.1	-	-
	TB	µg/L	3	<0.1	0.5	-	-
	TC	µg/L	3	<0.1	0.6	-	-
	TT	µg/L	6	<0.1	8.3	-	-
Sb (total)	IN	µg/L	25	10.2	21.0	14.6	2.1
	TA	µg/L	23	0.2	14.5	-	-
	TB	µg/L	23	0.1	14.6	-	-
	TC	µg/L	23	0.1	14.5	-	-
	TT	µg/L	10	0.5	14.0	-	-
Sb (soluble)	IN	µg/L	5	11.1	15.4	13.6	1.7
	TA	µg/L	3	0.1	9.9	-	-
	TB	µg/L	3	0.1	9.4	-	-
	TC	µg/L	3	0.1	9.3	-	-
	TT	µg/L	6	0.3	13.9	-	-
Silica (as SiO_2)	IN	mg/L	25	51.5	95.1	72.6	6.7
	TA	mg/L	23	5.0	75.2	-	-
	TB	mg/L	23	4.9	76.0	-	-
	TC	mg/L	23	4.4	75.6	-	-
	TT	mg/L	6	9.1	72.4	-	-
Total P (as PO_4)	IN	mg/L	23	0.27	0.46	0.35	0.05
	TA	mg/L	21	<0.03	0.28	-	-
	TB	mg/L	21	<0.03	0.27	-	-
	TC	mg/L	21	<0.03	0.26	-	-
	TT	mg/L	7	<0.03	0.62	-	-
Orthophosphate (as PO_4)	IN	mg/L	7	<0.05	0.13	0.08	0.03
	TA	mg/L	7	<0.05	<0.05	-	-
	TB	mg/L	7	<0.05	<0.05	-	-
	TC	mg/L	7	<0.05	<0.05	-	-
	TT	mg/L	4	<0.05	<0.05	-	-

(a) Average and standard deviation only provided for inlet samples; not meaningful for effluent data with breakthrough curves. One-half of detection limit used for less than detection calculations. Duplicate samples included in calculations.

Table 4-7. Summary of Other Water Quality Parameter Measurements

Parameter	Sampling Location	Unit	Number of Samples	Concentration			Standard Deviation
				Minimum	Maximum	Average	
Fe (total)	IN	µg/L	24	<25	<25	<25	0
	TA	µg/L	22	<25	<25	-	-
	TB	µg/L	22	<25	<25	-	-
	TC	µg/L	22	<25	<25	-	-
	TT	µg/L	9	<25	873	-	-
Fe (soluble)	IN	µg/L	5	<25	<25	<25	0
	TA	µg/L	2	<25	<25	-	-
	TB	µg/L	2	<25	<25	-	-
	TC	µg/L	2	<25	<25	-	-
	TT	µg/L	5	<25	72.4	-	-
Mn (total)	IN	µg/L	24	<0.1	0.8	0.1	0.2
	TA	µg/L	22	<0.1	0.6	-	-
	TB	µg/L	22	<0.1	0.3	-	-
	TC	µg/L	22	<0.1	0.7	-	-
	TT	µg/L	9	<0.1	40.4	-	-
Mn (soluble)	IN	µg/L	5	<0.1	0.2	0.1	0.1
	TA	µg/L	2	<0.1	0.4	-	-
	TB	µg/L	2	<0.1	0.2	-	-
	TC	µg/L	2	<0.1	0.2	-	-
	TT	µg/L	5	<0.1	1.9	-	-
Fluoride	IN	mg/L	5	<0.1	0.2	0.1	0.05
	TA	mg/L	3	<0.1	<0.1	<0.1	0
	TB	mg/L	3	<0.1	<0.1	<0.1	0
	TC	mg/L	3	<0.1	<0.1	<0.1	0
	TT	mg/L	5	<0.1	0.2	0.1	0
Nitrate (as N)	IN	mg/L	5	0.9	1.0	0.9	0.02
	TA	mg/L	3	0.9	0.9	0.9	0
	TB	mg/L	3	0.9	0.9	0.9	0
	TC	mg/L	3	0.9	0.9	0.9	0
	TT	mg/L	5	0.9	0.9	0.9	0.5
Sulfate	IN	mg/L	5	6.7	7.4	7.0	0.3
	TA	mg/L	3	7.0	8.0	7.5	0.5
	TB	mg/L	3	7.0	8.0	7.5	0.5
	TC	mg/L	3	7.0	8.0	7.5	0.5
	TT	mg/L	5	7.0	8.0	7.4	0.4
Alkalinity (as $CaCO_3$)	IN	mg/L	24	88.0	101	93.4	3.9
	TA	mg/L	22	83.0	101	92.2	3.7
	TB	mg/L	22	79.0	101	92.3	4.8
	TC	mg/L	22	80.0	97.0	92.1	3.9
	TT	mg/L	5	83.0	185	108	43.4
Turbidity	IN	NTU	24	<0.1	2.0	0.4	0.4
	TA	NTU	22	<0.1	0.8	0.3	0.2
	TB	NTU	22	<0.1	0.8	0.3	0.2
	TC	NTU	22	<0.1	1.2	0.3	0.3
	TT	NTU	5	0.2	9.5	2.2	4.1

Table 4-7. Summary of Other Water Quality Parameter Measurements (Continued)

Parameter	Sampling Location	Unit	Number of Samples	Concentration			Standard Deviation
				Minimum	Maximum	Average	
pH	IN	S.U.	26	6.5	7.9	7.1	0.3
	TA	S.U.	26	6.5	7.6	7.0	0.2
	TB	S.U.	26	6.5	7.6	7.0	0.2
	TC	S.U.	26	6.5	7.5	7.0	0.2
	TT	S.U.	24	6.5	7.5	7.0	0.2
Temperature	IN	°C	26	14.6	17.7	16.5	0.7
	TA	°C	26	14.6	17.7	16.4	0.8
	TB	°C	26	14.6	17.7	16.2	0.8
	TC	°C	26	10.6	17.6	15.9	1.3
	TT	°C	25	14.7	17.0	16.1	0.6
Dissolved Oxygen	IN	mg/L	26	0.8	6.2	1.9	1.4
	TA	mg/L	26	0.9	4.7	1.9	1.0
	TB	mg/L	26	0.9	4.6	1.9	1.0
	TC	mg/L	26	1.0	4.6	1.9	1.1
	TT	mg/L	25	0.8	6.0	2.0	1.3
ORP	IN	mV	26	115	381	255	52.8
	TA	mV	26	215	739	657	129
	TB	mV	26	236	744	672	129
	TC	mV	26	242	753	682	130
	TT	mV	25	264	754	699	97.8

Notes: Samples collected on first day of operation, i.e., September 27, 2006, not included because they were not representative of normal operation. See Appendix B for September 27, 2006 results. One-half of detection limit used for less than detection calculations. Duplicate samples included in calculations.

Because of the unexpectedly short run length experienced by the GFH media, the removal capacities of four adsorptive media, i.e., GFH, ARM 200 (an iron-based media by BASF), ArsenX^{np} (a hybrid ion exchange resin-based media manufactured by Purolite), and Adsorbsia GTO (a titania-based media by Dow Chemical), were later evaluated using a rapid small-scale column test (RSSCT) in the laboratory under a separate task order (Westerhoff et al., 2007). The results of the study indicated that all four media tested had a rather short run length for arsenic. The longest run length was achieved by GFH at approximately 11,000 BV, which was about 50% longer than that observed from the full-scale GFH system. The difference in run length was probably caused by the varying influent water quality between the laboratory RSSCT and full-scale system. The run lengths achieved by the other three media were progressively shorter, decreasing from approximately 9,000 BV for ArsenX^{np}, to 8,000 BV for ARM 200, and to 4,000 BV for Adsorbsia GTO. Therefore, the RSSCT results confirmed the full-scale data and that the Well No. 9 water at STMGID was difficult to treat.

Another round of RSSCT tests were conducted in the field to further evaluate the capacities of several more adsorptive media in order to determine the media to be used for rebedding at the site. The results of these RSSCT tests and the subsequent full-scale study will be reported in the Final Performance Evaluation Report at the conclusion of this study.

Antimony. Total antimony concentrations in raw water ranged from 10.2 to 21.0 μg/L and averaged 14.6 μg/L (Table 4-6), existing almost entirely in the soluble form. Figure 4-13 shows antimony breakthrough curves from Vessels A, B, and C and the entire system. The test results obtained by WCDWR on treated water samples also are included in the graph. Breakthrough above 6 μg/L occurred at approximately 3,000 BV, showing that the GFH media had a limited adsorptive capacity for antimony. However, one

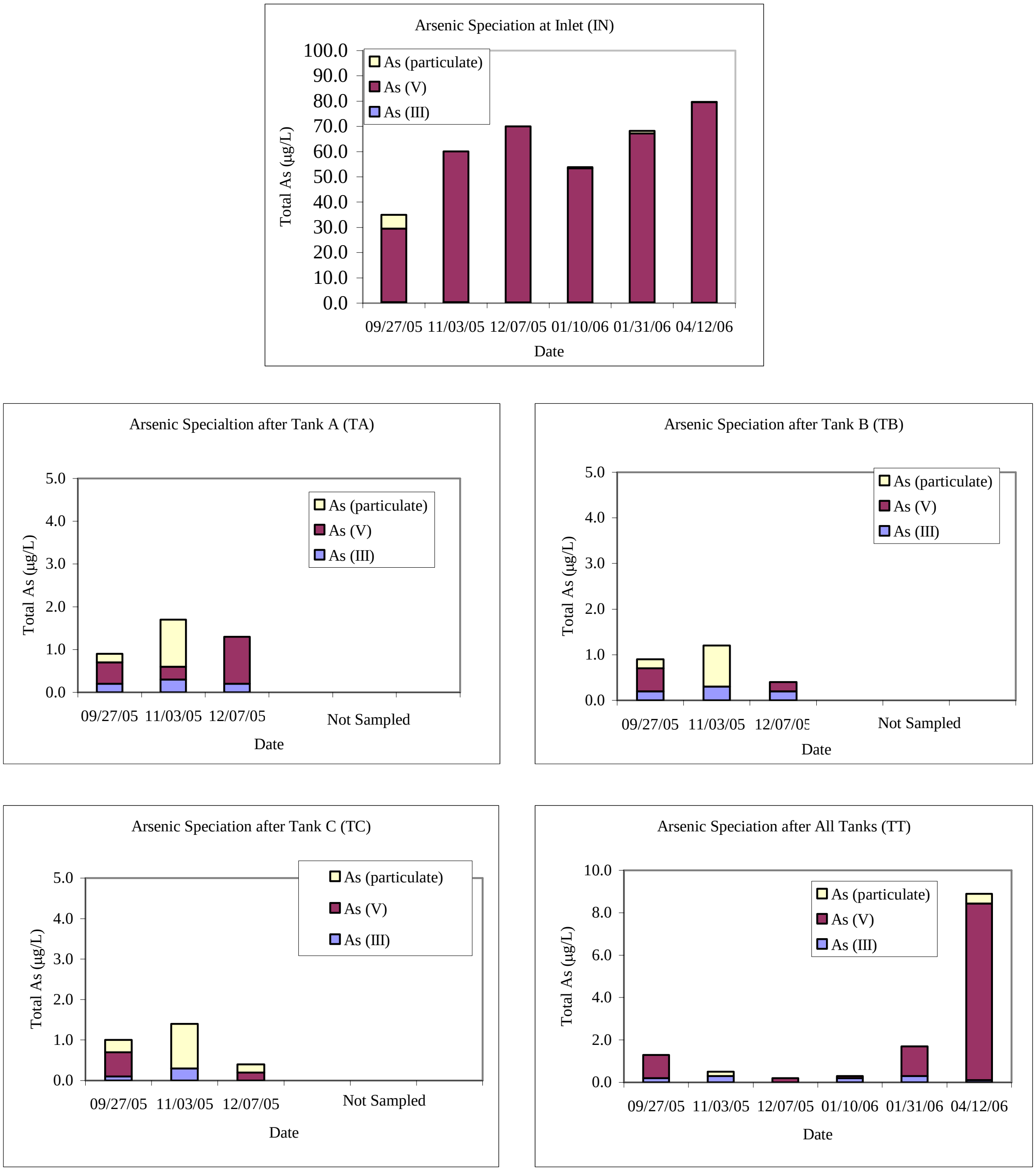


Figure 4-11. Concentrations of Various Arsenic Species in Influent and after Tanks A, B, C and Entire System (TT)

