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Arsenic Removal from Drinking Water by Iron Removal U.S. EPA Demonstration Project at Northeastern Elementary School in Fountain City, IN Final Performance Evaluation Report

by

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Sally Gutierrez, Director
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ABSTRACT

This report documents the activities performed and the results obtained from the arsenic removal treatment technology demonstration project at Northeastern Elementary School in Fountain City, IN. The main objective of the project was to evaluate the effectiveness of US Water Systems' iron removal (IR) system 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 skill levels, and (3) the capital and O&M cost of the technology. The project also characterized the water in the distribution system and process residuals produced by the treatment process. The types of data collected include system operation, water quality (both across the treatment train and in the distribution system), process residuals, and capital and O&M cost.

The system consisted of four 36-in × 72-in composite poly-glass vessels configured in parallel. Each vessel contained 17.7 ft^3 of G2® media consisting of a granular, calcined diatomite substrate coated with ferric hydroxide developed by ADI. The treatment system was designed for a peak flowrate of 60 gal/min (gpm) (15 gpm per vessel), which corresponds to a hydraulic loading rate of 2.1 gpm/ft^2. Over the performance evaluation period, the actual average flowrates were 11.3, 11.3, 11.4, and 13.1 gpm for Vessels A, B, C, and D, respectively, based on readings from the flow meter/totalizer installed on each vessel. The average hydraulic loading rates for Vessels A, B, C, and D were 1.6, 1.6, 1.6, and 1.8 gpm/ft^2, respectively.

The pre-existing chlorination system was replaced with a new Stenner Model 85MPHP5 peristaltic pump**,** a 30-gal chemical feed tank, an injector, and 2-in inline mixer. Sodium hypochlorite (NaOCl) was injected prior to the filtration vessels to oxidize As(III) to As(V) and form arsenic-laden iron solids, which were then filtered by G2® media. The chlorination system also was used to maintain a target combined chlorine residual of 1.0 mg/L (as Cl_2) in the distribution system for disinfection.

From September 22, 2008, through the end of the performance evaluation study on October 29, 2009, the treatment system operated for a total of 349.1 hr, treating approximately 941,500 gal of water. The average daily operation time was 1.4 hr/day when the school was in session and 0.3 hr/day when the school was out of session. The average system flowrate was 47.1 gpm.

Total arsenic concentrations in raw water ranged from 24.0 to 39.3 µg/L and averaged 29.4 µg/L. Soluble As(III) was the predominating arsenic species with concentrations ranging from 10.8 to 23.9 µg/L and averaging 17.7 µg/L. Total iron concentrations in raw water averaged 1,865 µg/L, while soluble iron concentrations averaged 1,058 µg/L, which was over 52 times the average soluble arsenic concentration (20.2 µg/L) in raw water. Therefore, supplemental iron addition was not necessary for arsenic removal. Following chlorination, over 85% of arsenic existed as particulate arsenic (23.8 µg/L [on average]), which was removed by the pressure filters to an average concentration of 3.6 µg/L. The system also reduced total iron concentrations to 99 µg/L (on average), while total manganese concentrations remained relatively unchanged.

During the performance evaluation period, the vessels were backwashed eight times. Backwash might be triggered manually or automatically with either a time, a throughput, or a pressure differential (Δp) as a setpoint. Throughput was chosen as the setpoint to initiate backwash. To give the operator better control over when backwash would occur, the throughput was set to 90,000 gal. Each backwash cycle lasted 26 min, including 14 min for counter-current backwash, 5 min for co-current slow rinse, and 7 min co-current fast rinse. Each vessel generated 1,137 gal of wastewater (on average), or 4,548 gal per event. Assuming an average of 677 mg/L of total suspended solids (TSS) in 1,137 gal of wastewater produced

by backwashing one vessel, 2,914 g of solids would be discharged to the sewer. The solids were composed of 2.2, 396, and 1.6 g of arsenic, iron, and manganese, respectively.

Comparison of the distribution system sampling results before and after the system startup showed a significant decrease in arsenic concentration (i.e., from 17.0 to 5.2 µg/L [on average]). Arsenic concentrations in the distribution system were slightly higher than those in the system effluent. Iron was significantly reduced in the distribution system, while manganese remained relatively unchanged. Copper levels in the distribution system increased after the system was put into service, but their concentrations were always below their respective action levels.

The capital investment cost for the system was $128,118, including $103,118 for equipment, $7,500 for site engineering, and $17,500 for installation. Using the system's rated capacity of 60 gpm (86,400 gal/day [gpd]), the normalized capital cost was $2,135/gpm ($1.48/gpd). The O&M cost was $2.26/1,000 gal of water treated and only included the cost associated with labor.

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ABBREVIATIONS AND ACRONYMS

Δp	differential pressure
AAL	American Analytical Laboratories
Al	aluminum
AM	adsorptive media
As	arsenic
ATS	Aquatic Treatment Systems
BL	baseline sampling
Ca	calcium
Cl	chloride
C/F	coagulation/filtration
CRF	capital recovery factor
DBP	disinfection byproduct
DO	dissolved oxygen
EBCT	empty bed contact time
EPA	U.S. Environmental Protection Agency
F	fluoride
Fe	iron
gpd	gallons per day
gpm	gallons per minute
HAA5	haloacetic acids
HCl	hydrochloric acid
HIX	hybrid ion exchanger
hp	horsepower
ICP-MS	inductively coupled plasma-mass spectrometry
i.d.	inner diameter
ID	identification
IDEM	Indiana Department of Environmental Management
IR	iron removal
IX	ion exchange
LCR	Lead and Copper Rule
MCL	maximum contaminant level
MDL	method detection limit
MEI	Magnesium Elektron, Inc.
Mg	magnesium

ABBREVIATIONS AND ACRONYMS (Continued)

Mn	manganese
MRDL	maximum residual disinfectant level
MRDLG	maximum residual disinfectant level goal
mV	millivolts
Na	sodium
NA	not analyzed
NaOCl	sodium hypochlorite
NRMRL	National Risk Management Research Laboratory
NS	not sampled
NTNC	non-transient, non-community
NTU	nephelometric turbidity unit
O&M	operation and maintenance
OIT	Oregon Institute of Technology
ORD	Office of Research and Development
ORP	oxidation-reduction potential
PCM	pump control module
psi	pounds per square inch
PO_4	orthophosphate
POU	point-of-use
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
RO	reverse osmosis
RFP	Request for Proposal
RPD	relative percent difference
Sb	antimony
SDWA	Safe Drinking Water Act
SiO_2	silica
SMCL	secondary maximum contaminant level
$SO4^{2-}$	sulfate
SOC	synthetic organic compound
STS	Severn Trent Services
TDS	total dissolved solids
TOC	total organic carbon
TSS	total suspended solids
TTHM	total trihalomethanes
VOC	volatile organic compound

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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 (As) at 0.05 mg/L. Amended in 1996, the SDWA required that EPA develop an arsenic research strategy and publish a proposal to revise the arsenic MCL by January 2000. On January 18, 2001, EPA finalized the arsenic MCL at 0.01 mg/L (EPA, 2001). In order to clarify the implementation of the original rule, EPA revised the rule text on March 25, 2003, to express the MCL as 0.010 mg/L (10 µg/L) (EPA, 2003). The final rule required all community and non-transient, non-community water systems to comply with the new standard by January 23, 2006.

In October 2001, EPA announced an initiative for additional research and development of cost-effective technologies to help small community water systems (<10,000 customers) meet the new arsenic standard, and to provide technical assistance to operators of small systems to reduce compliance costs. As part of this Arsenic Rule Implementation Research Program, EPA's Office of Research and Development (ORD) proposed a project to conduct a series of full-scale, on-site demonstrations of arsenic removal technologies, process modifications, and engineering approaches applicable to small systems. Shortly thereafter, an announcement was published in the *Federal Register* requesting water utilities interested in participating in Round 1 of this EPA-sponsored demonstration program to provide information on their water systems. In June 2002, EPA selected 17 out of 115 sites to host the demonstration studies.

In September 2002, EPA solicited proposals from engineering firms and vendors for cost-effective arsenic removal treatment technologies for the 17 host sites. EPA received 70 technical proposals for the 17 host sites, with each site receiving from one to six proposals. In April 2003, an independent technical panel reviewed the proposals and provided its recommendations to EPA on the technologies that it determined were acceptable for the demonstration at each site. Because of funding limitations and other technical reasons, only 12 of the 17 sites were selected for the demonstration project. Using the information provided by the review panel, EPA, in cooperation with the host sites and the drinking water programs of the respective states, selected one technical proposal for each site.

In 2003, EPA initiated Round 2 arsenic technology demonstration projects that were partially funded with Congressional add-on funding to the EPA budget. In June 2003, EPA selected 32 potential demonstration sites. In September 2003, EPA again solicited proposals from engineering firms and vendors for arsenic removal technologies. EPA received 148 technical proposals for the 32 host sites, with each site receiving from two to eight proposals. In April 2004, another technical panel was convened by EPA to review the proposals and provide recommendations to EPA with the number of proposals per site ranging from none (for two sites) to a maximum of four. The final selection of the treatment technology at the sites that received at least one proposal was made, again, through a joint effort by EPA, the state regulators, and the host site. Since then, four sites have withdrawn from the demonstration program, reducing the number of sites to 28.

With additional funding from Congress, EPA selected 10 more sites for demonstration under Round 2a. Somewhat different from the Round 1 and Round 2 selection process, Battelle, under EPA's guidance, issued a Request for Proposal (RFP) on February 14, 2007, to solicit technology proposals from vendors and engineering firms. Upon closing of the RFP on April 13, 2007, Battelle received from 14 vendors a total of 44 proposals, which were subsequently reviewed by a three-expert technical review panel convened at EPA on May 2 and 3, 2007. Copies of the proposals and recommendations of the review panel were later provided to and discussed with representatives of the 10 host sites and state regulators in a technology selection meeting held at each host site during April through August 2007. The final selections of the treatment technology were made, again, through a joint effort by EPA, the respective state regulators, and the host sites. A 60-gal/min (gpm) iron removal (IR) system fabricated by US Water Systems in Indianapolis, IN was selected for demonstration at Northeastern Elementary School in Fountain City, IN. The system used ADI's G2® media for filtration of arsenic-laden iron particles.

As of January 2011, 49 of the 50 systems were operational and the performance evaluations of all 49 systems were completed.

1.2 Treatment Technologies for Arsenic Removal

Technologies selected for Rounds 1, 2, and 2a demonstration included adsorptive media (AM), IR, coagulation/filtration (C/F), ion exchange (IX), reverse osmosis (RO), point-of-use (POU) RO, and system/process modification. Table 1-1 summarizes the locations, technologies, vendors, system flowrates, and key source water quality parameters (including As, iron [Fe], and pH). Table 1-2 presents the number of sites for each technology. AM technology was demonstrated at 30 sites, including four with IR pretreatment. IR technology was demonstrated at 12 sites, including four with supplemental iron addition. C/F, IX, and RO technologies were demonstrated at three, two, and one sites, respectively. The Sunset Ranch Development site that demonstrated POU RO technology had nine under-the-sink RO units. The Oregon Institute of Technology (OIT) site classified under AM had three AM systems and eight POU AM units. The Lidgerwood site encompassed only system/process modifications. An overview of the technology selection and system design for the 12 Round 1 demonstration sites and the associated capital costs is provided in two EPA reports (Wang et al., 2004; Chen et al., 2004), which are posted on the EPA Web site at http://www.epa.gov/ORD/NRMRL/arsenic/resource.htm.

1.3 Project Objectives

The objective of the arsenic demonstration program was to conduct full-scale performance evaluations of treatment technologies for arsenic removal from drinking water supplies. The specific objectives were 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 US Water Systems' IR system at Northeastern Elementary School in Fountain City, IN, from September 22, 2008, through, October 29, 2009. The types of data collected included system operation, water quality (both across the treatment train and in the distribution system), residuals, and capital and O&M cost.

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

Demonstration Location	Site Name	Technology (Media)	Vendor	Design Flowrate (gpm)	Source Water Quality		
					As (µg/L)	Fe (µg/L)	pH (S.U.)
Northeast/Ohio							
Carmel, ME	Carmel Elementary School	RO	Norlen's Water	1,200 gpd	21	<25	7.9
Wales, ME	Springbrook Mobile Home Park	AM (A/I Complex)	ATS	14	38[a]	<25	8.6
Bow, NH	White Rock Water Company	AM (G2)	ADI	70[b]	39	<25	7.7
Goffstown, NH	Orchard Highlands Subdivision	AM (E33)	AdEdge	10	33	<25	6.9
Rollinsford, NH	Rollinsford Water and Sewer District	AM (E33)	AdEdge	100	36[a]	46	8.2
Dummerston, VT	Charette Mobile Home Park	AM (A/I Complex)	ATS	22	30	<25	7.9
Houghton, NY[c]	Town of Caneadea	IR (Macrolite)	Kinetico	550	27[a]	1,806[d]	7.6
Woodstock, CT	Woodstock Middle School	AM (Adsorbsia)	Siemens	17	21	<25	7.7
Pomfret, CT	Seely-Brown Village	AM (ArsenX^{np})	SolmeteX	15	25	<25	7.3
Felton, DE	Town of Felton	C/F (Macrolite)	Kinetico	375	30[a]	48	8.2
Stevensville, MD	Queen Anne's County	AM (E33)	STS	300	19[a]	270[d]	7.3
Conneaut Lake, PA	Conneaut Lake Park	IR (Greensand Plus) with ID	AdEdge	250	28[a]	157[d]	8.0
Buckeye Lake, OH	Buckeye Lake Head Start Building	AM (ARM 200)	Kinetico	10	15[a]	1,312[d]	7.6
Springfield, OH	Chateau Estates Mobile Home Park	IR & AM (E33)	AdEdge	250[e]	25[a]	1,615[d]	7.3
Great Lakes/Interior Plains							
Brown City, MI	City of Brown City	AM (E33)	STS	640	14[a]	127[d]	7.3
Pentwater, MI	Village of Pentwater	IR (Macrolite) with ID	Kinetico	400	13[a]	466[d]	6.9
Sandusky, MI	City of Sandusky	IR (Aeralater)	Siemens	340[e]	16[a]	1,387[d]	6.9
Delavan, WI	Vintage on the Ponds	IR (Macrolite)	Kinetico	40	20[a]	1,499[d]	7.5
Goshen, IN	Clinton Christian School	IR & AM (E33)	AdEdge	25	29[a]	810[d]	7.4
Fountain City, IN	Northeastern Elementary School	IR (G2)	US Water	60	27[a]	1,547[d]	7.5
Waynesville, IL	Village of Waynesville	IR (Greensand Plus)	Peerless	96	32[a]	2,543[d]	7.1
Geneseo Hills, IL	Geneseo Hills Subdivision	AM (E33)	AdEdge	200	25[a]	248[d]	7.4
Greenville, WI	Town of Greenville	IR (Macrolite)	Kinetico	375	17[a]	7,827[d]	7.3
Climax, MN	City of Climax	IR (Macrolite) with ID	Kinetico	140	39[a]	546[d]	7.4
Sabin, MN	City of Sabin	IR (Macrolite)	Kinetico	250	34[a]	1,470[d]	7.3
Sauk Centre, MN	Big Sauk Lake Mobile Home Park	IR (Macrolite)	Kinetico	20	25[a]	3,078[d]	7.1
Stewart, MN	City of Stewart	IR &AM (E33)	AdEdge	250	42[a]	1,344[d]	7.7
Lidgerwood, ND	City of Lidgerwood	Process Modification	Kinetico	250	146[a]	1,325[d]	7.2
Lead, SD	Terry Trojan Water District	AM (ArsenX^{np})	SolmeteX	75	24	<25	7.3
Midwest/Southwest							
Willard, UT	Hot Springs Mobile Home Park	IR & AM (Adsorbsia)	Filter Tech	30	15.4[a]	332[d]	7.5
Arnaudville, LA	United Water Systems	IR (Macrolite)	Kinetico	770[e]	35[a]	2,068[d]	7.0
Alvin, TX	Oak Manor Municipal Utility District	AM (E33)	STS	150	19[a]	95	7.8
Bruni, TX	Webb Consolidated Independent School District	AM (E33)	AdEdge	40	56[a]	<25	8.0
Wellman, TX	City of Wellman	AM (E33)	AdEdge	100	45	<25	7.7
Anthony, NM	Desert Sands Mutual Domestic Water Consumers	AM (E33)	STS	320	23[a]	39	7.7

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

Demonstration Location	Site Name	Technology (Media)	Vendor	Design Flowrate (gpm)	Source Water Quality As (µg/L)	Source Water Quality Fe (µg/L)	Source Water Quality pH (S.U.)
	Association						
Nambe Pueblo, NM	Nambe Pueblo Tribe	AM (E33)	AdEdge	145	33	<25	8.5
Taos, NM	Town of Taos	AM (E33)	STS	450	14	59	9.5
Rimrock, AZ	Arizona Water Company	AM (E33)	AdEdge	90[b]	50	170	7.2
Tohono O'odham Nation, AZ	Tohono O'odham Utility Authority	AM (E33)	AdEdge	50	32	<25	8.2
Valley Vista, AZ	Arizona Water Company	AM (AAFS50/ARM 200)	Kinetico	37	41	<25	7.8
		Far West					
Three Forks, MT	City of Three Forks	C/F (Macrolite)	Kinetico	250	64	<25	7.5
Fruitland, ID	City of Fruitland	IX (A300E)	Kinetico	250	44	<25	7.4
Homedale, ID	Sunset Ranch Development	POU RO[f]	Kinetico	75 gpd	52	134	7.5
Okanogan, WA	City of Okanogan	C/F (Electromedia-I)	Filtronics	750	18	69[d]	8.0
Klamath Falls, OR	Oregon Institute of Technology	POE AM (Adsorbsia/ ARM 200/ArsenX^{np}) and POU AM (ARM 200)[g]	Kinetico	60/60/30	33	<25	7.9
Vale, OR	City of Vale	IX (Arsenex II)	Kinetico	525	17	<25	7.5
Reno, NV	South Truckee Meadows General Improvement District	AM (GFH)	Siemens	350	39	<25	7.4
Susanville, CA	Richmond School District	AM (A/I Complex)	ATS	12	37[a]	125	7.5
Lake Isabella, CA	Upper Bodfish Well CH2-A	AM (HIX)	VEETech	50	35	125	7.5
Tehachapi, CA	Golden Hills Community Service District	AM (Isolux)	MEI	150	15	<25	6.9

AM = adsorptive media process; C/F = coagulation/filtration; HIX = hybrid ion exchanger; IR = iron removal; IR with ID = iron removal with iron addition; IX = ion exchange process; RO = reverse osmosis

ATS = Aquatic Treatment Systems; MEI = Magnesium Elektron, Inc.; STS = Severn Trent Services

(a) Arsenic existing mostly as As(III).

(b) Design flowrate reduced by 50% due to system reconfiguration from parallel to series operation.

(c) Withdrew from program in 2007. Selected originally to replace Village of Lyman, NE site, which withdrew from program in June 2006.

(d) Iron existing mostly as Fe(II).

(e) Facilities upgraded systems in Springfield, OH from 150 to 250 gpm, Sandusky, MI from 210 to 340 gpm, and Arnaudville, LA from 385 to 770 gpm.

(f) Including nine residential units.

(g) Including eight under-the-sink units.

Table 1-2. Number of Demonstration Sites Under Each Arsenic Removal Technology

Technologies	Number of Sites
Adsorptive Media[a]	26
Adsorptive Media with Iron Removal Pretreatment	4
Iron Removal (Oxidation/Filtration)	8
Iron Removal with Supplemental Iron Addition	4
Coagulation/Filtration	3
Ion Exchange	2
Reverse Osmosis	1
Point-of-use Reverse Osmosis[b]	1
System/Process Modifications	1

(a) Oregon Institute of Technology (OIT) site at Klamath Falls, OR, had three AM systems and eight POU AM units.

(b) Including nine under-the-sink RO units.

2.0 SUMMARY AND CONCLUSIONS

US Water Systems' IR treatment system using ADI's G2® media was installed and has operated at Northeastern Elementary School in Fountain City, IN since September 22, 2008. Based on the information collected during the one year of system operation, the following conclusions were made relating to the overall objectives of the treatment technology demonstration study.

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

- Chlorination effectively oxidized As(III) and Fe(II) and formed arsenic-laden particles that were filtered by G2® media. Total arsenic concentrations were reduced from 29.4 µg/L (on average) in raw water to 3.6 µg/L (on average) in treated water.
- Iron concentrations were reduced from 1,865 µg/L (on average) in raw water to 99 µg/L (on average) in treated water. Manganese concentrations were unaffected by the IR process.
- The operation of the treatment system significantly lowered arsenic concentrations in the distribution system (i.e., from 17.0 to 5.2 µg/L [on average]). Although lead and copper concentrations were always below their respective action levels, somewhat elevated copper levels were observed in the distribution system water after system startup.

Required system O&M and operator skill levels:

- The daily demand on the operator was typically 20 min to visually inspect the system and record operational parameters.

Process residuals produced by the technology:

- Residuals produced by the operation of the treatment system consisted of only backwash wastewater.
- Backwashing produced 1,137 gal of wastewater per vessel, which contained 2,914 g of solids composed of 2.2, 396, and 1.6 g of arsenic, iron, and manganese, respectively.

Capital and O&M cost of the technology:

- The capital investment for the system was $128,118, including $103,118 for equipment, $7,500 for site engineering, and $17,500 for installation, shakedown, and startup.
- The unit capital cost was $2,135/gpm (or $1.48 gpd) based on a 60-gpm design capacity.
- The increased O&M cost was $2.26/1,000 gal of water treated consisting entirely of labor.

3.0 MATERIALS AND METHODS

3.1 General Project Approach

Following the predemonstration activities summarized in Table 3-1, the performance evaluation study of US Water Systems' iron removal system began on September 22, 2008, and ended on October 29, 2009. Table 3-2 summarizes the types of data collected and considered as part of the technology evaluation process. The overall system performance was evaluated based on its ability to consistently remove arsenic to below the MCL of 10 μg/L through the collection of water samples across the treatment train, as described in the Study Plan (Battelle, 2008). The reliability of the system was evaluated by tracking the unscheduled system downtime and frequency and extent of repair and replacement. The plant operator recorded unscheduled downtime and repair information on a Repair and Maintenance Log Sheet.

Table 3-1. Demonstration Activities and Completion Dates

Activity	Date
Introductory Meeting Held	September 26, 2006
Technology Selection Meeting Held	May 23, 2007
Project Planning Meeting Held	August 10, 2007
Draft Letter of Understanding Issued	August 27, 2007
Final Letter of Understanding Issued	September 10, 2007
Request for Quotation Issued to Vendor	October 8, 2007
Vendor Quotation Received by Battelle	December 3, 2007
Building Construction Began	December 26, 2007
Building Construction Completed	December 28, 2007
Purchase Order Completed and Signed	January 29, 2008
Letter Report Issued	January 29, 2008
Engineering Package Submitted to IDEM	April 22, 2008
System Permit Issued by IDEM	May 29, 2008
Equipment Arrived at Site	July 23, 2008
Study Plan Issued	July 25, 2008
System Installation Completed	August 20, 2008
System Shakedown Completed	September 2, 2008
Performance Evaluation Began	September 22, 2008
Sampling Completed	September 29, 2009
Performance Evaluation Completed	October 29, 2009

IDEM = Indiana Department of Environmental Management

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

The quantity of aqueous and solid residuals generated was estimated by tracking the volume of backwash wastewater produced during each backwash cycle. Backwash water and solids were sampled and analyzed for chemical characteristics.

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 encountered, materials and supplies needed, and associated labor and cost incurred
System O&M and Operator Skill Requirements	–Pre- and post-treatment requirements –Level of automation for system operation and data collection –Staffing requirements including number of operators and laborers –Task analysis of preventative maintenance including number, frequency, and complexity of tasks –Chemical handling and inventory requirements –General knowledge needed for relevant chemical processes and health and safety practices
Residual Management	–Quantity and characteristics of aqueous and solid residuals generated by system operation
Cost-Effectiveness	–Capital cost for equipment, engineering, and installation –O&M cost for chemical usage, electricity consumption, and labor

The cost of the system was evaluated based on the capital cost per gpm (or gal/day [gpd]) of design capacity and the O&M cost per 1,000 gal of water treated. This task required tracking the capital cost for equipment, engineering, and installation, as well as the O&M cost for media replacement and disposal, chemical supply, electrical usage, and labor.

3.2 System O&M and Cost Data Collection

The plant operator performed daily, biweekly, and monthly system O&M and data collection according to instructions provided by the vendor and Battelle. On a regular basis, the plant operator recorded system operational data such as pressure, flowrate, totalizer, and hour meter readings on a System Operation Log Sheet (see Appendix A) and conducted visual inspections to ensure normal system operations. If any problems occurred, the plant operator contacted the Battelle Study Lead, who determined if the vendor should be contacted for troubleshooting. The plant operator recorded all relevant information, including the problems encountered, course of actions taken, materials and supplies used, and associated cost and labor incurred on the Repair and Maintenance Log Sheet. During each sampling event, the plant operator also measured temperature, pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), and chlorine residuals and recorded the data on an Onsite Water Quality Parameters Log Sheet.

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

3.3 Sample Collection Procedures and Schedules

To evaluate system performance, samples were collected from the wellhead, across the treatment plant, during the oxidation/filtration vessel backwash, and from the distribution system. Table 3-3 presents the sampling schedules and analytes measured during each sampling event. Specific sampling requirements for analytical methods, sample volumes, containers, preservation, and holding times are presented in Table 4-1 of the EPA-endorsed Quality Assurance Project Plan (QAPP) (Battelle, 2007). The procedure for arsenic speciation is described in Appendix A of the QAPP.

3.3.1 Source Water. During the initial site visit on September 26, 2006, one set of source water samples from Well No. 1 was collected and speciated using an arsenic specitation 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.

3.3.2 Treatment Plant Water. 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 biweekly sampling, alternating between "regular" and "speciation" sampling. Regular sampling involved taking samples at the wellhead (IN), after chlorination (AC), and after Vessels A, B, C, and D (TA, TB, TC, and TD) and having them analyzed for the analytes listed under regular sampling in Table 3-3. Speciation sampling involved collecting and speciating samples at IN and AC and after effluent from the four vessels was combined (TT) and having them analyzed for the analytes listed under speciation sampling in Table 3-3. The actual sampling frequency varied from 3.5 to eight weeks for regular sampling and from two to seven weeks for speciation sampling. On August 31, 2009 when the speciation sampling was performed, regular samples also were taken from TA through TD.

3.3.3 Backwash Wastewater and Solids. The plant operator collected backwash wastewater samples from each vessel on four occasions. Over the duration of backwash for each vessel, a side stream of backwash wastewater was directed from the tap on the backwash wastewater discharge line to a clean, 32-gal plastic container at approximately 1 gpm. After the contents in the container were thoroughly mixed, one aliquot was collected as is and the other filtered with 0.45-µm disc filters. The samples were analyzed for analytes listed in Table 3-3.

