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Arsenic Removal from Drinking Water by Coagulation/Filtration U.S. EPA Demonstration Project at Town of Felton, DE Final Performance Evaluation Report

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Sally Gutierrez, Director
National Risk Management Research Laboratory

ABSTRACT

This report documents the activities performed during and the results obtained from the arsenic removal treatment technology demonstration project at the Town of Felton, DE. The objectives of the project were to evaluate: (1) the effectiveness of Kinetico's FM-348-AS coagulation/filtration (C/F) system using Macrolite® media in removing arsenic to meet the maximum contaminant level (MCL) of 10 µg/L, (2) the reliability of the C/F system for use at small water facilities, (3) the required system operation and maintenance (O&M) and operator skill levels, and (4) the capital and O&M cost of the technology. The project also characterized water in the distribution system and residuals generated by the treatment process. The types of data collected included system operation, water quality, process residuals, and capital and O&M cost.

After review and approval of the engineering plan by the state, the C/F system was installed and became operational on September 14, 2006. The system consisted of two 48-in × 72-in fiber reinforced plastic (FRP) contact tanks and three 48-in × 72-in FRP filtration vessels configured in parallel. Each filtration vessel was loaded with 25 ft^3 of M2 Macrolite® media for a design filtration rate of 10 gpm/ft^2. The system also used two chemical addition assemblies, one each for prechlorination and iron addition. An existing prechlorination system was used to oxidize As(III) and soluble iron (Fe[II]); an iron addition system was installed to inject ferric chloride ($FeCl_3$) to form arsenic-laden particles prior to Macrolite® pressure filtration. A recycle system was incorporated into the treatment system to reclaim backwash wastewater and eliminate the need to discharge wastewater into a sanitary sewer. The recycle system consisted of a pump controller, two booster pumps, and a 16-ft × 6-ft × 10-ft concrete recycle tank equipped with four float switches.

From September 14, 2006, through November 3, 2007, the treatment system operated at 263 gal/min (gpm) for 6.5 hr/day, on average, producing 43,446,110 gal of water. This average flowrate corresponded to a contact time of 4.3 min through the two contact tanks and a filtration rate of 7.0 gpm/ft^2. The recycle system operated for 29.4% of the time when the treatment system was in operation during the demonstration study.

Source water had an average pH value of 8.3 and contained 27.2 to 43.3 µg/L of total arsenic. The predominant arsenic species was As(III) with an average concentration of 29.1 µg/L. Total iron concentrations ranged from <25 to 62.5 µg/L and averaged 26.1 µg/L, existing mostly in the soluble form. This amount of soluble iron was not adequate for arsenic removal; therefore, ferric chloride was added to achieve an iron concentration of 1.2 to 2.0 mg/L to effectively remove arsenic to below the MCL.

Following prechlorination, arsenic existed mostly as particulate arsenic, which was removed by the pressure filters to levels below 7.4 µg/L (on average). Throughout the performance evaluation study, total arsenic concentrations in system effluent exceeded the arsenic MCL on 14 sampling occasions, which were due to either insufficient iron addition or particulate breakthrough from the filters. Shortening run lengths from 17.0 to 9.1 hr (by lowering the differential pressure [Δp] trigger from 25 to 18 lb/in^2 [psi]) appeared to be useful for decreasing particulate breakthrough from the pressure filters.

Each filter was backwashed automatically approximately 5 time/week with the backwashing process triggered by either high Δp, standby time, or run time. High Δp triggered approximately 94% of backwashes. Backwash durations averaged 6.7 min, generating approximately 724 gal of wastewater per vessel during each backwash. A total of 673,450 gal of wastewater was produced during the performance evaluation study, equivalent to 1.6% of the total amount of water treated. The backwash wastewater contained, on average, 336 mg/L of total suspended solids (TSS), 1,229 µg/L of arsenic, 107 mg/L of iron, and 551 µg/L of manganese, with the majority existing as particulates. As such, approximately 920

g of solids were discharged from each filtration vessel during each backwash event, including 3.4 g of arsenic, 293 g of iron, and 1.5 g of manganese.

Comparison of the distribution system water sampling results before and after system startup demonstrated a considerable decrease in arsenic concentration (i.e., 34.4 to 8.5 µg/L, on average). Arsenic levels in the distribution system were slightly higher than those in treatment system effluent, indicating resuspension and/or redissolution of arsenic in the distribution system. Copper concentrations decreased from an average baseline concentration of 85.6 to 44.0 µg/L after system startup. Manganese and lead concentrations decreased slightly from 1.7 to 0.5 µg/L and 2.4 to 1.6 µg/L, respectively. Iron concentrations increased slightly from 26.9 to 38.1 µg/L. pH and alkalinity levels did not appear to be affected.

The capital investment for the system was $334,297, including $201,292 for equipment, $44,520 for site engineering, and $88,485 for installation, shakedown, and startup. Using the system's rated capacity of 375 gpm (or 540,000 gal/day [gpd]), the capital cost was $891/gpm (or $0.62/gpd). This unit cost does not include the cost of the building to house the treatment system or the cost of the recycle system used for reclaiming the backwash wastewater. O&M cost, estimated at $0.30/1,000 gal, included the cost for chemical usage, electricity consumption, and labor.

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ABBREVIATIONS AND ACRONYMS

Δp	differential pressure
AAL	American Analytical Laboratories
Al	aluminum
AM	adsorptive media
As	arsenic
C/F	coagulation/filtration
Ca	calcium
Cl	chlorine
CRF	capital recovery factor
Cu	copper
DO	dissolved oxygen
DHSS	Delaware Health and Social Services
EPA	U.S. Environmental Protection Agency
F	fluoride
Fe	iron
$FeCl_3$	ferric chloride
FRP	fiber reinforced plastic
FTW	filter-to-waste
gpd	gallons per day
gph	gallons per hour
gpm	gallons per minute
HDPE	high-density polyethylene
HIX	hybrid ion exchanger
hp	horsepower
ICP-MS	inductively coupled plasma-mass spectrometry
ID	identification
IX	ion exchange
LCR	(EPA) Lead and Copper Rule
MCL	maximum contaminant level
MDL	method detection limit
Mg	magnesium
µm	micrometer
Mn	manganese
mV	millivolts
Na	sodium
NA	not analyzed
NaOCl	sodium hypochlorite

NA	not available
NTU	nephelometric turbidity unit
O&M	operation and maintenance
OIP	operator interface panel
ORD	Office of Research and Development
ORP	oxidation-reduction potential
P	phosphorus
P&ID	piping and instrumentation diagram
Pb	lead
pCi/L	picocuries per liter
psi	pounds per square inch
psig	pounds per square inch gauge
PLC	programmable logic controller
PO_4	phosphate
POU	point-of-use
PVC	polyvinyl chloride
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RPD	relative percent difference
RO	reverse osmosis
Sb	antimony
SDWA	Safe Drinking Water Act
SiO_2	silica
SO_4	sulfate
TDH	total dynamic head
TDS	total dissolved solids
THM	trihalomethanes
TOC	total organic carbon
TSS	total suspended solids
UPS	uninterruptible power supply
V	vanadium
VOC	volatile organic compound(s)

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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). 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 for reducing compliance cost. As part of this Arsenic Rule Implementation Research Program, EPA's Office of Research and Development (ORD) proposed a project to conduct a series of full-scale, onsite demonstrations of arsenic removal technologies, process modifications, and engineering approaches applicable to small systems. Shortly thereafter, an announcement published in the *Federal Register* requested water utilities interested in participating in the first Round of this EPA-sponsored demonstration program to provide information on their water systems. In June 2002, EPA selected 17 out of 115 sites to host the demonstration studies.

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

In 2003, EPA initiated Round 2 arsenic technology demonstration projects that were partially funded with Congressional add-on funding to the EPA budget. In June 2003, EPA selected 32 potential demonstration sites, and the community water system in the Town of Felton, DE was one of those selected.

In September 2003, EPA again solicited proposals from engineering firms and vendors for arsenic removal technologies. EPA received 148 technical proposals for the 32 host sites, with each site receiving from two to eight proposals. In April 2004, EPA convened another technical panel to review the proposals and provide recommendations to EPA; the number of proposals per site ranged from none (for two sites) to four. At the sites receiving at least one proposal, the final selection of the treatment technology was made 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. Kinetico's Macrolite® Arsenic Removal Technology was selected for demonstration at the Felton facility.

As of April 2010, 39 of the 40 systems were operational and the performance evaluation of 36 systems was completed.

1.2 Treatment Technologies for Arsenic Removal

The technologies selected for the Rounds 1 and 2 demonstration host sites include 25 adsorptive media (AM) systems (the Oregon Institute of Technology [OIT] site has three AM systems), 13 coagulation/ filtration (C/F) systems, two ion exchange (IX) systems, and 17 point-of-use (POU) units (including nine under-the-sink reverse osmosis [RO] units at the Sunset Ranch Development site and eight AM units at the OIT site), and one system modification. Table 1-1 summarizes the locations, technologies, vendors, system flowrates, and key source water quality parameters (including As, iron [Fe], and pH) at the 40 demonstration sites. An overview of the technology selection and system design for the 12 Round 1 demonstration sites and the associated capital cost 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/wswrd/dw/arsenic/index.html.

1.3 Project Objectives

The overall objective of the arsenic demonstration program is to conduct full-scale arsenic treatment technology demonstration studies on the removal of arsenic from drinking-water supplies. The specific objectives are to:

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

This report summarizes the performance of the Kinetico C/F system at the Town of Felton in Delaware from September 14, 2006, through November 3, 2007. The types of data collected included system operation, water quality (both across the treatment train and in the distribution system), residuals, and capital and O&M cost.

Table 1-1. Summary of Arsenic Removal Demonstration Sites

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

Table 1-1. Summary of Arsenic Removal Demonstration Sites (Continued)

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

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

(a) Arsenic existing mostly as As(III).
(b) Design flowrate reduced by 50% due to system reconfiguration from parallel to series operation.
(c) Iron existing mostly as Fe(II).
(d) Withdrew from program in 2007. Selected originally to replace Village of Lyman, NE site, which withdrew from program in June 2006.
(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.

2.0 SUMMARY AND CONCLUSIONS

Kinetico's C/F system using Macrolite® filtration media operated at the Town of Felton, DE, from September 14, 2006, through November 2, 2007. Based on the overall objectives of the performance evaluation study, the information collected is summarized and conclusions are drawn as follows.

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

- Chlorination was effective in oxidizing As(III) to As(V), reducing As(III) concentrations from 29.1 µg/L (on average) in source water to 0.7 µg/L (on average) after the contact tanks.
- The use of supplemental iron was effective in forming arsenic-laden iron particles, in creasing particulate arsenic concentrations from 3.4 µg/L (on average) in source water to 26.1 µg/L (on average) after the contact tanks.
- With proper pre-chlorination and supplemental iron addition, Macrolite® pressure filtration effectively removed arsenic to 7.4 µg/L (on average).
- Higher-than-the-MCL levels of arsenic were measured in system effluent during 14 sampling events. The elevated arsenic concentrations observed were due to either insufficient iron addition or particulate breakthrough from the pressure filters.
- Shortening filter run lengths (e.g., from 17.0 to 9.1 hr by lowering the differential pressure (Δp) backwash trigger from 25 to 18 lb/in^2 [psi]) could help reduce particulate breakthrough from the pressure filters.
- Backwashing at 6.0 gal/min/ft^2 (gpm/ft^2) (or 40% lower than the design value of 10 gpm/ft^2) for 6.7 min (on average) could restore the pressure filters for subsequent service runs. However, 20% of the Δp readings collected within 1 hr of backwashing were higher than the clean-bed-level of 10 psi.
- The treatment system improved water quality in the distribution system by decreasing arsenic concentrations from 34.4 to 8.5 µg/L (on average). Little or no effect was observed for lead, copper, or manganese. pH and alkalinity concentrations remained unchanged.

Required system O&M and operator skill levels:

- Minimal time was required to operate and maintain the system. The daily demand on the operator to perform routine O&M was 45 min.
- The level of accumulated wastewater solids should be periodically checked and removed when necessary to prevent solid levels above the recycle system intake line.

Characteristics of residuals produced by the technology:

- Backwash solids were the only residual produced by the treatment system, which accumulated at the bottom of the recycle tank. Approximately 850 kg of backwash solids were generated during the performance evaluation study, which included 0.34% (by weight) of arsenic, 32% (by weight) of iron, and 0.2% (by weight) of manganese.

Capital and O&M cost of the technology:

- The capital investment for the system was $334,297, including $201,292 for equipment, $44,520 for site engineering, and $88,485 for installation, shakedown, and startup.
- The unit capital cost was $891/gpm (or $0.62 gal/day [gpd]) based on a 375-gpm design capacity. This calculation does not reflect the cost for the building and recycle system as it was funded by the Town of Felton.
- The O&M cost was 0.30/1,000 gal, including incremental cost for chemicals, electricity, and labor.

3.0 MATERIALS AND METHODS

3.1 General Project Approach

Following the predemonstration activities summarized in Table 3-1, the performance evaluation study of the Kinetico treatment system began on September 14, 2006, and ended on November 3, 2007. Table 3-2 summarizes the types of data collected and considered as part of the technology evaluation process. The overall system performance was 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. The reliability of the system was evaluated by tracking unscheduled system downtime and frequency and the extent of repairs. Unscheduled downtime and repair information were recorded by the plant operator on a Repair and Maintenance Log Sheet.

O&M and operator skill requirements were assessed through quantitative data and qualitative considerations, including needs 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. 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 wastewater was sampled and analyzed for chemical characteristics.

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

Table 3-1. Demonstration Activities and Completion Dates

Activity	Date
Introductory meeting held	October 7, 2004
Project planning meeting held	December 14, 2004
Draft letter of understanding issued	December 24, 2004
Final letter of understanding issued	January 19, 2005
Request for quotation issued to vendor	January 28, 2005
Vendor quotation received	February 15, 2005
Purchase order established	February 23, 2005
Engineering package submitted to DHSS	April 26, 2005
Building construction permit granted by Kent County	April 28, 2005
System permit granted by DHSS	May 31, 2005
Building construction began	August 8, 2005
Letter report issued	October 4, 2005
FM-348-AS system delivered	March 20, 2006
Study plan issued	May 4, 2006
System installation completed	May 30, 2006
System shakedown completed	June 6, 2006
Building completed	July 7, 2006
Performance evaluation began	September 14, 2006
Performance evaluation completed	November 3, 2007

DHSS = Delaware Health and Social Services

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

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

3.2 System O&M and Cost Data Collection

The plant operator performed daily, weekly, and monthly system O&M and data collection according to instructions provided by the vendor and Battelle. On a daily basis, the plant operator recorded system operational data such as pressure, flowrate, totalizer, and hour meter readings (see Appendix A) on a Daily System Operation Log Sheet; checked sodium hypochlorite (NaOCl) and ferric chloride ($FeCl_3$) levels; and conducted visual inspections to ensure normal system operations. If any problem occurred, the plant operator contacted the Battelle Study Lead, who determined if the vendor should be contacted for troubleshooting. The plant operator recorded all relevant information, including the problem encountered, course of actions taken, materials and supplies used, and associated cost and labor incurred, on a Repair and Maintenance Log Sheet. On a weekly basis, the plant operator measured several water quality parameters onsite, including temperature, pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), and residual chlorine, and recorded the data on a Weekly Onsite Water Quality Parameters Log Sheet. Monthly backwash data also were recorded on a Backwash Log Sheet.

The capital cost for the arsenic removal system consisted of the cost for equipment, site engineering, and system installation. The O&M cost consisted of the cost for chemical use, electricity consumption, and labor. Consumption of NaOCl and $FeCl_3$ was tracked on the Daily System Operation Log Sheet. Electricity consumption was determined from utility bills. Labor for various activities such as routine system O&M, troubleshooting and repairs, and demonstration-related work, was tracked using an Operator Labor Hour Log Sheet. The routine system O&M included activities such as completing field logs, replenishing chemical solutions, ordering supplies, performing system inspections, and others as recommended by the vendor. The labor for demonstration-related work, including activities such as performing field measurements, collecting and shipping samples, and communicating with the Battelle Study Lead and the vendor, was recorded, but not used for the cost analysis.

3.3 Sample Collection Procedures and Schedules

To evaluate system performance, samples were collected at the wellhead, across the treatment plant, during Macrolite® filter backwash, and from the distribution system. Table 3-3 shows sampling schedule and analytes measured during each sampling event. Figure 3-1 presents a flow diagram of the treatment system, along with the analytes and schedule for each sampling location.

Table 3-3. Sampling Schedule and Analyses

Sample Type	Sample Locations[a]	No. of Samples	Frequency	Analytes	Collection Date(s)
Source water	IN	1	Once (during initial site visit)	Onsite: pH, temperature, DO, and ORP Offsite: As(III), As(V), As (total and soluble), Fe (total and soluble), Mn (total and soluble), U (total and soluble), V (total and soluble), Na, Ca, Mg, Cl, F, NH_3, NO_2, NO_3, SO_4, SiO_2, PO_4, TOC, TDS, turbidity, and alkalinity	10/07/04
Treatment Plant Water	IN, AC, TA, TB, TC	5	Weekly	Onsite[b]: pH, temperature, DO, ORP, and Cl_2 (free and total) Offsite: As (total), Fe (total), Mn (total), P (total), SiO_2, turbidity, and alkalinity	See Appendix B
	IN, AC, TT	3	Monthly	Same as weekly analytes shown above plus following: Offsite: As (soluble), As(III), As(V), Fe (soluble), Mn (soluble), Ca, Mg, F, NO_3, and SO_4	See Appendix B
Backwash Wastewater	BW	3	Monthly	As (total and soluble), Fe (total and soluble), Mn (total and soluble), pH, TDS, and TSS	See Table 4-11
Distribution Water	Three LCR Locations	3	Monthly	Total As, Fe, Mn, Cu, and Pb, pH, and alkalinity	See Table 4-13
Backwash Solids	BW	2	Twice	Total As, Ba, Ca, Fe, Mg, Mn, P, and Si	See Table 4-12

(a) Abbreviations corresponding to sample locations shown in Figure 3-1: IN = at wellhead; AC = after contact tank; TA = after Vessel A; TB = after Vessel B; TC = after Vessel C; TT = after filter effluent combined; and BW = at backwash discharge line.
(b) Onsite chlorine measurements not performed at IN.

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, 2004). The procedure for arsenic speciation is described in Appendix A of the QAPP.

3.3.1 Source Water. During the initial site visit on October 7, 2004, one set of source water samples was collected and speciated using an arsenic speciation kit (Section 3.4.1). The sample tap was flushed for several minutes before sampling; special care was taken to avoid agitation, which might cause unwanted oxidation. Table 3-3 lists analytes for the source water samples.

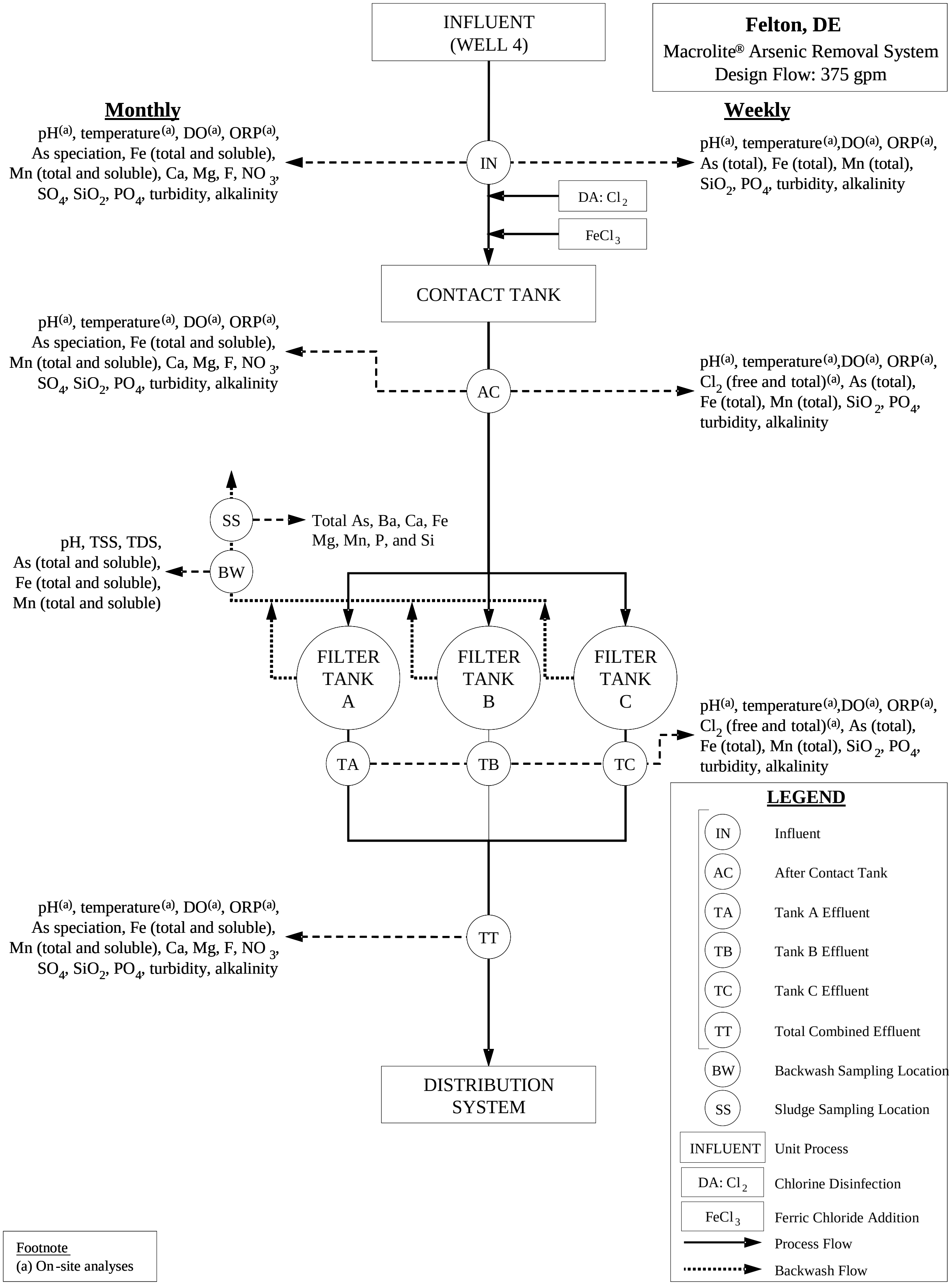


Figure 3-1. Process Flow Diagram and Sampling Schedule and Locations

3.3.2 Treatment Plant Water. The plant operator collected treatment plant water samples weekly, on a four-week cycle, for on and offsite analyses. For the first week of each four-week cycle, samples were collected at the wellhead (IN), after the contact tank (AC), and after filter effluent combined (TT), and speciated onsite and analyzed for the analytes listed in Table 3-3. For the next three weeks, samples were collected at IN, AC, after Vessel A (TA), after Vessel B (TB), and after Vessel C (TC) and analyzed for the analytes listed in Table 3-3.

3.3.3 Backwash Wastewater. Monthly backwash wastewater sampling was performed by directing a portion of backwash wastewater at approximately 1 gpm via a plastic tube connected to the tap on the backwash wastewater discharge line into a clean, 32-gal container over the duration of the backwash for each vessel. After the content in the container was thoroughly mixed, composite samples were collected and/or filtered onsite with 0.45-µm disc filters. Analytes for the backwash wastewater samples are listed in Table 3-3.

3.3.4 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 system startup from April to July 2005, four monthly baseline distribution water samples were collected from three locations within the distribution system. Following system startup, distribution system sampling continued on a monthly basis at the same locations. The three sampling locations, including the community center on Walnut Street, the Town Hall on Sewell Street, and the Mobil Service Station on Main Street (Rte. 13), were part of the historic Lead and Copper Rule (LCR) sampling network.

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

3.3.5 Residual Solids. Residual solids produced by the treatment process consisted of only backwash wastewater solids. After solids in the backwash wastewater containers (Section 3.3.3) had settled and supernatant carefully decanted, residual solids samples were collected on two separate occasions. A portion of each of the solids/water mixtures was air-dried for metals analyses.

3.4 Sampling Logistics

3.4.1 Preparation of Arsenic Speciation Kits. The arsenic field speciation method uses an anion exchange resin column to separate soluble arsenic species, i.e., 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 QAPP (Battelle, 2004).

3.4.2 Preparation of Sample 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 the demonstration site, the sampling date, a two-letter code for a specific sampling location, and a one-letter code designating the arsenic speciation bottle (if necessary). The sampling locations at the treatment plant were color-coded for easy identification. The labeled bottles were separated by sampling location, placed in zip-lock bags, and packed into 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 back to Battelle. Upon receipt, the sample custodian verified that all samples indicated on the chain-of-custody forms were included and intact. Sample IDs were checked against the chain-of-custody forms, and the samples were logged into the laboratory sample receipt log. Discrepancies noted by the sample custodian were addressed with the plant operator by the Battelle Study Lead.

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

3.5 Analytical Procedures

The analytical procedures described in Section 4.0 of the QAPP (Battelle, 2004) were followed by Battelle ICP-MS, AAL, TCCI Laboratories, and Belmont Labs. Laboratory quality assurance/quality control (QA/QC) of all methods followed the prescribed guidelines. Data quality in terms of precision, accuracy, method detection limits (MDLs), and completeness met the criteria established in the QAPP (i.e., relative percent difference [RPD] of 20%, percent recovery of 80 to 120%, and completeness of 80%). The quality assurance (QA) data associated with each analyte will be presented and evaluated in a QA/QC Summary Report to be prepared under separate cover upon completion of the Arsenic Demonstration Project.

Field measurements of pH, temperature, DO, and ORP were conducted by the plant operator using a handheld field meter, which was calibrated for pH and DO prior to use following the procedures provided in the user's manual. The ORP probe also was checked for accuracy by measuring the ORP of a standard solution and comparing it to the expected value. The plant operator collected a water sample in a clean, plastic beaker and placed the 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 Site Description

4.1.1 Pre-existing Facility. Located near the stone depot at 401 Lumbard Street, the water system in the Town of Felton, DE, supplied water to 428 residences and businesses. Among the four production wells, Well No. 1 was abandoned and Well No. 2 was used only for emergency purposes. Wells No. 3 and No. 4 were used for water production at a flowrate of 250 and 320 gpm, respectively. Well No. 4, a primary production well, was designated for the performance evaluation study. Well No. 3 was not used because it had low arsenic concentrations (but with high iron levels at as much as 4 mg/L).

Well No. 4 was 6-in in diameter and approximately 600 ft deep. Originally installed in the 1950s, the well was refurbished in 1999 with a new screen and a new well pump. This well contained elevated arsenic concentrations, but lower iron levels than those of Well No. 3. The well was equipped with a 40-horsepower (hp) submersible pump rated for 320 gpm and a maximum system pressure of 55 psi. The system typically operated 4 to 5 hr/day with an average daily demand of 100,000 gpd and an estimated peak daily demand of 353,600 gpd.

Prior to installation of the arsenic removal system, treatment consisted of chlorine addition in the Well No. 4 pump house (Figure 4-1). A 12.5% NaOCl solution stored in a 55-gal drum was injected at 2 to 3 mg/L using a metering pump (LMI Milton Roy Model B121-392SI rated for 2.5 gph) to attain a free chlorine residual of 0.3 to 0.7 mg/L (as Cl_2). Following chlorination, treated water was stored in a 200,000-gal elevated storage tank located near the center of town.

Figure 4-1. Pre-existing Facility
(From let to right: Chlorine Addition Equipment, Well No. 4 Pump House, and Water Tower)

4.1.2 Distribution System. Based on the existing utilities plan provided by the Town, the distribution system consisted of a looped distribution line with 6- and 10-in Schedule 40 polyvinyl chloride (PVC), 6-in transite, and 12-in C900 piping. The distribution system was supplied directly from the 200,000-gal elevated storage tank.

The plant operator sampled monthly for total coliform and quarterly or as directed by the Delaware Health and Social Services (DHSS) for volatile organic compounds (VOCs), trihalomethane compounds (THMs), inorganics, nitrate, and radionuclides. LCR samples were collected every three years from 20 locations in the town's historic LCR sampling network.

4.1.3 Source Water Quality. Source water samples were collected by Battelle from Well No. 4 on October 7, 2004. Table 4-1 presents the results and compares them to those provided by the facility to EPA for site selection and by the selected technology vendor (Kinetico).

Total arsenic concentrations in source water ranged from 28 to 30 µg/L. The October 7, 2004, test results showed a total arsenic concentration of 30 µg/L, which existed entirely in a soluble form. The soluble fraction consisted of 25.2 µg/L (or 84%) of As(III) and 5.2 µg/L (or 17%) of As(V). As such, As(III) was the predominant species. The Kinetico treatment process used prechlorination (pre-existing) to oxidize As(III) to As(V) and subsequent adsorption and co-precipitation to form As(V)-laden iron solids prior to pressure filtration.

Total iron concentrations in source water ranged from 48 to 110 µg/L, which existed primarily as particulate based on Battelle's October 7, 2004, speciation results. Therefore, an iron coagulant was added to raw water to remove arsenic.

Although the pH of raw water was at the upper end of a commonly agreed range of 5.5 to 8.5 for iron coagulation, no provisions were made for pH adjustment.

The October 7, 2004, test results also showed 0.32 mg/L (as N) of ammonia in source water. The presence of ammonia will increase chlorine demand. Chlorine added to source water will oxidize As(III) and any other reducing species such as Fe(II) and Mn(II) and react with ammonia and organic nitrogen compounds, if any, to form combined chlorine (i.e., mono- and dichloramines within a pH range of 4.5 to 8.5). To attain the target free chlorine residual of 0.5 mg/L (as Cl_2), "breakpoint" chlorination must be achieved with a dosage of approximately 3.0 mg/L (as Cl_2), which consisted of

(1) the amount needed to oxidize As(III), Fe(II), Mn(II), and any other reducing species, estimated to be 0.034 mg/L (as Cl_2) (Ghurye and Clifford, 2001)
(2) the amount needed to oxidize ammonia and combined chlorine formed during chlorination, estimated to be 2.45 mg/L (as Cl_2) (Clark et al., 1977)
(3) the amount needed to provide the target free chlorine residual of 0.5 mg/L (as Cl_2).

Other source water quality parameters obtained by Battelle on October 7, 2004, were not anticipated to adversely impact the treatment process.

4.1.4 Treated Water Quality. The pre-existing treatment consisted of only chlorination. Historic treated water quality data collected by DHSS from February 2002 through March 2004 were similar to the source water data provided by the facility and collected by Battelle. Total arsenic concentrations of treated water ranged from 26 to 35.4 µg/L. Arsenic speciation data were not available for water following chlorination. Total iron concentrations in treated water ranged from 50 to 1,280 µg/L, which is significantly higher than the Well No. 4 raw water data. It was likely these samples included water from Well No. 3, which had high iron levels. pH values ranged from 8.2 to 8.4.

Table 4-1. Felton, DE, Water Quality Data

Parameter	Unit	Facility Source Water Data	Kinetico Source Water Data	Battelle Source Water Data	DHSS Treated Water Data
Date	–	NA	NA	10/7/04	2/11/02–10/8/04
pH	S.U.	8.2	8.3	8.2	8.2–8.4
Temperature	°C	NA	NA	18.8	NA
DO	mg/L	NA	NA	2.8	NA
ORP	mV	NA	NA	7.7	NA
Total Alkalinity (as $CaCO_3$)	mg/L	285	304	288	275–295
Hardness (as $CaCO_3$)	mg/L	27	45	44	11-24
Turbidity	NTU	NA	NA	<0.1	NA
TDS	mg/L	NA	NA	326	363–430
TOC	mg/L	NA	NA	0.8	NA
Nitrate (as N)	mg/L	NA	NA	<0.04	<0.3
Nitrite (as N)	mg/L	NA	NA	<0.01	<0.1
Ammonia (as N)	mg/L	NA	NA	0.32	NA
Chloride	mg/L	4	7.9	6.4	9.9–11.5
Fluoride	mg/L	NA	1.5	2.2	1.31–1.48
Sulfate	mg/L	NA	10	9	10.1
Silica (as SiO_2)	mg/L	9.8	8.6	9.6	NA
Orthophosphate (as PO_4)	mg/L	NA	<0.5	<0.06	NA
As(total)	μg/L	28	30	30	26–35.4
As (total soluble)	μg/L	NA	NA	30.4	NA
As (particulate)	μg/L	NA	NA	<0.1	NA
As(III)	μg/L	NA	NA	25.2	NA
As(V)	μg/L	NA	NA	5.2	NA
Fe (total)	μg/L	80	110	48	50–1,280
Fe (soluble)	μg/L	NA	NA	<25	NA
Mn (total)	μg/L	<20	<10	3.4	NA
Mn (soluble)	μg/L	NA	NA	1.5	NA
U (total)	μg/L	NA	NA	<0.1	NA
U (soluble)	μg/L	NA	NA	<0.1	NA
V (total)	μg/L	NA	NA	0.53	NA
V (soluble)	μg/L	NA	NA	0.16	NA
Pb	μg/L	NA	NA	NA	6.3–7.0
Cu	μg/L	NA	NA	NA	50–142
Na	mg/L	108	128	138	133–138
Ca	mg/L	7	9	8.0	NA
Mg	mg/L	5	6	6.0	NA

DHSS = Delaware Health and Social Services; DO = dissolved oxygen; NA = not available; NTU = nephelometric turbidity unit; ORP = oxidation-reduction potential; TDS = total dissolved solids; TOC = total organic carbon.

4.2 Treatment Process Description

The treatment train consisted of prechlorination, iron addition, and Macrolite® pressure filtration. Macrolite®, a spherical, low density, chemically inert, ceramic media designed for filtration rates up to 10 gpm/ft^2, is approved for use in drinking water applications under NSF International (NSF) Standard 61. Table 4-2 presents physical properties of the M2 Macrolite® media.

Table 4-2. Physical Properties of M2 Macrolite® Media

Property	Value
Color	Taupe, Brown, Grey
Thermal Stability (°F)	2,000
Uniformity Coefficient	1.1
Sphere Size Range (mm)	0.21–0.42
Nominal Size (mm)	0.30
Bulk Density (g/cm^3 or lb/ft^3)	0.86 or 54
Specific Gravity (g/cm^3)	2.05

The C/F system was composed of two contact tanks, three pressure filtration vessels, and associated gauges and probes to monitor pressure, flowrate, and backwash water turbidity. The system also was equipped with a central control panel that housed a touch-screen operator interface panel (OIP), a programmable logic controller (PLC), a modem, and an uninterruptible power supply (UPS). The Allen Bradley PLC automatically controlled the system by actuating PVC pneumatic valves using a 7.5-hp, 80-gal compressor (Speedaire Model 1WD61) depending on various inputs and outputs of the system and corresponding PLC setpoints (Section 4.4.3.1). The system also featured schedule 80 PVC solvent-bonded plumbing and all necessary isolation and check valves and sampling ports. Figure 4-2 is a simplified system piping and instrumentation diagram (P&ID). Figures 4-3 and 4-4 contain photographs of the key system components and control and instrumentation, respectively. The system's design specifications are summarized in Table 4-3. The major processes included the following:

- **Intake**. Source water was pumped from Well No. 4 at approximately 320 gpm. The well pump was activated and deactivated based on pressure in the water tower. Pressure in the water tower was monitored through a pressure tank located inside the treatment building. Once the pressure dropped to 52 psi, a mercury switch was triggered and the well pump was energized. As treated water was supplied to the water tower, the pressure in the tower gradually increased. Once the pressure in the water tower reached 62 psi, the mercury switch was once again activated and the well pump was shut down. The mercury switch was equipped with a 30 sec delay to account for any brief fluctuations in pressure. The inlet piping from the well into the building and the secondary piping to bypass the treatment system, if needed, are shown in Figure 4-3.

- **Chlorination**. The existing chlorine addition system was used to oxidize soluble As(III) and Fe(II). The chlorine addition system consisted of a 55-gal day tank containing a 12.5% NaOCl solution and a 2.5-gph LMI chemical feed pump with stroke and speed settings for dosage adjustment. The target free chlorine residual was 0.5 mg/L. The feed pump was energized only when the well pump was on. NaOCl consumption was tracked by measuring solution levels in the day tank.

- **Iron Addition**. Ferric chloride ($FeCl_3$) was added to achieve a target iron dosage of 1.2 to 2.0 mg/L to effectively remove soluble arsenic through adsorption and/or coprecipitation with iron solids. The iron addition system included a 66-gal high-density polyethylene (HDPE) tank with containment, an overhead mixer (Pulsafeeder Model FMTEH/Vinyl), and a Pulsatron Model LPH5 chemical metering pump rated at 3.1 gal/hr (gph). The working

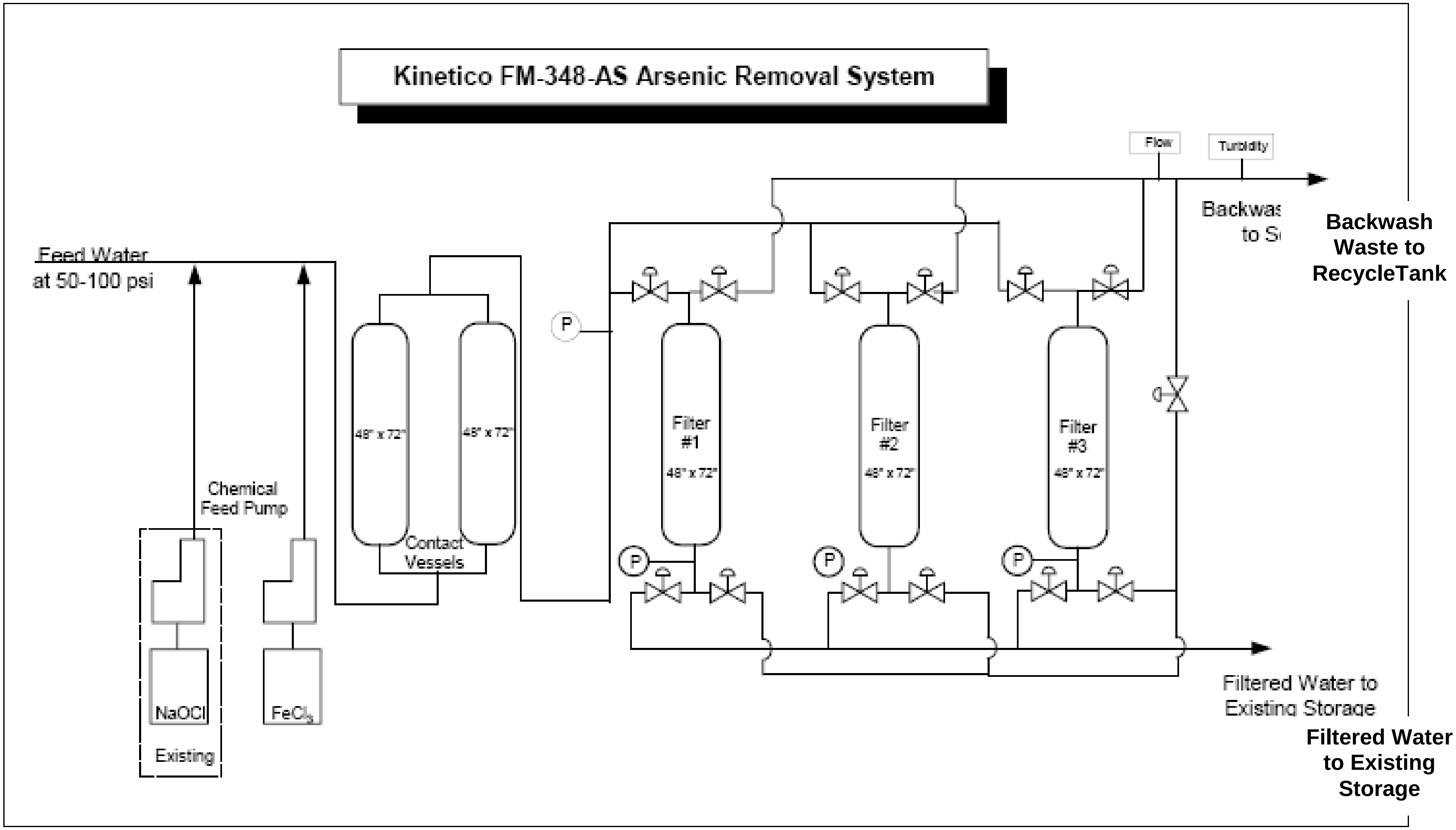


Figure 4-2. Schematic of Kinetico's Macrolite® Arsenic Removal System for Felton, DE, Site

Figure 4-3. Treatment System Components
(Clockwise from Top: Well No. 4 Bypass Valve; Well No. 4 Inlet with Iron Addition Point; Two Contact Tanks and Three Filtration Vessels; and Backwash Discharge Piping to Recycle Tank)

Figure 4-4. Control and Instrumentation
(Clockwise from Left: Control Panel Housing PLC; Turbidimeter Display; Compressor; Sample Tap and Pressure Gauge; Pressure Tank; and Mercury Switch)

Table 4-3. Design Features of Macrolite® System

Parameter	Value	Remarks
Influent Specifications		
Peak Flowrate (gpm)	375	–
Arsenic Concentration (μg/L)	≤ 35	–
Iron Concentration (μg/L)	≤ 110	–
Pretreatment		
Prechlorination (mg/L [as Cl_2])	2–3	NaOCl
Iron (mg/L [as Fe])	1.2–2.0	$FeCl_3$
Contact		
No. of Vessels	2	–
Configuration	Parallel	–
Vessel Size (in)	48 D × 72 H	–
Tank Volume (gal)	564	
Contact time (min)	3	–
Filtration		
No. of Vessels	3	–
Configuration	Parallel	–
Vessel Size (in)	48 D × 72 H	–
Vessel Cross Section (ft^2)	12.6	–
Media Volume (ft^3/vessel)	25	24-in bed depth of Macrolite®
Peak Flowrate (gpm)	375	125 gpm/vessel
Hydraulic Loading Rate (gpm/ft^2)	10	Based on 125 gpm/vessel flowrate
Backwash		
Frequency	Variable	Based on PLC setpoints for Δp across tank, run time, and standby time
Differential Pressure (psi)	10–12	Across a clean bed
Hydraulic Loading (gpm/ft^2)	8–10	100–125 gpm
Wastewater Production (gpd)	Variable	Based on PLC setpoints for minimum and maximum backwash time and turbidity
Effluent Specifications		
Peak Daily Demand (gpd)	353,600	
Maximum Daily Production (gpd)	540,000	Based on peak flow and 24 hr/day
Peak Hydraulic Utilization (%)	65	Estimate based on peak daily demand

D = diameter; H = height

solution was prepared by adding 9 gal of a 37% $FeCl_3$ stock solution into 57 gal of water (6:1 ratio). The consumption of the $FeCl_3$ solution was measured based on readings of day tank levels.

