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Arsenic Removal from Drinking Water by Point of Use Reverse Osmosis (POU RO) U.S. EPA Demonstration Project at Sunset Ranch Development in Homedale, ID Final Performance Evaluation Report

by

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Sally Gutierrez, Director
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ABSTRACT

This report documents the activities performed during and the results obtained from the arsenic removal technology demonstration project at the Sunset Ranch Development in Homedale, ID. The objectives of the project are to evaluate: 1) the effectiveness of a point of use (POU) reverse osmosis (RO) technology in removing arsenic, nitrate, and uranium to meet the respective maximum contaminant levels (MCLs) of 10 µg/L, 10 mg/L (as N), and 30 µg/L, 2) the reliability of the treatment units, 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 characterizes process residuals, i.e., reject water, produced by the RO units.

The treatment system at Sunset Ranch Development consisted of one POU RO unit at each of nine participating residences to remove arsenic, nitrate, and uranium from source water. Softening of source water was performed as pretreatment to meet the feed water quality requirements for the RO units. Six point of entry (POE) softeners (note that three homes had existing softeners) and nine POU RO units were provided by Kinetico. Each POU RO unit consisted of a 20-µm pre-filter, an RO module with a 1.7-in × 11-in thin film composite, semi-permeable membrane element, a 3-gal storage tank, and a MACguard post-filter. The RO units were capable of producing up to 35.5 gal/day (gpd) of permeate water and had a feed water to permeate water ratio of 2.7 to 1, a 37% recovery rating. The RO units automatically shut down production after 500 gal of permeate water have been processed and resume operation only after the replacement of pre- and post-filters.

The POU RO units began regular operation on July 15, 2005. The types of data collected included volume of permeate water produced; quality of feed, permeate, and reject water; required system operation and maintenance (O&M); and capital and O&M cost. Through the period of July 15, 2005, to January 17, 2006, one residence used 481 gal of water from the RO tap; another residence used 500 gal of water and the pre- and post-filters had to be replaced before the unit resumed operation. The rest of seven units were not tracked for water usage, but had not reached the 500-gal level.

Source water at the Sunset Ranch Development contained elevated levels of arsenic, nitrate, and uranium. Arsenic speciation results indicated that As(V) was the predominant species in raw water, ranging from 49.5 to 64.8 µg/L and averaging 56.3 µg/L. Only a trace amount of As(III) existed, ranging from 0.5 to 2.7 and averaging 1.5 µg/L. Nitrate concentrations averaged 10.2 mg/L (as N), just over the 10-mg/L (as N) MCL. Uranium concentrations ranged from 23.4 to 31.0 µg/L, very close to the 30-µg/L MCL.

As expected, the softeners did not remove any arsenic, but reduced the water hardness from 216 to 251 mg/L (as $CaCO_3$) to an average of 1.7 mg/L (as $CaCO_3$). Total arsenic concentrations in the permeate water were less than 0.1 µg/L for all samples except for four at 8.7, 5.1, 1.2, and 1.2 µg/L. Based on the average arsenic concentrations in the feed and permeate water, the RO units achieved higher than 99% removal efficiency for arsenic.

Nitrate was consistently removed by the RO units from an average of 10.2 mg/L (as N) in raw water to an average of 1.0 mg/L (as N) in the permeate water, representing a 90% reduction. Uranium was removed from 23.4 to 31.0 µg/L in raw water to below 0.1 µg/L in the permeate water. In addition, the RO units achieved 100% removal for iron, 99% for vanadium, 96% for silica, and 96% for total dissolved solids (TDS). pH values also were reduced to between 6.4 and 6.9, due to the reduction of alkalinity by the RO units.

Regeneration brine waste from the softener and reject water from the RO units was discharged to the septic tank at each residence. The RO reject water contained 55.9 to 92.3 µg/L of arsenic, 8.3 to 19.2 mg/L (as N) of nitrate, 23.0 to 42.3 µg/L of uranium, and 740 to 1,080 mg/L of TDS. The mass balance

across the RO unit was calculated for total arsenic and nitrate for each sampling event. During the entire study period, the mass balance data in terms of the mass recovered in the permeate and reject water against the mass in the raw water ranged from 63% to 114% and averaged 83% for total arsenic and from 66% to 100% and averaged 89% for nitrate.

Operational problems encountered during the reporting period included water pulsing from the faucet, incorrect outlet elbow installation, water quality monitor malfunction, a loose wire on the TDS monitor indicator light, and reduced flow from the RO tap. These problems were corrected promptly by the vendor; any cost incurred was covered under warranty.

The capital investment for this project was $31,877.50, including $21,732.50 for equipment and $10,145 for installation. Each water softener cost $2,395, including $1,585 for equipment and $810 for installation. Each RO unit cost $1,220, including $1,025 for equipment and $195 for installation. If the cost of materials and vendor travel was included, the total cost for each household system was near $4,000, which is equivalent to an annualized cost of $570 based on a 10-year life and a 7% interest rate. O&M cost per household during the performance evaluation period was near $202 or $17/month, which included salt usage and RO filter replacement. Neither electricity nor labor cost was incurred because the water softener and the RO unit did not consume electricity and did not require a certified operator.

