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Arsenic Removal from Drinking Water by Adsorptive Media
U.S. EPA Demonstration Project at Rimrock, AZ
Final Performance Evaluation Report

by

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Sally Gutierrez, Director
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ABSTRACT

This report documents the activities performed during and the results obtained from the arsenic removal treatment technology demonstration project at the Arizona Water Company (AWC) facility in Rimrock, AZ. The objectives of the project were to evaluate: (1) the effectiveness of AdEdge's Arsenic Package Unit-100 (APU-100) AD-33™ adsorptive media system in removing arsenic to meet the new arsenic maximum contaminant level (MCL) of 10 μg/L, (2) the reliability of the treatment system for use at small water facilities, (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 produced by the treatment process. The types of data collected included system operation, water quality, process residuals, and capital and O&M cost.

The APU-100 treatment system consisted of a 25-μm bag filter assembly, two 3-ft × 6-ft composite fiberglass pressure tanks, a backwash wastewater recycling system, associated piping and Fleck controller valves, and an instrument/control panel. Each tank contained 22 ft^3 of Bayoxide E33 iron-based adsorptive media, which was developed by Bayer AG and branded under the name of AD-33™ by AdEdge. Due to the loss of one of AWC's production wells, the system flowrate was reduced from 90 to 30 gal/min (gpm), which prompted a change in system configuration from parallel to series (lead/lag). The reconfigured APU-100 system had a design capacity of 45 gpm and began operation on June 24, 2004. The actual flowrates through the system averaged 30 gpm, corresponding to an empty bed contact time (EBCT) of 5.4 min/tank and a hydraulic loading rate of 4.2 gpm/ft^2.

Source water contained 43.8 to 81.4 μg/L of total arsenic with As(V) as the predominant species. Prechlorination, although not required for oxidation, was performed to provide disinfection throughout the treatment train and residuals within the distribution system at AWC's discretion. Concentrations of iron, manganese, silica, orthophosphate, and other ions in source water did not appear to impact arsenic removal by the AD-33™ media. The system operated for 12 or 24 hr/day on a timer with 1 to 2% downtime for repairs and media replacement. After treating 52,150 bed volumes (BV) or 17,164,000 gal of water during Media Run 1A based on 44 ft^3 of media in the lead and lag tanks, the system effluent reached the 10-μg/L arsenic MCL on August 9, 2006. Because the media in the lag tank still had about 50% of adsorptive capacity remaining, only the lead tank was rebedded. After rebedding, the tank positions were switched with Tank B containing partially exhausted media in the lead position and Tank A with virgin media in the lag position. Media Run 1B commenced as such on November 27, 2006. To ensure that normal operations continued following the media changeout, the system was monitored until March 28, 2007.

Backwashing of the media was initially conducted automatically, but due to initiation of several unscheduled backwash events and the need to take operational data and backwash wastewater samples, the programming was changed to manual initiation once every 30 days. The backwash frequency was eventually decreased to quarterly due to minimal differential pressure (Δp) increase across the tanks between backwash events. Backwash was performed using source water for 15 min/tank at approximately 47 gpm, or 6.6 gpm/ft^2. Backwash wastewater from the lead tank generally contained higher concentrations of all analytes than that from the lag tank, most likely because the lead tank removed the majority of the particulates from source water. A piping loop, a recycle tank, and a metering pump enabled the system to reclaim nearly 100% of the wastewater produced by blending it with intake after prechlorination but prior to the adsorption tanks at a rate of 0.5 gpm.

Comparison of the distribution system sampling results from three residences before and after startup of the APU-100 system showed a decrease in the average arsenic concentration from 48.8 to 19.3 μg/L. However, samples of the distribution system water exhibited higher arsenic concentrations than those of

the treatment system effluent due to blending of the treated water with untreated water from other source wells. pH, alkalinity, iron, manganese, lead, and copper concentrations did not appear to be affected by the system operation.

Treatment system residuals included spent media and backwash wastewater. Spent media including 620 lb of AD-33™ passed the Toxicity Characteristic Leaching Procedure (TCLP) test and could be disposed of as non-hazardous waste at a sanitary landfill. The arsenic loading on the spent media based on inductively coupled plasma-mass spectrometry (ICP-MS) results was 8.3 mg/g, which was about 80% of the arsenic mass loaded on the media based on the arsenic breakthrough curves.

The capital investment cost of the system was $88,307, consisting of $63,785 for equipment, $11,372 for site engineering, and $13,150 for installation. Using the system's rated capacity of 45 gpm (or 64,800 gal/day [gpd]), the capital cost was $1,962/gpm (or $1.36/gpd). The capital cost also was converted to an annualized cost of $8,335/yr based on a 7% interest rate and a 20-yr return period. During the first year, the system produced approximately 8,505,000 gal of water, so the unit capital cost increased to $0.98/1,000 gal. These costs do not include the cost of the system enclosure and backwash recycling system, which were funded separately by AWC.

The O&M cost for the treatment system included cost for media replacement and disposal, electricity consumption, and labor. Representing the majority of the O&M cost, the media replacement and disposal cost depended on the media run length, the number of tanks rebedded, and labor and material cost. With the long, 2.1-year duration of the media run and the remaining capacity of the lag tank when the system effluent reached 10 μg/L of arsenic, the media of only the lead tank was replaced at a cost of $10,908, or $0.64/1,000 gal. The combined electricity and labor cost was an additional $0.22/1,000 gal for a total O&M cost of $0.86/1,000 gal.

CONTENTS

DISCLAIMER ii
FOREWORD iii
ABSTRACT iv
APPENDICES vii
FIGURES vii
TABLES vii
ABBREVIATIONS AND ACRONYMS ix
ACKNOWLEDGMENTS xi

1.0 INTRODUCTION 1
1.1 Background 1
1.2 Treatment Technologies for Arsenic Removal 1
1.3 Project Objectives 2

2.0 SUMMARY AND CONCLUSIONS 3

3.0 MATERIALS AND METHODS 4
3.1 General Project Approach 4
3.2 System O&M and Cost Data Collection 5
3.3 Sample Collection Procedures and Schedules 6
3.3.1 Source Water 6
3.3.2 Treatment Plant Water 6
3.3.3 Backwash Water 6
3.3.4 Distribution System Water 7
3.3.5 Residual Solids 9
3.4 Sampling Logistics 9
3.4.1 Preparation of Arsenic Speciation Kits 9
3.4.2 Preparation of Sampling Coolers 9
3.4.3 Sample Shipping and Handling 9
3.5 Analytical Procedures 10

4.0 DEMONSTRATION SITE AND TECHNOLOGY EVALUATED 11
4.1 Site Description 11
4.1.1 Existing Facility 11
4.1.2 Distribution System 11
4.1.3 Source Water Quality 12
4.2 Treatment Process Description 13
4.3 Treatment System Installation 18
4.3.1 System Engineering and Permitting 18
4.3.2 System Installation, Startup, and Shakedown 18
4.3.3 System Enclosure 19

5.0 RESULTS AND DISCUSSION 20
5.1 System Operation 20
5.1.1 Service Operation 20
5.1.2 Backwash Operation 21
5.1.3 Media Changeout 22
5.1.4 Residual Management 22
5.1.5 System/Operation Reliability and Simplicity 23

5.1.5.1 Pre- and Post-Treatment Requirements 23
5.1.5.2 System Automation 23
5.1.5.3 Operator Skill Requirements 23
5.1.5.4 Preventative Maintenance Activities 23
5.1.5.5 Chemical/Media Handling and Inventory Requirements 24
5.2 System Performance 24
5.2.1 Treatment Plant Sampling 24
5.2.1.1 Arsenic 25
5.2.1.2 Iron and Manganese 27
5.2.1.3 Onsite Measurements 29
5.2.1.4 Other Water Quality Parameters 30
5.2.2 Backwash Water Sampling 30
5.2.3 Distribution System Water Sampling 30
5.2.4 Spent Media Sampling 33
5.3 Cost Information 34
5.3.1 Facility Cost 34
5.3.2 System Cost 34
5.3.3 O&M Cost 35

6.0 REFERENCES 37

APPENDICES

APPENDIX A: OPERATIONAL DATA A-1
APPENDIX B: ANALYTICAL DATA TABLES B-1

FIGURES

Figure 3-1. Process Flow Diagram and Sampling Locations 8
Figure 4-1. Predemonstration Site Photographs 11
Figure 4-2. Schematic of AdEdge's APU-100 Treatment System 15
Figure 4-3. Treatment System Components 17
Figure 4-4. Backwash Recycling System Components 17
Figure 4-5. Gravel Underbedding (Left) and AD-33™ Media (Right) Loading 18
Figure 4-6. System Enclosure 19
Figure 5-1. Flowrate Readings and Δp across Tanks 21
Figure 5-2. Arsenic Species during Media Run 1A at Wellhead, after Tank A, and after Tank B 28
Figure 5-3. Total Arsenic Breakthrough Curves for Media Runs 1A and 1B 29
Figure 5-4. Media Replacement (Lead Tank) and Total O&M Cost (Run 1A) 36

TABLES

Table 1-1. Summary of the Round 1 Arsenic Removal Demonstration Sites 2
Table 3-1. Predemonstration Study Activities and Completion Dates 4
Table 3-2. Evaluation Objectives and Supporting Data Collection Activities 5
Table 3-3. Sample Collection Schedule and Analyses 7
Table 4-1. Distribution System Water Quality Data Collected by AWC 12
Table 4-2. Source Water Quality Data 13

Table 4-3. Physical and Chemical Properties of AD-33™ Media 14
Table 4-4. Design Features for AdEdge's APU-100 Treatment System 16
Table 5-1. Summary of APU-100 System Operations 20
Table 5-2. Recommended Routine Maintenance Activities 24
Table 5-3. Summary of Arsenic, Iron, and Manganese Results 25
Table 5-4. Summary of Other Water Quality Parameter Results 26
Table 5-5. Backwash Water Sampling Results 31
Table 5-6. Distribution System Sampling Results 32
Table 5-7. TCLP Results of a Composite Spent Media Sample 33
Table 5-8. Metals' Analysis of Spent Media 33
Table 5-9. Capital Investment for AdEdge's APU-100 System 34
Table 5-10. O&M Cost for AdEdge's APU-100 System (Run 1A) 36

ABBREVIATIONS AND ACRONYMS

Δp	differential pressure
AAL	American Analytical Laboratories
ADEQ	Arizona Department of Environmental Quality
Al	aluminum
AM	adsorptive media
APU	arsenic package unit
As	arsenic
AWC	Arizona Water Company
Ba	barium
BET	Brunauer, Emmett, and Teller
bgs	below ground surface
BL	baseline
BV	bed volume(s)
Ca	calcium
CCR	Consumer Confidence Report
Cd	cadmium
Cl	chloride
C/F	coagulation/filtration
CRF	capital recovery factor
DO	dissolved oxygen
EBCT	empty bed contact time
EPA	U.S. Environmental Protection Agency
F	fluoride
Fe	iron
FedEx	Federal Express
GFO	granular ferric oxide
gpd	gallons per day
gph	gallons per hour
gpm	gallons per minute
HDPE	high-density polyethylene
ICP-MS	inductively coupled plasma-mass spectrometry
ID	identification
IX	ion exchange
LCR	(EPA) Lead and Copper Rule
MCL	maximum contaminant level
MDL	method detection limit
MDWCA	Mutual Domestic Water Consumers Association
Mg	magnesium

Mn	manganese
mV	millivolts
Na	sodium
NaOCl	sodium hypochlorite
ND	not detected
NS	not sampled
NSF	NSF International
NTU	nephlemetric turbidity units
O&M	operation and maintenance
ORD	Office of Research and Development
ORP	oxidation-reduction potential
P&ID	piping and instrumentation diagram
Pb	lead
PLC	programmable logic controller
PO_4	orthophosphate
psi	pounds per square inch
PVC	polyvinyl chloride
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RPD	relative percent difference
RCRA	Resource Conservation and Recovery Act
SDWA	Safe Drinking Water Act
SM	system modification
SiO_2	silica
SO_4	sulfate
STMGID	South Truckee Meadows General Improvement District
STS	Severn Trent Services
TCLP	Toxicity Characteristic Leaching Procedure
TDS	total dissolved solids
TO	Task Order
TOC	total organic carbon
TSS	total suspended solids
WRWC	White Rock Water Company

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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 that are known or anticipated to occur in public water supply systems. In 1975 under the SDWA, EPA established a maximum contaminant level (MCL) for arsenic at 0.05 mg/L. Amended in 1996, the SDWA required that EPA develop an arsenic research strategy and publish a proposal to revise the arsenic MCL by January 2000. On January 18, 2001, EPA finalized the arsenic MCL at 0.01 mg/L (EPA, 2001). In order to clarify the implementation of the original rule, EPA revised the rule text on March 25, 2003, to express the MCL as 0.010 mg/L (10 µg/L) (EPA, 2003). The final rule 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 costs. As part of this Arsenic Rule Implementation Research Program, EPA's Office of Research and Development (ORD) proposed a project to conduct a series of full-scale, onsite demonstrations of arsenic removal technologies, process modifications, and engineering approaches applicable to small systems. Shortly thereafter, an announcement was published in the *Federal Register* requesting water utilities interested in participating in 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. The Arizona Water Company (AWC) water system in Rimrock, AZ, was selected as one of the 17 Round 1 host sites for the demonstration program.

In September 2002, EPA solicited proposals from engineering firms and vendors for cost-effective arsenic removal treatment technologies for the 17 host sites. EPA received 70 technical proposals for the 17 host sites, with each site receiving from one to six proposals. In April 2003, an independent technical panel reviewed the proposals and provided its recommendations to EPA on the technologies that it determined were acceptable for 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. AdEdge's adsorptive media process was selected for the Rimrock facility. Designated as AD-33™ by AdEdge, the process uses the Bayoxide E33-S media developed by Bayer AG.

1.2 Treatment Technologies for Arsenic Removal

The technologies selected for the 12 Round 1 EPA arsenic removal demonstration host sites included nine adsorptive media (AM) systems, one anion exchange system, one coagulation/filtration (C/F) system, and one process modification with iron addition. Table 1-1 summarizes the locations, technologies, vendors, and key source water quality parameters of the 12 demonstration sites. An overview of the technology selection and system design (Wang et al., 2004) and the associated capital costs for each site (Chen et al., 2004) are provided on the EPA website (http://www.epa.gov/ORD/NRMRL/wswrd/dw/arsenic/index.html). As of January 2008, all of the systems were operational, and 10 performance evaluations were completed.

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

Demonstration Site	Technology (Media)	Vendor	Design Flowrate (gpm)	Source Water Quality		
				As (µg/L)	Fe (µg/L)	pH
WRWC, NH	AM (G2)	ADI	70[a]	39	<25	7.7
Rollinsford, NH	AM (E33-S)	AdEdge	100	36[b]	46	8.2
Queen Anne's County, MD	AM (E33-S)	STS	300	19[b]	270[c]	7.3
Brown City, MI	AM (E33-S)	STS	640	14[b]	127[c]	7.3
Climax, MN	C/F (Macrolite)	Kinetico	140	39[b]	546[c]	7.4
Lidgerwood, ND	SM	Kinetico	250	146[b]	1,325[c]	7.2
Desert Sands MDWCA, NM	AM (E33-S,E33-P)	STS	320	23[b]	39	7.7
Nambe Pueblo, NM	AM (E33-S)	AdEdge	145	33	<25	8.5
Rimrock, AZ	AM (E33-S)	AdEdge	90[a]	50	170	7.2
Valley Vista, AZ	AM (AAFS50/ARM 200)	Kinetico	37	41	<25	7.8
Fruitland, ID	IX (A300E)	Kinetico	250	44	<25	7.4
STMGID, NV	AM (GFH/Kemiron)	Siemens	350	39	<25	7.4

AM = adsorptive media; C/F = coagulation/filtration; E33-P = E33 pelletized; E33-S = E33 granular media; IX = ion exchange; SM = system modification; MDWCA = Mutual Domestic Water Consumer's Association; STMGID = South Truckee Meadows General Improvement District; WRWC = White Rock Water Company STS = Severn Trent Services

(a) Reduced by 50% due to system reconfiguration from parallel to series operation.
(b) Arsenic exists mostly as As(III).
(c) Iron exists mostly as soluble Fe(II).

1.3 Project Objectives

The objective of the Round 1 arsenic demonstration program is to conduct 12 full-scale arsenic treatment technology demonstration studies on the removal of arsenic from drinking water supplies. The 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 AdEdge system operated at Rimrock, AZ, from June 24, 2004, through March 28, 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.

2.0 SUMMARY AND CONCLUSIONS

The performance evaluation study of the AdEdge arsenic package unit (APU)-100 was conducted from June 24, 2004, through March 28, 2007. Based on the information collected during the 33-months of system operation, the following was summarized and concluded relating to the overall project objectives.

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

- AD-33™ media was effective at removing arsenic (existing mostly as As[V]) in source water, reducing its concentrations from 48.3 to 81.4 μg/L to <10 μg/L. Breakthrough at 10 μg/L from the lead tank occurred at 39,180 bed volumes (BV) (1 BV = 22 ft^3, the amount in one tank), which represented only 60% of the vendor-projected media run length. Breakthrough at 10 μg/L from the lag tank occurred much later at 52,150 BV (1BV = 44 ft^3, the amount in both the lead and lag tanks), twice as long empty bed contact time (EBCT) was believed to have contributed to the longer run length observed.
- Monthly backwash as recommended by the vendor did not appear to benefit the adsorption runs. The frequency was later reduced to quarterly.
- The APU-100 system was capable of reducing arsenic concentrations in the distribution system, although its levels were higher than those in the treated water. This was most likely due to the contribution of untreated water from other wells, which also contained arsenic.

Required system O&M and operator skill levels:

- The system was easy to operate, requiring minimum operator's attention. Daily demand on the operator was typically 20 min.
- The O&M issues encountered during the performance period were minor, consisting of only a malfunctioning chlorine injector and a few broken pressure gauges and flow meters/ totalizers. Unscheduled downtime was <2%.

Characteristics of residuals produced by the technology:

- Each backwash event produced 1,460 gal, on average, of wastewater; nearly 100% of the wastewater was reclaimed via a backwash recycle system.
- Backwash wastewater contained less arsenic than raw water, indicating removal of arsenic by the media during backwashing.
- Approximately 10.4 mg of arsenic was loaded on per gram of dry media, equivalent to about 1.04% arsenic loading. The spent media was non-hazardous and could be disposed of at a sanitary landfill.

Capital and O&M cost of the technology:

- The capital investment for the APU-100 system was $88,307, including $63,785 for equipment, $11,372 for site engineering, and $13,150 for installation.
- Based on a design capacity of 45 gal/min (gpm), the capital cost was $1,962/gpm, or $1.36/gpd.
- Media replacement cost represented the majority of the O&M cost. The media in the lead tank was replaced once at a cost of $10,908 or $0.64/1,000 gal, which accounted for 74% of the O&M cost. The rest of the O&M cost was incurred by electricity and labor.

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 AdEdge treatment system began on June 24, 2004. Table 3-2 summarizes the types of data collected and/or considered as part of the technology evaluation process. The overall system performance was based on its ability to consistently remove arsenic to below the target MCL of 10 μg/L through the collection of water samples across the treatment train. The reliability of the system was evaluated by tracking the unscheduled system downtime and frequency and extent of repair and replacement. The unscheduled downtime and repair information were recorded by the plant operator on a Repair and Maintenance Log Sheet.

The 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 quantity of aqueous and solid residuals generated was estimated by tracking the volume of backwash water produced during each backwash cycle and the need to replace the media upon arsenic breakthrough. Backwash water and spent media were sampled and analyzed for chemical characteristics.

Table 3-1. Predemonstration Study Activities and Completion Dates

Activity	Date
Introductory Meeting Held	July 31, 2003
Request for Quotation Issued to Vendor	August 4, 2003
Draft Letter of Understanding Issued	August 13, 2003
Final Letter of Understanding Issued	September 9, 2003
Vendor Quotation Received	September 9, 2003
Purchase Order Established	October 6, 2003
Letter Report Issued	October 17, 2003
Draft Study Plan Issued	November 26, 2003
Engineering Package Submitted to ADEQ	December 11, 2003
Final Study Plan Issued	December 19, 2003
Approval to Construct Granted by ADEQ	February 18, 2004
Construction Permit Issued by County	March 15, 2004
APU-100 Unit Shipped	March 30, 2004
Initial System Installation and Shakedown Completed	April 22, 2004
Initial Approval of Construction Granted by ADEQ	April 29, 2004
Shed Construction Completed	May 21, 2004
System Re-Configuration Completed	May 27, 2004
Revised Engineering Package Submitted to ADEQ	June 1, 2004
Final Approval of Construction Granted by ADEQ	June 15, 2004
Performance Evaluation Began	June 24, 2004

ADEQ = Arizona Department of Environmental Quality

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 system automation for system operation and data collection -Staffing requirements including number of operators and laborers -Task analysis of preventative maintenance including number, frequency, and complexity of tasks -Chemical handling and inventory requirements -General knowledge needed for relevant chemical processes and health and safety practices
Residual Management	-Quantity and characteristics of aqueous and solid residuals generated by system operation
System Cost	-Capital cost for equipment, site engineering, and installation -O&M cost for media, chemical consumption, electricity usage, and labor

The cost of the system was evaluated based on the capital cost per 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 AdEdge and Battelle. The plant operator recorded system operational data, such as pressure, flowrate, totalizer, and hour meter readings on a Daily System Operation Log Sheet; checked the sodium hypochlorite (NaOCl) drum level; and conducted visual inspections to ensure normal system operation on a regular basis. If any problems occurred, the plant operator contacted the Battelle Study Lead, who determined if the vendor should be contacted for troubleshooting. The plant operator recorded all relevant information on the Repair and Maintenance Log Sheet. Water quality parameters, including temperature, pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), and residual chlorine were measured and recorded on a Weekly Onsite Water Quality Parameters Log Sheet. Backwash data also were recorded on a Backwash Log Sheet when appropriate.

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

3.3 Sample Collection Procedures and Schedules

To evaluate the system performance, samples were collected from the wellhead, treatment plant, and distribution system. The sampling schedules and analytes for each sampling event are listed in Table 3-3. In addition, Figure 3-1 presents a flow diagram of the treatment system along with the analytes and schedules at each sampling location. Specific sampling requirements for analytical methods, sample volumes, containers, preservation, and holding times are presented in Table 4-1 of the EPA-endorsed Quality Assurance Project Plan (QAPP) (Battelle, 2003). The procedure for arsenic speciation is described in Appendix A of the QAPP.

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

3.3.2 Treatment Plant Water. Water samples were collected weekly across the treatment train at the wellhead (IN), after Tank A (TA), and after Tank B (TB) for on- and off-site analyses shown in Figure 3-1 and Table 3-3. Onsite measurements also were made on samples collected from after prechlorination (AC) location. Over the course of the demonstration study, several changes were made to the sampling schedules as listed below and in Table 3-3.

- Beginning on November 3, 2004, regular weekly sampling was reduced from three times per four week cycle to three times per eight week cycle.
- Speciation sampling was reduced from monthly to bimonthly beginning on October 20, 2004, and then discontinued after July 12, 2006.
- Since October 12, 2005, orthophosphate analysis was replaced with total phosphorous analysis due to lack of orthophosphate in raw water and issues related to the short hold time for orthophosphate.
- Onsite measurements were reduced to monthly beginning April 5, 2006, and to pH, temperature, and chlorine only beginning June 14, 2006.
- All analyses except for arsenic discontinued on November 28, 2006.

3.3.3 Backwash Water. Grab backwash wastewater samples were initially collected directly from the sample tap on the backwash wastewater discharge line during the backwash of each tank and filtered with 0.45-µm disc filters. Grab samples were analyzed for pH and total dissolved solids (TDS), and filtered samples were analyzed for soluble As, Fe, and Mn. Beginning on November 14, 2005, composite samples were collected following a modified procedure to allow for more representative characterization of the wastewater. Connected to the tap on the discharge line, tubing directed a portion of backwash water from the sample tap at approximately 1 gpm into a clean plastic container of adequate volume over the duration of the backwash for each tank. After the content in the container was thoroughly mixed, composite samples were collected and/or filtered onsite with 0.45-µm disc filters. Under this revised procedure, total As, Fe, and Mn and total suspended solids (TSS) also were measured. Backwash water sampling was conducted approximately monthly beginning in October 2004, quarterly beginning in August 2005, and then discontinued after May 2006. Table 3-3 lists the schedule and analytes for the backwash water samples.

Table 3-3. Sample Collection Schedule and Analyses

Sample Type	Sample Location(s)[a]	No. of Samples	Frequency	Analytes	Collection Date(s)
Source Water	IN	1	Once	Off-site: As (III), As(V), total and soluble Al, As, Fe, and Mn, Na, Ca, Mg, Cl, F, SO_4, SiO_2, PO_4, TOC, turbidity, pH, and alkalinity	10/22/03
Treatment Plant Water	IN, TA, and TB	3	Weekly [b]	Onsite[c]: pH, temperature, DO, ORP, and Cl_2 (free and total) Off-site: total As, Fe, and Mn, SiO_2, PO_4[d], turbidity, and alkalinity	See Appendix B
			Monthly[e]	Same as above plus the following off-site: As(III), As(V), soluble As, Fe, and Mn, Ca, Mg, F, NO_3, and SO_4	See Appendix B
Backwash Water	BW	2	Monthly[f]	Off-site: total[g] and soluble As, Fe, and Mn, pH, TDS, TSS[g], and turbidity[g]	See Table 5-5
Distribution Water	DS (three non-LCR homes)	3	Monthly[h]	Off-site: total As, Fe, Mn, Cu, and Pb, pH, alkalinity	See Table 5-6
Residual Solids	Top, middle, and bottom of Tank A	3	Once	Off-site: TCLP metals and total Al, As, Ca, Cd, Cu, Fe, Mg, Mn, Ni, P, Pb, Si, and Zn	11/08/06

(a) Corresponding to sample locations in Figure 3-1, i.e., IN = at wellhead, TA = after Tank A; TB = after Tank B; BW = at backwash water discharge line from Tanks A and B
(b) Three sets per four-week cycle from 07/07/04 to 10/27/04; three sets per eight-week cycle from 11/03/04 to 09/28/05 and 04/05/06 to 05/17/06; one set per four-week cycle from 11/09/05 to 01/04/06 and 06/14/06 to 08/09/06; and one set per four-week cycle from 11/28/06 to 02/02/07 for total As only.
(c) Performed for samples taken after prechlorination (AC), TA, and TB. Monthly from 04/05/06 to 08/09/06 and DO and ORP discontinued after 06/14/06.
(d) PO_4 analysis replaced with total phosphorus analysis since 10/12/05.
(e) One set per eight-week cycle from 10/20/04 to 02/01/06 and 03/08/06 to 07/12/06, and then discontinued.
(f) Quarterly from 08/17/05 to 05/17/06 and then discontinued.
(g) Total As, Fe, and Mn, and TSS analyses performed and turbidity discontinued since 11/14/05.
(h) Four baseline events before system startup from 12/17/03 through 02/05/04. Discontinued after 10/12/05.

3.3.4 Distribution System Water. Samples were collected from the distribution system to determine the impact of the arsenic treatment system on the water chemistry in the distribution system, specifically, the arsenic, lead, and copper levels. From December 2003 to February 2004, four sets of baseline distribution water samples were collected from three locations within the distribution system. Following system startup, distribution system sampling continued on a monthly basis at the same locations. Ideally, the sampling locations selected would have been the historical Lead and Copper Rule (LCR) locations served primarily by the source water well, Well No. 2. However, because the distribution system was supplied by Well No. 2 and five other wells, such LCR locations did not exist (Section 4.1.2). Thus, three non-LCR residences supplied in part by Well No. 2 were monitored by the distribution system sampling.

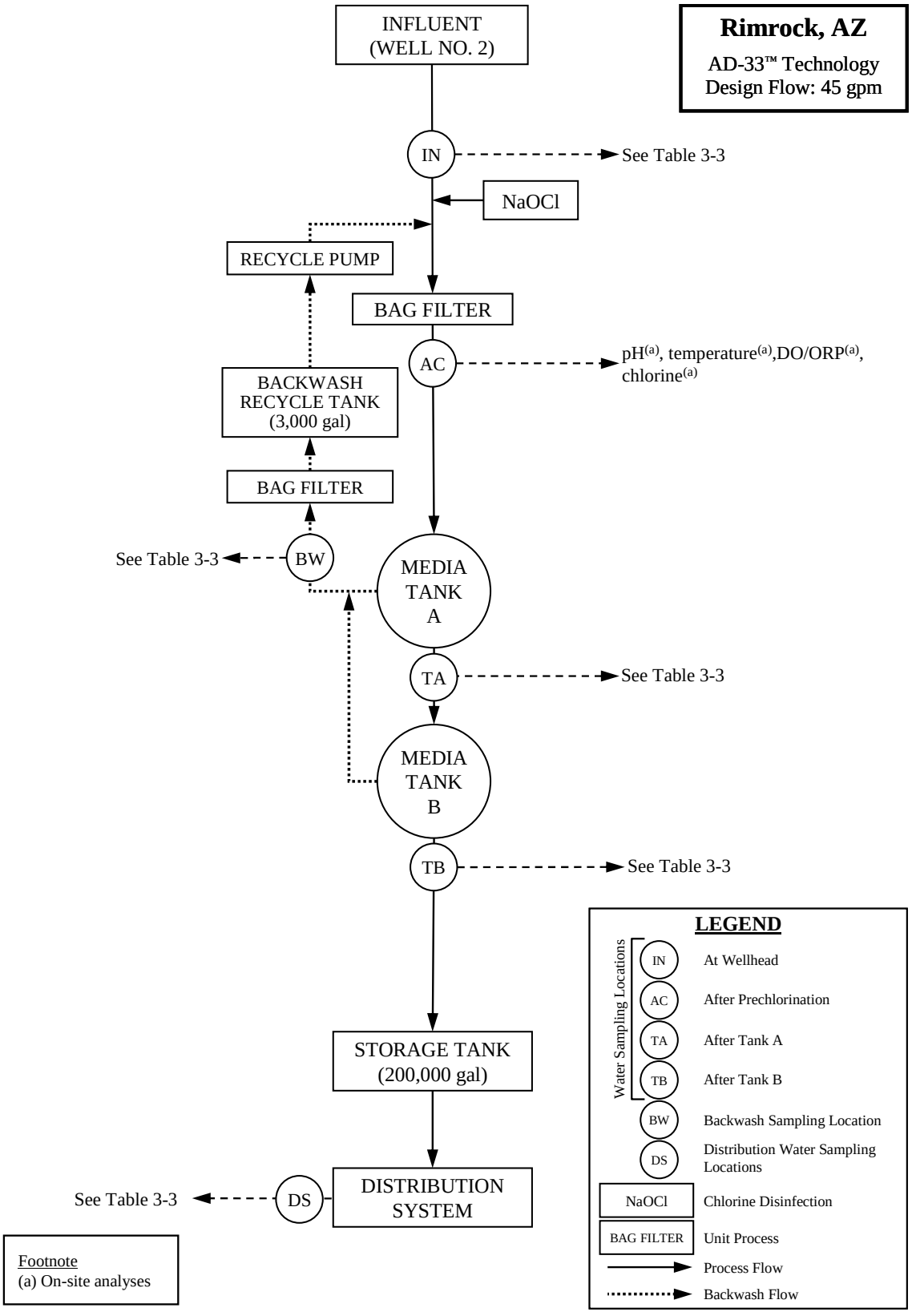


Figure 3-1. Process Flow Diagram and Sampling Locations

The samples were taken following an instruction sheet developed according to the *Lead and Copper Monitoring and Reporting Guidance for Public Water Systems* (EPA, 2002). The homeowners recorded the dates and times of last water usage before sampling and of sample collection for calculation 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.

3.3.5 Residual Solids. Because of the very small quantity of solids in backwash wastewater, only spent media was collected for residual solids analyses. A total of three spent media samples were collected from top, middle, and bottom layers of the lead tank (i.e., Tank A) on November 8, 2006. Spent media were sampled using a 5-gal wet/dry shop vacuum that had been thoroughly cleaned and disinfected before sampling. The media collected from each target layer were transferred from the shop vacuum, after mixing with a small garden spade, to a clean 5-gal bucket. A composite sample from each layer was collected into a wide-mouth, 2-gal plastic container for total metal analyses and a Toxicity Characteristic Leaching Procedure (TCLP) test. Metal analyses were conducted on air dried and acid digested samples (see analytes in Table 3-3), and the TCLP test was conducted on an unprocessed sample following the protocol described in the QAPP (Battelle, 2003).

3.4 Sampling Logistics

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 QAPP (Battelle, 2003).