- **Coprecipitation/Adsorption.** Two 48-in-diameter by 72-in-tall fiberglass reinforced plastic (FRP) contact tanks (Pentair Model 31285) were used to improve the formation of iron flocs prior to pressure filtration. The contact tanks arranged in parallel were designed for 3 min of contact time. The 463-gal tanks had 6-in top and bottom flanges connecting to the exit and inlet piping, respectively, for an upflow configuration (Figure 4-3).
- **Pressure Filtration**. Removal of arsenic-laden iron particles was achieved via downflow filtration through three 48-in-diameter by 72-in-tall FRP pressure vessels (Pentair Model 31283) configured in parallel (Figure 4-2). Each pressure vessel contained 25 ft^3 (or 24 in) of M2 Macrolite® media loaded on top of fine garnet underbedding filled to 1 in above the 0.006-in slotted, stainless steel, wedge-wire underdrain (Leem/LSS Filtration model L-3230-

60). The FRP vessels featured windows for media and backwash observation and were rated for a working pressure of 150 psi (Figure 4-3). The vessels were floor mounted and piped to a valve rack mounted on a welded, stainless steel frame. The flow through each vessel was regulated to 125 gpm using a flow-limiting device (Flo-Et model PE-300-14-125) to prevent filter overrun. System operation with all vessels in service could produce a total flowrate of 375 gpm. Effluent flowrates and throughput through each vessel were monitored using an insertion paddle wheel flow meter/totalizer (Data Industrial model 220PVCS).

- **Filter Backwash**. At a 10 gpm/ft^2 filtration rate, anticipated pressure drop across a clean filter bed was 10 to 12 psi. The filters were automatically backwashed in an upflow mode based on three potential triggers: 1) differential pressure, 2) standby time, and 3) run time (Section 4.4.3.1). The filters also could be backwashed manually. Backwash was performed one vessel at a time. Water was drained from a filter before an air compressor (Speedaire Model 1WD61 [Figure 4-4]) delivered a 2-min air sparge at 10 psi gauge (psig). After a 4-min settling period, the filter was backwashed at 100 to 125 gpm with treated water produced from the other two filters remaining in service.

  The backwash duration was controlled by a minimum and a maximum backwash time per vessel and turbidity of backwash wastewater measured using a turbidimeter (Hach™ Model Surface Scatter 6 [Figure 4-4]). Under the factory settings, if the target turbidity threshold was reached before the backwash time setpoint, backwash would end at the set minimum backwash time. Otherwise, backwash continued until the target turbidity threshold was reached. If the turbidity threshold was not reached at the end of the set maximum backwash time, then a backwash failure would be indicated and the operator had to acknowledge the alarm. A backwash failure resulted in a repeat backwash before the pressure filter could resume normal operation.

  Backwash wastewater was sent to a 7,180-gal recycle tank. After the backwash step, the filter underwent a 2-min filter-to-waste (FTW) step to remove any particulate from the filter before returning to service.

- **Backwash Recycle System.** A recycle system was incorporated into the C/F system to temporarily store wastewater generated during filter backwash. After settling, supernatant was recycled back to the head of the treatment system; sludge was pumped periodically to the local sanitary sewer.

  The recycle system consisted of a pump controller, two booster pumps, and a 16-ft-long by 6-ft-wide by 10-ft-high, 7,180-gal concrete recycle tank equipped with four float switches, an 8-in overflow pipe, and a 2-in Sch 40 PVC suction line (Figure 4-5). The recycle system controller was linked to four float switches (i.e., low-low, low, high, and high-high) that were placed at various heights inside the recycle tank. During filter backwash, wastewater was discharged into the recycle tank through an 8-in PVC pipe. Once the wastewater level reached the high-level float switch, the recycle system controller activated a single booster pump capable of 14 gpm of flow. The booster pump continued to operate until the wastewater level reached the low-level float switch. Once the low-level float switch was activated, the booster pump operation was stopped until the high-level switch was activated again. The two booster pumps alternated pumping cycles to reduce pump wear and increase pump life span.

  If a single booster pump could not keep up with the backwash flowrate during a recycling sequence, wastewater would rise and reach the high-high level alarm located below the overflow pipe. When the high-high level was reached, the recycle system controller would activate both booster pumps and the flowrate would increase to 28 gpm. This alarm is in

Figure 4-5. Recycle System Components, Control, and Instrumentation
(Clockwise from Left: Concrete Recycle Tank and Overflow Piping; Float Switches; Recycle System Controller; Booster Pumps; and Recycle Water Injection Point)

place to minimize the amount of wastewater overflowing into the sanitary sewer. (Due to a faulty pump, only one booster pump was used during the performance evaluation study.) The low-low level alarm is in place as a fail safe to protect the booster pumps from operating when the tank is dry. If the low-level alarm fails to shut down the booster pumps, the low-low level alarm would be activated and the recycle system controller would shut down the booster pumps.

To ensure that sludge in the recycle tank would not be recycled back to the pressure filters, adjustments had to be made to the recycle tank (Section 4.4.3.3) and periodic checks on sludge levels were included as part of routine O&M.

4.3 Treatment System Installation

This section provides a summary of the system installation, startup, and shakedown activities and the associated prerequisites including permitting and building construction.

4.3.1 System Permitting. The system engineering package, prepared by Kinetico and its subcontractor, Davis, Bowen and Friedel, Inc. of Milford, DE, included:

- A system design report
- A general arrangement and P&ID
- Electrical and mechanical drawings and component specifications

- Building construction drawings detailing connections from the system to the inlet piping and the town's water and sanitary sewer systems.

The engineering package was certified by a Professional Engineer registered in the State of Delaware and submitted to DHSS for review and approval on April 26, 2005. After DHSS's review comments were addressed, the package was resubmitted, along with a permit application, on April 28, 2005. A system construction permit was issued by DHSS on May 31, 2005, and system fabrication began thereafter.

4.3.2 Building Construction. A permit for building construction was applied for by the Town of Felton on March 23, 2005, and issued by Kent County on April 28, 2005. An Advertisement for Bids was sent to two Delaware newspapers on May 26, 2005, to be posted on June 1 and June 8, 2005. Bidding for building and concrete recycle tank construction and related plumbing work was closed on July 18, 2005, and the bid submitted by Arimore Construction Inc. was approved by the Town Council. A preconstruction meeting was held on August 2, 2005, and water and sewer infrastructure construction began on August 8, 2005. Due to delays with the town's subcontractor, the building was not completed until July 7, 2006. Due to leaks in the recycle tank, system startup was further delayed until September 6, 2006. Figures 4-6 and 4-7 present schematics of the building to house the treatment system and the recycle tank. Figure 4-8 presents a photograph of the treatment system building and recycle tank.

4.3.3 System Installation, Startup, and Shakedown. The C/F system was delivered to the site on March 20, 2006. The vendor, through its subcontractor, performed off-loading and began installation of the system, including connections to the entry and distribution piping and electrical interlocking. Due to construction delays, system installation, hydraulic testing, and media loading were not completed until May 30, 2006. A water sample collected on May 31, 2006, passed bacteriological tests and startup and shakedown activities were completed on June 6, 2006. Startup and shakedown activities included PLC testing, instrument calibration, prolonged backwashing to remove Macrolite® media fines, chlorine disinfection and residual testing, and operator training on system O&M. Due to inadequate recycle pumps and a leak in the recycle tank, the treatment system had remained offline until new pumps arrived and the leaky recycle tank was repaired. Upon installation of the new recycle pumps and repair of the recycle tank, the treatment system was placed into service on September 6, 2006.

Battelle performed system inspections and operator training on sample and data collection on October 12 and 13, 2006. As a result of the system inspections, several punch-list items were identified. Table 4-4 summarizes the items identified and corrective actions taken.

4.4 System Operation

4.4.1 Service Operation. Operational parameters of the C/F system are tabulated and attached as Appendix A with key parameters summarized in Table 4-5. The performance evaluation study began on September 14, 2006, and ended on November 3, 2007. The system operated for a total of 2,716 hr based on cumulative service hours of each of the three pressure filters recorded by the PLC. An hour meter also was installed at the wellhead on March 9, 2007, to track the well pump/system operating time. In general, the wellhead hour meter readings were in close agreement with PLC pressure filter hour meter readings, with the wellhead hour meter registering about 0.3 hr/day (on average) more than the PLC. As shown in Figure 4-9, daily operating times fluctuated significantly from 0 to 23.1 hr and averaged 6.5 hr. Seasonal variations were observed with a relatively longer operating time starting from late spring through early fall. Daily operating times through this duration averaged 8.4 hr/day (versus 6.0 hr/day for the rest of the year) with an average daily demand of 125,100 gpd (versus 94,100 gpd). Total system throughput was approximately 43,446,100 gal based on flow totalizer readings measured at the system outlet. The average daily demand was approximately 107,300 gal, equivalent to 30% of the system peak daily demand specified in Table 4-3.

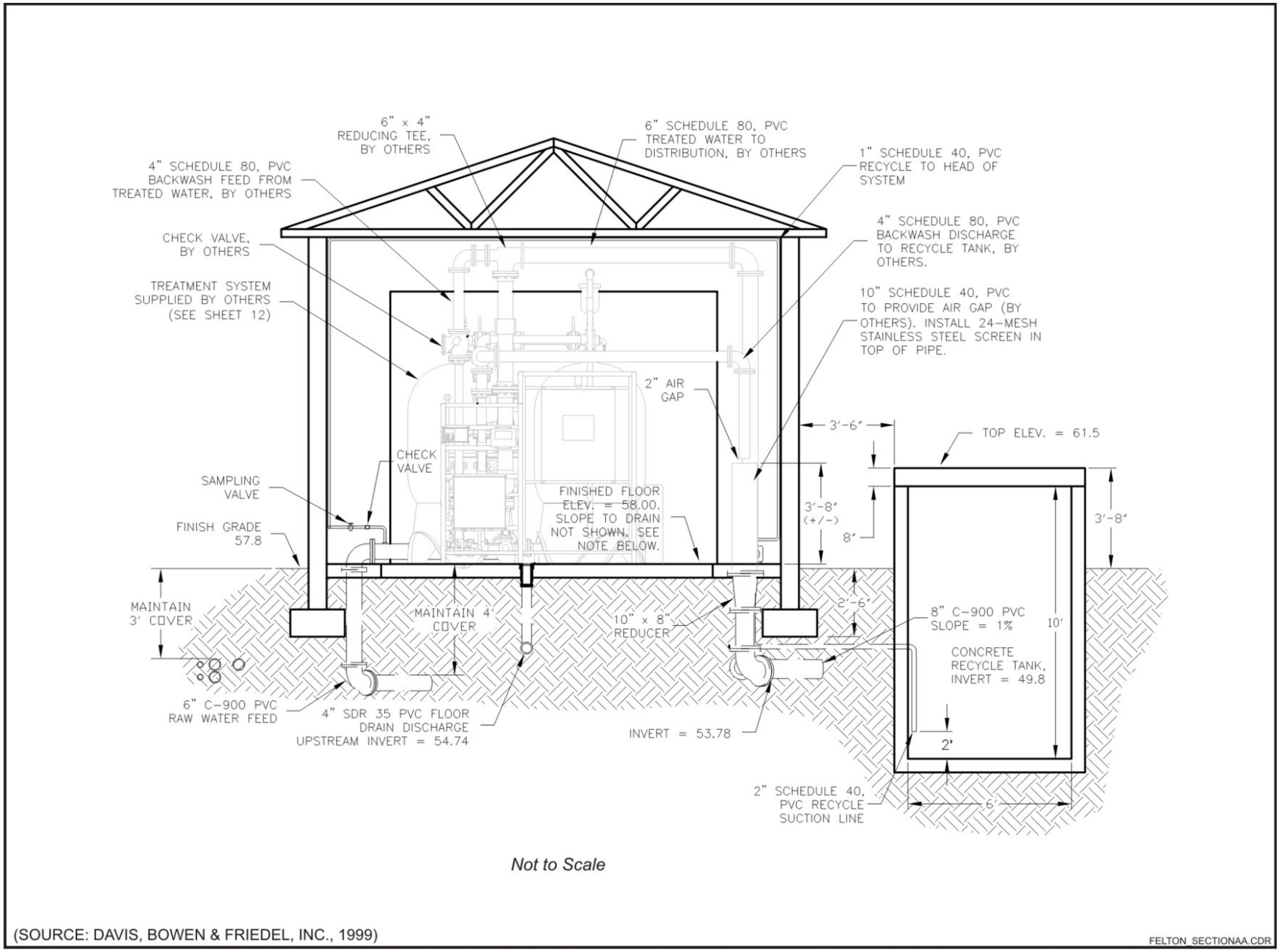


Figure 4-6. Schematic of Building and Recycle Tank (provided by DB&F)

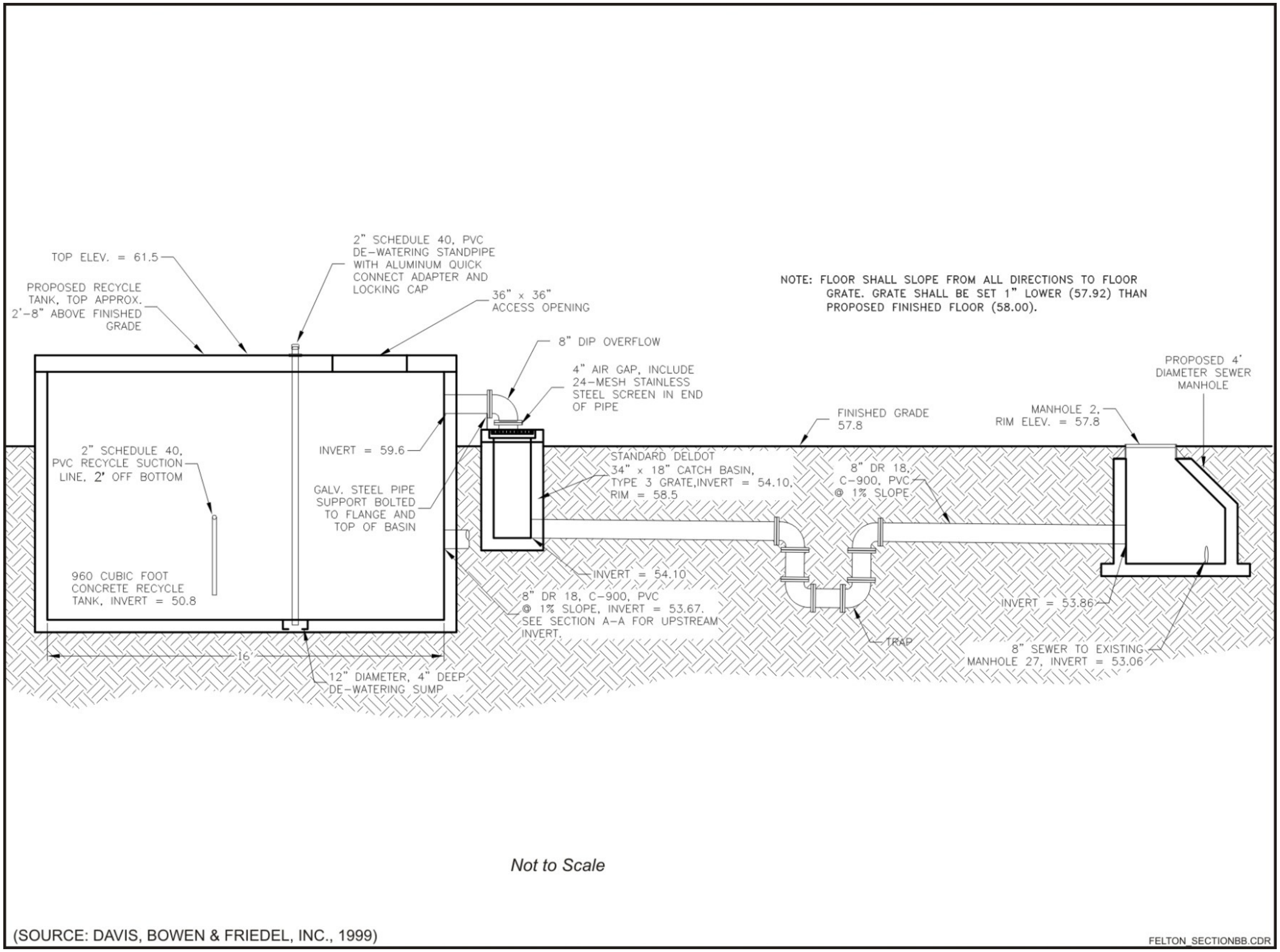


Figure 4-7. Schematic of Recycle Tank (provided by DB&F)

Figure 4-8. New Building and Recycle Tank

Table 4-4. System Inspection Punch-List Items

Item No.	Punch-List Item Description	Corrective Action(s) Taken	Resolution Date
1	Small amount of water continuously flowing from air release lines on Vessels A, B, and C while system was in service.	• Disassemble and cleaned air release lines • Updated O&M manual to include this procedure	04/04/07
2	A check valve and an isolation valve not installed between pipe entering building and $FeCl_3$ injection point. As such, water could drain from contact tanks through an existing spigot on inlet piping located within well house if the spigot was left opened inadvertently.	• Installed a check valve, a 6-in butterfly valve, and associated hardware kit	04/03/07
3	During Vessel C fast rinse, inlet pressure to system dropped to 59 psi and flow to two vessels in service dropped to 85 gpm, which was significantly lower than 320 gpm flow based on pump curve. This would equate to a fast-rinse flowrate of approximately 235 gpm, which was well above 125 gpm design flowrate for each vessel.	• Installed an orifice plate on fast rinse line to limit fast rinse flowrate to 125 gpm	04/03/07
4	Filters backwashed at 62 gpm, significantly below 100 to 125 gpm (or 8 to 10 gpm/ft^2) specifications.	• Confirmed flowrate using an ultrasonic flow meter; no further actions taken during trip. System operated at reduced backwash flowrates during performance evaluation study.	04/03/07

Table 4-4. System Inspection Punch-List Items (Continued)

Item No.	Punch-List Item Description	Corrective Action(s) Taken	Resolution Date
5	Recycle tank overflowed to sanitary sewer during a backwash event. Maximum backwash time incorrectly set at 40 min, which was outside range of typical PLC setting and could result in overflow of recycle tank should Hach turbidimeter malfunction.	• Modified setpoints via dial-in modem by Kinetico: – Decreased minimum backwash time from 10 to 5 min – Decreased maximum backwash time from 40 to 10 min – Increased turbidity threshold from 10 to 20 NTU	01/04/07
6	Leaking chemical feed line (over suction side).	• Installed by operator a new union shipped from offsite	12/13/06
7	Unclear instructions on how to change $FeCl_3$ pump speed (rate %) on PLC.	• Provided clear instruction and demonstrated to facility operator how to correctly adjust speed of chemical feed pump on PLC.	04/04/07
8	Short standby setpoint could trigger backwash while system was in standby mode, thus increasing chance to overflow recycle tank because recycle pumps were not energized.	• Increased standby setpoint from 48 to 96 hr	10/12/06

System flowrates were tracked by both instantaneous readings of the flow meter at the system outlet and calculated flowrates based on hour-meter and flow-totalizer readings at the system outlet. As shown in Figure 4-10, instantaneous flowrate readings ranged from 249 to 312 gpm and averaged 290 gpm, about 10% higher than calculated flowrates (which ranged from 163 to 368 gpm and averaged 263 gpm). The average calculated flowrate corresponded to a contact time of 4.3 min through the contact tanks (compared to the design value of 3.0 min) and a filtration rate of 7.0 gpm/ft^2 over the pressure filters (compared to the design value of 10 gpm/ft^2) (Table 4-3). Flows into the treatment system also were measured by a totalizer located at the wellhead. The cumulative throughput recorded by the wellhead totalizer was approximately 44,377,600 gal, which was within 2% of that recorded by the totalizer at the system outlet.

Differential pressure (Δp) readings ranged from 20 to 33 psi and averaged 25 psi across the system, and from 4 to 27 psi and averaged 12 psi across each pressure filter (Figure 4-11). As discussed in Section 4.4.3, 94% of backwash was triggered by high Δp. The setpoint of Δp trigger was reduced from 25 to 18 psi on January 17, 2007, resulting in visible reduction in Δp values as shown in Figure 4-11. As expected, Δp across pressure filters increased progressively with filter run time as shown in Figure 4-12. Δp readings recorded within 1 hr after backwash ranged from 5 to 17 psi and averaged 8.5 psi, with 20% of the readings higher than the clean-bed level of 10 psi. Lower-than-expected backwash flowrates (i.e., 61 to 87 gpm vs. design values of 100 to 125 gpm) might be responsible for the elevated Δp readings observed.

Filter run times between backwash cycles ranged from 7.9 to 24 hr and averaged 17 hr before January 17, 2007, and ranged from 2.0 to 24 hr and averaged 9.1 hr after January 17, 2007. On January 17, 2007, the Δp backwash trigger was reduced from 25 to 18 psi in an attempt to reduce run times between backwash cycles. In addition, iron dosage was increased on January 17, 2007 (Section 4.4.2), which also might have contributed to shortened filter run times. The reduction in filter run time after January 17, 2007 can be seen in Figure 4-13. The average throughput between backwash cycles was 89,580 gal/vessel before

Table 4-5. Treatment System Operational Parameters

Parameter	Value
Operating Period	09/14/06–11/03/07
Pretreatment Operation	
NaOCl Dosage (mg/L [as Cl_2])	4.3 [2.0–9.1]
$FeCl_3$ Dosage (mg/L [as Fe])	2.2 [1.0–4.8]
Service Operation	
Total Operating Time (hr)	2,716
Average Daily Operating Time (hr)	6.5
Throughput[(a)] (gal)	43,446,110
Average Daily Demand[(a)] (gal)	107,300
Instantaneous Flowrate (gpm)	290 [249–312]
Calculated Flowrate[(b)] (gpm)	263 [163–368]
Contact Time in Contact Tanks[(c)] (min)	4.3 [3.1–6.9]
Hydraulic Loading over Pressure Filter[(c)] (gpm/ft^2)	7.0 [4.3–9.7]
Δp across Each Vessel (psi)	12[4–27]
Δp across System[(d)] (psi)	25[20–33]
Filter Run Time between Backwash Cycles (hr)[(e)]	17[7.9–24] before 01/17/07 9.1[2.0–24] after 01/17/07
Estimated Averaged Throughput between Backwash Cycles (gal/vessel)	89,580 before 01/17/07 48,080 after 01/17/07
Backwash Operation	
Average Frequency[(f)] (backwash/vessel/week)	5
Number of Backwash Cycles (Tanks A/B/C)	259/354/314
Flowrate[(g)] (gpm)	76 [61–87]
Hydraulic Loading Rate[(g)] (gpm/ft^2)	6.0 [4.8–6.9]
Duration (min/tank)	6.7 [4.3–14.6]
Backwash Volume (gal/vessel/cycle)	474 [346–907]
Filter-to-Waste Volume (gal/vessel/cycle)	250
Wastewater Produced (gal/vessel/cycle)	724 [596–1,157]

Note: Data presented included average and [range].
(a) Based on totalizer readings at system outlet.
(b) Calculated flowrates based on daily throughput and daily operating hours.
(c) Based on instantaneous flowrate readings.
(d) Five outliers (i.e., 5, 8, 10, 7, and 13 psi on 09/19/06, 09/20/06, 09/21/06, 09/27/06, and 10/01/06, respectively) omitted.
(e) Excluding values triggered by standby time, run time, and manual initiation.
(f) Based on number of backwash cycles and number of weeks in service.
(g) Based on monthly data from Backwash Log Sheets.

January 17, 2007 and 48,080 gal/vessel after, based on a flowrate of 87.7 gpm through each vessel (i.e., one-third of the 263-gpm service flow).

4.4.2 Chlorine and Iron Additions. Chemical pretreatment consisted of chlorine and iron additions. Chlorine doses, as calculated based on daily NaOCl consumption (as measured through solution level changes in the chemical day tank) and daily throughput (according to the system effluent totalizer), ranged from 2.0 to 9.1 mg/L (as Cl_2) and averaged 4.3 mg/L (as Cl_2) (Figure 4-14). This average dosage was higher than the design dosage of 3.0 mg/L (as Cl_2) required to achieve a free chlorine residual of 0.5 mg/L (as Cl_2) as discussed in Section 4.1.3.

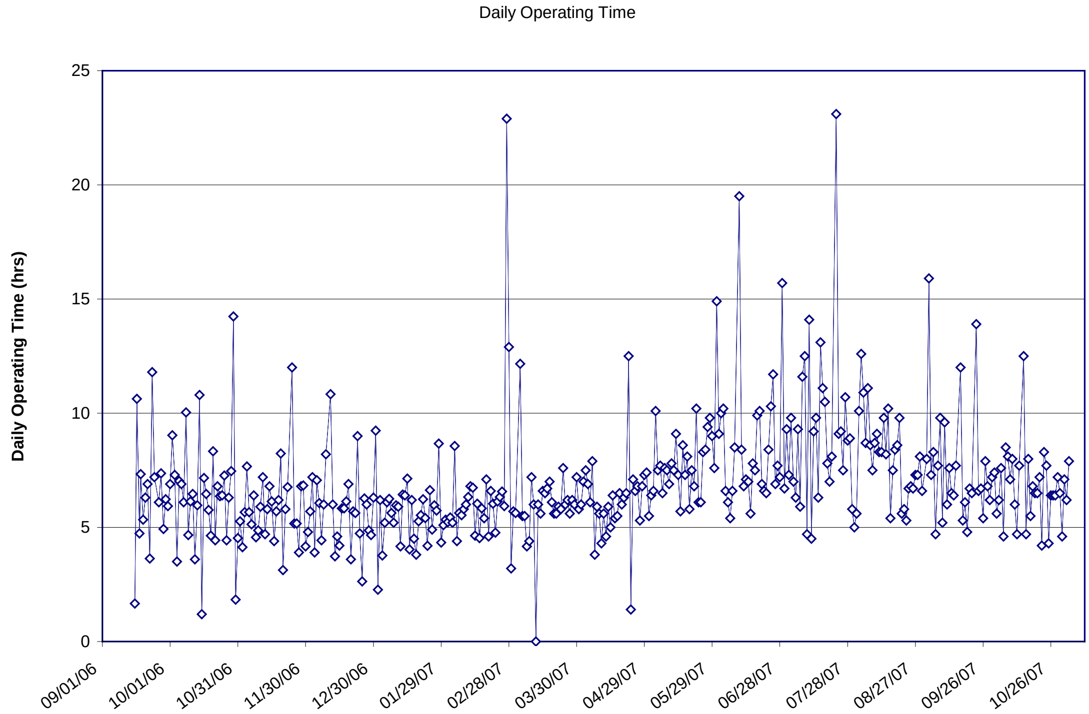


Figure 4-9. Treatment System Daily Operating Time

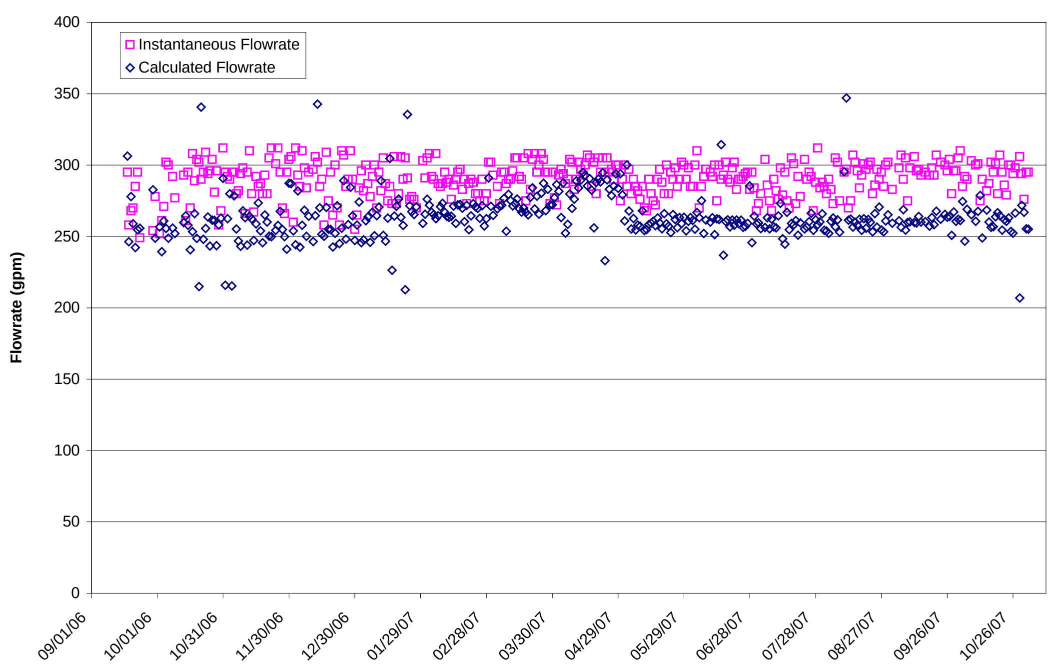
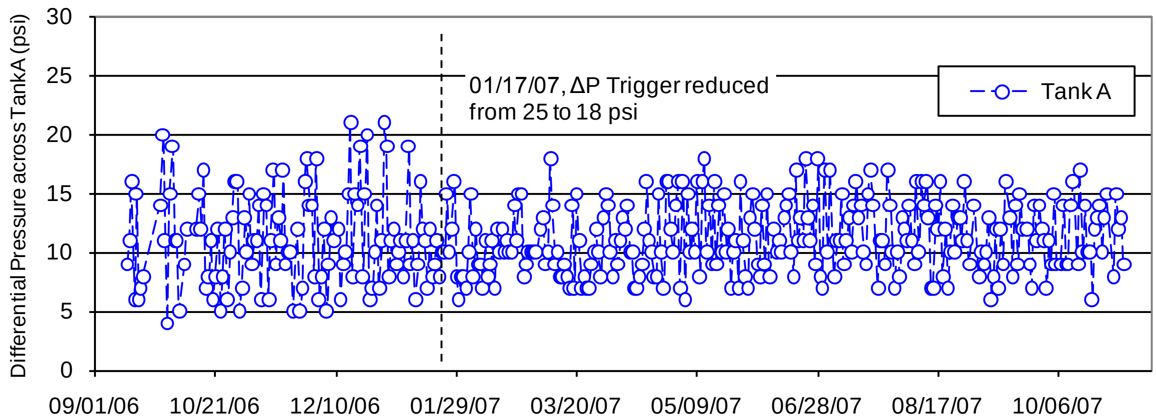
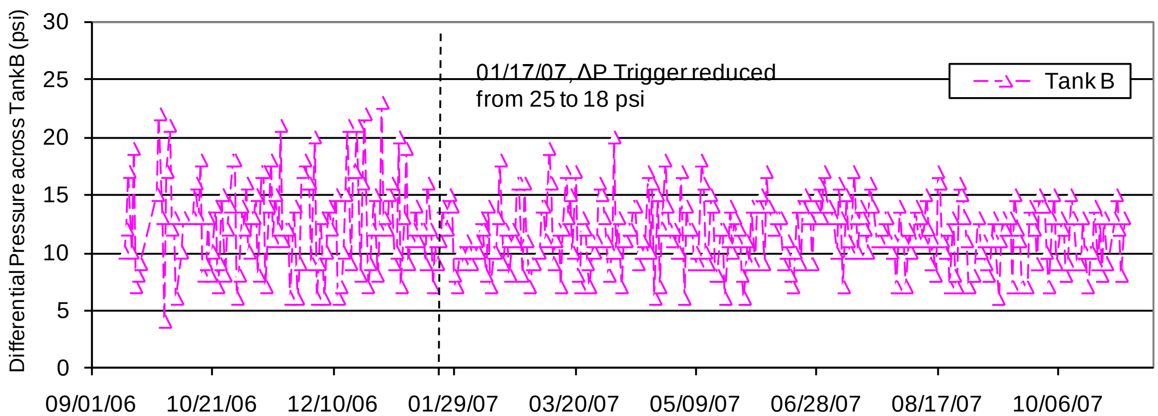


Figure 4-10. Treatment System Flowrates





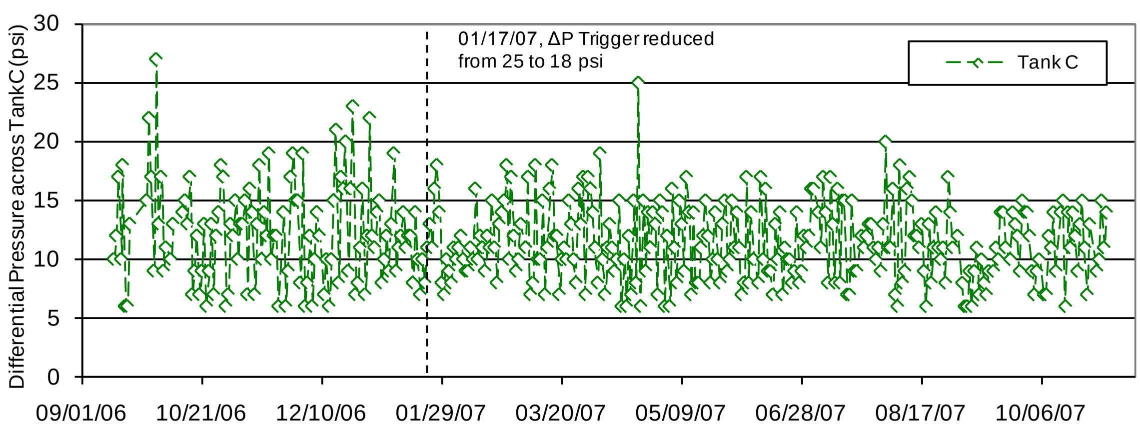


Figure 4-11. Differential Pressure Across Filtration Vessels

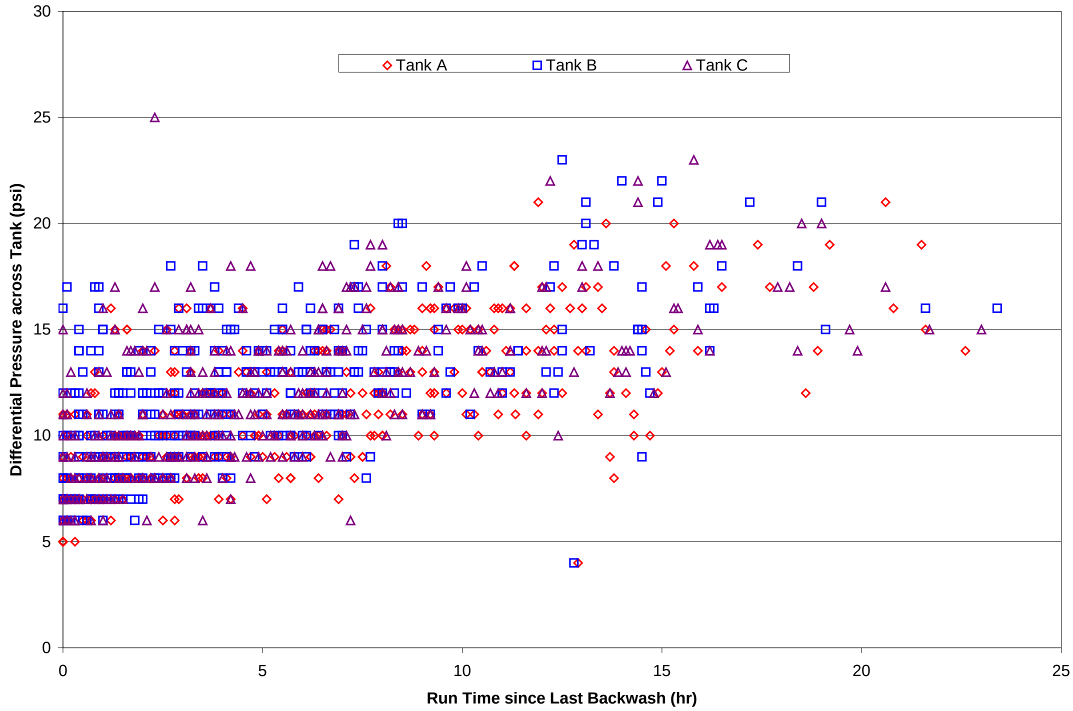


Figure 4-12. Differential Pressure vs. Filter Run Time

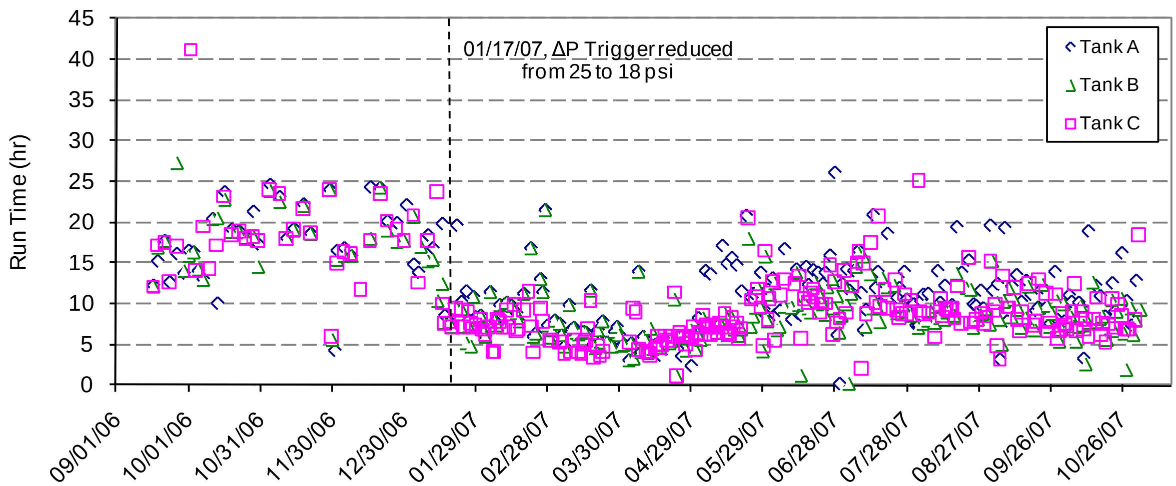


Figure 4-13. Filter Run Time Since Last Backwash

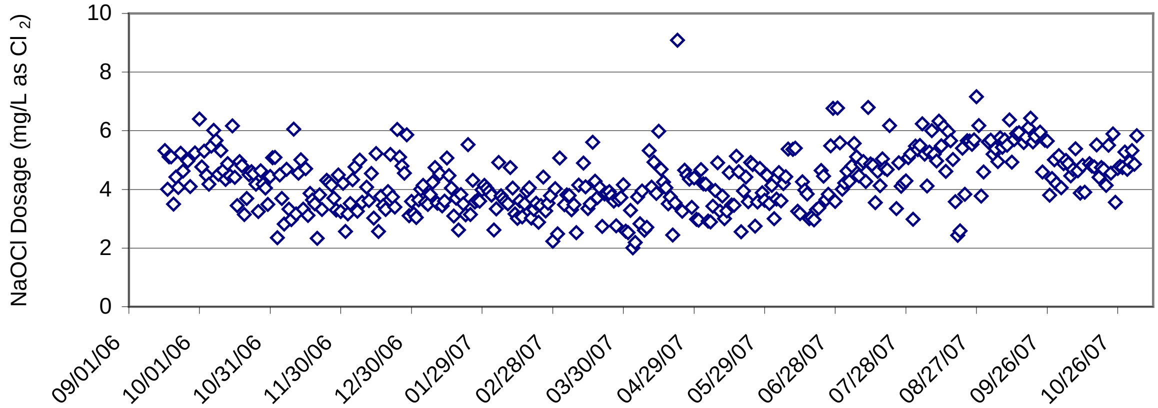


Figure 4-14. Chlorine Dosages over Demonstration Study Period

Iron was added to source water as a coagulant to remove soluble arsenic through adsorption and/or coprecipitation with iron solids. Figure 4-15 presents calculated $FeCl_3$ doses (mg/L as Fe) and measured iron concentrations (mg/L as Fe) over the entire study period. Similar to chlorine doses, iron doses were calculated based on daily $FeCl_3$ consumption (by changes of solution levels in the chemical day tank) and daily throughput (according to the system effluent totalizer). Iron concentrations were measured following the contact tanks.

To target an initial iron dose of 1.2 mg/L (as Fe), the 37% $FeCl_3$ stock solution was diluted six times and the pump stroke length was set at 18% (note that the pump speed is flow paced and non-adjustable). The iron target dosage was increased to 1.5 mg/L (as Fe) on November 3, 2006, by increasing the stroke length setting from 18 to 25%. The stroke length setting was increased, once again, to 32% on January 17, 2007, for a target iron dosage of 2.0 mg/L (as Fe). In response, average calculated iron doses increased correspondingly to 2.2 mg/L (as Fe). Measured iron concentrations, however, scattered extensively from 0.3 to 13.6 mg/L (as Fe) and averaged 2.6 mg/L (as Fe) as discussed in Section 4.5.1.2.

Initially, addition of $FeCl_3$ was flow-paced through the PLC, which automatically adjusted the amount of $FeCl_3$ injection based on system flowrate. This flow-paced injection approach was suspected to have caused scattered iron concentrations in contact-tank effluent. Therefore, on September 17, 2007, automatic control of the chemical feed pump was discontinued. The amount of $FeCl_3$ injection would remain constant as it was no longer determined based on system flowrate. Speed and stroke length on the chemical feed pump were set at 50 and 75%, respectively, for a target iron dosage of 2.0 mg/L. Calculated iron doses increased correspondingly to an average of 3.0 mg/L (as Fe) and iron concentrations following the contact tanks converged into a much narrower range from 1.2 to 2.6 mg/L (as Fe) and averaged 2.1 mg/L (as Fe).