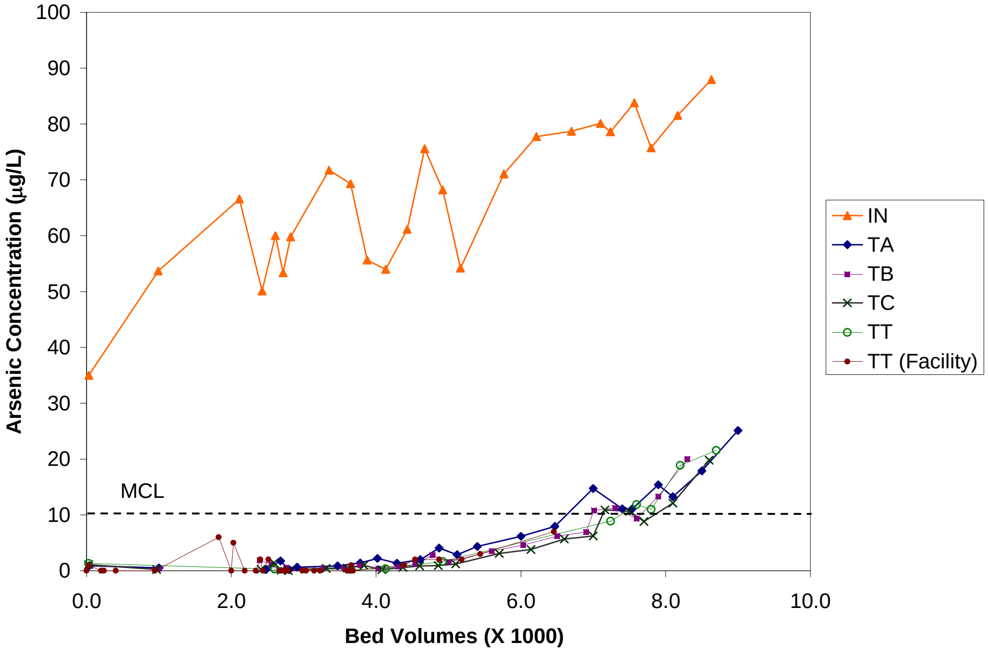


Figure 4-12. Arsenic Breakthrough Curves from GFH System

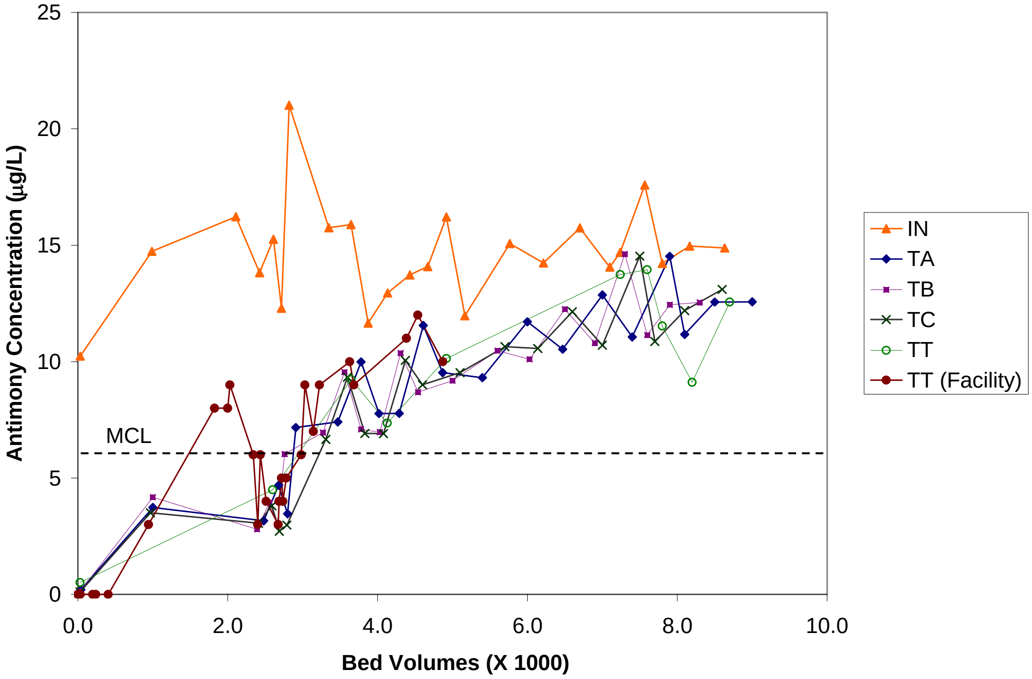


Figure 4-13. Antimony Breakthrough Curves from GFH System

pilot study conducted in Salt Lake County Service Area #3, Utah showed that GFH could remove antimony up to 50,000 BV (http://www.canyonwater.com/antimony.htm). More information on this pilot study is being obtained and will be included in the Final Performance Evaluation Report.

Silica. Silica concentrations in raw water ranged from 51.5 to 95.1 mg/L (as SiO_2) and averaging 72.6 mg/L (as SiO_2) (Table 4-6). Silica was removed until reaching complete breakthrough about halfway through the 32-week study period (Figure 4-14). Silica adsorption on porous metal-oxide adsorptive media can be a major factor that impacts arsenic and, perhaps, antimony, removal by these media (Smith et al., 2005). Several batch and column studies document that silica reduces arsenic adsorptive capacities on ferric oxides/hydroxides and activated alumina (Meng et al., 2002; Meng et al., 2000). Mechanisms proposed to describe the role of silica in iron-silica and iron-arsenic-silica systems include: (1) adsorption of silica may change the surface properties of adsorbents by lowering the iso-electric point (or pH_{zpc}), (2) silica may compete for arsenic adsorption sites, (3) polymerization of silica may accelerate silica sorption but lower the available surface sites for arsenic adsorption, and 4) chemical reactions of silica with divalent cations such as calcium, magnesium, and barium may form precipitates. Therefore, the high level of silica in Well No. 9 might have reduced GFH's arsenic and antimony removal capacities.

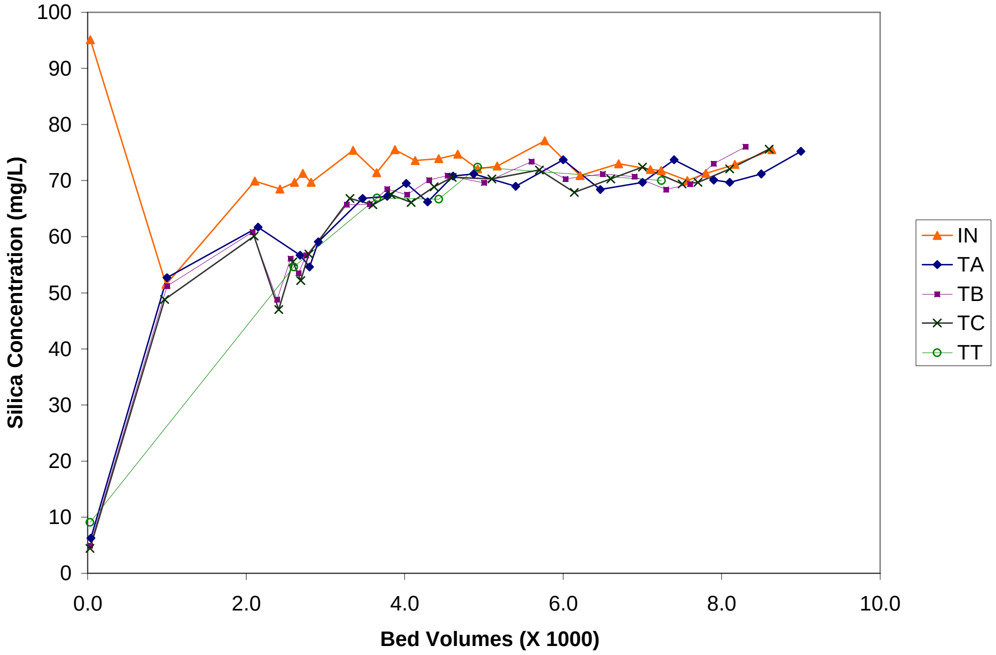


Figure 4-14. Silica Breakthrough Curves from GFH System

Phosphorous. Total phosphorous concentrations in raw water ranged from 0.27 to 0.46 mg/L (as PO_4) and averaged 0.35 mg/L (as PO_4). Orthophosphate was measured on seven occasions during the first three months of system operation, with concentrations peaked at 0.13 mg/L (as PO_4) and averaged 0.08 mg/L (as PO_4). Phosphorous was removed to below 0.03 mg/L (as PO_4) until about 3,500 BV and then gradually broke through from the adsorption vessels (see breakthrough curves in Figure 4-15). Phosphorous did not reach 100% breakthrough by the end of the 32-week study period. Phosphorous removal by iron-based adsorptive media has been observed at several EPA arsenic removal demonstration

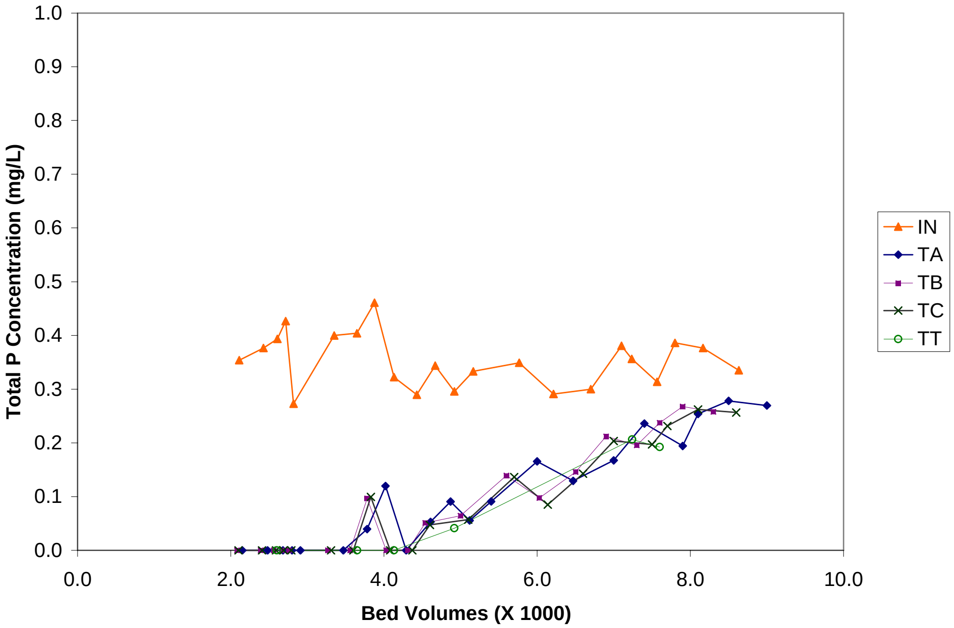


Figure 4-15. Phosphorous Breakthrough Curves from GFH System

sites and will be discussed in the Final Performance Evaluation Report as more data become available. Similar to silica, phosphorous apparently competed with arsenic and, perhaps, antimony for available adsorption sites, thus significantly reducing the useful media life for arsenic and antimony.

Other Water Quality Parameters. Table 4-7 provides a summary for the water quality parameters observed during normal system operation. During the first day of operation, the water quality measured was not typical of those measured thereafter. For example, an elevated iron concentration (i.e., 232 µg/L) was measured in the influent during startup on September 27, 2005, compared to <25 µg/L for all samples collected thereafter. Also, significant decreases in pH (from 7.1 to <4.5), alkalinity (from 92 to <1.0 mg/L [as $CaCO_3$]), and chlorine residuals (from 0.8 to 0.2 mg/L [as Cl_2]) were observed in the effluent of adsorption vessels shortly after the system was placed online, indicating removal of bicarbonate ions and consumption of chlorine by the GFH media. Within a week, the pH, alkalinity, and chlorine residual levels after the adsorption vessels returned to normal. Further, elevated total and dissolved manganese concentrations were measured in the effluent of the adsorption vessels on September 27, 2005, i.e., ranging from 12.4 to 16.8 µg/L as compared to an average of 0.1 mg/L for all samples collected thereafter), indicating leaching of some manganese from the GFH media during the initial operation.

As shown in Table 4-7, pH values of raw water varied from 6.5 to 7.9, with an average of 7.1, which fell within the desirable pH range for adsorptive media without any pH adjustment. The pH values of treated water ranged from 6.5 to 7.6. Therefore, the water pH did not change significantly after the treatment, except for shortly after the system was placed online. All other constituents in raw water did not appear to be altered by the GFH system.

4.5.2 Distribution System Water Sampling. Prior to the operation of the GFH system, baseline distribution water samples were collected from three locations for four consecutive months in 2004. Following system startup in September 2005, distribution sampling continued on a monthly basis at the same three locations. The sampling results are presented in Table 4-8. Figure 4-16 plots the total arsenic and antimony concentrations measured in the distribution system after system startup.

Table 4-8. Distribution System Sampling Results

	Location	DS1																	DS2									DS3								
	Sample Type	Non-Residence																	LCR									LCR								
	Flushed /1st Draw	1st Draw									Flushed[a]								1st Draw									1st Draw								
No. of Sampling Events	Sampling Date	Stagnation Time (hrs)	pH	Alkalinity	As	Fe	Mn	Pb	Cu	Sb	pH	Alkalinity	As	Fe	Mn	Pb	Cu	Sb	Stagnation Time (hrs)	pH	Alkalinity	As	Fe	Mn	Pb	Cu	Sb	Stagnation Time (hrs)	pH	Alkalinity	As	Fe	Mn	Pb	Cu	Sb
BL1	06/09/04	164	6.8	116	65.3	<25	0.6	8.9	13.1	15.4	6.8	91	63.2	<25	0.1	1.4	5.2	15.5	8.8	7.1	104	13.1	<25	<0.1	0.4	110	2.4	9.5	6.9	104	12.8	<25	<0.1	0.3	121	2.6
BL2	07/08/04	740	6.9	93	87.9	212	0.7	32.6	7.6	15.6	6.9	93	81.4	<25	<0.1	2.0	5.4	15.7	NA	7.0	97	20.4	<25	<0.1	0.3	43.9	2.9	NA	7.1	97	19.9	<25	<0.1	1.0	148	2.8
BL3	08/11/04	211	7.4	94	93.5	<25	0.8	3.4	8.2	15.3	7.3	94	93.4	<25	0.5	0.6	7.0	15.2	10.8	7.3	102	15.9	<25	<0.1	<0.1	17.1	2.2	8	7.5	102	18.1	<25	<0.1	0.1	83.0	2.8
BL4	09/08/04	672	7.2	97	108	555	2.2	46.2	13.3	21.3	7.3	93	111	<25	0.4	0.7	7.6	20.9	7.0	7.2	105	17.6	<25	<0.1	0.1	74.4	2.9	8.3[b]	7.4	109	18.7	<25	<0.1	<0.1	69.4	3.0
1	10/25/05	NA	NA	NA	NA	NA	NA	NA	NA	NA	7.3	97	3.1	106	1.5	4.5	51.2	2.0	NA	7.5	106	4.7	<25	<0.1	0.6	11.8	0.5	NA	7.5	106	4.4	<25	0.2	1.5	75.0	0.4
2	11/30/05	NA	NA	NA	NA	NA	NA	NA	NA	NA	7.2	88	4.1	<25	2.3	2.7	4.7	2.1	8.0	7.5	97	5.5	<25	<0.1	0.1	20.9	1.0	7.5	7.5	88	5.2	<25	<0.1	0.1	64.1	1.1
3	12/14/05	NA	NA	NA	NA	NA	NA	NA	NA	NA	7.5	101	4.0	<25	0.5	0.6	0.9	2.3	13.0	7.6	106	4.2	<25	<0.1	0.1	0.6	2.1	8.5	7.6	101	4.2	<25	<0.1	0.2	60.1	2.0
4	01/18/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	7.1	92	1.2	<25	0.5	1.2	10.4	10.5	8.5	7.4	101	3.9	<25	<0.1	0.4	172	2.1	NA	7.7	101	4.2	<25	<0.1	0.3	87.2	1.7
5	02/15/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	7.5	104	4.3	<25	1.0	0.7	6.5	2.2	7.3	7.5	104	4.4	<25	0.2	0.5	86.2	2.0	7.5	7.5	104	4.4	57.8	0.3	0.5	68.9	2.2
6	03/15/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	7.5	100	4.1	<25	<0.1	0.5	100	2.0	7.3	7.4	100	4.0	<25	<0.1	0.3	176	2.0	7.7	7.4	100	4.2	<25	0.5	1.0	9.3	1.9
7	04/12/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	7.6	106	7.2	<25	<0.1	0.2	2.1	3.2	7.5	7.4	106	7.2	<25	<0.1	0.2	121	3.3	8.0	7.4	106	6.4	<25	0.1	0.4	107	3.1

(a) DS1 was located upstream of the Well No. 9 blending point. First draw sampling discontinued after the baseline sampling due to infrequent use of sample tap as indicated by the long stagnation time. Stagnation times not appliable for flushed samples.