3.4.2 Preparation of Sampling Coolers. For each sampling event, a cooler was prepared with the appropriate number and type of sample bottles, disc filters, and/or speciation kits needed. All sample bottles were new and contained appropriate preservatives. Each sample bottle was affixed with a pre-printed, colored-coded label consisting of the sample identification (ID), date and time of sample collection, collector's name, site location, sample destination, analysis required, and preservative. The sample ID consisted of a two-letter code for the specific water facility, 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 (e.g., orange designated TA). The labeled bottles for each sampling location were bagged separately and packed in the cooler.

In addition, all sampling- and shipping-related materials, such as disposable gloves, sampling instructions, chain-of-custody forms, prepaid and addressed FedEx air bills, and bubble wrap, were included. The chain-of-custody forms and FedEx 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 off-site analyses were packed carefully in the original coolers with wet ice and shipped to Battelle. Upon receipt, the sample custodian checked sample IDs against the chain-of-custody forms and verified that all samples indicated on the forms were included and intact. Discrepancies noted by the sample custodian were addressed with the plant operator by the Battelle Study Lead. The shipment and receipt of all coolers by Battelle were recorded on a cooler tracking log.

Samples for metal analyses were stored at Battelle's Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) Laboratory. Samples for other water quality analyses by Battelle's subcontract laboratories, including American Analytical Laboratories (AAL) in Columbus, OH and TCCI Laboratories in New

Lexington, OH, were packed in coolers at Battelle and picked up by couriers. 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 QAPP (Battelle, 2003) were followed by 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 limit (MDL), and completeness met the criteria established in the QAPP (i.e., 20% relative percent difference [RPD], 80 to 120% recovery, and 80% completeness). The quality assurance (QA) data associated with each analyte will be presented and evaluated in a QA/QC Summary Report to be prepared under separate cover upon completion of the Arsenic Demonstration Project.

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

4.0 DEMONSTRATION SITE AND TECHNOLOGY EVALUATED

4.1 Site Description

4.1.1 Existing Facility. Seven wells owned by AWC supplied water to a population of 2,556 in Rimrock, AZ. Montezuma Haven Wells No. 1 and 2, with a combined capacity of 90 gpm, were selected for the demonstration study. Figure 4-1 shows photographs taken at the site prior to onset of the demonstration study.

Wells No. 1 and 2 were 6-in in diameter and 270- and 165-ft deep, respectively, both with an open borehole extending from 80 ft below ground surface (bgs). The main supply well, Well No. 3, was 1,000-ft deep and capable of producing a sustainable flow at 315 gpm. Before entering the distribution system, a 12% NaOCl solution was used to maintain a free chlorine residual of about 0.3 mg/L (as Cl_2).

From Summer 2003 to October 2003, Wells No. 1 and 2 were taken off-line for repairs and redevelopment. It was later discovered that Well No. 1 had become dry, and that Well No. 2 produced a sustainable flow of only 31 gpm. This finding prompted a change to the configuration of the two adsorption tanks of the proposed treatment system from parallel to series (Section 4.2). For the purpose of the demonstration study, Well No. 2 was operated for 12 hr/day during most of the 33-month study period.

Figure 4-1. Predemonstration Site Photographs
(Clockwise from Top: Condition in July 2003; Well No. 2 Wellhead after Redevelopment; and Chlorine Shed and Emergency Shower Station)

4.1.2 Distribution System. The distribution system was supplied by Montezuma Haven Wells No. 2 and 3, and four other production wells not including Well No. 1, which was out of service. The transmission main was constructed of 6-in-diameter asbestos cement piping. Service lines to the

individual homes were mostly black high-density polyethylene (HDPE) or polyvinyl chloride (PVC) piping (including the distribution sampling locations) with some homes having copper or galvanized steel piping. Well No. 2 water entered the distribution system and blended with Well No. 3 water at the fence line of the treatment plant. Additional blending with water from other supply wells occurred further downstream. The blended water was stored in a 200,000-gal tank.

Compliance samples are taken periodically by AWC from the distribution system. Every month, three samples are collected for bacteria analysis. Under the LCR, samples are collected from customer taps at 14 locations every three years. The monitoring results from AWC's Consumer Confidence Reports (CCRs) for 2003 to 2005 (AWC, 2004; 2005; 2006) are summarized in Table 4-1.

Table 4-1. Distribution System Water Quality Data Collected by AWC[(a)]

Parameter	Unit	2003	2004	2005
Alpha Emitters	pCi/L	ND–3.5	2.0–7.8	–
Arsenic	µg/L	20–54	ND–51	ND–48
Barium	mg/L	0.3–0.4	–	–
Chlorine	mg/L	–	–	0.3–0.6
Chromium	µg/L	11–15	–	–
Copper	mg/L	0.4[(b)]	–	0.3
Fluoride	mg/L	0.2–0.4	–	–
Lead	µg/L	–	–	13
Nitrate (as N)	mg/L	ND–0.9	ND–1	ND–0.6
Selenium	µg/L	3.2–4.2	–	–
Sodium	mg/L	38–45	–	–
Radium-226	pCi/L	ND–0.2	–	–
Radon[(c)]	pCi/L	60	–	–
Total Trihalomethanes	µg/L	–	ND–2.5	–
Uranium	µg/L	1.3–4.5	–	–

(a) All other constituents not detected.
(b) Sampled in 2002.
(c) Sampled in 1999.
ND = not detected

4.1.3 Source Water Quality. Samples of Well No. 2 water were collected on October 22, 2003, for analyses. The results, along with those provided by the facility to EPA for demonstration site selection and those independently collected and analyzed by EPA, are presented in Table 4-2.

Based on the October 22, 2003, sampling results, Well No. 2 contained 63.6 µg/L of arsenic existing solely as As(V). Because As(V) adsorbs better with AD-33™ media, prechlorination upstream of the treatment process was not required. The source water pH value was 7.1, which was preferred for effective arsenic adsorption by AD-33™ media. In general, pH values at the lower end of the 6.5 to 8.5 range are preferred.

The adsorption capacity of AD-33™ media can be impacted by high levels of competing ions such as silica, phosphate, and sulfate. Concentrations of these ions appeared to be low enough not to affect the media's adsorptive capacity for arsenic. The iron and manganese concentrations (36 and 7.5 µg/L, respectively) in Well No. 2 water were sufficiently low; therefore, pretreatment for these metals prior to adsorption was not required.

Table 4-2. Source Water Quality Data

Parameter	Unit	Wells No. 1 & 2 AWC Data[a]	Well No. 3 AWC Data	Wells No. 1 & 2 EPA Data	Well No. 2 Battelle Data
Sampling Date	–	Not specified	12/30/02	10/03/02	10/22/03
pH	–	7.2	7.6	NS	7.1
Alkalinity (as $CaCO_3$)	Mg/L	334	444	374	378
Hardness (as $CaCO_3$)	Mg/L	300	NS	330	335
Chloride	Mg/L	25.0	NS	30.8	32.0
Fluoride	Mg/L	NS	0.2	NS	0.5
Nitrate (as N)	Mg/L	NS	0.1	NS	NS
Sulfate	Mg/L	13.0	12.2	11.6	9.5
Silica (as SiO_2)	Mg/L	27.8	NS	26.3	24.8
Orthophosphate (as P)	Mg/L	<0.065[b]	NS	<0.065	<0.10
TOC	Mg/L	NS	NS	NS	3.4[c]
As (total)	µg/L	50.0	15.0	52.0	63.6
As (soluble)	µg/L	NS	NS	NS	64.8
As (particulate)	µg/L	NS	NS	NS	<0.10
As(III)	µg/L	NS	NS	NS	<0.10
As(V)	µg/L	NS	NS	NS	64.8
Fe (total)	µg/L	170[b]	NS	170	36
Fe (soluble)	µg/L	NS	NS	NS	<25
Al (total)	µg/L	NS	NS	<25	13
Al (soluble)	µg/L	NS	NS	NS	<10
Mn (total)	µg/L	NS	NS	<0.4	7.5
Mn (soluble)	µg/L	NS	NS	NS	8.1
Na (total)	Mg/L	35.0	93	41.6	40.3
Ca (total)	Mg/L	69.0	NS	80.2	82.8
Mg (total)	Mg/L	31.0	NS	31.6	31.0

(a) Provided to EPA for site selection.
(b) Provided by EPA.
(c) Datum questionable.
TOC = total organic carbon; NS = not sampled

4.2 Treatment Process Description

AdEdge's APU-100 system is a fixed-bed downflow adsorption system, which uses Bayoxide® E33-S granular ferric oxide (GFO) adsorptive media for arsenic removal from drinking water supplies. Developed by Bayer AG, the media is branded and referred to as AD-33™ by AdEdge. AD-33™ is delivered in a dry crystalline form and has received NSF International (NSF) approval for use in drinking water under NSF Standard 61. Table 4-3 presents key physical and chemical properties of the media as provided by the vendor.

The original design of the APU-100 system was for the two adsorption tanks to operate in parallel to treat an anticipated flowrate of 90 gpm. However, because Well No. 1 was no longer producing water, the tanks were reconfigured to operate in series for a design capacity of 45 gpm.

For series operation, the media in the lead tank is generally replaced when it completely exhausts its capacity or when the effluent from the lag tank reaches 10 µg/L of arsenic. After rebedding, the lead tank with new media, it is switched to the lag position, and the lag tank with the partially exhausted media is

Table 4-3. Physical and Chemical Properties of AD-33™ Media

Physical Properties	
Parameter	**Value**
Matrix	Iron oxide composite
Physical Form	Dry granular media
Color	Amber
Bulk Density (g/cm^3) [lb/ft^3]	0.45 [28.1]
BET Surface Area (m^2/g)	142
Attrition (%)	0.3
Moisture Content (%)	<15 (by weight)
Particle Size Ddistribution	10 × 35 mesh
Crystal Size (Å)	70
Crystal Phase	α – FeOOH
Chemical Analysis	
Constituents	**Weight (%)**
FeOOH	90.1
CaO	0.27
MgO	1.00
MnO	0.11
SO_3	0.13
Na_2O	0.12
TiO_2	0.11
SiO_2	0.06
Al_2O_3	0.05
P_2O_5	0.02
Cl	0.01

Source: Bayer AG
BET = Brunauer, Emmett, and Teller

switched to the lead position. In theory, the series operation better utilizes the arsenic removal capacity of the media when compared to parallel system design and operation.

The APU-100 system included a bag filter assembly for sediment removal from source water, two pressure tanks arranged in series with hub and lateral underdrains, a backwash recycle system, piping with an automated valve assembly, and an instrument/control panel with flow meters, pressure and differential pressure (Δp) gauges, and ball valve sample ports. Skid-mounted on a polyurethane coated, welded steel frame, the system was equipped with the necessary valves and schedule 80 PVC piping to allow the adsorption tanks to be switched from lead to lag position and vice versa. Figure 4-2 is a simplified piping and instrumentation diagram (P&ID) of the treatment system. The system's design features are summarized in Table 4-4. Figures 4-3 and 4-4 show integral components of the treatment and backwash recycle processes, respectively. The major process steps included:

- **Intake**. Source water was supplied by Montezuma Haven Well No. 2 at approximately 31 gpm (Item No. 5 in Figure 4-3).
- **Prechlorination**. Although not required for oxidation, a 12% NaOCl solution was injected into raw water prior to the adsorption tanks at AWC's discretion and expense to attain a target free chlorine residual of 0.3 mg/L (as Cl_2) in the treated water. The feed system consisted of a 1.5-gal/hr (gph) chemical metering pump with adjustable speed and stroke settings and a 30-gal day tank. The metering pump was interlocked with the well pump so

that both pumps operated at the same time. AWC also provided an emergency eyewash and shower station for safety measures.

- **Bag Filter Filtration.** After prechlorination, a 25-μm bag filter assembly (FSI model BFN12) with replaceable polypropylene filter bags was used to remove any sediment from source water to protect the treatment equipment (Item No. 1 in Figure 4-3).

- **Adsorption**. The two 3-ft × 6-ft pressure tanks (Structural model 31214) were configured in series, each containing 22 ft^3 of AD-33™ media supported by 4.5 ft^3 of gravel underbedding. Although 27 ft^3 of media was originally proposed per tank, less media was loaded to provide additional freeboard during backwash. The tanks were constructed of composite fiberglass and rated for a 150-pounds per square inch (psi) working pressure (Item No. 3 in Figure 4-3). Influent, effluent, and backwash piping were connected to a Fleck controller valve (Performance Water Products model 3150 Downflow) at the 6-in flanged connection on the top of each tank (Item 2 in Figure 4-3). The influent water entered the tank via the controller valve, flowed downward through the media bed, collected in the underdrain, and traveled upward through riser piping to the outlet of the controller valve. A restrictive orifice located on the effluent piping from each tank provided a safeguard against filter overrun. Based on 22 ft^3 of media and 45 gpm of design flowrate, the EBCT through each media bed would be 3.7 min and the hydraulic loading rate would be 6.4 gpm/ft^2. Based on the actual flowrate of 30 gpm, the EBCT in each tank was 5.4 min and the hydraulic loading rate was 4.2 gpm/ft^2.

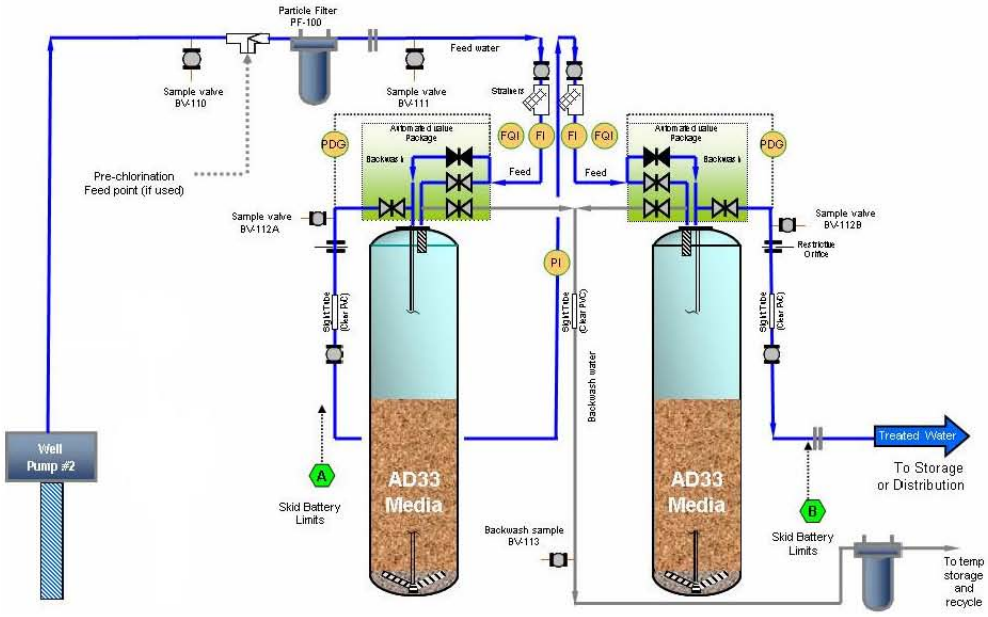


Figure 4-2. Schematic of AdEdge's APU-100 Treatment System

- **Backwash.** Backwash was recommended by the vendor to remove particulates and/or media fines accumulating in the media beds. The process might be initiated either manually or automatically based on a timer (Pentair model 3200NT) or a Δp setting for each tank. After the system was taken offline, upflow backwash using chlorinated water from the well was performed on Tank A followed by Tank B.

- **Backwash Wastewater Recycling.** Due to lack of sewer or other onsite wastewater discharge options, a backwash recycle loop was included in the system to reclaim the wastewater. The recycling system consisted of a 25-µm bag filter (FSI model BFN12), a 3,000-gal, flat-bottom, HDPE recycle tank with high and low level sensors (Burkert type 8181), and a positive displacement metering pump (ProMinent® Sigma/2 S2BA/S2Ca) (Figure 4-4). A turbine flow meter and a totalizer also were included to monitor flow. Wastewater from the recycle tank was metered into the head of the system between the chlorine injection point and the bag filter assembly at a rate of 0.5 gpm. Relays from the level sensors in the storage tank prevented the tank from overflowing and enabled automatic recycling.

Table 4-4. Design Features for AdEdge's APU-100 Treatment System

Parameter	Value[(a)]	Remarks
Pretreatment		
12% NaOCl (mg/L)	Not required	For providing residuals in distribution system
Bag Filter (µm)	25	For sediment removal
Adsorption		
Tank Quantity	2	Series configuration
Tank Size (ft)	3 D × 6 H	7.1 ft^2 cross-sectional area
AD-33™ Media Volume (ft^3/tank)	22	27 ft^3/tank per original design
Underbedding Volume (ft^3/tank)	4.5	Gravel
Maximum Flowrate (gpm)	50	
Design Flowrate (gpm)	45	31 gpm typically expected
EBCT (min/tank)	3.7	Based on design flowrate
Water Production (gpd)	32,400	Based on 45 gpm design flowrate and 12 hr/day operation
Hydraulic Utilization (%)	50	12 hr/day operation
Water Production (BV/tank/day)	197	Based on 22 ft^3/tank media volume, 45 gpm design flowrate, and 12 hr/day operation
Media Capacity to 10-µg/L As Breakthrough from Lead Tank (BV)	66,000	1 BV = 22 ft^3
Estimated throughput to 10 µg/L As breakthrough from Lead Tank (gal)	10,860,000	1 BV = 22 ft^3 = 165 gal
Estimated Media Life (month)	11	Based on media capacity and utilization
Backwash		
Frequency (time/month)	1	
Flowrate (gpm)	50	
Hydraulic Loading Rate (gpm/ft^2)	7	
Duration (min/tank)	15	
Wastewater Production (gal/tank)	750	
Recycle Flowrate (gpm)	0.5	

D = diameter; H = height

(a) AdEdge's original design modified from parallel to series reconfiguration.

Figure 4-3. Treatment System Components
([1] Inlet Bag Filter, [2] Fleck Controller Valve, [3] Adsorption Tank; [4] Instrument/Control Panel; [5] Piping from Wellhead, [6] Piping to Distribution System, and [7] System Enclosure)

Figure 4-4. Backwash Recycling System Components
(From Left: Backwash Bag Filter; 3,000-gal Storage Tank with Level Sensors; and Recycle Pump)

4.3 Treatment System Installation

This section summarizes the system engineering, installation, startup, and shakedown activities, which were carried out by AdEdge and its subcontractor, Fann Environmental, of Prescott, AZ. Installation of the system was completed in mid-April 2004 and reconfiguration of the system from parallel to series was completed in mid-May 2004.

4.3.1 System Engineering and Permitting. Engineering plans for the system permit application were submitted to ADEQ for approval on December 11, 2003. The plans included P&IDs and system specifications, control panel schematics, equipment cut sheets, and drawings of a site plan, treatment plan, and piping plan. After the Approval to Construct was granted on February 18, 2004, a construction permit was applied for and approved by Yavapai County in mid-March 2004. Upon completion of system installation, as-built drawings were submitted to ADEQ and Approval of Construction was granted on April 29, 2004. Following the system reconfiguration, updated information was submitted to ADEQ and a second approval was granted on June 15, 2004.

4.3.2 System Installation, Startup, and Shakedown. Upon arrival of the treatment system on March 30, 2004, the vendor's subcontractor performed off-loading and installation. The installation activities including connections to the existing intake and distribution piping, hydraulic testing (with no media), and media loading were completed on April 20, 2004. Figure 4-5 shows photographs from the media loading. Due to the loss of Well No. 1, piping from Well No. 3 was installed to allow additional flow for media backwash. Because some lubricating oil from the pump shaft was found in Well No. 3 water, a decision was made to forgo this supplementary input for backwash. Battelle provided operator training on data and sample collection from May 6 to 7, 2004.

Figure 4-5. Gravel Underbedding (Left) and AD-33™ Media (Right) Loading

Because of the reduced flowrate from 90 to 31 gpm, the corresponding EBCT across each tank would have almost tripled from 3.7 to 10.6 min (based on 22 ft^3 of media loaded in each tank) if the system configuration had remained in parallel. To evaluate the system performance near the originally designed EBCT and to fully utilize the media capacity, the tank configuration was changed to series. The required modifications were made in mid-May 2004, and shakedown and startup completed in early June 2004. After the system was sanitized and passed bacteria tests, the performance evaluation began with commencement of Media Run 1A on June 24, 2004.

4.3.3 System Enclosure. After the treatment system was installed, a sun shed with a base of 12 ft × 15 ft and a height of 9.5 ft was built by AWC over the system in late-May 2004 (Figure 4-6). Constructed of a galvanized steel frame by Versa-Tube, the sun shed was anchored to the concrete pad and sheeted with 29-gauge steel with a specially coated surface. The shed was pre-engineered with loading capacities of 90 mph for wind and 30 lb/ft^2 for snow. From late-November to mid-December 2004, the sides and ends of the sun shed were enclosed with metal covering; exposed piping was insulated; and heat lamps were installed within the building for added protection from below-freezing temperatures.

Figure 4-6. System Enclosure
(Clockwise from Left: System Installed on Concrete Pad in April 2004; Sun Shed Built in May 2004; and Enclosure Completed in December 2004)

5.0 RESULTS AND DISCUSSION

5.1 System Operation

5.1.1 Service Operation. The operational data collected during the performance evaluation study are tabulated and attached as Appendix A. Key parameters are summarized in Table 5-1. The system operated with Tank A in the lead position from June 24, 2004, through August 9, 2006 (designated as Run 1A). Starting from August 30, 2006, the system was turned off for well pump maintenance and Tank A rebedding (Section 5.1.3). System operation resumed for Run 1B on November 27, 2006, with Tank B containing partially exhausted media in the lead position and newly-rebedded Tank A in the lag position. Sampling was discontinued and the performance evaluation completed on March 28, 2007 after the results of monitoring confirmed on-spec system operation following the media changeout.

From June 24, 2004 through March 28, 2007, the system operated for a total of 12,024 hr on a 12-hr/day schedule from 8:00 a.m. to 8:00 p.m., except for the winters when the system operated at night from 11:00 p.m. to 11:00 a.m. to prevent system components from being damaged due to freezing ambient conditions, and from December 4, 2006, to March 7, 2007, when the system operated 24 hr/day to compensate for anticipated water shortage due to maintenance on a nearby well. The 12 hr/day run time was preset on a timer. Meanwhile, an hour meter was installed on November 4, 2004 to track total system run time.

Table 5-1. Summary of APU-100 System Operations

Parameter	Unit	Value
Evaluation Period	Date	06/24/04-03/28/07[a]
Treatment Operation		
Total Operation Time	hr	12,024
Daily Operating Time	hr/day	12 or 24
Average Flowrate [Range]	gpm	30 [16–36]
Average Hydraulic Loading Rate [Range]	gpm/ft^2	4.2 [2.3–5.1]
Average EBCT [Range]	min/tank	5.4 [4.6–10.3]
Average Δp across Tank [Range]	psi/tank	4.8 [1.5–6.5]
Media Run Length to 10-µg/L As following Lead Tank	1,000 gal/BV/yr	6,448/39,180[b]/0.8
Media Run Length to 10-µg/L As following Lag Tank	1,000 gal/BV/yr	17,164/52,150[c]/2.1
Media Run Length until Tank A Rebedding	1,000 gal/BV/yr	17,426/52,950[c]/2.2
Media Run Length after Tank A Rebedding	1,000 gal/BV/yr	4,717/14,330[c]/0.3
Backwash Operation		
Backwash Count	No	42[d]
Time Elapsed between Two Consecutive Backwash Cycles	Month	1–3
Average Flowrate [Range]	gpm	47 [22–54]
Average Hydraulic Loading Rate [Range]	gpm/ft^2	6.6 [3.1–7.6]
Average Backwash Duration [Range]	min/tank	15 [15–17]
Wastewater Generated	gal/tank	727 [245–996]
Total Wastewater Generated	gal	33,100
Average Recycle Flowrate [Range]	gpm	0.5 [0.5–1.5]

(a) System turned off on 08/30/06 and restarted on 11/27/06 after rebedding.
(b) Based on flow meter of lead tank and volume of media in lead tank.
(c) Based on flow meter of lag tank and volume of media in both tanks.
(d) Count for both tanks combined.

During Run 1A, the system produced 6,448,000 gal (or 39,180 BV [1 BV = 22 ft^3]) and 17,164,000 gal (or 52,150 BV [1 BV = 44 ft^3]) of water at 10 µg/L of arsenic breakthrough from the lead and lag tanks, respectively. After media changeout, an additional 4,717,000 gal (or 14,330 BV [1 BV = 44 ft^3]) was produced before sampling was discontinued. System flowrates ranged from 16 to 36 gpm and averaged 30 gpm and the corresponding hydraulic loading rates ranged from 2.3 to 5.1 gpm/ft^2 and averaged 4.2 gpm/ft^2. Flowrates as low as 16 gpm were measured when decreasing production by Well No. 2 was observed from June through August 2006 (Figure 5-1). Following the well maintenance, system flowrates returned to the typical values of around 30 gpm. The resulting EBCTs ranged from 4.6 to 10.3 min/tank and averaged 5.4 min/tank, compared to the design value of 3.7 min/tank (note that the design EBCT was calculated based on 22 ft^3 of media in each tank and 45 gpm of system flowrate).

Δp readings across each tank ranged from 1.5 to 6.5 psi and averaged 4.8 psi (Figure 5-1). As expected, Δp readings across each tank decreased with decreasing flowrates. Δp readings across Tank A were generally higher (i.e., about 0.5 psi) than those across Tank B, suggesting removal of some sediment by Tank A (the lead tank). During system startup, hydraulic testing performed with no media in the tanks measured a Δp reading of 4.3 psi at 33 gpm. This Δp was thought to have been caused primarily by the Fleck controller valve installed at the top of each tank, as demonstrated by the hydraulic testing performed on another APU-100 system at Rollinsford, NH (Oxenham et al., 2005). The Δp readings across each tank between two consecutive backwash events did not increase significantly, indicating that few particulates or media fines, if any, were accumulating in the media beds.

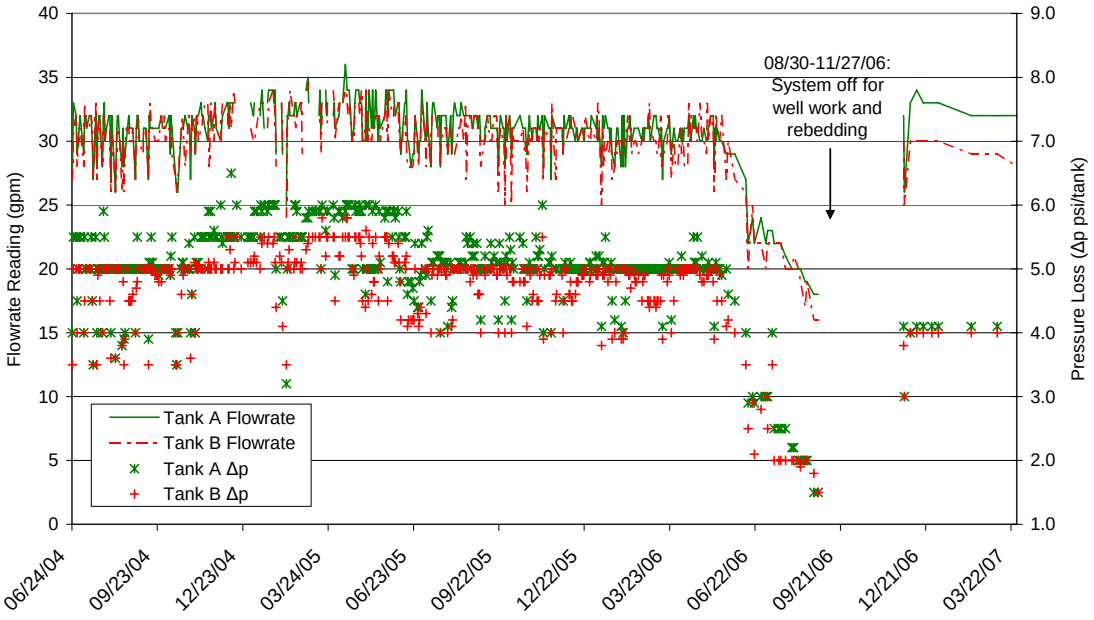


Figure 5-1. Flowrate Readings and Δp Across Tanks

5.1.2 Backwash Operation. The system was programmed to backwash automatically at 15 psi of Δp or 27 (for Tank A) or 28 (for Tank B) days of system operation. For the first one and a half months of operation, the system experienced four unscheduled backwash events, possibly caused by >15 psi pressure spikes resulting from the operation of the nearby Well No. 3. Because these backwash events took place unexpectedly, the operator was not onsite to record relevant operational data and take samples. In order to record backwash data and collect backwash wastewater samples, the Δp relays were disengaged on

August 12, 2004, so that backwash would be controlled solely by the 27/28-day timer. Since then, three more unscheduled backwash events occurred before the first set of samples could be taken on October 20, 2004, when the tanks were manually backwashed. After another backwash event was missed on November 15, 2004, the 27/28-day timer setting was changed to 30 days. After November 15, 2004, no other unscheduled backwashes occurred except on December 6, 2005, possibly due to a power outage. The vendor checked the backwash settings, tested the process, and ensured normal operation on December 14, 2005.

Backwash was performed with raw water at 47 gpm or 6.6 gpm/ft^2 (on average). Initially, a monthly backwash was performed as recommended by the vendor. After approximately one year of system operation, the backwash frequency was reduced to quarterly in August 2005. The decrease in backwash frequency was determined mainly by the minimal Δp increase across the tanks between two consecutive backwash events. The backwash duration was generally 15 min/tank, producing approximately 730 gal/tank. However, flows as low as 22 gpm or 3.1 gpm/ft^2 were used for backwash on August 16, 2006, due to decreasing well production. Nonetheless, Δp increase following the backwash was not observed. After media changeout, the system was thoroughly backwashed with anticipated flowrates following the well maintenance.

Several problems occurred with the backwash recycle pump and a control valve. In mid-August 2004, after a leak on the backwash recycle line was repaired, the shut-off valve from the backwash recycle pump was inadvertently left unopened. Consequently, when the recycle pump came on during a backwash on August 23, 2004, it was dead-headed, causing damages to the diaphragm. The recycle pump was fixed on September 1, 2004, and a pressure relief valve was installed on the pump discharge to prevent future problems. A control valve for Tank A began sticking after backwash on June 8, 2005, causing the tank not to return to service mode after backwash. The valve was repaired by the vendor on July 26, 2005. Additional problems were experienced with the backwash recycle pump after the media changeout on November 27, 2006. The system stopped recognizing the programmable logic controller (PLC) input signal from the level sensor in the recycle tank used to operate the recycle pump. Due to scheduling conflicts and troubleshooting difficulties, this issue was not resolved by the vendor until March 28, 2007.

5.1.3 Media Changeout. A media changeout request was made to the vendor and its subcontractor on August 16, 2006. Due to scheduling conflicts and media disposal and other issues, the changeout did not take place until almost three months later on November 8, 2006. After the tanks were drained and the pumps and isolation valves were turned off, the freeboards of Tanks A and B were measured at 17.3 and 19.0 in, respectively, from the flange at the top of each tank to the top of each media bed. The spent media and underbedding in Tank A were sampled and/or removed as described in Section 3.3.5. The tank was then half-filled with water before loading of 4.5 ft^3 of underbedding gravel and 22 ft^3 of virgin media through a large funnel. The tank was then completely filled with water and the media soaked to eliminate entrapped air. After the media was thoroughly backwashed, the freeboard of the tank was measured at 16.5 in, which was comparable to the 17.3-in measurement before rebedding. It appeared that minimum media loss was experienced over the 2.1 yr of system operation.

5.1.4 Residual Management. The backwash wastewater recycling system (Section 4.2) reclaimed nearly 100% of the backwash wastewater produced. Recycling was accomplished by blending the supernatant in the recycle tank with the influent water between the chlorine injection point and bag filter at a rate of 0.5 gpm (see Figure 3.1). Solids and media fines produced during backwash were removed by a 25 μm bag filter, which required replacement after each backwash. Any remaining solids not removed by the bag filter were allowed to settle in the recycle tank; accumulation was so negligible that removal and disposal of these solid were not needed during the course of the 33-month study period. If required, solid removal from the recycle tank would be a considerable undertaking because the flat-bottom is not

conducive to solid collection, and because the only access point to solid is at the top of the approximately 8-ft tall tank. The associated O&M requirements for sites with higher solid loading could easily be accommodated by using a conical-bottom recycle tank.

Spent media was the only quantifiable residual produced by operation of the treatment system. After treating 17,500,000 gal of water in 2.2 yr, approximately 620 lb of spent media and 450 lb of gravel underbedding were removed from the lead tank. After they were subjected to and passed the TCLP test (Section 5.2.4), the media were disposed of by Waste Management, Inc.

