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Arsenic Removal from Drinking Water by Adsorptive Media EPA Demonstration Project at Golden Hills Community Services District in Tehachapi, CA Final Performance Evaluation Report

by

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Sally Gutierrez, Director
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ABSTRACT

This report documents the activities performed and the results obtained for the arsenic removal treatment technology demonstration project at Golden Hills Community Services District (GHCSD) located in Tehachapi, CA. The objectives of the project were to evaluate (1) the effectiveness of Magnesium Elektron, Inc.'s (MEI) Isolux™ treatment system in removing arsenic to meet the new maximum contaminant level (MCL) of 10 µg/L; (2) the reliability of the treatment system; (3) the required system operation and maintenance (O&M) and operator skill levels; and (4) the capital and O&M cost of the technology. The project also characterized water in the distribution system and residuals generated by the treatment process. The types of data collected included system operation, water quality (both across the treatment train and in the distribution system), process residuals, and capital and O&M cost.

The Isolux™ arsenic treatment system consisted of two adsorption modules arranged in parallel, capable of treating up to 150 gal/min (gpm) of flow. Each module, designed for 75 gpm, consisted of a booster pump, a 1-µm bag filter, and two 20-in × 48-in carbon-steel filtration vessels, each containing nine Isolux™-302M media cartridges. Each media cartridge was 4.55-in in diameter and 42.25-in in length and contained 0.32 ft^3 of Isolux™-302M–a hydrous zirconium oxide media with amphoteric properties. During the performance evaluation study from October 26, 2005, through March 20, 2007, three media runs were performed, each operating for a total run time of 1,377, 1,900, and 1,422 hr (or 21.9, 20.2, and 16.7 hr/day). Average flowrates for the runs were 79, 74, and 85 gpm. Based on the average flowrates, the empty bed contact times (EBCT) ranged from 0.9 to 1.2 min, compared to the design value of 0.5 min.

Among the 13 active wells at GHCSD, only Well C had elevated arsenic concentrations, which averaged 12.2 µg/L and existed primarily as soluble As(V). The pH values of raw water ranged from 7.4 to 7.9 and averaged 7.6, which is much lower than the zero point of charge for zirconium hydroxide (i.e., 10 to 11).

During Media Run 1, the system treated approximately 61,600 bed volumes (BV) of water before reaching 10 µg/L arsenic breakthrough. This run length was 41% lower than the vendor's estimated 105,000 BV. An excessive amount of sediment was observed in the well water, necessitating frequent replacement of bag filters prior to the adsorption modules. It was possible that particles passed through the bag filters blocked (or partially blocked) some passages on the media cartridges' outer membrane, causing preferential flow and the short run length observed. Examination of the well revealed rusty areas on the drop-pipe, which prompted a decision by GHCSD to rehabilitate the well.

Following the well rehabilitation and media cartridge changeout, Media Run 2 began on April 27, 2006. The system treated 92,800 BV of water before reaching 10 µg/L arsenic breakthrough. Since Media Runs 1 and 2 operated under similar conditions, the well rehabilitation might have, in fact, contributed to the more extended media life observed. Following media cartridge changeout, Media Run 3 began on August 17, 2006, and ended on March 20, 2007, with the system operating intermittently due to a lower demand in the winter. The system treated approximately 85,100 BV after reaching 10 µg/L arsenic breakthrough. Similar run lengths were observed during Media Runs 2 and 3. The intermittent system operation (i.e., 16.7 versus 20.2 hr/day) did not seem to affect the media run length.

The treatment system did not require backwash; therefore, spent media cartridges were the only residue generated. Spent Isolux™-302M media passed TCLP tests and therefore could be disposed of as non-hazardous waste. However, MEI opted to send the spent media for beneficial reuse.

Comparison of the distribution system sampling results before and after system startup showed a slight decrease in the average arsenic concentration at each of the three sampling locations (i.e., from 2.8, 6.0, and 5.2 µg/L to 2.0, 3.3, and 3.1 µg/L, respectively). Most of the time, arsenic concentrations were much

lower than those of the treatment effluent, presumably due to blending of the treated water with untreated water from wells where arsenic levels were not of concern. Lead and copper concentrations at the three sampling locations did not appear to be significantly impacted by the arsenic treatment system.

The capital investment cost was $76,840, which included $58,500 for equipment, $8,500 for engineering, and $9,840 for installation. Using the system's rated capacity of 150 gpm, the capital cost was $512/gpm (or $0.36/gpd).

The O&M cost for the Isolux™ system included cost for media cartridge replacement and labor for routine operation. Based on the volumes processed during each media run prior to 10 µg/L arsenic breakthrough, the total O&M cost, including media cartridge replacement for Media Runs 1, 2, and 3, was $1.35, $0.89, and $0.98/1,000 gal, respectively. Routine activities to operate and maintain the system consumed only 2.5 hr per week. Therefore, the estimated labor cost was $0.14/1,000 gal of water treated, assuming that the system operates at 79.3 gpm for 19.6 hr/day and 7 days/week to produce 653,000 gal of water per week.

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ABBREVIATIONS AND ACRONYMS

AAL	American Analytical Laboratories
AC	asbestos cement
AM	adsorptive media
As	arsenic
ATS	Aquatic Treatment Systems
bgs	below ground surface
BV	bed volumes
Ca	calcium
CDPH	California Department of Public Health
CEQA	California Environmental Quality Act
Cl	chlorine
C/F	coagulation/filtration
Cu	copper
DO	dissolved oxygen
EBCT	empty bed contact time
EPA	U.S. Environmental Protection Agency
F	fluoride
Fe	iron
GFH	granular ferric hydroxide
GHCSD	Golden Hills Community Services District
gpd	gallons per day
gpm	gallons per minute
HIX	hybrid ion exchanger
hp	horsepower
ICP-MS	inductively coupled plasma-mass spectrometry
ID	identification
IX	ion exchange
LCR	Lead and Copper Rule
MCL	maximum contaminant level
MDL	method detection limit
MEI	Magnesium Elektron, Inc.
Mg	magnesium
mgd	mega gallons per day
mg/L	milligrams per liter
μg/L	micrograms per liter
μm	micrometer
Mn	manganese
mV	millivolts

Na	sodium
NA	not available
ND	not detected
NH_3	ammonia
NO_2	nitrite
NO_3	nitrate
NRMRL	National Risk Management Research Laboratory
NSF	NSF International
NTU	nephlemetric turbidity units
O&M	operation and maintenance
OIT	Oregon Institute of Technology
ORD	Office of Research and Development
ORP	oxidation-reduction potential
PE	polyethylene
Pb	lead
PO_4	orthophosphate
POE	point of entry
POU	point of use
psi	pounds per square inch
PVC	polyvinyl chloride
ΔP	pressure differential
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RO	reverse osmosis
RPD	relative percent difference
SDWA	Safe Drinking Water Act
SiO_2	silica
SO_4	sulfate
STS	Severn Trent Services
S.U.	standard unit
TCLP	Toxicity Characteristic Leaching Procedure
TDS	total dissolved solids
TO	task order
TOC	total organic carbon
U	uranium
V	vanadium
WET	whole effluent toxicity
Zpc	zero point of charge
Zr	zirconium

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1.0 INTRODUCTION

1.1 Background

The Safe Drinking Water Act (SDWA) mandates that U.S. Environmental Protection Agency (EPA) identify and regulate drinking-water contaminants that may have adverse human health effects and 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). To clarify 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 required 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 cost. 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, onsite demonstrations of arsenic removal technologies, process modifications, and engineering approaches applicable to small systems. Shortly thereafter, an announcement published in the *Federal Register* requested water utilities interested in participating in Round 1 of this EPA-sponsored demonstration program to provide information on their water systems. In June 2002, EPA selected 17 out of 115 sites to host the demonstration studies.

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 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 the demonstration at each site. Because of funding limitations and other technical reasons, only 12 of the 17 sites were selected for the demonstration project. 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.

In 2003, EPA initiated Round 2 arsenic technology demonstration projects that were partially funded with Congressional add-on funding to the EPA budget. In June 2003, EPA selected 32 potential demonstration sites, and the community water system at Golden Hills Community Services District (GHCSD) in Tehachapi, CA, was one of those selected.

In September 2003, EPA again solicited proposals from engineering firms and vendors for arsenic removal technologies. EPA received 148 technical proposals for the 32 host sites, with each site receiving from two to eight proposals. In April 2004, EPA convened another technical panel to review the proposals and provide recommendations to EPA; the number of proposals per site ranged from none (for two sites) to a maximum of four. The final selection of the treatment technology at sites receiving at least one proposal was made, again through a joint effort of EPA, the state regulators, and the host site. Since then, four sites have withdrawn from the demonstration program, reducing the number of sites to 28. In October 2004, Magnesium Elektron, Inc.'s (MEI) Isolux™ arsenic treatment system was selected for demonstration at GHCSD in Tehachapi, CA.

As of November 2009, 39 of the 40 systems were operational, and the performance evaluation of 34 systems was complete.

1.2 Treatment Technologies for Arsenic Removal

The technologies selected for the Rounds 1 and 2 demonstration host sites include 25 adsorptive media (AM) systems (the Oregon Institute of Technology [OIT] site has three AM systems), 13 coagulation/filtration (C/F) systems, two ion exchange (IX) systems, and 17 point-of-use (POU) units (including nine under-the-sink reverse osmosis [RO] units at the Sunset Ranch Development site and eight AM units at the OIT site) and one system modification. Table 1-1 summarizes the locations, technologies, vendors, system flowrates, and key source water quality parameters (including As, Fe, and pH) at the 40 demonstration sites. An overview of the technology selection and system design for the 12 Round 1 demonstration sites and associated capital cost is provided in two EPA reports (Wang, et al., 2004 and Chen, et al., 2004). These are posted on the EPA website at http://www.epa.gov/ORD/NRMRL/wswrd/dw/arsenic/tech/index.html.

1.3 Project Objectives

The purpose of the arsenic demonstration program is to conduct full-scale arsenic treatment technology demonstration studies on the removal of arsenic from drinking-water supplies at 40 sites. Specific objectives are to:

- Evaluate the performance of the arsenic removal technologies for use on small systems.
- Determine the required system operation and maintenance (O&M) and operator skill levels.
- Characterize process residuals produced by the technologies.
- Determine the capital and O&M cost of the technologies.

This report summarizes the performance of the Isolux™ arsenic treatment system at the GHCSD site in Tehachapi, CA, during the study period from October 25, 2005, through March 20, 2007. The types of data collected included system operation, water quality (both across the treatment train and in the distribution system), residuals, and capital and preliminary O&M cost.

Table 1-1. Summary of Rounds 1 and 2 Arsenic Removal Demonstration Locations, Technologies, and Source Water Quality

Demonstration Location	Site Name	Technology (Media)	Vendor	Design Flowrate (gpm)	Source Water Quality		
					As (µg/L)	Fe (µg/L)	pH (S.U.)
Northeast/Ohio							
Wales, ME	Springbrook Mobile Home Park	AM (A/I Complex)	ATS	14	38[a]	<25	8.6
Bow, NH	White Rock Water Company	AM (G2)	ADI	70[b]	39	<25	7.7
Goffstown, NH	Orchard Highlands Subdivision	AM (E33)	AdEdge	10	33	<25	6.9
Rollinsford, NH	Rollinsford Water and Sewer District	AM (E33)	AdEdge	100	36[a]	46	8.2
Dummerston, VT	Charette Mobile Home Park	AM (A/I Complex)	ATS	22	30	<25	7.9
Felton, DE	Town of Felton	C/F (Macrolite)	Kinetico	375	30[a]	48	8.2
Stevensville, MD	Queen Anne’s County	AM (E33)	STS	300	19[a]	270[c]	7.3
Houghton, NY[d]	Town of Caneadea	C/F (Macrolite)	Kinetico	550	27[a]	1,806[c]	7.6
Newark, OH	Buckeye Lake Head Start Building	AM (ARM 200)	Kinetico	10	15[a]	1,312[c]	7.6
Springfield, OH	Chateau Estates Mobile Home Park	AM (E33)	AdEdge	250[e]	25[a]	1,615[c]	7.3
Great Lakes/Interior Plains							
Brown City, MI	City of Brown City	AM (E33)	STS	640	14[a]	127[c]	7.3
Pentwater, MI	Village of Pentwater	C/F (Macrolite)	Kinetico	400	13[a]	466[c]	6.9
Sandusky, MI	City of Sandusky	C/F (Aeralater)	Siemens	340[e]	16[a]	1,387[c]	6.9
Delavan, WI	Vintage on the Ponds	C/F (Macrolite)	Kinetico	40	20[a]	1,499[c]	7.5
Greenville, WI	Town of Greenville	C/F (Macrolite)	Kinetico	375	17	7827[c]	7.3
Climax, MN	City of Climax	C/F (Macrolite)	Kinetico	140	39[a]	546[c]	7.4
Sabin, MN	City of Sabin	C/F (Macrolite)	Kinetico	250	34	1,470[c]	7.3
Sauk Centre, MN	Big Sauk Lake Mobile Home Park	C/F (Macrolite)	Kinetico	20	25[a]	3,078[c]	7.1
Stewart, MN	City of Stewart	C/F&AM (E33)	AdEdge	250	42[a]	1,344[c]	7.7
Lidgerwood, ND	City of Lidgerwood	Process Modification	Kinetico	250	146[a]	1,325[c]	7.2
Midwest/Southwest							
Arnaudville, LA	United Water Systems	C/F (Macrolite)	Kinetico	770[e]	35[a]	2,068[c]	7.0
Alvin, TX	Oak Manor Municipal Utility District	AM (E33)	STS	150	19[a]	95	7.8
Bruni, TX	Webb Consolidated Independent School District	AM (E33)	AdEdge	40	56[a]	<25	8.0
Wellman, TX	City of Wellman	AM (E33)	AdEdge	100	45	<25	7.7
Anthony, NM	Desert Sands Mutual Domestic Water Consumers Association	AM (E33)	STS	320	23[a]	39	7.7
Nambe Pueblo, NM	Nambe Pueblo Tribe	AM (E33)	AdEdge	145	33	<25	8.5
Taos, NM	Town of Taos	AM (E33)	STS	450	14	59	9.5
Rimrock, AZ	Arizona Water Company	AM (E33)	AdEdge	90[b]	50	170	7.2
Tohono O'odham Nation, AZ	Tohono O’odham Utility Authority	AM (E33)	AdEdge	50	32	<25	8.2
Valley Vista, AZ	Arizona Water Company	AM (AAFS50/ARM 200)	Kinetico	37	41	<25	7.8

Table 1-1. Summary of Rounds 1 and 2 Arsenic Removal Demonstration Locations, Technologies, and Source Water Quality (Continued)

Demonstration Location	Site Name	Technology (Media)	Vendor	Design Flowrate (gpm)	Source Water Quality As (µg/L)	Source Water Quality Fe (µg/L)	Source Water Quality pH (S.U.)
Far West							
Three Forks, MT	City of Three Forks	C/F (Macrolite)	Kinetico	250	64	<25	7.5
Fruitland, ID	City of Fruitland	IX (A300E)	Kinetico	250	44	<25	7.4
Homedale, ID	Sunset Ranch Development	POU RO[f]	Kinetico	75 gpd	52	134	7.5
Okanogan, WA	City of Okanogan	C/F (Electromedia-I)	Filtronics	750	18	69[c]	8.0
Klamath Falls, OR	Oregon Institute of Technology	POE AM (Adsorbsia/ARM 200/ArsenX^{np}) and POU AM (ARM 200)[g]	Kinetico	60/60/30	33	<25	7.9
Vale, OR	City of Vale	IX (Arsenex II)	Kinetico	525	17	<25	7.5
Reno, NV	South Truckee Meadows General Improvement District	AM (GFH/Kemiron)	Siemens	350	39	<25	7.4
Susanville, CA	Richmond School District	AM (A/I Complex)	ATS	12	37[a]	125	7.5
Lake Isabella, CA	Upper Bodfish Well CH2-A	AM (HIX)	VEETech	50	35	125	7.5
Tehachapi, CA	Golden Hills Community Service District	AM (Isolux)	MEI	150	15	<25	6.9

AM = adsorptive media process; C/F = coagulation/filtration; HIX = hybrid ion exchanger; IX = ion exchange process; RO = reverse osmosis
ATS = Aquatic Treatment Systems; MEI = Magnesium Elektron, Inc.; STS = Severn Trent Services.

(a) Arsenic existing mostly as As(III).
(b) Design flowrate reduced by 50% due to system reconfiguration from parallel to series operation.
(c) Iron existing mostly as Fe(II).
(d) Withdrew from program in 2007. Selected originally to replace Village of Lyman, NE, site, which withdrew from the program in June 2006.
(e) Facilities upgraded systems in Springfield, OH, from 150 to 250 gpm; in Sandusky, MI, from 210 to 340 gpm; and in Arnaudville, LA, from 385 to 770 gpm.
(f) Including nine residential units.
(g) Including eight under-the-sink units.

2.0 SUMMARY AND CONCLUSIONS

MEI's Isolux™ arsenic treatment system was installed at GHCSD in Tehachapi, CA, on October 21, 2005, and was put into service on October 25, 2005. Based on the information collected during the performance evaluation study, the following conclusions were drawn relating to the overall project objectives.

Performance of the arsenic removal technology for use on small systems:

- The Isolux™-302M media was effective at removing arsenic from drinking water to below the 10 µg/L MCL. The Isolux™ system achieved useful run lengths of 61,600, 92,800, and 85,100 BV during Media Runs 1, 2, and 3, respectively; this is 12 to 41% lower than the vendor-projected run length of 105,000 BV.
- Accumulation of submicron particles on the media cartridges might have caused preferential flow through the media cartridges and the relatively short run length observed during Media Run 1.
- Most of the time, arsenic concentrations in the distribution system were much lower than those of the treatment system effluent, presumably due to blending of the treated water with untreated water from wells where arsenic was not a concern. Lead and copper did not appear to be impacted by the treatment system.

Simplicity of required system O&M and operator skill levels:

- Under normal operating conditions, the system required little attention from the operator. The daily demand for operator labor was approximately 30 min to inspect the system visually and record operational parameters.
- Daily operation of the system did not require additional skills beyond those necessary to operate the existing water-supply equipment. The system was operated by a State of California-certified operator who has Level 2 certifications for both treatment and distribution systems.

Process residuals produced by the technology:

- Residuals produced by the Isolux™ system included spent media cartridges only; backwash was not a system requirement. The spent Isolux™-302M media passed Toxicity Characteristic Leaching Procedure (TCLP) tests and therefore could be disposed of as a non-hazardous waste. However, MEI sent the spent media for beneficial reuse.

Cost-effectiveness of the technology:

- The capital investment cost for the 150-gpm system was $76,840, including $58,500 for equipment, $8,500 for engineering, and $9,840 for installation. This cost equated to $512/gpm (or $0.36/gpd), not including cost for the building.
- The unit capital cost was $0.09/1,000 gal if the system operates at a 100% utilization rate. The system actual unit cost was $0.21/1,000 gal of treated water, based on an average flowrate of 79.3 gpm and an average daily operating time of 19.6 hr/day. The labor cost for routine O&M activities was $0.14/1,000 gal of water treated.

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 Isolux™ arsenic treatment system began on October 25, 2005, and ended on March 20, 2007. Table 3-2 summarizes the types of data collected and/or considered as part of the technology evaluation process. The overall system performance was evaluated based on its ability to consistently remove arsenic to below the target MCL of 10 µg/L for arsenic through the collection of water samples across the treatment train, as described in the Study Plan (Battelle, 2005). System reliability was evaluated by tracking the unscheduled system downtime and the frequency and extent of repair and replacement. The plant operator recorded the unscheduled downtime and repair information on a Repair and Maintenance Log Sheet.

Table 3-1. Predemonstration Study Activities and Completion Dates

Activity	Date
Introductory Meeting Held	October 13, 2004
Project Planning Meeting Held	April 12, 2005
Draft Letter of Understanding Issued	April 22, 2005
Final Letter of Understanding Issued	May 6, 2005
Request for Quotation Issued to Vendor	May 24, 2005
Vendor Quotation Submitted to Battelle	June 6, 2005
Purchase Order Completed and Signed	July 5, 2005
Engineering Package Submitted to CDPH	August 4, 2005
Final Study Plan Issued	September 23, 2005
Permit issued by CDPH	September 7, 2005
System Installation and Shakedown Completed	October 21, 2005
Performance Evaluation Began	October 26, 2005

CDPH = California Department of Health Services.

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

Evaluation Objective	Data Collection
Performance	-Ability to consistently meet 10 µg/L of arsenic in treated water
Reliability	-Unscheduled system downtime -Frequency and extent of repairs, including a description of problems, materials and supplies needed, and associated labor and cost
System O&M and Operator Skill Requirements	-Pre- and post-treatment requirements -Level of 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 for relevant chemical processes and for health and safety practices
Residual Management	-Quantity and characteristics of aqueous and solid residuals generated by system operation
System Cost	-Capital cost for equipment, engineering, and installation -O&M cost for chemical usage, electricity consumption, and labor

The system O&M and operator skill requirements were assessed through quantitative data and qualitative considerations, including the need for pre- and/or post-treatment; level of system automation; extent of preventative 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 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 the capital cost for equipment, engineering, and installation, as well as the O&M cost for media replacement and disposal, chemical supply, electricity usage, and labor.

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 instructions provided by MEI and Battelle. Each day, the plant operator recorded system operational data, such as pressure, flowrate, totalizer, and hour meter readings (see Appendix A) on a Daily System Operation Log Sheet, and also conducted visual inspections to ensure normal system operations. If any problem occurred, the plant operator contacted the Battelle Study Lead, who determined if the vendor should be contacted for troubleshooting. The plant operator recorded on the Repair and Maintenance Log Sheet all relevant information, including the problem encountered, course of action taken, materials and supplies used, and associated cost and labor incurred. Each week, the plant operator measured several water quality parameters onsite, including temperature, pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), and residual chlorine, and recorded the data on a Weekly Onsite Water Quality Parameters Log Sheet.

The capital cost for the Isolux™ system consisted of cost for equipment, site engineering, and system installation. The O&M cost consisted primarily of the cost for the media replacement and spent media disposal, electricity, and labor. Electricity consumption was determined using a kilowatt hour meter. Labor for various activities, such as routine system O&M, troubleshooting, repairs, and demonstration-related work, were tracked using an Operator Labor Hour Log Sheet. Routine O&M included activities such as completing field logs, ordering supplies, performing system inspections, and others as recommended by the equipment vendor. Labor was recorded 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, but was not used for the cost analysis.

3.3 Sample Collection Procedures and Schedules

To evaluate the system performance, samples were collected from the wellhead, across the treatment plant, and from the distribution system. Table 3-3 provides the sampling schedule and analytes measured during each sampling event. Figure 3-1 presents a flow diagram of the treatment system, along with the analytes and schedule for each sampling location. Specific sampling requirements for arsenic speciation, 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, 2004). Appenidx A of the QAPP describes the procedure for arsenic speciation.

3.3.1 Source Water. During the initial site visit on October 13, 2004, one set of source water samples was collected and speciated using an arsenic speciation kit (see 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. Table 3-3 lists analytes for the source water samples.

Table 3-3. Sampling and Analysis Schedule for GHCSD Site

Sample Type	Sample Locations[a]	No. of Samples	Frequency	Analytes	Sampling Date
Source Water	IN	1	Once during initial site visit	Onsite: pH, temperature, DO, and ORP Offsite: As(III), As(V), As (total and soluble), Fe (total and soluble), Mn (total and soluble), U (total and soluble), V (total and soluble), Na, Ca, Mg, Cl, F, NO_2, NO_3, NH_3, SO_4, SiO_2, PO_4, TDS, TOC, turbidity, and alkalinity	10/13/04
Treatment Plant Water	IN, AC, MA, and MB	4	Second, third, and fourth weeks of each 4-week cycle (regular sampling)	Onsite: pH, temperature, DO, ORP, and Cl_2 (total)[b] Offsite: As (total), Fe (total), Mn (total), Zr (total), Ca, Mg, SiO_2, P, turbidity, and alkalinity	See Appendix B
	IN, AC, and TM	3	First week of each 4-week cycle (speciation sampling)	Onsite: pH, temperature, DO, ORP, and Cl_2 (total)[b] Offsite: As(III), As (V), As (total and soluble), Fe (total and soluble), Mn (total and soluble), Zr (total and soluble), Ca, Mg, F, NO_3, SO_4, SiO_2, P, turbidity, and alkalinity.	See Appendix B
Distribution System Water	DS1, DS2, and DS 3	3	Monthly[c]	As (total), Fe (total), Mn (total), Pb, Cu, pH, and alkalinity	See Table 4-7

(a) Abbreviations corresponding to sample locations shown in Figure 3-1.
(b) Total chlorine residual analyzed at MB or TM beginning on July 5, 2006.
(c) Four baseline sampling events performed from July to August 2005 before the system became operational.
IN = at wellhead; AC = after chlorination; MA = after Module A; MB = after Module B; TM = after Modules A and B combined.
DS1 to 3 = distribution system sampling location 1 to 3.
DO = dissolved oxygen; ORP = oxidation-reduction potential; TDS = total dissolved solids; TOC = total organic carbon.

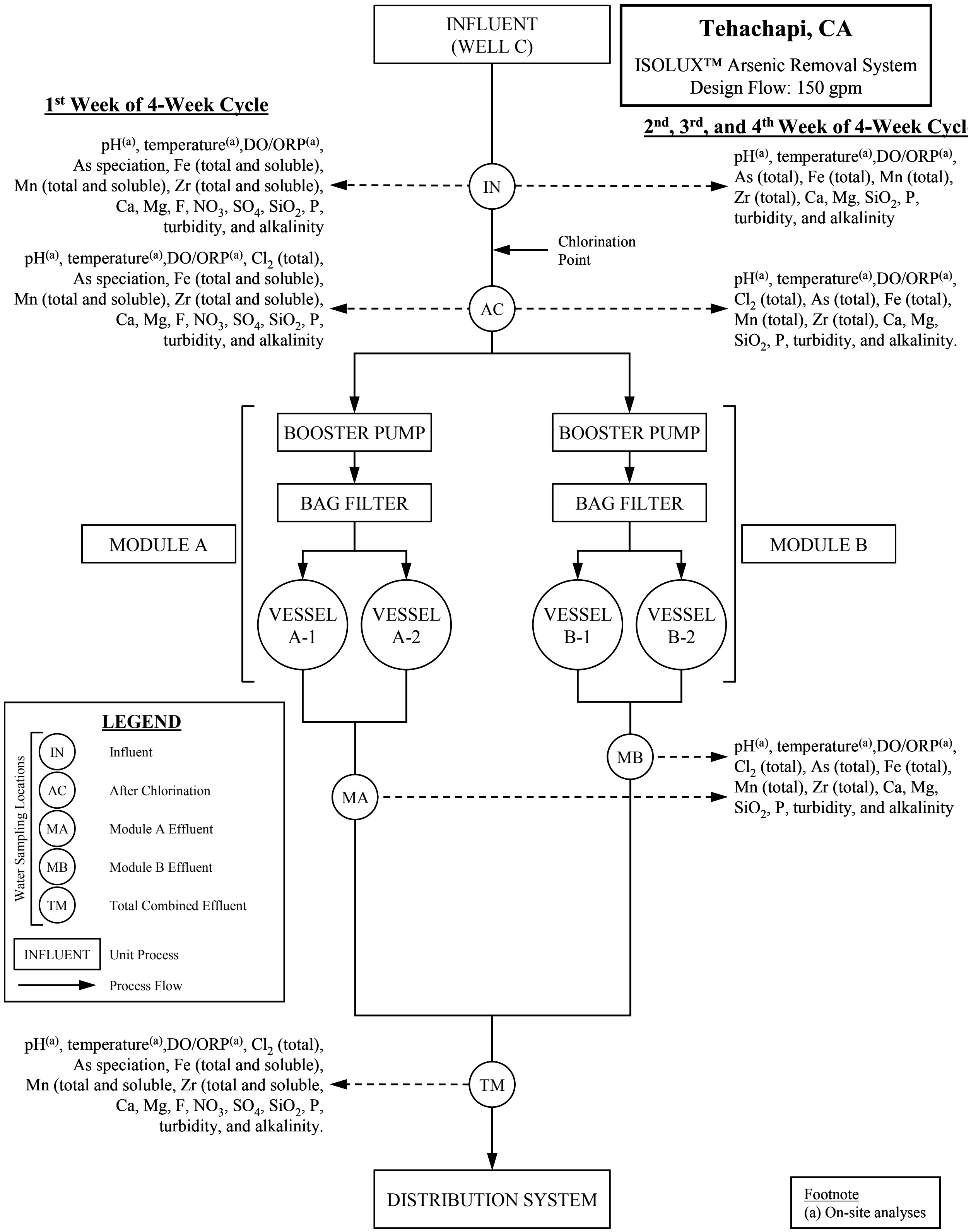


Figure 3-1. Process Flow Diagram and Sampling Schedule and Locations

3.3.2 Treatment Plant Water. During the system performance evaluation study, water samples were collected weekly, on a 4-week cycle, for onsite and offsite analyses. For the first week of each 4-week cycle, samples taken at the wellhead (IN), after chlorination (AC), and after Modules A and B combined (TM), were speciated onsite and analyzed for the analytes listed in Table 3-3 under speciation sampling. For the next three weeks, samples were collected at IN, AC, after Module A (MA), and after Module B (MB) and analyzed for the analytes listed in Table 3-3 under regular sampling. Speciation was discontinued on October 10, 2006, and since then, samples were collected weekly from IN, AC, MA, and MB and were analyzed only for total arsenic.

3.3.3 Distribution System Water. Samples were collected from the distribution system to determine any impacts of the Isolux™ arsenic treatment system on the water chemistry in the distribution system, specifically arsenic, lead, and copper levels. From July to August 2005, prior to the startup of the treatment system, four baseline distribution sampling events were conducted at three locations in the distribution system. Following system startup, distribution system sampling continued on a monthly basis at the same three locations for nine occasions.

Three residences were selected for distribution water sampling, including one each on San Lucas ("DS1"), Tiffany Circle ("DS2"), and Early Dawn Court ("DS3"). Only one residence (DS1) was part of the historic Lead and Copper Rule (LCR) sampling network serviced by the treatment well. Figure 3-2 is a distribution map showing the three sampling locations. The homeowners of the residences collected samples following an instruction sheet developed according to the *Lead and Copper Monitoring and Reporting Guidance for Public Water Systems* (EPA, 2002). The dates and times of last water usage before sampling and sample collection were recorded for calculations of the stagnation time. All samples were collected from a cold-water faucet that had not been used for at least 6 hr to ensure that stagnant water was sampled.