(b) Resident's roommate may have used the water before the draw.

Lead action level = 15 µg/L; copper action level = 1.3 mg/L

Unit of µg/L for all anlaytes except for pH and alkalinity (mg/L as $CaCO_3$)

BL = Baseline Sampling; NA = not available

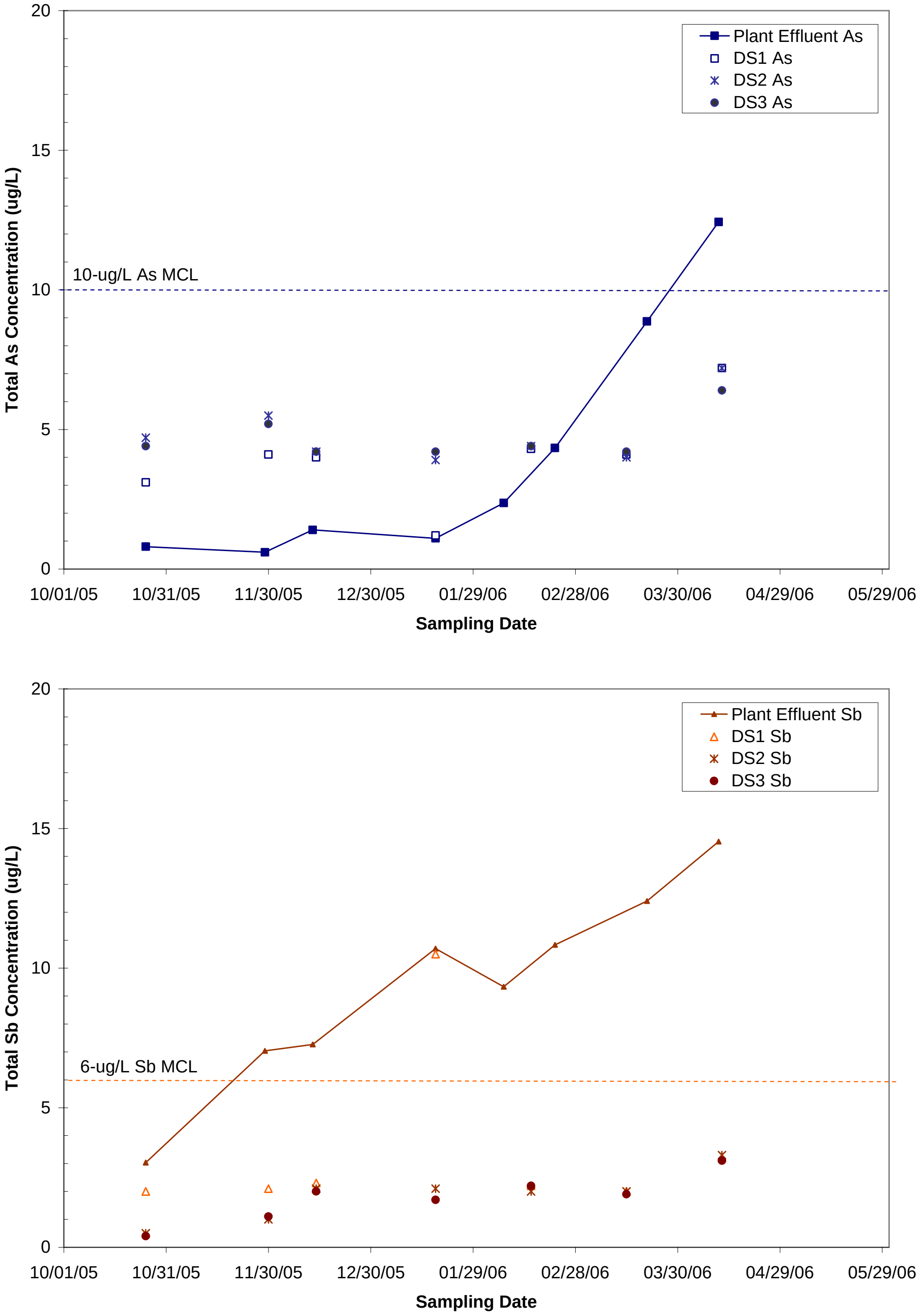


Figure 4-16. Total As and Sb Concentrations in Distribution System After System Startup

Prior to the installation of the GFH system, total arsenic and antimony concentrations in the distribution system upstream of the blending point (i.e., at DS1) averaged 87.2 and 16.8 µg/L, respectively, representing the high concentrations in Well No. 9 water. Downstream of the blending point (i.e., at DS2 and DS3), total arsenic concentrations averaged 16.7 µg/L at DS2 and 17.4 µg/L at DS3, whereas total antimony concentrations averaged 2.6 µg/L at DS2 and 2.8 µg/L at DS3. These values were significantly lower than those in Well No. 9 water due to blending with low-arsenic and low-antimony water from other wells supplying the distribution system. After the GFH system was put into service, both arsenic and antimony concentrations at all three locations were significantly reduced to below the respective MCLs (except for one exceedance), as shown in Figure 4-16. These concentration reductions were resulted primarily from treatment by GFH system and blending with other source waters. Due to lack of records of actual blending ratios and water quality of other source wells, the exact cause of the reductions observed may not be identified.

Lead levels in the first draw samples from two residences (DS2 and DS3) were low (< 0.1 to 1.5 µg/L) and did not appear to be affected by the treatment system. Copper levels fluctuated from time to time, ranging from 17.1 to 148 µg/L before the treatment system was installed and from 0.6 to 176 µg/L afterwards, which were well below the copper action level of 1,300 µg/L. Iron and manganese concentrations in the distribution system were below the respective detection limits most of the time. The pH and alkalinity values remained fairly constant in the distribution system.

4.6 System Cost

The cost of the system was evaluated based on the capital cost per gpm (or gpd) of design capacity and the O&M cost per 1,000 gallons of water treated. This required tracking of the capital cost for the equipment, site engineering, and installation and the O&M cost for the media replacement and disposal, electricity consumption, and labor. The cost incurred for treatment building construction ($186,000 funded by STMGID) and well reconfiguration (provided by EPA with partial funding of $34,840) were not included in this cost evaluation.

4.6.1 Capital Cost. The capital investment for equipment, site engineering, and installation was 232,147 (see Table 4-9) as provided by Siemens in a cost proposal to Battelle dated October 1, 2003. The equipment cost was $157,647 (or 68% of the total capital investment), which included the cost for three skid-mounted carbon steel pressure vessels ($45,500), 240 ft^3 of GFH media ($238/$ft^3$ or $3.03/lb for a total cost of $57,000), process piping and valving ($11,000), instrumentation and controls ($9,500), and field services, labor, and travel ($27,000). The equipment cost also included a change order of $7,647 for adding three flow meters and three differential pressure gauge assemblies. The items on the change order were not standard items and added for monitoring purposes.

WCDWR prepared, at its own cost, the required engineering plans and permit submittals, which included the system layout and footprint, piping connections to the entry and distribution tie-in points, and system specifications and P&IDs provided by Siemens. The engineering cost charged by Siemens was $16,000, about 7% of the total capital investment. The engineering work performed by Siemens was limited to its system design information and PE-stamped P&IDs. The cost incurred by WCDWR for the plans preparation and submittals are not included in Table 4-9.

The installation cost included the cost of labor and materials to unload and install the treatment system; complete the piping installation and tie-ins; and perform the system start-up and shakedown (Section 4.3.3). The installation cost was $58,500, or 25% of the total capital investment.

The capital cost of $232,147 was normalized to $663/gpm (or $0.46/gpd) of the design capacity using the system's rated capacity of 350 gpm (or 504,000 gpd). The capital cost also was converted to an annualized cost of $21,912 by applying a capital recovery factor of 0.09439 based on a 7% interest rate and a 20-yr return. Assuming that the system operated 24 hr/day, 7 day/wk at the design flowrate of 350 gpm to produce 183,960,000 gal of water per year, the unit capital cost would be $0.12/1,000 gal.

Table 4-9. Summary of Capital Investment Cost of GFH System

Description	Quantity	Cost	% of Capital Investment Cost
Equipment Costs			
GFH Media (ft^3)	240	$57,000	–
Vessels	3	$45,500	–
Process Piping and Valves	–	$11,000	–
Instrumentation and Controls	–	$9,500	–
Field Services and Miscellaneous Items	–	$12,000	–
Labor	–	$10,000	–
Travel	–	$5,000	–
Change Order for Adding Three Flow Three Flow Meters and Three Differential Pressure Gauge Assembles	–	$7,647	–
Equipment Total	–	**$157,647**	**68%**
Engineering Costs			
Labor	–	$16,000	–
Engineering Total	–	**$16,000**	**7%**
Installation Costs			
Material	–	$13,500	–
Labor	–	$30,000	–
Travel	–	$10,000	–
Subcontractor	–	$5,000	–
Installation Total	–	**$58,500**	**25%**
Total Capital Investment	–	**$232,147**	**100%**

using the 3.8 hr/day of average daily system run time and 275 gpm of average system flowrate, the system would produce only 22,885,500 gal of water per year. At this reduced rate of operation, the unit capital cost increased to $0.96/1,000 gal.

4.6.2 Operation and Maintenance Cost. The O&M cost for the Siemens GFH system included only the incremental cost associated with the system, such as media replacement and disposal, electricity consumption, and labor, as presented in Table 4-10. Additional electricity use associated with the air compressor and PLC was minimal. The routine, non-demonstration-related labor activities consumed about 30 min/day, 5 day/wk as noted in Section 4.4.4. Therefore, the labor cost was calculated to be $0.18/1,000 gal of water treated (Table 4-10).

The unit O&M cost is driven primarily by the cost to replace the spent media and is a function of the media run length. The media run length is measured by the number of bed volumes treated by the system until reaching 10-µg/L arsenic breakthrough or 6-µg/L antimony breakthrough in the combined effluent, whichever occurs first. The pending media replacement cost is estimated to be $70,550, including 240 ft^3 of virgin GFH media ($57,600) and labor and spent media disposal ($12,950). By averaging the media replacement cost over the media life, the cost per 1,000 gal of water treated was plotted as a function of the media run length in BV or the system throughput in gal (see Figure 4-17). The media run length in BV was calculated by dividing the total system throughput by the total quantity of media, i.e., 240 ft^3. As shown in this figure, the unit media replacement cost would be $5.46/1,000 gal for a media run length of 7,200 BV (or 12,925,000 gal) – if the system operation was governed by arsenic. If the system operation was governed by antimony, the media would have been replaced around 3,000 BV (or 5,386,000 gal) and the unit replacement cost would be higher at $13.10/1,000 gal.