5.1.5 System/Operation Reliability and Simplicity. Unscheduled backwashes, problems with the recycling pump and one control valve (Section 5.1.2), and delays on media changeout (Section 5.1.3) were the primary source of concerns during this performance evaluation study. Other O&M issues encountered were problems with the chlorine injector, inlet and outlet pressure gauges, recycle flow meter, and backwash totalizer. The pressure gauges, flow meter, and totalizer were damaged as a result of unusually cold weather in late November 2004. The inlet and outlet pressure gauges broke a second time on December 19, 2005. The unscheduled downtime for system component repairs amounted to about 1 to 2% of the total system run time.

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

5.1.5.1 Pre- and Post-Treatment Requirements. Although not required for treatment, chlorine was injected upstream of the adsorption tanks to provide disinfection throughout the treatment train and a chlorine residual within the distribution system. A 25-μm bag filter following the chlorine injection point was used to remove sediment from the inlet water. No post-treatments were required.

5.1.5.2 System Automation. The system was equipped with a backwash control to initiate backwash automatically by a timer and/or a Δp setpoint. Because the system experienced a number of unscheduled backwashes at the beginning of system operation (Section 5.1.2), the automatic backwash control was disabled so that the operator could take backwash data and samples during each manual backwash. Backwash wastewater recycling also was accomplished automatically as operation of the recycle pump was controlled by the level sensors in the reclaim tank.

5.1.5.3 Operator Skill Requirements. Under normal operating conditions, the daily demand on the operator was typically 20 min for visual inspection of the system and recording of operational parameters on the log sheets. During backwash, the operator spent approximately 2 hr onsite to collect operational data and perform backwash wastewater sampling. Under normal system operation, backwash can be initiated automatically, as such, the operator's presence would not be necessary.

In Arizona, operator certifications are classified by grade on a scale of 1 (least complex) to 4 (most complex) according to facility type, size, complexity, and population served (ADEQ, 2005). One AWC operator had a Level 4 Distribution Grade and a Level 4 Treatment Grade, and the other had a Level 4 Distribution Grade and a Level 3 Treatment Grade. After receiving proper training by the vendor during the system startup, the operator understood the system and was able to work with the vendor to troubleshoot and perform minor onsite repairs.

5.1.5.4 Preventative Maintenance Activities. Preventative maintenance tasks recommended by the vendor are summarized in Table 5-2. The system had few moving parts that required regular maintenance per the O&M manual. Replacement bag filters were installed without the use of special equipment. With vendor's concurrence, the frequency for backwash and bag filter replacement was reduced from monthly

to quarterly or upon 6 to 7 psi Δp rise (Section 5.1.2). Many of the tasks such as sampling and analysis and operational data recording including pressure checks were conducted more frequently due to the nature of the demonstration project.

Because the backwash bag filter assembly was located before the recycle tank, bag filters had to be replaced after each backwash event. If the backwash bag filter had been located after the recycle tank, its replacement frequency could be reduced by allowing solids to settle in the recycle tank. To have the bag filter after the recycle tank, however, could increase the need for solids removal from the recycle tank.

Table 5-2. Recommended Routine Maintenance Activities

Task	Frequency			
	Daily	Weekly	Monthly	Quarterly
Ensure Normal System Operation	√			
Check Site Security	√			
Check for Leaks and Integrity		√		
Read Inlet/Outlet Pressure and Δp Gauges		√		
Check Backwash Recycle Tank Level		√		
Record Totalizer Throughput			√	
Record System Flowrate			√	
Check Effluent Water Clarity			√	
Backwash and Replace Backwash Bag Filter			√(a)	√(b)
Check Inlet Bag Filter for Debris/Sediment				√
Conduct Sampling and Analysis(c)			√	√
Perform Equipment Maintenance(d)				√

Source: AdEdge, 2004
(a) At beginning of system operation.
(b) or 6 to 7 psi Δp.
(c) Frequency depending on anticipated proximity to arsenic breakthrough.
(d) Per O&M manual.

5.1.5.5 Chemical/Media Handling and Inventory Requirements. Chemical usage was not required except for disinfection. AWC coordinated the supply of 12% NaOCl supply with Hill Brothers Chemical Co., refilled the day tank when required, and provided an emergency eyewash and shower station for safety measures. Rebedding of the lead tank was required when the lag tank effluent reached 10-µg/L of arsenic after 2.1 yr of system operation or 17,146,000 gal of water treated. Media sampling and removal were labor-intensive, taking 45 labor hr (i.e., 15 hr each for three people). In contrast, media loading took only 9 labor hr (3 hr each for three people).

5.2 System Performance

5.2.1 Treatment Plant Sampling. The treatment plant water was sampled on 64 occasions (including five duplicate samples), with field speciation performed on 16 occations. Table 5-3 summarizes the analytical results of arsenic, iron, and manganese at the IN, TA, and TB sampling locations. Table 5-4 summarizes the results of the other water quality parameters including those measured onsite at the IN, AC, TA, and TB sampling locations. Appendix B contains a complete set of analytical results.

Table 5-3. Summary of Arsenic, Iron, and Manganese Results

Parameter (Figure, if any)	Sampling Location	Sample Count	Concentration (μg/L)			Standard Deviation
			Minimum	Maximum	Average	
As (total) (Figure 5-3)	IN	64	43.8	81.4	59.7	9.5
	TA	64	0.7	56.1	-	-
	TB	64	0.2	31.7	-	-
As (soluble)	IN	16	50.2	66.7	57.3	5.1
	TA	16	0.9	41.9	-	-
	TB	16	0.3	7.3	-	-
As (particulate) (Figure 5-2)	IN	16	<0.1	21.7	3.8	6.4
	TA	16	<0.1	15.2	3.0	4.7
	TB	16	<0.1	1.1	0.3	0.3
As(III) (Figure 5-2)	IN	16	0.3	2.2	1.1	0.5
	TA	16	0.3	2.7	1.0	0.6
	TB	16	0.2	1.9	0.8	0.5
As(V) (Figure 5-2)	IN	16	48.1	65.5	56.2	5.1
	TA	16	<0.1	41.7	-	-
	TB	16	<0.1	7.0	-	-
Fe (total)	IN	59[(a)]	<25	27.2	<25	1.9
	TA	60	<25	31.1	<25	3.5
	TB	60	<25	55.7	<25	7.7
Fe (soluble)	IN	16	<25	<25	<25	-
	TA	16	<25	<25	<25	-
	TB	16	<25	<25	<25	-
Mn (total)	IN	60	<0.1	1.6	0.3	0.3
	TA	60	<0.1	1.2	0.1	0.2
	TB	59[(b)]	<0.1	0.9	0.1	0.2
Mn (soluble)	IN	16	<0.1	1.1	0.3	0.3
	TA	16	<0.1	0.7	0.1	0.2
	TB	16	<0.1	0.6	0.1	0.1

(a) One outlier (i.e., 127 μg/L on 09/22/04) omitted.
(b) One outlier (i.e., 12.4 μg/L on 02/02/05) omitted.
One-half of the detection limit used for nondetect results and duplicates included for calculations.

5.2.1.1 Arsenic. Total arsenic concentrations in source water ranged from 43.8 to 81.4 μg/L and averaged 59.7 μg/L, with As(V) as the predominant soluble species at 56.2 μg/L (Table 5-3). Figure 5-2 contains bar charts showing the concentrations of particulate arsenic, As(III), and As(V) for each speciation sampling event. (Note that results for TA and TB in Figure 5-2 were plotted on reduced scales compared to IN to better show the effluent species.) The arsenic concentrations measured during this period were consistent with that of source water collected on October 22, 2003 (Table 4-2). Generally, low levels of particulate arsenic and As(III) existed in raw water at average concentrations of 3.8 and 1.1 μg/L, respectively. However, highly elevated particulate arsenic concentrations (e.g., up to 21.7 μg/L on March 8, 2006) were observed beginning in February 2006, possibly due to overextraction from the source well. Most of particulate arsenic was trapped in the media beds (and later removed during backwash) as evident by the decrease in concentrations from 3.8 to 3.0 and then to 0.3 μg/L at IN, TA, and TB, respectively. As much as 2.2 μg/L As(III) was measured in source water and not completely oxidized with chlorine addition. Because the AD-33™ media had little capacity for As(III), up to 2.7 and 1.9 μg/L of As(III) were measured in the tank effluent even in the presence of 0.3 mg/L (as Cl_2) of free chlorine (Table 5-3).

Table 5-4. Summary of Other Water Quality Parameter Results

Parameter (Figure, if any)	Sampling Location	Unit	Sample Count	Concentration			Standard Deviation
				Minimum	Maximum	Average	
Alkalinity (as $CaCO_3$)	IN	mg/L	60	330	414	379	14
	TA	mg/L	60	345	424	380	12
	TB	mg/L	60	351	410	381	13
Fluoride	IN	mg/L	16	0.2	0.4	0.3	0.1
	TA	mg/L	16	0.2	0.5	0.3	0.1
	TB	mg/L	16	0.2	0.4	0.3	0.1
Sulfate	IN	mg/L	16	8.1	11	9.7	0.6
	TA	mg/L	16	7.8	10	9.6	0.6
	TB	mg/L	16	8.1	11	9.7	0.7
Orthophosphate (as P)	IN	mg/L	11[(a)]	<0.06	<0.10	<0.06	0.0
	TA	mg/L	11[(a)]	<0.06	<0.10	<0.06	0.0
	TB	mg/L	11[(a)]	<0.06	<0.10	<0.06	0.0
Phosphorus (as P)	IN	µg/L	14	<10	20.4	10.2	5.8
	TA	µg/L	14	<10	21.4	11.7	5.9
	TB	µg/L	14	<10	10.9	<10	2.1
Silica (as SiO_2)	IN	mg/L	60	23.6	27.6	25.6	0.8
	TA	mg/L	60	23.9	27.5	25.5	0.9
	TB	mg/L	60	23.7	27.4	25.4	0.9
Nitrate (as N)	IN	mg/L	16	0.2	0.6	0.2	0.1
	TA	mg/L	16	0.2	0.3	0.2	0.0
	TB	mg/L	16	0.2	0.3	0.2	0.0
Turbidity	IN	NTU	60	0.1	0.7	0.2	0.2
	TA	NTU	60	0.1	1.6	0.3	0.3
	TB	NTU	60	0.1	3.4	0.3	0.5
pH	IN	S.U.	50	6.8	7.1	6.9	0.1
	AC	S.U.	50	6.8	7.6	7.0	0.2
	TA	S.U.	50	6.7	7.1	7.0	0.1
	TB	S.U.	50	6.8	7.1	6.9	0.1
Temperature	IN	ºC	51	18.6	26.1	21.0	1.3
	AC	ºC	51	19.2	24.5	20.8	1.0
	TA	ºC	51	19.4	26.7	20.9	1.2
	TB	ºC	51	19.6	24.0	21.0	1.1
DO	IN	mg/L	48	3.2	6.0	3.9	0.5
	AC	mg/L	48	3.0	6.8	4.2	0.9
	TA	mg/L	48	3.0	6.6	3.9	0.6
	TB	mg/L	48	3.0	6.9	3.9	0.6
ORP	IN	mV	48	148	510	305	125
	AC	mV	48	365	646	597	46
	TA	mV	48	565	688	630	29
	TB	mV	48	470	710	639	39
Free Chlorine (as Cl_2)	AC	mg/L	51	0.2	0.5	0.4	0.1
	TA	mg/L	51	0.2	0.5	0.3	0.1
	TB	mg/L	51	0.2	0.5	0.3	0.1
Total Chlorine (as Cl_2)	AC	mg/L	50	0.2	0.7	0.4	0.1
	TA	mg/L	50	0.2	0.6	0.4	0.1
	TB	mg/L	50	0.2	0.6	0.4	0.1
Total Hardness (as $CaCO_3$)	IN	mg/L	16	287	384	327	26
	TA	mg/L	16	298	397	334	27
	TB	mg/L	16	298	377	331	22

Table 5-4. Summary of Other Water Quality Parameter Results (Continued)

Parameter (Figure, if any)	Sampling Location	Unit	Sample Count	Concentration			Standard Deviation
				Minimum	Maximum	Average	
Ca Hardness (as $CaCO_3$)	IN	mg/L	16	171	241	198	16
	TA	mg/L	16	161	236	199	19
	TB	mg/L	16	174	235	199	14
Mg Hardness (as $CaCO_3$)	IN	mg/L	16	110	151	129	11
	TA	mg/L	16	112	161	135	12
	TB	mg/L	16	115	149	132	11

(a) Data invalid from 01/01/05 to 10/03/05 due to laboratory issue.
One-half of the detection limit used for nondetect results and duplicates included for calculations.

The key parameter for evaluating the effectiveness of the APU-100 system was the arsenic concentration in the treated water. Shown in Figure 5-3, the arsenic breakthrough curves are presented as gallons of water treated with the number of bed volumes to arsenic breakthrough at 10 µg/L from the lead and lag tanks specified. Bed volumes of the lead tank were calculated based on the amount of media in the lead tank only; however, bed volumes of the lag tank were calculated based on the combined media volume in both lead and lag tanks since water exiting the lag tank had been treated by this entire media volume. Initially, the lead tank (TA) removed the majority of arsenic from source water until its capacity gradually decreased. Afterwards, the lag tank (TB) served as an effective polishing unit, removing arsenic to <10 µg/L throughout most of Run 1A. Both breakthrough curves in Figure 5-3a gradually increased over time, but effluent concentrations of the lead tank were largely influenced by the fluctuating source water arsenic concentrations (including elevated levels of particulate arsenic) near the end of Run 1A. The lag tank, however, was able to dampen the fluctuations observed and produce rather steady arsenic concentrations in the tank effluent.

Breakthrough of arsenic at 10 µg/L from Tank A occurred at 39,180 BV, which was 60% of the vendor-estimated working capacity, i.e., 66,000 BV, based on 22 ft^3 of media in the lead tank as shown in Table 4-4. In theory, the media should have outperformed the projection, because the system was operating with a longer EBCT than was originally designed (i.e., 5.4 vs. 3.7 min/tank [based on 22 ft^3 of media and 45 gpm of design flowrate]), which potentially could help increase the media run length.

Breakthrough of arsenic at 10 µg/L from Tank B, or the entire system, occurred at 52,150 BV (1 BV = 44 ft^3), which was 33% higher than the 39,180 BV observed following the lead tank. The average EBCT of the system was 10.8 min, which was twice as long as that of the lead tank only. The longer EBCT apparently benefited arsenic adsorption, extending the media run length for 33%.

Starting with a partially exhausted Tank B in the lead position and newly rebedded Tank A in the lag position on November 27, 2006, Media Run 1B was carried out to ensure that normal system operations continued following the media changeout. Results of the initial sampling indicated that the arsenic concentration in Tank B had dropped from 9.8 (as lag tank on August 9, 2006) to 6.2 µg/L (as lead tank on November 28, 2006). Because intraparticle mass transport is believed to be a rate-limiting step (Badruzzaman et al., 2004; Lin and Wu, 2001), the system downtime from August 30 to November 27, 2006, might have temporarily facilitated and improved pore diffusion by allowing additional time for arsenic on the media surface to move into the pores and provide more easily accessible sites for adsorption. Total arsenic concentrations continued to be monitored through March 7, 2007, when the sampling was discontinued and the performance evaluation was completed (Figure 5-3b).

5.2.1.2 Iron and Manganese. Low concentrations of total and soluble iron and manganese existed in source water and throughout the treatment system. Total iron concentrations were near or below the

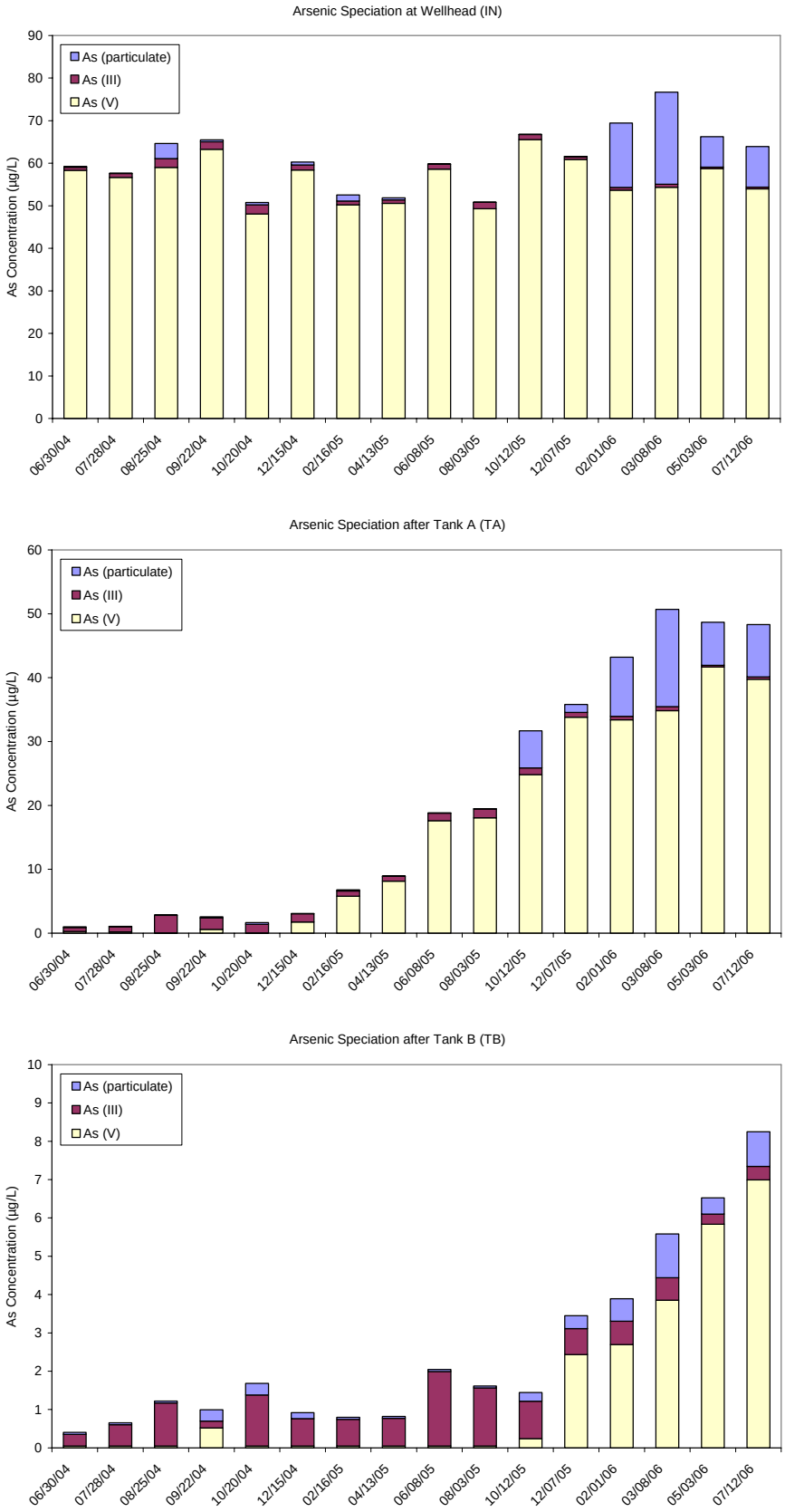


Figure 5-2. Arsenic Species During Media Run 1A at Wellhead, After Tank A, and After Tank B

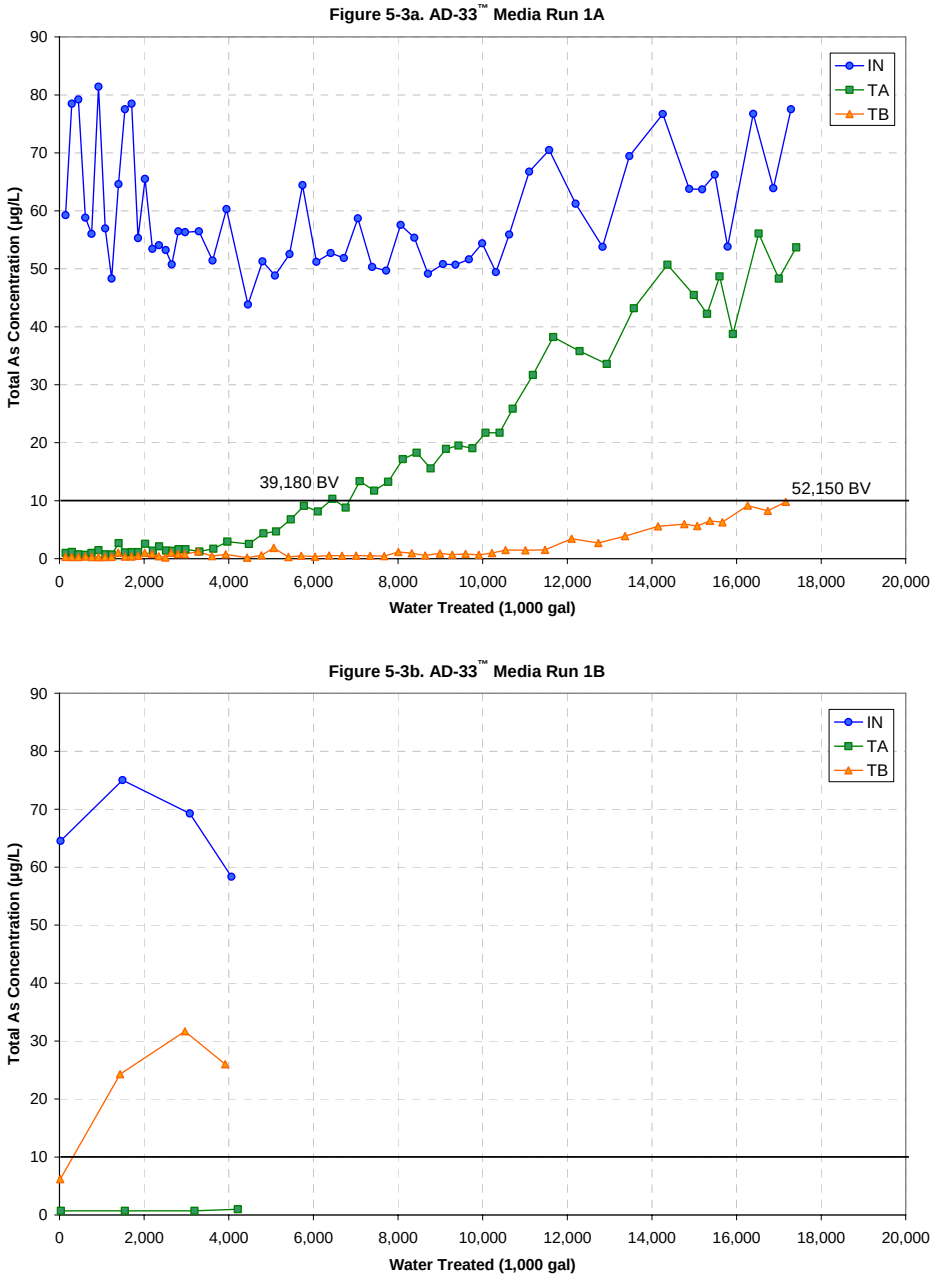


Figure 5-3. Total Arsenic Breakthrough Curves for Media Runs 1A and 1B

25-µg/L method reporting limit for all samples with one exception (i.e., 127 µg/L at IN on September 22, 2004). Soluble iron concentrations were <25 µg/L for all samples. Total manganese levels ranged from <0.1 to 1.6 µg/L except for one outlier (i.e., 12.4 µg/L at TB on February 2, 2005), with the majority existing as soluble manganese. Average total and soluble manganese levels in raw water were reduced from 0.3 µg/L to 0.1 µg/L after the adsorption tanks, indicating some removal by the media.

5.2.1.3 Onsite Measurements. Average pH values across the treatment train were 6.9 to 7.0, which were the lowest among the 12 Round 1 demonstration sites (Table 1-1). Near neutral pH is desirable for

adsorptive media, which, in general, have greater arsenic removal capacities when treating lower-pH water. Source water was oxidizing as indicated by the relatively high DO and ORP levels, which averaged 3.9 mg/L and 305 millivolts (mV), respectively. These measurements might explain the absence of As(III) in source water. As a result of prechlorination, ORP readings at the AC, TA, and TB locations increased to the range of 365 to 710 mV. Free and total chlorine residuals measured at the TA and TB locations were comparable to those measured at the AC location, indicating little or no chlorine consumption by the AD-33™ media.

5.2.1.4 Other Water Quality Parameters. Alkalinity, fluoride, sulfate, orthophosphate, phosphorus, silica, nitrate, and turbidity concentrations were relatively low and remained fairly constant throughout the treatment train. Total hardness ranged from 287 to 397 mg/L (as $CaCO_3$), consisting of approximately 60% of calcium hardness and 40% of magnesium hardness. Hardness was not significantly affected by the treatment process.

5.2.2 Backwash Water Sampling. Backwash wastewater was sampled in 13 sampling events. The analytical results are presented in Table 5-5. (Note that Sampling Events 11, 12, and 13 followed a modified sampling procedure as described in Section 3.3.3.) pH values of the backwash wastewater, ranging from 7.0 to 7.9, were somewhat higher than those of raw water (Table 5-4). Arsenic concentrations in the backwash wastewater from Tank A and, especially, Tank B, were lower than those in raw water used for backwash (except for Event 13), indicating removal of arsenic by the media during backwash. During Event 13, overextraction of the source well most likely contributed to the elevated particulate arsenic concentration as discussed in Section 5.2.1.1. The backwash wastewater from Tank A contained higher amounts of turbidity and particulate iron and manganese than from Tank B, suggesting filtering of most of particulates by Tank A. Nonetheless, the amounts removed by Tank A were minute, as reflected by the low levels of TSS, i.e., <1 to 16 mg/L, in the backwash wastewater. The sampling events did not show significant differences for pH or TDS between the two tanks.

5.2.3 Distribution System Water Sampling. The results of the 20 distribution system water sampling events (including four baseline [BL] events) are summarized in Table 5-6. Water from the source well, Well No. 2, blended with water from up to five other wells within the distribution system would impact the water quality at the three sampling locations as discussed in Section 3.3.4. The most noticeable change since system startup was the decrease in arsenic concentrations. After system startup, arsenic concentrations, which ranged from 20.8 to 80.1 μg/L and averaged 48.8 μg/L during baseline sampling, were reduced to the range of 2.2 to 45.6 μg/L and average of 19.3 μg/L. Water samples from the distribution system exhibited significantly higher arsenic concentrations than those following the treatment system due to the contribution of untreated water from other wells which also contained arsenic (Tables 4-1 and 4-2).

pH, alkalinity, manganese, lead, and copper concentrations after system startup were comparable to baseline levels except for the pH results for Event BL2 at all locations and the manganese result for Event BL1 at DS2. Furthermore, lead and copper concentrations were well below the action levels of 15 and 1,300 μg/L, respectively. Although iron levels appeared to decrease somewhat compared to the baseline levels, the system operation probably did not influence this reduction since Well No. 2 source water contained little or no iron.

Table 5-5. Backwash Water Sampling Results

Sampling Event		Tank A											Tank B										
		pH	Turbidity	TDS	TSS	As (total)	As (soluble)	As (particulate)	Fe (total)	Fe (soluble)	Mn (total)	Mn (soluble)	pH	Turbidity	TDS	TSS	As (total)	As (soluble)	As (particulate)	Fe (total)	Fe (soluble)	Mn (total)	Mn (soluble)
No.	Date	S.U.	NTU	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	S.U.	NTU	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
1	10/20/04	7.3	22	486	NS	NS	48.2	NS	NS	<25	NS	0.1	7.3	6.5	442	NS	NS	2.7	NS	NS	<25	NS	0.1
2	12/15/04	7.1	45	358	NS	NS	48.0	NS	NS	<25	NS	0.4	7.1	25	306	NS	NS	1.6	NS	NS	<25	NS	<0.1
3	01/19/05	7.1	19	462	NS	NS	50.7	NS	NS	<25	NS	<0.1	7.1	4.3	464	NS	NS	4.5	NS	NS	<25	NS	0.5
4	02/16/05	7.3	16	446	NS	NS	51.7	NS	NS	<25	NS	<0.1	7.2	7.6	444	NS	NS	13.2	NS	NS	<25	NS	0.1
5	03/16/05	7.2	37	414	NS	NS	52.2	NS	NS	<25	NS	<0.1	NA[a]	NA[a]	NA[a]	NS	NS	7.5	NS	NS	<25	NS	<0.1
6	04/13/05	7.4	19	564	NS	NS	55.4	NS	NS	<25	NS	0.6	7.4	3.4	512	NS	NS	13.2	NS	NS	<25	NS	0.3
7	05/11/05	7.2	44[b]	486	NS	NS	47.6	NS	NS	<25	NS	<0.1	7.2	9.9[b]	470	NS	NS	10.2	NS	NS	<25	NS	<0.1
8	06/08/05	7.3	32	466	NS	NS	49.6	NS	NS	<25	NS	0.3	NA[a]	NA[a]	NA[a]	NS	NS	20.0	NS	NS	<25	NS	0.5
9	07/06/05	7.0	52	440	NS	NS	48.2	NS	NS	<25	NS	0.1	7.0	7.1	486	NS	NS	16.6	NS	NS	<25	NS	0.1
10	08/17/05	7.9	28	438	NS	NS	55.5	NS	NS	<25	NS	0.3	7.3	6.8	434	NS	NS	18.7	NS	NS	<25	NS	0.1
11	11/14/05	7.3	NS	430	<1	55.6	NA[c]	NA[c]	423	NA[c]	12.8	NA[c]	NA[a]	NA[a]	NA[a]	NA[a]	23.3	23.9	<0.1	58.2	<25	<0.1	<0.1
12	02/15/06	7.2	NS	420	5	68.6	59.3	9.4	273	<25	1.8	0.5	7.2	NS	422	5	33.7	36.1	<0.1	<25	<25	0.3	0.1
13	05/17/06	7.2	NS	420	16	97.3	52.8	44.5	1,456	<25	9.1	<0.1	7.2	NS	428	7	41.2	37.0	4.2	123	<25	1.0	<0.1

NA = not available; NS = not sampled; TDS = total dissolved solids; TSS = total suspended solids

(a) Insufficient sample for analysis due to loss during transit.

(b) Analyzed outside of hold time.

(c) Laboratory error.