3.3.4 Residual Solids. The Isolux™ system did not require backwash; therefore, only spent media were collected for residual solid analysis. Nine spent media cartridges from the first media run (from October 26, 2005, to January 17, 2006) were shipped to Battelle on April 13, 2006. Of the nine spent media cartridges, the outer membrane on one cartridge was opened to expose the media. Spent media was sampled across the annular space of the cartridge from (1) the outer surface (i.e., immediately under the porous outer member where water after chlorination entered the media bed); (2) the subsurface (immediately under the outer surface); (3) the middle; and (4) the inner portion (i.e., where water exited the media bed) of the cartridge. Metal analyses were conducted on air-dried and acid-digested samples. Meanwhile, MEI conducted its own TCLP, total threshold limit concentration (TTLC), and soluble threshold limit concentration (STLC) tests on the spent media and provided the results to Battelle.

3.4 Sampling Logistics

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, 2004).

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-

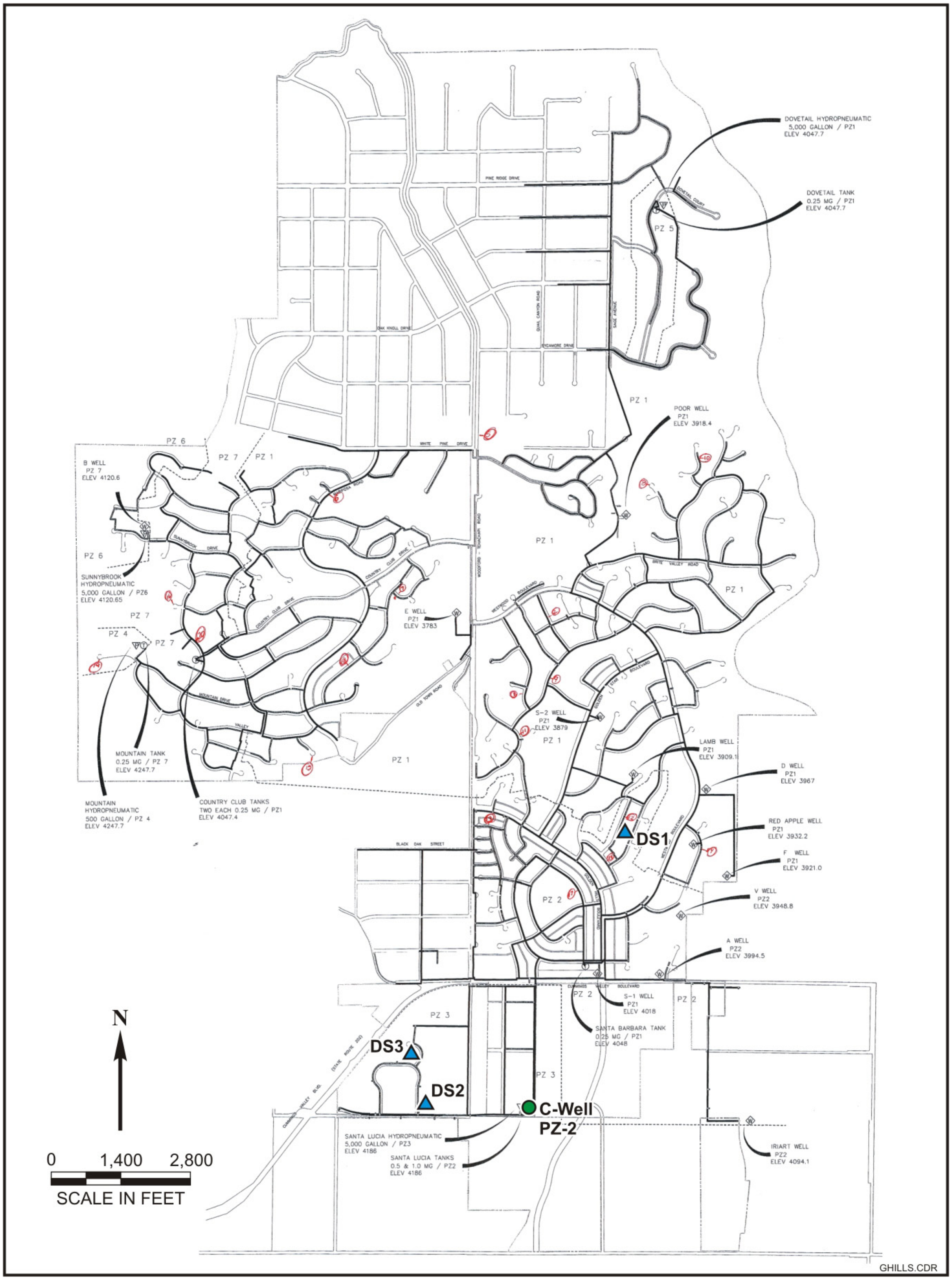


Figure 3-2. Water Distribution System at GHCSD

printed, colored-coded label consisting of the sample identification (ID), data 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, the sampling date, a two-letter code for a specific sampling location, and a one-letter code designating the arsenic speciation bottle (if necessary). The sampling locations at the treatment plant were color-coded for easy identification. The labeled bottles were separated by sampling location, placed in Ziplock™ bags, and packed in the cooler.

In addition, all sampling- and shipping-related materials, such as disposable gloves, sampling instructions, chain-of-custody forms, prepaid/addressed FedEx air bills, and bubble wrap, were included. The chain-of-custody forms and air bills were complete except for the operator's signature and the sample dates and times. 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 offsite analyses were packed carefully in the original coolers with wet ice and shipped to Battelle. Upon receipt, sample custodians 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. The Battelle Study Lead addressed discrepancies noted by the sample custodians with the plant operator.

Samples for metal analyses were stored at Battelle's inductively coupled plasma-mass spectrometry (ICP-MS) laboratory. Samples for other water quality parameters 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 contracted by 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, 2004) were followed by the Battelle ICP-MS Laboratory, 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 80-120%, 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.

The plant operator conducted field measurements of pH, temperature, DO, and ORP using a VWR Symphony SP90MS handheld multimeter, which was calibrated for pH and DO prior to use following 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 VWR probe in the beaker until a stable value was obtained.

4.0 RESULTS AND DISCUSSION

4.1 Facility Description

At an elevation of 3,973 ft above sea level, GHCSD is located immediately west of Tehachapi, CA, and has approximately 7,900 residents. Prior to the demonstration study, there were 13 active wells at GHCSD, but only Well C had elevated arsenic concentrations up to 20 µg/L. Figure 4-1 shows the Well C pump house, which is located near the southeast corner of the district, east of State Route 202.

Drilled in 1997, Well C was 10-in in diameter and 700 ft deep, with a pumping water level of 517 ft below ground surface (bgs) and a static water level of 258 ft bgs. The well was equipped with a 25-horsepower (hp) Grundfos pump rated for 145 gpm. The maximum flowrate of the well, however, was 100 gpm, yielding 81,462 and 71,687 gpd (on average) of water in 2003 and 2004, respectively. The well was controlled by a telemetry system based on time of day (shut off between 12 p.m. and 6 p.m.), level of water in storage tanks, or both. One 1,000,000- and one 500,000-gal storage tanks, located close to the Well C pump house and a dry van container that housed the new arsenic treatment system (Figure 4-2), were used to store water before it entered the distribution system. An existing chlorination system (Figure 4-3) provided a total chlorine residual of 1.25 mg/L (as Cl_2) in the distribution system.

Figure 4-1. Well C Pump House

4.1.1 Source Water Quality. Source water samples were collected from Well C on October 13, 2004, by a Battelle staff member who attended an introductory meeting for this project. Source water also was filtered for soluble arsenic, iron, manganese, uranium, and vanadium and was speciated for As(III) and As(V). In addition, pH, temperature, DO, and ORP were measured onsite using a WTW 340i meter. Table 4-1 presents the analytical results from the source water sampling event and compares them

Figure 4-2. Storage Tanks, Well C Pump House, and Dry Van Container

Figure 4-3. Pre-existing Chlorine Addition System

Table 4-1. Quality of Well C Source Water and GHCSD Treated Water

Parameter	Unit	CDPH Treated Water Data	CDPH Raw Water Data	Facility Raw Water Data[(a)]	Battelle Raw Water Data
Date		10/11/00	11/19/03	NA	10/13/04
pH	–	8.0	8.3	8.2	6.9[(b)]
DO	mg/L	NA	NA	NA	1.7
ORP	mV	NA	NA	NA	4.9
Total Alkalinity (as $CaCO_3$)	mg/L	180	170	175, 180*	171
Hardness (as $CaCO_3$)	mg/L	183	158	183	179
Turbidity	NTU	0.06	0.19	NA	0.2
TDS	mg/L	NA	NA	NA	292
TOC	mg/L	NA	NA	NA	<0.7
Nitrate (as N)	mg/L	0.34	< 0.44	NA	0.32
Nitrite (as N)	mg/L	< 0.02	< 0.02	NA	<0.01
Ammonia (as N)	mg/L	NA	NA	NA	<0.05
Chloride	mg/L	12	15	14, 15*	12.0
Fluoride	mg/L	0.23	0.24	NA	0.2
Sulfate	mg/L	42	45	26, 50*	40.0
Silica (as SiO_2)	mg/L	NA	NA	28*	27.0
Orthophosphate (as OPO_4)	mg/L	NA	NA	<0.065*	<0.06
As (total)	μg/L	9	14	20, 14*	14.7
As (soluble)	μg/L	NA	NA	NA	13.0
As (particulate)	μg/L	NA	NA	NA	1.7
As(III)	μg/L	NA	NA	NA	3.9
As(V)	μg/L	NA	NA	NA	9.2
Fe (total)	μg/L	< 50	< 50	153, 48*	<25
Fe (soluble)	μg/L	NA	NA	NA	<25
Mn (total)	μg/L	< 10	< 10	<10, 5*	8.8
Mn (soluble)	μg/L	NA	NA	NA	5.0
U (total)	μg/L	NA	NA	NA	0.8
U (soluble)	μg/L	NA	NA	NA	0.9
V (total)	μg/L	NA	NA	NA	2.5
V (soluble)	μg/L	NA	NA	NA	2.4
Na (soluble)	mg/L	29	30	24, 31*	34.8
Ca (total)	mg/L	52	45	53, 51*	52.3
Mg (total)	mg/L	13	11	13, 12*	11.8

(a) Provided by the facility to EPA for site selection.
(b) Data questionable.
CDPH = California Department of Public Health; DO = dissolved oxygen; NA = not available; NTU = nephlemetric turbidity unit; ORP = oxidation-reduction potential; TDS = total dissolved solids; TOC = total organic carbon;
* = EPA sample analysis

to those provided to EPA for site selection by the California Department of Public Health (CDPH) and the facility.

Arsenic. Total arsenic concentrations in source water ranged from 14 to 20 μg/L. Based on the October 13, 2004, speciation results, out of 14.7 μg/L of total arsenic, 13.0 μg/L existed in the soluble form. Of the soluble fraction, 9.2 μg/L existed as As(V) and 3.9 μg/L as As(III). As such, the majority of soluble arsenic can be removed directly by Isolux™-302M media without preoxidation. The presence of As(V) as the predominating arsenic species implies that Well C water is rather oxidizing. This is somewhat contradictory to the relatively low DO and ORP levels (i.e., 1.7 mg/L and 4.9 mV, respectively) measured during the October 13, 2004, sampling event. Care was used during the performance evaluation study to confirm that these, in fact, were the results of erroneous field measurements.

Interfering Ions. According to MEI, the presence of iron, manganese, phosphate, and silica in source water can potentially impact the performance of Isolux™-302M media. Total iron concentrations in source water ranged from <25 to 153 μg/L. Battelle and CDPH results were less than the respective method reporting limits of 25 and 50 μg/L, respectively. The EPA data was 48 μg/L, close to the Battelle and CDPH data. At 153 μg/L, the facility data was high. Manganese concentrations in raw water were <10 μg/L, and therefore should not impact Isolux™-302M media performance.

Orthophosphate concentrations were below the reporting limit of 0.06 mg/L. Silica levels ranged from 27 to 28 mg/L. Based on the data collected during the pilot study, MEI concluded that the presence of these competing ions did not adversely affect Isolux™-302M media performance.

Other Water Quality Parameters. pH values of raw water ranged from 8.2 to 8.3, which is at the high end of the operational range from 4.0 to 8.5, and could potentially impact Isolux™-302M media performance. Sulfate concentrations ranged from 26 to 50 mg/L; sodium from 24 to 34.8 mg/L; calcium from 45 to 53; and magnesium from 11 to 13 mg/L. Total alkalinity concentrations ranged from 170 to 180 mg/L (as $CaCO_3$); hardness from 158 to 183 mg/L (as $CaCO_3$); chloride from 12 to 15 mg/L; and fluoride from 0.2 to 0.24 mg/L. The presence of these ions in source water was not expected to impede arsenic removal by Isolux™-302M media.

4.1.2 Distribution System. Prior to and during the performance evaluation study, the distribution system at GHCSD was supplied by 13 wells, of which two were used as stand-by wells and one was used only seasonally. The maximum water demand was 2,050,000 gpd, which usually occurred in July. Water from Well C was pumped first to the 1,000,000- and 500,000-gal storage tanks and then to the distribution system, while water from the other wells was pumped to the distribution system and then to the same storage tanks. The distribution system is composed primarily of polyvinyl chloride (PVC) and asbestos cement (AC) piping. Service lines within residences are mainly copper pipe. Under the U.S. EPA LCR, GHCSD collects samples from customer taps at 20 locations every 3 years. GHCSD also conducts bacterial analysis monthly at 10 specified locations and quarterly at the wellheads.

4.2 Treatment Process Description

The 150-gpm Isolux™ arsenic treatment system uses Isolux™-302M powder media developed by MEI for arsenic removal. Table 4-2 presents physical and chemical properties of the media, which has NSF Standard 61 approval for use in drinking-water applications.

The Isolux™ arsenic treatment system at GHCSD consisted of two parallel adsorption modules, each containing a booster pump, a flow regulator, a 1-μm bag filter, and two parallel carbon steel adsorption vessels. Each adsorption vessel contained nine replaceable media cartridges (Figure 4-4), or 36 for the entire system. The system was designed to treat approximately 150 gpm of flow, with 75 gpm by each module. Figure 4-5 is a schematic of MEI's Isolux™ arsenic treatment system.

Chlorinated water was supplied to the two adsorption modules by a booster pump. As groundwater was pumped through the media cartridges, soluble arsenic was removed via adsorption, thus reducing total arsenic concentration to below the 10 μg/L MCL. A flow totalizer/meter was installed on the downstream end of each adsorption module to measure throughput and flowrate through each module.

Table 4-2. Properties of Isolux™-302M Media

Parameter	Value
Matrix	Hydrous zirconium oxide
Physical form	Amorphous powder
Color	White, bulky powder
Specific density	3.25
Bulk density (lb/ft^3)	60
Particle size (micron)	1–3 to 40–50
Mesoporosity (Å)	20–40
BET surface area (m^2/g)	300–350
Functional group	Zr-OH
Ion exchange capacity (meq/g)	8
Operational pH	4.0–8.5

Source: MEI

Pressure gauges located downstream of the well, flow control valve, bag filter, and adsorption module were used to monitor the system pressure and pressure drop across the treatment modules. The effluent of each module was combined and directed into the storage tanks. The system was instrumented with on/off valves and sample collection ports. The system was installed in an 8-ft × 40-ft enclosure.

Figure 4-4. Replaceable Isolux™-302M Media Cartridges (Provided by MEI)

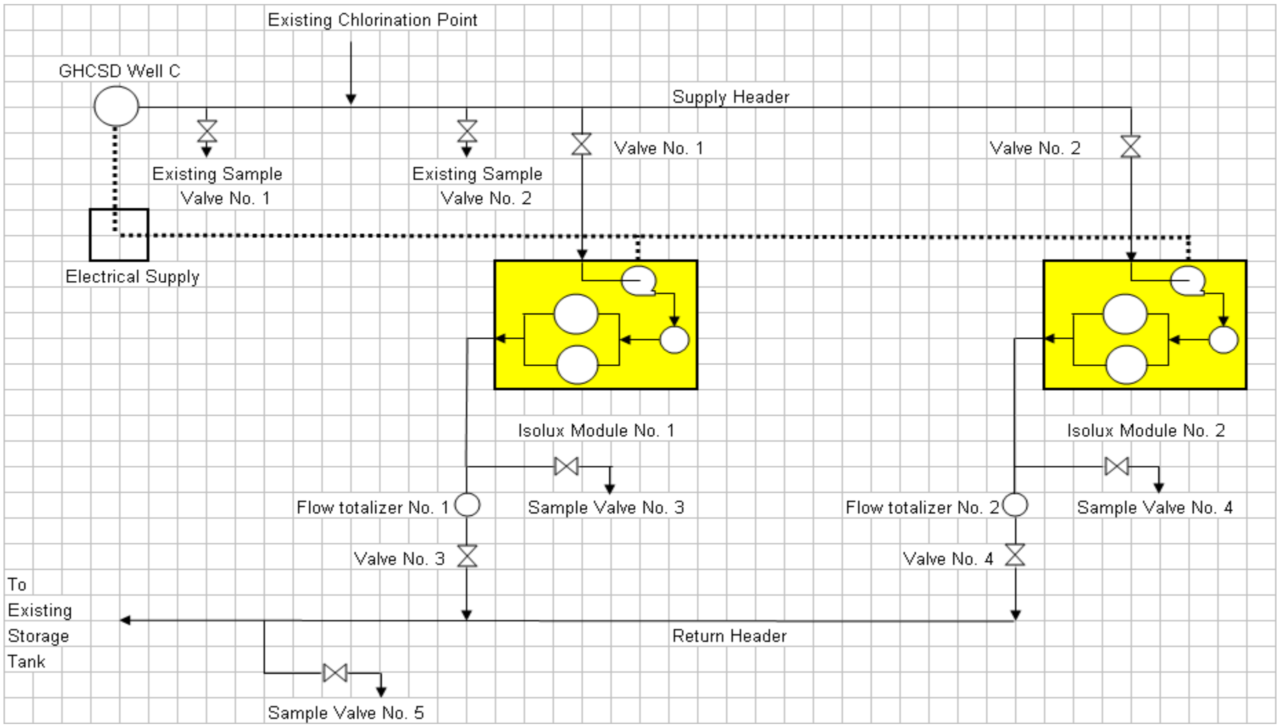


Figure 4-5. Schematic of MEI's Isolux™ Arsenic Treatment System (Provided by MEI)

Independent from this demonstration study, GHCSD hosted a pilot study on Isolux™-302M media from July 2003 to August 2004 at Well C. Figure 4-6 presents the pilot unit (in the wooden structure) and an Isolux™ media cartridge used for the pilot study. The initial testing used a 0.8-gpm, 10-in pilot unit equipped with a 5-µm particulate pre-filter, an activated carbon filter, an Isolux™ media cartridge (containing 1 lb of Isolux™-302M media), a flowmeter, and a flow totalizer. After operating for nearly 90

Figure 4-6. Isolux™ Pilot Facility (left) and Isolux™ Media Cartridge (right)

days and treating approximately 8,300 gal (or 66,578 bed volumes [BV]) of water, over 2 µg/L of arsenic were detected in the treated water. The pilot unit was then scaled up to a 10-gpm unit containing 22 lb of Isolux™-302M media. Operating at 8 gpm, the unit treated 254,887 gal (or 92,934 BV) of water from March 10 through April 3, 2004, prior to reaching 10 µg/L of arsenic breakthrough. A second adsorption run with the 10-gpm unit from July 17 through August 29, 2004, yielded slightly better performance results (i.e.,112,099 BVs) than the first run. Results of the pilot study indicated that:

- The Isolux™ arsenic treatment system could remove arsenic to below a detection limit of 2.0 µg/L. An elevated pH value of 8.2 and competing ions (including silica, phosphate, and iron) in the source water did not adversely affect the performance of Isolux™-302M media.
- Pre-treatment of Well C source water was not required.
- Spent Isolux™-302M media passed EPA TCLP and California whole effluent toxicity (WET) tests, so they could be disposed of as a non-hazardous waste.
- No backwash was required.

Table 4-3 summarizes the key system design parameters for the Isolux™ arsenic treatment system. The treatment system includes the following major process and system components:

- **Intake** – Raw water from Well C was chlorinated and fed to the Isolux™ arsenic treatment system. An hour meter was installed on the well pump to record the operation time.
- **Chlorination** – Prior to entering the system, water was injected with chlorine for disinfection purposes. A 12.5% sodium hypochlorite (NaClO) solution was stored in a 35-gal drum and injected by a solenoid-driven metering pump with a maximum capacity of 1.0 gal/hr (gph). Operation of the chlorine feed system was linked to the well pump such that chlorine was injected only when the well was operating. The system operator monitored chlorine consumption weekly by recording the chlorine levels in the chlorine supply tank and by measuring the volume of chlorine added to the tank. The target total chlorine residual was 1.25 mg/L (as Cl_2).
- **Isolux™ Adsorption** – Two Isolux™ adsorption modules arranged in parallel provided a total of 150-gpm treatment capacity. Figure 4-7 shows the treatment system installed at GHCSD. Each Isolux™ adsorption module contained the following elements:

  - **Booster Pump With Flow Regulator** – Use of two booster pumps with flow regulators (one per module) located prior to the adsorption vessels ensured adequate inlet pressure to the treatment system. Each EBARA Model CDU booster pump was constructed of 304L stainless steel, rated at 3 hp, and could provide a maximum flowrate of 95 gpm. The operation of the booster pumps was synchronized with the well pump so that they would turn on and off at the same time. During the performance evaluation study, operation of the booster pumps was found to be unnecessary.

  - **Bag Filter** – Each Isolux™ module contained a 1-µm bag filter. Source water flowed through the 1-µm bag-type particulate pre-filter to remove any sediment from the source water. The bag filters were changed periodically due to increased pressure readings.

  - **Media Vessel –** Each module contained two 20-in × 48-in media vessels, with each vessel containing nine Isolux™-302M media cartridges.

Table 4-3. Isolux™ Arsenic Treatment System Specifications and Design Parameters

Design Parameter	Value	Remark
No. of modules	2	Arranged in parallel
Module size (in.)	48 W × 48L × 60 H	–
Module weight (lb)	1,500	As shipped (dry with no media)
Module weight (lb)	3,200	In operation
No. of vessels	4	Two vessels arranged in parallel per module; 100 psi-rated carbon steel with NSF-rated epoxy coating
Vessel size (in.)	20 OD × 48 H	–
No. of cartridges per vessel	9	36 cartridges total
Cartridge length (in)	42.25	–
Cartridge OD (in)	4.55	–
Cartridge ID (in)	4.35	–
Cartridge outer membrane nominal pore size (μm)	30	Constructed of polyethylene porous membrane
Cartridge inner membrane nominal pore size (μm)	10	Constructed of polyethylene porous membrane
Cartridge outer membrane thickness (in)	0.20	–
Cartridge inner membrane thickness (in)	0.52	–
Cartridge weight (lb)	21	–
Type of media used	Isolux™-302M	Particle size of 20–40 μm
Quantity of media per vessel (ft^3)	2.88	Each cartridge contained 0.32 ft^3; two modules each contained 5.7 ft^3; total was 11.4 ft^3
Internal piping	2-in schedule 40 PVC glued	–
Inlet and outlet connections	1.5-in PVC female national pipe thread	–
Backwashing requirements	None	–
Inlet pressure (psi)	80	Into vessels
Outlet pressure (psi)	45	Outlet from vessels
Pressure drop (psi)	<30	Across vessels
Area of contact (ft^2)	4.1	Per cartridge
Hydraulic loading rate (gpm/ft^2)	1.0	Per cartridge
Estimated bed contact time (min)	0.5	Per cartridge
Peak flowrate (gpm)	150	Maximum flowrate of system
Average daily throughput to system (gpd)	100,000	Estimate provided by GHCSD
Estimated working capacity (BV)	105,000	Bed volumes to 10 μg/L arsenic breakthrough
Estimated volume to breakthrough (gal)	8,950,000	1 BV = 11.4 ft^3 = 85.3 gal
Estimated media life (months)	3	Estimated frequency of media cartridge changeout based on average throughput of 100,000 gpd
No. of BV/day	1,200	Based on estimated working capacity versus estimated media life

Figure 4-7. Isolux™ Adsorption Module at GHCSD

- **Isolux™ Media Cartridges –** Each media cartridge was 4.5-in in diameter by 42-in in height and contained approximately 0.32 ft^3 of Isolux™-302M media. The total amount of media in each module was 5.7 ft^3, providing about 0.5 min of contact time at the specified flowrate of 75 gpm. The media are sandwiched between two thin layers of tubular membranes constructed of porous polyethylene (PE). The outer membrane measured 4.55in in diameter by 42.25in in length and had a nominal pore size of 30 µm. The inner membrane measured 1.60in in diameter by 42.25in in length and had a nominal pore size of 10 µm. The upper end of the cartridge was completely sealed with a PE end-cap; the lower end also was sealed with a PE end-cap but with a discharge tube. Untreated water entered the vessel and passed through the porous outer membrane, coming into contact with the media within the annular space of the cartridge. After contacting the media, the water flowed through the porous inner membrane and into the hollow center portion of the cartridge before flowing downward in the lower (discharge) portion of the vessel. Figure 4-8 presents a schematic of an assembled Isolux™-302M media cartridge.

- **Media Cartridge Replacement –** When the capacity of the media cartridges in the vessels was exhausted, the operator replaced the spent media cartridges with virgin ones. Cartridges for both modules were replaced at the same time. Thus, 36 cartridges were needed for complete replacement. One module was completely serviced before service on the second module began. The spent media cartridges were stored at the facility until enough cartridges accumulated to facilitate efficient shipment to MEI.

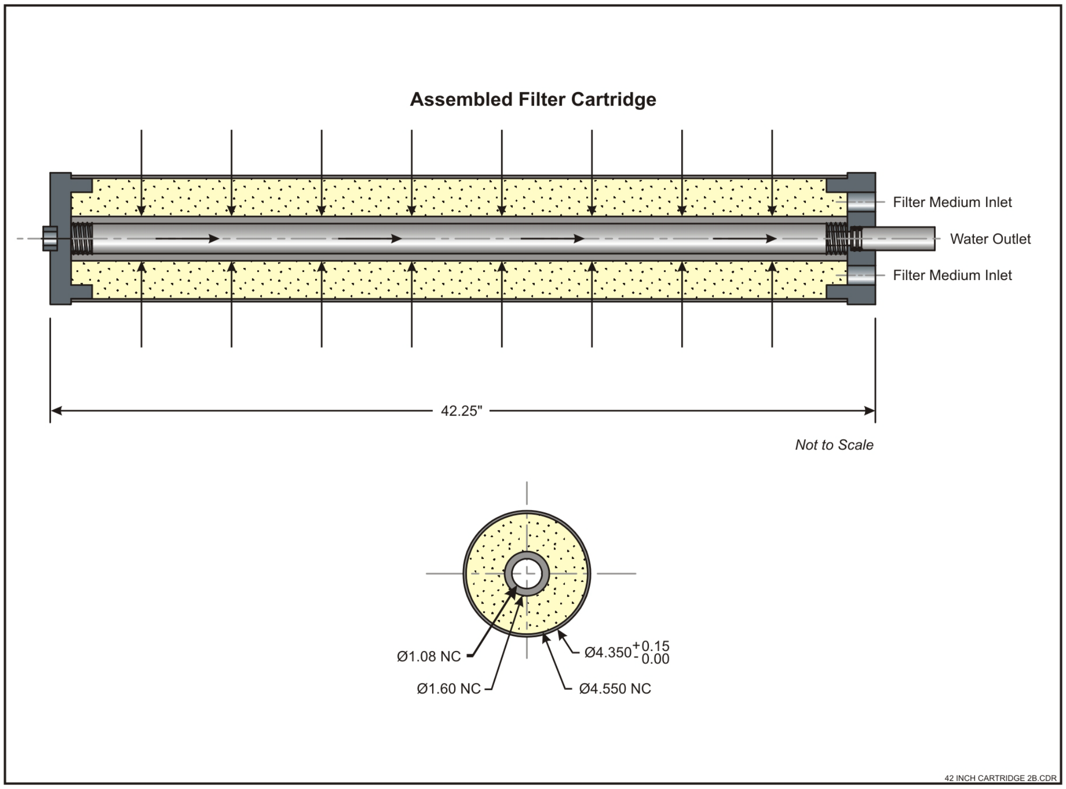


Figure 4-8. Schematic of Assembled Isolux™ Media Cartridge

- **Storage Tanks –** Treated water from Well C was stored in the 1,000,000- and 500,000-gal storage tanks before it entered the distribution system.

4.3 Treatment System Installation

4.3.1 System Permitting. The permit application for the Isolux™ system was simplified and expedited by CDPH because (1) only a "temporary" permit was granted and valid for the duration of the EPA demonstration study and (2) waste disposal was not anticipated to be an issue, considering that the Isolux™ system would not require backwashing and that any spent media cartridges would be returned to MEI for disposal.

The submittal for the permit application included a schematic of MEI's Isolux™ arsenic treatment system, a written description of the system, and an O&M manual. After the vendor incorporated review comments from GHCSD and Battelle, the submittal package was sent to CDPH for review on August 4, 2005. CDPH provided Approval-to-Construct on September 7, 2005.

According to CDPH, upon completion of the EPA demonstration study, GHCSD must secure a permanent permit if it plans to keep the Isolux™ system and continue its operation. GHCSD must also comply with the California Environmental Quality Act (CEQA) requirements as part of the permitting process. A regular water supply permit application takes 30 days for initial completeness review by CDPH. Once the application has been determined complete, it normally takes 90 days to issue a final permit document.

4.3.2 Building Construction. GHCSD installed the Isolux™ system in a steel, dry, van container. Required building preparation included grading of the ground, installation of floor drains, interconnection of the piping, and provision of an electrical supply. Distributed by On Site Storage Solutions, the container was 8 ft wide, 40 ft long, and 8 ft high (Figure 4-9). The cost of the container was approximately $4,218, including delivery.

4.3.3 Installation, Shakedown, and Startup. The Isolux™ arsenic treatment system was delivered to the site on September 16, 2005. The staff of GHCSD performed the off-loading and installation under the supervision of MEI's local engineer. Installation included piping connections to the existing entry and distribution system. System installation was completed on October 21, 2005.

Figure 4-9. Isolux™ Treatment System Enclosure (Storage Tank in Background)

4.4 System Operation

4.4.1 Operational Parameters. The operational parameters for the performance evaluation study were tabulated and are attached as Appendix A. Key parameters for each media run are summarized in Table 4-4. Media Run 1 began on October 26, 2005, and ended on January 17, 2006, after the arsenic concentration in the system effluent had reached that of system influent. The well was producing a significant amount of sediment/particulate matter, making it necessary to replace the bag filters rather frequently (see Section 4.5.3). Accumulation of well sediment caused a rapid increase in differential pressure (Δp) across the bag filters.