Once during the 13-month study period, the contents in a 32-gal plastic container were allowed to settle and the supernatant was removed by siphoning using a piece of plastic tubing. Care was taken to avoid agitating the settled solids in the container. The remaining solids/water mixture was then transferred to a 1-gal plastic jar. After the solids in the jar were settled and the supernatant was carefully decanted, one aliquot of the solids/water mixture was air-dried before being acid-digested and analyzed for the metals listed in Table 3-3.

3.3.4 Spent Media. The media in the oxidation/filtration vessels was not replaced, therefore, no spent media was produced as residual solids during this demonstration study.

3.3.5 Distribution System Water. Water samples were collected from the distribution system to determine the impact of the arsenic treatment system on the water chemistry in the distribution system, specifically, the arsenic, lead and copper levels. Prior to the system start-up from April to August 2008, four sets of baseline distribution system water samples were collected at the kitchen sink (DS1), which was one of the Lead and Copper Rule (LCR) locations used by the school for LCR sampling. On August 14, 2008, two additional distribution locations were added: north water fountain (DS2) and south water fountain (DS3). Only one set of distribution system water samples was collected from DS2 and DS3

Table 3-3. Sampling Schedule and Analytes

Sample Type	Sample Locations[a]	No. of Samples	Frequency	Analytes	Sampling Date
Source Water	IN	1	Once (During initial site visit)	Onsite: pH and temperature Offsite: As (III), As(V), As (total and soluble), Fe (total and soluble), Mn (total and soluble), V (total), Na, Ca, Mg, Cl, F, NO_3, NO_2, NH_3, SO_4, SiO_2, PO_4, P (total), turbidity, alkalinity, TDS, and TOC	09/26/06
Treatment Plant Water (Speciation)	IN, AC, and TT	3	Every 2 to 7 weeks	Onsite: pH, temperature, DO, ORP, and total and/or free Cl_2[c,d] Offsite: As(III), As(V), As (total and soluble), Fe (total and soluble), Mn (total and soluble), Ca, Mg, F, NO_3, NH_3, SO_4, SiO_2, P (total), turbidity, alkalinity, and TOC	10/09/08, 11/06/08, 12/04/08, 01/07/09, 02/11/09, 03/03/09, 03/31/09, 04/28/09, 05/12/09, 06/09/09, 07/30/09, 08/31/09, 09/15/09 (see Appendix B)
Treatment Plant Water (Regular)	IN, AC, TA, TB, TC, and TD	6	Every 3.5 to 8 weeks	Onsite: : pH, temperature, DO, ORP, and total and/or free Cl_2[e] Offsite: As (total), Fe (total), Mn (total), NH_3, SiO_2, turbidity, alkalinity, and TOC	10/22/08, 11/20/08, 12/29/08, 01/22/09, 02/23/09, 03/17/09, 04/14/09, 05/26/09, 07/06/09, 08/31/09[f], 09/29/09 (see Appendix B)
Distribution System Water[b]	Kitchen Sink (DS1), North Water Fountain (DS2), and South Water Fountain (DS3)	3	Monthly	As (total), Fe (total), Mn (total), Cu, Pb, pH, and alkalinity	Baseline Sampling: 04/01/08, 06/10/08, 07/01/08, 08/07/08[g] 10/22/08, 11/20/08, 12/17/08, 01/22/09, 02/23/09, 03/17/09, 04/14/09, 05/12/09, 06/09/09, 07/06/09, 08/31/09, 09/29/09
Backwash Wastewater	Backwash Discharge Line (BW)	2	Every 3 to 4 months	As (total and soluble), Fe (total and soluble), Mn (total and soluble), pH, TDS, TSS, and SiO_2,	12/03/08, 04/08/09, 07/06/09, 10/13/09
Backwash Solids	Wastewater Container from Each Vessel	4	Once	Total Al, As, Ba, Ca, Cd, Cu, Fe, Mg, Mn, Ni, P, Pb, Si, Zn	07/06/09

(a) Abbreviations in parenthesis corresponding to sample locations shown in Figure 4-5, i.e., IN = at wellhead; AC = after chlorination; TA = after Vessel A; TB = after Vessel B; TC = after Vessel C;

Table 3-3. Sampling Schedule and Analytes (Continued)

TD = after Vessel D; TT = after total combined effluent; BW = backwash discharge line; DS1 = distribution system sampling location 1; DS2 = distribution system sampling location 2; DS3 = distribution system sampling location 3.
(b) Four baseline sampling events taking place from April through August 2009 prior to system startup.
(c) Free chlorine measurements discontinued on April 28, 2009.
(d) Total and free chlorine measured at IN location during some sampling events.
(e) Except for two occasions on October 22, 2008, and January 22, 2009, measurements were made at IN, AC, and TT locations.
(f) Samples also taken at TA, TB, TC, and TD locations during speciation sampling event.
(g) DS2 and DS3 samples collected on August 14, 2008.
DO = dissolved oxygen; ORP = oxidation-reduction potential; TDS = total dissolved solids; TOC = total organic carbon; TSS = total suspended solids

prior to system startup. Following system startup, distribution system sampling continued on a monthly basis at the three aformentioned sampling locations.

The plant operator collected the samples following an instruction sheet developed in accordance with the *Lead and Copper Monitoring and Reporting Guidance for Public Water Systems* (EPA, 2002). The date and time of last water usage before sampling and of actual sample collection were recorded for calculation of stagnation time. All samples were collected from a cold-water faucet that had not been used for at least 6 hr to ensure that stagnant water was sampled.

3.4 Sampling Logistics

3.4.1 Preparation of Arsenic Speciation Kits. The arsenic field speciation method used an anion exchange resin column to separate the soluble arsenic species, As(V) and As(III) (Edwards et al., 1998). Resin columns were prepared in batches at Battelle laboratories in accordance with the procedures detailed in Appendix A of the EPA-endorsed QAPP (Battelle, 2007).

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 label consisting of 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 a specific water facility, sampling date, a two-letter code for a specific sampling location, and a one-letter code designating the arsenic speciation bottle (if necessary). The sampling locations at the treatment plant were color-coded for easy identification. The labeled bottles for each sampling location were placed in separate zip-lock bags and packed in the cooler.

In addition, all sampling- and shipping-related materials, such as disposable gloves, sampling instructions, chain-of-custody forms, prepaid/addressed FedEx air bills, and bubble wrap, were included. The chain-of-custody forms and air bills were complete except for the operator's signature and the sample dates and times. After preparation, the sample cooler was sent to the site via FedEx for the following week's sampling event.

3.4.3 Sample Shipping and Handling. After sample collection, samples for offsite analyses were packed carefully in the original coolers with wet ice and shipped to Battelle. Upon receipt, 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 metals analyses were stored at Battelle's inductively coupled plasma-mass spectrometry (ICP-MS) laboratory. Samples for other water analyses were packed in separate coolers and picked up by couriers from American Analytical Laboratories (AAL) in Columbus, OH, which was 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, 2007) were followed by Battelle's ICP-MS laboratory and AAL. Laboratory quality assurance/quality control (QA/QC) of all methods followed the prescribed guidelines. Data quality in terms of precision, accuracy, method detection limits (MDL), and completeness met the criteria established in the QAPP (i.e., relative percent difference [RPD] of 20%, percent recovery of 80 to 120%, and completeness of 80%). The QA data associated with each analyte will be presented and evaluated in a QA/QC Summary Report to be prepared under separate cover upon completion of the Arsenic Demonstration Project.

Field measurements of pH, temperature, DO, and ORP were conducted by the plant operator using a VWR Symphony SP90M5 Handheld Multimeter, which was calibrated for pH and DO prior to use following the procedures provided in the user's manual. The ORP probe also was checked for accuracy by measuring the ORP of a standard solution and comparing it to the expected value. The plant operator collected a water sample in a clean, plastic beaker and placed the Symphony SP90M5 probe in the beaker until a stable value was obtained. The plant operator also performed free and total chlorine measurements using Hach chlorine test kits following the user's manual.

4.0 RESULTS AND DISCUSSION

4.1 Facility Description and Pre-existing Treatment System Infrastructure

Northeastern Elementary School is located at 7295 U.S. 27 North in Fountain City, IN. The facility is classified as a non-transient, non-community (NTNC) water system, which, per EPA definition, serves at least the same 25 non-resident individuals during six months of the year. Prior to the performance evaluation study, the facility supplied water to approximately 600 students and staff members during the academic year. Located in the school's mechanical room, the pre-existing water system included inlet piping, a chlorine addition system, a bulk storage tank, and a water softener (Figure 4-1). The water system was supplied by a single well, i.e., Well No. 1, which is 8-in in diameter and approximately 126 ft deep. The well was equipped with a three-phase, 460-volt, 5-horsepower (hp) submersible pump rated for 50 gpm. The submersible well pump typically operated 2 hr/day to meet the average daily demand of approximately 5,000 gal.

Figure 4-1. Pre-existing Water System at Northeastern Elementary School in Fountain City, IN
(Storage Tank [top left], Water Softener [top right], and Chlorine Addition System [bottom])

Source water was piped from the supply well to the school's mechanical room where it was first chlorinated with a sodium hypochlorite (NaOCl) solution to maintain a target free chlorine residual level of 0.2 mg/L (as Cl_2). Following chlorination the water was stored in a 750-gal, vertical, bulk storage tank constructed of carbon steel. Figure 4-2 shows a detailed view of the existing chlorination pump and injection port prior to the storage tank. Following the storage tank, water was divided into two separate streams for cold and hot water distribution. The stream dedicated for hot water distribution was further treated by a water softener prior to heating. Figure 4-3 shows the water softener and water heater.

Figure 4-2. Chlorination Pump and Injection Port

4.1.1 Source Water Quality. Source water samples were collected on September 26, 2006, when a Battelle staff member traveled with EPA to the site for an introductory meeting for this demonstration project. Table 4-1 presents the analytical results along with the data provided by EPA and Indiana Department of Environmental Management (IDEM). Overall, Battelle's data are comparable to those provided by EPA and IDEM.

Arsenic. Historic total arsenic concentrations in Well No. 1 water ranged from 2.7 to 27.0 µg/L. Based on the speciation results obtained by Battelle on September 26, 2006, out of 26.9 µg/L of total arsenic, 8.8 µg/L existed as particulate arsenic. For the soluble fraction, 12.6 and 5.5 µg/L existed as As(III) and As(V), respectively. Therefore, chlorination was used to oxidize soluble As(III) to soluble As(V). The As(V) formed co-precipitated with and/or adsorbed onto iron solids to form As(V)-laden iron particles prior to pressure filtration.

Figure 4-3. Water Softener (left) and Water Heater (right)

Ammonia and Total Organic Carbon. Well No. 1 water contained between 0.7 to 1.0 mg/L of ammonia (as N) and 1.6 to 2.8 mg/L of organic carbon (as C). When in contact with chlorine, ammonia will react with chlorine to form chloramines, which most likely will not react with organic carbon, to the extent as chlorine does, to form disinfection byproducts (DBPs), such as total trihalomethanes (TTHMs) and haloacetic acids (HAA5). The stoichiometric quantity of chlorine consumed by the reaction with ammonia is 5:1 (w/w) with chlorine expressed as Cl_2 and ammonia as N. The stoichiometric quantity of chlorine consumed to completely oxidize the chloramines formed, or to reach the breakpoint chlorination, is 7.6:1 (w/w). From the metal data presented in Table 4-1, 0.7 mg/L of chlorine (as Cl_2) will be required to oxidize reduced metals, including As(III), Fe(II), and Mn(II). To achieve the target free chlorine residual level of 0.2 mg/L (as Cl_2), 6.2 to 8.5 mg/L of chlorine (as Cl_2) will be needed, including:

- 0.7 mg/L of chlorine (as Cl_2) to react with 12.6 µg/L of As(III), 855 µg/L of Fe(II), and 53.1 µg/L of Mn(II)
- 5.3 to 7.6 mg/L of chlorine (as Cl_2) to completely oxidize 0.7 to 1.0 mg/L of ammonia (as N) at the breaking point
- 0.2 mg/L of chlorine (as Cl_2) to provide the required 0.2 mg/L of free chlorine residual.

The use of 6.2 to 8.5 mg/L of chlorine (as Cl_2) will add to the chemical cost, increase the formation potential of DBPs, and exceed the maximum residual disinfectant level (MRDL) and maximum residual disinfectant level goal (MRDLG) of 4 mg/L (as Cl_2) as stipulated in the Stage 1 Disinfectants and Disinfection Byproducts Rule (http://www.epa.gov/OGWDW/mdbp/dbp1.html).

Table 4-1. Source Water Data for Northeastern Elementary School in Fountain City, IN

Parameter	Unit	EPA Data		Battelle Data	IDEM Data
Date		*02/07/06*	*09/26/06*		*09/93–09/06*
pH	S.U.	NA	NA	7.5	NA
Temperature	°C	NA	NA	25.0	NA
Total Alkalinity (as $CaCO_3$)	mg/L	NA	317	337	NA
Total Hardness (as $CaCO_3$)	mg/L	234	218	255	NA
Turbidity	NTU	NA	NA	5.8	NA
Total Dissolved Solids	mg/L	NA	NA	304	NA
Total Organic Carbon	mg/L	2.8	NA	1.6	NA
Nitrate (as N)	mg/L	NA	NA	<0.05	0.28–0.95
Nitrite (as N)	mg/L	NA	NA	<0.05	<0.01–0.09
Ammonia (as N)	mg/L	NA	1.0	0.7	NA
Chloride	mg/L	NA	<5	2	NA
Fluoride	mg/L	NA	NA	1.5	1.6–2.2
Sulfate	mg/L	2.1	2.4	2.0	<5
Silica (as SiO_2)	mg/L	13.5	13.4	13.9	NA
Orthophosphate (as PO_4)	mg/L	NA	0.01	<0.1	NA
P (as PO_4)	mg/L	<0.2	<0.2	<0.03	NA
Al (total)	µg/L	<25	<25	NA	NA
As (total)	µg/L	20.0	19.0	26.9	2.7–27.0
As (soluble)	µg/L	NA	NA	18.1	NA
As (particulate)	µg/L	NA	NA	8.8	NA
As(III)	µg/L	NA	NA	12.6	NA
As(V)	µg/L	NA	NA	5.5	NA
Fe (total)	µg/L	1,292	1,114	1,547	NA
Fe (soluble)	µg/L	NA	NA	855	NA
Mn (total)	µg/L	49.4	49.6	53.5	NA
Mn (soluble)	µg/L	NA	NA	53.1	NA
Sb (total)	µg/L	<25	<25	NA	<1–6
V (total)	µg/L	NA	NA	<0.1	NA
Na (total)	mg/L	27.8	26.9	29.0	21–26
Ca (total)	mg/L	54.6	51.2	57.9	NA
Mg (total)	mg/L	23.8	21.9	26.7	NA

IDEM = Indiana Department of Environmental Management
NA = Not Available

Therefore, the chlorine dosage must be significantly reduced to levels such as 1 mg/L (as Cl_2), by adding only 1.7 mg/L of chlorine (as Cl_2):

- 0.7 mg/L of chlorine (as Cl_2) to react with 12.6 µg/L of As(III), 855 µg/L of Fe(II), and 53.1 µg/L of Mn(II),
- 1.0 mg/L of chlorine (as Cl_2) to react with 0.2 mg/L of ammonia (as N) and form 1.0 mg/L of combined chlorine (existing primarily as monochloramine).

Although less effective, the 1 mg/L combined chlorine residuals will provide the needed disinfection in the distribution system and will not cause damages to the cationic exchange resin in the softening unit located downstream from the treatment system and pressure tank. The untreated ammonia at 0.5 to 0.8 mg/L (as N) can be further removed by the softener.

Iron and Manganese. Total iron concentrations in Well No. 1 water ranged from 1,114 to 1,547 µg/L, which exceeded the 300-µg/L secondary maximum contaminant level (SMCL). Battelle's speciation results indicated that, out of 1,547 µg/L of total iron, 855 µg/L (or 55%) existed as soluble iron, which is 47 times the soluble arsenic level (i.e., 18.1 µg/L) mentioned above. EPA's February 7 and September 26, 2006 total iron results, i.e., 1,292 and 1,114 µg/L, respectively, were slightly lower than Battelle's total iron result. No historical iron data were available from IDEM. The presence of soluble iron in source water will help remove arsenic once an oxidant, such as chlorine, is introduced to raw water. The use of chlorination prior to the G2® media would oxidize and precipitate iron, enabling removal of arsenic-laden iron solids via filtration through the media.

Total manganese concentrations ranged from 49.4 to 53.5 µg/L, which, based on the data obtained by Battelle on September 26, 2006, existed almost entirely as soluble manganese.

Competing Anions Based on the results shown in Table 4-1, concentrations of silica (13.4 to 13.9 mg/L) and phosphate (less than the MDL) in raw water do not appear to be high enough to impact the IR process.

Other Water Quality Parameters. Battelle's data indicate a pH value of 7.5, which is within the commonly-agreed target range of 5.5 to 8.5 for arsenic removal via IR. The raw water samples also were analyzed for additional parameters as listed in Table 4-1. Collectively, total hardness concentrations ranged from 218 to 255 mg/L (as $CaCO_3$); nitrate from <0.05 to 0.95 mg/L (as N); nitrite from <0.01 to 0.09 mg/L (as N), and sodium from 21 to 29.0 mg/L. Turbidity was 5.8 nephelometric turbidity unit (NTU) and total dissolved solids (TDS) were 304 mg/L. All other analytes were below detection limits and/or anticipated to be low enough not to adversely affect the arsenic removal process.

4.1.2 Distribution System. Based on the information provided by the facility, the distribution system was comprised of a combination of copper, galvanized, and polyvinyl chloride (PVC) piping. The pipe material between the supply well and the mechanical room was a combination of galvanized and PVC piping and the piping within the building was primarily copper. Three locations within the school (kitchen sink, north water fountain, and south water fountain) were selected for monthly baseline and distribution system water sampling to evaluate the effect of the treatment system on the distribution system water quality.

Northeastern Elementary School samples water periodically for several parameters. Raw water samples are collected quarterly for arsenic; yearly for nitrate; once every three years for cyanide, volatile organic compounds (VOCs), synthetic organic compounds (SOC), and inorganic compounds (IOCs). Distribution system water samples are collected yearly for HAA5 and TTHMs, once every three years under LCR, and once every nine years for asbestos.

4.2 Treatment Process Description

This section provides a general technology description and site-specific details on US Waters Systems' IR system using ADI's G2® as a filtration media.

4.2.1 Technology Description. Developed by ADI, G2® is an adsorptive/filtration media consisting of a granular, calcined diatomite substrate coated with ferric hydroxide. Because of the presence of elevated levels of soluble iron in raw water and because of the addition of chlorine to raw water to oxide As(III), arsenic-laden iron solids were formed and had to be removed via filtration. Therefore, G2® media acted more like a filtration media than an adsorptive media. Table 4-2 presents physical and chemical properties of G2® media. G2® is delivered in dry, granular form and has NSF International (NSF) Standard 61 approval for use in drinking water. The G2® media require a pre-

Table 4-2. Physical and Chemical Properties of G2® Media Provided by ADI

Physical Properties	
Parameter	**Value**
Matrix	Diatomite impregnated with ferric hydroxide
Physical Form	Dry granules
Color	Dark brown
Bulk Density (lb/ft^3)	47
Specific Gravity (dry)	0.75
Hardness (lb/in^2)	210
Effective Size (mm)	0.32
Uniformity Coefficient	1.8–2.0
Bulk Relative Density	1.073
Adsorption (%)	51.1
Chemical Analysis	
Constituents	**Weight %**
Fe	5– 30
Na	9–10
Al	0.5
Diatomaceous Earth (a silica-based material)	Balance
Trace Elements	< 0.1

conditioning step prior to use. Details concerning the pre-conditioning step are presented in Section 4.2.2.

The IR system is a fixed-bed, down-flow filtration system. Water with arsenic-laden iron particles was pumped through four G2® filtration vessels to remove the solids. Solids accumulated in the vessels were then removed from the media beds via backwash. Backwash wastewater generated was discharged to the sanitary sewer.

4.2.2 System Design and Treatment Process. The treatment system consisted of a chlorine injection system (pre-existing), four parallel filtration vessels (with a balance header to ensure equal flows to the four vessels), and a pressure tank (pre-existing) prior to the distribution system. Figure 4-4 presents a simplified system schematic showing only one filtration vessel and associated instrumentation. Table 4-3 specifies key system design parameters. Figure 4-5 presents a process flowchart along with the sampling/analysis schedule. Key process components of the treatment system are discussed as follows:

- **Intake** – Raw water was pumped from Well No. 1 and fed to the treatment system via a 3-in copper pipe. The well pump was rated at 50 gpm, which could not be verified due to the lack of a flow meter at the wellhead.
- **Pre-chlorination** – Chlorine was added to raw water using a chlorine addition system (Figure 4-6) consisting of a 5-gal/day (gpd) Stenner peristaltic pump (Model 85MPHP5), a Stenner pump control module (PCM), a SeaMetrics pulse meter (MJ-Series), a chlorine injection tap, a 30-gal polyethylene chemical feed tank (containing a 12.5% NaOCl solution), and a 2-in in-line mixer. When water flowed through the SeaMetrics pulse meter, a signal was sent to the PCM, which, in turn, sent a signal to the Stenner pump to dose NaOCl through the injection tap. The PCM was set at 55% based on calculations using equations provided by the manufacturer. Chemical consumption was monitored by visually inspecting and measuring levels of NaOCl in the day tank on a daily basis and recording the levels on field log sheets.

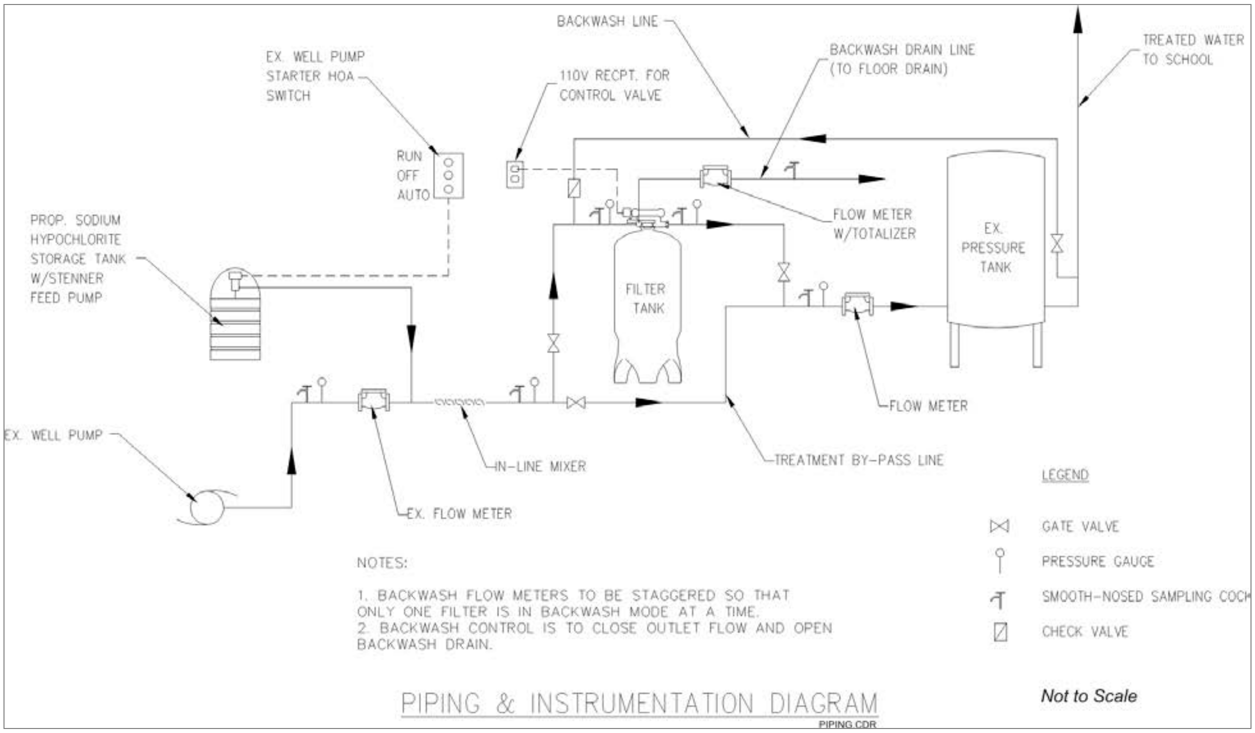

Figure 4-4. Simplified Schematic of US Water Systems' Iron Removal System

Table 4-3. Key System Design Parameters

Parameter	Value	Remarks
Prechlorination		
Target Dose (mg/L [as Cl_2])	1.7	–
Target Combined Residual (mg/L [as Cl_2])	1.0	–
G2® Filtration Vessels		
No. of Vessels	4	–
Configuration	Parallel	–
Vessel Size (in)	36 D × 72 H	Composite poly-glass
Vessel Cross Sectional Area (ft^2)	7.1	–
Media Quantity (ft^3)	100	Four vessels; 25 ft^3 in each vessel
Media Bed Depth (in)	42	–
Design Flowrate (gpm/vessel)	15	60 gpm total
Hydraulic Loading Rate (gpm/ft^2)	2.1	–
EBCT (min)	12.5	15 gpm flowrate through each vessel
Average Use Rate (gal/day)	5,000	Facility estimated
Backwash		
Backwash Flowrate (gpm)	40	–
Backwash Hydraulic Loading Rate (gpm/ft^2)	5.7	–
Backwash Duration (min/vessel)	18	–
Backwash Wastewater Generated (gal/vessel)	720	2,880 gal per event
Design Backwash Frequency (times/month)	2	–

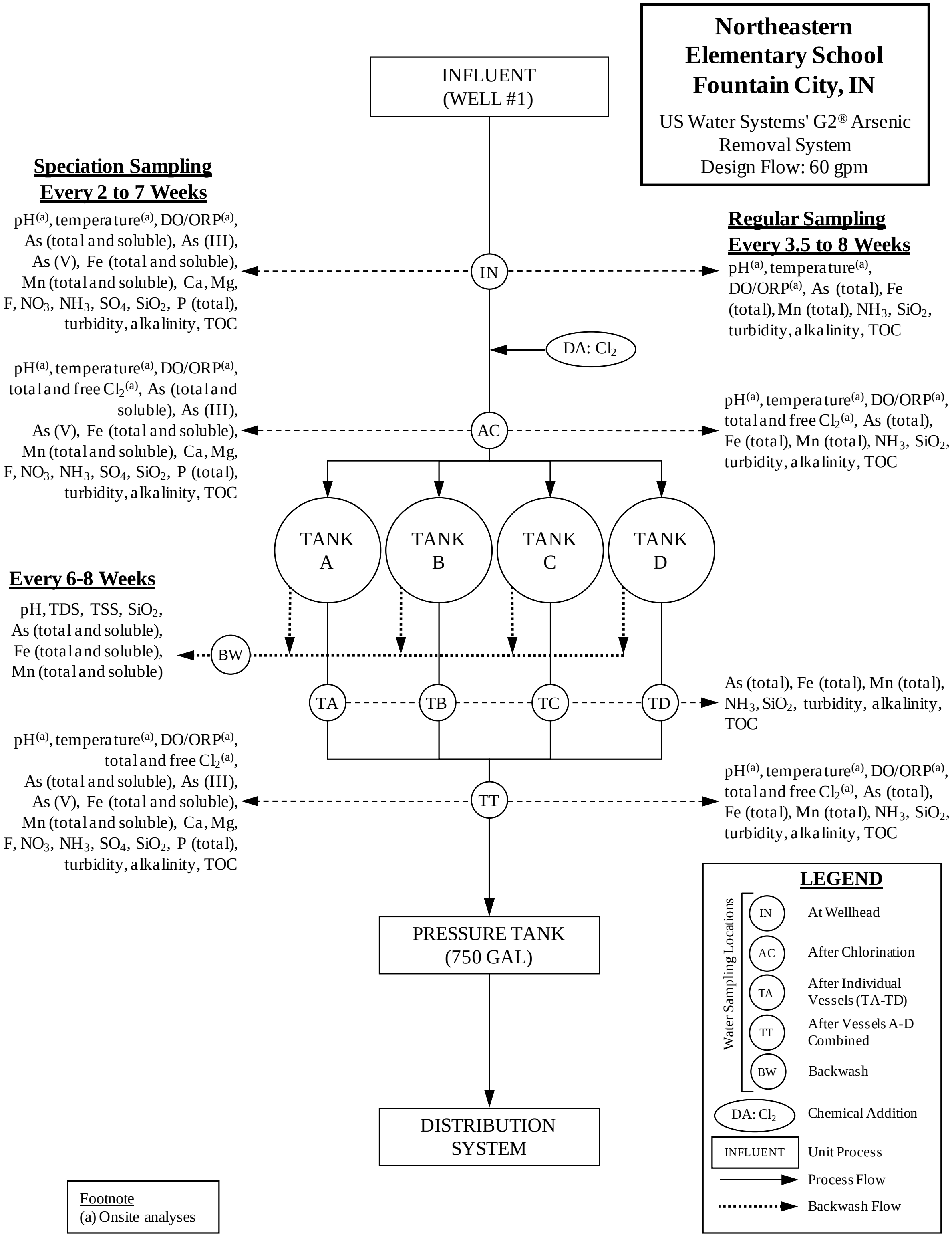

Figure 4-5. Process Flow Diagram and Sampling Locations

Figure 4-6. Chlorine Addition System
(Stenner Pump and 30-gal Day Tank [top left], Stenner Pump Control Module [top right], SeaMetrics Pulse Meter [bottom left], and 2-in inline mixer [bottom right])

Since raw water contained 0.7 to 1.0 mg/L (as N) of ammonia, it was necessary to add enough chlorine (i.e., 7.6 times of 0.7 to 1.0 mg/L plus the amount required to oxidize all reducing species) to reach the breakpoint. Breakpoint chlorination would ensure complete removal of ammonia and chloramines and leave free chlorine residuals in the treated water. Due to the high levels of chlorine that would be required to reach the breakpoint, only the amount of chlorine necessary to oxidize reducing metals (i.e., 0.7 mg/L [as Cl_2]) and to produce 1.0 mg/L of combined chlorine residuals (i.e., 1.0 mg/L [as Cl_2]) was added to the water. This resulted in a total chlorine dose of 1.7 mg/L of chlorine (as Cl_2).