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FIGURES

TABLES

ABBREVIATIONS AND ACRONYMS

AAL	American Analytical Laboratories
AM	adsorptive media
As	arsenic
ATS	Aquatic Treatment Systems
bgs	below ground surface
Ca	calcium
C/F	coagulation/filtration
Cl	chlorine
Cu	copper
EPA	U.S. Environmental Protection Agency
F	fluoride
Fe	iron
GFH	granular ferric hydroxide
gpd	gallons per day
gpm	gallons per minute
HDPE	high-density polyethylene
HIX	hybrid ion exchanger
hp	horsepower
ICP-MS	inductively coupled plasma-mass spectrometry
ID	identification
IDEQ	Idaho Department of Environmental Quality
IX	ion exchange
MCL	maximum contaminant level
MDL	method detection limit
MEI	Magnesium Elektron, Inc.
Mg	magnesium
mg/L	milligrams per liter
µg/L	micrograms per liter
µm	micrometer
Mn	manganese
Na	sodium
NA	not available
ND	not detectable
NRMRL	National Risk Management Research Laboratory
NO_2	nitrite
NO	nitrate
NSF	NSF International
O&M	operation and maintenance

OIT	Oregon Institute of Technology
ORD	Office of Research and Development
PO_4	orthophosphate
POC	point of contact
POE	point of entry
POU	point of use
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
R1	Residence 1
RO	reverse osmosis
RPD	relative percent difference
SDWA	Safe Drinking Water Act
SiO_2	silica
SO_4	sulfate
STS	Severn Trent Services
TDS	total dissolved solids
TOC	total organic carbon
U	uranium
V	vanadium
VOC	volatile organic compound

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1.0 INTRODUCTION

1.1 Background

The Safe Drinking Water Act (SDWA) mandates that the United States Environmental Protection Agency (EPA) identify and regulate drinking water contaminants that may have adverse human health effects and are known or anticipated to occur in public water supply systems. In 1975, under the SDWA, EPA established a maximum contaminant level (MCL) for arsenic at 0.05 mg/L. Amended in 1996, the SDWA required that EPA develop an arsenic research strategy and publish a proposal to revise the arsenic MCL by January 2000. On January 18, 2001, EPA finalized the arsenic MCL at 0.01 mg/L (EPA, 2001). In order to clarify the implementation of the original rule, EPA revised the rule text on March 25, 2003, to express the MCL as 0.010 mg/L (10 µg/L) (EPA, 2003). The final rule requires all community and non-transient, non-community water systems to comply with the new standard by January 23, 2006.

In October 2001, EPA announced an initiative for additional research and development of cost-effective technologies to help small community water systems (<10,000 customers) meet the new arsenic standard, and to provide technical assistance to operators of small systems in order to reduce compliance costs. As part of this Arsenic Rule Implementation Research Program, EPA's Office of Research and Development (ORD) proposed a project to conduct a series of full-scale, on-site demonstrations of arsenic removal technologies, process modifications, and engineering approaches applicable to small systems. Shortly thereafter, an announcement was published in the *Federal Register* requesting water utilities interested in participating in 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 from one to six proposals. In April 2003, an independent technical panel reviewed the proposals and provided its recommendations to EPA on the technologies that it determined were acceptable for 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. As of June 2007, all 12 systems were operational and the performance evaluations of nine systems were completed.

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 Sunset Ranch Development in Homedale, ID, was one of them.

In September 2003, EPA again solicited proposals from engineering firms and vendors for arsenic removal technologies. EPA received 148 technical proposals for the 32 potential host sites, with each site receiving from two to eight proposals. In April 2004, another technical panel was convened by EPA to review the proposals and provide recommendations to EPA with the number of proposals per site ranging from none (for two sites) to a maximum of four. The final selection of the treatment technology at the sites that received at least one proposal was made, again through a joint effort by EPA, the state regulators, and the host site. Since then, four sites have withdrawn from the demonstration program, reducing the number of sites to 28. In December 2004, the point of use (POU) reverse osmosis (RO) treatment technology from Kinetico was selected for demonstration at the Sunset Ranch Development site in Homedale, ID.

1.2 Treatment Technologies for Arsenic Removal

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

1.3 Project Objectives

The objective of the Round 1 and Round 2 arsenic demonstration program is to conduct 40 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 Kinetico's POU RO system operation from July 15, 2005, through June 28, 2006, at the Sunset Ranch Development in Homedale, ID. The types of data collected included system operation, water quality, and capital and O&M cost.

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

Demonstration Location	Site Name	Technology (Media)	Vendor	Design Flowrate (gpm)	Source Water Quality		
					As (µg/L)	Fe (µg/L)	pH (S.U.)
Northeast/Ohio							
Wales, ME	Springbrook Mobile Home Park	AM (A/I Complex)	ATS	14	38[a]	<25	8.6
Bow, NH	White Rock Water Company	AM (G2)	ADI	70[b]	39	<25	7.7
Goffstown, NH	Orchard Highlands Subdivision	AM (E33)	AdEdge	10	33	<25	6.9
Rollinsford, NH	Rollinsford Water and Sewer District	AM (E33)	AdEdge	100	36[a]	46	8.2
Dummerston, VT	Charette Mobile Home Park	AM (A/I Complex)	ATS	22	30	<25	7.9
Felton, DE	Town of Felton	C/F (Macrolite)	Kinetico	375	30[a]	48	8.2
Stevensville, MD	Queen Anne's County	AM (E33)	STS	300	19[a]	270[c]	7.3
Houghton, NY[d]	Town of Caneadea	C/F (Macrolite)	Kinetico	550	27[a]	1,806[c]	7.6
Buckeye Lake, 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)	USFilter	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)	Kinetico	37	41	<25	7.8

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

Demonstration Location	Site Name	Technology (Media)	Vendor	Design Flowrate (gpm)	Source Water Quality		
					As (µg/L)	Fe (µg/L)	pH
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)	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	California Water Service Company	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; C/F = coagulation/filtration; GFH = granular ferric hydroxide; HIX = hybrid ion exchanger; IX = ion exchange; 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% after system was switched from parallel to serial configuration.
(c) Iron existing mostly as Fe(II).
(d) Replaced Village of Lyman, NE site which withdrew from program in June 2006.
(e) Faculties upgraded Springfield, OH system from 150 to 250 gpm, Sandusky, MI system from 210 to 340 gpm, and Arnaudville, LA system from 385 to 770 gpm.
(f) Including nine residential units.
(g) Including eight under-the-sink units.