A video log on Well C was conducted by Bakersfield Well and Pump Company on February 13, 2006, to determine if any corrective actions would be necessary. The result revealed rusty areas on the drop-pipe, which prompted GHCSD's decision to rehabilitate the well. From March 7 to 8, 2006, Bakersfield Well and Pump Company performed well rehabilitation, which included (1) pulling the submersible pump and drop-pipe, (2) wire-brushing and bailing the well casing, and (3) installing 651 ft of new 3-in galvanized-steel drop-pipe and a new 25-hp Franklin submersible pump rated at 120 gpm. GHCSD also installed a wire strainer upstream of the system to further reduce the amount of sediment/particulate matter to the system. Once the well was rehabilitated and the media cartridges were replaced, Media Run 2 began on April 27, 2006. The treatment system produced water below the arsenic MCL until August 8, 2006, whereupon arrangements were made to replace the media cartridges, again in both modules. Media Run 3 began on August 17, 2006, and continued through March 20, 2007, which concluded the performance evaluation study.

Table 4-4. Summary of Isolux™ Treatment System Operations

Operational Parameter	Media Run 1		Media Run 2		Media Run 3	
Duration[(a)]	10/26/05–01/17/06		04/27/06–08/15/06		08/17/06–03/20/07	
Module	A	B	A	B	A	B
Total operating time (hr)	1,377	1,377	1,900	1,900	1,422	1,422
No. of days in operation (day)	63	63	94	94	85	85
Average daily operating time (hr/day)[(b)]	21.9	21.9	20.2	20.2	16.7	16.7
Throughput to 10µg/L As breakthrough (gal)	2,676,700	2,579,100	3,903,400	3,697,755	3,883,500	3,249,800
Throughput to 10µg/L As breakthrough (BV)[(c)]	62,760	60,470	91,520	86,700	91,100	76,200
Range of/average flowrate (gpm)[(d)]	30–59/ 40	26–59/ 40	23–56/ 41	20–69/ 37	17–71/ 46	21–56/ 39
Range of/average EBCT (min)	0.72–1.4/ 1.1	0.72–1.6/ 1.1	0.75–1.9/ 1.1	0.62–2.1/ 1.2	0.60–2.5/ 0.92	0.76–2.0/ 1.1
Range of/average Δp across module (psi)	12–26/ 17	8–26/ 16	2–18/ 11	2–19/ 12	2–20/ 10	2–241 13
Range of/average Δp across bag filter (psi)	0–38/ 6	0–40/ 7	0–53/ 8	0–40/ 8	0–84/ 10	0–72/ 9
Range of/average combined flowrate (gpm)[(e)]	62–118/ 79		50–106/ 74		51–126/ 85	
Range of/average daily flowrate (gpm)[(f)]	70–97/ 94		NA/ NA		55–142/ 81	
Cumulative throughput to 10µg/L As breakthrough[(g)] (gal)	5,255,800		7,915,800		7,256,800	
Media run length to 10µg/L As breakthrough (BV)[(h)]	61,600		92,800		85,100	

NA=not available.
(a) System shutdown from January 18 through April 26, 2006, due to well rehabilitation activities.
(b) Calculated based on total operating time and number of days in operation.
(c) Calculated based on throughput from individual totalizer and 5.7 ft^3 (or 42.65 gal) of media in each module.
(d) Instantaneous flowrate readings from individual flow meters.
(e) Combined instantaneous flowrate readings from both modules.
(f) Calculated by dividing incremental wellhead volume readings by corresponding operating times.
(g) Breakthrough when average arsenic concentration from both modules exceeded 10 µg/L.
(h) Calculated based on throughput from individual totalizers and 11.4 ft^3 (or 85.3 gal) of media in both modules combined.

The Isolux™ treatment system operated for 1,377, 1,900, and 1,422 hr during Media Runs 1, 2, and 3, respectively, based on the system throughput and average instantaneous flowrate from both modules combined. During Media Runs 1 and 2, from October 26, 2005, through August 15, 2006 (except when the system was shut down for well rehabilitation), the system operated daily (with some weekends); average operating times were 21.9 and 20.2 hr/day, respectively. Due to seasonal fluctuation in water demand, the system only operated periodically during Media Run 3, with an average operating time of 16.7 hr/day.

During the performance evaluation study, the system throughput values at 10 µg/L arsenic breakthrough in the combined effluent of both modules were 5,255,800 gal (or 61,600 BV), 7,915,800 gal (or 92,800 BV), and 7,256,800 (or 85,100 BV) during Media Runs 1, 2, and 3, respectively. The BV for the system was calculated based on a total of 11.4 ft^3 (or 85.3 gal) of media in both modules, while the BV for each module was based on 5.7ft^3 (or 42.65 gal) of media in each module. The total flow processed through the system was based on the sum of the throughput values through each of the two modules measured, with individual totalizers installed on the modules. Individually, the number of BV processed through each module during each media run was slightly different. During Media Runs 1, 2, and 3, Module A processed 62,760, 91,520, and 91,100 BV, or 4%, 6%, and 20% more water than Module B, respectively. This indicated an imbalanced flow between Modules A and B.

Figure 4-10 compares instantaneous flowrates through Module A, Module B, combined instantaneous flowrates, and average flowrates at the wellhead (when the hour meter was functioning correctly). The average flowrates at the wellhead were calculated by dividing incremental volume readings that the wellhead totalizer recorded by the corresponding operating times recorded by the hour meter. Due to lack of equipment and/or equipment failure, hour meter readings used to calculate the average flowrates were available only from December 8, 2005, through January 17, 2006, and from December 26, 2006, through March 20, 2007. The flowrates through each module recorded by the individual flow meters/totalizers

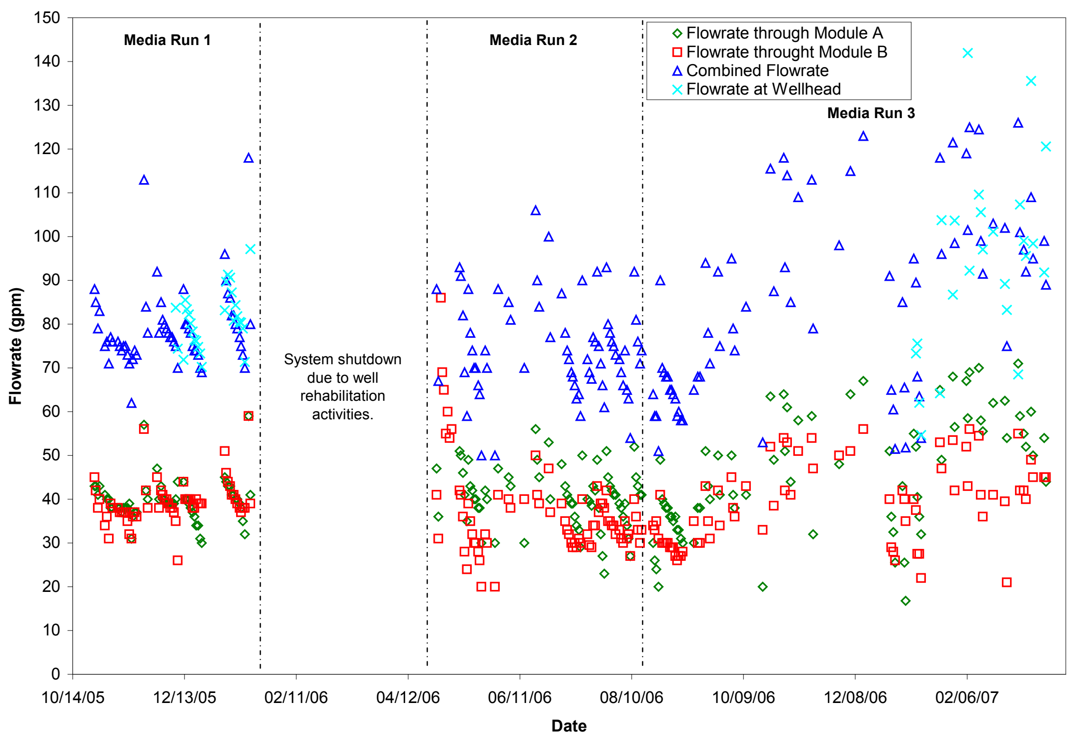


Figure 4-10. Isolux™ Treatment System Daily Flowrates

installed on the adsorption modules varied significantly, ranging from 17 to 71 gpm through Module A and from 20 to 69 gpm through Module B. The average flowrate for all media runs was 42 and was 38 gpm for Modules A and B, respectively. The average flowrate through Module A was 10% higher than that through Module B, again indicating imbalanced flow. Flowrates calculated based on the totalizer at the wellhead averaged 94 and 81 gpm for Media Runs 1 and 3, respectively, which was approximately 19% higher than the 79 gpm measured by individual flow meters during Media Run 1 and 4.7% lower than the 85 gpm measured by individual flow meters during Media Run 3, respectively. Based on the respective average flowrates, the average EBCTs in Modules A and B were 1.0 and 1.1 min, respectively, which were 100% and 120 % higher than the design value of 0.5 min as shown in Table 4-3.

Figure 4-11 presents measured pressure readings across the Isolux™ Treatment System. The pressure readings prior to the bag filter at each module varied significantly due to the accumulation of particulate/sediment matter in the bag filter and periodic replacement of the bag filter. Prior to the bag filter, pressure readings ranged from 14 to 106 psi. Inlet or after bag-filter pressure readings varied somewhat, ranging from 11 to 46 psi; outlet pressures remained relatively constant, ranging from 8 to 17 psi.

Figures 4-12 and 4-13, respectively, presents differential pressure (Δp) readings across bag filters and across Modules A and B. Δp readings across the bag filters varied significantly, ranging from 0 to 84 psi. The variation in Δp readings was due mainly to the accumulation of particulates in the bag filter and replacement of the bag filters. The Δp readings across Modules A and B also varied significantly, ranging from 2 to 26 psi and averaging 13 and 14 psi, respectively. The variance in Δp readings across the modules most likely was caused by the significant variation in instantaneous flowrate readings. As shown in Figure 4-14, there is a direct relationship between Δp across Modules A and B and the instantaneous flowrate readings.

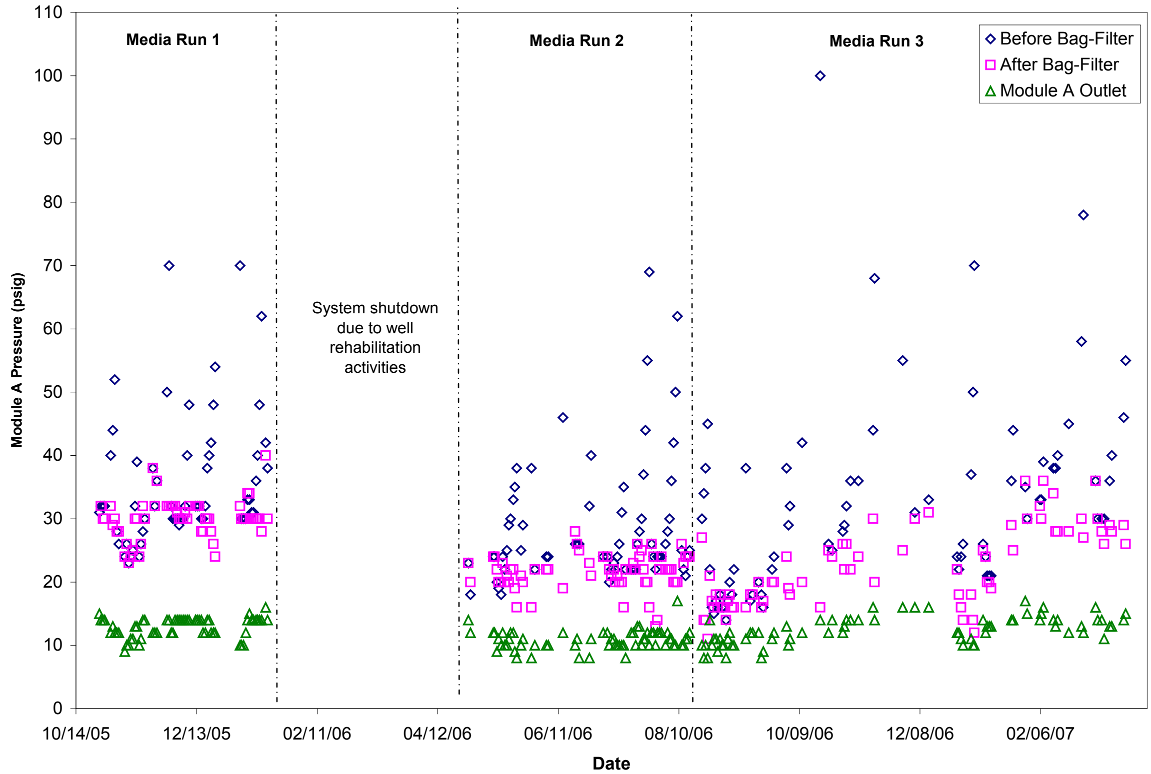
4.4.2 System/Operation Reliability and Simplicity. The simplicity of the system operation and operator skill requirements are discussed according to pre-and post-treatment activities, levels of system automation, operator skill requirements, preventative maintenance activities, and frequency of chemical/media handling and inventory requirements.

Pre- and Post-Treatment Requirements. The majority of arsenic in raw water existed as As(V). As such, a pre-oxidation step was not required. However, the facility has a pre-chlorination system in place for disinfectant purposes. The only pre-treatment required was the use of 1-µm bag filters to remove sediments/particulate matter from raw water.

System Automation. All major functions of the treatment system were automated and would require only minimal operator oversight and intervention if all functions were operating as intended. The operator controlled the system operation manually. Once the treated water in the storage tanks reached a determined level, the high-level alarm was triggered, notifying the operator to shut down the system.

Operator Skill Requirements. Under normal operating conditions, the skill requirements to operate the system were minimal. The operator was typically onsite five times per week and spent approximately 30 min each day performing visual inspections and recording system operating parameters on the daily log sheets. The operator replaced the bag filter periodically. Normal operation of the system did not require additional skills beyond those necessary to operate the existing water supply equipment.

The State of California requires that all individuals who operate or supervise the operation of a drinking-water treatment facility possess a water treatment operator certificate. The state also requires those who make decisions on maintenance and operation of any portion of the distribution system possess a



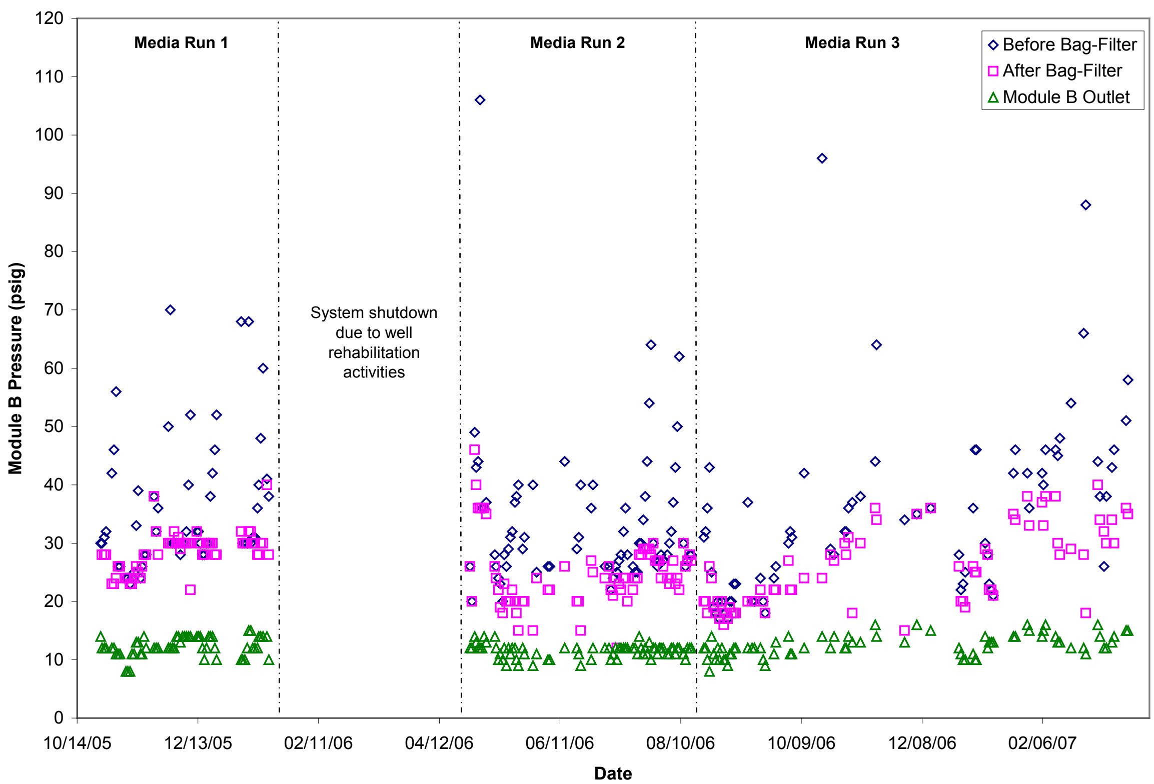


Figure 4-11. Pressure Readings Across Bag Filter and Module A (top) and Bag Filter and Module B (bottom)

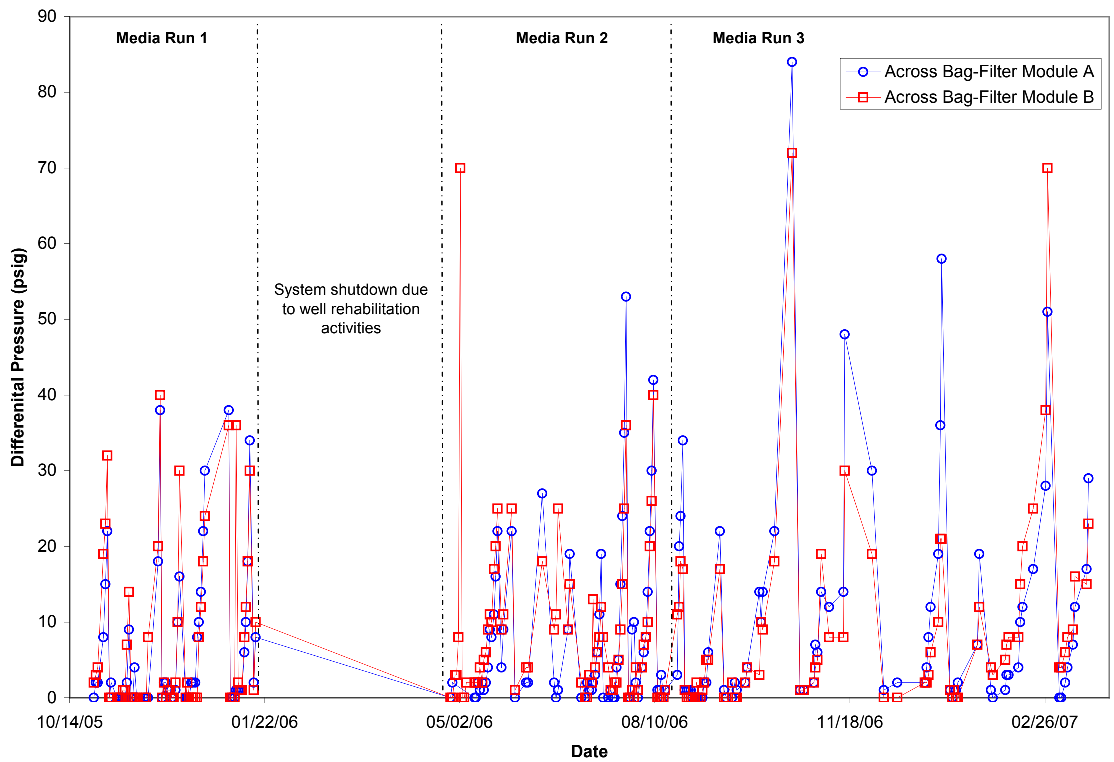


Figure 4-12. Differential Pressure Readings Across Bag Filters

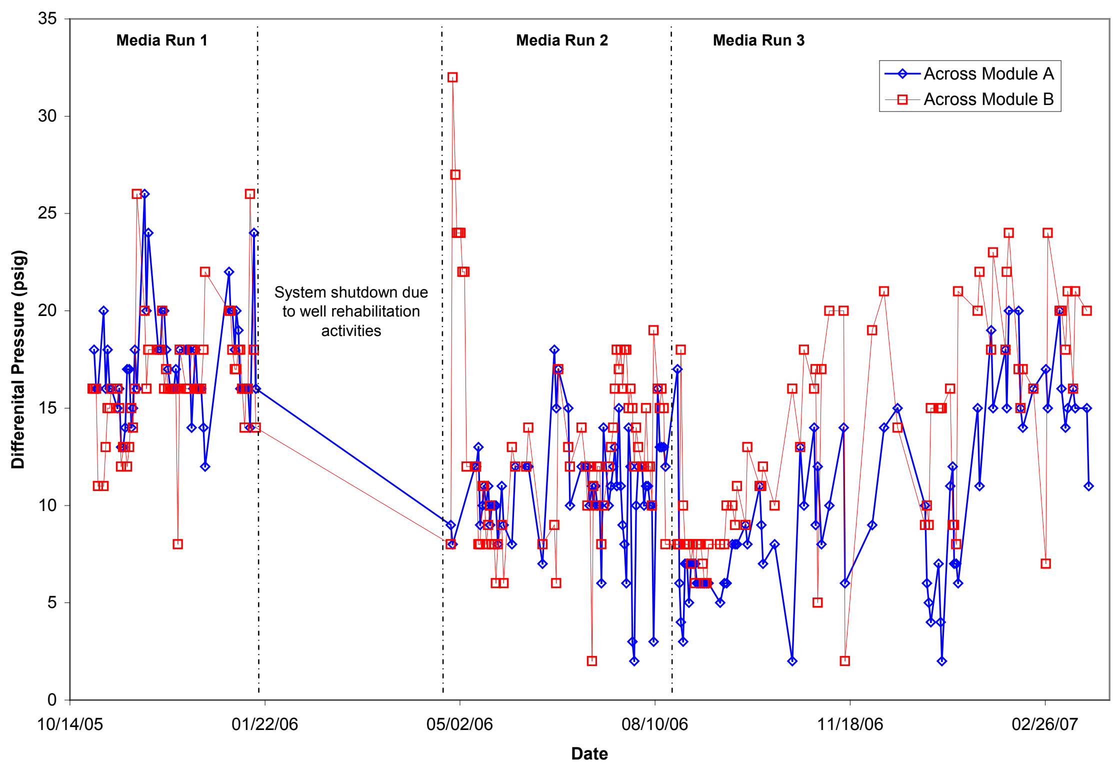


Figure 4-13. Differential Pressure Readings Across Modules A and B

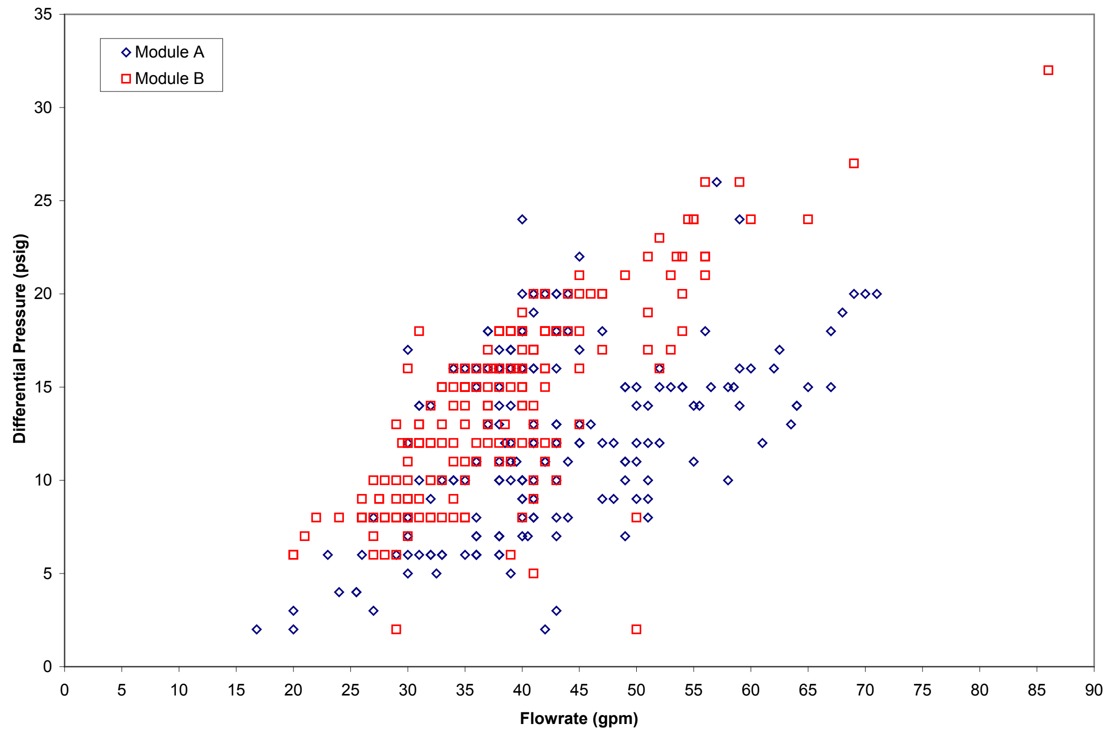


Figure 4-14. Instantaneous Flowrate vs. Differential Pressure

distribution operator certificate (CDPH, 2001). Operator certifications are granted by CDPH after minimum requirements are met; these include passing an examination and maintaining a minimum number of hours of specialized training. There are five grades of operators for both the water treatment (i.e., T1 to T5) and distribution (i.e., D1 to D5), with T5 and D5 being the highest. The operator of the Isolux™ system possessed T2 and D2 certifications for treatment and distribution, respectively.

Preventive Maintenance Activities. Preventive maintenance tasks included items such as periodic checks of flowmeters and pressure gauges and inspection of system piping and valves. The vendor recommended replacing the bag filters once it was necessary to replace the media cartridges; however, the operator had to replace the bag filters periodically due to increased differential pressure readings.

Chemical/Media Handling and Inventory Requirements. After installation of the Isolux™ treatment system, chlorine addition continued at the GHCSD site. Inventory requirements for chlorine addition remained the same as before. To facilitate change-out when needed, the only onsite inventory requirements associated with the Isolux™ system were bag filters and media cartridges.

4.5 System Performance

The performance of the Isolux™ arsenic treatment system was evaluated based on analyses of water samples collected from the treatment plant and distribution system.

4.5.1 Treatment Plant Sampling. The treatment plant water was sampled on 54 occasions (including one duplicate sampling), with field speciation performed 11 times. Table 4-5 summarizes the analytical results for arsenic, iron, manganese, and zirconium.