Table 5-6. Distribution System Sampling Results

Sampling Event		DS1 Non-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	hr	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	hr	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	hr	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BL1	12/17/03[a]	12.0	7.1	387	38.5	<25	1.2	2.3	119	7.0	7.2	405	20.8	182	68.4	1.6	106	8.5	7.2	407	37.1	<25	0.3	1.3	89.7
BL2	01/06/04	14.0	8.9	411	49.3	<25	0.8	0.5	24.2	11.3	8.5	407	48.4	<25	0.6	2.4	64.0	6.0	8.2	419	49.5	<25	0.6	1.0	64.2
BL3	01/21/04	34.0	7.2	367	80.1	<25	0.2	1.2	24.0	11.0	7.2	371	57.0	<25	0.3	3.8	128	7.8	7.1	336	47.0	<25	0.3	2.1	142
BL4	02/05/04	23.0	7.1	394	52.8	46.1	0.5	0.5	31.3	9.8	7.1	406	52.2	40.2	0.2	0.8	34.4	7.0	7.1	406	52.7	47.9	0.3	1.1	121
1	07/28/04[b]	11.0	7.2	373	11.7	<25	<0.1	4.4	147	Homeowner unavailable								5.3	7.2	413	22.7	<25	0.1	2.1	107
2	08/26/04[b]	20.5	6.9	379	15.4	<25	0.3	4.8	112	10.0	6.9	395	28.5	<25	0.3	4.3	66.7	7.5	6.9	395	45.6	<25	0.3	1.4	46.7
3	09/22/04[c]	12.0	7.2	402	18.0	<25	1.3	4.4	194	10.5	6.9	373	9.3	<25	0.3	2.9	33.8	7.3	7.0	381	23.3	<25	1.8	2.4	116
4	10/20/04	19.0	6.7	406	22.9	<25	0.4	2.9	99.6	9.0	6.9	410	19.8	<25	3.0	7.0	129	6.5	7.0	394	21.3	<25	0.7	1.3	43.3
5	11/17/04	7.5	7.0	418	21.2	<25	0.4	1.4	79.5	Homeowner unavailable								6.3	7.1	418	15.6	<25	0.5	1.8	68.2
6	12/15/04[b]	9.0	7.1	370	15.0	<25	0.7	4.1	52.5	9.0	7.2	403	21.8	<25	1.1	6.6	139	9.0	7.2	394	14.4	<25	0.8	2.7	124
7	01/12/05[b,d]	9.5	7.1	408	27.1	<25	0.5	1.1	38.3	7.0	7.1	396	21.2	<25	0.7	3.9	142	8.3	7.0	360	9.9	<25	4.8	1.3	72.3
8	02/09/05[b]	9.0	7.5	392	6.0[e]	<25	<0.1	1.1	89.4	9.5	7.3	437	21.2	<25	0.1	1.6	32.4	7.5	7.3	401	15.7	<25	0.5	1.3	66.5
9	03/09/05[b]	11.0	7.3	433	26.1	<25	0.4	1.3	51.8	9.5	7.3	442	20.0	<25	3.4	3.9	147	8.5	7.2	410	15.6	<25	0.5	0.7	49.5
10	04/06/05[b]	10.0	7.6	418	20.2	<25	0.3	3.4	67.0	10.0	7.5	437	20.3	<25	0.5	2.3	47.2	8.0	7.5	410	9.9	<25	0.3	0.8	35.5
11	05/04/05[b]	6.0	7.6	404	6.5	<25	0.9	1.7	58.0	17.0	7.3	413	33.9	<25	0.8	7.3	49.0	8.3	7.4	431	20.6	<25	1.4	2.1	123
12	06/08/05[b]	10.0	7.2	405	18.0	<25	0.3	1.5	108	Homeowner unavailable								8.0	7.1	392	19.8	<25	0.2	1.0	32.6
13	07/07/05[b]	9.5	7.0	409	22.3	<25	0.2	2.4	118	17.5	6.9	427	23.6	<25	0.3	5.0	131	9.0	6.9	418	39.1	<25	0.2	1.2	42.9
14	08/09/05[b]	7.0	7.3	NA[f]	2.2	<25	<0.1	1.5	25.9	7.0	7.0	378	10.5	<25	0.2	5.2	113	8.8	6.9	414	19.6	<25	<0.1	2.0	107
15	09/14/05	6.0	6.9	418	24.8	<25	0.2	0.9	24.7	9.5	7.1	405	13.6	<25	0.2	4.3	107	7.9	7.0	418	23.4	<25	0.4	1.9	82.2
16	10/12/05[g]	11.0	7.2	383	5.9	<25	<0.1	0.4	36.1	10.0	7.3	392	17.6	<25	0.1	0.7	10.0	8.8	7.2	383	27.3	<25	<0.1	<0.1	<0.1

(a) Sample DS2 collected from nearby residence. (b) Sample DS1 collected on previous day. (c) Sample DS1 taken on 09/30/04; pH analyzed outside of hold time.
(d) Samples DS1 and DS2 switched for this event; correct results shown. (e) Rerun result similar to original result. (f) Insufficient sample for analysis.
(g) Samples DS1, DS2, and DS3 collected on 10/11/05, 10/13/05, and 10/12/05, respectively.
Lead action level = 15 µg/L; copper action level = 1.3 mg/L; BL = baseline sampling; NA = data not available

5.2.4 Spent Media Sampling. The treatment system was shut down on August 30, 2006, and spent media samples were collected from Tank A on November 8, 2006, and analyzed as discussed in Section 3.3.5. TCLP and total metals results are presented in Tables 5-7 and 5-8, respectively. The TCLP results indicated that only barium was detected at 1.5 mg/L and that the media was non-hazardous and could be disposed of in a sanitary landfill.

The ICP-MS results of the spent media indicated that the media, as expected, contained mostly iron at 569 mg/g (as Fe), or 904 mg/g (as FeOOH), which matches closely with the 90.1% (by weight) specified by Bayer AG (Table 4-3). The spent media also contained trace levels of Ca, Mg, Mn, Si, Al, and P at 3.8, 1.4, 2.0, 0.23, 0.33, and 1.5 mg/g, respectively, which, except for Mn and P, also match closely with Bayer AG's analyses. Trace amounts of Mn and P, both detected in source water, apparently were removed by the AD-33™ media, increasing the respective loadings from the baseline levels of 0.11 and 0.02% to 0.52 and 0.34%. The spent media also appeared to have removed some amounts of Cu and Pb from source water, as evidenced by the decreasing loadings from the top to the bottom of Tank A.

The arsenic loading on the spent media based on the ICP-MS results was 8.3 mg/g (average across bed from Table 5-8). For comparison to the spent media results, the adsorptive capacity was calculated by dividing the arsenic mass represented by the area between the influent and lead tank breakthrough curves, as shown in Figure 5-3a, by the amount of dry media in each tank. The dry weight of the media, i.e., 527 lb, was calculated based on a wet weight of 620 lb (i.e., 22 ft^3 of media at 28.1 lb/ft^3) and a maximum moisture content of 15% (Table 4-3). Using this approach, the arsenic loading for the spent media was 10.4 mg/g, of which 80% was recovered via ICP-MS analysis. The arsenic loading on the media in Tank B was calculated to be 4.9 mg/g, which further supported the decision to rebed only Tank A due to the remaining capacity of the media in Tank B. This value (4.9 mg/g) was close to that of 5.2 mg/g calculated for the media in Tank A at the 10-µg/L arsenic breakthrough point (as of March 30, 2005).

Table 5-7. TCLP Results of a Composite Spent Media Sample

RCRA Metal	Concentration mg/L
Arsenic	<0.10
Barium	1.5
Cadmium	<0.010
Chromium	<0.010
Lead	<0.050
Mercury	<0.0020
Selenium	<0.10
Silver	<0.010

RCRA = Resource Conservation and Recovery Act

Table 5-8. Metals' Analysis of Spent Media

Tank A Location	Mg mg/g	Al mg/g	Si mg/g	P mg/g	Ca mg/g	Fe mg/g	Mn mg/g	Ni mg/g	Cu mg/g	Zn mg/g	As mg/g	Cd mg/g	Pb mg/g	As/Fe µg/mg
Top	1.4	0.39	0.25	1.4	4.0	579	2.1	0.13	0.57	1.2	8.7	<0.0005	0.03	15.0
Middle	1.3	0.29	0.19	1.4	3.8	557	2.0	0.13	0.36	1.2	8.6	<0.0005	0.01	15.4
Bottom	1.4	0.30	0.26	1.6	3.7	570	1.9	0.13	0.11	1.3	7.8	0.00	0.00	13.7

5.3 Cost Information

5.3.1 Facility Cost. As part of the facility requirements, AWC provided an enclosure, an eye wash station, and a backwash wastewater recycling system. The total cost for the sun shed structure was $13,677, which included $3,500 for materials and $10,177 for labor to assemble the structure. The backwash recycling system cost $11,546 for material, engineering, and installation. These costs were not included in the cost analysis because they were funded separately by AWC and not included under the demonstration project.

5.3.2 System Cost. The system cost was evaluated based on the capital cost per gpm (or gpd) of design capacity and the O&M cost per 1,000 gal of water treated. The capital investment for the equipment, site engineering, and installation was $88,307 (Table 5-9). The equipment cost was $63,785 (or 72.2% of the total capital investment), which included the cost for two pressure tanks, 44 ft^3 of AD-33™ media, piping and valves, instrumentation and controls, field services (for operator training, technical support, and system shakedown), miscellaneous materials and supplies, and a change order for system reconfiguration from parallel to series operation.

Table 5-9. Capital Investment for AdEdge's APU-100 System

Description	Quantity	Cost	% of Capital Investment Cost
Equipment			
Adsorption Tanks	2	$21,800	–
AD-33™ Media	44 ft^3	$10,690	–
Piping and Valves	1	$7,520	–
Instrumentation and Controls	1	$4,575	–
O&M Manual, Operator Training, Technical Support	1	$3,800	–
Procurement, Assembly, Labor, Shakedown	1	$12,575	–
Freight	1	$1,855	–
Change Order for System Reconfiguration	1	$880	–
Equipment Total	–	**$63,785**	**72.2%**
Engineering			
Materials, Submittals, FedEx, Postage, Supplies	1	$75	–
Oversight, Specification Preparation	1	$3,420	–
Design, Drawings, Coordination	1	$4,970	–
Review Meeting, Airfare, Lodging, and Meals	1	$1,017	–
Change Order for System Reconfiguration	–	$1,890	–
Engineering Total	–	**$11,372**	**12.9%**
Installation			
Subcontractor	1	$6,750	–
Vendor Labor	4 days	$3,040	–
Vendor Travel	4 days	$1,290	–
Change Order for System Reconfiguration	–	$2,070	–
Installation Total	–	**$13,150**	**14.9%**
Total Capital Investment[(a)]	–	**$88,307**	**100%**

$11,546 for backwash recycling system not included.

The engineering cost included preparation of the engineering plans, system layout and footprint, drawings of site and piping plans, and equipment cut sheets for the permit application submittal (Section 4.3.1). The cost also included resubmission of the redesigned system layout and piping plans following reconfiguration to ADEQ for approval. The engineering cost of $11,372 was 12.9% of the total capital investment.

The installation cost included equipment and labor to unload and install the APU-100 system, perform the piping tie-ins and electrical work, load and backwash the media, and reconfigure the system (Section 4.3.2). The installation cost of $13,150 was 14.9% of the total capital investment.

The capital cost of $88,307 was normalized to $1,962/gpm ($1.36/gpd) of design capacity using the system's design capacity of 45 gpm (or 64,800 gpd). The capital cost also was converted to an annualized cost of $8,335/yr by multiplying a capital recovery factor (CRF) of 0.09439 based on a 7% interest rate and a 20-yr return period. If the system had operated for 24 hr/day, 7 day/week at the 45-gpm design flowrate to produce 23,652,000 gal/yr, the unit capital cost would have been $0.35/$1,000 gal. During the first year, the system produced approximately 8,505,000 gal of water (based on flow meter after the lead tank), so the unit capital cost increased to $0.98/1,000 gal.

5.3.3 O&M Cost. The O&M cost included media replacement and disposal, incremental chemical supply, electricity, and labor as summarized in Table 5-10. Because the system was under warranty, no additional cost was incurred for repairs. Due to the long duration of Media Run 1A, it was most cost-effective to replace the media of the lead tank only when the lag tank effluent reached 10 μg/L of arsenic. The media replacement cost of one tank was $10,908, including $5,830 for 22 ft^3 of AD-33 media (or $265/$ft^3$), $4,240 for labor, and $375 for spent media analysis, and $463 for freight.

By averaging the media replacement cost over the life of the media, the cost per 1,000 gal of water treated was calculated as shown in Figure 5-4. Note that after the partially exhausted lag tank is switched to the lead position with the newly rebedded tank in the lag position, the run length for the subsequent run will be shorter than the initial run, thus resulting in an increased replacement frequency and cost than presented in Table 5-10.

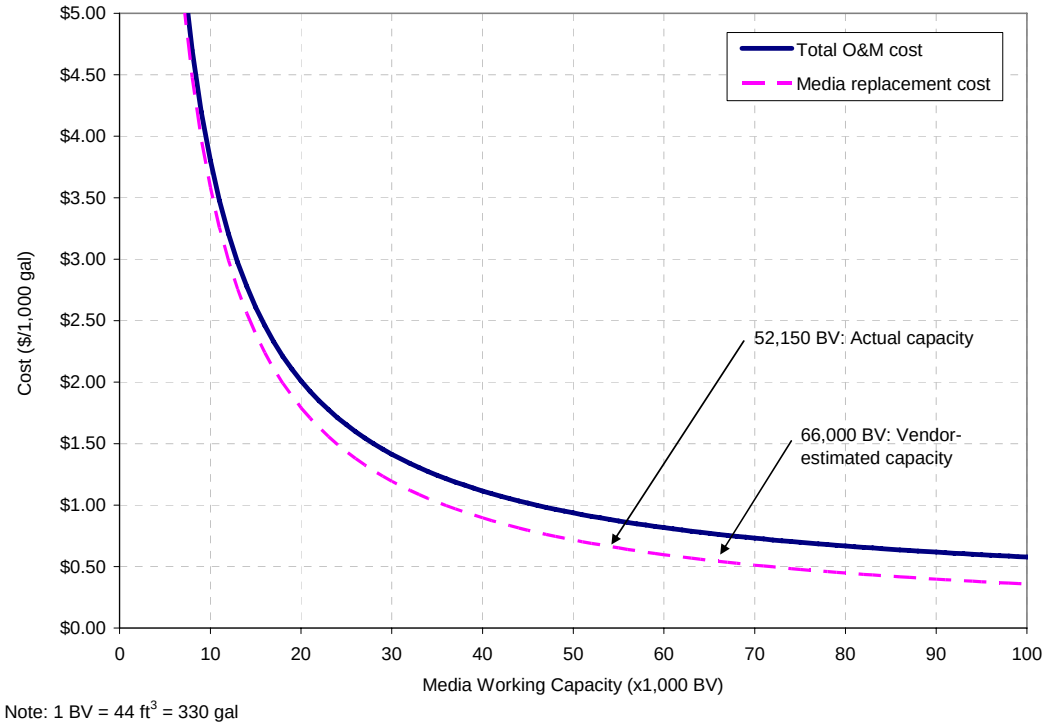
Chemical usage consisted of NaOCl, which was added to provide disinfection and residual in the distribution system. Since NaOCl was not required for the treatment process, its usage was not included in the O&M cost. Electricity consumption was approximately 2.07 kWh/day based on electric meter readings for one day (or 12 hr) of system operation (including usage from the recycle pump). Therefore, the electricity cost was $0.008/1,000 gal of water treated. The routine, non-demonstration related labor activities (Section 5.1.5.4), including preventative maintenance activities and repairs, consumed 15 to 20 min/day. Based on this time commitment and a labor rate of $21/hr, the labor cost was $0.22/1,000 gal of water treated.

By averaging the total O&M cost over the life of the media, the cost per 1,000 gal of water treated was plotted as a function of the media run length as shown in Figure 5-4. Note that the bed volumes were calculated based on the quantity of media in both tanks (i.e., 44 ft^3 or 330 gal).

Table 5-10. O&M Cost for AdEdge's APU-100 System (Run 1A)[(a)]

Cost Category	Value	Remarks
Media Replacement and Disposal		
Media Cost ($)	$5,830	$265/ft^3; 22 ft^3 for one tank
Labor Cost ($)	$4,240	
Spent Media Analysis ($)	$375	Including TCLP test
Travel ($)	$0	None
Freight ($)	$463	
Subtotal ($)	$10,908	
Media Replacement and Disposal Cost ($/1,000 gal)	$0.64	Based on 17,164,000 gal until 10-µg/L arsenic breakthrough from lag tank
Chemical Usage		
Chemical Cost ($)	$0.000	No additional chemicals required
Electricity		
Electricity Cost ($/kWh)	$0.089	Rate provided by AWC
Electricity Usage (kWh/day)	2.07	Based on 12 hr/day operation
Electricity Cost ($/1,000 gal)	$0.008	
Labor		
Labor (hr/week)	1.6	15 to 20 min/day, 5 day/week
Labor Cost ($/1,000 gal)	$0.22	Labor rate = $21/hr
Total O&M cost ($/1,000 gal)	$0.86	Based upon media run length at 10-µg/L arsenic breakthrough

(a) O&M cost based upon replacement of lead tank media only.



Note: 1 BV = 44 ft^3 = 330 gal

Figure 5-4. Media Replacement (Lead Tank) and Total O&M Cost (Run 1A)

6.0 REFERENCES

AdEdge. 2004. *Operation and Maintenance Manual, APU Adsorption Package Units for Arsenic and Heavy Metals Removal, Rimrock,Arizona (Montezuma Haven Wells)*.

AWC. 2004. *2003 Annual water Quality Report for Rimrock, Arizona PWSID# 13-046.*

AWC. 2005. *2004 Annual water Quality Report for Rimrock, Arizona PWSID# 13-046.*

AWC. 2006. *2005 Annual water Quality Report for Rimrock, Arizona PWSID# 13-046.*

Battelle. 2003. *Revised Quality Assurance Project Plan for Evaluation of Arsenic Removal Technology*. Prepared under Contract No. 68-C-00-185, Task Order No. 0019, for U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH.

Badruzzaman, M., P. Westerhoff, and D.R.U. Knappe. 2004. "Intraparticle diffusion and adsorption of arsenate onto granular ferric hydroxide (GFH)." *Water Research, 38(18)*: 4002-4012.

Chen, A.S.C., L. Wang, J.L. Oxenham, and W.E. Condit. 2004. *Capital Costs of Arsenic Removal Technologies: U.S. EPA Arsenic Removal Technology Demonstration Program Round 1*. EPA/600/R-04/201. U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH.

Edwards, M., S. Patel, L. McNeill, H. Chen, M. Frey, A.D. Eaton, R.C. Antweiler, and H.E. Taylor. 1998. "Considerations in As analysis and speciation." *J. AWWA, 90(3)*: 103-11.

EPA. 2003. Minor Clarification of the National Primary Drinking Water Regulation for Arsenic. *Federal Register*, 40 CFR Part 141.

EPA. 2002. *Lead and Copper Monitoring and Reporting Guidance for Public Water Systems*. EPA/816/R-02/009. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

EPA. 2001. National Primary Drinking Water Regulations: Arsenic and Clarifications to Compliance and New Source Contaminants Monitoring. *Federal Register*, 40 CFR Parts 9, 141, and 142.

Lin, T.F. and J.K. Wu. 2001. "Adsorption of arsenite and arsenate within activated alumina grains: Equilibrium and kinetics." *Water Research, 35(8)*: 2049-2057.

Oxenham, J.L., A.S.C. Chen, and L. Wang. 2005. *Arsenic Removal from Drinking Water by Adsorptive Media, EPA Demonstration Project at Rollinsford, NH, Six-Month Evaluation Report.* EPA/600/R-05/116. U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH.

Wang, L., W.E. Condit, and A.S.C. Chen. 2004. *Technology Selection and System Design: U.S. EPA Arsenic Removal Technology Demonstration Program Round 1*. EPA/600/R-05/001. U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Cincinnati, OH.

APPENDIX A

OPERATIONAL DATA

EPA Arsenic Demonstration Project at Rimrock, AZ - Daily System Operation Log Sheet

Date and Time	Hour Meter	Lead/Lag	Well #3	Tank A Flow Meter				Tank B Flow Meter				dP		Pressure			Recycling	
				Flowrate	Totalizer	Cum. Flow	Bed Volume	Flowrate	Totalizer	Cum. Flow	Bed Volume	TA	TB	Inlet	Between Tanks	Outlet	Flow Rate	Totalizer
	hr	A/B	On/Off	gpm	gal	gal		gpm	gal	gal		psi	psi	psig	psig	psig	gpm	gal
06/24/04 12:32	NA	A/B	NA	28	23971	NA	NA	27	23294	NA	NA	4.0	3.5	105	104	100+	0	0
06/25/04 11:30	NA	A/B	NA	33	44991	21020	128	31	44375	21081	64	5.5	5.0	98	95	92	0	0
06/28/04 09:17	NA	A/B	NA	32	108441	84470	513	32	108075	84781	258	5.5	5.0	100	96	93	0	0
06/29/04 09:19	NA	A/B	NA	29	131386	107415	653	28	130974	107680	327	4.5	4.0	105	103	100+	1.5	287
06/30/04 16:01	NA	A/B	NA	30	166117	142146	864	30	165692	142398	433	5.0	5.0	101	100	90	0	511
07/01/04 13:59	NA	A/B	NA	31	185223	161252	980	30	184858	161564	491	5.5	5.0	100	96	93	0	511
07/02/04 14:56	NA	A/B	NA	32	209871	185900	1130	31	209636	186342	566	5.5	5.0	100	96	94	0	511
07/06/04 13:30	NA	A/B	ON	29	297899	273928	1665	28	297866	274572	834	4.0	4.0	105	109	100+	0	511
07/07/04 09:00	NA	A/B	OFF	32	312011	288040	1750	33	311809	288515	877	5.5	4.5	100	95	94	0	511
07/08/04 16:32	NA	A/B	NA	32	348968	324997	1975	32	349009	325715	990	5.0	5.0	100	97	93	0	511
07/09/04 13:35	NA	A/B	NA	31	365938	341967	2078	31	366086	342792	1042	5.0	5.0	100	97	94	0	511
07/12/04 13:30	NA	A/B	NA	32	433271	409300	2487	31	433584	410290	1247	5.0	5.0	100	96	92	0	511
07/13/04 10:00	NA	A/B	NA	32	449425	425454	2585	32	449865	426571	1296	5.0	5.0	100	95	93	0	511
07/14/04 09:30	NA	A/B	NA	32	470700	446729	2715	32	471247	447953	1361	5.5	5.0	100	93	92	0	511
07/15/04 13:30	NA	A/B	ON	30	500630	476659	2897	31	500527	477233	1450	4.5	4.5	101	100	87	0.5	851
07/16/04 14:25	NA	A/B	ON	27	525019	501048	3045	27	524715	501421	1524	3.5	3.5	110	110	100+	0.5	1220
07/19/04 09:30	NA	A/B	NA	32	584077	560106	3404	33	583614	560320	1702	5.5	5.0	99	95	92	0	1290
07/20/04 08:57	NA	A/B	ON	28	605379	581408	3533	27	604867	581573	1767	4.0	3.5	102	104	104	0	1290
07/21/04 14:02	NA	A/B	NA	31	637557	613586	3729	30	637111	613817	1865	5.0	4.9	100	97	94	0	1290
07/22/04 16:12	NA	A/B	NA	32	664233	640262	3891	32	663800	640506	1946	5.0	5.0	99	95	93	0	1290
07/23/04 14:48	NA	A/B	NA	32	683833	659862	4010	31	683350	660056	2006	5.0	4.5	100	96	94	0	1290
07/26/04 09:16	NA	A/B	NA	28	740859	716888	4356	28	740026	716732	2178	4.0	4.0	102	102	101	1	1420
07/27/04 14:12	NA	A/B	NA	32	772923	748952	4551	32	772091	748797	2275	5.9	5.0	100	95	93	1	1910
07/28/04 09:46	NA	A/B	NA	33	787316	763345	4639	32	786508	763214	2319	5.5	5.0	100	95	92	0	2060
07/29/04 09:01	NA	A/B	NA	30	808295	784324	4766	30	807403	784109	2382	5.0	5.0	100	96	94	0	2060
07/30/04 16:18	NA	A/B	NA	31	844137	820166	4984	31	843320	820026	2492	5.0	5.0	100	96	94	0	2060
08/02/04 10:29	NA	A/B	NA	32	899068	875097	5318	31	898410	875116	2659	5.0	5.0	100	96	90	0	2060
08/03/04 09:27	NA	A/B	NA	32	919909	895938	5444	31	919248	895954	2722	5.0	4.5	100	96	90	0	2060
08/04/04 09:47	NA	A/B	NA	27	943057	919086	5585	26	942185	918891	2792	4.0	3.6	105	103	96	0	2060
08/05/04 08:58	NA	A/B	NA	32	963804	939833	5711	30	962970	939676	2855	5.0	5.0	100	96	90	0	2060
08/06/04 14:25	NA	A/B	NA	30	996229	972258	5908	30	995478	972184	2954	5.0	5.0	100	98	90	0	2060
08/09/04 09:45	NA	A/B	ON	26	1055151	1031180	6266	26	1054232	1030938	3132	3.6	3.6	103	104	99	0	2060
08/10/04 16:09	NA	A/B	OFF	31	1089574	1065603	6475	30	1087899	1064605	3235	5.0	5.0	100	98	90	0.5	2130
08/11/04 11:09	NA	A/B	OFF	32	1102913	1078942	6557	31	1100798	1077504	3274	5.0	5.0	100	97	90	0.5	2330
08/12/04 09:19	NA	A/B	OFF	32	1122569	1098598	6676	31	1120172	1096878	3333	5.0	5.0	100	97	90	0.5	2630
08/13/04 17:18	NA	A/B	OFF	30	1160528	1136557	6907	30	1157685	1134391	3447	5.0	5.0	100	97	90	0	2840
08/16/04 09:00	NA	A/B	ON	28	1214460	1190489	7234	26	1210860	1187566	3608	3.8	3.8	105	103	98	0	2840
08/17/04 12:00	NA	A/B	OFF	31	1240824	1216853	7395	30	1236957	1213663	3688	5.0	4.8	100	98	90	0	2840
08/18/04 09:00	NA	A/B	ON	28	1259075	1235104	7505	26	1255175	1231881	3743	3.9	3.5	105	103	97	0	2840
08/19/04 11:30	NA	A/B	ON	29	1284888	1260917	7662	29	1280719	1257425	3821	4.0	3.9	101	101	96	0	2840
08/20/04 15:34	NA	A/B	OFF	30	1315490	1291519	7848	31	1310625	1287331	3911	5.0	5.0	100	98	90	0	2840
08/23/04 10:18	NA	A/B	OFF	32	1375391	1351420	8212	31	1369612	1346318	4091	5.0	4.5	100	96	90	NA	NA
08/24/04 12:31	NA	A/B	OFF	31	1401393	1377422	8370	30	1395087	1371793	4168	5.0	4.5	100	96	90	0	2840
08/25/04 09:12	NA	A/B	OFF	31	1418118	1394147	8472	30	1411570	1388276	4218	5.0	4.5	100	97	90	0	2840
08/26/04 13:54	NA	A/B	OFF	31	1449870	1425899	8665	30	1442950	1419656	4313	5.0	4.5	100	97	89	0	2840
08/27/04 15:31	NA	A/B	OFF	31	1475337	1451366	8820	31	1468239	1444945	4390	5.0	4.6	100	97	90	0	2840

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Date and Time	Hour Meter	Lead/Lag	Well #3	Tank A Flow Meter				Tank B Flow Meter				dP		Pressure			Recycling	
				Flowrate	Totalizer	Cum. Flow	Bed Volume	Flowrate	Totalizer	Cum. Flow	Bed Volume	TA	TB	Inlet	Between Tanks	Outlet	Flow Rate	Totalizer
	hr	A/B	On/Off	gpm	gal	gal		gpm	gal	gal		psi	psi	psig	psig	psig	gpm	gal
08/30/04 16:13	NA	A/B	ON	27	1544210	1520239	9238	27	1536384	1513090	4597	4.0	4.0	104	101	106	0	2840
08/31/04 11:17	NA	A/B	OFF	31	1557388	1533417	9318	30	1549642	1526348	4638	5.0	4.7	100	97	90	0	2840
09/01/04 11:00	NA	A/B	OFF	32	1578093	1554122	9444	31	1570127	1546833	4700	5.5	4.8	100	97	90	0.5	3100
09/02/04 13:54	NA	A/B	OFF	32	1605790	1581819	9612	32	1597517	1574223	4783	5.0	5.0	100	96	89	0	3370
09/03/04 12:42	NA	A/B	OFF	30	1625872	1601901	9734	30	1617330	1594036	4843	5.0	5.0	100	97	90	0	3370
09/07/04 16:52	NA	A/B	OFF	30	1723558	1699587	10328	29	1714199	1690905	5138	5.0	5.0	100	97	90	0	3370
09/08/04 10:57	NA	A/B	OFF	31	1734996	1711025	10398	31	1725572	1702278	5172	5.0	5.0	100	97	90	0	3370
09/09/04 17:29	NA	A/B	OFF	31	1769316	1745345	10606	31	1759727	1736433	5276	5.0	5.0	100	97	90	0	3370
09/10/04 16:45	NA	A/B	OFF	31	1790558	1766587	10735	31	1780911	1757617	5340	5.0	5.0	100	96	90	0	3370
09/13/04 09:43	NA	A/B	ON	27	1844869	1820898	11065	27	1835049	1811755	5505	3.9	3.5	102	103	99	0	3370
09/14/04 09:30	NA	A/B	OFF	32	1867121	1843150	11200	31	1857243	1833949	5572	5.1	5.0	100	95	89	0	3370
09/15/04 09:30	NA	A/B	OFF	31	1889587	1865616	11337	33	1879663	1856369	5640	5.1	5.0	100	95	90	0	3370
09/16/04 08:22	NA	A/B	OFF	31	1911446	1887475	11470	31	1901462	1878168	5707	5.5	5.0	100	96	90	0	3370
09/17/04 13:30	NA	A/B	OFF	31	1944096	1920125	11668	31	1933954	1910660	5805	5.1	5.0	100	95	90	0	3370
09/20/04 13:00	NA	A/B	OFF	31	2011723	1987752	12079	30	2001410	1978116	6010	5.0	4.9	100	96	91	0	3370
09/21/04 10:00	NA	A/B	OFF	31	2029216	2005245	12185	30	2018904	1995610	6063	5.0	4.9	100	96	91	0	3370
09/22/04 10:00	NA	A/B	OFF	31	2050996	2027025	12318	30	2040690	2017396	6130	5.0	4.9	100	96	91	0	3370
09/23/04 09:00	NA	A/B	OFF	31	2074455	2050484	12460	30	2064162	2040868	6201	5.0	4.9	100	96	91	0	3370
09/24/04 11:30	NA	A/B	OFF	31	2101154	2077183	12623	30	2090817	2067523	6282	4.9	4.8	100	97	91	0	3370
09/27/04 10:00	NA	A/B	OFF	32	2167484	2143513	13026	32	2156478	2133184	6481	5.0	4.8	100	96	91	0.5	3630
09/28/04 11:34	NA	A/B	OFF	31	2192360	2168389	13177	31	2181238	2157944	6557	5.0	5.0	100	97	91	0.5	4010
09/29/04 15:10	NA	A/B	OFF	31	2221335	2197364	13353	31	2210018	2186724	6644	5.0	5.0	100	96	90	0.4	4452
09/30/04 11:16	NA	A/B	OFF	31	2236812	2212841	13447	32	2225389	2202095	6691	5.0	5.0	100	97	91	0.5	4690
10/01/04 13:43	NA	A/B	OFF	31	2264087	2240116	13613	30	2252590	2229296	6774	5.0	5.0	100	97	90	0	4849
10/05/04 10:42	NA	A/B	OFF	32	2348918	2324947	14128	31	2337120	2313826	7030	5.0	5.0	100	96	90	0	4849
10/06/04 17:31	NA	A/B	ON	29	2383918	2359947	14341	30	2372015	2348721	7136	4.9	4.9	102	100	95	0	4849
10/07/04 10:54	NA	A/B	OFF	32	2394302	2370331	14404	31	2382373	2359079	7168	5.2	5.0	100	96	89	0	4849
10/08/04 11:38	NA	A/B	OFF	31	2417168	2393197	14543	29	2405125	2381831	7237	5.5	5.0	100	96	89	0	4849
10/12/04 17:29	NA	A/B	ON	27	2515357	2491386	15140	27	2502458	2479164	7533	4.0	3.5	102	104	99	0	4849
10/13/04 17:41	NA	A/B	ON	26	2538203	2514232	15279	26	2525203	2501909	7602	3.5	3.5	104	107	104	0	4849
10/14/04 18:20	NA	A/B	ON	26	2561400	2537429	15419	27	2548271	2524977	7672	4.0	4.0	103	105	100	0	4849
10/18/04 14:49	NA	A/B	OFF	31	2644969	2620998	15927	31	2631513	2608219	7925	5.0	4.6	100	98	92	0	4849
10/19/04 15:01	NA	A/B	OFF	31	2667528	2643557	16064	32	2654020	2630726	7993	5.1	5.0	100	97	91	0	4849
10/20/04 10:35	NA	A/B	OFF	31	2682128	2658157	16153	31	2667888	2644594	8035	5.1	4.9	100	97	91	0.5	4870
10/22/04 12:02	NA	A/B	OFF	32	2730730	2706759	16448	28	2716319	2693025	8183	5.0	5.0	100	97	91	0.5	5621
10/25/04 10:46	NA	A/B	OFF	31	2796639	2772668	16849	31	2781672	2758378	8381	5.0	5.0	100	96	100	0	6323
10/26/04 15:02	NA	A/B	OFF	31	2827402	2803431	17036	32	2811839	2788545	8473	5.4	5.0	100	97	90	0	6323
10/27/04 10:00	NA	A/B	OFF	31	2840201	2816230	17114	30	2824366	2801072	8511	5.0	5.0	100	96	90	0	6323
10/28/04 10:32	NA	A/B	ON	27	2864858	2840887	17264	29	2848575	2825281	8584	4.0	3.6	109	105	100	0	6323
10/29/04 14:18	NA	A/B	OFF	32	2895024	2871053	17447	31	2878185	2854891	8674	4.6	4.6	100	98	93	0	6323
11/01/04 15:10	NA	A/B	OFF	31	2966104	2942133	17879	32	2948057	2924763	8887	5.5	5.1	100	96	90	0	6327
11/02/04 11:50	NA	A/B	ON	29	2982700	2958729	17980	29	2964350	2941056	8936	4.0	4.0	105	101	96	0	6327
11/03/04 09:45	NA	A/B	OFF	31	3002182	2978211	18098	32	2983630	2960336	8995	5.1	5.0	100	98	98	0	6327
11/04/04 14:56	3.2	A/B	OFF	32	3033540	3009569	18289	32	3014434	2991140	9088	5.0	5.0	100	98	99	0	6327
11/05/04 12:36	12.8	A/B	OFF	32	3052755	3028784	18405	30	3033038	3009744	9145	5.1	5.0	100	97	98	0	6327