2.0 SUMMARY AND CONCLUSIONS

Based on the information collected during one year of system operation, the following conclusions were made relating to the overall objectives of the treatment technology demonstration study.

Performance of the arsenic removal technology for use on small systems

- The RO units were effective in removing arsenic from raw water, reducing its concentrations from 57.8 to <0.1 µg/L (on average) for all but four samples (i.e., with concentrations ranging from 1.2 to 8.7 µg/L), achieving over 99% removal efficiency for arsenic.
- The RO units also were effective in reducing nitrate concentrations from 5.8 to 13.6 mg/L (as N) in raw water to an average of 1.0 mg/L (as N) in the permeate water, achieving 90% removal for nitrate.
- The RO units were capable of removing uranium to below its analytical quantitation limit of 0.1 µg/L. This level of system performance was sustained throughout the entire study period.
- The RO units also were capable of achieving high levels of removal efficiency for total dissolved solids (TDS) (at 96%), iron (at 100%), vanadium (at 99%), and silica (at 96%).
- As expected, pH values were reduced to levels ranging from 6.4 to 6.9. The decrease in permeate pH values was due to the reduction of alkalinity by the RO units.
- Although not effective at removing arsenic or nitrate, the water softeners removed almost all calcium and magnesium hardness in raw water, reducing the hardness values from 216 to 251 mg/L (as $CaCO_3$) to an average of 1.7 mg/L (as $CaCO_3$). Removal of hardness was necessary to meet the RO feed water quality requirements.

Process residuals produced by the technology

- Two types of residuals were produced from the point of entry (POE) softening and POU RO processes. The water softener spent brine wastewater and the RO reject water were allowed to discharge directly to the septic tanks at individual homes. As expected, the RO reject water contained elevated levels of TDS, arsenic, nitrate, and other inorganic salts when compared with those in raw water.

Required system operation and maintenance

- The POE water softeners and POU RO units were designed for residential use; therefore, the skill requirements to operate both systems were minimal. Each home required the addition of salt to the water softener periodically and replacement of pre- and post-filters for the RO unit every six to 12 months.

Capital and O&M cost

- For home installation of a water softener and a RO unit, total equipment ($2,610) and installation ($1,005) cost amounted to $3,615. If the cost of materials and vendor travel was added, the total cost for each household system was near $4,000, which is equivalent to an annualized cost of $570 based on a 10-year life and a 7% interest rate.
- Only five homeowners used 500 gal of treated water during this six month reporting period. For these homeowners with the largest water usage, the one year O&M cost for salt usage ($115) and filter replacement ($86.50) was $201.50, or $17 per month.

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 POU systems began on July 15, 2005. Table 3-2 summarizes the types of data collected and considered as part of the technology evaluation process. The overall system performance was evaluated based on its ability to consistently remove arsenic and nitrate to below the target MCL of 10 µg/L for arsenic and 10 mg/L (as N) for nitrate. The reliability of the system was evaluated by tracking the unscheduled system downtime and frequency and extent of repair and replacement activities. The unscheduled downtime and repair information were recorded by a designated homeowner on a Repair and Maintenance Log Sheet.

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

Table 3-1. Predemonstration Study Activities and Completion Dates

Activity	Date
Introductory Meeting Held	December 1, 2004
Project Planning Meeting Held	February 10, 2005
Draft Letter of Understanding Issued	February 21, 2005
Final Letter of Understanding Issued	February 28, 2005
Request for Quotation Issued to Vendor	March 15, 2005
Vendor Quotation Submitted to Battelle	April 1, 2005
Purchase Order Completed and Signed	May 24, 2005
Engineering Package Submitted to IDEQ	June 10, 2005
Final Study Plan Issued	June 18, 2005
Permit issued by IDEQ	June 20, 2005
Initial System Installation and Shakedown Completed	July 1, 2005
Performance Evaluation Begun	July 15, 2005

IDEQ = Idaho Department of Environmental Quality

3.2 System O&M and Cost Data Collection

The routine O&M activities for the water softeners and RO units included visual inspections of the systems for leaks or faults and checking for the salt tank levels for the softeners and the TDS monitors for the RO units. The Residence 1 (R1) homeowner, who also is the President of the Sunset Ranch Development and designated point of contact (POC) for this demonstration project, recorded weekly flow totalizer readings on the RO permeate line. If any problems occurred at any residences, homeowner R1 would contact the Battelle Study Lead, who would then determine if Kinetico should be contacted for troubleshooting. Homeowner R1 recorded all relevant information on the Repair and Maintenance Log Sheet. Each month, homeowner R1 measured pH and temperature using a handheld meter and recorded the data on an On-Site Water Quality Parameters Log Sheet.

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

Evaluation Objective	Data Collection
Performance	-Ability to consistently meet 10 μg/L of arsenic and 10 mg/L of nitrate (as N) 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
Cost-Effectiveness	-Capital cost for equipment, engineering, and installation -O&M cost for chemical usage, electricity consumption, and labor

The O&M cost consisted of cost for salt usage for regeneration of the water softeners and replacement of pre- and post-RO filter cartridges. Labor cost was not included because the treatment systems were maintained by individual homeowners. Electricity was not required because the treatment systems were non-electrical and operated by water pressure.

