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Arsenic Removal from Drinking Water by Adsorptive Media U.S. EPA Demonstration Project at Nambe Pueblo, New Mexico Final Performance Evaluation Report

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Sally Gutierrez, Director
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ABSTRACT

This report documents the activities performed and the results obtained from this arsenic removal treatment technology demonstration project at the Nambe Pueblo, New Mexico. The main objective of the project was to evaluate the effectiveness of AdEdge Technologies' AD-33 media in removing arsenic to meet the new arsenic maximum contaminant level (MCL) of 10 μg/L. Additionally, this project evaluated (1) the reliability of the treatment system, (2) the required system operation and maintenance (O&M) and operator skills, and (3) the capital and O&M cost of the technology. The project also characterized the water in the distribution system and residuals produced by the treatment process. The types of data collected included system operation, water quality (both across the treatment train and in the distribution system), process residuals, and capital and O&M cost.

The treatment system consisted of two 48-in × 72-in FRP vessels in parallel configuration, each containing 35.6 ft^3 of AD-33 media. Delivered in granules, AD-33 media is an iron-based adsorptive media developed by Bayer AG and marketed under the name of AD-33 by AdEdge. The treatment system was designed for a peak flowrate of 160 gal/min (gpm) (80 gpm per vessel) and an empty bed contact time (EBCT) of approximately 3.3 min. Over the performance evaluation period, the actual average flowrate was at 114 gpm, corresponding to an EBCT of 4.7 min.

The treatment system began regular operation on May 15, 2007. From May 15, 2007, through the end of the performance evaluation study on September 28, 2009, the treatment system operated for a total of 10,134 hr, treating approximately 64,580,000 gal (or 121,390 bed volumes [BV]) of water. The average daily operation time was 12.3 hr/day and the average daily demand was 78,360 gal/day (gpd).

As part of the water treatment system, a pH adjustment/control system was used to adjust pH values of source water from as high as 9.1 to a target value of 7.0. The pH adjustment system consisted of a carbon dioxide (CO_2) supply assembly, an automatic pH control panel, a CO_2 membrane module (that injected CO_2 into a CO_2 loop), and an in-line pH probe. During the performance evaluation study, the treatment system experienced periodic losses of pH control due to lack of a constant CO_2 supply. Real-time pH values monitored/recorded after pH adjustments by an in-line pH meter/datalogger cycled between 7 and 8 and over 9.

Total arsenic concentrations in source water ranged from 10.7 to 59.0 μg/L, and averaged 32.2 μg/L with soluble As(V) as the predominating species, ranging from 34.2 to 36.5 μg/L based on the results of two speciation sampling events. Total uranium concentrations in source water ranged from 19.9 to 55.8 μg/L, and averaged 39.3 μg/L. Except for some occasions, total arsenic and uranium concentrations were removed to below 3 and 20 μg/L, respectively, in system effluent throughout the 28-month study period. Significantly elevated arsenic and uranium concentrations (often higher than the respective source water concentrations) were measured during a number of sampling events, which coincided with the time periods when the system was operating without pH control.

Periodic losses of pH control apparently had caused the media beds to operate under constant adsorption/desorption cycles, with the captured arsenic and uranium intermittently "flushed" out of the media beds. Therefore, the AD-33 media was not exhausted as expected even after treating 121,390 BV of water (twice the projected working capacity estimated by the vendor). Analyses of media samples collected at 78,200 BV revealed that the adsorptive media were loaded only minimally with arsenic and uranium (i.e., 0.38% and 3.2% of the respective mass in 78,200 BV of source water), which supported the speculation that adsorbed arsenic and uranium were intermittently "flushed" out of the media beds.

Comparison of the distribution system sampling results before and after system startup showed a significant decrease in arsenic concentration (from an average of 33.7 to <10 μg/L), except for three occasions when the treatment system had lost pH control. Uranium concentrations in distribution water also were reduced to below its MCL of 30 μg/L, except for four occasions. Lead and copper concentrations did not appear to have been affected by the operation of the treatment system.

The capital investment cost of $143,113 included $116,645 for equipment, $11,638 for site engineering, and $14,830 for installation. Using the system's rated capacity of 160 gpm (or 230,400 gpd), the capital cost was $894/gpm (or $0.62/gpd) of design capacity. The unit capital cost would be $0.16/1,000 gal if the 160 gpm system were operating around the clock. Based on the average daily operating times (12.3 hr/day) and average system flowrate (114 gpm), the unit capital cost increased to $0.44/1,000 gal at this reduced rate of use.

The O&M cost included only the cost associated with the adsorption system, such as media replacement and disposal, CO_2 and chlorine use, electricity consumption, and labor. Although media replacement did not take place during the performance evaluation study, the media replacement cost would have represented the majority of the O&M cost and was estimated to be $29,532 to change out both vessels (71.2 ft^3 AD-33 media and associated labor for media changeout and disposal).

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ABBREVIATIONS AND ACRONYMS

Δp	differential pressure
AAL	American Analytical Laboratories
AM	adsorptive media
APU	arsenic package unit
As	arsenic
ATSI	Applied Technology Systems, Inc.
AWC	Arizona Water Company
BET	Brunauer, Emmett, and Teller
BV	bed volume
Ca	calcium
CAD	computer-aided design
C/F	coagulation/filtration process
CISD	Consolidated Independent School District
Cl	chlorine
CO_2	carbon dioxide
CRF	capital recovery factor
Cu	copper
DO	dissolved oxygen
EBCT	empty bed contact time
EPA	U.S. Environmental Protection Agency
F	fluorine
Fe	iron
FRP	fiber-reinforced plastic
gpd	gallons per day
gph	gallons per hour
gpm	gallons per minute
ICP-MS	inductively coupled plasma-mass spectrometry
ID	identification
IHS	Indian Health Services
ISFET	Ion Sensitive Field Effect Transistor
IX	ion exchange
LCR	Lead and Copper Rule
MCL	maximum contaminant level
MDL	method detection limit
MDWCA	Mutual Domestic Water Comsumer's Association
Mg	magnesium
Mn	manganese

ABBREVIATIONS AND ACRONYMS (Continued)

mV	millivolts
Na	sodium
NA	not analyzed
NaOCl	sodium hypochlorite
NMED	New Mexico Environment Department
NRMRL	National Risk Management Research Laboratory
NSF	NSF International
O&M	operation and maintenance
ORD	Office of Research and Development
ORP	oxidation-reduction potential
PID	Proportional Integral Derivative
PLC	programmable logic controller
PO_4	phosphate
psi	pounds per square inch
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
RPD	relative percent difference
SDWA	Safe Drinking Water Act
SiO_2	silica
SM	system modification
SMCL	secondary maximum contaminant level
SO_4^{2-}	sulfate
STMGID	South Truckee Meadows General Improvement District
STS	Severn Trent Services
TOC	total organic carbon
U	uranium
V	vanadium
WRWC	White Rock Water Company

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1.0 INTRODUCTION

1.1 Background

The Safe Drinking Water Act (SDWA) mandates that the U.S. Environmental Protection Agency (EPA) identify and regulate drinking water contaminants that may have adverse human health effects and that are known or anticipated to occur in public water supply systems. In 1975 under the SDWA, EPA established a maximum contaminant level (MCL) for arsenic at 0.05 mg/L. Amended in 1996, the SDWA required that EPA develop an arsenic research strategy and publish a proposal to revise the arsenic MCL by January 2000. On January 18, 2001, EPA finalized the arsenic MCL at 0.01 mg/L (EPA, 2001). 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 operator of small systems in order to reduce compliance cost. As part of this Arsenic Rule Implementation Research Program, EPA's Office of Research and Development (ORD) proposed a project to conduct a series of full-scale, onsite demonstrations of arsenic removal technologies, process modifications, and engineering approaches applicable to small systems. Shortly thereafter, an announcement 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 candidate sites to host the demonstration studies. The facility at Nambe Pueblo in New Mexico was selected to participate in this 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 program. Using the information provided by the review panel, EPA in cooperation with the host sites and the drinking water programs of the respective states (or Indian Health Services [IHS] and EPA Region 6 in the case of the Nambe Pueblo site) selected one technical proposal for each site. An adsorptive media (AM) system proposed by AdEdge Technologies (AdEdge) using the Bayoxide E33 (AD-33) media developed by Bayer AG was selected for demonstration at the Nambe Pueblo site.

1.2 Treatment Technologies for Arsenic Removal

The technologies selected for the 12 Round 1 arsenic removal demonstration host sites included nine AM systems, one coagulation/filtration (C/F) system, one ion exchange (IX) system, and one process modification with iron addition. Table 1-1 summarizes the locations, technologies, vendors, system flowrates, and key source water quality parameters (including arsenic, iron, and pH) of the 12 demonstration sites. An overview of the technology selection and system design for the 12 demonstration sites and the associated capital cost is provided in two EPA reports (Wang et al., 2004; Chen et al., 2004), which are posted on the EPA Arsenic Research Program Web site at http://www.epa.gov/ORD/NRMRL/wswrd/dw/arsenic/index.html.

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

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

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

(a) Design flowrate reduced by 50% due to system reconfiguration from parallel to series operation.
(b) Arsenic existing mostly as As(III).
(c) Iron existing mostly as Fe(II).

As of December 7, 2010, the performance evaluation of all 12 systems has been completed, and the final performance evaluation reports of ten demonstration sites have been completed and posted on the EPA Arsenic Research Program Web site.

1.3 Project Objectives

The objective of the arsenic demonstration program is to conduct full-scale arsenic removal 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 at the Nambe Pueblo in New Mexico, from May 15, 2007, through September 28, 2009. The types of data collected included system operation, water quality (both across the treatment train and in the distribution system), residuals characterization, and capital and preliminary O&M cost.

2.0 SUMMARY AND CONCLUSIONS

AdEdge's APU-160 treatment system with AD-33 granular media was installed and has operated at the Nambe Pueblo site in New Mexico since May 15, 2007. Based on the information collected during May 15, 2007, through September 28, 2009, the following summary and conclusion statements are provided:

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

- AD-33 media effectively lowered arsenic and uranium concentrations to below 3 and 20 μg/L, respectively, in system effluent throughout the 28-month study period.
- Significantly elevated arsenic and uranium concentrations (often higher than the corresponding source water concentrations) were measured in system effluent during a number of sampling events, presumably due to loss of pH control during system operation.
- The operation of the treatment system significantly lowered arsenic and uranium concentrations to below 10 and 30 μg/L, respectively, in distribution system water. Elevated arsenic and uranium concentrations were observed during a few sampling events presumably caused by loss of pH control during system operation. The treatment system did not appear to have impacted lead or copper concentrations in distribution system water.

Required system O&M and operator skill levels:

- The facility experienced difficulties in maintaining a constant carbon dioxide (CO_2) supply, caused by non-standard working hours of the operator, remote site location, and/or delivery delays by the CO_2 vendor. Interruption of CO_2 supply caused periodic losses of pH control during system operation.
- Operation of the system did not appear to require additional skills beyond those necessary to operate the existing water supply equipment.

Process residuals produced by the technology:

- No backwash residuals were produced because of low pressure drop (i.e., 1.1 lb/in^2 [psi]) across the media beds.
- The adsorptive media did not need to be replaced even though it had treated twice as much water as projected by the vendor. Periodic losses of pH control might have caused arsenic and uranium to be "flushed" from the adsorptive media beds, thus extending the media life.

Cost-effectiveness of the technology:

- Based on the system's rated capacity of 160 gal/min (gpm) (or 230,400 gal/day [gpd]), the capital cost was $894/gpm (or $0.62/gpd) of design capacity.
- Media replacement and disposal did not occur during system performance evaluation; however, the cost to change out both vessels (71.2 ft^3 AD-33 media) was estimated to be $29,532, which included the replacement media, spent media disposal, shipping, labor, and travel.

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 AM system began on May 15, 2007, and ended on September 28, 2009. Table 3-2 summarizes the types of data collected and/or considered as part of the technology evaluation study. Overall performance of the system was evaluated based on its ability to consistently remove arsenic to below the arsenic MCL of 10 µg/L through the collection of water samples across the treatment plant, as described in a Performance Evaluation Study Plan (Battelle, 2005). The reliability of the system was evaluated by tracking the unscheduled system downtime and frequency and extent of repair and replacement.

Table 3-1. Predemonstration Study Activities and Completion Dates

Activities[(a)]	Date
Introductory Meeting Held	08/19/03
Draft Letter of Understanding Issued	09/03/03
Final Letter of Understanding Issued	09/10/03
Request for Quotation Issued to Vendor	08/22/03
Vendor Quotation Received by Battelle	09/09/03
Purchase Order Completed and Signed	10/06/03
APU System Shipped	05/04/05
Final Study Plan Issued	06/01/05
System Installation Completed	05/15/07
System Shakedown Completed	05/15/07
Performance Evaluation Begun	05/15/07

(a) Additional activities related to treatment building preparation and system installation, shakedown, and startup presented in Table 4-6.

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

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

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

The cost of the system was evaluated based on the capital cost per gpm (or gpd) of design capacity and the O&M cost per 1,000 gal of water treated. This requires tracking the capital cost for equipment, site engineering, and installation, as well as the O&M cost for media replacement and disposal, chemical consumption, electrical power usage, and labor. Data on Nambe Pueblo's O&M cost were limited to CO_2 consumption, electricity usage, and labor because media replacement did not take place during the system performance evaluation.

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 the vendor and Battelle. The plant operator recorded system operational data such as pressure, flowrate, system throughput, and hour meter readings on a Daily System Operation Log Sheet; checked sodium hypochlorite (NaOCl) and CO_2 levels; and conducted visual inspections to ensure normal system operations. If any problem occurred, the plant operator contacted the Battelle Study Lead, who determined if the vendor should be contacted for troubleshooting. The plant operator recorded all relevant information, including problems encountered, course of actions taken, materials and supplies used, and associated cost and labor incurred, on the Repair and Maintenance Log Sheet.

The capital cost for the arsenic-removal system consisted of the cost for equipment, site engineering, and system installation. The O&M cost consisted of the expenditure for chemical use, electricity consumption, and labor. Liquid CO_2 was delivered in 50-lb cylinders by Airgas West (Santa Fe, NM) on an as-needed basis and its use was tracked by recording on the Daily System Operation Log Sheets whenever CO_2 cylinders were replaced. Electricity consumption was tracked through an onsite electric meter. Labor hours for routine system O&M, system troubleshooting and repairs, and demonstration-related work, were tracked using an Operator Labor Hour Log Sheet. Routine O&M included activities such as completing field logs, replacing CO_2 cylinders, ordering supplies, performing system inspections, and others as recommended by the vendor. Demonstration-related work, including activities such as performing field measurements, collecting and shipping samples, and communicating with the Battelle Study Lead and vendor, was recorded but not used for the cost analysis.

3.3 Sample Collection Procedures and Schedules

To evaluate system performance, samples were collected from the wellhead, across the treatment plant, and from the distribution system. Table 3-3 provides the sampling schedule and analytes measured during each sampling event. 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).

3.3.1 Source Water Sample Collection. During the initial visit to the site on August 19, 2003, one set of source water samples was collected from the Buffalo Well for detailed water quality analyses. Source water also was speciated onsite using a speciation kit (see Section 3.4.1). The sample tap was flushed for several minutes before sampling; special care was taken to avoid agitation, which might cause unwanted oxidation. Analytes for the source water samples are listed in Table 3-3.

Table 3-3. Sampling Schedule and Analytes

Sample Type	Sampling Locations[a]	No. of Sampling Locations	Frequency	Analytes	Sampling Date
Source Water	IN	1	Once during initial site visit	Onsite: pH Offsite: Al (total and soluble), As (total and soluble), As(III), As(V), Fe (total and soluble), Mn (total and soluble), Mo (total and soluble), Sb (total and soluble), V (total and soluble), Na, Ca, Mg, Cl, F, SO_4, SiO_2, PO_4, TOC, alkalinity, and turbidity	08/19/03
Treatment Plant Water	IN, AP, TT	3	Once in each 4-week cycle[b] (Speciation Sampling)	Onsite: pH, temperature, DO, ORP, and Cl_2 (total and free)[c] Offsite: As (total and soluble), As(III), As(V), Fe (total and soluble), Mn (total and soluble), U (total and soluble), Ca, Mg, F, NO_3, SO_4, SiO_2, P, TOC, alkalinity, and turbidity	07/09/07 08/10/07
	IN, AP, TA, TB	4	Three times in each 4-week cycle[d] (Regular Sampling)	Onsite: pH[e], temperature, DO, ORP, and Cl_2 (total and free)[c] Offsite: As (total), Fe (total), Mn (total), U (total), SiO_2, P, alkalinity, and turbidity	See Appendix B
Distribution Water	Three locations supplied plant water	3	Monthly[f]	pH, alkalinity, and total As, Fe, Mn, U, Pb, and Cu	Baseline sampling: See Table 4-14 Monthly sampling: See Table 4-14

(a) Abbreviations in parentheses corresponding to sample locations shown in Figure 4-7: IN = at wellhead; AP = after pH adjustment; TA = after Vessel A; TB = after Vessel B; and TT = after effluent combined.
(b) Although scheduled monthly, speciation sampling performed only twice on July 9 and August 10, 2007.
(c) Total and free chlorine to be measured at AP and TT only but none was measured during actual sampling.
(d) Actual sampling frequency varied from 1 to 8 weeks.
(e) Onsite water quality parameters not measured during performance evaluation study; real-time pH readings monitored with an in-line pH meter at AP location.
(f) Monthly sampling discontinued after September 10, 2008.

3.3.2 Treatment Plant Water Sample Collection. During the system performance evaluation study, the plant operator collected water samples across the treatment train for onsite and offsite analyses. The Battelle Study Plan called for weekly sampling: One week in each four-week cycle, treatment plant samples were collected at the wellhead (IN), after pH adjustment but before the split to the two adsorption vessels (AP), and after effluent from the two vessels combined (TT). These samples were speciated and analyzed for the analytes listed under "Speciation Sampling" in Table 3-3. For the other three weeks in each four-week cycle, treatment plant samples were collected at four locations, i.e., IN, AP, and after Vessels A and B (TA and TB), and analyzed for the analytes listed under "Regular Sampling" in Table 3-3.

Because only trace amounts of As(III) existed in source water, speciation was performed only twice (on July 9 and August 10, 2007). Regular sampling was normally performed weekly between June 26, 2007, when the performance evaluation study began and August 28, 2008. The sampling frequency was extended to once every two weeks on seven occasions (on September 11, September 26, and November 26, 2007, and on March 4, April 8, May 6, and June 3, 2008), and to once every four weeks on one occasion (on January 16, 2008). After August 28, 2008, the sampling frequncy occurred monthly on a regular basis. Although called for in the Study Plan, the operator did not perform onsite water quality analyses during all regular sampling events. The operator did, however, record pH values at the AP location using an in-line pH meter.

3.3.3 Backwash Wastewater/Solids and Spent Media Samples. Because the system was not backwashed during the entire study period, no backwash residuals were produced. Further, because media replacement did not take place, there were no spent media. However, media samples were collected during the performance evaluation study as described in Section 4.5.2.

3.3.4 Distribution System Water Sample Collection. 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 arsenic, uranium, lead, and copper levels. Prior to system startup from December 2003 to March 2004, four sets of baseline distribution system water samples were collected at three locations within the distribution system. Following system startup, distribution system water sampling continued on a monthly basis through September 10, 2008.

The three locations selected for baseline sampling included one resident home, the Housing Department Office, and the Senior Center, which were partially served by the Buffalo Well. After system startup, sampling locations were moved to three residences that received only the treatment plant water. The baseline and monthly distribution system samples were collected following an instruction sheet developed according to the *Lead and Copper Monitoring and Reporting Guidance for Public Water Systems* (EPA, 2002). First-draw samples were collected from cold-water faucets that had not been used for at least 6 hr to ensure that stagnant water was sampled. Samplers recorded date and time of last water use before sampling and the date and time of sample collection for calculations of the stagnation time. The samples were analyzed for the analytes listed in Table 3-3. Arsenic speciation was not conducted on the distribution system water samples.

3.4 Sampling Logistics

All sampling logistics, including preparation of arsenic speciation kits and sample coolers, and sample shipping and handling are discussed as follows:

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

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

In addition, all sampling and shipping-related materials, such as latex gloves, sampling instructions, chain-of-custody forms, pre-paid/pre-addressed FedEx air bills, and bubble wrap, were included in each cooler. Except for the operator's signature, the chain-of-custody forms and air bills had already been completed with the required information. The sample coolers were shipped via FedEx to the facility approximately 1 week prior to the scheduled sampling date.

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

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

3.5 Analytical Procedures

The analytical procedures described in detail in Section 4.0 of the EPA-endorsed QAPP (Battelle, 2003) were followed by Battelle ICP-MS, AAL, and TCCI Laboratories. Laboratory quality assuarnce/quality control (QA/QC) of all methods followed the prescribed guidelines. Data quality in terms of precision, accuracy, method detection limits (MDLs), and completeness met the criteria established in the QAPP (i.e., relative percent difference [RPD] of 20%, percent recovery of 80 to120%, and completeness of 80%). The quality assurance 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, dissolved oxygen (DO), and oxidation-reduction potential (ORP) were conducted only twice on July 9 and August 10, 2007 by the plant operator using a VWR Symphony SP90M5 Handheld Multimeter. The meter was calibrated for pH and DO prior to use following the procedures provided in the user's manual. The ORP probe also was checked for accuracy by measuring the ORP of a standard solution and comparing it to the expected value. The plant operator collected a water sample in a clean, plastic beaker and placed the Symphony SP90M5 probe in the beaker until a stable value was obtained. pH values at the AP location (after pH adjustment) also were monitored by an in-line pH meter, which was connected to the system's programmable logic controller (PLC). Measured pH values were recorded at 30-min intervals during system operation and saved at the PLC for later download.

4.0 RESULTS AND DISCUSSION

4.1 Facility Description and Pre-existing Treatment System Infrastructure

The Nambe Pueblo water system supplied drinking water to approximately 500 community members with 150 service connections. Located on a hilltop adjacent to a buffalo range (Figure 4-1), the pre-existing system consisted of a 145-gpm well (Buffalo Well [Figure 4-2]), a pump house (located about 10 ft from the well), and a 17-ft-diameter, 24-ft-tall water storage tank (Figure 4-3). Groundwater was pumped intermittently from the well to the pump house where a totalizer was used to track the total volume of feed water to the system. Liquid chlorine was added (Figure 4-4) using a peristaltic pump to maintain a residual chlorine level of approximately 0.58 mg/L (as Cl_2) in the 40,000-gal water storage tank and distribution system. Water in the storage tank was gravity-fed through the distribution system to the community. The system typically operated for 3 to 4 hr/day, with a daily demand of approximately 34,000 gpd.

Figure 4-1. Nambe Pueblo Buffalo Range

4.1.1 Source Water Quality. Water samples from the Buffalo Well were collected and speciated on August 19, 2003. The results are presented in Table 4-1 and compared to those taken by the facility for the EPA demonstration site selection and independently collected and analyzed by EPA.

Arsenic. Total arsenic concentrations of the Buffalo Well water ranged from 29 to 33.2 µg/L, which existed primarily as soluble As(V) (94% based on the August 2003 Battelle sampling results). Trace amounts of soluble As(III) and particulate arsenic also existed at 0.2 and 1.8 µg/L, respectively.

Figure 4-2. Pump Head on Buffalo Well at Nambe Pueblo, NM

Figure 4-3. Pre-existing Pump House and Water Storage Tank

Figure 4-4. Chlorination Before Distribution at Nambe Pueblo, NM

Iron and Manganese. Iron and manganese concentrations in the Buffalo Well water were low, ranging from <30 to 138 μg/L and from 1.3 to 22.9 μg/L, respectively. In general, adsorptive media technologies are best suited to sites with relatively low iron levels (e.g., less than 300 μg/L, the secondary maximum contaminant level [SMCL]). Iron concentrations greater than 300 μg/L can cause taste, odor, and color problems and an increased potential for fouling of adsorption system components.

pH. pH values of source water ranged between 8.5 and 8.8. Arsenic adsorption by AD-33 media can be performed at pH values ranging between 6.0 and 9.0, but is more effective when the pH is <8.0. Because of the high pH, the vendor recommended pH adjustment of source water to approximately 7.0 using CO_2.

Competing Anions. Arsenic adsorption can be influenced by competing anions such as silica, phosphorus, and vanadium. Concentrations of these ions as presented in Table 4-1do not appear to be high enough to cause any adverse effect on arsenic adsorption.

Other Water Quality Parameters. Concentrations of other water quality parameters were low and do not appear to have any impact on arsenic adsorption.

4.1.2 Distribution System. The Nambe Pueblo distribution system consists of a 10-mile long, partially looped distribution line and two 88,000-gal storage tanks supplied by the Buffalo Well, Lower Well, and Upper Well with a combined production capacity of approximately 285 gpm. The two storage tanks are located approximately 1 mile apart and are connected to the distribution system with 6-in polyvinyl chloride (PVC) pipe. The distribution system is constructed of 2- to 6-in PVC pipe.

Table 4-1. Water Quality Data for Buffalo Well at Nambe Pueblo, NM

Parameter	Unit	Utility Data	EPA Data	Battelle Data
Sampling Date		-	10/09/02	08/19/03
pH	S.U.	8.8	NA	8.5
Total Alkalinity (as $CaCO_3$)	mg/L	204.0	163.2	168.0
Hardness (as $CaCO_3$)	mg/L	199.0	NA	5.4
Turbidity	mg/L	NA	NA	NA
Chloride	mg/L	<10	5.6	8.4
Fluoride	mg/L	NA	0.9	0.1
Sulfide	mg/L	NA	9.4	NA
Sulfate	mg/L	<10	28.2	28.0
Silica (as SiO_2)	mg/L	15.0*	15.1	14.1
Orthophosphate (as PO_4)	mg/L	<0.065*	<0.005	<0.10
TOC	mg/L	NA	NA	2.1
As(total)	μg/L	32.0	29.0	33.2
As (soluble)	μg/L	NA	NA	31.4
As (particulate)	μg/L	NA	NA	1.8
As(III)	μg/L	NA	NA	0.2
As(V)	μg/L	NA	NA	31.2
Fe (total)	μg/L	<100	138.0	<30
Fe (soluble)	μg/L	NA	NA	<30
Al (total)	μg/L	NA	<25	10.0
Al (soluble)	μg/L	NA	NA	28.7
Mn (total)	μg/L	<50	22.9	1.3
Mn (soluble)	μg/L	NA	NA	1.3
V (total)	μg/L	NA	NA	9.2
V (soluble)	μg/L	NA	NA	8.6
Mo (total)	μg/L	NA	NA	<0.1
Mo (soluble)	μg/L	NA	NA	<0.1
Sb (total)	μg/L	NA	<25	<0.1
Sb (soluble)	μg/L	NA	NA	<0.1
Na (total)	μg/L	22.0	88.6	93.3
Ca (total)	mg/L	73.0	2.1	2.1
Mg (total)	mg/L	4.0	<0.04	0.0

* = data provided by EPA; NA = not analyzed; TOC = total organic carbon

The distribution system is subdivided into the lower and upper zones. The lower zone is supplied by all three wells, whereas the upper zone is served primarily by the Buffalo Well. All three locations for distribution system water sampling were located in the upper zone. Figure 4-5 presents an aerial photograph map of the Nambe Pueblo distribution system.