Table 4-10. Summary of O&M Cost

Cost Category	Value	Assumptions
Volume Processed (1,000 gal)	15,567	Actual volume treated for 32-week period
Media Replacement and Disposal		
Volume of Media Replaced (ft^3)	240	
Replacement Media ($)	$57,600	$240/ft^3 of media, includes shipping
Labor and Disposal($)	$12,950	
Subtotal ($)	$70,550	Estimated cost
Media Replacement and Disposal Cost ($/1,000 gal)	See Figure 4-17	As a function of media run length to 10-µg/L As or 6-µg/L Sb breakthrough
Chemical Usage		
Chemical Cost ($)	$0.00	No additional chemicals required
Electricity		
Electricity Cost ($/1,000 gal)	$0.001	Incremental electrical cost negligible
Labor		
Average Weekly Labor (hr)	2.5	30 min/day, 5 day/wk
Labor Cost ($)	2,800	80 hr × $35/hr for 32-wk period
Labor Cost ($/1,000 gal)	0.18	Based on 15,567,000 gal of water treated
Total O&M Cost ($/1,000 gal)	See Figure 4-17	

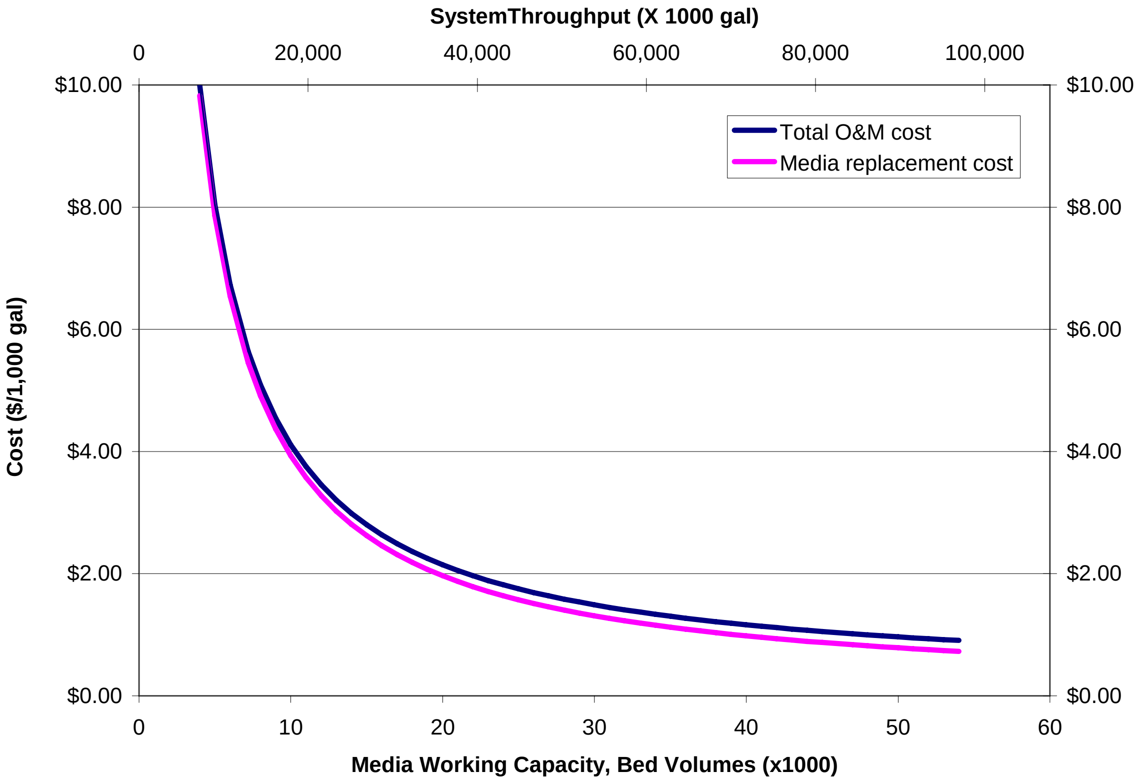


Figure 4-17. Media Replacement and Total O&M Curves for GFH System

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APPENDIX A

OPERATIONAL DATA

EPA Arsenic Demonstration Project at STGMID in Washoe County, NV – Summary of Daily System Operation

		Pump House				Total System Operation Data								Tank Pressure Operation Data											
Week	Date	Hour Meter	Avg. Op Hours	Total Hours	Avg. Flowrate	Master Flow Meter	Treated Volume	Total Treated Volume	Flow Totalizer Tank A	Flow Totalizer Tank B	Flow Totalizer Tank C	Cumulative Flow	Cumulative Bed Volume	Tank A			Tank B			Tank C			Total System Pressure Data		
		hr	hr	hr	gpm	gal	Kgal	Kgal	gal	gal	gal	Kgal	# of BV	◊P	Inlet	Outlet	◊P	Inlet	Outlet	◊P	Inlet	Outlet	◊P	Inlet	Outlet
1	09/27/05	6564.9		4	270	116,028,000	62	62	21,142	20,218	20,218	62	34.0	0.0	101.0	100.0	0.0	99.0	100.0	0.5	100.0	100.0	0.0	99.0	99.0
	09/28/05	6583.8	18.9	23	288	116,355,000	327	389	129,929	124,431	124,431	379	211.1	1.0	103.0	102.0	1.0	103.0	102.0	1.0	102.0	101.0	1.0	104.0	103.0
	09/29/05	6587.7	11.4	27	278	116,420,000	65	454	151,832	145,433	145,433	443	246.8	1.1	105.0	105.0	1.1	106.0	106.0	1.1	104.0	102.0	0.9	105.0	104.0
	09/30/05	6606.4	13.8	45	287	116,742,000	322	776	258,020	248,072	248,072	754	420.4	1.1	103.0	103.0	1.0	104.0	102.0	1.1	102.0	100.0	0.9	105.0	103.0
2	10/03/05	6653.3	14.7	92	286	117,548,000	806	1,582	524,876	507,150	508,370	1,540	858.6	1.3	104.0	102.0	0.5	106.0	101.0	1.0	102.0	100.0	1.0	104.0	100.0
	10/04/05	6666.5	14.5	105	287	117,775,000	227	1,809	599,420	599,420	581,426	1,780	992.3	1.1	101.0	101.0	1.0	103.0	101.0	0.6	101.0	99.0	1.0	103.0	100.0
	10/05/05	6688.6	15.5	128	287	118,156,000	381	2,190	725,650	725,650	705,298	2,157	1202.1	1.1	104.0	103.0	1.0	104.0	103.0	0.6	103.0	101.0	0.9	104.0	102.0
	10/06/05	6702.2	15.3	141	287	118,390,000	234	2,424	801,333	801,333	779,650	2,382	1327.9	1.1	103.0	103.0	1.0	104.0	103.0	0.6	102.0	100.0	1.0	104.0	101.0
	10/07/05	6716.9	15.2	156	286	118,642,000	252	2,676	884,862	884,862	861,230	2,631	1466.5	1.2	101.0	101.0	1.0	102.0	101.0	0.7	102.0	100.0	1.0	102.0	99.0
3	10/10/05	6765.0	15.4	204	287	119,469,000	827	3,503	1,157,292	1,121,250	1,128,411	3,407	1899.1	1.3	101.0	101.0	1.1	102.0	101.0	1.2	102.0	100.0	0.9	103.0	100.0
	10/11/05	6779.8	15.4	219	331	119,763,000	294	3,797	1,240,530	1,202,300	1,210,200	3,653	2036.2	1.3	101.0	101.0	1.1	101.0	101.0	1.2	101.0	99.0	0.9	102.0	100.0
	10/12/05	6788.0	14.9	227	205	119,864,000	101	3,898	1,287,858	1,246,258	1,255,442	3,790	2112.4	1.1	102.0	102.0	1.1	102.0	102.0	1.1	102.0	100.0	0.9	103.0	101.0
	10/13/05	6800.0	14.7	239	285	120,069,000	205	4,103	1,357,570	1,310,324	1,321,711	3,990	2223.9	1.2	102.0	102.0	1.0	103.0	103.0	1.2	104.0	101.0	0.9	104.0	103.0
4	10/17/05	6810.4	12.3	249	282	120,245,000	176	4,279	1,417,138	1,365,029	1,378,363	4,161	2319.1	0.0	2.0	2.0	0.0	3.0	2.0	0.0	2.0	2.0	0.0	0.0	0.0
	10/18/05	6810.4	11.7	249	0	120,245,000	0	4,279	1,417,138	1,365,029	1,378,363	4,161	2319.1	0.0	2.0	2.0	0.0	3.0	2.0	0.0	2.0	2.0	0.0	0.0	0.0
	10/19/05	6810.5	11.2	249	333	120,247,000	2	4,281	1,417,700	1,365,600	1,378,990	4,162	2320.1	0.0	104.0	103.0	0.0	104.0	104.0	0.0	104.0	104.0	0.0	104.0	102.0
	10/20/05	6816.2	10.9	255	287	120,345,000	98	4,379	1,449,942	1,395,794	1,409,061	4,255	2371.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10/21/05	6816.2	10.5	255	0	120,345,000	0	4,379	1,450,500	1,395,700	1,409,600	4,256	2372.2	0.4	103.0	101.0	1.1	102.0	101.0	0.6	102.0	102.0	1.0	102.0	102.0
5	10/24/05	6822.3	9.5	261	279	120,447,005	102	4,481	1,485,546	1,427,875	1,442,384	4,356	2428.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10/25/05	6822.4	9.2	261	166	120,448,000	1	4,482	1,486,127	1,428,431	1,442,971	4,358	2428.9	0.9	102.0	101.0	1.3	101.0	100.0	1.0	101.0	101.0	1.2	101.0	99.0
	10/26/05	6829.2	9.1	268	284	120,564,000	116	4,598	1,527,269	1,463,755	1,478,871	4,470	2491.6	0.0	25.0	25.0	0.0	25.0	25.0	0.0	24.0	24.0	0.0	24.0	25.0
	10/27/05	6832.8	8.9	272	292	120,627,000	63	4,661	1,549,712	1,483,007	1,498,466	4,531	2525.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	10/31/05	6832.8	7.9	272	0	120,627,000	0	4,661	1,549,712	1,483,007	1,498,466	4,531	2525.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	11/01/05	6837.9	7.8	277	288	120,715,000	88	4,749	1,580,898	1,509,900	1,525,900	4,617	2573.4	0.8	102.0	101.0	1.2	102.0	101.0	1.1	101.0	101.0	1.2	100.0	99.0
	11/02/05	6839.3	7.6	278	262	120,737,000	22	4,771	1,588,801	1,516,666	1,532,747	4,638	2585.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	11/03/05	6841.9	7.5	281	282	120,781,000	44	4,815	1,604,500	1,530,200	1,546,600	4,681	2609.4	0.8	103.0	101.0	1.2	102.0	101.0	1.1	101.0	101.0	1.2	101	100
	11/04/05	6846.1	7.4	285	282	120,852,000	71	4,886	1,629,640	1,552,000	1,568,800	4,750	2648.0	0.8	102.0	101.0	1.3	102.0	101.0	1.1	101.0	101.0	1.2	101	100
7	11/07/05	6852.7	7.0	292	288	120,966,000	114	5,000	1,669,050	1,586,400	1,603,830	4,859	2708.6	1.0	102.0	101.0	1.3	101.0	100.0	1.00	102.0	101.0	1.0	101.0	100
	11/08/05	6853.9	6.9	293	278	120,986,000	20	5,020	1,676,500	1,593,100	1,610,700	4,880	2720.3	1.0	103.0	102.0	1.4	102.0	101.0	1.10	102.0	102.0	1.3	102.0	100
	11/09/05	6859.4	6.8	298	288	121,081,000	95	5,115	1,708,705	1,622,368	1,640,596	4,972	2771.3	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0
	11/10/05	6860.9	6.7	300	278	121,106,000	25	5,140	1,717,600	1,630,500	1,648,800	4,997	2785.3	1.0	104.0	102.0	1.4	103.0	102.0	1.20	102.0	102.0	1.3	102.0	100
8	11/14/05	6862.9	6.2	302	275	121,139,000	33	5,173	1,728,625	1,640,491	1,659,012	5,028	2802.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
	11/15/05	6864.9	6.1	304	275	121,172,000	33	5,206	1,741,600	1,652,400	1,671,100	5,065	2823.4	1.0	103.0	101.0	1.4	102.0	101.0	1.2	102.0	102.0	1.3	102.0	100
	11/16/05	6866.4	6.0	305	311	121,200,000	28	5,234	1,749,080	1,659,240	1,678,070	NA	NA	1.0	102.0	101.0	1.4	102.0	101.0	1.2	101.0	101.0	1.4	101.0	99
	11/17/05	6868.0	5.9	307	271	121,226,000	26	5,260	1,758,400	1,667,800	1,686,600	5,113	2849.9	1.0	103.0	102.0	1.4	103.0	102.0	1.2	102.0	102.0	1.3	103.0	101
	11/18/05	6871.4	5.9	310	284	121,284,000	58	5,318	1,778,300	1,686,200	1,705,100	5,170	2881.6	1.0	103.0	102.0	1.4	102.0	102.0	1.2	102.0	102.0	1.3	102.0	100
9	11/21/05	6890.1	5.9	329	283	121,602,000	318	5,636	1,885,360	1,784,250	1,804,250	5,474	3051.2	0.0	8.0	8.0	0.0	7.0	7.0	0.0	7.0	7.0	0.0	0.0	0
	11/22/05	6893.4	5.9	332	278	121,657,000	55	5,691	1,904,560	1,801,850	1,821,980	5,528	3081.6	1.0	106.0	105.0	1.4	104.0	103.0	1.2	104.0	104.0	1.5	100.0	98
	11/23/05	6898.9	5.9	338	288	121,752,000	95	5,786	1,938,100	1,832,417	1,855,248	5,626	3135.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	11/28/05	6919.3	5.7	358	283	122,099,000	347	6,133	2,056,000	1,937,850	1,960,250	5,954	3318.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
	11/29/05	6922.9	5.7	362	278	122,159,000	60	6,193	2,075,850	1,956,010	1,978,700	6,011	3350.4	1.1	104.0	103.0	1.4	104.0	103.0	1.3	102.0	102.0	1.3	103.0	101.0
	11/30/05	6924.6	5.6	364	294	122,189,000	30	6,223	2,086,230	1,965,500	1,988,460	6,040	3366.9	1.1	104.0	102.0	1.4	103.0	102.0	1.3	102.0	102.0	1.3	103.0	101.0
	12/1/05	6928.1	5.6	367	276	122,247,000	58	6,281	2,105,990	1,983,600	2,006,840	6,096	3398.2	1.1	103.0	102.0	1.4	103.0	102.0	1.3	103.0	102.0	1.4	102.0	100.0
	12/2/05	6932.5	5.6	371	284	122,322,000	75	6,356	2,131,260	2,006,720	2,030,410	6,168	3438.3	1.1	106.0	105.0	1.4	105.0	104.0	1.2	105.0	105.0	1.2	105.0	103.0

EPA Arsenic Demonstration Project at STGMID in Washoe County, NV – Summary of Daily System Operation (Continued)