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Date and Time	Hour Meter	Lead/Lag	Well #3	Tank A Flow Meter				Tank B Flow Meter				dP		Pressure			Recycling	
				Flowrate	Totalizer	Cum. Flow	Bed Volume	Flowrate	Totalizer	Cum. Flow	Bed Volume	TA	TB	Inlet	Between Tanks	Outlet	Flow Rate	Totalizer
	hr	A/B	On/Off	gpm	gal	gal		gpm	gal	gal		psi	psi	psig	psig	psig	gpm	gal
08/30/04 16:13	NA	A/B	ON	27	1544210	1520239	9238	27	1536384	1513090	4597	4.0	4.0	104	101	106	0	2840
08/31/04 11:17	NA	A/B	OFF	31	1557388	1533417	9318	30	1549642	1526348	4638	5.0	4.7	100	97	90	0	2840
09/01/04 11:00	NA	A/B	OFF	32	1578093	1554122	9444	31	1570127	1546833	4700	5.5	4.8	100	97	90	0.5	3100
09/02/04 13:54	NA	A/B	OFF	32	1605790	1581819	9612	32	1597517	1574223	4783	5.0	5.0	100	96	89	0	3370
09/03/04 12:42	NA	A/B	OFF	30	1625872	1601901	9734	30	1617330	1594036	4843	5.0	5.0	100	97	90	0	3370
09/07/04 16:52	NA	A/B	OFF	30	1723558	1699587	10328	29	1714199	1690905	5138	5.0	5.0	100	97	90	0	3370
09/08/04 10:57	NA	A/B	OFF	31	1734996	1711025	10398	31	1725572	1702278	5172	5.0	5.0	100	97	90	0	3370
09/09/04 17:29	NA	A/B	OFF	31	1769316	1745345	10606	31	1759727	1736433	5276	5.0	5.0	100	97	90	0	3370
09/10/04 16:45	NA	A/B	OFF	31	1790558	1766587	10735	31	1780911	1757617	5340	5.0	5.0	100	96	90	0	3370
09/13/04 09:43	NA	A/B	ON	27	1844869	1820898	11065	27	1835049	1811755	5505	3.9	3.5	102	103	99	0	3370
09/14/04 09:30	NA	A/B	OFF	32	1867121	1843150	11200	31	1857243	1833949	5572	5.1	5.0	100	95	89	0	3370
09/15/04 09:30	NA	A/B	OFF	31	1889587	1865616	11337	33	1879663	1856369	5640	5.1	5.0	100	95	90	0	3370
09/16/04 08:22	NA	A/B	OFF	31	1911446	1887475	11470	31	1901462	1878168	5707	5.5	5.0	100	96	90	0	3370
09/17/04 13:30	NA	A/B	OFF	31	1944096	1920125	11668	31	1933954	1910660	5805	5.1	5.0	100	95	90	0	3370
09/20/04 13:00	NA	A/B	OFF	31	2011723	1987752	12079	30	2001410	1978116	6010	5.0	4.9	100	96	91	0	3370
09/21/04 10:00	NA	A/B	OFF	31	2029216	2005245	12185	30	2018904	1995610	6063	5.0	4.9	100	96	91	0	3370
09/22/04 10:00	NA	A/B	OFF	31	2050996	2027025	12318	30	2040690	2017396	6130	5.0	4.9	100	96	91	0	3370
09/23/04 09:00	NA	A/B	OFF	31	2074455	2050484	12460	30	2064162	2040868	6201	5.0	4.9	100	96	91	0	3370
09/24/04 11:30	NA	A/B	OFF	31	2101154	2077183	12623	30	2090817	2067523	6282	4.9	4.8	100	97	91	0	3370
09/27/04 10:00	NA	A/B	OFF	32	2167484	2143513	13026	32	2156478	2133184	6481	5.0	4.8	100	96	91	0.5	3630
09/28/04 11:34	NA	A/B	OFF	31	2192360	2168389	13177	31	2181238	2157944	6557	5.0	5.0	100	97	91	0.5	4010
09/29/04 15:10	NA	A/B	OFF	31	2221335	2197364	13353	31	2210018	2186724	6644	5.0	5.0	100	96	90	0.4	4452
09/30/04 11:16	NA	A/B	OFF	31	2236812	2212841	13447	32	2225389	2202095	6691	5.0	5.0	100	97	91	0.5	4690
10/01/04 13:43	NA	A/B	OFF	31	2264087	2240116	13613	30	2252590	2229296	6774	5.0	5.0	100	97	90	0	4849
10/05/04 10:42	NA	A/B	OFF	32	2348918	2324947	14128	31	2337120	2313826	7030	5.0	5.0	100	96	90	0	4849
10/06/04 17:31	NA	A/B	ON	29	2383918	2359947	14341	30	2372015	2348721	7136	4.9	4.9	102	100	95	0	4849
10/07/04 10:54	NA	A/B	OFF	32	2394302	2370331	14404	31	2382373	2359079	7168	5.2	5.0	100	96	89	0	4849
10/08/04 11:38	NA	A/B	OFF	31	2417168	2393197	14543	29	2405125	2381831	7237	5.5	5.0	100	96	89	0	4849
10/12/04 17:29	NA	A/B	ON	27	2515357	2491386	15140	27	2502458	2479164	7533	4.0	3.5	102	104	99	0	4849
10/13/04 17:41	NA	A/B	ON	26	2538203	2514232	15279	26	2525203	2501909	7602	3.5	3.5	104	107	104	0	4849
10/14/04 18:20	NA	A/B	ON	26	2561400	2537429	15419	27	2548271	2524977	7672	4.0	4.0	103	105	100	0	4849
10/18/04 14:49	NA	A/B	OFF	31	2644969	2620998	15927	31	2631513	2608219	7925	5.0	4.6	100	98	92	0	4849
10/19/04 15:01	NA	A/B	OFF	31	2667528	2643557	16064	32	2654020	2630726	7993	5.1	5.0	100	97	91	0	4849
10/20/04 10:35	NA	A/B	OFF	31	2682128	2658157	16153	31	2667888	2644594	8035	5.1	4.9	100	97	91	0.5	4870
10/22/04 12:02	NA	A/B	OFF	32	2730730	2706759	16448	28	2716319	2693025	8183	5.0	5.0	100	97	91	0.5	5621
10/25/04 10:46	NA	A/B	OFF	31	2796639	2772668	16849	31	2781672	2758378	8381	5.0	5.0	100	96	100	0	6323
10/26/04 15:02	NA	A/B	OFF	31	2827402	2803431	17036	32	2811839	2788545	8473	5.4	5.0	100	97	90	0	6323
10/27/04 10:00	NA	A/B	OFF	31	2840201	2816230	17114	30	2824366	2801072	8511	5.0	5.0	100	96	90	0	6323
10/28/04 10:32	NA	A/B	ON	27	2864858	2840887	17264	29	2848575	2825281	8584	4.0	3.6	109	105	100	0	6323
10/29/04 14:18	NA	A/B	OFF	32	2895024	2871053	17447	31	2878185	2854891	8674	4.6	4.6	100	98	93	0	6323
11/01/04 15:10	NA	A/B	OFF	31	2966104	2942133	17879	32	2948057	2924763	8887	5.5	5.1	100	96	90	0	6327
11/02/04 11:50	NA	A/B	ON	29	2982700	2958729	17980	29	2964350	2941056	8936	4.0	4.0	105	101	96	0	6327
11/03/04 09:45	NA	A/B	OFF	31	3002182	2978211	18098	32	2983630	2960336	8995	5.1	5.0	100	98	98	0	6327
11/04/04 14:56	3.2	A/B	OFF	32	3033540	3009569	18289	32	3014434	2991140	9088	5.0	5.0	100	98	99	0	6327
11/05/04 12:36	12.8	A/B	OFF	32	3052755	3028784	18405	30	3033038	3009744	9145	5.1	5.0	100	97	98	0	6327
11/08/04 11:09	47.1	A/B	OFF	33	3120094	3096123	18815	31	3099099	3075805	9346	5.5	5.0	100	98	99	0	6330

EPA Arsenic Demonstration Project at Rimrock, AZ - Daily System Operation Log Sheet

Date and Time	Hour Meter	Lead/Lag	Well #3	Tank A Flow Meter				Tank B Flow Meter				dP		Pressure			Recycling	
				Flowrate	Totalizer	Cum. Flow	Bed Volume	Flowrate	Totalizer	Cum. Flow	Bed Volume	TA	TB	Inlet	Between Tanks	Outlet	Flow Rate	Totalizer
	hr	A/B	On/Off	gpm	gal	gal		gpm	gal	gal		psi	psi	psig	psig	psig	gpm	gal
11/09/04 11:19	59.9	A/B	OFF	32	3143725	3119754	18958	31	3122431	3099137	9416	5.5	5.0	100	97	98	0	6330
11/10/04 16:57	77.7	A/B	OFF	32	3177995	3154024	19166	32	3156140	3132846	9519	5.5	5.0	101	96	98	0	6330
11/12/04 17:15	102.0	A/B	OFF	31	3225113	3201142	19453	33	3202655	3179361	9660	5.5	5.0	100	96	97	0	6330
11/15/04 18:03	139.1	A/B	OFF	30	3296170	3272199	19885	33	3272583	3249289	9873	5.0	5.0	101	99	100	0.5	6451
11/16/04 10:12	143.6	A/B	OFF	32	3304356	3280385	19934	31	3280723	3257429	9897	5.9	5.1	100	97	97	0.5	6565
11/17/04 09:46	154.6	A/B	OFF	32	3326877	3302906	20071	28	3303126	3279832	9965	5.5	5.0	101	98	99	0.5	6913
11/18/04 14:49	172.0	A/B	OFF	32	3359732	3335761	20271	33	3335681	3312387	10064	5.9	5.0	101	97	97	0.5	7406
11/19/04 15:40	184.7	A/B	OFF	31	3384711	3360740	20423	32	3360410	3337116	10140	5.5	5.0	101	99	99	0.5	7784
11/22/04 09:38	215.2	A/B	OFF	32	3443037	3419066	20777	30	3418182	3394888	10315	5.6	5.1	100	97	99	0	7905
11/23/04 10:00	227.7	A/B	OFF	33	3466574	3442603	20920	33	3441496	3418202	10386	5.5	5.0	101	98	98	0	7905
11/24/04 14:11	240.7	A/B	OFF	31	3492632	3468661	21078	31	3467298	3444004	10464	5.5	5.0	101	97	98	0	7905
11/29/04 10:14	299.1	A/B	OFF	30	3605433	3581462	21764	30	3579122	3555828	10804	6.0	5.0	122*	97	115	0	7908
11/30/04 10:47	310.1	A/B	OFF	31	3629181	3605210	21908	32	3602681	3579387	10876	5.5	5.0	NA	98	NA	0	7908
12/01/04 10:58	NA	A/B	OFF	32	3652572	3628601	22050	33	3625889	3602595	10946	5.4	5.0	NA	97	NA	0	7908
12/06/04 09:35	382.5	A/B	OFF	33	3766441	3742470	22742	33	3738862	3715568	11289	5.5	5.5	NA	96	NA	0	7908
12/07/04 09:15	394.4	A/B	OFF	33	3788938	3764967	22879	31	3761091	3737797	11357	5.5	5.0	NA	97	NA	0	7908
12/08/04 10:04	406.7	A/B	OFF	31	3813731	3789760	23030	32	3785617	3762323	11431	5.5	5.0	NA	97	NA	0	7908
12/09/04 09:32	418.3	A/B	OFF	33	3835866	3811895	23164	33	3807480	3784186	11498	5.5	5.3	NA	97	NA	0	7908
12/10/04 14:00	432.1	A/B	OFF	33	3863117	3839146	23330	31	3834341	3811047	11580	6.5	5.5	NA	97	NA	0	7908
12/13/04 08:15	NA	A/B	OFF	33	3927415	3903444	23720	34	3897613	3874319	11772	5.5	5.0	NA	98	NA	0	7908
12/14/04 14:00	NA	A/B	OFF	33	3957724	3933753	23905	33	3927319	3904025	11862	5.5	5.1	NA	98	NA	0	7908
12/15/04 17:00	492.2	A/B	OFF	NA	3982673	3958702	24056	NA	3950999	3927705	11934	NA	NA	NA	85	NA	0	23
12/16/04 15:13	505.2	A/B	OFF	33	4008571	3984600	24214	31	3976384	3953090	12011	6.0	5.5	NA	97	NA	0.5	403
12/17/04 16:39	517.1	A/B	OFF	NA	4032260	4008289	24358	NA	3999641	3976347	12082	NA	NA	NA	NA	NA	NA	751
12/20/04 17:14	552.8	A/B	OFF	NA	4103115	4079144	24788	NA	4068989	4045695	12292	NA	NA	NA	NA	NA	0	1610
12/21/04 09:24	NA	A/B	OFF	32	4122253	4098282	24904	33	4087888	4064594	12350	5.5	5.0	NA	97	NA	0	1610
12/22/04 15:02	NA	A/B	OFF	NA	4149825	4125854	25072	NA	4114985	4091691	12432	NA	NA	NA	NA	NA	0	1610
12/27/04 15:15	636.0	A/B	OFF	NA	4266102	4242131	25779	NA	4229848	4206554	12781	NA	NA	NA	NA	NA	0	1610
12/28/04 10:05	NA	A/B	OFF	32	4286326	4262355	25902	31	4249930	4226636	12842	5.5	5.1	NA	97	NA	0	1610
12/29/04 14:33	659.8	A/B	ON	NA	4312023	4288052	26058	NA	4275421	4252127	12920	NA	NA	NA	NA	NA	0	1610
12/31/04 11:01	683.1	A/B	OFF	33	4357919	4333948	26337	31	4321069	4297775	13058	5.5	5.1	NA	97	NA	0	1610
01/03/05 11:07	718.8	A/B	OFF	32	4427087	4403116	26757	30	4389855	4366561	13267	5.5	5.1	NA	98	NA	0	1612
01/04/05 09:34	729.4	A/B	OFF	33	4447210	4423239	26879	30	4409801	4386507	13328	5.9	5.2	NA	97	NA	0	1615
01/06/05 11:26	755.4	A/B	OFF		4497385	4473414	27184	31	4459637	4436343	13479	5.9	5.1	NA	97	NA	0	1615
01/10/05 10:27	NA	A/B	OFF	32	4588277	4564306	27736	33	4549897	4526603	13754	5.5	5.0	NA	97	NA	0	1615
01/11/05 10:08	813.2	A/B	OFF	33	4590667	4566696	27751	33	4552270	4528976	13761	6.0	5.5	NA	97	NA	0	1615
01/12/05 08:59	823.8	A/B	OFF	34	4612117	4588146	27881	33	4573178	4549884	13824	5.9	5.4	NA	97	NA	0	1615
01/14/05 16:49	879.6	A/B	OFF	31	4723345	4699374	28557	33	4681745	4658451	14154	6.0	5.5	104	97	88	0	1615
01/17/05 11:56	915.7	A/B	OFF	NA	4795278	4771307	28994	NA	4751893	4728599	14367	NA	NA	NA	NA	NA	0	1615
01/18/05 09:19	925.5	A/B	OFF	33	4814502	4790531	29111	31	4770599	4747305	14424	5.9	5.4	103	88	88	0	1615
01/19/05 12:45	939.7	A/B	OFF	34	4842508	4818537	29281	33	4797759	4774465	14507	6.0	5.5	103	94	88	0.5	1668
01/24/05 09:53	975.2	A/B	OFF	34	4914174	4890203	29717	34	4868118	4844824	14721	6.0	5.4	104	98	88	0.5	2704
01/25/05 08:58	986.1	A/B	OFF	33	4935926	4911955	29849	33	4889629	4866335	14786	6.0	5.5	104	98	88	0.5	3036
01/26/05 11:05	1000.0	A/B	OFF	34	4964184	4940213	30021	32	4917217	4893923	14870	6.0	5.1	104	96	88	0.5	3440
01/27/05 10:14	1011.1	A/B	ON	29	4986039	4962068	30154	28	4938853	4915559	14935	5.0	4.4	107	100	93	0.5	3764
01/28/05 15:08	1028.1	A/B	OFF	NA	5019189	4995218	30355	NA	4971767	4948473	15035	NA	NA	NA	NA	NA	0	4055

EPA Arsenic Demonstration Project at Rimrock, AZ - Daily System Operation Log Sheet

Date and Time	Hour Meter	Lead/Lag	Well #3	Tank A Flow Meter				Tank B Flow Meter				dP		Pressure			Recycling	
				Flowrate	Totalizer	Cum. Flow	Bed Volume	Flowrate	Totalizer	Cum. Flow	Bed Volume	TA	TB	Inlet	Between Tanks	Outlet	Flow Rate	Totalizer
	hr	A/B	On/Off	gpm	gal	gal		gpm	gal	gal		psi	psi	psig	psig	psig	gpm	gal
01/31/05 09:55	1062.3	A/B	OFF	32	5086168	5062197	30762	32	5038276	5014982	15238	5.5	5.2	104	97	88	0	4055
02/01/05 16:00	1075.6	A/B	OFF	NA	5112646	5088675	30923	NA	5064534	5041240	15317	NA	NA	NA	NA	NA	0	4055
02/02/05 11:20	1087.5	A/B	OFF	33	5135971	5112000	31065	33	5087715	5064421	15388	5.5	5.1	103	97	88	0	4055
02/03/05 08:45	1096.8	A/B	ON	29	5153884	5129913	31174	29	5105543	5082249	15442	4.5	4.1	107	102	94	0	4055
02/04/05 16:16	1111.3	A/B	OFF	NA	5182326	5158355	31346	NA	5133796	5110502	15528	NA	NA	NA	NA	NA	0	4055
02/07/05 10:53	1146.5	A/B	OFF	25	5251055	5227084	31764	24	5202212	5178918	15736	3.2	3.5	96	83	86	0	4055
02/08/05 10:47	1170.2	A/B	OFF	32	5297104	5273133	32044	31	5248015	5224721	15875	5.0	5.0	100	99	89	0	4055
02/09/05 10:05	1181.5	A/B	OFF	32	5318931	5294960	32176	32	5269749	5246455	15941	5.5	5.1	104	98	89	0	4055
02/10/05 09:00	1192.6	A/B	OFF	33	5340324	5316353	32306	32	5291091	5267797	16006	5.5	5.3	104	98	90	0	4055
02/11/05 11:08	1206.2	A/B	OFF	32	5367723	5343752	32473	34	5318390	5295096	16089	5.5	5.0	104	98	89	0	4055
02/15/05 10:35	1254.2	A/B	OFF	32	5462717	5438746	33050	32	5412813	5389519	16376	5.5	5.0	104	98	89	0	4060
02/16/05 11:05	1265.8	A/B	OFF	33	5486396	5462425	33194	32	5435484	5412190	16444	6.0	5.1	104	96	89	0.5	4117
02/17/05 10:33	1277.8	A/B	OFF	33	5510522	5486551	33341	31	5459325	5436031	16517	6.0	5.5	104	96	88	0.5	4468
02/18/05 11:54	1290.7	A/B	OFF	32	5513120	5489149	33357	32	5461900	5438606	16525	5.9	5.1	104	99	110	0.5	4839
02/22/05 10:17	1337.2	A/B	OFF	33	5606998	5583027	33927	32	5553239	5529945	16802	5.5	5.0	104	98	88	0	5694
02/23/05 10:09	1349.1	A/B	OFF	33	5630977	5607006	34073	33	5576539	5553245	16873	5.5	5.1	104	96	88	0	5694
02/24/05 09:06	1359.9	A/B	OFF	33	5652469	5628498	34203	29	5597591	5574297	16937	5.5	5.0	104	98	88	0	5694
02/25/05 16:46	1374.0	A/B	ON	NA	5681376	5657405	34379	NA	5625653	5602359	17022	NA	NA	NA	NA	NA	0	5694
02/28/05 08:58	1407.3	A/B	OFF	34	5748368	5724397	34786	34	5690798	5667504	17220	5.8	5.3	104	98	88	0	5694
03/02/05 09:24	1431.3	A/B	OFF	35	5797131	5773160	35082	34	5738226	5714932	17364	5.8	5.4	104	99	88	0	5694
03/03/05 11:05	1445.5	A/B	OFF	33	5825380	5801409	35254	35	5765640	5742346	17448	5.9	5.5	104	97	88	0	5694
03/04/05 15:05	1457.7	A/B	ON	NA	5850439	5826468	35406	NA	5789651	5766357	17521	NA	NA	NA	NA	NA	0	5694
03/07/05 09:31	1491.4	A/B	OFF	34	5919211	5895240	35824	32	5855916	5832622	17722	5.9	5.5	104	97	88	0	5894
03/08/05 15:26	1505.2	A/B	OFF	NA	5947481	5923510	35996	NA	5883084	5859790	17804	NA	NA	NA	NA	NA	0	5894
03/09/05 15:59	1517.1	A/B	OFF	NA	5971533	5947562	36142	NA	5906386	5883092	17875	NA	NA	NA	NA	NA	0	5894
03/10/05 08:39	1526.3	A/B	OFF	32	5989742	5965771	36253	32	5924129	5900835	17929	5.9	5.5	105	89	84	0	5894
03/11/05 14:26	1540.9	A/B	ON	NA	6020129	5996158	36438	NA	5953383	5930089	18018	NA	NA	NA	NA	NA	0	5894
03/14/05 09:30	1574.9	A/B	OFF	32	6088744	6064773	36854	33	6019922	5996628	18220	5.9	5.5	105	98	90	0	5894
03/15/05 10:50	1588.0	A/B	OFF	34	6115750	6091779	37019	33	6045938	6022644	18299	5.9	5.5	104	97	90	0	5894
03/16/05 08:00	1597.0	A/B	ON	31	6133650	6109679	37127	29	6063495	6040201	18353	5.0	5.0	106	98	90	0	5894
03/17/05 08:46	1609.4	A/B	OFF	33	6159461	6135490	37284	32	6087891	6064597	18427	6.0	5.8	104	97	89	0.5	6021
03/18/05 17:02	1623.9	A/B	OFF	NA	6189230	6165259	37465	NA	6116938	6093644	18515	NA	NA	NA	NA	NA	0	6447
03/21/05 10:12	1658.4	A/B	OFF	34	6259086	6235115	37890	33	6185027	6161733	18722	5.6	5.2	104	88	89	0	7328
03/22/05 09:40	1669.7	A/B	OFF	32	6281871	6257900	38028	32	6207279	6183985	18789	5.9	5.5	104	89	89	0	7328
03/23/05 11:21	1683.3	A/B	OFF	33	6309100	6285129	38194	31	6233889	6210595	18870	5.9	5.5	104	89	89	0	7328
03/24/05 16:40	1695.2	A/B	OFF	NA	6333095	6309124	38339	NA	6257541	6234247	18942	NA	NA	NA	NA	NA	0	7328
03/25/05 14:06	1707.1	A/B	OFF	NA	6356848	6332877	38484	NA	6280886	6257592	19013	NA	NA	NA	NA	NA	0	7328
03/28/05 15:35	1742.8	A/B	OFF	NA	6427387	6403416	38912	NA	6350621	6327327	19225	NA	NA	NA	NA	NA	0	7328
03/29/05 09:26	1752.6	A/B	OFF	32	6446729	6422758	39030	34	6369758	6346464	19283	6.0	5.5	104	98	88	0	7328
03/30/05 10:19	1765.5	A/B	OFF	33	6472133	6448162	39184	33	6394797	6371503	19359	5.8	5.5	104	98	89	0	7328
03/31/05 09:16	1776.3	A/B	OFF	31	6493593	6469622	39315	30	6415987	6392693	19424	4.9	4.5	108	102	93	0	7328
04/04/05 11:19	1826.0	A/B	OFF	32	6592527	6568556	39916	33	6513805	6490511	19721	5.9	5.2	104	98	89	0	7328
04/05/05 10:48	1837.2	A/B	OFF	33	6615187	6591216	40054	33	6536228	6512934	19789	5.9	5.2	104	97	89	0	7328
04/06/05 15:36	1849.8	A/B	OFF	NA	6640145	6616174	40205	NA	6560887	6537593	19864	NA	NA	NA	NA	NA	0	7328
04/07/05 16:29	1861.7	A/B	OFF	NA	6663770	6639799	40349	NA	6584247	6560953	19935	NA	NA	NA	NA	NA	0	7328
04/08/05 14:17	1868.7	A/B	OFF	33	6677708	6653737	40434	33	6598005	6574711	19977	5.8	5.5	105	97	88	0	7328

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Date and Time	Hour Meter	Lead/Lag	Well #3	Tank A Flow Meter				Tank B Flow Meter				dP		Pressure			Recycling	
				Flowrate	Totalizer	Cum. Flow	Bed Volume	Flowrate	Totalizer	Cum. Flow	Bed Volume	TA	TB	Inlet	Between Tanks	Outlet	Flow Rate	Totalizer
	hr	A/B	On/Off	gpm	gal	gal		gpm	gal	gal		psi	psi	psig	psig	psig	gpm	gal
04/11/05 11:14	1902.2	A/B	OFF	36	6744490	6720519	40839	34	6663930	6640636	20177	5.9	5.5	104	97	89	0	7328
04/12/05 11:45	1915.1	A/B	OFF	35	6769857	6745886	40993	34	6688978	6665684	20253	6.0	5.8	105	97	90	0	7328
04/13/05 07:30	1922.8	A/B	OFF	34	6785197	6761226	41087	33	6704130	6680836	20299	6.0	5.8	105	97	90	0	7328
04/14/05 11:00	1938.5	A/B	OFF	34	6817030	6793059	41280	32	6734745	6711451	20392	6.0	5.5	105	97	90	0.5	7710
04/15/05 09:45	1949.2	A/B	OFF	34	6838395	6814424	41410	33	6755800	6732506	20456	6.0	5.5	105	98	90	0.5	8022
04/18/05 14:30	1990.8	A/B	ON	30	6921707	6897736	41916	30	6837851	6814557	20705	5.0	5.0	107	101	93	0	8931
04/20/05 11:31	2012.3	A/B	ON	31	6963999	6940028	42173	30	6879575	6856281	20832	5.0	4.9	107	101	93	0	8931
04/21/05 12:09	2020.1	A/B	OFF	33	6979520	6955549	42268	33	6894870	6871576	20879	6.0	5.5	104	97	89	0	8931
04/22/05 14:36	2034.7	A/B	OFF	34	7008297	6984326	42442	33	6923246	6899952	20965	5.9	5.5	104	97	89	0	8931
04/25/05 13:45	2070.3	A/B	OFF	34	7079621	7055650	42876	33	6993594	6970300	21179	5.9	5.5	105	97	89	0	8931
04/26/05 16:45	2085.7	A/B	OFF	33	7110054	7086083	43061	32	7023634	7000340	21270	6.0	5.5	105	97	89	0	8931
04/27/05 10:32	2091.2	A/B	OFF	33	7121605	7097634	43131	33	7035028	7011734	21304	5.9	5.4	105	98	89	0	8931
04/28/05 09:36	2102.9	A/B	OFF	33	7143856	7119885	43266	34	7056963	7033669	21371	5.9	5.2	105	98	89	0	8931
04/29/05 16:32	2122.1	A/B	ON	30	7182069	7158098	43498	30	7094744	7071450	21486	5.0	4.5	108	101	95	0	8931
05/02/05 13:48	2155.9	A/B	ON	30	7249253	7225282	43907	31	7160993	7137699	21687	4.6	4.4	108	103	95	0	8931
05/03/05 13:17	2167.7	A/B	OFF	34	7271983	7248012	44045	34	7183391	7160097	21755	6.0	5.6	104	98	88	0	8931
05/04/05 09:30	2176.0	A/B	ON	30	7288280	7264309	44144	30	7199462	7176168	21804	5.0	5.0	108	102	93	0	8931
05/05/05 13:31	2191.3	A/B	ON	31	7319966	7295995	44336	30	7230715	7207421	21899	5.0	4.5	108	101	93	0	8931
05/06/05 14:43	2205.7	A/B	OFF	34	7346749	7322778	44499	31	7257140	7233846	21979	6.0	5.5	104	98	89	0	8931
05/09/05 09:29	2237.0	A/B	ON	31	7408975	7385004	44877	30	7318530	7295236	22166	5.0	4.6	108	102	95	0	8931
05/10/05 10:28	2250.3	A/B	OFF	34	7434485	7410514	45032	31	7343756	7320462	22243	5.9	5.4	105	97	90	0	8931
05/11/05 08:30	2260.4	A/B	ON	31	7454512	7430541	45154	31	7363585	7340291	22303	5.0	4.8	108	102	95	0	8931
05/12/05 08:00	2272.2	A/B	ON	31	7478212	7454241	45298	31	7386221	7362927	22372	5.0	4.8	108	102	95	0.5	9248
05/13/05 13:00	2289.5	A/B	OFF	34	7512395	7488424	45506	32	7419923	7396629	22474	6.0	5.5	106	98	90	0.5	9734
05/16/05 09:42	2322.5	A/B	ON	30	7577780	7553809	45903	32	7484426	7461132	22670	5.0	4.5	109	104	96	0	10538
05/17/05 09:47	2334.8	A/B	OFF	32	7601788	7577817	46049	32	7508093	7484799	22742	5.9	5.2	105	99	90	0	10538
05/18/05 15:07	2348.7	A/B	ON	31	7636716	7612745	46261	30	7542552	7519258	22847	5.1	5.0	106	100	92	0	10538
05/23/05 09:27	2407.7	A/B	OFF	32	7747128	7723157	46932	32	7649935	7626641	23173	5.8	5.5	105	99	90	0	10538
05/24/05 09:07	2419.6	A/B	OFF	34	7771155	7747184	47078	33	7673116	7649822	23243	5.9	5.5	105	99	89	0	10538
05/25/05 10:30	2433.3	A/B	OFF	34	7798620	7774649	47245	33	7699640	7676346	23324	5.9	5.5	105	99	90	0	10538
05/26/05 08:40	2443.5	A/B	ON	32	7819144	7795173	47370	30	7719595	7696301	23384	4.8	4.5	108	102	95	0	10538
05/27/05 16:45	2463.8	A/B	OFF	34	7860113	7836142	47619	34	7759187	7735893	23505	5.9	5.4	105	97	90	0	10538
05/31/05 09:57	2505.8	A/B	OFF	34	7944635	7920664	48132	32	7841126	7817832	23754	5.5	5.2	105	97	90	0	10538
06/01/05 16:43	2524.8	A/B	OFF	34	7983619	7959648	48369	32	7878227	7854933	23866	5.9	5.2	105	99	90	0	10538
06/02/05 11:35	2531.9	A/B	OFF	33	7998110	7974139	48457	33	7891957	7868663	23908	5.9	5.1	105	98	90	0	10538
06/03/05 14:10	2546.6	A/B	OFF	32	8028056	8004085	48639	33	7920685	7897391	23995	5.8	5.1	105	98	90	0	10538
06/06/05 15:23	2584.4	A/B	OFF	33	8103916	8079945	49100	33	7993978	7970684	24218	5.9	5.4	105	98	90	0	10538
06/07/05 13:13	2594.5	A/B	OFF	33	8123811	8099840	49221	31	8013258	7989964	24277	5.5	5.1	105	97	90	0	10538
06/08/05 10:00	2603.7	A/B	ON	31	8141844	8117873	49331	30	8030813	8007519	24330	5.0	4.8	105	102	94	0	10538
06/09/05 10:00	2615.7	A/B	ON	29	8166136	8142165	49478	29	8053634	8030340	24399	4.8	4.2	109	102	95	0.5	10858
06/13/05 14:30	2664.1	A/B	OFF	33	8262128	8238157	50062	32	8147515	8124221	24685	5.5	5.1	104	98	90	0.5	12088
06/14/05 14:00	2675.9	A/B	OFF	33	8285731	8261760	50205	32	8170129	8146835	24753	5.5	5.0	106	98	90	0	12088
06/15/05 09:33	2683.5	A/B	OFF	34	8301036	8277065	50298	30	8184680	8161386	24798	5.9	5.2	106	98	92	0	12088
06/16/05 11:25	2697.7	A/B	ON	30	8329836	8305865	50473	28	8212046	8188752	24881	4.6	4.1	110	103	96	0	12088
06/17/05 15:56	2714.3	A/B	ON	30	8363080	8339109	50675	28	8244031	8220737	24978	4.8	4.2	109	102	96	0	12088
06/20/05 09:24	2744.3	A/B	ON	28	8422922	8398951	51039	28	8301802	8278508	25153	4.8	4.2	109	103	97	0	12088