The Nambe Pueblo Tribe collects water samples from the distribution system for several analytes. Three samples are collected each month for bacteria analysis. The bacteriological sampling locations vary from month to month. Under the Lead and Copper Rule (LCR) (EPA, 2002), water samples were collected from customer taps at five locations. As an example, Table 4-2 presents the results of LCR samples collected in October 2003.

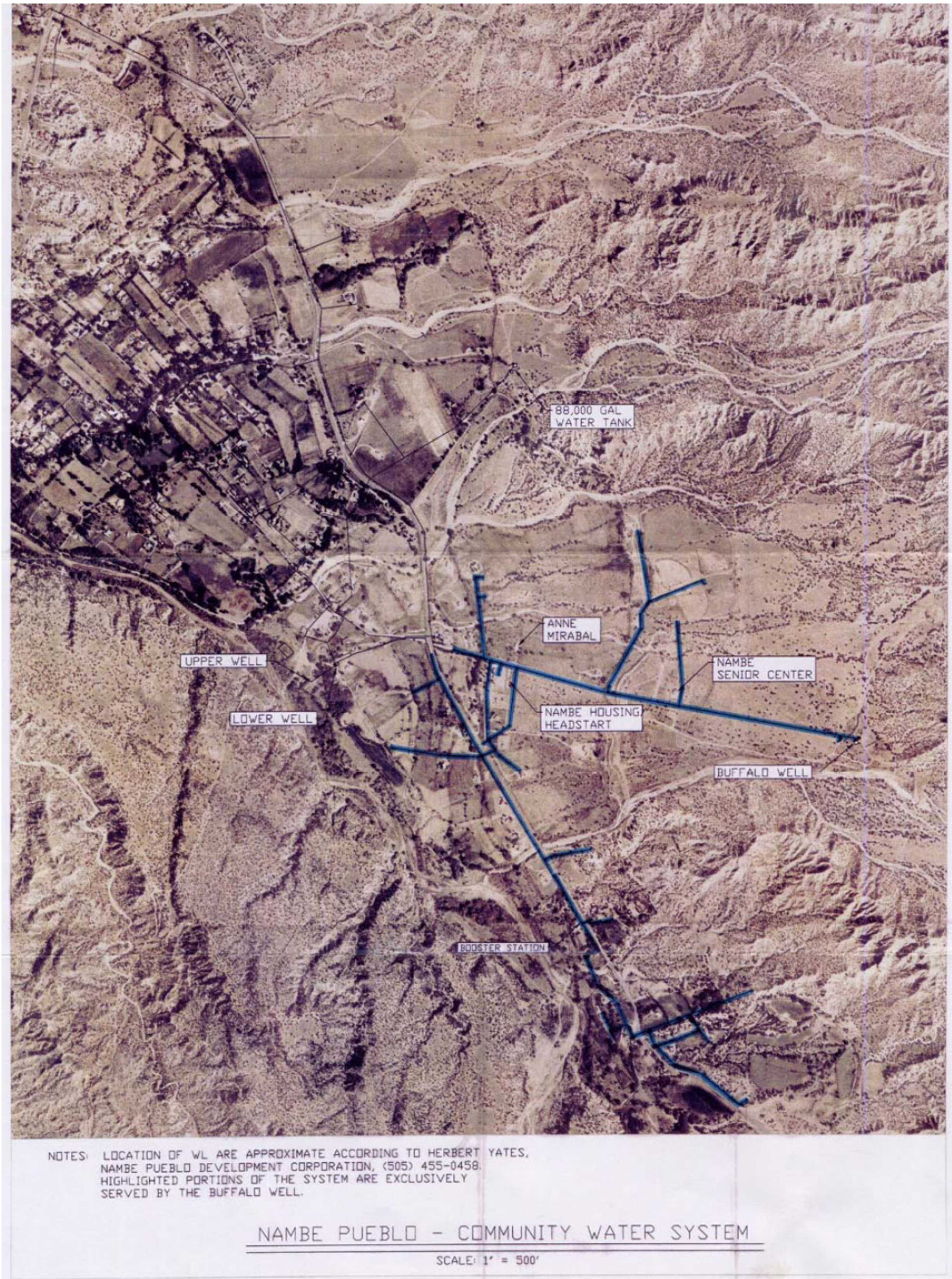


Figure 4-5. Nambe Pueblo Water Distribution System Map

Table 4-2. Nambe Pueblo Lead and Copper Rule Sampling Results, October 2003

Location	Date	Unit	Copper	Lead
LCR 01	10/27/03	µg/L	51.5	<2.0
LCR 08	10/26/03	µg/L	12.7	<2.0
LCR 09	10/27/03	µg/L	129	<2.0
LCR38	10/27/03	µg/L	269	<2.0
LCR 40	10/30/03	µg/L	72.4	<2.0
90^{th} percentile[(a)]	-	µg/L	199	<2.0

Analysis performed by EPA Region 6 Laboratory.
(a) To determine 90^{th} percentile concentration for five samples, average highest and second-highest concentrations.

4.2 Treatment Process Description

The arsenic package unit (APU) marketed by AdEdge is a fixed-bed, down-flow adsorption system used for small water systems in the flow range of 5 to 300 gpm. It uses Bayoxide E33 media (branded as AD-33 by AdEdge), an iron-based adsorptive media developed by Bayer AG, for arsenic removal from drinking water supplies. Table 4-3 presents physical and chemical properties of the media. AD-33 media is delivered in a dry crystalline form and listed by NSF International (NSF) under Standard 61 for use in drinking water applications. The media exists in both granular and pelletized forms, which have similar physical and chemical properties, except that pellets are denser than granules (i.e., 35 vs. 28 lb/ft^3). For the Nambe Pueblo site, the granular media was selected for use.

The AdEdge arsenic treatment system consisted of two adsorption vessels (i.e., A and B) arranged in parallel. The original proposal for this demonstration site specified an 150-gpm APU-150 system; however, due to the experience gained at other demonstration sites, the vendor upgraded the system to treat 160 gpm of water. Figure 4-6 is a schematic of the AdEdge APU-160 system.

The APU-160 system can be either manually or automatically backwashed on an as-needed basis, as determined by the pressure loss across the adsorption vessels or time elapsed since the last backwash. However, no backwash was conducted during the performance evaluation study due to minimal pressure drop across the vessels. Figure 4-7 shows a process flow diagram with the sampling locations and analytes. Table 4-4 presents key system design parameters. The system included CO_2 addition to reduce the pH to approximately 7. No post treatment was proposed.

Key process steps and major system components are discussed as follows:

- **Intake**. Source water was pumped from the Buffalo Well and chlorinated before being fed to the treatment system.
- **Prechlorination**. Although prechlorination was not required (because arsenic existed primarily as As[V]), the existing chlorination system was retained to provide disinfection to the treatment system. In addition, a post-chlorination point was included to ensure that the target chlorine residual level of 0.58 mg/L (as Cl_2) was met before treated water entered the distribution system. Figure 4-8 presents photographs of the chlorine metering pumps, the chlorine storage drum, and the pre- and post-chlorination injection points.

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 (lb/ft^3)	28
BET Area (m^2/g)	142
Attrition (%)	0.3
Moisture Content (%)	<15 (by weight)
Particle Size Distribution (U.S. standard mesh)	10 × 35
Crystal Size (Å)	70
Crystal Phase	α – FeOOH
Chemical Analysis	
Constituents	**Weight (%)**
FeOOH	90.1
CaO	0.27
MgO	1.00
MnO	0.23
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: Provided by AdEdge
BET = Brunauer, Emmett, and Teller

The chlorine addition system consisted of a peristaltic pump, a chemical feed tank (containing a 10% NaOCl solution), and a secondary containment. Chlorine addition was synchronized with the well pump. Proper operation of the chlorine feed system was tracked through tank level measurements.

- **pH adjustment.** pH values of source water were lowered from 8.5 to 8.8 to a target value of 7.0 using CO_2. CO_2 was selected for pH adjustments because (1) it is less corrosive than mineral acids, such as H_2SO_4, and (2) when treated water is depressurized after exiting the adsorption vessels, some CO_2 may degas, thereby raising the pH of the treated water and reducing its corrosivity to the distribution piping.

  A carbon dioxide gas flow control system manufactured by Applied Technology Systems, Inc. (ATSI) in Souderton, PA, was used for pH control. The pH control system consisted of a liquid CO_2 supply assembly, an automatic pH control panel, a CO_2 membrane assembly, and a pH probe located downstream of the membrane module.

  Figure 4-9 presents a process flow diagram of the control system, which is designed to introduce gaseous CO_2 into the water in a side-stream configuration, or a CO_2 loop. Figure 4-10 provides a series of photographs showing various system components.

  - Liquid CO_2 in two 50-lb cylinders vaporizes into gaseous CO_2 via a feed vaporizer prior to entering a pH control panel.

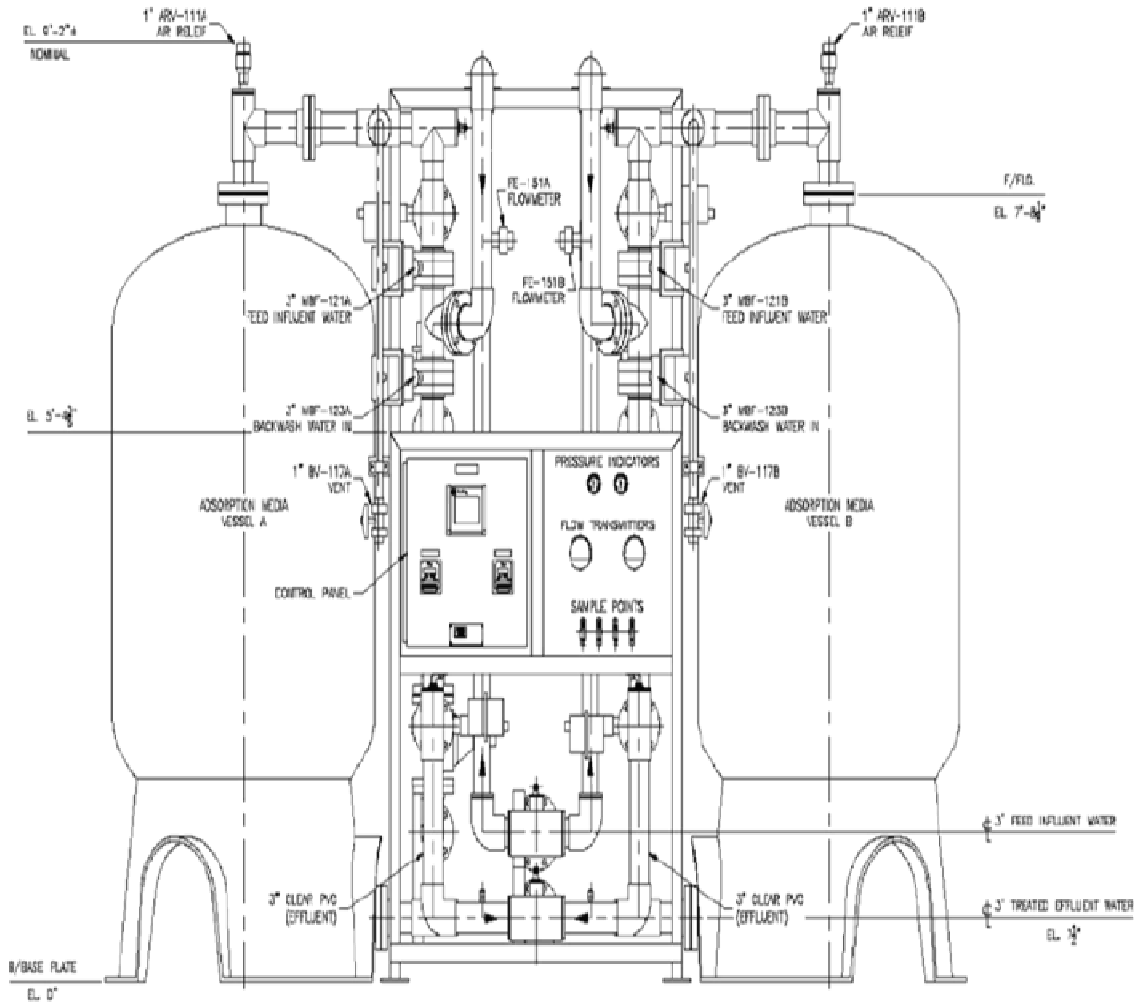


Figure 4-6. Schematic of AdEdge APU-160 Arsenic Removal System

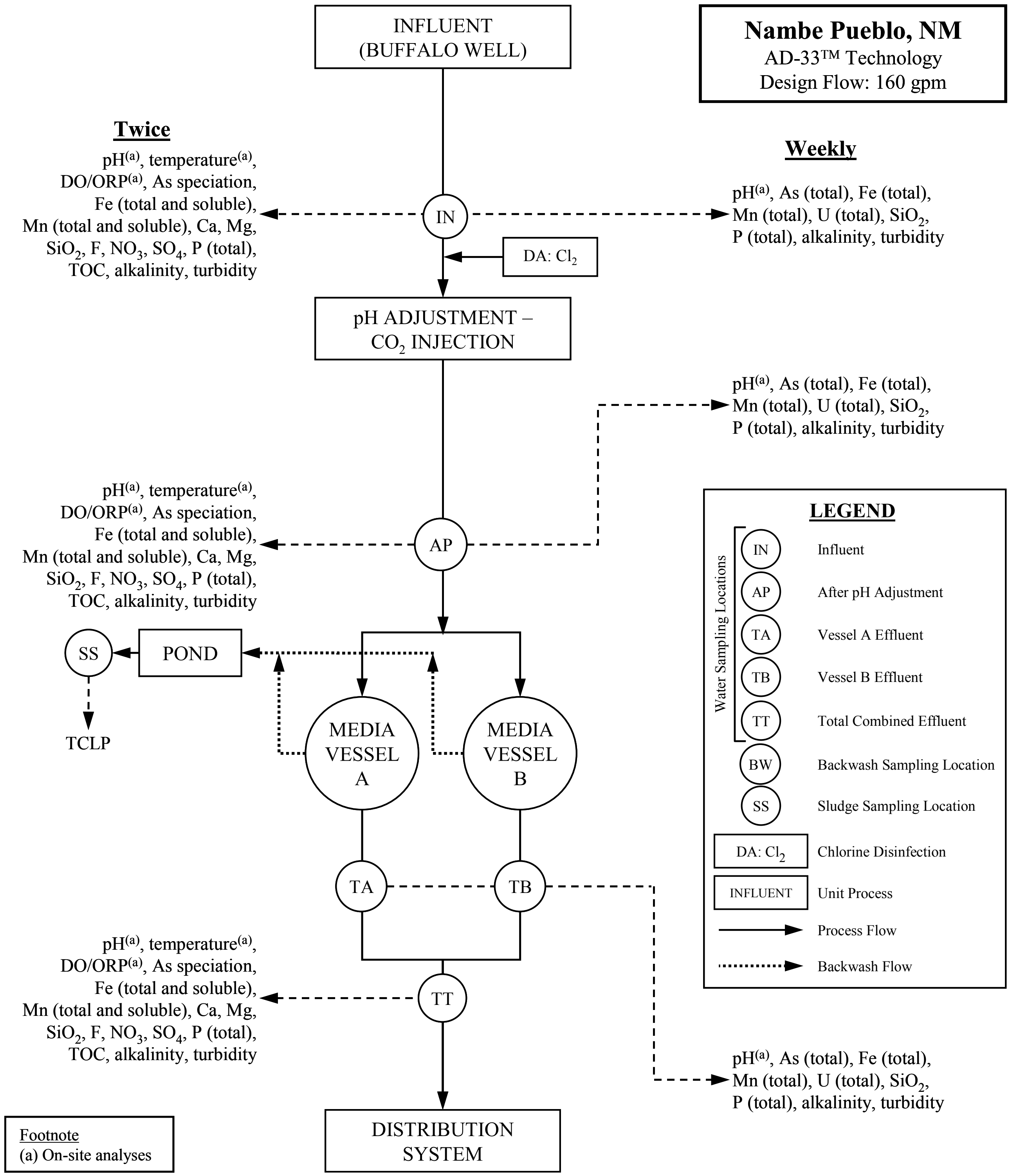


Figure 4-7. Process Flow Diagram and Sampling Schedule and Locations

Table 4-4. Design Specifications for AdEdge APU-160 System

Parameter	Value	Remarks
Pre-treatment		
Target pH Value after Adjustment (S.U.)	7.0	Using CO_2
Target Chlorine Residual (mg/L [as Cl_2])	0.58	Using NaClO
Adsorption Vessels		
Vessel Size (in)	48 D × 72 H	–
Cross-Sectional Area (ft^2/vessel)	12.6	–
Number of Vessels	2	–
Configuration	Parallel	–
AD-33 Adsorption Media		
Media Bed Depth (in)	34	
Media Quantity (lb)	1,994	997 lb/vessel
Media Volume (ft^3)	71.2	35.6 ft^3/vessel
Media Type	AD-33	Granular form
Service		
Design Flowrate (gpm)	160	80 gpm/vessel
Hydraulic Loading Rate (gpm/ft^2)	6.3	–
EBCT (min)	3.3	Based on 160 gpm design flow
Estimated Working Capacity (BV)	61,296	To 10 µg/L total arsenic breakthrough
Throughput to Breakthrough (gal)	32,609,500	1 BV = 71.2 ft^3 = 532 gal
Average Use Rate (gal/day)	45,000	Based on 6.25 hr/day operation at 120 gpm
Estimated Media Life (months)	24.2	Vendor estimated media life
Backwash		
Pressure Differential Set Point (psi)	10	–
Backwash Flowrate (gpm)	113 to125	–
Hydraulic Loading Rate (gpm/ft^2)	9 to 10	–
Backwash Frequency (per month)	1	–
Backwash Duration (min/vessel)	17 to 19	–
Wastewater Production (gal/vessel)	1,920–2,380	–

- As the CO_2 gas flowed to the pH control panel, the gas flowrate is automatically controlled and adjusted by a JUMO pH/Proportional Integral Derivative (PID) controller and an Alicat mass flowmeter (Figure 4-10) to reach a desired pH setpoint. As an alternative, manual regulation of the gas flowrate also can be achieved via the use of a three-way ball valve and a rotameter. Further, a solenoid valve interlocks with the well pump, allowing gas to flow only when the well pump is turned on.
- After flowing out of the control panel, CO_2 is injected into water through a Celgard® microporous hollow fiber membrane module housed in a 1.5-in stainless steel sanitary cross. Table 4-5 lists the properties and specifications of the hollow fiber membrane module. The sanitary cross is located in a side stream from the main water line to allow only a portion of water to flow through the membrane module to minimize the pressure drop. The membrane introduced CO_2 gas into the water at a near molecular level for rapid mixing/reaction with water to achieve a quick pH response/change.
- Located downstream from the sanitary cross, a Sentron ion sensitive field effect transistor (ISFET) type silicon chip sanitary pH probe with automatic temperature compensation continuously monitors pH levels of treated water and sends signals back to the pH/PID controller for pH control. Data from the in-line pH meter are recorded and stored in a datalogger.

Figure 4-8. Chlorination Feed System
(Clockwise from top left: NaClO storage tank and chlorine metering pumps; Prechlorination injection point; and Post-chlorination injection point)

- Throughout the study, the CO_2 pH control system supplied CO_2 at approximately 16.2 ft^3/hr, or 23.3 lb/day (Section 4.4.2). The CO_2 gas supplied from two 50-lb cylinders provided CO_2 for about 4.3 days before requiring change-out.

- **Adsorption**. The AdEdge APU-160 arsenic removal system consists of two 48-in × 72-in vessels configured in parallel, each containing 35.6 ft^3 of AD-33 media supported by a gravel underbed. The vessels are fiber-reinforced plastic (FRP) construction rated for 150 psi working pressure. The FRP vessels are skid-mounted and piped to a valve rack mounted on a polyurethane coated, welded frame. The empty bed contact time (EBCT) for the system is 3.3 min and the hydraulic loading to each vessel is 6.3 gpm/ft^2, based on the design flowrate of 160 gpm.

Source: Applied Technology Systems, Inc. (ATSI)

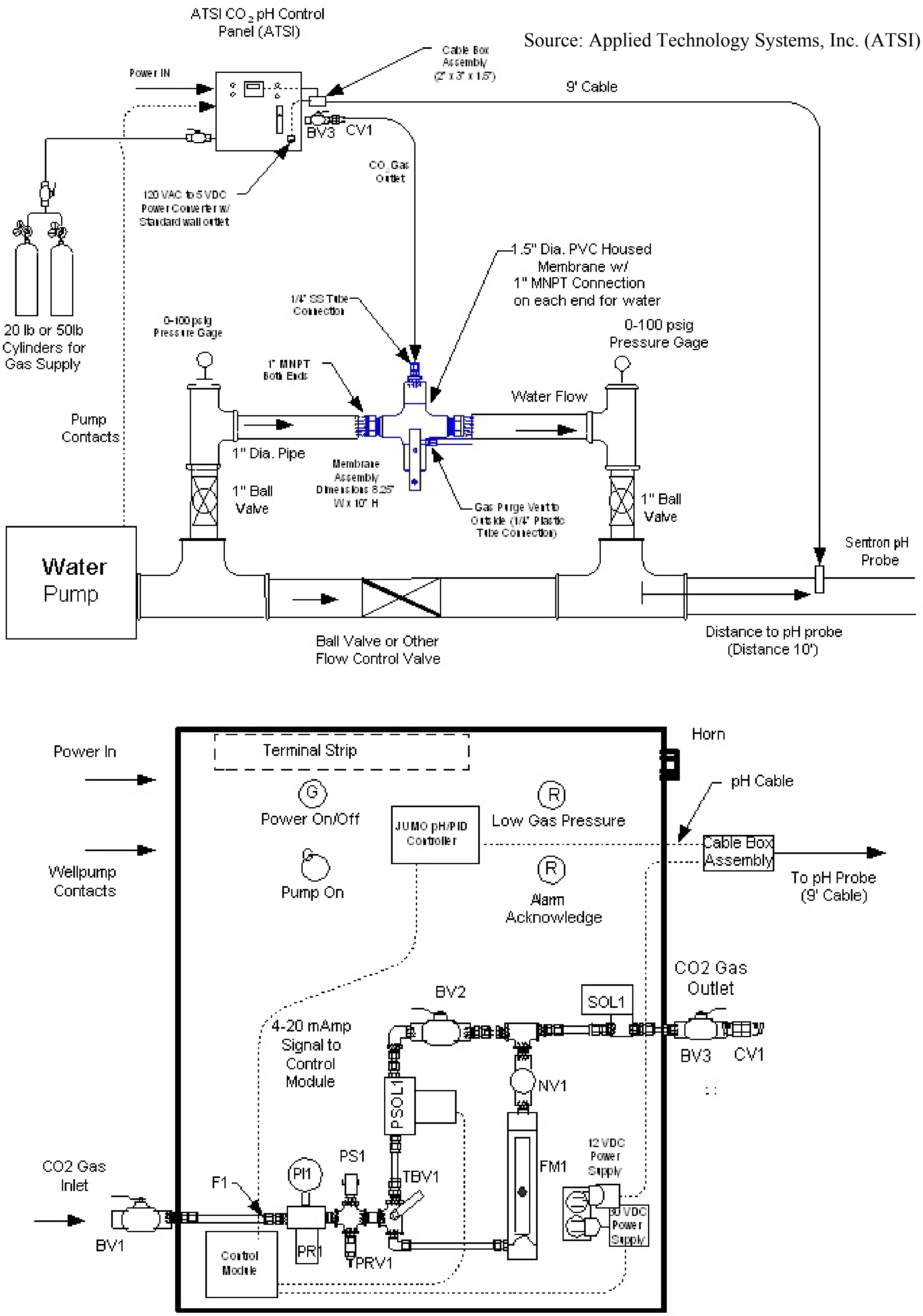


Figure 4-9. Process Diagram of CO_2 pH Adjustment System (top) and pH/PID Control Panel (bottom)

Figure 4-10. Carbon Dioxide Gas Flow Control System for pH Adjustment
(Clockwise from top left: Liquid CO_2 supply assembly; Automatic pH control Panel; CO_2 Membrane Module; and Port for pH Probe)

Table 4-5. Properties of Celgard®, X50-215 Microporous Hollow Fiber Membrane

Parameter	Value
Porosity (%)	40
Pore Dimensions (µm)	0.04 × 0.10
Effective Pore Size (µm)	0.04
Minimum Burst Strength (psi)	400
Tensile Break Strength (g/filament)	≥300
Average Resistance to Air Flow (Gurley sec)	50
Axial Direction Shrinkage (%)	≤5
Fiber Internal Diameter, nominal (µm)	220
Fiber Wall Thickness, nominal (µm)	40
Fiber Outer Diameter, nominal (µm)	300
Module Dimensions (in)	1.5 × 3.0

Data Source: Celgard®

Each pressure vessel is interconnected with Schedule 80 PVC piping and five electrically actuated butterfly valves, which make up the valve tree as shown in Figure 4-11. During normal operation, the feed valves and effluent valves are opened and the other six valves are closed to direct water downward through the two adsorptive vessels. During backwashing, the feed and effluent valves are closed and the backwash feed valves and backwash effluent valves are opened to divert water upward through the two adsorption vessels. The butterfly valves are controlled by a Square D Telemechanique PLC with a Magelis G2220 color touch interface screen.

- **Backwash**. The vendor recommended that the APU-160 system be backwashed approximately once per month, either manually or automatically, to remove particulates and media fines that accumulate in the media beds. Automatic backwash can be initiated by either timer or differential pressure across the vessels (i.e., when $\Delta p>10$ psi). Backwash is to be performed upflow at a flowrate of 113 to 125 gpm to achieve a hydraulic loading rate of about 9 to 10 gpm/ft^2. Each backwash cycle is set to last for about 17 to 19 min/vessel, generating approximately 1,920 to 2,380 gal/vessel of wastewater. The backwash water is discharged into a drainage pond adjacent to the treatment facility.