		Pump House				Total System Operation Data								Tank Pressure Operation Data											
		Hour Meter	Avg. Op Hours	Total Hours	Avg. Flowrate	Master Flow Meter	Treated Volume	Total Treated Volume	Flow Totalizer Tank A	Flow Totalizer Tank B	Flow Totalizer Tank C	Cumulative Flow	Cumulative Bed Volume	Tank A			Tank B			Tank C			Total System Pressure Data		
Week	Date	hr	hr	hr	gpm	gal	Kgal	Kgal	gal	gal	gal	Kgal	# of BV	◊P	Inlet	Outlet	◊P	Inlet	Outlet	◊P	Inlet	Outlet	◊P	Inlet	Outlet
11	12/5/05	6945.9	5.5	385	282	122,549,000	227	6,583	2,207,880	2,076,960	2,101,980	6,387	3560.1	0.0	32.0	32.00	0.0	32.0	32.0	0.0	31.0	31.0	0.0	31.0	32.0
	12/6/05	6951.0	5.5	390	353	122,657,000	108	6,691	2,237,370	2,103,970	2,129,550	6,471	3607.0	0.0	8.0	8.00	0.0	8.0	8.0	0.0	7.0	7.0	0.0	6.0	7.0
	12/7/05	6954.4	5.5	393	181	122,694,000	37	6,728	2,259,500	2,127,100	2,153,400	6,540	3645.5	1.1	103.0	102.0	1.4	103.0	102.0	1.3	103.0	103.0	1.3	103.0	101.0
	12/8/05	6958.7	5.5	398	279	122,766,000	72	6,800	2,283,850	2,149,441	2,176,221	6,610	3684.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	12/9/05	6961.5	5.4	400	280	122,813,000	47	6,847	2,300,000	2,164,000	2,191,000	6,655	3709.6	1.1	104.0	103.0	1.4	103.0	102.0	1.3	102.0	102.0	1.3	102.0	100.0
12	12/12/05	6974.9	5.4	414	284	123,041,000	228	7,075	2,377,000	2,235,000	2,263,000	6,875	3832.2	0.0	103.0	101.0	1.0	103.0	102.0	0.0	102.0	101.0	0.0	102.0	100.0
	12/13/05	6979.3	5.4	418	288	123,117,000	76	7,151	2,403,000	2,258,000	2,288,000	6,949	3873.5	1.1	102.0	101.0	1.5	102.0	101.0	1.3	103.0	103.0	1.3	103.0	101.0
	12/14/05	6982.5	5.4	421	281	123,171,000	54	7,205	2,422,000	2,275,000	2,305,000	7,002	3903.0	1.1	103.0	101.0	1.5	102.0	101.0	1.3	102.0	102.0	1.3	103.0	101.0
	12/15/05	6986.6	5.3	426	285	123,241,000	70	7,275	2,445,000	2,297,000	2,327,000	7,069	3940.4	1.2	104.0	102.0	1.5	102.0	101.0	1.3	102.0	102.0	1.3	103.0	100.0
	12/16/05	6991.4	5.3	430	295	123,326,000	85	7,360	2,473,000	2,322,000	2,353,000	7,148	3984.4	1.1	103.0	102.0	1.5	102.0	101.0	1.2	102.0	102.0	1.3	103.0	100.0
16	01/09/06	7006.8	5.5	446	NA	123,537,000	211	7,571	2,547,000	2,389,000	2,422,000	5,005	2789.9	0	104	104.0	1.0	104.0	103.0	0.0	103.0	103.0	1.0	104.0	102
	01/10/06	7010.5	5.5	449	288	123,601,000	64	7,635	2,568,000	2,408,000	2,441,000	7,417	4134.3	1.2	104	103.0	1.5	103.0	102.0	1.3	102.0	102.0	1.4	102.0	100.0
	01/11/06	7014.3	5.5	453	285	123,666,000	65	7,700	2,590,000	2,428,000	2,462,000	7,480	4169.5	1.1	104	103.0	1.5	103.0	102.0	1.2	103.0	103.0	0.8	103.0	101.0
	01/12/06	7018.1	5.5	457	276	123,729,000	63	7,763	2,613,000	2,449,000	2,483,000	7,545	4205.7	1.1	104	103.0	1.5	104.0	102.0	1.2	103.0	103.0	0.8	103.0	101.0
	01/13/06	7022.4	5.4	461	275	123,800,000	71	7,834	2,637,000	2,471,000	2,506,000	7,614	4244.1	1.1	103	102.0	1.5	103.0	102.0	1.2	102.0	102.0	1.1	102.0	100
17	01/17/06	7035.0	5.3	474	340	124,057,000	257	8,091	2,728,000	2,554,000	2,591,000	7,873	4388.5	0.0	103	102.0	1.0	103.0	102.0	0.0	103.0	102.0	0.0	103.0	101.0
	01/18/06	7042.4	5.4	481	164	124,130,000	73	8,164	2,755,000	2,579,000	2,616,000	7,950	4431.4	1.0	104	102.0	1.5	103.0	102.0	1.3	102.0	102.0	1.1	102.0	100.0
	01/19/06	7047.2	5.4	486	271	124,208,000	78	8,242	2,781,000	2,603,000	2,641,000	8,025	4473.2	1.1	103	102.0	1.5	103.0	102.0	1.3	103.0	103.0	1.3	102.0	100.0
	01/20/06	7050.6	5.3	490	279	124,265,000	57	8,299	2,801,000	2,621,000	2,659,000	8,081	4504.5	1.0	103	102.0	1.5	102.0	101.0	1.3	101.0	101.0	1.3	101.0	99.0
18	01/23/06	7064.6	5.3	504	275	124,496,000	231	8,530	2,883,000	2,696,000	2,736,000	8,315	4634.9	0.0	100	98.0	1.0	106.0	104.0	0.0	100.0	100.0	0.0	104.0	100.0
	01/24/06	7067.8	5.3	507	276	124,549,000	53	8,583	2,910,000	2,712,000	2,753,000	8,375	4668.3	1.0	104	103.0	1.5	103.0	102.0	1.3	102.0	102.0	1.3	102.0	100.0
	01/25/06	7074.1	5.3	513	270	124,651,000	102	8,685	2,936,000	2,745,000	2,787,000	8,468	4720.2	1.0	104	103.0	1.4	103.0	102.0	1.2	102.0	102.0	1.2	102.0	100.0
	01/26/06	7076.4	5.3	515	275	124,689,000	38	8,723	2,950,000	2,758,000	2,800,000	8,508	4742.5	1.0	104	103.0	1.5	103.0	102.0	1.2	102.0	102.0	1.2	102.0	100.0
	01/27/06	7079.7	5.3	519	273	124,743,000	54	8,777	2,969,000	2,775,000	2,818,000	8,562	4772.6	1.0	103	103.0	1.5	103.0	102.0	1.3	101.0	101.0	1.2	103.0	101.0
19	01/30/06	7091.7	5.2	531	275	124,941,000	198	8,975	3,039,000	2,839,000	2,883,000	8,761	4883.5	0.0	103	102.0	0.0	103.0	102.0	0.0	102.0	102.0	0.0	103.0	101.0
	01/31/06	7095.5	5.2	534	276	125,004,000	63	9,038	3,061,000	2,859,000	2,904,000	8,824	4918.6	1.1	104	103.0	1.5	103.0	102.0	1.2	102.0	102.0	1.4	102.0	100.0
	02/01/06	7100.1	5.2	539	275	125,080,000	76	9,114	3,087,000	2,884,000	2,929,000	8,900	4961.0	1.1	104	103.0	1.5	104.0	103.0	1.2	103.0	103.0	1.2	103.0	101.0
	02/02/06	7105.5	5.2	544	272	125,168,000	88	9,202	3,118,000	2,912,000	2,958,000	8,988	5010.0	1.1	104	103.0	1.5	103.0	103.0	1.2	103.0	103.0	1.3	103.0	101.0
	02/03/06	7108.9	5.2	548	275	125,224,000	56	9,258	3,137,000	2,930,000	2,977,000	9,044	5041.2	1.1	104	103.0	1.5	103.0	102.0	1.3	103.0	102.0	1.3	102.0	100.0
20	02/06/06	7120.7	5.1	560	274	125,418,000	194	9,452	3,206,000	2,993,000	3,041,000	9,240	5150.5	0.0	104	102.0	0.0	103.0	102.0	0.0	102.0	102.0	0.0	102.0	100.0
	02/07/06	7124.3	5.1	563	278	125,478,000	60	9,512	3,227,000	3,012,000	3,061,000	9,300	5183.9	1.0	106	105.0	1.5	106.0	105.0	1.3	105.0	105.0	1.3	105.0	103.0
	02/08/06	7127.9	5.1	567	269	125,536,000	58	9,570	3,247,000	3,030,000	3,080,000	9,357	5215.7	1.0	104	103.0	1.5	103.0	102.0	1.3	102.0	102.0	1.3	103.0	101.0
	02/09/06	7131.0	5.1	570	274	125,587,000	51	9,621	3,265,000	3,047,000	3,097,000	9,409	5244.7	1.0	104	102.0	1.5	103.0	102.0	1.0	103.0	102.0	1.0	103.0	101.0
	02/10/06	7135.0	5.1	574	275	125,653,000	66	9,687	3,287,000	3,068,000	3,118,000	9,473	5280.4	0.9	104	103.0	1.5	103.0	102.0	1.3	102.0	102.0	1.3	103.0	101.0
21	02/13/06	7147.1	5.1	586	274	125,852,000	199	9,886	3,358,000	3,133,000	3,185,000	9,676	5393.5	1.0	103	102.0	1.5	104.0	102.0	1.0	102.0	102.0	1.0	102.0	100.0
	02/14/06	7152.1	5.1	591	270	125,933,000	81	9,967	3,386,000	3,159,000	3,212,000	9,757	5438.7	1.0	104	103.0	1.5	104.0	103.0	1.0	103.0	102.0	1.5	103.0	100.0
	02/15/06	7155.6	5.0	595	276	125,991,000	58	10,025	3,406,000	3,177,000	3,231,000	9,814	5470.5	1.0	104	103.0	1.5	104.0	103.0	1.0	104.0	103.0	1.0	103.0	101.0
	02/16/06	7159.1	5.0	598	271	126,048,000	57	10,082	3,426,000	3,195,000	3,249,000	9,870	5501.7	1.0	104	103.0	1.5	103.0	102.0	1.3	102.0	102.0	1.3	103.0	101.0
	02/17/06	7164.1	5.0	603	277	126,131,000	83	10,165	3,455,000	3,222,000	3,276,000	9,953	5547.9	1.0	104	103.0	1.5	103.0	102.0	1.3	102.0	102.0	1.3	103.0	101.0
22	02/21/06	7180.9	5.0	620	273	126,406,000	275	10,440	3,553,000	3,312,000	3,369,000	10,234	5704.6	1.0	107	106.0	1.5	106.0	105.0	1.0	106.0	105.0	1.0	106.0	104.0
	02/22/06	7184.3	5.0	623	275	126,462,000	56	10,496	3,571,000	3,329,000	3,387,000	10,287	5734.1	0.9	105	104.0	1.6	105.0	104.0	1.3	104.0	104.0	1.5	105.0	103.0
	02/23/06	7187.3	5.0	626	267	126,510,000	48	10,544	3,588,000	3,345,000	3,403,000	10,336	5761.4	1.0	105	104.0	1.5	104.0	103.0	1.3	103.0	103.0	1.5	104.0	103.0
23	02/27/06	7205.7	5.0	645	274	126,812,000	302	10,846	3,694,000	3,442,000	3,504,000	10,640	5930.9	1.0	104	103.0	1.5	104.0	103.0	1.0	103.0	103.0	1.0	103.0	101
	02/28/06	7208.6	5.0	648	282	126,861,000	49	10,895	3,711,000	3,458,000	3,520,000	10,689	5958.2	0.9	104	103.0	1.4	103.0	102.0	1.3	103.0	102.0	1.3	103.0	101
	03/01/06	7212.1	4.9	651	271	126,918,000	57	10,952	3,731,000	3,476,000	3,539,000	10,746	5990.0	1.0	104	103.0	1.5	102.0	101.0	1.3	102.0	101.0	0.9	102.0	100
	03/02/06	7215.7	4.9	655	273	126,977,000	59	11,011	3,753,000	3,496,000	3,559,000	10,808	6024.5	1.0	104	103.0	1.6	103.0	101.0	1.4	102.0	102.0	1.7	103.0	101
	03/03/06	7221.1	4.9	660	275	127,066,000	89	11,100	3,783,000	3,523,000	3,587,000	10,893	6071.9	1.0	104	103.0	1.5	103.0	102.0	1.3	102.0	102.0	1.4	103.0	101

EPA Arsenic Demonstration Project at STGMID in Washoe County, NV – Summary of Daily System Operation (Continued)