3.3 Sample Collection Procedures and Schedules

To evaluate the system performance, samples were collected monthly at the wellhead, after the water softener, and after the RO unit at each of the nine participating homes, and from the reject water discharge line at the R1 residence. The sampling schedules and analytes measured for each sampling event are listed in Table 3-3. In addition, Figure 3-1 presents a flow diagram of the treatment system along with the analytes and schedules at each sampling location. Specific sampling requirements for analytical methods, sample volumes, containers, preservation, and holding times are presented in Table 4-1 of the EPA-endorsed Quality Assurance Project Plan (QAPP) (Battelle, 2004). The procedure for arsenic speciation is described in Appendix A of the QAPP.

3.3.1 Source Water Sample Collection. During the initial site visit on December 1, 2004, one set of source water samples was collected and speciated using an arsenic speciation kit (see Section 3.4.1). The sample tap was flushed for several minutes before sampling was performed; special care was taken to avoid agitation, which might cause unwanted oxidation. Analytes for the source water samples are listed in Table 3-3.

3.3.2 Treatment Plant Water Sample Collection. During the system performance study, homeowner R1 collected monthly water samples at the wellhead (IN), after the water softener (WS), and after the RO unit (RO) at each of the nine participating homes. On-site arsenic speciation also was performed at the IN and R1 residence's WS and RO sampling locations on a quarterly basis. Analytes for the treatment system water samples are shown in Table 3-3 and Figure 3-1.

Table 3-3. Sampling and Analysis Schedule for Sunset Ranch Development in Homedale, ID

Sample Type	Sampling Locations	No. of Sampling Locations	Frequency	Analytes	Sampling Date(s)
Source Water	At Wellhead (IN)	1	Once during Initital Site Visit	On-site: pH, temperature, DO, and ORP Off-site: As (total and soluble), As(III), As(V), Fe (total and soluble), Mn (total and soluble), U (total and soluble), V (total and soluble), Na, Ca, Mg, F, Cl, NH_3, NO_2, NO_3, SO_4, SiO_2, PO_4, TDS, TOC, turbidity, and alkalinity	12/01/04
Treatment System Water	At Wellhead (IN)[(a)] After Water Softener at Nine Homes (WS1–WS9) After RO units at Nine Homes (RO1–RO9)	19	Monthly	On-site: pH and temperature (at Wellhead and R1 residence only) Off-site: As (total), Fe (total), Mn (total), Ca, Mg, F, NO_3, SO_4, SiO_2, PO_4, TDS, turbidity and alkalinity (U [total] and V [total] at Wellhead and R1 residence only)	07/20/05, 08/24/05, 09/20/05, 10/19/05, 11/16/05, 12/14/05, 01/17/06, 02/15/06, 03/15/06, 04/19/06, 05/17/06, 06/28/06,
	At Wellhead (IN)[(a)] After Water Softener at R1 residence (WS1) After RO unit at R1 residence (RO1)	3	Quarterly	On-site: pH and temperature (Wellhead and R1 residence only) Off-site: As (total and soluble), As(III), As(V), Fe (total and soluble), Mn (total and soluble), U (total and soluble), and V (total and soluble)	09/20/05, 12/14/05, 03/15/06, 06/28/06
Reject Water	RO Reject Water Discharge Line at R1 residence (RW1)	1	Monthly	Off-site: As (total and/or soluble), Fe (total and/or soluble), Mn (total and/or soluble), U (total and/or soluble), V (total and/or soluble), NO_3, SO_4, TDS, turbidity, and pH	07/20/05, 08/24/05, 09/20/05, 10/19/05, 11/16/05, 12/14/05, 01/17/06, 02/15/06, 03/15/06, 04/19/06, 05/17/06, 06/28/06

(a) One wellhead sample taken monthly at pump house.