Figure 4-11. Adsorption System Valve Tree and Piping Configuration

4.3 System Installation

The installation of the APU system was completed by AdEdge and its subcontractor, Pumps and Services, Inc., on May 15, 2007. The following briefly summarizes predemonstration activities, including permitting, building preparation, system offloading, installation, shakedown, and startup.

4.3.1 Permitting. The Nambe Pueblo community water system was not subject to State of New Mexico Environment Department (NMED) drinking water permit requirements due to the sovereignty of Nambe Pueblo as a tribal land; therefore, no engineering submittals or permit packages were prepared for this demonstration.

4.3.2 Building Preparation. The existing building (Figure 4-3) at the Buffalo Well was too small to house the APU system, therefore, a new building (Figure 4-12) was constructed by the IHS to house the treatment system. To facilitate the building design, conceptual system footprint and structural requirements were provided by AdEdge to IHS on November 14, 2003, and computer-aided design (CAD) drawings of the system were provided on November 28, 2003. IHS signed a contract with a general contractor for construction of the building on October 5, 2004, and site work began on November 8, 2004. The concrete foundation was completed on December 2, 2004, and geotechnical samples were collected to determine if the concrete would support the wet weight of the APU. The concrete was approved in January 2005, and building construction was resumed.

Construction of the first phase of building, including the walls, roof, and doors, was completed in April 2005; however, the electrical and plumbing work was not complete, and the construction contract funding was depleted. Construction of the building stopped in April 2005, pending the award of additional federal funding to pay for the remaining construction effort. Additional funding was received by IHS on August 2, 2005, but the new construction contract was not issued until May 31, 2006. Construction activities resumed on June 26, 2006, and the final electrical work was completed on August 29, 2006. A summary of building preparation completion dates is included in Table 4-6.

4.3.3 System Installation, Shakedown, and Startup. The treatment system was delivered to the new building on May 9, 2005. However, as noted in Section 4.3.2, the plumbing and electrical portions of the building were not completed, and system installation could not be performed. The system was secured in the unfinished building pending completion of the plumbing and electrical work required to support installation of the system. After building construction was completed on August 29, 2006, plumbing and electrical connections for the system (with the exception of CO_2 gas line) were completed on September 5, 2006. Due to various issues among the Nambe Pueblo Tribe, IHS, and EPA Region 6, approval to finalize the installation of the system was not reached until February 2007.

On May 7, 2007, the vendor returned to the site to complete the plumbing, install the CO_2 system, and perform shakedown testing and operator training. Hydraulic testing of the system (prior to media loading) was conducted on May 8, 2007. The flow and differential pressure measurements were approved, and the underbedding gravels and adsorptive media were loaded into the vessels on May 8, 2007. Final installation activities, including initial backwash of the media, plumbing of sample ports, and installation of the pH control system, was conducted from May 11 through 15, 2007, with personnel present from AdEdge, IHS, EPA Region 6, and Nambe Pueblo Tribe (the operator and assistant operator). The system officially went into service on May 15, 2007, and operator training was provided by AdEdge on May 16, 2007. Battelle staff arrived at Nambe Pueblo on July 9, 2007, to inspect the system and provide additional operator training (Figure 4-13). Training included calibration and use of the field water quality meters, collection and recording of operational data, proper sample collection techniques, arsenic speciation, and sample handling and shipping procedures. Table 4-6 summarizes key activities and completed dates during system installation, shakedown, and startup.

Figure 4-12. Nambe Pueblo Treatment Plant Building
(Top: Building under construction; Bottom: Completed building)

Table 4-6. Key Milestones for Building Preparation and System Installation

Activity	Date
Building Preparation	
Footprint and Structural Requirements from AdEdge to HIS	November 14, 2003
CAD Drawings provided by AdEdge to IHS	November 28, 2003
IHS Signed Contract with General Contractor	October 5, 2004
Site Work Began	November 8, 2004
Concrete Foundation Completed	December 2, 2004
Concrete Pour Approved	January 2005
First Phase of Construction Completed; Funding Exhausted	April 2005
Additional Federal Funds Received by HIS	August 2, 2005
New Construction Contract Issued	May 31, 2006
Construction Resumed	June 26, 2006
Final Electrical Work Completed	August 29, 2006
Installation, Shakedown, and Startup	
APU Delivered to Nambe Building	May 9, 2005
Plumbing and Electrical Connections Completed	September 5, 2006
Approval to Finalize Installation Received	February 2007
Hydraulic Testing Performed	May 8, 2007
Adsorptive Media Loaded	May 8, 2007
Final Installation and Startup	May 11–15, 2007
System Startup	May 15, 2007
Operator Training Performed by AdEdge	May 16, 2007
Operator Training Performed by Battelle	July 9, 2007

Figure 4-13. Operator Training at Nambe Pueblo

Table 4-7 summarizes the punch-list items identified by Battelle during system shakedown and operator training, and corrective actions taken by AdEdge. The first two items were addressed quickly. The uneven flow through Vessels A and B did not cause a problem; the flow imbalance was not significant during the demonstration study (i.e. 51.5% through Vessel A and 48.5% through Vessel B [Section 4.3.1]). Therefore, no action was taken on this item. Vendors were contacted to determine cost and feasibility of installing a large CO_2 tank, and it was determined that the most efficient approach would be to have more CO_2 cylinders on hand and provide better coordination for delivery.

Table 4-7. System Punch-List/Operational Issues

Item No.	Punch-List/ Operational Issues	Corrective Action(s) Taken	Resolution Date
1	Rotameter for CO_2 system too small	• Ordered and install a larger rotameter	June 2007
2	pH control system appears to have a high CO_2 use rate	• Checked for leaks in system, but none was found	June 2007
3	Water flow through Tank A higher than Tank B	• Observe to determine if uneven flow becomes a problem	Not needed
4	Operator prefers to have a large CO_2 storage tank with a fill connection outside fenced area so that CO_2 vendor can replenish supplies when operator is not onsite	• Vendors contacted to determine cost and feasibility of installing a large CO_2 tank, and it was determined that most efficient approach would be to have more CO_2 cylinders on hand and provide better coordination for delivery	Not needed

4.4 System Operation

4.4.1 Operational Parameters. Operational data were collected from July 9, 2007, through September 28, 2009, and are attached as Appendix A. Table 4-8 summarizes key parameters. According to the well pump hour meter, the treatment system operated for a total of 9,445 hr. Daily operating times fluctuated significantly from 2 to 24 hr and remained low at 2.1 hr/day (on average) from October 11 through December 3, 2007 (see Figure 4-14). This was due to testing of a rehabilitated well in the distribution system, which reduced daily demand from the treatment plant. Excluding the period from October 11 to December 3, 2007, the average daily operation time was 12.3 hr/day. Because no daily operational data were collected from system startup on May 15, 2007 to July 9, 2007, operation hours (689 hr) during this period were estimated by multiplying the average daily operation time (12.3 hr/day) by the number of days (56 day). Total system operation time during the entire performance evaluation study (i.e. from May 15, 2007, through September 28, 2009) was calculated to be 10,134 hr.

Total volume throughput during the performance evaluation study was 64,580,000 gal, or 121,390 bed volumes (BV) (1 BV = 71.2 ft^3 of media in both vessels), based on two totalizers installed at the inlet side of the adsorption vessels. The average daily demand was 78,360 gpd, excluding the period from October 11 to December 3, 2007, when a rehabilitated well was tested in the distribution system.

System flowrates were tracked by electromagnetic flow meters/totalizers installed at the inlet side of the vessels. Flowrates also were calculated based on flow totalizer and hour meter readings from the same electromagnetic flow meters/totalizers. Instantaneous flowrate readings for Vessels A and B were 58.8 and 55.5 gpm (on average), respectively, which were 4% to 5% higher than the corresponding calculated flowrates of 56.7 and 53.0 gpm (on average). As shown in Figure 4-15, there was slight flow imbalance between Vessels A and B, i.e., 51.5 and 48.5%, respectively, based on instantaneous flowrate readings.

Table 4-8. Summary of AdEdge APU-160 System Operation

Parameter	Actual
Study Duration	05/15/07–09/28/09
Estimated Total Operating Time (hr)	10,134
Average Daily Operating Time[(a)] (hr)	12.3
Volume Throughput (gal)	Vessel A: 33,460,647
	Vessel B: 31,119,352
	System: 64,580,000
System Throughput[(b)] (BV)	121,390
System Average Daily Use[(a)] (gpd)	78,360
Average (Range) of Instantaneous Flowrate (gpm)	Vessel A: 58.8 (49.7 to 72.2)
	Vessel B: 55.5 (44.2 to 67.5)
	System: 114 (97 to 140)
Average (Range) of Hydraulic Loading Rate (gpm/ft^2)	Vessel A: 4.7(3.9 to 5.7)
	Vessel B: 4.4 (3.5 to 5.4)
	System: 4.5 (3.8 to 5.6)
Average (Range) of EBCT (min)	Vessel A: 4.5 (3.7 to 5.4)
	Vessel B: 4.8 (3.9 to 6.0)
	System: 4.7 (3.8 to 5.5)
Average (Range) of Δp (psi)	Vessel A: 1.1 (0.0 to 4.0)
	Vessel B: 1.1 (0.0 to 5.0)
	System: 1.1 (0.0 to 5.0)

(a) Not including period from 10/11/07 through 12/03/07.
(b) 1 BV = 71.2 ft^3 or 532 gal.

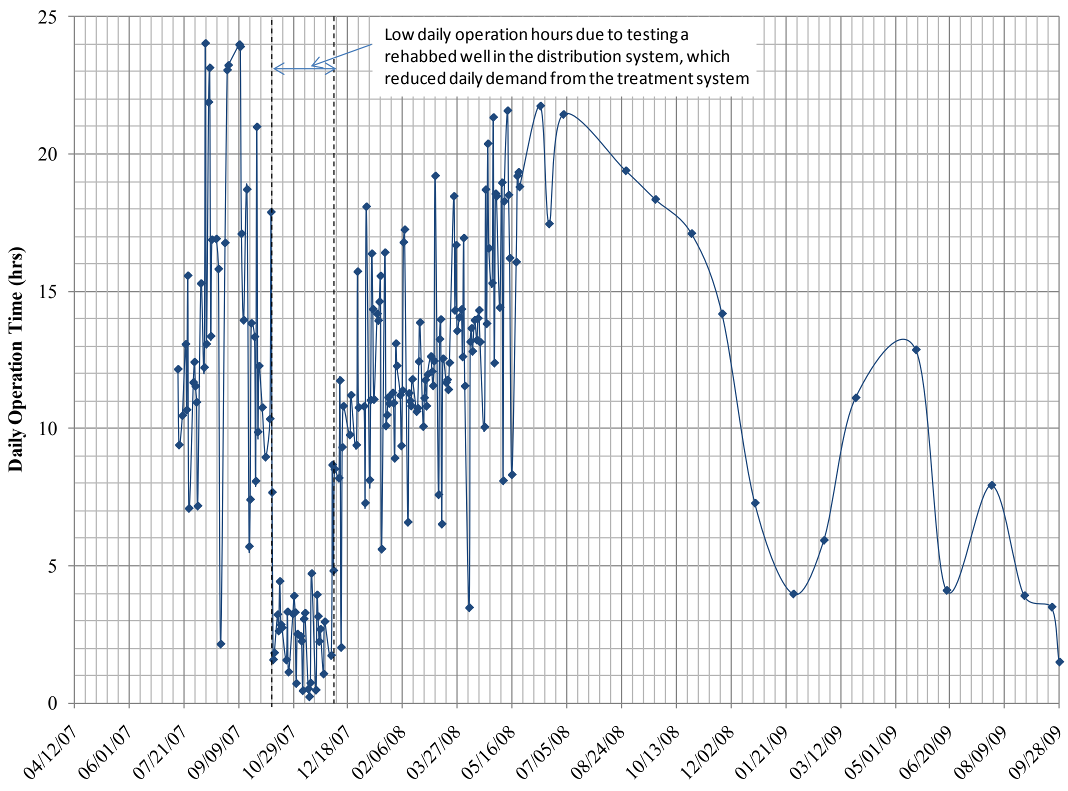


Figure 4-14. Treatment System Daily Operating Times

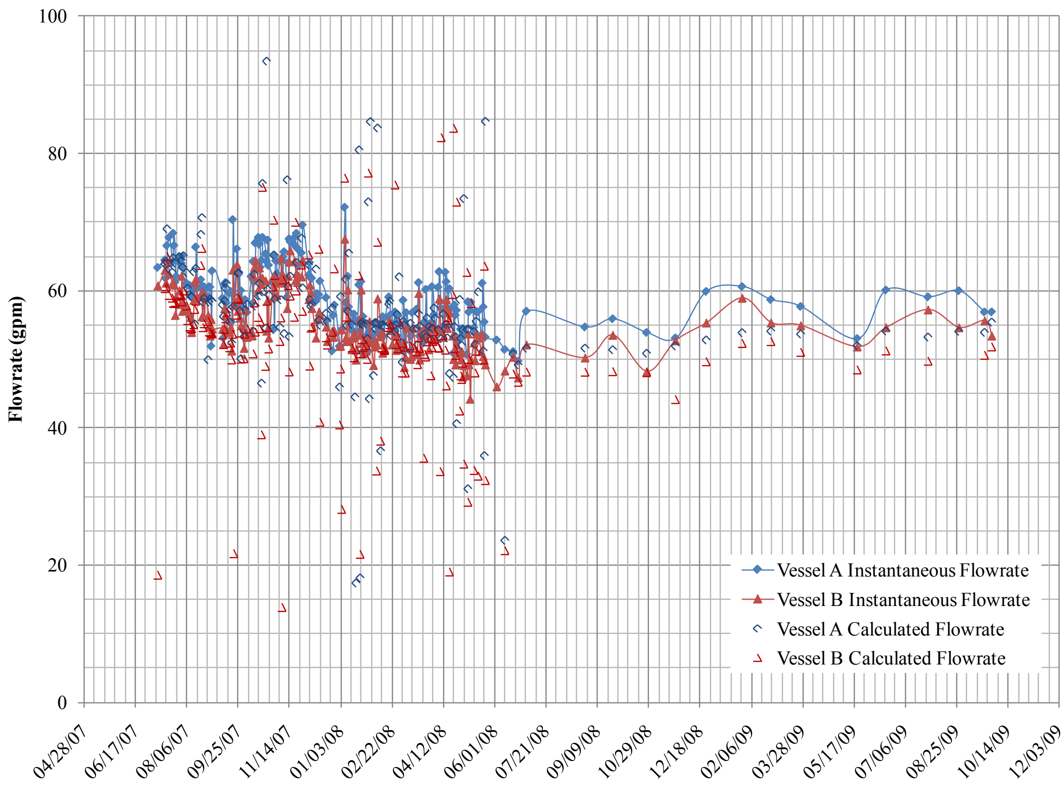


Figure 4-15. System Instantaneous and Calculated Flowrates

Instantaneous flowrates through the treatment system ranged from 97 to 140 gpm and averaged 114 gpm, which was lower than the design flowrate of 160 gpm (Table 4-4). This average flowrate represented an average hydraulic loading rate of 4.5 gpm/ft^2 and an average EBCT of 4.7 min. The average hydraulic loading rate was lower than the design value of 6.3 gpm/ft^2, and the average EBCT was longer than the design value of 3.3 min.

Differential pressure (Δp) readings across the system ranged from 0 to 5 psi and averaged 1.1 psi (Figure 4-16). Δp readings across Vessel A ranged from 0 to 4 psi and averaged 1.1 psi. Δp readings across Vessel B ranged from 0 to 5 psi and averaged 1.1 psi. Due to the low Δp readings across the media vessels, no backwash was conducted during the performance evaluation study.

4.4.2 pH Adjustments. pH adjustment was provided by a carbon dioxide gas flow control system manufactured by ATSI (Section 4.2). Carbon dioxide gas was supplied to the system by a pair of 50-lb cylinders connected in parallel. The water system operator monitored the CO_2 cylinders and ordered and received replacement cylinders when necessary. During the course of the performance evaluation study, the operator reported difficulties in coordinating the delivery of replacement cylinders and maintaining a constant CO_2 supply to the pH control system. Factors for the difficulties might have included the non-standard working hours of the operator, remote site location, and reported delivery delays by the CO_2 vendor.

The lack of constant CO_2 supply to the pH adjustment system resulted in periodic losses of pH control. The pH values recorded by an in-line pH meter/logger at the AP location were downloaded for two time periods from March 31 through June 20, 2008, and from September 17, 2008, through January 8, 2009, and the data are plotted in Figures 4-17a and 17b, respectively. The datalogger recorded pH readings

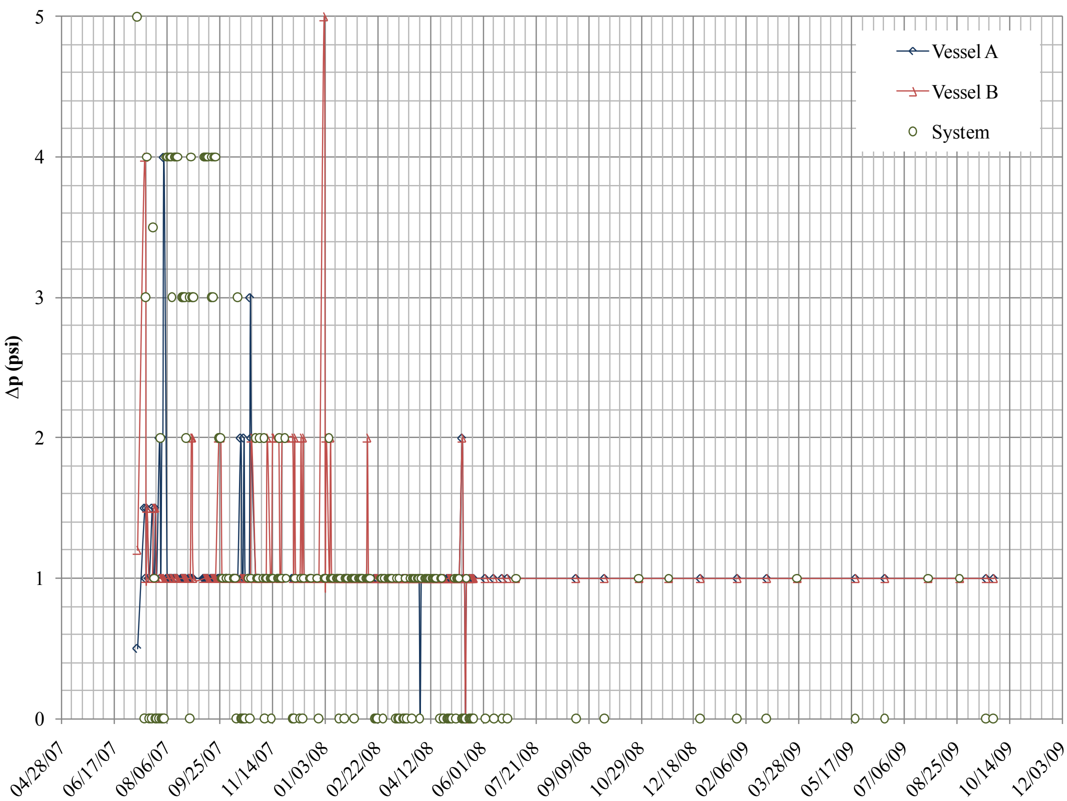


Figure 4-16. Operational Pressure Readings

from the in-line pH probe at 30-min intervals only when the well pump and APU system were operating. An additional data point was recorded when the well pump shut off. Based on the operational data sheets in Appendix A, the treatment system operated for 17.4 and 10.5 hr/day (on average) during the first and second time periods, respectively. It can be seen easily on Figure 4-17b, during December 7, 2008, through January 8, 2009, when the system was on or off. However, it is more difficult to differentiate the system's on/off outside of this time period because of the large number of data points presented in the figures.

Shaded areas shown in Figures 4-17a and 4-17b denote the durations when the treatment system operated without pH control. Based on the datalogger, the system operated without pH control for 55.2% of the time during the first period. pH control improved significantly in the second period with only 14.3% of the time operating without pH control. The improvement was probably due to an improved coordination of the plant operator to maintain a more constant CO_2 supply, when analytical results started to indicate that losing pH control might flush adsorbed arsenic and uranium out of the adsorptive media beds (Section 4.5.1).

As also shown in Figures 4-17a and 4-17b, pH values measured by the in-line pH probe and recorded in the datalogger during periods without pH control were higher than those of source water, i.e., 9.0 and 9.1, as presented in Table 4-11. It is possible that the calibration of the in-line pH probe was off; however, due to lack of pH readings from a handheld meter, there were no additional data that might be used to compare the in-line pH probe readings. While the exact pH values might be incorrect due to lack of calibration, it does appear that the probe was able to detect the relative changes in pH during system operation.

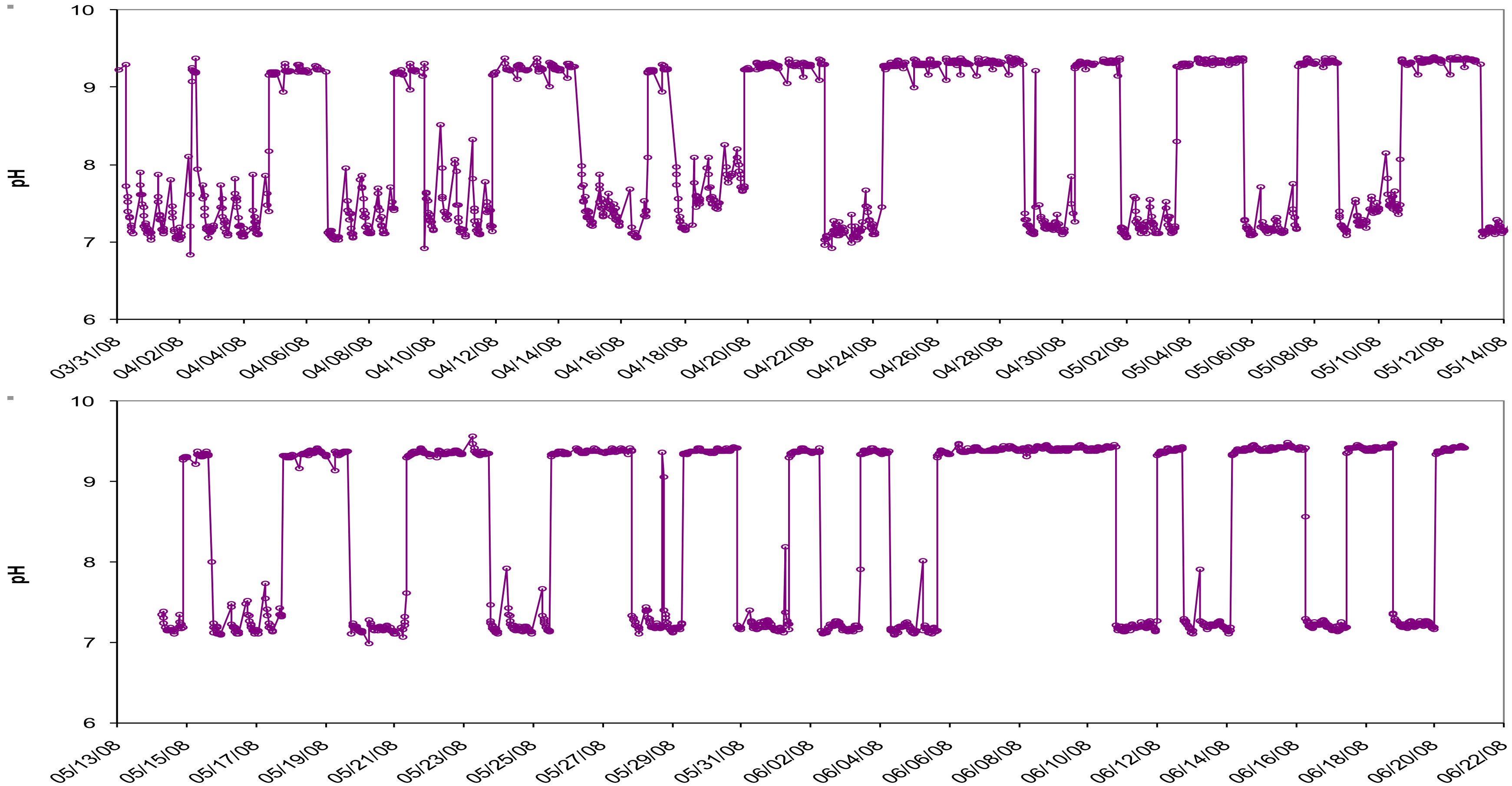


Figure 4-17a. In-line pH Data for Period from March 31 Through June 20, 2008

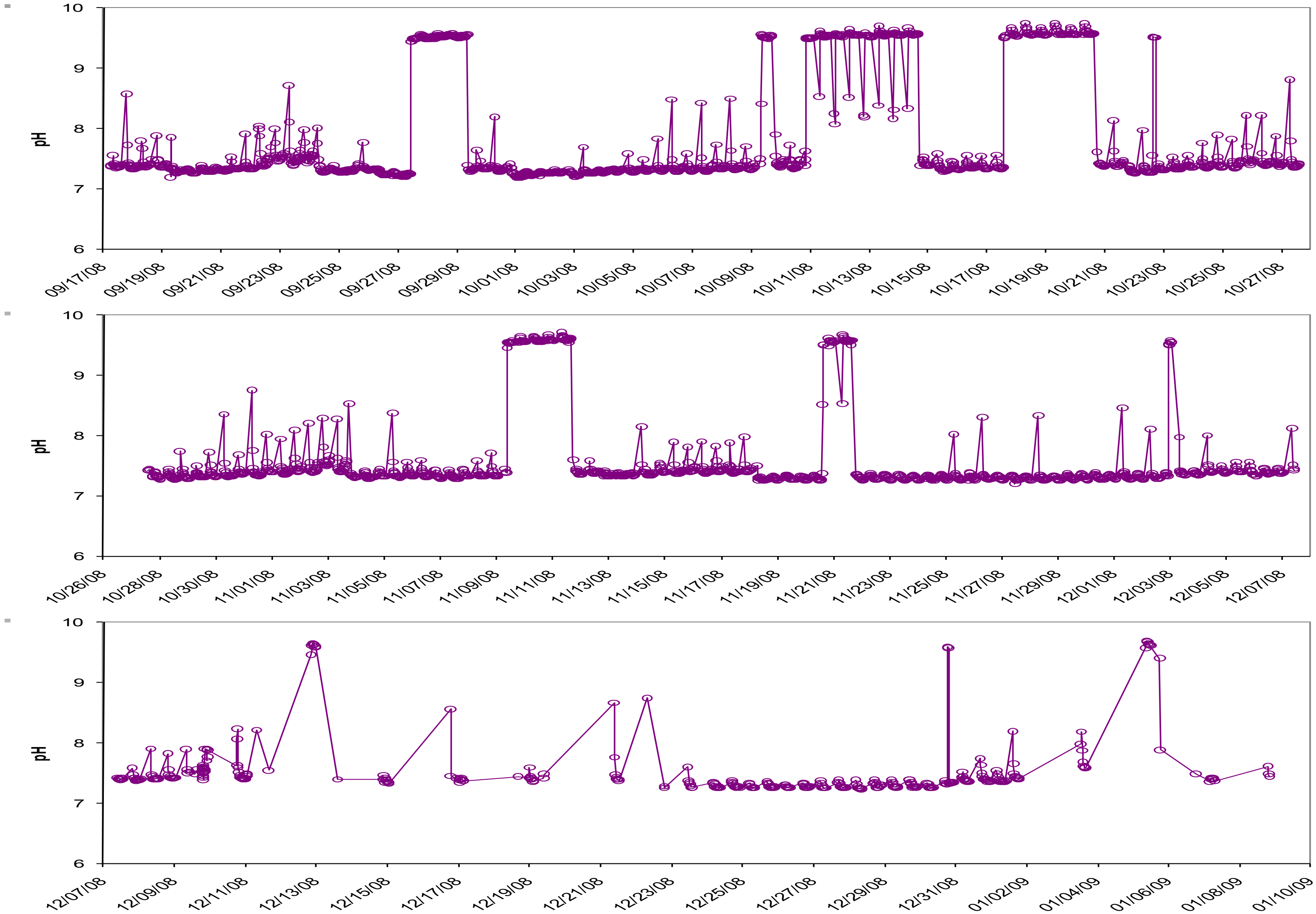


Figure 4-17b. In-line pH Data for Period from September 17, 2008, Through January 08, 2009