		Pump House				Total System Operation Data								Tank Pressure Operation Data											
		Hour Meter	Avg. Op Hours	Total Hours	Avg. Flowrate	Master Flow Meter	Treated Volume	Total Treated Volume	Flow Totalizer Tank A	Flow Totalizer Tank B	Flow Totalizer Tank C	Cumulative Flow	Cumulative Bed Volume	Tank A			Tank B			Tank C			Total System Pressure Data		
Week	Date	hr	hr	hr	gpm	gal	Kgal	Kgal	gal	gal	gal	Kgal	# of BV	⊿P	Inlet	Outlet	⊿P	Inlet	Outlet	⊿P	Inlet	Outlet	⊿P	Inlet	Outlet
24	03/06/06	7232.4	4.9	671	274	127,252,000	186	11,286	3,848,000	3,584,000	3,650,000	11,082	6177.3	1.0	104	103.0	1.5	103.0	102.0	1.3	104.0	103.0	1.3	103.0	101
	03/07/06	7236.1	4.9	675	275	127,313,000	61	11,347	3,869,000	3,603,000	3,669,000	11,141	6210.1	1.0	103	102.0	1.6	103.0	102.0	1.4	103.0	103.0	1.3	103.0	101
	03/08/06	7239.9	4.9	679	272	127,375,000	62	11,409	3,891,000	3,623,000	3,690,000	11,204	6245.3	1.0	104	103.0	1.5	103.0	102.0	1.3	103.0	102.0	1.3	103.0	101
	03/09/06	7244.1	4.9	683	274	127,444,000	69	11,478	3,915,000	3,643,000	3,713,000	11,271	6282.6	1.4	103	102.0	1.5	102.0	101.0	1.3	102.0	102.0	1.4	103.0	101
	03/10/06	7248.5	4.9	687	277	127,517,000	73	11,551	3,940,000	3,668,000	3,737,000	11,345	6323.9	1.4	104	103.0	1.5	103.0	102.0	1.3	102.0	102.0	1.3	103.0	101
25	03/13/06	7258.7	4.9	698	271	127,683,000	166	11,717	3,999,000	3,723,000	3,793,000	11,515	6418.6	1.4	106	105.0	1.4	105.0	104.0	1.3	105.0	104.0	1.3	104.0	102
	03/14/06	7263.0	4.8	702	275	127,754,000	71	11,788	4,023,000	3,745,000	3,816,000	11,584	6457.1	1.8	104	102.0	1.5	103.0	102.0	1.4	103.0	102.0	1.5	103.0	101
	03/15/06	7267.5	4.8	706	278	127,829,000	75	11,863	4,050,000	3,769,000	3,841,000	11,660	6499.4	1.8	103	101.0	1.5	103.0	102.0	1.3	103.0	102.0	1.3	103.0	100
	03/16/06	7271.6	4.8	711	272	127,896,000	67	11,930	4,073,000	3,791,000	3,863,000	11,727	6536.8	1.8	104	102.0	1.5	104.0	102.0	1.3	103.0	102.0	1.3	103.0	101
	03/17/06	7276.5	4.8	715	276	127,977,000	81	12,011	4,102,000	3,817,000	3,890,000	11,809	6582.5	1.8	104	102.0	1.5	103.0	102.0	1.3	103.0	102.0	1.3	103.0	101
26	03/20/06	7288.8	4.8	728	275	128,180,000	203	12,214	4,173,000	3,882,000	3,958,000	12,013	6696.2	1.5	104	103.0	1.5	104.0	102.0	1.0	103.0	102.0	1.0	103.0	100
	03/21/06	7291.3	4.8	730	273	128,221,000	41	12,255	4,187,000	3,895,000	3,971,000	12,053	6718.5	1.1	104	103.0	1.6	103.0	102.0	1.4	103.0	102.0	1.6	103.0	101
	03/22/06	7295.1	4.8	734	268	128,282,000	61	12,316	4,208,000	3,915,000	3,992,000	12,115	6753.1	1.0	104	103.0	1.5	104.0	102.0	1.4	103.0	102.0	1.4	103.0	101
	03/23/06	7299.3	4.8	738	278	128,352,000	70	12,386	4,233,000	3,938,000	4,015,000	12,186	6792.6	1.0	104	103.0	1.5	104.0	102.0	1.4	103.0	102.0	1.4	103.0	101
	03/24/06	7302.7	4.8	742	275	128,408,000	56	12,442	4,252,000	3,956,000	4,034,000	12,242	6823.9	1.1	104	103.0	1.6	103.0	102.0	1.4	103.0	102.0	1.3	103.0	101
27	03/27/06	7315.7	4.8	755	273	128,621,000	213	12,655	4,327,000	4,024,000	4,105,000	12,456	6943.1	1.0	105	103.0	1.5	103.0	102.0	1.0	104.0	103.0	1.0	103.0	101
	03/28/06	7319.1	4.8	758	275	128,677,000	56	12,711	4,346,000	4,042,000	4,124,000	12,512	6974.4	1.0	104	103.0	1.5	103.0	102.0	1.3	103.0	102.0	1.4	103.0	101
	03/29/06	7323.3	4.8	762	274	128,746,000	69	12,780	4,370,000	4,065,000	4,147,000	12,582	7013.4	1.0	103	102.0	1.5	104.0	103.0	1.0	103.0	102.0	1.0	103.0	101
	03/30/06	7327.9	4.8	767	272	128,821,000	75	12,855	4,396,000	4,088,000	4,171,000	12,655	7054.1	1.0	104	103.0	1.5	103.0	102.0	1.3	103.0	102.0	1.4	103.0	101
	03/31/06	7332.4	4.8	771	274	128,895,000	74	12,929	4,422,000	4,112,000	4,196,000	12,730	7095.9	1.0	104	103.0	1.5	103.0	102.0	1.3	103.0	102.0	1.3	103.0	101
28	04/03/06	7344.3	4.8	783	272	129,089,000	194	13,123	4,490,000	4,175,000	4,262,000	12,927	7205.7	1.0	104	103.0	1.5	104.0	102.0	1.0	103.0	103.0	1.0	103.0	101
	04/04/06	7347.9	4.7	787	273	129,148,000	59	13,182	4,510,000	4,194,000	4,281,000	12,985	7238.0	1.9	104	102.0	1.6	103.0	102.0	1.4	103.0	102.0	1.7	103.0	101
	04/05/06	7353.2	4.7	792	274	129,235,000	87	13,269	4,540,000	4,222,000	4,312,000	13,074	7287.6	1.8	104	103.0	1.5	103.0	102.0	1.4	103.0	102.0	1.2	103.0	102
	04/06/06	7355.2	4.7	794	275	129,268,000	33	13,302	4,553,000	4,234,000	4,323,000	13,110	7307.7	1.8	104	102.0	1.5	103.0	102.0	1.3	103.0	102.0	1.3	103.0	101
	04/07/06	7361.8	4.7	801	275	129,377,000	109	13,411	4,590,000	4,268,000	4,359,000	13,217	7367.3	1.8	102	100.0	1.5	102.0	101.0	1.3	102.0	101.0	1.2	102.0	100
28	04/03/06	7344.3	4.8	783	272	129,089,000	194	13,123	4,490,000	4,175,000	4,262,000	12,927	7205.7	1.0	104	103.0	1.5	104.0	102.0	1.0	103.0	103.0	1.0	103.0	101
	04/04/06	7347.9	4.7	787	273	129,148,000	59	13,182	4,510,000	4,194,000	4,281,000	12,985	7238.0	1.9	104	102.0	1.6	103.0	102.0	1.4	103.0	102.0	1.7	103.0	101
	04/05/06	7353.2	4.7	792	274	129,235,000	87	13,269	4,540,000	4,222,000	4,312,000	13,074	7287.6	1.8	104	103.0	1.5	103.0	102.0	1.4	103.0	102.0	1.2	103.0	102
	04/06/06	7355.2	4.7	794	275	129,268,000	33	13,302	4,553,000	4,234,000	4,323,000	13,110	7307.7	1.8	104	102.0	1.5	103.0	102.0	1.3	103.0	102.0	1.3	103.0	101
	04/07/06	7361.8	4.7	801	275	129,377,000	109	13,411	4,590,000	4,268,000	4,359,000	13,217	7367.3	1.8	102	100.0	1.5	102.0	101.0	1.3	102.0	101.0	1.2	102.0	100
29	04/10/06	7381.2	4.8	820	274	129,696,000	319	13,730	4,700,000	4,370,000	4,467,000	13,537	7545.7	1.5	105	103.0	1.5	104.0	103.0	1.0	103.0	102.0	1.5	104.0	101
	04/11/06	7383.9	4.8	823	272	129,740,000	44	13,774	4,713,000	4,383,000	4,480,000	13,576	7567.4	0.9	104	103.0	1.5	103.0	102.0	1.4	103.0	102.0	1.7	103.0	101
	04/12/06	7388.2	4.8	827	271	129,810,000	70	13,844	4,739,000	4,407,000	4,505,000	13,651	7609.3	1.0	104	103.0	1.5	103.0	102.0	1.3	103.0	102.0	1.5	103.0	101
	04/13/06	7392.7	4.8	832	274	129,884,000	74	13,918	4,764,000	4,431,000	4,513,000	13,708	7641.0	1.0	104	103.0	1.5	104.0	103.0	1.3	103.0	102.0	1.4	103.0	101
	04/14/06	7406.8	4.8	846	279	130,120,000	236	14,154	4,845,000	4,506,000	4,611,000	13,962	7782.6	1.1	104	103.0	1.5	103.0	102.0	1.4	103.0	102.0	1.4	103.0	101
30	04/17/06	7407.0	4.7	846	167	130,122,000	2	14,156	4,846,000	4,507,000	4,612,000	13,965	7784.3	1.0	104	103.0	1.5	104.0	103.0	1.0	103.0	102.0	1.5	103.0	101
	04/18/06	7410.4	4.7	849	275	130,178,000	56	14,212	4,865,000	4,525,000	4,631,000	14,021	7815.5	1.1	104	102.0	1.6	104.0	103.0	1.4	103.0	102.0	1.7	103.0	101
	04/19/06	7414.6	4.7	854	270	130,246,000	68	14,280	4,888,000	4,546,000	4,654,000	14,088	7852.8	1.1	104	103.0	1.6	103.0	102.0	1.4	103.0	102.0	1.6	103.0	101
	04/20/06	7419.6	4.7	859	280	130,330,000	84	14,364	4,917,000	4,573,000	4,683,000	14,173	7900.2	1.0	104	102.0	1.5	103.0	102.0	1.0	104.0	103.0	1.0	103.0	100
	04/21/06	7427.7	4.7	867	272	130,462,000	132	14,496	4,962,000	4,615,000	4,729,000	14,306	7974.4	NA	104	102.0	1.6	103.0	102.0	1.5	103.0	102.0	1.4	103.0	101
31	04/24/06	7448.2	4.8	887	275	130,800,000	338	14,834	5,080,000	4,723,000	4,842,000	14,645	8163.3	1.0	104	103.0	1.5	104.0	102.0	1.0	104.0	103.0	1.0	103.0	101
	04/25/06	7453.6	4.8	893	275	130,889,000	89	14,923	5,111,000	4,752,000	4,872,000	14,735	8213.5	1.2	104	102.0	1.6	103.0	102.0	1.4	103.0	102.0	1.4	103.0	101
	04/26/06	7460.2	4.8	899	275	130,998,000	109	15,032	5,149,000	4,787,000	4,908,000	14,844	8274.2	1.7	104	102.0	1.5	103.0	102.0	1.3	102.0	102.0	1.5	103.0	101
	04/27/06	7465.3	4.8	904	275	131,082,000	84	15,116	5,179,000	4,814,000	4,936,000	14,929	8321.6	1.7	104	102.0	1.6	103.0	102.0	1.3	103.0	102.0	1.3	103.0	101
	04/28/06	7470.4	4.8	909	275	131,166,000	84	15,200	5,208,000	4,840,000	4,964,000	15,012	8367.9	1.7	104	102.0	1.5	103.0	102.0	1.3	102.0	101.0	1.3	103.0	101
32	05/01/06	7492.8	4.8	932	272	131,531,000	365	15,565	5,336,000	4,958,000	5,086,000	15,380	8573.0	1.5	103	102.0	1.5	103.0	102.0	1.0	103.0	102.0	1.0	103.0	101
	05/02/06	7502.5	4.9	941	273	131,690,000	159	15,724	5,392,000	5,008,000	5,139,000	15,539	8661.6	0.9	103	102.0	1.6	103.0	102.0	1.4	102.0	102.0	1.4	103.0	101
	05/03/06	7504.3	4.8	943	269	131,719,000	29	15,753	5,402,000	5,017,000	5,148,000	15,567	8677.3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

APPENDIX B

ANALYTICAL DATA TABLES

Analytical Results from Treatment Plant Sampling at Reno, NV

Sampling Date		09/27/05						10/04/05					10/12/05				
Sampling Location Parameter	Unit	IN	AC	TA	TB	TC	TT	IN	AC	TA	TB	TC	IN	AC	TA	TB	TC
Bed Volume	10^3	-	-	0.0	0.0	0.0	0.0	-	-	1.0	1.0	1.0	-	-	2.2	2.1	2.1
Alkalinity	mg/L(a)	92	-	<1	<1	<1	<1	88	-	92	92	92	97	-	92	97	88
Fluoride	mg/L	<0.1	-	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	6.1	-	<1	<1	<1	<1	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	0.9	-	0.6	0.3	0.1	0.4	-	-	-	-	-	-	-	-	-	-
Orthophosphate	mg/L(b)	<0.05	-	<0.05	<0.05	<0.05	<0.05	0.1	-	<0.05	<0.05	<0.05	-	-	-	-	-
Total P (as PO_4)	mg/L(b)	-	-	-	-	-	-	-	-	-	-	-	0.4	-	<0.03	<0.03	<0.03
Silica (as SiO_2)	mg/L	95.1	-	6.3	4.9	4.4	9.1	51.5	-	52.7	51.2	48.8	69.9	-	61.7	60.8	60.1
Turbidity	NTU	0.3	-	0.1	0.1	0.2	0.1	0.3	-	0.2	<0.1	<0.1	0.5	-	<0.1	0.2	0.1
pH	S.U.	7.1	-	4.3	4.5	4.2	4.2	7.0	-	6.9	6.9	7.0	7.4	-	7.3	7.3	7.3
Temperature	°C	16.2	-	16.3	16.6	16.6	16.6	14.6	-	14.6	14.6	14.7	15.7	-	15.5	15.5	15.4
DO	mg/L	4.4	-	4.3	4.8	4.7	4.6	5.2	-	4.1	4.3	4.5	4.7	-	4.2	4.1	4.2
ORP	mV	269	-	280	392	280	269	237	-	626	648	650	242	-	598	603	592
Free Chlorine	mg/L	-	1.1	-	-	-	0.2	-	0.0	-	-	-	-	0.8	-	-	-
Total Chlorine	mg/L	-	1.1	-	-	-	-	-	0.0	-	-	-	-	0.9	-	-	-
Total Hardness	mg/L(a)	29.3	-	24.8	27.4	31.8	29.2	-	-	-	-	-	-	-	-	-	-
Ca Hardness	mg/L(a)	20.2	-	14.9	16.6	20.7	18.5	-	-	-	-	-	-	-	-	-	-
Mg Hardness	mg/L(a)	9.1	-	9.9	10.8	11.1	10.7	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	35.0	-	0.9	0.9	1.1	1.3	53.7	-	0.5	0.3	0.2	66.5	-	0.5	0.8	0.3
As (soluble)	µg/L	29.5	-	0.7	0.7	0.8	1.2	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	5.5	-	0.2	0.2	0.3	<0.1	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	0.4	-	0.2	0.2	0.1	0.2	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	29.1	-	0.5	0.5	0.6	1.1	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	232	-	<25	35.9	<25	34.1	<25	-	<25	<25	<25	<25	-	<25	<25	<25
Fe (soluble)	µg/L	<25	-	<25	<25	<25	<25	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	0.9	-	15.1	14.8	16.0	12.4	<0.1	-	<0.1	<0.1	<0.1	<0.1	-	<0.1	<0.1	<0.1
Mn (soluble)	µg/L	1.0	-	15.3	15.4	16.8	13.3	-	-	-	-	-	-	-	-	-	-
Sb (total)	µg/L	10.2	-	0.2	0.1	0.1	0.5	14.7	-	3.7	4.2	3.5	16.2	-	8.4	7.8	7.4
Sb (soluble)	µg/L	11.1	-	0.1	0.1	0.1	0.4	-	-	-	-	-	-	-	-	-	-

(a) As $CaCO_3$.
(b) As PO_4.