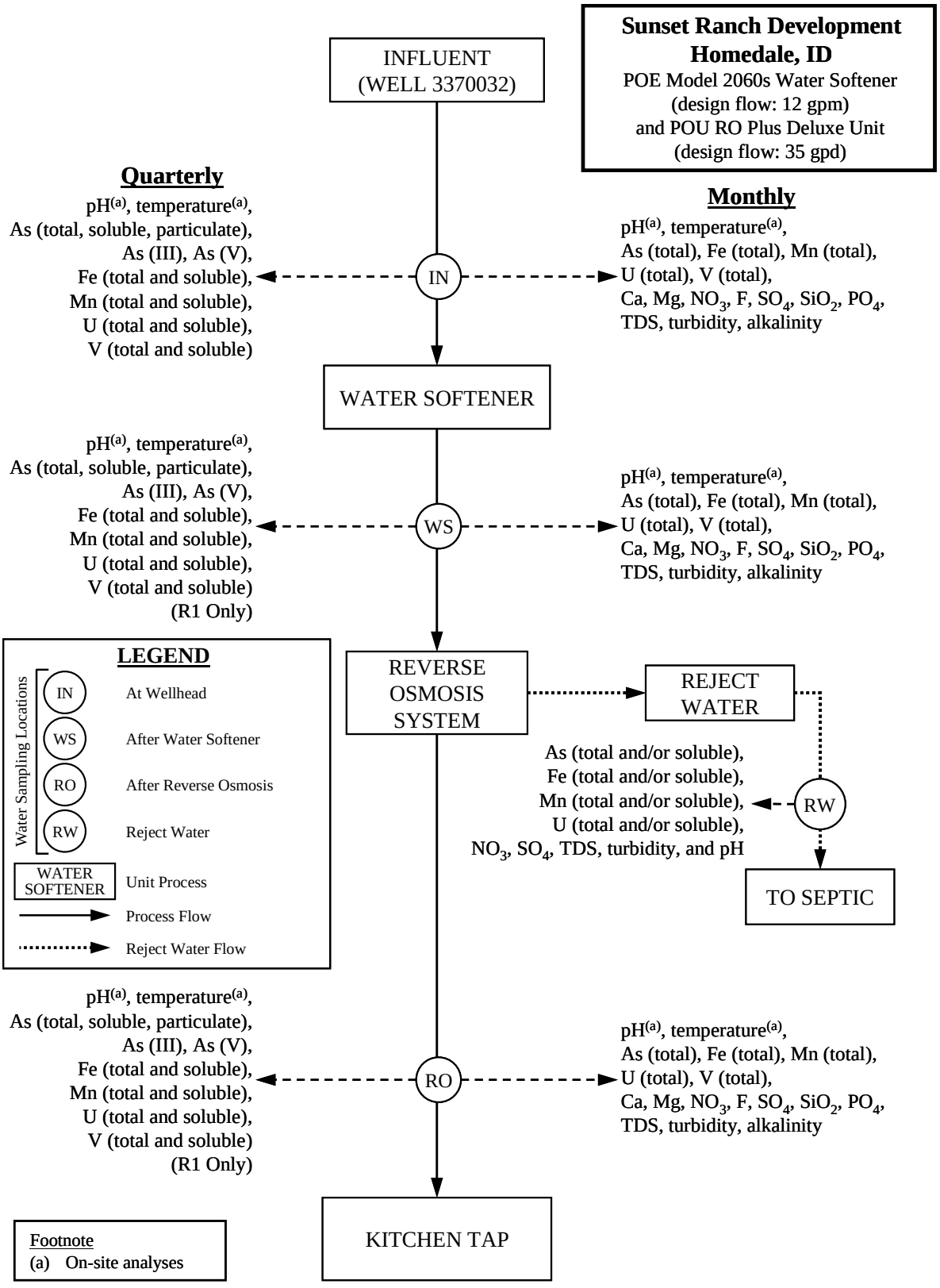

Figure 3-1. Process Flow Diagram and Sampling Locations for Sunset Ranch Development

3.3.3 Reject Water Sample Collection. Reject water samples were collected monthly at the R1 residence by the homeowner from a sampling tap on the reject water discharge line leading from the RO unit to the home septic system. For each sampling event, an unfiltered sample from the RO reject water line was collected in an unpreserved 1-gal wide-mouth high-density polyethylene (HDPE) bottle for water quality analyses, and a 60-mL sample filtered on-site with 0.45-µm filters in a 125-mL HDPE bottle preserved with nitric acid for metal analyses. Analytes for the reject water samples are listed in Table 3-3 and Figure 3-1.

3.4 Sampling Logistics

All sampling logistics including arsenic speciation kit preparation, sample cooler preparation, and sample shipping and handling are discussed as follows.

3.4.1 Preparation of Arsenic Speciation Kits. The arsenic field speciation method uses an anion exchange resin column to separate the soluble arsenic species, As(V) and As(III) (Edwards et al., 1998). Resin columns were prepared in batches at Battelle laboratories according to the procedures detailed in Appendix A of the EPA-endorsed QAPP (Battelle, 2004).

3.4.2 Preparation of Sampling Coolers. For each sampling event, a cooler was prepared with an 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, colored-coded label consisting of the sample identification (ID), date and time of sample collection, collector's name, site location, sample destination, analysis required, and preservative. The sample ID consisted of a two-letter code for a specific water facility, the sampling date, a two-letter code for a specific sampling location, and a one-letter code designating the arsenic speciation bottle (if necessary). The labeled bottles then were grouped separately into ziplock bags according to the sampling locations and placed in the cooler.

In addition, all sampling- and shipping-related materials, such as disposable gloves, sampling instructions, chain-of-custody forms, prepaid and addressed FedEx air bills, and bubble wrap, were packed in the coolers. The chain-of-custody forms and prepaid FedEx air bills were completed with the required information, except for the operator's signature and the sample date and time. After preparation, sample coolers were sent to the site via FedEx for the following week's sampling event.

3.4.3 Sample Shipping and Handling. After sample collection, samples for off-site analyses were packed carefully in the original coolers with wet ice and shipped to Battelle. Upon receipt, the sample custodian 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 water quality analyses by Battelle's subcontract laboratories were packed in separate coolers and picked up by couriers from American Analytical Laboratories (AAL) in Columbus, OH, and TCCI Laboratories in New Lexington, OH. Samples for metal analyses were stored at Battelle's inductively coupled plasma-mass spectrometry (ICP-MS) laboratory. The chain-of-custody forms remained with the samples from the time of preparation through analysis and final disposition. All samples were archived by the appropriate laboratories for the respective duration of the required hold time and disposed of properly thereafter.

3.5 Analytical Procedures

The analytical procedures described in Section 4.0 of the EPA-endorsed QAPP (Battelle, 2004) were followed by the Battelle ICP-MS Laboratory, AAL, and TCCI Laboratories. Laboratory quality assurance/quality control (QA/QC) of all methods followed the prescribed guidelines. Data quality in terms of precision, accuracy, method detection limits (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 were conducted by homeowner R1 using a WTW Multi 340i handheld meter, which was calibrated for pH prior to use following the procedures provided in the user's manual. Homeowner R1 collected a water sample in a clean plastic beaker and placed the WTW probe in the beaker until a stable value was obtained.

4.0 RESULTS AND DISCUSSION

4.1 Facility Description

Homedale is located in Owyhee County, Idaho, approximately 40 miles west of Boise at the intersection of U.S. Highway 95 and Idaho Route 19. The Sunset Ranch Development, composed of 10 homes, is located approximately three miles west of Homedale, on Route 19 at Northside Road. Nine homes participated in the EPA demonstration; one homeowner opted to use a private well.