Table 4-9. Example pH Data from In-line pH Probe

Date and Time	pH (in-line probe)
April 10, 2008 11:00	7.28
April 10, 2008 11:28	7.35
April 10, 2008 17:00	8.01
April 10, 2008 17:30	8.06
April 10, 2008 18:00	7.91
April 10, 2008 18:30	7.47
April 10, 2008 19:00	7.47
April 10, 2008 19:30	7.31
April 10, 2008 20:00	7.26
April 10, 2008 20:30	7.16
April 10, 2008 21:00	7.18
April 10, 2008 21:30	7.12
April 10, 2008 22:00	7.16
April 10, 2008 22:30	7.16
April 10, 2008 23:00	7.13
April 10, 2008 23:30	7.16
April 11, 2008 00:00	7.16
April 11, 2008 00:30	7.09
April 11, 2008 01:00	7.09
April 11, 2008 01:04	7.07
April 11, 2008 06:30	8.32
April 11, 2008 07:00	7.82
April 11, 2008 07:30	7.44

Table 4-9 shows a subset of pH datalogger recordings for April 10 and 11, 2008, at periods during system operation, shutdown, and startup. On April 10, the system was operating and recording data at 30-min intervals, as noted for the 11:00 data point. The datalogger then recorded another point at 11:28 when the well pump turned off. The next data point was recorded at 17:00 after the system had restarted. The period of time between 11:28 and 17:00 represented system downtime. The exact restart time of the system was unknown, but had to have occurred between 16:30 and 17:00. The pH data shown in Table 4-9 suggested CO_2 degassing during periods when the well pump (and consequently the pH control system and datalogger) was not operating. During this time, pH values in the in-line probe cell began to drift upwards, as shown by the pH readings increasing from 7.35, when the system shut down at 11:28, up to a level presumably higher than the 8.01 value measured by the time of the first reading at 17:00, or between 0 and 29 min after system restart. A similar pattern was shown for April 11, 2008, where the system shut off at 01:04 with a pH value of 7.07, and restarted between 06:00 and 06:30 with a pH value measured at 8.32 at 06:30. The data show that the pH continued to decrease with continued system operation. The pattern shown for each of these days was repeated on other dates where the datalogger pH data exist. Data collected during routine treatment plant sampling across the treatment train at TA, TB, and TT did not include pH measurements; it was therefore unclear if CO_2 degassing phenomenon also had occurred within the adsorption vessels.

In order to address the difficulty with maintaining proper pH control, alternative CO_2 storage and delivery options were investigated. Quotes for the purchase and/or lease of a large CO_2 storage tank were solicited from local vendors, and the costs for tank purchase and installation were compared to the costs of 50-lb cylinder rental. Analysis of the cost comparison indicated that the purchase and installation of a large

CO_2 storage tank, while potentially more convenient for the operator, was not economically feasible due to the significant capital cost. Therefore, it was decided not to install a large CO_2 storage tank at the site.

During the period from July 9, 2007 to May 22, 2008, the treatment system operated 318 days and consumed a total of 148 50-lb CO_2 cylinders. (Note that the consumption of CO_2 cylinders was not recorded before July 9, 2007 and after May 22, 2008). Therefore, the treatment system consumed an average of 23.3 lb/day of CO_2, corresponding to 16.2 ft^3/hr of CO_2 based on a gas density of 0.117 lb/ft^3 and an average system operating time of 12.3 hr/day. The CO_2 gas supplied from two 50-lb cylinders provided CO_2 for about 4.3 days' operation before requiring replacement. Using a CO_2 consumption model, the vendor estimated the theoretical CO_2 usage based on source water quality and system flowrate. The theoretical usage was 15.8 ft^3/hr (including 4 ft^3/hr on the purge line), which was very close to the actual average usage of 16.2 ft^3/hr.

4.4.3 Residual Management. No residuals were produced because neither backwash nor media replacement was required.

4.4.4 System/Operation Reliability and Simplicity. In addition to the pH adjustment problem discussed in Section 4.4.2, no major operational problems were encountered. The only O&M issues encountered were a broken pre-chlorination injector and malfunctioning main solenoid valve in the CO_2 gas system. Both issues were solved quickly and did not cause any system downtime. The system O&M and operator skill requirements are discussed below in relation to pre- and post-treatment requirements, levels of system automation, operator skill requirements, preventive maintenance activities, and frequency of chemical/media handling and inventory requirements.

Pre- and Post-Treatment Requirements. Pre- and post-treatment consisted of pH adjustment, prechlorination, and postchlorination. CO_2 was used to lower pH values of source water to a target value of 7.0 in order to increase the arsenic removal capacity of the adsorptive media. The CO_2 injection point and in-line pH probe used to monitor and control the adjusted pH levels were installed downstream of the chlorine injection point. O&M of the pH adjustment system required routine system pressure checks and regular changeout of CO_2 supply bottles as pressure was depleted. The operator also recorded daily pH readings from the in-line probe, as needed. The use of CO_2 for pH adjustment also required safety training for and awareness by the operator due to potential hazards.

For pre- and post-chlorination, the existing chlorination system was upgraded and installed inside the treatment building. The upgraded chlorination system, as discussed in Section 4.2 and shown on Figure 4-8, utilized a 10% NaOCl solution to reach a target residual level of 0.58 mg/L (as Cl_2) at the entry point. The upgraded chlorination system did not require maintenance or skills other than those required by the previous system. The operator monitored chlorine tank levels (to estimate consumption rates) and residual chlorine levels (using a Hach meter).

System Automation. The system was fitted with automated controls to allow for automatic backwash. The system also was equipped with an automated carbon dioxide gas flow control system for pH control/adjustment. Each media vessel was equipped with five electrically actuated butterfly valves, which were controlled by a Square D Telemechanique PLC with a Magelis G2220 color touch interface screen.

The automated portion of the system did not require regular O&M; however, operator awareness and an ability to detect unusual system measurements were necessary when troubleshooting system automation failures. The equipment vendor provided hands-on training and a supplemental operations manual to the operator.

Operator Skill Requirements. Skill requirements to operate the system demanded a higher level of awareness and attention than the previous system. The system offered increased operational flexibility, which, in turn, required increased monitoring of system parameters. The operator's knowledge of system limitations and typical operational parameters were key to achieve system performance objectives. The two operators were onsite typically five times a week and spent a total of approximately 6.5 hr each time, as claimed by the operators, to perform visual inspections and record relevant system operating parameters on the Daily System Operation Log Sheets. The basis for the operator skills began with onsite training and a thorough review of the system operations manual; however, increased knowledge and invaluable system troubleshooting skills were gained through hands-on operational experience.

Preventive Maintenance Activities. Preventive maintenance tasks included periodic checks of flow meters and pressure gauges and inspection of system piping and valves. Checking the CO_2 cylinders and supply lines for leaks and adequate pressure and calibrating the in-line pH probe also were performed. Typically, the operator performed these duties while onsite for routine activities.

Chemical/Media Handling and Inventory Requirements. NaOCl was used for pre- and post-chlorination. The operator ordered the chemical as done prior to installation of the APU-160 system. CO_2 used for pH adjustment was ordered on an as-needed basis. Typically, 15 50-lb cylinders were used per month. As CO_2 cylinders were delivered to the site by Airgas, empty cylinders were returned for reuse.

4.5 System Performance

4.5.1 Treatment Plant Sampling. Treatment plant water samples were collected on 63 occasions (including four duplicate samples collected during four regular sampling events) with field speciation performed during two of the 63 occasions at IN, AP, and TT sampling locations. Table 4-10 summarizes the analytical results of arsenic, iron, manganese, and uranium measured at the five sampling locations across the treatment train. Table 4-11 summarizes the results of other water quality parameters. Appendix B contains a complete set of analytical results throughout the performance evaluation study.

Arsenic. Total arsenic concentrations in source water ranged from 10.7 to 59.0 μg/L and averaged 32.2 μg/L. Based on the two speciation sampling events taking place on July 9 and August 10, 2007, soluble As(V) was the predominating species, ranging from 34.2 to 36.5 μg/L and averaging 35.4 μg/L. Trace levels of soluble As(III) also existed, with concentrations ranging from 0.3 to 1.0 μg/L and averaging 0.7 μg/L. Particulate arsenic concentrations were low as well, ranging from <0.1 to 2.9 μg/L and averaging 1.5 μg/L. Arsenic concentrations measured during the performance evaluation study were consistent with those collected previously during source water sampling (Table 4-1).

As expected, arsenic concentrations and speciation remained essentially unchanged after pH adjustments, with As(V) existing as the predominating species at 31.0 μg/L (on average).

Figure 4-18 presents total arsenic breakthrough curves. Throughout the performance evaluation study (i.e., from May 15, 2007, through September 28, 2009, treating approximately 64,580,000 gal [or 121,390 BV) of water), total arsenic concentrations were reduced to below 3 μg/L in system effluent (at TA, TB, and/or TT) during most sampling events. Exceptionally high total arsenic concentrations (i.e., from 14.7 to 46.9 μg/L) were measured on six occasions (August 15, 2007, September 26, 2007, February 13, 2008, April 22, 2008, May 13, 2008, and August 27, 2009, at 17,240, 27,730, 40,830, 51,320, 55,500, and 120,242 BV, respectively). After each spike, arsenic concentrations returned to the respective pre-spike levels, suggesting that the concentration spikes observed were not due to normal arsenic breakthrough.

Table 4-10. Summary of Analytical Results for Arsenic, Iron, Manganese, and Uranium

Parameter	Sampling Location	Sample Count	Concentration (µg/L) Minimum	Maximum	Average	Standard Deviation
As (total)	IN	63	10.7	59.0	32.2	7.1
	AP	63	10.6	44.9	31.6	7.6
	TA	61	<0.1	46.9	-[(a)]	-[(a)]
	TB	61	<0.1	44.7	-[(a)]	-[(a)]
	TT	2	1.3	2.5	-[(a)]	-[(a)]
As (soluble)	IN	2	34.5	37.7	36.1	2.2
	AP	2	30.9	32.5	31.7	1.2
	TA	NM	NM	NM	NM	NM
	TB	NM	NM	NM	NM	NM
	TT	2	1.4	2.3	-[(a)]	-[(a)]
As (particulate)	IN	2	<0.1	2.9	1.5	2.0
	AP	2	0.8	4.4	2.6	2.6
	TA	NM	NM	NM	NM	NM
	TB	NM	NM	NM	NM	NM
	TT	2	<0.1	0.1	-[(a)]	-[(a)]
As (III)	IN	2	0.3	1.2	0.7	0.6
	AP	2	0.3	1.1	0.7	0.6
	TA	NM	NM	NM	NM	NM
	TB	NM	NM	NM	NM	NM
	TT	2	0.3	1.0	-[(a)]	-[(a)]
As (V)	IN	2	34.2	36.5	35.4	1.6
	AP	2	29.7	32.2	31.0	1.8
	TA	NM	NM	NM	NM	NM
	TB	NM	NM	NM	NM	NM
	TT	2	0.4	2.0	-[(a)]	-[(a)]
Fe (total)	IN	63	<25	154	<25	22.8
	AP	63	<25	28.4	<25	2.0
	TA	61	<25	44.5	<25	5.5
	TB	61	<25	56.7	<25	6.3
	TT	2	<25	<25	<25	0.0
Fe (soluble)	IN	2	<25	<25	<25	0.0
	AP	2	<25	<25	<25	0.0
	TA	NM	NM	NM	NM	NM
	TB	NM	NM	NM	NM	NM
	TT	2	<25	<25	<25	0.0
Mn (total)	IN	63	<0.1	10.8	0.8	1.7
	AP	63	<0.1	63.8	1.3	8.0
	TA	61	<0.1	0.3	<0.1	0.1
	TB	61	<0.1	0.3	<0.1	0.0
	TT	2	<0.1	<0.1	<0.1	0.0
Mn (soluble)	IN	2	<0.1	1	0.4	0.4
	AP	2	<0.1	0.2	0.1	0.1
	TA	NM	NM	NM	NM	NM
	TB	NM	NM	NM	NM	NM
	TT	2	<0.1	0.3	0.2	0.2
U (total)	IN	63	19.9	55.8	39.3	4.8
	AP	63	26.6	48.9	39.3	3.7
	TA	61	1.3	135	-[(a)]	-[(a)]

Table 4-10. Summary of Analytical Results for Arsenic, Iron, Manganese, and Uranium (Continued)

Parameter	Sampling Location	Sample Count	Concentration (µg/L)			Standard Deviation
			Minimum	Maximum	Average	
U (total) (Continued)	TB	61	1.4	90.9	-[(a)]	-[(a)]
	TT	2	2.8	71.6	-[(a)]	-[(a)]
U (soluble)	IN	2	<0.1	41	20.3	28.7
	AP	2	24.8	41.0	32.9	11.4
	TA	NM	NM	NM	NM	NM
	TB	NM	NM	NM	NM	NM
	TT	2	<0.1	72.0	-[(a)]	-[(a)]

(a) Statistics not provided; see Figures 4-14 and 4-16 for breakthrough curves.
NM = not measured.
One-half of detection limit used for samples with concentrations <MDL for calculations.

Table 4-11. Summary of Water Quality Parameter Sampling Results

Parameter	Sampling Location	Unit	Sample Count	Concentration			Standard Deviation
				Minimum	Maximum	Average	
Alkalinity (as $CaCO_3$)	IN	mg/L	63	155	190	169	7.2
	AP	mg/L	63	158	196	169	7.0
	TA	mg/L	61	156	209	172	13.0
	TB	mg/L	61	156	219	172	12.3
	TT	mg/L	2	186	211	199	17.7
Fluoride	IN	mg/L	3	0.9	1.1	1.0	0.1
	AP	mg/L	3	0.8	1.1	0.9	0.2
	TA	mg/L	1	0.5	0.5	0.5	NA
	TB	mg/L	1	0.8	0.8	0.8	NA
	TT	mg/L	2	0.6	0.8	0.7	0.1
Sulfate	IN	mg/L	3	26.1	29.0	27.4	1.5
	AP	mg/L	3	25.0	37.0	29.7	6.4
	TA	mg/L	1	26.2	26.2	26.2	NA
	TB	mg/L	1	31.2	31.2	31.2	NA
	TT	mg/L	2	27.0	32.0	29.5	3.5
Nitrate (as N)	IN	mg/L	3	0.7	0.8	0.7	0.1
	AP	mg/L	3	0.7	0.8	0.7	0.1
	TA	mg/L	1	0.4	0.4	0.4	NA
	TB	mg/L	1	0.6	0.6	0.6	NA
	TT	mg/L	2	0.7	0.8	0.7	0.0
Total P (as PO_4)	IN	µg/L	63	<10	26.1	<10	2.9
	AP	µg/L	63	<10	23.4	<10	3.0
	TA	µg/L	61	<10	13.0	<10	1.6
	TB	µg/L	61	<10	15.3	<10	1.9
	TT	µg/L	2	<10	<10	<10	0.0
Silica (as SiO_2)	IN	mg/L	63	11.1	15.7	14.1	0.9
	AP	mg/L	63	11.1	16.3	14.0	1.0
	TA	mg/L	61	9.3	30.4	15.8	3.5
	TB	mg/L	61	10.2	25.9	15.3	2.7
	TT	mg/L	2	15.7	21.7	18.7	4.2
Turbidity	IN	NTU	63	<1.0	3.1	<1.0	0.6
	AP	NTU	63	<0.1	6.2	0.6	0.9
	TA	NTU	61	<0.1	3.9	0.6	0.7

Table 4-11. Summary of Water Quality Parameter Sampling Results (Continued)

Parameter	Sampling Location	Unit	Sample Count	Concentration Minimum	Concentration Maximum	Concentration Average	Standard Deviation
Turbidity (Continued)	TB	NTU	61	<0.1	2.6	0.6	0.5
	TT	NTU	2	0.3	0.4	0.4	0.1
TOC	IN	mg/L	2	<1.0	<1.0	<1.0	0
	AP	mg/L	2	<1.0	<1.0	<1.0	0
	TA	mg/L	NA	NA	NA	NA	NA
	TB	mg/L	NA	NA	NA	NA	NA
	TT	mg/L	2	<1.0	<1.0	<1.0	0
pH	IN	S.U.	2	9.0	9.1	9.0	0.1
	AP	S.U.	56	6.9	8.1	7.3	0.2
	TA	S.U.	1	8.0	8.0	8.0	NA
	TB	S.U.	1	8.1	8.1	8.1	NA
	TT	S.U.	2	8.3	8.6	8.5	0.2
Temperature	IN	°C	2	20.4	22.3	21.4	1.3
	AP	°C	2	20.4	21.8	21.1	1.0
	TA	°C	NA	NA	NA	NA	NA
	TB	°C	NA	NA	NA	NA	NA
	TT	°C	2	20.2	22.6	21.4	1.7
Dissolved Oxygen	IN	mg/L	2	6.8	6.9	6.9	0.1
	AP	mg/L	2	3.4	3.8	3.6	0.3
	TA	mg/L	NA	NA	NA	NA	NA
	TB	mg/L	NA	NA	NA	NA	NA
	TT	mg/L	2	4.2	4.7	4.5	0.3
ORP	IN	mV	2	391.3	396	394	3.3
	AP	mV	2	409	442	426	23.1
	TA	mV	NA	NA	NA	NA	NA
	TB	mV	NA	NA	NA	NA	NA
	TT	mV	2	424	467	446	30.2
Total Hardness (as $CaCO_3$)	IN	mg/L	3	6	7	7	0.6
	AP	mg/L	3	6	7	7	0.8
	TA	mg/L	1	8	8	8	NA
	TB	mg/L	1	8	8	8	NA
	TT	mg/L	2	7	41	24	23.8
Ca Hardness (as $CaCO_3$)	IN	mg/L	3	6	7	7	0.6
	AP	mg/L	3	6	7	6	0.8
	TA	mg/L	1	8	8	8	NA
	TB	mg/L	1	8	8	8	NA
	TT	mg/L	2	7	40	23	23.5
Mg Hardness (as $CaCO_3$)	IN	mg/L	3	0.1	0	0.1	0.0
	AP	mg/L	3	0.1	0	0.1	0.0
	TA	mg/L	1	0.6	1	1	NA
	TB	mg/L	1	0.5	1	1	NA
	TT	mg/L	2	0.1	1	0	0.3

One-half of detection limit used for samples with concentrations <MDL for calculations.

It is well established that arsenic adsorption on iron-based media performs the best between pH 6.0 to 8.0. As pH increases and approaches the point of zero charge, the availability of adsorption sites on the media surface diminishes. As such, arsenic not only will no longer be adsorbed onto the media but also will begin to desorb. During the performance evaluation study, there were difficulties maintaining a constant CO_2 supply at the site (Section 4.4.2), thus causing repeated losses of pH control prior to adsorption.

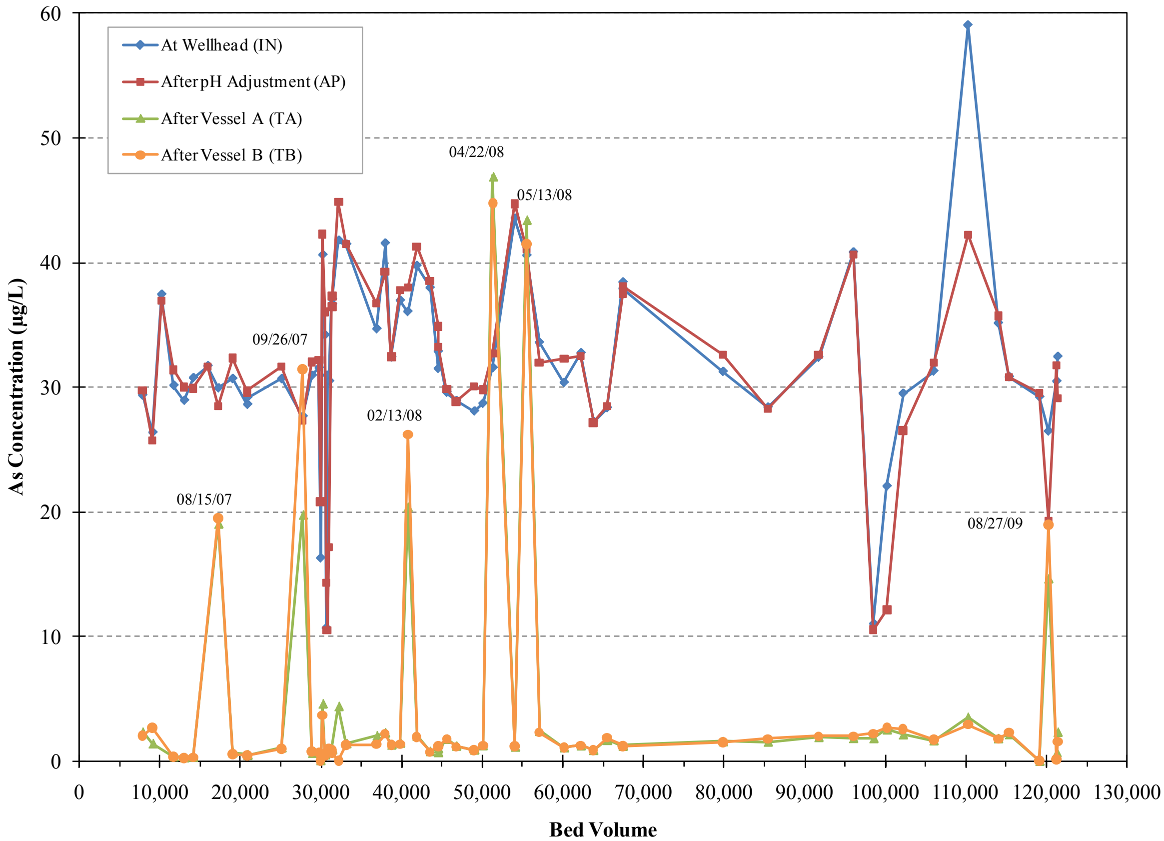


Figure 4-18. Total Arsenic Breakthrough Curves

Figure 4-19 superimposes effluent arsenic and uranium concentrations with the downloaded in-line pH data during March 31 through June 20, 2008, as plotted in Figure 4-17a. The four concentration spikes observed during this period, i.e., 46.9 and 44.7 µg/L on April 22, 2008, and 43.5 and 41.5 µg/L on May 13, 2008, occurred when the system was operating without pH control. The fact that the concentration spikes had concentrations even higher than those in the system influent (i.e., 31.5 and 40.5 µg/L on April 22 and May 13, 2008, respectively) indicate probable arsenic desorption without pH control.

Since the treatment system lost pH control periodically, the adsorptive media beds apparently operated at repeated adsorption and desorption cycles, with captured arsenic being intermittently "flushed" from the media beds. The loss of pH control is likely the reason for the adsorption vessels not exhausting as expected, even after treating 121,390 BV of water (or twice the working capacity [61,300 BV] projected by the vendor) by the end of the performance evaluation study.

Uranium. Originating from rocks and mineral deposits, uranium found in most drinking water sources is naturally occurring and contains three isotopes: U-238 (over 99% by weight), U-235, and U-234. Due to varying amounts of each isotope in the water, the ratio of uranium concentration (µg/L) to activity (pCi/L) varies with drinking water sources from region to region. Based on considerations of kidney toxicity and carcinogenicity, EPA proposed a uranium MCL of 20 µg/L in 1991 (corresponding to 30 pCi/L based on a mass/activity ratio of 1.5 pCi/µg of uranium). The final rule was set at 30 µg/L in December 2000 after the conversion factor was revised to 1 pCi/µg (EPA, 2000). In this study, uranium was analyzed by an ICP-MS method (EPA Method 200.8) with the results expressed in µg/L. Uranium activity (pCi/L) was not reported to avoid potential confusion associated with the use of different conversion factors.