Table 4-5. Summary of Analytical Results for Arsenic, Iron, Manganese, and Zirconium

Parameter	Sampling Location	Unit	Count	Concentration			
				Minimum	Maximum	Average	Standard Deviation[a]
As (total)	IN - R1	µg/L	9	11.4	14.0	12.7	0.9
	IN - R2	µg/L	16	10.0	14.4	11.5	1.2
	IN - R3	µg/L	29	9.8	16.9	12.3	1.4
	AC - R1	µg/L	9	11.5	13.9	12.5	0.8
	AC - R2	µg/L	16	10.0	12.8	11.3	0.9
	AC - R3	µg/L	29	10.4	16.1	12.1	1.2
	MA - R1	µg/L	5	0.3	12.4	-[b]	-[b]
	MA - R2	µg/L	11	5.2	9.3	-[b]	-[b]
	MA - R3	µg/L	27	5.0	11.1	-[b]	-[b]
	MB - R1	µg/L	5	0.4	11.9	-[b]	-[b]
	MB - R2	µg/L	11	3.0	12.2	-[b]	-[b]
	MB - R3	µg/L	27	0.4	11.3	-[b]	-[b]
	TM - R1	µg/L	4	0.4	12.2	-[b]	-[b]
	TM - R2	µg/L	5	1.3	10.5	-[b]	-[b]
	TM - R3	µg/L	2	4.1	4.7	-[b]	-[b]
As (soluble)	IN - R1	µg/L	4	11.1	13.9	12.5	1.3
	IN - R2	µg/L	5	0.4	14.3	11.9	1.6
	IN - R3	µg/L	2	11.1	12.3	11.7	0.8
	AC - R1	µg/L	4	12.1	13.9	12.8	0.8
	AC - R2	µg/L	5	10.4	12.8	11.7	1.0
	AC - R3	µg/L	2	11.4	12.0	11.7	-
	TM - R1	µg/L	4	0.4	13.1	-[b]	-[b]
	TM - R2	µg/L	5	1.3	10.5	-[b]	-[b]
	TM - R3	µg/L	2	3.9	4.5	-[b]	-[b]
As (particulate)	IN - R1	µg/L	4	<0.1	0.99	0.49	0.5
	IN - R2	µg/L	5	<0.1	0.83	0.24	0.4
	IN - R3	µg/L	2	<0.1	1.7	1.1	-
	AC - R1	µg/L	4	<0.1	0.31	0.15	0.2
	AC - R2	µg/L	5	<0.1	<0.1	<0.1	-
	AC - R3	µg/L	2	0.26	0.78	0.52	-
	TM - R1	µg/L	4	<0.1	0.16	-[b]	-[b]
	TM - R2	µg/L	5	<0.1	0.22	-[b]	-[b]
	TM - R3	µg/L	2	0.15	0.21	-[b]	-[b]
As(III)	IN - R1	µg/L	4	2.0	2.8	2.5	0.4
	IN - R2	µg/L	5	0.14	1.6	0.61	0.4
	IN - R3	µg/L	2	1.5	1.8	1.6	-
	AC - R1	µg/L	4	0.46	1.2	0.76	0.3
	AC - R2	µg/L	5	0.14	0.96	0.26	0.1
	AC - R3	µg/L	2	0.24	0.59	0.44	-
	TM - R1	µg/L	4	0.17	0.96	-[b]	-[b]
	TM - R2	µg/L	5	0.17	0.43	-[b]	-[b]
	TM - R3	µg/L	2	0.17	0.58	-[b]	-[b]
As(V)	IN - R1	µg/L	4	8.3	11.1	10.0	1.4
	IN - R2	µg/L	5	9.4	13.8	11.1	1.7
	IN - R3	µg/L	2	9.6	10.4	10.0	-
	AC - R1	µg/L	4	11.4	13.4	12.1	0.9
	AC - R2	µg/L	5	10.2	12.3	11.5	1.0
	AC - R3	µg/L	2	11.2	11.4	11.3	-

Table 4-5. Summary of Analytical Results for Arsenic, Iron, Manganese, and Zirconium (Continued)

Parameter	Sampling Location	Unit	Count	Concentration Minimum	Maximum	Average	Standard Deviation[(a)]
As(V) (Con't)	TM - R1	µg/L	4	<0.1	12.7	-[(b)]	-[(b)]
	TM - R2	µg/L	5	1.1	10.1	-[(b)]	-[(b)]
	TM - R3	µg/L	2	3.4	4.3	-[(b)]	-[(b)]
Fe (total)	IN - R1	µg/L	9	<25	<25	<25	-
	IN - R2	µg/L	16	<25	<25	<25	-
	IN - R3	µg/L	7	<25	<25	<25	-
	AC - R1	µg/L	9	<25	<25	<25	-
	AC - R2	µg/L	16	<25	<25	<25	-
	AC - R3	µg/L	7	<25	<25	<25	-
	MA - R1	µg/L	5	<25	<25	<25	-
	MA - R2	µg/L	11	<25	<25	<25	-
	MA - R3	µg/L	5	<25	<25	<25	-
	MB - R1	µg/L	5	<25	<25	<25	-
	MB - R2	µg/L	11	<25	<25	<25	-
	MB - R3	µg/L	5	<25	<25	<25	-
	TM - R1	µg/L	4	<25	<25	<25	-
	TM - R2	µg/L	5	<25	<25	<25	-
	TM - R3	µg/L	2	<25	<25	<25	-
Fe (soluble)	IN - R1	µg/L	4	<25	<25	<25	-
	IN - R2	µg/L	5	<25	<25	<25	-
	IN - R3	µg/L	2	<25	<25	<25	-
	AC - R1	µg/L	4	<25	<25	<25	-
	AC - R2	µg/L	5	<25	<25	<25	-
	AC - R3	µg/L	2	<25	<25	<25	-
	TM - R1	µg/L	4	<25	<25	<25	-
	TM - R2	µg/L	5	<25	<25	<25	-
	TM - R3	µg/L	2	<25	<25	<25	-
Mn (total)	IN - R1	µg/L	9	2.9	5.3	3.8	0.7
	IN - R2	µg/L	16	2.9	4.3	3.9	0.4
	IN - R3	µg/L	7	3.7	4.7	4.1	0.3
	AC - R1	µg/L	9	2.8	4.8	3.8	0.6
	AC - R2	µg/L	16	2.9	4.5	3.8	0.4
	AC - R3	µg/L	2	3.5	3.8	3.6	-
	MA - R1	µg/L	5	<0.1	0.23	0.12	0.1
	MA - R2	µg/L	11	0.17	2.1	1.0	0.6
	MA - R3	µg/L	5	0.27	0.91	0.56	0.2
	MB - R1	µg/L	5	<0.1	0.64	0.26	0.3
	MB - R2	µg/L	11	0.14	0.95	0.53	0.3
	MB - R3	µg/L	5	0.11	0.29	0.20	0.1
	TM - R1	µg/L	4	0.13	0.31	0.23	0.1
	TM - R2	µg/L	5	0.38	1.7	0.7	0.5
	TM - R3	µg/L	2	0.30	0.5	0.4	-
Mn (soluble)	IN - R1	µg/L	4	3.4	5.3	4.0	0.9
	IN - R2	µg/L	5	3.8	4.4	4.1	0.2
	IN - R3	µg/L	2	3.9	4.3	4.1	-
	AC - R1	µg/L	4	3.2	4.8	3.7	0.8
	AC - R2	µg/L	5	2.7	4.0	3.5	0.5
	AC - R3	µg/L	2	3.5	3.8	3.6	-
	TM - R1	µg/L	4	0.02	0.56	0.25	0.2
	TM - R2	µg/L	5	0.38	1.7	0.72	0.5

Table 4-5. Summary of Analytical Results for Arsenic, Iron, Manganese, and Zirconium (Continued)

Parameter	Sampling Location	Unit	Count	Concentration			
				Minimum	Maximum	Average	Standard Deviation[(a)]
Mn (soluble) (Con't)	TM - R3	µg/L	2	0.30	0.53	0.41	-
Zr (total)	IN - R1	µg/L	9	<0.1	<0.1	<0.1	-
	IN - R2	µg/L	16	<0.1	<0.1	<0.1	-
	IN - R3	µg/L	7	<0.1	<0.1	<0.1	-
	AC - R1	µg/L	9	<0.1	<0.1	<0.1	-
	AC - R2	µg/L	16	<0.1	<0.1	<0.1	-
	AC - R3	µg/L	7	<0.1	<0.1	<0.1	-
	MA - R1	µg/L	5	<0.1	<0.1	<0.1	-
	MA - R2	µg/L	11	<0.1	<0.1	<0.1	-
	MA - R3	µg/L	5	<0.1	<0.1	<0.1	-
	MB - R1	µg/L	5	<0.1	<0.1	<0.1	-
	MB - R2	µg/L	11	<0.1	<0.1	<0.1	-
	MB - R3	µg/L	5	<0.1	<0.1	<0.1	-
	TM - R1	µg/L	4	<0.1	<0.1	<0.1	-
	TM - R2	µg/L	5	<0.1	<0.1	<0.1	-
	TM - R3	µg/L	2	<0.1	<0.1	<0.1	-

(a) Standard deviation for parameters that were non-detect for all samples or had <3 sample counts are not meaningful and therefore are not presented.
(b) Statistics not meaningful; see arsenic breakthrough curves at MA, MB, and TM locations in Figure 4-16.
See Appendix B for complete analytical results.
One-half of the detection limit was used for non-detect results, duplicate samples were included for calculations.
R1 = Media Run 1; R2 = Media Run 2; R3 = Media Run 3.

Table 4-6 summarizes the results of other water quality parameters. Appendix B contains a complete set of analytical results for the study. Results of the water samples collected throughout the treatment plant are discussed below.

Arsenic Removal. Figure 4-15 contains three bar charts showing the concentrations of total As, particulate As, As(III), and As(V) at the IN, AC, and TM locations for each of the 11 speciation events. Arsenic concentrations in source water were consistent for Media Runs 1, 2, and 3 (Table 4-5). Total arsenic concentrations in source water ranged from 9.8 to 16.9 µg/L and averaged 12.2 µg/L. As expected, of the soluble fraction, As(V) was the predominating species, ranging from 8.3 to 13.8 µg/L and averaging 10.4 µg/L. As(III) concentrations ranged from 0.14 to 2.8 µg/L and averaged 1.6 µg/L. Particulate As concentrations were low, averaging 0.61 µg/L. The arsenic concentrations measured during the study were consistent with those of the source water sample collected by Battelle on October 13, 2004 (Table 4-1).

As expected, arsenic concentrations at the AC locations were essentially the same as those in source water and were consistent for Media Runs 1, 2, and 3 (Table 4-5). Total arsenic concentrations ranged from 10.0 to 16.1 µg/L and averaged 12.0 µg/L. Of the soluble fraction, As(V) was the predominating species, ranging from 10.2 to 13.4 µg/L and averaging 11.6 µg/L. Due to prechlorination, and thus oxidation of As(III) to As(V), As(III) concentrations were slightly lower than for source water, ranging from 0.14 to 1.2 µg/L and averaging 0.49 µg/L. Particulate As concentrations were low, averaging 0.24 µg/L.

Table 4-6. Summary of Water Quality Parameter Sampling Results

Parameter	Sampling Location	Unit	Count	Concentration Minimum	Maximum	Average	Standard Deviation[(a)]
Alkalinity (as $CaCO_3$)	IN – R1	mg/L	9	176	330	201	48.7
	IN – R2	mg/L	16	188	200	193	3.8
	IN – R3	mg/L	7	190	209	201	7.6
	AC - R1	mg/L	9	176	198	188	7.0
	AC - R2	mg/L	16	184	205	193	5.6
	AC - R3	mg/L	7	192	208	202	5.5
	MA - R1	mg/L	5	176	194	186	7.4
	MA - R2	mg/L	11	184	200	193	6.4
	MA - R3	mg/L	5	190	209	203	7.7
	MB - R1	mg/L	5	176	189	182	5.0
	MB - R2	mg/L	11	188	204	192	4.6
	MB - R3	mg/L	5	190	203	200	5.5
	TM - R1	mg/L	4	185	189	187	2.3
	TM - R2	mg/L	5	171	194	188	9.4
	TM - R3	mg/L	2	202	207	205	-
Fluoride	IN - R1	mg/L	4	0.14	0.20	0.16	0.0
	IN - R2	mg/L	5	0.20	10.2	2.3	4.4
	IN - R3	mg/L	2	0.30	0.90	0.60	-
	AC - R1	mg/L	4	0.14	0.20	0.16	0.0
	AC - R2	mg/L	5	0.20	12.3	3.1	5.2
	AC - R3	mg/L	2	0.10	0.60	0.35	-
	TM - R1	mg/L	4	0.14	0.20	0.16	0.0
	TM - R2	mg/L	5	0.20	8.4	1.9	3.6
	TM - R3	mg/L	2	<0.1	0.60	0.33	-
Sulfate	IN - R1	mg/L	4	39.0	46.0	42.0	3.2
	IN - R2	mg/L	5	47.0	49.0	47.8	0.8
	IN - R3	mg/L	2	46.0	52.0	49.0	-
	AC - R1	mg/L	4	40.0	46.0	42.6	2.6
	AC - R2	mg/L	5	46.0	56.0	49.4	4.2
	AC - R3	mg/L	2	46.0	52.0	49.0	-
	TM - R1	mg/L	4	40.0	46.0	43.3	2.5
	TM - R2	mg/L	5	46.0	57.0	49.4	4.5
	TM - R3	mg/L	2	46.0	51.0	48.5	-
Nitrate (as N)	IN - R1	mg/L	4	0.36	0.48	0.43	0.1
	IN - R2	mg/L	5	0.56	0.72	0.65	0.1
	IN - R3	mg/L	2	0.67	0.73	0.70	-
	AC - R1	mg/L	4	0.35	0.48	0.43	0.1
	AC - R2	mg/L	5	0.58	0.75	0.68	0.1
	AC - R3	mg/L	2	0.65	0.72	0.69	-
	TM - R1	mg/L	4	0.35	0.5	0.44	0.1
	TM - R2	mg/L	5	0.58	0.69	0.64	0.0
	TM - R3	mg/L	2	<0.05	0.66	0.34	-

Table 4-6. Summary of Water Quality Parameter Sampling Results (Continued)

Parameter	Sampling Location	Unit	Count	Concentration Minimum	Maximum	Average	Standard Deviation[a]
Silica (as SiO_2)	IN - R1	mg/L	9	26.7	29.5	27.7	0.8
	IN - R2	mg/L	16	27.2	31.7	28.4	1.3
	IN - R3	mg/L	7	26.4	28.6	27.3	0.7
	AC - R1	mg/L	9	26.9	28.9	27.8	0.6
	AC - R2	mg/L	16	26.9	32.3	28.5	1.4
	AC - R3	mg/L	7	26	29.2	27.4	1.0
	MA - R1	mg/L	5	26.3	28.3	27.2	0.8
	MA - R2	mg/L	11	23.8	32.8	28.2	2.3
	MA - R3	mg/L	5	25.8	26.9	26.4	0.4
	MB - R1	mg/L	5	26.7	27.9	27.3	0.5
	MB - R2	mg/L	11	27.1	32.0	28.9	1.4
	MB - R3	mg/L	5	25.6	27.8	26.6	1.0
	TM - R1	mg/L	4	21.0	28.7	26.1	3.5
	TM - R2	mg/L	5	26.9	30.5	28.0	1.4
	TM - R3	mg/L	2	24.4	28.3	26.4	-
P (as P)	IN - R1	µg/L	9	<10	<10	<10	-
	IN - R2	µg/L	16	<10	15.7	5.4	3.1
	IN - R3	µg/L	7	<10	11.1	5.9	2.3
	AC - R1	µg/L	9	<10	<10	<10	-
	AC - R2	µg/L	16	<10	11.3	5.4	1.6
	AC - R3	µg/L	7	<10	11.4	5.9	2.4
	MA - R1	µg/L	5	<10	<10	<10	-
	MA - R2	µg/L	11	<10	<10	<10	-
	MA - R3	µg/L	5	<10	<10	<10	-
	MB - R1	µg/L	5	<10	<10	<10	-
	MB - R2	µg/L	11	<10	<10	<10	-
	MB - R3	µg/L	5	<10	<10	<10	-
	TM - R1	µg/L	4	<10	<10	<10	-
	TM - R2	µg/L	5	<10	<10	<10	-
	TM - R3	µg/L	2	<10	<10	<10	-
Turbidity	IN - R1	NTU	9	<0.1	1.6	0.3	0.5
	IN - R2	NTU	16	0.1	4.6	0.6	1.1
	IN - R3	NTU	7	<0.1	6.2	1.0	2.3
	AC - R1	NTU	9	<0.1	1.1	0.2	0.3
	AC - R2	NTU	16	0.1	2.6	0.5	0.6
	AC - R3	NTU	7	0.1	0.3	0.3	0.1
	MA - R1	NTU	5	<0.1	1.1	0.3	0.4
	MA - R2	NTU	11	0.1	1.1	0.5	0.3
	MA - R3	NTU	5	0.1	0.2	0.2	0.0
	MB - R1	NTU	5	<0.1	0.2	0.1	0.1
	MB - R2	NTU	11	0.1	2	0.6	0.7
	MB - R3	NTU	5	0.1	0.1	0.1	0.0
	TM - R1	NTU	4	<0.1	0.2	0.1	0.1
	TM - R2	NTU	5	0.2	0.5	0.3	0.1
	TM - R3	NTU	2	0.3	0.5	0.4	-

Table 4-6. Summary of Water Quality Parameter Sampling Results (Continued)

Parameter	Sampling Location	Unit	Count	Concentration Minimum	Maximum	Average	Standard Deviation[a]
pH	IN - R1	S.U.	9	7.5	7.7	7.6	0.1
	IN - R2	S.U.	15	7.4	7.7	7.5	0.1
	IN - R3	S.U.	28	7.4	7.9	7.6	0.1
	AC - R1	S.U.	9	7.4	7.8	7.6	0.1
	AC - R2	S.U.	15	7.5	7.7	7.5	0.1
	AC - R3	S.U.	28	7.5	8.0	7.7	0.1
	MA - R1	S.U.	8	7.5	7.7	7.6	0.1
	MA - R2	S.U.	14	7.4	7.6	7.5	0.0
	MA - R3	S.U.	28	7.5	7.9	7.6	0.1
	MB - R1	S.U.	8	7.5	7.7	7.6	0.1
	MB - R2	S.U.	15	7.5	7.7	7.5	0.1
	MB - R3	S.U.	28	7.5	7.9	7.6	0.1
	TM - R1	S.U.	6	7.3	7.7	7.5	0.2
	TM - R2	S.U.	15	7.4	7.7	7.5	0.1
	TM - R3	S.U.	28	7.5	7.9	7.6	0.1
Temperature	IN - R1	ºC	9	15.7	20.3	18.1	1.3
	IN - R2	ºC	15	14.9	30.8	22.1	3.6
	IN - R3	ºC	28	14.5	22.6	17.9	2.3
	AC - R1	ºC	9	16.0	20.6	18.4	1.4
	AC - R2	ºC	15	19.1	26.4	21.4	2.0
	AC - R3	ºC	28	15.2	22.2	18.2	2.0
	MA - R1	ºC	8	14.0	25.6	18.6	3.4
	MA - R2	ºC	14	19.2	26.3	21.4	2.1
	MA - R3	ºC	28	15.8	22.0	18.4	1.8
	MB - R1	ºC	8	15.8	25.7	19.2	2.9
	MB - R2	ºC	15	19.1	26.2	21.3	2.1
	MB - R3	ºC	28	15.8	21.9	18.5	1.6
	TM - R1	ºC	6	14.8	19.3	17.8	1.6
	TM - R2	ºC	15	19.2	26.2	21.9	2.0
	TM - R3	ºC	28	15.2	22.9	18.3	2.0
DO	IN - R1	mg/L	6	1.8	2.7	2.3	0.3
	IN - R2	mg/L	13	2.0	3.2	2.5	0.4
	IN - R3	mg/L	28	1.4	4.5	2.9	0.8
	AC - R1	mg/L	6	1.7	2.2	1.9	0.2
	AC - R2	mg/L	13	1.8	3.0	2.2	0.3
	AC - R3	mg/L	28	1.4	4.2	2.5	0.6
	MA - R1	mg/L	6	1.8	2.3	2.1	0.1
	MA - R2	mg/L	12	1.9	2.9	2.3	0.3
	MA - R3	mg/L	28	1.5	3.6	2.6	0.5
	MB - R1	mg/L	6	1.8	2.9	2.0	2.0
	MB - R2	mg/L	13	1.7	4.3	2.5	0.7
	MB - R3	mg/L	28	1.7	3.5	2.6	0.5
	TM - R1	mg/L	5	1.6	2.6	2.3	0.4
	TM - R2	mg/L	13	1.7	2.9	2.3	0.3
	TM - R3	mg/L	28	1.6	3.6	2.6	0.5

Table 4-6. Summary of Water Quality Parameter Sampling Results (Continued)

Parameter	Sampling Location	Unit	Count	Concentration			
				Minimum	Maximum	Average	Standard Deviation[a]
ORP	IN - R1	mV	9	359	472	422	38.3
	IN - R2	mV	15	257	450	336	54.5
	IN - R3	mV	28	219	507	319	58.2
	AC - R1	mV	9	470	647	585	62.5
	AC - R2	mV	15	280	686	557	125
	AC - R3	mV	28	288	666	551	132
	MA - R1	mV	8	597	675	643	24.6
	MA - R2	mV	14	285	660	597	116
	MA - R3	mV	28	295	679	573	135
	MB - R1	mV	8	579	676	645	31.0
	MB - R2	mV	15	293	679	613	112
	MB - R3	mV	28	308	682	580	136
	TM - R1	mV	6	534	680	629	56.7
	TM - R2	mV	15	66	676	573	179
	TM - R3	mV	28	311	683	581	136
Total Hardness (as $CaCO_3$)	IN - R1	mg/L	9	153	184	174	9.1
	IN - R2	mg/L	16	158	220	184	15.0
	IN - R3	mg/L	7	174	207	192	11.2
	AC - R1	mg/L	9	154	186	175	8.8
	AC - R2	mg/L	16	116	154	133	9.4
	AC - R3	mg/L	7	174	209	194	11.9
	MA - R1	mg/L	5	169	184	176	7.5
	MA - R2	mg/L	11	163	211	185	11.6
	MA - R3	mg/L	5	173	206	188	12.0
	MB - R1	mg/L	5	170	184	176	6.7
	MB - R2	mg/L	11	166	212	184	11.2
	MB - R3	mg/L	5	153	206	188	10.6
	TM - R1	mg/L	4	153	184	173	13.4
	TM - R2	mg/L	5	171	209	190	14.7
	TM - R3	mg/L	2	201	215	208	-
Ca Hardness (as $CaCO_3$)	IN - R1	mg/L	9	100	137	127	10.8
	IN - R2	mg/L	16	117	161	134	11.1
	IN - R3	mg/L	7	124	157	141	11.2
	AC - R1	mg/L	9	101	138	126	10.5
	AC - R2	mg/L	16	116	154	133	9.4
	AC - R3	mg/L	7	124	157	143	12.3
	MA - R1	mg/L	5	122	137	130	6.1
	MA - R2	mg/L	11	122	153	135	8.7
	MA - R3	mg/L	5	101	155	137	12.8
	MB - R1	mg/L	5	121	137	130	6.2
	MB - R2	mg/L	11	122	154	133	8.2
	MB - R3	mg/L	5	127	154	137	10.9
	TM - R1	mg/L	4	101	136	124	16.0
	TM - R2	mg/L	5	122	150	138	11.1
	TM - R3	mg/L	2	150	160	155	-

Table 4-6. Summary of Water Quality Parameter Sampling Results (Continued)

Parameter	Sampling Location	Unit	Count	Concentration Minimum	Maximum	Average	Standard Deviation[(a)]
Mg Hardness (as $CaCO_3$)	IN - R1	mg/L	9	41.7	52.8	47.2	3.2
	IN - R2	mg/L	16	41.0	59.7	50.1	4.6
	IN - R3	mg/L	7	47.0	54.0	51.1	2.8
	AC - R1	mg/L	9	42.8	55.5	48.8	3.7
	AC - R2	mg/L	16	39.8	57.8	50.2	4.3
	AC - R3	mg/L	7	46.5	54.9	51.5	3.0
	MA - R1	mg/L	5	42.9	49.6	46.3	3.0
	MA - R2	mg/L	11	40.7	58.0	50.6	4.2
	MA - R3	mg/L	5	45.3	53.5	50.4	3.4
	MB - R1	mg/L	5	42.7	51.6	46.6	3.8
	MB - R2	mg/L	11	40.9	57.5	50.2	4.2
	MB - R3	mg/L	5	44.6	53.6	50.8	3.7
	TM - R1	mg/L	4	47.3	52.7	48.7	2.6
	TM - R2	mg/L	5	48.4	58.5	52.2	3.9
	TM - R3	mg/L	2	50.6	54.5	52.5	-

(a) Standard deviation for parameters that were non-detect for all samples or had <3 sample counts are not meaningful, and therefore are not presented.
See Appendix B for complete analytical results.
One-half detection limit used for nondetect results; duplicate samples were included for calculations.
R1 = Media Run 1; R2 = Media Run 2; R3 = Media Run 3.

The key parameter for evaluating the effectiveness of the Isolux™ system was the concentration of arsenic in the treated water. The arsenic breakthrough curves for each media run are shown in Figure 4-16, in which total arsenic concentrations are plotted against the volume of water treated in gallons and bed volumes (BV).

Bed volumes for MA and MB were calculated based on 5.7 ft^3 or 42.65 gal of media in each module; however, bed volumes of the combined effluent (TM) were calculated based on the combined media volume and throughput of both modules, since water at the sampling location had been treated by the entire media volume.

Media Run 1 began with system start-up on October 26, 2005, and ended on January 17, 2006. During Media Run 1, arsenic concentrations at MA and MB reached 10 µg/L at approximately 61,600 BV, which was 41% lower than the 105,000 BV estimated by the vendor. The bag-filters were changed six times due to increased differential pressure readings caused by the build-up of sediments and particulates. Thus, it was possible that sub-micron particulates that passed through the bag filters accumulated in and partially blocked some of the passages on the media cartridges' outer membrane, causing preferential flow through the media cartridges. Preferential flow could cause portions of a media cartridge to filter a larger amount of water, thus exhausting the media at a higher rate. To investigate the cartridges, analyses were conducted on a spent media cartridge; results are presented in Section 4.5.3.

Media Run 2 began on April 27, 2006, following media cartridge change-out and ended on August 15, 2006. Prior to the start of Media Run 2, the well was bailed and wire-brushed on March 7, 2006, and a wire strainer was installed upstream of the Isolux™ system to reduce the amount of sediment/particulate matter produced by the well and introduced into the treatment system. During Media Run 2, the initial

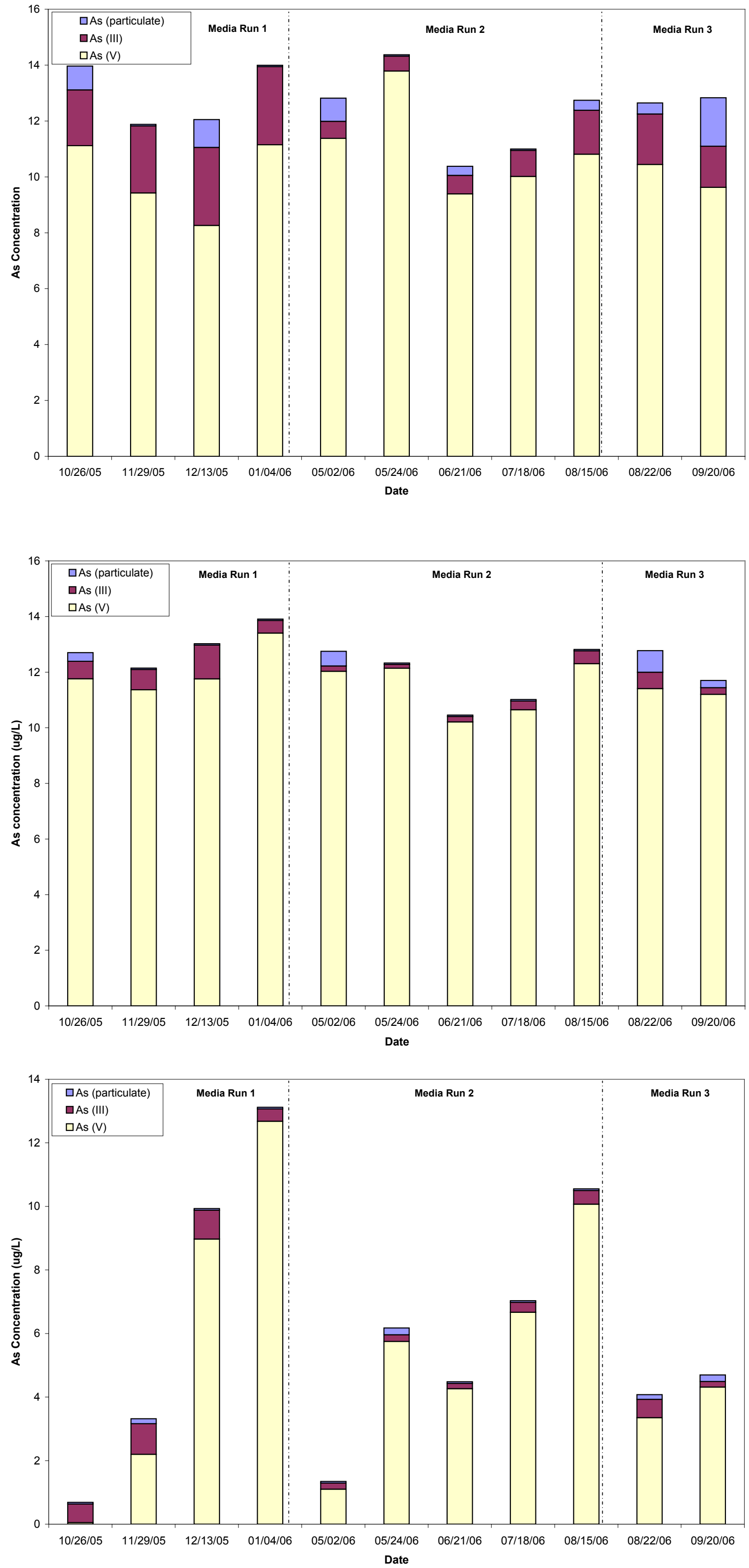


Figure 4-15. Concentrations of Various Arsenic Species at IN, AC, and TM Sampling Locations

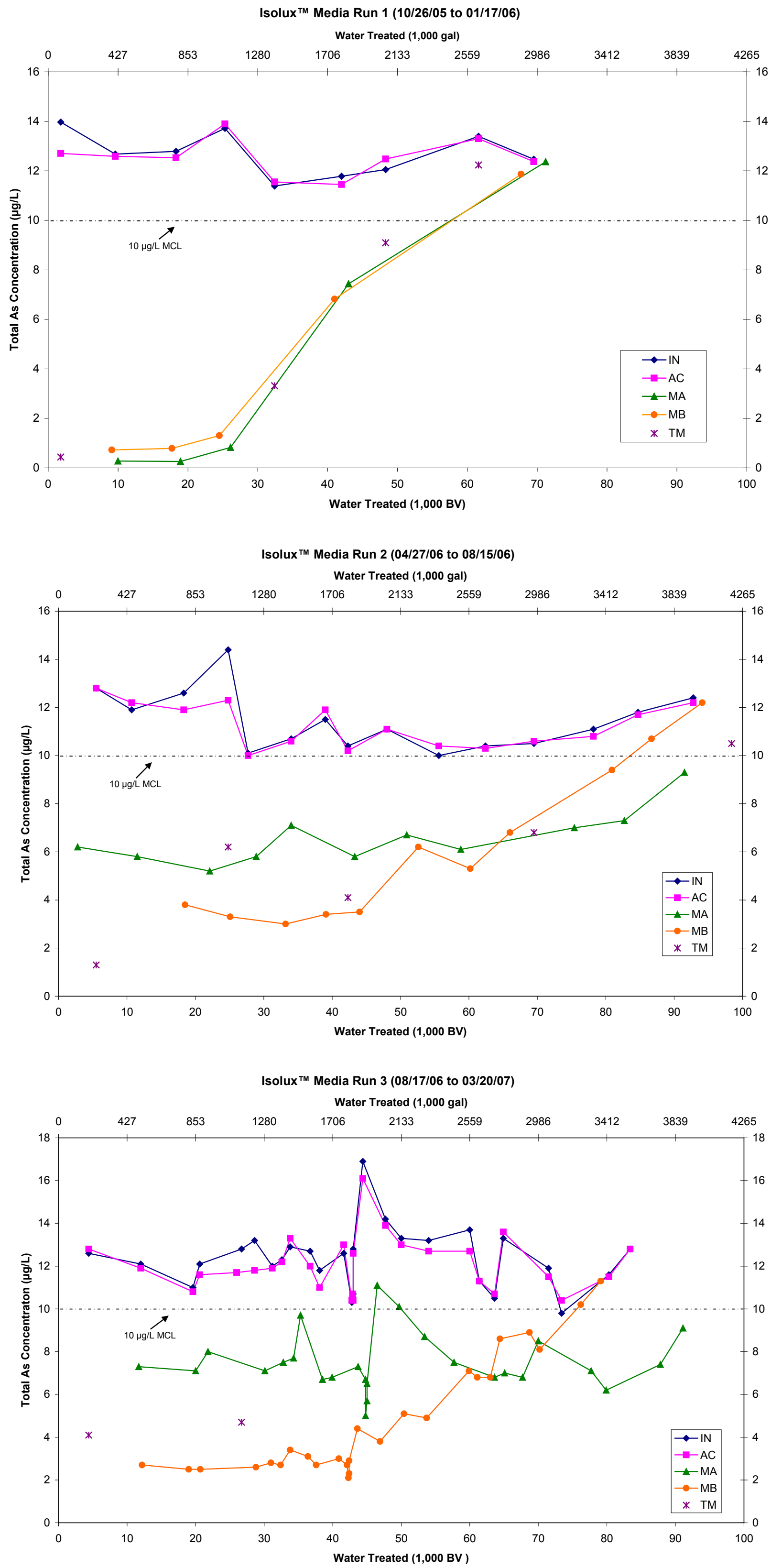


Figure 4-16. Total Arsenic Concentrations Through Treatment System During Media Runs 1 to 3

arsenic concentrations measured at MA and MB were approximately 6.0 and 4.0 μg/L, respectively, where they remained until gradually increasing to 10 μg/L breakthrough. Arsenic concentrations at MB reached 10 μg/L at about 86,700 BV; arsenic concentrations at MA increased to 9.3 μg/L after approximately 91,520 BV. However, the average effluent of MA and MB did not exceed 10 μg/L until August 8, 2006, after approximately 92,800 BV of throughput. Longer media run lengths were observed during Media Run 2; however, the calculated system operating time (i.e., 21.9 versus 20.2 hr/day) and EBCT (i.e., 1.1 versus 1.2 min) were similar. The well thereby rehabilitation might have reduced the amount of sediments and particulates produced by the well, thereby reducing the potential for preferential flow through the media cartridges and thus extending the life of the media.