The residents of the Sunset Ranch Development are served by a 10-in diameter well (No. 3370032) installed to a depth of 130 ft below ground surface (bgs) with a screen interval from 50 to 130 ft bgs. The static water level was measured at 46 ft bgs on December 14, 2004. The well is equipped with a 15-horsepower (hp) submersible pump, providing a flowrate of approximately 20 gal/min (gpm). Figure 4-1 shows the exterior of the central well house, and Figure 4-2 shows the plumbing and sample tap within the well house. There is no centralized water treatment system currently in place.

Water from the well is stored in a pressure tank located in the community pump house (Figure 4-2). The tank maintains pressure to the individual homes. When water is consumed and the tank pressure decreases to a pre-set level, the well pump is activated by a pressure switch. The pump continues to run until the tank pressure returns to a specified level.

Figure 4-1. Central Pump House at Sunset Ranch Development Site

Figure 4-2. Plumbing from Well and Sample Tap at Sunset Ranch Development Site

4.1.1 Source Water Quality. The analytical results from the source water sampling event on December 1, 2004, are presented in Table 4-1 and compared to those submitted by the facility to EPA for the demonstration site selection and to those provided by the vendor. The treatment process consists of POE water softeners and POU RO units for arsenic, nitrate, and uranium removal. Results of the source water analyses and implications for water treatment are discussed below.

Arsenic. Total arsenic concentrations in source water ranged from 51.6 to 80 μg/L. Based on the December 1, 2004, sampling results obtained by Battelle, the total arsenic concentration in the source water was 51.6 μg/L with most of the soluble fraction present as As(V) (i.e., 46.8 μg/L). A small amount of the total arsenic also existed as particulate As (1.9 μg/L). Because arsenic was present primarily as As(V), oxidation of the water prior to the water softeners and POU RO units was not required.

Nitrate and Uranium. Nitrate concentrations in source water ranged from 8.9 to 11.5 mg/L (as N). Uranium concentration was 30.1 μg/L, existing primarily in the soluble form. Both nitrate and uranium were monitored monthly during the one-year performance evaluation study to determine if their concentrations in the treated water would be reduced to less than their respective MCLs of 10 mg/L and 30 μg/L.

Other Water Quality Parameters. TDS concentrations in source water ranged from 692 to 698 mg/L, which were composed primarily of calcium (91.5 to 98.2 mg/L), magnesium (15.7 to 17.0 mg/L), sodium (102 to 132 mg/L), sulfate (195 to 210 mg/L), silica (65.5 to 66.3 mg/L), nitrate (8.9 to 11.5 mg/L [as N]), chloride (19.0 to 21.7 mg/L), and fluoride (0.90 to 0.94 mg/L). Other ions present in source water included iron (134 to 330 μg/L) and vanadium (30.3 to 31.2 μg/L). Because relatively high concentrations of vanadium were measured, its concentrations were monitored monthly during the one-year performance evaluation study. Hardness values of 310 and 198 mg/L (as $CaCO_3$) were recorded by Battelle and Kinetico, respectively. Softening of this water prior to the RO systems was recommended by the vendor to prevent scaling of the RO membrane.

Table 4-1. Sunset Ranch Development Water Quality Data (Well 3370032)

Parameter	Unit	Kinetico Source Water Data	Facility Source Water Data	Battelle Source Water Data	Battelle Treated Water Data[(a)]
Date	-	-	-	12/01/04	12/01/04
pH	S.U.	7.6	7.3	7.5	NA
Temperature	°C	NA	NA	12.7	NA
DO	mg/L	NA	NA	5.4	NA
ORP	mV	NA	NA	249	NA
Total Alkalinity (as $CaCO_3$)	mg/L	300	252	305	15
Hardness (as $CaCO_3$)	mg/L	298	NA	310	0.10
Turbidity	NTU	NA	NA	0.8	0.1
TDS	mg/L	NA	692	698	48
TOC	mg/L	NA	NA	1.8	NA
Nitrate (as N)	mg/L	NA	11.5	8.9	1.1
Nitrite (as N)	mg/L	NA	NA	<0.01	<0.01
Ammonia (as N)	mg/L	NA	NA	<0.05	<0.05
Chloride	mg/L	21.7	19.0	21.0	<1.0
Fluoride	mg/L	0.94	NA	0.9	<0.10
Sulfate	mg/L	195	NA	210	4.0
Silica (as SiO_2)	mg/L	66.3	NA	65.5	7.9
Orthophosphate (as PO_4)	mg/L	<0.5	NA	<0.06	<0.06
As (total)	µg/L	65.0	80.0	51.6	<0.1
As (soluble)	µg/L	NA	NA	49.7	NA
As (particulate)	µg/L	NA	NA	1.9	NA
As(III)	µg/L	NA	NA	2.9	NA
As(V)	µg/L	NA	NA	46.8	NA
Fe (total)	µg/L	<30	330	134	<25
Fe (soluble)	µg/L	NA	NA	<25	NA
Mn (total)	µg/L	<10	ND	2.1	<0.1
Mn (soluble)	µg/L	NA	NA	1.5	NA
U(total)	µg/L	NA	NA	29.3	<0.1
U (soluble)	µg/L	NA	NA	30.1	NA
V (total)	µg/L	NA	NA	30.3	0.7
V (soluble)	µg/L	NA	NA	31.2	NA
Na (total)	mg/L	125	102	132	16.5
Ca (total)	mg/L	91.5	NA	98.2	0.02
Mg (total)	mg/L	17	NA	15.7	0.006

(a) Sample taken at a cold water tap at R1 residence with water already treated by undersink RO unit.
NA = not available; ND = not detectable; TOC = total organic carbon; TDS = total dissolved solids

4.1.2 Treated Water Quality. As noted above, although there was no centralized treatment system at Sunset Ranch Development, several homeowners had installed a softener and/or an RO unit. A sample was collected from the kitchen tap at the R1 residence after the water had been treated by a softener and an RO unit on December 1, 2004. Total arsenic, nitrate, and uranium concentrations in the treated water were <0.1 µg/L, 1.1 mg/L (as N), and 0.1 µg/L, respectively. Other cations and anions also were removed to low levels as shown in Table 4-1.