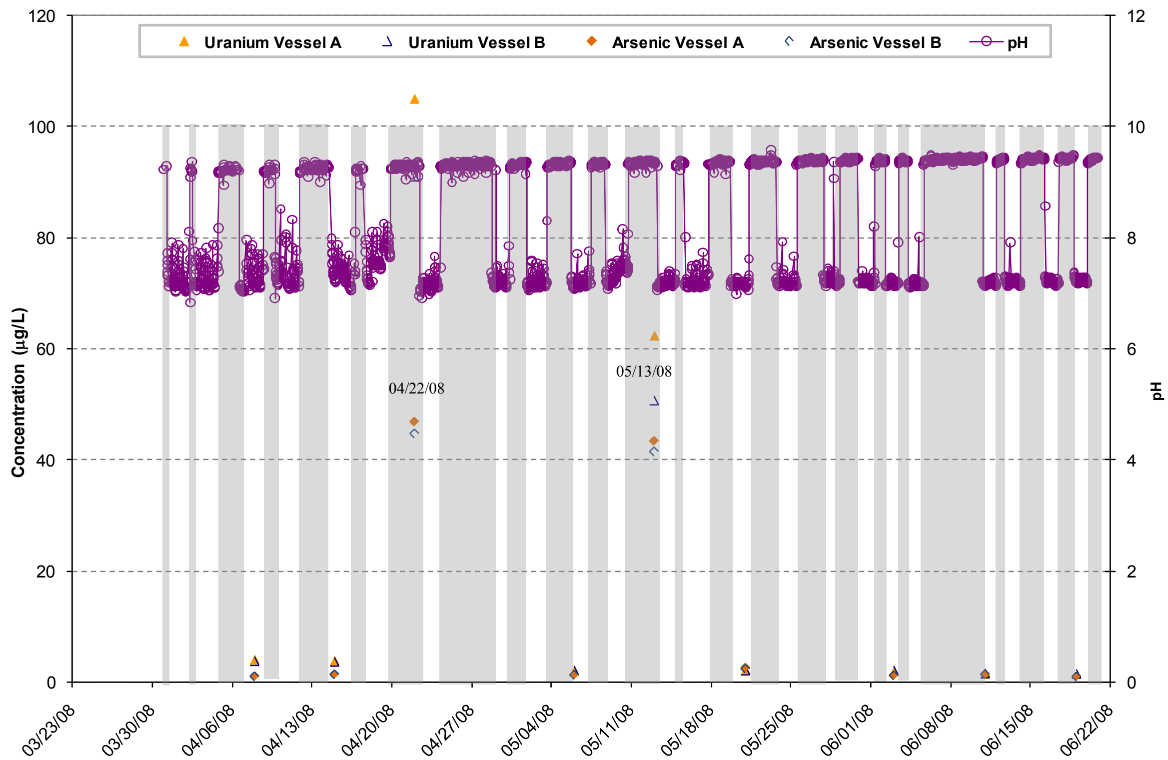


Figure 4-19. Real-time pH values at AP Location vs. Effluent As and U Concentrations

Total uranium concentrations in source water ranged from 19.9 to 55.8 µg/L and averaged 39.3 µg/L. Figure 4-20 shows that uranium was removed to <20 µg/L during the entire study period, except for eight occasions, indicating that AD-33 media was capable of removing uranium. The eight occasions with elevated uranium included the six when arsenic concentrations also were elevated (Figure 4-18).

Similar to arsenic, the uranium concentration spikes observed in the system effluent were likely caused by loss of pH control. As shown in Figure 4-19, the four uranium spikes (i.e., 105 and 90.9 µg/L on April 22, 2008, and 62.4 and 50.6 µg/L on May 13, 2008) occurred when pH values at AP were above 9. These concentrations were higher than the corresponding influent concentrations of 41.5 and 37.4 µg/L on April 22 and May 13, 2008, respectively, indicating desorption from the media beds. Similar to arsenic, uranium breakthrough at MCL did not occur during the performance evaluation study.

Competing Anions. Phosphate and silica, which might influence arsenic adsorption, were measured at the five sampling locations across the treatment train. Phosphate concentrations in source water were low, i.e., less than 26 µg/L (as PO_4). Silica concentrations in source water ranged from 11.1 to 15.7 mg/L and averaged 14.1 mg/L. Figure 4-21 presents the silica concentration curves across the treatment train. No silica concentration reduction was observed. Instead, silica concentrations in system effluent were frequently higher than measured in source water, as shown in Figure 4-21. The reason for higher silica concentrations in effluent is unknown.

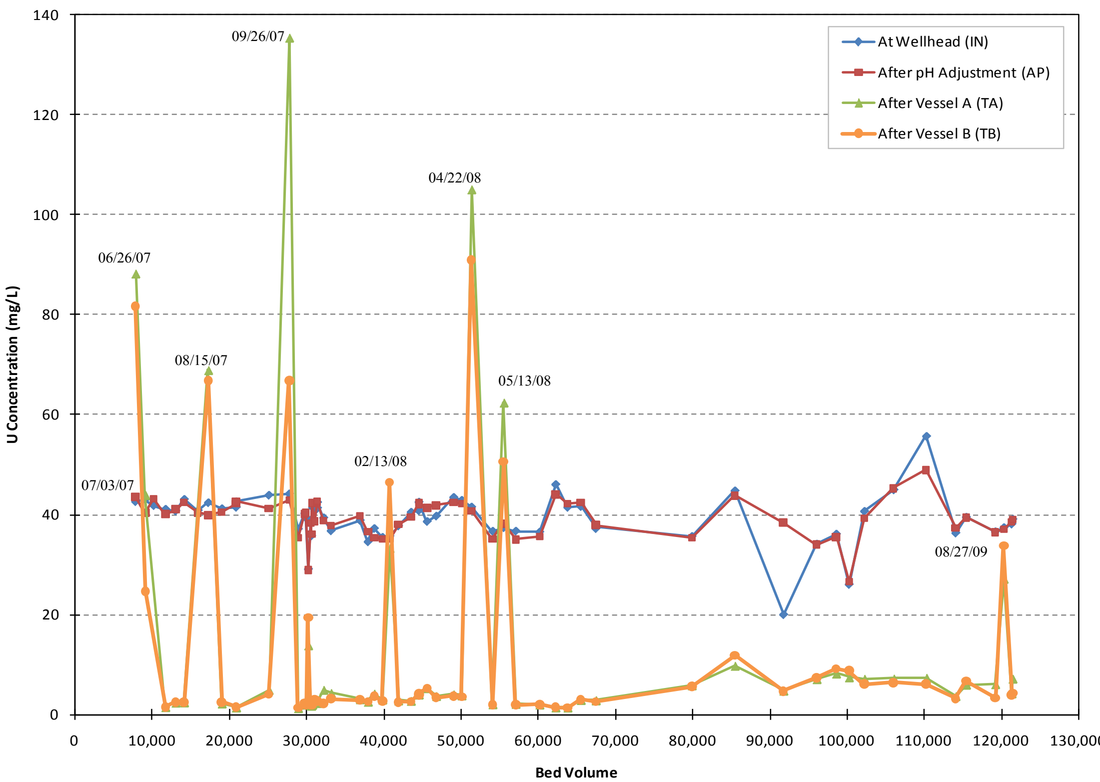


Figure 4-20. Total Uranium Breakthrough Curves

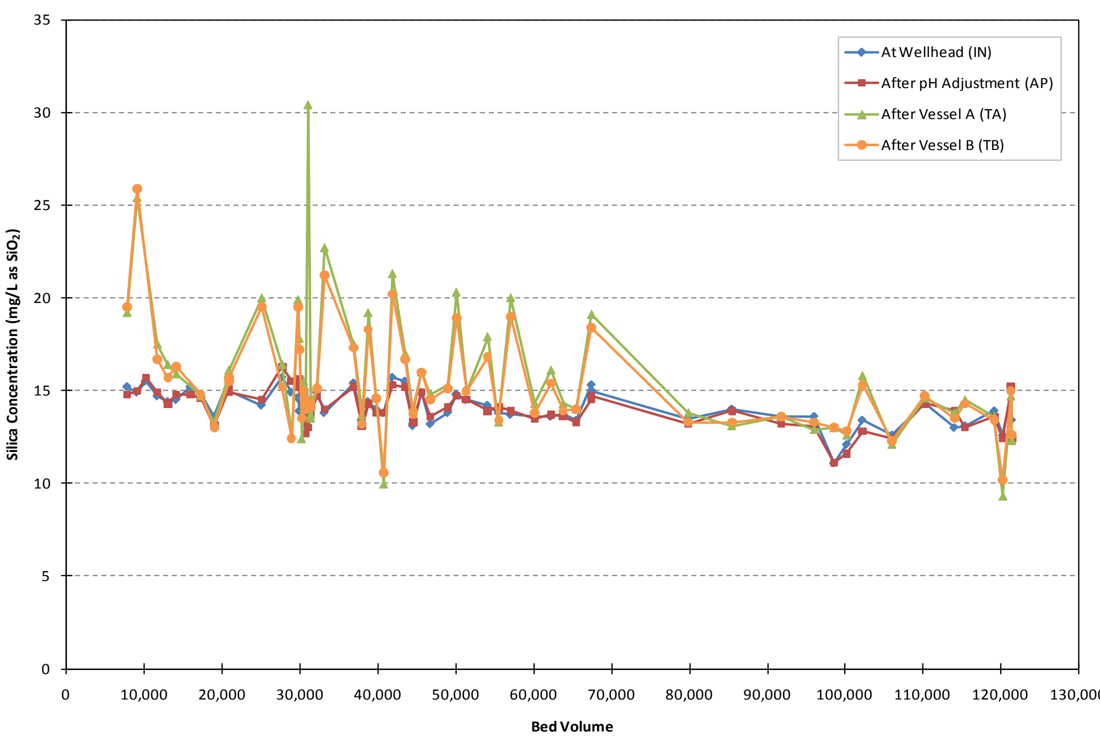


Figure 4-21. Total Silica (as SiO_2) Breakthrough Curves

Iron and Manganese. Total iron concentrations in source water and following the adsorption vessels were mostly below the MDL of 25 µg/L (Table 4-10). Total manganese levels in source water also were low, ranging from <0.1 to 10.8 µg/L and averaging 0.8 µg/L. Total manganese levels were reduced to mostly below the MDL of 0.1 µg/L in system effluent.

Other Water Quality Parameters. As shown in Table 4-11, alkalinity, reported as $CaCO_3$, ranged from 155 to 190 mg/L and averaged 169 mg/L in source water. As expected, alkalinity after pH adjustment and adsorption remained essentially unchanged at 169 mg/L (on average) at AP and 172 mg/L (on average) at TA and TB, since CO_2, instead of mineral acids, was used for pH adjustment.

The treatment plant water samples were analyzed for hardness only during three sampling events. Total hardness concentrations, reported as $CaCO_3$, ranged from 6 to 7 mg/L and averaged 7 mg/L in source water. Total hardness existed primarily as calcium hardness. Total hardness remained unchanged at 7 to 8 mg/L, on average, following pH adjustment (at AP) and adsorption (at TA and TB).

Sulfate and fluoride concentrations were measured only during three sampling events. Sulfate concentrations in source water ranged from 26.1 to 29.0 mg/L and averaged 27.4 mg/L. After pH adjustment and adsorption, sulfate levels remained unchanged at 26.2 to 31.2mg/L (on average). Fluoride concentrations in source water ranged from 0.9 to 1.1 mg/L and averaged 1.0 mg/L. Fluoride concentrations following the treatment vessels reduced slightly to 0.5 to 0.8 mg/L.

Average DO levels ranged from 3.6 to 6.9 mg/L throughout the treatment train. ORP readings averaged 394 mV in source water and increased to an average of 426 mV at AP and an average of 446 in system effluent. High DO levels and ORP readings suggest that the source water was oxidizing.

4.5.2 Spent Media Sampling. On August 20, 2008, after treating approximately 41,600,000 gal (or 78,200 BV) of water, the operator collected a media sample approximately 6 in below the surface of the media beds from both vessels. Each sample was split, with a portion of each sent to Battelle and Teledyne Brown Laboratories (a subcontractor to AdEdge) for ICP/MS and uranium activity analysis, respectively. Table 4-12 presents the ICP/MS results.

Table 4-12. Spent Media Total Metal Analysis

	Concentrations (µg/g)															
Analytes	**Mg**	**Al**	**Si**	**P**	**Ca**	**V**	**Fe**	**Mn**	**Ni**	**Cu**	**Zn**	**As**	**Cd**	**Ba**	**Pb**	**U**
Vessel A	575	1,607	1,548	84.0	1,708	490	232,724	408	91.9	23.2	301	21.5	0.1	135	1.7	300
Vessel B	575	2,310	2,361	89.8	1,509	441	197,188	413	69.0	42.9	381	28.8	0.0	89.2	3.9	213

As shown in the table, arsenic and uranium concentrations in the spent media were low, ranging from 21.5 to 28.8 µg/g (or 0.002 to 0.003%) and from 213 to 300 µg/g (or 0.02 to 0.03%), respectively. The ICP/MS results indicated that the media were only minimally loaded with arsenic and uranium even after treating 41,600,000 gal of water.

These arsenic and uranium loadings were compared to the 6,593- and 8,049-µg/g loadings assuming 100% arsenic and uranium removal from source water (this was close to the actual percentage removal based on the breakthrough curves). The media analytical data indicate that only 0.38% and 3.2% of influent arsenic and uranium mass were retained on the media, which would be possible only if captured arsenic and uranium had been intermittently "flushed" out of the media beds due presumably to losses of pH control as discussed in Section 4.4.2.

Table 4-13 presents the results of uranium activity analysis conducted by Teledyne Brown Laboratories. An average uranium activity of 120 pCi/g (dry wt) was measured for the spent media.

Table 4-13. Spent Media Uranium Activity Analysis

Analyte	U-233/234 (pCi/g)	U-235 (pCi/g)	U-238 (pCi/g)	U (pCi/g)
Vessel A	78.5	2.75	60.1	141
Vessel B	55.4	1.45	41.3	98.2
Average	67.0	2.1	50.7	120

4.5.3 Backwash Water Sampling. Backwash was not performed during the performance evaluation study.

4.5.4 Distribution System Water Sampling. Table 4-14 summarizes the results of the distribution system sampling. The stagnation times for the first draw samples ranged from 5.0 to 23.8 hr, which met the requirements of the EPA LCR sampling protocol (EPA, 2002).

Prior to the installation/operation of the treatment system, baseline distribution system water samples were collected from three sampling locations served by three production wells including the Buffalo Well. After system startup, the sampling locations were moved to three new locations served only by the treated water supplied by the Buffalo Well. Comparison of water quality between the Buffalo Well (IN location in Tables 4-10 and 4-11) and the three wells combined (baseline in Table 4-14) revealed that while pH of the Buffalo Well water was slightly higher than the three wells combined (i.e., 9.0 vs. 8.7 on average), concentrations of arsenic, iron, manganese and alkalinity were rather comparable.

Figure 4-22 plots arsenic concentrations of distribution system water. Average arsenic concentrations in distribution water were reduced from an average of 33.7 µg/L in baseline samples to below MCL during most sampling events, with exceptions on August 15, 2007, February 27, 2008, and May 29, 2008. Loss of pH control most likely was the reason for the elevated concentrations observed. This was confirmed by the August 15, 2007, system effluent data that included elevated arsenic concentrations at 19.1 and 19.5 µg/L (Figure 4-18). Available in-line pH data indicated a source-water level pH value on May 29, 2008. In-line pH data were not available for August 15, 2007 and February 27, 2008.

Figure 4-23 plots uranium concentrations measured in distribution system water. Similar to arsenic, uranium concentrations in distribution water were reduced to below MCL (i.e., 30 µg/L) during most sampling events. The exceptions were on July 10, 2007, August 15, 2007, February 27, 2008, and April 2, 2008, when higher than MCL concentrations were measured. On August 15, 2007, elevated uranium concentrations at 68.9 and 66.9 µg/L also were measured in system effluent (Figure 4-20). In-line pH data indicated elevated pH values on April 2, 2008. In-line pH data for the other three sampling events were not available.

Lead concentrations ranged from 0.1 to 12.8 µg/L, with no sample exceeding the action level of 15 µg/L. Copper concentrations ranged from 4.8 to 385 µg/L, with no sample exceeding the 1,300 µg/L action level. Measured pH values ranged from 7.0 to 8.9 and averaged 7.5, which were 0.5 to 1.0 units lower than the avearge pH value immediately after the adsorption vessels (i.e. at TA, TB, and TT). Compared to an average value of 8.7 before the treatment system became operational, the significantly lowered pH values did not appear to have affected the lead or copper concentrations in the distribution system.

Table 4-14. Distribution System Sampling Results

Sampling Event		DS1									DS2									DS3								
		Serafin Vigil									Balerie Vigil									Frank Romero								
		Stagnation Time	pH	Alkalinity	As	Fe	Mn	U	Pb	Cu	Stagnation Time	pH	Alkalinity	As	Fe	Mn	U	Pb	Cu	Stagnation Time	pH	Alkalinity	As	Fe	Mn	U	Pb	Cu
No.	Date	hr	S.U	mg/L	µg/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	µg/L	hr	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BL1[(a)]	12/23/03	7.0	8.9	170	28.7	<25	1.5	NS	<0.1	50.8	NA	8.9	175	29.6	<25	0.5	NS	2.3	8.8	NA	9.0	175	30.5	41	1.3	NS	0.2	63.2
BL2[(a)]	01/21/04	11.8	9.0	165	39.7	<25	0.3	NS	0.9	51.0	15.5	8.9	173	38.5	<25	0.4	NS	2.0	2.7	15.8	9.1	173	40.4	<25	0.3	NS	0.5	60.4
BL3[(a)]	02/19/04	8.0	8.7	176	42.3	<25	0.6	NS	3.3	57.7	14.8	8.7	182	44.2	<25	0.7	NS	1.9	7.0	15.8	8.8	168	43.8	<25	1.2	NS	0.4	70.8
BL4[(a)]	03/31/04	10.5	6.9	214	2.6	<25	0.1	NS	1.0	236	15.8	8.7	167	32.7	<25	0.9	NS	2.3	11.2	17.0	8.7	163	32.0	<25	0.9	NS	0.2	60.7
1	07/10/07	8.5	8.1	176	4.3	<25	0.1	27.8	3.1	125	7.0	8.3	185	8.8	<25	<0.1	38.3	<0.1	37.4	8.5	8.2	183	8.3	<25	0.1	40.8	<0.1	28.3
2	08/15/07	9.3	8.5	165	16.6	<25	<0.1	73.7	1.5	42.4	7.8	8.7	162	18.9	<25	<0.1	63.2	0.2	11.4	6.5	8.9	165	21.2	<25	<0.1	61.8	0.2	4.8
3	09/13/07	8.4	7.7	181	6.6	<25	<0.1	19.5	1.1	70.7	6.0	7.4	173	5.4	<25	<0.1	15.6	1.2	134	6.5	7.2	171	4.6	<25	<0.1	15.5	0.7	198
4	10/25/07	NS	NS	NS	NS	NS	NS	NS	NS	NS	9.8	7.3	165	5.1	<25	0.1	10.4	1.8	125	8.0	7.2	168	5.4	<25	0.1	11.2	0.4	162
5	11/20/07	23.8	7.3	192	1.9	<25	5.7	7.5	12.8	13.2	5.5	7.3	167	2.0	<25	0.1	5.6	1.6	284	6.8	7.3	171	2.1	<25	0.2	6.5	1.0	228
6	01/17/08	7.8	7.3	163	6.1	<25	<0.1	19.6	3.4	385	8.0	7.6	174	5.8	<25	0.7	15.7	<0.1	31.0	8.0	7.3	176	6.5	<25	0.2	23.1	1.0	260
7	01/31/08	5.3	7.3	178	5.7	26	0.1	24.7	0.9	42.6	7.0	7.3	174	5.3	34	0.1	24.2	0.8	129	7.0	7.1	170	4.7	56	0.9	18.6	0.5	136
8	02/27/08	8.5	7.5	172	15.0	<25	<0.1	35.6	0.5	56.4	19.3	7.1	168	10.3	<25	0.6	32.0	<0.1	152	7.0	7.2	170	10.8	<25	<0.1	27.8	0.2	199
9	04/02/08	8.0	7.2	171	8.4	<25	<0.1	30.3	0.8	51.7	6.0	7.0	169	9.0	<25	<0.1	27.2	0.3	99.3	6.0	7.1	173	11.2	<25	<0.1	37.7	0.3	127
10	05/29/08	9.0	7.3	177	16.6	<25	<0.1	25.2	3.5	283	5.0	7.2	177	16.6	<25	<0.1	25.9	0.1	28.1	5.5	7.3	175	12.8	<25	0.2	25.6	0.3	158
11	07/24/08	8.0	7.1	169	6.3	<25	<0.1	12.2	1.2	146	7.0	7.1	167	2.5	<25	<0.1	6.1	0.3	37.3	6.5	7.2	167	4.3	<25	0.2	10.3	1.3	182
12	09/10/08	7.5	7.6	NA	10.2	<25	<0.1	20.3	0.8	327	9.0	7.2	NA	4.4	<25	<0.1	7.4	<0.1	168	6.5	7.1	NA	3.8	<25	<0.1	8.2	<0.1	184

Lead action level = 15 µg/L; copper action level = 1.3 mg/L
BL = Baseline Sampling; NA = Not Available; NS = Not Sampled.
(a) Baseline sampling locations moved to locations served by only Buffalo Well after system startup.

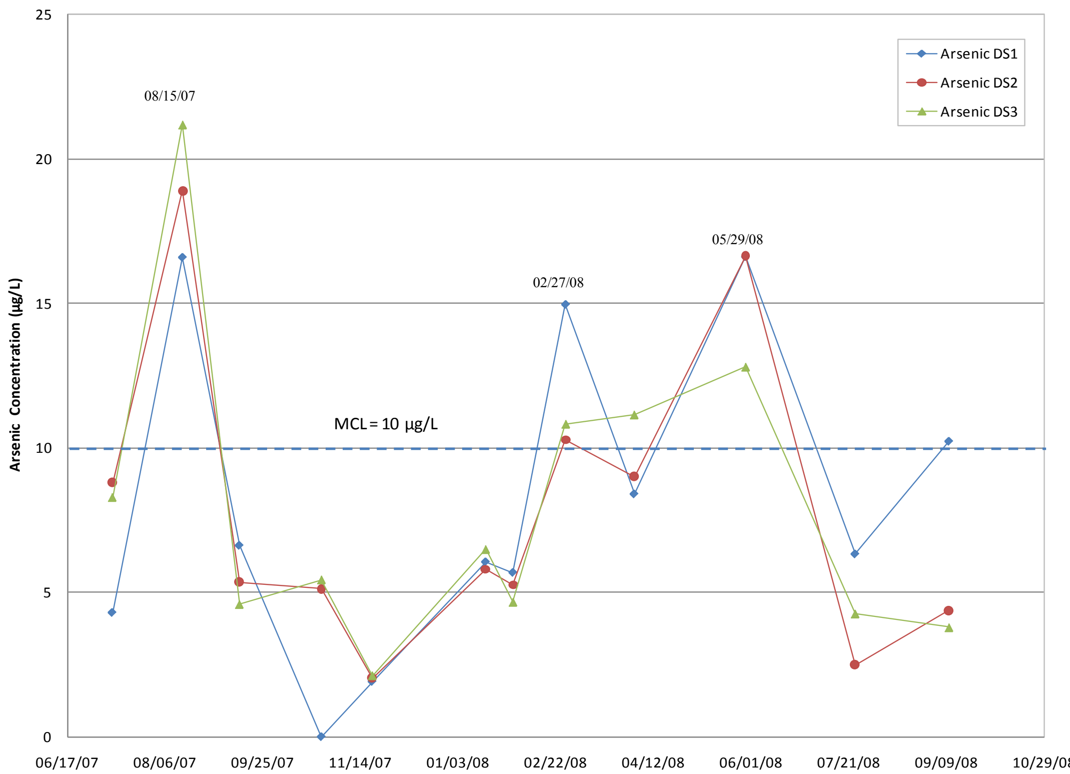


Figure 4-22. Arsenic Concentrations Measured in Distribution System Water

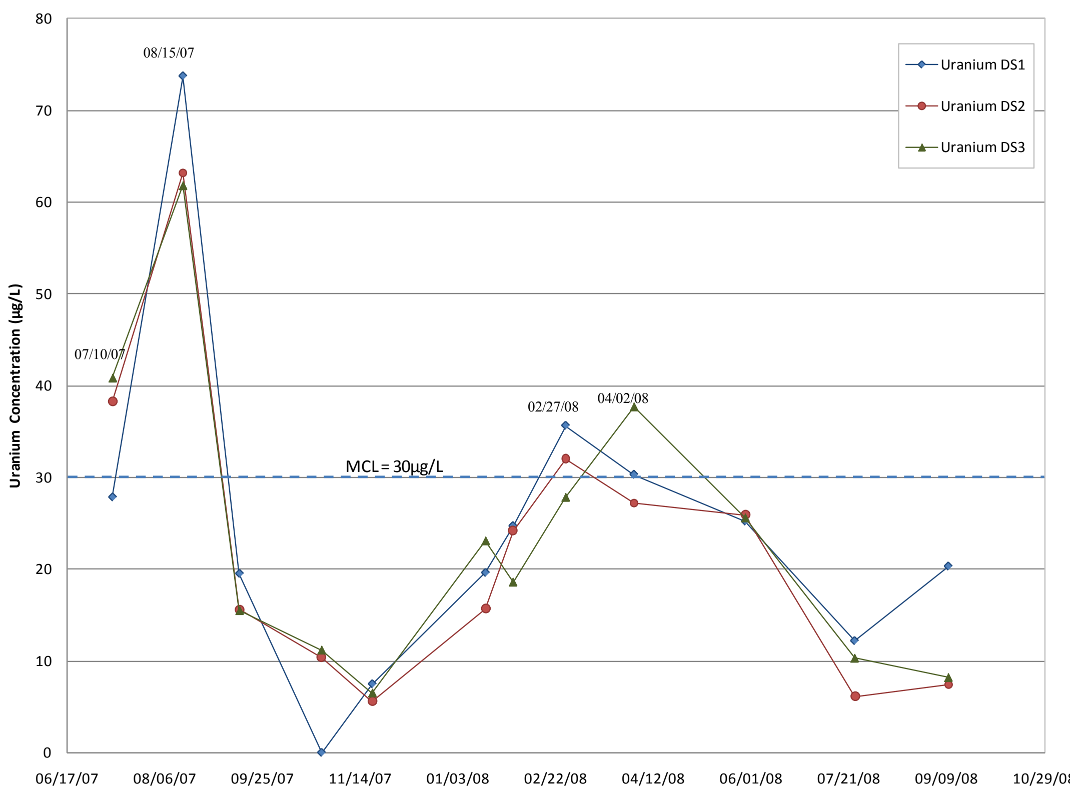


Figure 4-23. Uranium Concentrations Measured in Distribution System Water

Alkalinity levels ranged from 162 to 192 mg/L (as $CaCO_3$). Iron was detected in one of the sampling events; manganese concentrations ranged from <0.1 to 5.7 µg/L. The arsenic treatment system did not seem to affect these water quality parameters in the distribution system.

4.6 System Cost

System cost is evaluated based on the capital cost per gpm (or gpd) of the design capacity and the O&M cost per 1,000 gal of water treated. The capital cost includes the cost for equipment, site engineering, and installation. The O&M cost includes the cost for media replacement and disposal, electrical use, and labor.