Media Run 3 began on August 17, 2006, following media cartridge change-out and ended with the conclusion of the performance evaluation study on March 20, 2007. During Media Run 3, initial arsenic concentrations at MA and MB also were elevated at 7.0 and 3.0 μg/L, respectively. Arsenic concentrations at MA spiked above 10 μg/L at about 49,700 BV before gradually decreasing to 6.8 μg/L at 63,600 BV. On March 13, 2007, arsenic concentrations at MB reached 10 μg/L at about 76,200 BV, while arsenic concentration at MA remained below 10 μg/L at 7.4 μg/L after the system had treated approximately 82,000 BV of water. The average effluent of MA and MB exceeded 10 μg/L on March 20, 2007, after treating approximately 85,100 BV of water. Similar media run lengths were observed during Media Runs 2 and 3; the intermittent system operation (i.e., 16.7 versus 20.2 hr/day) did not seem to affect the media run length.

Iron, Manganese, and Zirconium. The treatment plant water samples were analyzed for total iron, manganese, and zirconium at each sampling event and for soluble iron, manganese, and zirconium during speciation sampling. Total and soluble iron concentrations were below the method detection limit of 25 μg/L in source water and throughout the treatment train. Manganese concentrations in source water ranged from 2.9 to 5.3 μg/L, which existed primarily in the soluble form at an average concentration of 4.1 μg/L. Total manganese concentrations in the effluent of MA and MB averaged 0.6 and 0.3 μg/L, respectively. Figure 4-17 presents total manganese concentrations versus bed volumes across the treatment train for all media runs. Zirconium concentrations in raw water and across the treatment train were below its detection limit of 0.1 μg/L, indicating zirconium was not leached from the Isolux™-302M media.

pH. The pH of Zero Point of Charge (pH_{zpc}) for zirconium hydroxide based media such as Isolux™-302M is 10 to 11. Above the pH of the ZPC, the media surface is negatively charged, and electrostatic repulsion will occur between the surface and an anion; this repulsion must be overcome for sorption to occur by a specific chemical bond. As(V) is more strongly sorbed and affected by pH in the range of 4 to 9 (Siegel, et al., 2007). pH of source water ranged from 7.4 to 7.9 and averaged 7.6, which is well below the pH of the ZPC and within the operational range of 4 to 8.5 (Figure 4-18).

DO and ORP. DO and ORP readings averaged 2.6 mg/L and 359 millivolts (mV), respectively, in source water. Both parameters indicated that the well water was oxidizing, which was consistent with the presence of As(V) in raw water. As a result of prechlorination, the ORP readings at AC, MA, MB, and TM increased to an average of 597 mV.

Other Water Quality Parameters. Alkalinity ranged from 176 to 330 mg/L (as $CaCO_3$) in raw water and remained unchanged after treatment. Sulfate, fluoride, and nitrate were measured during speciation sampling, and silica was measured at each sampling event. Their concentrations in raw water ranged from 39 to 52 mg/L for sulfate; 0.1 to 0.9 mg/L for fluoride, with one outlier of 10.2 mg/L; 0.4 to 0.7 mg/L (as N) for nitrate; and 26.4 to 31.7 mg/L for silica (as SiO_2) and remained unchanged after treatment.

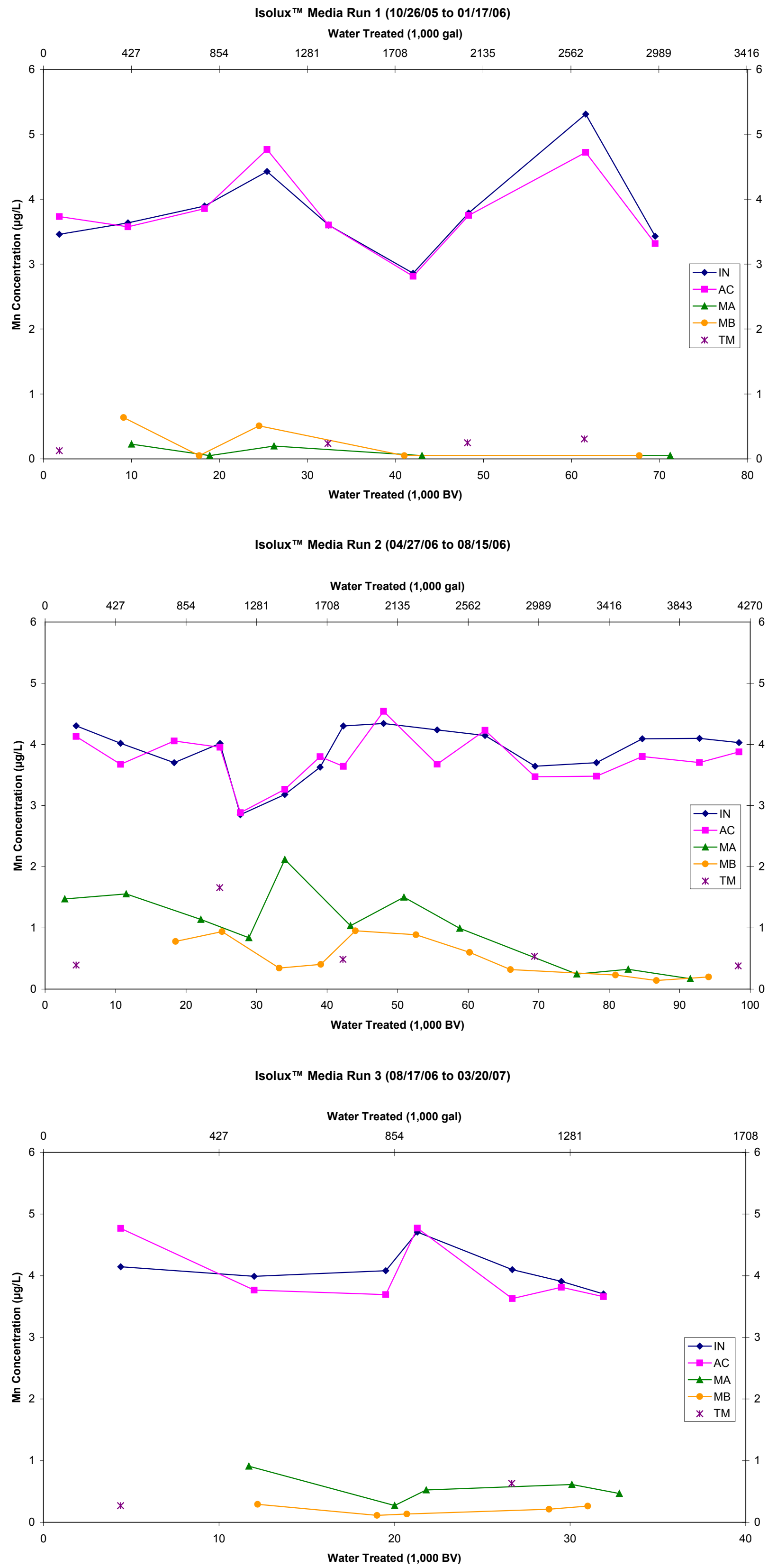


Figure 4-17. Total Mn Concentrations Through Treatment System During Media Runs 1 to 3

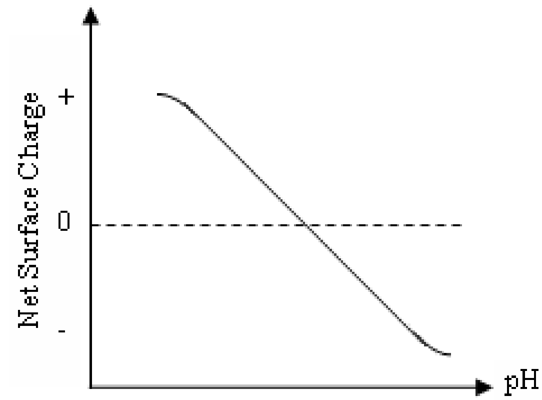


Figure 4-18. Relationship Between pH and Surface Charge of Media (Modified from Stumm and Morgan, 1981)

Total phosphorous (as P) concentrations were below the detection limit of 10 µg/L for all measurements, except for four detections of (10.2, 10.6, 15.7, and 11.1 µg/L on March 30, June 13, June 21, and October 4, 2006, respectively) at the IN location and 11.3 and 11.4 µg/L on June 13 and October 4, 2006, respectively, at the AC location (Appendix B). Total hardness ranged from 153 to 220 mg/L (as $CaCO_3$), and remained relatively constant throughout the treatment train.

4.5.2 Distribution System Sampling. Distribution water samples were collected at three residences before and after the installation/operation of the Isolux™ system to determine whether the treatment system had any impacts on the lead and copper levels and water chemistry in the distribution system. The samples were analyzed for pH, alkalinity, arsenic, iron, manganese, lead, and copper; results are presented in Table 4-7. Since system startup, arsenic concentrations in the distribution system decreased slightly from the baseline levels of 2.8, 6.0, and 5.2 µg/L (on average) to 2.0, 3.3, and 3.1 µg/L at the DS1, DS2, and DS3 sampling locations, respectively. These concentrations were somewhat lower than those of the plant effluent (Figure 4-19), presumably due to blending of the treated water with untreated water from wells that did not have elevated arsenic levels.

Lead and copper concentrations ranged from <0.1 to 8.7 µg/L and 19.9 to 885.1 µg/L, respectively. No samples exceeded the 15 µg/L-Pb or 1,300 µg/L-Cu action levels. Due to blending of water from 12 other wells, it was inconclusive whether these distribution system concentrations had been affected by the arsenic treatment system.

pH, alkalinity, and manganese concentrations remained fairly consistent, with average baseline levels at 7.6, 173 mg/L, and 0.6 µg/L, and after startup levels at 7.8, 173 mg/L, and 0.2 µg/L, respectively. Iron was not detected in any samples.

4.5.3 Spent Media Sampling. Samples of spent Isolux™-302M media samples from Media Run 1 were collected according to Section 3.3.4 for TCLP and total metals analyses. Figure 4-20 presents photographs taken during spent media sampling.

The TCLP results provided by MEI (Table 4-8) indicated that the Isolux™-302M media was non-hazardous and could be disposed of in a standard solid waste landfill. However, MEI opted to send the spent media cartridges to GemChem, Inc., an Environmental Management Company in Lititz, PA, for beneficial reuse. The spent media was combined with similar products for use as fill materials in applications such as quarry reclamation.

Table 4-7. Distribution System Sampling Results

Sampling Event		DS1[(a)] LCR Residence 1st draw								DS2 Non-LCR Residence 1st draw								DS3 Non-LCR Residence 1st Draw							
		Stagnation Time	pH	Alkalinity (as $CaCO_3$)	As	Fe	Mn	Pb	Cu	Stagnation Time	pH	Alkalinity (as $CaCO_3$)	As	Fe	Mn	Pb	Cu	Stagnation Time	pH	Alkalinity (as $CaCO_3$)	As	Fe	Mn	Pb	Cu
No.	Date	hrs	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	hrs	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	hrs	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BL1	07/19/05	10.5	7.6	176	3.1	<25	0.8	1.9	221	9.4	7.5	176	6.3	<25	1.1	0.8	110	7.5	7.6	176	4.5	<25	0.5	1.1	773
BL2	08/04/05	11.0	7.6	176	5.1	<25	1.1	0.6	148	Homeowner not present for sample collection.								9.5	7.6	180	5.1	<25	0.8	0.9	789
BL3	08/16/05	8.3	7.7	163	1.7	<25	0.1	1.0	136	9.2	7.6	176	5.1	<25	0.5	0.4	90.7	8.5	7.6	176	6.3	<25	0.6	0.8	724
BL4	08/30/05	9.0	7.6	163	1.5	<25	<0.1	0.3	78.0	8.2	7.5	172	6.6	<25	0.7	0.2	41.1	9.0	7.5	167	4.9	<25	0.6	0.9	724
1	11/01/05	11.8	7.6	176	3.7	<25	0.2	0.5	75.5	9.4	7.8	167	6.7	<25	0.3	0.6	85.7	19.5	7.9	167	6.6	<25	0.4	0.9	885
2	12/06/05	8.5	7.8	145	2.5	<25	0.2	0.2	56.4	8.7	7.8	167	3.9	<25	0.3	0.3	59.7	7.0	8.0	167	3.4	<25	0.3	0.3	357
3	01/04/06	11.5	7.8	180	1.6	<25	<0.1	0.5	53.5	9.6	7.9	180	4.5	<25	<0.1	0.4	105	Homeowner not present for sample collection.							
4	05/17/06[(b)]	Homeowner not present for sample collection.								8.4	7.7	155	2.6	<25	18.2	7.5	183	8.0	7.7	159	2.6	<25	18.4	8.7	208
5	06/06/06	8.8	7.8	160	1.6	<25	<0.1	0.1	106	9.1	7.7	173	2.5	<25	0.5	<0.1	19.9	8.5	7.8	169	2.5	<25	0.1	0.2	247
6	07/12/06[(c)]	12.3	7.7	168	1.4	<25	0.3	0.3	66.0	8.1	7.7	184	2.3	<25	0.4	0.6	133	7.0	NA[(d)]	NA[(d)]	2.4	<25	0.3	0.7	857
7	08/09/06	8.5	7.7	168	1.8	<25	<0.1	0.3	77.2	9.0	7.7	181	3.8	<25	0.1	0.7	151	8.3	7.7	181	3.7	<25	<0.1	0.7	508
8	09/13/06	9.0	7.8	165	1.6	<25	<0.1	0.1	106	9.4	7.8	183	1.6	<25	<0.1	0.5	84.4	7.8	7.8	186	1.7	<25	<0.1	0.8	574
9	10/11/06	Homeowner not present for sample collection.								8.3	7.6	194	1.9	<25	<0.1	0.9	529	8.8	7.7	210	1.8	<25	<0.1	0.6	130

(a) BL1 and BL2 were collected from a non-LCR residence.
(b) DS3 sample collected on 05/18/06.
(c) DS3 sample collected on 07/13/06.
(d) Samples were past hold time.
BL = Baseline sampling; NA = data not available.

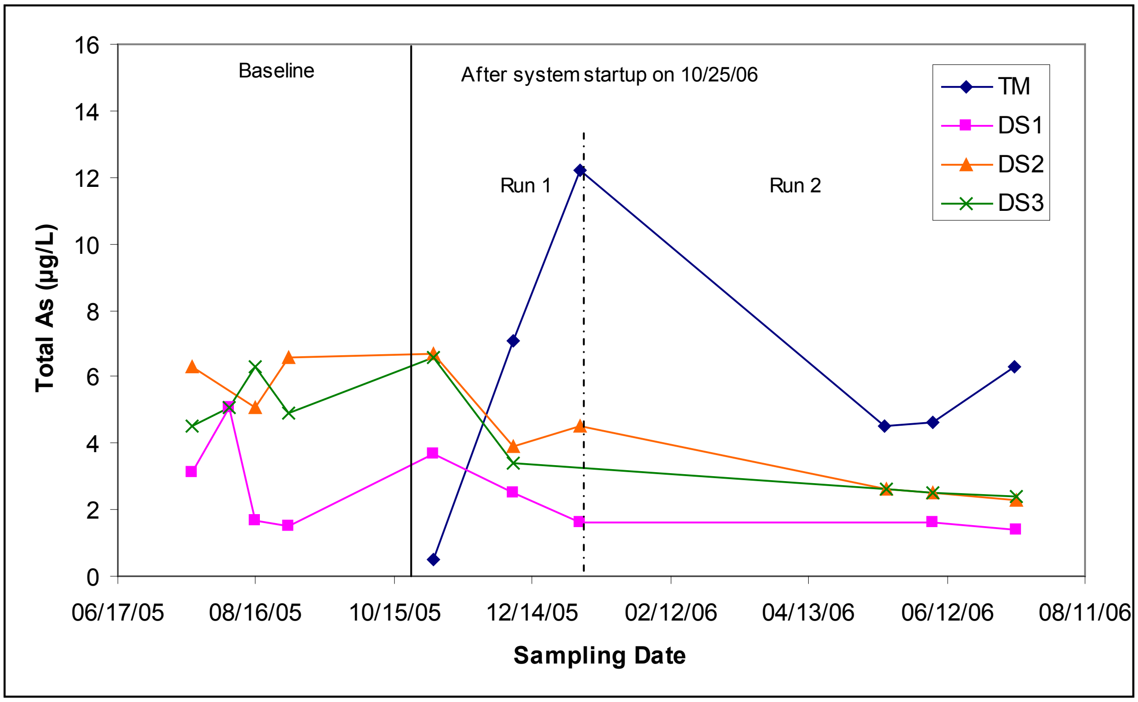


Figure 4-19. Total Arsenic Concentrations in Distribution System

Figure 4-20. Spent Media Sampling
(Clockwise from Top Left: Spent Media Surface with Outer Membrane Removed, Visual of Spent Media from Outer Surface to Inner Membrane [I] and [II], Sample Collection into Dishes, Mottled Appearance on Outer Surface)

Table 4-8. TCLP Results of Spent Media

Parameter	Isolux™-302M Leachate Concentration (mg/L)
As	<0.05
Ba	1.4
Cd	<0.05
Cr	<0.05
Pb	<0.1
Hg	<0.003
Se	<0.3
Ag	<0.05

Provided by MEI.

Visual observations of the spent media cartridge indicated sediment accumulation on the outer membrane of the cartridge and on the outer surface of the annular space immediately under the outer membrane. Figure 4-21 shows dark to light brown colors of the outer membrane of a typical cartridge removed from the system. Once the outer membrane was cut away, the outer surface of the media displayed a mottled appearance (Figure 4-22), which may be indicative of the actual distribution of the incoming flow. Iron concentrations of the spent media taken across the annular space of the cartridge averaged 800, 30, <0.5, and 128 μg/g for the outer surface, subsurface, mid-portion, and inner portion, respectively, thus confirming the visual observations of sediment accumulation on the media. The iron concentration measured at the inner portion was higher than at the mid-portion; this suggests channeling of the incoming flow, which might have contributed, in part, to the short run length observed during Media Run 1.

Figure 4-21. Spent Media Cartridge Removed from Isolux™ System (Provided by MEI)

Figure 4-22. Spent Media Cartridge with Outer Membrane Cut Away (Provided by MEI)

Table 4-9 presents the results of metals analyses. Arsenic concentrations across the annular space of the media cartridge were relatively consistent, averaging 271, 285, 321, and 249 µg/g from the outer surface to the inner portion. These values were lower than the loading (i.e., 814 µg/g or about 0.08%) based on the system throughput and the arsenic concentrations before and after the treatment system. The differences observed most likely were caused by the relatively small quantaties of the samples taken for the metal analyses. Also, the results of Al, Si, P, Mn, and Cu analyses further support the speculation of channeling, which resulted in metal concentrations measured at the inner portion being higher than those of the mid-portion of the media cartridge.

4.6 System Cost

The system cost was evaluated based on the capital cost per gpm (or gpd) of the design capacity and the O&M cost per 1,000 gal of water treated. The capital cost included the cost for equipment, site engineering, and installation. The O&M cost included cost for media cartridges, bag filters, electricity, and labor.

4.6.1 Capital Cost. The capital investment for equipment, site engineering, and installation of the Isolux™ treatment system was $76,840 (see Table 4-10). The equipment cost was $58,500 (or 76% of the total capital investment), which included $48,000 for two 75-gpm Isolux™ Modules, $8,000 for 36 Isolux™ technology media cartridges (18 media cartridges per module), and $2,500 for shipping.

The engineering cost included the cost for preparing the required permit application submittal, including system specifications, P&IDs, electrical diagrams, interconnection of piping layouts, and obtaining the required permit approval from CDPH. The engineering cost was $8,500, or 11% of the total capital investment.

Table 4-9. Spent Media Analysis

Sample Description	Analysis	Analyte Concentration (µg/g)												
		Mg	Al	Si	P	Ca	Mn	Fe	Ni	Cu	Zn	As	Cd	Pb
Outer surface	A	576	535	410	722	5,925	790	847	0.7	38.2	724	258	1.9	1.3
	B	541	485	380	734	6,030	748	755	0.6	37.7	723	279	1.8	1.3
	C	602	512	375	736	6,083	776	799	0.8	39.4	749	275	1.9	1.3
	Average	**573**	**511**	**389**	**731**	**6,013**	**771**	**800**	**0.7**	**38.4**	**732**	**271**	**1.8**	**1.3**
Subsurface	A	551	187	353	636	5,620	<125	30.3	<0.5	5.8	789	304	2.1	<0.5
	B	551	186	379	626	5,645	<125	33.8	<0.5	5.6	752	290	2.1	<0.5
	C	500	169	248	627	5,486	<125	26.0	<0.5	5.4	755	262	2.0	<0.5
	Average	**534**	**181**	**327**	**629**	**5,584**	**-**	**30.0**	**-**	**5.6**	**765**	**285**	**2.0**	**-**
Mid-portion	A	500	78.2	400	309	5,617	<125	<0.5	<0.5	<0.5	587	334	2.0	<0.5
	B	481	47.6	284	280	5,258	<125	<0.5	<0.5	<0.5	574	307	2.1	<0.5
	C	519	66.8	417	303	5,592	<125	<0.5	<0.5	<0.5	572	322	1.9	<0.5
	Average	**500**	**64.2**	**367**	**297**	**5,489**	**-**	**-**	**-**	**-**	**577**	**321**	**2.0**	**-**
Inner portion	A	481	116	455	383	5,458	156	118	<0.5	5.0	578	234	2.0	<0.5
	B	525	144	441	380	5,686	154	133	<0.5	5.2	584	268	1.9	<0.5
	C	517	122	426	372	5,554	162	134	<0.5	5.2	587	246	2.1	<0.5
	Average	**508**	**127**	**441**	**378**	**5,566**	**157**	**128**	**-**	**5.1**	**583**	**249**	**2.0**	**-**

The installation, shakedown, and startup cost covered the labor and materials required to unload, install, and test the system for proper operation. All installation activities were performed by MEI and GHCSD; startup and shakedown activities were performed by MEI with the operator's assistance. The installation, startup, and shakedown costs, were $9,840, or 13% of the total capital investment.

Table 4-10. Capital Investment for MEI's Isolux™ Treatment System

Description	Quantity	Cost	% of Capital Investment Cost
Equipment			
Isolux™ 75 gpm module	2	$48,000	–
Isolux™ technology media cartridges	36	$8,000	–
Freight	-	$2,500	–
Equipment Total	-	**$58,500**	**76%**
Engineering			
Vendor material	-	$1,500	–
Vendor labor	-	$2,000	–
Subcontractor material	-	$2,000	–
Subcontractor labor	-	$3,000	–
Engineering Total	-	**$8,500**	**11%**
Installation, Shakedown, and Startup			
Material (mechanical)	-	$500	–
Material (electrical)	-	$300	
Vendor labor (mechanical)	-	$6,480	
Vendor travel	-	$2,560	
Installation, Shakedown, and Startup	-	**$9,840**	**13%**
Total Capital Investment	-	**$76,840**	**100%**

The total capital cost of $76,840 was normalized to $512/gpm ($0.36/gpd) of design capacity using the system's rated capacity of 150 gpm (or 216,000 gpd). The total capital cost also was converted to an annualized cost of $7,253/year, using a capital recovery factor of 0.09439 based on a 7% interest rate and a 20-year return. Assuming that the system was operated 24 hours a day, 7 days a week at the design flow rate of 150 gpm to produce 78,840,000 gal of water per year, the unit capital cost would be $0.09/1,000 gal. This calculation assumed that the system operated 24 hr/day at its rated capacity. The system operated 19.6 hr/day (on average) at approximately 79.3 gpm (on average) (see Table 4-4). Based on this reduced use rate, the system would produce only 34,038,700 gal of water in one year (assuming 365 days per year), and the unit capital cost would increase to $0.21/1,000 gal.

4.6.2 Operation and Maintenance Cost. The O&M cost included media cartridge replacement and disposal, electricity consumption, and labor. Table 4-11 summarizes the O&M cost.

The cost to replace and dispose of the spent media cartridges represented the majority of the O&M cost (i.e., $7,080 for 36 cartridges in two modules). By averaging this cost over the useful life of the media, the unit cost per 1,000 gal of water treated was plotted as a function of the media life (i.e., run length in BV), as shown in Figure 4-23. The media run length (in BV) was calculated by dividing the system throughput (in gal) by the quantity of media in both modules (i.e., 11.4 ft^3 [or 85.3 gal]). The Isolux™ system processed an average of 61,600, 92,800, and 85,100 BV prior to reaching the 10 µg/L arsenic breakthrough during Media Runs 1, 2, and 3, respectively. Based on these volumes, the unit media replacement cost was $1.35, $0.89, and $0.98/1,000 gal, respectively.

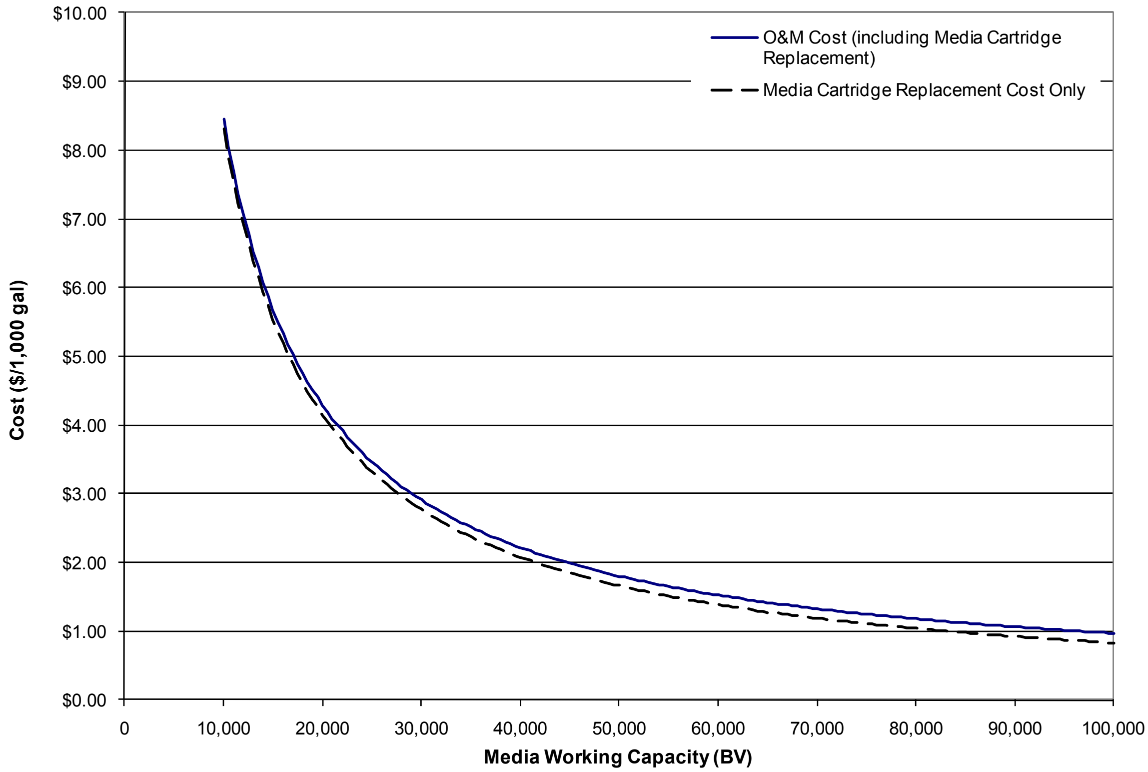
Table 4-11. O&M Cost for MEI's Isolux™ Treatment System

Category	Value	Remarks
Media Cartridge Replacement		
Isolux™ media cartridges ($/changeout)	$6,480	36 cartridges (18 cartridges/module)
Transportation	$600	36 cartridges (18 cartridges/module)
Media cartridge replacement ($/1,000 gal)	See Figure 4-23	
Electricity Consumption		
Electricity Cost ($/1,000 gal)	$0.001	Electrical cost negligible
Labor		
Labor (hr/week)	2.5	30 min/day, 5 day/week
Labor Cost ($/1,000 gal)	$0.14	Labor rate = $37.5/hr[(a)]
Total O&M Cost ($/1,000 gal)	See Figure 4-23	

(a) O/M labor would be higher if a contract operator was required.

The Isolux™ treatment modules contained booster pumps that required electricity; however, the booster pumps were not used during the study. Therefore, additional electrical cost incurred by the Isolux™ system operation was assumed to be negligible.

Under normal operating conditions, routine labor activities to operate and maintain the system consumed 2.5 per week as noted in Section 4.4.2. Assuming that the system operates at an average flowrate of 79.3 gpm for 19.6 hr/day and 7 day/week to produce 653,000 gal of water per week, the estimated labor cost would be $0.14/1,000 gal of water treated.