The water system was required to test for total and free chlorine residuals on days that school was in session. Meanwhile, total chlorine residuals were controlled to <1 mg/L (as Cl_2) in order to minimize any adverse effect on the resin in the downstream softener.

- **Filtration** – The treatment system consisted of four 36-in × 72-in composite poly-glass vessels configured in parallel, each containing 25 ft^3 of G2® media (100 ft^3 total) underlain by washed gravel. Each vessel had a 6-in flange opening on the top for loading media and assessing vessel contents. A GE Magnum IT valve and GE Logix 764 controller were installed on each vessel. The GE Logix 764 controllers were used for setting custom parameters such as backwashing frequency, external notifications for alarm conditions, and other inputs and outputs. Through 2-in piping, water flowed in parallel into the vessels, from upper distributors downward though the media and then collected at the bottom through high-flow slotted hub and lateral assemblies. The treated water then traveled up through 1.5-in riser piping in the vessels before it exited at the outlet of the Magnum IT valves.

  Based on a design flowrate of 15 gpm/vessel (60 gpm total), the empty bed contact time (EBCT) was 12.5 min and the hydraulic loading rate on each filter was 2.1 gpm/ft^2. The anticipated pressure drop across a clean bed was approximately 2 lb/in^2 (psi), and the anticipated pressure differential across the whole system was 10 psi. The flow through each vessel was monitored using a flow meter and totalizer that was built in to the GE Magnum IT valve. Figure 4-7 shows filter vessels, Magnum IT valves, and the Logix 764 controller.

  Before the system could be put into service, the media had to be conditioned to lower its pH, from as high as 11.5 to less than 8. Details on the conditioning procedure are discussed in Section 4.3.3.

Figure 4-7. Magnum IT Valves and Logix 764 Controllers on G2® Filtration Vessels

- **Filter Backwash** – Due to accumulation of iron solids in the media, the filter beds needed to be backwashed to remove the solids and fluff the media to minimize channeling. Backwashing might be performed manually or automatically with either time, throughput, or pressure differential (Δp) setpoint. The vessels were backwashed individually with treated water from the 750-gal pressure tank and supplemental well water when the pressure tank reached its low-pressure setpoint. US Water Systems recommended that backwash be performed every two to three weeks at a flowrate of 40 gpm for 18 min. The amount of wastewater produced was 720 gal/vessel (or 2,880 gal per event), which was discharged directly into the sump and then to the sanitary sewer. Under IDEM regulations, no permit was necessary for the discharge.

4.3 System Installation

US Water Systems completed system installation and shakedown on September 2, 2008. The following briefly summarizes system installation activities, including permitting, building preparation, and system installation, shakedown, and startup.

4.3.1 Permitting. Design drawings and a process description of the proposed treatment system were submitted to IDEM by Ladd Engineering on April 22, 2008. IDEM did not have any review comments and the permit was issued on May 29, 2008.

4.3.2 Building Preparation. The pre-existing system was located on an elevated concrete pad in the school's utility room. To accommodate the new treatment system, an extension to the pre-existing concrete pad was poured to bring the floor level to that of the pre-existing pad. The construction was funded by the school and took approximately three days to complete (i.e., December 26 to 28, 2007).

4.3.3 Installation, Shakedown, and Startup. System components and materials were delivered by US Water Systems to the school starting the week of July 28, 2008. The system was built onsite (not prefabricated). System fabrication and installation took place over the next three weeks and were completed on August 20, 2008. Installation activities included placing the vessels, building all connective piping between vessels (including a backwash discharge line to the sanitary sewer), connecting the system to tie-in points, and assembling the chlorine injection system. Figure 4-8 shows photographs of the treatment system.

Upon completion of system installation and prior to media loading, the system was tested hydraulically for pressure losses and leaks on August 20, 2008. Minimal pressure losses ($\leq$ 2 psi) were observed across each vessel and no leaks were detected in any piping or joints. After the vessels were drained, 500 lb of washed gravel underbedding and 20 ft^3 of G2® media were loaded into each vessel on August 25, 2008. Freeboard measurements were taken following gravel underbedding and G2® media loading. The amount of G2® media loaded (20 ft^3/vessel) was less than the design value of 25 ft^3/vessel. After the control valves were reinstalled on the vessels, the system was re-pressurized.

On August 28, 2008, the media in each vessel was backwashed (or "conditioned" per vendor) at 42 gpm for approximately 25 min. The wastewater produced was collected in a 500-gal holding tank. Once the holding tank was full, backwash was temporarily suspended and the pH of the wastewater was measured and adjusted, if needed, using hydrochloric acid (HCl) before being discharged to the sanitary sewer. This process was repeated until the wastewater pH was less than 8 and until the wastewater was free of particulate. Approximately 1,000 gal of wastewater was produced from each vessel (or 4,500 gal from all four vessels). Figure 4-9 presents pictures of G2® media conditioning. Upon completion of media conditioning, the control valves were removed from the vessels for freeboard measurements again. Based upon these measurements, media volume in each vessel was calculated to be 17.7 ft^3/vessel (or 70.8 ft^3

Figure 4-8. Treatment System Installed
(Filtration Vessels with Magnum IT Valves and Logix 764 Controllers [top left], Backwash Discharge Line [top right], Flowmeter/Totalizer on Backwash Discharge Line [bottom])

total). Table 4-4 presents freeboard measurements before and after media backwashing (or media conditioning) along with calculated media volumes.

On September 5, 2008, the treatment system was disinfected by increasing the chlorine dosage at the system inlet to approximately 40 mg/L (as Cl_2). The system was allowed to sit for 24 hr before being flushed of residual chlorine. After flushing, the chlorine dosage was reset for 0.5 mg/L (as Cl_2) of residuals at the system outlet. An initial bacteria sample collected by US Water Systems on September 10, 2008, returned negative. Per IDEM request, two additional bacteria samples were collected on October 9, 2008, with both results returning negative. The results from the three bacteria tests were submitted to IDEM on October 21, 2008.

Figure 4-9. Conditioning of G2® Media

Table 4-4. Freeboard Measurements and Media Volumes Before and After Backwash (or Media Conditioning)

Measurement	Vessel A	Vessel B	Vessel C	Vessel D
To Top of Gravel (in)	63	63	63	63
Before Backwash (or Media Conditioning)				
To Top of Media (in)	29.5	29.25	29.5	29.5
Bed Depth (in)	33.5	33.75	33.5	33.5
Media Volume (ft^3)	19.7	19.9	19.7	19.7
Total Volume (ft^3)	**79.0**			
After Backwash (or Media Conditioning)				
To Top of Media (in)	33	33	33	33
Bed Depth (in)	30	30	30	30
Media Volume (ft^3)	17.7	17.7	17.7	17.7
Total Volume (ft^3)	**70.8**			

On September 22, 2008, two Battelle staff members visited the school to inspect the system. After inspections, several installation/operational issues were identified. Table 4-5 summarizes the punch-list items and corrective actions taken. One Battelle staff member returned to the school on October 9, 2008, to provide sample collection training to the operator and inspect changes made to the punch-list items.

Table 4-5. Punch-List Items and Corrective Actions

Date(s)	Issues/Problems Encountered	Corrective Action Taken	Work Performed by
09/22/08 – 10/02/08	Total combined effluent (TT) sample tap not installed as requested in RFQ	TT sample tap installed on combined effluent line before entering pressure tank	US Water Systems
09/22/08 – 10/02/08	Backwash (BW) sample tap not installed as requested in RFQ	BW sample tap installed on backwash discharge line	US Water Systems
09/22/08 – 10/02/08	Pressure gauges on filtration vessels not as specified in RFQ (0-200 psi)	Pressure gauges on vessels replaced with 0-100 psi gauges as specified on RFQ	US Water Systems
09/22/08 – 10/02/08	Well pump hour meter not reliable and needed to be replaced	New hour meter installed on well pump	US Water Systems
09/22/08 – 10/02/08	Backwash flowmeter/totalizer not functioning properly	Backwash flowmeter/totalizer replaced with new version of the same model	US Water Systems
09/22/08 – 10/31/08	Each Logix 764 controller controls two Magnum IT valves; displays hard to read due to location on top of vessels	Two additional Logix 764 controllers purchased for Magnum IT valves by EPA; all four Logix 764 controllers relocated to mounted panel for easier use	US Water Systems

4.4 System Operation

4.4.1 Operational Parameters. The operational parameters for the one-year performance evaluation study were tabulated and are attached as Appendix A. Key parameters are summarized in Table 4-6. From September 22, 2008, through October 29, 2009, the system operated for a total of 279 days, excluding weekends and Thanksgiving (from November 28 through 29, 2008) and Christmas holidays (from December 22, 2008, through January 2, 2009). Based on the wellhead hour meter, the system operated for 349.1 hr. Daily operating times fluctuated between 0 to 6.7 hr (Figure 4-10) and averaged 1.4 hr/day when the school was in session and 0.3 hr/day when the school was out of session (from June 3, 2009, through August 16, 2009).

The system treated approximately 941,500 gal of water based on totalizer readings from the Magnum IT valves installed on each filter vessel. This throughput value matches well with that (941,142 gal) based on a SeaMetrics MJR-200-2P totalizer installed at the wellhead. Imbalanced flows were observed among the four vessels, with throughput values ranging from 21.5% to 27.8% of the total flow.

Flowrates through the four vessels (Figure 4-11) were tracked by both instantaneous readings from the flowmeters on the vessels and calculated values by dividing incremental volume throughputs recorded from each vessel totalizer by incremental operating times. As shown in Table 4-6, instantaneous flowrate

Table 4-6. Summary of Treatment System Operational Parameters

Operational Parameter	Value/Condition			
Duration	09/22/08–10/29/09			
Average Daily Run Time (hr/day)	1.4	(When school was in session)		
	0.3	(When school was out of session)		
Total Operating Time (hr)	349.1			
Throughput (gal)[a] & Hydraulic Loading Rate (gpm/ft^2)	Vessel	09/22/08–10/29/09	Hydraulic Loading Rate	
	A	241,900	1.6 (0.8–1.8)	
	B	202,500	1.6 (0.7–2.1)	
	C	235,800	1.6 (1.1–1.8)	
	D	261,300	1.8 (1.3–2.3)	
	System	941,500	–	
Instantaneous Flowrate (gpm)	Vessel	Range	Average	
	A	6–13[c]	11.3	
	B	5–15[c]	11.3	
	C	8–13[c]	11.4	
	D	9–16[c]	13.1	
	System	28–50 [c]	47.1	
Calculated Flowrate (gpm)[b]	Vessel	Range	Average	
	A	0.9–20.0[d]	12.0	
	B	0.7–23.6[e]	11.7	
	C	0.7–25.9[f]	11.8	
	D	0.8–27.8[g]	13.4	
	System	22.7–66.7[h]	49.4	
Operational Pressures (psi)	Vessel	Inlet	Outlet	Δp
	A	43 (32–56)	38 (28–54)	5 (0–10)[i]
	B	43 (32–54)	38 (28–56)	5 (0–10)[j]
	C	43 (30–56)	39 (28–57)	5 (0–12)[k]
	D	43 (32–56)	39 (28–57)	5 (0–12)[l]
	System	63 (30–80)	38 (30–58)	25 (0–43)[m]

(a) Including amount of treated and source water used for backwashing filtration vessels.
(b) Data calculated by dividing incremental throughput by incremental hour meter readings recorded during 09/22/08 through 10/29/09.
(c) Excluding all instantaneous flowrate data from 09/22/08 through 10/31/08 due to configuration of Logix 764 controllers, which provided flowrate readings only for combined flows.
(d) Excluding four outliers on 10/13/08, 04/02/09, 08/11/09, and 08/12/09.
(e) Excluding all calculated flowrate data from 09/22/08 through 10/31/08 due to malfunctioning valve; excluding seven outliers on 02/23/09, 03/31/09, 04/02/09, 06/30/09, 08/11/09, 08/12/09, and 10/12/09.
(f) Excluding five outliers on 10/13/08, 01/20/09, 04/02/09, 07/23/09, and 08/12/09.
(g) Excluding two outliers on 04/02/09 and 08/12/09.
(h) Excluding data from 09/22/08 through 10/31/08 as noted under footnote e and outliers on 12/03/08, 01/20/09, 02/23/09, 02/25/09, 03/31/09, 04/02/09, 06/30/09, 07/13/09, 07/23/09, 08/11/09, 08/12/09, and 10/12/09.
(i) Excluding three outliers from 11/12/08, 11/21/08, and 11/26/08.
(j) Excluding two outliers from 11/21/08 and 11/26/08.
(k) Excluding six outliers from 09/22/08, 10/13/08, 10/14/08, 10/16/08, 11/21/08, and 12/05/08.
(l) Excluding four outliers from 09/22/08, 10/09/08, 10/14/08, and 11/21/08.
(m) Excluding two outliers from 10/09/08 and 11/04/08.

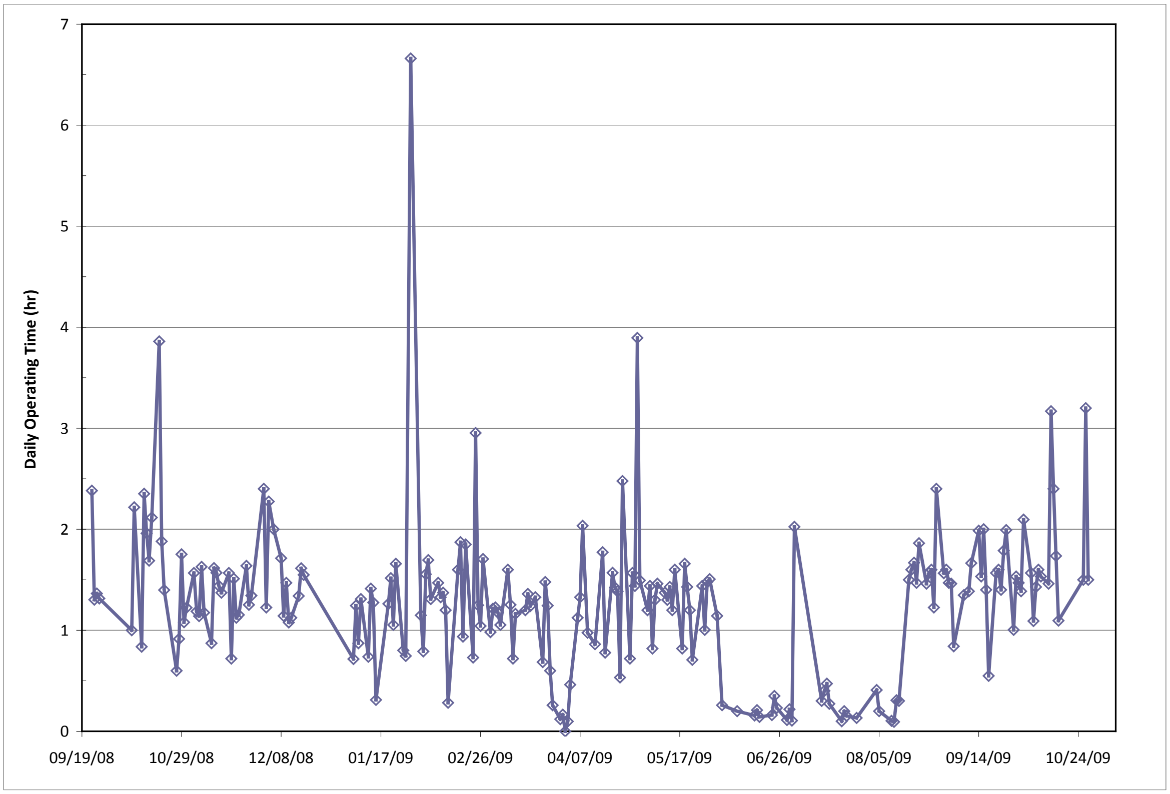

Figure 4-10. Treatment System Daily Operating Times

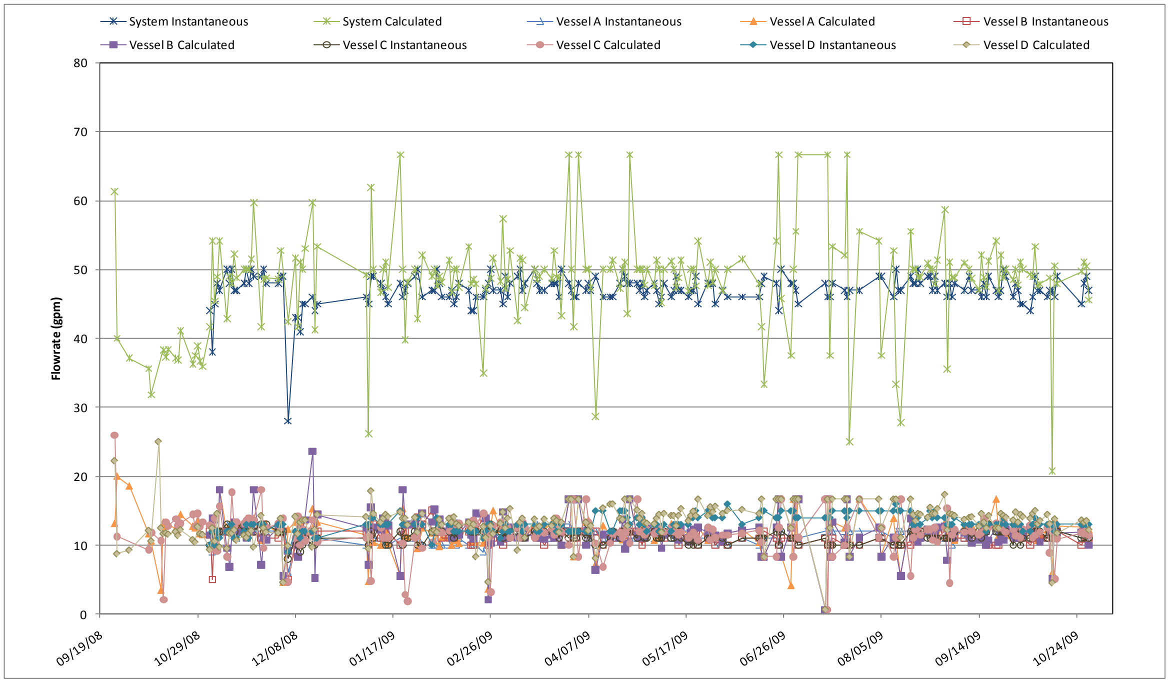

Figure 4-11. Comparison of Instantaneous Flowrate Readings and Calculated Flowrate Values

readings for Vessels A, B, C, and D averaged 11.3, 11.3, 11.4, and 13.1 gpm, respectively; calculated flowrates for the same vessels averaged 12.0, 11.7, 11.8, and 13.4 gpm, respectively. Instantaneous system flowrates ranged from 28 to 50 gpm and averaged 47.1 gpm, while calculated system flowrates ranged from 22.7 to 66.7 gpm and averaged 49.4 gpm. Based upon these flowrates, the system operated at approximately 80% of the design value of 60 gpm. While these two sets of flowrate data were comparable to each other, the calculated values appeared to be scattered somewhat more than the instantaneous readings (Figure 4-11). As such, only instantaneous readings were used for hydraulic loading rate calculations.

Based on the instantaneous flowrates to the individual vessels, hydraulic loading rates for Vessels A, B, C, and D ranged from 0.7 to 2.3 gpm/ft^2 and averaged 1.6, 1.6, 1.6, and 1.8 gpm/ft^2, respectively. The hydraulic loading rates on the vessels were 14% to 24% lower than the design value of 2.1 gpm/ft^2 (Table 4-3).

Δp across each vessel ranged from 0 to 12 psi and averaged 5 psi (Figure 4-12). The inlet pressure of the system ranged from 30 to 80 psi and averaged 63 psi, while the outlet pressure of the system ranged from 30 to 58 psi and averaged 38 psi. The average system differential pressure was 25 psi.

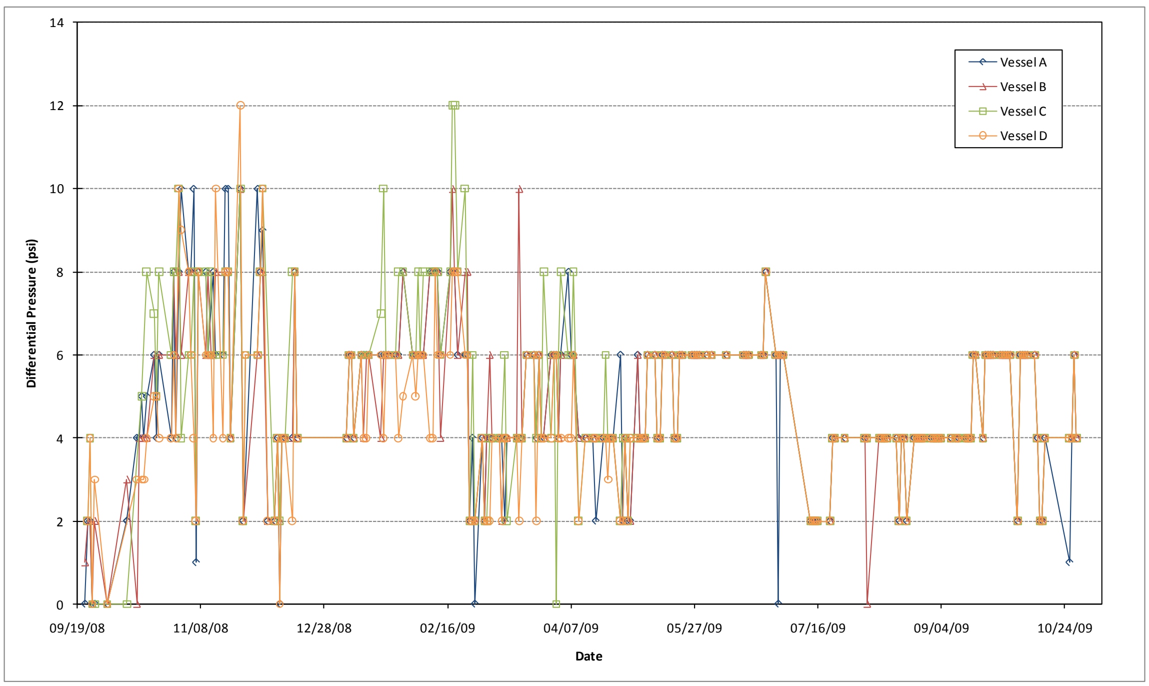

Figure 4-12. Differential Pressures Across Filtration Vessels

4.4.2 Chlorine Injection. As described in Section 4.2, a 12.5% NaOCl solution was used to oxidize As(III) and Fe(II). The chlorine injection system experienced no operational irregularities during the performance evaluation study. The PCM was set at approximately 55% by the vendor during system startup and remained at that level throughout the entire duration of the study.

Chlorine dosages to the treatment system were carefully monitored by measuring solution levels in the chlorine feed tank on a daily basis. The average dosage during the entire study period was 4.0 mg/L (as Cl_2), which was about 2.3 times higher than the target dosage of 1.7 mg/L (as Cl_2) as shown in Table 4-3.

Since free and total chlorine residual levels at the TT location were satisfactory and the average dose was at the MDRL level, no adjustments were made to the pump or PCM during the study.

4.4.3 Backwash. As mentioned in Section 4.2.2, backwash can be performed manually or automatically with either a time-, a throughput-, or a Δp-setpoint. Throughput was chosen as the setpoint while the time and Δp setpoints were disabled. The Logix 764 controller on each vessel was set to backwash after 90,000 gal of water had been processed with the controller starting at 90,000 gal and counting down. The value was intentionally set high to allow the operator more control over when a backwash was to occur. Due to the design of the system, a valve had to be manually opened to allow treated water from the pressure tank to be used for backwash.