EPA Arsenic Demonstration Project at Rimrock, AZ - Daily System Operation Log Sheet

Date and Time	Hour Meter	Lead/Lag	Well #3	Tank A Flow Meter				Tank B Flow Meter				dP		Pressure			Recycling	
				Flowrate	Totalizer	Cum. Flow	Bed Volume	Flowrate	Totalizer	Cum. Flow	Bed Volume	TA	TB	Inlet	Between Tanks	Outlet	Flow Rate	Totalizer
	hr	A/B	On/Off	gpm	gal	gal		gpm	gal	gal		psi	psi	psig	psig	psig	gpm	gal
06/22/05 10:30	2769.8	A/B	ON	29	8472259	8448288	51339	28	8350099	8326805	25300	4.7	4.2	111	103	100	0	12088
06/23/05 10:07	2781.7	A/B	ON	29	8494850	8470879	51476	29	8372309	8349015	25368	4.5	4.2	109	103	95	0	12088
06/24/05 15:02	2798.8	A/B	OFF	32	8528617	8504646	51681	32	8405363	8382069	25468	5.4	5.0	105	98	90	0	12088
06/27/05 13:55	NA	A/B	ON	30	8596930	8572959	52096	29	8472476	8449182	25672	4.4	4.3	109	103	96	0	12088
06/28/05 15:24	2847.9	A/B	ON	29	8623299	8599328	52256	28	8498135	8474841	25750	4.4	4.1	110	103	97	0	12088
06/29/05 09:46	2854.5	A/B	ON	30	8636181	8612210	52335	30	8510646	8487352	25788	4.8	4.2	109	102	96	0	12088
06/30/05 09:55	2866.8	A/B	ON	30	8660434	8636463	52482	30	8534051	8510757	25859	4.9	4.4	109	101	95	0	12088
07/01/05 15:48	2884.9	A/B	OFF	34	8695429	8671458	52695	33	8567897	8544603	25962	5.4	5.0	105	98	90	0	12088
07/05/05 14:11	2932.1	A/B	OFF	30	8786414	8762443	53248	30	8656450	8633156	26231	5.0	5.0	105	97	90	0	12088
07/06/05 08:00	2938.3	A/B	ON	30	8798083	8774112	53319	28	8667915	8644621	26266	4.9	4.3	105	100	90	0	12088
07/07/05 08:58	2951.1	A/B	OFF	33	8822760	8798789	53469	32	8691560	8668266	26338	5.5	5.0	105	97	90	0.5	12418
07/08/05 16:05	2970.5	A/B	OFF	31	8859990	8836019	53695	30	8727748	8704454	26448	5.6	5.0	105	97	90	0.5	12942
07/11/05 15:07	3006.1	A/B	ON	28	8927782	8903811	54107	28	8793516	8770222	26647	4.5	4.0	110	102	96	0	13452
07/12/05 14:38	3017.8	A/B	OFF	32	8949528	8925557	54239	32	8814692	8791398	26712	5.1	4.9	105	87	90	0	13452
07/13/05 10:30	3026.1	A/B	OFF	33	8965572	8941601	54336	32	8830271	8806977	26759	5.1	5.0	106	98	90	0	13452
07/14/05 09:30	3036.9	A/B	OFF	33	8988425	8964454	54475	32	8849575	8826281	26818	5.1	5.0	106	98	90	0	13452
07/18/05 09:32	3085.8	A/B	OFF	31	9077394	9053423	55016	32	8939776	8916482	27092	5.2	4.9	105	97	92	0	13452
07/19/05 09:51	3098.4	A/B	OFF	32	9100845	9076874	55158	30	8962875	8939581	27162	5.2	5.0	105	97	90	0	13452
07/20/05 17:07	3117.8	A/B	OFF	32	9137432	9113461	55381	30	8998883	8975589	27271	5.2	5.0	105	97	90	0	13452
07/21/05 13:24	3126.3	A/B	ON	28	9153108	9129137	55476	28	9014321	8991027	27318	4.0	4.0	110	103	96	0	13452
07/22/05 16:01	3139.9	A/B	OFF	32	9179099	9155128	55634	30	9039784	9016490	27396	5.1	5.0	105	97	90	0	13452
07/25/05 09:30	3170.2	A/B	OFF	32	9236804	9212833	55985	31	9096171	9072877	27567	5.1	5.0	104	97	90	0	13452
07/26/05 08:30	3181.3	A/B	OFF	32	9257866	9233895	56113	31	9116834	9093540	27630	5.1	5.0	105	98	90	0	13452
07/27/05 13:30	3196.5	A/B	OFF	32	9286958	9262987	56289	31	9145039	9121745	27716	5.0	4.9	104	97	90	0	13747
07/28/05 10:00	3205.3	A/B	OFF	31	9303471	9279500	56390	30	9161253	9137959	27765	5.1	4.9	105	97	90	0	13747
07/29/05 11:00	3218.9	A/B	ON	29	9329436	9305465	56548	29	9186908	9163614	27843	4.1	4.0	109	102	98	0	13747
08/01/05 12:00	3256.2	A/B	OFF	32	9400245	9376274	56978	31	9256407	9233113	28054	5.1	5.0	106	97	95	0	13747
08/02/05 14:03	3270.2	A/B	ON	29	9427211	9403240	57142	30	9282369	9259075	28133	4.4	4.1	109	101	96	0	13747
08/03/05 15:32	3283.4	A/B	ON	30	9452963	9428992	57298	29	9307022	9283728	28208	4.5	4.2	109	101	93	0	13747
08/04/05 09:05	3289.1	A/B	OFF	32	9464168	9440197	57366	29	9317756	9294462	28240	5.0	5.0	108	97	92	0	13747
08/05/05 16:04	3308.2	A/B	OFF	33	9500919	9476948	57590	29	9353436	9330142	28349	5.0	5.0	107	97	91	0	13747
08/08/05 10:45	3339.5	A/B	OFF	32	9561750	9537779	57959	30	9411832	9388538	28526	5.0	5.0	106	97	89	0	13747
08/09/05 09:30	3350.7	A/B	OFF	32	9583390	9559419	58091	31	9432561	9409267	28589	5.0	5.0	107	97	92	0	13747
08/10/05 12:30	3365.6	A/B	OFF	32	9612512	9588541	58268	31	9460748	9437454	28675	5.1	5.0	107	97	90	0	13747
08/11/05 11:30	3376.9	A/B	OFF	32	9634529	9610558	58402	31	9481779	9458485	28739	5.1	5.0	107	97	90	0	13747
08/12/05 16:44	3394.0	A/B	OFF	33	9667841	9643870	58604	32	9513861	9490567	28836	5.1	5.0	107	97	92	0	13747
08/15/05 09:33	3423.4	A/B	OFF	32	9724754	9700783	58950	30	9568794	9545500	29003	5.0	5.0	106	97	89	0	13747
08/17/05 13:15	3449.3	A/B	OFF	32	9774656	9750685	59253	33	9617017	9593723	29150	5.1	5.0	107	97	90	0.5	13890
08/18/05 09:49	3457.7	A/B	OFF	32	9790540	9766569	59350	27	9632641	9609347	29197	5.5	5.0	107	97	90	0.5	14127
08/19/05 14:59	3475.0	A/B	OFF	32	9823674	9799703	59551	31	9665271	9641977	29296	5.4	5.0	105	97	90	0.5	14618
08/22/05 10:24	3507.0	A/B	OFF	32	9884693	9860722	59922	32	9725167	9701873	29478	5.5	4.8	108	97	92	0	15115
08/23/05 10:28	3518.9	A/B	OFF	32	9908120	9884149	60064	32	9747914	9724620	29547	5.0	5.0	107	97	92	0	15115
08/24/05 17:07	3538.1	A/B	OFF	31	9944394	9920423	60285	31	9783282	9759988	29655	5.2	5.0	107	97	90	0	15115
08/25/05 09:35	3542.8	A/B	OFF	31	9953242	9929271	60338	31	9791942	9768648	29681	5.4	4.9	108	97	92	0	15115
08/26/05 16:18	3561.7	A/B	OFF	32	9989501	9965530	60559	32	9827501	9804207	29789	5.2	5.0	107	97	90	0	15115
08/29/05 10:18	3592.1	A/B	OFF	32	10047028	10023057	60908	32	9883968	9860674	29961	5.4	4.9	107	87	90	0	15115

EPA Arsenic Demonstration Project at Rimrock, AZ - Daily System Operation Log Sheet

Date and Time	Hour Meter	Lead/Lag	Well #3	Tank A Flow Meter				Tank B Flow Meter				dP		Pressure			Recycling	
				Flowrate	Totalizer	Cum. Flow	Bed Volume	Flowrate	Totalizer	Cum. Flow	Bed Volume	TA	TB	Inlet	Between Tanks	Outlet	Flow Rate	Totalizer
	hr	A/B	On/Off	gpm	gal	gal		gpm	gal	gal		psi	psi	psig	psig	psig	gpm	gal
08/30/05 14:03	3608.2	A/B	OFF	31	10076976	10053005	61090	31	9913251	9889957	30050	5.0	4.6	106	87	90	0	15115
08/31/05 14:00	3620.8	A/B	OFF	32	10099296	10075325	61226	31	9934131	9910837	30113	5.0	4.6	107	87	90	0	15115
09/01/05 09:56	3628.4	A/B	OFF	32	10115320	10091349	61323	31	9950753	9927459	30164	5.0	4.6	107	87	92	0	15115
09/02/05 17:31	3648.1	A/B	ON	30	10152861	10128890	61551	28	9987510	9964216	30275	4.2	4.0	109	101	96	0	15115
09/06/05 17:34	3696.9	A/B	OFF	30	10245525	10221554	62114	30	10078371	10055077	30551	5.0	5.0	108	97	92	0	15115
09/07/05 08:46	3700.3	A/B	OFF	31	10252019	10228048	62154	30	10084718	10061424	30571	5.2	4.9	108	97	90	0	15115
09/09/05 14:24	3730.3	A/B	OFF	32	10309110	10285139	62501	32	10140652	10117358	30741	5.0	5.0	107	97	90	0	15115
09/12/05 18:04	3770.4	A/B	OFF	32	10385368	10361397	62964	30	10215455	10192161	30968	5.0	5.0	107	97	90	0	15115
09/13/05 08:57	3773.6	A/B	OFF	31	10391055	10367084	62999	30	10221043	10197749	30985	5.4	5.0	106	97	90	0	15115
09/14/05 10:15	3787.1	A/B	OFF	31	10416438	10392467	63153	30	10246065	10222771	31061	5.1	5.0	106	97	90	0	15115
09/16/05 16:57	3818.1	A/B	OFF	31	10475134	10451163	63510	32	10303863	10280569	31237	5.2	5.0	107	97	90	0	15115
09/19/05 16:50	3854.6	A/B	OFF	31	10543917	10519946	63928	32	10371487	10348193	31442	5.1	4.9	107	97	90	0	15115
09/20/05 09:12	3859.2	A/B	OFF	31	10552372	10528401	63979	30	10379847	10356553	31467	5.1	4.9	108	97	90	0	15115
09/21/05 09:47	3871.9	A/B	ON	28	10576374	10552403	64125	26	10403492	10380198	31539	4.2	4.0	112	103	96	0	15115
09/22/05 16:29	3890.9	A/B	OFF	31	10612198	10588227	64343	30	10438705	10415411	31646	5.4	5.0	108	97	90	0	15115
09/23/05 16:00	3902.5	A/B	OFF	32	10634175	10610204	64476	31	10460351	10437057	31712	5.1	5.0	108	96	92	0	15115
09/26/05 15:36	3938.8	A/B	OFF	31	10702288	10678317	64890	30	10527599	10504305	31916	5.0	5.0	108	97	92	0	15115
09/27/05 09:23	3944.8	A/B	OFF	31	10713714	10689743	64960	30	10538885	10515591	31951	5.1	5.0	108	97	92	0	15115
09/28/05 09:47	3957.2	A/B	ON	28	10737217	10713246	65102	25	10562096	10538802	32021	4.5	4.0	111	100	96	0	15115
09/29/05 11:23	3971.2	A/B	OFF	32	10763271	10739300	65261	32	10587778	10564484	32099	5.2	5.0	108	97	92	0	15115
09/30/05 15:09	3987.1	A/B	OFF	30	10793468	10769497	65444	31	10617574	10594280	32190	5.1	4.9	107	96	92	0	15115
10/03/05 10:08	4018.7	A/B	OFF	32	10852841	10828870	65805	32	10676208	10652914	32368	5.5	5.0	107	96	90	0	15115
10/04/05 14:35	4035.3	A/B	OFF	31	10883701	10859730	65993	29	10706699	10683405	32461	5.3	5.0	107	97	92	0	15115
10/05/05 11:00	4043.9	A/B	ON	29	10899707	10875736	66090	25	10722505	10699211	32509	4.2	4.0	112	104	98	0	15115
10/06/05 09:12	4054.3	A/B	OFF	31	10919178	10895207	66208	31	10741755	10718461	32567	5.1	4.8	108	97	92	0	15115
10/07/05 15:35	4072.9	A/B	OFF	31	10954110	10930139	66420	30	10776250	10752956	32672	5.0	4.8	108	97	92	0	15115
10/14/05 11:00	4155.9	A/B	OFF	32	11106988	11083017	67349	30	10927069	10903775	33130	5.5	4.8	108	92	90	0	15115
10/17/05 16:18	4195.5	A/B	OFF	31	11185423	11161452	67826	31	11004554	10981260	33366	5.4	5.0	108	96	92	0	15115
10/18/05 09:30	4200.9	A/B	OFF	31	11195564	11171593	67888	30	11014569	10991275	33396	5.0	4.8	108	97	92	0	15115
10/19/05 18:17	4221.8	A/B	OFF	31	11234854	11210883	68126	29	11053414	11030120	33514	5.0	4.8	108	97	92	0	15115
10/20/05 10:12	4226.0	A/B	OFF	31	11242548	11218577	68173	30	11061031	11037737	33537	5.0	5.0	108	97	92	0	15115
10/21/05 17:26	4245.4	A/B	ON	29	11278815	11254844	68394	26	11096836	11073542	33646	4.5	4.1	110	102	96	0	15115
10/24/05 11:00	4275.9	A/B	OFF	32	11336213	11312242	68742	31	11153520	11130226	33818	5.1	5.0	108	96	92	0	15115
10/25/05 11:00	4288.8	A/B	OFF	31	11360491	11336520	68890	30	11177498	11154204	33891	5.0	4.9	108	96	92	0	15115
10/26/05 10:19	4299.3	A/B	OFF	31	11379945	11355974	69008	30	11196745	11173451	33949	5.0	5.0	108	97	90	0	15115
10/27/05 09:24	4310.5	A/B	OFF	30	11401267	11377296	69138	30	11217774	11194480	34013	5.0	4.5	108	97	92	0	15115
10/28/05 14:04	4320.0	A/B	OFF	31	11419110	11395139	69246	31	11235400	11212106	34067	5.0	4.6	108	96	90	0	15115
10/31/05 11:06	4353.6	A/B	OFF	31	11482442	11458471	69631	31	11297916	11274622	34257	5.5	5.0	108	96	90	0	15115
11/01/05 17:01	4371.7	A/B	OFF	30	11516502	11492531	69838	30	11331497	11308203	34359	5.0	4.5	108	97	92	0	15115
11/02/05 09:43	4376.6	A/B	OFF	32	11525818	11501847	69895	31	11340668	11317374	34387	5.2	5.0	107	90	90	0	15115
11/03/05 11:47	4389.7	A/B	OFF	31	11550593	11526622	70045	30	11365192	11341898	34461	5.2	4.5	108	87	90	0	15115
11/04/05 16:39	4406.8	A/B	OFF	31	11584807	11560836	70253	31	11396879	11373585	34558	5.3	4.9	106	97	90	0	15115
11/07/05 10:24	4437.1	A/B	OFF	32	11640019	11616048	70589	30	11453255	11429961	34729	6.0	5.5	110	97	92	0	15115
11/08/05 10:57	4449.9	A/B	OFF	28	11664539	11640568	70738	27	11477493	11454199	34803	4.0	3.9	112	103	99	0	15115
11/09/05 12:00	NA	A/B	OFF	32	11688867	11664896	70885	31	11501543	11478249	34876	5.0	4.9	110	97	92	0	15115
11/14/05 10:40	4522.7	A/B	OFF	31	11802270	11778299	71574	30	11613126	11589832	35215	5.1	4.9	108	96	90	0	15115

EPA Arsenic Demonstration Project at Rimrock, AZ - Daily System Operation Log Sheet

Date and Time	Hour Meter	Lead/Lag	Well #3	Tank A Flow Meter				Tank B Flow Meter				dP		Pressure			Recycling	
				Flowrate	Totalizer	Cum. Flow	Bed Volume	Flowrate	Totalizer	Cum. Flow	Bed Volume	TA	TB	Inlet	Between Tanks	Outlet	Flow Rate	Totalizer
	hr	A/B	On/Off	gpm	gal	gal		gpm	gal	gal		psi	psi	psig	psig	psig	gpm	gal
11/15/05 17:00	4536.0	A/B	OFF	31	11826912	11802941	71724	30	11637458	11614164	35289	5.1	4.9	108	96	90	0.5	15522
11/16/05 16:27	4552.7	A/B	ON	27	11858080	11834109	71914	29	11668285	11644991	35382	4.0	4.0	112	104	96	0.5	16010
11/17/05 10:19	4558.7	A/B	OFF	32	11869513	11845542	71983	33	11679599	11656305	35417	5.2	5.0	105	97	92	0.5	16189
11/21/05 09:36	4606.8	A/B	OFF	31	11959525	11935554	72530	27	11768503	11745209	35687	5.0	4.5	108	97	90	0	16334
11/22/05 13:20	4622.7	A/B	OFF	31	11989320	11965349	72711	31	11797907	11774613	35776	5.0	4.6	108	97	90	0	16334
11/28/05 10:37	4693.1	A/B	OFF	31	12121394	12097423	73514	31	11928098	11904804	36172	5.0	4.9	107	97	90	0	16334
11/29/05 09:41	4704.4	A/B	ON	29	12142811	12118840	73644	29	11949244	11925950	36236	4.5	4.0	110	102	96	0	16334
11/30/05 10:12	4717.1	A/B	OFF	32	12166165	12142194	73786	30	11972288	11948994	36306	5.0	4.5	108	97	92	0	16334
12/01/05 14:12	4733.3	A/B	OFF	31	12196751	12172780	73972	30	12002502	11979208	36398	5.1	5.0	105	96	90	0	16334
12/02/05 14:22	4745.7	A/B	OFF	31	12219644	12195673	74111	30	12025126	12001832	36466	5.0	5.0	108	97	90	0	16334
12/05/05 17:26	4785.3	A/B	OFF	32	12293908	12269937	74562	31	12098345	12075051	36689	5.0	4.6	108	96	92	0	16334
12/06/05 11:35	4791.7	A/B	OFF	31	12305709	12281738	74634	31	12109942	12086648	36724	5.0	4.6	108	97	90	0	16334
12/07/05 09:30	4801.3	A/B	ON	32	12323575	12299604	74742	31	12127187	12103893	36777	5.1	4.8	108	97	90	0.5	16445
12/08/05 11:26	4815.4	A/B	OFF	31	12350329	12326358	74905	32	12153894	12130600	36858	5.0	4.5	108	96	92	0.5	16859
12/09/05 12:47	4828.9	A/B	OFF	31	12375855	12351884	75060	32	12178641	12155347	36933	5.0	4.5	108	97	92	0	16970
12/12/05 13:41	4865.3	A/B	OFF	30	12444309	12420338	75476	31	12246261	12222967	37138	5.0	4.6	108	98	92	0	16969
12/13/05 15:30	4879.6	A/B	OFF	31	12470869	12446898	75637	30	12272512	12249218	37218	5.0	4.8	108	97	92	0	16969
12/14/05 10:00	4886.1	A/B	OFF	31	12483160	12459189	75712	30	12284644	12261350	37255	5.0	4.8	108	97	92	0	16969
12/15/05 10:24	4898.6	A/B	OFF	30	12506930	12482959	75857	30	12307967	12284673	37326	5.0	4.8	108	97	90	0	17046
12/19/05 09:00	4945.6	A/B	OFF	31	12594669	12570698	76390	31	12394830	12371536	37590	5.0	4.9	NA	97	NA	0	17046
12/20/05 10:30	4959.0	A/B	OFF	31	12619722	12595751	76542	31	12419638	12396344	37665	5.0	4.9	NA	97	NA	0	17046
12/21/05 10:00	4970.7	A/B	OFF	30	12642262	12618291	76679	30	12441925	12418631	37733	5.0	4.9	NA	97	NA	0	17046
12/22/05 16:46	4989.9	A/B	OFF	31	12677448	12653477	76893	32	12475779	12452485	37836	5.0	5.0	NA	97	NA	0	17046
12/27/05 11:57	5046.0	A/B	OFF	31	12782236	12758265	77530	30	12580323	12557029	38153	5.1	4.8	NA	97	NA	0	17046
12/28/05 10:00	5056.2	A/B	OFF	31	12801474	12777503	77646	30	12599304	12576010	38211	5.1	4.9	NA	97	NA	0	17046
12/29/05 09:09	5067.6	A/B	OFF	32	12822799	12798828	77776	31	12620385	12597091	38275	5.0	5.0	NA	97	NA	0	17046
01/03/06 17:11	5136.6	A/B	OFF	31	12951474	12927503	78558	30	12747775	12724481	38662	5.2	4.9	NA	97	NA	0	17046
01/04/06 10:52	5142.4	A/B	OFF	32	12962384	12938413	78624	30	12758551	12735257	38695	5.0	4.9	NA	96	NA	0	17046
01/05/06 08:30	5152.2	A/B	OFF	30	12980720	12956749	78736	33	12776667	12753373	38750	5.0	4.9	NA	97	NA	0	17046
01/06/06 15:10	5171.1	A/B	OFF	31	13016134	12992163	78951	32	12811702	12788408	38856	5.2	5.0	NA	97	NA	0	17046
01/09/06 08:32	5201.1	A/B	ON	28	13072457	13048486	79293	25	12867467	12844173	39026	4.1	3.8	NA	103	NA	0	17046
01/10/06 16:42	5221.4	A/B	OFF	32	13110211	13086240	79523	31	12904801	12881507	39139	5.1	4.9	NA	97	NA	0	17046
01/11/06 09:25	5226.3	A/B	OFF	31	13119286	13095315	79578	28	12913760	12890466	39166	5.1	5.0	NA	97	NA	0	17046
01/12/06 09:58	5239.1	A/B	OFF	31	13143237	13119266	79723	30	12937427	12914133	39238	5.1	4.9	NA	97	NA	0	17046
01/13/06 15:28	5256.5	A/B	OFF	32	13175833	13151862	79921	29	12969599	12946305	39336	5.5	5.0	100	97	89	0	17046
01/16/06 09:59	5287.6	A/B	OFF	31	13234001	13210030	80275	30	13027239	13003945	39511	5.0	4.8	103	97	90	0	17046
01/17/06 12:30	5302.3	A/B	OFF	31	13261493	13237522	80442	29	13054497	13031203	39594	5.0	5.0	102	97	90	0	17046
01/18/06 17:05	5319.1	A/B	OFF	30	13292885	13268914	80633	30	13085544	13062250	39688	5.0	4.9	102	97	90	0	17046
01/19/06 10:00	5324.3	A/B	OFF	31	13302588	13278617	80692	30	13095162	13071868	39718	5.1	5.0	102	97	90	0	17046
01/20/06 16:14	5342.6	A/B	ON	29	13336767	13312796	80899	27	13129051	13105757	39821	4.5	3.9	105	100	95	0	17046
01/23/06 09:28	5372.4	A/B	OFF	28	13392515	13368544	81238	28	13184043	13160749	39988	4.2	4.0	105	102	96	0	17046
01/24/06 16:39	5391.8	A/B	OFF	30	13428623	13404652	81458	30	13219770	13196476	40096	5.0	4.8	102	98	90	0	17046
01/25/06 16:18	5403.6	A/B	OFF	31	13450751	13426780	81592	29	13241694	13218400	40163	5.0	5.0	102	97	90	0	17046
01/26/06 13:24	5412.9	A/B	OFF	31	13468232	13444261	81698	30	13259030	13235736	40216	5.0	5.0	102	97	90	0	17046
01/30/06 09:40	5458.0	A/B	ON	28	13552347	13528376	82209	30	13342307	13319013	40469	4.1	3.9	107	102	95	0	17046
01/31/06 10:12	5470.0	A/B	OFF	32	13574880	13550909	82346	29	13364371	13341077	40536	5.0	5.0	102	97	90	0	17046

EPA Arsenic Demonstration Project at Rimrock, AZ - Daily System Operation Log Sheet

Date and Time	Hour Meter	Lead/Lag	Well #3	Tank A Flow Meter				Tank B Flow Meter				dP		Pressure			Recycling	
				Flowrate	Totalizer	Cum. Flow	Bed Volume	Flowrate	Totalizer	Cum. Flow	Bed Volume	TA	TB	Inlet	Between Tanks	Outlet	Flow Rate	Totalizer
	hr	A/B	On/Off	gpm	gal	gal		gpm	gal	gal		psi	psi	psig	psig	psig	gpm	gal
02/01/06 10:21	5482.4	A/B	ON	28	13597797	13573826	82486	29	13387078	13363784	40605	4.0	3.9	108	104	98	0	17046
02/02/06 11:26	5495.7	A/B	OFF	32	13622566	13598595	82636	30	13411577	13388283	40679	5.0	5.0	102	97	90	0	17046
02/03/06 16:43	5513.1	A/B	ON	28	13655366	13631395	82835	30	13444092	13420798	40778	4.5	4.0	105	101	95	0	17046
02/06/06 09:36	5542.6	A/B	OFF	31	13710347	13686376	83170	32	13498557	13475263	40943	5.0	5.0	103	97	90	0	17046
02/07/06 10:39	5555.9	A/B	OFF	31	13735360	13711389	83322	31	13523375	13500081	41019	5.0	4.9	103	97	90	0	17046
02/08/06 09:31	5566.9	A/B	OFF	32	13756133	13732162	83448	30	13543974	13520680	41081	5.0	4.9	103	97	90	0	17046
02/09/06 09:03	5578.7	A/B	OFF	31	13777697	13753726	83579	31	13565327	13542033	41146	5.0	4.7	104	97	90	0	17046
02/10/06 14:24	5596.2	A/B	OFF	30	13810507	13786536	83778	29	13597829	13574535	41245	5.0	5.0	101	96	90	0	17046
02/13/06 09:57	5628.4	A/B	OFF	31	13870469	13846498	84143	30	13657256	13633962	41426	5.0	4.9	103	97	90	0	17046
02/14/06 13:00	5644.1	A/B	OFF	31	13899550	13875579	84319	30	13686045	13662751	41513	5.0	4.8	102	97	89	0	17046
02/15/06 09:00	5651.9	A/B	OFF	31	13914029	13890058	84407	30	13700395	13677101	41557	5.0	4.8	102	97	89	0	17046
02/17/06 13:25	5680.3	A/B	OFF	31	13967257	13943286	84731	29	13752459	13729165	41715	5.0	4.9	103	97	90	0.5	17871
02/21/06 10:24	5726.2	A/B	OFF	30	14052141	14028170	85247	30	13836534	13813240	41970	5.0	4.5	103	97	90	0	18147
02/22/06 09:39	5737.6	A/B	OFF	31	14073075	14049104	85374	30	13857251	13833957	42033	5.0	4.8	102	96	90	0	18147
02/23/06 09:08	5749.2	A/B	OFF	30	14094513	14070542	85504	31	13878460	13855166	42098	5.0	4.9	103	96	90	0	18147
02/24/06 13:00	5765.7	A/B	OFF	31	14124826	14100855	85688	31	13908472	13885178	42189	5.0	4.9	105	96	90	0	18147
02/27/06 10:12	5799.1	A/B	OFF	31	14186417	14162446	86063	31	13969479	13946185	42374	5.0	4.5	102	97	90	0	18147
02/28/06 10:03	5811.1	A/B	OFF	32	14208458	14184487	86196	32	13991295	13968001	42440	5.0	4.5	102	97	90	0	18147
03/01/06 09:46	5823.1	A/B	OFF	31	14230332	14206361	86329	33	14012925	13989631	42506	5.0	4.4	103	97	90	0	18147
03/02/06 09:25	5834.9	A/B	OFF	30	14251995	14228024	86461	31	14034347	14011053	42571	5.0	4.5	103	97	91	0	18147
03/06/06 08:56	5883.2	A/B	OFF	32	14341511	14317540	87005	30	14122679	14099385	42840	5.0	4.5	103	97	91	0	18147
03/07/06 08:36	5895.1	A/B	OFF	32	14363575	14339604	87139	30	14144475	14121181	42906	5.0	4.5	103	97	90	0	18147
03/08/06 10:30	5909.3	A/B	OFF	32	14389539	14365568	87297	30	14170139	14146845	42984	5.0	4.4	105	97	90	0	18147
03/09/06 14:52	5925.7	A/B	OFF	31	14419956	14395985	87482	29	14200242	14176948	43075	5.0	4.5	103	97	90	0	18147
03/10/06 14:38	5937.7	A/B	OFF	31	14442175	14418204	87617	29	14222212	14198918	43142	5.0	4.5	103	97	90	0	18147
03/13/06 09:24	5969.1	A/B	OFF	30	14499221	14475250	87963	32	14279124	14255830	43315	5.0	4.5	103	96	90	0	18147
03/14/06 09:07	5981.0	A/B	OFF	31	14521661	14497690	88100	28	14300850	14277556	43381	5.0	4.9	103	96	90	0	18147
03/15/06 09:09	5993.2	A/B	ON	27	14544115	14520144	88236	29	14323065	14299771	43449	4.1	3.9	106	103	97	0	18147
03/16/06 10:30	6006.7	A/B	OFF	30	14568595	14544624	88385	29	14347291	14323997	43522	5.0	4.9	103	96	90	0	18147
03/20/06 10:00	6054.4	A/B	OFF	31	14657330	14633359	88924	30	14435059	14411765	43789	5.0	4.8	104	96	91	0	18147
03/21/06 16:26	6073.7	A/B	OFF	31	14693234	14669263	89142	32	14470576	14447282	43897	5.0	5.0	104	96	91	0	18147
03/22/06 14:58	6084.4	A/B	OFF	32	14713145	14689174	89263	32	14490217	14466923	43956	5.1	4.9	103	96	90	0	18147
03/24/06 16:50	6110.7	A/B	OFF	29	14761852	14737881	89559	27	14538348	14515054	44103	4.2	4.0	105	101	95	0	18147
03/27/06 09:02	6139.5	A/B	OFF	31	14815294	14791323	89884	30	14591157	14567863	44263	5.0	4.5	103	97	91	0	18147
03/29/06 09:48	6164.6	A/B	OFF	30	14861749	14837778	90166	28	14637115	14613821	44403	5.0	5.0	104	96	90	0	18147
03/31/06 16:24	6195.7	A/B	OFF	30	14919782	14895811	90519	28	14694554	14671260	44577	5.0	5.0	103	97	90	0	18147
04/03/06 09:04	6224.9	A/B	OFF	31	14974180	14950209	90850	31	14748252	14724958	44740	5.0	4.9	104	97	91	0	18147
04/04/06 14:46	6242.8	A/B	OFF	30	15007455	14983484	91052	29	14781152	14757858	44840	5.2	5.0	102	97	90	0	18147
04/05/06 09:14	6249.4	A/B	OFF	31	15019762	14995791	91127	30	14793291	14769997	44877	5.0	5.0	104	97	91	0	18147
04/06/06 10:20	6262.7	A/B	OFF	30	15044705	15020734	91278	30	14817909	14794615	44952	5.0	4.9	103	97	91	0	18147
04/07/06 16:25	6281.0	A/B	OFF	31	15078882	15054911	91486	28	14851638	14828344	45055	5.0	5.0	102	97	90	0	18147
04/10/06 10:02	6311.2	A/B	OFF	31	15134563	15110592	91824	28	14906823	14883529	45222	5.0	5.0	103	97	90	0	18147
04/11/06 09:57	6323.3	A/B	OFF	31	15157471	15133500	91963	28	14929104	14905810	45290	5.0	5.0	103	97	90	0	18147
04/12/06 10:18	6335.9	A/B	OFF	32	15180919	15156948	92106	33	14952248	14928954	45360	5.0	5.0	102	97	90	0	18147
04/13/06 09:35	6347.3	A/B	OFF	31	15202283	15178312	92236	30	14973340	14950046	45424	5.0	5.0	102	97	90	0	18147
04/14/06 14:21	6364.3	A/B	OFF	30	15234224	15210253	92430	32	15004900	14981606	45520	5.0	5.0	103	98	90	0	18147