Note: 1 BV = media volume in both modules

Figure 4-23. Total O&M Cost, Including Media Replacement

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APPENDIX A

OPERATIONAL DATA

Table A-1. U.S. EPA Arsenic Demonstration Project at Tehachapi, CA – Daily System Operation Log Sheet

Week	Day of Week	Date and Time	Well C: Meter Hours	Well C: Op Hours	Well C: Totalizer to Treatment (acre-ft)	Well C: Totalizer to Treatment (gal)	Well C: Volume In (gal)	Well C: Average Flowrate (gpm)	Module A Flow Totalizer (gpm)	Module A Flow Totalizer (gal)	Module A Cum Flow Totalizer (gal)	Module A Volume In (gal)	Module A Bed Volumes (BV)	Module B Flow Totalizer (gpm)	Module B Flow Totalizer (gal)	Module B Cum Flow Totalizer (gal)	Module B Volume In (gal)	Module B Bed Volumes (BV)	Total Water Treated (gal)	Cum Water Treated	Cum Bed Volumes	Module A Pressure (psig): Before Bag-Filter	Module A Pressure (psig): After Bag-Filter	Module A Pressure (psig): Outlet	Module A Pressure (psig): ΔP Across Bag-Filter	Module A Pressure (psig): ΔP Across Module	Module B Pressure (psig): Before Bag-Filter	Module B Pressure (psig): After Bag-Filter	Module B Pressure (psig): Outlet	Module B Pressure (psig): ΔP Across Bag-Filter	Module B Pressure (psig): ΔP Across Module
1	T	10/25/05 16:00	NM	NA	446.95	145,436,879	NA	NA	43	33,500	33,500	33,500	785	45	31,400	31,400	31,400	736	64,900	64,900	761	31	NM	15	NA	NA	30	NM	14	NA	NA
	W	10/26/05 9:30	NM	NA	447.22	145,526,690	89,810	NA	43	77,200	77,200	43,700	1,810	42	75,100	75,100	43,700	1,761	87,400	152,300	1,785	32	32	14	0	18	30	28	12	2	16
	R	10/27/05 11:40	NM	NA	447.60	145,649,040	122,350	NA	41	142,500	142,500	65,300	3,341	38	138,800	138,800	63,700	3,254	129,000	281,300	3,298	32	30	14	2	16	31	28	12	3	16
	F	10/28/05 8:15	NM	NA	447.93	145,754,795	105,755	NA	43	187,700	187,700	45,200	4,401	40	182,200	182,200	43,400	4,272	88,600	369,900	4,336	32	30	14	2	16	32	28	12	4	16
2	M	10/31/05 6:25	NM	NA	448.96	146,090,282	335,487	NA	41	363,300	363,300	175,600	8,518	34	336,900	336,900	154,700	7,899	330,300	700,200	8,209	40	32	12	8	20	42	23	12	19	11
	T	11/1/05 8:00	NM	NA	449.31	146,205,799	115,517	NA	40	424,800	424,800	61,500	9,960	36	388,000	388,000	51,100	9,097	112,600	812,800	9,529	44	29	13	15	16	46	23	12	23	11
	W	11/2/05 8:15	NM	NA	449.65	146,315,134	109,334	NA	40	483,300	483,300	58,500	11,332	31	435,000	435,000	47,000	10,199	105,500	918,300	10,766	52	30	12	22	18	56	24	11	32	13
	R	11/3/05 8:20	NM	NA	449.99	146,425,444	110,311	NA	38	54,200	537,500	54,200	12,603	39	52,400	487,400	52,400	11,428	106,600	1,024,900	12,015	28	28	12	0	16	26	26	11	0	15
	F	11/4/05 6:30	NM	NA	450.30	146,528,922	103,477	NA	38	104,500	587,800	50,300	13,782	38	103,000	538,000	50,600	12,614	100,900	1,125,800	13,198	26	28	12	2	16	26	26	11	0	15
3	M	11/7/05 6:45	NM	NA	451.34	146,866,687	337,765	NA	38	268,900	752,200	164,400	17,637	38	267,700	702,700	164,700	16,476	329,100	1,454,900	17,056	24	24	9	0	15	24	24	8	0	16
	T	11/8/05 6:15	NM	NA	451.68	146,976,672	109,985	NA	38	322,200	805,500	53,300	18,886	37	320,900	755,900	53,200	17,723	106,500	1,561,400	18,305	26	26	10	0	16	24	24	8	0	16
	W	11/9/05 6:45	NM	NA	452.03	147,089,911	113,239	NA	37	364,900	848,200	42,700	19,887	37	363,500	798,500	42,600	18,722	85,300	1,646,700	19,305	23	23	10	0	13	23	23	8	0	15
	R	11/10/05 6:45	NM	NA	452.37	147,199,896	109,985	NA	38	419,000	902,300	54,100	21,156	37	416,400	851,400	52,900	19,962	107,000	1,753,700	20,559	24	24	11	0	13	24	23	11	1	12
	F	11/11/05 8:27	NM	NA	452.72	147,314,112	114,215	NA	38	476,000	959,300	57,000	22,492	37	470,300	905,300	53,900	21,226	110,900	1,864,600	21,859	25	25	11	0	14	25	24	11	1	13
	Sa	11/12/05 8:27	NM	NA	453.05	147,423,446	109,334	NA	38	532,500	1,015,800	56,500	23,817	35	521,100	956,100	50,800	22,417	107,300	1,971,900	23,117	32	30	13	2	17	33	26	13	7	13
	Su	11/13/05 8:25	NM	NA	453.38	147,528,876	105,430	NA	39	589,000	1,072,300	56,500	25,142	32	567,700	1,002,700	46,600	23,510	103,100	2,075,000	24,326	39	30	13	9	17	39	25	13	14	12
4	M	11/14/05 12:00	NM	NA	453.78	147,660,988	132,112	NA	31	589,400	1,072,700	400	25,151	31	568,000	1,003,000	300	23,517	700	2,075,700	24,334	24	24	10	0	14	24	24	11	0	13
	T	11/15/05 7:10	NM	NA	454.05	147,747,545	86,556	NA	36	631,500	1,114,800	42,100	26,138	36	610,300	1,045,300	42,300	24,509	84,400	2,160,100	25,324	26	26	11	0	15	26	26	11	0	15
	W	11/16/05 6:25	NM	NA	454.31	147,830,847	83,302	NA	37	672,000	1,155,300	40,500	27,088	37	651,000	1,086,000	40,700	25,463	81,200	2,241,300	26,275	28	32	14	4	18	28	28	14	0	14
	R	11/17/05 6:55	NM	NA	454.64	147,940,832	109,985	NA	37	726,000	1,209,300	54,000	28,354	36	704,500	1,139,500	53,500	26,717	107,500	2,348,800	27,536	30	30	14	0	16	28	28	12	0	16
5	M	11/21/05 6:20	NM	NA	454.65	147,941,483	651	NA	57	726,300	1,209,600	300	28,361	56	704,900	1,139,900	400	26,727	700	2,349,500	27,544	38	38	12	0	26	38	38	12	0	26
	T	11/22/05 6:20	NM	NA	455.03	148,068,064	126,581	NA	42	789,300	1,272,600	63,000	29,838	42	765,100	1,200,100	60,200	28,138	123,200	2,472,700	28,988	32	32	12	0	20	32	32	12	0	20
	W	11/23/05 6:00	NM	NA	455.40	148,185,533	117,469	NA	40	848,900	1,332,200	59,600	31,236	38	820,600	1,255,600	55,500	29,440	115,100	2,587,800	30,338	36	36	12	0	24	36	28	12	8	16
6	M	11/28/05 7:45	NM	NA	455.57	148,240,851	55,318	NA	47	876,500	1,359,800	27,600	31,883	45	846,200	1,281,200	25,600	30,040	53,200	2,641,000	30,961	50	32	14	18	18	50	30	12	20	18
	T	11/29/05 8:20	NM	NA	455.95	148,366,130	125,279	NA	40	939,300	1,422,600	62,800	33,355	38	905,800	1,340,800	59,600	31,437	122,400	2,763,400	32,396	70	32	14	38	18	70	30	12	40	18
	W	11/30/05 8:50	NM	NA	456.34	148,492,385	126,255	NA	43	1,001,100	1,484,400	61,800	34,804	42	967,300	1,402,300	61,500	32,879	123,300	2,886,700	33,842	32	32	12	0	20	30	30	12	0	18
	R	12/1/05 6:50	NM	NA	456.69	148,607,251	114,866	NA	40	1,056,800	1,540,100	55,700	36,110	41	1,023,100	1,458,100	55,800	34,188	111,500	2,998,200	35,149	30	32	12	2	20	30	32	12	2	20
	F	12/2/05 8:45	NM	NA	457.10	148,739,364	132,112	NA	40	1,120,900	1,604,200	64,100	37,613	40	1,087,500	1,522,500	64,400	35,698	128,500	3,126,700	36,655	30	32	14	2	18	30	30	14	0	16
	Sa	12/3/05 9:00	NM	NA	457.47	148,860,087	120,723	NA	39	1,179,600	1,662,900	58,700	38,989	40	1,146,500	1,581,500	59,000	37,081	117,700	3,244,400	38,035	30	31	14	1	17	30	31	14	1	17
	Su	12/4/05 8:35	NM	NA	457.83	148,976,255	116,168	NA	39	1,236,100	1,719,400	56,500	40,314	39	1,203,200	1,638,200	56,700	38,410	113,200	3,357,600	39,362	29	30	14	1	16	28	29	13	1	16
7	M	12/5/05 8:00	NM	NA	458.17	149,089,494	113,239	NA	39	1,291,400	1,774,700	55,300	41,611	38	1,291,400	1,726,400	88,200	40,478	143,500	3,501,100	41,045	30	30	14	0	16	30	30	14	0	16
	T	12/6/05 8:00	NM	NA	458.53	149,205,662	116,168	NA	39	1,348,500	1,831,800	57,100	42,950	38	1,314,400	1,749,400	23,000	41,018	80,100	3,581,200	41,984	30	30	14	0	16	30	30	14	0	16
	W	12/7/05 8:00	0.0	0.0	458.88	149,318,250	112,588	NA	39	1,404,500	1,887,800	56,000	44,263	37	1,368,000	1,803,000	53,600	42,274	109,600	3,690,800	43,268	32	31	14	1	17	32	30	14	2	16
	R	12/8/05 8:00	22.4	22.4	459.22	149,430,839	112,588	83.8	40	1,462,500	1,945,800	58,000	45,623	35	1,419,700	1,854,700	51,700	43,487	109,700	3,800,500	44,555	40	30	14	10	16	40	30	14	10	16
	F	12/9/05 8:00	46.1	23.7	459.55	149,536,594	105,755	74.4	44	1,522,500	2,005,800	60,000	47,029	26	1,463,300	1,898,300	43,600	44,509	103,600	3,904,100	45,769	48	32	14	16	18	52	22	14	30	8
8	M	12/12/05 12:00	71.0	24.9	459.88	149,643,976	107,382	71.9	44	1,597,800	2,081,100	75,300	48,795	44	1,497,800	1,932,800	34,500	45,318	109,800	4,013,900	47,056	32	32	14	0	18	32	32	14	0	18
	T	12/13/05 8:45	93.0	22.0	460.22	149,756,890	112,914	85.5	40	1,649,900	2,133,200	52,100	50,016	40	1,550,200	1,985,200	52,400	46,546	104,500	4,118,400	48,281	32	32	14	0	18	32	30	14	2	16
	W	12/14/05 5:50	114	21.0	460.55	149,861,994	105,104	83.4	40	1,700,900	2,184,200	51,000	51,212	40	1,601,600	2,036,600	51,400	47,751	102,400	4,220,800	49,482	32	32	14	0	18	30	30	14	0	16
	R	12/15/05 8:00	139	25.0	460.93	149,985,320	123,327	82.2	39	1,760,400	2,243,700	59,500	52,607	40	1,661,900	2,096,900	60,300	49,165	119,800	4,340,600	50,886	30	28	14	2	14	28	28	12	0	16
	F	12/16/05 5:50	162	23.0	461.27	150,095,956	110,636	80.2	38	1,813,600	2,296,900	53,200	53,855	40	1,716,400	2,151,400	54,500	50,443	107,700	4,448,300	52,149	30	28	12	2	16	28	28	10	0	18
	Sa	12/17/05 8:40	189	27.0	461.66	150,222,862	126,906	78.3	37	1,874,300	2,357,600	60,700	55,278	38	1,779,400	2,214,400	63,000	51,920	123,700	4,572,000	53,599	32	30	12	2	18	30	30	12	0	18
	Su	12/18/05 8:25	213	24.0	461.99	150,332,848	109,985	76.4	36	1,925,900	2,409,200	51,600	56,488	38	1,834,700	2,269,700	55,300	53,217	106,900	4,678,900	54,852	38	30	14	8	16	30	30	14	0	16
9	M	12/19/05 6:40	235	22.0	462.30	150,433,396	100,549	76.2	34	1,972,500	2,455,800	46,600	57,580	40	1,886,300	2,321,300	51,600	54,427	98,200	4,777,100	56,004	40	30	14	10	16	38	30	14	8	16
	T	12/20/05 6:50	259	24.0	462.63	150,541,104	107,707	74.8	34	2,020,900	2,504,200	48,400	58,715	39	1,942,600	2,377,600	56,300	55,747	104,700	4,881,800	57,231	42	28	12	14	16	42	30	14	12	16
	W	12/21/05 10:00	286	27.0	463.00	150,659,875	118,771	73.3	31	2,073,000	2,556,300	52,100	59,937	39	2,006,600	2,441,600	64,000	57,247	116,100	4,997,900	58,592	48	26	12	22	14	46	28	12	18	16
	R	12/22/05 6:50	307	21.0	463.27	150,748,383	88,509	70.2	30	2,110,300	2,593,600	37,300	60,811	39	2,055,000	2,490,000	48,400	58,382	85,700	5,083,600	59,597	54	24	12	30	12	52	28	10	24	18
11	T	1/3/06 14:35	310	3.00	463.317	150,763,352	14,968	83.2	45	2,116,600	2,599,900	6,300	60,959	51	2,063,300	2,498,300	8,300	58,577	14,600	5,098,200	59,768	70	32	10	38	22	68	32	10	36	22
	W	1/4/06 8:00	340	30.0	463.813	150,924,750	161,398	89.7	44	2,193,400	2,676,700	76,800	62,760	46	2,144,100	2,579,100	80,800	60,471	157,600	5,255,800	61,615	30	30	10	0	20	30	30	10	0	20
	R	1/5/06 8:00	364	24.0	464.217	151,056,212	131,462	91.3	43	2,256,400	2,739,700	63,000	64,237	44	2,208,800	2,643,800	64,700	61,988	127,700	5,383,500	63,113	30	30	10	0	20	30	30	10	0	20
	F	1/6/06 12:40	392	28.0	464.685	151,208,499	152,287	90.6	43	2,329,700	2,813,000	73,300	65,955	43	2,283,900	2,718,900	75,100	63,749	148,400	5,531,900	64,852	30	30	12	0	18	30	30	12	0	18
	Sa	1/7/06 7:48	415	22.5	465.047	151,326,294	117,795	87.3	41	2,377,400	2,860,700	47,700	67,074	41	2,332,800	2,767,800	48,900	64,896	96,600	5,628,500	65,985	33	34	14	1	20	68	32	15	36	17
	Su	1/8/06 8:40	437	22.5	465.382	151,435,303	109,009	80.7	41	2,439,900	2,923,200	62,500	68,539	41	2,396,600	2,831,600	63,800	66,392	126,300	5,754,800	67,465	33	34	15	1	19	30	32	15	2	17
12	M	1/9/06 8:30	460	23.4	465.746	151,553,748	118,446	84.4	40	2,496,600	2,979,900	56,700	69,869	40	2,453,300	2,888,300	56,700	67,721	113,400	5,868,200	68,795	31	30	14	1	16	31	30	12	1	18
	T	1/10/06 8:00	484	23.6	466.102	151,669,591	115,842	81.8	40	2,553,800	3,037,100	57,200	71,210	39	2,453,300	2,888,300	0	67,721	57,200	5,925,400	69,465	31	30	14	1	16	31	30	12	1	18
	W	1/11/06 15:00	515	31.0	466.562	151,819,275	149,684	80.5	39	2,627,300	3,110,600	73,500	72,933	38	2,581,100	3,016,100	127,800	70,717	201,300	6,126,700	71,825	36	30	14	6	16	36	28	12	8	16
	R	1/12/06 7:25	531	16.0	466.799	151,896,395	77,120	80.3	38	2,665,100	3,148,400	37,800	73,819	37	2,618,200	3,053,200	37,100	71,587	74,900	6,201,600	72,703	40	30	14	10	16	40	28	14	12	14
	F	1/13/06 7:00	554	23.0	467.134	152,005,404	109,009	79.0	35	2,717,500	3,200,800	52,400	75,048	38	2,671,900	3,106,900	53,700	72,846	106,100	6,307,700	73,947	48	30	14	18	16	48	30	14	18	16
	Sa	1/14/06 8:50	580	26.0	467.476	152,116,690	111,287	71.3	32	2,767,900	3,251,200	50,400	76,230	38	2,729,700	3,164,700	57,800	74,202	108,200	6,415,900	75,216	62	28	14	34	14	60	30	14	30	16
13	M	1/16/06 9:00	580	0.0	467.420	152,098,468	NA	NA	59	2,768,200	3,251,500	300	76,237	59	2,730,000	3,165,000	300	74,209	600	6,416,500	75,223	42	40	16	2	24	41	40	14	1	26
	T	1/17/06 7:30	603	23.0	467.832	152,232,533	134,065	97.1	41	2,825,100	3,308,400	56,900	77,571	39	2,785,300	3,220,300	55,300	75,505	112,200	6,528,700	76,538	38	30	14	8	16	38	28	10	10	18

Table A-1. U.S. EPA Arsenic Demonstration Project at Tehachapi, CA – Daily System Operation Log Sheet (Continued)

			Well C						Treatment System																						
					Totalizer to Treatment	Totalizer to Treatment	Volume In	Average Flowrate	Module A Flow Totalizer		Module A Cum Flow Totalizer	Module A Volume In	Module A Bed Volumes	Module B Flow Totalizer		Module B Cum Flow Totalizer	Module B Volume In	Module B Bed Volumes	Total Water Treated	Cum Water Treated	Cum Bed Volumes	Module A Pressure (psig)					Module B Pressure (psig)				
																						Before Bag-Filter	After Bag-Filter	Outlet	ΔP Across Bag-Filter	ΔP Across Module	Before Bag-Filter	After Bag-Filter	Outlet	ΔP Across Bag-Filter	ΔP Across Module
Week	Day of Week	Date and Time	Meter Hours	Op Hours	acre-ft	gal	gal	gpm	gpm	gal	gal	gal	BV	gpm	gal	gal	gal	BV	gal												
14 -26	SYSTEM NOT RUNNING DUE TO WELL ISSUES																														
27	R	4/27/2006 6:30	NM	NA	471.483	153,420,568	NA	NA	47	2,828,400	3,300	3,300	77	41	2,788,100	2,800	2,800	66	6,100	6,100	72	23	23	14	0	9	26	26	12	0	14
	F	4/28/2006 6:15	NM	NA	471.781	153,517,537	96,969	NA	36	2,880,900	55,800	52,500	1,308	31	2,830,400	45,100	42,300	1,057	94,800	100,900	1,183	18	20	12	2	8	20	20	12	0	8
	Sa	4/29/2006 14:30	NM	NA	472.151	153,637,935	120,398	NA	NM	NM	NA	NA	NA	68	2,939,500	154,200	109,100	3,615	109,100	210,000	4,924	NM	NM	NM	NM	NM	49	46	14	3	32
	Su	4/30/2006 8:30	NM	NA	472.395	153,717,333	79,398	NA	NM	NM	NA	NA	NA	69	3,018,000	232,700	78,500	5,456	78,500	288,500	3,382	NM	NM	NM	NM	NM	43	40	13	3	27
28	M	5/1/2006 6:30	NM	NA	472.669	153,806,493	89,160	NA	NM	NM	NA	NA	NA	65	3,105,800	320,500	87,800	7,515	87,800	376,300	4,411	NM	NM	NM	NM	NM	44	36	12	8	24
	T	5/2/2006 6:30	NM	NA	472.954	153,899,232	92,739	NA	NM	NM	NA	NA	NA	55	3,198,600	413,300	92,800	9,691	92,800	469,100	5,499	NM	NM	NM	NM	NM	106	36	12	70	24
	W	5/3/2006 6:25	NM	NA	473.216	153,984,486	85,255	NA	NM	NM	NA	NA	NA	60	3,281,000	495,700	82,400	11,623	82,400	551,500	6,465	NM	NM	NM	NM	NM	36	36	12	0	24
	R	5/4/2006 6:35	NM	NA	473.485	154,072,019	87,533	NA	NM	NM	NA	NA	NA	54	3,370,100	584,800	89,100	13,712	89,100	640,600	7,510	NM	NM	NM	NM	NM	36	36	14	0	22
	F	5/5/2006 8:15	NM	NA	473.720	154,148,488	76,469	NA	NM	NM	NA	NA	NA	56	3,454,000	668,700	83,900	15,679	83,900	724,500	8,494	NM	NM	NM	NM	NM	37	35	13	2	22
29	T	5/9/2006 14:32	NM	NA	473.957	154,225,608	77,120	NA	51	2,893,400	68,300	12,500	1,601	42	3,533,100	747,800	79,100	17,533	91,600	816,100	9,567	24	24	12	0	12	28	26	14	2	12
	W	5/10/2006 6:30	NM	NA	474.238	154,317,045	91,437	NA	50	2,942,400	117,300	49,000	2,750	41	3,574,000	788,700	40,900	18,492	89,900	906,000	10,621	24	24	12	0	12	26	24	12	2	12
	R	5/11/2006 10:45	NM	NA	474.699	154,467,055	150,009	NA	46	3,023,900	198,800	81,500	4,661	36	3,640,000	854,700	66,000	20,040	147,500	1,053,500	12,351	20	22	9	2	13	24	22	10	2	12
	F	5/12/2006 8:00	NM	NA	475.007	154,567,278	100,223	NA	41	3,079,400	254,300	55,500	5,962	28	3,682,900	897,600	42,900	21,046	98,400	1,151,900	13,504	19	20	11	1	9	23	19	11	4	8
	Sa	5/13/2006 14:00	NM	NA	475.346	154,677,588	110,311	NA	35	3,144,300	319,200	64,900	7,484	24	3,728,400	943,100	45,500	22,113	110,400	1,262,300	14,798	18	20	10	2	10	20	18	10	2	8
	Su	5/14/2006 8:13	NM	NA	475.542	154,741,367	63,778	NA	49	3,182,100	357,000	37,800	8,370	39	3,754,000	968,700	25,600	22,713	63,400	1,325,700	15,542	24	23	12	1	11	28	23	12	5	11
30	M	5/15/2006 8:50	NM	NA	475.908	154,860,463	119,096	NA	43	3,248,500	423,400	66,400	9,927	35	3,804,800	1,019,500	50,800	23,904	117,200	1,442,900	16,916	22	20	10	2	10	26	20	9	6	11
	T	5/16/2006 10:35	NM	NA	476.273	154,979,234	118,771	NA	42	3,315,100	490,000	66,600	11,489	32	3,854,500	1,069,200	49,700	25,069	116,300	1,559,200	18,279	25	21	10	4	11	29	20	12	9	8
	W	5/17/2006 8:50	NM	NA	476.560	155,072,624	93,390	NA	40	3,368,100	543,000	53,000	12,732	30	3,893,500	1,108,200	39,000	25,984	92,000	1,651,200	19,358	29	20	11	9	9	31	20	11	11	9
	R	5/18/2006 6:45	NM	NA	476.856	155,168,942	96,318	NA	40	3,422,900	597,800	54,800	14,016	30	3,933,500	1,148,200	40,000	26,921	94,800	1,746,000	20,469	30	22	12	8	10	32	22	12	10	10
	F	5/19/2006 14:25	NM	NA	477.258	155,299,753	130,811	NA	38	3,498,100	673000	75,200	15,780	28	3,986,800	1,201,500	53,300	28,171	128,500	1,874,500	21,975	33	22	12	11	10	37	20	12	17	8
	Sa	5/20/2006 9:20	NM	NA	477.486	155,373,944	74,191	NA	38	3,541,500	716400	43,400	16,797	26	4,017,000	1,231,700	30,200	28,879	73,600	1,948,100	22,838	35	19	9	16	10	38	18	10	20	8
	Su	5/21/2006 8:40	NM	NA	477.730	155,453,342	79,398	NA	30	3,589,200	764100	47,700	17,916	20	4,049,300	1,264,000	32,300	29,637	80,000	2,028,100	23,776	38	16	8	22	8	40	15	9	25	6
31	T	5/23/2006 10:00	NM	NA	477.738	155,455,945	2,603	NA	42	3,590,400	765,300	1,200	17,944	32	4,050,100	1,264,800	800	29,655	2,000	2,030,100	23,800	25	21	10	4	11	29	20	12	9	8
	W	5/24/2006 8:08	NM	NA	478.007	155,543,478	87,533	NA	40	3,640,200	815,100	49,800	19,111	30	4,086,800	1,301,500	36,700	30,516	86,500	2,116,600	24,814	29	20	11	9	9	31	20	11	11	9
	Su	5/28/2006 14:30	NM	NA	478.030	155,550,962	7,484	NA	30	3,644,500	819400	4,300	19,212	20	4,089,900	1,304,600	3,100	30,589	7,400	2,124,000	24,900	38	16	8	22	8	40	15	9	25	6
32	T	5/30/2006 8:36	NM	NA	478.760	155,788,504	237,542	NA	47	3,769,200	944,100	124,700	22,136	41	4,199,400	1,414,100	109,500	33,156	234,200	2,358,200	27,646	22	22	10	0	12	25	24	11	1	13
33	M	6/5/2006 0:00	NM	NA	480.354	156,307,192	518,688	NA	45	3,989,300	1,164,200	220,100	27,297	40	4,393,400	1,608,100	194,000	37,705	414,100	2,772,300	32,501	24	22	10	2	12	26	22	10	4	12
	T	6/6/2006 0:00	NM	NA	480.448	156,337,779	30,588	NA	43	4,056,200	1,231,100	66,900	28,865	38	4,452,700	1,667,400	59,300	39,095	126,200	2,898,500	33,980	24	22	10	2	12	26	22	10	4	12
34	T	6/13/2006 7:52	NM	NA	481.842	156,791,387	453,608	NA	30	4,274,800	1,449,700	218,600	33,991	40	4,680,100	1,894,800	227,400	44,427	446,000	3,344,500	39,209	46	19	12	27	7	44	26	12	18	14
35	M	6/19/2006 10:00	NM	NA	481.883	156,804,728	13,341	NA	56	4,280,600	1,455,500	5,800	34,127	50	4,687,400	1,902,100	7,300	44,598	13,100	3,357,600	39,362	26	28	10	2	18	29	20	12	9	8
	T	6/20/2006 7:26	NM	NA	482.262	156,928,055	123,327	NA	49	4,346,100	1,521,000	65,500	35,662	41	4,743,500	1,958,200	56,100	45,913	121,600	3,479,200	40,788	26	26	11	0	15	31	20	11	11	9
	W	6/21/2006 8:20	NM	NA	482.674	157,062,120	134,065	NA	45	4,417,200	1592100	71,100	37,329	39	4,803,700	2,018,400	60,200	47,325	131,300	3,610,500	42,327	26	25	8	1	17	40	15	9	25	6
36	M	6/26/2006 11:35	NM	NA	483.867	157,450,322	388,202	NA	53	4,621,700	1,796,600	204,500	42,124	47	4,980,600	2,195,300	176,900	51,472	381,400	3,991,900	46,798	32	23	8	9	15	36	27	10	9	17
	T	6/27/2006 8:00	NM	NA	484.175	157,550,545	100,223	NA	40	4,672,800	1,847,700	51,100	43,322	37	5,028,400	2,243,100	47,800	52,593	98,900	4,090,800	47,958	40	21	11	19	10	40	25	12	15	13
37	M	7/3/2006 9:25	NM	NA	485.406	157,951,112	400,567	NA	48	4,866,400	2,041,300	193,600	47,862	39	5,230,400	2,445,100	202,000	57,329	395,600	4,486,400	52,596	24	24	12	0	12	26	24	12	2	12
	W	7/5/2006 8:35	NM	NA	486.127	158,185,726	234,613	NA	43	4,995,000	2,169,900	128,600	50,877	35	5,353,400	2,568,100	123,000	60,213	251,600	4,738,000	55,545	24	24	12	0	12	26	26	12	0	14
	R	7/6/2006 8:35	NM	NA	486.474	158,298,640	112,914	NA	41	5,057,600	2,232,500	62,600	52,345	33	5,382,400	2,597,100	29,000	60,893	91,600	4,829,600	56,619	20	22	10	2	12	22	22	10	0	12
	F	7/7/2006 9:10	NM	NA	486.826	158,413,180	114,541	NA	40	5,115,400	2290300	57,800	53,700	32	5,428,600	2,643,300	46,200	61,977	104,000	4,933,600	57,838	22	21	11	1	10	24	21	11	3	10
	Sa	7/8/2006 15:00	NM	NA	487.107	158,504,618	91,437	NA	39	5,173,200	2348100	57,800	55,055	30	5,470,200	2,684,900	41,600	62,952	99,400	5,033,000	59,004	23	22	11	1	11	26	24	12	2	12
	Su	7/9/2006 7:55	NM	NA	487.414	158,604,516	99,898	NA	39	5,227,000	2401900	53,800	56,317	29	5,514,200	2,728,900	44,000	63,984	97,800	5,130,800	60,150	22	20	10	2	10	25	12	10	13	2
38	M	7/10/2006 9:05	NM	NA	487.734	158,708,644	104,128	NA	36	5,284,200	2,459,100	57,200	57,658	30	5,559,800	2,774,500	45,600	65,053	102,800	5,233,600	61,355	24	21	10	3	11	27	23	12	4	11
	T	7/11/2006 8:45	NM	NA	488.023	158,802,684	94,041	NA	34	5,334,600	2,509,500	50,400	58,839	29	5,601,400	2,816,100	41,600	66,028	92,000	5,325,600	62,434	26	20	10	6	10	28	22	12	6	10
	W	7/12/2006 14:45	NM	NA	488.365	158,913,971	111,287	NA	33	5,392,900	2,567,800	58,300	60,206	31	5,653,000	2,867,700	51,600	67,238	109,900	5,435,500	63,722	31	20	10	11	10	32	24	12	8	12
	R	7/13/2006 12:30	NM	NA	488.622	158,997,599	83,628	NA	29	5,433,400	2,608,300	40,500	61,156	30	5,691,900	2,906,600	38,900	68,150	79,400	5,514,900	64,653	35	16	10	19	6	36	24	12	12	12
	F	7/14/2006 12:30	NM	NA	488.632	159,000,853	3,254	NA	50	5,437,600	2,612,500	4,200	61,254	40	5,696,200	2,910,900	4,300	68,251	8,500	5,523,400	64,753	22	22	8	0	14	28	20	12	8	8
39	M	7/17/2006 6:10	NM	NA	489.578	159,308,681	307,828	NA	40	5,607,300	2,782,200	169,700	65,233	32	5,825,800	3,040,500	129,600	71,290	299,300	5,822,700	68,261	22	22	12	0	10	26	22	12	4	10
	T	7/18/2006 8:00	NM	NA	489.710	159,351,634	42,953	NA	40	5,669,200	2,844,100	61,900	66,685	30	5,872,300	3,087,000	46,500	72,380	108,400	5,931,100	69,532	22	23	12	1	11	25	24	12	1	12
	W	7/19/2006 12:00	NM	NA	490.271	159,534,183	182,549	NA	39	5,734,700	2,909,600	65,500	68,220	29	5,922,100	3,136,800	49,800	73,547	115,300	6,046,400	70,884	22	22	10	0	12	25	24	11	1	13
	R	7/20/2006 8:54	NM	NA	490.626	159,649,700	115,517	NA	43	5,799,000	2,973,900	64,300	69,728	34	5,971,200	3,185,900	49,100	74,699	113,400	6,159,800	72,213	26	26	13	0	13	30	28	14	2	14
	F	7/21/2006 9:10	NM	NA	490.878	159,731,701	82,001	NA	42	5,843,600	3,018,500	44,600	70,774	34	6,007,800	3,222,500	36,600	75,557	81,200	6,241,000	73,165	28	24	13	4	11	30	28	12	2	16
	Sa	7/22/2006 10:45	NM	NA	490.975	159,763,265	31,564	NA	49	5,860,800	3,035,700	17,200	71,177	43	6,022,000	3,236,700	14,200	75,890	31,400	6,272,400	73,533	30	25	10	5	15	34	29	11	5	18
	Su	7/23/2006 8:49	NM	NA	491.303	159,869,996	106,731	NA	38	5,914,900	3,089,800	54,100	72,445	37	6,072,800	3,287,500	50,800	77,081	104,900	6,377,300	74,763	37	22	11	15	11	38	29	12	9	17
40	M	7/24/2006 8:40	NM	NA	491.638	159,979,005	109,009	NA	32	5,966,100	3,141,000	51,200	73,646	39	6,128,900	3,343,600	56,100	78,396	107,300	6,484,600	76,021	44	20	11	24	9	44	29	11	15	18
	T	7/25/2006 8:05	NM	NA	491.945	160,078,903	99,898	NA	27	6,008,300	3,183,200	42,200	74,635	39	6,184,500	3,399,200	55,600	79,700	97,800	6,582,400	77,168	55	20	12	35	8	54	29	13	25	16
	W	7/26/2006 6:45	NM	NA	492.160	160,148,864	69,961	NA	23	6,042,700	3,217,600	34,400	75,442	38	6,237,700	3,452,400	53,200	80,947	87,600	6,670,000	78,195	69	16	10	53	6	64	28	10	36	18
	R	7/27/2006 10:23	NM	NA	492.210	160,165,134	16,270	NA	51	6,043,400	3,218,300	700	75,458	42	6,238,300	3,453,000	600	80,961	1,300	6,671,300	78,210	26	26	12	0	14	30	30	12	0	18
	F	7/28/2006 8:53	NM	NA	492.570	160,282,278	117,144	NA	45	6,105,900	3,280,800	62,500	76,924	35	6,287,500	3,502,200	49,200	82,115	111,700	6,783,000	79,519	24	24	12	0	12	27	27	12	0	15
	Sa	7/29/2006 9:28	NM	NA	492.936	160,401,374	119,096	NA	43	6,171,800	3,346,700	65,900	78,469	35	6,339,300	3,554,000	51,800	83,329	117,700	6,900,700	80,899	22	13	10	9	3	26	27	11	1	16
	Su	7/30/2006 8:11	NM	NA	493.268	160,509,407	108,033	NA	42	6,321,200	3,496,100	149,400	81,972	34	6,385,900	3,600,600	46,600	84,422	196,000	7,096,700	83,197	24	14	12	10	2	27	27	12	0	15
41	M	7/31/2006 6:30	NM	NA	493.586	160,612,884	103,477	NA	41	NA	NA	NA	NA	34	6,433,600	3,648,300	47,700	85,540	NA	NA	NA	24	22	12	2	10	28	24	12	4	12
	T	8/1/2006 8:40	NM	NA	493.948	160,730,679	117,795	NA	41	6,353,300	3,528,200	32,100	82,725	32	6,481,100	3,695,800	47,500	86,654	79,600	7,176,300	84,130	24	24	12	0	12	27	26	12	1	14
	R	8/3/2006 8:45	NM	NA	494.599	160,942,515	211,835	NA	39	6,470,200	3,645,100	116,900	85,465	33	6,593,100	3,807,800	112,000	89,280	228,900	7,405,200	86,814	26	22	10	4	12	28	24	11	4	13
	F	8/4/2006 8:30	NM	NA	494.743	160,989,372	46,858	NA	38	6,520,200	3,695,100	50,000	86,638	31	6,615,500	3,830,200	22,400	89,805	72,400	7,477,600	87,662	28	22	12	6	10	30	23	11	7	12
	Sa	8/5/2006 8:55	NM	NA	495.226	161,146,540	157,168	NA	36	6,580,500	3,755,400	60,300	88,052	30	6,663,500	3,878,200	48,000	90,931	108,300	7,585,900	88,932	30	22	11	8	11	32	24	12	8	12
	Su	8/6/2006 8:18	NM	NA	495.514	161,240,256	93,715	NA	39	6,630,500	3,805,400	50,000	89,224	35	6,705,900	3,920,600	42,400	91,925	92,400	7,678,300	90,015	36	22	11	14	11	37	27	12	10	15
42	M	8/7/2006 9:30	NM	NA	495.834	161,344,384	104,128	NA	34	6,684,000	3,858,900	53,500	90,478	31	6,754,900	3,969,600	49,000	93,074	102,500	7,780,800	91,217	42	20	10	22	10	43	23	11	20	12
	T	8/8/2006 8:15	NM	NA	496.107	161,433,218	88,834	NA	31	6,728,500	3,903,400	44,500	91,522	32	6,797,700	4,012,400	42,800	94,077	87,300	7,915,800	92,800	50	20	10	30	10	50	24	12	26	12
	W	8/9/2006 6:30	NM	NA	496.348	161,511,639	78,421	NA	27	6,766,300	3,941,200	37,800	92,408	27	6,838,000	4,052,700	40,300	95,022	78,100	7,993,900	93,715	62	20	17	42	3	62	22	12	40	10
	F	8/11/2006 9:03	NM	NA	496.350	161,512,290	651	NA	52	6,766,800	3,941,700	500	92,420	40	6,838,500	4,053,200	500	95,034	1,000	7,994,900	93,727	25	26	10	1	16	30	30	11	0	19
	Sa	8/12/2006 9:15	NM	NA	496.719	161,632,363	120,073	NA	45	6,832,900	4,007,800	66,100	93,970	36	6,890,300	4,105,000	51,800	96,249	117,900	8,112,800	95,109	22	23	10	1	13	26	26	10	0	16
	Su	8/13/2006 8:05	NM	NA	497.055	161,741,697	109,334	NA	43	6,893,100	4,068,000	60,200	95,381	33	6,937,500	4,152,200	47,200	97,355	107,400	8,220,200	96,368	21	24	11	3	13	27	27	12	0	15