Analytical Results from Treatment Plant Sampling at Reno, NV (Continued)

Sampling Date		10/25/05					11/03/05(c,d)					11/08/05(d)				
Sampling Location		IN	AC	TA	TB	TC	IN	TA	TB	TC	TT	IN	TA	TB	TC	TT
Parameter	Unit															
Bed Volume	10^3	-	-	2.5	2.4	2.4	-	2.7	2.6	2.6	2.6	-	2.8	2.7	2.7	2.7
Alkalinity	mg/L(a)	92	-	88	88	88	88	83	79	80	83	97	101	88	92	-
Fluoride	mg/L	-	-	-	-	-	0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	7	8	8	8	8	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	0.9	0.9	0.9	0.9	0.9	-	-	-	-	-
Orthophosphate	mg/L(b)	0.1	-	<0.05	<0.05	<0.05	0.1	<0.05	<0.05	<0.05	<0.05	-	-	-	-	-
Total P (as PO_4)	mg/L(b)	0.4	-	<0.03	<0.03	<0.03	0.4	<0.03	<0.03	<0.03	<0.03	0.4	<0.03	<0.03	<0.03	-
Silica (as SiO_2)	mg/L	68.5	-	5.0	48.8	47.0	69.7	56.7	56.1	55.5	54.6	-	-	-	-	-
Turbidity	NTU	0.2	-	0.2	0.5	<0.1	0.3	0.1	0.1	<0.1	9.5	-	-	-	-	-
pH	S.U.	7.1	-	7.1	7.2	7.1	6.7	6.6	6.5	7.0	6.7	7.1	6.9	6.9	6.9	6.9
Temperature	°C	17.0	-	17.0	16.9	16.9	15.6	15.4	15.3	15.4	15.4	16.5	16.7	16.6	16.6	16.6
DO	mg/L	6.2	-	4.7	4.6	4.6	1.0	1.3	1.3	1.2	1.7	1.1	1.3	1.2	1.5	1.1
ORP	mV	307	-	603	619	629	252	699	723	733	732	245	688	714	721	724
Free Chlorine	mg/L	-	0.7	-	-	-	-	-	-	-	0.8	-	-	-	-	0.6
Total Chlorine	mg/L	-	0.8	-	-	-	-	-	-	-	0.8	-	-	-	-	1.7
Total Hardness	mg/L(a)	-	-	-	-	-	17.3	18.0	17.4	17.5	17.9	-	-	-	-	-
Ca Hardness	mg/L(a)	-	-	-	-	-	9.5	9.9	9.4	9.4	9.4	-	-	-	-	-
Mg Hardness	mg/L(a)	-	-	-	-	-	7.8	8.1	7.9	8.1	8.4	-	-	-	-	-
As (total)	µg/L	50.1	-	0.2	1.9	0.3	60.0	1.8	1.1	1.4	0.3	53.4	0.2	0.1	0.1	-
As (soluble)	µg/L	-	-	-	-	-	60.1	0.7	0.2	0.3	0.1	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	<0.1	1.1	0.9	1.1	0.2	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	0.4	0.3	0.3	0.3	0.3	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	59.7	0.3	<0.1	<0.1	<0.1	-	-	-	-	-
Fe (total)	µg/L	<25	-	<25	<25	<25	<25	<25	<25	<25	42.4	<25	<25	<25	<25	-
Fe (soluble)	µg/L	-	-	-	-	-	<25	<25	<25	<25	72.4	-	-	-	-	-
Mn (total)	µg/L	0.2	-	0.1	0.3	0.2	0.2	0.6	0.2	0.7	0.8	0.2	0.1	0.1	0.1	-
Mn (soluble)	µg/L	-	-	-	-	-	0.2	0.4	0.2	0.2	1.9	-	-	-	-	-
Sb (total)	µg/L	13.8	-	3.2	2.8	3.1	15.3	4.7	4.0	3.8	4.5	12.3	3.5	3.0	2.7	-
Sb (soluble)	µg/L	-	-	-	-	-	14.4	4.6	3.8	3.7	4.7	-	-	-	-	-

(a) As $CaCO_3$.
(b) As PO_4.
(c) Water quality parameters measured on 11/04/05.
(d) Chlorine residual not measured at AC.

Analytical Results from Treatment Plant Sampling at Reno, NV (Continued)

Sampling Date		11/15/05						11/29/05						12/07/05					
Sampling Location Parameter	Unit	IN	AC	TA	TB	TC	TT	IN	AC	TA	TB	TC	TT	IN	AC	TA	TB	TC	TT
Bed Volume	10^3	-	-	2.9	2.8	2.8	2.8	-	-	3.5	3.3	3.3	3.4	-	-	3.8	3.6	3.6	3.6
Alkalinity	mg/L(a)	94	-	91	91	91	-	88	-	88	92	92	-	88	-	88	90	90	91
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	0.1	-	<0.1	<0.1	<0.1	<0.1
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	7.1	-	7.4	7.4	7.4	7.4
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	0.9	-	0.9	0.9	0.9	0.9
Orthophosphate	mg/L(b)	-	-	-	-	-	-	-	-	-	-	-	-	0.1	-	<0.05	<0.05	<0.05	<0.05
Total P (as PO_4)	mg/L(b)	0.3	-	<0.03	<0.03	<0.03	-	0.4	-	<0.03	<0.03	<0.03	-	0.4	-	0.04	<0.03	<0.03	<0.03
Silica (as SiO_2)	mg/L	69.7	-	59.1	56.7	56.9	-	75.4	-	66.8	65.7	66.8	-	71.4	-	67.2	65.8	65.7	66.9
Turbidity	NTU	<0.1	-	0.1	<0.1	<0.1	-	2.0	-	0.1	0.1	0.2	-	0.2	-	<0.1	0.2	0.1	0.2
pH	S.U.	6.8	-	6.9	6.9	6.5	6.8	7.0	-	6.8	6.9	6.9	6.9	7.2	-	7.1	7.1	7.1	7.1
Temperature	°C	16.7	-	17.0	16.7	10.7	16.7	17.1	-	16.9	16.7	16.6	14.9	15.9	-	15.2	15.3	15.1	15.8
DO	mg/L	1.1	-	1.7	1.7	1.7	1.7	0.8	-	1.0	0.9	1.0	0.9	1.1	-	1.3	1.3	1.3	4.3
ORP	mV	245	-	739	742	753	739	260	-	675	712	721	730	381	-	735	742	741	741
Free Chlorine	mg/L	-	1.2	-	-	-	1.1	-	1.7	-	-	-	0.7	-	1.0	-	-	-	1.0
Total Chlorine	mg/L	-	1.3	-	-	-	1.3	-	0.7	-	-	-	0.7	-	1.0	-	-	-	1.0
Total Hardness	mg/L(a)	-	-	-	-	-	-	-	-	-	-	-	-	20.1	-	20.9	20.9	21.0	17.5
Ca Hardness	mg/L(a)	-	-	-	-	-	-	-	-	-	-	-	-	12.0	-	12.0	11.9	12.0	10.9
Mg Hardness	mg/L(a)	-	-	-	-	-	-	-	-	-	-	-	-	8.1	-	8.9	8.9	9.1	6.6
As (total)	µg/L	59.8	-	0.6	0.6	<0.1	-	71.7	-	0.9	0.5	0.4	-	69.3	-	1.4	0.5	0.5	0.2
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	70.1	-	1.4	0.4	0.3	0.3
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	-	<0.1	<0.1	0.2	<0.1
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	0.2	0.2	<0.1	<0.1
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	69.7	-	1.1	0.2	0.2	0.2
Fe (total)	µg/L	<25	-	<25	<25	<25	-	<25	-	<25	<25	<25	-	<25	-	<25	<25	<25	<25
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<25	-	<25	<25	<25	<25
Mn (total)	µg/L	<0.1	-	<0.1	<0.1	<0.1	-	0.4	-	0.1	0.2	0.1	-	0.1	-	0.1	0.1	<0.1	<0.1
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	-	<0.1	<0.1	<0.1	<0.1
Sb (total)	µg/L	21.0	-	7.2	6.0	3.0	-	15.8	-	7.4	7.0	6.7	-	15.9	-	10.0	9.6	9.3	9.2
Sb (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.9	9.4	9.3	9.2

(a) As $CaCO_3$.
(b) As PO_4

Analytical Results from Treatment Plant Sampling at Reno, NV (Continued)

Sampling Date		12/13/05						01/10/06						01/18/06					
Sampling Location Parameter	Unit	IN	AC	TA	TB	TC	TT	IN	AC	TA	TB	TC	TT	IN	AC	TA	TB	TC	TT
Bed Volume	10^3	-	-	4.0	3.8	3.8	3.9	-	-	4.3	4.0	4.1	4.1	-	-	4.6	4.3	4.4	4.4
Alkalinity	mg/L[(a)]	88	-	92	88	92	-	92	-	92	92	92	185	97	-	92	92	92	-
Fluoride	mg/L	-	-	-	-	-	-	<0.1	-	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	6.7	-	7	7	7	7	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	0.9	-	0.9	0.9	0.9	0.9	-	-	-	-	-	-
Orthophosphate	mg/L[(b)]	-	-	-	-	-	-	0.1	-	<0.05	<0.05	<0.05	<0.05	-	-	-	-	-	-
Total P (as PO_4)	mg/L[(b)]	0.5	-	0.1	0.1	0.1	-	0.3	-	<0.03	<0.03	<0.03	<0.03	0.3	-	0.1	<0.03	<0.03	-
Silica (as SiO_2)	mg/L	75.5	-	69.5	68.5	67.5	-	73.6	-	66.2	67.5	66.1	66.7	73.9	-	70.8	70.1	68.9	-
Turbidity	NTU	0.1	-	0.1	0.3	0.1	-	0.4	-	0.4	0.4	0.3	0.5	0.4	-	0.2	0.2	0.2	-
pH	S.U.	7.1	-	6.9	6.9	6.9	6.9	7.4	-	7.3	7.2	7.2	7.2	7.3	-	7.3	7.2	7.2	7.3
Temperature	°C	16.8	-	16.1	16.1	15.7	16.1	15.8	-	15.1	15.0	15.1	15.9	16.6	-	16.6	16.4	16.2	15.4
DO	mg/L	1.4	-	1.5	1.4	1.5	1.5	1.5	-	1.3	1.2	1.3	1.2	1.4	-	1.3	1.3	1.3	1.4
ORP	mV	202	-	682	693	711	703	260	-	264	273	273	264	279	-	719	732	740	740
Free Chlorine	mg/L	-	0.7	-	-	-	0.6	-	0.0	-	-	-	0.0	-	0.9	-	-	-	0.9
Total Chlorine	mg/L	-	0.7	-	-	-	0.7	-	0.0	-	-	-	0.0	-	1.0	-	-	-	1.0
Total Hardness	mg/L[(a)]	-	-	-	-	-	-	20.6	-	22.7	22.3	22.0	21.9	-	-	-	-	-	-
Ca Hardness	mg/L[(a)]	-	-	-	-	-	-	13.3	-	14.5	14.3	14.3	14.1	-	-	-	-	-	-
Mg Hardness	mg/L[(a)]	-	-	-	-	-	-	7.3	-	8.2	8.0	7.6	7.8	-	-	-	-	-	-
As (total)	µg/L	55.6	-	2.2	1.0	1.0	-	54.0	-	1.3	0.3	0.2	0.3	61.1	-	2.0	0.7	0.6	-
As (soluble)	µg/L	-	-	-	-	-	-	53.4	-	-	-	-	0.3	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	0.5	-	-	-	-	<0.1	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	0.3	-	-	-	-	0.2	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	53.1	-	-	-	-	0.1	-	-	-	-	-	-
Fe (total)	µg/L	<25	-	<25	<25	<25	-	<25	-	<25	<25	<25	<25	<25	-	<25	<25	<25	-
Fe (soluble)	µg/L	-	-	-	-	-	-	<25	-	-	-	-	25.0	-	-	-	-	-	-
Mn (total)	µg/L	0.3	-	0.2	0.2	0.2	-	0.8	-	0.3	0.1	<0.1	0.9	<0.1	-	<0.1	<0.1	<0.1	-
Mn (soluble)	µg/L	-	-	-	-	-	-	0.2	-	-	-	-	1.0	-	-	-	-	-	-
Sb (total)	µg/L	11.7	-	7.8	7.1	6.9	-	13.0	-	7.8	7.0	6.9	7.4	13.7	-	11.6	10.4	10.1	-
Sb (soluble)	µg/L	-	-	-	-	-	-	12.6	-	-	-	-	0.4	-	-	-	-	-	-

(a) As $CaCO_3$.