4.4.3 Backwash Operation. The system PLC was set to initiate a backwash based on one of four potential triggers: (1) Δp across pressure filters, (2) system standby time, (3) system run time, or (4) manual initiation. Backwash duration was controlled by a set minimum and maximum backwash time (per vessel) and a set backwash wastewater turbidity threshold as measured by an inline Hach™ turbidimeter. If the turbidity threshold was reached before the set minimum backwash time, backwash would end at the set minimum backwash time. Otherwise, it would continue until the target turbidity threshold was reached. If the turbidity threshold was not reached at the end of the set maximum

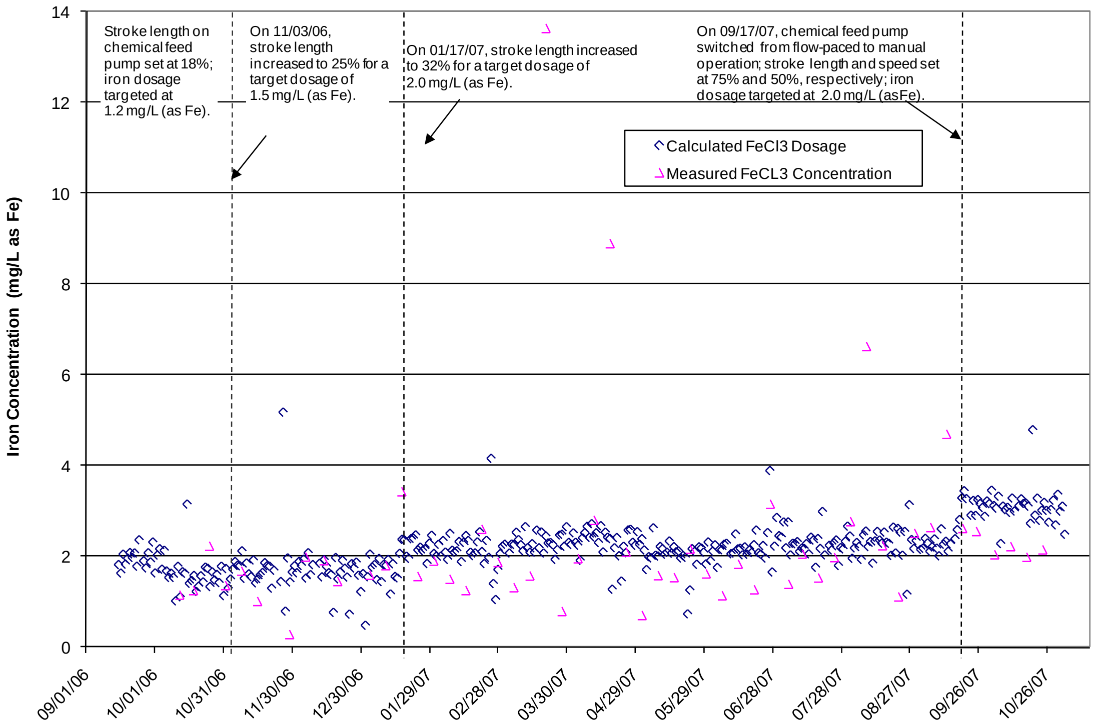


Figure 4-15. Calculated Iron Doses vs. Measured Iron Concentrations

backwash time, then a backwash failure would be indicated and the operator would have to acknowledge the alarm. This would result in a repeat backwash before the pressure filter could resume service. The use of turbidity as one of the backwash setpoints was designed as a potential water-saving measure. Backwash was followed by a 2-min FTW step to remove any particulates from the filter.

Filter Vessels A, B, and C were backwashed 259, 354, and 314 times, respectively, from September 14, 2006, to November 3, 2007. Beginning from October 10, 2006, the operator tracked the trigger that activated each backwash. Among the 883 backwashes since then, Δp triggered 833 backwashes (or 94%); system standby time triggered six; system run time triggered eight; and manual operation triggered 36 (for backwash wastewater/solids sampling only).

Backwash durations ranged from 4.3 to 14.6 min and averaged 6.7 min based on monthly Backwash Log Sheets (Appendix C). Amounts of wastewater generated during each backwash ranged from 600 to 1,160 gal/vessel and averaged 720 gal/vessel (including 250 gal/vessel produced during the 2-min FTW step).

4.4.3.1 ***PLC Settings.*** Table 4-6 summarizes the initial backwash PLC settings at system startup and three subsequent modifications on October 12, 2006, and January 4 and 15, 2007. Initially, the PLC was set in the field on June 6, 2006, to backwash with a standby time of 48 hr, which could result in filter backwash while the system was not in operation. If this occurred, the recycle pumps would not be charged and there would be an increased possibility that the recycle tank would overflow. To ensure that a backwash would be triggered by Δp or run time while the system was in operation and to reduce the chance of overflowing the recycle tank, the standby time was increased from 48 to 96 hr on October 12, 2006.

Table 4-6. Summary of PLC Settings for Backwash Operations

Parameter (for Each Vessel)	Adjustment Date			
	06/06/06[a]	10/12/06	01/04/07	01/17/07
Δp Trigger (psi)	25	25	25	18
Standby Time Trigger (hr)	48	96	96	96
Run Time Trigger (hr)	24	24	24	24
Drain Time (min)	3	3	3	3
Air Sparge Time (min)	2	2	2	2
Settling Time (min)	4	4	4	4
Minimum Backwash Time (min)	10	10	5	5
Maximum Backwash Time (min)	40	40	15	15
Turbidity Threshold (NTU)	10	10	20	20
Low Flowrate Threshold (gpm)	20	20	20	20
Filter-to-Waste Time (min)	2	2	2	2

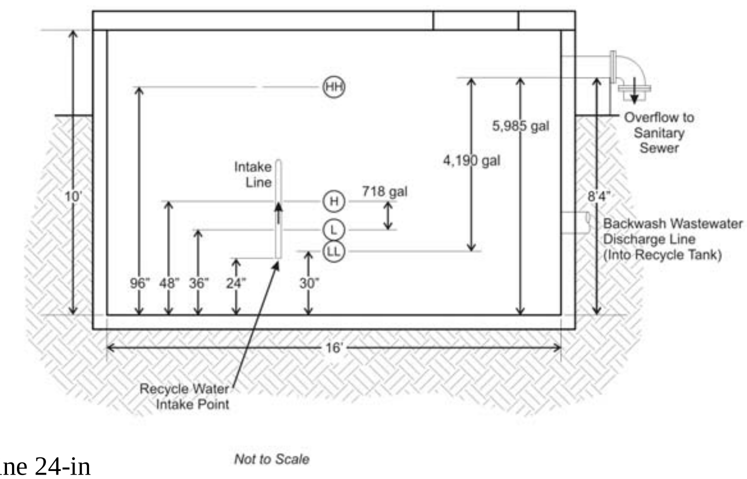
(a) Initial field settings.

On January 4, 2007, several changes were made to the PLC settings, including decreasing the setpoints for minimum backwash time (from 10 to 5 min) and maximum backwash time (from 40 to 15 min), and increasing the setpoints for turbidity threshold (from 10 to 20 NTU). These changes were made in an attempt to alleviate the possibility of overflowing the recycle tank during sequential backwash events by minimizing the duration, and, therefore, volume of water required to reach the turbidity threshold. With these changes, average backwash durations decreased from approximately 10.4 to 5.6 min based on the monthly Backwash Log Sheet. On January 17, 2007, Δp backwash trigger was decreased from 25 to 18 psi in an attempt to reduce run times between backwash events and, therefore, the likelihood of particulate breakthrough from the filters. With this change, filter run times decreased from 17.0 to 9.1 hr (on average) (Table 4-5 and Figure 4-13).

4.4.3.2 Increase in Backwash Frequency. From April 2 to May 4, 2007, a dramatic increase in backwash frequency was observed. During this period, 174 backwashes were triggered resulting in a backwash frequency of approximately 12 cycles/vessel/week, which is an increase of 132% from the average of 5 cycle/vessel/week. The average filter run time during this period dropped from the average of 9.1 min (Table 4-5) to 5.7 min. Upon inspection of the recycle tank, it became apparent that sludge in the recycle tank had accumulated to a level above the intake line, thus introducing particles back into the pressure filters and decreasing filter run times. On May 4, 2007, the recycle tank was temporarily shut off and the backwash frequency returned to normal. On May 11, 2007, sludge in the recycle tank was pumped and discharged into a sanitary sewer. (Note that sludge was discharged only once during the study.) To prevent the introduction of sludge back into the pressure filters, adjustments were made to the recycle tank (Section 4.4.3.3) and periodic sludge level checks were included as part of routine O&M.

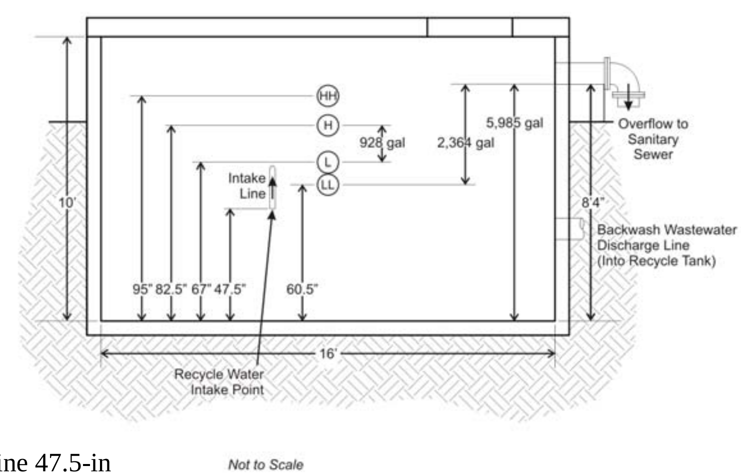
4.4.3.3 Recycle System Operation. Figure 4-16a presents a schematic of the recycle tank and the initial settings of the float switches. The low-low-, low-, high-, and high-high-level float switches were placed at 30, 36, 48, and 96 in from the bottom of the tank, respectively. Based on these levels, the working range of the recycle tank (i.e., from the low-low level to overflow) was 4,190 gal with a 718-gal capacity between the low and high levels and 2,873 gal between the high level and overflow. In the event that each filter would backwash in succession, there would be adequate storage to hold the 2,172 gal of wastewater produced (based on average wastewater production of 724 gal/vessel).

Due to the concerns over recycling sludge back into the filters, adjustments were made to the recycle tank by raising (1) the intake pipe from 24 to 47.5 in above the bottom of the recycle tank and (2) the low-low, low-, high-, and high-high-level float switches to 60.5, 67, 82.5, and 95 in, respectively (Figure 4-16b).



Note: Intake line 24-in
above tank bottom

Figure 4-16a. Initial Float Switch Levels in Recycle Tank



Note: Intake line 47.5-in
above tank bottom

Figure 4-16b. Revised Float Switch Levels in Recycle Tank

Based on the adjusted levels, the working range of the recycle system was reduced from 4,190 to 2,364 gal. These adjustments reduced the likelihood of reintroducing solids into the pressure filters, however, increased the possibility of overflowing wastewater into the sanitary sewer in the event of sequential backwashes.

Total operation hours of the recycle booster pump were estimated based on the total amount of wastewater generated and the booster pump flowrate of 14 gpm, assuming the amount of wastewater overflowing into the sanitary sewer was negligible. The total amount of wastewater generated during the performance evaluation study was 671,148 gal, which was calculated based on the average wastewater production rate of 724 gal/vessel/cycle and a total of 927 backwash cycles. Therefore, the recycle system operated for 799 hr, or 29.4% of the time the treatment system was in operation.

4.4.4 Residual Management. Residual requiring disposal consisted of only backwash solids, which accumulated at the bottom of the recycle tank. Approximately 850 kg of backwash solids were produced during the performance evaluation study based on 927 backwash events (Table 4-5) and 920 g of backwash solids produced per backwash event (Section 4.5.2). Sludge accumulating in the recycle tank was pumped to the sanitary sewer.

4.4.5 System/Operation Reliability and Simplicity. There was no downtime for the treatment system during the performance study. After all items on the system inspection punch list (Section 4.3.3, Table 4-4) were fixed, no major operational problems were encountered. The simplicity of system operation and operator skill requirements are discussed according to pre- and post-treatment requirements, levels of system automation, operator skill requirements, preventative maintenance activities, and frequency of chemical/media handling and inventory requirements.

4.4.5.1 Pre- and Post-Treatment Requirements. Pre-treatment consisted of chemical additions to improve arsenic removal. A 12.5% NaOCl solution was added using the pre-existing equipment 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 day tank, the operator measured chlorine concentrations to ensure that residuals existed throughout the treatment train. A 37% $FeCl_3$ solution diluted six times was added upstream of the contact tanks. Solution levels in the day tank were tracked daily. No post-treatment was required.

4.4.5.2 System Automation. The C/F system was automatically controlled by the PLC in the central control panel. The control panel contained a modem and a touch screen OIP that facilitated monitoring of system parameters, changing of system setpoints, and checking the alarm status. System run time, standby time, and Δp settings (Table 4-6) automatically determined when the pressure filters needed to be backwashed. The touch screen OIP also enabled the operator to manually initiate a backwash sequence.

4.4.5.3 Operator Skill Requirements. Under normal operating conditions, the daily demand on the operator was about 45 min for visual inspection of the system and recording of operational parameters such as pressure, volume, flowrate, and chemical usage on field log sheets. After receiving proper training during system startup, the operator understood the PLC, knew how to use the touch screen OIP, and was able to work with the vendor to troubleshoot problems and perform minor onsite repairs.

The State of Delaware requires all operators of public water treatment and distribution systems to have a valid base-level license, which requires the operator to have:

- High school diploma or equivalent and one year of acceptable operating experience, or;
- Three years of acceptable operating experience, and;
- Successful completion of base-level written examination.

4.4.5.4 Preventative Maintenance Activities. The vendor recommended several routine maintenance activities to prolong the integrity of the treatment system (Kinetico, 2005). Daily preventative maintenance tasks included recording pressure and flowrate readings and chemical drum levels and visually checking for leaks, overheating components, proper manual valve positioning and pumps' lubricant levels, and any unusual conditions. The vendor recommended weekly checking for trends in the recorded data that might indicate a decline in system performance, and semi-annually servicing and inspecting ancillary equipment and replacing worn components. Cleaning and replacement of sensors and replacement of o-ring seals and gaskets of valves were performed as needed.

4.4.5.5 Chemical Handling and Inventory Requirements. Chlorine and iron additions were required for effective arsenic removal. The operator tracked usage of the chemical solutions daily (by solution levels), coordinated supplies, and refilled the day tanks as needed. A 12.5% NaOCl solution, supplied in 55-gal drums by Wilbur-Ellis, was transferred to the day tank and injected without dilution. A 37% $FeCl_3$ solution, supplied in 180-lb drums by Hawkins Chemical, was diluted by a factor of six in the 66-gal day tank prior to injection into the chlorinated water. Speed and stroke settings of the chemical pumps were adjusted, as needed, to acquire the target chlorine residuals as measured regularly with a Hach pocket colorimeter and iron concentrations after the contact tanks.

4.5 System Performance

The performance of the Macrolite® Arsenic Removal System was evaluated based on analyses of water samples collected from the treatment plant, system backwash, and distribution system.

4.5.1 Treatment Plant Sampling. Treatment plant water was sampled on 57 occasions (including four duplicate events) during the 13.5 months of system operation. Field speciation also was performed for 14 of the 57 occasions. Table 4-7 summarizes the analytical results for arsenic, iron, and manganese. Five outliers with either significantly low (on November 29, 2006) or significantly high arsenic, iron, and/or manganese concentrations (on March 21, April 18, and August 8, 2007) at the AC sampling location were not included in statistical calculations shown in Table 4-7. These significantly elevated arsenic, iron, and manganese concentrations probably were due to introduction of backwash solids from the recycle tank. The August 8 event took place even after the level float switches in the recycle tank and the intake line from the recycle tank had been moved up from the bottom of the tank in May 2007 (Section 4.4.3.3). It was not clear, however, what had caused the low concentrations to be measured on November 29, 2006. Table 4-8 summarizes the results of the other water quality parameters. Appendix B contains a complete set of analytical results. The results of the water samples collected across the treatment train are discussed below.

4.5.1.1 Arsenic. Figure 4-17 shows total arsenic concentrations measured across the treatment train and Figure 4-18 presents the results of the 14 speciation events. Total arsenic concentrations in source water ranged from 27.2 to 43.3 µg/L and averaged 34.4 µg/L with soluble As(III) existing as the predominant species at 29.1 µg/L (on average) (Table 4-7 and Figure 4-18). Low concentrations of particulate arsenic and soluble As(V) also were present in source water, with concentrations averaging 3.4 and 2.1 µg/L, respectively. The arsenic concentrations measured during the 13.5-month performance evaluation study were consistent with those of source water collected during the initial site visit on October 7, 2004.

Following prechlorination and the contact tanks, total arsenic concentrations remained essentially unchanged at 35.1 µg/L (on average). Arsenic, however, existed mostly as particulate arsenic (26.1 µg/L [on average]) with only a small fraction remaining in the soluble form (8.9 µg/L). Of the soluble fraction,

Table 4-7. Summary of Arsenic, Iron, and Manganese Analytical Results

Parameter	Sampling Location	Unit	Number of Samples	Minimum Concentration	Maximum Concentration	Average Concentration	Standard Deviation
As (total)	IN	µg/L	57	27.2	43.3	34.4	3.6
	AC	µg/L	52[(a)]	27.0	53.7	35.1	4.9
	TA	µg/L	43	3.1	15.9	7.5	2.9
	TB	µg/L	43	3.4	17.2	7.4	2.7
	TC	µg/L	43	3.4	17.6	7.2	2.8
	TT	µg/L	14	1.8	13.4	8.3	3.6
As (soluble)	IN	µg/L	14	26.1	38.1	31.2	3.1
	AC	µg/L	14	3.6	18.1	8.9	4.3
	TT	µg/L	14	2.5	13.0	7.2	3.1
As (particulate)	IN	µg/L	14	<0.1	5.8	3.4	1.9
	AC	µg/L	14	19.5	33.6	26.1	4.2
	TT	µg/L	14	<0.1	2.5	1.2	0.9
As(III)	IN	µg/L	14	19.9	38.3	29.1	3.9
	AC	µg/L	13[(b)]	<0.1	2.2	0.7	0.6
	TT	µg/L	13[(c)]	<0.1	1.8	0.6	0.5
As(V)	IN	µg/L	14	<0.1	8.8	2.1	2.1
	AC	µg/L	13[(d)]	3.1	15.9	8.1	4.2
	TT	µg/L	14	2.2	10.6	6.0	2.7
Fe (total)	IN	µg/L	57	<25	62.5	26.1	13.6
	AC	µg/L	52[(e)]	704	4,699	1,905	709
	TA	µg/L	43	<25	290	45.6	61.6
	TB	µg/L	43	<25	327	48.4	57.2
	TC	µg/L	43	<25	217	37.1	44.8
	TT	µg/L	14	<25	148	37.9	41.9
Fe (soluble)	IN	µg/L	14	<25	50.0	21.6	13.4
	AC	µg/L	13[(f)]	<25	<25	<25	-
	TT	µg/L	14	<25	<25	<25	-
Mn (total)	IN	µg/L	57	<0.1	2.9	1.4	0.4
	AC	µg/L	52[(g)]	5.1	23.7	10.1	3.6
	TA	µg/L	43	<0.1	1.7	0.2	0.3
	TB	µg/L	43	<0.1	1.9	0.3	0.4
	TC	µg/L	43	<0.1	1.5	0.2	0.3
	TT	µg/L	14	<0.1	1.6	0.3	0.4
Mn (soluble)	IN	µg/L	14	1.3	3.0	1.7	0.5
	AC	µg/L	14	<0.1	1.0	0.3	0.4
	TT	µg/L	14	<0.1	1.6	0.3	0.5

(a) Five outliers (i.e., 12.2 µg/L on 11/29/06, 210 and 174 µg/L on 03/21/07, 142 µg/L on 04/18/07, and 104 µg/L on 08/08/07) omitted.
(b) One outlier (i.e., 8.6 µg/L on 01/31/07) omitted.
(c) One outlier (i.e., 10.1 µg/L on 01/31/07) omitted.
(d) One outlier (i.e., 0.9 µg/L on 01/31/07) omitted.
(e) Five outliers (i.e., 279 µg/L on 11/29/06, 13,646 and 10,937 µg/L on 03/21/07, 8,962 µg/L on 04/18/07, and 6,632 µg/L on 08/08/07) omitted.
(f) One outlier (i.e., 177 µg/L on 12/6/06) omitted.
(g) Five outliers (i.e., 1.6 µg/L on 11/29/06, 59.2 and 48.8 µg/L on 03/21/07, 37.7 µg/L on 04/18/07, and 35.2 µg/L on 08/08/07) omitted.

Table 4-8. Summary of Other Water Quality Parameter Results

Parameter	Sampling Location	Unit	Number of Samples	Minimum Concentration	Maximum Concentration	Average Concentration	Standard Deviation
Alkalinity (as $CaCO_3$)	IN	mg/L	57	276	349	321	11.8
	AC	mg/L	57	283	339	315	11.7
	TA	mg/L	43	280	341	313	10.8
	TB	mg/L	43	274	339	312	12.7
	TC	mg/L	43	270	331	311	11.7
	TT	mg/L	14	300	327	316	8.2
Fluoride	IN	mg/L	14	1.0	2.0	1.4	0.3
	AC	mg/L	14	1.0	1.8	1.4	0.2
	TT	mg/L	14	1.0	2.8	1.6	0.5
Sulfate	IN	mg/L	14	9.0	21.0	10.8	3.0
	AC	mg/L	14	8.8	18.0	10.4	2.3
	TT	mg/L	14	8.8	18.0	10.3	2.3
Nitrate (as N)	IN	mg/L	14	<0.05	<0.05	<0.05	-
	AC	mg/L	14	<0.05	<0.05	<0.05	-
	TT	mg/L	14	<0.05	<0.05	<0.05	-
Silica (as SiO_2)	IN	mg/L	57	8.5	11.6	9.5	0.6
	AC	mg/L	57	8.6	13.7	9.7	0.9
	TA	mg/L	43	8.4	11.1	9.2	0.6
	TB	mg/L	43	8.3	11.3	9.1	0.6
	TC	mg/L	43	8.3	11.2	9.1	0.6
	TT	mg/L	14	8.5	10.3	9.2	0.5
Phosphorous (as P)	IN	µg/L	57	23.3	110	44.7	13.4
	AC	µg/L	57	21.7	298	57.3	48.2
	TA	µg/L	43	<10	47.9	11.5	9.7
	TB	µg/L	43	<10	48.1	11.2	9.5
	TC	µg/L	43	<10	49.3	10.8	8.9
	TT	µg/L	14	<10	79.0	16.6	19.7
Turbidity	IN	NTU	57	0.2	4.8	1.2	1.1
	AC	NTU	57	0.9	20.0	3.1	3.5
	TA	NTU	43	0.2	5.1	1.3	1.2
	TB	NTU	43	0.2	4.5	1.1	1.0
	TC	NTU	43	0.3	3.6	1.1	0.9
	TT	NTU	14	0.3	3.3	1.0	0.8
pH	IN	S.U.	39[a]	7.8	8.9	8.3	0.2
	AC	S.U.	39[b]	7.7	8.9	8.3	0.2
	TA	S.U.	29[c]	7.7	8.9	8.3	0.3
	TB	S.U.	29[d]	7.7	9.0	8.3	0.3
	TC	S.U.	29[e]	7.7	9.0	8.3	0.3
	TT	S.U.	10[f]	7.9	8.5	8.3	0.2
Temperature	IN	°C	41	14.7	20.8	19.2	1.1
	AC	°C	41	14.7	20.2	18.8	0.8
	TA	°C	30	14.7	21.0	18.9	1.0
	TB	°C	30	14.8	20.3	18.8	0.9
	TC	°C	30	14.8	19.9	18.7	1.2
	TT	°C	11	18.1	19.3	18.8	0.4

Table 4-8. Summary of Other Water Quality Parameter Results

Parameter	Sampling Location	Unit	Number of Samples	Minimum Concentration	Maximum Concentration	Average Concentration	Standard Deviation
DO	IN	Mg/L	41	0.5	1.4	1.0	0.2
	AC	Mg/L	41	0.4	1.7	1.1	0.3
	TA	Mg/L	30	0.6	2.6	1.2	0.4
	TB	Mg/L	30	0.6	1.9	1.0	0.3
	TC	Mg/L	30	0.5	1.7	1.0	0.3
	TT	Mg/L	11	0.6	1.1	0.9	0.2
ORP	IN	mV	41	216	444	320	72.7
	AC	mV	41	251	630	456	97.3
	TA	mV	30	277	651	500	101
	TB	mV	30	287	652	536	96.1
	TC	mV	30	486	673	580	47.1
	TT	mV	11	335	572	490	71.5
Free Chlorine (as Cl_2)	AC	Mg/L	41	0.2	1.7	0.8	0.3
	TA	Mg/L	30	0.2	1.3	0.7	0.3
	TB	Mg/L	30	0.2	1.4	0.74	0.2
	TC	Mg/L	30	0.2	1.4	0.77	0.3
	TT	Mg/L	11	0.4	1.2	0.83	0.2
Total Chlorine (as Cl_2)	AC	Mg/L	41	0.3	1.8	0.83	0.3
	TA	Mg/L	30	0.3	1.4	0.76	0.3
	TB	Mg/L	30	0.3	1.4	0.76	0.2
	TC	Mg/L	30	0.3	1.4	0.81	0.2
	TT	Mg/L	11	0.5	1.3	0.86	0.2
Total Hardness (as $CaCO_3$)	IN	Mg/L	14	35.4	41.3	39.3	1.8
	AC	Mg/L	14	34.6	42.6	39.1	1.9
	TT	Mg/L	14	36.1	40.6	38.6	1.3
Ca Hardness (as $CaCO_3$)	IN	Mg/L	14	13.9	19.4	16.8	1.7
	AC	Mg/L	14	14.1	20.2	17.0	1.5
	TT	Mg/L	14	14.1	19.8	16.8	1.4
Mg Hardness (as $CaCO_3$)	IN	Mg/L	14	20.0	25.2	22.4	1.3
	AC	Mg/L	14	18.6	24.9	22.1	1.7
	TT	Mg/L	14	19.7	23.9	21.8	1.3

(a) Two outliers (i.e., 9.3 on 06/13/07 and 9.8 on 06/20/07) omitted.
(b) Two outliers (i.e., 9.3 on 06/13/07 and 10.0 on 06/20/07) omitted.
(c) One outlier (i.e., 9.3 on 06/13/07) omitted.
(d) One outlier (i.e., 9.4 on 06/13/07) omitted.
(e) One outlier (i.e., 9.3 on 06/13/07) omitted.
(f) One outlier (i.e., 10.0 on 06/20/07) omitted.

only 0.7 µg/L (on average) existed as As(III) (except for one data point at 8.6 µg/L on January 31, 2007), indicating effective oxidation of As(III) by chlorine. The reason for the exceptionally high As(III) concentration on January 31, 2007, was unclear. Free and total chlorine concentrations measured in the system effluent on that day were 0.8 and 0.8 mg/L, respectively, which were consistent with the respective average values shown in Table 4-8. As much as 8.1 µg/L of As(V) was measured following the contact tanks, suggesting the need for further increasing iron doses.

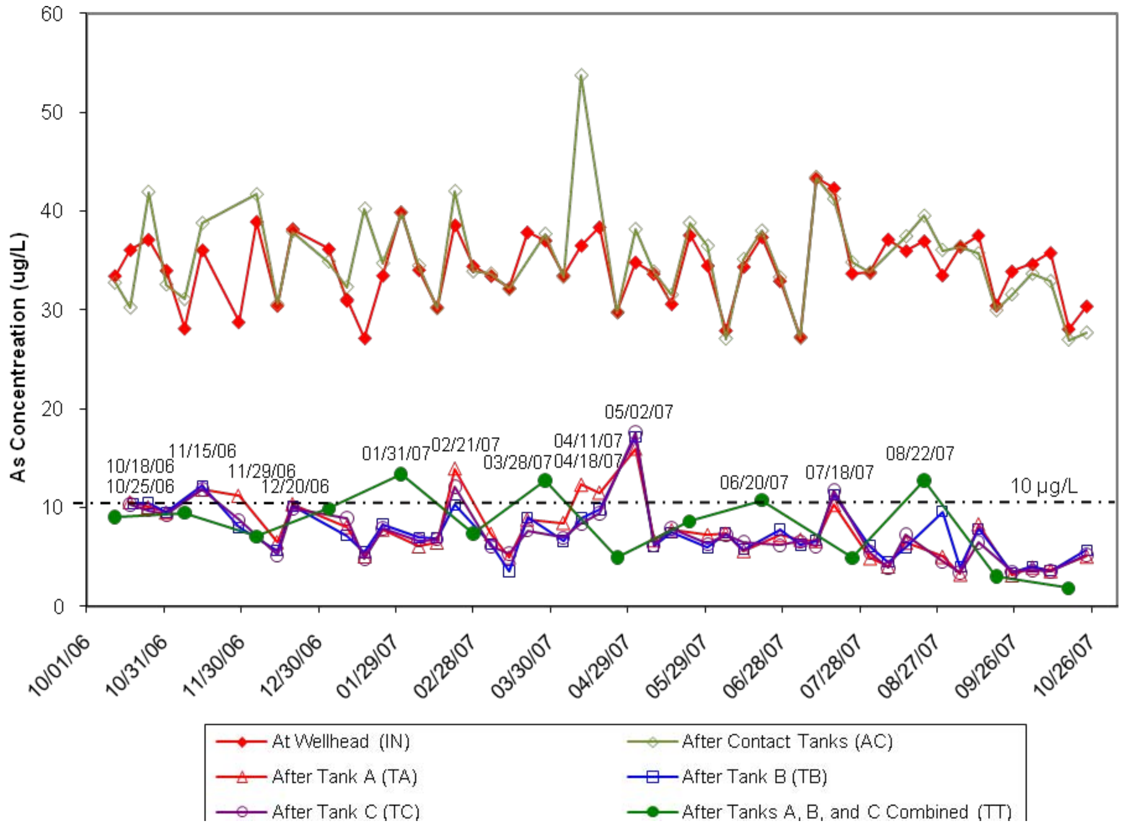


Figure 4-17. Total Arsenic Concentrations Across Treatment Train

Total arsenic concentrations ranged from 3.1 to 17.6 µg/L and averaged 7.4 µg/L after Vessels A, B, and C. Based on the speciation results, arsenic in system effluent existed primarily as As(V) with concentrations ranging from 2.2 to 10.6 µg/L and averaging 6.0 µg/L. Some soluble As(III) (0.6 µg/L [on average]) and particulate arsenic (1.2 µg/L [on average]) also existed in system effluent.

As shown in Figure 4-17, total arsenic concentrations in system effluent exceeded the arsenic MCL for 14 sampling occasions on October 18, October 25, November 15, November 29, and December 20, 2006, and January 31, February 21, March 28, April 11, April 18, May 2, May 9, June 20, July 18, and August 22, 2007. As discussed above, the January 31, 2007, sampling event resulted in an uncharacteristically high As(III) concentration at the AC location, which led to high total arsenic and As(III) concentrations in system effluent. It is known that As(III) cannot be effectively removed via the iron coagulation/filtration process.

Careful examination of arsenic and iron data revealed that elevated arsenic concentrations observed during the remaining 13 sampling events were caused either by insufficient iron addition or by particulate iron/arsenic breakthrough from the pressure filters. Among the 13 events, seven were thought to have been caused by insufficient iron addition. As shown in Table 4-9, while total arsenic concentrations in filter effluent (as measured at TA, TB, TC, and/or TT) were higher than 10 µg/L, corresponding total iron concentrations were below the MDL of 25 µg/L (for all but one sample on October 18, 2006). These results suggest that the high effluent arsenic concentrations were not caused by filter leakage. Speciation results for the three samples collected at TT showed As(V) as the predominant

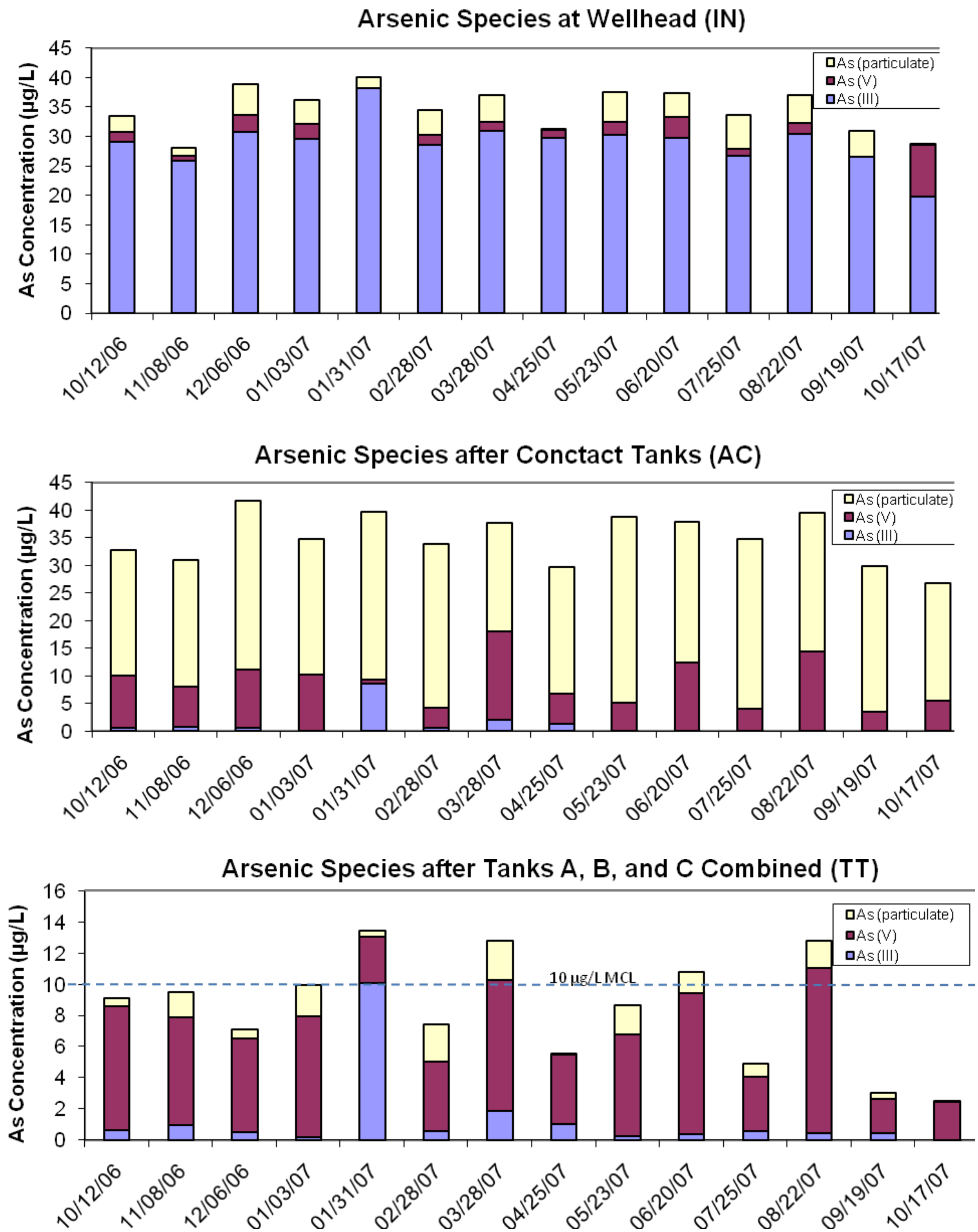


Figure 4-18. Arsenic Speciation Results

Table 4-9. Ineffective Arsenic Removal Due to Inadequate Iron Addition

	TA		TB		TC		TT			AC	
Date	**Total As (µg/L)**	**Total Fe (µg/L)**	**Total As (µg/L)**	**Total Fe (µg/L)**	**Total As (µg/L)**	**Total Fe (µg/L)**	**Total As (µg/L)**	**As(V) (µg/L)**	**Total Fe (µg/L)**	**Total Fe (µg/L)**	**Soluble Fe (µg/L)**
10/18/06	10.6	50.3	10.4	<25	10.3	<25	NM	NM	NM	1,252	NM
11/15/06	11.8	<25	12.2	<25	11.9	<25	NM	NM	NM	1,017	NM
03/28/07	NM	NM	NM	NM	NM	NM	12.8	8.5	<25	788	<25
05/02/07	17.9	<25	19.5	<25	19.3	<25	NM	NM	NM	704	NM
06/20/07	NM	NM	NM	NM	NM	NM	10.8	9.0	<25	1,268	<25
07/18/07	10.3	<25	11.3	<25	11.7	<25	NM	NM	NM	1,528	NM
08/22/07	NM	NM	NM	NM	NM	NM	12.8	10.6	<25	1,111	<25

NM = not measured

species (66 to 83% of the total As), implying that more iron would need to be added for more complete arsenic removal. Total iron concentrations measured following the contact tanks (AC) were all significantly lower than the average concentration at AC (i.e. 1,905 µg/L, Table 4-9), which further supports the need for more iron addition.

Conversely, the six events shown in Table 4-10 seem to suggest particulate arsenic/iron breakthrough being the main reason for the elevated arsenic concentrations observed. These samples were all collected close to the end of a filter run before a backwash was triggered. As shown in Table 4-10, elevated iron concentrations were measured in filter effluent for all samples except one on April 18, 2007, implying particulate arsenic/iron leakage. Arsenic/iron leakage occurred occasionally even after the Δp trigger had been decreased from 25 to 18 psi on January 17, 2007 (in an attempt to reduce run times and, therefore, the likelihood of arsenic/iron particle breakthrough from the filters [Section 4.4.3.1]). Note that increases in arsenic concentrations at the AC location on March 21, April 18, August 8, 2007, due to introduction of backwash solids from the recycle tank did not cause excessive arsenic breakthrough from the pressure filters.

Table 4-10. Ineffective Arsenic Removal Due to Arsenic/Iron Leakage

	TA		TB		TC	
Date	Total As (µg/L)	Total Fe (µg/L)	Total As (µg/L)	Total Fe (µg/L)	Total As (µg/L)	Total Fe (µg/L)
10/25/06	10.1	83.0	10.5	85.1	–[(a)]	57.4
11/29/06	11.2	164.0	–[(a)]	<25	–[(a)]	<25
12/20/06	10.4	124	10.2	92.7	–[(a)]	97.9
02/21/07	13.9	289	10.3	101	12.1	217
04/11/07	12.3	216	–[(a)]	35.9	–[(a)]	36.1
04/18/07	11.5	<25	–[(a)]	<25	–[(a)]	<25

(a) Data not presented since total arsenic concentration did not exceed 10 µg/L MCL.

4.5.1.2 ***Iron.*** Figure 4-19 presents total iron concentration measured across the treatment train. Total iron concentrations in source water ranged from <25 to 62.5 µg/L and averaged 26.1 µg/L, which existed primarily in the soluble form.

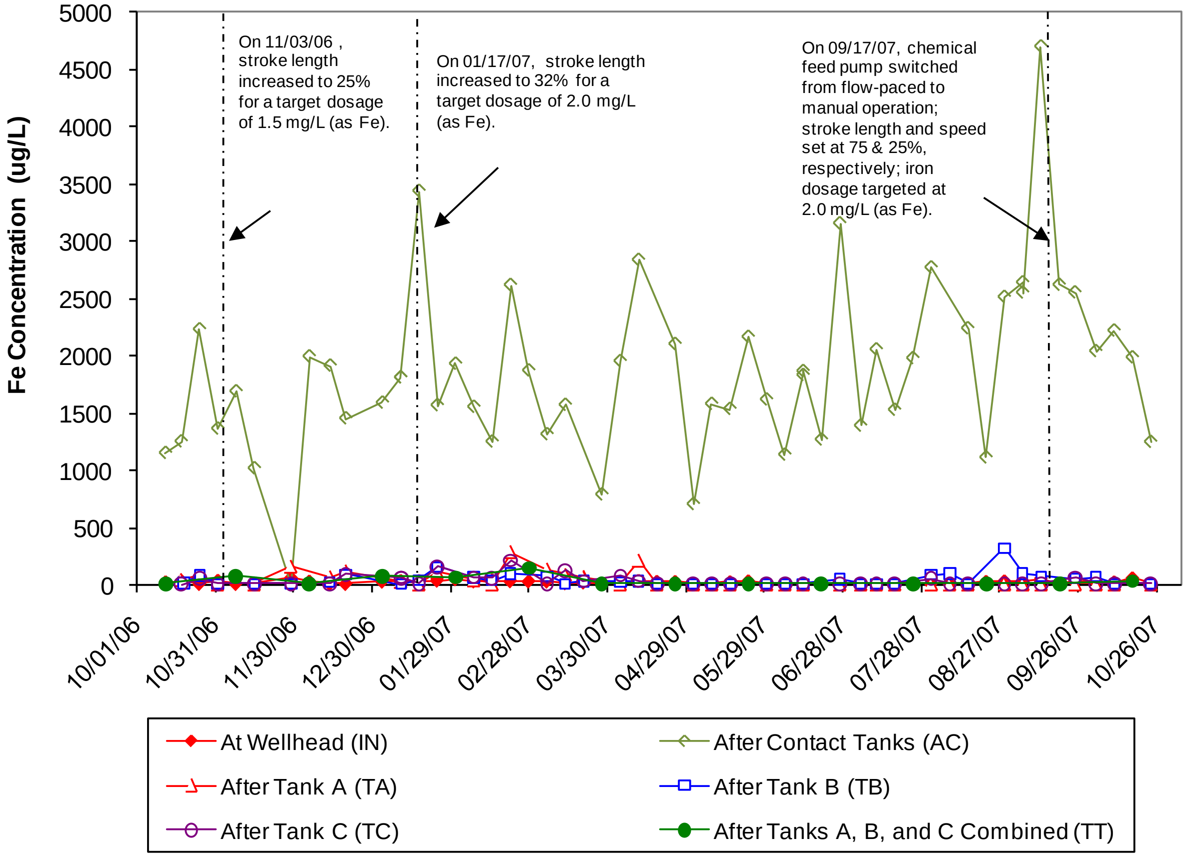


Figure 4-19. Total Iron Concentrations Across Treatment Train

Total iron concentrations after the contact tanks varied significantly, ranging from 704 to 4,699 µg/L and averaging 1,905 µg/L (not including the five outliers noted in footnote e). Variations in iron concentrations were caused primarily by the difficulties encountered operating the flow-paced iron injection pump (Section 4.4.2). As expected, iron after the contact tanks existed solely as particulate iron (except for one data point at 177 µg/L on December 6, 2006).

Total iron concentrations in system effluent ranged from <25 to 327 µg/L, and averaged 43.1 µg/L. Approximately 60% of the samples collected at the system outlet had total iron concentrations below the method reporting limit of 25 µg/L. The remaining 40% of samples had iron concentrations higher than 25 µg/L, with one sample collected on August 29, 2007, containing 327 µg/L. Iron in system effluent existed only in the particulate form, indicating leakage through the pressure filters. The frequency of particulate iron leakage did decrease after January 17, 2007, i.e. from 3 times during the initial 4 months before January 17, 2007 to 3 times during the remaining 10 months afterwards. As described in Section 4.4.3.1, on January 17, 2007, the Δp backwash trigger was reduced to help shorten run times and reduce iron breakthrough from the filters. As described in Section 4.5.1.1, particulate iron leakage often occurred together with particulate arsenic leakage.