4.6.1 Capital Cost. The capital investment for equipment, site engineering, and installation of the treatment system was $143,113 (see Table 4-15). The equipment cost was $116,645 (or 82% of the total capital investment), which included the cost for two APU-160 vessels, 71.2 ft^3 of AD-33 media, pH adjustment module, instrumentation and controls, miscellaneous materials and supplies, labor, and shipping.

The site engineering cost was $11,638, or 8% of the total capital investment. Because an engineering plan or a permit submittal package was not required for the Nambe Pueblo site, the site engineering cost represents a small fraction of total capital cost.

Table 4-15. Capital Investment Cost for Nambe Pueblo System

Description	Quantity	Cost	% of Capital Investment Cost
Equipment Costs			
APU-160 Tanks	2	$33,697	–
AD-33 Media	71.2 ft^3	$18,620	–
Piping and Valves	–	$11,656	–
Instrument and Controls	–	$7,735	–
pH Adjustment Module	–	$17,100	–
O&M Manual and Training	–	$4,535	–
Vendor Labor	–	$20,377	–
Shipping CO_2 System	–	$350	–
Shipping APU System and Media	–	$2,575	–
Equipment Total	–	**$116,645**	**82**
Engineering Costs			
Materials	–	$75	–
Vendor Labor	–	$3,420	–
Subcontractor Labor	–	$7,150	–
Vendor Travel	–	$993	–
Engineering Total	–	**$11,638**	**8**
Installation Costs			
Material	–	$400	–
Subcontractor	–	$10,100	–
Vendor Labor	–	$3,040	–
Vendor Travel	–	$1,290	–
Installation Total	–	**$14,830**	**10**
Total Capital Investment	–	**$143,113**	**100**

The installation cost included the equipment and labor to unload and install the skid-mounted unit, perform piping tie-ins and electrical work, load and backwash the media, perform system shakedown and startup, and conduct operator training. The installation cost was $14,830, or 10% of the total capital investment.

The total capital cost of $143,113 was normalized to the system's rated capacity of 160 gpm (230,400 gpd), which resulted in $894/gpm of design capacity ($0.62/gpd). The capital cost also was converted to an annualized cost of $13,508/yr using a capital recovery factor (CRF) of 0.09439 based on a 7% interest rate and a 20-year return period. Assuming that the system operated 24 hours a day, 7 days a week at the system design flowrate of 160 gpm to produce 84,096,000 gal of water per year, the unit capital cost would be $0.16/1,000 gal. Because the system operated an average of 12.3 hr/day at approximately 114 gpm (see Table 4-8), producing 30,708,180 gal of water annually, the unit capital cost increased to $0.44/1,000 gal at this reduced rate of use.

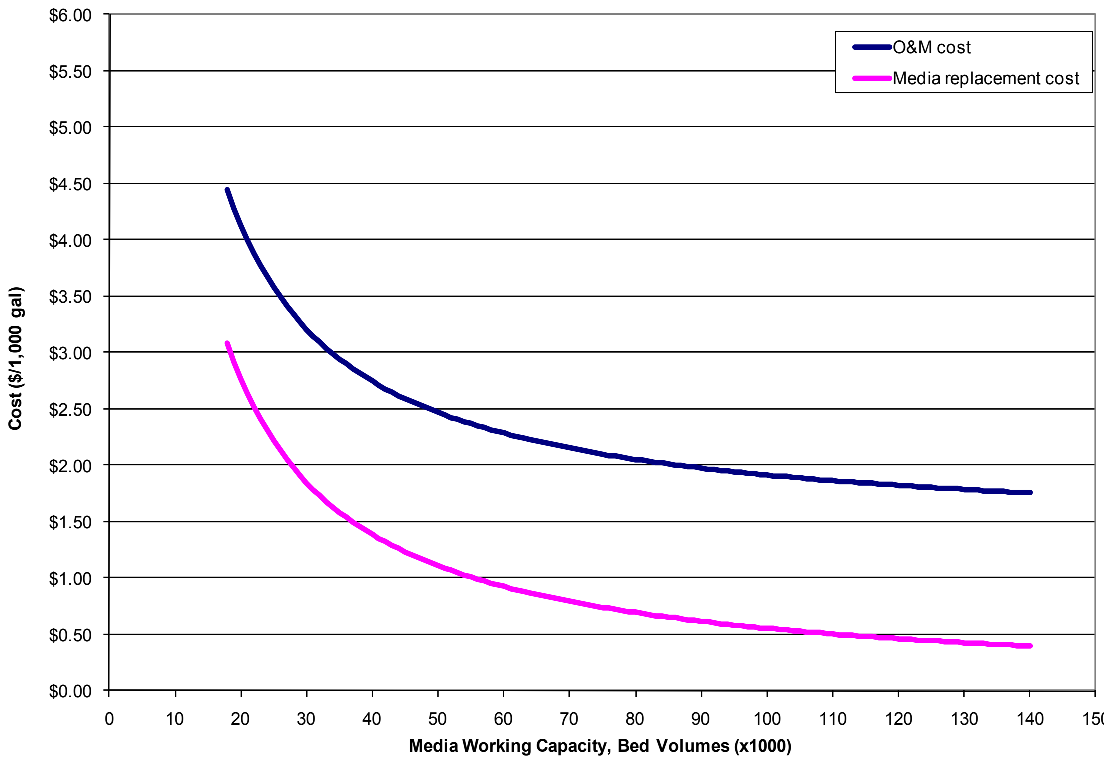
4.6.2 Operation and Maintenance Cost. The O&M cost included the cost for media replacement and disposal, CO_2 use, electricity consumption, and labor (Table 4-16). Although media replacement did not occur during the system performance evaluation, the media replacement cost for both vessels would have represented the majority of the O&M cost and was estimated to be $29,532. This media change-out cost would include the cost for media, underbedding gravels, freight, labor, travel, spent media analysis, and media disposal fee. This cost was used to estimate the media replacement cost per 1,000 gal of water treated as a function of the projected media run length at the 10 μg/L arsenic breakthrough from the adsorption vessels (Figure 4-24).

Table 4-16. Operation and Maintenance Cost for the Nambe Pueblo System

Cost Category	Value	Assumptions
Volume Processed (kgal)	11,500	05/15/07–09/28/09
Media Replacement and Disposal		
Media Cost ($/ft^3)	274	Vendor quote
Total Media Volume (ft^3)	71.2	Both vessels
Media Replacement Cost ($)	19,525	Vendor quote
Freight ($)	707	Vendor quote
Labor Cost ($)	4,200	Vendor quote
Disposal of Spent Media ($)	5,100	Vendor quote
Subtotal	29,532	Vendor quote
Media Replacement and Disposal Cost ($/1,000 gal)	See Figure 4-24	Based upon media run length at 10-μg/L arsenic breakthrough
Chemical Usage		
CO_2 Gas ($/1,000 gal)	$0.20	Based on the cost of CO_2 cylinders for pH adjustment
Electricity		
Electricity Cost ($/1,000 gal)	0.00	Electrical cost assumed negligible
Labor		
Average Weekly Labor (hrs)	32.5	6.5 hr/day (5 days/week)
Labor Cost ($/1,000 gal)	$1.16	Labor rate = $21/hr
Total O&M Cost/1,000 gal	See Figure 4-24	Based upon media run length at 10-μg/L arsenic breakthrough

The chemical cost included the cost for NaClO for pre- and post-chlorination and CO_2 gas for pH adjustment. NaClO was already used at the site prior to the installation of the APU unit for disinfection purposes prior to distribution. The presence of the APU system did not affect the use rate of the NaClO solution. Therefore, the incremental chemical cost for chlorine was negligible. The CO_2 cost for pH adjustment was recorded to be $6,260 per year or $0.20/1,000 gal of water treated.

Comparison of electrical bills supplied by the utility prior to system installation and since startup did not indicate a noticeable increase in power consumption. Therefore, electrical cost associated with operation of the system was assumed to be negligible. Under normal operating conditions, routine labor activities to operate and maintain the system consumed 6.5 hr per day, 5 days per week, as noted in Section 4.4.4. Therefore, the estimated labor cost was $1.16/1,000 gal of water treated. This estimation assumes that maintenance and operational procedures were consistently performed through the completion of the system performance evaluation.



Note: One bed volume equals 71.2 ft^3 (532 gal)

Figure 4-24. Media Replacement and Operation and Maintenance Cost

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APPENDIX A

OPERATIONAL DATA

Table A-1 EPA Arsenic Demonstration Project at Nambe Pueblo, NM - Daily System Operation Log Sheet

Week No.	Date	Buffalo Well		Instrument Panel												
		Pump Hour Meter	Incr. Hours	Vessel A Flow Meter				Vessel B Flow Meter				System Throughput		ΔP		
				Flowrate	Totalizer	Incr. Flow	Calculated Flowrate	Flowrate	Totalizer	Incr. Flow	Calculated Flowrate			Vessel A	Vessel B	System
		hr	hr	gpm	gal	gal	gpm	gpm	gal	gal	gpm	gal	BV	psig	psig	psi
	05/15/07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	07/09/07	2,345.6	NA	63.4	2,807,920	NA	NA	60.7	2,610,655	NA	NA	5,418,575	10,185	0.5	1.2	5
	07/16/07	2,428.2	82.6	64.5	3,124,554	316,634	63.9	63.0	2,909,728	299,073	60.3	6,034,282	11,343	1.5	4.0	0
	07/17/07	2,443.2	15.0	61.8	3,182,383	57,829	64.3	61.1	2964292	54,564	60.6	6,146,675	11,554	1.0	1.0	3
	07/18/07	2,453.0	9.8	66.6	3,222,963	40,580	69.0	64.1	3,002,523	38,231	65.0	6,225,486	11,702	1.5	1.5	4
	07/20/07	2,479.1	26.1	67.8	3,321,797	98,834	63.1	62.4	3,095,457	92,934	59.3	6,417,254	12,063	1.0	1.0	NA
2	07/23/07	2,512.2	33.1	64.1	3,446,277	124,480	62.7	61.0	3,212,544	117,087	59.0	6,658,821	12,517	1.5	1.0	0
	07/24/07	2,521.6	9.4	68.4	3,482,810	36,533	64.8	61.2	3,245,392	32,848	58.2	6,728,202	12,647	1.0	1.5	4
	07/25/07	2,540.4	18.8	66.6	3,555,184	72,374	64.2	60.8	3,311,010	65,618	58.2	6,866,194	12,906	1.0	1.5	1
	07/26/07	2,548.6	8.2	61.2	3,586,675	31,491	64.0	56.4	3,339,705	28,695	58.3	6,926,380	13,020	1.5	1.5	NA
	07/27/07	2,550.6	2.0	62.1	NA	NA	NA	59.1	NA	NA	NA	NA	NA	1.0	1.0	0
3	07/30/07	2,592.7	42.1	65.0	3,758,554	171,879	65.0	60.0	3,497,128	157,423	59.5	7,255,682	13,639	2.0	1.0	0
	07/31/07	2,605.6	12.9	64.0	3,808,614	50,060	286.7	58.0	3,543,142	46,014	59.4	7,351,756	13,819	1.0	1.0	2
	08/01/07	2,616.5	10.9	64.0	3,850,739	42,125	64.4	62.1	3,581,913	38,771	59.3	7,432,652	13,971	2.0	1.0	0
	08/02/07	2,627.5	11.0	65.0	3,892,596	41,857	63.4	57.0	3,620,474	38,561	58.4	7,513,070	14,122	2.0	1.0	0
	08/03/07	2,635.7	8.2	63.4	3,924,622	32,026	65.1	58.1	3,649,995	29,521	60.0	7,574,617	14,238	4.0	1.0	0
4	08/06/07	2,679.3	43.6	61.1	4,088,525	163,903	62.7	57.3	3,801,246	151,251	57.8	7,889,771	14,830	1.0	1.0	4
	08/07/07	2,714.3	35.0	60.8	4,215,243	126,718	60.3	57.1	3,918,186	116,940	55.7	8,133,429	15,288	1.0	1.0	4
	08/09/07	2,739.1	24.8	60.8	4,303,663	88,420	59.4	56.7	3,999,709	81,523	54.8	8,303,372	15,608	1.0	1.0	4
	08/10/07	2,763.6	24.5	60.6	4,390,682	87,019	59.2	56.1	4,079,920	80,211	54.6	8,470,602	15,922	1.0	1.0	4
	08/11/07	2,775.0	11.4	59.2	4,431,111	40,429	59.1	53.9	4,117,167	37,247	54.5	8,548,278	16,068	1.0	1.0	3
5	08/13/07	2,829.1	54.1	60.1	4,634,775	203,664	62.7	58.6	4,295,982	178,815	55.1	8,930,757	16,787	1.0	1.0	4
	08/14/07	2,852.8	23.7	60.3	4,713,195	78,420	55.1	61.3	4,377,465	81,483	57.3	9,090,660	17,088	1.0	1.0	4
	08/15/07	2,864.1	11.3	66.4	4,756,069	42,874	63.2	61.7	4,417,138	39,673	58.5	9,173,207	17,243	1.0	1.0	4
	08/16/07	2,877.0	12.9	60.3	4,757,001	932	1.2	59.1	4,418,240	1,102	1.4	9,175,241	17,247	1.0	1.0	4
6	08/20/07	2,949.0	72.0	61.6	5,051,630	294,629	68.2	59.5	4,693,468	275,228	63.7	9,745,098	18,318	1.0	1.0	3
	08/21/07	2,974.1	25.1	60.7	5,158,025	106,395	70.6	56.2	4,793,149	99,681	66.2	9,951,174	18,705	1.0	1.0	3
	08/22/07	2,997.2	23.1	60.3	5,238,846	80,821	58.3	59.8	4,868,906	75,757	54.7	10,107,752	19,000	1.0	1.0	3
	08/23/07	3,022.7	25.5	60.6	5,328,955	90,109	58.9	56.1	4,953,405	84,499	55.2	10,282,360	19,328	1.0	1.0	3
	08/24/07	3,024.8	2.1	60.1	5,388,102	59,147	469.4	59.1	4,953,512	107	0.8	10,341,614	19,439	1.0	1.0	2

(a) Bed volume = 35.6 cu.ft. (266 gal) in each vessel or 71.2 cu.ft. (532 gal) total for tw o vessels.

NA = Not Availble.

Table A-1. EPA Arsenic Demonstration Project at Nambe Pueblo, NM - Daily System Operation Log Sheet (Continued)

Week No.	Date	Buffalo Well		Instrument Panel												
		Pump Hour Meter	Incr. Hours	Vessel A Flow Meter				Vessel B Flow Meter				System Throughput		ΔP		
				Flowrate	Totalizer	Incr. Flow	Calculated Flowrate	Flowrate	Totalizer	Incr. Flow	Calculated Flowrate			Vessel A	Vessel B	System
		hr	hr	gpm	gal	gal	gpm	gpm	gal	gal	gpm	gal	BV	psig	psig	psi
7	08/27/07	3,115.2	90.4	59.1	5,658,901	270,799	49.9	56.4	5,254,908	301,396	55.6	10,913,809	20,515	1.0	1.0	3
	08/28/07	3,141.9	26.7	60.6	5,752,359	93,458	58.3	54.7	5,341,489	86,581	54.0	11,093,848	20,853	1.0	1.0	NA
	08/29/07	3,163.4	21.5	60.5	5,828,198	75,839	58.8	53.4	5,411,096	69,607	54.0	11,239,294	21,126	1.0	2.0	4
	08/30/07	3,191.1	27.7	51.9	5,925,460	173,101	58.6	55.8	5,500,466	89,370	53.8	11,425,926	21,477	1.0	2.0	3
	08/31/07	3,203.2	12.1	62.9	5,967,883	42,423	58.4	54.4	5,539,485	39,019	53.7	11,507,368	21,630	1.0	1.0	3
9	09/10/07	3,453.1	249.9	58.9	6,836,737	868,854	57.9	54.4	6,342,914	803,429	53.6	13,179,651	24,774	1.0	1.0	4
	09/11/07	3,478.5	25.4	53.1	6,922,456	85,719	56.2	52.2	6,422,449	79,535	52.2	13,344,905	25,084	1.0	1.0	4
	09/12/07	3,494.4	15.9	61.0	6,978,299	55,843	58.5	57.4	6,474,329	51,880	54.4	13,452,628	25,287	1.0	1.0	4
	09/13/07	3,509.7	15.3	61.2	7,033,757	55,458	60.4	56.4	6,525,692	51,363	56.0	13,559,449	25,488	1.0	1.0	4
	09/14/07	3,524.1	14.4	58.2	7,086,492	108,193	60.7	54.1	6,574,841	49,149	56.9	13,661,333	25,679	1.0	1.0	4
10	09/17/07	3,576.9	52.8	59.7	7,262,245	175,753	55.5	53.9	6,738,734	163,893	51.7	14,000,979	26,318	1.0	1.0	3
	09/18/07	3,603.6	26.7	59.9	7,354,100	91,855	57.3	54.6	6,822,670	83,936	52.4	14,176,770	26,648	1.0	1.0	4
	09/19/07	3,610.7	7.1	55.4	7,376,413	114,168	56.3	51.2	6,843,950	21,280	50.0	14,220,363	26,730	1.0	1.0	3
	09/20/07	3,622.4	11.7	70.4	7,416,870	40,457	57.6	63.0	6,881,640	37,690	53.7	14,298,510	26,877	1.0	1.0	4
	09/21/07	3,629.6	7.2	59.4	7,477,069	60,199	139.3	57.9	6,891,028	9,388	21.7	14,368,097	27,008	1.0	1.0	4
11	09/24/07	3,668.2	38.6	66.1	7,569,652	152,782	40	63.8	7,021,813	130,785	56.5	14,591,465	27,428	1.0	2.0	2
	09/25/07	3,680.8	12.6	57.4	7,616,949	47,297	62.6	57.0	7,066,357	44,544	58.9	14,683,306	27,600	1.0	2.0	2
	09/26/07	3,690.2	9.4	62.4	7,652,262	35,313	62.6	59.1	7,099,503	33,146	58.8	14,751,765	27,729	1.0	2.0	2
	09/27/07	3,707.0	16.8	57.9	7,709,793	57,531	57.1	56.0	7,153,809	54,306	53.9	14,863,602	27,939	1.0	1.0	1
	09/28/07	3,715.6	8.6	60.0	7,735,632	25,839	50.1	54.9	7,179,650	25,841	50.1	14,915,282	28,036	1.0	1.0	1
12	10/01/07	3,747.4	31.8	54.1	7,837,308	101,676	53.3	51.6	7,275,279	95,629	50.1	15,112,587	28,407	1.0	1.0	1
	10/02/07	3,766.1	18.7	58.7	7,901,529	64,221	57.2	57.2	7,335,541	60,262	53.7	15,237,070	28,641	1.0	1.0	1
	10/04/07	3,785.1	19.0	56.8	7,967,646	130,338	57.6	53.2	7,397,668	62,127	54.5	15,365,314	28,882	1.0	1.0	1
13	10/08/07	3,830.1	45.0	62.1	8,163,893	196,247	72.7	54.1	7,582,755	185,087	68.6	15,746,648	29,599	1.0	1.0	1
	10/09/07	3,846.3	16.2	58.1	8,178,980	15,087	15.5	53.4	7,595,875	13,120	13.5	15,774,855	29,652	1.0	1.0	1
	10/10/07	3,851.1	4.8	64.3	8,194,555	15,575	54.1	62.1	7,610,517	14,642	50.8	15,805,072	29,709	1.0	1.0	1
	10/11/07	3,852.6	1.5	61.3	8,200,169	5,614	62.4	63.4	7,615,760	5,243	58.3	15,815,929	29,729	1.0	1.0	0
	10/12/07	3,854.4	1.8	67.0	8,206,406	6,237	57.7	64.4	7,621,592	5,832	54.0	15,827,998	29,752	1.0	1.0	3
14	10/15/07	3,864.0	9.6	67.8	8,240,515	34,109	59.2	60.2	7,653,931	32,339	56.1	15,894,446	29,877	2.0	1.0	0
	10/16/07	3,867.2	3.2	66.8	8,252,243	11,728	61.1	63.3	7,664,397	10,466	54.5	15,916,640	29,918	1.0	1.0	0
	10/17/07	3,870.6	3.4	63.4	8,264,334	12,091	59.3	61.9	7,675,719	11,322	55.5	15,940,053	29,963	1.0	1.0	0
	10/18/07	3,874.9	4.3	64.4	8,276,334	12,000	46.5	60.9	7,685,795	10,076	39.1	15,962,129	30,004	2.0	1.0	0
	10/19/07	3,877.5	2.6	67.8	8,288,132	11,798	75.6	61.8	7,697,509	11,714	75.1	15,985,641	30,048	1.0	1.0	0

(a) Bed volume = 35.6 cu.ft. (266 gal) in each vessel or 71.2 cu.ft. (532 gal) total for tw o vessels.

NA = Not Availble.

Table A-1. EPA Arsenic Demonstration Project at Nambe Pueblo, NM - Daily System Operation Log Sheet (Continued)

		Buffalo Well		Instrument Panel												
		Pump Hour Meter	Incr. Hours	Vessel A Flow Meter				Vessel B Flow Meter				System Throughput		ΔP		
Week No.	Date			Flowrate	Totalizer	Incr. Flow	Calculated Flowrate	Flowrate	Totalizer	Incr. Flow	Calculated Flowrate			Vessel A	Vessel B	System
		hr	hr	gpm	gal	gal	gpm	gpm	gal	gal	gpm	gal	BV	psig	psig	psi
15	10/22/07	3,873.7	NA	65.4	8,275,698	-12,434	NA	61.4	7,686,334	NA	NA	15,962,032	30,004	1.0	1.0	1
	10/23/07	3,883.8	6.3	64.3	8,311,026	35,328	93.5	54.1	7,719,620	33,286	88.1	16,030,646	30,133	1.0	1.0	0
	10/24/07	3,887.1	3.3	67.4	8,322,944	11,918	60.2	58.6	7,730,445	10,825	54.7	16,053,389	30,176	3.0	1.0	0
	10/25/07	3,888.1	1.0	63.7	8,326,509	3,565	59.4	53.1	7,733,538	3,093	51.6	16,060,047	30,188	2.0	2.0	1
16	10/29/07	3,901.1	13.0	61.2	8,369,032	42,523	54.5	61.9	7,780,785	47,247	60.6	16,149,817	30,357	1.0	1.0	2
	10/30/07	3,903.1	2.0	54.3	8,376,856	7,824	65.2	59.1	7,789,222	8,437	70.3	16,166,078	30,387	1.0	1.0	1
	10/31/07	3,906.8	3.7	65.1	8,389,901	13,045	58.8	61.1	7,803,044	13,822	62.3	16,192,945	30,438	1.0	1.0	1
	11/01/07	3,907.4	0.6	64.4	8,390,411	510	14.2	61.4	7,803,429	385	10.7	16,193,840	30,440	1.0	1.0	1
	11/02/07	3,910.1	2.7	62.5	8,401,810	11,399	70.4	59.3	7,814,455	11,026	68.1	16,216,265	30,482	1.0	1.0	2
17	11/05/07	3,917.1	7.0	64.3	8,424,774	22,964	54.7	61.7	7,836,564	22,109	52.6	16,261,338	30,566	1.0	1.0	1
	11/06/07	3,920.0	2.9	64.5	8,434,984	10,210	58.7	64.7	7,846,320	9,756	56.1	16,281,304	30,604	1.0	1.0	2
	11/07/07	3,920.3	0.3	61.4	8,435,255	271	15.1	61.4	7,846,570	250	13.9	16,281,825	30,605	1.0	1.0	NA
	11/08/07	3,923.4	3.1	64.9	8,447,201	11,946	64.2	62.2	7,858,027	11,457	61.6	16,305,228	30,649	1.0	1.0	1
	11/09/07	3,927.4	4.0	65.7	8,460,101	12,900	53.8	61.1	7,868,041	10,014	41.7	16,328,142	30,692	1.0	2.0	1
18	11/12/07	3,928.7	1.3	59.1	8,466,041	5,940	76.2	57.4	7,876,010	7,969	102.2	16,342,051	30,718	1.0	1.0	1
	11/13/07	3,929.0	0.3	64.1	8,467,132	1,091	60.6	62.1	7,877,104	1,094	60.8	16,344,236	30,722	1.0	1.0	0
	11/14/07	3,929.4	0.4	67.6	8,468,411	1,279	53.3	64.2	7,878,261	1,157	48.2	16,346,672	30,727	1.0	2.0	1
	11/15/07	3,934.0	4.6	67.2	8,485,553	17,142	62.1	65.8	7,894,614	16,353	59.3	16,380,167	30,790	1.0	2.0	1
19	11/19/07	3,936.0	2.0	66.7	8,500,184	14,631	121.9	64.3	7,901,354	6,740	56.2	16,401,538	30,830	1.0	2.0	1
	11/20/07	3,940.0	4.0	67.9	8,510,643	10,459	43.6	61.5	7,918,155	16,801	70.0	16,428,798	30,881	1.0	2.0	1
	11/21/07	3,943.0	3.0	68.4	8,522,182	11,539	64.1	62.5	7,928,954	10,799	60.0	16,451,136	30,923	1.0	1.0	2
	11/22/07	3,944.2	1.2	66.2	8,530,012	7,830	108.8	61.2	7,939,691	10,737	149.1	16,469,703	30,958	1.0	1.0	1
	11/23/07	3,946.7	2.5	63.6	8,534,739	4,727	31.5	62.1	7,940,709	1,018	6.8	16,475,448	30,969	1.0	2.0	1
20	11/26/07	3,949.8	3.1	65.5	8,547,323	12,584	67.7	62.0	7,952,572	11,863	63.8	16,499,895	31,015	1.0	2.0	2
	11/27/07	3,952.8	3.0	69.6	8,558,197	10,874	60.4	64.4	7,962,837	10,265	57.0	16,521,034	31,055	1.0	2.0	1
21	12/03/07	3,963.2	10.4	62.3	8,597,981	39,784	63.8	58.7	8,003,550	40,713	65.2	16,601,531	31,206	1.0	2.0	0
	12/04/07	3,971.5	8.3	64.1	8,627,214	29,233	58.7	60.8	8,027,979	24,429	49.1	16,655,193	31,307	1.0	1.0	NA
	12/05/07	3,976.2	4.7	61.9	8,643,492	16,278	57.7	59.7	8,043,375	15,396	54.6	16,686,867	31,366	1.0	2.0	0
	12/06/07	3,984.7	8.5	61.8	8,673,104	29,612	58.1	57.4	8,071,317	27,942	54.8	16,744,421	31,474	1.0	1.0	1

(a) Bed volume = 35.6 cu.ft. (266 gal) in each vessel or 71.2 cu.ft. (532 gal) total for tw o vessels.