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Date and Time	Hour Meter	Lead/Lag	Well #3	Tank A Flow Meter				Tank B Flow Meter				dP		Pressure			Recycling	
				Flowrate	Totalizer	Cum. Flow	Bed Volume	Flowrate	Totalizer	Cum. Flow	Bed Volume	TA	TB	Inlet	Between Tanks	Outlet	Flow Rate	Totalizer
	hr	A/B	On/Off	gpm	gal	gal		gpm	gal	gal		psi	psi	psig	psig	psig	gpm	gal
04/17/06 09:55	6396.5	A/B	OFF	32	15294114	15270143	92794	31	15064081	15040787	45700	5.5	5.0	102	97	90	0	18147
04/18/06 10:30	6409.2	A/B	OFF	31	15317499	15293528	92936	31	15087194	15063900	45770	5.1	5.0	102	97	90	0	18147
04/19/06 08:00	6419.0	A/B	OFF	32	15335733	15311762	93047	31	15105208	15081914	45825	5.1	5.0	102	97	90	0	18147
04/20/06 09:15	6432.4	A/B	OFF	31	15360560	15336589	93198	31	15129713	15106419	45899	5.1	5.0	102	97	90	0	18147
04/21/06 15:04	6450.6	A/B	OFF	31	15393895	15369924	93400	30	15162566	15139272	45999	5.5	5.0	102	98	90	0	18147
04/24/06 08:57	6480.8	A/B	OFF	30	15450227	15426256	93742	33	15218285	15194991	46169	5.0	4.9	103	98	91	0	18147
04/26/06 10:17	6491.5	A/B	OFF	30	15470207	15446236	93864	30	15238095	15214801	46229	5.2	4.8	102	97	90	0	18147
04/28/06 15:44	6521.3	A/B	OFF	31	15526235	15502264	94204	30	15293195	15269901	46396	5.0	4.8	103	98	91	0	18147
05/01/06 09:24	6551.6	A/B	OFF	30	15582515	15558544	94546	29	15348554	15325260	46564	5.0	4.9	102	98	90	0	18147
05/02/06 10:54	6565.3	A/B	OFF	30	15608029	15584058	94701	33	15373668	15350374	46641	5.0	4.9	101	97	90	0	18147
05/03/06 08:56	6575.5	A/B	OFF	31	15626650	15602679	94815	30	1539	NA	NA	5.1	4.9	102	97	90	0	18147
05/05/06 15:23	6608.4	A/B	OFF	32	15683501	15659530	95160	32	15447916	15424622	46866	5.0	5.0	103	97	91	0	18147
05/08/06 09:02	6636.6	A/B	OFF	32	15738939	15714968	95497	31	15502595	15479301	47032	5.0	4.8	102	97	91	0	18147
05/09/06 09:24	6649.2	A/B	ON	28	15761981	15738010	95637	26	15525303	15502009	47101	4.1	3.9	105	102	96	0	18147
05/10/06 10:25	6662.4	A/B	OFF	31	15786431	15762460	95785	30	15549413	15526119	47175	5.0	5.0	102	97	90	0	18147
05/11/06 10:42	6674.9	A/B	OFF	30	15809513	15785542	95926	32	15572156	15548862	47244	5.1	5.0	101	98	90	0	18147
05/12/06 15:01	6691.4	A/B	OFF	31	15839966	15815995	96111	31	15602128	15578834	47335	5.0	4.5	102	97	90	0	18147
05/15/06 10:11	6723.2	A/B	OFF	30	15898105	15874134	96464	30	15659420	15636126	47509	5.0	4.9	101	97	91	0	18147
05/17/06 08:50	6746.2	A/B	OFF	30	15940100	15916129	96719	32	15700792	15677498	47635	4.9	4.5	103	97	92	0	18147
05/22/06 09:50	6808.0	A/B	OFF	29	16052050	16028079	97400	27	15811485	15788191	47971	5.0	4.1	102	96	91	0	18147
05/24/06 10:00	6832.6	A/B	OFF	29	16096980	16073009	97673	30	15854988	15831694	48103	4.6	4.2	101	97	91	0	18147
05/31/06 10:35	6918.5	A/B	OFF	29	16249404	16225433	98599	27	16005244	15981950	48560	4.5	4.0	100	97	91	0	19153
06/12/06 09:06	7063.5	A/B	ON	27	16493174	16469203	100080	26	16245932	16222638	49291	4.0	3.5	104	101	96	0	19153
06/14/06 14:26	7093.1	A/B	ON	22	16538489	16514518	100356	20	16290798	16267504	49427	2.9	2.5	101	96	90	0	19153
06/19/06 09:41	7149.3	A/B	OFF	24	16619819	16595848	100850	25	16371519	16348225	49673	3.0	2.9	96	84	90	0	19153
06/21/06 09:16	7173.3	A/B	ON	22	16654163	16630192	101059	22	16405587	16382293	49776	2.9	2.1	101	100	93	0	19153
06/28/06 10:06	7259.5	A/B	OFF	24	16776981	16753010	101805	22	16527171	16503877	50145	3.0	2.8	96	94	90	0	19153
07/03/06 10:10	7320.6	A/B	OFF	22	16862233	16838262	102323	20	16611740	16588446	50402	3.0	3.0	96	94	90	0	19153
07/05/06 09:41	7344.5	A/B	OFF	23	16894723	16870752	102520	22	16644007	16620713	50500	3.0	2.5	98	94	92	0	19153
07/10/06 09:53	7405.4	A/B	OFF	23	16979702	16955731	103037	22	16728392	16705098	50757	4.0	3.5	95	95	90	0	19153
07/12/06 12:15	7432.2	A/B	OFF	22	17016599	16992628	103261	22	16764976	16741682	50868	2.5	2.0	94	92	89	0	19153
07/17/06 08:30	7489.6	A/B	OFF	22	17089490	17065519	103704	22	16837581	16814287	51089	2.5	2.0	95	93	90	0	19153
07/19/06 10:30	7516.1	A/B	OFF	22	17123085	17099114	103908	22	16871032	16847738	51190	2.5	2.0	95	93	90	0	19153
07/24/06 10:18	7576.5	A/B	OFF	21	17199655	17175684	104373	20	16947251	16923957	51422	2.5	2.0	92	92	90	0	19153
07/31/06 10:13	7661.8	A/B	OFF	20	17306311	17282340	105022	20	17053404	17030110	51744	2.2	2.0	95	94	90	0	19153
08/02/06 09:51	7685.9	A/B	OFF	20	17336224	17312253	105203	21	17083209	17059915	51835	2.2	2.0	95	93	90	0	19153
08/07/06 09:55	7746.9	A/B	OFF	20	17412012	17388041	105664	20	17158558	17135264	52064	2.0	2.0	94	93	90	0	19153
08/09/06 09:46	7771.2	A/B	OFF	20	17441042	17417071	105840	19	17187481	17164187	52152	2.0	1.9	94	93	90	0	19153
08/14/06 10:12	7832.6	A/B	OFF	19	17513794	17489823	106282	17	17260085	17236791	52372	2.0	2.0	93	93	90	0	19153
08/16/06 10:43	7857.5	A/B	OFF	19	17545866	17521895	106477	19	17291792	17268498	52469	2.0	2.0	93	92	90	0.5	19182
08/23/06 17:20	7949.3	A/B	OFF	18	17647726	17623755	107096	16	17393291	17369997	52777	1.5	1.8	94	90	91	0	19857
08/28/06 08:31	8001.5	A/B	OFF	18	17703458	17679487	107435	16	17448958	17425664	52946	1.5	1.5	93	93	91	0	19857
11/07/06 00:00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
11/27/06 10:45	8052.6	B/A	OFF	32	17733317	0	NA	30	17479226	0	0	4.1	3.8	103	100	93	0	19857
11/28/06 08:40	8062.8	B/A	ON	26	17752542	19225	58	25	17496940	17714	108	3.0	3.0	109	106	102	0	19857
12/04/06 14:00	8141.2	B/A	OFF	33	17903261	169944	516	30	17634963	155737	946	4.0	4.0	102	101	93	0	19857

EPA Arsenic Demonstration Project at Rimrock, AZ - Daily System Operation Log Sheet

Date and Time	Hour Meter	Lead/Lag	Well #3	Tank A Flow Meter				Tank B Flow Meter				dP		Pressure			Recycling	
				Flowrate	Totalizer	Cum. Flow	Bed Volume	Flowrate	Totalizer	Cum. Flow	Bed Volume	TA	TB	Inlet	Between Tanks	Outlet	Flow Rate	Totalizer
	hr	A/B	On/Off	gpm	gal	gal		gpm	gal	gal		psi	psi	psig	psig	psig	gpm	gal
12/11/06 10:30	8294.1	B/A	OFF	34	18202419	469102	1425	30	17912510	433284	2633	4.1	4.0	102	101	93	0	19857
12/18/06 09:00	8460.6	B/A	OFF	33	18530106	796789	2421	30	18216417	737191	4480	4.1	4.0	102	101	93	0	19857
12/27/06 10:13	8677.6	B/A	OFF	33	18956487	1223170	3716	30	18612813	1133587	6889	4.1	4.0	104	100	93	0	19857
01/03/07 00:00	8844.2	B/A	OFF	33	19281942	1548625	4705	30	18915750	1436524	8729	4.1	4.0	104	101	93	0	19857
02/07/07 09:30	9684.4	B/A	OFF	32	20921512	3188195	9687	29	20435149	2955923	17963	4.1	4.0	103	100	93	0	19857
03/07/07 07:15	10223	B/A	OFF	32	21958312	4224995	12837	29	21395094	3915868	23796	4.1	4.0	103	101	94	0	19857
03/28/07 11:30	10482	B/A	OFF	32	22449876	4716559	14331	28	21849540	4370314	26558	3.9	3.9	103	101	94	0.5	19871

Note: Bed volume calculation based on 22 ft^3 of media per vessel.
Highlighted rows indicate backwash; highlighted columns indicated calculated values; NA = data not available.

APPENDIX B

ANALYTICAL DATA TABLES

Analytical Results from Long-Term Sampling, Rimrock, AZ

Sampling Date		06/30/04				07/07/04				07/14/04				07/21/04			
Sampling Location Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB
Bed Volume	10^3	–	–	0.9	0.4	–	–	1.8	0.9	–	–	2.7	1.4	–	–	3.7	1.9
Alkalinity	mg/L[(a)]	355	–	367	351	330	–	382	365	383	–	371	367	379	–	375	383
Fluoride	mg/L	0.3	–	0.3	0.3	–	–	–	–	–	–	–	–	–	–	–	–
Sulfate	mg/L	9.4	–	9.4	9.4	–	–	–	–	–	–	–	–	–	–	–	–
Nitrate (as N)	mg/L	0.3	–	0.3	0.3	–	–	–	–	–	–	–	–	–	–	–	–
Orthophosphate (as P)	mg/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
Silica (as SiO_2)	mg/L	26.0	–	25.4	23.9	25.7	–	24.4	24.1	24.0	–	24.3	23.9	26.1	–	25.9	25.1
Turbidity	NTU	0.5	–	0.3	0.4	0.3	–	0.2	0.6	<0.1	–	0.2	0.9	0.3	–	0.3	0.4
pH	–	7.0	7.4	7.0	7.0	7.0	7.2	7.0	7.0	7.0	7.2	7.1	7.1	6.9	7.2	7.0	7.0
Temperature	ºC	21.5	21.2	22.9	23.7	24.1	22.3	21.9	22.1	22.4	22.4	22.7	23.1	24.1	23.5	23.1	23.2
DO	mg/L	3.8	4.9	3.6	3.8	4.1	5.0	4.1	3.7	3.5	4.7	3.7	3.6	4.7	6.8	6.6	6.9
ORP	mV	475	637	637	649	476	596	596	611	488	607	619	628	510	608	621	624
Free Chlorine (as Cl_2)	mg/L	–	0.4	0.4	0.4	–	0.4	0.4	0.4	–	0.4	0.4	0.4	–	0.5	0.5	0.4
Total Chlorine (as Cl_2)	mg/L	–	0.6	0.6	0.6	–	0.7	0.6	0.5	–	0.6	0.6	0.6	–	0.5	0.5	0.5
Total Hardness	mg/L[(a)]	287	–	298	299	–	–	–	–	–	–	–	–	–	–	–	–
Ca Hardness	mg/L[(a)]	171	–	175	174	–	–	–	–	–	–	–	–	–	–	–	–
Mg Hardness	mg/L[(a)]	116	–	123	124	–	–	–	–	–	–	–	–	–	–	–	–
As (total)	µg/L	59.2	–	1.0	0.3	78.5	–	1.2	0.3	79.2	–	0.8	0.3	58.8	–	0.7	0.4
As (soluble)	µg/L	59.1	–	0.9	0.3	–	–	–	–	–	–	–	–	–	–	–	–
As (particulate)	µg/L	0.1	–	0.1	<0.1	–	–	–	–	–	–	–	–	–	–	–	–
As (III)	µg/L	0.8	–	0.6	0.3	–	–	–	–	–	–	–	–	–	–	–	–
As (V)	µg/L	58.3	–	0.3	<0.1	–	–	–	–	–	–	–	–	–	–	–	–
Fe (total)	µg/L	<25	–	<25	<25	<25	–	<25	<25	<25	–	<25	<25	<25	–	<25	47.3
Fe (soluble)	µg/L	<25	–	<25	<25	–	–	–	–	–	–	–	–	–	–	–	–
Mn (total)	µg/L	1.0	–	0.4	0.4	0.7	–	<0.1	<0.1	0.4	–	<0.1	<0.1	1.6	–	0.4	0.4
Mn (soluble)	µg/L	1.1	–	0.7	0.6	–	–	–	–	–	–	–	–	–	–	–	–

(a) As $CaCO_3$.
IN = at inlet; AC = after prechlorination (field parameters only); TA = after tank A; TB = after tank B.

Analytical Results from Long-Term Sampling, Rimrock, AZ (Continued)

Sampling Date		07/28/04				08/04/04				08/11/04				08/18/04			
Sampling Location Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB
Bed Volume	10^3	–	–	4.6	2.3	–	–	5.6	2.8	–	–	6.6	3.3	–	–	7.5	3.7
Alkalinity	mg/L[(a)]	369	–	381	377	379	–	367	395	376	–	376	381	363	–	375	367
Fluoride	mg/L	0.3	–	0.3	0.3	–	–	–	–	–	–	–	–	–	–	–	–
Sulfate	mg/L	10.0	–	10.0	10.0	–	–	–	–	–	–	–	–	–	–	–	–
Nitrate (as N)	mg/L	0.2	–	0.2	0.2	–	–	–	–	–	–	–	–	–	–	–	–
Orthophosphate (as P)	mg/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
Silica (as SiO_2)	mg/L	24.6	–	24.5	24.3	25.3	–	25.6	25.0	25.3	–	25.2	25.0	25.6	–	25.6	25.3
Turbidity	NTU	0.2	–	0.3	0.2	0.3	–	0.3	0.5	0.1	–	0.2	0.1	0.3	–	0.4	0.7
pH	–	7.0	7.2	7.1	7.1	7.0	7.0	7.0	7.0	7.0	7.2	7.1	7.0	7.0	7.4	7.1	7.0
Temperature	ºC	26.1	24.5	26.7	24.0	22.0	21.7	21.0	21.1	21.9	21.0	21.2	21.1	22.0	21.7	21.3	22.2
DO	mg/L	4.4	5.5	4.2	4.1	4.2	4.1	4.0	3.8	4.2	5.8	4.1	4.1	4.1	4.5	3.9	5.1
ORP	mV	484	590	599	613	203	609	634	647	247	587	627	641	239	552	614	622
Free Chlorine (as Cl_2)	mg/L	–	0.5	0.5	0.4	–	0.5	0.4	0.4	–	0.4	0.4	0.4	–	0.4	0.4	0.4
Total Chlorine (as Cl_2)	mg/L	–	0.6	0.6	0.5	–	0.5	0.5	0.5	–	0.4	0.4	0.4	–	0.4	0.4	0.4
Total Hardness	mg/L[(a)]	351	–	397	352	–	–	–	–	–	–	–	–	–	–	–	–
Ca Hardness	mg/L[(a)]	208	–	236	207	–	–	–	–	–	–	–	–	–	–	–	–
Mg Hardness	mg/L[(a)]	143	–	161	145	–	–	–	–	–	–	–	–	–	–	–	–
As (total)	µg/L	56.0	–	1.0	0.3	81.4	–	1.4	0.3	57.0	–	0.7	0.3	48.3	–	0.7	0.3
As (soluble)	µg/L	57.6	–	1.0	0.3	–	–	–	–	–	–	–	–	–	–	–	–
As (particulate)	µg/L	<0.1	–	<0.1	<0.1	–	–	–	–	–	–	–	–	–	–	–	–
As (III)	µg/L	1.0	–	0.8	0.6	–	–	–	–	–	–	–	–	–	–	–	–
As (V)	µg/L	56.6	–	0.2	<0.1	–	–	–	–	–	–	–	–	–	–	–	–
Fe (total)	µg/L	<25	–	<25	<25	<25	–	<25	<25	<25	–	<25	<25	<25	–	<25	<25
Fe (soluble)	µg/L	<25	–	<25	<25	–	–	–	–	–	–	–	–	–	–	–	–
Mn (total)	µg/L	0.3	–	<0.1	<0.1	0.5	–	<0.1	<0.1	0.8	–	0.2	<0.1	0.4	–	<0.1	0.1
Mn (soluble)	µg/L	0.4	–	<0.1	<0.1	–	–	–	–	–	–	–	–	–	–	–	–

(a) As $CaCO_3$.
IN = at inlet; AC = after prechlorination (field parameters only); TA = after tank A; TB = after tank B.

Analytical Results from Long-Term Sampling, Rimrock, AZ (Continued)

Sampling Date		08/25/04				09/01/04				09/08/04				09/15/04			
Sampling Location Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB
Bed Volume	10^3	–	–	8.5	4.2	–	–	9.4	4.7	–	–	10.4	5.2	–	–	11.3	5.6
Alkalinity	mg/L[(a)]	359	–	363	367	371	–	375	371	383	–	375	375	372 376	–	376 372	372 384
Fluoride	mg/L	0.3	–	0.3	0.3	–	–	–	–	–	–	–	–	–	–	–	–
Sulfate	mg/L	10.0	–	9.8	10.0	–	–	–	–	–	–	–	–	–	–	–	–
Nitrate (as N)	mg/L	0.2	–	0.2	0.2	–	–	–	–	–	–	–	–	–	–	–	–
Orthophosphate (as P)	mg/L	<0.1	–	<0.1	<0.1	<0.1	–	<0.1	<0.1	<0.1	–	<0.1	<0.1	<0.06 <0.06	–	<0.06 <0.06	<0.06 <0.06
Silica (as SiO_2)	mg/L	26.7	–	27.2	26.9	25.3	–	25.2	25.1	25.6	–	25.2	25.6	25.9 25.6	–	25.6 25.0	25.9 25.5
Turbidity	NTU	0.1	–	0.1	<0.1	0.1	–	0.3	0.2	0.1	–	0.1	0.2	0.6 0.5	–	0.5 0.5	0.6 0.5
pH	–	7.0	7.0	7.0	6.9	7.1	7.6	7.1	7.1	6.9	7.1	6.9	6.9	7.1	7.4	7.1	7.1
Temperature	ºC	21.9	21.2	21.2	21.4	21.2	21.6	21.2	21.2	22.6	22.3	21.5	22.0	21.5	21.9	21.2	21.3
DO	mg/L	3.3	4.7	3.6	3.4	4.6	4.5	4.4	4.6	3.5	3.4	3.6	3.5	3.8	6.1	4.9	4.7
ORP	mV	210	610	649	658	213	608	637	637	431	642	668	685	226	578	619	633
Free Chlorine (as Cl_2)	mg/L	–	0.5	0.3	0.3	–	0.4	0.3	0.3	–	0.4	0.4	0.4	–	0.4	0.4	0.4
Total Chlorine (as Cl_2)	mg/L	–	0.5	0.4	0.4	–	0.4	0.4	0.4	–	0.5	0.5	0.5	–	0.4	0.4	0.4
Total Hardness	mg/L[(a)]	305	–	319	328	–	–	–	–	–	–	–	–	–	–	–	–
Ca Hardness	mg/L[(a)]	183	–	182	182	–	–	–	–	–	–	–	–	–	–	–	–
Mg Hardness	mg/L[(a)]	122	–	137	145	–	–	–	–	–	–	–	–	–	–	–	–
As (total)	µg/L	64.6	–	2.7	1.0	77.5	–	1.1	0.4	78.5	–	1.1	0.4	55.3 60.2	–	1.1 1.1	0.5 0.3
As (soluble)	µg/L	61.1	–	2.8	1.2	–	–	–	–	–	–	–	–	–	–	–	–
As (particulate)	µg/L	3.5	–	<0.1	<0.1	–	–	–	–	–	–	–	–	–	–	–	–
As (III)	µg/L	2.1	–	2.7	1.1	–	–	–	–	–	–	–	–	–	–	–	–
As (V)	µg/L	59.0	–	0.1	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	1.4	–	1.2	0.9	0.4	–	<0.1	<0.1	0.3	–	<0.1	0.1	0.4 0.3	–	0.2 0.2	0.1 <0.1
Mn (soluble)	µg/L	0.5	–	0.3	0.1	–	–	–	–	–	–	–	–	–	–	–	–

(a) As $CaCO_3$.
IN = at inlet; AC = after prechlorination (field parameters only); TA = after tank A; TB = after tank B.

Analytical Results from Long-Term Sampling, Rimrock, AZ (Continued)

Sampling Date		09/22/04				09/29/04				10/06/04				10/13/04			
Sampling Location Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB
Bed Volume	10^3	–	–	12.3	6.1	–	–	13.4	6.6	–	–	14.3	7.1	–	–	15.3	7.6
Alkalinity	mg/L[(a)]	369	–	373	373	369	–	369	369	370	–	370	370	353	–	345	353
Fluoride	mg/L	0.4	–	0.5	0.3	–	–	–	–	–	–	–	–	–	–	–	–
Sulfate	mg/L	8.9	–	8.8	8.7	–	–	–	–	–	–	–	–	–	–	–	–
Nitrate (as N)	mg/L	0.2	–	0.2	0.2	–	–	–	–	–	–	–	–	–	–	–	–
Orthophosphate (as P)	mg/L	<0.06	–	<0.06	<0.06	<0.06	–	<0.06	<0.06	<0.06	–	<0.06	<0.06	<0.06	–	<0.06	<0.06
Silica (as SiO_2)	mg/L	25.9	–	25.7	25.6	25.6	–	25.8	25.8	25.7	–	25.6	25.0	24.9	–	25.2	24.9
Turbidity	NTU	0.1	–	<0.1	0.1	<0.1	–	<0.1	0.1	0.3	–	0.5	0.2	0.2	–	0.2	0.2
pH	–	7.0	7.4	7.0	7.0	7.0	7.0	7.0	7.1	7.0	7.0	7.0	7.0	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]
Temperature	ºC	20.1	20.0	20.2	20.3	20.9	21.0	21.0	21.0	20.8	20.6	20.7	20.6	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]
DO	mg/L	4.1	6.4	5.7	4.2	4.1	5.2	4.4	4.2	3.9	6.3	3.5	4.0	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]
ORP	mV	214	584	605	622	224	568	605	617	148	552	590	593	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]
Free Chlorine (as Cl_2)	mg/L	–	0.4	0.4	0.4	–	0.3	0.3	0.3	–	0.2	0.2	0.2	–	NA[(b)]	NA[(b)]	NA[(b)]
Total Chlorine (as Cl_2)	mg/L	–	0.5	0.4	0.4	–	0.4	0.4	0.4	–	0.2	0.2	0.2	–	NA[(b)]	NA[(b)]	NA[(b)]
Total Hardness	mg/L[(a)]	332	–	340	332	–	–	–	–	–	–	–	–	–	–	–	–
Ca Hardness	mg/L[(a)]	191	–	196	201	–	–	–	–	–	–	–	–	–	–	–	–
Mg Hardness	mg/L[(a)]	141	–	143	131	–	–	–	–	–	–	–	–	–	–	–	–
As (total)	µg/L	65.5	–	2.6	1.0	53.5	–	1.4	0.9	54.1	–	2.1	0.4	53.2	–	1.4	0.2
As (soluble)	µg/L	65.0	–	2.4	0.7	–	–	–	–	–	–	–	–	–	–	–	–
As (particulate)	µg/L	0.5	–	0.2	0.3	–	–	–	–	–	–	–	–	–	–	–	–
As (III)	µg/L	1.8	–	1.8	0.2	–	–	–	–	–	–	–	–	–	–	–	–
As (V)	µg/L	63.2	–	0.6	0.5	–	–	–	–	–	–	–	–	–	–	–	–
Fe (total)	µg/L	127	–	27	56	<25	–	<25	<25	<25	–	<25	<25	<25	–	<25	<25
Fe (soluble)	µg/L	<25	–	<25	<25	–	–	–	–	–	–	–	–	–	–	–	–
Mn (total)	µg/L	0.8	–	0.3	0.5	0.3	–	0.4	0.2	0.1	–	0.2	<0.1	0.4	–	<0.1	<0.1
Mn (soluble)	µg/L	0.4	–	0.1	0.1	–	–	–	–	–	–	–	–	–	–	–	–

(a) As $CaCO_3$. (b) Onsite water quality parameter not measured.
IN = at inlet; AC = after prechlorination (field parameters only); TA = after tank A; TB = after tank B; NA = data not available.

Analytical Results from Long-Term Sampling, Rimrock, AZ (Continued)

Sampling Date		10/20/04				10/27/04				11/03/04				11/17/04			
Sampling Location Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB
Bed Volume	10^3	–	–	16.2	8.0	–	–	17.1	8.5	–	–	18.1	9.0	–	–	20.1	10.0
Alkalinity	mg/L[(a)]	377	–	377	373	386	–	382	390	369	–	377	369	390	–	386	390
Fluoride	mg/L	0.4	–	0.3	0.4	–	–	–	–	–	–	–	–	–	–	–	–
Sulfate	mg/L	9.8	–	9.4	9.6	–	–	–	–	–	–	–	–	–	–	–	–
Nitrate (as N)	mg/L	0.2	–	0.2	0.2	–	–	–	–	–	–	–	–	–	–	–	–
Orthophosphate (as P)	mg/L	<0.06	–	<0.06	<0.06	<0.06	–	<0.06	<0.06	<0.06	–	<0.06	<0.06	<0.06	–	<0.06	<0.06
Silica (as SiO_2)	mg/L	24.9	–	25.0	24.6	25.2	–	25.5	25.3	24.7	–	25.0	25.0	25.6	–	25.1	25.1
Turbidity	NTU	0.1	–	0.1	0.2	0.1	–	0.1	0.3	0.2	–	0.2	0.2	0.3	–	0.3	0.3
pH	–	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	6.9	6.9	6.9	6.9	6.9[(b)]	6.9	6.9	6.8
Temperature	ºC	20.1	20.1	20.3	20.3	19.5	19.8	19.7	19.7	20.4	20.6	20.6	20.6	20.7[(b)]	20.7	21.2	20.8
DO	mg/L	4.0	4.5	4.1	4.1	4.2	3.6	3.7	3.6	4.0	3.8	4.1	3.9	3.8[(b)]	4.0	3.5	4.1
ORP	mV	190	637	681	710	216	552	577	590	180	491	565	591	504[(b)]	619	640	651
Free Chlorine (as Cl_2)	mg/L	–	0.2	0.2	0.2	–	0.3	0.3	0.3	–	0.3	0.3	0.3	–	0.3	0.3	0.3
Total Chlorine (as Cl_2)	mg/L	–	0.2	0.2	0.2	–	0.4	0.4	0.4	–	0.4	0.4	0.4	–	0.3	0.3	0.3
Total Hardness	mg/L[(a)]	366	–	365	361	–	–	–	–	–	–	–	–	–	–	–	–
Ca Hardness	mg/L[(a)]	214	–	214	212	–	–	–	–	–	–	–	–	–	–	–	–
Mg Hardness	mg/L[(a)]	152	–	150	149	–	–	–	–	–	–	–	–	–	–	–	–
As (total)	µg/L	50.8	–	1.3	1.0	56.5	–	1.6	0.8	56.3	–	1.6	0.8	56.5	–	1.3	1.3
As (soluble)	µg/L	50.2	–	1.1	0.7	–	–	–	–	–	–	–	–	–	–	–	–
As (particulate)	µg/L	0.6	–	0.3	0.3	–	–	–	–	–	–	–	–	–	–	–	–
As (III)	µg/L	2.2	–	1.3	1.3	–	–	–	–	–	–	–	–	–	–	–	–
As (V)	µg/L	48.0	–	<0.1	<0.1	–	–	–	–	–	–	–	–	–	–	–	–
Fe (total)	µg/L	<25	–	<25	<25	<25	–	27.0	<25	<25	–	31.1	<25	<25	–	<25	<25
Fe (soluble)	µg/L	<25	–	<25	<25	–	–	–	–	–	–	–	–	–	–	–	–
Mn (total)	µg/L	0.6	–	<0.1	0.3	0.2	–	0.2	<0.1	0.3	–	0.4	0.2	<0.1	–	<0.1	0.9
Mn (soluble)	µg/L	1.0	–	<0.1	<0.1	–	–	–	–	–	–	–	–	–	–	–	–

(a) As $CaCO_3$. (b) Measurement possibly taken from incorrect location.
IN = at inlet; AC = after prechlorination (field parameters only); TA = after tank A; TB = after tank B.

Analytical Results from Long-Term Sampling, Rimrock, AZ (Continued)

Sampling Date		12/01/04				12/15/04[b]				01/05/05[c]				01/19/05			
Sampling Location / Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB
Bed Volume	10^3	–	–	22.1	10.9	–	–	24.1	11.9	–	–	27.2	13.5	–	–	29.3	14.5
Alkalinity	mg/L[a]	365 365	–	365 365	365 370	383	–	370	366	380	–	372	389	378	–	387	374
Fluoride	mg/L	–	–	–	–	0.4	–	0.4	0.3	–	–	–	–	–	–	–	–
Sulfate	mg/L	–	–	–	–	9.7	–	9.1	8.8	–	–	–	–	–	–	–	–
Nitrate (as N)	mg/L	–	–	–	–	0.2	–	0.2	0.2	–	–	–	–	–	–	–	–
Orthophosphate (as P)	mg/L	<0.06 <0.06	–	<0.06 <0.06	<0.06 <0.06	<0.06	–	<0.06	<0.06	–	–	–	–	–	–	–	–
Silica (as SiO_2)	mg/L	25.5 25.3	–	25.2 25.4	25.3 25.3	25.9	–	26.4	26.3	26.1	–	26.3	26.9	23.9	–	24.8	24.9
Turbidity	NTU	0.1 0.1	–	0.1 0.2	0.1 0.3	0.2	–	0.2	0.1	0.3	–	<0.1	0.2	<0.1	–	<0.1	<0.1
pH	–	7.0	6.9	6.9	6.9	6.9	6.9	6.9	6.9	NA[d]	NA[d]	NA[d]	NA[d]	7.1	7.0	7.0	7.0
Temperature	ºC	20.1	21.2	20.6	21.1	20.6	20.1	20.4	20.0	20.5	20.7	20.7	20.3	21.1	20.9	20.9	20.3
DO	mg/L	4.3	3.4	3.9	3.5	4.0	3.2	3.5	3.4	3.5	4.1	3.4	4.1	4.3	4.0	4.1	4.1
ORP	mV	267	626	646	673	230	618	660	672	223	571	605	470	214	620	645	658
Free Chlorine (as Cl_2)	mg/L	–	0.4	0.4	0.4	–	0.3	0.3	0.3	–	0.2	0.2	0.2	–	0.4	0.4	0.4
Total Chlorine (as Cl_2)	mg/L	–	0.5	0.5	0.5	–	0.4	0.3	0.3	–	NA[e]	NA[e]	NA[e]	–	0.5	0.5	0.5
Total Hardness	mg/L[a]	–	–	–	–	384	–	374	377	–	–	–	–	–	–	–	–
Ca Hardness	mg/L[a]	–	–	–	–	241	–	234	235	–	–	–	–	–	–	–	–
Mg Hardness	mg/L[a]	–	–	–	–	143	–	140	142	–	–	–	–	–	–	–	–
As (total)	µg/L	51.4 52.3	–	1.7 1.7	0.4 0.4	60.3	–	3.0	0.8	43.8	–	2.5	0.2	51.3	–	4.4	0.6
As (soluble)	µg/L	–	–	–	–	59.6	–	3.0	0.6	–	–	–	–	–	–	–	–
As (particulate)	µg/L	–	–	–	–	0.7	–	<0.1	0.2	–	–	–	–	–	–	–	–
As (III)	µg/L	–	–	–	–	1.2	–	1.3	0.7	–	–	–	–	–	–	–	–
As (V)	µg/L	–	–	–	–	58.4	–	1.7	<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	0.1 0.1	–	<0.1 0.4	<0.1 <0.1	0.3	–	<0.1	0.2	<0.1	–	<0.1	<0.1	0.2	–	<0.1	0.3
Mn (soluble)	µg/L	–	–	–	–	0.1	–	<0.1	<0.1	–	–	–	–	–	–	–	–

(a) As $CaCO_3$. (b) Water quality measurements taken on 12/16/04. (c) Water quality measurements taken on 01/06/05. (d) pH probe not working properly.
(e) Onsite water quality parameter not measured.
IN = at inlet; AC = after prechlorination (field parameters only); TA = after tank A; TB = after tank B; NA = data not available.