4.5.1.3 Manganese. Figure 4-20 presents total manganese concentrations measured during the demonstration study. In source water, manganese concentrations ranged from <0.1 to 2.9 µg/L and averaged 1.4 µg/L, existing primarily in the soluble form. After chlorination, iron addition, and contact tanks, total manganese concentrations increased significantly to an average of 10.1 µg/L, existing

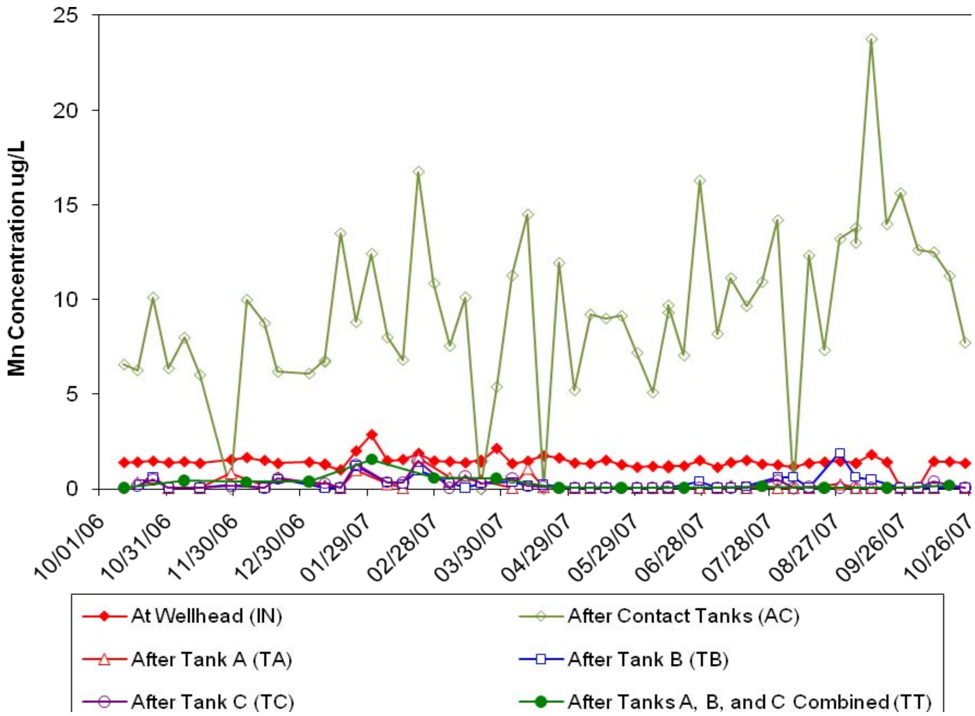


Figure 4-20. Total Manganese Concentrations Across Treatment Train

primarily (over 97%) as particulate manganese. The increase in manganese concentration probably was caused by trace amounts of manganese in the pretreatment chemicals. Particulate manganese apparently was removed by the pressure filters, leaving only trace amounts (0.3 μg/L) in filter effluent.

4.5.1.4 pH, DO, and ORP. pH values in source water ranged from 7.8 to 8.9 and averaged 8.3. This range was consistent with the pH measurements taken by Battelle during source water sampling on October 7, 2004 (i.e., 8.2 in Table 4-1). DO levels of source water were low, ranging from 0.5 to 1.4 mg/L and averaging 1.0 mg/L. DO levels remained low across the treatment train, with average values ranging from 0.9 to 1.2 mg/L. ORP readings of source water were uncharacteristically high, ranging from 216 to 444 mV and averaging 320 mV. These high values most likely were caused by the handheld meter, which tends to drift during measurements. After prechlorination, average ORP readings increased significantly to 456 mV after the contact tanks and to 527 mV after the pressure filters.

4.5.1.5 Chlorine. Figure 4-21 presents total and free chlorine residuals measured throughout the treatment train. As shown in the figure, data were scattered extensively, with total chlorine residuals ranging from 0.3 to 1.8 mg/L (as Cl_2) and free chlorine residuals ranging from 0.2 to 1.7 mg/L (as Cl_2). Assuming that 4.3 mg/L of NaOCl (as Cl_2) had been applied to source water, 0.044 mg/L (as Cl_2) would have reacted with As(III), Fe(II), and Mn(II) based on the respective average concentrations (i.e., 29.1, 21.6, and 1.7 μg/L) in source water (Table 4-7), and 2.45 mg/L would have reacted with 0.32 mg/L of ammonia (as N) to reach breakpoint chlorination. As such, 1.8 mg/L (as Cl_2) would have been present as free chlorine in treated water. These theoretical amounts appear to fall just inside (and outside) the measured ranges for total and free residuals.

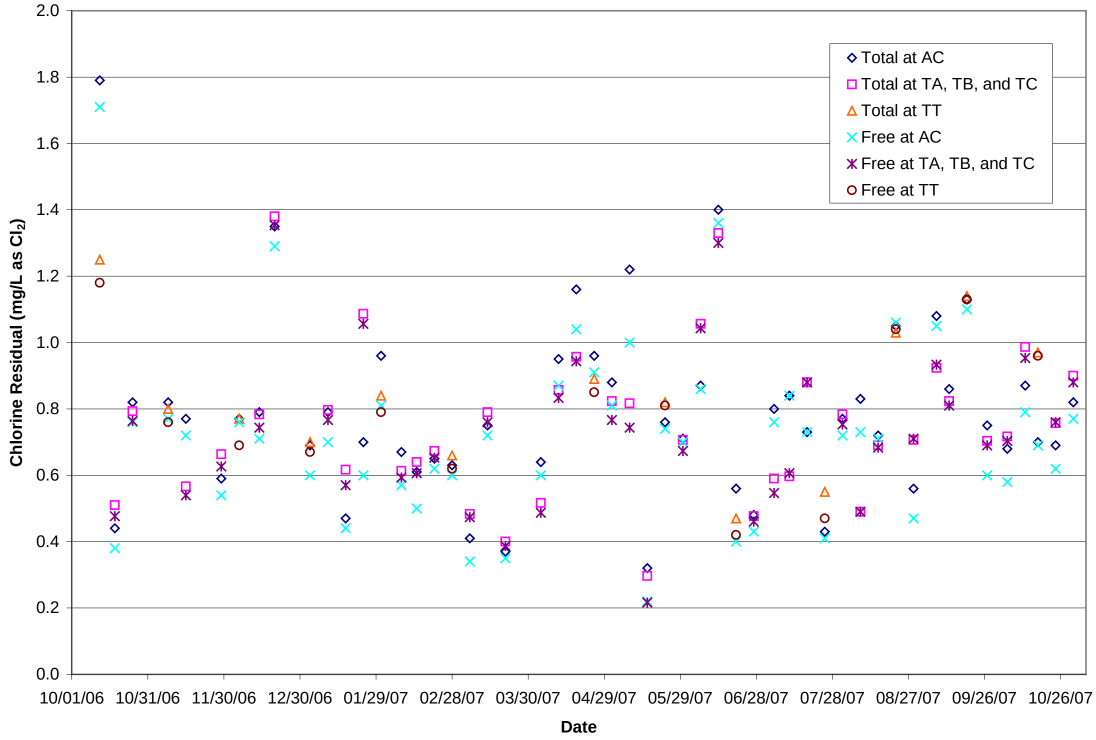


Figure 4-21. Chlorine Residuals Measured Throughout Treatment Train

4.5.1.6 Other Water Quality Parameters. Alkalinity, fluoride, sulfate, nitrate, silica, pH, temperature, and hardness levels remained relatively constant across the treatment train and were not affected by the treatment process (Table 4-8). Phosphorus levels after the contact tanks were slightly higher than those in source water (i.e., 57.3 vs. 44.7 μg/L [on average]), probably due to the presence of trace quantities in the pretreatment chemicals. Phosphorus levels decreased significantly to <17.0 μg/L (on average) after the pressure filters, indicating removal via coagulation/filtration. Turbidity also decreased slightly with treatment (i.e., from 3.1 to <1.3 NTU on average).

4.5.2 Backwash Water and Solids Sampling. Treated water was used for backwash. Table 4-11 presents analytical results from 11 backwash wastewater sampling events starting from November 30, 2006, through October 10, 2007. Results for the November 30, 2006, sampling event are not included in the table because these samples were collected from an incorrect sampling tap.

pH, TDS, and total suspended solids (TSS) values ranged from 7.9 to 8.1 (averaged 8.0), from 324 to 1,040 mg/L (averaged 370 mg/L), and from 125 to 685 mg/L (averaged 336 mg/L), respectively. The average pH value of backwash wastewater (i.e., 8.0) was somewhat lower than that across the treatment train (i.e., 8.3). Concentrations of total arsenic, iron, and manganese ranged from 371 to 2,203 μg/L (averaged 1,229 μg/L), 27.5 to 188 mg/L (averaged 107 mg/L), and 151 to 955 μg/L (averaged 551 μg/L), respectively. Over 99% of these metals were present in the partculate form.

Assuming that 724 gal (Table 4-5) of backwash wastewater would be generated from each vessel during each backwash event and that 336 mg/L of TSS would be produced, approximately 920 g of solids were generated from each filtration vessel during each backwash and were discharged into and accumulated in the recycle tank. Based on the average particulate metal data in Table 4-11, approximately 3.4 g of

Table 4-11. Backwash Wastewater Sampling Results

Sampling Event		BW1 Backwash Tank A										BW2 Backwash Vessel Tank B										BW3 Backwash Tank C									
		pH	TDS	TSS	As (total)	As (soluble)	As (particulate)	Fe (total)	Fe (soluble)	Mn (total)	Mn (soluble)	pH	TDS	TSS	As (total)	As (soluble)	As (particulate)	Fe (total)	Fe (soluble)	Mn (total)	Mn (soluble)	pH	TDS	TSS	As (total)	As (soluble)	As (particulate)	Fe (total)	Fe (soluble)	Mn (total)	Mn (soluble)
No.	Date	S.U.	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	S.U.	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	S.U.	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
1	11/30/2006[(a)]	Samples were collected from the wrong sample taps during the first sample collection on 11/30/06; data was not reported.																													
2	01/03/07	8.0	328	190	800	9.6	790	73,404	<25	364	0.2	8.0	324	430	1,462	15.2	1,447	130,280	78.1	621	0.4	8.0	326	285	1,247	15.6	1,231	124,876	76.8	584	0.3
3	02/07/07	8.1	332	266	1,108	6.7	1,101	90,169	85.3	398	0.5	8.0	338	450	1,518	5.9	1,512	117,655	37.2	545	0.3	8.0	334	515	2,061	6.8	2,054	151,885	69.0	745	0.5
4	03/07/07	8.1	344	410	1,656	7.6	1,648	135,760	<25	592	<0.1	8.1	348	635	2,049	7.7	2,041	165,859	<25	800	<0.1	8.0	354	590	2,203	8.1	2,195	171,373	<25	829	<0.1
5	04/05/07	8.0	344	265	765	5.7	759	62,605	29.0	320	1.4	8.0	336	685	1,679	5.7	1,674	135,388	<25	708	0.3	8.0	346	565	1,848	6.2	1,842	148,509	30.6	735	1.1
6	05/09/07	7.9	352	155	769	6.9	762	54,835	<25	316	0.2	7.9	354	215	750	6.4	744	62,365	<25	375	<0.1	7.9	362	240	1,021	6.3	1,015	84,375	<25	500	<0.1
7	06/14/07	7.9	358	335	1,559	6.3	1,553	121,064	<25	616	<0.1	7.9	342	195	627	5.7	621	51,888	<25	274	<0.1	8.0	1,040	255	1,347	6.2	1,341	83,132	<25	439	0.1
8	07/11/07	8.0	356	420	1,997	6.3	1,990	187,504	<25	955	0.2	8.0	352	330	1,309	6.6	1,302	113,355	<25	611	<0.1	8.1	362	320	1,495	6.8	1,488	131,067	<25	706	0.1
9	08/08/07	8.1	354	195	876	7.0	869	64,893	<25	364	<0.1	8.1	324	125	371	7.1	364	27,492	<25	151	<0.1	8.1	334	250	1,434	7.0	1,427	108,815	<25	601	<0.1
10	09/05/07	8.0	360	390	1,039	3.4	1,036	131,939	<25	686	<0.1	8.0	370	420	761	3.9	757	114,914	<25	595	0.1	8.0	360	220	601	5.5	596	64,245	<25	327	<0.1
11	10/10/07	8.0	356	205	716	3.0	713	76,129	<25	392	0.2	8.0	358	190	618	3.3	615	83,641	<25	449	<0.1	8.0	358	345	1,191	2.9	1,188	140,627	<25	929	0.1

(a) November 2006 results omitted since samples collected from an incorrect tap.

arsenic (i.e. 0.4% by weight), 293 g of iron (i.e. 31.8 % by weight), and 1.5 g of manganese (i.e. 0.2 % by weight) were generated from each vessel during each backwash event.

Solids loadings to the recycle tank also were monitored through collection of backwash solids (Section 3.3.5). Table 4-12 presents analytical results of the solid samples collected in May and October 2007. Arsenic, iron, and manganese levels in the solids averaged 3.4 mg/g (or 0.34% by weight), 324 mg/g (or 32.4% by weight), and 2.0 mg/g (or 0.2 % by weight), respectively. These amounts matched very well with those derived from the backwash wastewater metal analysis (i.e. 0.4%, 31.8%, and 0.2%, respectively).

Table 4-12. Backwash Solids Sampling Results

Date: Location	Mg	Si	P	Ca	Fe	Mn	As	Ba
	mg/g	µg/g	mg/g	mg/g	mg/g	mg/g	mg/g	µg/g
05/09/07: Vessel A	4.8	681	5.1	19.8	245	1.7	3.2	45.9
05/09/07: Vessel B	5.4	558	4.5	24.1	311	2.0	3.6	43.5
05/09/07: Vessel C	4.5	372	6.4	23.3	344	2.1	4.5	37.7
10/10/07: Vessel A	4.5	126	6.2	17.4	343	2.0	3.2	24.6
10/10/07: Vessel B	4.2	244	5.3	14.1	303	1.9	2.8	31.6
10/10/07: Vessel C	3.9	393	6.0	15.2	400	2.3	3.3	20.6

4.5.3 Distribution System Water Sampling. Table 4-13 summarizes results of the distribution system sampling. The stagnation times for the samples ranged from 6.0 to 18.0 hr and averaged 9.5 hr, which is 58% longer than the 6-hr minimum stagnation time required by LCR.

There was no change in pH values before and after system startup. pH values before startup ranged from 7.6 to 8.3 and averaged 8.0; pH values after system startup ranged from 7.7 to 8.1 and averaged 8.0. Alkalinity levels stayed essentially unchanged, with concentrations ranging from 304 to 326 mg/L (as $CaCO_3$) before startup and from 301 to 332 mg/L (as $CaCO_3$) after startup.

Arsenic concentrations in the baseline samples were similar among the three LCR locations, ranging from 24.8 to 47.0 µg/L and averaging 34.4 µg/L. These concentrations were consistent with those in source water (i.e., 27.2 to 43.3 µg/L and averaged 34.4 µg/L) as shown in Table 4-7. After system startup, arsenic concentrations decreased significantly to an average of 8.5 µg/L. Arsenic levels in the distribution system were slightly higher than those in treatment system effluent (i.e., 8.3 µg/L [on average] in Table 4-7), indicating some resuspension and redissolution of arsenic in the distribution system. Figure 4-22 illustrates the effect of the treatment system on As, Fe, and Mn concentrations in the distribution system.

Iron concentrations in the baseline samples were low, ranging from <25 to 47.0 µg/L and averaging 26.9 µg/L. These concentrations were consistent with those in source water (i.e., ranging from <25 to 62.5 µg/L and averaging 26.1 µg/L in Table 4-7). After system startup, the average iron concentration increased slightly to 38.1 µg/L, which was consistent with the average iron concentration of 43.7 µg/L in system effluent (Table 4-7). The slight increase in iron levels was likely due to instances of iron breakthrough from the pressure filters. For the most part, iron concentrations in the distribution system mirrored those in treatment system effluent (Figure 4-22).

Total manganese concentrations in the distribution system averaged 1.7 and 0.5 µg/L before and after system startup. Total manganese levels in the distribution system were consistent with those measured in system effluent (i.e., 0.3 µg/L [on average] at TT location).

Table 4-13. Distribution System Sampling Results

Sampling Event		DS1								DS2								DS3							
		24 E. Sewell St.								Community Center, Walnut St								Mobil, Rt 3							
		LCR								LCR								LCR							
		1st draw								1st draw								1st draw							
		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	04/13/05	7.5	8.3	326	33.0	28.3	1.4	1.5	55.1	10.0	8.3	321	39.7	<25	2.2	3.4	35.3	8.0	8.3	326	47.0	47.0	2.2	1.4	152
BL2	05/11/05	6.0	7.8	317	31.4	<25	1.0	1.3	61.7	6.0	7.8	317	29.6	<25	2.0	2.3	37.7	6.0	7.9	317	32.0	<25	1.3	1.8	138
BL3	06/15/05	18.0	8.2	312	33.3	29.4	1.2	1.5	77.9	18.0	8.1	312	45.9	33.0	3.2	7.7	44.7	8.0	8.2	312	33.3	<25	1.1	1.2	162
BL4	07/13/05	7.5	7.9	304	31.5	38.1	1.4	1.8	78.4	8.3	7.6	308	24.8	<25	2.6	3.6	33.9	8.0	8.0	304	31.1	26.1	1.2	1.5	151
1	11/08/06	9.0	7.8	330	11.7	<25	0.3	1.7	66.9	10.8	7.8	326	9.6	<25	0.8	2.0	28.3	8.0	7.8	332	10.2	<25	0.2	<1	77.7
2	12/20/07	8.0	7.7	316	9.5	26.3	0.3	1.1	30.6	11.3	7.8	320	7.2	<25	0.8	2.1	23.4	8.8	7.8	320	6.6	<25	0.3	0.5	49.9
3	01/17/07	10.0	7.9	310	7.5	68.8	<0.1	2.3	73.4	13.0	8.0	317	6.5	51.6	0.3	3.9	26.1	8.0	8.0	301	7.1	82.1	0.1	0.9	77.9
4	02/14/07	7.4	8.0	325	7.9	75.5	2.1	2.1	75.0	10.3	8.0	320	7.3	55.6	2.5	1.2	14.8	7.9	8.0	318	8.0	100	2.5	0.6	73.2
5	03/14/07	7.6	8.0	323	8.7	131	0.7	3.0	74.0	11.5	8.0	323	8.2	110	1.3	2.4	29.3	8.0	8.0	323	7.2	<25	0.2	0.3	41.3
6	04/11/07	9.0	8.0	324	10.1	76.5	0.4	2.3	60.3	12.0	8.0	324	8.8	<25	0.6	0.9	21.2	8.0	8.1	320	8.3	45.4	0.4	0.3	37.6
7	05/09/07	8.0	8.0	305	11.0	160	1.5	2.5	46.2	12.0	8.0	307	7.5	<25	0.5	0.9	16.3	8.0	7.9	305	6.1	<25	<0.1	0.3	84.0
8	06/14/07	7.9	8.0	301	9.9	<25	<0.1	1.5	28.3	10.5	8.1	310	8.6	<25	0.3	1.6	10.0	8.0	8.0	318	8.0	<25	<0.1	0.5	47.0
9	07/19/07	8.0	8.1	305	12.1	<25	0.1	0.8	12.3	10.8	8.1	312	9.4	<25	0.3	0.8	4.5	8.0	8.1	312	11.5	<25	<0.1	0.3	38.1
10	08/15/07	8.0	8.0	332	8.0	<25	0.3	2.8	34.7	17.8	8.0	330	6.9	<25	0.3	3.4	13.2	11.3	8.0	320	6.2	<25	<0.1	1.2	87.4
11	09/12/07	6.3	8.1	322	10.4	<25	<0.1	2.4	56.3	11.5	8.1	312	7.5	<25	<0.1	2.2	15.6	8.3	8.1	314	7.2	<25	<0.1	1.1	76.3

BL = baseline sampling; NA = data not available
Lead action level = 15 µg/L; copper action level = 1.3 mg/L
Alkalinity measured in mg/L as $CaCO_3$.

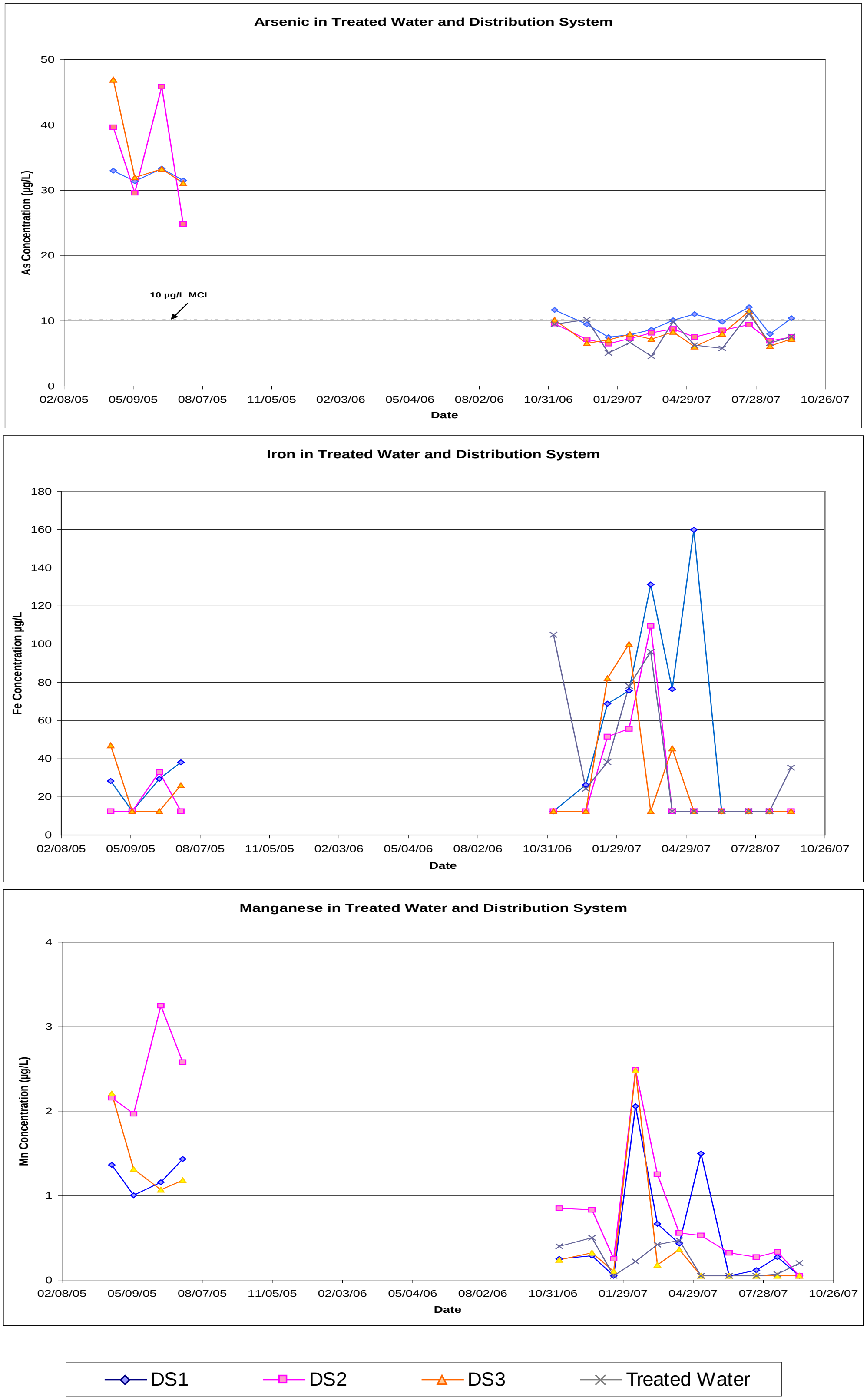


Figure 4-22. Effects of Treatment System on Arsenic, Iron, and Manganese in Distribution System

Lead and copper concentrations within the distribution system decreased slightly from baseline levels. Baseline lead concentrations ranged from 1.2 to 7.7 μg/L and averaged 2.4 μg/L; baseline copper concentrations ranged from 33.9 to 162 μg/L and averaged 85.6 μg/L. After system startup, lead levels decreased slightly to 1.6 μg/L (on average) with no samples exceeding the action level of 15 μg/L. Copper concentrations decreased to 44.0 μg/L with no samples exceeding the 1,300 μg/L action level.

4.6 System Cost

The system cost was evaluated based on the capital cost per gpm (or gpd) of design capacity and the O&M cost per 1,000 gal of water treated. Capital cost of the C/F system included cost for equipment, site engineering, and system installation, shakedown, and startup. O&M cost included cost for chemicals, electricity, and labor. Cost associated with the building, including the recycle system, sanitary sewer connections, and water system telemetry, was not included in the capital cost because it was not included in the scope of this demonstration project and was funded separately by the Town of Felton.

4.6.1 Capital Cost. The capital investment for the Macrolite® Arsenic Removal System was $334,297 (Table 4-14). The equipment cost was $201,292 (or 60% of the total capital investment), which included cost for an iron addition system, two contact tanks, three pressure vessels, 75 ft^3 of Macrolite®, instrumentation and controls, miscellaneous materials and supplies, labor, and system warranty. The system warranty cost covered the cost for repair and replacement of defective system components and installation workmanship for 12 months after system startup.

Table 4-14. Capital Investment for Kinetico's C/F System

Description	Quantity	Cost	% of Capital Investment Cost
Equipment			
Welded stainless steel frame	1	$12,500	–
Fiberglass pressure vessel	3	$24,426	–
Fiberglass contact tank	2	$16,284	–
Wedge wire distributors	3	$9,909	–
Macrolite® media (75 ft^3)	1	$18,750	–
Process valves and piping	1	$26,278	–
Air scour system	1	$6,300	–
Chemical feed equipment	1	$6,402	–
Instrumentation and controls	1	$18,723	–
Turbidimeter	1	$6,612	–
Additional sample taps/totalizer/meters	–	$1,700	–
Shipping	1	$2,600	–
Labor	1	$50,808	–
Equipment Total	**–**	**$201,292**	**60%**
Engineering			
Labor	1	$44,520	–
Engineering Total	**–**	**$44,520**	**13%**
Installation, Shakedown, and Startup			
Labor	1	$15,400	–
Subcontractor	1	$68,300	–
Travel	1	$4,785	–
Installation, Shakedown, and Startup	**–**	**$88,485**	**27%**
Total Capital Investment	**–**	**334,297**	**100%**

The site engineering cost covered the cost for preparing the required permit application submittal (including a process design report, a general arrangement drawing, P&IDs, electrical diagrams, interconnecting piping layouts, tank fill details, and a schematic of the PLC panel) and obtaining the required permit approval from DHSS. The engineering cost of $44,520 was 13% of the total capital investment. The installation, shakedown, and startup cost covered the labor and materials required to unload, install, and test the system for proper operation. All installation activities were performed by the vendor's subcontractor, and startup and shakedown activities were performed by the vendor with the operator's assistance. The installation, startup, and shakedown cost of $88,485 was 27% of the total capital investment.

The total capital cost of $334,297 was normalized to $891/gpm ($0.62/gpd) of design capacity using the system's rated capacity of 375 gpm (or 540,000 gpd). The total capital cost also was converted to an annualized cost of $31,554 gal/yr using a capital recovery factor (CRF) of 0.09439 based on a 7% interest rate and a 20-yr return period. Assuming that the system operated 24 hr/day, 7 day/week at the design flowrate of 375 gpm to produce 197,100,000 gal/yr, the unit capital cost would be $0.16/1,000 gal. During the 13-month demonstration study, the system produced 43,446,110 gal of water (Table 4-5), corresponding to 38,211,600 gal/year, so the unit capital cost increased to $0.83/1,000 gal.

A 38 ft × 18 ft building with a ceiling height of 14 ft was constructed by the Town of Felton to house the treatment system (Section 4.3.2). In addition to the building, a recycle system was installed and included a 16 ft × 6 ft × 10 ft concrete recycle tank, recycle system controller, booster pumps, and associated piping (Section 4.2). Not included in the capital cost, the total cost of the building, recycle system, and supporting utilities was approximately $240,000.

4.6.2 O&M Cost. O&M costs included chemical use, electricity consumption, and labor for a combined unit cost of $0.30/1,000 gal (Table 4-15). No cost was incurred for repairs because the system was under warranty. Since chlorination already existed prior to the demonstration study, incremental chemical cost for iron addition was $0.05/1,000 gal. Electrical power consumption was calculated based on the difference between the average monthly cost from electric bills before and after building construction and system startup. The difference in cost was approximately $150/month or $0.045/1,000 gal of water treated. The routine, non-demonstration related labor activities consumed approximately 45 min/day (Section 4.4.5.3). Based on this time commitment and a labor rate of $30/hr, the labor cost was $0.21/1,000 gal of water treated.

Table 4-15. O&M Cost for Kinetico's C/F System

Category	Value	Remarks
Volume processed (1,000 gal)	43,446	From 09/14/06 through 11/03/07
Chemical Usage		
37–42% $FeCl_3$ unit cost ($/lb)	$0.99	Supplied in 12 180-lb drums, including cost for drum deposit and freight
$FeCl_3$ consumption (1b/1,000 gal)	0.049	–
Chemical cost ($/1,000 gal)	$0.05	–
Electricity Consumption		
Electricity cost ($/month)	$150.00	Average incremental consumption including building heating and lighting
Electricity cost ($/1,000 gal)	$0.045	–
Labor		
Labor (hr/week)	5.25	45 min/day, 7 day/week
Labor cost ($/1,000 gal)	$0.21	Labor rate = $30/hr
Total O&M cost ($/1,000 gal)	$0.30	Including $FeCl_3$ usage

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APPENDIX A

OPERATIONAL DATA

Table A-1. US EPA Demonstration Project at Felton, DE - Daily Operational Log Sheet

Start-up Date: October 12, 2006

Week No.	Day of Week	Date	Time	Cumulative Hrs in Service TA	Cumulative Hrs in Service TB	Cumulative Hrs in Service TC	Avg Run Time	Hour Meter	Run Time	Chlorine: Chlorine Tank Level	Chlorine: Cl dosage	Totalizer to: Totalizer	Totalizer to: Avg Flow Rate	Pressure Filtration: Influent	Pressure Filtration: Outlet TA	Pressure Filtration: Outlet TB	Pressure Filtration: Outlet TC	Pressure Filtration: Effluent	Flow/Totalizer to: Flow Rate	Flow/Totalizer to: Totalizer	Flow/Totalizer to: Avg Flow Rate	Ferric Chloride: $FeCl_3$ Tank Level	Ferric Chloride: Fe Dosage	Backwash: Tank A	Backwash: Tank B	Backwash: Tank C	Backwash: Total	Since Last BW Run Time Tank A	Since Last BW Run Time Tank B	Since Last BW Run Time Tank C	Since Last BW Standby Time Tank A	Since Last BW Standby Time Tank B	Since Last BW Standby Time Tank C	Actual Run Time Between BW Tank A	Actual Run Time Between BW Tank B	Actual Run Time Between BW Tank C
No.	Week	Date	Time	hr	hr	hr	hr	hr	hr	gal	mg/L	kgal	gpm	psig	psig	psig	psig	psig	gpm	kgal	gpm	gal	mg/L	No.	No.	No.	kgal	hr	hr	hr	hr	hr	hr	hr	hr	hr
1	R	09/14/06	8:00	72.1	79.3	77.7	NA	NA	NA	36	-	24,022.8	NA	81	72	71	71	56	293	921.8	NA	40	NA	5	5	5	10.1	0.0	0.1	0.0	NA	NA	NA	-	-	-
	F	09/15/06	8:00	77.1	79.3	77.7	1.7	NA	1.7	32	-	24,105.1	NA	82	71	70	70	62	270	1,002.6	NA	35	1.8	5	5	5	10.1	5.1	5.1	5.1	33.4	37.0	38.8	-	-	-
	Sa	09/16/06	5:30	84.8	91.4	89.8	10.6	NA	10.6	27	5.3	24,215.2	173	85	69	68	68	60	265	1,106.6	163	29	1.6	5	5	5	10.1	12.2	12.2	12.1	46.5	40.1	46.9	12.2	12.1	12.1
	Su	09/17/06	10:10	87.6	97.1	95.5	4.7	NA	4.7	24	4.0	24,302.9	309	80	74	70	70	60	295	1,193.6	306	23	2.0	6	6	6	12.8	2.8	5.7	5.7	12.2	21.8	21.5	-	-	-
2	M	09/18/06	8:20	95.0	104.4	102.8	7.3	NA	7.3	19	5.1	24,417.5	260	86	71	67	68	60	258	1,302.0	246	16	1.8	6	6	6	12.8	10.2	13.0	13.0	26.5	36.1	35.8	15.2	16.9	17.2
	T	09/19/06	7:45	100.6	109.6	108.0	5.3	NA	5.3	15	5.1	24,509.2	287	63	57	56	57	58	268	1,391.0	278	10	2.0	7	7	7	16.6	0.6	1.3	1.0	6.2	6.2	6.2	-	-	-
	W	09/20/06	7:45	106.9	115.9	114.3	6.3	NA	6.3	12	3.5	24,609.8	266	66	59	58	60	58	270	1,488.9	259	3	2.1	7	7	7	16.6	6.9	7.6	7.2	21.9	23.9	23.9	-	-	-
	Thur	09/21/06	8:20	113.8	122.8	121.2	6.9	NA	6.9	23	4.4	24,715.8	256	68	60	59	55	58	285	1,589.2	242	31	2.0	7	7	7	16.6	13.8	14.5	14.1	41.5	41.5	41.5	17.7	17.7	17.6
	F	09/22/06	9:00	117.7	126.3	124.7	3.6	NA	3.6	21	4.1	24,773.5	265	NA	NA	NA	NA	NA	295	1,644.7	255	27	2.1	8	8	8	18.7	0.0	0.3	0.0	17.1	17.4	17.4	-	-	-
	Sa	09/23/06	16:20	129.5	138.1	136.5	11.8	NA	11.8	12	5.2	24,975.0	285	NA	NA	NA	NA	NA	249	1,825.8	256	15	1.8	8	8	8	18.7	11.8	12.2	11.9	37.5	37.8	37.8	12.6	-	12.7
	Su	09/24/06	20:12	136.7	145.3	143.7	7.2	NA	7.2	25	4.6	25,076.3	234	NA	NA	NA	NA	NA	0.0	1,937.5	259	7	2.4	9	9	9	21.2	6.4	6.4	6.4	9.3	9.9	9.6	-	-	-
3	M	09/25/06	7:15	136.7	145.3	143.7	0.0	NA	0.0	25	NA	25,076.3	NA	NA	NA	NA	NA	NA	0.0	1,937.5	NA	7	NA	9	9	9	21.2	6.4	6.4	6.4	19.1	19.7	19.4	-	-	-
	T	09/26/06	8:00	142.8	151.4	149.8	6.1	NA	6.1	21	5.0	25,170.7	258	NA	NA	NA	NA	NA	0.0	2,027.4	246	31	1.9	9	9	9	21.2	11.7	12.5	12.5	37.7	38.3	38.0	16.1	24.3	17.0
	W	09/27/06	8:00	147.3	163.7	155.1	7.4	NA	7.4	18	4.1	25,256.5	194	62	NA	56	NA	55	0.0	2,108.9	184	26	1.7	10	10	10	23.0	0.1	0.5	0.8	14.3	14.3	14.3	-	-	-
	R	09/28/06	7:55	153.5	166.0	161.4	4.9	NA	4.9	14	4.7	25,357.3	341	86	72	71	71	62	274	2,207.2	NA	19	2.1	10	10	10	23.0	6.3	6.8	7.1	32.1	32.0	32.0	-	-	-
	F	09/29/06	7:10	160.8	170.2	168.6	6.2	NA	6.2	9	5.2	25,469.0	299	90	70	68	68	61	254	2,312.9	283	12	1.9	10	10	10	23.0	13.6	14.0	14.4	47.9	47.8	47.8	13.7	14.0	-
	Sa	09/30/06	6:30	166.8	176.1	174.5	5.9	NA	5.9	25	NA	25,559.5	254	82	71	69	65	58	278	2,401.5	249	5	2.3	11	11	10	24.1	5.9	5.9	20.6	17.4	17.1	65.3	-	-	-
	Su	10/01/06	7:00	173.7	183.0	181.4	6.9	NA	6.9	19	6.4	25,669.4	265	69	65	65	60	56	0.0	2,500.0	238	34	1.6	11	11	10	24.1	12.9	12.8	27.6	34.4	34.1	82.3	16.5	15.9	
4	M	10/02/06	7:55	182.8	192.0	190.4	9.0	NA	9.0	13	4.8	25,817.0	272	88	73	71	61	60	252	2,639.2	257	24	2.0	12	12	10	25.4	5.5	5.9	37.1	15.0	15.0	97.4	-	-	-
	T	10/03/06	8:10	190.1	199.3	197.7	7.3	NA	7.3	8	5.3	25,927.5	252	86	67	65	73	59	261	2,744.0	239	16	2.2	12	12	11	26.0	12.8	13.1	3.2	31.9	31.9	16.9	16.3	16.3	-
	W	10/04/06	5:15	193.6	202.8	201.2	3.5	NA	3.5	6	4.5	25,979.8	249	82	71	70	65	59	271	2,798.8	261	13	1.7	13	13	11	27.2	0.0	0.3	7.1	17.3	17.2	34.2	-	-	14.1
	R	10/05/06	7:40	200.7	209.8	208.2	7.0	NA	7.0	35	4.2	26,092.1	266	81	70	68	72	56	302	2,906.7	256	5	2.1	13	13	12	27.2	7.1	7.3	0.0	36.2	36.2	4.8	14.0	14.2	-
	F	10/06/06	8:00	207.6	216.7	215.1	6.9	NA	6.9	30	5.5	26,199.1	258	78	73	72	67	55	300	3,009.6	249	35	1.7	14	14	12	28.9	0.0	0.0	6.9	5.2	4.8	22.1	-	-	-
	Sa	10/07/06	12:35	213.7	222.8	221.2	6.1	NA	6.1	25	6.0	26,296.6	266	NA	NA	NA	NA	NA	0.0	3,103.9	257	30	1.5	14	14	12	28.9	6.1	6.1	13.0	27.6	27.3	44.5	13.0	12.9	19.5
	Su	10/08/06	20:00	223.8	232.8	231.2	10.0	NA	10.0	17	5.7	26,462.0	275	81	72	71	71	60	292	3,258.0	256	21	1.6	15	15	13	30.6	3.2	3.2	3.5	0.3	0.0	16.8	-	-	-
5	M	10/09/06	16:25	228.4	237.5	235.9	4.7	NA	4.7	14	4.5	26,540.0	279	81	69	68	68	58	277	3,328.5	252	17	1.5	15	15	13	30.6	7.8	7.8	8.1	16.0	15.7	32.5	-	-	-
	T	10/10/06[(a)]	7:45	234.6	243.6	242.0	6.1	NA	6.1	10	5.3	26,628.1	239	67	NA	NA	NA	NA	0.0	3,416.8	240	14	1.0	15	15	13	30.6	14.0	14.0	14.3	25.1	24.8	41.6	-	-	14.3
	W	10/11/06	8:00	241.0	250.1	248.5	6.5	NA	6.5	6	4.6	26,729.0	260	67	NA	NA	NA	NA	0.0	3,514.1	251	8	1.8	15	15	14	31.2	20.4	20.4	6.5	43.0	42.7	11.1	20.4	20.4	-
	R	10/12/06[(b)]	8:00	244.6	253.7	252.1	3.6	NA	3.6	36	4.3	26,810.0	375	86	NA	NA	NA	NA	0.0	3,571.3	265	32	1.1	16	16	14	32.3	3.6	3.6	10.1	14.7	14.4	31.2	-	-	-
	F	10/13/06	8:45	250.5	259.7	258.1	6.0	NA	6.0	33	4.9	26,882.1	201	83	71	70	69	57	293	3,664.3	260	28	1.7	16	16	14	32.3	9.6	9.7	16.2	33.3	33.1	49.8	10.0	20.5	17.2
	Sa	10/14/06	16:00	261.3	270.5	192.3	10.8	NA	10.8	26	4.5	27,066.0	284	85	70	69	70	59	261	3,835.6	264	18	1.6	17	17	15	34.1	10.4	0.0	9.6	19.9	19.9	19.9	-	-	-
	Su	10/15/06	12:55	262.5	271.7	193.5	1.2	NA	1.2	25	6.2	27,085.0	264	82	70	69	69	57	295	3,854.2	258	16	3.2	17	17	15	34.1	11.6	11.2	10.8	34.5	39.5	39.5	-	-	-
6	M	10/16/06	15:00	269.7	278.9	200.6	7.2	NA	7.2	21	4.4	27,191.4	247	85	68	67	68	55	270	3,957.7	241	11	1.4	17	17	15	34.1	18.8	18.4	17.9	57.8	57.8	57.8	23.7	22.8	23.2
	T	10/17/06	13:50	276.1	285.3	207.2	6.5	NA	6.5	18	3.4	27,293.5	263	78	71	70	71	57	308	4,056.0	253	6	1.5	18	18	16	36.0	1.5	2.0	1.3	16.5	16.5	16.5	-	-	-
	W	10/18/06	10:05	281.9	291.1	212.9	5.8	NA	5.8	14	4.9	27,388.3	274	79	71	70	70	57	289	4,148.0	266	36	1.6	18	18	16	36.0	7.3	7.7	7.0	30.8	30.7	30.7	-	-	-
	R	10/19/06	10:10	286.5	295.8	217.5	4.6	NA	4.6	11	4.8	27,461.5	263	82	71	69	70	56	304	4,217.1	249	33	1.2	18	18	16	36.0	11.9	12.4	11.6	50.1	50.1	50.1	19.1	18.8	18.4
	F	10/20/06	12:05	294.9	304.1	225.8	8.3	NA	8.3	8	3.1	27,573.2	223	78	72	70	71	55	302	4,324.6	215	28	1.3	19	19	17	38.2	1.2	1.9	1.5	17.2	17.2	17.2	-	-	-
	Sa	10/21/06	11:00	299.3	308.5	230.3	4.4	NA	4.4	37	3.7	27,668.5	358	78	70	68	69	54	290	4,415.2	341	23	1.6	19	19	17	38.2	5.7	6.4	6.0	35.4	35.4	35.5	-	-	-
	Su	10/22/06	11:45	306.1	315.3	237.1	6.8	NA	6.8	33	4.5	27,772.7	255	83	71	69	70	57	295	4,516.4	248	18	1.4	19	19	17	38.2	12.5	13.2	12.8	53.2	53.2	53.2	18.9	18.8	18.9
7	M	10/23/06	11:50	312.5	321.6	243.5	6.4	NA	6.4	29	4.6	27,874.6	267	77	72	70	71	56	309	4,614.0	256	12	1.8	20	20	18	40.7	0.0	0.7	0.3	17.3	17.3	17.2	-	-	-
	T	10/24/06	12:00	318.9	328.0	249.9	6.4	NA	6.4	25	4.5	27,978.0	269	78	70	69	69	57	294	4,715.3	264	6	1.7	20	20	18	40.7	6.4	7.1	6.7	34.9	34.9	34.8	-	-	-
	W	10/25/06	9:45	326.2	335.3	257.1	7.3	NA	7.3	21	4.2	28,090.2	257	84	72	69	71	55	296	4,821.4	243	36	1.3	20	20	18	40.7	13.7	14.4	13.9	49.2	49.2	49.1	18.2	18.1	18.0
	R	10/26/06	8:00	330.7	339.7	261.5	4.4	NA	4.4	19	3.2	28,162.4	271	78	72	70	71	57	304	4,890.9	261	32	1.7	21	21	19	43.0	0.0	0.7	0.3	16.2	16.2	16.2	-	-	-
	F	10/27/06	9:15	337.0	346.0	267.8	6.3	NA	6.3	15	4.6	28,263.6	268	80	70	68	68	56	281	4,989.7	261	27	1.5	21	21	19	43.0	6.3	7.0	6.6	35.4	35.4	35.4	-	-	-
	Sa	10/28/06	12:20	344.5	353.5	275.2	7.5	NA	7.5	28	4.2	28,375.8	250	83	70	69	69	55	296	5,098.7	244	21	1.6	21	21	19	43.0	13.8	14.5	14.0	55.8	55.8	55.8	21.3	18.2	18.2
	Su	10/29/06	19:45	358.7	367.7	289.5	14.2	NA	14.2	20	4.1	28,607.4	271	87	71	69	69	59	258	5,319.2	258	10	1.4	22	22	20	45.0	9.8	10.5	10.1	17.5	17.5	17.5	-	-	-