4.1.3 Wastewater Disposal. The individual homes within the Sunset Ranch Development employed septic systems for wastewater disposal. Regeneration wastewater from the softeners and reject water from the RO units were discharged to the septic system at each home.

4.2 Treatment Process Description

The treatment train for the Sunset Ranch Development site included a POE water softener and a POU RO unit at each of the nine participating homes. This POE/POU combination at each home was a modification to the originally proposed approach that would use a centralized water softening system in the pump house for all participating homes. The POE approach was preferred because it utilized the existing septic system at each residence for the regeneration waste disposal, thus eliminating the need to construct a septic system at the pump house.

RO processes typically are used to remove dissolved salts and other dissolved materials from drinking water. Softening was performed as a pretreatment to prevent scaling of the RO membranes using either a new or an existing water softener (Table 4-2). Figure 4-3 is a schematic of the treatment train. Figure 3-1 presents a process flowchart, including sample locations, frequency, and analytes.

Table 4-2. Water Softener Systems at Participating Sunset Ranch Development Homes

Residence ID	Water Softener
R1	Culligan Mark 100 (existing)
R2	Kinetico Model 2060s
R3	Kinetico Model 2060s
R4	Kinetico Model 30 (existing)
R5	Kinetico Model 2060s
R6	Kinetico Model 2060s
R7	Kinetico Model 2060s
R8	Kinetico Model 2060s
R9	Kinetico, model unknown (existing)

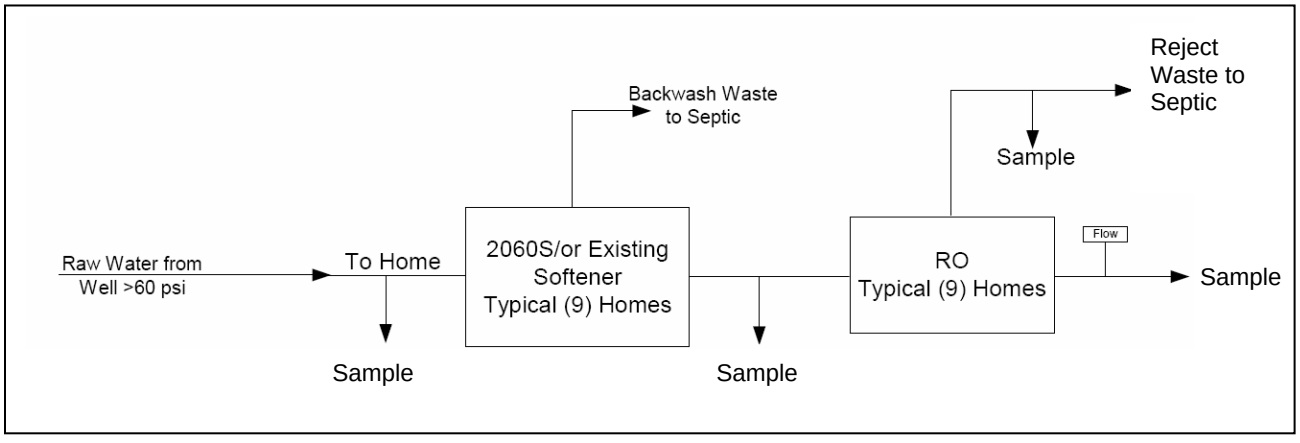

Figure 4-3. Schematic of Kinetico's POE Water Softener and POU RO Unit

4.2.1 Water Softener. Kinetico's Model 2060s water softener consisted of two 8-in × 40-in polyethylene wrapped resin tanks and one 12-in × 40-in or 18-in × 35-in brine tank (Figure 4-4). Each resin tank contained 0.7 ft^3 of non-solvent cation exchange resin. The water softener was equipped with a built-in water meter and did not require electricity to operate. The system was configured for alternating flow between the two resin tanks at a maximum flowrate of 12 gpm. After processing 625 gal of water, water production was switched to the standby tank while the exhausted tank was being regenerated. Regeneration used approximately 3.6 lb of salt and 35 gal of softened water and took 45 min to complete. The two preexisting Kinetico units at the R4 and R9 residences also were regenerated based on volume throughput. The regeneration of the Culligan system at the R1 residence was based on a time setting, which was set to regenerate twice a week. The Model 2060s water softener has been tested and listed under NSF International (NSF) Standard 44; the key performance specifications of the unit are summarized in Table 4-3.

Figure 4-4. Kinetico Model 2060s Water Softener

4.2.2 RO Plus Deluxe Unit. The softened water was further treated prior to the kitchen tap by a RO unit for arsenic, nitrate, and uranium removal. The RO Plus Deluxe unit from Kinetico consisted of a prefilter cartridge, an RO module, a storage tank, and a post-filter cartridge (Figure 4-5).

- **Prefilter Cartridge** – Prior to entering the RO module, water passed through a 20-μm prefilter to remove particles.