NA = Not Availble.

Table A-1. EPA Arsenic Demonstration Project at Nambe Pueblo, NM - Daily System Operation Log Sheet (Continued)

Week No.	Date	Buffalo Well: Pump Hour Meter (hr)	Buffalo Well: Incr. Hours (hr)	Vessel A Flow Meter: Flowrate (gpm)	Vessel A Flow Meter: Totalizer (gal)	Vessel A Flow Meter: Incr. Flow (gal)	Vessel A Flow Meter: Calculated Flowrate (gpm)	Vessel B Flow Meter: Flowrate (gpm)	Vessel B Flow Meter: Totalizer (gal)	Vessel B Flow Meter: Incr. Flow (gal)	Vessel B Flow Meter: Calculated Flowrate (gpm)	System Throughput (gal)	System Throughput (BV)	ΔP Vessel A (psig)	ΔP Vessel B (psig)	ΔP System (psi)
22	12/10/07	4,017.4	32.7	58.4	8,797,024	123,920	63.2	53.1	8,088,164	16,847	8.6	16,885,188	31,739	1.0	1.0	0
	12/11/07	4,035.0	17.6	59.6	8,846,154	49,130	46.5	55.8	8,234,547	146,383	138.6	17,080,701	32,107	1.0	2.0	1
	12/12/07	4,036.0	1.0	58.9	8,863,309	17,155	285.9	56.0	8,250,648	16,101	268.4	17,113,957	32,169	1.0	1.0	1
	12/13/07	4,045.3	9.3	59.4	8,894,410	31,101	55.7	56.9	8,287,513	36,865	66.1	17,181,923	32,297	1.0	2.0	0
	12/14/07	4,056.1	10.8	61.4	8,930,021	35,611	55.0	56.5	8,314,002	26,489	40.9	17,244,023	32,414	1.0	1.0	1
23	12/20/07	4,114.2	58.1	59.0	9,127,694	197,673	56.7	54.7	8,499,449	185,447	53.2	17,627,143	33,134	1.0	1.0	1
	12/21/07	4,132.4	18.2	55.7	9,188,263	60,569	55.5	52.6	8,556,362	56,913	52.1	17,744,625	33,355	1.0	1.0	1
24	12/26/07	4,178.9	46.5	51.2	9,348,594	160,331	57.5	54.1	8,706,924	150,562	54.0	18,055,518	33,939	1.0	1.0	1
	12/27/07	4,186.1	7.2	56.4	9,398,410	49,816	115.3	53.2	8,751,831	44,907	104	18,150,241	34,117	1.0	1.0	1
	12/28/07	4,197.3	11.2	57.9	9,431,614	33,204	49.4	54.1	8,794,317	42,486	63.2	18,225,931	34,259	1.0	1.0	0
25	01/02/08	4,250.6	53.3	51.9	9,578,566	146,952	46.0	51.9	8,923,809	129,492	40.5	18,502,375	34,779	1.0	5.0	1
	01/03/08	4,261.8	11.2	51.9	9,618,311	39,745	59.1	51.9	8,956,486	32,677	48.6	18,574,797	34,915	1.0	1.0	1
	01/04/08	4,279.5	17.7	54.3	9,645,043	26,732	25.2	54.3	8,986,416	29,930	28.2	18,631,459	35,022	1.0	2.0	1
26	01/07/08	4,302.8	23.3	72.2	9,758,579	113,536	81.2	67.5	9,093,256	106,840	76.4	18,851,835	35,436	1.0	1.0	2
	01/08/08	4,315.2	12.4	58.3	9,804,465	45,886	61.7	53.1	9,013,730	-79,526	NA	18,818,195	35,373	1.0	2.0	1
	01/09/08	4,322.7	7.5	57.3	9,829,182	24,717	54.9	52.7	9,160,331	67,075	56.2	18,989,513	35,695	1.0	1.0	1
	01/10/08	4,345.4	22.7	62.1	9,906,807	77,625	57.0	60.1	9,173,342	13,011	9.6	19,080,149	35,865	1.0	1.0	1
	01/11/08	4,350.0	4.6	57.6	9,924,879	18,072	65.5	52.6	9,250,514	77,172	279.6	19,175,393	36,044	1.0	1.0	1
27	01/14/08	4,392.5	42.5	54.3	10,065,231	140,352	55.0	51.4	9,382,356	131,842	51.7	19,447,587	36,556	1.0	1.0	1
	01/15/08	4,407.1	14.6	55.3	10,062,491	NA	NA	53.1	NA	NA	NA	NA	NA	1.0	1.0	1
	01/16/08	4,421.0	13.9	56.6	10,156,567	91,336	112.8	53.7	9,468,325	85,969	50.3	19,624,892	36,889	1.0	1.0	0
	01/17/08	4,437.2	16.2	55.8	10,199,825	43,258	44.5	53.6	NA	NA	NA	NA	NA	1.0	1.0	1
	01/18/08	4,446.2	9.0	53.0	10,209,213	9,388	17.4	49.9	9,546,100	77,775	51.4	19,755,313	37,134	1.0	1.0	1
28	01/21/08	4,484.7	38.5	60.9	10,395,213	186,000	80.5	55.7	9,689,821	143,721	62.2	20,085,034	37,754	1.0	1.0	0
	01/22/08	4,495.2	10.5	54.1	10,406,631	11,418	18.1	53.5	9,703,448	13,627	21.6	20,110,079	37,801	1.0	1.0	1
	01/23/08	4,505.6	10.4	61.3	10,441,031	34,400	55.1	60.1	9,735,182	31,734	50.9	20,176,213	37,925	1.0	1.0	1
	01/24/08	4,516.8	11.2	51.0	10,478,275	37,244	55.4	52.3	9,770,736	35,554	52.9	20,249,011	38,062	1.0	1.0	1
	01/25/08	4,527.7	10.9	56.2	10,514,264	35,989	55.0	50.8	9,804,581	33,845	51.8	20,318,845	38,193	1.0	1.0	1

(a) Bed volume = 35.6 cu.ft. (266 gal) in each vessel or 71.2 cu.ft. (532 gal) total for tw o vessels.

NA = Not Availble.

Table A-1. EPA Arsenic Demonstration Project at Nambe Pueblo, NM - Daily System Operation Log Sheet (Continued)

Week No.	Date	Buffalo Well		Instrument Panel												
		Pump Hour Meter	Incr. Hours	Vessel A Flow Meter				Vessel B Flow Meter				System Throughput		ΔP		
				Flowrate	Totalizer	Incr. Flow	Calculated Flowrate	Flowrate	Totalizer	Incr. Flow	Calculated Flowrate			Vessel A	Vessel B	System
		hr	hr	gpm	gal	gal	gpm	gpm	gal	gal	gpm	gal	BV	psig	psig	psi
29	01/28/08	4,567.2	39.5	53.4	10,645,076	130,812	55.2	51.2	9,927,900	123,319	52.0	20,572,976	38,671	1.0	1.0	1
	01/29/08	4,572.2	5.0	55.0	10,660,984	15,908	53.0	53.1	9,942,911	15,011	50.0	20,603,895	38,729	1.0	1.0	1
	01/30/08	4,581.1	8.9	51.1	10,699,940	38,956	73.0	52.4	9,984,121	41,210	77.2	20,684,061	38,880	1.0	1.0	1
	01/31/08	4,598.0	16.9	54.0	10,744,790	44,850	44.2	55.5	10,022,060	37,939	37.4	20,766,850	39,035	1.0	1.0	0
	02/01/08	4,607.2	9.2	54.1	10,791,510	46,720	84.6	53.1	10,244,130	222,070	402.3	21,035,640	39,541	1.0	1.0	1
30	02/04/08	4,642.2	35.0	53.6	10,891,540	100,030	47.6	49.1	10,160,099	-84,031	NA	21,051,639	39,571	1.0	1.0	1
	02/05/08	4,654.8	12.6	52.6	10,933,316	41,776	55.3	51.8	10,199,438	39,339	NA	21,132,754	39,723	1.0	1.0	1
	02/06/08	4,660.8	6.0	55.4	10,952,911	19,595	54.4	52.6	10,217,890	18,452	NA	21,170,801	39,795	1.0	1.0	1
	02/07/08	4,678.1	17.3	54.9	11,010,332	57,421	55.3	52.1	10,279,190	61,300	59.1	21,289,522	40,018	1.0	1.0	1
	02/08/08	4,694.8	16.7	53.9	11,094,210	83,878	83.7	58.8	10,346,421	67,231	67.1	21,440,631	40,302	1.0	1.0	1
31	02/11/08	4,714.5	19.7	54.2	11,137,523	43,313	36.6	53.3	10,391,483	45,062	38.1	21,529,006	40,468	1.0	1.0	1
	02/12/08	4,725.3	10.8	55.3	11,173,139	35,616	55.0	53.9	10,424,972	33,489	51.7	21,598,111	40,598	1.0	2.0	1
	02/13/08	4,736.4	11.1	56.2	11,209,816	36,677	55.1	50.9	10,459,415	34,443	51.7	21,669,231	40,732	1.0	1.0	1
	02/14/08	4,752.5	16.1	53.3	11,262,804	52,988	54.9	52.1	10,509,144	49,729	51.5	21,771,948	40,925	1.0	1.0	1
	02/15/08	4,764.9	12.4	56.0	11,303,488	40,684	54.7	51.5	10,547,330	38,186	51.3	21,850,818	41,073	1.0	1.0	1
32	02/19/08	4,807.2	42.3	59.1	11,450,791	147,303	58.0	55.6	10,686,097	138,767	54.7	22,136,888	41,611	1.0	1.0	0
	02/20/08	4,817.7	10.5	56.4	11,487,622	36,831	58.5	54.2	10,720,812	34,715	55.1	22,208,434	41,745	1.0	1.0	0
	02/21/08	4,823.7	6.0	55.3	11,506,882	19,260	53.5	54.2	10,758,974	38,162	106	22,265,856	41,853	1.0	1.0	0
	02/22/08	4,842.7	19.0	54.2	11,569,408	62,526	54.8	52.1	10,748,053	-10,921	NA	22,317,461	41,950	1.0	1.0	0
33	02/25/08	4,869.1	26.4	56.9	11,655,000	85,592	54.0	53.5	10,878,461	130,408	82.3	22,533,461	42,356	1.0	1.0	1
	02/26/08	4,880.2	11.1	55.4	11,691,646	36,646	55.0	51.3	10,913,227	34,766	52.2	22,604,873	42,490	1.0	1.0	1
	02/27/08	4,899.3	19.1	53.4	11,756,464	64,818	56.6	52.4	10,974,454	61,227	53.4	22,730,918	42,727	1.0	1.0	0
	02/28/08	4,909.2	9.9	56.3	11,788,754	32,290	54.4	51.9	11,005,101	30,647	51.6	22,793,855	42,846	1.0	1.0	1
	02/29/08	4,920.7	11.5	55.1	11,831,551	42,797	62.0	52.0	11,043,388	38,287	55.5	22,874,939	42,998	1.0	1.0	1
34	03/03/08	4,952.2	31.5	52.4	11,925,248	93,697	49.6	51.4	11,134,203	90,815	48.1	23,059,451	43,345	1.0	1.0	1
	03/04/08	4,964.3	12.1	58.6	11,965,565	40,317	55.5	52.2	11,172,225	38,022	52.4	23,137,790	43,492	1.0	1.0	1
	03/05/08	4,982.3	18.0	52.4	12,024,989	59,424	55.0	48.8	11,228,181	55,956	51.8	23,253,170	43,709	1.0	1.0	1
	03/06/08	4,995.0	12.7	55.0	12,063,879	38,890	51.0	50.3	11,264,778	36,597	48.0	23,328,657	43,851	1.0	1.0	1
	03/07/08	5,014.2	19.2	56.8	12,328,105	264,226	229.4	54.6	11,373,315	108,537	94.2	23,701,420	44,552	1.0	1.0	1

(a) Bed volume = 35.6 cu.ft. (266 gal) in each vessel or 71.2 cu.ft. (532 gal) total for two vessels.

NA = Not Availble.

Table A-1. EPA Arsenic Demonstration Project at Nambe Pueblo, NM - Daily System Operation Log Sheet (Continued)

Week No.	Date	Buffalo Well		Instrument Panel												
		Pump Hour Meter	Incr. Hours	Vessel A Flow Meter				Vessel B Flow Meter				System Throughput		ΔP		
				Flowrate	Totalizer	Incr. Flow	Calculated Flowrate	Flowrate	Totalizer	Incr. Flow	Calculated Flowrate			Vessel A	Vessel B	System
		hr	hr	gpm	gal	gal	gpm	gpm	gal	gal	gpm	gal	BV	psig	psig	psi
35	03/10/08	5,032.5	18.3	0	12,190,789	126,910	NA	0	11,384,145	10,830	9.9	23,574,934	44,314	1.0	1.0	0
	03/11/08	5,048.5	16.0	51.2	12,243,822	53,033	55.2	50.0	11,434,061	49,916	52.0	23,677,883	44,507	1.0	1.0	1
	03/12/08	5,067.7	19.2	53.4	12,290,147	46,325	40.2	50.4	11,477,654	43,593	37.8	23,767,801	44,676	1.0	1.0	0
	03/13/08	5,074.2	6.5	56.8	12,328,105	37,958	97.3	54.6	11,513,015	35,361	90.7	23,841,120	44,814	1.0	1.0	1
	03/14/08	5,083.6	9.4	0	12,358,817	30,712	54.5	0	11,542,162	29,147	51.7	23,900,979	44,927	1.0	1.0	0
36	03/17/08	5,121.5	37.9	57.3	12,482,568	123,751	54.4	50.7	11,658,495	116,333	51.2	24,141,063	45,378	1.0	1.0	0
	03/18/08	5,126.4	4.9	0	12,497,898	15,330	52.1	0	11,672,980	14,485	49.3	24,170,878	45,434	1.0	1.0	0
	03/19/08	5,137.8	11.4	61.2	12,536,640	38,742	56.6	59.6	11,709,362	36,382	53.2	24,246,002	45,575	1.0	1.0	1
	03/20/08	5,157.4	19.6	53.4	12,601,109	64,469	54.8	49.9	11,770,081	60,719	51.6	24,371,190	45,811	1.0	1.0	0
	03/21/08	5,149.1	NA	54.1	12,682,090	80,981	NA	51.1	11,811,120	41,039	NA	24,493,210	46,040	1.0	1.0	0
37	03/24/08	5,213.7	64.6	52.4	12,791,884	190,775	49.2	54.5	11,949,211	138,091	35.6	24,741,095	46,506	1.0	1.0	1
	03/25/08	5,227.4	13.7	55.5	12,836,029	44,145	53.7	53.4	11,990,941	41,730	50.8	24,826,970	46,667	1.0	1.0	0
	03/26/08	5,235.1	7.7	60.2	12,860,627	24,598	53.2	54.6	12,014,216	23,275	50.4	24,874,843	46,757	1.0	1.0	1
	03/27/08	5,248.6	13.5	54.2	12,906,019	45,392	56.0	54.0	12,056,815	42,599	52.6	24,962,834	46,923	1.0	1.0	1
	03/29/08	5,283.7	35.1	54.4	13,021,358	115,339	54.8	51.4	12,168,680	111,865	53.1	25,190,038	47,350	1.0	1.0	1
38	03/31/08	5,305.2	21.5	55.3	13,089,520	68,162	52.8	55.0	12,230,152	61,472	47.7	25,319,672	47,593	1.0	1.0	1
	04/01/08	5,324.1	18.9	60.6	13,151,374	61,854	54.5	52.8	12,288,839	58,687	51.8	25,440,213	47,820	1.0	1.0	1
	04/02/08	5,336.8	12.7	0	13,192,882	41,508	54.5	0	12,328,945	40,106	52.6	25,521,827	47,973	Off		NA
	04/03/08	5,351.7	14.9	56.5	13,244,271	51,389	57.5	54.8	12,377,264	48,319	54.0	25,621,535	48,161	1.0	1.0	1
	04/04/08	5,391.4	39.7	54.2	13,377,678	133,407	56.0	52.9	12,503,437	126,173	53.0	25,881,115	48,649	1.0	1.0	1
39	04/07/08	5,400.1	8.7	60.5	13,406,024	161,753	55.7	54.4	12,530,430	26,993	51.7	25,936,454	48,753	1.0	1.0	1
	04/08/08	5,413.3	13.2	62.8	13,499,228	93,204	177.7	58.8	12,571,340	40,910	51.7	26,070,568	49,005	1.0	1.0	1
	04/09/08	5,434.0	20.7	58.4	13,517,864	18,636	15	54.2	12,613,183	41,843	33.7	26,131,047	49,119	1.0	1.0	1
	04/10/08	5,446.8	12.8	57.4	13,558,576	40,712	53.0	54.1	12,676,414	63,231	82.3	26,234,990	49,314	1.0	1.0	1
	04/12/08	5,474.1	27.3	54.8	13,651,282	92,706	56.6	53.2	12,764,047	87,633	53.5	26,415,329	49,653	1.0	1.0	1
40	04/14/08	5,494.2	20.1	62.7	13,716,992	65,710	54.5	57.5	12,826,014	61,967	51.4	26,543,006	49,893	1.0	1.0	1
	04/15/08	5,508.2	14.0	61.3	13,763,265	46,273	55.1	58.7	12,864,795	38,781	46.2	26,628,060	50,053	1.0	1.0	1
	04/16/08	5,522.5	14.3	54.7	13,808,840	45,575	53.1	54.5	12,912,929	48,134	56.1	26,721,769	50,229	1.0	1.0	1
	04/17/08	5,542.2	19.7	60.2	13,819,777	10,937	9.3	57.1	12,978,759	65,830	55.7	26,798,536	50,373	1.0	1.0	1
	04/18/08	5,570.1	27.9	60.3	13,900,019	80,242	47.9	56.8	13,010,674	31,915	19.1	26,910,693	50,584	1.0	1.0	1

(a) Bed volume = 35.6 cu.ft. (266 gal) in each vessel or 71.2 cu.ft. (532 gal) total for tw o vessels.

NA = Not Availble.

Table A-1. EPA Arsenic Demonstration Project at Nambe Pueblo, NM - Daily System Operation Log Sheet (Continued)

Week No.	Date	Buffalo Well: Pump Hour Meter	Buffalo Well: Incr. Hours	Instrument Panel: Vessel A Flow Meter: Flowrate	Vessel A: Totalizer	Vessel A: Incr. Flow	Vessel A: Calculated Flowrate	Vessel B Flow Meter: Flowrate	Vessel B: Totalizer	Vessel B: Incr. Flow	Vessel B: Calculated Flowrate	System Throughput	System Throughput	ΔP: Vessel A	ΔP: Vessel B	ΔP: System
		hr	hr	gpm	gal	gal	gpm	gpm	gal	gal	gpm	gal	BV	psig	psig	psi
41	04/21/08	5,595.2	25.1	57.6	14,054,100	154,081	102.3	53.4	13,100,249	89,575	59.5	27,154,349	51,042	1.0	1.0	0
	04/22/08	5,613.9	18.7	50.9	14,107,195	53,095	47.3	50.0	13,194,149	93,900	83.7	27,301,344	51,318	1.0	1.0	1
	04/23/08	5,634.9	21.0	57.9	14,176,189	68,994	54.8	53.4	13,259,170	65,021	51.6	27,435,359	51,570	1.0	1.0	1
	04/24/08	5,654.0	19.1	56.4	14,237,241	61,052	53.3	49.2	13,317,163	57,993	50.6	27,554,404	51,794	1.0	1.0	0
	04/25/08	5,670.9	16.9	57.1	14,278,421	41,180	40.6	52.1	13,391,121	73,958	72.9	27,669,542	52,010	1.0	1.0	0
42	04/28/08	5,717.4	46.5	52.8	14,442,242	163,821	58.7	50.9	13,509,719	118,598	42.5	27,951,961	52,541	1.0	1.0	0
	04/29/08	5,739.4	22.0	54.4	14,512,272	70,030	53.1	49.9	13,572,600	62,881	47.6	28,084,872	52,791	1.0	1.0	NA
	04/30/08	5,745.2	5.8	53.1	14,530,374	18,102	52.0	51.1	13,588,994	16,394	47.1	28,119,368	52,856	1.0	1.0	NA
	05/01/08	5,773.8	28.6	54.5	14,623,601	93,227	54.3	47.4	13,673,915	84,921	49.5	28,297,516	53,191	1.0	1.0	0
	05/02/08	5,791.1	17.3	53.7	14,699,810	76,209	73.4	49.1	13,710,010	36,095	34.8	28,409,820	53,402	1.0	1.0	0
43	05/05/08	5,834.3	43.2	50.7	14,840,708	140,898	54.4	47.6	13,872,532	162,522	62.7	28,713,240	53,972	1.0	1.0	1
	05/06/08	5,847.1	12.8	58.4	14,864,610	23,902	31.1	53.7	13,894,972	22,440	29.2	28,759,582	54,059	1.0	1.0	0
	05/07/08	5,875.7	28.6	56.9	14,957,913	93,303	54.4	49.2	13,980,806	85,834	50.0	28,938,719	54,396	1.0	1.0	1
	05/08/08	5,885.7	10.0	57.0	15,033,981	76,068	126.8	44.2	14,050,768	69,962	116.6	29,084,749	54,671	1.0	1.0	1
	05/09/08	5,900.1	14.4	58.3	15,033,494	-487	NA	49.9	14,101,021	50,253	58.2	29,134,515	54,764	1.0	1.0	1
44	05/12/08	5,953.3	53.2	54.6	15,205,944	171,963	42.4	52.4	14,209,062	108,041	33.8	29,415,006	55,291	2.0	2.0	NA
	05/13/08	5,971.8	18.5	53.8	15,263,842	57,898	52.2	49.8	14,262,403	53,341	48.1	29,526,245	55,500	1.0	1.0	0
	05/14/08	5,988.0	16.2	57.0	15,317,823	53,981	55.5	53.7	14,312,201	49,798	51.2	29,630,024	55,696	1.0	1.0	0
	05/15/08	6,112.6	124.6	0	15,395,218	77,395	10.4	0	14,383,656	71,455	9.6	29,778,874	55,975	0.0	0.0	0
	05/16/08	6,120.9	8.3	56.9	15,425,018	29,800	59.8	53.1	14,400,101	16,445	33.0	29,825,119	56,062	1.0	1.0	1
45	05/19/08	6,077.1	NA	53.5	15,603,788	178,770	NA	51.1	14,582,169	182,068	NA	30,185,957	56,741	1.0	1.0	0
	05/20/08	6,084.0	96.0	61.1	15,630,183	26,395	NA	53.6	14,602,232	20,063	3.5	30,232,415	56,828	1.0	1.0	0
	05/21/08	6,103.6	19.6	57.6	15,690,424	60,241	51.2	50.4	14,660,970	58,738	49.9	30,351,394	57,051	1.0	1.0	0
	05/22/08	6,132.2	28.6	55.4	15,752,112	61,688	35.9	49.8	14,770,120	109,150	63.6	30,522,232	57,373	1.0	1.0	NA
	05/23/08	6,151.0	18.8	53.2	15,847,626	95,514	84.7	49.2	14,806,644	36,524	32.4	30,654,270	57,621	1.0	1.0	0
47	06/03/08	NA	NA	52.8	16,535,004	687,378	NA	46.0	15,457,241	650,597	NA	31,992,245	60,136	1.0	1.0	0
48	06/11/08	6,554.3	403.3	51.4	17,105,814	570,810	23.6	48.3	15,993,699	536,458	22.2	33,099,513	62,217	1.0	1.0	0
49	06/19/08	6,693.9	139.6	51.1	17,531,117	425,303	50.8	50.3	16,394,910	401,211	47.9	33,926,027	63,771	1.0	1.0	0
50	06/24/08	6,852.9	159.0	49.7	18,000,351	469,234	49.2	47.3	16,840,407	445,497	46.7	34,840,758	65,490	1.0	1.0	0
51	07/02/08	7,024.9	172.0	57.0	18,532,902	532,551	51.6	52.1	17,337,632	497,225	48.2	35,870,534	67,426	1.0	1.0	1
58	08/28/08	8,129.7	1104.8	54.7	21,954,007	3,421,105	51.6	50.2	20,530,591	3,192,959	48.2	42,484,598	79,858	1.0	1.0	0

(a) Bed volume = 35.6 cu.ft. (266 gal) in each vessel or 71.2 cu.ft. (532 gal) total for tw o vessels.

NA = Not Availble.

Table A-1. EPA Arsenic Demonstration Project at Nambe Pueblo, NM - Daily System Operation Log Sheet (Continued)

		Buffalo Well		Instrument Panel													
				Vessel A Flow Meter				Vessel B Flow Meter				System Throughput		ΔP			
Week No.	Date	Pump Hour Meter	Incr. Hours	Flowrate	Totalizer	Incr. Flow	Calculated Flowrate	Flowrate	Totalizer	Incr. Flow	Calculated Flowrate			Vessel A	Vessel B	System
		hr	hr	gpm	gal	gal	gpm	gpm	gal	gal	gpm	gal	BV	psig	psig	psi
62	09/24/08	8,625.0	495.3	55.9	23,481,108	1,527,101	51.4	53.5	21,964,421	1,433,830	48.2	45,445,529	85,424	1.0	1.0	0
67	10/27/08	9,189.3	564.3	53.9	25,203,427	1,722,319	50.9	48.2	23,592,913	1,628,492	48.1	48,796,340	91,722	1.0	1.0	1
71	11/24/08	9,586.1	396.8	53.1	26,439,978	1,236,551	51.9	52.7	24,644,715	1,051,802	44.2	51,084,693	96,024	1.0	1.0	1
75	12/24/08	9,804.1	218.0	59.9	27,130,764	690,786	52.8	55.3	25,294,639	649,924	49.7	52,425,403	98,544	1.0	1.0	0
80	01/28/09	9,942.5	138.4	60.6	27,578,121	447,357	53.9	58.9	25,729,321	434,682	52.3	53,307,442	100,202	1.0	1.0	0
84	02/25/09	10,108.0	165.5	58.7	28,115,307	537,186	54.1	55.3	26,251,886	522,565	52.6	54,367,193	102,194	1.0	1.0	0
88	03/26/09	10,430.1	322.1	57.7	29,152,606	1,037,299	53.7	54.9	27,238,667	986,781	51.1	56,391,273	105,999	1.0	1.0	1
97	05/20/09	11,137.4	707.3	53.0	31,358,125	2,205,519	52.0	51.8	29,296,854	2,058,187	48.5	60,654,979	114,013	1.0	1.0	0
101	06/17/09	11,251.8	114.4	60.1	31,729,595	371,470	54.1	54.6	29,648,739	351,885	51.3	61,378,334	115,373	1.0	1.0	0
107	07/28/09	11,576.4	324.6	59.1	32,766,407	1,036,812	53.2	57.2	30,617,917	969,178	49.8	63,384,324	119,143	1.0	1.0	1
111	08/27/09	11,693.2	116.8	60.0	33,145,283	378,876	54.1	54.6	205,432	205,432	NA	63,968,632	NA	1.0	1.0	1
115	09/21/09	11,780.1	86.9	56.9	33,426,403	281,120	53.9	55.6	469,393	263,961	50.6	64,513,713	121,266	1.0	1.0	0
116	09/28/09	11,790.4	10.3	56.9	33,460,647	34,244	55.4	53.4	501,435	32,042	51.8	64,579,999	121,391	1.0	1.0	0

(a) Bed volume = 35.6 cu.ft. (266 gal) in each vessel or 71.2 cu.ft. (532 gal) total for tw o vessels.