Table A-1. US EPA Demonstration Project at Felton, DE - Daily Operational Log Sheet (Continued)

Start-up Date: October 12, 2006

Week No.	Day of Week	Date	Time	Cumulative Hrs in Service TA (hr)	Cumulative Hrs in Service TB (hr)	Cumulative Hrs in Service TC (hr)	Avg Run Time (hr)	Hour Meter (hr)	Run Time (hr)	Chlorine Tank Level (gal)	Cl dosage (mg/L)	Totalizer to Totalizer (kgal)	Totalizer to Avg Flow Rate (gpm)	Pressure Filtration Influent (psig)	Pressure Filtration Outlet TA (psig)	Pressure Filtration Outlet TB (psig)	Pressure Filtration Outlet TC (psig)	Pressure Filtration Effluent (psig)	Flow/Totalizer to Flow Rate (gpm)	Flow/Totalizer to Totalizer (kgal)	Flow/Totalizer to Avg Flow Rate (gpm)	Ferric Chloride $FeCl_3$ Tank Level (gal)	Ferric Chloride Fe Dosage (mg/L)	Backwash Tank A (No.)	Backwash Tank B (No.)	Backwash Tank C (No.)	Backwash Total (kgal)	Since Last BW Run Time Tank A (hr)	Since Last BW Run Time Tank B (hr)	Since Last BW Run Time Tank C (hr)	Since Last BW Standby Time Tank A (hr)	Since Last BW Standby Time Tank B (hr)	Since Last BW Standby Time Tank C (hr)	Actual Run Time Between BW Tank A (hr)	Actual Run Time Between BW Tank B (hr)	Actual Run Time Between BW Tank C (hr)
8	M	10/30/06	16:20	360.5	369.6	291.3	1.8	NA	1.8	19	3.5	28,641.0	305	85	69	67	68	56	268	5,348.1	263	8	1.8	22	22	20	45.0	11.6	12.3	12.0	26.1	36.1	36.1	17.3	14.5	17.7
	T	10/31/06	14:55	366.2	371.8	297.0	4.5	NA	4.5	16	4.4	28,720.2	291	77	72	71	71	57	312	5,427.1	291	5	1.1	23	23	21	47.1	0.0	0.0	0.0	16.2	16.8	16.5	-	-	-
	W	11/01/06	9:25	370.5	379.0	301.3	5.3	NA	5.3	30	5.1	28,789.4	219	77	70	69	70	57	295	5,495.4	216	36	1.7	23	23	21	47.1	4.2	4.2	4.2	30.4	31.0	30.7	-	-	-
	R	11/02/06	8:40	374.6	383.2	305.4	4.1	NA	4.1	27	5.1	28,858.5	279	83	70	69	70	57	292	5,560.4	262	33	1.3	23	23	21	47.1	8.4	8.4	8.4	49.5	50.1	49.8	-	-	-
	F	11/3/06(c)	10:10	380.9	387.5	311.8	5.7	NA	5.7	25	2.4	28,958.2	293	80	70	68	68	55	290	5,655.6	280	28	1.5	23	23	21	47.1	14.7	14.7	14.8	68.3	68.4	68.6	-	-	-
	Sa	11/04/06	12:00	387.8	396.7	318.7	7.7	NA	7.7	21	4.5	29,062.7	227	85	70	69	70	57	295	5,754.7	215	22	1.7	23	23	21	47.1	21.6	21.6	21.7	87.2	87.8	87.5	24.6	23.9	24.0
	Su	11/05/06	12:30	393.6	402.1	324.5	5.7	NA	5.7	18	3.7	29,158.0	280	80	71	70	70	58	295	5,849.4	278	16	1.9	24	24	22	49.1	2.8	3.1	3.5	18.3	18.3	18.3	-	-	-
9	M	11/06/06	13:30	398.7	407.2	329.7	5.1	NA	5.1	16	2.8	29,241.2	270	81	70	68	68	57	280	5,928.0	255	11	1.8	24	24	22	49.1	7.9	8.2	8.7	37.3	37.3	37.4	-	-	-
	T	11/07/06	16:00	405.1	413.6	336.1	6.4	NA	6.4	12	4.7	29,341.4	261	81	70	68	68	57	282	6,022.8	247	5	1.8	24	24	22	49.1	14.3	14.6	15.1	58.0	58.0	58.1	-	-	-
	W	11/08/06	10:00	409.7	418.1	340.7	4.6	NA	4.6	10	3.3	29,412.0	258	84	70	69	69	56	294	6,089.4	243	35	2.1	24	24	22	49.1	18.9	19.1	19.7	72.4	72.4	72.4	23.1	22.5	23.6
	R	11/09/06	7:30	414.6	422.9	345.6	4.9	NA	4.9	8	3.0	29,491.0	271	76	70	68	69	55	298	6,167.6	268	31	1.5	25	25	23	51.5	0.7	1.4	1.0	14.8	14.8	14.8	-	-	-
	F	11/10/06	12:00	420.5	428.8	351.5	5.9	NA	5.9	38	6.1	29,587.9	274	84	69	67	68	57	266	6,260.8	263	25	1.9	25	25	23	51.5	6.6	7.3	6.9	34.8	34.8	34.8	-	-	-
	Sa	11/11/06	10:30	427.7	436.0	358.7	7.2	NA	7.2	35	3.2	29,699.2	258	85	71	68	71	57	295	6,366.2	244	19	1.6	25	25	23	51.5	13.8	14.5	14.1	52.7	52.7	52.7	18.0	18.0	18.0
	Su	11/12/06	10:30	432.4	440.7	363.4	4.7	NA	4.7	32	4.6	29,776.4	274	78	72	71	71	56	310	6,440.7	264	15	1.6	26	26	24	53.5	0.5	1.2	0.8	18.7	18.7	18.7	-	-	-
10	M	11/13/06	10:30	438.2	446.5	369.2	5.8	NA	5.8	28	5.0	29,870.0	269	81	70	67	68	56	280	6,532.0	262	9	1.9	26	26	24	53.5	6.3	7.0	6.6	36.8	36.8	36.9	-	-	-
	T	11/14/06	13:00	445.0	453.3	376.0	6.8	NA	6.8	25	3.3	29,975.7	259	85	68	67	67	55	267	6,632.8	247	4	1.4	26	26	24	53.5	13.1	13.8	13.4	55.8	55.7	55.8	19.2	19.0	19.2
	W	11/15/06	13:00	451.3	459.4	382.0	6.1	NA	6.1	21	4.7	30,075.4	271	81	72	70	71	58	292	6,728.0	259	34	1.5	27	27	25	56.3	0.2	0.9	0.2	14.9	14.9	15.3	-	-	-
	R	11/16/06	12:30	455.7	463.8	386.4	4.4	NA	4.4	19	3.1	30,150.6	285	84	71	69	70	57	285	6,800.3	274	30	1.6	27	27	25	56.3	4.6	5.3	4.9	33.6	33.6	34.0	-	-	-
	F	11/17/06	9:15	461.4	469.5	392.1	5.7	NA	5.7	16	3.9	30,241.7	266	80	69	68	68	56	287	6,887.1	254	25	1.6	27	27	25	56.3	10.3	11.0	10.3	51.1	51.1	51.5	-	-	-
	Sa	11/18/06	11:35	467.6	475.7	398.3	6.2	NA	6.2	13	3.6	30,338.3	260	88	71	67	69	57	280	6,978.5	246	19	1.9	27	27	25	56.3	16.5	17.2	16.5	70.1	70.2	70.5	22.2	22.0	21.7
	Su	11/19/06	13:30	475.9	483.8	406.6	8.2	NA	8.2	9	3.5	30,472.0	271	81	72	70	71	58	293	7,109.5	265	11	1.8	28	28	26	58.3	2.6	3.3	3.1	18.7	18.7	18.7	-	-	-
11	M	11/20/06	11:00	479.0	487.0	409.7	3.1	NA	3.1	8	2.3	30,522.3	268	80	70	68	68	57	280	7,158.4	260	8	1.8	28	28	26	58.3	5.8	6.5	6.2	36.0	36.0	36.0	-	-	-
	T	11/21/06	11:15	484.8	492.8	415.5	5.8	NA	5.8	5	3.8	30,614.5	265	81	71	69	69	57	305	7,245.4	250	4	1.3	28	28	26	58.3	11.6	12.3	12.0	55.0	54.9	54.9	18.6	18.6	18.7
	W	11/22/06	15:30	491.8	499.4	422.2	6.8	NA	6.8	34	3.3	30,720.6	261	77	72	71	71	56	312	7,346.9	250	39	1.7	29	29	27	60.2	0.0	0.3	0.0	20.9	21.2	21.2	-	-	-
	R	11/23/06	NM	NM	NM	NM	NA	NA	NA	NM	NA	NM	NA	NM	NM	NM	NM	NM	NM	NM	NA	NM	NA	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	-	-	-
	F	11/24/06	17:00	503.8	511.4	434.2	12.0	NA	12.0	27	4.3	30,911.1	265	84	72	70	70	56	301	7,530.0	254	28	1.7	29	29	27	60.2	12.0	12.5	12.0	58.0	58.3	58.3	17.2	17.0	16.9
	Sa	11/25/06	17:00	509.0	516.5	439.4	5.2	NA	5.2	24	4.2	30,994.0	267	77	72	71	71	56	312	7,609.9	258	24	1.4	30	30	28	62.2	0.0	0.6	0.3	18.3	18.3	18.3	-	-	-
	Su	11/26/06	12:00	514.1	521.7	444.6	5.2	NA	5.2	21	4.2	31,078.7	273	79	72	70	70	57	295	7,692.8	268	18	2.1	30	30	28	62.2	5.1	5.8	5.5	32.1	32.0	32.0	-	-	-
12	M	11/27/06	12:50	518.0	525.6	448.5	3.9	NA	3.9	19	3.7	31,142.0	271	85	69	68	68	57	270	7,752.5	255	15	1.4	30	30	28	62.2	9.0	9.7	9.4	49.7	49.6	49.6	-	-	-
	T	11/28/06	14:10	524.8	532.4	455.3	6.8	NA	6.8	16	3.3	31,248.7	262	86	68	68	67	56	266	7,854.4	250	8	2.0	30	30	28	62.2	15.8	16.5	16.2	69.5	69.3	69.3	-	-	-
	W	11/29/06	13:45	531.6	539.3	462.1	6.8	NA	6.8	12	4.5	31,353.0	254	85	71	69	70	56	295	7,953.2	241	3	1.4	30	30	28	62.2	22.6	23.4	23.0	87.9	87.7	87.7	24.0	24.0	24.0
	R	11/30/06	10:25	535.8	543.4	466.3	4.2	NA	4.2	10	3.2	31,425.3	289	86	72	70	71	57	304	8,025.0	287	34	1.7	31	31	29	64.4	2.8	3.5	3.2	16.1	16.1	16.1	4.2	5.5	6.0
	F	12/01/06	8:10	540.6	548.2	471.1	4.8	NA	4.8	7	4.2	31,508.8	290	79	71	70	71	56	306	8,107.7	287	29	1.8	32	32	30	66.2	3.4	2.8	2.0	16.3	16.4	16.3	-	-	-
	Sa	12/02/06	13:50	546.3	553.9	476.8	5.7	NA	5.7	38	2.6	31,600.2	267	87	69	67	68	57	260	8,194.5	254	24	1.6	32	32	30	66.2	9.1	8.5	7.7	37.5	39.4	37.6	16.5	15.4	15.0
	Su	12/03/06	12:00	553.7	560.8	484.1	7.2	NA	7.2	35	3.2	31,711.2	257	78	72	72	72	57	312	8,300.0	244	17	1.9	33	33	31	68.2	0.0	0.0	0.0	16.6	17.2	16.9	-	-	-
13	M	12/04/06	10:40	557.8	564.4	488.1	3.9	NA	3.9	33	3.5	31,777.8	285	77	69	68	69	56	293	8,366.0	282	13	1.8	33	33	31	68.2	4.1	4.1	4.0	35.2	35.9	35.5	-	-	-
	T	12/05/06	14:15	564.7	571.8	495.0	7.1	NA	7.1	29	4.3	31,886.0	255	81	69	68	69	56	285	8,468.8	243	6	1.9	33	33	31	68.2	11.0	11.0	10.9	55.9	56.6	56.2	16.8	15.9	16.4
	W	12/06/06	11:25	570.8	577.7	501.2	6.1	NA	6.1	25	4.8	31,984.4	270	78	73	72	72	57	310	8,562.7	258	37	1.5	34	34	32	71.0	0.3	1.0	0.7	14.6	14.6	14.6	-	-	-
	R	12/07/06	8:00	575.2	582.1	505.7	4.4	NA	4.4	23	3.3	32,056.4	271	79	70	69	69	55	298	8,634.1	268	32	2.1	34	34	32	71.0	4.7	5.4	5.2	30.6	30.6	30.6	-	-	-
	F	12/08/06	10:30	581.2	588.1	511.7	6.0	NA	6.0	19	5.0	32,150.2	261	81	68	67	67	56	284	8,724.1	250	27	1.6	34	34	32	71.0	10.7	11.4	11.2	51	51	51	15.8	15.9	16.1
	Sa	12/09/06	13:30	589.6	596.2	519.8	8.2	NA	8.2	15	3.6	32,282.0	268	82	71	70	70	58	295	8,854.1	264	19	1.8	35	35	33	73.1	3.3	3.6	3.2	18.1	18.3	18.4	-	-	-
	Su	12/10/06	NM	NM	NM	NM	NA	NA	NA	NM	NA	NM	NA	NM	NM	NM	NM	NM	NM	NM	NA	NM	NA	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	-	-	-
14	M	12/11/06	15:15	600.4	607.1	530.6	10.8	NA	10.8	9	4.1	32,454.4	265	82	70	67	75	57	297	9,014.3	246	10	NA	35	35	35	74.3	14.1	14.5	0.1	56.7	56.8	5.9	20.6	19.5	-
	T	12/12/06	14:45	606.9	612.1	537.1	6.0	NA	6.0	6	3.6	32,551.6	270	79	73	73	69	57	306	9,109.5	265	4	1.8	36	36	35	75.5	0.0	0.0	6.5	9.7	10.0	15.9	-	-	11.7
	W	12/13/06	15:00	612.5	612.5	542.3	3.7	NA	3.7	36	4.5	32,629.0	346	79	70	72	73	57	302	9,186.3	343	14	1.5	36	36	36	76.1	5.6	0.4	0.0	35.0	23.8	18.5	-	-	-
	R	12/14/06	14:15	617.3	617.3	546.5	4.6	NA	4.6	34	3.0	32,706.7	282	79	69	69	69	56	285	9,260.9	270	9	1.9	36	36	36	76.1	10.4	5.2	4.2	53.3	42.1	36.8	-	-	-
	F	12/15/06	10:20	621.5	621.5	550.7	4.2	NA	4.2	31	5.2	32,774.0	267	84	69	69	69	56	290	9,324.2	252	5	1.8	36	36	36	76.1	14.6	9.4	8.4	68.7	57.3	52.2	-	-	-
	Sa	12/16/06	11:45	627.5	627.0	556.7	5.8	NA	5.8	29	2.6	32,865.4	261	88	67	67	67	56	258	9,411.8	250	35	1.6	36	36	36	76.1	20.6	14.9	14.4	87.1	75.9	70.6	24.3	18.0	17.7
	Su	12/17/06	11:35	633.4	633.0	562.3	5.8	NA	5.8	26	3.8	32,959.0	267	79	71	70	71	56	309	9,506.4	270	30	1.6	37	37	37	78.0	2.2	2.9	2.3	18.6	18.6	19.0	-	-	-
15	M	12/18/06	14:40	639.5	639.1	568.5	6.1	NA	6.1	23	3.4	33,061.0	277	84	69	67	67	56	275	9,600.3	255	25	1.5	37	37	37	78.0	8.3	9.0	8.4	32.9	32.9	33.3	-	-	-
	T	12/19/06	15:15	646.4	646.0	575.4	6.9	NA	6.9	20	3.3	33,167.2	257	85	71	68	69	56	295	9,705.8	255	18	2.0	37	37	37	78.0	15.2	15.9	15.3	56.9	56.9	57.3	-	-	-
	W	12/20/06	8:55	650.4	649.1	579.1	3.6	NA	3.6	18	3.9	33,226.9	276	87	68	66	67	56	265	9,758.2	243	15	1.5	37	37	37	78.0	19.2	19.0	19.0	69.6	69.6	70.0	24.2	24.3	23.6
	R	12/21/06	8:15	656.1	654.8	584.8	5.7	NA	5.7	14	5.2	33,317.2	264	79	71	71	70	57	300	9,844.5	252	10	1.7	38	38	38	80.0	0.7	0.4	1.1	17.0	17.0	17.0	-	-	-
	F	12/22/06	11:30	661.4	660.6	590.6	5.6	NA	5.6	11	3.7	33,411.1	278	84	69	68	68	57	270	9,936.3	272	4	1.9	38	38	38	80.0	6.5	6.2	6.9	37.4	37.4	37.3	-	-	-
	Sa	12/23/06	15:00	670.7	669.4	599.5	9.0	NA	9.0	40	3.4	33,549.0	255	89	69	67	66	57	258	10,068.5	245	31	1.7	38	38	38	80.0	15.3	15.0	15.8	58.1	58.1	58.0	20.1	19.0	20.2
	Su	12/24/06	10:40	675.5	674.1	604.2	4.7	NA	4.7	36	6.0	33,626.6	273	79	73	72	72	56	310	10,141.2	256	27	1.5	39	39	39	82.4	0.0	0.7	0.3	12.5	12.5	12.5	-	-	-
16	M	12/25/06	8:00	678.3	676.4	607.0	2.6	NA	2.6	34	5.1	33,672.6	291	79	72	70	71	56	307	10,186.8	289	24	2.0	39	39	39	82.4	2.8	3.5	3.1	30.8	30.8	30.9	-	-	-
	T	12/26/06	10:15	684.4	683.0	613.1	6.3	NA	6.3	30	4.8	33,770.4	260	80	70	68	69	56	285	10,280.1	248	18	1.8	39	39	39	82.4	8.9	9.6	9.2	50.8	50.7	50.8	-	-	-
	W	12/27/06	13:10	691.4	687.8	619.3	6.0	NA	6.0	26	4.5	33,873.5	286	85	71	70	69	56	290	10,373.2	258	12	1.7	39	39	39	82.4	15.9	14.4	15.4	70.7	70.6	70.7	19.9	17.6	19.1
	R	12/28/06	10:00	696.3	692.6	624.2	4.9	NA	4.9	22	5.9	33,953.5	274	79	72	71	72	57	310	10,456.2	284	7	1.9	40	40	40	84.8	0.9	1.6	1.2	15.3	15.3	15.3	-	-	-
	F	12/29/06	10:30	701.0	697.2	628.9	4.7	NA	4.7	20	3.1	34,029.1	270	80	69	68	68	56	290	10,530.2	264	3	1.6	40	40	40	84.8	5.6	6.2	5.9	35.6	35.6	35.6	-	-	-
	Sa	12/30/06	17:30	707.3	703.5	635.2	6.3	NA	6.3	17	3.6	34,127.0	259	90	69	67	68	57	255	10,623.7	247	34	1.2	40	40	40	84.8	11.9	12.5	12.2	56.0	56.0	56.0	-	17.7	17.8
	Su	12/31/06	18:45	716.8	712.6	644.3	9.2	NA	9.2	13	3.2	34,275.0	267	84	65	71	72	58	265	10,766.6	258	26	1.6	40	41	41	86.2	21.5	3.9	3.5	75.1	19.2	19.2	22.1	-	-
17	M	01/01/07	17:35	718.8	715.0	646.7	2.3	NA	2.3	12	3.0	34,313.5	283	79	71	67	68	55	284	10,803.9	274	23	2.3	41	41	41	86.9	1.4	6.3	5.9	20.4	39.6	39.6	-	-	-
	T	01/02/07	16:00	725.0	721.2	652.9	6.2	NA	6.2	9	3.6	34,410.1	260	84	73	69	70	57	296	10,895.3	246	18	1.5	41	41	41	86.9	7.6	12.5	12.1	36.5	55.6	55.7	-	-	-
	W	01/03/07	8:50	728.7	725.0	656.7	3.8	NA	3.8	7	4.0	34,468.6	259	83	71	67	68	55	282	10,951.2	248	14	2.0	41	41	41	86.9	11.3	16.3	15.9	49.4	68.5	68.6	14.8	20.7	20.9
	R	01/04/07(d)	8:15	733.9	730.2	661.9	5.2	NA	5.2	4	4.1	34,553.6	272	79	70	70	71	56	300	11,032.7	261	9	1.8	42	42	42	89.0	1.7	0.8	0.2	17.0	17.0	17.0	-	-	-
	F	01/05/07	9:15	740.0	736.3	668.0	6.1	NA	6.1	34	3.6	34,652.5	270	79	69	69	69	55	287	11,129.2	264	3	1.8	42	42	42	89.0	7.8	6.9	6.3	36.6	36.6	36.6	753.8	-	12.6
	Sa	01/06/07(e)	16:20	746.0	742.5	674.3	6.3	NA	6.3	31	3.5	34,753.3	269	84	73	64	72	56	278	11,221.4	246	33	1.5	43	42	43	89.8	0.0	13.1	0.0	20.8	57.3	20.5	-	17.0	-
	Su	01/07/07	11:00	751.6	747.9	680.1	5.6	NA	5.6	28	3.8	34,845.3	274	78	70	71	69	56	292	11,311.6	269	27	2.0	43	43	43	90.4	5.7	1.5	5.8	37.5	16.7	37.2	-	-	-

Table A-1. US EPA Demonstration Project at Felton, DE - Daily Operational Log Sheet (Continued)

Start-up Date: October 12, 2006

Week No.	Day of Week	Date	Time	Cumulative Hrs in Service			Avg Run Time	Hour Meter	Run Time	Chlorine		Totalizer to		Pressure Filtration					Flow/Totalizer to			Ferric Chloride		Backwash				Since Last BW: Run Time			Since Last BW: Standby Time			Actual Run Time Between BW		
				TA	TB	TC				Chlorine Tank Level	Cl dosage	Totalizer	Avg Flow Rate	Influent	Outlet TA	Outlet TB	Outlet TC	Effluent	Flow Rate	Totalizer	Avg Flow Rate	$FeCl_3$ Tank Level	Fe Dosage	Tank A	Tank B	Tank C	Total	Tank A	Tank B	Tank C	Tank A	Tank B	Tank C	Tank A	Tank B	Tank C
				hr	hr	hr	hr	hr	hr	gal	mg/L	kgal	gpm	psig	psig	psig	psig	psig	gpm	kgal	gpm	gal	mg/L	No.	No.	No.	kgal	hr	hr	hr	hr	hr	hr	hr	hr	hr
	M	01/08/07	11:10	756.9	753.1	685.3	5.2	NA	5.2	25	4.2	34,928.3	264	82	71	69	69	55	300	11,389.8	249	23	1.4	43	43	43	90.4	10.9	6.7	11.0	56.2	35.4	55.9	-	-	-
	T	01/09/07	15:00	763.4	759.1	690.7	6.0	NA	6.0	21	4.7	35,027.1	276	86	67	67	67	55	270	11,484.5	265	17	1.8	43	43	43	90.4	17.4	13.3	16.4	70.5	55.7	76.2	18.4	15.2	17.7
	W	01/10/07	11:20	769.4	764.9	696.6	5.9	NA	5.9	18	3.5	35,126.8	282	79	70	70	70	56	295	11,580.3	271	11	1.8	44	44	44	91.7	5.0	3.9	4.6	14.7	14.6	14.4	-	-	-
18	R	01/11/07	10:00	774.5	770.0	698.9	4.2	NA	4.2	15	4.5	35,204.4	310	81	70	70	70	56	282	11,652.6	289	6	1.9	44	44	44	91.7	10.1	9.0	6.9	32.1	32.0	31.7	16.8	15.4	-
	F	01/12/07	13:15	781.2	776.4	705.1	6.4	NA	6.4	12	3.4	35,306.7	265	79	73	67	67	55	305	11,749.4	251	36	1.2	45	45	44	92.7	0.0	0.0	13.7	15.5	15.7	47.4	-	-	-
	Sa	01/13/07	16:30	787.4	782.6	711.9	6.4	NA	6.4	25	3.6	35,404.5	255	80	71	66	66	55	287	11,844.1	247	30	1.8	45	45	44	92.7	6.2	6.2	19.9	41.3	41.6	73.1	-	10.3	23.8
	Su	01/14/07	18:10	794.7	789.6	719.0	7.1	NA	7.1	20	5.1	35,520.0	270	81	65	70	70	56	275	11,956.7	263	24	1.6	45	46	45	93.6	13.5	2.9	3.2	59.9	18.6	18.6	-	-	-
	M	01/15/07	16:50	799.8	791.6	724.0	4.0	NA	4.0	17	4.5	35,598.6	325	81	69	69	69	55	285	12,030.4	305	20	1.5	45	46	45	93.6	18.6	7.9	8.2	77	35.7	35.7	19.8	12.4	10.0
	T	01/16/07	15:00	805.0	799.8	729.2	6.2	NA	6.2	14	4.0	35,685.6	234	81	70	69	69	57	273	12,114.6	226	14	2.1	46	47	46	95.0	4.0	3.7	3.4	15.5	15.6	15.6	8.5	7.6	7.6
	W	01/17/07[f]	9:45	809.5	804.3	733.7	4.5	NA	4.5	12	3.1	35,761.3	280	79	72	70	71	57	306	12,186.0	264	8	2.4	47	48	47	96.3	0.0	0.6	0.3	14.8	14.8	14.8	-	-	-
19	R	01/18/07	9:00	813.3	808.1	737.5	3.8	NA	3.8	10	3.7	35,824.7	278	82	70	66	68	57	273	12,247.8	271	3	2.4	47	48	47	96.3	3.8	4.4	4.1	33.2	33.2	33.2	7.7	7.6	7.7
	F	01/19/07	9:30	818.6	813.3	742.8	5.3	NA	5.3	8	2.6	35,914.4	284	79	71	67	69	56	280	12,335.1	276	30	2.0	48	49	48	97.6	1.4	2.0	1.7	18.6	18.6	18.6	-	7.1	7.1
	Sa	01/20/07	9:40	824.4	818.7	748.2	5.5	NA	5.5	38	3.8	36,006.3	277	79	70	72	72	57	306	12,422.5	263	24	2.0	48	50	49	98.5	7.2	0.3	0.0	37.9	19.4	19.3	-	-	-
	Su	01/21/07	10:00	830.6	824.9	754.5	6.2	NA	6.2	35	3.5	36,106.6	268	80	69	69	70	56	290	12,518.9	258	16	2.4	48	50	49	98.5	13.4	6.5	6.3	56.2	37.7	37.6	19.6	9.4	9.5
	M	01/22/07	9:30	838.4	829.1	758.7	5.4	NA	5.4	33	3.1	36,181.5	231	79	71	70	71	56	305	12,587.9	213	10	2.4	49	51	50	99.8	1.6	1.3	1.0	17.4	17.5	17.4	-	-	-
	T	01/23/07	9:30	840.2	834.5	764.1	4.2	NA	4.2	29	5.5	36,266.3	337	79	69	68	68	55	291	12,672.3	336	3	2.5	49	51	50	99.8	7.0	6.7	6.4	36.6	36.8	36.7	10.2	9.3	9.3
	W	01/24/07	9:40	846.8	841.1	770.8	6.6	NA	6.6	26	3.1	36,378.2	281	81	71	67	68	56	276	12,780.4	272	31	2.1	50	52	51	101.1	3.4	4.0	3.8	16.6	16.6	16.6	-	7.1	7.2
20	R	01/25/07	9:40	851.9	845.9	775.6	4.9	NA	4.9	23	4.3	36,459.8	278	81	66	69	70	56	278	12,859.0	267	25	2.2	50	53	52	102.0	8.5	1.7	1.4	35.1	18.5	18.5	11.5	5.1	-
	F	01/26/07	9:40	857.7	851.8	781.8	6.0	NA	6.0	20	3.6	36,558.4	275	81	71	69	65	56	276	12,954.0	265	18	2.1	51	54	52	102.9	2.8	2.5	7.6	19.0	19.0	37.6	7.9	7.2	9.1
	Sa	01/27/07	14:15	863.5	857.5	787.5	5.7	NA	5.7	34	3.6	36,655.2	281	84	72	69	66	56	270	13,047.1	271	32	2.2	52	55	53	104.2	0.7	1.0	4.2	18.8	18.8	18.8	-	4.7	7.6
	Su	01/28/07	14:00	872.4	866.1	796.0	8.7	NA	8.7	31	3.6	36,752.8	188	83	67	69	69	56	276	13,095.4	NA	26	1.8	52	56	54	105.1	9.6	4.9	5.1	39.2	20.4	20.4	10.8	6.4	7.0
	M	01/29/07	12:10	876.7	870.4	800.4	4.3	NA	4.3	27	4.0	36,870.5	453	78	70	70	70	56	290	13,256.2	NA	17	2.3	53	57	55	106.5	3.1	2.8	2.5	15	15	15	8.3	7.5	7.4
	T	01/30/07	11:35	882.0	875.4	805.4	5.1	NA	5.1	24	4.1	36,955.6	278	78	72	71	71	55	303	13,335.5	259	10	2.5	54	58	56	107.8	0.1	0.3	0.1	17.6	17.9	17.9	-	-	-
	W	01/31/07	10:40	887.4	880.8	810.6	5.3	NA	5.3	21	4.0	37,042.7	272	78	70	68	68	55	291	13,420.5	266	4	2.1	54	58	56	107.8	5.4	5.7	5.3	35.3	35.6	35.6	8.5	8.2	8.1
21	R	02/01/07	9:40	892.7	886.0	815.8	5.2	NA	5.2	18	3.9	37,132.4	286	79	71	69	70	56	305	13,507.2	276	34	2.0	55	59	57	109.0	2.2	2.7	2.4	17.2	17.2	17.1	6.8	6.7	6.8
	F	02/02/07	9:45	898.1	891.4	821.3	5.4	NA	5.4	15	3.8	37,224.9	284	79	72	70	71	56	308	13,595.9	272	27	2.3	56	60	58	110.3	0.8	1.4	1.1	18.3	18.3	18.3	5.9	6.2	6.2
	Sa	02/03/07	11:00	903.3	896.6	826.5	5.2	NA	5.2	13	2.6	37,314.6	287	81	71	70	70	55	292	13,679.2	267	21	2.0	57	61	59	111.5	0.1	0.4	0.1	18.3	18.3	18.3	-	7.2	7.1
	Su	02/04/07	14:30	912.0	905.0	835.1	8.6	NA	8.6	9	3.3	37,455.0	273	82	67	72	72	57	290	13,815.6	265	10	2.3	57	62	60	112.3	8.8	1.6	1.6	38.0	19.7	19.5	11.4	4.8	-
	M	02/05/07	11:50	916.3	909.3	839.7	4.4	NA	4.4	6	4.9	37,526.5	271	80	72	71	69	56	308	13,884.8	262	5	2.1	58	63	60	113.2	1.7	1.4	6.2	16.4	16.4	35.9	-	3.9	8.1
	T	02/06/07	11:15	922.1	914.8	845.3	5.6	NA	5.6	36	3.8	37,619.5	275	80	68	70	68	55	287	13,974.3	265	34	1.9	58	64	61	114.0	7.5	3.3	3.6	NA	NA	NA	7.8	4.2	4.0
	W	02/07/07	12:10	927.7	920.4	850.7	5.5	NA	5.5	33	3.7	37,715.1	288	79	70	68	69	55	285	14,064.2	271	26	2.5	59	65	62	115.3	5.3	5.0	5.0	18.9	18.9	18.7	7.3	7.6	8.2
22	R	02/08/07	13:00	933.5	926.2	856.5	5.8	NA	5.8	30	3.6	37,813.3	282	78	69	68	69	56	287	14,159.3	273	19	2.1	60	66	63	116.6	3.8	3.2	2.6	18.5	18.5	18.5	9.8	7.6	7.8
	F	02/09/07	11:10	939.5	932.2	862.5	6.0	NA	6.0	27	3.5	37,913.6	279	80	73	67	71	56	295	14,255.3	267	12	2.1	61	67	64	118.0	0.0	1.6	0.8	15.6	15.6	15.6	-	5.8	7.1
	Sa	02/10/07	12:00	946.1	938.3	868.8	6.3	NA	6.3	23	4.7	38,012.5	260	80	69	68	69	56	288	14,355.7	264	40	2.1	61	68	65	118.9	6.6	2.1	0.0	33.7	18.1	18.1	9.9	7.5	-
	Su	02/11/07	12:30	952.8	945.0	875.8	6.8	NA	6.8	19	4.0	38,128.4	284	78	70	70	68	54	290	14,463.1	263	31	2.3	62	69	65	119.8	3.4	1.6	7.0	17.6	17.6	35.7	10.1	6.4	9.2
	M	02/12/07	13:30	959.6	951.7	882.5	6.7	NA	6.7	16	3.2	38,239.7	275	82	73	68	66	57	276	14,569.9	264	24	1.9	63	70	66	121.2	0.0	1.9	4.5	16.8	16.8	16.8	-	6.4	7.2
	T	02/13/07	10:50	964.5	956.2	887.0	4.6	NA	4.6	14	3.0	38,317.6	280	78	67	71	68	55	286	14,645.3	271	18	2.3	63	71	67	122.0	4.9	0.0	1.8	34.1	17.3	17.3	9.7	-	-
	W	02/14/07	10:00	970.3	962.3	893.2	6.0	NA	6.0	11	3.6	38,415.1	269	79	72	69	67	56	290	14,739.1	259	10	2.5	64	71	67	122.5	1.3	6.1	8.0	17.3	34.6	34.6	-	9.3	9.9
23	R	02/15/07	9:45	975.1	966.7	897.6	4.5	NA	4.5	9	3.1	38,491.6	281	81	69	71	70	56	295	14,813.1	272	4	2.3	64	72	68	123.3	6.1	1.2	2.5	35.3	18.0	18.0	8.8	8.8	6.7
	F	02/16/07	8:30	981.0	972.7	903.2	5.8	NA	5.8	22	3.5	38,591.9	287	81	71	68	72	56	297	14,908.5	272	39	2.1	65	73	69	124.7	3.3	2.2	1.4	16.6	16.6	16.6	7.8	4.0	6.8
	Sa	02/17/07	11:00	986.4	978.0	908.7	5.4	NA	5.4	19	3.9	38,681.0	275	84	72	66	72	57	283	14,995.9	270	33	2.0	66	74	70	126.0	0.8	3.5	0.1	18.4	18.4	18.4	-	6.6	-
	Su	02/18/07	9:00	993.6	984.9	915.9	7.1	NA	7.1	15	4.1	38,796.5	271	80	70	71	69	56	290	15,106.8	260	25	2.1	66	75	70	126.4	8.0	3.8	7.3	35.9	17.1	35.5	11.2	8.2	9.3
	M	02/19/07	12:20	998.2	989.5	920.5	4.6	NA	4.6	13	3.0	38,874.0	281	82	71	70	67	57	273	15,181.8	272	19	2.3	67	76	71	127.7	1.4	0.2	2.6	18.9	18.8	18.8	-	-	-
	T	02/20/07	8:00	1,004.8	996.1	927.1	6.6	NA	6.6	10	3.3	38,980.1	268	80	70	69	69	56	287	15,282.7	255	10	2.5	67	76	71	127.7	8.0	6.8	9.2	35.2	35.1	35.1	-	10.1	11.5
	W	02/21/07	9:15	1,011.1	1,002.0	933.0	6.0	NA	6.0	7	3.5	39,079.7	275	78	68	70	70	56	290	15,378.4	264	3	2.1	67	77	72	128.6	14.3	2.6	3.6	53.9	18.7	18.7	16.8	6.9	7.3
24	R	02/22/07	8:00	1,015.9	1,006.7	937.8	4.8	NA	4.8	37	2.9	39,161.1	285	83	69	71	70	56	288	15,456.5	273	44	1.8	68	78	73	129.9	2.3	0.4	1.1	17.0	17.0	17.1	5.9	4.5	4.0
	F	02/23/07	8:00	1,022.0	1,012.9	943.9	6.1	NA	6.1	34	3.5	39,263.0	277	80	69	69	66	55	280	15,556.1	271	36	2.4	69	79	74	131.2	2.5	2.0	3.2	17.6	17.6	17.6	6.3	6.3	-
	Sa	02/24/07	14:00	1,028.4	1,019.4	950.0	6.3	NA	6.3	30	4.4	39,369.0	279	84	69	68	69	56	280	15,658.6	270	29	2.0	70	80	76	133.0	2.6	3.7	0.0	20.3	20.3	20.3	-	6.1	-
	Su	02/25/07	15:00	1,035.1	1,025.7	956.7	6.6	NA	6.6	27	3.3	39,476.6	273	85	70	69	67	56	275	15,762.2	263	21	2.2	70	81	76	133.5	9.3	3.9	6.7	40.7	20.4	40.7	13.0	8.6	9.5
	M	02/26/07	9:30	1,041.0	1,031.7	962.6	5.9	NA	5.9	24	3.5	39,576.4	280	77	69	69	67	55	290	15,858.8	271	14	2.1	71	82	77	134.7	2.2	1.3	3.1	12.9	12.9	12.9	11.4	8.0	7.8
	T	02/27/07	8:30	1,063.9	1,054.6	985.5	22.9	NA	22.9	12	3.8	39,948.0	270	78	69	62	61	51	275	16,212.4	257	1	1.0	72	83	78	136.0	13.7	16.2	18.2	0.0	0.0	0.0	-	-	-
25	W	02/28/07	11:15	1,077.0	1,067.4	998.3	12.9	NA	12.9	38	2.2	40,158.2	272	81	71	70	69	56	280	16,415.6	263	35	1.7	73	85	80	138.2	5.3	4.1	4.7	13.1	13.1	13.1	-	-	-
	R	03/01/07	8:30	1,080.4	1,070.5	1,001.4	3.2	NA	3.2	36	4.0	40,216.4	303	79	69	72	70	56	302	16,471.4	291	31	2.1	74	87	82	140.4	1.4	0.0	0.6	17.2	17.2	17.2	5.8	5.7	5.5
	F	03/02/07	9:40	1,086.1	1,076.2	1,007.1	5.7	NA	5.7	34	2.5	40,310.7	276	80	70	71	70	56	302	16,564.2	271	24	2.2	75	88	83	141.7	1.3	0.0	0.8	18.5	18.5	18.5	6.7	-	5.4
	Sa	03/03/07	10:40	1,091.6	1,082.1	1,012.6	5.6	NA	5.6	30	5.1	40,403.2	274	81	71	72	68	56	293	16,653.7	265	17	2.3	76	88	84	142.6	0.1	5.9	0.9	17.2	17.2	17.2	7.9	-	-
	M	03/05/07	12:40	1,104.1	1,093.9	1,024.8	12.2	NA	12.2	24	3.5	40,605.5	277	80	68	70	69	56	285	16,850.4	269	31	2.1	77	91	86	145.1	4.7	2.0	3.0	18.8	18.8	18.8	7.8	5.3	5.3
	T	03/06/07	13:00	1,109.9	1,099.4	1,030.3	5.6	NA	5.6	21	3.8	40,697.8	275	83	70	69	66	56	273	16,940.0	267	24	2.3	78	92	87	146.5	2.7	2.2	3.2	18.3	18.2	18.2	5.8	4.6	-
	W	03/07/07	10:50	1,115.2	1,105.0	1,035.6	5.4	NA	5.4	18	3.8	40,790.5	286	81	72	67	74	56	295	17,029.7	277	17	2.3	79	93	89	148.2	2.2	3.2	0.0	15.8	15.6	15.4	4.7	6.5	3.9
26	R	03/08/07	10:00	1,119.4	1,109.2	1,039.7	4.2	NA	4.2	16	3.3	40,861.5	284	80	70	69	72	56	295	17,098.9	277	11	2.5	80	94	90	149.5	1.7	0.9	0.2	17.2	17.3	17.3	-	-	-
	F	03/09/07[g]	9:30	1,125.8	1,115.6	1,046.0	6.4	4.4	4.4	13	3.5	40,962.7	383	85	67	66	67	56	287	17,195.8	254	3	2.4	80	94	90	149.5	8.1	7.3	6.5	35.4	35.5	35.5	9.8	-	-
	Sa	03/10/07	10:15	1,131.4	1,121.1	1,051.2	5.4	11.6	7.2	11	2.5	41,055.7	215	83	69	67	73	56	290	17,286.9	279	31	2.3	81	96	92	151.7	3.9	2.9	0.3	18.4	18.3	18.4	6.8	-	4.0
	Su	03/11/07	10:40	1,138.2	1,127.6	1,058.0	6.7	17.6	6.0	7	4.2	41,168.7	314	79	70	70	69	56	290	17,397.5	275	23	2.1	82	98	93	153.5	3.9	2.2	3.1	16.7	16.7	16.8	7.0	5.7	5.5

Table A-1. US EPA Demonstration Project at Felton, DE - Daily Operational Log Sheet (Continued)