A total of eight backwash events occurred during the entire study period (Table 4-7). All but one of the events were engaged manually by the operator. The only event initiated automatically occurred on February 20, 2009, when the operator noticed that Vessel D had just been backwashed (as indicated by the throughput counter that had been reset to 90,000 gal). Upon noticing this, Vessel B began to go into backwash even though the throughput counter was far from reaching 0 gal. The operator aborted the backwash and notified the Battelle Study Lead, who, in turn, contacted US Water Systems because none of the throughput counters on the vessels was near 0 gal when backwash was initiated. Upon checking the valve programming, it was determined that the "reserve capacity" on the valve was set at 30% of the total capacity (i.e., 90,000 gal), causing the vessel to backwash at 27,000 gal. To prevent this from happening again, the reserve capacity was set to 0% to allow the total capacity to be utilized before backwash. After the adjustment, all vessels, including Vessel D, were backwashed by the operator on February 25, 2009. (Because the valve to the pressure tank was not open during the automatic backwash of Vessel D, the vessel was backwashed with insufficient pressure and flow. Therefore, Vessel D was backwashed again.) According to the operator, wastewater from Vessel D was still "very dirty" during its second backwash.

Table 4-7. Summary of Backwash Events

Event No.	Date(s)	Vessel(s) Backwashed	Remarks
1	09/22/08	A (×2) B (×1)	Initiated to demonstrate valve controls during Battelle's site visit; each backwash was aborted after initiation
2	10/02/08	A, B, C, D	Taking place during operator training by US Water Systems
3	10/31/08	A, B, C, D	Initiated by US Water Systems after installation and relocation of Logix 764 controllers
4	12/03/08	A, B, C, D	Initiated by operator at request of Battelle for backwash wastewater sample collection
5	02/20/09–02/25/09	A, B, C, D (×2)	Vessel D automatically backwashed on 02/20/09; Vessel B automatically backwashed on 02/23/09, but backwash aborted by operator; all vessels backwashed by operator on 02/25/09
6	04/08/09	A, B, C, D	Initiated by operator at request of Battelle for backwash wastewater sample collection
7	07/06/09	A, B, C, D	Initiated by operator at request of Battelle for backwash wastewater sample collection
8	10/13/09	A, B, C, D	Initiated by operator at request of Battelle for backwash wastewater sample collection

Backwash wastewater samples were collected during four of seven manually initiated backwash events. Backwash start/end times, durations, flowrates, and volumes of wastewater generated were tabulated and are attached as Appendix C. Table 4-8 summarizes key parameters from the four backwash events. The vessels were backwashed on an as-needed basis by the operator at the request of Battelle. The need for backwash was primarily based on iron and arsenic levels in the finished water with volume processed and time since last backwash being taken into consideration.

Table 4-8. Summary of System Backwash Operations

Vessel	Date	Instantaneous Flowrate (gpm)	Duration (min)	Wastewater Generated (gal)
A	12/03/08	50.1	26	1,196.2
	04/08/09	52.0	26	1,027.1
	07/06/09	55.0	26	944.0
	10/13/09	47.0	26	866.6
	Average	**51.0**	**Total**	**4,033.9**
B	12/03/08	46.8	26	1,119.3
	04/08/09	43.0	26	1,098.9
	07/06/09	54.2	26	1,150.0
	10/13/09	54.0	26	1,142.6
	Average	**49.5**	**Total**	**4,510.8**
C	12/03/08	51.0	26	1,282.1
	04/08/09	46.4	26	1,087.5
	07/06/09	55.0	26	1,227.0
	10/13/09	56.0	26	1,259.3
	Average	**52.1**	**Total**	**4,855.9**
D	12/03/08	48.0	26	1,210.0
	04/08/09	55.7	26	1,194.0
	07/06/09	54.0	26	1,201.7
	10/13/09	58.0	26	1,180.1
	Average	**53.9**	**Total**	**4,785.8**
Average Wastewater per Vessel (gal)				**1,137**
Combined Total Wastewater (gal)				**18,186**

The four filters were backwashed one at time for 26 min. The backwash process consisted of counter-current backwash for 14 min, co-current slow rinse for 5 min, and co-current fast rinse (7 min). During Battelle's site visit on September 22, 2008, valve backwash settings were programmed for a 20 min counter-current backwash followed by a 15 min co-current fast rinse. After the two additional Logix 764 controllers were installed on October 31, 2008, the backwash settings were inadvertently reset to their default settings (i.e., backwash for 14 min, slow rinse for 5 min, and fast rinse for 7 min). Because backwash results at these settings appeared to be satisfactory, these settings remained unchanged during the remainder of the study.

Instantaneous backwash flowrates averaged 51.0, 49.5, 52.1, and 53.9 gpm for Vessels A, B, C, and D, respectively; total amounts of backwash wastewater generated were 4,034, 4,511, 4,856, and 4,786 gal, respective. The total volume of wastewater produced from the four vessels was 18,186 gal. The flowrate and volume of the wastewater were recorded by a flowmeter/totalized located on the backwash discharge line.

4.4.4 Residual Management. Residuals expected by the operation of the system included backwash wastewater and spent media. The G2® media was not replaced during the study period; therefore, the only residual produced was backwash wastewater. Backwash wastewater was discharged to the sanitary sewer via a sump. No permits were required by IDEM for discharging to the sewer.

4.4.5 System/Operation Reliability and Simplicity. There was no downtime for the treatment system during the performance evaluation study. Minor control issues with the Logix 764 controllers had been experienced before two additional controllers were purchased and mounted on an easily accessible panel (Figure 4-13) on October 31, 2008. Before the two additional controllers were installed, one controller was responsible for controlling two valves. Due to this configuration, only combined flowrates could be read from the display, making it difficult to determine flowrates through each vessel. In addition, when backwash was initiated manually by pressing the backwash button on the controller, the vessel that had not been backwashed previously would undergo backwash. The vessel undergoing backwash was not indicated on the display, therefore, the vessel that was being backwashed had to be determined by other methods. After all the remaining items on the system inspection punch list (Section 4.3.3, Table 4-5) were fixed, no operational problems were encountered.

Figure 4-13. System Control Panel with Logix 764 Controllers

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. Pretreatment consisted of chlorination using a 12.5% NaOCl solution to oxidize As(III) and Fe(II), and provide chlorine residuals to the distribution system. In addition to tracking levels of the NaOCl solution in the chemical feed tank, the operator measured chlorine concentrations to ensure that residuals existed throughout the treatment train. Post-treatment was not needed for this system.

System Automation. On and off of the treatment system was controlled by the 750-gal pressure tank located downstream of the treatment system. When the pressure in the tank reached its low pressure setpoint, the well pump was turned on. The well pump provided the necessary flow and pressure to move chlorinated water through the filter vessels to the pressure tank, which would turn off the well pump when the high pressure setpoint was reached. Chlorine injection was automated and would only occur when flow was sensed by the SeaMetrics pulse meter. As previously mentioned, the pulse meter would send a signal to the PCM, which, in turn, signaled the pump to inject the NaOCl solution. In addition, the system was fitted with automated controls to allow for automatic backwash of the vessels based on time, throughput, or Δp.

Operator Skill Requirements. Under normal operating conditions, the daily demand on the operator was about 20 min for visual inspection of the system and recording of operational parameters such as pressure, volume, flowrate, and chemical usage on field log sheets. The operator's duties were to monitor and refill the chlorine feed tank, adjust the chlorine dosage via the PCM, if necessary, and ensure that the valve to the pressure tank was open during backwash. The operator's knowledge of the system limitations and typical operational parameters were key to achieve the system performance objectives. The basis for the operator's skills began with onsite training and a thorough review of the system operations manual; however, increased knowledge and system troubleshooting skills were gained through hands-on operational experience.

All Indiana public water systems (both community and non-transient/non-community) serving more than 250 people must have a certified operator. Operator certifications are granted by the State of Indiana after passing an exam and maintaining a minimum amount of continuing education hours at professional training events. The number of continuing education hours required depends on the type of distribution and water treatment systems. Operator certifications are classified by the type of systems: distribution systems are classified as small, medium, or large (DSS, DSM, DSL); water treatment systems are classified from Classes 1 to 6 (WT1 to WT6). A DSS/WT2 certification is required to operate the treatment system at Northeastern Elementary School. The school operator had a DSS/WT3 certification.

Preventive Maintenance Activities. Preventative maintenance tasks included inspecting the system piping and monitoring NaOCl levels in the chemical feed tank. Periodically, the operator checked and cleaned, if needed, the paddlewheel in the flowmeter/totalizer on the backwash discharge line. Particulates in backwash wastewater could build up on the paddles and impede and/or stop its rotation.

Chemical/Media Handling and Inventory Requirements. The only chemical required for system operation was the NaOCl solution used for chlorination. A 12.5% NaOCl solution, supplied by Environmental Management and Development, Inc., was purchased as needed in 5-gal increments. The solution was transferred via a hand pump to the day tank and injected without dilution.

4.5 System Performance

4.5.1 Treatment Plant Sampling. Table 4-9 summarizes analytical results of arsenic, iron, and manganese measured at all sampling locations across the treatment train. Table 4-10 summarizes results of other water quality parameters. Appendix B contains a complete set of analytical results for the demonstration study. The treatment plant results are discussed below.

Table 4-9. Summary of Arsenic, Iron, and Manganese Analytical Results

Parameter	Sampling Location	Sample Count	Concentration (µg/L) Minimum	Maximum	Average	Standard Deviation
As (total)	IN	26	24.0	39.3	29.4	3.3
	AC	26	20.2	36.1	28.1	3.2
	TA	14	0.8	9.1	3.7	1.9
	TB	14	0.8	7.9	4.1	1.8
	TC	14	0.7	11.2	4.1	2.9
	TD	14	1.9	9.4	3.8	2.0
	TT	19	1.9	6.2	3.6	1.4
As (soluble)	IN	13	14.0	26.4	20.2	3.2
	AC	13	2.1	4.9	3.0	0.7
	TT	13	1.5	3.1	2.3	0.4
As (particulate)	IN	13	4.8	15.7	8.2	3.4
	AC	13	17.3	27.4	23.8	3.1
	TT	13	<0.1	3.9	1.3	1.4
As (III)	IN	13	10.8	23.9	17.7	3.8
	AC	13	<0.1	0.8	0.4	0.2
	TT	13	<0.1	0.8	0.4	0.2
As (V)	IN	13	0.8	10.7	2.5	2.6
	AC	13	1.5	4.8	2.6	0.8
	TT	13	1.3	2.6	1.9	0.4
Fe (total)	IN	26	1,418	2,333	1,865	250
	AC	26	1,206	2,369	1,762	270
	TA	14	<25	466	100	131
	TB	14	<25	422	142	135
	TC	14	<25	661	141	210
	TD	14	<25	556	136	152
	TT	19	<25	291	99	89.6
Fe (soluble)	IN	12[(a)]	407	1,491	1,058	326
	AC	13	<25	219	53	61.9
	TT	13	<25	34	<25	5.9
Mn (total)	IN	26	41.8	59.7	51.3	4.6
	AC	26	40.0	62.3	51.5	4.8
	TA	14	29.6	71.0	50.1	11.1
	TB	14	28.9	71.9	49.8	11.2
	TC	14	33.2	71.3	50.4	10.6
	TD	14	27.2	69.0	48.6	12.0
	TT	19	19.5	72.7	52.0	13.3
Mn (soluble)	IN	13	46.5	58.8	52.3	3.3
	AC	13	26.1	59.0	41.6	10.4
	TT	13	20.1	73.2	51.1	16.1

(a) One outlier (i.e., 33 µg/L) on 04/28/09 was omitted.

Arsenic. The key parameter for evaluating the effectiveness of the IR system was arsenic concentration in treated water. Treatment plant water samples were collected on 26 occasions (including three set of duplicate samples taken on December 29, 2008, March 17, 2009, and July 6, 2009) with field speciation performed during 13 occasions at IN, AC, and TT sampling locations.

Table 4-10. Summary of Other Water Quality Parameter Results

Parameter	Sampling Location	Unit	Sample Count	Concentration Minimum	Concentration Maximum	Concentration Average	Standard Deviation
Alkalinity (as $CaCO_3$)	IN	mg/L	26	309	361	328	14.0
	AC	mg/L	26	309	357	328	12.6
	TA	mg/L	14	309	359	329	14.9
	TB	mg/L	14	307	355	329	14.4
	TC	mg/L	14	312	355	329	12.2
	TD	mg/L	14	309	356	330	12.5
	TT	mg/L	19	304	350	329	11.8
Ammonia (as N)	IN	mg/L	26	0.9	1.1	1.0	0.0
	AC	mg/L	26	0.9	1.0	0.9	0.0
	TA	mg/L	14	0.8	1.0	0.9	0.1
	TB	mg/L	14	0.9	1.0	0.9	0.0
	TC	mg/L	14	0.8	1.0	0.9	0.0
	TD	mg/L	14	0.8	1.0	0.9	0.1
	TT	mg/L	19	0.8	1.0	0.9	0.1
Fluoride	IN	mg/L	13	1.4	2.4	1.8	0.2
	AC	mg/L	13	1.6	2.6	1.8	0.2
	TT	mg/L	13	1.6	1.8	1.7	0.1
Sulfate	IN	mg/L	13	1.5	2.4	2.0	0.2
	AC	mg/L	13	1.4	2.3	2.0	0.2
	TT	mg/L	13	1.6	2.4	2.1	0.2
Nitrate (as N)	IN	mg/L	13	<0.05	<0.05	<0.05	-
	AC	mg/L	13	<0.05	<0.05	<0.05	-
	TT	mg/L	13	<0.05	<0.05	<0.05	-
Total P (as P)	IN	µg/L	13	<10	22.3	11.0	6.8
	AC	µg/L	13	<10	17.5	<10	4.4
	TT	µg/L	13	<10	19.7	<10	5.3
Silica (as SiO_2)	IN	mg/L	26	13.6	17.0	15.2	0.7
	AC	mg/L	26	13.2	17.6	15.3	0.8
	TA	mg/L	14	15.7	30.6	19.5	4.6
	TB	mg/L	14	15.6	29.3	18.8	4.5
	TC	mg/L	14	15.5	28.6	18.7	4.2
	TD	mg/L	14	15.6	29.8	19.1	4.6
	TT	mg/L	19	16.0	25.6	18.6	2.5
Turbidity	IN	NTU	26	11.0	24.0	16.8	3.4
	AC	NTU	26	1.3	12.0	3.5	2.2
	TA	NTU	14	<0.1	1.2	0.5	0.4
	TB	NTU	14	0.1	1.6	0.6	0.4
	TC	NTU	14	<0.1	2.0	0.6	0.6
	TD	NTU	14	0.2	2.1	0.6	0.5
	TT	NTU	19	0.1	2.8	0.7	0.6
TOC	IN	mg/L	25	1.4	7.7	1.8	1.2
	AC	mg/L	25	1.3	2.6	1.7	0.3
	TA	mg/L	13	1.3	1.9	1.5	0.2
	TB	mg/L	13	1.3	2.1	1.5	0.3
	TC	mg/L	13	1.3	1.9	1.5	0.2
	TD	mg/L	13	1.3	1.9	1.6	0.2
	TT	mg/L	18	1.3	1.9	1.5	0.2

Table 4-10. Summary of Other Water Quality Parameter Results (Continued)

Parameter	Sampling Location	Unit	Sample Count	Concentration Minimum	Concentration Maximum	Concentration Average	Standard Deviation
pH	IN	S.U.	22	7.4	7.7	7.6	0.1
	AC	S.U.	22	7.4	7.6	7.5	0.1
	TT	S.U.	20	7.4	7.6	7.5	0.1
Temperature	IN	°C	22	10.6	19.2	15.3	2.0
	AC	°C	22	11.9	18.4	15.3	1.8
	TT	°C	20	10.0	21.2	15.9	2.3
Dissolved Oxygen (DO)	IN	mg/L	13	1.6	4.5	2.9	1.0
	AC	mg/L	13	1.4	3.6	2.3	0.7
	TT	mg/L	12	0.9	6.4	2.2	1.6
Oxidation-Reduction Potential (ORP)	IN	mV	22	148	353	238	44.6
	AC	mV	22	214	418	275	44.2
	TT	mV	20	242	409	284	40.3
Free Chlorine (as Cl_2)	IN	mg/L	12	0.0	0.1	0.1	0.0
	AC	mg/L	12	0.0	0.9	0.4	0.3
	TT	mg/L	10	0.0	0.9	0.4	0.3
Total Chlorine (as Cl_2)	IN	mg/L	12	0.0	0.1	0.0	0.0
	AC	mg/L	22	0.0	1.4	0.7	0.4
	TT	mg/L	20	0.0	1.4	0.5	0.4
Total Hardness (as $CaCO_3$)	IN	mg/L	13	210	303	259	28.2
	AC	mg/L	13	206	298	258	26.7
	TT	mg/L	13	208	289	257	23.4
Ca Hardness (as $CaCO_3$)	IN	mg/L	13	120	179	152	18.4
	AC	mg/L	13	122	189	153	18.9
	TT	mg/L	13	121	182	152	15.4
Mg Hardness (as $CaCO_3$)	IN	mg/L	13	70.9	153	106	20.3
	AC	mg/L	13	65.7	139	105	18.1
	TT	mg/L	13	73.2	143	105	19.2

Figure 4-14 contains three bar charts showing concentrations of particulate arsenic, As(III), and As(V) at the IN, AC, and TT sampling locations for each of the 13 speciation events. Total arsenic concentrations in raw water ranged from 24.0 to 39.3 µg/L and averaged 29.4 µg/L (Table 4-9). Of the soluble fraction, As(III) was the predominating species, with concentrations ranging from 10.8 to 23.9 µg/L and averaging 17.7 µg/L. Soluble As(V) concentrations were low, ranging from 0.8 to 10.7 µg/L and averaging 2.5 µg/L. Particulate arsenic concentrations ranged from 4.8 to 15.7 µg/L and averaged 8.2 µg/L. The arsenic concentrations were consistent with those collected previously during source water sampling (Table 4-1).

Following chlorination (AC), total arsenic concentrations remained essentially unchanged at 28.1 µg/L (on average). Arsenic, however, existed mostly as particulate arsenic (23.8 µg/L [on average]) with only a small fraction remaining in the soluble form (3.0 µg/L). Of the soluble fraction, 0.4 µg/L (on average) existed as As(III) and 2.6 µg/L (on average) as As(V), indicating effective oxidation of As(III) by chlorine.

The oxidized arsenic was adsorbed onto and/or co-precipitated with iron solids, which also formed upon chlorination. The solids were filtered out by the G2® media, reducing the average total arsenic concentration from 29.4 µg/L in raw water to 3.6 µg/L in the system effluent at the TT sampling location. Total arsenic concentrations after each vessel ranged from 0.7 to 11.2 µg/L and averaged 4.1, 4.1, 3.8, and 3.6 µg/L for Vessels A, B, C, and D, respectively.

As shown in Figure 4-14, arsenic concentrations at the TT sampling location never exceeded the 10 µg/L arsenic MCL during the 13 speciation sampling events. Effluent samples from the four filter vessels exceeded the MCL only once during the 14 regular, non-speciation sampling events: on February 23, 2009, Vessel C had an effluent concentration of 11.2 µg/L (see Figure 4-15).

Iron. Total iron concentrations at the wellhead ranged from 1,418 to 2,333 µg/L and averaged 1,865 µg/L. About 57% (on average) of iron existed as soluble iron. Following chlorination, the average total iron concentration remained essentially unchanged at 1,762 µg/L with iron existing almost entirely as iron solids. Arsenic-laden iron solids were removed by the four G2® media filters to levels that ranged from <MDL of 25 µg/L to 661 µg/L. Average effluent iron concentrations in the vessel effluent were 100, 142, 141, and 136 µg/L following Vessels A, B, C, and D, respectively. Due to infrequent backwash, iron concentrations greater than the 300 µg/L SMCL were measured from at least one vessel on October 22, 2008, November 20, 2008, and February 23, 2009 (see Figure 4-16). After the performance evaluation period, Battelle recommended that all four vessels be backwashed at least once a month to avoid elevated iron and/or arsenic breakthrough.

Manganese. Total manganese levels in source water ranged from 41.8 to 59.7 µg/L and averaged 51.3 µg/L, which existed almost entirely in the soluble form. After chlorination, only 19% (on average) of the soluble manganese was precipitated, presumably, to form MnO_2 solids. Based on the data, essentially no manganese was removed by the filters. Total manganese concentrations in the combined effluent ranged from 19.5 to 72.7 µg/L and averaged 52.0 µg/L, which is above its 50 µg/L SMCL.

Other Water Quality Parameters. Alkalinity, ammonia, fluoride, sulfate, silica, total organic carbon (TOC), and hardness levels remained relatively constant across the treatment train and were not affected by the treatment process (Table 4-10). Total phosphorus levels (on average) in the combined effluent were always less than the MDL of 10 µg/L; nitrate levels at every stage of treatment were less than the MDL of 0.05 mg/L. Turbidity decreased significantly with treatment (i.e., from 16.8 to 0.7 NTU on average).

***pH, DO, and* ORP.** pH values of source water ranged from 7.4 to 7.7 and averaged 7.6. This range was consistent with the pH measurements taken by Battelle during source water sampling on September 26, 2006 (i.e., 7.5 in Table 4-1). DO levels in source water ranged from 1.6 from 4.5 mg/L and averaged 2.9 mg/L. DO levels remained steady across the treatment train, with average values of 2.3 and 2.2 mg/L at AC and TT respectively. Due to difficulties experienced by the operator using the VWR Symphony SP90M5 handheld meter, DO was measured only 13 times while pH and ORP were each measured 22 times. Throughout the study, the operator was supplied with several replacement DO probes. ORP readings of source water ranged from 148 to 353 mV and averaged 238 mV. After chlorination (AC), average ORP readings increased to 275 mV. Because almost all of the chlorine existed in the combined form, a significant increase in the ORP was not observed. Average ORP readings for the combined effluent (TT) remained essentially unchanged at 284 mV.

Chlorine. Figure 4-17 presents total and free chlorine residuals measured after chlorination (AC) and after the combined effluent at TT. As shown in the figure, data for AC and TT were scattered extensively. At AC, total chlorine residuals ranged from 0 to 1.4 mg/L (as Cl_2) and averaged 0.7 mg/L (as Cl_2) while free chlorine residuals ranged from 0 to 0.9 mg/L (as Cl_2) and averaged 0.4 mg/L (as Cl_2). Total and free residuals at TT were almost identical to those at AC. Due to the presence of ammonia in source water (i.e., ~1 mg/L [as N]), chlorine at AC and TT should be present as combined chlorine. Residual measurements also were made for source water at the wellhead (see Table 4-10), but were not plotted in Figure 4-17 due to the expected absence of chlorine in source water. Any reported values at the IN location were assumed to be “background noise” from the VWR Symphony SP90M5 handheld meter used by the operator.

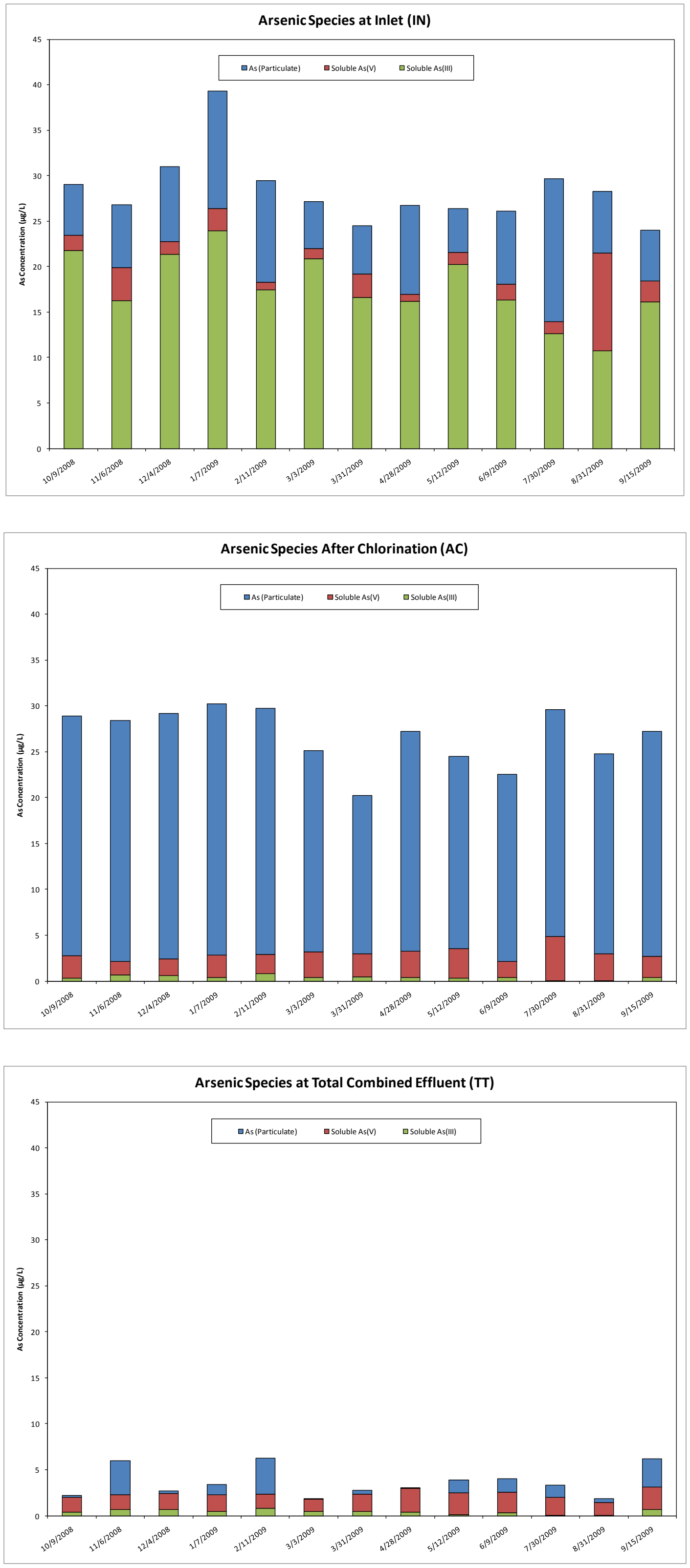

Figure 4-14. Concentrations of Various Arsenic Species at IN, AC, and TT Sampling Locations