NA = Not Availble.

APPENDIX B

ANALYTICAL DATA

Table B-1. Analytical Results from Treatment Plant Sampling at Nambe Pueblo, NM

Sampling Date		06/26/07[a]				07/03/07				07/09/07			07/18/07				07/26/07			
Sampling Location / Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TT	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	$\times 10^3$	-	-	-	-	-	-	-	-	-	-	10.2	-	-	12.1	11.3	-	-	13.4	12.4
Alkalinity (as $CaCO_3$)	mg/L	173	173	209	211	171	175	207	197	168	168	211	173	171	171	168	170	165	165	168
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	1.1	0.8	0.6	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	29	37	32	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	0.8	0.8	0.8	-	-	-	-	-	-	-	-
Total P (as P)	µg/L	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	15.2	14.8	19.2	19.5	14.9	15.0	25.4	25.9	15.5	15.7	21.7	14.7	14.9	17.5	16.7	14.4	14.3	16.4	15.7
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	0.3	0.2	0.4	0.5	0.9	0.2	0.7	0.4	0.4	0.6	0.4	0.5	0.7	0.5	0.7	0.7	2.1	1.5	0.9
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOC	mg/L	-	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	-	-	-	-	-	-	-	-
pH	S.U.	-	-	-	-	-	-	-	-	9.1	7.1	8.6	-	7.7[c]	-	-	-	7.1[c]	-	-
Temperature	°C	-	-	-	-	-	-	-	-	20.4	20.4	20.2	-	-	-	-	-	-	-	-
DO	mg/L	-	-	-	-	-	-	-	-	6.8	3.4	4.7	-	-	-	-	-	-	-	-
ORP	mV	-	-	-	-	-	-	-	-	396	442	467	-	-	-	-	-	-	-	-
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	7.2	7.1	40.7	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	7.0	7.0	40.1	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	0.1	0.1	0.6	-	-	-	-	-	-	-	-
As (total)	µg/L	29.3	29.8	2.4	2.1	26.4	25.8	1.5	2.7	37.4	36.9	2.5	30.1	31.4	0.4	0.4	28.9	30.0	0.3	0.3
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	-	-	34.5	32.5	2.3	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	2.9	4.4	0.1	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	0.3	0.3	0.3	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	34.2	32.2	2.0	-	-	-	-	-	-	-	-
Fe (total)	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	<25	<25	<25	-	-	-	-	-	-	-	-
Mn (total)	µg/L	0.2	0.2	<0.1	<0.1	0.5	1.2	<0.1	<0.1	0.2	0.1	<0.1	0.2	0.2	0.3	0.1	0.1	0.1	<0.1	<0.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	0.7	0.2	0.3	-	-	-	-	-	-	-	-
U (total)	µg/L	42.6	43.5	88.2	81.8	43.0	40.4	43.9	24.7	41.8	43.2	71.6	41.1	40.1	1.5	1.5	40.7	41.1	2.4	2.5
		(42.6)	(42.4)	(88.2)	(79.8)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U (soluble)	µg/L	-	-	-	-	-	-	-	-	40.6	41.0	72.0	-	-	-	-	-	-	-	-

(a) Results in parathensis are reruns. (b) Operator training completed. (c) pH reading taken from inline probe.

Table B-1. Analytical Results from Treatment Plant Sampling at Nambe Pueblo, NM (Continued)

Sampling Date		08/02/07				08/10/07			08/15/07				08/22/07				08/28/07			
Sampling Location / Parameter	Unit	IN	AP	TA	TB	IN	AP	TT	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	$\times 10^3$	-	-	14.6	13.6	-	-	15.4	-	-	17.9	16.6	-	-	19.7	18.3	-	-	21.6	20.1
Alkalinity (as $CaCO_3$)	mg/L	189	196	179	189	184	189	186	165	165	179	179	168	168	170	168	170	170	170	168
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	170	168	170	170
Fluoride	mg/L	-	-	-	-	0.9	0.8	0.8	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	27	27	27	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	0.8	0.7	0.7	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<10	<10	<10	<10
Silica (as SiO_2)	mg/L	14.5	14.8	15.9	16.3	15.2	14.8	15.7	14.8	14.6	14.7	14.8	13.6	13.1	13.3	13.0	15.7	15.1	15.9	15.5
		-	-	-	-	-	-	-									15.0	14.9	16.1	15.7
Turbidity	NTU	0.5	0.7	0.8	0.3	0.3	0.2	0.3	0.3	0.3	0.2	0.2	0.9	0.4	0.5	0.5	1.7	1.2	2.7	1.3
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.1	1.0	1.8	2.1
TOC	mg/L	-	-	-	-	<1	<1	<1	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	-	7.4[(c)]	-	-	9.0	7.1	8.3	-	7.7[(c)]	-	-	-	7.3[(c)]	-	-	-	7.2[(c)]	-	-
Temperature	°C	-	-	-	-	22.3	21.8	22.6	-	-	-	-	-	-	-	-	-	-	-	-
DO	mg/L	-	-	-	-	6.9	3.8	4.2	-	-	-	-	-	-	-	-	-	-	-	-
ORP	mV	-	-	-	-	391	409	424	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	6.9	6.9	7.0	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	6.9	6.8	6.9	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	0.1	0.1	0.1	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	30.7	29.9	0.4	0.3	31.7	31.7	1.3	29.9	28.5	19.1	19.5	30.7	32.3	0.7	0.6	28.6	29.6	0.6	0.5
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29.1	29.8	0.5	0.5
As (soluble)	µg/L	-	-	-	-	37.7	30.9	1.4	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	<0.1	0.8	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	1.2	1.1	1.0	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	36.5	29.8	0.4	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<25	<25	<25	<25
Fe (soluble)	µg/L	-	-	-	-	<25	<25	<25	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.4	0.4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.2	<0.1	<0.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	0.1	<0.1	<0.1
Mn (soluble)	µg/L	-	-	-	-	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
U (total)	µg/L	43.1	42.5	2.4	2.5	40.9	40.4	2.8	42.4	39.9	68.9	66.9	41.2	40.4	2.2	2.5	41.5	42.2	1.4	1.5
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	42.6	42.6	1.4	1.5
U (soluble)	µg/L	-	-	-	-	<0.1	24.8	<0.1	-	-	-	-	-	-	-	-	-	-	-	-

Table B-1. Analytical Results from Treatment Plant Sampling at Nambe Pueblo, NM (Continued)

Sampling Date		09/11/07				09/26/07				10/04/07				10/11/07				10/16/07			
Sampling Location Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	$\times 10^3$	-	-	26.0	24.1	-	-	28.8	26.7	-	-	30.0	27.8	-	-	30.8	28.6	-	-	31.0	28.8
Alkalinity (as $CaCO_3$)	mg/L	171	177	179	177	190	175	209	177	170	170	164	168	176	164	168	168	179	169	163	165
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	11.1	17.8	<10	11.0
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	14.2	14.5	20.0	19.5	15.7	16.3	16.4	15.2	14.9	15.5	12.6	12.4	14.6	15.2	19.9	19.5	13.9	15.6	17.8	17.2
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	0.2	0.6	0.7	0.7	1.2	0.6	0.8	1.2	1.7	0.9	1.7	1.4	0.3	0.4	0.3	0.6	0.6	1.1	1.2	1.8
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	-	7.3[(c)]	-	-	-	8.1[(c)]	-	-	-	7.2[(c)]	-	-	-	7.0[(c)]	-	-	-	7.5[(c)]	-	-
Temperature	°C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DO	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ORP	mV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	30.7	31.7	1.1	1.0	27.6	27.4	19.8	31.5	30.9	32.0	0.7	0.8	31.5	32.2	0.8	0.7	16.3	20.8	0.1	<0.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.3	0.3	<0.1	<0.1	0.6	1.1	<0.1	<0.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U (total)	µg/L	43.9	41.2	4.9	4.0	44.2	42.9	135.4	66.9	37.1	35.4	1.3	1.4	40.3	40.1	2.4	2.3	39.3	40.4	2.0	2.0
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table B-1. Analytical Results from Treatment Plant Sampling at Nambe Pueblo, NM (Continued)

Sampling Date		10/25/07[a]				11/02/07				11/07/07				11/14/07				11/26/07			
Sampling Location		IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Parameter	Unit																				
Bed Volume	$\times 10^3$	-	-	31.3	29.1	-	-	31.6	29.4	-	-	31.7	29.5	-	-	31.8	29.6	-	-	32.1	30.0
Alkalinity (as $CaCO_3$)	mg/L	163	163	196	200	168	174	174	174	178	174	170	174	171	188	167	165	169	169	169	171
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	15.1	15.0	12.4	13.5	14.9	14.8	15.5	15.0	13.3	13.4	15.2	14.6	14.4	12.7	14.4	14.0	13.6	13.0	30.4	14.2
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	3.0	6.2	3.9	2.6	0.5	0.6	0.3	0.5	0.5	0.5	0.8	0.5	0.5	0.5	0.4	0.4	0.5	1.5	0.6	0.4
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	-	7.0[c]	-	-	-	7.1[c]	-	-	-	7.0[c]	-	-	-	7.3[c]	-	-	-	7.1[c]	-	-
Temperature	°C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DO	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ORP	mV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	40.6	42.3	4.6	3.7	34.2	36.1	0.6	0.5	10.7	14.3	0.7	0.7	30.9	10.6	0.8	0.7	30.5	17.2	1.0	1.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	56	<25	42	34	<25	<25	<25	<25
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	0.4	0.4	0.1	<0.1	0.2	0.2	<0.1	<0.1	0.5	1.1	<0.1	0.1	3.6	2.3	0.3	0.3	1.8	1.0	0.1	0.2
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U (total)	µg/L	29.0	28.9	13.9	19.4	38.9	38.3	1.9	2.0	35.7	36.1	1.8	1.9	41.5	42.3	2.0	2.0	40.7	38.7	2.5	3.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(a) Alkalinity, silica, and turbidity results collected on 10/23/07.

Table B-1. Analytical Results from Treatment Plant Sampling at Nambe Pueblo, NM (Continued)

Sampling Date		12/05/07				12/12/07				12/20/07				01/16/08				01/23/08			
Sampling Location Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	$\times 10^3$	-	-	32.5	30.2	-	-	33.3	31.0	-	-	34.3	32.0	-	-	38.2	35.6	-	-	39.3	36.6
Alkalinity (as $CaCO_3$)	mg/L	167	168	172	170	163	163	161	161	158	164	171	175	161	159	161	159	162	166	172	168
		165	170	168	167	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
		<10	<10	<10	<10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	14.3	14.1	13.7	14.1	14.9	14.7	15.3	15.1	13.8	14.0	22.7	21.2	15.4	15.2	17.5	17.3	13.4	13.1	13.7	13.2
		14.5	13.7	13.5	14.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	0.3	0.3	0.4	0.5	0.5	0.3	0.3	0.6	0.4	0.2	0.9	0.3	1.0	0.3	0.7	0.6	0.8	0.5	0.6	0.5
		0.4	0.4	0.4	0.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	-	7.0[(c)]	-	-	-	7.1[(c)]	-	-	-	7.2[(c)]	-	-	-	7.0[(c)]	-	-	-	7.0[(c)]	-	-
Temperature	°C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DO	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ORP	mV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	37.0	37.3	1.0	0.9	41.7	44.9	4.4	<0.1	41.4	41.5	1.5	1.3	34.7	36.8	2.1	1.4	41.5	39.3	2.3	2.2
		36.6	36.5	1.0	0.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
		<25	<25	<25	<25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	1.0	0.4	<0.1	<0.1	2.9	0.3	0.1	<0.1	0.3	0.3	<0.1	<0.1	0.2	0.2	<0.1	<0.1	0.3	0.3	<0.1	<0.1
		0.8	0.4	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U (total)	µg/L	41.3	42.5	2.3	2.6	39.4	38.7	5.0	2.3	36.8	37.8	4.3	3.2	38.8	39.8	3.1	2.9	34.6	36.6	2.6	2.6
		42.5	42.7	2.4	2.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table B-1. Analytical Results from Treatment Plant Sampling at Nambe Pueblo, NM (Continued)

Sampling Date		01/29/08				02/06/08				02/13/08				02/21/08				03/04/08			
Sampling Location Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	$\times 10^3$	-	-	40.0	37.4	-	-	41.2	38.4	-	-	42.1	39.3	-	-	43.5	40.4	-	-	45.0	42.0
Alkalinity (as $CaCO_3$)	mg/L	168	168	170	166	160	166	160	164	162	164	192	188	167	163	167	167	167	169	165	167
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	14.4	14.3	19.2	18.3	14.0	13.8	14.6	14.6	13.8	13.8	10.0	10.6	15.7	15.3	21.3	20.2	15.5	15.2	17.0	16.7
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	0.4	0.7	0.3	0.2	0.8	1.6	0.9	1.3	0.2	0.2	0.4	0.4	0.6	0.9	0.6	0.3	0.7	0.5	0.5	0.4
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	-	7.2[(c)]	-	-	-	7.1[(c)]	-	-	-	7.0[(c)]	-	-	-	7.3[(c)]	-	-	-	7.1[(c)]	-	-
Temperature	°C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DO	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ORP	mV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	32.4	32.5	1.4	1.3	36.9	37.8	1.5	1.4	36.0	38.0	20.4	26.2	39.7	41.3	2.1	2.0	38.0	38.5	0.8	0.8
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	<25	28	<25	<25	25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	0.3	0.2	0.1	<0.1	1.9	0.2	<0.1	<0.1	0.2	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.4	<0.1	<0.1	<0.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U (total)	µg/L	37.2	35.3	4.2	3.7	35.5	35.1	3.0	2.8	35.7	35.2	33.3	46.5	37.7	38.1	2.8	2.5	40.5	39.5	2.8	2.6
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table B-1. Analytical Results from Treatment Plant Sampling at Nambe Pueblo, NM (Continued)

Sampling Date		03/11/08				03/19/08				03/26/08				04/08/08				04/15/08			
Sampling Location Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	$\times 10^3$	-	-	46.0	43.0	-	-	47.1	44.0	-	-	48.3	45.2	-	-	50.7	47.3	-	-	51.7	48.4
Alkalinity (as $CaCO_3$)	mg/L	169	169	174	171	172	168	166	164	168	168	164	166	167	169	171	167	171	169	173	169
		171	169	171	174	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
		<10	<10	<10	<10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	13.2	13.3	14.0	13.9	14.9	14.9	16.0	16.0	13.2	13.6	14.8	14.5	13.8	14.1	15.3	15.1	14.8	14.7	20.3	18.9
		13.1	13.3	13.9	13.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	0.3	0.3	0.2	0.4	0.6	0.8	0.4	1.2	0.5	0.3	0.3	0.6	1.0	0.3	1.0	0.7	0.7	0.5	0.7	0.9
		0.4	0.1	0.3	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	-	6.9[(c)]	-	-	-	7.2[(c)]	-	-	-	7.3[(c)]	-	-	-	7.2[(c)]	-	-	-	7.2[(c)]	-	-
Temperature	℃	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DO	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ORP	mV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	31.5	34.9	1.1	1.2	29.6	29.9	1.8	1.8	28.9	28.9	1.3	1.2	28.1	30.1	1.0	0.9	28.7	29.8	1.3	1.3
		32.8	33.2	0.7	1.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
		<25	<25	<25	<25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	<0.1	<0.1	<0.1	<0.1	0.3	0.5	<0.1	<0.1	0.2	63.8	0.2	<0.1	0.3	0.6	<0.1	<0.1	0.4	0.5	<0.1	<0.1
		<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U (total)	µg/L	40.8	42.5	4.0	4.0	38.6	41.4	5.3	5.2	39.7	41.9	3.7	3.4	43.5	42.4	4.1	3.7	42.9	42.2	3.9	3.6
		42.5	42.1	4.1	4.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(c) pH reading taken from inline probe.

Table B-1. Analytical Results from Treatment Plant Sampling at Nambe Pueblo, NM (Continued)

Sampling Date		04/22/08				05/06/08				05/13/08				05/21/08				06/03/08			
Sampling Location Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	$\times 10^3$	-	-	53.0	49.6	-	-	55.9	52.2	-	-	57.4	53.6	-	-	59.0	55.1	-	-	62.2	58.1
Alkalinity (as $CaCO_3$)	mg/L	166	164	204	202	157	161	165	163	162	162	182	178	170	168	166	170	177	170	173	173
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	1.0	1.1	0.5	0.8	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	26.1	25.0	26.2	31.2	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	0.7	0.7	0.4	0.6	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L	<10	<10	13.0	12.6	<10	<10	<10	<10	<10	<10	<10	<10	12.1	10.7	<10	<10	<10	<10	<10	<10
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	14.5	14.5	15.0	15.0	14.2	13.9	17.9	16.8	13.8	14.1	13.3	13.4	13.7	13.9	20.0	19.0	13.6	13.5	14.3	13.8
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	0.6	0.6	0.6	0.6	0.5	0.5	0.6	0.7	0.7	0.4	0.8	0.9	0.3	1.0	1.4	0.6	0.1	<0.1	<0.1	0.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	-	7.2[(c)]	-	-	-	7.6[(c)]	-	-	-	7.6[(c)]	-	-	-	7.2[(c)]	-	-	-	7.1[(c)]	-	-
Temperature	°C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DO	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ORP	mV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	6.1	5.7	8.2	8.1	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	5.9	5.6	7.5	7.5	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	0.2	0.2	0.6	0.5	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	31.5	32.7	46.9	44.7	43.5	44.7	1.2	1.2	40.5	41.0	43.5	41.5	33.6	32.0	2.5	2.3	30.4	32.3	1.1	1.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	<0.1	<0.1	<0.1	<0.1	0.2	0.2	<0.1	<0.1	0.2	0.1	<0.1	<0.1	1.3	0.4	<0.1	<0.1	0.1	<0.1	<0.1	<0.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U (total)	µg/L	41.5	40.7	105.0	90.9	36.7	35.2	2.1	2.0	37.4	38.2	62.4	50.6	36.7	35.0	2.2	2.0	36.5	35.6	2.0	2.0
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table B-1. Analytical Results from Treatment Plant Sampling at Nambe Pueblo, NM (Continued)

Sampling Date		06/11/08				06/19/08				06/24/08				07/02/08				08/28/08			
Sampling Location Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	$\times 10^3$	-	-	64.3	60.1	-	-	65.9	61.6	-	-	67.6	63.3	-	-	69.6	65.1	-	-	82.5	77.2
Alkalinity (as $CaCO_3$)	mg/L	179	173	168	166	173	168	171	171	173	175	173	171	159	161	156	159	168	162	166	173
		-	-	-	-	-	-	-	-	-	-	-	-	159	159	156	159	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
		-	-	-	-	-	-	-	-	-	-	-	-	<10	<10	<10	<10	-	-	-	-
Silica (as SiO_2)	mg/L	13.6	13.7	16.1	15.4	13.7	13.6	14.3	13.9	13.4	13.3	14.0	14.0	15.3	14.5	19.1	18.4	13.5	13.2	13.8	13.3
		-	-	-	-	-	-	-	-	-	-	-	-	15.0	14.7	19.1	18.4	-	-	-	-
Turbidity	NTU	<0.1	<0.1	<0.1	<0.1	0.4	0.7	0.3	0.9	0.1	0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1
		-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	-	-	-	-
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	NA	7.2[c]	NA	NA	NA	7.2[c]	NA	NA	NA	7.2[c]	NA	NA	NA	7.1[c]	NA	NA	NA	7.2[c]	NA	NA
Temperature	°C	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DO	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ORP	mV	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	32.7	32.5	1.3	1.3	27.2	27.2	0.9	0.9	28.3	28.5	1.7	1.9	38.4	37.5	1.3	1.3	31.2	32.6	1.6	1.5
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.1	<0.1	<0.1	0.1	0.1	<0.1	<0.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U (total)	µg/L	46.1	44.1	1.5	1.5	41.5	42.2	1.4	1.4	41.6	42.4	2.9	3.0	37.2	38.1	2.9	2.6	35.6	35.4	5.9	5.6
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table B-1. Analytical Results from Treatment Plant Sampling at Nambe Pueblo, NM (Continued)

Sampling Date		09/24/08				10/27/08				11/24/08				12/22/08				01/28/09			
Sampling Location / Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	$\times 10^3$	-	-	88.3	82.6	-	-	94.8	88.7	-	-	99.4	96.0	-	-	102	95.1	-	-	104	96.7
Alkalinity (as $CaCO_3$)	mg/L	166	168	166	161	155	159	164	164	158	158	156	156	184	182	157	168	168	175	164	166
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	14.0	13.9	13.1	13.3	13.6	13.2	13.6	13.6	13.6	13.1	12.9	13.3	11.1	11.1	13.0	13.0	12.1	11.6	12.6	12.8
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	<0.1	<0.1	<0.1	0.2	<0.1	0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	0.2	<0.1	0.1	0.1	0.2	0.2	0.2	0.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	NA	7.5[(c)]	NA	NA	NA	7.3[(c)]	NA	NA	NA	7.4[(c)]	NA	NA	NA	7.4[(c)]	NA	NA	NA	7.4[(c)]	NA	NA
Temperature	°C	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DO	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ORP	mV	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	28.4	28.3	1.6	1.8	32.4	32.6	2.0	2.0	40.8	40.7	1.9	2.0	11.0	10.6	1.9	2.2	22.0	12.2	2.6	2.7
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	120	<25	<25	<25	<25	<25	<25	<25
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	0.4	0.3	<0.1	<0.1	0.7	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	6.8	0.7	<0.1	<0.1	1.1	0.4	<0.1	<0.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U (total)	µg/L	44.8	43.8	9.8	11.8	19.9	38.4	4.8	4.7	34.1	34.0	7.1	7.4	36.1	35.5	8.2	9.1	26.0	26.6	7.5	8.7
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table B-1. Analytical Results from Treatment Plant Sampling at Nambe Pueblo, NM (Continued)

Sampling Date		02/25/09				03/26/09				04/24/09				05/20/09				06/17/09			
Sampling Location Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	$\times 10^3$	-	-	106	98.7	-	-	110	102	-	-	NA	NA	-	-	118	110	-	-	119	111
Alkalinity (as $CaCO_3$)	mg/L	167	171	169	163	169	173	167	165	166	166	168	171	177	174	172	177	175	175	175	173
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L	10.4	10.5	<10	<10	<10	<10	<10	<10	26.1	23.4	12.7	11.4	<10	<10	<10	<10	<10	<10	<10	<10
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	13.4	12.8	15.8	15.3	12.6	12.4	12.1	12.3	14.3	14.3	14.6	14.7	13.0	13.9	13.8	13.5	13.1	13.0	14.5	14.3
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	<0.1	<0.1	<0.1	<0.1	0.4	0.3	0.5	0.2	0.1	<0.1	0.1	0.3	0.8	0.1	0.2	0.5	0.5	0.9	0.6	0.6
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	NA	7.7[(c)]	NA	NA	NA	7.5[(c)]	NA	NA	NA	NA	NA	NA	NA	7.6[(c)]	NA	NA	NA	7.5[(c)]	NA	NA
Temperature	℃	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DO	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ORP	mV	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	29.5	26.5	2.2	2.6	31.3	32.0	1.7	1.8	59.0	42.2	3.6	3.0	35.1	35.7	1.9	1.8	30.8	30.8	2.2	2.3
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	154	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	10.8	0.5	<0.1	<0.1	2.4	0.5	<0.1	<0.1	0.3	0.2	<0.1	<0.1	0.2	0.1	<0.1	<0.1	0.8	0.5	0.3	<0.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U (total)	µg/L	40.7	39.2	7.2	6.0	45.0	45.3	7.2	6.4	55.8	48.9	7.4	6.1	36.3	37.3	3.7	3.3	39.5	39.4	6.0	6.7
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table B-1. Analytical Results from Treatment Plant Sampling at Nambe Pueblo, NM (Continued)

Sampling Date		07/28/09				08/27/09				09/21/09				09/28/09			
Sampling Location Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	$\times 10^3$	-	-	123	115	-	-	125	NA	-	-	126	116	-	-	126	117
Alkalinity (as $CaCO_3$)	mg/L	165	170	156	159	175	177	208	219	168	167	159	159	174	172	169	167
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L	<10	<10	<10	<10	<10	10.9	11.4	15.3	<10	<10	<10	<10	<10	<10	<10	<10
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	13.9	13.6	13.6	13.4	12.6	12.4	9.3	10.2	15.0	15.2	14.7	15.0	13.4	12.4	12.3	12.6
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	0.4	0.2	0.2	0.9	2.4	2.5	1.8	1.1	0.6	0.4	0.7	0.9	0.2	0.3	0.4	0.3
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	NA	7.2[(c)]	NA	NA	NA	7.2[(c)]	NA	NA	NA	7.2[(c)]	NA	NA	NA	7.6[(c)]	NA	NA
Temperature	℃	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DO	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ORP	mV	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	29.2	29.6	<0.1	<0.1	26.5	19.3	14.7	19.0	30.5	31.7	0.7	0.1	32.4	29.1	2.4	1.6
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	29	<25	<25	<25	28	<25	45	57	<25	<25	<25	<25	<25	<25	<25	<25
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	1.9	1.0	0.2	<0.1	1.0	0.5	0.1	0.2	0.8	0.7	<0.1	<0.1	1.2	0.8	0.1	<0.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U (total)	µg/L	36.6	36.5	6.1	3.3	37.4	37.0	27.2	33.8	38.1	38.6	4.3	3.9	39.1	39.1	7.2	4.3
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-