Start-up Date: October 12, 2006

Week No.	Day of Week	Date	Time	Cumulative Hrs in Service TA	Cumulative Hrs in Service TB	Cumulative Hrs in Service TC	Avg Run Time	Hour Meter	Run Time	Chlorine: Chlorine Tank Level	Chlorine: Cl dosage	Totalizer to: Totalizer	Totalizer to: Avg Flow Rate	Pressure Filtration: Influent	Pressure Filtration: Outlet TA	Pressure Filtration: Outlet TB	Pressure Filtration: Outlet TC	Pressure Filtration: Effluent	Flow/Totalizer to: Flow Rate	Flow/Totalizer to: Totalizer	Flow/Totalizer to: Avg Flow Rate	Ferric Chloride: $FeCl_3$ Tank Level	Ferric Chloride: Fe Dosage	Backwash: Tank A	Backwash: Tank B	Backwash: Tank C	Backwash: Total	Since Last BW Run Time Tank A	Since Last BW Run Time Tank B	Since Last BW Run Time Tank C	Since Last BW Standby Time Tank A	Since Last BW Standby Time Tank B	Since Last BW Standby Time Tank C	Actual Run Time Between BW Tank A	Actual Run Time Between BW Tank B	Actual Run Time Between BW Tank C
				hr	hr	hr	hr	hr	hr	gal	mg/L	kgal	gpm	psig	psig	psig	psig	psig	gpm	kgal	gpm	gal	mg/L	No.	No.	No.	kgal	hr	hr	hr	hr	hr	hr	hr	hr	hr
	M	03/12/07	8:30	1,143.8	1,133.1	1,063.5	5.5	17.6	0.0	5		41,259.0	NA	82	72	71	67	56	296	17,487.6	271	15	2.7	83	99	94	154.8	2.5	2.0	3.1	15.9	15.9	15.9	6.4	4.7	-
	T	03/13/07	9:30	1,149.4	1,138.7	1,068.8	5.5	23.6	6.0	35	4.9	41,354.7	266	80	72	68	73	56	305	17,577.8	273	8	2.2	84	100	96	156.5	1.7	2.9	0.0	19.0	19.0	18.9	6.2	-	4.0
	W	03/14/07	9:00	1,154.5	1,143.5	1,074.0	5.0	29.2	5.6	32	4.1	41,440.7	256	79	71	72	68	55	305	17,661.2	276	39	2.1	85	102	97	158.3	0.6	0.0	1.2	17.7	17.7	17.7	6.4	4.9	3.8
27	R	03/15/07	8:20	1,160.8	1,149.8	1,080.3	6.3	35.8	6.6	29	3.3	41,545.9	266	82	73	70	66	56	292	17,763.0	269	31	2.3	86	103	98	159.6	0.5	1.4	3.7	16.3	16.2	16.3	6.5	3.7	5.0
	F	03/16/07	9:15	1,166.8	1,155.9	1,086.3	6.0	42.3	6.5	26	3.5	41,646.1	257	84	76	67	66	56	290	17,859.7	267	24	2.1	87	104	99	160.9	0.0	3.8	4.7	18.1	18.1	18.1	6.4	5.3	5.6
	Sa	03/17/07	10:00	1,173.2	1,162.2	1,092.3	6.2	49.0	6.7	21	5.6	41,750.7	260	81	74	68	69	56	305	17,960.7	270	15	2.6	88	105	100	162.2	0.0	4.8	5.1	18.8	18.8	19.0	-	5.8	6.9
	Su	03/18/07	13:00	1,180.1	1,168.7	1,098.8	6.6	56.0	7.0	17	4.3	41,860.3	261	82	68	67	70	56	275	18,066.9	267	7	2.2	88	106	101	163.0	6.9	5.5	4.7	39.2	20.4	20.4	11.6	8.9	10.4
	M	03/19/07	11:00	1,185.8	1,174.4	1,104.5	5.7	62.1	6.1	14	3.7	41,954.7	258	79	72	69	72	56	308	18,157.6	265	9	2.5	89	107	102	164.4	1.0	2.3	0.0	16.2	16.2	16.2	4.9	-	3.4
	T	03/20/07	12:00	1,191.0	1,179.3	1,109.7	5.1	67.7	5.6	11	4.1	42,041.4	258	84	69	67	74	56	283	18,242.5	277	38	2.1	90	109	103	166.2	1.3	0.9	1.8	17.2	17.2	17.2	4.5	-	-
	W	03/21/07	9:15	1,196.2	1,184.2	1,114.5	5.0	73.3	5.6	9	2.7	42,127.1	255	80	69	72	69	56	304	18,327.1	284	31	2.4	91	111	105	168.4	2.0	0.1	0.6	17.0	17.0	17.0	6.7	5.4	4.8
28	R	03/22/07	8:20	1,201.6	1,189.7	1,120.0	5.5	79.2	5.9	6	3.8	42,218.5	258	79	72	72	69	56	308	18,415.4	269	24	2.3	92	112	106	169.7	0.7	0.2	1.3	17.3	17.3	17.3	5.3	3.9	3.6
	F	03/23/07	8:20	1,206.9	1,195.1	1,125.4	5.4	85.0	5.8	18	3.9	42,309.5	261	82	74	69	67	55	295	18,505.0	278	17	2.3	93	113	107	171.1	0.7	1.7	3.1	18.0	18.0	18.0	7.8	3.2	4.1
	Sa	03/24/07	10:10	1,214.1	1,202.3	1,132.6	7.2	92.6	7.6	14	3.9	42,428.9	262	81	74	69	68	56	300	18,619.8	266	8	2.3	94	114	108	172.4	0.1	5.7	6.2	18.2	18.3	18.3	5.2	-	-
	Su	03/25/07	10:10	1,219.7	1,207.6	1,137.9	5.4	98.6	6.0	11	3.8	42,521.9	258	80	73	71	70	57	308	18,710.6	280	42	1.9	95	116	110	174.7	0.5	0.9	1.4	18.0	18.0	18.0	5.2	-	-
	M	03/26/07	8:00	1,225.4	1,213.0	1,143.3	5.5	104.8	6.2	8	3.6	42,619.5	262	78	69	71	70	56	304	18,805.4	287	35	2.1	96	118	112	176.9	1.0	0.3	0.6	15.7	15.7	15.7	-436.3	-	-
	T	03/27/07	8:00	789.7	1,218.2	1,148.5	-141.8	110.4	5.6	6	2.8	42,704.4	253	82	72	71	66	55	295	18,889.6	-10	28	2.5	97	119	113	178.2	1.6	1.3	2.0	17.9	17.8	17.8	445.7	-	-
	W	03/28/07	8:00	1,236.5	1,223.7	1,154.0	152.6	116.6	6.2	3	3.6	42,800.8	259	81	69	71	68	55	295	18,984.7	10	20	2.5	98	121	115	180.5	2.7	1.1	1.9	17.4	17.4	17.5	6.5	5.3	-
29	R	03/29/07	8:00	1,242.1	1,229.3	1,159.6	5.6	122.6	6.0	32	3.7	42,895.2	262	81	71	70	64	56	273	19,076.1	272	13	2.2	99	122	116	181.8	1.8	1.4	2.3	17.4	17.4	17.5	7.1	4.8	-
	F	03/30/07	8:00	1,248.9	1,236.1	1,166.1	6.7	129.8	7.2	28	4.2	43,008.1	261	81	73	65	74	56	295	19,185.5	272	3	2.7	100	123	118	183.6	1.5	3.4	0.1	18.2	18.2	18.2	6.1	-	-
	Sa	03/31/07	10:00	1,254.3	1,241.1	1,171.6	5.3	135.6	5.8	26	2.6	43,099.0	261	83	70	68	66	56	277	19,273.6	277	38	2.3	101	125	119	185.3	0.8	0.4	1.3	18.0	18.0	18.0	4.8	-	-
	Su	04/01/07	11:30	1,259.9	1,246.2	1,176.8	5.3	141.6	6.0	24	2.5	43,191.7	257	83	68	70	67	56	272	19,364.7	286	31	2.3	102	127	121	187.6	1.6	0.5	1.0	19.0	19.0	19.0	4.9	-	-
	M	04/02/07	9:30	1,266.4	1,252.3	1,183.0	6.3	148.6	7.0	21	3.3	43,298.8	255	82	68	71	68	55	293	19,470.6	282	22	2.5	103	129	123	189.8	3.2	1.0	1.6	16.9	16.9	16.9	-	-	-
	T	04/03/07	9:00	1,275.2	1,258.8	1,189.5	7.3	156.1	7.5	19	2.0	43,415.6	260	80	70	72	69	56	297	19,585.4	263	13	2.3	105	132	126	193.3	1.3	0.4	0.9	15.7	15.7	15.7	3.0	5.4	5.3
	W	04/04/07	10:00	1,279.6	1,266.2	1,195.9	6.1	163.0	6.9	17	2.2	43,522.4	258	78	70	68	70	55	294	19,690.1	288	5	2.2	106	133	127	194.7	2.7	2.4	2.0	15.2	15.2	15.2	-	-	-
30	R	04/05/07	11:35	1,284.8	1,271.2	1,201.9	5.4	169.1	6.1	14	3.7	43,616.4	257	86	75	66	67	55	287	19,771.9	252	41	1.9	108	133	127	195.5	2.8	8.4	8.0	19.2	34.5	34.5	3.2	9.3	9.4
	F	04/06/07	12:30	1,292.7	1,279.1	1,209.8	7.9	177.0	7.9	28	2.8	43,740.8	262	80	71	70	70	57	290	19,894.4	259	31	2.4	109	134	128	196.8	7.5	7.0	6.5	12.9	12.9	12.8	-	-	9.0
	Sa	04/07/07	12:30	1,296.5	1,282.8	1,212.3	3.3	180.8	3.8	26	3.9	43,800.2	261	81	70	68	74	56	304	19,950.4	280	26	2.5	109	134	129	197.2	11.3	10.7	0.0	33.4	33.4	20.5	13.9	-	4.4
	Su	04/08/07	11:00	1,301.9	1,287.6	1,218.7	5.5	186.7	5.9	24	2.6	43,890.3	255	81	68	74	70	56	302	20,039.9	270	18	2.7	110	137	130	199.5	2.8	0.1	2.0	16.1	16.1	16.1	4.0	-	3.6
	M	04/09/07	10:00	1,307.1	1,292.7	1,223.8	5.1	192.3	5.6	22	2.7	43,977.0	258	81	69	70	68	56	283	20,125.0	276	11	2.4	111	138	131	200.8	4.0	3.1	3.5	17.3	17.3	17.4	5.9	-	-
	T	04/10/07	11:30	1,311.0	1,296.3	1,227.4	3.7	196.6	4.3	19	5.3	44,043.1	256	81	67	70	70	56	290	20,189.2	289	5	2.7	112	140	133	203.0	2.0	0.4	0.0	20.2	20.2	20.2	5.5	-	4.2
	W	04/11/07	9:45	1,316.1	1,301.1	1,232.6	5.0	202.2	5.6	16	4.1	44,129.3	257	81	71	69	72	56	302	20,274.9	284	27	2.4	113	142	134	204.8	1.6	1.3	1.0	17.6	17.6	17.6	3.9	-	4.0
31	R	04/12/07	10:30	1,320.3	1,304.9	1,236.8	4.1	206.8	4.6	13	4.9	44,200.7	259	81	71	69	71	56	297	20,345.5	289	21	2.5	114	144	135	206.5	1.9	1.5	1.2	17.4	17.4	17.4	-	-	3.7
	F	04/13/07	11:00	1,325.4	1,309.7	1,242.2	5.1	212.7	5.9	10	3.9	44,291.7	257	82	75	68	67	56	293	20,435.8	295	14	2.3	116	147	136	209.2	0.1	0.4	2.9	18.0	18.0	18.0	4.4	-	-
	Sa	04/14/07	11:55	1,330.0	1,313.9	1,246.6	4.4	217.7	5.0	6	6.0	44,370.1	261	80	73	66	74	55	300	20,513.1	293	7	2.7	117	149	138	211.5	0.3	0.7	0.1	19.9	19.9	19.8	4.9	-	4.5
	Su	04/15/07	11:15	1,335.9	1,319.2	1,252.7	5.8	224.1	6.4	18	4.7	44,470.2	261	80	72	71	70	56	307	20,611.8	285	29	2.1	118	152	139	213.7	1.3	1.0	1.7	16.8	16.9	16.8	4.1	-	6.2
	M	04/16/07	8:30	1,340.8	1,323.8	1,257.3	4.7	229.5	5.4	15	4.2	44,553.0	256	79	70	69	73	55	305	20,693.8	291	22	2.5	119	154	141	215.9	2.1	0.4	0.1	15.7	15.7	15.7	3.6	-	2.6
	T	04/17/07	8:30	1,346.0	1,328.7	1,262.4	5.1	235.0	5.5	12	4.1	44,639.6	262	80	68	69	68	56	285	20,779.6	282	15	2.4	120	156	142	217.6	3.7	2.2	2.6	17.5	17.5	17.5	-	-	8.6
	W	04/18/07	8:30	1,352.5	1,334.7	1,268.5	6.2	241.5	6.5	9	3.5	44,739.8	257	81	65	71	74	56	302	20,874.8	256	7	2.4	120	157	143	218.4	9.2	0.7	0.1	36.0	18.5	18.5	-	-	4.4
32	R	04/19/07	8:00	1,357.8	1,339.9	1,274.1	5.4	247.5	6.0	39	3.7	44,833.8	261	83	72	66	68	55	280	20,967.5	288	36	1.3	122	159	144	220.6	0.1	0.8	1.3	17.0	17.0	17.0	4.4	-	-
	F	04/20/07	8:15	1,363.6	1,345.0	1,279.5	5.4	253.8	6.3	37	2.4	44,929.6	253	80	70	70	72	56	305	21,062.2	290	29	2.2	123	162	146	223.2	1.5	0.8	0.4	18.5	18.5	18.5	-	-	4.1
	Sa	04/21/07	8:10	1,369.3	1,350.4	1,285.5	5.7	260.3	6.5	34	3.5	45,028.9	255	83	75	67	58	56	295	21,160.7	288	21	2.4	125	165	147	225.9	0.2	0.9	2.3	17.3	17.4	17.4	-	-	-
	Su	04/22/07	15:00	1,380.8	1,360.9	1,296.9	11.1	272.8	12.5	27	9.1	45,222.5	258	79	71	73	73	56	305	21,357.5	295	8	2.0	128	172	151	232.0	0.6	0.1	0.3	0.0	0.0	0.0	-	-	-
	M	04/23/07	8:40	1,382.1	1,361.9	1,298.1	1.2	274.2	1.4	27		45,243.1	245	84	69	69	69	55	295	21,373.8	233	39	1.5	128	172	151	232.0	1.6	1.0	1.3	16.2	16.2	16.1	-	-	-
	T	04/24/07	8:30	1,388.5	1,367.6	1,304.5	6.2	281.3	7.1	24	3.3	45,351.0	253	79	69	72	70	55	305	21,481.0	290	31	2.2	130	176	153	235.6	0.6	0.1	0.3	16.8	16.8	16.9	-	-	-
	W	04/25/07	7:40	1,394.4	1,373.5	1,310.4	5.9	287.9	6.6	20	4.7	45,451.8	255	81	74	69	67	55	295	21,581.2	283	24	2.1	132	178	155	238.3	0.1	1.4	2.0	16.3	16.3	16.3	3.5	-	-
33	R	04/26/07	8:15	1,400.9	1,379.6	1,316.5	6.2	294.7	6.8	16	4.5	45,556.3	256	82	66	64	71	56	297	21,685.4	279	15	2.6	133	180	157	240.5	3.1	2.7	0.1	17.1	17.1	17.1	5.1	-	3.0
	F	04/27/07	8:00	1,405.8	1,383.8	1,321.5	4.7	300.0	5.3	13	4.4	45,637.1	254	83	67	69	69	55	290	21,765.9	285	8	2.6	134	183	158	242.7	2.9	0.9	2.1	18.6	18.6	18.6	-	-	-
	Sa	04/28/07	8:00	1,411.7	1,389.5	1,327.5	5.9	306.8	6.8	43	3.4	45,740.9	254	82	70	70	69	55	300	21,869.3	294	35	2.3	136	186	160	245.8	4.0	2.8	3.2	17.9	17.9	17.9	-	-	-
	Su	04/29/07	8:20	1,417.8	1,396.2	1,333.4	6.2	314.1	7.3	39	4.4	45,847.8	244	81	71	70	74	56	300	21,975.4	284	27	2.2	139	190	164	250.9	1.3	0.9	0.4	16.9	16.9	16.9	2.3	-	4.2

Table A-1. US EPA Demonstration Project at Felton, DE - Daily Operational Log Sheet (Continued)

Start-up Date: October 12, 2006

Week No.	Day of Week	Date	Time	Cumulative Hrs in Service TA (hr)	Cumulative Hrs in Service TB (hr)	Cumulative Hrs in Service TC (hr)	Avg Run Time (hr)	Hour Meter (hr)	Run Time (hr)	Chlorine: Chlorine Tank Level (gal)	Chlorine: Cl dosage (mg/L)	Totalizer to: Totalizer (kgal)	Totalizer to: Avg Flow Rate (gpm)	Pressure Filtration: Influent (psig)	Pressure Filtration: Outlet TA (psig)	Pressure Filtration: Outlet TB (psig)	Pressure Filtration: Outlet TC (psig)	Pressure Filtration: Effluent (psig)	Flow/Totalizer to: Flow Rate (gpm)	Flow/Totalizer to: Totalizer (kgal)	Flow/Totalizer to: Avg Flow Rate (gpm)	Ferric Chloride: $FeCl_3$ Tank Level (gal)	Ferric Chloride: Fe Dosage (mg/L)	Backwash: Tank A (No.)	Backwash: Tank B (No.)	Backwash: Tank C (No.)	Backwash: Total (kgal)	Backwash Since Last BW Run Time: Tank A (hr)	Backwash Since Last BW Run Time: Tank B (hr)	Backwash Since Last BW Run Time: Tank C (hr)	Backwash Since Last BW Standby Time: Tank A (hr)	Backwash Since Last BW Standby Time: Tank B (hr)	Backwash Since Last BW Standby Time: Tank C (hr)	Actual Run Time Between BW: Tank A (hr)	Actual Run Time Between BW: Tank B (hr)	Actual Run Time Between BW: Tank C (hr)
	M	04/30/07	8:10	1,424.8	1,402.1	1,340.6	6.7	321.5	7.4	36	3.0	45,965.6	265	83	69	71	68	56	275	22,093.6	294	17	2.5	140	192	165	252.6	4.9	2.2	3.4	16.4	16.4	16.4	5.5	-	
	T	05/01/07	8:00	1,430.2	1,406.4	1,344.9	4.7	327.0	5.5	34	3.0	46,045.0	241	83	67	73	69	56	290	22,171.8	279	11	2.3	141	196	169	257.1	3.7	0.1	1.7	16.6	16.6	16.6	6.0	-	4.6
	W	05/02/07	8:00	1,436.7	1,412.6	1,351.4	6.4	333.4	6.4	30	4.7	46,145.4	261	78	71	68	72	56	300	22,272.0	261	3	2.4	142	198	170	259.3	3.9	0.3	3.5	16.4	16.4	16.4	-	-	-
34	R	05/03/07	8:00	1,443.4	1,418.1	1,357.7	6.2	340.0	6.6	26	4.2	46,257.4	283	84	68	67	72	57	285	22,383.0	300	38	2.1	144	203	174	264.6	1.2	0.1	0.6	14.8	14.7	14.7	6.9	-	-
	F	05/04/07[(h)]	8:45	1,452.5	1,426.3	1,366.2	8.6	350.1	10.1	21	4.2	46,397.8	232	75	69	69	69	55	297	22,521.3	268	30	1.7	145	207	177	269.6	2.5	1.8	2.1	19.2	19.2	19.2	-	8.9	-
	Sa	05/05/07	11:00	1,460.0	1,433.5	1,373.7	7.4	357.6	7.5	18	2.9	46,518.1	267	83	68	69	67	56	280	22,634.6	255	22	2.0	145	208	177	270.1	10.0	0.4	9.6	36.2	17.0	36.2	14.0	-	10.9
	Su	05/06/07	10:20	1,467.2	1,441.1	1,380.9	7.3	365.3	7.7	15	2.9	46,640.0	264	80	70	68	69	56	290	22,750.1	263	14	2.0	146	208	178	271.0	3.6	8.0	6.0	17.4	34.3	17.3	-	9.7	11.1
	M	05/07/07	9:00	1,473.6	1,447.3	1,387.1	6.3	371.8	6.5	12	3.4	46,742.6	263	79	67	67	71	55	285	22,845.8	255	5	2.6	146	209	179	271.8	10.0	4.5	1.1	33	15.6	15.7	13.6	10.1	
	T	05/08/07	8:45	1,480.7	1,454.4	1,394.5	7.2	379.4	7.6	8	4.0	46,861.0	260	79	69	70	64	55	282	22,957.3	258	32	2.0	147	210	179	272.7	3.5	1.5	8.5	16.2	16.2	31.9	-	8.3	10.9
	W	05/09/07	8:20	1,488.2	1,461.6	1,401.7	7.3	386.9	7.5	3	4.9	46,980.5	266	81	65	71	68	56	276	23,069.9	257	24	2.0	147	211	180	273.5	11.0	0.4	4.8	31.5	1.6	6.0	-	6.4	10.6
35	R	05/10/07	8:00	1,494.2	1,468.0	1,408.2	6.3	393.8	6.9	32	3.3	47,088.6	261	77	69	68	68	55	285	23,171.2	268	16	2.2	149	212	181	275.6	0.1	0.4	0.7	16.0	16.1	16.1	-	-	-
	F	05/11/07	8:00	1,501.9	1,475.7	1,415.9	7.7	401.6	7.8	28	3.8	47,213.0	266	84	68	66	67	55	270	23,288.6	254	7	2.2	149	212	181	275.6	7.7	8.0	8.4	32.6	32.7	32.7	-	9.6	9.6
	Sa	05/12/07	9:30	1,509.3	1,482.8	1,423.0	7.2	409.1	7.5	25	3.0	47,330.1	260	84	66	68	70	55	268	23,398.7	255	34	2.0	149	213	182	276.4	15.1	5.5	3.8	50.1	17.5	17.5	17.1	9.8	11.9
	Su	05/13/07	8:30	1,517.9	1,491.6	1,431.7	8.7	418.2	9.1	21	3.3	47,473.5	263	78	68	68	71	56	290	23,533.6	258	24	2.1	150	214	183	277.7	6.6	4.5	0.6	15.6	15.6	15.6	-	8.9	
	M	05/14/07[(i)]	8:00	1,524.4	1,497.7	1,438.1	6.3	425.5	7.3	17	4.6	47,576.0	234	80	66	71	66	55	280	23,632.1	259	16	2.3	150	215	183	278.1	13.1	1.7	7.1	32.5	16.9	32.5	14.9	-	10.5
	T	05/15/07	8:00	1,530.3	1,504.1	1,444.2	6.1	431.2	5.7	14	3.5	47,677.4	296	81	72	66	73	56	275	23,728.1	261	9	2.1	151	215	184	278.9	4.1	8.0	2.7	16.4	33.2	16.3	-	10.0	9.9
	W	05/16/07	9:15	1,538.9	1,512.3	1,452.5	8.4	439.8	8.6	10	3.5	47,812.8	262	84	68	70	76	56	272	23,857.4	258	34	2.2	151	216	185	279.8	12.7	6.2	1.1	34.2	17.9	17.8	15.6	10.7	-
36	R	05/17/07	9:15	1,545.7	1,519.1	1,459.7	6.9	447.1	7.3	21	5.1	47,927.0	261	78	69	70	67	55	290	23,966.8	263	26	2.1	152	217	185	280.6	3.9	2.3	8.3	16.6	16.5	34.4	-	10.0	11.5
	F	05/18/07	10:00	1,553.6	1,526.8	1,467.4	7.8	455.2	8.1	16	4.6	48,054.2	262	81	67	73	69	56	297	24,087.7	259	17	2.1	152	218	186	281.5	11.9	0.0	4.5	33.3	16.7	16.7	14.7	-	-
	Sa	05/19/07	10:30	1,559.0	1,532.8	1,473.1	5.7	461.0	5.8	14	2.6	48,145.8	263	80	70	68	65	56	288	24,175.1	255	39	2.0	153	218	186	281.9	2.6	5.7	10.2	18.5	35.2	35.3	-	8.8	11.3
	Su	05/20/07	11:00	1,566.3	1,539.6	1,480.1	7.0	468.5	7.5	10	3.9	48,264.6	264	81	66	69	69	56	280	24,287.3	266	31	2.0	153	219	187	282.8	9.9	3.7	5.9	35.8	17.3	17.2	11.5	9.9	10.0
	M	05/21/07	8:45	1,572.7	1,545.9	1,486.5	6.4	475.3	6.8	6	4.4	48,370.6	260	79	69	73	71	55	300	24,386.3	259	24	2.0	154	220	188	284.0	4.8	0.1	2.3	14.7	14.7	14.7	-	-	-
	T	05/22/07	14:00	1,582.8	1,556.0	1,496.6	10.1	485.5	10.2	17	3.6	48,534.5	268	80	68	69	70	56	280	24,542.1	257	20	NA	154	220	188	284.0	14.9	10.2	12.4	30.7	30.7	30.7	20.8	-	-
	W	05/23/07	10:00	1,588.8	1,562.0	1,502.6	6.0	491.6	6.1	13	4.9	48,629.8	260	82	75	68	68	56	295	24,633.1	253	16	1.3	155	220	188	284.0	0.1	16.2	18.4	14.2	452.0	45.2	-	18.0	20.6
37	R	05/24/07	9:15	1,594.9	1,567.7	1,508.4	5.9	497.7	6.1	9	4.8	48,726.6	264	78	68	68	68	55	290	24,726.5	265	9	2.2	155	221	189	285.3	6.1	3.9	3.6	31.2	17.1	17.1	10.7	7.1	10.5
	F	05/25/07	9:00	1,602.7	1,575.5	1,516.2	7.8	506.0	8.3	38	2.7	48,854.8	257	80	69	67	72	55	298	24,849.1	262	36	2.1	156	222	190	286.6	3.2	4.6	0.9	15.1	15.1	15.1	11.2	8.4	-
	Sa	05/26/07	8:30	1,610.7	1,583.5	1,524.6	8.1	514.4	8.4	34	3.6	48,986.2	261	81	74	70	68	54	285	24,974.1	256	28	1.8	157	223	190	287.4	0.0	4.2	9.3	15.3	15.3	30.3	-	9.5	10.8
	Su	05/27/07	9:15	1,620.0	1,592.7	1,533.6	9.2	523.8	9.4	28	4.7	49,135.5	265	83	67	71	68	55	290	25,118.8	263	17	2.2	157	224	191	288.2	9.3	3.9	7.5	30.7	15.4	15.4	11.4	11.9	11.9
	M	05/28/07	9:45	1,629.2	1,601.9	1,542.9	9.2	533.6	9.8	23	3.9	49,286.5	257	80	69	72	71	55	302	25,262.4	259	6	2.2	158	225	192	289.5	7.1	1.2	4.9	14.6	14.6	14.6	13.8	9.5	9.6
	T	05/29/07	8:00	1,637.6	1,610.4	1,551.5	8.5	542.6	9.0	19	3.6	49,415.5	239	78	70	72	68	55	300	25,396.7	263	32	2.1	159	226	193	290.7	1.7	0.2	3.9	13.5	13.5	13.5	8.9	4.1	4.8
	W	05/30/07	8:00	1,645.2	1,618.0	1,558.8	7.5	550.2	7.6	14	4.5	49,546.4	287	82	75	71	67	56	290	25,511.0	254	24	1.8	160	227	194	292.0	0.4	3.7	6.4	0.0	0.0	11.3	-	15.8	16.5
38	R	05/31/07	8:00	1,659.6	1,632.0	1,573.2	14.3	565.1	14.9	7	3.5	49,779.3	261	81	68	72	70	55	298	25,734.1	261	6	2.3	160	228	195	292.8	9.8	1.9	4.3	21.1	11.2	11.2	11.7	7.8	8.1
	F	06/01/07	15:00	1,668.2	1,640.7	1,581.9	8.7	574.2	9.1	35	4.1	49,920.9	259	82	67	68	68	56	285	25,871.0	263	33	1.9	161	229	196	294.1	6.7	2.8	4.9	12.9	12.9	12.9	10.0	11.1	10.6
	Sa	06/02/07	13:30	1,677.7	1,650.2	1,591.5	9.5	584.2	10.0	31	3.0	50,076.9	260	78	66	69	67	55	285	26,020.4	261	22	2.1	162	230	197	295.4	6.2	1.2	3.9	14.0	14.0	14.0	13.1	-	12.8
	Su	06/03/07	16:00	1,687.5	1,660.4	1,601.3	9.9	594.4	10.2	26	3.7	50,236.6	261	80	71	66	73	55	300	26,172.5	255	10	2.2	163	230	198	296.2	2.9	11.4	0.9	16.6	30.6	16.6	8.6	12.5	5.6
	M	06/04/07	15:35	1,693.6	1,666.6	1,607.5	6.2	601.0	6.6	22	4.6	50,339.1	259	81	73	67	73	56	310	26,271.2	267	39	1.8	164	231	199	297.5	0.4	5.1	1.5	16.8	16.9	16.8	-	6.7	-
	T	06/05/07	12:40	1,699.6	1,672.3	1,613.6	5.9	607.1	6.1	19	3.6	50,436.5	266	84	70	69	67	56	270	26,364.9	263	32	2.2	164	232	199	298.0	6.4	4.1	7.6	29.2	12.4	29.3	9.1	7.1	11.0
	W	06/06/07	8:00	1,704.5	1,677.2	1,618.5	4.9	612.5	5.4	16	4.2	50,520.3	259	77	68	68	69	56	285	26,445.7	275	26	2.1	165	233	200	299.2	2.2	1.9	1.5	15.6	15.6	15.6	-	-	-
39	R	06/07/07	8:00	1,711.0	1,683.8	1,625.1	6.6	619.1	6.6	12	4.4	50,626.1	267	84	69	67	70	56	292	26,545.1	252	18	2.3	165	233	200	299.2	8.7	8.5	8.1	33.1	33.2	33.1	16.7	9.6	13.0
	F	06/08/07	8:00	1,719.0	1,691.8	1,633.1	8.0	627.6	8.5	6	5.4	50,757.1	257	80	72	66	70	56	297	26,670.6	262	8	2.3	166	234	201	300.4	0.0	6.9	3.1	15.5	15.5	15.5	-	-	-
	Sa	06/09/07	NM	NM	NM	NM	NA	NM	NA	NM		NA	NA		NA	NA	NA	NA	NA	NA	NA	NM	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Su	06/10/07	8:55	1,737.9	1,710.5	1,651.7	18.7	647.1	19.5	24	5.4	51,062.9	261	81	69	69	73	56	295	26,963.0	260	24	2.1	167	236	203	302.5	7.9	6.8	1.9	14.5	14.5	14.5	8.0	9.5	-
	M	06/11/07	7:35	1,745.7	1,718.4	1,659.9	8.0	655.5	8.4	18	5.4	51,193.1	258	82	72	69	65	56	292	27,088.7	263	15	2.1	168	237	203	303.3	7.7	5.2	10.1	14.3	14.3	28.9	-	-	12.4
	T	06/12/07	16:15	1,752.5	1,725.3	1,666.4	6.7	662.3	6.8	15	3.3	51,301.2	265	81	70	68	71	55	300	27,190.3	251	6	2.5	168	237	204	303.7	8.5	12.1	4.2	32.9	32.9	18.7	14.2	13.8	-
	W	06/13/07	11:25	1,759.2	1,732.0	1,673.4	6.8	669.4	7.1	12	3.2	51,412.0	260	81	71	68	65	56	275	27,297.3	262	34	2.2	169	238	204	304.6	1.0	5.0	11.2	18.5	18.5	37.3		9.8	13.5
40	R	06/14/07	11:00	1,766.1	1,738.6	1,679.9	6.7	676.4	7.0	8	4.3	51,522.1	262	81	68	72	72	56	300	27,402.0	262	26	2.2	169	239	205	305.4	7.9	1.8	4.2	35.6	17.1	17.1	8.5	1.1	5.8
	F	06/15/07	11:45	1,771.2	1,742.0	1,685.1	4.6	682.0	5.6	20	4.0	51,610.6	263	78	64	68	69	56	290	27,488.1	314	20	2.0	170	240	206	306.7	4.5	4.1	3.6	19.1	19.2	19.2	-	10.0	10.6
	Sa	06/16/07	10:30	1,779.0	1,751.3	1,692.5	8.2	689.8	7.8	16	3.8	51,732.7	261	81	66	70	74	56	293	27,604.2	237	11	2.2	170	241	207	307.5	12.3	3.4	0.4	33.8	14.8	14.7	14.5	9.8	-
	Su	06/17/07	9:50	1,786.1	1,758.3	1,699.9	7.2	697.3	7.5	13	3.0	51,849.9	260	80	70	72	67	56	302	27,716.2	261	38	2.0	171	242	207	308.3	4.9	0.6	7.8	15.9	15.9	30.6	12.3	9.4	10.1
	M	06/18/07	11:20	1,795.5	1,767.8	1,709.3	9.4	707.2	9.9	9	3.0	52,004.0	259	77	69	70	67	55	290	27,864.4	262	27	2.1	172	243	208	309.6	2.0	0.7	7.1	NM	NM	NM	-	8.9	11.3
	T	06/19/07	10:45	1,805.5	1,777.5	1,719.0	9.8	717.3	10.1	5	3.0	52,162.3	261	83	66	73	69	56	288	28,015.3	257	16	2.1	172	244	209	310.4	12.0	1.5	5.5	NM	NM	NM	14.1	-	11.9
	W	06/20/07	9:40	1,811.8	1,784.3	1,725.4	6.5	724.2	6.9	17	3.3	52,268.6	257	80	69	66	73	55	298	28,117.3	262	8	2.3	173	244	210	311.2	4.2	8.3	0.0	NM	NM	NM	-	12.5	-
41	R	06/21/07	8:40	1,818.3	1,790.5	1,732.0	6.4	730.8	6.6	14	3.4	52,373.2	264	81	68	72	70	56	302	28,216.8	258	36	2.6	173	245	210	311.7	10.7	2.0	6.6	NM	NM	NM	13.8	-	10.9
	F	06/22/07	9:20	1,824.4	1,796.9	1,738.2	6.2	737.3	6.5	10	4.6	52,474.1	259	79	68	65	69	55	283	28,314.6	262	29	2.1	174	245	211	312.5	3.0	8.4	1.9	NM	NM	NM	-	10.9	8.9
	Sa	06/23/07	10:15	1,832.7	1,804.9	1,746.1	8.1	745.7	8.4	20	4.5	52,605.8	261	83	65	68	73	56	290	28,439.9	259	20	2.0	174	246	212	313.3	11.3	5.5	0.9	NM	NM	NM	12.4	9.9	10.0
	Su	06/24/07	10:35	1,842.5	1,814.8	1,755.9	9.8	756.0	10.3	15	3.6	52,766.5	260	81	68	68	73	56	290	28,594.2	261	8	2.2	175	247	213	314.6	8.7	5.5	0.7	NM	NM	NM	13.8	8.6	10.0
	M	06/25/07	13:55	1,853.8	1,826.2	1,767.4	11.4	767.7	11.7	9	3.8	52,949.9	261	81	70	68	72	56	292	28,769.5	256	24	2.0	176	248	214	315.8	6.2	8.3	2.2	15.4	15.4	15.5	-	12.0	-
	T	06/26/07	12:20	1,860.5	1,832.6	1,774.1	6.6	774.6	6.9	38	5.5	53,056.8	258	82	68	73	68	56	294	28,871.3	257	15	2.5	176	249	214	316.2	12.9	2.7	8.9	31.1	2.9	9.1	15.9	-	14.8
	W	06/27/07	11:15	1,867.7	1,840.3	1,781.4	7.4	782.3	7.7	34	6.8	53,126.1	150	80	71	66	72	55	295	28,986.4	259	6	3.9	177	249	215	317.1	4.2	10.4	1.4	15.3	31.0	15.3	-	13.0	6.2
42	R	06/28/07	10:30	1,874.8	1,847.1	1,786.2	6.2	789.5	7.2	29	3.6	53,289.2	378	83	65	68	74	55	283	29,093.1	285	33	1.7	177	250	216	317.9	11.3	4.2	0.0	30.0	14.7	14.7	26.1	9.4	12.7
	F	06/29/07	10:00	1,889.6	1,862.3	1,803.5	15.8	805.2	15.7	15	6.8	53,531.6	257	81	73	65	69	55	295	29,325.5	246	15	2.2	179	251	217	319.6	0.0	10.0	4.6	9.0	9.0	9.0	6.1	10.9	7.7
	Sa	06/30/07	8:45	1,895.9	1,868.7	1,809.9	6.4	811.9	6.7	10	5.6	53,636.5	261	81	74	68	70	56	284	29,426.4	264	32	2.9	180	252	218	320.9	0.2	5.5	3.3	16.1	16.1	16.1	-	6.4	8.2
	Su	07/01/07	9:30	1,905.2	1,877.6	1,818.9	9.1	821.2	9.3	5	4.0	53,783.0	263	83	66	66	71	56	268	29,567.2	259	20	2.5	180	253	218	321.7	9.4	8.0	4.1	31.2	15.1	15.1	12.4	8.5	-

Table A-1. US EPA Demonstration Project at Felton, DE - Daily Operational Log Sheet (Continued)