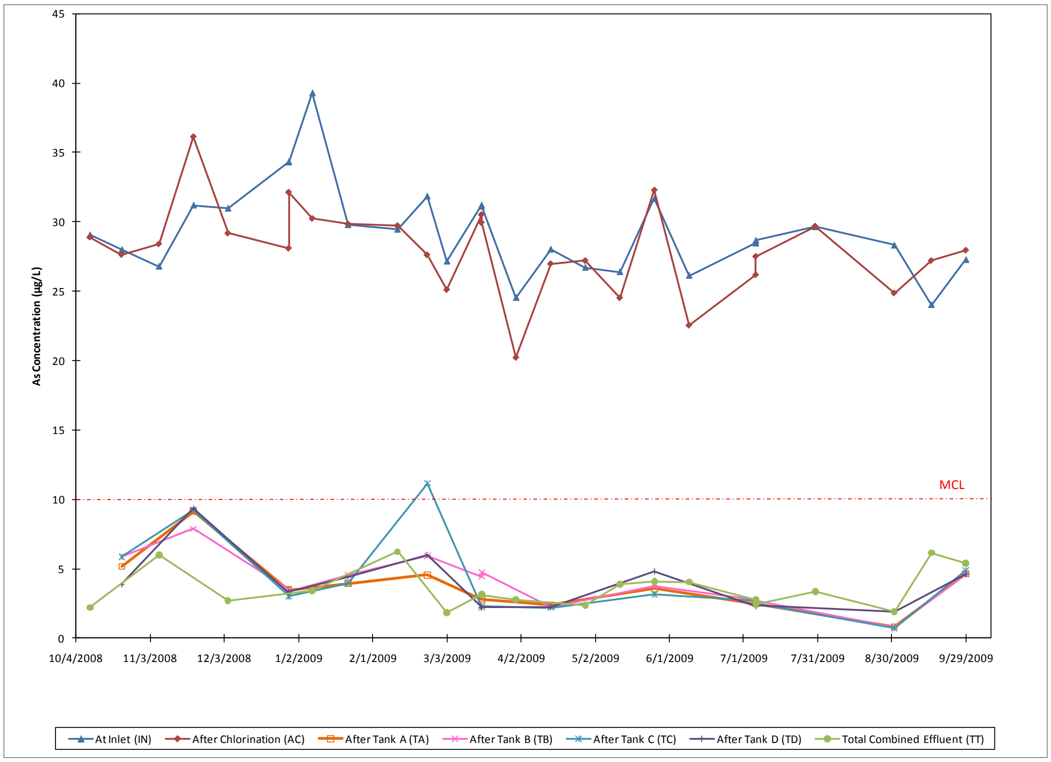

Figure 4-15. Total Arsenic Concentrations Across Treatment Train

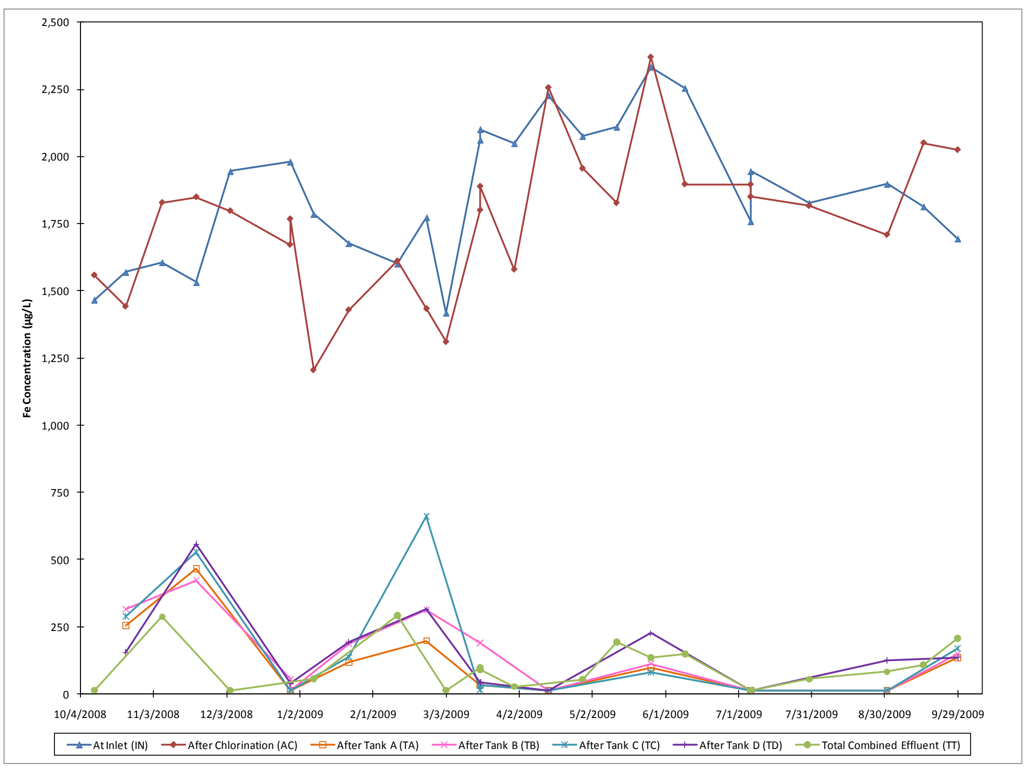

Figure 4-16. Total Iron Concentrations Across Treatment Train

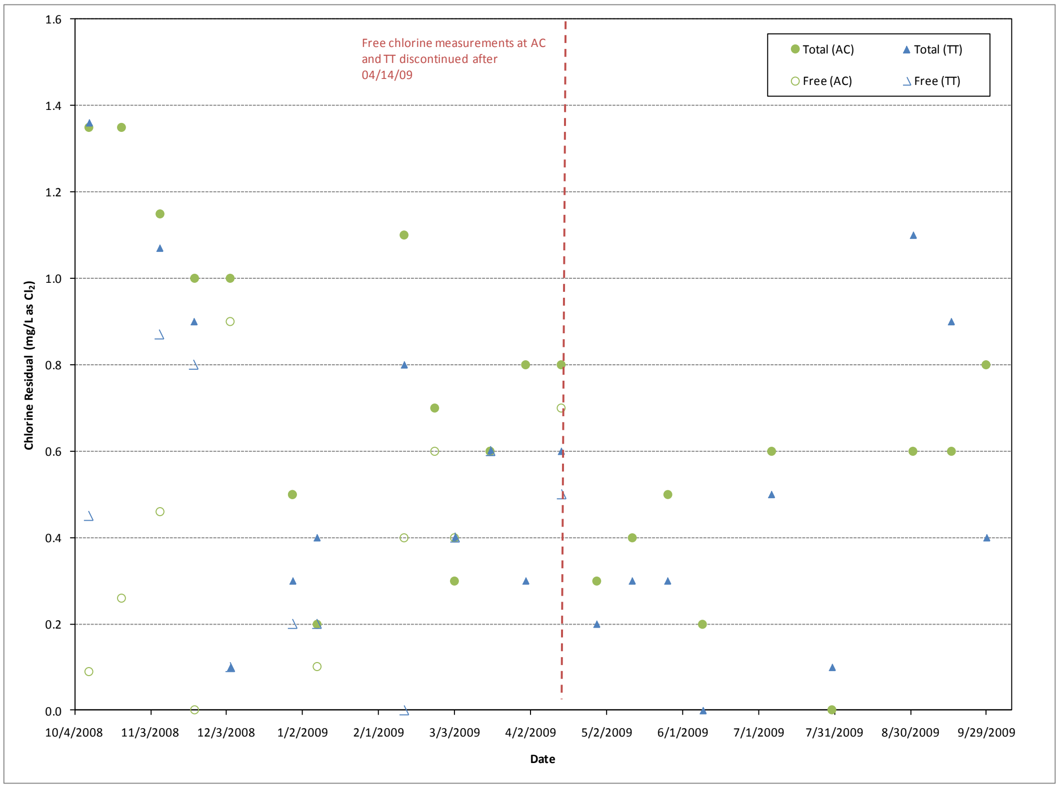

Figure 4-17. Chlorine Residuals Measured at AC and TT

4.5.2 Backwash Water and Solids Sampling. Table 4-11 presents analytical results of backwash wastewater sampling. Backwash wastewater samples were collected by the operator from each of the four G2® filtration vessels under four separate occasions. pH values of backwash wastewater ranged from 7.7 to 7.8 and averaged 7.7, which was approximately 0.2 pH units higher than that of the treated water. TDS concentrations ranged from 288 to 420 mg/L and averaged 320 mg/L. TSS concentrations ranged from 252 to 1,040 mg/L and averaged 677 mg/L. Concentrations of total arsenic, iron, and manganese ranged from 92 to 1,081 µg/L (averaged 521 µg/L), 20,528 to 145,337 µg/L (averaged 92,030 µg/L), and 136 to 563 µg/L (averaged 373 µg/L), respectively.

As expected, total arsenic, iron, and manganese were present mostly as particulate in backwash wastewater. Assuming that 1,137 gal of backwash wastewater would be generated (on average) from each vessel during each backwash event (see Table 4-8) and that 677 mg/L of TSS would be produced, approximately 2,914 g of solids were generated from each filtration vessel during each backwash event and were discharged to the sewer. Based on the average particulate metal data in Table 4-11, approximately 2.2 g of arsenic (i.e. 0.08% by weight), 396 g of iron (i.e. 13.6 % by weight), and 1.6 g of manganese (i.e. 0.05 % by weight) were generated from each vessel during each backwash event.

Solids loadings to the sewer also were monitored through collection of backwash solids (Section 3.3.3). Table 4-12 presents analytical results of the solid samples collected on July 6, 2009. Arsenic, iron, and manganese levels in the solids averaged 1,120 µg/g (or 0.1% by weight), 176,582 µg/g (or 17.7% by weight), and 429 µg/g (or 0.04 % by weight), respectively. These amounts were comparable to those derived from the backwash wastewater metal analysis (i.e. 0.08%, 13.6%, and 0.05%, respectively).

Table 4-11. Filtration Vessel Backwash Sampling Results

Sampling Event	pH	TDS	TSS	Silica (as SiO_2)[(a)]	As (total)	As (soluble)	As (Particulate)	Fe (total)	Fe (soluble)	Mn (Total)	Mn (soluble)
Date	S.U.	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Filtration Vessel A											
12/03/08	7.7	320	755	NA	526	4.0	522	97,012	53	437	44.6
04/08/09	7.7	320	660	67.3	531	4.2	527	117,322	144	443	64.6
07/06/09	7.7	326	552	92.2	421	3.8	417	68,262	105	242	53.7
10/13/09	7.8	294	984	79.9	1,081	1.9	1,079	145,337	78	479	46.7
Filtration Vessel B											
12/03/08	7.7	314	930	NA	536	3.6	533	111,983	35	563	47.1
04/08/09	7.7	318	675	85.9	435	3.5	432	101,975	100	412	62.0
07/06/09	7.7	320	638	81.2	409	2.8	406	84,209	<25	288	53.8
10/13/09	7.8	304	700	94.7	825	1.9	823	113,067	72	392	48.7
Filtration Vessel C											
12/03/08	7.8	320	970	NA	628	3.7	625	113,839	37	524	48.2
04/08/09	7.7	322	395	71.6	242	3.7	238	54,886	114	239	58.2
07/06/09	7.7	314	344	70.2	302	3.3	299	49,439	54	190	52.3
10/13/09	7.8	300	575	156	828	2.6	825	110,581	134	389	47.6
Filtration Vessel D											
12/03/08	7.7	320	1,040	NA	428	3.8	424	91,379	48	466	43.5
04/08/09	7.7	420	535	79.7	272	4.0	268	79,411	167	349	54.9
07/06/09	7.8	324	252	56.5	92.1	2.8	89.3	20,528	<25	136	49.9
10/13/09	7.7	288	820	125	777	1.5	775	113,245	<25	417	49.8

(a) Silica added after 12/03/08 sampling event.
NA = not analyzed; TDS = total dissolved solids; TSS = total suspended solids

4.5.3 Distribution System Water Sampling. Prior to the installation/operation of the treatment system, four first draw baseline distribution system water samples were collected from the kitchen sink tap on April 1, 2008, June 10, 2008, July 1, 2008, and August 7, 2008. Prior to system installation, two additional distribution locations were added – north water fountain and south water fountain. One baseline sample was collected from each water fountain on August 14, 2008. Following the installation of the treatment system, distribution water sampling continued on a monthly basis from October 2008 through September 2009. Table 4-13 presents the results of the distribution system sampling.

The most noticeable change in the distribution water samples since system startup was a decrease in arsenic, iron, and manganese concentrations. Baseline arsenic concentrations ranged from 4.7 to 37.6 µg/L and averaged 17.0 µg/L. After system startup, arsenic concentrations ranged from 2.1 to 10.9 µg/L and averaged 5.2 µg/L. Out of the 10 distribution samplings only one location (i.e, DS1 – kitchen sink) had an arsenic concentration above the 10 µg/L MCL (i.e., 10.9 µg/L), which occurred on July 6, 2009. The baseline iron concentrations ranged from less than the MDL of 25 µg/L to 2,013 µg/L, and averaged 986. After system startup, iron concentrations ranged from less than the MDL of 25 µg/L to 375 and averaged 84 µg/L. Reduction in manganese levels was less significant than arsenic or iron with baseline concentrations averaging 61.7 µg/L and after-startup concentrations averaging 50.5 µg/L, which is just above the SMCL of 50 µg/L.

Table 4-12. Backwash Solids Sampling Results

Sample	Unit	Mg	Al	Si	P	Ca	Fe	Mn	Ni	Cu	Zn	As	Cd	Ba	Pb
Vessel A-Solids-A	µg/g	2,396	11,864	32,153	648	18,845	187,512	467	25.0	61.7	760	1,223	<15	757	20.2
Vessel A-Solids-B	µg/g	2,518	13,639	39,008	668	19,143	194,741	468	26.2	65.1	795	1,246	<15	769	20.7
Average	**µg/g**	**2,457**	**12,751**	**35,580**	**658**	**18,994**	**191,127**	**468**	**25.6**	**63.4**	**777**	**1,234**	**<15**	**763**	**20.4**
Vessel B-Solids-A	µg/g	2,097	12,104	19,120	577	17,466	193,821	434	25.3	59.1	756	1,269	<15	807	19.2
Vessel B-Solids-B	µg/g	1,994	12,071	18,829	560	16,772	183,901	418	25.2	54.0	713	1,242	<15	779	19.5
Average	**µg/g**	**2,045**	**12,087**	**18,975**	**569**	**17,119**	**188,861**	**426**	**25.3**	**56.5**	**734**	**1,256**	**<15**	**793**	**19.3**
Vessel C-Solids-A	µg/g	2,943	11,577	20,576	527	16,363	187,162	391	26.9	52.7	736	1,305	<15	768	18.6
Vessel C-Solids-B	µg/g	2,365	11,223	18,632	549	17,075	186,555	404	26.4	54.4	781	1,252	<15	754	18.8
Average	**µg/g**	**2,654**	**11,400**	**19,604**	**538**	**16,719**	**186,858**	**398**	**26.7**	**53.5**	**759**	**1,278**	**<15**	**761**	**18.7**
Vessel D-Solids-A	µg/g	3,647	13,435	9,012	394	15,241	136,932	416	28.9	57.4	618	719	<15	709	21.8
Vessel D-Solids-B	µg/g	3,549	14,019	13,045	411	15,978	142,033	437	27.8	56.0	708	706	<15	712	21.6
Average	**µg/g**	**3,598**	**13,727**	**11,029**	**403**	**15,610**	**139,482**	**426**	**28.4**	**56.7**	**663**	**713**	**<15**	**710**	**21.7**
Overall Average	**µg/g**	**2,689**	**12,492**	**21,297**	**542**	**17,110**	**176,582**	**429**	**26**	**58**	**733**	**1,120**	**<15**	**757**	**20**

Collected on 07/06/09.

Table 4-13. Distribution System Sampling Results

No. of Sampling Events		DS1								DS2[a]								DS3[a]							
	Address	Kitchen Sink								North Water Fountain								South Water Fountain							
	Sample Type	LCR								LCR								LCR							
	Flushed / 1st Draw	1st Draw								1st Draw								1st Draw							
	Sampling Date	Stagnation Time	pH	Alkalinity	As	Fe	Mn	Pb	Cu	Stagnation Time	pH	Alkalinity	As	Fe	Mn	Pb	Cu	Stagnation Time	pH	Alkalinity	As	Fe	Mn	Pb	Cu
No.	Date	hrs	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	hrs	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	hrs	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BL1	04/01/08	89.5	7.5	318	4.7	<25	59.1	2.0	66.1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BL2	06/10/08	18.0	7.6	328	6.8	49	60.1	0.8	44.5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BL3	07/01/08	26.0	7.7	317	37.6	2,013	67.9	0.7	61.4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
BL4	08/07/08 & 08/14/08[b]	3.0	7.8	326	6.5	61	63.5	0.2	87.8	NA	7.8	323	22.4	1,390	59.9	0.4	6.5	NA	7.8	320	24.0	1,439	60.1	0.4	6.7
1	10/22/08	NA	7.8	326	8.6	183	31.4	5.9	520	NA	7.8	326	5.3	100	27.0	0.3	261	NA	7.8	324	6.1	93	28.2	1.1	527
2	11/20/08	NA	7.7	309	5.1	96	29.9	0.6	130	NA	7.7	307	5.6	93	30.1	0.2	210	NA	7.7	309	5.5	122	30.8	<0.1	67.1
3	12/17/08	16.8	7.8	319	4.1	<25	35.8	3.9	532	16.8	7.9	323	4.4	33	36.4	2.8	667	16.8	7.8	321	4.5	<25	34.4	1.3	399
4	01/22/09	24.5	7.6	319	3.7	45	41.7	0.4	29.1	24.5	7.7	317	9.9	298	38.0	1.5	387	18.5	7.7	319	4.3	59	43.7	<0.1	72.0
5	02/23/09	2.5	7.8	347	3.3	<25	50.8	0.1	73.0	2.5	7.7	342	4.7	<25	45.8	0.1	145	2.5	7.7	349	4.0	<25	56.3	<0.1	79.1
6	03/17/09	0.0	7.9	337	3.4	<25	46.3	0.7	130	0.0	7.7	346	4.1	<25	43.2	0.9	183	0.0	7.6	348	3.2	<25	49.7	0.4	106
7	04/14/09	0.0	7.7	327	5.3	<25	43.1	2.0	151	0.0	7.8	327	5.4	<25	37.6	0.8	134	0.0	8.0	325	4.8	<25	41.5	0.5	115
8	05/12/09	9.0	8.1	341	4.1	89	56.1	0.9	36.7	10.0	7.8	344	5.1	111	49.8	0.6	128	9.0	7.7	346	4.7	102	55.4	0.2	71.2
9	06/09/09	5.0	7.7	331	4.4	<25	61.7	0.2	269	5.0	7.6	337	4.9	<25	62.1	<0.1	206	5.0	7.6	335	4.9	66	4.9	<0.1	231
10	07/06/09	18.0	7.6	352	10.9	375	197	2.3	282	17.5	7.7	355	5.3	<25	148	0.6	291	17.5	7.6	352	9.7	296	123	2.6	297
11	08/31/09	0.5	7.6	327	2.1	<25	61.3	0.6	33.8	2.0	7.6	325	2.4	<25	39.9	0.3	122	2.0	7.6	330	2.5	26	52.1	0.1	83.0
12	09/29/09	8.0	7.6	326	8.2	338	50.5	1.0	27.5	8.0	7.7	324	6.7	160	22.2	1.3	314	8.0	7.6	330	6.6	132	13.9	0.5	143

BL = Baseline Sampling; NA = not available; NS = not sampled
Lead action level = 15 µg/L; copper action level = 1.3 mg/L
The unit for analytical parameters is µg/L except for alkalinity (mg/L as $CaCO_3$).
(a) Additional sampling locations added on 07/17/08.
(b) DS1 sample collected on 08/07/08; DS2 and DS3 collected on 08/14/08.

Lead concentrations within the distribution system increased slightly from baseline levels while a significant increase in the copper concentration was observed. Baseline lead concentrations ranged from 0.2 to 2.0 µg/L and averaged 0.8 µg/L; baseline copper concentrations ranged from 6.5 to 87.8 µg/L and averaged 45.5 µg/L. After system startup, lead levels increased slightly to 1.1 µg/L (on average) with no samples exceeding the action level of 15 µg/L. Copper concentrations increased significantly to an average of 207 µg/L with no samples exceeding the 1,300 µg/L action level.

Measured pH values ranged from 7.6 to 8.1 and averaged 7.7. Alkalinity levels ranged from 307 to 355 mg/L (as $CaCO_3$) and averaged 331 mg/L (as $CaCO_3$). The arsenic treatment system did not affect these water quality parameters of the distributed water.

4.6 System Cost

The cost of the treatment system was evaluated based on the capital cost per gpm (or gpd) of the design capacity and the O&M cost per 1,000 gal of water treated. This required tracking of the capital cost for the equipment, site engineering, and installation and the O&M cost for media replacement and disposal, electricity consumption, and labor.

4.6.1 Capital Cost. The capital investment for equipment, site engineering, and installation for the 60-gpm treatment system was $128,118 (Table 4-14). The equipment cost was $103,118 (or 80% of the total capital investment), which included $19,200 for four media vessels, $19,250 for 100 ft^3 of G2® media ($192.50/$ft^3$ or $4.10/lb), $20,314 for process valves and piping, $22,950 for instrumentation and controls, $2,250 for additional sample taps, $2,780 for the totalizer on the backwash discharge line and $3,400 for shipping. Three O&M manuals and one-year O&M support were $256 and $6,000, respectively. A change order for $2,118 was issued to the vendor on October 28, 2008 for the purchase of two additional Logix 764 controllers, a mounting panel, and an hour meter.

The site engineering cost included the cost for the preparation of a process flow diagram and relevant mechanical drawings of the treatment system, piping, valves, and a backwash discharge line, as well as submission of a permit application package to IDEM for approval. The site engineering cost was $7,500, or 6% of the total capital investment. Site engineering was performed by Ladd Engineering, a subcontractor for US Water Systems.

The installation cost included the equipment and labor to unload and install the system, perform piping tie-ins and electrical work, load and backwash the media, perform system shakedown and startup, and conduct operator training. The installation was performed by US Water Systems and cost $17,500, or 14% of the total capital investment.

The capital cost of $128,118 was normalized to the system's rated capacity of 60 gpm (or 86,400 gpd), which results in $2,135/gpm (or $1.48 gpd) of design capacity. The capital cost also was converted to an annualized cost of $12,093/year 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 hr/day, 7 day/wk at the design flowrate of 60 gpm to produce 86,400 gal/day, the unit capital cost would be $0.38/1,000 gal. During the 13-month demonstration period, the system produced approximately 941,500 gal of water (see Table 4-6) or 844,600 gal from October 30, 2008 through October 29, 2009; at this reduced rate of usage, the unit capital cost increased to $14.32/1,000 gal.

4.6.2 Operation and Maintenance Cost. The O&M cost included cost for electricity and labor for a combined unit cost of $2.26/1,000 gal as summarized in Table 4-15. Chlorination using NaOCl existed prior to the installation of the treatment system for disinfection purposes. Because the presence of the system did not affect the use rate of the NaOCl solution, the incremental chemical cost for

Table 4-14. Capital Investment Cost for US Water Systems' Treatment System

Description	Quantity	Cost	% of Capital Investment
Equipment Cost			
Media Vessel (36-in ×72-in)	4	$19,200	-
G2® Media (ft^3)	100	$19,250	-
Process Valves and Piping	-	$20,314	-
Instrumentation and Controls	-	$22,950	-
Additional Sample Taps	-	$2,250	-
Totalizer on Backwash Line	-	$2,780	-
O&M Manuals	-	$256	-
One-Year O&M Support	-	$6,000	-
Labor	-	$4,600	-
Shipping	-	$3,400	-
subtotal	-	$101,000	-
Controller Panel (Change Order)	-	$1,858	-
Hour Meter (Change Order)	-	$260	-
subtotal	-	$2,118	-
Equipment Total	-	**$103,118**	**80%**
Engineering Cost			
Subcontractor Material	-	$7,500	-
Subcontractor Labor	-		-
Subcontractor Travel	-		-
Engineering Total	-	**$7,500**	**6%**
Installation Cost			
Vendor Material	-	$9,500	-
Vendor Labor	-	$8,000	-
Installation Total	-	**$17,500**	**14%**
Total Capital Investment	-	**$128,118**	**100%**

chlorination was negligible. Electrical power consumption was calculated based on the difference between the average monthly cost from electric bills before and after system startup. The difference in cost was negligible. The routine, non-demonstration related labor activities consumed approximately 20 min/day (Section 4.4.5). Based on this time commitment and a labor rate of $22/hr, the labor cost was $2.26/1,000 gal of water treated.