Table A-1. U.S. EPA Arsenic Demonstration Project at Tehachapi, CA – Daily System Operation Log Sheet (Continued)

			Well C						Treatment System																						
					Totalizer to Treatment	Totalizer to Treatment	Volume In	Average Flowrate	Module A Flow Totalizer		Module A Cum Flow Totalizer	Module A Volume In	Module A Bed Volumes	Module B Flow Totalizer		Module B Cum Flow Totalizer	Module B Volume In	Module B Bed Volumes	Total Water Treated	Cum Water Treated	Cum Bed Volumes	Module A Pressure (psig)					Module B Pressure (psig)				
Week	Day of Week	Date and Time	Meter Hours	Op Hours	acre-ft	gal	gal	gpm	gpm	gal	gal	gal	BV	gpm	gal	gal	gal	BV	gal			Before Bag-Filter	After Bag-Filter	Outlet	ΔP Across Bag-Filter	ΔP Across Module	Before Bag-Filter	After Bag-Filter	Outlet	ΔP Across Bag-Filter	ΔP Across Module
43	M	8/14/2006 11:49	NM	NA	497.450	161,870,230	128,533	NA	41	6,964,300	4,139,200	71,200	97,050	30	6,992,900	4,207,600	55,400	98,654	126,600	8,346,800	97,852	24	24	11	0	13	28	28	12	0	16
	T	8/15/2006 8:34	NM	NA	497.744	161,965,898	95,668	NA	41	7,016,800	4,191,700	52,500	98,281	33	7,033,900	4,248,600	41,000	99,615	93,500	8,440,300	98,948	25	24	12	1	12	28	27	12	1	15
44	M	8/21/2006 11:58	NM	NA	498.683	162,271,448	305,551	NA	30	7,169,100	152,300	152,300	3,571	34	7,185,400	151,500	151,500	3,560	303,800	303,800	3,562	30	27	10	3	17	31	20	12	11	8
	T	8/22/2006 9:50	NM	NA	498.915	162,346,941	75,493	NA	26	7,202,200	185,400	33,100	4,347	33	7,226,600	192,700	41,200	4,526	74,300	378,100	4,433	34	14	8	20	6	32	20	12	12	8
	W	8/23/2006 5:55	NM	NA	499.136	162,418,854	71,913	NA	24	7,232,000	215,200	29,800	5,046	35	7,268,300	234,400	41,700	5,503	71,500	449,600	5,271	38	14	10	24	4	36	18	10	18	8
	R	8/24/2006 8:20	NM	NA	499.404	162,506,062	159,121	NA	20	7,265,800	249,000	33,800	5,838	31	7,322,600	288,700	54,300	6,777	88,100	537,700	6,304	45	11	8	34	3	43	26	8	17	18
	F	8/25/2006 8:12	NM	NA	499.612	162,573,745	67,683	NA	49	7,291,500	274,700	25,700	6,441	41	7,368,400	334,500	45,800	7,850	71,500	609,200	7,142	22	21	14	1	7	25	24	14	1	10
	Sa	8/26/2006 10:50	NM	NA	499.976	162,692,190	118,446	NA	40	7,355,600	338,800	64,100	7,944	30	7,421,300	387,400	52,900	9,091	117,000	726,200	8,513	16	17	10	1	7	19	19	11	0	8
	Su	8/27/2006 8:29	NM	NA	500.263	162,785,580	93,390	NA	39	7,406,400	389,600	50,800	9,135	30	7,462,900	429,000	41,600	10,066	92,400	818,600	9,597	15	16	11	1	5	18	18	10	0	8
45	M	8/28/2006 11:12	NM	NA	500.611	162,898,819	113,239	NA	38	7,467,700	450,900	61,300	10,572	30	7,513,200	479,300	50,300	11,245	111,600	930,200	10,905	17	18	11	1	7	20	20	12	0	8
	T	8/29/2006 8:25	NM	NA	500.883	162,987,328	88,509	NA	38	7,515,500	498,700	47,800	11,693	30	7,552,300	518,400	39,100	12,162	86,900	1,017,100	11,924	16	16	9	0	7	17	17	10	0	7
	W	8/30/2006 12:30	NM	NA	501.235	163,101,869	114,541	NA	36	7,578,000	561,200	62,500	13,158	29	7,603,200	569,300	50,900	13,356	113,400	1,130,500	13,253	18	18	11	0	7	20	20	12	0	8
	R	8/31/2006 9:17	NM	NA	501.492	163,185,497	198,169	NA	36	7,623,700	606,900	45,700	14,230	29	7,639,900	606,000	36,700	14,216	82,400	1,212,900	14,219	16	16	10	0	6	18	16	10	2	6
	F	9/1/2006 5:30	NM	NA	501.739	163,265,871	80,374	NA	35	7,667,700	650,900	44,000	15,261	29	7,675,500	641,600	35,600	15,051	79,600	1,292,500	15,152	16	16	10	0	6	18	18	10	0	8
	Sa	9/2/2006 9:48	NM	NA	502.077	163,375,856	109,985	NA	36	7,727,600	710,800	59,900	16,666	27	7,724,200	690,300	48,700	16,193	108,600	1,401,100	16,426	14	14	8	0	6	17	17	9	0	8
	Su	9/3/2006 9:06	NM	NA	502.349	163,464,365	88,509	NA	33	7,776,100	759,300	48,500	17,803	26	7,763,500	729,600	39,300	17,114	87,800	1,488,900	17,455	17	17	11	0	6	20	19	11	1	8
46	M	9/4/2006 6:40	NM	NA	502.596	163,544,738	80,374	NA	33	7,819,500	802,700	43,400	18,821	27	7,799,200	765,300	35,700	17,951	79,100	1,568,000	18,382	20	18	12	2	6	20	18	11	2	7
	T	9/5/2006 9:32	NM	NA	502.893	163,641,382	96,644	NA	31	7,871,400	854,600	51,900	20,038	27	7,843,200	809,300	44,000	18,983	95,900	1,663,900	19,506	18	16	10	2	6	23	18	12	5	6
	W	9/6/2006 8:27	NM	NA	503.139	163,721,431	80,048	NA	30	7,913,600	896,800	42,200	21,027	28	7,880,500	846,600	37,300	19,857	79,500	1,743,400	20,438	22	16	10	6	6	23	18	12	5	6
47	T	9/12/2006 8:15	NM	NA	503.365	163,794,971	73,540	NA	30	7,947,900	931,100	34,300	21,831	35	7,918,400	884,500	37,900	20,746	72,200	1,815,600	21,285	38	16	11	22	5	37	20	12	17	8
	R	9/14/2006 11:45	NM	NA	503.948	163,984,679	189,708	NA	38	8,027,400	1,010,600	79,500	23,695	30	8,027,800	993,900	109,400	23,311	188,900	2,004,500	23,499	17	18	12	1	6	20	20	12	0	8
	F	9/15/2006 16:25	NM	NA	504.167	164,055,942	71,263	NA	38	8,066,000	1,049,200	38,600	24,600	30	8,058,900	1,025,000	31,100	24,040	69,700	2,074,200	24,317	18	18	12	0	6	20	20	12	0	8
48	M	9/18/2006 15:48	NM	NA	504.169	164,056,593	651	NA	51	8,066,300	1,049,500	300	24,607	43	8,059,200	1,025,300	300	24,047	600	2,074,800	24,324	20	20	12	0	8	24	22	12	2	10
	W	9/20/2006 0:00	NM	NA	504.814	164,266,476	209,883	NA	43	8,180,400	1,163,600	114,100	27,283	35	8,152,300	1,118,400	93,100	26,230	207,200	2,282,000	26,753	18	16	8	2	8	20	20	10	0	10
	R	9/21/2006 0:00	NM	NA	505.142	164,373,207	106,731	NA	40	8,238,800	1,222,000	58,400	28,652	31	8,199,300	1,165,400	47,000	27,332	105,400	2,387,400	27,988	16	17	9	1	8	18	18	9	0	9
49	M	9/25/2006 9:10	NM	NA	505.145	164,374,183	976	NA	50	8,239,400	1,222,600	600	28,666	42	8,199,800	1,165,900	500	27,344	1,100	2,388,500	28,001	22	20	11	2	9	24	22	11	2	11
	T	9/26/2006 8:36	NM	NA	505.493	164,487,422	113,239	NA	41	8,299,800	1,283,000	60,400	30,082	34	8,250,700	1,216,800	50,900	28,537	111,300	2,499,800	29,306	24	20	12	4	8	26	22	13	4	9
50	M	10/2/2006 14:50	NM	NA	505.580	164,515,732	28,310	NA	50	8,315,400	1,298,600	15,600	30,448	45	8,264,000	1,230,100	13,300	28,849	28,900	2,528,700	29,645	38	24	13	14	11	30	27	14	3	13
	T	10/3/2006 11:39	NM	NA	505.900	164,619,860	104,128	NA	41	8,369,200	1,352,400	53,800	31,709	38	8,312,400	1,278,500	48,400	29,984	102,200	2,630,900	30,843	29	19	10	10	9	32	22	11	10	11
	W	10/4/2006 6:54	NM	NA	506.174	164,709,020	89,160	NA	38	8,414,600	1,397,800	45,400	32,774	36	8,354,900	1,321,000	42,500	30,981	87,900	2,718,800	31,873	32	18	11	14	7	31	22	11	9	11
51	T	10/10/2006 8:23	NM	NA	506.567	164,836,902	127,882	NA	41	8,478,800	1,462,000	64,200	34,279	43	8,417,200	1,383,300	62,300	32,441	126,500	2,845,300	33,356	42	20	12	22	8	42	24	12	18	12
52	R	10/19/2006 8:23	NM	NA	506.870	164,935,498	98,596	NA	20	8,520,300	1,503,500	41,500	35,252	33	8,476,800	1,442,900	59,600	33,839	101,100	2,946,400	34,542	100	16	14	84	2	96	24	14	72	10
53	T	10/23/2006 10:50	NM	NA	506.884	164,940,054	4,556	NA	64	8,521,900	1,505,100	1,600	35,290	52	8,479,300	1,445,400	2,500	33,897	4,100	2,950,500	34,590	26	25	12	1	13	29	28	12	1	16
	R	10/25/2006 7:01	NM	NA	507.637	165,185,080	245,026	NA	49	8,657,900	1,641,100	136,000	38,478	39	8,586,300	1,552,400	107,000	36,406	243,000	3,193,500	37,438	25	24	14	1	10	28	27	14	1	13
54	M	10/30/2006 14:20	NM	NA	507.692	165,202,977	17,897	NA	64	8,667,500	1,650,700	9,600	38,703	54	8,594,100	1,560,200	7,800	36,589	17,400	3,210,900	37,642	28	26	12	2	14	32	30	12	2	18
	T	10/31/2006 6:35	NM	NA	507.986	165,298,644	95,668	NA	51	8,720,000	1,703,200	52,500	39,934	42	8,636,900	1,603,000	42,800	37,593	95,300	3,306,200	38,760	29	22	13	7	9	32	28	12	4	16
	W	11/1/2006 9:30	NM	NA	508.151	165,352,335	53,691	NA	61	8,749,000	1,732,200	29,000	40,614	53	8,660,900	1,627,000	24,000	38,155	53,000	3,359,200	39,381	32	26	14	6	12	36	31	14	5	17
	F	11/3/2006 8:12	NM	NA	508.924	165,603,870	251,534	NA	44	8,880,900	1,864,100	131,900	43,707	41	8,777,300	1,743,400	116,400	40,884	248,300	3,607,500	42,292	36	22	14	14	8	37	18	13	19	5
55	T	11/7/2006 8:08	NM	NA	508.928	165,605,171	1,302	NA	58	8,881,500	1,864,700	600	43,721	51	8,777,800	1,743,900	500	40,896	1,100	3,608,600	42,305	36	24	14	12	10	38	30	13	8	17
56	T	11/14/2006 16:05	NM	NA	508.980	165,622,092	16,921	NA	59	8,890,100	1,873,300	8,600	43,923	54	8,785,700	1,751,800	7,900	41,081	16,500	3,625,100	42,498	44	30	16	14	14	44	36	16	8	20
	W	11/15/2006 8:05	NM	NA	509.230	165,703,442	81,350	NA	32	8,925,600	1,908,800	35,500	44,755	47	8,831,000	1,797,100	45,300	42,144	80,800	3,705,900	43,445	68	20	14	48	6	64	34	14	30	20
58	W	11/29/2006 8:23	NM	NA	509.256	165,711,902	8,460	NA	48	8,929,300	1,912,500	3,700	44,842	50	8,835,800	1,801,900	4,800	42,256	8,500	3,714,400	43,545	55	25	16	30	9	34	15	13	19	2
59	T	12/5/2006 8:48	NM	NA	509.288	165,722,315	10,413	NA	64	8,934,800	1,918,000	5,500	44,971	51	8,840,800	1,806,900	5,000	42,373	10,500	3,724,900	43,668	31	30	16	1	14	35	35	16	0	19
60	M	12/12/2006 8:09	NM	NA	509.305	165,727,847	5,532	NA	67	8,938,400	1,921,600	3,600	45,055	56	8,843,100	1,809,200	2,300	42,427	5,900	3,730,800	43,737	33	31	16	2	15	36	36	15	0	21
61	T	12/26/2006 9:00	3,592	NA	509.344	165,740,538	12,691	NA	51	8,945,100	1,928,300	6,700	45,212	40	8,849,300	1,815,400	6,200	42,573	12,900	3,743,700	43,889	24	22	12	2	10	28	26	12	2	14
	W	12/27/2006 8:26	3,615	23.5	509.649	165,839,785	99,247	NA	36	9,001,100	1,984,300	56,000	46,525	29	8,892,500	1,858,600	43,200	43,585	99,200	3,842,900	45,052	22	18	12	4	6	22	20	11	2	9
	R	12/28/2006 8:51	3,639	24.4	509.938	165,933,825	94,041	NA	33	9,052,600	2,035,800	51,500	47,733	28	8,934,500	1,900,600	42,000	44,570	93,500	3,936,400	46,148	24	16	11	8	5	23	20	10	3	10
	F	12/29/2006 10:14	3,665	25.4	510.191	166,016,151	82,326	NA	26	9,095,300	2,078,500	42,700	48,734	26	8,975,400	1,941,500	40,900	45,529	83,600	4,020,000	47,128	26	14	10	12	4	25	19	10	6	9
62	T	1/2/2007 8:38	3,665	0.50	510.197	166,018,104	1,952	NA	43	9,096,500	2,079,700	1,200	48,762	42	8,976,500	1,942,600	1,100	45,555	2,300	4,022,300	47,155	37	18	11	19	7	36	26	11	10	15
	W	1/3/2007 8:39	3,689	23.9	510.499	166,116,375	98,271	NA	26	9,137,900	2,121,100	41,400	49,733	40	9,032,900	1,999,000	56,400	46,877	97,800	4,120,100	48,301	50	14	10	36	4	46	25	10	21	15
	R	1/4/2007 14:20	3,719	29.8	510.814	166,218,876	102,501	NA	17	9,173,200	2,156,400	35,300	50,560	35	9,100,300	2,066,400	67,400	48,458	102,700	4,222,800	49,505	70	12	10	58	2	46	25	10	21	15
63	M	1/8/2007 8:10	3,719	0.10	510.815	166,219,201	325	NA	55	9,174,000	2,157,200	800	50,579	40	9,101,000	2,067,100	700	48,474	1,500	4,224,300	49,523	26	25	14	1	11	30	29	14	1	15
	T	1/9/2007 14:04	3,747	27.6	511.188	166,340,575	121,374	73.3	52	9,245,200	2,228,400	71,200	52,249	38	9,149,200	2,115,300	48,200	49,604	119,400	4,343,700	50,923	24	24	12	0	12	28	28	12	0	16
	W	1/10/07 8:03	3,765	18.3	511.443	166,423,552	82,977	75.6	41	9,293,500	2,276,700	48,300	53,381	28	9,182,900	2,149,000	33,700	50,394	82,000	4,425,700	51,884	21	20	13	1	7	23	22	13	1	9
	R	1/11/2007 9:08	3,790	25.0	511.729	166,516,617	93,064	62.0	36	9,349,100	2,332,300	55,600	54,685	28	9,182,900	2,149,000	0	50,394	55,600	4,481,300	52,536	21	20	13	1	7	22	22	13	0	9
	F	1/12/2007 9:02	3,815	25.0	511.981	166,598,617	82,001	54.7	32	9,397,800	2,381,000	48,700	55,826	22	9,253,900	2,220,000	71,000	52,059	119,700	4,601,000	53,939	21	19	13	2	6	21	21	13	0	8
65	M	1/22/2007 10:01	3,819	3.80	512.026	166,613,260	14,643	64.2	65	9,406,500	2,389,700	8,700	56,030	53	9,260,000	2,226,100	6,100	52,202	14,800	4,615,800	54,113	36	29	14	7	15	42	35	14	7	21
	T	1/23/2007 8:00	3,841	21.9	512.445	166,749,603	136,343	103.8	49	9,478,000	2,461,200	71,500	57,707	47	9,323,600	2,289,700	63,600	53,693	135,100	4,750,900	55,696	44	25	14	19	11	46	34	14	12	20
66	M	1/29/2007 8:11	3,913	72.4	513.603	167,126,416	376,813	86.7	68	9,644,800	2,628,000	166,800	61,618	54	9,528,600	2,494,700	205,000	58,500	371,800	5,122,700	60,055	35	36	17	1	19	42	38	16	4	22
	T	1/30/2007 7:05	3,937	23.8	514.058	167,274,473	148,057	103.7	57	9,728,200	2,711,400	83,400	63,573	42	9,590,400	2,556,500	61,800	59,949	145,200	5,267,900	61,757	30	30	15	0	15	36	33	15	3	18
67	M	2/5/2007 15:15	3,942	5.20	514.079	167,281,307	6,833	NA	67	9,732,600	2,715,800	4,400	63,676	52	9,593,600	2,559,700	3,200	60,024	7,600	5,275,500	61,846	33	32	14	1	18	42	37	14	5	23
	T	2/6/2007 8:18	3,955	12.8	514.414	167,390,316	109,009	141.9	59	9,794,100	2,777,300	61,500	65,118	43	9,639,300	2,605,400	45,700	61,095	107,200	5,382,700	63,103	33	30	15	3	15	40	33	15	7	18
	W	2/7/2007 8:26	3,956	1.00	514.431	167,395,847	5,532	92.2	69	9,797,100	2,780,300	3,000	65,189	56	9,641,500	2,607,600	2,200	61,147	5,200	5,387,900	63,164	39	36	16	3	20	46	38	16	8	22
68	M	2/12/2007 9:13	3,961	4.90	514.530	167,428,062	32,215	109.6	70	9,815,000	2,798,200	17,900	65,608	55	9,655,400	2,621,500	13,900	61,473	31,800	5,419,700	63,537	38	34	14	4	20	46	38	14	8	24
	T	2/13/2007 9:25	3,985	24.2	515.001	167,581,325	153,263	105.6	58	9,902,800	2,886,000	87,800	67,667	41	9,719,100	2,685,200	63,700	62,966	151,500	5,571,200	65,313	38	28	13	10	15	45	30	13	15	17
	W	2/14/07 11:28	4,011	26.1	515.468	167,733,287	151,962	97.0	56	9,941,000	2,924,200	38,200	68,563	36	9,779,900	2,746,000	60,800	64,392	99,000	5,670,200	66,474	40	28	14	12	14	48	28	13	20	15
69	T	2/20/2007 0:00	4,014	53.1	515.520	167,750,208	322,146	101.1	62	10,001,300	2,984,500	60,300	69,977	41	9,780,700	2,746,800	800	64,411	61,100	5,731,300	67,190	45	28	12	17	16	54	29	12	25	17
70	M	2/26/2007 8:12	4,087	73.2	516.724	168,141,990	391,782	89.2	63	10,250,300	3,233,500	249,000	75,815	40	9,924,900	2,891,000	144,200	67,792	393,200	6,124,500	71,800	58	30	13	28	17	66	28	12	38	16
	T	2/27/2007 8:11	4,111	23.9	517.091	168,261,411	119,422	83.3	54	10,330,600	3,313,800	80,300	77,698	21	9,961,900	2,928,000	37,000	68,659	117,300	6,241,800	73,175	78	27	12	51	15	88	18	11	70	7
71	M	3/5/2007 9:13	4,113	1.90	517.115	168,269,221	7,810	68.5	71	10,336,400	3,319,600	5,800	77,834	55	9,964,300	2,930,400	2,400	68,716	8,200	6,250,000	73,271	36	36	16	0	20	44	40	16	4	24
	T	3/6/2007 9:20	4,137	24.1	517.592	168,424,437	155,216	107.3	59	10,424,900	3,408,100	88,500	79,909	42	10,028,800	2,994,900	64,500	70,228	153,000	6,403,000	75,064	30	30	14	0	16	38	34	14	4	20
	R	3/8/2007 9:10	4,184	47.0	518.450	168,703,630	279,193	99.0	55	10,584,900	3,568,100	160,000	83,660	42	10,144,500	3,110,600	115,700	72,941	275,700	6,678,700	78,297	30	28	14	2	14	26	32	12	6	20
	F	3/9/2007 14:04	4,214	29.8	518.975	168,874,465	170,835	95.5	52	10,681,300	3,664,500	96,400	85,920	40	10,216,400	3,182,500	71,900	74,627	168,300	6,847,000	80,270	30	26	11	4	15	38	30	12	8	18
72	M	3/12/2007 8:32	4,214	0.20	518.980	168,876,092	1,627	135.6	60	10,682,200	3,665,400	900	85,941	49	10,217,100	3,183,200	700	74,643	1,600	6,848,600	80,288	36	29	13	7	16	43	34	13	9	21
	T	3/13/2007 9:50	4,239	25.4	519.441	169,026,101	150,009	98.4	50	10,763,500	3,746,700	81,300	87,848	45	10,283,700	3,249,800	66,600	76,204	147,900	6,996,500	82,022	40	28	13	12	15	46	30	14	16	16
73	M	3/19/2007 8:30	4,264	24.4	519.854	169,160,492	134,390	91.8	54	10,834,500	3,817,700	71,000	89,512	45	10,345,900	3,312,000	62,200	77,663	133,200	7,129,700	83,584	46	29	14	17	15	51	36	15	15	21
	T	3/20/2007 8:12	4,282	17.9	520.252	169,290,001	129,509	120.6	44	10,900,300	3,883,500	65,800	91,055	45	10,407,200	3,373,300	61,300	79,100	127,100	7,256,800	85,074	55	26	15	29	11	58	35	15	23	20

1 BV = 5.7 ft3 = 42.65 gal for each module, 1 BV = 11.4 ft3 = 85.3 gal for two modules

APPENDIX B

ANALYTICAL DATA

Table B-1. Analytical Results from Long-Term Sampling At Tehachapi, CA

Sampling Date		10/26/05[c]			11/01/05				11/08/05				11/15/05			
Sampling Location Parameter	Unit	IN	AC	TM	IN	AC	MA	MB	IN	AC	MA	MB	IN	AC	MA	MB
Bed Volume	BV	-	-	1.8	-	-	10.0	9.1	-	-	18.9	17.7	-	-	26.1	24.5
Alkalinity	mg/L[a]	176	185	185	185	176	180	180	189	198	189	176	330	189	176	180
Fluoride	mg/L	0.2	0.2	0.2	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	46	46	46	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	0.47	0.48	0.47	-	-	-	-	-	-	-	-	-	-	-	-
Total P	µg/L[b]	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Silica (as SiO_2)	mg/L	27.8	28.0	21.0	27.7	27.8	27.3	27.6	26.7	27.2	26.3	26.7	27.1	26.9	26.7	26.9
Turbidity	NTU	<0.1	0.1	0.1	<0.1	0.2	0.2	0.1	0.4	<0.1	<0.1	<0.1	0.1	0.2	1.1	0.2
pH	S.U.	7.5	7.6	7.5	7.5	7.4	7.5	7.5	7.6	7.6	7.7	7.6	7.5	7.5	7.5	7.5
Temperature	°C	18.2	17.2	17.9	20.3	20.6	25.6	25.7	18.3	18.8	18.7	18.7	19.1	19.5	19.7	19.6
DO	mg/L	NA[d]	NA[d]	NA[d]	1.8	1.7	2.1	1.9	-	-	-	-	-	-	-	-
ORP	mV	444	616	589	449	470	649	653	468	642	647	659	359	593	623	625
Total Chlorine	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness	mg/L[a]	177	176	178	181	182	184	183	181	176	184	184	173	174	174	172
Ca Hardness	mg/L[a]	130	128	131	133	134	134	134	133	129	137	137	131	131	130	129
Mg Hardness	mg/L[a]	47.9	47.9	47.3	47.7	48.2	49.6	48.8	48.0	46.7	47.2	46.8	41.7	42.8	43.3	43.1
As (total)	µg/L	14.0 -	12.7 -	0.4 -	12.7 -	12.6 -	0.3 -	0.7 -	12.8 -	12.5 -	0.3 -	0.8 -	13.7 -	13.9 -	0.8 -	1.3 -
As (soluble)	µg/L	13.1	12.4	0.4	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	0.9	0.3	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	2.0	0.6	0.6	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	11.1	11.8	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Fe (soluble)	µg/L	<25	<25	<25	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	3.5	3.7	0.1	3.6	3.6	0.2	0.6	3.9	3.9	<0.1	<0.1	4.4	4.8	0.2	0.5
Mn (soluble)	µg/L	3.4	3.2	0.2	-	-	-	-	-	-	-	-	-	-	-	-
Zr (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
Zr (soluble)	µg/L	<0.1	<0.1	0.1	-	-	-	-	-	-	-	-	-	-	-	-

(a) As $CaCO_3$.
(b) As P.
(c) Water quality parameters measured on 10/25/05.
(d) Water quality parameter not measured.