Start-up Date: October 12, 2006

Week No.	Day of Week	Date	Time	Cumulative Hrs in Service TA	Cumulative Hrs in Service TB	Cumulative Hrs in Service TC	Avg Run Time	Hour Meter	Run Time	Chlorine Tank Level	Cl dosage	Totalizer to: Totalizer	Totalizer to: Avg Flow Rate	Pressure Filtration: Influent	Outlet TA	Outlet TB	Outlet TC	Effluent	Flow/Totalizer to: Flow Rate	Totalizer	Avg Flow Rate	Ferric Chloride: $FeCl_3$ Tank Level	Fe Dosage	Backwash: Tank A	Tank B	Tank C	Total	Since Last BW Run Time Tank A	Run Time Tank B	Run Time Tank C	Standby Time Tank A	Standby Time Tank B	Standby Time Tank C	Actual Run Time Between BW Tank A	Tank B	Tank C
				hr	hr	hr	hr	hr	hr	gal	mg/L	kgal	gpm	psig	psig	psig	psig	psig	gpm	kgal	gpm	gal	mg/L	No.	No.	No.	kgal	hr	hr	hr	hr	hr	hr	hr	hr	hr
	M	07/02/07	7:45	1,911.9	1,884.4	1,826.0	6.9	828.5	7.3	16	4.2	53,894.2	254	81	71	67	65	56	273	29,674.1	260	11	2.4	181	254	219	322.6	3.7	6.3	11.2	13.8	13.9	29.0	-	12.3	14
	T	07/03/07	8:00	1,921.6	1,893.7	1,835.3	9.4	838.3	9.8	10	4.6	54,046.3	259	83	66	69	67	56	280	29,818.7	256	32	2.8	181	255	220	323.4	13.4	3.3	6.5	29.3	14.2	14.2	14.2	9.9	8.9
	W	07/04/07	9:10	1,928.1	1,900.4	1,841.9	6.6	845.3	7.0	6	4.3	54,155.9	261	NA	NA	NA	NA	NA	NA	29,923.9	266	24	2.2	182	256	221	324.6	5.7	0.1	4.2	NM	NM	NM	11.6	-	-
43	R	07/05/07	8:30	1,934.0	1,906.6	1,848.1	6.1	851.6	6.3	18	4.8	54,253.7	259	80	72	67	66	54	304	30,017.7	256	15	2.8	183	256	221	325.0	0.0	6.2	10.4	25.8	36.8	36.7	-	11.2	12.1
	F	07/06/07	10:45	1,943.2	1,915.4	1,857.0	9.0	860.9	9.3	11	5.6	54,401.2	264	79	68	69	68	55	286	30,159.3	263	5	2.0	183	257	222	325.9	9.2	3.8	7.2	42.7	16.9	16.9	14.0	-	-
	Sa	07/07/07	9:30	1,948.6	1,921.2	1,862.8	5.7	866.8	5.9	7	5.1	54,492.9	259	81	70	65	64	55	275	30,246.1	255	33	2.3	184	257	222	326.3	0.6	9.6	13.0	14.3	31.3	31.3	-	14.5	15.1
	Su	07/08/07	7:45	1,960.1	1,932.3	1,874.0	11.3	878.4	11.6	34	4.5	54,677.0	265	82	67	69	68	57	268	30,423.4	262	19	2.3	184	258	223	327.1	12.1	6.2	9.1	27.4	13.0	13.1	16.5	16.2	16.4
	M	07/09/07	12:00	1,972.0	1,944.3	1,886.0	12.0	890.9	12.5	26	4.8	54,870.5	258	78	69	71	70	56	290	30,607.6	257	4	2.3	185	259	224	328.4	7.5	2.0	4.7	15.6	6.6	6.7	11.3	-	2.0
	T	07/10/07	8:10	1,976.1	1,948.8	1,890.5	4.4	895.6	4.7	23	4.9	54,941.6	252	81	70	66	64	55	282	30,674.7	256	41	2.1	186	259	224	328.8	0.3	6.5	7.2	14.7	21.3	21.3	6.7	15.8	15.0
	W	07/11/07	10:00	1,989.6	1,962.2	1,903.8	13.4	909.7	14.1	15	4.3	55,161.5	260	82	69	71	69	57	276	30,887.3	264	25	2.2	187	261	226	330.9	7.1	4.1	5.5	12.3	12.3	12.3	9.2	7.1	8.8
44	R	07/12/07	11:10	1,993.6	1,966.3	1,907.8	4.0	914.2	4.5	26	6.8	55,230.5	256	79	69	69	71	56	298	30,953.4	273	20	2.2	188	262	227	332.1	1.9	1.1	0.7	20.3	20.3	20.1	-	-	-
	F	07/13/07	13:45	2,002.8	1,975.5	1,917.0	9.2	923.4	9.2	20	4.9	55,375.1	262	82	68	65	66	55	279	31,090.5	248	9	2.3	188	262	227	332.1	11.1	10.3	9.9	37.9	37.9	37.7	-	13.6	17.6
	Sa	07/14/07	11:15	2,012.5	1,984.8	1,926.4	9.5	933.2	9.8	30	4.8	55,521.0	248	83	67	70	75	57	295	31,229.4	245	35	2.1	188	263	228	333.0	20.8	6.0	1.7	49.7	11.8	11.8	20.9	9.4	-
	Su	07/15/07	9:50	2,018.3	1,990.7	1,932.7	6.0	939.5	6.3	27	3.6	55,620.0	262	80	67	70	65	55	275	31,325.5	267	27	2.4	189	264	228	333.9	5.7	2.5	8.0	16.3	16.3	28.1	11.9	10.2	10.2
	M	07/16/07	11:15	2,031.0	2,003.4	1,945.4	12.7	952.6	13.1	19	4.6	55,823.3	259	82	68	68	67	56	270	31,519.6	255	11	2.4	190	265	229	335.1	6.5	5.0	10.5	11.7	11.8	11.7	13.9	9.4	20.8
	T	07/17/07	12:30	2,041.6	2,014.0	1,955.7	10.5	963.7	11.1	13	4.1	55,993.7	256	80	70	67	73	56	305	31,682.9	259	1	1.8	191	266	231	336.7	3.2	6.2	0.0	14.6	14.6	14.6	10.0	7.7	9.7
	W	07/18/07	11:00	2,051.7	2,024.1	1,965.8	10.1	974.2	10.5	6	5.0	56,156.6	259	80	71	68	73	56	301	31,839.3	258	29	2.4	192	267	232	338.0	3.3	8.6	0.4	11.9	11.9	11.9	-	13.1	-
45	R	07/19/07	7:20	2,059.2	2,031.5	1,973.4	7.5	982.0	7.8	34	4.7	56,280.7	265	81	66	71	66	56	273	31,956.9	261	20	2.2	192	268	232	338.5	10.8	2.9	8.0	24.4	12.5	24.4	-	-	11.7
	F	07/20/07	8:15	2,066.1	2,038.4	1,980.0	6.8	989.0	7.0	30	4.7	56,381.0	239	83	66	67	74	55	292	32,059.2	251	10	3.0	192	268	233	338.8	17.7	9.9	2.9	42.3	30.4	17.9	18.6	12.0	9.5
	Sa	07/21/07	8:40	2,073.9	2,046.2	1,987.9	7.8	997.1	8.1	23	6.2	56,513.8	273	80	66	66	71	55	278	32,181.3	260	36	2.0	193	269	234	340.0	6.9	5.7	1.3	15.8	15.9	15.8	-	-	-
	Su	07/22/07	NM	NM	NM	NM	NA	NM	NA	NM		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	-	20.7	13.3
	M	07/23/07	13:20	2,096.2	2,068.4	2,010.6	22.4	1,020.2	23.1	6		56,874.5	260	81	74	70	69	56	304	32,524.3	255	9	2.2	195	271	235	342.1	0.0	7.2	10.7	12.4	12.5	12.4	-	12.2	12.9
	T	07/24/07	15:20	2,105.2	2,077.1	2,019.3	8.8	1,029.3	9.1	34	3.3	57,014.6	257	79	68	68	68	55	290	32,659.8	257	34	2.1	195	272	236	342.9	9.0	3.7	6.5	29.4	17.0	17.0	10.7	8.8	9.3
	W	07/25/07	10:05	2,113.9	2,085.9	2,028.1	8.8	1,038.5	9.2	28	4.9	57,158.0	260	82	71	70	70	57	295	32,796.8	260	23	2.3	196	273	237	344.1	7.0	3.7	6.0	9.4	9.4	9.5	11.9	9.7	8.3
46	R	07/26/07	8:00	2,120.8	2,092.8	2,035.1	6.9	1,046.0	7.5	24	4.1	57,272.3	254	80	71	67	67	57	292	32,907.6	266	14	2.4	197	274	238	345.4	2.0	0.9	4.7	0.0	0.0	14.5	-	9.6	8.8
	F	07/27/07	8:00	2,131.3	2,103.1	2,045.5	10.4	1,056.7	10.7	18	4.2	57,439.1	260	82	65	69	69	57	268	33,066.3	254	4	1.8	197	275	239	346.2	12.5	1.6	6.3	13.4	0.0	13.3	13.9	9.6	11.2
	Sa	07/28/07	9:30	2,139.7	2,111.6	2,054.0	8.5	1,065.5	8.8	13	4.3	57,575.8	259	82	68	71	71	58	288	33,199.3	262	36	2.2	198	276	240	347.4	7.0	0.5	3.6	16.5	0.0	0.0	10.5	9.0	8.7
	Su	07/29/07	22:10	2,148.1	2,120.1	2,062.4	8.4	1,074.4	8.9	7	5.1	57,714.3	259	79	69	69	69	56	312	33,329.9	258	26	2.2	199	277	241	348.6	4.9	0.0	3.3	12.7	12.7	12.7	9.5	-	-
	M	07/30/07	16:00	2,153.4	2,125.8	2,068.1	5.6	1,080.2	5.8	19	5.2	57,804.3	259	79	72	68	68	56	284	33,416.9	260	19	2.3	200	277	241	349.1	0.7	5.7	9.0	12.0	24.7	24.7	-	8.5	10.5
	T	07/31/07	12:45	2,158.4	2,130.5	2,072.7	4.8	1,085.2	5.0	17	3.0	57,883.0	262	78	68	71	69	56	288	33,492.9	266	12	2.7	200	278	242	349.4	5.7	1.9	3.1	27.5	15.5	15.6	9.9	-	-
	W	08/01/07	9:05	2,163.5	2,136.0	2,078.1	5.3	1,090.8	5.6	13	5.5	57,968.7	255	79	71	65	66	55	285	33,574.3	254	5	2.4	201	278	242	350.3	0.9	7.4	8.5	14.8	30.3	30.4	7.3	-	-
47	R	08/02/07	11:00	2,173.1	2,145.3	2,088.1	9.6	1,100.9	10.1	6	5.4	58,121.9	253	84	71	73	64	55	280	33,720.9	254	37	2.0	202	280	242	351.6	3.2	1.4	18.5	15.0	15.0	15.4	7.3	7.0	25.1
	F	08/03/07	14:10	2,185.2	2,157.7	2,100.2	12.2	1,113.5	12.6	29	5.5	58,313.9	254	79	67	68	68	55	290	33,905.6	252	23	2.2	203	281	243	352.9	8.0	6.8	5.5	15.3	15.3	15.3	10.3	-	9.1
	Sa	08/04/07	11:00	2,195.7	2,167.9	2,110.7	10.4	1,124.4	10.9	20	6.2	58,483.0	259	79	68	72	68	56	283	34,068.2	261	10	2.3	204	283	244	354.5	8.2	1.4	6.9	9.9	9.9	9.9	11.1	7.5	8.7
	Su	08/05/07	11:00	2,204.0	2,176.4	2,119.0	8.4	1,133.1	8.7	14	5.2	58,618.2	259	81	67	69	65	55	273	34,200.2	263	35	2.2	205	284	245	355.8	5.4	2.4	6.5	15.3	15.3	15.3	-	-	-
	M	08/06/07	13:20	2,214.6	2,186.9	2,129.4	10.5	1,144.2	11.1	8	4.1	58,788.9	256	79	68	69	72	55	305	34,362.0	257	24	1.9	206	285	247	357.3	6.6	5.5	0.9	15.2	15.1	15.2	11.2	7.9	8.9
	T	08/07/07	11:40	2,222.7	2,195.1	2,137.6	8.2	1,152.8	8.6	33	5.3	58,922.2	258	79	70	68	73	56	302	34,490.2	262	13	2.5	207	286	248	358.6	3.5	5.8	0.2	13.6	13.6	13.6	-	9.1	-
	W	08/08/07	9:50	2,230.1	2,202.2	2,145.1	7.3	1,160.3	7.5	27	6.0	59,039.4	260	83	67	69	65	55	275	34,601.6	253	3	2.6	207	287	248	359.0	10.9	3.8	7.7	27.5	13.8	27.5	-	-	-
48	R	08/09/07	7:45	2,237.7	2,210.0	2,162.9	11.1	1,169.0	8.7	21	5.2	59,174.7	259	77	67	66	69	55	290	34,732.5	197	23	2.2	209	289	250	361.4	3.8	3.3	2.7	14.2	14.2	14.2	-	7.6	5.9
	F	08/10/07	12:30	2,246.9	2,218.9	2,167.9	7.7	1,178.1	9.1	15	5.0	59,316.4	260	81	65	68	72	55	295	34,868.9	295	12	2.3	209	290	251	362.2	13.0	4.6	1.8	33.8	19.6	19.5	14.0	9.6	-
	Sa	08/11/07	16:50	2,254.8	2,226.8	2,170.1	6.0	1,186.4	8.3	24	6.3	59,446.0	260	82	68	71	66	55	297	34,993.9	347	39	1.8	210	291	251	363.0	6.9	2.9	10.0	19.9	19.8	39.3	10.1	8.2	10.6
	Su	08/12/07	17:30	2,262.5	2,234.5	2,178.0	7.8	1,194.7	8.3	18	5.5	59,574.1	257	82	66	67	65	56	270	35,115.7	261	29	2.3	211	292	252	364.3	4.5	2.4	7.3	14.8	14.8	14.8	9.4	8.5	8.4
	M	08/13/07	13:55	2,271.8	2,243.9	2,187.4	9.4	1,204.5	9.8	10	6.1	59,727.0	260	81	68	69	66	55	275	35,263.1	262	16	2.5	212	293	253	365.5	4.4	3.3	8.3	11.8	11.7	11.8	12.2	8.0	9.5
	T	08/14/07	12:45	2,279.6	2,251.8	2,195.2	7.8	1,212.7	8.2	5	4.6	59,854.0	258	80	73	71	68	56	307	35,383.6	256	6	2.4	213	294	254	366.7	0.0	3.2	6.6	15.0	15.0	15.0	9.2	8.9	9.3
	W	08/15/07	10:20	2,289.3	2,261.5	2,204.9	9.7	1,222.9	10.2	12	6.0	60,011.1	257	81	74	70	69	57	302	35,535.0	260	31	2.3	214	295	255	367.9	0.5	4.0	7.0	11.3	11.3	11.3	-	9.0	9.3
49	R	08/16/07	8:15	2,294.6	2,266.5	2,209.9	5.1	1,228.3	5.4	8	5.7	60,093.9	256	80	66	72	69	55	296	35,613.9	258	24	2.5	214	296	256	368.8	5.5	0.0	2.7	27.4	16.1	16.2	9.8	-	9.5
	F	08/17/07	8:00	2,301.7	2,273.9	2,216.9	7.2	1,235.8	7.5	35	5.0	60,210.6	259	82	70	65	69	55	284	35,726.6	262	15	2.3	215	296	257	369.5	2.8	7.4	0.2	15.7	31.8	15.8	-	8.5	8.2
	Sa	08/18/07	8:45	2,310.1	2,281.9	2,225.0	8.2	1,244.2	8.4	31	3.6	60,341.6	260	82	66	66	73	55	293	35,851.2	254	5	2.3	215	297	258	370.3	11.2	6.9	0.1	32.5	16.9	16.8	-	-	-
	Su	08/19/07	11:40	2,321.8	2,293.7	2,237.0	11.8	1,252.8	8.6	27	2.4	60,534.5	374	79	71	68	73	55	301	36,037.6	262	34	2.0	217	299	260	372.8	3.5	5.0	0.0	14.8	14.8	14.8	-	-	-
	M	08/20/07	11:00	2,327.6	2,299.1	2,242.7	5.6	1,262.6	9.8	25	2.6	60,625.2	154	81	69	71	68	56	297	36,124.0	256	26	2.6	217	300	260	373.2	9.3	2.8	5.7	32.1	17.4	32.1	13.8	-	7.6
	T	08/21/07	11:45	2,332.8	2,304.6	2,247.9	5.3	1,268.2	5.6	21	5.4	60,711.9	258	79	72	67	71	56	300	36,207.3	262	20	2.1	218	300	261	374.0	0.7	8.3	3.3	19.1	36.5	19.1	-	11.9	-
	W	08/22/07	10:50	2,338.5	2,309.9	2,253.7	5.6	1,274.0	5.8	17	3.8	60,803.6	264	80	70	73	69	57	302	36,294.7	260	12	2.6	218	301	261	374.5	6.4	1.7	9.0	36.3	17.2	36.3	-	-	-
50	R	08/23/07	11:25	2,343.7	2,315.1	2,258.9	5.2	1,279.3	5.3	13	5.7	60,886.4	260	81	67	68	67	56	280	36,373.7	253	5	2.5	218	301	261	374.5	11.6	6.9	14.2	55.4	36.3	55.3	15.3	11.7	15.7
	F	08/24/07	11:50	2,350.0	2,321.3	2,265.2	6.3	1,286.0	6.7	8	5.7	60,990.1	258	78	68	70	67	56	286	36,473.7	266	40	2.0	219	302	262	375.7	2.6	1.4	4.8	17.8	17.8	17.8	-	7.0	7.7
	Sa	08/25/07	11:15	2,356.7	2,327.8	2,271.6	6.5	1,292.8	6.8	35	5.5	61,096.0	260	80	67	73	70	56	297	36,574.3	257	31	2.5	219	303	263	376.5	9.3	0.9	3.5	34.5	16.7	16.7	9.9	-	7.7
	Su	08/26/07	11:40	2,362.4	2,334.3	2,277.8	6.1	1,299.5	6.7	30	5.7	61,199.1	256	82	69	66	71	55	290	36,673.8	271	27	1.2	220	303	264	377.4	5.1	7.4	2.0	17.7	34.5	17.8	9.7	8.0	8.1
	M	08/27/07	10:00	2,369.9	2,341.4	2,284.8	7.2	1,306.8	7.3	23	7.2	61,313.7	262	81	70	66	73	56	295	36,783.8	255	15	3.1	221	304	265	378.6	2.9	6.5	0.9	14.5	14.5	14.5	-	8.6	-
	T	08/28/07	11:50	2,377.1	2,348.3	2,292.1	7.1	1,314.1	7.3	17	6.2	61,427.6	260	83	67	70	66	55	285	36,892.2	253	6	2.4	221	305	265	379.0	10.1	4.8	8.2	33.1	18.4	33.0	11.6	8.7	8.9
51	W	08/29/07	10:20	2,384.6	2,356.1	2,299.7	7.6	1,322.2	8.1	13	3.8	61,551.8	256	82	71	71	68	56	300	37,011.7	261	39	2.2	222	306	266	380.3	6.0	3.9	6.9	14.7	14.7	14.7	9.4	9.3	7.6
	R	08/30/07	9:30	2,390.7	2,362.3	2,306.0	6.2	1,328.8	6.6	38	4.6	61,653.9	258	78	69	71	67	55	302	37,110.4	265	31	2.3	223	307	267	381.5	2.7	0.8	5.6	16.6	16.6	16.6	-	7.4	8.4
	F	09/01/07	10:55	2,398.6	2,369.9	2,313.7	7.7	1,336.8	8.0	32	5.6	61,779.2	261	79	65	71	67	55	283	37,230.7	259	22	2.2	223	308	268	382.3	10.6	1.0	4.9	33.8	17.2	17.2	19.6	15.2	15.2
	Su	09/02/07	11:00	2,413.5	2,385.1	2,328.8	15.1	1,352.7	15.9	20	5.7	62,026.9	260	NA	NA	NA	NA	55	NA	NA	NA	25	2.2	225	310	270	384.8	5.9	1.0	4.8	NM	NM	NM	11.6	-	9.1
	M	09/03/07	14:55	2,420.2	2,392.3	2,335.6	6.9	1,360.0	7.3	15	5.2	62,139.5	257	78	70	65	70	55	285	37,577.3	NA	16	2.4	226	310	271	385.6	1.0	8.2	2.5	13.5	32.2	13.5	-	10.1	10.0
	T	09/04/07	11:00	2,428.5	2,400.2	2,343.1	7.9	1,368.3	8.3	9	5.4	62,270.1	262	80	70	70	74	57	298	37,701.0	261	6	2.3	226	311	272	386.5	9.3	6.0	0.0	25.1	11.7	11.7	12.4	8.0	4.8
	W	09/05/07	9:45	2,432.8	2,404.5	2,347.9	4.5	1,373.0	4.7	38	5.0	62,341.1	252	79	70	68	73	55	307	37,769.7	256	36	2.1	227	312	273	387.7	1.2	2.3	0.0	18.1	18.1	18.1	3.1	4.9	3.2
52	R	09/06/07	12:50	2,440.1	2,411.9	2,355.3	7.4	1,380.7	7.7	32	5.8	62,463.3	265	77	67	68	68	55	290	37,888.5	269	27	2.2	228	313	274	388.9	5.4	4.8	4.2	19.2	19.2	19.2	-	10.2	13.5
	F	09/07/07	12:50	2,449.7	2,421.3	2,364.6	9.4	1,390.5	9.8	25	5.4	62,614.2	257	80	67	72	74	56	305	38,032.5	254	15	2.4	228	314	275	389.7	15.0	4.0	0.0	33.6	14.4	14.4	19.3	-	-
	Sa	09/08/07	14:00	2,454.5	2,426.5	2,369.8	5.1	1,395.7	5.2	21	5.7	62,696.7	264	79	73	68	70	57	275	38,111.5	260	9	2.2	229	314	275	390.1	0.5	9.2	5.2	17.4	34.1	34.1	7.8	11.8	9.6
	Su	09/09/07	12:15	2,463.7	2,435.7	2,378.9	9.2	1,405.3	9.6	14	5.5	62,845.8	259	81	73	68	70	56	298	38,254.6	260	34	2.0	230	315	276	391.3	1.9	6.6	4.7	15.1	15.1	15.1	-	8.3	9.6
	M	09/10/07	10:20	2,469.6	2,441.2	2,384.4	5.6	1,411.3	6.0	9	6.4	62,937.8	256	79	67	68	72	55	296	38,343.3	NA	26	2.6	230	316	277	392.2	7.8	3.8	0.6	31.7	16.7	16.7	12.1	10.5	-
	T	09/11/07	12:15	2,476.8	2,448.4	2,391.9	7.3	1,418.9	7.6	4	4.9	63,056.8	261	78	71	72	68	55	306	38,457.1	260	17	2.3	231	317	277	393.0	2.9	0.5	8.1	17.6	17.6	17.6	-	-	12.0
53	W	09/12/07	12:40	2,483.2	2,454.8	2,398.0	6.3	1,425.4	6.5	31	5.7	63,159.6	264	80	68	69	72	55	296	38,555.1	259	9	2.3	231	317	278	393.4	9.3	6.9	2.2	35.4	35.4	17.8	13.5	9.2	8.1
	R	09/13/07	16:00	2,489.1	2,461.0	2,404.1	6.1	1,431.8	6.4	26	5.9	63,259.0	259	79	70	66	72	55	297	38,651.3	264	39	2.1	232	318	279	394.6	1.7	3.9	0.2	20.9	20.9	20.9	-	7.0	6.7
	F	09/14/07	16:25	2,496.6	2,468.1	2,411.3	7.3	1,439.5	7.7	20	5.9	63,377.5	256	82	66	70	73	56	293	38,764.7	260	30	2.3	232	319	280	395.4	9.2	4.0	0.7	37.4	16.5	16.5	10.2	8.2	9.0
	Su	09/16/07	18:10	2,508.1	2,479.6	2,422.9	11.5	1,451.5	12.0	11	5.6	63,565.9	262	82	69	69	73	57	295	38,944.9	260	15	2.4	233	320	281	396.7	10.5	7.3	3.3	37.8	38.0	14.0	12.8	12.1	-

Table A-1. US EPA Demonstration Project at Felton, DE - Daily Operational Log Sheet (Continued)

Start-up Date: October 12, 2006

Week No.	Day of Week	Date	Time	Cumulative Hrs in Service TA (hr)	Cumulative Hrs in Service TB (hr)	Cumulative Hrs in Service TC (hr)	Avg Run Time (hr)	Hour Meter (hr)	Run Time (hr)	Chlorine Tank Level (gal)	Cl dosage (mg/L)	Totalizer to: Totalizer (kgal)	Totalizer to: Avg Flow Rate (gpm)	Pressure Filtration: Influent (psig)	Pressure Filtration: Outlet TA (psig)	Pressure Filtration: Outlet TB (psig)	Pressure Filtration: Outlet TC (psig)	Pressure Filtration: Effluent (psig)	Flow/Totalizer to: Flow Rate (gpm)	Flow/Totalizer to: Totalizer (kgal)	Flow/Totalizer to: Avg Flow Rate (gpm)	Ferric Chloride: $FeCl_3$ Tank Level (gal)	Ferric Chloride: Fe Dosage (mg/L)	Backwash: Tank A (No.)	Backwash: Tank B (No.)	Backwash: Tank C (No.)	Backwash: Total (kgal)	Since Last BW Run Time Tank A (hr)	Since Last BW Run Time Tank B (hr)	Since Last BW Run Time Tank C (hr)	Since Last BW Standby Time Tank A (hr)	Since Last BW Standby Time Tank B (hr)	Since Last BW Standby Time Tank C (hr)	Actual Run Time Between BW Tank A (hr)	Actual Run Time Between BW Tank B (hr)	Actual Run Time Between BW Tank C (hr)
54	M	09/17/07[j]	13:40	2,512.9	2,484.4	2,428.1	4.9	1,456.8	5.3	7	5.8	63,647.0	255	80	72	73	69	56	312	39,022.3	NA	8	2.6	234	321	281	397.5	2.5	0.0	8.5	14.2	14.2	28.2	-	-	12.4
	T	09/18/07	11:05	2,518.9	2,490.5	2,433.9	6.0	1,462.9	6.1	35	6.1	63,743.0	262	83	69	68	73	57	293	39,114.4	257	41	2.8	234	321	282	397.9	8.5	6.1	1.9	29.6	29.6	1.9	11.1	6.7	-
	W	09/19/07	10:45	2,523.2	2,494.8	2,438.6	4.4	1,467.7	4.8	31	6.4	63,815.9	253	81	72	69	67	56	298	39,184.4	263	33	3.3	235	322	282	398.8	1.7	3.7	6.6	19.0	19.0	34.3	-	6.7	7.4
	R	09/20/07	13:15	2,529.9	2,501.1	2,445.0	6.5	1,474.4	6.7	26	5.6	63,920.3	260	82	67	71	68	56	293	39,284.6	258	21	3.4	235	323	283	399.6	8.4	3.3	5.6	38.6	19.6	19.6	9.1	9.4	7.8
	F	09/21/07	16:10	2,535.9	2,507.2	2,451.0	6.0	1,480.9	6.5	21	5.8	64,021.1	258	80	68	73	69	56	307	39,381.5	268	10	3.3	236	324	284	400.8	5.3	0.0	3.8	20.3	20.3	20.3	9.5	12.3	13.0
	Su	09/23/07	16:20	2,549.3	2,520.5	2,464.2	13.3	1,494.8	13.9	10	6.0	64,237.7	260	80	68	73	70	56	302	39,590.6	262	24	2.9	237	326	286	402.9	9.2	1.0	4.0	34.2	13.8	13.8	11.9	-	-
55	M	09/24/07	16:30	2,555.4	2,527.0	2,470.7	6.4	1,501.4	6.6	6	4.6	64,339.7	258	82	73	68	68	56	296	39,687.9	NA	13	3.2	238	326	286	403.3	3.4	7.5	10.5	17.5	31.3	31.3	9.4	9.7	11.3
	T	09/25/07	13:50	2,561.6	2,533.3	2,477.0	6.3	1,508.1	6.7	34	5.7	64,443.0	257	81	74	68	68	57	300	39,787.7	266	38	2.9	239	327	287	404.5	0.2	4.1	5.5	14.6	14.6	14.6	-	7.1	6.6
	W	09/26/07	15:10	2,566.9	2,538.3	2,481.9	5.1	1,513.5	5.4	30	5.7	64,526.0	256	81	67	69	69	55	296	39,867.8	263	29	3.2	239	328	288	405.3	5.5	2.0	3.8	34.5	193.9	19.9	7.5	8.7	7.7
	R	09/27/07	14:45	2,574.4	2,545.8	2,489.4	7.5	1,521.4	7.9	26	3.8	64,649.2	260	79	68	70	70	55	304	39,986.6	264	16	3.2	240	329	289	406.6	5.5	0.8	3.6	15.7	15.7	15.7	-	-	-
	F	09/28/07	14:10	2,581.2	2,552.6	2,496.2	6.8	1,528.2	6.8	22	4.4	64,756.4	263	82	68	67	67	56	280	40,088.9	251	5	3.1	240	329	289	406.6	12.3	7.6	10.4	32.1	32.0	32.1	13.9	10.3	11.2
	Sa	09/29/07	15:25	2,586.8	2,558.3	2,501.9	5.7	1,534.4	6.2	18	5.0	64,850.0	252	82	70	68	68	56	296	40,179.8	267	38	2.9	241	330	290	407.9	4.0	3.0	4.9	19.2	19.2	19.2	8.0	5.3	5.7
	Su	09/30/07	14:10	2,593.6	2,565.2	2,508.7	6.8	1,541.6	7.2	14	4.2	64,961.7	259	82	71	68	68	56	296	40,286.6	261	26	3.2	242	331	291	409.1	2.8	4.6	6.0	17.6	17.6	17.6	9.7	6.8	6.7
56	M	10/01/07	15:25	2,600.5	2,572.1	2,515.7	6.9	1,549.0	7.4	9	5.2	65,075.5	256	81	74	71	69	56	305	40,395.7	262	14	3.2	243	332	292	410.4	0.0	4.7	6.3	15.7	15.7	15.7	-	9.9	8.7
	T	10/02/07	13:55	2,606.0	2,577.3	2,520.8	5.3	1,554.6	5.6	6	4.1	65,162.2	258	80	69	73	71	57	310	40,478.2	261	4	3.5	243	333	293	411.2	5.5	0.0	2.7	32.6	16.9	16.9	7.8	-	7.5
	W	10/03/07	13:40	2,611.0	2,583.5	2,526.7	5.7	1,560.8	6.2	28	4.9	65,258.3	258	78	69	65	71	55	285	40,572.1	275	29	3.1	244	333	294	412.0	2.7	6.2	1.1	17.4	34.3	17.4	-	7.3	6.9
	R	10/04/07	15:35	2,619.3	2,590.7	2,533.9	7.6	1,568.4	7.6	23	5.0	65,375.8	258	82	67	67	73	55	292	40,684.1	247	17	3.1	244	334	295	412.8	10.2	6.1	1.4	35.6	18.2	18.2	11.0	8.3	-
	F	10/05/07	11:30	2,623.5	2,594.9	2,538.5	4.3	1,573.0	4.6	20	4.9	65,447.9	261	77	68	68	67	55	290	40,754.1	269	9	3.3	245	335	295	413.6	3.4	2.0	6.0	15.4	15.4	33.6	10.2	7.2	9.1
	Sa	10/06/07	12:00	2,631.5	2,603.0	2,546.6	8.1	1,581.5	8.5	32	4.5	65,579.3	258	NM	NM	NM	NM	NM	NM	40,879.9	260	40	2.3	246	336	296	414.9	1.2	2.9	5.0	NM	NM	NM	7.3	5.3	12.4
	Su	10/07/07	15:30	2,639.2	2,610.7	2,554.0	7.6	1,589.6	8.1	27	4.7	65,704.7	258	80	71	67	73	56	303	41,000.8	265	27	3.1	247	337	298	416.5	1.6	5.3	0.0	13.7	13.8	13.8	-	7.1	6.7
57	M	10/08/07	16:10	2,646.2	2,617.3	2,560.7	6.8	1,596.7	7.1	22	5.4	65,813.6	256	81	67	69	74	55	307	41,104.8	NA	16	3.0	247	338	299	417.3	8.6	4.8	0.0	31.7	18.0	18.0	10.1	9.7	-
	T	10/09/07	16:00	2,653.9	2,624.9	2,568.7	7.8	1,604.7	8.0	17	4.6	65,940.1	264	80	71	72	68	55	300	41,226.3	261	3	3.1	248	339	299	418.0	6.2	2.7	8.0	16.0	16.0	34.0	9.5	7.3	9.1
	W	10/10/07	12:10	2,659.4	2,630.4	2,574.2	5.5	1,610.7	6.0	14	3.9	66,031.0	252	80	71	71	69	57	301	41,314.6	268	29	3.0	249	340	300	419.4	2.2	0.9	4.4	14.2	14.2	14.2	3.2	2.5	6.9
	R	10/11/07	14:00	2,663.6	2,634.7	2,578.5	4.3	1,615.4	4.7	11	4.8	66,104.0	259	82	68	67	68	55	275	41,385.9	279	21	3.3	250	341	301	420.7	3.2	2.7	1.8	20.2	20.2	20.2	-	7.6	8.1
	F	10/12/07	12:55	2,671.2	2,642.7	2,585.8	7.6	1,623.1	7.7	7	3.9	66,224.0	260	83	67	70	74	58	290	41,499.9	249	9	3.0	250	342	302	421.5	10.8	3.1	1.0	35.9	15.7	15.7	18.9	12.6	6.0
	Su	10/14/07	13:00	2,682.8	2,653.7	2,597.8	11.5	1,635.6	12.5	30	4.9	66,416.4	257	80	71	71	66	57	282	41,685.8	269	24	3.1	252	344	303	423.7	3.5	1.5	7.0	12.8	12.8	35.8	-	-	8.2
58	M	10/15/07	14:20	2,687.4	2,658.3	2,602.1	4.5	1,640.3	4.7	27	4.8	66,489.8	260	83	66	74	68	57	287	41,756.0	260	16	3.3	252	344	304	424.1	8.2	6.1	3.1	11.2	0.0	6.1	12.2	7.7	10.7
	T	10/16/07	12:10	2,695.0	2,665.9	2,609.7	7.6	1,648.3	8.0	22	4.8	66,612.9	256	81	71	68	75	57	302	41,872.9	256	3	3.2	253	345	305	425.3	3.6	6.0	0.0	15.4	15.4	15.4	-	8.1	-
	W	10/17/07	12:00	2,700.4	2,671.0	2,615.1	5.3	1,653.8	5.5	18	5.5	66,697.9	258	82	68	72	68	56	295	41,954.5	257	15	3.2	253	346	305	425.7	9.0	3.0	5.4	33.8	18.4	33.8	10.9	8.4	6.1
	R	10/18/07	13:25	2,706.8	2,677.5	2,621.6	6.5	1,660.6	6.8	14	4.4	66,804.1	260	79	69	72	68	56	301	42,056.9	264	4	3.1	254	347	306	427.0	4.5	1.1	5.8	18.6	18.6	18.6	8.0	5.5	7.7
	F	10/19/07	13:35	2,712.7	2,683.6	2,627.7	6.0	1,667.1	6.5	10	4.7	66,903.0	254	79	69	69	65	56	280	42,153.4	267	38	2.7	255	348	307	428.3	2.4	1.7	4.2	17.6	17.6	17.6	8.4	5.5	5.3
	Sa	10/20/07	14:15	2,718.7	2,689.6	2,633.7	6.0	1,673.6	6.5	38	4.7	67,003.1	257	80	74	70	68	55	307	42,248.7	265	28	4.8	256	349	308	429.6	0.0	2.2	4.9	18.2	18.2	18.2	-	-	7.5
	Su	10/21/07	10:40	2,725.9	2,696.8	2,640.6	7.1	1,680.8	7.2	34	4.1	67,116.5	262	83	71	69	74	58	295	42,357.1	254	17	2.9	256	349	309	430.0	7.2	9.4	4.3	31.4	31.4	13.1	-	10.4	-
59	M	10/22/07	9:45	2,729.9	2,700.5	2,644.7	3.9	1,685.0	4.2	31	5.5	67,180.4	254	79	66	70	66	55	286	42,418.8	262	10	3.3	256	350	309	430.4	11.2	2.7	8.4	50.2	18.8	31.9	12.5	6.6	10.6
	T	10/23/07	14:00	2,737.8	2,708.5	2,652.6	7.9	1,693.3	8.3	26	4.6	67,309.2	259	82	68	69	67	55	279	42,542.9	261	33	2.8	257	351	310	431.6	6.6	4.1	5.7	19.4	19.4	19.4	9.0	9.0	7.0
	W	10/24/07	10:35	2,745.0	2,715.8	2,659.8	7.2	1,701.0	7.7	20	5.9	67,428.5	258	81	71	73	70	57	300	42,657.0	263	21	3.0	258	352	311	432.9	4.8	2.4	5.9	13.4	13.3	13.3	-	-	9.9
	R	10/25/07	9:30	2,749.2	2,720.0	2,663.8	4.1	1,705.3	4.3	18	3.6	67,494.3	255	81	68	68	74	57	300	42,719.9	253	14	3.2	258	352	312	433.3	9.0	6.6	0.0	32.0	31.9	18.6	-	10.6	-
	F	10/26/07	10:20	2,755.5	2,726.0	2,670.2	6.2	1,711.7	6.4	14	4.7	67,593.8	259	82	67	73	69	57	294	42,814.3	252	4	3.0	258	353	312	433.7	15.3	2.0	6.4	50.3	18.3	36.9	16.2	6.3	8.6
	Sa	10/27/07	12:45	2,761.4	2,731.9	2,676.2	5.9	1,718.1	6.4	29	4.8	67,691.8	255	81	68	72	69	56	298	42,909.1	266	35	2.7	259	354	313	436.0	5.0	1.6	3.8	20.2	20.2	20.2	6.8	1.8	6.9
	Su	10/28/07	NM	2,767.3	2,733.0	2,682.2	4.3	1,724.5	6.4	25	4.7	67,790.7	258	NM	NM	NM	NM	NM	NM	43,004.9	368	25	3.0	260	355	314	436.2	4.1	0.9	2.9	NM	NM	NM	10.3	-	6.9
60	M	10/29/07	13:50	2,774.1	2,745.1	2,689.0	8.6	1,731.7	7.2	20	5.3	67,901.8	257	81	73	68	72	57	306	43,111.3	207	13	3.2	261	355	315	437.1	0.6	8.0	2.8	13.9	34.7	13.9	-	9.4	6.8
	T	10/30/07	11:35	2,780.0	2,750.8	2,694.9	5.8	1,738.2	6.5	16	4.7	68,002.0	257	84	69	69	74	57	294	43,206.4	272	38	2.7	261	356	316	437.9	6.6	4.3	1.9	29.5	15.6	15.6	7.3	6.1	-
	W	10/31/07	10:30	2,784.2	2,755.0	2,699.5	4.3	1,742.8	4.6	13	4.9	68,073.2	258	81	69	69	66	55	276	43,275.8	267	30	3.4	262	357	316	438.8	3.5	2.4	6.4	17.5	17.5	33.2	-	7.9	8.0
	R	11/01/07	11:20	2,791.2	2,761.8	2,706.2	6.8	1,749.9	7.1	8	5.3	68,183.3	258	81	68	73	70	56	295	43,380.5	255	19	3.0	262	358	317	439.6	10.5	1.3	5.1	35.9	18.4	18.4	12.8	-	-
	F	11/02/07	11:25	2,796.9	2,768.0	2,712.3	6.0	1,756.1	6.2	4	4.9	68,279.8	259	81	72	68	67	55	295	43,472.4	255	9	3.1	263	358	317	440.0	3.4	7.4	11.2	17.5	36.0	35.9	8.5	9.2	18.4
	Sa	11/03/07	8:45	2,804.4	2,775.5	2,719.5	7.4	1,764.0	7.9	31	5.8	68,400.4	254	NM	NM	NM	NM	NM	NM	43,588.7	262	34	2.5	264	359	319	441.7	2.4	5.7	0.0	NM	NM	NM	-	-	-

(a) Operator began tracking the trigger that activated each backwash.
(b) Battelle personnel onsite for system inspection and operator training.
(c) Increased stroke on $FeCl_3$ chemical feed pump from 18 to 25. Target iron concentration of 1.5 mg/L.
(d) Minimum and maximum backwash time decreased from 10 to 5 min and 40 to 15 min, respectively. Turbidity threshold increased from 10 to 20 NTU.
(e) Cumulative hours in service for Tank A reset on its own.
(f) Differential pressure backwash trigger was reduced from 24 to 18 psi; stroke on chemical feed pump from 25 to 32 (target iron concentration of 2.0 mg/L).
(g) Hour meter installed at wellhead.
(h) Recycle system shut-off due to level of solids in recycle tank.
(i) Recycle system back on-line after solids were removed from the tank on May 11, 2007.
(j) Iron addition was switched to manual operation; FeCl3 pump settings: stroke = 75 and speed = 50.

APPENDIX B

ANALYTICAL DATA TABLES

Table B-1. Analytical Results from Long Term Sampling, Felton, DE

Sampling Date		10/12/06			10/18/06					10/25/06					11/01/06				
Sampling Location Parameter	Unit	IN	AC	TT	IN	AC	TA	TB	TC	IN	AC	TA	TB	TC	IN	AC	TA	TB	TC
Alkalinity	mg/L[(a)]	322	320	322	324	318	318	318	322	343	324	326	330	330	335	329	326	329	326
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	1.1	1.2	1.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	11	10	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P (total)	µg/L[(b)]	46.3	47.8	13.9	40.4	32.9	12.3	12.7	12.2	40.4	45.3	<10	<10	<10	50.7	50.2	18.1	18.7	17.7
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	9.7	9.6	9.0	9.9	9.7	9.5	9.5	9.6	9.6	9.5	8.7	9.0	8.5	8.9	9.2	9.7	8.6	8.7
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	0.5	1.1	0.6	0.7	1.5	3.4	4.2	1.0	1.8	2.2	2.0	1.2	1.1	1.4	1.9	0.9	0.7	1.0
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	8.3	8.3	8.4	8.1	7.9	7.9	7.9	8.0	8.1	7.9	7.9	7.9	7.9	NA	NA	NA	NA	NA
Temperature	°C	19.6	19.1	19.1	20.2	20.2	20.3	20.3	14.8	14.7	14.7	14.7	14.8	14.8	NA	NA	NA	NA	NA
DO	mg/L	0.9	0.7	0.7	1.0	1.1	1.3	1.4	1.4	1.0	1.4	1.3	1.2	1.4	NA	NA	NA	NA	NA
ORP	mV	417	539	572	392	530	560	567	556	303	507	560	583	556	NA	NA	NA	NA	NA
Free Chlorine	mg/L	-	1.7	1.2	-	0.4	0.4	0.5	0.5	-	0.8	0.8	0.8	0.7	-	NA	NA	NA	NA
Total Chlorine	mg/L	-	1.8	1.3	-	0.4	0.5	0.5	0.6	-	0.8	0.8	0.8	0.7	-	NA	NA	NA	NA
Total Hardness (as $CaCO_3$)	mg/L	37.1	37.8	36.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	13.9	14.1	14.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	23.2	23.8	22.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	33.5	32.7	9.1	36.1	30.2	10.6	10.4	10.3	37.1	41.9	10.1	10.5	9.7	34.0	32.6	9.5	9.5	9.2
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	30.7	10.2	8.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	2.7	22.5	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	29.1	0.7	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	1.6	9.5	8.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	27	1,151	<25	38	1,252	50	<25	<25	<25	2,230	83	85	57	40	1,363	<25	<25	<25
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	<25	<25	<25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	1.4	6.6	<0.1	1.4	6.3	0.3	0.2	0.2	1.5	10.1	0.6	0.6	0.5	1.4	6.4	<0.1	<0.1	<0.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	1.3	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(a) As CaCO3. (b) As P.

Table B-1. Analytical Results from Long Term Sampling, Felton, DE (Continued)

Sampling Date		11/8/2006[c]			11/15/06					11/29/06					12/06/06		
Sampling Location Parameter	Unit	IN	AC	TT	IN	AC	TA	TB	TC	IN	AC	TA	TB	TC	IN	AC	TT
Alkalinity	mg/L[a]	334	330	322	323	319	315	315	319	312	324	318	314	308	335	315	321
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	2.0	1.7	1.9	-	-	-	-	-	-	-	-	-	-	1.9	1.8	2.8
Sulfate	mg/L	10	10	10	-	-	-	-	-	-	-	-	-	-	11	11	11
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05
P (total)	µg/L[b]	28.5	35.1	<10	47.3	50.8	18.9	18.8	16.7	57.8	36.8	39.3	38.4	31.3	41.8	44.2	<10
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	9.1	9.5	9.5	9.5	9.2	9.0	8.8	8.9	9.1	8.6	8.6	9.1	8.9	9.3	9.4	8.8
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	0.7	1.2	1.0	0.9	1.2	1.1	0.9	1.1	4.8	1.0	0.8	0.8	0.6	1.0	2.1	1.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	8.1	7.9	7.9	8.5	8.5	7.9	8.2	8.3	8.2	8.2	8.2	8.2	8.2	8.1	8.1	8.2
Temperature	°C	18.8	18.7	18.7	18.8	18.7	18.6	18.6	18.5	18.5	18.5	18.4	18.4	18.5	18.2	18.1	18.1
DO	mg/L	1.2	1.1	1.1	0.5	1.4	1.2	0.9	0.8	0.9	0.9	0.8	0.7	1.2	1.1	1.2	1.1
ORP	mV	248	313	335	237	284	303	500	517	230	486	540	583	610	251	504	540
Free Chlorine	mg/L	-	0.8	0.8	-	0.7	0.6	0.5	0.5	-	0.5	0.6	0.6	0.7	-	0.8	0.7
Total Chlorine	mg/L	-	0.8	0.8	-	0.8	0.6	0.6	0.6	-	0.6	0.7	0.7	0.7	-	0.8	0.8
Total Hardness (as $CaCO_3$)	mg/L	38.6	39.3	39.0	-	-	-	-	-	-	-	-	-	-	41.3	40.9	39.7
Ca Hardness (as $CaCO_3$)	mg/L	16.9	17.3	17.2	-	-	-	-	-	-	-	-	-	-	19.3	20.2	19.8
Mg Hardness (as $CaCO_3$)	mg/L	21.7	22.0	21.9	-	-	-	-	-	-	-	-	-	-	22.0	20.7	19.9
As (total)	µg/L	28.1	31.1	9.5	36.1	38.8	11.8	12.2	11.9	28.8	12.2	11.2	8.0	8.7	39.0	41.7	7.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	26.8	8.1	7.9	-	-	-	-	-	-	-	-	-	-	33.7	11.3	6.5
As (particulate)	µg/L	1.3	22.9	1.6	-	-	-	-	-	-	-	-	-	-	5.2	30.4	0.6
As (III)	µg/L	25.9	0.9	0.9	-	-	-	-	-	-	-	-	-	-	30.7	0.6	0.5
As (V)	µg/L	0.9	7.3	7.0	-	-	-	-	-	-	-	-	-	-	3.0	10.6	6.0
Fe (total)	µg/L	<25	1,689	81	<25	1,017	<25	<25	<25	62	279	164	<25	<25	33	1,994	<25
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	<25	<25	<25	-	-	-	-	-	-	-	-	-	-	33	177	<25
Mn (total)	µg/L	1.4	8.0	0.4	1.4	6.0	<0.1	<0.1	<0.1	1.5	1.6	0.8	0.2	0.2	1.7	10.0	0.4
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	1.3	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	2.7	1.0	1.5

(a) As CaCO3. (b) As P. (c) Stroke on chemical feed pump was increased from 18 to 25 on 11/03/06. Target iron level was 1.5 mg/L.