Table 4-15. Operation and Maintenance Cost for AdEdge Treatment System

Cost Category	Value	Remarks
Volume Processed (gal)	844,600	From 10/30/08 through 10/29/09
Electricity Cost		
Electricity Cost ($/month)	Negligible	–
Electricity Cost ($/1,000 gal)	Negligible	–
Labor Cost		
Labor (hr/wk)	1.67	20 min/day; 5 days/wk
Labor Cost ($/1,000 gal)	$2.26	Labor rate = $22/hr
Total O&M Cost ($/1,000 gal)	**$2.26**	Electricity Cost ($) + Labor Cost ($)

5.0 REFERENCES

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APPENDIX A

OPERATIONAL DATA

Table A-1. EPA Arsenic Demonstration Project at Fountain City, IN - Daily System Operation Log Sheet

			Supply Well				Vessel A					Vessel B					Vessel C					Vessel D					System				NaOCl Addn.
			Daily Op Hours	Incremental Volume	Calculated Flowrate	Wellhead Pressure	Instant. Flowrate A	Incremental Volume A	Calculated Flowrate A	Pressure Before Vessel A	Pressure After Vessel A	Instant. Flowrate B	Incremental Volume B	Calculated Flowrate B	Pressure Before Vessel B	Pressure After Vessel B	Instant. Flowrate C	Incremental Volume C	Calculated Flowrate C	Pressure Before Vessel C	Pressure After Vessel C	Instant. Flowrate D	Incremental Volume D	Calculated Flowrate D	Pressure Before Vessel D	Pressure After Vessel D	Instant. System Flowrate (A+B+C+D)	System Calculated Flowrate (A+B+C+D)	Inlet Pressure	Outlet Pressure	Solution Tank Level
Week No.	Date	Time	hr/day	gal	gpm	psi	gpm	gal	gpm	psi	psi	gpm	gal	gpm	psi	psi	gpm	gal	gpm	psi	psi	gpm	gal	gpm	psi	psi	gpm	gpm	psi	psi	in
1	09/22/08	16:22		-	-	48	0	-	-	44	44	0	-	-	45	44	0	-	-	42	45	0	-	-	42	44	0	-	48	48	26 gal
	09/23/08	10:10	2.4	4,700	44.3	46	16	NA	NA	44	42	17	NA	NA	44	42	17	NA	NA	44	42	17	NA	NA	44	42	34	NA	46	42	26 gal
	09/24/08	10:25	1.3	3,000	38.0	48	17	NA	NA	45	43	16	NA	NA	45	43	18	NA	NA	45	41	18	NA	NA	45	41	35	NA	48	41	25.5 gal
	09/25/08	10:10	1.4	4,400	54.3	55	18	3,500	13.2	40	40	17	0	0.0	40	40	18	2,100	25.9	40	40	18	1,800	22.2	40	40	36	61	55	40	25.5 gal
	09/26/08	10:30	1.3	3,700	46.3	50	18	1,600	20.0	48	48	17	0	0.0	50	48	20	900	11.3	50	50	17	700	8.8	48	45	36	40	50	48	25 gal
2	10/01/08	NA	NA	10,600	44.7	55	16	4,400	18.6	50	50	16	0	0.0	50	50	18	2,200	9.3	50	50	16	2,200	9.3	50	50	33	37	55	45	25 gal
	10/02/08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3	10/09/08	8:30	NA	36,900	67.6	54	13	NA	NA	40	38	13	NA	NA	43	40	24	NA	NA	42	42	24	NA	NA	42	43	37	NA	54	42	24 gal
	10/09/08	16:00	1.0	3,224	44.8	50	12	7,300	11.8	56	54	13	100	0.2	NA	56	22	7,400	12.0	NA	57	24	7,600	12.3	NA	58	36	36	56	58	NA
	10/10/08	15:48	2.2	NA	NA	NA	NA	1,400	10.6	NA	NA	NA	0	0.0	NA	NA	NA	1,400	10.6	NA	NA	NA	1,400	10.6	NA	NA	NA	32	NA	NA	18.1875
4	10/13/08	9:00	0.8	NA	NA	52	0	2,400	66.7	46	42	0	0	0.0	42	42	0	2,100	58.3	42	44	0	1,000	27.8	45	42	0	153	52	46	24 gal
	10/14/08	9:30	2.4	14,476	46.4	50	13	500	3.5	42	38	13	0	0.0	42	38	24	300	2.1	38	42	24	1,800	12.5	38	42	37	18	50	44	23.75 gal
	10/15/08	10:00	2.0	5,200	43.3	48	13	1,600	13.3	40	35	13	0	0.0	40	36	24	1,600	13.3	42	37	24	1,400	11.7	40	37	37	38	48	40	18.25
	10/16/08	10:10	1.7	4,500	44.1	52	12	1,300	12.7	42	38	12	0	0.0	44	40	23	1,300	12.7	38	42	23	1,200	11.8	42	39	35	37	52	38	18
	10/17/08	12:15	2.1	6,500	47.1	52	7	1,800	13.0	43	38	2	0	0.0	42	38	25	1,900	13.8	48	40	24	1,600	11.6	44	40	29	38	52	42	17.875
5	10/20/08	12:30	3.9	10,598	45.3	52	10	2,900	12.4	36	30	10	0	0.0	38	32	25	3,000	12.8	40	33	25	2,800	12.0	40	35	35	37	52	36	17.625
	10/21/08	12:45	1.9	4,997	43.8	48	13	1,400	12.3	42	38	12	0	0.0	42	36	24	1,500	13.2	40	35	24	1,300	11.4	43	38	37	37	48	46	17.5
	10/22/08	14:30	1.4	4,248	47.2	48	12	1,300	14.4	42	36	12	0	0.0	44	38	23	1,300	14.4	46	38	23	1,100	12.2	46	42	35	41	48	44	17.375
	10/23/08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10/24/08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6	10/27/08	12:30	0.6	4,534	44.4	52	13	1,300	12.7	42	38	13	0	0.0	42	36	24	1,300	12.7	42	36	25	1,100	10.8	42	38	38	36	52	38	17.25
	10/28/08	9:30	0.9	2,286	47.6	54	12	600	12.5	38	30	12	0	0.0	38	30	23	700	14.6	38	30	23	500	10.4	38	32	35	38	54	39	17.25
	10/29/08	14:15	1.8	5,602	44.5	48	12	1,700	13.5	40	36	12	0	0.0	40	34	25	1,600	12.7	40	32	25	1,600	12.7	40	36	37	39	48	42	17.125
	10/30/08	12:30	1.1	2,725	45.4	50	12	700	11.7	46	38	12	0	0.0	46	38	26	800	13.3	46	36	26	700	11.7	46	36	38	37	50	44	17.125
	10/31/08	14:00	1.2	3,473	44.5	48	12	900	11.5	44	34	12	0	0.0	44	38	24	1,000	12.8	42	38	24	900	11.5	44	35	36	36	48	44	17
7	11/03/08	14:30	1.6	4,136	43.1	46	12	1,200	12.5	46	38	12	1,200	12.5	46	38	10	1,000	10.4	46	40	10	1,000	10.4	46	38	44	46	46	42	16.75
	11/04/08	14:45	1.2	3,221	44.7	40	9	1,000	13.9	44	36	5	1,000	13.9	44	36	12	1,000	13.9	44	38	12	900	12.5	44	38	38	54	40	42	16.75
	11/05/08	13:55	1.1	2,994	45.4	58	12	800	12.1	44	34	13	900	13.6	44	36	10	600	9.1	44	36	10	700	10.6	42	38	45	45	58	44	16.625
	11/06/08	13:30	1.6	4,925	51.3	42	12	900	9.4	42	41	12	900	9.4	42	40	12	1,500	15.6	42	40	12	1,400	14.6	42	40	48	49	42	42	16.5
	11/07/08	14:00	1.2	2,744	38.1	38	12	1,300	18.1	36	28	12	1,300	18.1	36	28	12	600	8.3	36	28	11	700	9.7	36	28	47	54	38	30	16.25
8	11/10/08	9:15	0.9	1,701	40.5	34	13	500	11.9	38	30	12	400	9.5	38	32	13	500	11.9	38	30	12	400	9.5	40	34	50	43	34	30	16.375
	11/11/08	10:30	1.6	4,868	47.7	46	12	1,300	12.7	44	38	12	700	6.9	46	38	12	1,800	17.6	46	40	12	1,200	11.8	46	40	48	49	46	42	16.25
	11/12/08	12:30	1.6	4,182	41.0	52	12	1,200	11.8	36	38	12	1,200	11.8	36	30	13	1,300	12.7	38	30	13	1,200	11.8	38	32	50	48	52	36	16.125
	11/13/08	13:30	1.4	4,030	44.8	40	12	1,200	13.3	44	36	12	1,200	13.3	44	38	12	1,200	13.3	44	38	11	1,100	12.2	44	40	47	52	40	38	16
	11/14/08	14:00	1.4	3,767	44.8	50	11	1,100	13.1	36	30	12	1,000	11.9	38	30	13	1,100	13.1	38	32	11	900	10.7	38	28	47	49	50	30	16
9	11/17/08	14:30	1.6	4,184	43.6	42	12	1,200	12.5	40	34	12	1,200	12.5	42	34	12	1,300	13.5	42	36	12	1,100	11.5	42	38	48	50	42	38	15.875
	11/18/08	10:30	0.7	1,753	48.7	50	12	500	13.9	40	30	13	400	11.1	38	30	12	500	13.9	38	30	13	400	11.1	40	32	50	50	50	40	15.875
	11/19/08	13:30	1.5	4,609	45.2	30	13	1,300	12.7	40	30	12	1,300	12.7	38	30	12	1,300	12.7	38	30	11	1,200	11.8	40	32	48	50	30	30	15.75
	11/20/08	13:00	1.1	3,224	48.8	30	12	900	13.6	34	30	12	800	12.1	34	30	13	900	13.6	34	30	13	800	12.1	34	30	50	52	30	30	15.75
	11/21/08	14:00	1.2	3,068	42.6	50	12	1,000	13.9	38	40	12	1,300	18.1	36	42	12	1,300	18.1	36	40	13	700	9.7	36	40	49	60	50	40	15.75
10	11/24/08	10:30	1.6	3,745	44.6	58	12	900	10.7	40	30	11	600	7.1	40	30	13	800	9.5	40	30	13	1,200	14.3	42	30	49	42	58	40	15.625
	11/25/08	9:30	1.3	3,079	42.8	48	12	900	12.5	44	42	13	800	11.1	44	42	12	900	12.5	44	42	13	900	12.5	44	42	50	49	48	44	15.5
	11/26/08	10:30	1.3	3,415	40.7	52	12	1,100	13.1	42	44	11	900	10.7	42	44	13	1,100	13.1	44	38	12	1,000	11.9	44	38	48	49	52	40	15.5
	11/27/08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	11/28/08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
11	12/01/08	14:30	2.4	6,681	46.4	50	12	1,700	11.8	50	40	11	1,800	12.5	50	44	12	1,800	12.5	50	44	13	1,700	11.8	50	44	48	49	50	42	15.375
	12/02/08	14:00	1.2	3,225	44.8	52	12	900	12.5	40	32	12	900	12.5	40	32	12	1,000	13.9	40	32	13	1,000	13.9	40	32	49	53	52	40	15.375
	12/03/08	9:00	2.3	1,961	18.2	46	12	500	4.6	40	31	12	600	5.6	40	32	12	500	4.6	42	32	13	500	4.6	42	32	49	19	46	40	15.25
	12/04/08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	12/05/08	11:30	2.0	14,211	56.4	48	6	3,200	12.7	32	30	5	2,400	9.5	32	30	8	2,900	11.5	30	32	9	2,600	10.3	32	30	28	44	48	30	15
12	12/08/08	15:30	1.7	5,599	46.7	34	10	1,600	13.3	32	30	10	1,200	10.0	32	30	11	1,700	14.2	32	30	12	1,700	14.2	32	30	43	52	34	30	14.5
	12/09/08	12:30	1.1	2,561	42.7	52	10	700	11.7	34	30	11	500	8.3	34	30	10	600	10.0	34	30	12	700	11.7	34	30	43	42	52	37	14.375
	12/10/08	13:00	1.5	4,019	44.7	48	10	1,200	13.3	42	42	11	1,100	12.2	42	40	9	1,100	12.2	42	40	11	1,200	13.3	41	41	41	51	48	45	14.375
	12/11/08	13:30	1.1	3,008	45.6	44	11	900	13.6	40	36	12	800	12.1	40	36	10	700	10.6	40	36	12	900	13.6	40	36	45	50	44	40	14.25
	12/12/08	13:00	1.1	2,912	44.1	40	11	800	12.1	42	38	11	900	13.6	42	38	11	900	13.6	42	38	12	900	13.6	42	38	45	53	40	38	14.25
13	12/15/08	10:30	1.3	3,227	44.8	50	12	1,100	15.3	42	38	12	1,700	23.6	42	38	10	800	11.1	44	36	12	700	9.7	42	40	46	60	50	45	14.125
	12/16/08	14:45	1.6	3,847	33.7	40	11	1,500	13.2	38	30	12	600	5.3	38	30	10	1,200	10.5	38	30	11	1,400	12.3	38	30	44	41	40	35	14.125
	12/17/08	14:00	1.5	5,282	58.7	48	11	1,200	13.3	46	42	12	1,300	14.4	46	42	11	1,000	11.1	46	42	11	1,300	14.4	46	42	45	53	48	40	14.125
16	01/06/09	10:30	0.9	34,620	44.0	44	10	9,000	11.5	44	40	12	9,800	12.5	44	40	11	8,800	11.2	44	40	13	11,100	14.1	44	40	46	49	44	40	13.5
	01/07/09	10:00	0.7	2,034	48.4	62	10	200	4.8	50	44	12	300	7.1	50	44	10	200	4.8	50	44	13	400	9.5	50	44	45	26	62	45	13.375
	01/08/09	13:00	1.2	3,521	41.9	40	11	1,200	14.3	38	32	12	1,300	15.5	38	32	12	1,200	14.3	38	32	14	1,500	17.9	38	32	49	62	40	35	13.25
	01/09/09	11:00	0.9	2,273	47.4	42	11	500	10.4	42	38	13	600	12.5	42	38	11	600	12.5	42	38	14	700	14.6	42	38	49	50	42	40	13.25
17	01/12/09	14:30	1.3	3,751	41.7	56	11	900	10.0	42	36	11	1,100	12.2	42	36	13	1,000	11.1	42	36	13	1,200	13.3	42	36	48	47	56	40	13.125
	01/13/09	10:00	0.7	1,654	45.9	40	10	400	11.1	42	36	13	500	13.9	42	38	11	400	11.1	44	38	13	500	13.9	42	38	47	50	40	35	13
	01/14/09	11:30	1.4	3,958	44.0	42	10	1,100	12.2	42	36	13	1,200	13.3	46	40	10	1,000	11.1	44	38	13	1,300	14.4	42	38	46	51	42	35	13
	01/15/09	12:00	1.3	3,509	45.0	54	10	800	10.3	54	48	12	1,000	12.8	54	48	10	800	10.3	54	48	13	1,100	14.1	54	48	45	47	54	45	12.875
18	01/20/09	9:40	0.3	2,483	46.0	70	11	300	5.6	44	38	10	300	5.6	44	40	12	2,200	40.7	44	37	15	800	14.8	44	38	48	67	70	42	13
	01/21/09	8:30	1.3	2,954	41.0	66	11	1,100	15.3	42	36	12	1,300	18.1	44	38	10	200	2.8	46	36	13	1,000	13.9	42	38	46	50	66	35	12.875
	01/22/09	13:00	1.5	4,815	44.6	74	11	1,200	11.1	52	46	12	1,400	13.0	52	46	11	200	1.9	52	46	13	1,500	13.9	52	46	47	40	74	45	12.875
	01/23/09	9:30	1.1	2,195	40.6	74	11	600	11.1	44	38	13	700	13.0	46	40	11	600	11.1	44	38	13	700	13.0	44	38	48	48	74	42	12.75
19	01/26/09	13:00	1.7	5,290	46.4	70	11	1,300	11.4	40	34	13	1,500	13.2	40	34	12	1,300	11.4	40	34	13	1,600	14.0	40	34	49	50	70	40	12.5
	01/27/09	10:00	0.8	1,765	42.0	72	12	400	9.5	42	36	14	500	11.9	44	38	10	400	9.5	46	38	14	500	11.9	42	38	50	43	72	40	12.5
	01/29/09	13:30	0.7	4,351	45.3	76	10	1,200	12.5	48	40	13	1,400	14.6	50	42	10	1,000	10.4	48	40	13	1,400	14.6	45	40	46	52	76	45	12.375
20	02/02/09	14:30	6.7	36,131	44.3	68	10	9,600	11.8	44	38	15	10,900	13.4	46	40	12	9,800	12.0	44	38	10	9,700	11.9	46	40	47	49	68	40	11.75
	02/03/09	13:30	1.1	2,859	43.3	74	10	700	10.6	42	36	13	1,000	15.2	42	36	12	800	12.1	44	38	12	800	12.1	45	40	47	50	74	45	11.75
	02/04/09	10:45	0.8	1,994	47.5	70	12	500	11.9	42	36	12	500	11.9	46	40	12	500	11.9	46	38	14	500	11.9	44	38	50	48	70	35	11.5
	02/05/09	13:00	1.6	4,350	42.6	68	10	1,000	9.8	40	34	13	1,400	13.7	40	34	12	1,200	11.8	42	36	13	1,400	13.7	42	36	48	49	68	35	11.5
	02/06/09	14:30	1.7	4,696	43.5	76	10	1,200	11.1	48	42	11	1,300	12.0	48	42	12	1,300	12.0	50	42	13	1,400	13.0	50	44	46	48	76	40	11.5

Table A-1. EPA Arsenic Demonstration Project at Fountain City, IN - Daily System Operation Log Sheet (Continued)

Week No.	Date	Time	Supply Well: Daily Op Hours (hr/day)	Supply Well: Incremental Volume (gal)	Supply Well: Calculated Flowrate (gpm)	Supply Well: Wellhead Pressure (psi)	Vessel A: Instant. Flowrate A (gpm)	Vessel A: Incremental Volume A (gal)	Vessel A: Calculated Flowrate A (gpm)	Vessel A: Pressure Before Vessel A (psi)	Vessel A: Pressure After Vessel A (psi)	Vessel B: Instant. Flowrate B (gpm)	Vessel B: Incremental Volume B (gal)	Vessel B: Calculated Flowrate B (gpm)	Vessel B: Pressure Before Vessel B (psi)	Vessel B: Pressure After Vessel B (psi)	Vessel C: Instant. Flowrate C (gpm)	Vessel C: Incremental Volume C (gal)	Vessel C: Calculated Flowrate C (gpm)	Vessel C: Pressure Before Vessel C (psi)	Vessel C: Pressure After Vessel C (psi)	Vessel D: Instant. Flowrate D (gpm)	Vessel D: Incremental Volume D (gal)	Vessel D: Calculated Flowrate D (gpm)	Vessel D: Pressure Before Vessel D (psi)	Vessel D: Pressure After Vessel D (psi)	System: Instant. System Flowrate (A+B+C+D) (gpm)	System: System Calculated Flowrate (A+B+C+D) (gpm)	System: Inlet Pressure (psi)	System: Outlet Pressure (psi)	NaOCl Addn.: Solution Tank Level (in)
21	02/09/09	12:30	1.3	3,415	47.4	66	10	800	11.1	42	34	11	900	12.5	48	40	12	1,000	13.9	46	38	13	1,000	13.9	42	38	46	51	66	35	11.375
	02/10/09	13:00	1.5	3,787	42.1	64	10	900	10.0	40	32	12	1,000	11.1	40	32	12	1,100	12.2	44	36	13	1,200	13.3	42	38	47	47	64	30	11.375
	02/11/09	12:30	1.3	3,637	46.6	70	11	900	11.5	48	40	11	900	11.5	48	40	11	1,000	12.8	48	40	12	1,100	14.1	48	40	45	50	70	40	11.25
	02/12/09	13:00	1.4	5,455	64.9	68	10	900	10.7	44	36	12	1,100	13.1	46	38	12	1,100	13.1	46	38	12	1,100	13.1	44	38	46	50	68	35	11.25
	02/13/09	15:00	1.2	1,654	21.2	72	11	800	10.3	44	38	12	900	11.5	44	40	13	1,000	12.8	44	38	12	1,000	12.8	44	38	48	47	72	40	11.125
22	02/17/09	9:30	0.3	1,333	44.4	72	10	400	13.3	44	36	12	400	13.3	44	36	13	400	13.3	46	38	12	400	13.3	42	36	47	53	72	35	10.875
	02/18/09	9:30	1.6	4,155	43.3	74	10	1,000	10.4	48	40	10	1,100	11.5	50	40	12	1,300	13.5	50	38	12	1,200	12.5	48	40	44	48	74	45	10.75
	02/19/09	15:00	1.9	6,220	45.1	72	10	1,600	11.6	46	38	10	1,500	10.9	48	40	12	1,800	13.0	50	38	12	1,800	13.0	48	40	44	49	72	45	10.75
	02/20/09	11:30	0.9	2,088	43.5	68	10	500	10.4	46	40	12	700	14.6	46	40	12	700	14.6	48	40	12	500	10.4	48	40	46	50	68	40	10.625
23	02/23/09	14:45	1.8	5,390	42.8	70	9	1,300	10.3	46	40	14	100	0.8	48	40	12	1,500	11.9	50	40	11	1,600	12.7	50	44	46	36	70	40	10.5
	02/24/09	10:30	0.7	1,414	39.3	76	11	400	11.1	56	50	12	500	13.9	52	44	12	400	11.1	56	50	12	400	11.1	56	50	47	47	76	45	10.375
	02/25/09	12:30	3.0	8,877	46.2	70	13	800	4.2	40	38	10	400	2.1	40	38	12	700	3.6	40	38	13	1,000	5.2	40	38	48	15	70	45	10.25
	02/26/09	13:30	1.2	3,247	41.6	68	13	1,000	12.8	38	34	11	800	10.3	40	38	13	1,000	12.8	42	36	13	1,000	12.8	38	36	50	49	68	35	10.25
	02/27/09	12:30	1.0	2,856	47.6	70	12	900	15.0	42	42	11	700	11.7	44	42	12	800	13.3	44	42	12	700	11.7	44	42	47	52	70	40	10.25
24	03/02/09	15:15	1.7	4,836	42.4	76	11	1,400	12.3	50	46	13	1,200	10.5	50	46	12	1,400	12.3	50	46	11	1,500	13.2	50	46	47	48	76	45	10.125
	03/03/09	13:15	1.0	2,753	51.0	74	12	800	14.8	48	46	10	800	14.8	48	46	11	700	13.0	48	46	12	800	14.8	48	46	45	57	74	45	10.125
	03/04/09	13:00	1.2	3,024	42.0	68	12	800	11.1	38	34	12	800	11.1	40	36	12	900	12.5	40	38	13	900	12.5	40	38	49	47	68	35	10.125
	03/05/09	12:30	1.2	3,182	44.2	70	11	900	12.5	46	42	11	800	11.1	48	42	12	800	11.1	48	44	12	1,000	13.9	48	46	46	49	70	40	10
	03/06/09	13:00	1.2	3,059	42.5	70	12	900	12.5	44	40	12	900	12.5	44	40	12	900	12.5	44	40	12	1,100	15.3	44	40	48	53	70	40	10
25	03/09/09	9:30	1.1	2,436	45.1	66	12	600	11.1	40	36	12	600	11.1	42	38	12	600	11.1	42	38	13	500	9.3	40	36	49	43	66	35	10
	03/10/09	15:30	1.6	5,518	46.0	70	13	1,500	12.5	40	36	12	1,500	12.5	40	38	12	1,600	13.3	42	38	13	1,600	13.3	42	40	50	52	70	35	9.875
	03/11/09	14:30	1.3	3,130	43.5	78	12	900	12.5	40	38	12	900	12.5	42	38	11	900	12.5	44	38	12	1,000	13.9	44	40	47	51	78	35	9.875
	03/12/09	10:30	0.7	1,653	45.9	64	12	400	11.1	36	32	12	400	11.1	36	32	11	400	11.1	38	36	13	400	11.1	38	34	48	44	64	30	9.75
26	03/16/09	10:00	1.2	6,025	43.7	68	13	1,800	13.0	36	32	12	1,600	11.6	38	34	12	1,600	11.6	40	36	13	1,900	13.8	36	32	50	50	68	40	9.625
	03/17/09	10:00	1.2	3,139	43.6	70	13	900	12.5	42	38	11	800	11.1	42	32	12	900	12.5	44	40	12	900	12.5	42	40	48	49	70	35	9.625
	03/18/09	16:00	1.4	4,401	43.1	72	12	1,300	12.7	50	46	11	1,200	11.8	50	46	12	1,200	11.8	50	46	12	1,300	12.7	50	46	47	49	72	45	9.5
	03/20/09	12:30	1.2	6,409	46.4	70	12	1,800	13.0	46	40	10	1,500	10.9	46	40	12	1,700	12.3	46	40	13	1,900	13.8	46	40	47	50	70	40	9.5
27	03/23/09	12:00	1.3	3,336	42.8	72	11	1,000	12.8	46	40	12	900	11.5	46	40	12	900	11.5	46	40	13	1,000	12.8	46	40	48	49	72	45	9.25
	03/24/09	9:00	0.7	1,642	45.6	70	12	500	13.9	42	38	11	400	11.1	44	38	12	500	13.9	44	40	13	500	13.9	42	40	48	53	70	40	9.25
	03/25/09	11:00	1.5	4,301	44.8	74	12	1,100	11.5	48	42	12	1,100	11.5	48	42	12	1,200	12.5	48	42	12	1,300	13.5	48	42	48	49	74	45	9.125
	03/26/09	14:00	1.2	3,671	43.7	74	12	1,100	13.1	52	48	11	1,000	11.9	52	48	11	1,000	11.9	52	48	12	1,000	11.9	52	48	46	49	74	45	9.125
	03/27/09	10:00	0.6	1,299	43.3	66	13	300	10.0	38	34	12	300	10.0	42	38	12	300	10.0	42	34	13	400	13.3	44	40	50	43	66	35	9.125
28	03/30/09	14:00	0.3	1,089	60.5	66	13	300	16.7	38	32	12	300	16.7	38	32	11	300	16.7	40	36	12	300	16.7	40	36	48	67	66	30	9
	03/31/09	10:00	0.1	35	5.8	70	11	100	16.7	48	42	12	0	0.0	50	44	12	100	16.7	50	44	12	100	16.7	48	42	47	50	70	40	9
	04/01/09	15:00	0.2	579	48.3	74	12	100	8.3	44	38	11	200	16.7	48	42	11	100	8.3	48	48	12	100	8.3	46	40	46	42	74	45	9
	04/02/09	7:30	0.0	0	0.0	40	12	0	0.0	40	36	11	0	0.0	42	38	11	0	0.0	44	38	12	0	0.0	42	38	46	0	68	40	9
	04/03/09	8:00	0.1	223	37.2	70	12	100	16.7	46	40	12	100	16.7	50	44	12	100	16.7	48	40	12	100	16.7	52	48	48	67	70	45	9
29	04/06/09	10:00	0.5	1,367	45.6	75	12	400	13.3	48	40	12	300	10.0	48	42	11	400	13.3	50	44	12	400	13.3	50	46	47	50	75	40	9
	04/07/09	9:30	1.1	2,953	44.7	80	11	900	13.6	46	40	12	800	12.1	48	42	13	800	12.1	50	44	12	800	12.1	52	48	48	50	80	40	8.875
	04/08/09	9:00	1.3	3,292	42.2	80	12	1,000	12.8	48	42	12	900	11.5	50	44	11	800	10.3	50	42	12	1,000	12.8	52	46	47	47	80	45	8.875
	04/10/09	7:00	2.0	10,687	45.7	68	12	1,800	7.7	40	36	12	1,600	6.8	40	36	10	1,700	7.3	40	38	15	2,000	8.5	40	38	49	30	68	35	8.75
30	04/13/09	15:00	1.0	3,506	45.0	70	11	1,000	12.8	44	40	10	900	11.5	44	40	10	800	10.3	44	40	15	1,200	15.4	44	40	46	50	70	40	8.5
	04/16/09	7:00	0.9	6,108	44.3	70	12	1,600	11.6	46	42	11	1,500	10.9	46	42	11	1,600	11.6	48	44	12	2,200	15.9	48	44	46	50	70	40	8.25
	04/17/09	15:30	1.8	6,578	45.7	70	11	1,700	11.8	44	42	11	1,700	11.8	46	42	12	1,700	11.8	48	44	12	2,300	16.0	48	44	46	51	70	40	8.25
31	04/20/09	10:00	0.8	1,659	46.1	70	11	400	11.1	44	40	11	400	11.1	46	42	11	400	11.1	46	42	15	500	13.9	44	40	48	47	70	40	8
	04/21/09	12:00	1.6	4,337	42.5	66	11	1,100	10.8	46	42	12	1,400	13.7	48	44	12	1,200	11.8	46	40	15	1,400	13.7	48	44	50	50	66	40	8
	04/22/09	15:00	1.4	4,326	45.1	66	11	1,200	12.5	40	36	11	900	9.4	42	38	12	1,200	12.5	42	38	15	1,600	16.7	41	38	49	51	66	38	7.875
	04/23/09	13:30	1.4	3,296	42.3	70	11	800	10.3	46	42	11	800	10.3	46	42	12	800	10.3	46	42	14	1,000	12.8	46	42	48	44	70	40	7.75
	04/24/09	7:30	0.5	1,209	50.4	66	11	400	16.7	40	36	12	400	16.7	40	36	12	400	16.7	40	36	13	400	16.7	40	36	48	67	66	35	7.75
32	04/27/09	14:30	2.5	8,658	45.1	68	11	2,200	11.5	40	34	12	2,200	11.5	40	38	11	2,300	12.0	40	38	14	2,900	15.1	40	38	48	50	68	34	7.5
	04/28/09	10:30	0.7	1,663	46.2	68	11	400	11.1	40	38	11	400	11.1	42	38	12	500	13.9	42	38	13	500	13.9	40	38	47	50	68	36	7.5
	04/29/09	11:00	1.6	4,239	44.2	70	12	1,200	12.5	44	40	10	1,100	11.5	44	40	12	1,100	11.5	44	40	14	1,400	14.6	44	40	48	50	70	40	7.25
	04/30/09	12:00	1.4	3,806	42.3	72	11	1,000	11.1	50	48	11	1,000	11.1	50	48	11	1,100	12.2	50	48	13	1,200	13.3	50	48	46	48	72	45	7.25
	05/01/09	14:30	3.9	11,271	43.7	74	12	3,300	12.8	50	48	12	3,200	12.4	50	48	11	3,000	11.6	52	48	12	3,400	13.2	52	48	47	50	74	45	7.125
33	05/04/09	13:00	1.5	3,640	43.3	74	11	900	10.7	48	42	12	1,000	11.9	48	42	12	1,000	11.9	48	44	13	1,100	13.1	48	44	48	48	74	38	6.875
	05/05/09	13:00	1.2	3,103	43.1	68	11	900	12.5	42	38	12	900	12.5	42	38	11	900	12.5	42	38	13	1,000	13.9	42	38	47	51	68	35	6.75
	05/06/09	14:00	1.4	4,145	46.1	72	11	1,000	11.1	46	42	11	1,100	12.2	46	42	11	1,100	12.2	46	42	12	1,300	14.4	46	42	45	50	72	40	6.75
	05/07/09	10:30	0.8	1,826	43.5	64	11	500	11.9	38	34	12	400	9.5	38	34	11	500	11.9	38	34	12	500	11.9	38	34	46	45	64	30	6.625
	05/08/09	16:00	1.3	4,144	43.2	62	12	1,100	11.5	38	32	11	1,100	11.5	38	32	12	1,200	12.5	38	32	13	1,400	14.6	38	32	48	50	62	30	6.5
34	05/11/09	15:00	1.5	3,747	44.6	72	11	1,100	13.1	46	40	12	1,000	11.9	46	40	11	1,000	11.9	48	42	12	1,200	14.3	48	42	46	51	72	40	6.375
	05/12/09	15:30	1.4	3,658	43.6	70	11	1,000	11.9	42	38	12	1,000	11.9	42	38	11	1,000	11.9	42	38	13	1,200	14.3	42	38	47	50	70	38	6.375
	05/13/09	15:30	1.3	3,214	41.2	64	12	900	11.5	38	34	12	900	11.5	38	34	12	900	11.5	38	34	13	1,000	12.8	38	34	49	47	64	30	6.25
	05/14/09	15:00	1.4	3,780	45.0	68	12	1,000	11.9	44	38	10	900	10.7	44	38	12	1,000	11.9	44	38	13	1,200	14.3	44	38	47	49	68	37	6.25
	05/15/09	15:00	1.2	3,336	46.3	72	12	900	12.5	48	42	11	900	12.5	48	42	11	800	11.1	48	42	13	1,100	15.3	48	42	47	51	72	45	6.125
35	05/18/09	15:00	1.6	3,971	41.4	70	12	1,100	11.5	46	40	11	1,000	10.4	46	40	10	1,100	11.5	46	40	13	1,300	13.5	46	40	46	47	70	40	6.125
	05/19/09	11:30	0.8	1,855	44.2	70	11	500	11.9	42	38	11	500	11.9	42	38	11	500	11.9	42	38	14	600	14.3	42	38	47	50	70	35	6
	05/20/09	15:00	1.7	5,093	44.7	68	12	1,300	11.4	40	36	11	1,400	12.3	42	38	10	1,300	11.4	42	38	14	1,700	14.9	42	38	47	50	68	35	6
	05/21/09	14:30	1.4	3,180	37.9	66	11	1,000	11.9	40	34	12	900	10.7	40	34	11	900	10.7	40	34	15	1,200	14.3	40	34	49	48	66	30	5.875
	05/22/09	14:30	1.2	3,636	50.5	76	11	900	12.5	50	44	10	900	12.5	50	44	10	900	12.5	50	44	14	1,200	16.7	50	44	45	54	76	40	5.875
36	05/26/09	14:00	0.7	3,612	43.0	68	11	900	10.7	42	36	11	1,000	11.9	42	36	11	900	10.7	42	36	15	1,200	14.3	42	36	48	48	68	35	5.75
	05/27/09	15:00	1.4	4,095	45.5	66	11	1,100	12.2	40	34	11	1,000	11.1	40	34	11	1,100	12.2	40	34	15	1,400	15.6	40	34	48	51	66	35	5.75
	05/28/09	12:30	1.0	2,299	42.6	76	11	600	11.1	52	46	12	600	11.1	52	46	11	600	11.1	52	46	14	800	14.8	52	46	48	48	76	45	5.5
	05/29/09	14:30	1.5	4,052	42.2	72	10	1,100	11.5	48	42	10	1,100	11.5	48	42	11	1,100	11.5	48	42	14	1,500	15.6	48	42	45	50	72	40	5.5
37	06/01/09	16:00	1.5	4,110	42.8	66	11	1,000	10.4	40	34	11	1,000	10.4	40	34	11	1,100	11.5	42	36	14	1,400	14.6	42	36	47	47	66	33	5.25
	06/03/09	10:00	1.1	5,324	44.4	78	10	1,400	11.7	52	46	10	1,400	11.7	52	46	10	1,400	11.7	52	46	16	1,800	15.0	52	46	46	50	78	45	5.25
38	06/09/09	16:00	0.3	3,013	45.7	70	11	800	12.1	46	40	11	800	12.1	46	40	11	800	12.1	46	40	13	1,000	15.2	46	40	46	52	70	40	5
39	06/16/09	5:30	0.2	1,931	40.2	74	10	500	10.4	48	42	11	600	12.5	48	42	11	500	10.4	48	42	14	700	14.6	48	42	46	48	74	40	5
	06/17/09	12:00	0.2	673	56.1	66	11	100	8.3	40	34	11	100	8.3	40	34	11	100	8.3	40	34	15	200	16.7	40	34	48	42	66	35	5
	06/18/09	11:00	0.2	213	17.8	64	11	100	8.3	38	32	12	100	8.3	38	32	11	100	8.3	38	32	15	100	8.3	38	32	49	33	64	30	5
40	06/23/09	6:30	0.1	1,174	48.9	76	11	300	12.5	50	44	11	300	12.5	50	44	12	300	12.5	50	44	14	400	16.7	50	44	48	54	76	45	5
	06/24/09	12:30	0.2	536	44.6	74	10	200	16.7	46	40	10	200	16.7	46	40	10	200	16.7	46	40	14	200	16.7	46	40	44	67	74	40	4.875
	06/25/09	16:00	0.3	1,177	49.0	64	12	200	8.3	40	32	11	200	8.3	40	32	12	300	12.5	40	32	15	400	16.7	40	32	50	46	64	30	4.875