IN – influent; MA = after module A; MB = after module B; TM = after combined module effluent.
NA = not available.

Table B-1. Analytical Results from Long-Term Sampling At Tehachapi, CA (Continued)

Sampling Date		11/29/05			12/06/05				12/13/05			01/04/06		
Sampling Location Parameter	Unit	IN	AC	TM	IN	AC	MA	MB	IN	AC	TM	IN	AC	TM
Bed Volume	BV	-	-	32.4	-	-	43.0	41.0	-	-	48.3	-	-	61.6
Alkalinity	mg/L[(a)]	176	189	189	185	189	189	185	185	180	185	189	194	189
Fluoride	mg/L	0.1	0.1	0.1	-	-	-	-	0.2	0.1	0.1	-	-	-
Sulfate	mg/L	39	41	44	-	-	-	-	40	40	40	-	-	-
Nitrate (as N)	mg/L	0.48	0.47	0.50	-	-	-	-	0.42	0.42	0.42	-	-	-
Total P	μg/L[(b)]	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Silica (as SiO_2)	mg/L	27.2	27.2	27.5	28.1	27.9	27.5	27.6	29.5	28.9	28.7	27.5	27.7	27.3
Turbidity	NTU	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.6	1.1	0.2	0.3	0.1	0.2
pH	S.U.	7.6	7.6	7.3	7.7	7.6	7.6	7.6	7.7	7.6	7.6	7.7	7.8	7.7
Temperature	°C	15.7	16.0	14.8	17.0	17.5	17.7	17.5	17.3	17.7	18.0	18.5	19.1	19.3
DO	mg/L	2.7	2.2	2.3	2.6	1.8	1.8	1.8	2.2	2.2	2.3	2.2	1.7	2.5
ORP	mV	472	578	534	388	647	667	672	398	618	651	409	494	644
Total Chlorine	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness	mg/L[(a)]	184	186	184	171	178	169	170	153	154	153	177	174	176
Ca Hardness	mg/L[(a)]	137	138	136	127	123	126	127	100	101	101	128	127	128
Mg Hardness	mg/L[(a)]	46.3	48.2	47.4	43.4	55.5	42.9	42.7	52.8	53.3	52.7	48.6	47.5	47.6
As (total)	μg/L	11.4 -	11.5 -	3.3 -	11.8 -	11.5 -	7.4 -	6.8 -	12.1 -	12.5 -	9.1 -	13.4 -	13.3 -	12.2 -
As (soluble)	μg/L	11.8	12.1	3.2	-	-	-	-	11.1	13.0	9.9	13.9	13.9	13.1
As (particulate)	μg/L	<0.1	<0.1	0.2	-	-	-	-	1.0	<0.1	<0.1	<0.1	<0.1	<0.1
As (III)	μg/L	2.4	0.7	1.0	-	-	-	-	2.8	1.2	0.9	2.8	0.5	0.4
As (V)	μg/L	9.4	11.4	2.2	-	-	-	-	8.3	11.8	9.0	11.1	13.4	12.7
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	<25	<25	<25	<25
Mn (total)	μg/L	3.6	3.6	0.2	2.9	2.8	<0.1	<0.1	3.8	3.7	0.2	5.3	4.7	0.3
Mn (soluble)	μg/L	3.5	3.5	0.0	-	-	-	-	3.7	3.3	0.3	5.3	4.8	0.6
Zr (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
Zr (soluble)	μg/L	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	-	-	-

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

IN – influent; MA = after module A; MB = after module B; TM = after combined module effluent.
NA = not available.

Table B-1. Analytical Results from Long-Term Sampling At Tehachapi, CA (Continued)

Sampling Date		01/10/06				05/02/06			05/10/06				05/16/06				05/24/06		
Sampling Location / Parameter	Unit	IN	AC	MA	MB	IN	AC	TM	IN	AC	MA	MB	IN	AC	MA	MB	IN	AC	TM
Bed Volume	BV	-	-	71.2	67.7	-	-	5.5	-	-	2.8	18.5	-	-	11.5	25.1	-	-	24.8
Alkalinity	mg/L(a)	194	194	194	189	192	196	192	192	188	184	188	200	184	184	192	191	191	191
Fluoride	mg/L	-	-	-	-	0.2	0.2	0.2	-	-	-	-	-	-		-	0.2	0.2	0.2
Sulfate	mg/L	-	-	-	-	48	48	46	-	-	-	-	-	-		-	47	46	46
Nitrate (as N)	mg/L	-	-	-	-	0.7	0.7	0.6	-	-	-	-	-	-		-	0.6	0.6	0.6
Total P	µg/L(b)	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Silica (as SiO_2)	mg/L	27.9	28.2	28.3	27.9	28.3	28.6	26.9	28.9	28.5	23.8	28.6	29	28.6	28.3	30	27.2	27.9	27.3
Turbidity	NTU	0.2	0.1	0.3	0.2	0.3	0.2	0.2	0.3	0.2	0.4	0.1	0.3	0.2	0.3	0.2	0.4	0.6	0.4
pH	S.U.	7.7	7.8	7.7	7.7	7.7	7.7	7.7	7.5	7.5	7.4	7.5	7.6	7.5	7.5	7.5	7.6	7.5	7.5
Temperature	°C	18.2	19.0	14.0	19.0	14.9	20.1	20.4	30.8	20.4	20.3	19.4	22.3	20.6	20.9	21.0	20.0	20.0	23.2
DO	mg/L	2.2	1.8	2.0	2.3	2.1	3.0	2.5	-	-	-	-	-	-	-	-	2.8	2.1	2.4
ORP	mV	413	609	675	676	450	686	66.4	337	571	629	634	388	392	541	563	353	652	644
Total Chlorine	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness	mg/L(a)	171	176	170	173	185	180	182	180	187	182	185	213	212	211	212	181	182	171
Ca Hardness	mg/L(a)	123	127	122	121	134	130	132	129	134	130	132	154	154	153	154	130	131	122
Mg Hardness	mg/L(a)	48.1	48.8	48.3	51.6	50.3	49.6	50.0	51.5	52.8	51.8	53.6	58.7	57.8	58.0	57.5	50.6	51.0	48.4
As (total)	µg/L	12.5 -	12.4 -	12.4 -	11.9 -	12.8 -	12.8 -	1.3 -	11.9 -	12.2 -	6.2 -	3.8 -	12.6 -	11.9 -	5.8 -	3.3 -	14.4 -	12.3 -	6.2 -
As (soluble)	µg/L	-	-	-	-	12.0	12.2	1.3	-	-	-	-	-	-	-	-	14.3	12.3	6.0
As (particulate)	µg/L	-	-	-	-	0.8	0.5	<0.1	-	-	-	-	-	-	-	-	<0.1	<0.1	0.2
As (III)	µg/L	-	-	-	-	0.6	0.2	0.2	-	-	-	-	-	-	-	-	0.5	0.1	0.2
As (V)	µg/L	-	-	-	-	11.4	12.0	1.1	-	-	-	-	-	-	-	-	13.8	12.1	5.8
Fe (total)	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Fe (soluble)	µg/L	-	-	-	-	<25	<25	<25	-	-	-	-	-	-		-	<25	<25	<25
Mn (total)	µg/L	3.4	3.3	<0.1	<0.1	4.3	4.1	0.4	4.0	4.1	1.6	0.9	3.7	3.7	1.5	0.8	4.0	4.0	1.7
Mn (soluble)	µg/L	-	-	-	-	4.1	4.0	0.5	-	-	-	-	-	-		-	4.4	3.9	1.7
Zr (total)	µg/L	<0.1	<0.1	<0.1	<0.1	0.3	<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
Zr (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-

(a) As $CaCO_3$.
(b) As P.
(c) Media replacement took place on February 20, 2006.

IN – influent; MA = after module A; MB = after module B; TM = after combined module effluent.
NA = not available.

Table B-1. Analytical Results from Long-Term Sampling At Tehachapi, CA (Continued)

Sampling Date		05/30/06				06/06/06				06/13/06				06/21/06			6/28/2006[c]			
Sampling Location / Parameter	Unit	IN	AC	MA	MB	IN	AC	MA	MB	IN	AC	MA	MB	IN	AC	TM	IN	AC	MA	MB
Bed Volume	BV	-	-	22.1	33.2	-	-	28.9	39.1	-	-	33.9	44.4	-	-	42.3	-	-	43.3	52.6
Alkalinity	mg/L[a]	192	192	200	188	190	194	198	194	200	200	200	204	190	186	190	192	200	196	192
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	0.2	0.2	0.2	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	47	56	57	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	0.7	0.7	0.7	-	-	-	-
Total P	μg/L[b]	10.2	<10	<10	<10	<10	<10	<10	<10	10.6	11.3	<10	<10	15.7	<10	<10	<10	<10	<10	<10
Silica (as SiO_2)	mg/L	27.2	26.9	25.8	27.1	29.0	29.0	28.5	28.9	29.8	30.1	29.9	30.1	27.2	27.7	27.7	30	29.5	29.3	29.3
Turbidity	NTU	0.5	0.2	0.4	0.4	0.3	0.5	0.7	0.5	0.4	0.6	0.5	0.4	0.3	0.4	0.5	0.3	0.3	0.3	2
pH	S.U.	7.5	7.5	7.5	7.5	7.6	7.6	7.5	7.5	7.6	7.6	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Temperature	°C	20.9	20.3	20.3	20.3	25.7	25.9	26.0	26.1	18.8	19.1	19.2	19.1	22.3	21.8	21.6	26.6	26.4	26.3	26.2
DO	mg/L	2.8	2.6	2.2	2.4	2.3	2.1	2.1	2.1	2.4	2.2	2.5	2.5	2.5	2.1	2.3	3.2	2.3	2.9	2.8
ORP	mV	257	280	285	293	273	454	647	668	332	371	390	409	388	667	676	376	638	659	665
Total Chlorine	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness	mg/L[a]	158	156	163	166	170	171	178	174	186	190	192	182	220	200	209	188	184	179	180
Ca Hardness	mg/L[a]	117	116	122	125	120	122	125	122	137	140	141	133	161	143	150	133	129	126	128
Mg Hardness	mg/L[a]	41.0	39.8	40.7	40.9	49.4	49.1	53.1	51.4	49.2	50.5	50.9	48.8	59.7	57.0	58.5	54.6	54.3	52.9	52.2
As (total)	μg/L	10.1 -	10.0 -	5.2 -	3.0 -	10.7 -	10.6 -	5.8 -	3.4 -	11.5 -	11.9 -	7.1 -	3.5 -	10.4 -	10.2 -	4.1 -	11.1 -	11.1 -	5.8 -	6.2 -
As (soluble)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	10.1	10.4	4.4	-	-	-	-
As (particulate)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	0.3	<0.1	<0.1	-	-	-	-
As (III)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	0.7	0.2	0.2	-	-	-	-
As (V)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	9.4	10.2	4.3	-	-	-	-
Fe (total)	μg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Fe (soluble)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	<25	<25	<25	-	-	-	-
Mn (total)	μg/L	2.9	2.9	1.1	0.3	3.2	3.3	0.8	0.4	3.6	3.8	2.1	1.0	4.3	3.6	0.5	4.3	4.5	1.0	0.9
Mn (soluble)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	4.1	3.6	0.5	-	-	-	-
Zr (total)	μg/L	<0.1	0.7	<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	<0.1
Zr (soluble)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(a) As $CaCO_3$.
(b) As P.
(c) Water quality parameters measured on 06/27/06.

IN – influent; MA = after module A; MB = after module B; TM = after combined module effluent.
NA = not available.

Table B-1. Analytical Results from Long-Term Sampling At Tehachapi, CA (Continued)

Sampling Date		07/05/06				07/11/06				07/18/06			07/26/06[c]				08/02/06[d]			
Sampling Location / Parameter	Unit	IN	AC	MA	MB	IN	AC	MA	MB	IN	AC	TM	IN	AC	MA	MB	IN	AC	MA	MB
Bed Volume	BV	-	-	50.9	60.2	-	-	58.8	66.0	-	-	69.5	-	-	75.4	80.9	-	-	82.7	86.7
Alkalinity	mg/L[a]	193	193	197	188	193	197	197	193	188	205	171	188	196	192	192	189	189	185	189
Fluoride	mg/L	-	-	-	-	-	-	-	-	10.2	12.3	8.4	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	48	46	49	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	0.7	0.7	0.7	-	-	-	-	-	-	-	-
Total P	μg/L[b]	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Silica (as SiO_2)	mg/L	27.3	27.6	28	28	27.8	26.9	27.2	27.6	27.3	27.3	30.5	27.8	28.2	28.5	28.5	31.7	32.3	32.8	32
Turbidity	NTU	0.2	0.6	0.4	0.3	4.6	2.6	0.5	1.8	0.5	0.6	0.4	0.1	0.7	0.4	0.2	0.1	0.2	0.1	0.2
pH	S.U.	7.4	7.5	7.5	7.5	7.6	7.5	7.5	7.5	7.6	7.6	7.5	7.6	7.6	7.6	7.6	7.8	7.8	7.8	7.8
Temperature	°C	21.7	20.8	20.5	20.4	22.9	21.4	21.4	21.3	21.2	21.0	21.7	22.1	21.6	21.6	21.6	20.3	20.2	20.2	20.2
DO	mg/L	2.8	2.0	2.2	4.3	3.1	2.3	2.3	2.2	2.0	2.0	1.7	2.2	2.0	2.0	1.7	2.5	1.9	2.3	2.1
ORP	mV	275	551	647	661	350	564	647	656	338	632	666	265	645	660	665	310	563	638	661
Total Chlorine	mg/L	-	-	-	1.27	-	-	-	1.3	-	-	1.6	-	-	-	1.3	-	-	-	1.4
Total Hardness	mg/L[a]	181	186	185	183	181	187	191	183	169	165	198	186	186	187	186	181	183	185	181
Ca Hardness	mg/L[a]	132	135	134	133	135	138	141	135	121	118	145	136	135	136	135	136	137	137	133
Mg Hardness	mg/L[a]	49.7	50.6	50.7	50.1	46.9	49.7	50.6	48.4	47.2	46.7	53.3	50.2	50.9	50.8	51.1	45.6	46.0	47.6	47.5
As (total)	μg/L	10.0 -	10.4 -	6.7 -	5.3 -	10.4 -	10.3 -	6.1 -	6.5 -	10.5 -	10.6 -	6.8 -	11.1 -	10.8 -	7.0 -	9.4 -	11.8 -	11.7 -	7.3 -	10.7 -
As (soluble)	μg/L	-	-	-	-	-	-	-	-	11.0	11.0	7.0	-	-	-	-	-	-	-	-
As (particulate)	μg/L	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-
As (III)	μg/L	-	-	-	-	-	-	-	-	0.9	0.3	0.3	-	-	-	-	-	-	-	-
As (V)	μg/L	-	-	-	-	-	-	-	-	10.0	10.6	6.7	-	-	-	-	-	-	-	-
Fe (total)	μg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Fe (soluble)	μg/L	-	-	-	-	-	-	-	-	<25	<25	<25	-	-	-	-	-	-	-	-
Mn (total)	μg/L	4.2	3.7	1.5	0.6	4.1	4.2	1.0	0.3	3.6	3.5	0.5	3.7	3.5	0.2	0.2	4.1	3.8	0.3	0.1
Mn (soluble)	μg/L	-	-	-	-	-	-	-	-	3.8	2.7	0.6	-	-	-	-	-	-	-	-
Zr (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	<0.1	<0.1	<0.1
Zr (soluble)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(a) As $CaCO_3$.
(b) As P.
(c) Water quality parameters measured on 07/25/06.
(d) Water quality parameters measured on 08/01/06.

IN – influent; MA = after module A; MB = after module B; TM = after combined module effluent.
NA = not available.

Table B-1. Analytical Results from Long-Term Sampling At Tehachapi, CA (Continued)

Sampling Date		08/08/06				08/15/06			08/22/06			08/29/06				09/05/06			
Sampling Location Parameter	Unit	IN	AC	MA	MB	IN	AC	TM	IN	AC	TM	IN	AC	MA	MB	IN	AC	MA	MB
Bed Volume	BV	-	-	91.5	94.1	-	-	98.4	-	-	4.4	-	-	11.7	12.2	-	-	20.0	19.0
Alkalinity	mg/L[(a)]	193	189	189	189	198	190	194	209	207	207	209	203	209	201	199	208	208	202
Fluoride	mg/L	-	-	-	-	0.7	2.6	0.6	0.9	0.6	0.6	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	49	51	49	46	46	46	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	0.6	0.8	0.6	0.7	0.7	0.7	-	-	-	-	-	-	-	-
Total P	µg/L[(b)]	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Silica (as SiO_2)	mg/L	27.9	27.7	28.1	28.3	28.7	28.6	27.8	27.1	27.3	24.4	26.7	26.8	25.8	25.6	26.4	26	26.3	26
Turbidity	NTU	0.2	0.6	1.1	0.3	0.1	0.1	0.2	0.3	0.3	0.3	<0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.1
pH	S.U.	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.6	7.6	7.5	7.6	7.5	7.5	7.5	7.5	7.6	7.6	7.5
Temperature	°C	20.5	20.5	20.1	20.5	20.9	21.0	21.5	21.7	21.8	21.2	20.8	20.9	20.9	20.7	22.6	22.2	22.0	21.9
DO	mg/L	2.1	1.8	2.0	1.9	2.0	2.2	2.5	1.9	2.1	2.2	2.8	2.0	2.0	2.0	2.1	2.1	2.1	2.1
ORP	mV	296	634	651	663	356	623	660	507	664	484	323	614	613	655	304	623	652	659
Total Chlorine	mg/L	-	-	-	1.5	-	-	1.5	-	-	1.3	-	-	-	1.5	-	-	-	1.4
Total Hardness	mg/L[(a)]	186	182	185	188	187	186	190	193	202	201	207	209	206	206	174	174	173	178
Ca Hardness	mg/L[(a)]	137	133	136	137	139	137	139	144	153	150	157	157	155	154	124	124	123	127
Mg Hardness	mg/L[(a)]	49.3	48.8	49.3	51.1	48.4	48.9	50.9	48.4	49.6	50.6	50.5	51.5	50.2	51.7	50.3	50.3	49.8	50.9
As (total)	µg/L	12.4 -	12.2 -	9.3 -	12.2 -	12.7 -	12.3 -	10.5 -	12.6 -	12.8 -	4.1 -	12.1 -	11.9 -	7.3 -	2.7 -	11.0 -	10.8 -	7.1 -	2.5 -
As (soluble)	µg/L	-	-	-	-	12.4	12.8	10.5	12.3	12.0	3.9	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	0.4	<0.1	<0.1	0.4	0.8	0.1	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	1.6	0.5	0.4	1.8	0.6	0.6	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	10.8	12.3	10.1	10.4	11.4	3.4	-	-	-	-	-	-	-	-
Fe (total)	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Fe (soluble)	µg/L	-	-	-	-	<25	<25	<25	<25	<25	<25	-	-	-	-	-	-	-	-
Mn (total)	µg/L	4.1	3.7	0.2	0.2	4.0	3.9	0.4	4.1	4.8	0.3	4.0	3.8	0.9	0.3	4.1	3.7	0.3	0.1
Mn (soluble)	µg/L	-	-	-	-	4.2	3.5	0.4	4.3	3.8	0.3	-	-	-	-	-	-	-	-
Zr (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	<0.1	<0.1
Zr (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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

IN – influent; MA = after module A; MB = after module B; TM = after combined module effluent.
NA = not available.

Table B-1. Analytical Results from Long-Term Sampling At Tehachapi, CA (Continued)

Sampling Date		09/12/06				09/20/06			09/26/06				10/04/06			
Sampling Location Parameter	Unit	IN	AC	MA	MB	IN	AC	TM	IN	AC	MA	MB	IN	AC	MA	MB
Bed Volume	BV	-	-	21.8	20.7	-	-	26.7	-	-	30.1	28.6	-	-	32.8	31
Alkalinity	mg/L[(a)]	190	192	190	190	195	202	202	198	198	205	203	208	203	205	203
Fluoride	mg/L	-	-	-	-	0.3	0.1	<0.1	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	52	52	51	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	0.7	0.7	<0.05	-	-	-	-	-	-	-	-
Total P	µg/L[(b)]	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	11.1	11.4	<10	<10
Silica (as SiO_2)	mg/L	27.1	27.1	26.1	26	28.6	29.2	28.3	27.6	27.6	26.9	27.5	27.6	27.6	26.7	27.8
Turbidity	NTU	0.3	0.1	0.2	0.1	6.2	0.3	0.5	0.1	0.1	0.2	0.1	0.2	0.2	0.2	0.1
pH	S.U.	7.5	7.5	7.5	7.5	7.5	7.6	7.5	7.5	7.6	7.5	7.6	7.7	7.8	7.8	7.8
Temperature	°C	20.5	20.4	20.4	20.3	20.0	20.0	20.3	21.0	20.7	20.5	20.6	16.5	17.1	17.4	17.4
DO	mg/L	2.1	1.5	2.0	1.8	1.5	1.8	1.5	2.5	2.1	2.2	2.0	3.7	2.6	2.6	2.7
ORP	mV	356	631	655	674	261	600.7	675	344	594	644	658	316	598	664	671
Total Chlorine	mg/L	-	-	-	1.3	-	-	1.3	-	-	-	1.4	-	-	-	1.3
Total Hardness	mg/L[(a)]	192	192	190	186	205	205	215	187	188	183	185	188	190	187	186
Ca Hardness	mg/L[(a)]	145	145	144	142	151	152	160	134	134	130	132	134	135	134	132
Mg Hardness	mg/L[(a)]	47.0	46.5	45.3	44.6	54.0	53.1	54.5	53.8	54.9	53.4	53.6	53.7	54.7	53.5	53.2
As (total)	µg/L	12.1 -	11.6 -	8.0 -	2.5 -	12.8 -	11.7 -	4.7 -	13.2 -	11.8 -	7.1 -	2.6 -	12.0 -	11.9 -	7.5 -	2.8 -
As (soluble)	µg/L	-	-	-	-	11.1	11.4	4.5	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	1.7	0.3	0.2	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	1.5	0.2	0.2	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	9.6	11.2	4.3	-	-	-	-	-	-	-	-
Fe (total)	µg/L	<25	<25	<25	<25	123	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Fe (soluble)	µg/L	-	-	-	-	<25	<25	<25	-	-	-	-	-	-	-	-
Mn (total)	µg/L	4.7	4.8	0.5	0.1	4.1	3.6	0.6	3.9	3.8	0.6	0.2	3.7	3.7	0.5	0.3
Mn (soluble)	µg/L	-	-	-	-	3.9	3.5	0.5	-	-	-	-	-	-	-	-
Zr (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
Zr (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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

IN – influent; MA = after module A; MB = after module B; TM = after combined module effluent.
NA = not available.

Table B-1. Analytical Results from Long-Term Sampling At Tehachapi, CA (Continued)

Sampling Date		10/10/06				10/19/06				10/25/06				10/31/06				11/07/06			
Sampling Location / Parameter	Unit	IN	AC	MA	MB	IN	AC	MA	MB	IN	AC	MA	MB	IN	AC	MA	MB	IN	AC	MA	MB
Bed Volume	BV	-	-	34.3	32.4	-	-	35.3	33.8	-	-	38.5	36.4	-	-	39.9	37.6	-	-	43.7	40.9
pH	S.U.	7.9	8.0	7.9	7.9	7.7	7.7	7.7	7.7	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.5	7.7	7.7	7.7	7.7
Temperature	°C	18.0	18.3	18.7	18.6	18.5	18.9	19.0	19.0	16.5	17.1	17.3	17.5	15.5	16.0	16.4	16.9	19.9	20.1	20.2	20.2
DO	mg/L	2.2	1.8	2.1	1.8	2.3	2.4	2.5	2.5	3.4	2.9	2.9	3.0	2.9	3.0	3.2	2.8	1.4	1.4	1.5	1.7
ORP	mV	350	654	671	679	327	622	656	664	280	666	677	680	322	654	676	681	249	631	651	659
Total Chlorine	mg/L	-	-	-	1.4	-	-	-	1.3	-	-	-	1.5	-	-	-	1.4	-	-	-	1.5
As (total)	µg/L	12.3	12.0	7.7	2.7	12.9	13.3	9.7	3.4	12.7	12.0	6.7	3.1	11.8	11.0	6.8	2.7	12.6	13.0	7.3	3.0
		12.0	12.2	7.4	2.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Sampling Date		11/15/06				11/29/06				12/05/06				12/12/06				12/27/06			
Sampling Location / Parameter	Unit	IN	AC	MA	MB	IN	AC	MA	MB	IN	AC	MA	MB	IN	AC	MA	MB	IN	AC	MA	MB
Bed Volume	BV	-	-	44.8	42.1	-	-	44.8	42.3	-	-	45.0	42.4	-	-	45.1	42.4	-	-	46.5	43.6
pH	S.U.	7.7	7.7	7.7	7.6	7.7	7.7	7.7	7.7	7.6	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.6	7.6
Temperature	°C	17.8	18.0	18.3	18.4	14.5	15.2	15.8	16.3	17.5	17.8	18.1	18.2	16.0	16.5	16.9	16.9	14.5	15.4	15.8	15.8
DO	mg/L	3.1	2.7	2.8	2.5	2.4	2.1	2.3	2.4	3.2	2.9	2.9	3.0	4.5	2.8	3.1	3.1	4.3	4.2	3.6	3.5
ORP	mV	373	664	674	680	343	666	679	681	402	641	676	682	373	615	679	682	388	600	620	627
Total Chlorine	mg/L	-	-	-	1.35	-	-	-	1.5	-	-	-	1.4	-	-	-	1.3	-	-	-	1.2
As (total)	µg/L	10.3	10.4	6.7	2.7	10.6	10.7	5.0	2.1	10.7	10.4	5.7	2.3	12.8	12.6	6.5	2.9	16.9	16.1	11.1	4.4
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Sampling Date		01/03/07				01/10/07				01/23/07				01/30/07				02/06/07			
Sampling Location / Parameter	Unit	IN	AC	MA	MB	IN	AC	MA	MB	IN	AC	MA	MB	IN	AC	MA	MB	IN	AC	MA	MB
Bed Volume	BV	-	-	49.7	46.9	-	-	53.4	50.4	-	-	57.7	53.7	-	-	63.6	59.9	-	-	65.1	61.1
pH	S.U.	7.7	7.7	7.7	7.7	7.6	7.6	7.6	7.6	7.7	7.7	7.7	7.7	7.4	7.5	7.5	7.5	7.6	7.6	7.7	7.7
Temperature	°C	17.1	17.7	17.9	18.0	16.3	16.9	17.2	17.3	15.8	16.6	17.0	17.3	16.5	16.7	17.2	17.4	18.2	18.6	18.8	18.8
DO	mg/L	3.6	3.2	3.2	3.3	3.1	2.9	3.1	2.9	3.5	3.0	3.1	3.1	2.7	2.3	2.5	2.5	3.2	2.8	2.7	2.5
ORP	mV	313	505	536	551	320	638	654	657	301	490	536	553	290	629	647	654	310	516	540	551
Total Chlorine	mg/L	-	-	-	1.4	-	-	-	1.3	-	-	-	1.4	-	-	-	1.3	-	-	-	1.5
As (total)	µg/L	14.2	13.9	10.1	3.8	13.3	13.0	8.7	5.1	13.2	12.7	7.5	4.9	13.7	12.7	6.8	7.1	11.3	11.3	7.0	6.8
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

IN – influent; MA = after module A; MB = after module B; TM = after combined module effluent.
NA = not available.

Table B-1. Analytical Results from Long-Term Sampling At Tehachapi, CA (Continued)

Sampling Date		02/13/07				02/20/07				02/27/07				03/06/07				03/13/07			
Sampling Location Parameter	Unit	IN	AC	MA	MB	IN	AC	MA	MB	IN	AC	MA	MB	IN	AC	MA	MB	IN	AC	MA	MB
Bed Volume	BV	-	-	67.7	63.0	-	-	70.0	64.4	-	-	77.7	68.7	-	-	79.9	70.2	-	-	87.8	76.2
pH	S.U.	7.5	7.6	7.6	7.6	7.8	7.8	7.7	7.7	7.8	7.8	7.8	7.8	7.7	7.6	7.7	7.7	7.8	7.7	7.8	7.7
Temperature	°C	15.1	16.0	16.4	16.9	17.9	18.2	18.4	18.4	15.0	16.0	16.1	16.5	19.9	19.9	19.8	19.8	19.8	19.8	19.9	19.8
DO	mg/L	3.9	2.8	2.9	2.8	2.7	2.2	2.5	2.4	2.8	2.8	3.0	3.1	2.4	2.4	2.5	2.7	2.6	2.5	2.7	2.6
ORP	mV	263	288	295	308	285	337	366	371	285	330	347	354	235	325	338	340	284	294	313	318
Total Chlorine	mg/L	-	-	-	1.4	-	-	-	1.6	-	-	-	1.6	-	-	-	1.3	-	-	-	1.5
As (total)	µg/L	10.5 -	10.7 -	6.8 -	6.8 -	13.3 -	13.6 -	8.5 -	8.6 -	11.9 -	11.5 -	7.1 -	8.9 -	9.8 -	10.4 -	6.2 -	8.1 -	11.6 -	11.5 -	7.4 -	10.2 -

Sampling Date		03/20/07			
Sampling Location Parameter	Unit	IN	AC	MA	MB
Bed Volume	BV	-	-	91.1	79.1
pH	S.U.	7.5	7.5	7.5	7.5
Temperature	°C	17.5	17.9	18.4	18.4
DO	mg/L	3.4	2.7	3.1	3.2
ORP	mV	219	332	335	331
Total Chlorine	mg/L	-	-	-	1.5
As (total)	µg/L	12.8 -	12.8 -	9.1 -	11.3 -

IN – influent; MA = after module A; MB = after module B; TM = after combined module effluent.
NA = not available.