(b) As PO_4

Analytical Results from Treatment Plant Sampling at Reno, NV (Continued)

Sampling Date		01/24/06						01/31/06						02/07/06					
Sampling Location Parameter	Unit	IN	AC	TA	TB	TC	TT	IN	AC	TA	TB	TC	TT	IN	AC	TA	TB	TC	TT
Bed Volume	10^3	-	-	4.9	4.5	4.6	4.7	-	-	5.1	4.8	4.9	4.9	-	-	5.4	5.1	5.2	5.2
Alkalinity	mg/L$^{(a)}$	97	-	92	97	97	-	93	-	-	-	-	93	92	-	92	90	91	-
Fluoride	mg/L	-	-	-	-	-	-	0.1	-	-	-	-	<0.1	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	7.0	-	-	-	-	7.1	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	0.9	-	-	-	-	0.9	-	-	-	-	-	-
Orthophosphate	mg/L$^{(b)}$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as PO_4)	mg/L$^{(b)}$	0.3	-	0.1	0.1	0.05	-	0.3	-	-	-	-	0.04	0.3	-	0.1	0.1	0.1	-
Silica (as SiO_2)	mg/L	74.7	-	71.2	70.9	70.6	-	72.1	-	-	-	-	72.4	72.6	-	69	69.6	70.3	-
Turbidity	NTU	0.3	-	0.4	0.2	0.4	-	0.3	-	-	-	-	0.6	0.3	-	0.7	0.5	0.3	-
pH	S.U.	7.4	-	7.2	7.1	7.1	7.1	7.8	-	7.5	7.4	7.4	7.4	7.9	-	7.6	7.6	7.5	7.5
Temperature	°C	16.2	-	14.9	14.8	15.8	16.0	16.5	-	17.0	17.0	17.0	16.7	16.8	-	16.9	16.9	16.8	17.0
DO	mg/L	1.4	-	1.3	1.4	1.3	1.1	1.3	-	1.3	1.2	1.3	1.1	1.4	-	1.3	1.3	1.3	1.2
ORP	mV	278	-	729	736	744	749	256	-	691	709	713	725	380	-	713	725	733	730
Free Chlorine	mg/L	-	0.9	-	-	-	0.9	-	0.7	-	-	-	0.7	-	0.7	-	-	-	0.7
Total Chlorine	mg/L	-	0.9	-	-	-	1.0	-	0.7	-	-	-	0.7	-	0.7	-	-	-	0.7
Total Hardness	mg/L$^{(a)}$	-	-	-	-	-	-	21.8	-	-	-	-	22.1	-	-	-	-	-	-
Ca Hardness	mg/L$^{(a)}$	-	-	-	-	-	-	15.0	-	-	-	-	15.2	-	-	-	-	-	-
Mg Hardness	mg/L$^{(a)}$	-	-	-	-	-	-	6.8	-	-	-	-	6.8	-	-	-	-	-	-
As (total)	µg/L	75.6	-	4.1	1.1	0.9	-	68.2	-	2.9	2.8	0.9	1.7	54.2	-	4.4	1.5	1.2	-
As (soluble)	µg/L	-	-	-	-	-	-	67.2	-	-	-	-	1.7	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	1.0	-	-	-	-	<0.1	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	0.3	-	-	-	-	0.3	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	66.9	-	-	-	-	1.4	-	-	-	-	-	-
Fe (total)	µg/L	<25	-	<25	<25	<25	-	<25	-	-	-	-	<25	<25	-	<25	<25	<25	-
Fe (soluble)	µg/L	-	-	-	-	-	-	<25	-	-	-	-	<25	-	-	-	-	-	-
Mn (total)	µg/L	<0.1	-	<0.1	<0.1	<0.1	-	<0.1	-	-	-	-	0.4	<0.1	-	<0.1	<0.1	<0.1	-
Mn (soluble)	µg/L	-	-	-	-	-	-	<0.1	-	-	-	-	0.4	-	-	-	-	-	-
Sb (total)	µg/L	14.1	-	9.5	8.7	9.0	-	16.2	-	-	-	-	10.1	12.0	-	9.3	9.2	9.5	-
Sb (soluble)	µg/L	-	-	-	-	-	-	15.4	-	-	-	-	10.3	-	-	-	-	-	-

(a) As $CaCO_3$.
(b) As PO_4

Analytical Results from Treatment Plant Sampling at Reno, NV (Continued)

Sampling Date		02/22/06						03/07/06(c)						03/21/06					
Sampling Location Parameter	Unit	IN	AC	TA	TB	TC	TT	IN	AC	TA	TB	TC	TT	IN	AC	TA	TB	TC	TT
Bed Volume	10^3		-	6.0	5.6	5.7	5.7	-	-	6.5	6.0	6.1	6.2	-	-	7.0	6.5	6.6	6.7
Alkalinity	mg/L(a)	96 96	-	96 91	91 96	96 91	-	95	-	95	95	91	-	91	-	91	91	91	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Orthophosphate	mg/L(b)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as PO_4)	mg/L(b)	0.3 0.4	-	0.2 0.2	0.1 0.1	0.1 0.1	-	0.3	-	0.1	0.1	0.1	-	0.3	-	0.2	0.1	0.1	-
Silica (as SiO_2)	mg/L	77.1 76.0	-	73.7 73.8	73.4 72.4	71.9 75.1	-	70.9	-	68.4	70.3	67.9	-	73	-	69.7	71.2	70.3	-
Turbidity	NTU	0.5 0.4	-	0.8 0.7	0.5 0.4	0.5 0.5	-	0.4	-	0.3	0.7	1.2	-	0.3	-	0.3	0.4	0.3	-
pH	S.U.	7.4	-	7.3	7.2	7.2	7.2	7.1	-	7.0	6.9	6.9	6.9	7.1	-	7.1	7.0	7.0	7.0
Temperature	°C	16.8	-	16.3	14.8	14.6	15.2	17.2	-	16.9	16.8	16.7	16.5	16.5	-	16.2	16.1	1.7	15.4
DO	mg/L	1.5	-	1.3	1.3	1.3	1.1	1.2	-	1.9	1.6	1.7	1.7	1.7	-	2.1	2.2	2.4	3.3
ORP	mV	263	-	696	723	731	707	115	-	676	695	706	710	219	-	699	710	716	722
Free Chlorine	mg/L	-	0.6	-	-	-	0.6	-	0.6	-	-	-	0.7	-	0.7	-	-	-	0.7
Total Chlorine	mg/L	-	0.6	-	-	-	0.6	-	0.7	-	-	-	0.7	-	0.7	-	-	-	0.8
Total Hardness	mg/L(a)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness	mg/L(a)	-	-	-	-	-	-	-	-	-	-	-	-	10.2	-	10.6	10.7	11.0	-
Mg Hardness	mg/L(a)	-	-	-	-	-	-	-	-	-	-	-	-		-				-
As (total)	µg/L	71.1 75.9	-	6.2 6.7	3.5 3.4	3.1 3.1	-	77.7	-	7.9	4.6	3.8	-	78.7	-	14.7	6.2	5.7	-
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	<25 <25	-	<25 <25	<25 <25	<25 <25	-	<25	-	<25	<25	<25	-	<25	-	<25	<25	<25	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	<0.1 <0.1	-	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	-	<0.1	-	<0.1	<0.1	<0.1	-	<0.1	-	<0.1	<0.1	<0.1	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sb (total)	µg/L	15.1 14.1	-	11.7 11.3	10.5 10.7	10.6 10.3	-	14.2	-	10.5	10.1	10.6	-	15.7	-	12.9	12.2	12.1	-
Sb (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(a) As $CaCO_3$.
(b) As PO_4.
(c) Water quality measurements taken on 03/02/06.

Analytical Results from Treatment Plant Sampling at Reno, NV (Continued)

Sampling Date		03/28/06						04/04/06						04/11/06					
Sampling Location Parameter	Unit	IN	AC	TA	TB	TC	TT	IN	AC	TA	TB	TC	TT	IN	AC	TA	TB	TC	TT
Bed Volume	10^3	-	-	7.4	6.9	7.0	7.1	-	-	7.5	7.0	7.2	7.2	-	-	7.9	7.3	7.5	7.6
Alkalinity	mg/L(a)	91	-	91	91	95	-	95	-	-	-	-	87	101		97	101	97	-
Fluoride	mg/L	-	-	-	-	-	-	0.2	-	-	-	-	0.2	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	7.4	-	-	-	-	7.4	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	1.0	-	-	-	-	2.0	-	-	-	-	-	-
Orthophosphate	mg/L(b)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as PO_4)	mg/L(b)	0.4	-	0.2	0.2	0.2	-	0.4	-	-	-	-	0.2	0.3	-	0.2	0.2	0.2	0.2
Silica (as SiO_2)	mg/L	72	-	73.7	70.7	72.4	-	71.8	-	-	-	-	70	70	-	70.1	68.4	69.4	-
Turbidity	NTU	0.4	-	0.6	0.4	0.5	-	0.3	-	-	-	-	0.3	0.7	-	0.7	0.8	1.2	-
pH	S.U.	6.9	-	6.9	6.9	6.9	6.9	7.2	-	7.0	7.0	7.0	-	7.1	-	7.0	7.0	7.0	7.0
Temperature	°C	17.1	-	17.0	17.0	16.5	16.4	16.5	-	16.6	16.4	15.3	16.4	17.0	-	16.9	16.6	16.5	16.4
DO	mg/L	1.9	-	2.1	2.3	2.5	2.2	1.1	-	1.3	1.4	1.5	1.5	0.8	-	0.9	1.0	0.9	0.8
ORP	mV	220	-	713	719	723	728	218	-	706	720	728	731	273	-	730	744	751	754
Free Chlorine	mg/L	-	0.7	-	-	-	0.7	-	0.7	-	-	-	0.7	-	0.8	-	-	-	0.8
Total Chlorine	mg/L	-	0.7	-	-	-	0.7	-	0.8	-	-	-	0.7	-	0.8	-	-	-	0.8
Total Hardness	mg/L(a)	22.8	-	24.2	24.4	24.4	-	25.1	-	-	-	-	26.9	-	-	-	-	-	-
Ca Hardness	mg/L(a)	16.7	-	17.6	17.7	17.7	-	18.4	-	-	-	-	19.5	-	-	-	-	-	-
Mg Hardness	mg/L(a)	6.1	-	6.6	6.6	6.7	-	6.7	-	-	-	-	7.4	-	-	-	-	-	-
As (total)	µg/L	80.1	-	11.1	6.9	6.2	-	78.6	-	11.1	10.8	10.9	8.9	83.8	-	15.4	11.2	10.7	11.9
As (soluble)	µg/L	-	-	-	-	-	-	79.7	-	-	-	-	8.4	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	<0.1	-	-	-	-	0.5	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	0.2	-	-	-	-	0.1	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	79.4	-	-	-	-	8.3	-	-	-	-	-	-
Fe (total)	µg/L	<25	-	<25	<25	<25	-	<25	-	-	-	-	<25	<25	-	<25	<25	<25	<25
Fe (soluble)	µg/L	-	-	-	-	-	-	<25	-	-	-	-	<25	-	-	-	-	-	-
Mn (total)	µg/L	<0.1	-	<0.1	<0.1	<0.1	-	<0.1	-	-	-	-	0.7	<0.1	-	<0.1	<0.1	<0.1	0.5
Mn (soluble)	µg/L	-	-	-	-	-	-	<0.1	-	-	-	-	1.2	-	-	-	-	-	-
Sb (total)	µg/L	14.1	-	11.1	10.8	10.7	-	14.7	-	-	-	-	13.7	17.6	-	14.5	14.6	14.5	14.0
Sb (soluble)	µg/L	-	-	-	-	-	-	14.4	-	-	-	-	13.9	-	-	-	-	-	-

(a) As $CaCO_3$.

(b) As PO_4.

Analytical Results from Treatment Plant Sampling at Reno, NV (Continued)

Sampling Date		04/18/06						04/25/06						05/02/06					
Sampling Location Parameter	Unit	IN	AC	TA	TB	TC	TT	IN	AC	TA	TB	TC	TT	IN	AC	TA	TB	TC	TT
Bed Volume	10^3	-	-	8.1	7.6	7.7	7.8	-	-	8.5	7.9	8.1	8.2	-	-	9.0	8.4	8.6	8.7
Alkalinity	mg/L[(a)]	101	-	96	101	97	-	92	-	92	92	96	-	92	-	96	96	96	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Orthophosphate	mg/L[(b)]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as PO_4)	mg/L[(b)]	0.4	-	0.3	0.2	0.2	-	0.4	-	0.3	0.3	0.3	0.6	0.3	-	0.3	0.3	0.3	-
Silica (as SiO_2)	mg/L	71.3	-	69.7	69.4	69.7	-	72.9	-	71.2	73	72.1	-	75.5	-	75.2	76.0	75.6	-
Turbidity	NTU	0.6	-	0.3	0.1	0.2	-	0.2	-	0.3	0.3	0.2	-	0.1	-	0.5	0.1	0.2	-
pH	S.U.	7.1	-	7.0	7.0	7.0	7.0	7.1	-	6.9	6.9	6.9	7.1	6.9	-	6.9	6.9	6.9	-
Temperature	°C	15.9	-	16.3	16.2	15.8	15.6	17.1	-	16.7	16.7	16.6	16.6	17.7	-	17.7	17.7	17.6	-
DO	mg/L	1.1	-	1.1	1.2	1.3	1.3	1.6	-	2.0	2.0	203.0	2.3	1.6	-	2.0	1.9	1.9	-
ORP	mV	263	-	721	733	743	748	241	-	739	739	749	746	230	-	215	236	242	-
Free Chlorine	mg/L	-	0.9	-	-	-	0.8	-	0.9	-	-	-	0.9	-	0.0	-	-	-	0.0
Total Chlorine	mg/L	-	0.9	-	-	-	0.9	-	0.9	-	-	-	1.0	-	0.0	-	-	-	0.0
Total Hardness	mg/L[(a)]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness	mg/L[(a)]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness	mg/L[(a)]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	75.7	-	13.2	9.3	8.8	11.0	81.5	-	17.9	13.3	12.1	18.9	88.0	-	25.1	20.0	19.8	21.6
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	<25	-	<25	<25	<25	<25	<25	-	<25	<25	<25	873	<25	-	<25	<25	<25	110
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	<0.1	-	<0.1	<0.1	<0.1	0.4	<0.1	-	<0.1	<0.1	<0.1	40.4	<0.1	-	<0.1	<0.1	<0.1	2.2
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sb (total)	µg/L	14.2	-	11.2	11.1	10.9	11.5	15.0	-	12.6	12.4	12.2	9.1	14.9	-	12.6	12.5	13.1	12.6
Sb (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(a) As $CaCO_3$.
(b) As PO_4.