Table B-1. Analytical Results from Long Term Sampling, Felton, DE (Continued)

Sampling Date		12/14/06					12/20/06					01/03/07			01/10/07				
Sampling Location Parameter	Unit	IN	AC	TA	TB	TC	IN	AC	TA	TB	TC	IN	AC	TT	IN	AC	TA	TB	TC
Alkalinity	mg/L[(a)]	323	323	317	317	325	322	322	316	320	320	341	339	327	345	328	341	339	331
		-	-	-	-	-	-	-	-	-	-	-	-	-	349	339	328	328	331
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	1.3	1.2	1.4	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	9	10	9	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	-
P (total)	µg/L[(b)]	23.8	21.7	<10	<10	<10	48.3	48.8	15.1	16.4	14.3	40.8	39.7	11.3	45.1	41.0	<10	<10	<10
		-	-	-	-	-	-	-	-	-	-	-	-	-	40.3	41.9	<10	<10	<10
Silica (as SiO_2)	mg/L	9.0	9.0	8.6	8.7	8.5	8.9	9.3	8.7	8.8	8.5	9.6	9.3	9.3	9.2	9.3	9.1	9.1	9.0
		-	-	-	-	-	-	-	-	-	-	-	-	-	9.3	9.1	10.0	8.7	9.2
Turbidity	NTU	0.4	1.5	1.1	0.7	0.3	1.0	1.1	0.7	0.7	0.6	0.5	1.4	0.5	0.8	1.8	1.0	0.9	0.6
		-	-	-	-	-	-	-	-	-	-	-	-	-	0.9	1.7	1.1	0.9	0.7
pH	S.U.	8.1	8.3	8.2	8.3	8.3	8.1	8.2	8.1	8.2	8.3	8.1	8.1	8.2	8.1	8.3	8.3	8.3	8.3
Temperature	°C	18.5	18.4	18.4	18.3	18.4	18.1	18.4	18.2	18.4	18.4	17.9	18.1	18.2	17.9	18.3	18.3	18.2	18.1
DO	mg/L	0.8	0.5	0.9	0.7	0.5	0.9	1.1	1.3	1.0	0.6	1.0	1.1	0.8	1.0	0.7	1.1	1.1	0.7
ORP	mV	216	319	382	465	486	234	582	574	606	617	277	305	503	240	293	315	325	514
Free Chlorine	mg/L	-	0.7	0.7	0.8	0.7	-	1.3	1.3	1.4	1.4	-	0.6	0.7	-	0.7	0.8	0.8	0.7
Total Chlorine	mg/L	-	0.8	0.8	0.8	0.8	-	1.4	1.4	1.4	1.4	-	0.7	0.7	-	0.8	0.8	0.8	0.8
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	40.4	39.6	39.1	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	18.0	18.0	17.3	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	22.4	21.6	21.8	-	-	-	-	-
As (total)	µg/L	30.4	30.6	6.5	5.6	5.2	38.2	37.9	10.4	10.2	9.9	36.2	34.9	9.9	30.9	32.3	8.1	7.2	8.9
		-	-	-	-	-	-	-	-	-	-	-	-	-	31.1	31.8	7.4	6.7	7.8
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	32.2	10.3	7.9	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	4.0	24.6	2.0	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	29.7	<0.1	0.1	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	2.5	10.2	7.8	-	-	-	-	-
Fe (total)	µg/L	<25	1,913	74	27	<25	<25	1,453	124	93	98	32	1,590	82	38	1,810	36	8	65
		-	-	-	-	-	-	-	-	-	-	-	-	-	33	1,811	36	7	68
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	42	<25	<25	-	-	-	-	-
Mn (total)	µg/L	1.5	8.8	0.2	<0.1	<0.1	1.3	6.2	0.6	0.5	0.5	1.4	6.1	0.4	1.3	6.8	0.2	<0.1	0.3
		-	-	-	-	-	-	-	-	-	-	-	-	-	1.3	6.7	0.2	<0.1	0.3
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	1.8	<0.1	0.4	-	-	-	-	-

(a) As CaCO3. (b) As P.

Table B-1. Analytical Results from Long Term Sampling, Felton, DE (Continued)

Sampling Date		01/17/07[c]					01/24/07					01/31/07			02/07/07[d]				
Sampling Location		IN	AC	TA	TB	TC	IN	AC	TA	TB	TC	IN	AC	TT	IN	AC	TA	TB	TC
Parameter	Unit																		
Alkalinity	mg/L[a]	315	292	310	299	302	276	283	280	274	270	325	318	323	335	325	327	327	330
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	1.0	1.4	1.0	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	10	9	10	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	-
P (total)	µg/L[b]	28.2	50.3	<10	<10	<10	43.3	45.3	11.4	12.4	13.0	109.5	120.1	79.0	38.6	40.5	<10	<10	<10
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	9.4	10.1	9.4	9.1	8.6	9.3	9.5	9.2	9.1	9.3	9.1	9.1	8.5	8.8	9.0	8.5	8.4	8.7
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	1.6	3.1	0.8	0.5	0.4	1.4	1.9	1.8	1.7	0.7	0.5	1.8	0.4	1.0	3.8	0.6	0.8	1.4
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	8.4	8.2	8.1	8.2	8.2	8.3	8.3	8.3	8.3	8.3	8.2	8.2	8.2	8.2	7.8	7.8	7.9	7.9
Temperature	°C	18.1	18.1	17.8	18.0	18.0	18.1	18.3	18.2	18.2	18.3	17.5	18.2	17.9	15.4	15.4	15.4	15.5	15.5
DO	mg/L	1.4	1.5	2.6	1.4	1.2	1.2	0.7	0.9	0.8	0.6	1.1	0.8	1.1	1.3	1.0	0.9	1.4	1.5
ORP	mV	222	251	277	287	527	257	335	338	582	617	259	458	578	226	295	326	334	352
Free Chlorine	mg/L	-	0.4	0.5	0.5	0.8	-	0.6	0.9	1.3	1.0	-	0.8	0.8	-	0.6	0.6	0.6	0.6
Total Chlorine	mg/L	-	0.5	0.5	0.5	0.9	-	0.7	0.9	1.4	1.0	-	1.0	0.8	-	0.7	0.6	0.6	0.6
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	40.7	40.0	38.0	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	15.5	15.5	15.2	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	25.2	24.5	22.8	-	-	-	-	-
As (total)	µg/L	27.2	40.2	5.1	5.5	4.8	33.5	34.7	7.8	8.3	7.9	39.9	39.8	13.4	34.1	34.5	6.1	7.0	6.7
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	38.1	9.5	13.0	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	1.8	30.3	0.4	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	38.3	8.6	10.1	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	<0.1	0.9	3.0	-	-	-	-	-
Fe (total)	µg/L	38	3,438	<25	48	<25	40	1,567	115	159	162	53	1,930	71	34	1,553	48	69	69
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	50	<25	<25	-	-	-	-	-
Mn (total)	µg/L	1.0	13.5	<0.1	<0.1	<0.1	2.0	8.8	1.0	1.2	1.3	2.9	12.4	1.6	1.5	8.0	0.2	0.4	0.3
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	3.0	1.0	1.6	-	-	-	-	-

(a) As CaCO3. (b) As P. (c) ΔP reduced from 24 to 18 psi; stroke increased from 25 to 32. Target iron level was 2.0 mg/L. (d) Water quality parameters taken on 02/08/07.

Table B-1. Analytical Results from Long Term Sampling, Felton, DE (Continued)

Sampling Date		02/14/07					02/21/07					02/28/07			03/07/07				
Sampling Location / Parameter	Unit	IN	AC	TA	TB	TC	IN	AC	TA	TB	TC	IN	AC	TT	IN	AC	TA	TB	TC
Alkalinity	mg/L[(a)]	325	315	318	315	315	332	327	322	322	310	330	325	322	337	320	317	324	317
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	1.5	1.5	1.4	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	9	9	9	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	-
P (total)	µg/L[(b)]	50.4	53.4	17.1	19.2	16.5	74.3	86.3	47.9	48.1	49.3	52.8	51.5	16.1	33.6	36.1	<10	<10	<10
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	9.1	9.1	9.4	9.4	9.0	9.6	9.2	8.8	8.8	9.1	9.9	9.7	10.3	9.2	8.9	8.8	9.2	8.3
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	0.7	1.7	1.1	0.6	1.6	0.3	6.0	1.7	0.4	0.6	0.8	2.1	3.3	0.8	2.0	2.7	2.9	3.2
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	8.2	8.2	8.3	8.3	8.3	8.2	7.9	7.9	8.1	8.0	8.2	8.2	8.2	8.1	8.4	8.4	8.4	8.4
Temperature	°C	17.4	17.9	18.1	18.2	18.1	18.0	18.1	18.1	18.1	18.1	16.7	18.1	18.1	17.7	17.8	17.9	17.8	17.8
DO	mg/L	1.1	1.3	0.9	0.7	0.8	1.7	1.2	0.9	0.8	1.0	1.9	1.5	1.2	1.1	1.0	0.9	0.8	0.8
ORP	mV	247	284	317	372	418	242	282	298	313	541	479	531	500	327	451	465	497	547
Free Chlorine	mg/L	-	0.5	0.7	0.5	0.6	-	0.6	0.6	0.6	0.8	-	0.6	0.6	-	0.3	0.4	0.5	0.5
Total Chlorine	mg/L	-	0.6	0.7	0.6	0.6	-	0.7	0.6	0.6	0.8	-	0.6	0.7	-	0.4	0.5	0.5	0.5
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	38.2	38.8	39.0	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	16.0	16.2	16.2	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	22.2	22.6	22.8	-	-	-	-	-
As (total)	µg/L	30.3	30.1	6.5	6.9	6.8	38.6	42.0	13.9	10.3	12.1	34.5	33.9	7.4	33.5	33.7	7.4	6.3	6.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	30.4	4.3	5.0	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	4.1	29.5	2.4	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	28.6	0.6	0.6	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	1.7	3.7	4.5	-	-	-	-	-
Fe (total)	µg/L	43	1,250	<25	42	60	36	2,617	289	101	217	33	1,871	148	33	1,314	140	77	<25
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	29	<25	<25	-	-	-	-	-
Mn (total)	µg/L	1.6	6.8	<0.1	0.3	0.3	1.9	16.7	1.7	1.0	1.5	1.5	10.9	0.6	1.4	7.5	0.6	0.3	<0.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	1.5	<0.1	<0.1	-	-	-	-	-

(a) As CaCO3. (b) As P.

Table B-1. Analytical Results from Long Term Sampling, Felton, DE (Continued)

Sampling Date		03/14/07					03/21/07					03/28/07			04/04/07				
Sampling Location / Parameter	Unit	IN	AC	TA	TB	TC	IN	AC	TA	TB	TC	IN	AC	TT	IN	AC	TA	TB	TC
Alkalinity	mg/L(a)	328	318	316	316	314	323	318	316	316	318	320	312	310	319	307	310	307	305
		-	-	-	-	-	328	323	316	318	316	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	1.5	1.5	1.6	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	10	11	11	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	-
P (total)	μg/L(b)	46.6	47.2	11.5	<10	12.3	54.7	298.1	19.9	18.5	17.4	64.2	63.8	32.3	52.8	55.9	22.5	18.9	20.0
		-	-	-	-	-	52.0	243.1	17.6	17.3	17.1	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	9.9	9.4	8.7	9.0	9.0	9.4	13.7	9.4	9.2	9.1	8.5	9.0	8.8	8.8	8.7	8.4	8.3	8.7
		-	-	-	-	-	9.6	12.5	9.3	9.3	9.4	-	-	-	-	-	-	-	-
Turbidity	NTU	3.7	3.9	2.7	1.8	2.6	0.8	20.0	1.1	0.8	0.9	0.5	0.9	0.8	1.1	2.3	0.5	0.6	1.0
		-	-	-	-	-	1.1	16.0	0.7	0.7	0.3	-	-	-	-	-	-	-	-
pH	S.U.	8.1	8.3	8.3	8.3	8.3	8.2	8.2	8.2	8.6	8.6	NA	NA	NA	8.2	8.1	8.2	8.2	8.2
Temperature	℃	18.3	18.5	18.2	18.2	18.3	17.3	17.8	17.8	18.2	17.5	NA	NA	NA	18.3	18.3	18.4	18.4	18.8
DO	mg/L	1.7	1.1	1.0	0.7	1.0	1.4	1.9	1.4	0.7	0.8	NA	NA	NA	1.1	0.8	0.6	0.7	0.7
ORP	mV	288	338	464	477	533	314	358	492	532	535	NA	NA	NA	302	332	429	440	411
Free Chlorine	mg/L	-	0.7	0.8	0.8	0.8	-	0.4	0.4	0.4	0.4	-	NA	NA	-	0.6	0.5	0.5	0.5
Total Chlorine	mg/L	-	0.8	0.8	0.8	0.8	-	0.4	0.4	0.4	0.4	-	NA	NA	-	0.6	0.6	0.5	0.5
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	40.6	42.6	40.2	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	16.8	17.7	16.4	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	23.8	24.9	23.9	-	-	-	-	-
As (total)	μg/L	32.2	32.1	5.0	3.5	5.3	37.9	210(a)	8.8	9.0	7.7	37.1	37.7	12.8	33.5	33.3	8.5	6.6	7.0
		-	-	-	-	-	36.7	174(a)	8.2	8.9	7.7	-	-	-	-	-	-	-	-
As (soluble)	μg/L	-	-	-	-	-	-	-	-	-	-	32.5	18.1	10.3	-	-	-	-	-
As (particulate)	μg/L	-	-	-	-	-	-	-	-	-	-	4.5	19.5	2.5	-	-	-	-	-
As (III)	μg/L	-	-	-	-	-	-	-	-	-	-	31.0	2.2	1.8	-	-	-	-	-
As (V)	μg/L	-	-	-	-	-	-	-	-	-	-	1.5	15.9	8.5	-	-	-	-	-
Fe (total)	μg/L	18	1,571	93	<25	129	27	13,646(c)	76	39	38	<25	788	<25	<25	1,952	<25	32	85
		-	-	-	-	-	25	10,937(c)	68	34	37	-	-	-	-	-	-	-	-
Fe (soluble)	μg/L	-	-	-	-	-	-	-	-	-	-	<25	<25	<25	-	-	-	-	-
Mn (total)	μg/L	1.4	10.1	0.5	<0.1	0.7	1.5	59.2(c)	0.5	0.3	0.3	2.1	5.4	0.6	1.3	11.3	<0.1	0.4	0.6
		-	-	-	-	-	1.4	48.8(c)	0.4	0.3	0.3	-	-	-	-	-	-	-	-
Mn (soluble)	μg/L	-	-	-	-	-	-	-	-	-	-	1.8	0.4	0.2	-	-	-	-	-

(a) As CaCO3. (b) As P. (c) Data was questionable; however, were verified through re-analysis.

Table B-1. Analytical Results from Long Term Sampling, Felton, DE (Continued)

Sampling Date		04/11/07					04/18/07					04/25/07			05/02/07				
Sampling Location Parameter	Unit	IN	AC	TA	TB	TC	IN	AC	TA	TB	TC	IN	AC	TT	IN	AC	TA	TB	TC
Alkalinity	mg/L[(a)]	327	327	324	320	322	326	323	319	314	309	332	327	322	325	325	320	320	320
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	1.1	1.1	1.0	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	10	9	9	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	-
P (total)	µg/L[(b)]	57.7	81.8	26.7	21.0	21.2	51.6	206.4	21.4	17.8	15.3	40.9	40.5	<10	46.1	54.1	24.1	24.8	24.6
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	8.7	9.9	8.5	8.9	8.7	9.7	11.6	9.4	9.2	9.1	9.6	9.6	9.3	10.2	10.0	9.6	9.8	10.0
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	3.8	6.6	4.6	3.4	2.0	1.3	11.0	0.9	0.8	0.6	0.3	1.6	0.3	0.6	2.4	0.4	0.7	0.5
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	7.8	8.3	8.4	8.4	8.4	8.4	8.3	8.3	8.3	8.3	8.4	8.2	8.2	8.1	8.3	8.4	8.4	8.4
Temperature	°C	18.0	18.2	18.3	18.3	18.4	17.9	18.1	18.3	18.3	18.4	18.7	18.7	18.6	18.8	18.6	18.6	18.6	18.6
DO	mg/L	1.1	1.6	1.0	1.2	1.0	1.3	0.8	0.9	0.8	0.8	1.2	1.1	1.0	0.9	1.2	0.9	1.1	0.9
ORP	mV	245	379	592	610	616	248	276	277	296	519	325	522	477	414	479	507	521	535
Free Chlorine	mg/L	-	0.9	0.9	0.8	0.8	-	1.0	1.1	0.9	0.9	-	0.9	0.9	-	0.8	0.8	0.7	0.8
Total Chlorine	mg/L	-	1.0	0.9	0.8	0.9	-	1.2	1.1	0.9	0.9	-	1.0	0.9	-	0.9	0.8	0.8	0.8
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	39.4	40.2	39.9	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	17.0	17.8	18.0	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	22.3	22.4	21.9	-	-	-	-	-
As (total)	µg/L	36.5	53.7	12.3	8.9	8.4	38.4	142	11.5	9.8	9.4	29.8	29.8	5.0	34.8	38.2	17.9	19.5	19.3
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	31.2	6.8	5.5	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	<0.1	22.9	<0.1	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	29.8	1.5	1.0	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	1.4	5.3	4.5	-	-	-	-	-
Fe (total)	µg/L	39	2,836	216	36	36	31	8,962	<25	<25	<25	30	2,102	<25	<25	704	<25	<25	<25
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	<25	<25	<25	-	-	-	-	-
Mn (total)	µg/L	1.5	14.5	1.1	0.2	0.1	1.7	37.7	0.1	0.2	0.1	1.6	11.9	<0.1	1.4	5.2	<0.1	<0.1	<0.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	1.5	0.2	<0.1	-	-	-	-	-

(a) As CaCO3. (b) As P.

Table B-1. Analytical Results from Long Term Sampling, Felton, DE (Continued)

Sampling Date		05/09/07					05/16/07					05/23/07			05/30/07				
Sampling Location Parameter	Unit	IN	AC	TA	TB	TC	IN	AC	TA	TB	TC	IN	AC	TT	IN	AC	TA	TB	TC
Alkalinity	mg/L[(a)]	312	317	310	303	307	309	309	309	305	307	315	303	310	310	312	306	294	303
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	1.0	1.0	1.0	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	10	10	10	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	-
P (total)	μg/L[(b)]	35.2	34.7	10.9	<10	<10	40.2	42.6	11.8	11.0	11.1	50.1	48.7	13.0	45.3	46.5	11.4	11.9	11.2
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	9.5	9.4	9.3	9.3	9.1	9.2	9.3	9.5	9.3	9.2	9.6	9.4	9.3	9.4	9.8	9.5	9.7	9.3
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	0.6	1.4	0.5	0.4	0.4	0.3	1.0	0.2	0.4	0.3	0.5	1.5	0.6	1.0	1.5	0.2	0.2	0.6
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	8.1	8.1	8.1	8.2	7.9	8.5	8.4	8.4	8.4	8.3	8.4	8.4	8.4	8.4	8.4	8.5	8.5	8.6
Temperature	°C	19.0	18.6	18.8	18.6	19.6	19.3	18.8	18.8	18.8	18.8	19.3	18.9	18.9	19.3	18.9	18.8	18.7	18.8
DO	mg/L	1.1	1.1	1.1	0.6	1.0	0.9	1.0	1.4	1.0	0.7	1.0	0.9	1.1	0.9	1.0	1.7	0.9	0.7
ORP	mV	416	512	608	572	620	410	423	460	467	520	421	463	524	363	443	464	614	618
Free Chlorine	mg/L	-	1.0	0.8	0.7	0.7	-	0.2	0.2	0.2	0.2	-	0.7	0.8	-	0.7	0.7	0.6	0.7
Total Chlorine	mg/L	-	1.2	0.9	0.8	0.8	-	0.3	0.3	0.3	0.3	-	0.8	0.8	-	0.7	0.7	0.7	0.8
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	35.4	34.6	36.1	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	15.4	16.0	16.4	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	20.0	18.6	19.7	-	-	-	-	-
As (total)	μg/L	33.7	33.9	25.6	6.1	6.2	30.6	31.5	7.7	7.5	7.9	37.6	38.8	8.6	34.5	36.5	7.3	6.0	6.3
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	μg/L	-	-	-	-	-	-	-	-	-	-	32.5	5.2	6.8	-	-	-	-	-
As (particulate)	μg/L	-	-	-	-	-	-	-	-	-	-	5.1	33.6	1.9	-	-	-	-	-
As (III)	μg/L	-	-	-	-	-	-	-	-	-	-	30.4	0.3	0.2	-	-	-	-	-
As (V)	μg/L	-	-	-	-	-	-	-	-	-	-	2.1	4.9	6.5	-	-	-	-	-
Fe (total)	μg/L	<25	1,579	<25	<25	<25	27	1,535	<25	<25	<25	35	2,164	<25	<25	1,618	<25	<25	<25
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	μg/L	-	-	-	-	-	-	-	-	-	-	36	<25	<25	-	-	-	-	-
Mn (total)	μg/L	1.3	9.2	<0.1	<0.1	<0.1	1.5	9.0	0.1	<0.1	<0.1	1.3	9.1	<0.1	1.1	7.2	<0.1	<0.1	<0.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	μg/L	-	-	-	-	-	-	-	-	-	-	1.6	0.1	<0.1	-	-	-	-	-

(a) As CaCO3. (b) As P.

Table B-1. Analytical Results from Long Term Sampling, Felton, DE (Continued)

Sampling Date		06/06/07					06/13/07					06/20/07			06/27/07				
Sampling Location / Parameter	Unit	IN	AC	TA	TB	TC	IN	AC	TA	TB	TC	IN	AC	TT	IN	AC	TA	TB	TC
Alkalinity	mg/L[(a)]	325	318	313	316	313	318	309	311	311	311	315	317	315	322	312	300	308	300
		-	-	-	-	-	313	313	304	311	311	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	1.5	1.6	1.6	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	11	10	10	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	-
P (total)	µg/L[(b)]	36.1	37.3	<10	<10	<10	35.9	40.6	<10	<10	<10	38.4	37.9	<10	35.4	36.4	<10	<10	<10
		-	-	-	-	-	38.5	40.9	<10	<10	<10	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	9.3	9.5	9.1	9.3	9.4	9.6	9.5	9.0	9.6	9.3	9.0	9.3	9.0	11.1	11.7	11.1	11.1	10.9
		-	-	-	-	-	9.4	9.4	9.3	9.7	9.5	-	-	-	-	-	-	-	-
Turbidity	NTU	4.1	4.0	1.8	0.8	1.6	0.4	1.2	0.4	0.5	0.7	4.1	2.3	0.3	0.7	1.9	0.3	1.0	0.9
		-	-	-	-	-	0.3	1.3	0.6	0.7	0.5	-	-	-	-	-	-	-	-
pH	S.U.	8.8	8.9	8.8	8.9	8.9	9.3	9.3	9.3	9.4	9.3	9.8	10.0	10.0	8.9	8.9	8.9	9.0	9.0
Temperature	°C	19.2	18.7	18.9	18.9	18.9	19.3	18.9	19.0	19.0	19.0	20.8	19.2	18.9	20.2	19.8	19.3	19.5	19.4
DO	mg/L	0.8	0.6	0.8	0.8	0.7	0.8	0.8	1.8	1.2	1.0	1.2	1.0	1.0	0.8	1.4	1.1	0.8	0.6
ORP	mV	342	532	617	634	633	444	630	651	649	652	362	391	441	247	278	324	552	591
Free Chlorine	mg/L	-	0.9	1.0	1.0	1.2	-	1.4	1.3	1.2	1.4	-	0.4	0.4	-	0.4	0.4	0.5	0.5
Total Chlorine	mg/L	-	0.9	1.0	1.0	1.2	-	1.4	1.3	1.3	1.4	-	0.6	0.5	-	0.5	0.4	0.5	0.5
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	38.8	37.4	38.1	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	18.2	17.5	17.9	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	20.6	19.9	20.2	-	-	-	-	-
As (total)	µg/L	27.9	27.1	7.4	7.4	7.2	33.9	35.1	5.7	5.6	6.5	37.4	38.0	10.8	32.9	33.3	7.2	7.8	6.2
		-	-	-	-	-	34.4	34.8	5.2	5.8	6.4	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	33.3	12.4	9.4	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	4.1	25.6	1.3	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	29.9	0.4	0.4	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	3.4	12.0	9.0	-	-	-	-	-
Fe (total)	µg/L	<25	1,136	<25	<25	<25	<25	1,831	<25	<25	<25	<25	1,268	<25	25	3,155	<25	53	<25
		-	-	-	-	-	<25	1,865	<25	<25	<25	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	<25	<25	<25	-	-	-	-	-
Mn (total)	µg/L	1.2	5.1	<0.1	<0.1	<0.1	1.1	9.3	<0.1	<0.1	0.1	1.2	7.0	<0.1	1.5	16.3	<0.1	0.4	<0.1
		-	-	-	-	-	1.2	9.7	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	1.3	<0.1	<0.1	-	-	-	-	-

(a) As CaCO3. (b) As P.

Table B-1. Analytical Results from Long Term Sampling, Felton, DE (Continued)

Sampling Date		07/05/07					07/11/07					07/18/07					07/25/07		
Sampling Location Parameter	Unit	IN	AC	TA	TB	TC	IN	AC	TA	TB	TC	IN	AC	TA	TB	TC	IN	AC	TT
Alkalinity	mg/L[(a)]	317	320	308	308	308	318	309	311	311	302	320	310	310	312	308	314	297	302
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.5	1.5	1.5
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.0	8.8	8.8
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05
P (total)	μg/L[(b)]	30.0	29.5	<10	<10	<10	61.0	59.9	15.4	13.5	12.9	52.0	47.6	<10	<10	11.9	33.9	36.1	<10
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	11.5	11.5	11.1	11.3	11.2	9.2	9.3	9.2	9.1	9.3	9.0	9.4	9.7	9.3	9.1	9.2	9.2	8.5
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	0.9	1.4	0.5	0.9	0.7	0.8	1.8	0.5	0.3	0.5	1.0	1.8	3.4	2.6	3.3	1.7	4.0	2.2
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	8.4	8.5	8.4	8.5	8.4	8.6	8.6	8.5	8.6	8.6	8.7	8.6	8.6	8.7	8.7	8.5	8.3	8.4
Temperature	℃	19.7	18.9	19.3	19.2	19.3	20.4	19.1	19.2	19.2	19.2	19.8	19.4	19.5	19.5	19.3	19.7	19.3	19.2
DO	mg/L	1.0	1.2	1.5	1.9	1.1	1.0	1.1	0.9	0.9	1.0	0.6	1.2	1.7	1.3	1.7	0.9	1.6	0.8
ORP	mV	422	424	533	573	575	423	466	513	495	570	345	482	475	514	625	375	436	413
Free Chlorine	mg/L	-	0.8	0.4	0.6	0.6	-	0.8	0.6	0.6	0.6	-	0.7	0.6	0.9	1.1	-	0.4	0.5
Total Chlorine	mg/L	-	0.8	0.4	0.6	0.7	-	0.8	0.6	0.6	0.6	-	0.7	0.6	0.9	1.1	-	0.4	0.6
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40.0	38.3	37.9
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16.9	16.5	16.4
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23.1	21.8	21.5
As (total)	μg/L	27.3	27.2	6.8	6.2	6.6	43.3	43.4	6.7	6.7	6.1	42.4	41.2	10.3	11.3	11.7	33.7	34.8	4.9
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28.0	4.2	4.0
As (particulate)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.8	30.6	0.9
As (III)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	26.8	0.6	0.5
As (V)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.2	3.6	3.5
Fe (total)	μg/L	<25	1,389	<25	<25	<25	<25	2,055	<25	<25	<25	<25	1,528	<25	<25	<25	<25	1,978	<25
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<25	<25	<25
Mn (total)	μg/L	1.1	8.2	<0.1	<0.1	<0.1	1.4	11.1	0.2	<0.1	<0.1	1.5	9.7	<0.1	0.1	<0.1	1.3	10.9	0.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0	0.6	0.3

(a) As CaCO3. (b) As P.

Table B-1. Analytical Results from Long Term Sampling, Felton, DE (Continued)

Sampling Date		08/01/07					08/08/07					08/15/07					08/22/07		
Sampling Location		IN	AC	TA	TB	TC	IN	AC	TA	TB	TC	IN	AC	TA	TB	TC	IN	AC	TT
Parameter	Unit																		
Alkalinity	mg/L[(a)]	312	302	300	300	300	319	324	331	336	324	330	320	318	325	315	314	306	312
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.6	1.6	1.6
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.1	9.1	9.0
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05
P (total)	µg/L[(b)]	38.5	38.4	<10	<10	<10	42.8	114.8	<10	<10	<10	45.0	45.0	<10	<10	<10	46.6	48.6	14.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	9.2	9.5	8.7	8.8	8.8	9.6	10.6	9.1	8.6	8.8	9.2	9.1	8.7	8.5	8.6	11.6	9.9	10.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	0.8	2.6	0.5	1.0	1.0	3.0	11.0	2.2	1.0	2.8	0.2	1.6	0.3	0.2	0.5	1.2	1.9	1.4
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	8.7	8.3	8.3	8.3	8.4	8.6	8.3	8.3	8.2	8.3	8.3	8.3	8.3	8.3	8.0	8.2	8.5	8.5
Temperature	°C	19.9	19.2	19.1	19.1	19.3	20.2	19.5	21.0	19.8	19.9	20.4	19.1	19.1	19.1	19.5	19.6	18.9	18.9
DO	mg/L	0.8	1.2	1.2	0.9	1.0	0.8	1.7	1.3	1.0	1.0	1.0	1.1	1.0	1.0	1.1	1.0	0.7	1.0
ORP	mV	272	530	476	522	546	336	473	486	593	583	428	482	506	582	545	277	510	484
Free Chlorine	mg/L	-	0.7	0.8	0.8	0.7	-	0.7	0.4	0.6	0.5	-	0.7	0.7	0.7	0.6	-	1.1	1.0
Total Chlorine	mg/L	-	0.8	0.8	0.8	0.8	-	0.8	0.5	0.5	0.5	-	0.7	0.7	0.7	0.6	-	1.1	1.0
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	37.2	38.3	37.8
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14.4	15.4	15.5
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22.8	22.8	22.4
As (total)	µg/L	33.8	33.8	4.9	6.1	5.5	37.2	104	4.1	4.5	3.9	36.0	37.4	6.5	5.9	7.3	37.0	39.5	12.8
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	32.3	14.5	11.0
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.7	25.0	1.8
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30.5	0.5	0.4
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.8	14.0	10.6
Fe (total)	µg/L	<25	2,770	<25	87	58	<25	6,632	<25	99	<25	<25	2,239	<25	<25	<25	30	1,111	<25
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<25	<25	<25
Mn (total)	µg/L	1.3	14.2	<0.1	0.6	0.5	1.2	35.2	<0.1	0.6	<0.1	1.4	12.3	<0.1	<0.1	0.1	1.4	7.3	<0.1
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.4	<0.1	<0.1

(a) As CaCO3. (b) As P.

Table B-1. Analytical Results from Long Term Sampling, Felton, DE (Continued)

Sampling Date		08/29/07					09/05/07[c]					09/12/07					09/19/07		
Sampling Location		IN	AC	TA	TB	TC	IN	AC	TA	TB	TC	IN	AC	TA	TB	TC	IN	AC	TT
Parameter	Unit																		
Alkalinity	mg/L[a]	316	299	303	303	303	315	300	304	306	306	320	301	307	296	305	320	318	314
		-	-	-	-	-	311	302	304	304	306	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.7	1.6	1.9
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21	18	18
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05
P (total)	µg/L[b]	47.7	51.6	<10	17.4	<10	41.9	43.3	<10	<10	<10	40.3	48.0	<10	<10	<10	23.3	27.5	<10
		-	-	-	-	-	42.6	45.9	<10	<10	<10	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	10.2	9.6	9.2	9.3	9.3	10.0	9.7	9.6	8.9	8.9	9.0	9.2	9.0	8.8	8.6	10.0	9.9	9.0
		-	-	-	-	-	9.8	9.7	9.1	9.2	9.5	-	-	-	-	-	-	-	-
Turbidity	NTU	2.4	3.8	2.2	1.9	1.8	0.8	1.6	0.3	0.5	0.6	1.3	3.3	0.6	0.8	1.3	1.3	2.7	1.4
		-	-	-	-	-	0.6	1.8	0.7	0.9	0.6	-	-	-	-	-	-	-	-
pH	S.U.	8.0	7.9	7.9	8.1	8.1	8.3	8.3	8.4	8.4	8.4	8.2	8.0	8.0	8.0	8.0	8.3	8.2	8.1
Temperature	℃	20.5	19.8	19.8	19.4	19.5	20.1	19.5	19.3	19.5	19.7	20.4	19.0	19.0	19.1	19.1	19.2	19.0	18.4
DO	mg/L	1.2	1.4	1.4	1.4	1.4	1.0	1.2	1.0	1.0	0.7	1.3	1.3	0.9	0.8	1.1	0.6	1.2	0.6
ORP	mV	269	501	464	534	577	289	436	538	534	598	314	625	642	649	641	273	526	550
Free Chlorine	mg/L	-	0.5	0.6	0.7	0.8	-	1.1	1.1	0.7	1.0	-	0.8	0.8	0.8	0.9	-	1.1	1.1
Total Chlorine	mg/L	-	0.6	0.6	0.7	0.8	-	1.1	1.1	0.7	1.0	-	0.9	0.8	0.8	0.9	-	1.1	1.1
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	41.0	39.3	40.6
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18.1	17.2	17.5
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22.9	22.2	23.0
As (total)	µg/L	33.5	36.0	5.1	9.6	4.5	36.0	36.4	3.3	3.9	3.4	37.6	35.7	8.3	7.9	6.5	30.4	29.9	3.0
		-	-	-	-	-	36.4	35.6	3.1	4.0	3.4	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	26.1	3.6	2.6
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.4	26.3	0.4
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	26.6	0.5	0.4
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	3.1	2.2
Fe (total)	µg/L	35	2,512	<25	327	<25	30	2,640	<25	103	<25	57	4,699	<25	81	<25	<25	2,619	<25
		-	-	-	-	-	28	2,551	<25	103	<25	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<25	<25	<25
Mn (total)	µg/L	1.5	13.2	0.3	1.9	<0.1	1.4	13.8	<0.1	0.6	<0.1	1.8	23.7	<0.1	0.5	<0.1	1.4	14.0	<0.25
		-	-	-	-	-	1.4	13.0	<0.1	0.6	<0.1	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.5	0.3	<0.25

(a) As CaCO3. (b) As P. (c) Water quality parameters measured on 09/07/07.

Table B-1. Analytical Results from Long Term Sampling, Felton, DE (Continued)

Sampling Date		09/25/07[c]					10/03/07[d]					10/10/07[e]					10/17/07		
Sampling Location Parameter	Unit	IN	AC	TA	TB	TC	IN	AC	TA	TB	TC	IN	AC	TA	TB	TC	IN	AC	TT
Alkalinity	mg/L[a]	320	314	309	314	309	301	299	299	293	295	315	297	297	297	295	304	294	300
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.5	1.5	2.0
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	11	10
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05
P (total)	µg/L[b]	30.4	27.6	<10	<10	<10	34.3	32.3	<10	<10	<10	35.9	31.1	<10	<10	<10	65.5	59.9	22.8
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	9.8	10.2	9.3	9.4	9.0	9.3	9.7	9.1	8.8	9.1	9.2	9.5	8.8	8.8	8.7	9.3	9.2	9.4
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	1.3	2.0	0.6	1.0	0.6	1.4	4.3	2.4	1.4	3.0	0.8	1.7	0.6	0.7	0.8	0.8	1.6	0.5
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	8.3	8.3	8.3	8.3	8.3	8.4	8.3	8.3	8.3	8.3	7.9	7.7	7.7	7.7	7.7	8.2	8.0	8.2
Temperature	°C	20.8	19.3	19.6	19.7	19.8	19.5	19.1	19.3	19.3	19.3	18.9	18.8	18.8	18.8	18.8	19.6	19.5	19.3
DO	mg/L	1.2	1.1	1.0	1.3	1.0	0.6	0.4	0.6	0.6	0.7	1.1	1.2	1.1	1.0	0.9	1.4	1.5	1.0
ORP	mV	257	473	509	578	593	420	533	576	604	617	330	536	562	652	673	277	489	556
Free Chlorine	mg/L	-	0.6	0.7	0.7	0.7	-	0.6	0.6	0.7	0.8	-	0.8	1.0	1.0	0.9	-	0.7	1.0
Total Chlorine	mg/L	-	0.8	0.7	0.7	0.7	-	0.7	0.6	0.7	0.8	-	0.9	1.0	1.0	1.0	-	0.7	1.0
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40.9	39.5	38.2
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19.4	18.6	17.8
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21.6	20.9	20.4
As (total)	µg/L	33.9	31.6	3.2	3.4	3.5	34.6	33.7	4.0	4.0	3.6	35.8	32.9	3.6	3.6	3.6	28.1	27.0	1.8
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28.7	5.7	2.5
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	21.3	<0.1
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19.9	<0.1	<0.1
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.8	5.6	2.4
Fe (total)	µg/L	32	2,552	<25	55	67	30	2,040	<25	73	<25	26	2,219	<25	<25	<25	60	1,985	37
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<25	<25	<25
Mn (total)	µg/L	<0.1	15.6	<0.1	<0.1	<0.1	<0.1	12.6	<0.1	<0.1	<0.1	1.5	12.5	<0.1	<0.1	0.4	1.4	11.2	0.2
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.4	<0.1	0.3

(a) As CaCO3. (b) As P. (c) Water quality parameters measured on 09/27/07. (d) Water quality parameters measured on 10/05/07. (e)Water quality parameters measured on 10/12/07.

Table B-1. Analytical Results from Long Term Sampling, Felton, DE (Continued)

Sampling Date		10/24/07				
Sampling Location		IN	AC	TA	TB	TC
Parameter	Unit					
Alkalinity	mg/L[(a)]	306	304	302	296	300
		-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-
P (total)	µg/L[(b)]	34.3	31.5	<10	<10	<10
		-	-	-	-	-
Silica (as SiO_2)	mg/L	9.1	9.1	8.8	8.7	9.0
		-	-	-	-	-
Turbidity	NTU	3.2	3.7	5.1	4.5	3.6
		-	-	-	-	-
pH	S.U.	8.3	8.4	8.3	8.4	8.4
Temperature	°C	19.7	19.1	19.2	19.2	19.2
DO	mg/L	1.1	1.0	1.1	1.4	1.0
ORP	mV	291	518	515	453	563
Free Chlorine	mg/L	-	0.6	0.7	0.7	0.8
Total Chlorine	mg/L	-	0.7	0.7	0.7	0.8
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-
As (total)	µg/L	30.4	27.7	5.1	5.7	5.2
		-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-
Fe (total)	µg/L	<25	1,248	<25	<25	<25
		-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-
Mn (total)	µg/L	1.4	7.7	<0.1	<0.1	0.1
		-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-

(a) As CaCO3. (b) As P.

APPENDIX C

BACKWASH LOG SHEETS

Table C-1. Backwash Operation (Vessel A)

Sampling Event		After Filtration "TA" Backwash								
		Backwash Start			Backwash End			Backwash Flowrate	Backwash Duration	Wastewater Generated
No.	Date	Time	GAL	NTU	Time	GAL	NTU	GPM	Min	GAL
1	10/13/06	9:18	32,311	142.3	9:29	32,944	5	61.2	10.5	633
2	11/30/06	11:48	64,414	127.4	12:58	65,044	4.2	64.3	10.1	630
3	01/03/07	12:28	86,882	199.4	12:38	87,520	4.9	64.4	10.1	638
4	02/07/07	14:11	115,268	197.1	14:18	115,730	17.3	64.5	7.2	462
5	03/07/07	13:14	148,208	165.2	13:21	148,630	16.7	65.6	6.4	422
6	04/05/07	11:59	195,528	123.4	12:05	195,874	14.7	66.1	5.3	346
7	05/09/07	13:57	275,107	82.2	14:02	275,552	10.5	86.4	5.2	445
8	06/05/07	13:01	297,955	104.7	13:06	298,389	9.3	85.7	5.2	434
9	06/14/07	11:44	305,409	112.8	11:49	305,847	14.2	85.6	5.2	438
10	07/11/07	12:12	330,885	119.0	12:17	331,300	15.1	86.1	5.0	415
11	08/08/07	13:26	360,213	74.3	13:31	360,649	10.8	84.8	5.2	436
12	09/05/07	11:51	387727	102.6	11:56	388,094	15.1	84.5	4.4	367
13	10/10/07	13:20	419,409	83.1	13:25	419,849	7.7	84.7	5.2	440

Table C-1. Backwash Operation (Vessel B)

Sampling Event		After Filtration "TB" Backwash								
		Backwash Start			Backwash End			Backwash Flowrate	Backwash Duration	Wastewater Generated
No.	Date	Time	GAL	NTU	Time	GAL	NTU	GPM	Min	GAL
1	10/13/06	9:40	32,944	230.2	9:50	33,508	9.3	60.5	10	564
2	11/30/06	12:30	65,044	278.2	3:40	65,665	9.2	63.4	10	621
3	01/03/07	13:18	87,520	394.7	13:33	88,427	8	64.8	14.6	907
4	02/07/07	14:50	115,730	274.2	14:58	116,199	17.8	64.6	7.5	469
5	03/07/07	14:02	148,630	356.7	14:09	149,100	14.6	66.4	7.3	470
6	04/05/07	12:29	195,874	321.2	12:37	196,349	14.1	66.4	7.4	475
7	05/09/07	13:37	274,683	140.1	13:43	275,107	13.8	85.1	5.3	424
8	06/05/07	13:20	298,389	114.6	13:25	298,784	14.6	83.7	4.8	395
9	06/14/07	12:15	305,847	87.1	12:20	306,221	14.4	84.1	4.7	374
10	07/11/07	12:59	331,300	132.1	13:05	331,720	13.6	84.6	5.1	420
11	08/08/07	14:00	360,649	70.2	14:05	361,003	15.3	83.8	4.4	354
12	09/05/07	12:26	388,094	129.7	12:32	388,509	12.9	83.4	5.1	415
13	10/10/07	13:54	419,849	94.8	13:59	420,235	14.6	83.6	4.8	386

Table C-1. Backwash Operation (Vessel C)

Sampling Event		After Filtration "TC" Backwash								
		Backwash Start			Backwash End			Backwash Flowrate	Backwash Duration	Wastewater Generated
No.	Date	Time	GAL	NTU	Time	GAL	NTU	GPM	Min	GAL
1	10/13/06	10:08	33,508	212.2	10:18	34,079	3.5	61.4	10	571
2	11/30/06	13:18	65,665	219.8	13:27	66,242	4	64.5	9.4	577
3	01/03/07	13:55	88,427	286.8	14:04	89,008	5.5	65.4	9.3	581
4	02/07/07	15:22	116,199	268.3	15:29	116,624	13.1	65.2	6.6	425
5	03/07/07	14:40	149,100	251.9	14:46	149,505	11.5	66.8	6.2	405
6	04/05/07	13:01	196,349	230.3	13:08	196,766	11.1	67.1	6.5	417
7	05/09/07	13:14	273,995	110.5	13:23	274,683	14.9	86.5	8.4	688
8	06/05/07	13:45	298,784	116.1	13:50	299,177	12.3	85.7	4.8	393
9	06/14/07	12:44	306,221	95.8	12:50	306,655	7.1	85.8	5.2	444
10	07/11/07	13:43	331,720	116.3	13:48	332,139	13.8	86.1	4.9	419
11	08/08/07	14:32	361,003	105.3	14:37	361,404	14.1	84.6	4.8	401
12	09/05/07	13:01	388,509	72.3	13:05	388,860	12.9	84.5	4.3	351
13	10/10/07	14:46	420,235	110.1	14:51	420,676	7.8	84.6	5.3	441