Table A-1. EPA Arsenic Demonstration Project at Fountain City, IN - Daily System Operation Log Sheet (Continued)

			Supply Well				Vessel A					Vessel B					Vessel C					Vessel D					System				NaOCl Addn.
Week No.	Date	Time	Daily Op Hours	Incremental Volume	Calculated Flowrate	Wellhead Pressure	Instant. Flowrate A	Incremental Volume A	Calculated Flowrate A	Pressure Before Vessel A	Pressure After Vessel A	Instant. Flowrate B	Incremental Volume B	Calculated Flowrate B	Pressure Before Vessel B	Pressure After Vessel B	Instant. Flowrate C	Incremental Volume C	Calculated Flowrate C	Pressure Before Vessel C	Pressure After Vessel C	Instant. Flowrate D	Incremental Volume D	Calculated Flowrate D	Pressure Before Vessel D	Pressure After Vessel D	Instant. System Flowrate (A+B+C+D)	System Calculated Flowrate (A+B+C+D)	Inlet Pressure	Outlet Pressure	Solution Tank Level
			hr/day	gal	gpm	psi	gpm	gal	gpm	psi	psi	gpm	gal	gpm	psi	psi	gpm	gal	gpm	psi	psi	gpm	gal	gpm	psi	psi	gpm	gpm	psi	psi	in
41	06/29/09	9:30	0.2	966	40.3	70	11	100	4.2	42	36	11	300	12.5	42	36	11	200	8.3	42	36	15	300	12.5	42	36	48	37	70	35	4.875
	06/30/09	7:00	0.1	120	20.0	66	11	100	16.7	42	42	11	0	0.0	40	34	11	100	16.7	40	34	15	100	16.7	40	34	48	50	66	30	4.875
	07/01/09	16:00	0.2	989	55.0	70	11	200	11.1	42	36	11	300	16.7	42	36	11	200	11.1	42	36	14	300	16.7	42	36	47	56	70	35	4.875
	07/02/09	14:30	0.1	263	43.8	74	11	100	16.7	48	42	10	100	16.7	48	42	10	100	16.7	48	42	14	100	16.7	48	42	45	67	74	40	4.875
42	07/13/09	16:00	2.0	37,780	44.0	64	12	800	0.9	36	34	11	600	0.7	36	34	11	600	0.7	36	34	14	700	0.8	36	34	48	3	64	30	3.875
	07/14/09	16:00	0.3	1,083	60.2	68	12	300	16.7	42	40	10	300	16.7	42	40	10	300	16.7	42	40	14	300	16.7	42	40	46	67	68	35	3.875
	07/15/09	16:00	0.4	1,429	59.5	68	12	200	8.3	42	40	10	200	8.3	42	40	10	200	8.3	42	40	14	300	12.5	42	40	46	37	68	40	3.875
	07/16/09	17:30	0.5	698	23.3	64	12	400	13.3	40	38	11	400	13.3	40	38	10	300	10.0	40	38	15	500	16.7	40	38	48	53	64	35	3.75
43	07/21/09	16:00	0.3	2,355	49.1	62	12	600	12.5	36	34	10	500	10.4	36	34	10	600	12.5	36	34	15	800	16.7	36	34	47	52	62	30	3.75
	07/22/09	16:00	0.1	219	36.6	66	11	100	16.7	38	34	11	100	16.7	38	34	10	100	16.7	38	34	14	100	16.7	38	34	46	67	66	35	3.75
	07/23/09	16:00	0.2	331	27.6	64	12	100	8.3	38	34	10	100	8.3	38	34	10	0	0.0	38	34	15	100	8.3	38	34	47	25	64	35	3.75
44	07/27/09	15:30	0.2	809	45.0	74	12	300	16.7	48	44	10	200	11.1	48	44	10	200	11.1	48	44	15	300	16.7	48	44	47	56	74	45	3.75
45	08/04/09	16:30	0.1	2,366	49.3	66	12	600	12.5	40	36	11	600	12.5	40	36	11	600	12.5	40	36	15	800	16.7	40	36	49	54	66	35	3.625
	08/05/09	16:00	0.4	967	40.3	64	12	200	8.3	38	34	11	200	8.3	38	38	11	200	8.3	38	34	15	300	12.5	38	34	49	37	64	35	3.625
46	08/10/09	16:00	0.2	1,474	40.9	72	11	500	13.9	50	46	10	400	11.1	50	46	10	400	11.1	50	46	15	600	16.7	50	46	46	53	72	45	3.5
	08/11/09	15:00	0.1	312	52.1	60	12	0	0.0	34	30	11	0	0.0	34	30	11	100	16.7	34	30	16	100	16.7	34	30	50	33	60	30	3.5
	08/12/09	16:30	0.1	652	108.6	72	12	200	33.3	48	44	10	200	33.3	48	44	10	200	33.3	48	44	15	200	33.3	48	44	47	133	72	40	3.5
	08/13/09	16:00	0.3	475	26.4	70	12	100	5.6	46	42	10	100	5.6	46	42	10	100	5.6	46	42	15	200	11.1	46	42	47	28	70	40	3.5
47	08/17/09	16:00	0.3	1,710	47.5	62	12	500	13.9	36	32	10	500	13.9	36	32	12	400	11.1	36	32	15	600	16.7	36	32	49	56	62	30	3.5
	08/18/09	16:00	1.5	3,934	43.7	66	12	1,100	12.2	38	36	11	1,000	11.1	38	36	12	1,100	12.2	38	36	13	1,300	14.4	38	36	48	50	66	35	3.5
	08/19/09	16:00	1.6	4,217	43.9	68	11	1,100	11.5	42	38	12	1,200	12.5	42	38	12	1,200	12.5	42	38	13	1,300	13.5	42	38	48	50	68	35	3.25
	08/20/09	15:00	1.7	4,206	43.8	62	12	1,200	12.5	36	32	12	1,000	10.4	36	32	12	1,100	11.5	36	32	14	1,400	14.6	36	32	50	49	62	30	3.25
	08/21/09	15:30	1.5	4,030	44.8	72	11	1,000	11.1	36	34	12	1,000	11.1	36	34	12	1,100	12.2	36	34	13	1,300	14.4	36	34	48	49	72	35	3.25
48	08/24/09	16:00	1.9	5,078	44.5	66	12	1,400	12.3	40	36	12	1,400	12.3	40	36	11	1,400	12.3	40	36	14	1,600	14.0	40	36	49	51	66	35	14.75
	08/25/09	15:00	1.5	3,572	42.5	62	11	1,000	11.9	36	32	12	1,000	11.9	36	32	11	900	10.7	36	32	15	1,300	15.5	36	32	49	50	62	30	14.5
	08/26/09	15:30	1.6	4,448	46.3	68	11	1,100	11.5	44	40	11	1,100	11.5	44	40	11	1,200	12.5	44	40	14	1,400	14.6	44	40	47	50	68	40	14.5
	08/27/09	15:30	1.6	4,080	42.5	66	11	1,100	11.5	42	38	12	1,100	11.5	42	38	11	1,000	10.4	42	38	15	1,400	14.6	42	38	49	48	66	35	14.25
	08/28/09	15:00	1.2	3,195	44.4	72	11	800	11.1	48	44	11	900	12.5	48	44	11	900	12.5	48	44	14	1,100	15.3	48	44	47	51	72	40	14.25
49	08/31/09	16:00	2.4	2,196	14.6	70	11	2,000	13.3	46	42	12	1,900	12.7	46	42	11	2,300	15.3	46	42	14	2,600	17.3	46	42	48	59	70	40	14.125
	09/01/09	15:00	1.6	8,560	95.1	62	11	1,000	11.1	44	40	11	700	7.8	44	40	11	400	4.4	44	40	13	1,100	12.2	44	40	46	36	62	30	14.125
	09/02/09	15:00	1.6	4,119	42.9	64	12	1,200	12.5	42	38	12	1,200	12.5	42	38	11	1,100	11.5	42	38	13	1,400	14.6	42	38	48	51	64	35	14.125
	09/03/09	15:30	1.5	4,033	44.8	72	10	1,000	11.1	48	44	12	1,000	11.1	48	44	11	1,100	12.2	48	44	13	1,300	14.4	48	44	46	49	72	45	14
	09/04/09	14:30	1.5	3,602	42.9	70	11	900	10.7	44	40	11	1,000	11.9	44	40	12	1,000	11.9	44	40	14	1,200	14.3	44	40	48	49	70	45	14
50	09/08/09	15:00	0.8	4,598	45.1	72	11	1,300	12.7	44	40	11	1,200	11.8	44	40	12	1,300	12.7	44	40	13	1,400	13.7	44	40	47	51	72	40	13.75
	09/10/09	11:30	1.3	6,600	44.0	64	13	1,900	12.7	38	34	11	1,700	11.3	38	34	12	1,800	12.0	38	34	13	2,100	14.0	38	34	49	50	64	35	13.5
	09/11/09	10:00	1.4	3,410	43.7	70	12	1,000	12.8	42	38	11	800	10.3	42	38	11	900	11.5	42	38	13	1,100	14.1	42	38	47	49	70	40	13.25
51	09/14/09	10:30	1.7	4,313	42.3	70	11	1,200	11.8	46	42	11	1,100	10.8	46	42	12	1,200	11.8	46	42	13	1,300	12.7	46	42	47	47	70	40	13.25
	09/15/09	15:30	2.0	6,507	45.2	70	11	1,700	11.8	46	42	11	1,700	11.8	46	42	11	2,000	13.9	46	42	13	2,100	14.6	46	42	46	52	70	40	13.125
	09/16/09	15:00	1.5	3,742	41.6	62	11	1,100	12.2	38	34	12	1,000	11.1	38	34	12	1,100	12.2	38	34	13	1,200	13.3	38	34	48	49	62	30	13
	09/17/09	15:00	2.0	5,153	42.9	66	12	1,500	12.5	42	36	10	1,200	10.0	42	36	12	1,500	12.5	42	36	12	1,500	12.5	42	36	46	48	66	35	12.75
	09/18/09	15:00	1.4	3,893	46.3	62	13	1,100	13.1	38	32	10	900	10.7	38	32	13	1,100	13.1	38	32	13	1,200	14.3	38	32	49	51	62	30	NA
52	09/21/09	8:30	0.5	969	40.4	68	12	400	16.7	42	38	10	300	12.5	42	38	12	300	12.5	42	38	13	300	12.5	42	38	47	54	68	35	12.75
	09/22/09	9:00	1.6	3,713	38.7	70	11	1,100	11.5	46	40	10	1,000	10.4	46	40	12	1,200	12.5	46	40	13	1,200	12.5	46	40	46	47	70	40	12.5
	09/23/09	9:00	1.6	4,659	48.5	66	11	1,200	12.5	42	36	11	1,100	11.5	42	36	12	1,300	13.5	42	36	13	1,400	14.6	42	36	47	52	66	35	12.375
	09/24/09	9:00	1.4	3,639	43.3	64	12	1,000	11.9	40	34	12	900	10.7	40	34	12	1,000	11.9	40	34	14	1,200	14.3	40	34	50	49	64	30	12.25
	09/25/09	10:30	1.8	5,115	44.9	64	12	1,300	11.4	40	34	12	1,400	12.3	40	34	12	1,400	12.3	40	34	13	1,600	14.0	40	34	49	50	64	30	12.125
53	09/28/09	13:00	2.0	5,636	42.7	72	12	1,600	12.1	46	40	11	1,500	11.4	46	40	10	1,500	11.4	46	40	13	1,800	13.6	46	40	46	48	72	45	12
	09/29/09	10:30	1.0	2,297	42.5	64	12	600	11.1	38	32	11	600	11.1	38	32	12	700	13.0	38	32	13	800	14.8	38	32	48	50	64	30	11.875
	09/30/09	10:00	1.5	3,958	44.0	68	11	1,100	12.2	42	36	11	1,000	11.1	42	36	12	1,000	11.1	42	36	13	1,200	13.3	42	36	47	48	68	35	11.75
	10/01/09	10:30	1.5	4,114	45.7	74	11	1,100	12.2	52	46	11	1,100	12.2	52	46	10	1,100	12.2	52	46	13	1,300	14.4	52	46	45	51	74	45	11.625
	10/02/09	9:00	1.4	3,076	39.4	70	11	900	11.5	44	38	11	900	11.5	44	38	11	1,000	12.8	44	38	12	1,100	14.1	44	38	45	50	70	40	11.5
54	10/05/09	12:30	2.1	6,414	44.5	78	11	1,700	11.8	50	48	10	1,800	12.5	50	48	11	1,600	11.1	50	48	12	2,000	13.9	50	48	44	49	78	45	11.5
	10/06/09	13:00	1.6	4,143	43.2	70	11	1,100	11.5	44	38	11	1,100	11.5	44	38	11	1,100	11.5	44	38	13	1,400	14.6	44	38	46	49	70	40	11.375
	10/07/09	11:00	1.1	2,863	47.7	68	11	800	13.3	42	36	12	700	11.7	42	36	12	800	13.3	42	36	14	900	15.0	42	36	49	53	68	40	11.25
	10/08/09	10:30	1.4	3,432	40.9	64	11	900	10.7	38	32	11	1,000	11.9	38	32	12	1,000	11.9	38	32	13	1,100	13.1	38	32	47	48	64	30	11.25
	10/09/09	10:30	1.6	4,259	44.4	70	11	1,100	11.5	44	38	11	1,000	10.4	44	38	12	1,200	12.5	44	38	13	1,300	13.5	44	38	47	48	70	35	11.125
55	10/12/09	10:00	1.5	3,876	43.1	70	11	1,100	12.2	44	38	11	3,400	37.8	44	38	11	800	8.9	44	38	13	1,300	14.4	44	38	46	73	70	40	11.0625
	10/13/09	9:00	1.5	3,703	44.1	72	11	1,000	11.9	50	46	11	1,000	11.9	50	46	12	1,000	11.9	50	46	13	1,100	13.1	50	46	47	49	72	45	11
	10/14/09	10:00	3.2	8,854	44.7	70	12	1,300	6.6	42	40	11	1,100	5.6	42	40	11	1,100	5.6	42	40	13	1,000	5.1	42	40	47	23	70	40	10.625
	10/15/09	15:00	2.4	8,354	48.0	72	12	2,400	13.8	44	42	11	2,100	12.1	44	42	11	1,900	10.9	44	42	12	2,400	13.8	44	42	46	51	72	40	10.5
	10/16/09	14:30	1.7	3,831	37.6	60	12	1,300	12.7	36	32	12	1,200	11.8	36	32	12	1,200	11.8	36	32	13	1,200	11.8	36	32	49	48	60	30	10.375
57	10/26/09	15:00	1.1	17,256	43.6	74	11	5,000	12.6	45	44	10	4,700	11.9	48	44	11	4,600	11.6	48	44	13	5,400	13.6	48	44	45	50	74	45	10.25
	10/27/09	15:00	1.5	4,056	45.1	66	12	1,200	13.3	38	34	12	1,100	12.2	38	34	11	1,100	12.2	38	34	13	1,200	13.3	38	34	48	51	66	35	10.125
	10/28/09	15:00	3.2	8,537	44.5	62	13	2,500	13.0	36	30	11	2,400	12.5	36	30	12	2,200	11.5	36	30	13	2,600	13.5	36	30	49	51	62	30	10
	10/29/09	15:00	1.5	4,112	45.7	65	12	1,100	12.2	40	36	11	900	10.0	40	36	11	1,000	11.1	40	36	13	1,100	12.2	40	36	47	46	65	30	9.875

NOTE:
NA = not available
Tank: 1 BV = 17.7 ft3, 17.7 ft3 = 132 gal
System has 4 Tanks in parallel configuration.
System: 1 BV = 70.7 ft3, 70.7 ft3 = 528 gal
(a) Water used since last regeneration in gallons
(b) 1st reading from all four valve displays & countdown reset to 90,000

APPENDIX B

ANALYTICAL DATA

Table B-1. Analytical Results from Long-Term Sampling at Fountain City, IN

Sampling Date		10/09/08			10/22/08						11/06/08			11/20/08						
Sampling Location		IN	AC	TT	IN	AC	TA	TB	TC	TD	IN	AC	TT	IN	AC	TA	TB	TC	TD	TT
Parameter	Unit																			
Bed Volume	10^3	-	-	0.1	-	-	0.2	0.0	0.2	0.2	-	-	0.2	-	-	0.4	0.1	0.4	0.3	0.3
Alkalinity	mg/L [(a)]	319	321	321	324	322	322	328	328	328	315	317	310	309	309	312	307	312	309	NA
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ammonia	mg/L	1.0	0.9	0.8	1.0	0.9	0.9	0.9	0.9	0.9	1.0	0.9	0.9	1.0	0.9	0.9	0.9	0.9	0.9	NA
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	1.7	1.7	1.6	-	-	-	-	-	-	1.6	1.7	1.7	-	-	-	-	-	-	-
Sulfate	mg/L	2.3	2.3	2.2	-	-	-	-	-	-	2.1	2.2	2.2	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	-	-	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	-	-	-
Total P (as P)	μg/L	<10	<10	<10	-	-	-	-	-	-	<10	11.1	19.7	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	15.9	15.8	19.7	15.3	15.3	20.0	18.8	18.3	19.9	14.2	14.0	18.8	15.2	15.3	20.7	19.6	19.3	20.4	NA
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	12.0	3.5	0.3	11.0	1.9	1.0	1.2	0.9	0.6	19.0	2.4	0.9	13.0	12.0	1.2	1.3	1.4	2.1	NA
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOC	mg/L	1.5	1.5	1.5	1.8	1.8	1.9	1.9	1.8	1.9	1.0	0.9	0.9	1.9	2.6	1.8	1.8	1.8	1.7	NA
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	7.7	7.5	7.5	7.5	7.5	7.4	NA	7.4	NA	7.6	7.5	7.6	7.7	7.6	NA	NA	NA	NA	7.6
Temperature	°C	15.0	15.4	15.3	14.0	15.7	14.7	NA	14.6	NA	19.2	18.4	19.2	16.2	15.4	NA	NA	NA	NA	16.1
DO	mg/L	4.2	1.8	0.9	2.1	1.8	1.8	NA	1.8	NA	2.2	2.0	2.5	NA [(b)]	NA [(b)]	NA	NA	NA	NA	NA [(b)]
ORP	mV	254	262	294	241	259	270	NA	265	NA	197	266	269	204	214	NA	NA	NA	NA	252
Free Chlorine (as Cl_2)	mg/L	0.0	0.1	0.5	0.0	0.3	0.3	NA	0.3	NA	0.1	0.5	0.9	0.0	0.0	NA	NA	NA	NA	0.8
Total Chlorine (as Cl_2)	mg/L	0.0	1.4	1.4	0.0	1.4	1.3	NA	1.3	NA	0.0	1.2	1.1	0.1	1.0	NA	NA	NA	NA	0.9
Total Hardness	mg/L [(a)]	247	258	260	-	-	-	-	-	-	210	214	208	-	-	-	-	-	-	-
Ca Hardness	mg/L [(a)]	147	154	156	-	-	-	-	-	-	120	122	121	-	-	-	-	-	-	-
Mg Hardness	mg/L [(a)]	101	103	104	-	-	-	-	-	-	89.6	92.1	87.5	-	-	-	-	-	-	-
As (total)	μg/L	29.0	28.9	2.2	28.0	27.6	5.2	5.9	5.9	3.9	26.8	28.4	6.0	31.2	36.1	9.1	7.9	9.3	9.4	NA
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	μg/L	23.4	2.7	2.0	-	-	-	-	-	-	19.9	2.1	2.2	-	-	-	-	-	-	-
As (particulate)	μg/L	5.6	26.1	0.2	-	-	-	-	-	-	6.9	26.2	3.7	-	-	-	-	-	-	-
As (III)	μg/L	21.8	0.3	0.4	-	-	-	-	-	-	16.3	0.6	0.6	-	-	-	-	-	-	-
As (V)	μg/L	1.7	2.4	1.6	-	-	-	-	-	-	3.7	1.5	1.6	-	-	-	-	-	-	-
Fe (total)	μg/L	1,466	1,558	<25	1,570	1,442	254	314	287	154	1,606	1,828	286	1,532	1,849	466	422	527	556	NA
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	μg/L	1,085	<25	<25	-	-	-	-	-	-	812	<25	<25	-	-	-	-	-	-	-
Mn (total)	μg/L	49.8	50.4	19.5	59.7	62.3	29.6	28.9	33.2	27.2	52.8	53.1	27.8	47.6	48.6	34.6	34.1	35.1	30.1	NA
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	μg/L	51.5	26.1	20.1	-	-	-	-	-	-	52.1	31.8	26.8	-	-	-	-	-	-	-

(a) As $CaCO_3$ (b) DO measurement not taken due to probe calibration error

Table B-1. Analytical Results from Long-Term Sampling at Fountain City, IN (Continued)