Analytical Results from Long-Term Sampling, Rimrock, AZ (Continued)

Sampling Date		02/02/05				02/16/05				03/02/05				03/16/05			
Sampling Location Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB
Bed Volume	10^3	–	–	31.1	15.4	–	–	33.2	16.4	–	–	35.1	17.4	–	–	37.1	18.4
Alkalinity	mg/L[(a)]	414	–	387	405	392	–	374	405	378 378	–	369 373	391 386	388	–	392	401
Fluoride	mg/L	–	–	–	–	0.3	–	0.3	0.3	–	–	–	–	–	–	–	–
Sulfate	mg/L	–	–	–	–	10.0	–	10.0	10.0	–	–	–	–	–	–	–	–
Nitrate (as N)	mg/L	–	–	–	–	0.3	–	0.3	0.3	–	–	–	–	–	–	–	–
Silica (as SiO_2)	mg/L	24.9	–	24.5	24.8	27.6	–	27.5	27.4	26.2 26.2	–	26.4 26.3	26.5 26.1	26.4	–	26.4	25.8
Turbidity	NTU	0.1	–	<0.1	<0.1	0.1	–	<0.1	0.2	<0.1 <0.1	–	0.1 <0.1	0.1 0.1	<0.1	–	0.1	<0.1
pH	–	6.8	6.8	6.8	6.8	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.8	6.8	6.8	6.8	6.8
Temperature	°C	18.6	19.2	19.7	20.1	20.4	20.0	20.2	20.1	20.5	20.2	20.2	20.3	18.8	19.5	19.4	19.6
DO	mg/L	4.2	3.9	3.6	4.2	3.6	3.6	3.6	3.7	3.4	3.3	4.1	4.1	4.8	4.4	4.5	3.6
ORP	mV	258	643	664	670	448	643	671	693	490	625	654	673	209	616	645	656
Free Chlorine (as Cl_2)	mg/L	–	0.5	0.4	0.4	–	0.4	0.3	0.3	–	0.3	0.3	0.3	–	0.3	0.3	0.3
Total Chlorine (as Cl_2)	mg/L	–	0.5	0.5	0.5	–	0.5	0.4	0.4	–	0.4	0.4	0.4	–	0.3	0.4	0.4
Total Hardness	mg/L[(a)]	–	–	–	–	302	–	311	305	–	–	–	–	–	–	–	–
Ca Hardness	mg/L[(a)]	–	–	–	–	183	–	161	188	–	–	–	–	–	–	–	–
Mg Hardness	mg/L[(a)]	–	–	–	–	119	–	150	117	–	–	–	–	–	–	–	–
As (total)	µg/L	48.8	–	4.7	1.9	52.5	–	6.8	0.3	64.4 67.4	–	9.1 9.8	0.5 0.5	51.2	–	8.2	0.4
As (soluble)	µg/L	–	–	–	–	51.1	–	6.6	0.3	–	–	–	–	–	–	–	–
As (particulate)	µg/L	–	–	–	–	1.4	–	0.2	<0.1	–	–	–	–	–	–	–	–
As (III)	µg/L	–	–	–	–	0.9	–	0.8	0.7	–	–	–	–	–	–	–	–
As (V)	µg/L	–	–	–	–	50.2	–	5.8	<0.1	–	–	–	–	–	–	–	–
Fe (total)	µg/L	<25	–	<25	32.7	<25	–	<25	<25	<25 <25	–	<25 <25	<25 <25	<25	–	<25	<25
Fe (soluble)	µg/L	–	–	–	–	<25	–	<25	<25	–	–	–	–	–	–	–	–
Mn (total)	µg/L	1.2	–	0.2	12.4	0.3	–	<0.1	<0.1	<0.1 <0.1	–	<0.1 <0.1	0.1 <0.1	<0.1	–	<0.1	<0.1
Mn (soluble)	µg/L	–	–	–	–	<0.1	–	<0.1	<0.1	–	–	–	–	–	–	–	–

(a) As $CaCO_3$.
IN = at inlet; AC = after prechlorination (field parameters only); TA = after tank A; TB = after tank B.

Analytical Results from Long-Term Sampling, Rimrock, AZ (Continued)

Sampling Date		03/30/05				04/13/05				04/27/05				05/11/05			
Sampling Location Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB
Bed Volume	10^3	–	–	39.2	19.4	–	–	41.1	20.3	–	–	43.1	21.3	–	–	45.2	22.3
Alkalinity	mg/L[(a)]	383	–	378	383	401	–	424	410	405	–	396	396	400	–	396	400
Fluoride	mg/L	–	–	–	–	0.3	–	0.3	0.3	–	–	–	–	–	–	–	–
Sulfate	mg/L	–	–	–	–	8.1	–	7.8	8.1	–	–	–	–	–	–	–	–
Nitrate (as N)	mg/L	–	–	–	–	0.2	–	0.2	0.2	–	–	–	–	–	–	–	–
Silica (as SiO_2)	mg/L	26.1	–	26.1	26.0	27.0	–	27.3	27.0	26.1	–	26.3	26.1	26.0	–	26.2	26.2
Turbidity	NTU	<0.1	–	<0.1	<0.1	0.2	–	0.4	<0.1	0.1	–	0.1	<0.1	<0.1	–	<0.1	<0.1
pH	–	6.9	6.9	6.9	6.8	6.9	6.9	6.9	6.9	6.8	6.9	6.9	6.9	6.9	6.9	6.9	6.9
Temperature	ºC	20.6	20.1	20.2	20.2	20.0	20.0	20.2	20.3	20.9	20.3	20.5	20.5	19.8	20.0	20.0	20.0
DO	mg/L	6.0	3.4	3.6	3.5	3.8	3.9	4.1	3.9	4.7	3.3	5.4	4.3	3.5	3.6	3.7	3.7
ORP	mV	308	365	668	686	201	605	631	648	467	646	680	694	217	580	605	613
Free Chlorine (as Cl_2)	mg/L	–	0.4	0.4	0.4	–	0.4	0.4	0.4	–	0.5	0.5	0.5	–	0.5	0.5	0.5
Total Chlorine (as Cl_2)	mg/L	–	0.5	0.5	0.5	–	0.4	0.4	0.4	–	0.6	0.6	0.6	–	0.6	0.6	0.6
Total Hardness	mg/L[(a)]	–	–	–	–	325	–	322	326	–	–	–	–	–	–	–	–
Ca Hardness	mg/L[(a)]	–	–	–	–	199	–	190	197	–	–	–	–	–	–	–	–
Mg Hardness	mg/L[(a)]	–	–	–	–	126	–	131	129	–	–	–	–	–	–	–	–
As (total)	µg/L	52.7	–	10.3	0.5	51.9	–	8.8	0.5	58.7	–	13.3	0.5	50.3	–	11.7	0.5
As (soluble)	µg/L	–	–	–	–	51.4	–	8.9	0.4	–	–	–	–	–	–	–	–
As (particulate)	µg/L	–	–	–	–	0.5	–	<0.1	<0.1	–	–	–	–	–	–	–	–
As (III)	µg/L	–	–	–	–	0.8	–	0.7	0.7	–	–	–	–	–	–	–	–
As (V)	µg/L	–	–	–	–	50.6	–	8.2	<0.1	–	–	–	–	–	–	–	–
Fe (total)	µg/L	<25	–	<25	<25	27.2	–	<25	<25	<25	–	<25	<25	<25	–	<25	25.8
Fe (soluble)	µg/L	–	–	–	–	<25	–	<25	<25	–	–	–	–	–	–	–	–
Mn (total)	µg/L	0.5	–	0.4	0.4	0.2	–	<0.1	<0.1	0.4	–	0.2	0.2	<0.1	–	<0.1	<0.1
Mn (soluble)	µg/L	–	–	–	–	0.2	–	<0.1	<0.1	–	–	–	–	–	–	–	–

(a) As $CaCO_3$.
IN = at inlet; AC = after prechlorination (field parameters only); TA = after tank A; TB = after tank B.

Analytical Results from Long-Term Sampling, Rimrock, AZ (Continued)

Sampling Date		05/25/05				06/08/05				06/22/05				07/06/05			
Sampling Location Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB
Bed Volume	10^3	–	–	47.2	46.6	–	–	49.3	24.3	–	–	51.3	25.3	–	–	53.3	26.3
Alkalinity	mg/L[(a)]	392 401	–	401 401	401 397	400	–	387	387	374	–	374	383	374	–	374	374
Fluoride	mg/L	–	–	–	–	0.3	–	0.2	0.2	–	–	–	–	–	–	–	–
Sulfate	mg/L	–	–	–	–	11.0	–	10.0	11.0	–	–	–	–	–	–	–	–
Nitrate (as N)	mg/L	–	–	–	–	0.6	–	0.3	0.3	–	–	–	–	–	–	–	–
Silica (as SiO_2)	mg/L	25.6 25.3	–	25.9 25.0	25.3 25.9	26.8	–	26.6	26.5	25.3	–	25.3	25.3	26.2	–	26.1	25.9
Turbidity	NTU	0.2 0.5	–	1.3 0.4	0.2 0.7	<0.1	–	<0.1	<0.1	0.7	–	0.9	0.2	0.2	–	<0.1	0.1
pH	–	7.0	7.0	7.0	7.0	6.8	6.8	6.8	6.8	7.0	7.0	7.1	7.0	7.1	7.0	7.0	7.0
Temperature	ºC	20.9	20.6	20.6	20.7	21.4	20.8	21.1	21.1	21.0	21.1	21.0	21.0	21.1	20.7	20.6	20.9
DO	mg/L	4.1	3.0	3.3	3.5	3.3	3.3	3.5	3.5	3.2	3.3	3.1	3.0	3.5	3.3	3.4	3.8
ORP	mV	194	571	608	611	447	594	620	627	182	600	628	637	182	580	618	624
Free Chlorine (as Cl_2)	mg/L	–	0.5	0.5	0.5	–	0.3	0.3	0.3	–	0.3	0.3	0.3	–	0.3	0.3	0.3
Total Chlorine (as Cl_2)	mg/L	–	0.5	0.5	0.5	–	0.3	0.3	0.3	–	0.3	0.3	0.3	–	0.3	0.3	0.3
Total Hardness	mg/L[(a)]	–	–	–	–	323	–	323	329	–	–	–	–	–	–	–	–
Ca Hardness	mg/L[(a)]	–	–	–	–	197	–	196	204	–	–	–	–	–	–	–	–
Mg Hardness	mg/L[(a)]	–	–	–	–	127	–	126	125	–	–	–	–	–	–	–	–
As (total)	µg/L	49.7 50.3	–	13.3 13.3	0.4 0.5	57.6	–	17.2	1.2	55.4	–	18.3	0.9	49.2	–	15.6	0.5
As (soluble)	µg/L	–	–	–	–	59.8	–	18.8	1.1	–	–	–	–	–	–	–	–
As (particulate)	µg/L	–	–	–	–	<0.1	–	<0.1	<0.1	–	–	–	–	–	–	–	–
As (III)	µg/L	–	–	–	–	1.2	–	1.2	1.9	–	–	–	–	–	–	–	–
As (V)	µg/L	–	–	–	–	58.6	–	17.6	<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	0.1 0.2	–	<0.1 <0.1	<0.1 <0.1	0.2	–	<0.1	0.1	0.3	–	0.2	0.2	0.2	–	<0.1	<0.1
Mn (soluble)	µg/L	–	–	–	–	0.2	–	0.1	<0.1	–	–	–	–	–	–	–	–

(a) As $CaCO_3$.

IN = at inlet; AC = after prechlorination (field parameters only); TA = after tank A; TB = after tank B.

Analytical Results from Long-Term Sampling, Rimrock, AZ (Continued)

Sampling Date		07/21/05				08/03/05				08/17/05				08/31/05			
Sampling Location Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB
Bed Volume	10^3	–	–	55.5	27.3	–	–	57.3	28.2	–	–	59.3	29.2	–	–	61.2	30.1
Alkalinity	mg/L[(a)]	374	–	374	378	383	–	378	378	374	–	383	387	365	–	378	374
Fluoride	mg/L	–	–	–	–	0.3	–	0.3	0.3	–	–	–	–	–	–	–	–
Sulfate	mg/L	–	–	–	–	10.0	–	10.0	10.0	–	–	–	–	–	–	–	–
Nitrate (as N)	mg/L	–	–	–	–	0.3	–	0.2	0.2	–	–	–	–	–	–	–	–
Silica (as SiO_2)	mg/L	24.8	–	25.0	24.8	24.4	–	24.8	25.0	25.4	–	25.2	25.3	26.6	–	27.3	27.1
Turbidity	NTU	0.3	–	1.6	3.4	0.1	–	0.1	0.1	<0.1	–	<0.1	0.1	0.3	–	0.2	0.1
pH	–	6.9	7.0	7.0	6.9	7.0	6.9	6.9	6.9	6.9	7.0	6.9	6.9	6.9	7.0	6.9	6.9
Temperature	ºC	22.1	21.4	22.5	22.8	21.7	21.2	21.5	22.0	21.3	21.0	21.0	21.5	22.5	21.4	21.8	22.7
DO	mg/L	3.3	3.1	3.4	3.6	3.5	3.4	3.3	3.7	3.6	4.3	3.9	3.6	3.3	4.0	3.5	3.7
ORP	mV	439	608	628	636	434	611	630	642	399	593	593	633	470	612	610	608
Free Chlorine (as Cl_2)	mg/L	–	0.2	0.2	0.2	–	0.4	0.3	0.3	–	0.3	0.2	0.2	–	0.3	0.3	0.3
Total Chlorine (as Cl_2)	mg/L	–	0.3	0.3	0.3	–	0.5	0.4	0.4	–	0.3	0.3	0.3	–	0.4	0.4	0.4
Total Hardness	mg/L[(a)]	–	–	–	–	296	–	301	306	–	–	–	–	–	–	–	–
Ca Hardness	mg/L[(a)]	–	–	–	–	186	–	188	191	–	–	–	–	–	–	–	–
Mg Hardness	mg/L[(a)]	–	–	–	–	110	–	112	115	–	–	–	–	–	–	–	–
As (total)	µg/L	50.8	–	18.9	0.9	50.7	–	19.5	0.7	51.6	–	19.1	0.8	54.4	–	21.7	0.7
As (soluble)	µg/L	–	–	–	–	50.8	–	19.5	0.7	–	–	–	–	–	–	–	–
As (particulate)	µg/L	–	–	–	–	<0.1	–	<0.1	<0.1	–	–	–	–	–	–	–	–
As (III)	µg/L	–	–	–	–	1.5	–	1.4	1.5	–	–	–	–	–	–	–	–
As (V)	µg/L	–	–	–	–	49.3	–	18.1	<0.1	–	–	–	–	–	–	–	–
Fe (total)	µg/L	<25	–	<25	<25	<25	–	<25	<25	<25	–	<25	<25	<25	–	<25	<25
Fe (soluble)	µg/L	–	–	–	–	<25	–	<25	<25	–	–	–	–	–	–	–	–
Mn (total)	µg/L	0.2	–	<0.1	0.1	<0.1	–	<0.1	<0.1	0.2	–	0.1	<0.1	0.3	–	<0.1	<0.1
Mn (soluble)	µg/L	–	–	–	–	<0.1	–	<0.1	<0.1	–	–	–	–	–	–	–	–

(a) As $CaCO_3$.
IN = at inlet; AC = after prechlorination (field parameters only); TA = after tank A; TB = after tank B.

Analytical Results from Long-Term Sampling, Rimrock, AZ (Continued)

Sampling Date		09/14/05				09/28/05				10/12/05				11/09/05			
Sampling Location / Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB
Bed Volume	10^3	–	–	63.2	31.1	–	–	65.1	32.0	–	–	NA[b]	NA[b]	–	–	70.9	34.9
Alkalinity	mg/L[a]	374	–	378	374	383	–	387	396	378	–	383	387	378	–	378	396
Fluoride	mg/L	–	–	–	–	–	–	–	–	0.2	–	0.2	0.2	–	–	–	–
Sulfate	mg/L	–	–	–	–	–	–	–	–	10	–	9.9	9.9	–	–	–	–
Nitrate (as N)	mg/L	–	–	–	–	–	–	–	–	0.2	–	0.2	0.2	–	–	–	–
Phosphorus (as P)	µg/L	–	–	–	–	–	–	–	–	16.8	–	14.8	<10	11.5	–	12.1	<10
Silica (as SiO_2)	mg/L	23.6	–	23.9	23.7	26.7	–	26.7	26.4	24.9	–	24.2	23.9	25	–	24.7	25.3
Turbidity	NTU	0.1	–	0.3	0.4	0.1	–	<0.1	0.1	<0.1	–	<0.1	<0.1	0.1	–	<0.1	<0.1
pH	–	7.0	7.0	7.0	7.0	7.0	7.0	6.7	7.0	NA[c]	NA[c]	NA[c]	NA[c]	7.0	7.0	7.0	7.0
Temperature	ºC	20.7	20.5	20.5	20.4	21.0	20.6	20.9	21.4	NA[c]	NA[c]	NA[c]	NA[c]	20.2	20.2	20.3	20.3
DO	mg/L	3.9	3.8	4.0	4.0	3.7	3.7	4.1	3.9	NA[c]	NA[c]	NA[c]	NA[c]	3.7	3.7	4.0	4.0
ORP	mV	199	565	595	603	469	600	618	631	NA[c]	NA[c]	NA[c]	NA[c]	181	559	594	603
Free Chlorine (as Cl_2)	mg/L	–	0.3	0.3	0.3	–	0.3	0.2	0.2	–	NA[c]	NA[c]	NA[c]	–	0.3	0.2	0.2
Total Chlorine (as Cl_2)	mg/L	–	0.4	0.4	0.4	–	0.3	0.3	0.3	–	NA[c]	NA[c]	NA[c]	–	0.3	0.3	0.3
Total Hardness	mg/L[a]	–	–	–	–	–	–	–	–	322	–	325	328	–	–	–	–
Ca Hardness	mg/L[a]	–	–	–	–	–	–	–	–	196	–	198	199	–	–	–	–
Mg Hardness	mg/L[a]	–	–	–	–	–	–	–	–	125	–	127	129	–	–	–	–
As (total)	µg/L	49.4	–	21.7	1.0	55.9	–	25.9	1.5	66.8	–	31.7[d]	1.4	70.5	–	38.2	1.5
As (soluble)	µg/L	–	–	–	–	–	–	–	–	66.7	–	25.9[d]	1.2	–	–	–	–
As (particulate)	µg/L	–	–	–	–	–	–	–	–	11.5	–	5.8	0.2	–	–	–	–
As (III)	µg/L	–	–	–	–	–	–	–	–	1.2	–	1.0	1.0	–	–	–	–
As (V)	µg/L	–	–	–	–	–	–	–	–	57.0	–	24.8	0.2	–	–	–	–
Fe (total)	µg/L	<25	–	<25	<25	<25	–	<25	<25	<25	–	<25	<25	<25	–	<25	<25
Fe (soluble)	µg/L	–	–	–	–	–	–	–	–	<25	–	<25	<25	–	–	–	–
Mn (total)	µg/L	<0.1	–	<0.1	<0.1	<0.1	–	<0.1	<0.1	<0.1	–	<0.1	<0.1	<0.1	–	<0.1	<0.1
Mn (soluble)	µg/L	–	–	–	–	–	–	–	–	<0.1	–	<0.1	<0.1	–	–	–	–

(a) As $CaCO_3$. (b) Daily readings not recorded this week. (c) Onsite water quality parameter not measured. (d) Reanalysis indicated similar result.
IN = at inlet; AC = after prechlorination (field parameters only); TA = after tank A; TB = after tank B; NA = data not available.

Analytical Results from Long-Term Sampling, Rimrock, AZ (Continued)

Sampling Date		12/07/05				01/04/06				02/01/06				03/08/06			
Sampling Location / Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB
Bed Volume	10^3	–	–	74.7	36.8	–	–	78.6	38.7	–	–	82.5	40.6	–	–	87.3	43.0
Alkalinity	mg/L[a]	383	–	383	378	396	–	396	396	390	–	382	386	377	–	381	381
Fluoride	mg/L	0.2	–	0.2	0.2	–	–	–	–	0.2	–	0.2	0.2	0.2	–	0.2	0.2
Sulfate	mg/L	10	–	10	10	–	–	–	–	10	–	10	10	10	–	10	10
Nitrate (as N)	mg/L	0.2	–	0.2	0.2	–	–	–	–	0.2	–	0.2	0.2	0.2	–	0.2	0.2
Phosphorus (as P)	µg/L	<10	–	<10	<10	12.7	–	15.1	<10	<10	–	<10	<10	15.4	–	17.0	<10
Silica (as SiO_2)	mg/L	25.2	–	25.5	25.7	25.4	–	25.2	25.2	26.3	–	26.4	26.2	24.7	–	23.9	24.3
Turbidity	NTU	0.1	–	<0.1	<0.1	0.2	–	0.4	0.1	0.1	–	<0.1	<0.1	0.3	–	0.6	0.3
pH	–	6.9	7.0	6.9	6.9	6.9	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.9	6.9	6.9	6.9
Temperature	ºC	19.9	19.5	19.9	19.9	19.7	19.8	19.9	20.0	20.0	19.9	20.0	20.1	19.7	19.4	19.6	19.6
DO	mg/L	3.6	3.9	3.8	3.9	4.0	4.0	4.3	4.2	4.1	3.8	3.8	3.8	3.7	3.5	3.0	3.6
ORP	mV	205	595	611	633	232	630	649	663	475	634	663	683	481	644	671	684
Free Chlorine (as Cl_2)	mg/L	–	0.3	0.2	0.2	–	0.3	0.3	0.3	–	0.3	0.3	0.3	–	0.4	0.4	0.4
Total Chlorine (as Cl_2)	mg/L	–	0.3	0.3	0.3	–	0.4	0.4	0.4	–	0.3	0.3	0.3	–	0.4	0.4	0.4
Total Hardness	mg/L[a]	325	–	337	341	–	–	–	–	330	–	339	353	341	–	342	346
Ca Hardness	mg/L[a]	199	–	207	205	–	–	–	–	202	–	206	208	206	–	207	208
Mg Hardness	mg/L[a]	125	–	130	136	–	–	–	–	128	–	134	144	135	–	135	138
As (total)	µg/L	61.2	–	35.8	3.4	53.8	–	33.6	2.7	69.4[b]	–	43.2[b]	3.9	76.7	–	50.7	5.6
As (soluble)	µg/L	61.6	–	34.6	3.1	–	–	–	–	54.3[b]	–	33.9[b]	3.3	55.0	–	35.5	4.4
As (particulate)	µg/L	<0.1	–	1.3	0.3	–	–	–	–	15.1	–	9.3	0.6	21.7	–	15.2	1.1
As (III)	µg/L	0.7	–	0.7	0.7	–	–	–	–	0.7	–	0.5	0.6	0.7	–	0.6	0.6
As (V)	µg/L	60.9	–	33.8	2.4	–	–	–	–	53.7	–	33.4	2.7	54.3	–	34.8	3.9
Fe (total)	µg/L	<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	0.2	–	0.2	0.2	<0.1	–	<0.1	<0.1	<0.1	–	<0.1	<0.1	0.1	–	0.1	<0.1
Mn (soluble)	µg/L	0.2	–	0.1	0.1	–	–	–	–	<0.1	–	<0.1	<0.1	<0.1	–	<0.1	<0.1

(a) As $CaCO_3$. (b) Reanalysis indicated similar result.
IN = at inlet; AC = after prechlorination (field parameters only); TA = after tank A; TB = after tank B.

Analytical Results from Long-Term Sampling, Rimrock, AZ (Continued)

Sampling Date		04/05/06				04/19/06				05/03/06				05/17/06			
Sampling Location Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB
Bed Volume	10^3	–	–	91.1	44.9	–	–	93.0	45.8	–	–	94.8	NA	–	–	96.7	47.6
Alkalinity	mg/L[a]	372	–	376	376	406	–	401	388	374	–	386	382	380 384	–	388 380	384 355
Fluoride	mg/L	–	–	–	–	–	–	–	–	0.3	–	0.2	0.3	–	–	–	–
Sulfate	mg/L	–	–	–	–	–	–	–	–	9	–	9	9	–	–	–	–
Nitrate (as N)	mg/L	–	–	–	–	–	–	–	–	0.2	–	0.2	0.2	–	–	–	–
Phosphorus (as P)	µg/L	<10	–	10.7	<10	20.4	–	21.4	10.4	<10	–	13.4	<10	<10 <10	–	<10 <10	<10 <10
Silica (as SiO_2)	mg/L	25.3	–	24.4	25.0	24.7	–	24.3	24.4	26.0	–	25.6	25.9	26.8 26.3	–	26.7 26.2	25.7 26.4
Turbidity	NTU	0.3	–	0.5	0.6	0.3	–	0.4	0.2	0.3	–	0.2	0.2	0.3 0.3	–	0.2 0.4	0.4 0.2
pH	–	6.9	6.9	6.9	6.9	NA[b]	NA[b]	NA[b]	NA[b]	7.0	7.0	6.9	6.9	NA[b]	NA[b]	NA[b]	NA[b]
Temperature	ºC	19.3	19.5	19.6	19.6	NA[b]	NA[b]	NA[b]	NA[b]	20.5	20.4	20.9	20.7	NA[b]	NA[b]	NA[b]	NA[b]
DO	mg/L	3.7	3.7	3.8	3.5	NA[b]	NA[b]	NA[b]	NA[b]	3.7	3.9	3.8	3.8	NA[b]	NA[b]	NA[b]	NA[b]
ORP	mV	211	616	649	659	NA[b]	NA[b]	NA[b]	NA[b]	217	646	666	685	NA[b]	NA[b]	NA[b]	NA[b]
Free Chlorine (as Cl_2)	mg/L	–	0.4	0.4	0.4	–	NA[b]	NA[b]	NA[b]	–	0.4	0.4	0.4	–	NA[b]	NA[b]	NA[b]
Total Chlorine (as Cl_2)	mg/L	–	0.4	0.4	0.4	–	NA[b]	NA[b]	NA[b]	–	0.4	0.4	0.4	–	NA[b]	NA[b]	NA[b]
Total Hardness	mg/L[a]	–	–	–	–	–	–	–	–	342	–	332	341	–	–	–	–
Ca Hardness	mg/L[a]	–	–	–	–	–	–	–	–	204	–	198	202	–	–	–	–
Mg Hardness	mg/L[a]	–	–	–	–	–	–	–	–	138	–	135	138	–	–	–	–
As (total)	µg/L	63.8	–	45.5	6.0	63.7	–	42.2	5.6	66.2	–	48.7	6.5	53.8 54.3	–	38.8 39.2	6.3 6.4
As (soluble)	µg/L	–	–	–	–	–	–	–	–	59.1	–	41.9	6.1	–	–	–	–
As (particulate)	µg/L	–	–	–	–	–	–	–	–	7.1	–	6.7	0.4	–	–	–	–
As (III)	µg/L	–	–	–	–	–	–	–	–	0.3	–	0.3	0.3	–	–	–	–
As (V)	µg/L	–	–	–	–	–	–	–	–	58.7	–	41.7	5.8	–	–	–	–
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	<0.1	–	<0.1	<0.1	0.2	–	0.1	0.1	<0.1	–	<0.1	<0.1	0.1 <0.1	–	<0.1 <0.1	<0.1 <0.1
Mn (soluble)	µg/L	–	–	–	–	–	–	–	–	<0.1	–	<0.1	<0.1	–	–	–	–

(a) As $CaCO_3$. (b) Onsite water quality parameter not measured.
IN = at inlet; AC = after prechlorination (field parameters only); TA = after tank A; TB = after tank B; NA = data not available.

Analytical Results from Long-Term Sampling, Rimrock, AZ (Continued)

Sampling Date		06/14/06				07/12/06[c]				08/09/06[d]			
Sampling Location Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB
Bed Volume	10^3	–	–	100.4	49.4	–	–	103.3	50.9	–	–	105.8	52.2
Alkalinity	mg/L[a]	378	–	386	386	377	–	390	373	378	–	386	382
Fluoride	mg/L	–	–	–	–	0.2	–	0.2	0.2	–	–	–	–
Sulfate	mg/L	–	–	–	–	10	–	10	10	–	–	–	–
Nitrate (as N)	mg/L	–	–	–	–	0.2	–	0.2	0.2	–	–	–	–
Phosphorus (as P)	µg/L	18.0	–	20.0	10.9	13.4	–	14.3	<10	<10	–	<10	<10
Silica (as SiO_2)	mg/L	27.0	–	26.8	26.5	25.4	–	24.8	25.5	25.0	–	24.0	24.2
Turbidity	NTU	0.5	–	0.5	0.2	0.3	–	0.4	0.1	0.2	–	0.4	0.4
pH	–	6.9	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Temperature	ºC	21.2	20.6	21.7	22.4	21.5	20.7	21.1	21.1	21.2	20.8	21.2	21.7
DO	mg/L	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]
ORP	mV	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]
Free Chlorine (as Cl_2)	mg/L	–	0.5	0.5	0.5	–	0.3	0.3	0.3	–	0.4	0.4	0.4
Total Chlorine (as Cl_2)	mg/L	–	0.5	0.5	0.5	–	0.3	0.3	0.3	–	0.4	0.4	0.4
Total Hardness	mg/L[a]	–	–	–	–	304	–	314	303	–	–	–	–
Ca Hardness	mg/L[a]	–	–	–	–	185	–	192	185	–	–	–	–
Mg Hardness	mg/L[a]	–	–	–	–	119	–	122	118	–	–	–	–
As (total)	µg/L	76.7	–	56.1	9.2	63.9	–	48.3	8.2	77.5	–	53.7	9.8
As (soluble)	µg/L	–	–	–	–	54.4	–	40.1	7.3	–	–	–	–
As (particulate)	µg/L	–	–	–	–	9.5	–	8.2	0.9	–	–	–	–
As (III)	µg/L	–	–	–	–	0.4	–	0.4	0.4	–	–	–	–
As (V)	µg/L	–	–	–	–	54.0	–	39.8	7.0	–	–	–	–
Fe (total)	µg/L	<25	–	<25	<25	<25	–	<25	<25	<25	–	<25	<25
Fe (soluble)	µg/L	–	–	–	–	<25	–	<25	<25	–	–	–	–
Mn (total)	µg/L	0.1	–	<0.1	<0.1	0.7	–	0.6	0.6	<0.1	–	<0.1	0.1
Mn (soluble)	µg/L	–	–	–	–	0.2	–	0.1	0.2	–	–	–	–

(a) As $CaCO_3$. (b) Onsite water quality parameter not measured. (c) Due to low water levels, well pump throttled from 31 to <25 gpm since 06/16/06.
(d) TA and TB sample bottles likely switched and corrected for this event.
IN = at inlet; AC = after prechlorination (field parameters only); TA = after tank A; TB = after tank B; NA = data not available.

Analytical Results from Long-Term Sampling, Rimrock, AZ (Continued)

Sampling Date		11/28/06[a]			01/03/07			02/07/07			03/07/07		
Sampling Location Parameter	Unit	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB
Bed Volume	10^3	–	0.1	0.1	–	4.7	8.7	–	9.7	18.0	–	12.8	23.8
As (total)	µg/L	64.5	0.7	6.2	75.0	0.7	24.3	69.3	0.7	31.7	58.4	1.0	26.0

(a) System offline and well pump pulled for cleaning on 08/30/06. System operation resumed on 11/27/06 after Tank A media replaced and tank positions switched. Partially exhausted Tank B continues operation in lead position.
IN = at inlet; TA = after tank A; TB = after tank B.