Sampling Date		12/04/08			12/29/08(c)							01/07/09			1/22/09(d)						
Sampling Location / Parameter	Unit	IN	AC	TT	IN	AC	TA	TB	TC	TD	TT	IN	AC	TT	IN	AC	TA	TB	TC	TD	TT
Bed Volume	10^3	-	-	0.4	-	-	0.6	0.3	0.6	0.6	0.5	-	-	0.5	-	-	0.7	0.4	0.6	0.6	0.6
Alkalinity	mg/L (a)	332	334	330	312	309	309	316	316	318	NA	312	310	321	317	319	319	317	315	321	NA
		-	-	-	314	312	316	316	316	318	NA	-	-	-	-	-	-	-	-	-	NA
Ammonia	mg/L	1.0	0.9	0.9	1.1	0.9	1.0	1.0	0.9	1.0	NA	0.9	0.9	0.9	1.0	1.0	0.8	0.9	0.9	0.8	NA
		-	-	-	1.0	1.0	1.0	1.0	0.9	1.0	NA	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	1.7	1.7	1.7	-	-	-	-	-	-	-	1.8	1.8	1.8	-	-	-	-	-	-	-
Sulfate	mg/L	2.1	2.1	2.1	-	-	-	-	-	-	-	2.0	2.0	2.0	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	-	-	-
Total P (as P)	µg/L	22.3	11.5	<10	-	-	-	-	-	-	-	22.3	13.5	10.3	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	15.2	16.3	20.8	15.6	15.4	30.6	29.3	28.6	28.9	NA	14.3	14.5	17.1	14.0	14.9	18.6	16.7	17.2	18.1	NA
		-	-	-	15.5	15.3	29.3	28.9	27.9	29.8	NA	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	19.0	2.7	0.3	22.0	4.3	0.3	0.4	0.3	0.6	NA	12.0	6.3	0.4	15.0	2.7	0.5	0.6	0.4	0.6	NA
		-	-	-	24.0	3.4	0.4	0.5	0.2	0.5	NA	-	-	-	-	-	-	-	-	-	-
TOC	mg/L	1.6	1.6	1.7	1.6	2.4	1.7	2.1	1.8	1.8	NA	1.7	1.5	1.4	1.4	1.6	1.5	1.4	1.5	1.5	NA
		-	-	-	1.6	1.7	1.9	1.8	1.9	1.8	NA	-	-	-	-	-	-	-	-	-	-
pH	S.U.	7.5	7.4	7.4	7.4	7.4	NA	NA	NA	NA	7.4	7.6	7.5	7.4	NA	NA	NA	NA	NA	NA	NA
Temperature	°C	14.8	14.4	14.6	12.0	17.5	NA	NA	NA	NA	17.8	13.8	14.2	14.2	NA	NA	NA	NA	NA	NA	NA
DO	mg/L	NA (b)	NA (b)	NA (b)	NA (b)	NA (b)	NA	NA	NA	NA	NA (b)	NA (b)	NA (b)	NA (b)	NA	NA	NA	NA	NA	NA	NA
ORP	mV	207	285	283	148	270	NA	NA	NA	NA	242	207	271	274	NA	NA	NA	NA	NA	NA	NA
Free Chlorine (as Cl_2)	mg/L	0.0	0.9	0.1	0.1	0.5	NA	NA	NA	NA	0.2	0.1	0.1	0.2	NA	NA	NA	NA	NA	NA	NA
Total Chlorine (as Cl_2)	mg/L	0.0	1.0	0.1	0.0	0.5	NA	NA	NA	NA	0.3	0.0	0.2	0.4	NA	NA	NA	NA	NA	NA	NA
Total Hardness	mg/L (a)	286	286	280	-	-	-	-	-	-	-	303	284	286	-	-	-	-	-	-	-
Ca Hardness	mg/L (a)	167	167	164	-	-	-	-	-	-	-	150	145	143	-	-	-	-	-	-	-
Mg Hardness	mg/L (a)	119	118	116	-	-	-	-	-	-	-	153	139	143	-	-	-	-	-	-	-
As (total)	µg/L	31.0	29.2	2.7	34.3	28.1	3.5	3.5	3.0	3.3	NA	39.3	30.2	3.4	29.8	29.8	3.9	4.5	3.9	4.4	NA
		-	-	-	34.3	32.1	3.4	3.3	3.0	3.4	NA	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	22.8	2.4	2.4	-	-	-	-	-	-	-	26.4	2.8	2.2	-	-	-	-	-	-	-
As (particulate)	µg/L	8.2	26.8	0.2	-	-	-	-	-	-	-	12.9	27.4	1.2	-	-	-	-	-	-	-
As (III)	µg/L	21.3	0.6	0.7	-	-	-	-	-	-	-	23.9	0.4	0.5	-	-	-	-	-	-	-
As (V)	µg/L	1.4	1.8	1.8	-	-	-	-	-	-	-	2.5	2.4	1.8	-	-	-	-	-	-	-
Fe (total)	µg/L	1,945	1,797	<25	1,980	1,671	<25	54	<25	37	NA	1,786	1,206	57	1,677	1,429	116	186	136	191	NA
		-	-	-	1,980	1,767	<25	<25	<25	40	NA	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	1,282	<25	<25	-	-	-	-	-	-	-	1,395	<25	<25	-	-	-	-	-	-	-
Mn (total)	µg/L	52.5	53.2	41.9	42.0	43.2	40.1	38.3	39.7	35.3	NA	41.8	40.0	35.3	50.9	49.5	49.3	50.5	48.9	48.2	NA
		-	-	-	42.0	42.1	36.7	37.6	36.9	34.7	NA	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	52.2	39.8	42.7	-	-	-	-	-	-	-	46.5	29.7	37.2	-	-	-	-	-	-	-

(a) As $CaCO_3$

(b) DO measurement not taken due to probe calibration error

(c) Bed volumes from 01/06/09

(d) Water quality measurements were not taken on 01/22/09

Table B-1. Analytical Results from Long-Term Sampling at Fountain City, IN (Continued)

Sampling Date		02/11/09			02/23/09							03/03/09			03/17/09						
Sampling Location		IN	AC	TT	IN	AC	TA	TB	TC	TD	TT	IN	AC	TT	IN	AC	TA	TB	TC	TD	TT
Parameter	Unit																				
Bed Volume	10^3	-	-	0.7	-	-	0.9	0.6	0.8	0.8	0.8	-	-	0.8	-	-	1.0	0.7	0.9	1.0	0.9
Alkalinity	mg/L [(a)]	331	340	338	342	344	340	340	344	356	NA	324	328	330	341	337	328	337	331	337	331
		-	-	-	-	-	-	-	-	-	NA	-	-	-	339	335	341	339	331	337	344
Ammonia	mg/L	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.9	NA	1.0	1.0	0.9	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
Fluoride	mg/L	2.0	1.8	1.8	-	-	-	-	-	-	-	1.9	1.8	1.8	-	-	-	-	-	-	-
Sulfate	mg/L	2.2	2.1	2.1	-	-	-	-	-	-	-	2.1	2.2	2.1	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	-	-	-
Total P (as P)	µg/L	13.4	13.7	<10	-	-	-	-	-	-	-	16.4	10.5	<10	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	15.1	15.6	18.1	14.6	15.0	17.1	16.4	16.7	16.2	NA	15.8	15.4	17.0	15.2	14.6	16.5	16.2	16.2	16.5	17.0
		-	-	-	-	-	-	-	-	-	NA	-	-	-	14.7	14.5	16.0	16.3	15.8	16.3	16.7
Turbidity	NTU	14.0	2.7	1.0	18.0	2.3	0.5	0.8	2.0	0.8	NA	11.0	2.7	0.2	17.0	2.5	0.1	0.4	0.2	0.2	0.2
		-	-	-	-	-	-	-	-	-	NA	-	-	-	19.0	2.9	0.1	0.5	0.2	0.2	0.3
TOC	mg/L	1.4	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.3	NA	1.7	1.7	1.6	1.5	1.4	1.3	1.3	1.3	1.4	1.3
		-	-	-	-	-	-	-	-	-	-	-	-	-	1.4	1.4	1.3	1.3	1.3	1.3	1.3
pH	S.U.	7.6	7.6	7.4	7.6	7.4	NA	NA	NA	NA	NA [(e)]	7.6	7.6	7.4	7.6	7.5	NA	NA	NA	NA	7.4
Temperature	°C	16.5	16.8	16.8	13.1	13.0	NA	NA	NA	NA	NA [(e)]	10.6	11.9	10.0	15.3	13.8	NA	NA	NA	NA	12.8
DO	mg/L	NA [(b)]	NA [(b)]	NA [(b)]	NA [(b)]	NA [(b)]	NA	NA	NA	NA	NA [(e)]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ORP	mV	327	324	325	213	242	NA	NA	NA	NA	NA [(e)]	266	261	257	220	247	NA	NA	NA	NA	256
Free Chlorine (as Cl_2)	mg/L	0.1	0.4	0.0	0.1	0.6	NA	NA	NA	NA	NA [(e)]	0.0	0.4	0.4	0.0	0.6	NA	NA	NA	NA	0.7
Total Chlorine (as Cl_2)	mg/L	0.0	1.1	0.8	0.0	0.7	NA	NA	NA	NA	NA [(e)]	0.0	0.3	0.4	0.0	0.6	NA	NA	NA	NA	0.7
Total Hardness	mg/L [(a)]	260	266	258	-	-	-	-	-	-	-	215	206	221	-	-	-	-	-	-	-
Ca Hardness	mg/L [(a)]	157	163	158	-	-	-	-	-	-	-	144	140	148	-	-	-	-	-	-	-
Mg Hardness	mg/L [(a)]	103	104	100	-	-	-	-	-	-	-	70.9	65.7	73.2	-	-	-	-	-	-	-
As (total)	µg/L	29.4	29.7	6.2	31.9	27.6	4.5	5.9	11.2	6.0	NA	27.1	25.1	1.9	31.2	30.5	2.8	4.4	2.2	2.2	3.2
		-	-	-	-	-	-	-	-	-	-	-	-	-	31.1	29.9	2.8	4.7	2.3	2.2	3.1
As (soluble)	µg/L	18.2	2.9	2.4	-	-	-	-	-	-	-	22.0	3.2	1.8	-	-	-	-	-	-	-
As (particulate)	µg/L	11.2	26.8	3.9	-	-	-	-	-	-	-	5.2	21.9	0.1	-	-	-	-	-	-	-
As (III)	µg/L	17.5	0.8	0.8	-	-	-	-	-	-	-	20.9	0.4	0.4	-	-	-	-	-	-	-
As (V)	µg/L	0.8	2.1	1.6	-	-	-	-	-	-	-	1.1	2.8	1.3	-	-	-	-	-	-	-
Fe (total)	µg/L	1,601	1,611	291	1,773	1,433	197	312	661	313	NA	1,418	1,310	<25	2,062	1,800	33	188	<25	41	96
		-	-	-	-	-	-	-	-	-	-	-	-	-	2,101	1,888	32	188	32	41	90
Fe (soluble)	µg/L	407	<25	<25	-	-	-	-	-	-	-	1,035	43.9	<25	-	-	-	-	-	-	-
Mn (total)	µg/L	47.9	49.8	49.8	50.9	48.9	50.3	51.8	52.1	53.2	NA	52.5	49.3	53.0	54.0	54.5	54.9	55.2	55.7	55.3	55.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	54.8	53.7	54.0	54.8	55.3	55.2	55.3
Mn (soluble)	µg/L	46.5	29.9	48.2	-	-	-	-	-	-	-	53.2	50.2	51.3	-	-	-	-	-	-	-

(a) As $CaCO_3$

(b) DO measurement not taken due to probe calibration error

(e) TT water quality measurements not taken on 02/23/09

Table B-1. Analytical Results from Long-Term Sampling at Fountain City, IN (Continued)

Sampling Date		03/31/09			4/14/09[f]							04/28/09			05/12/09			05/26/09						
Sampling Location / Parameter	Unit	IN	AC	TT	IN	AC	TA	TB	TC	TD	TT	IN	AC	TT	IN	AC	TT	IN	AC	TA	TB	TC	TD	TT
Bed Volume	10^3	-	-	0.9	-	-	1.1	0.8	1.0	1.1	1.0	-	-	1.1	-	-	1.1	-	-	1.3	1.0	1.3	1.3	1.2
Alkalinity	mg/L[a]	329	329	334	332	334	329	325	332	323	NA	332	332	344	346	341	346	332	332	329	332	329	329	329
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ammonia	mg/L	1.0	1.0	0.9	1.0	0.9	0.9	0.9	0.9	0.9	NA	1.0	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	1.7	1.7	1.8	-	-	-	-	-	-	-	1.8	1.7	1.7	1.7	1.9	1.8	-	-	-	-	-	-	-
Sulfate	mg/L	1.8	1.8	2.1	-	-	-	-	-	-	-	2.1	2.1	2.1	2.2	2.0	2.1	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	-	-	-	-	-
Total P (as P)	µg/L	<10	12.8	<10	-	-	-	-	-	-	-	10.2	<10	<10	10.5	<10	<10	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	13.6	13.2	18.9	14.5	14.6	18.3	18.0	17.8	17.9	NA	17.0	17.6	18.5	16.0	16.5	19.1	15.6	15.6	19.1	18.3	18.9	18.0	18.7
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	19.0	5.3	2.8	16.0	3.6	0.7	0.3	0.3	0.6	NA	19.0	2.4	1.6	19.0	2.4	1.0	21.0	6.1	1.2	0.4	0.6	0.8	0.5
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOC	mg/L	1.4	1.5	1.4	1.5	1.7	1.3	1.4	1.5	1.4	NA	1.4	1.4	1.4	1.9	1.6	1.5	1.6	1.6	1.5	1.5	1.5	1.7	1.7
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	7.6	7.6	7.6	7.7	7.6	NA	NA	NA	NA	7.5	7.6	7.6	7.6	7.6	7.5	7.4	7.6	7.5	NA	NA	NA	NA	7.5
Temperature	°C	13.7	13.7	13.7	17.1	17.1	NA	NA	NA	NA	17.1	15.2	15.2	15.1	14.8	13.0	14.8	15.7	13.5	NA	NA	NA	NA	17.0
DO	mg/L	NA	NA	NA	2.0	2.1	NA	NA	NA	NA	1.9	1.6	3.6	6.4	2.1	1.5	0.9	3.5	2.8	NA	NA	NA	NA	1.4
ORP	mV	212	253	255	215	255	NA	NA	NA	NA	270	272	278	275	217	283	280	224	242	NA	NA	NA	NA	281
Free Chlorine (as Cl_2)	mg/L	NA	NA	NA	0.1	0.7	NA	NA	NA	NA	0.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Chlorine (as Cl_2)	mg/L	NA	0.8	0.3	0.1	0.8	NA	NA	NA	NA	0.6	NA	0.3	0.2	0.0	0.4	0.3	NA	0.5	NA	NA	NA	NA	0.3
Total Hardness	mg/L[a]	266	249	240	-	-	-	-	-	-	-	271	273	261	222	236	260	-	-	-	-	-	-	-
Ca Hardness	mg/L[a]	163	156	150	-	-	-	-	-	-	-	164	164	159	121	130	143	-	-	-	-	-	-	-
Mg Hardness	mg/L[a]	103	92.3	90.0	-	-	-	-	-	-	-	107	108	102	100	105	117	-	-	-	-	-	-	-
As (total)	µg/L	24.5	20.2	2.8	28.0	27.0	2.4	2.2	2.2	2.2	NA	26.7	27.2	2.4	26.4	24.5	3.9	31.7	32.3	3.6	3.8	3.2	4.8	4.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	19.2	2.9	2.4	-	-	-	-	-	-	-	16.9	3.3	3.0	21.6	3.6	2.5	-	-	-	-	-	-	-
As (particulate)	µg/L	5.4	17.3	0.4	-	-	-	-	-	-	-	9.8	23.9	<0.1	4.8	21.0	1.4	-	-	-	-	-	-	-
As (III)	µg/L	16.6	0.5	0.4	-	-	-	-	-	-	-	16.2	0.4	0.4	20.3	0.3	0.1	-	-	-	-	-	-	-
As (V)	µg/L	2.6	2.5	1.9	-	-	-	-	-	-	-	0.8	2.9	2.6	1.3	3.2	2.3	-	-	-	-	-	-	-
Fe (total)	µg/L	2,049	1,579	27	2,228	2,255	<25	<25	<25	<25	NA	2,076	1,955	54	2,110	1,826	192	2,333	2,369	97	112	79	225	135
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	1,241	107	<25	-	-	-	-	-	-	-	33	46	<25	1,491	112	34	-	-	-	-	-	-	-
Mn (total)	µg/L	50.5	53.1	49.8	53.8	54.7	55.6	54.8	55.4	54.7	NA	58.1	58.9	58.3	56.6	54.6	57.8	53.0	51.3	54.6	54.7	53.3	53.2	54.0
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	51.3	48.4	51.3	-	-	-	-	-	-	-	55.6	38.7	59.8	55.0	53.0	58.7	-	-	-	-	-	-	-

(a) As $CaCO_3$ (f) bed volumes from 04/13/09

Table B-1. Analytical Results from Long-Term Sampling at Fountain City, IN (Continued)

Sampling Date		06/09/09			07/06/09 [g]							07/30/09 [h]			08/31/09						
Sampling Location		IN	AC	TT	IN	AC	TA	TB	TC	TD	TT	IN	AC	TT	IN	AC	TA	TB	TC	TD	TT
Parameter	Unit																				
Bed Volume	10^3	-	-	1.3	-	-	1.3	1.1	1.3	1.4	1.3	-	-	1.3	-	-	1.5	1.2	1.4	1.6	1.4
Alkalinity	mg/L [a]	333	329	329	359	350	355	355	341	346	350	320	322	320	325	327	325	323	325	325	325
		-	-	-	361	357	359	355	355	340	330	-	-	-	-	-	-	-	-	-	-
Ammonia	mg/L	1.0	0.9	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9
		-	-	-	1.0	1.0	0.9	0.9	0.9	0.9	0.9	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	1.8	2.0	1.7	-	-	-	-	-	-	-	2.4	1.8	1.8	1.4	2.6	-	-	-	-	1.8
Sulfate	mg/L	1.8	1.9	1.8	-	-	-	-	-	-	-	1.5	1.4	1.6	2.4	2.2	-	-	-	-	2.4
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05
Total P (as P)	µg/L	<10	<10	<10	-	-	-	-	-	-	-	17.8	17.5	18.5	<10	<10	-	-	-	-	<10
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	15.5	15.3	23.5	15.7	16.1	16.6	16.3	16.7	16.5	16.7	15.1	14.9	25.6	15.4	15.3	15.7	15.6	15.5	15.6	16.0
		-	-	-	15.9	15.9	17.5	16.2	16.4	16.3	16.8	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	18.0	3.9	0.9	17.0	1.3	0.2	0.2	0.1	0.2	0.1	18.0	4.4	0.2	13.0	1.9	0.1	1.6	<0.1	0.2	1.0
		-	-	-	18.0	1.3	<0.1	0.1	0.1	0.2	0.3	-	-	-	-	-	-	-	-	-	-
TOC	mg/L	1.5	1.5	1.6	1.5	1.5	1.5	1.4	1.5	1.5	1.6	7.7	2.0	1.9	1.8	1.8	1.5	1.5	1.5	1.6	1.6
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	7.5	7.6	7.5	7.4	7.5	NA	NA	NA	NA	7.4	7.6	7.5	7.4	7.6	7.4	NA	NA	NA	NA	7.4
Temperature	°C	16.2	16.0	16.2	15.2	14.1	NA	NA	NA	NA	16.6	17.5	17.5	21.2	15.1	15.1	NA	NA	NA	NA	15.1
DO	mg/L	2.0	1.4	1.4	3.8	3.0	NA	NA	NA	NA	2.2	3.6	1.8	1.1	4.5	3.5	NA	NA	NA	NA	2.2
ORP	mV	288	287	285	235	247	NA	NA	NA	NA	274	248	256	267	250	258	NA	NA	NA	NA	270
Free Chlorine (as Cl_2)	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Chlorine (as Cl_2)	mg/L	0.0	0.2	0.0	NA	0.6	NA	NA	NA	NA	0.5	NA	0.0	0.1	NA	0.6	NA	NA	NA	NA	1.1
Total Hardness	mg/L [a]	267	264	251	-	-	-	-	-	-	-	271	260	265	-	-	-	-	-	-	-
Ca Hardness	mg/L [a]	175	173	166	-	-	-	-	-	-	-	137	131	134	-	-	-	-	-	-	-
Mg Hardness	mg/L [a]	92	91	85	-	-	-	-	-	-	-	134	128	132	-	-	-	-	-	-	-
As (total)	µg/L	26.1	22.5	4.0	28.5	26.2	2.5	2.7	2.7	2.3	2.8	29.6	29.7	3.4	28.3	24.9	0.8	0.8	0.7	1.9	1.9
		-	-	-	28.7	27.5	2.5	2.7	2.5	2.3	2.4	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	18.1	2.2	2.6	-	-	-	-	-	-	-	14.0	4.9	2.0	21.5	3.0	-	-	-	-	1.5
As (particulate)	µg/L	8.0	20.4	1.5	-	-	-	-	-	-	-	15.7	24.8	1.3	6.8	21.9	-	-	-	-	0.4
As (III)	µg/L	16.3	0.4	0.3	-	-	-	-	-	-	-	12.6	<0.1	<0.1	10.8	<0.1	-	-	-	-	<0.1
As (V)	µg/L	1.8	1.8	2.3	-	-	-	-	-	-	-	1.3	4.8	1.9	10.7	2.9	-	-	-	-	1.4
Fe (total)	µg/L	2,255	1,896	148	1,758	1,895	<25	<25	<25	<25	<25	1,827	1,816	54	1,898	1,708	<25	<25	<25	125	82
		-	-	-	1,945	1,850	<25	<25	<25	<25	<25	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	1,167	<25	<25	-	-	-	-	-	-	-	571	219	<25	-	-	-	-	-	-	-
Mn (total)	µg/L	53.8	53.9	56.3	49.7	50.7	55.7	54.7	55.1	54.7	52.6	57.8	56.9	72.7	51.4	51.9	71.0	71.9	71.3	69.0	71.8
		-	-	-	48.8	50.6	55.8	54.5	55.5	53.7	54.6	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	53.9	51.4	57.5	-	-	-	-	-	-	-	58.8	59.0	73.2	-	-	-	-	-	-	-

(a) As $CaCO_3$

(g) bed volumes from 07/13/09

(h) bed volume from 07/27/09

Table B-1. Analytical Results from Long-Term Sampling at Fountain City, IN (Continued)

Sampling Date		09/15/09			09/29/09						
Sampling Location / Parameter	Unit	IN	AC	TT	IN	AC	TA	TB	TC	TD	TT
Bed Volume	10^3	-	-	1.5	-	-	1.6	1.3	1.6	1.8	1.6
Alkalinity	mg/L [(a)]	309	317	304	322	320	326	322	324	326	324
		-	-	-	-	-	-	-	-	-	-
Ammonia	mg/L	1.0	0.9	0.9	1.0	0.9	0.9	0.9	0.8	0.9	0.9
		-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	1.5	1.6	1.6	-	-	-	-	-	-	-
Sulfate	mg/L	2.0	2.1	1.9	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	-	-	-	-	-	-	-
Total P (as P)	µg/L	<10	<10	<10	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	15.3	15.1	17.1	15.1	15.2	17.6	17.0	17.0	17.2	17.3
		-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	15.3	15.1	17.1	17.0	2.6	0.6	0.7	1.7	0.4	0.8
		-	-	-	-	-	-	-	-	-	-
TOC	mg/L	1.7	1.6	1.6	1.4	1.3	1.3	1.3	1.3	1.3	1.3
		-	-	-	-	-	-	-	-	-	-
pH	S.U.	7.6	7.5	7.5	7.4	7.4	NA	NA	NA	NA	7.4
Temperature	°C	18.3	18.3	18.3	16.8	15.8	NA	NA	NA	NA	16.0
DO	mg/L	3.6	2.1	1.2	2.9	2.6	NA	NA	NA	NA	4.0
ORP	mV	243	365	365	353	418	NA	NA	NA	NA	409
Free Chlorine (as Cl_2)	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Chlorine (as Cl_2)	mg/L	NA	0.6	0.9	NA	0.8	NA	NA	NA	NA	0.4
Total Hardness	mg/L [(a)]	283	298	289	-	-	-	-	-	-	-
Ca Hardness	mg/L [(a)]	179	189	182	-	-	-	-	-	-	-
Mg Hardness	mg/L [(a)]	104	109	107	-	-	-	-	-	-	-
As (total)	µg/L	24.0	27.2	6.2	27.3	27.9	4.6	4.6	4.9	4.6	5.4
		-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	18.4	2.7	3.1	-	-	-	-	-	-	-
As (particulate)	µg/L	5.6	24.5	3.0	-	-	-	-	-	-	-
As (III)	µg/L	16.1	0.4	0.7	-	-	-	-	-	-	-
As (V)	µg/L	2.3	2.3	2.4	-	-	-	-	-	-	-
Fe (total)	µg/L	1,814	2,050	108	1,694	2,024	134	147	167	135	205
		-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	953	<25	<25	-	-	-	-	-	-	-
Mn (total)	µg/L	51.7	53.8	64.4	49.3	50.1	58.9	55.4	57.8	56.3	57.8
		-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	52.1	37.2	65.9	-	-	-	-	-	-	-

(a) As $CaCO_3$

APPENDIX C
BACKWASH DATA

Date	Tank A "TA" Backwash						
	Backwash Start		Backwash End		Backwash Flowrate	Backwash Duration	Wastewater Generated
	Time	gal x100	Time	gal x100	gpm	min	gal
12/03/08	9:00 AM	686	9:26 AM	899	50.1	26	1,196.2
04/08/09	9:30 AM	664	10:00 AM	899	52.0	26	1,027.1
07/06/09	8:00 AM	488	8:26 AM	899	55.0	26	944.0
10/13/09	10:30 AM	0	10:59 AM	867	47.0	26	866.6

Date	Tank B "TB" Backwash						
	Backwash Start		Backwash End		Backwash Flowrate	Backwash Duration	Wastewater Generated
	Time	gal x100	Time	gal x100	gpm	min	gal
12/03/08	9:30 AM	696	9:56 AM	899	46.8	26	1,119.3
04/08/09	10:00 AM	682	10:30 AM	899	43.0	26	1,098.9
07/06/09	8:30 AM	495	8:56 AM	899	54.2	26	1,150.0
10/13/09	11:03 AM	0	11:33 AM	1143	54.0	26	1,142.6

Date	Tank C "TC" Backwash						
	Backwash Start		Backwash End		Backwash Flowrate	Backwash Duration	Wastewater Generated
	Time	gal x100	Time	gal x100	gpm	min	gal
12/03/08	10:10 AM	680	10:36 AM	899	51.0	26	1,282.1
04/08/09	10:30 AM	674	10:55 AM	899	46.4	26	1,087.5
07/06/09	9:00 AM	490	9:26 AM	899	55.0	26	1,227.0
10/13/09	11:33 AM	0	12:00 PM	1259	56.0	26	1,259.3

Date	Tank D "TD" Backwash						
	Backwash Start		Backwash End		Backwash Flowrate	Backwash Duration	Wastewater Generated
	Time	gal x100	Time	gal x100	gpm	min	gal
12/03/08	10:45 AM	700	11:11 AM	899	48.0	26	1,210.0
04/08/09	11:00 AM	655	11:30 AM	899	55.7	26	1,194.0
07/06/09	9:30 AM	391	9:56 AM	899	54.0	26	1,201.7
10/13/09	12:07 PM	0	12:33 PM	1180	58.0	26	1,180.1