- **RO Module** – After passing through the prefilter, water was forced through a 1.7-in × 11-in thin film composite, semi-permeable membrane element where most soluble minerals and chemicals were removed. The RO unit could produce up to 35.5 gal/day (gpd) of permeate water. While yielding permeate water, the RO unit also produced reject water, which

Table 4-3. Kinetico Model 2060s Water Softener Performance Specifications

Parameter	Value
System Components	
No. of Media Vessels	2
Media Vessel Size (in)	8-in D × 40-in H
Media Vessel Construction	Wrapped polyethylene
Tank Volume (ft^3)	1.0
Media Type	Non-solvent cation exchange resin
Media Volume (ft^3)	0.7
Bed Depth (in)	25
Free Board Depth (in)	15
Riser Tube (in)	1
Upper Distributor (in)	0.014
Lower Distributor (in)	0.014
Regeneration Control	Non-electric use meter
Regeneration Type	Counter-current
Inlet Water Quality	
Pressure Range (psi)	15–125
Temperature Range (ºF)	35–120
pH Range (S.U.)	5–10
Free Chlorine (max, mg/L [as Cl_2])	2
Hardness (max, grains per gallon [as $CaCO_3$])	66
Operation Specifications	
Flow Range (gpm)	11.5–18.0
Flow Configuration	Alternating
Regeneration Frequency (gal)	625
Regeneration Waste Volume (gal)	35
Regeneration Time (min)	45
Brine Tank Specifications	
No. of Brine Tanks	1
Brine Tank Size (in)	Varying (12-in D × 40-in H, 18-in D × 35-in H)
Brine Tank Construction	High-density polyethylene
Salt Capacity (lb)	Varying (100, 200)

Data source: Kinetico

included water rejected by the RO membrane and rinse water used to rinse the RO membrane. The reject water produced represented approximately 63% of the volume reaching the RO unit. The RO unit was rated as 2.7:1, that is, for every 2.7 gal of feed water, 1 gal of permeate water and 1.7 gal of reject water (including approximately 400 mL of permeate water to flush the membrane) were produced. The volume of reject water produced daily was dependent on the volume of water consumed at the kitchen tap.

- **Storage Tank** – Permeate water was stored in a 3-gal QuickFlo storage tank, which used water pressure to ensure a constant flow at the tap.

Figure 4-5. Under-the-Sink RO Plus Deluxe Unit

- **Post-Filter** – The water from the storage tank flowed to a Metered Automatic Cartridge Guard Filter (MACguard), which contained activated carbon to remove any volatile organic compounds (VOCs) and unpleasant taste and odor. The MACguard filter was equipped with an automatic shut-off, which discontinued water production after 500 gal of water had been processed. Water production resumes only after the pre- and post-filters have been replaced.

In addition to the above-mentioned system components, the system also was equipped with a PureMometer Filter Life Indicator to alert the user for the remaining capacity of the filter cartridge. Further, a TDS monitor installed at the kitchen tap measured TDS levels in the treated water. A green light on the monitor indicated that a proper amount of reject water was generated and a yellow light indicated that it was not. A non-standard Kent Model C-700 TP water meter was installed between the RO module and the storage tank at the R1 residence to track the permeate production. The RO Plus Deluxe system has been tested and listed under NSF Standard 58 for the reduction of arsenic, barium, radium 226/228, cadmium, copper, cysts, fluoride, nitrate/nitrite, TDS, turbidity, and other contaminants. Table 4-4 summarizes the key performance specifications for the RO Plus Deluxe unit.

4.3 System Permitting and Installation

4.3.1 Permitting. The engineering plans for the systems were prepared by Kinetico and submitted to IDEQ for approval on June 10, 2005. The plans included a written description of Kinetico's POE water softener and the POU RO unit, a schematic diagram of the system, system specification sheets, Notice to the Public, an executive summary of managed POU treatment systems, and a Maintenance, Monitoring, and Sampling Plan for POU treatment systems. The permit approval was granted by IDEQ on June 20, 2005.

Table 4-4. Kinetico RO Plus Deluxe Unit Performance Specifications

Parameter	Value
System Components	
No. of Pre-filters	1
Pre-filter Size (µm)	20
No. of RO Membrane Elements	1
RO Membrane Construction	Thin film composite
Membrane Element Size (in)	1.7-in D x 11-in H
No. of Post-filters	1
Permeate Flush	Internal Permeate Reservoir
Element Configuration	Single
System Shutoff Control	Hydraulic
System Shutdown Volume (gal)	500
System Controller	Hydraulic
Inlet Water Quality	
Pressure Range (psi)	40–100
Temperature Range (°F)	35–100
pH Range (S.U.)	3–11
Free Chlorine (max, mg/L [as Cl_2])	0.05
Hardness (max, mg/L [as $CaCO_3$])	<170
Silica (max, mg/L)	10
Iron (max, mg/L)	<0.01
TDS (max, mg/L)	<4,000
Operating Specifications	
Maximum Daily Production (gpd)	75
Daily Production (gpd)	35.5
Discharge Water (or Feed Water)/Product Water Ratio	2.7 to 1
Normal Operating Pressure (psi)	60
Storage Tank	
Storage Tank Volume (gal)	3
Storage Tank Footprint (in)	8-in D × 17-in H
Storage Tank Material	Zytel

Data source: Kinetico

4.3.2 System Installation, Shakedown, and Startup. Water softeners and RO units were delivered to the site on June 24, 2005. Kinetico's local dealer in Meridian, ID, performed the off-loading and installation. The installation consisted of plumbing, initial salt filling, outside faucet isolation (from water softener systems), and equipment inspections. The shakedown/start-up consisted of pressurizing the systems and making all necessary adjustments to bring the systems on-line and operational. While on-site, Kinetico technicians provided training to two homeowners for hands-on operation and routine maintenance. The mechanical installation and shakedown of the systems were completed on July 1, 2005. On July 8, 2005, a Kent Model C-700 TP water meter was installed at the R1 residence. The performance evaluation officially began on July 15, 2005. Battelle staff members were on-site on September 20, 2005, to inspect the systems and conduct operator training, which included calibration and use of a WTW field handheld meter, collection of field data, collection of water samples from the treatment systems, field arsenic speciation, and proper handling of chain-of-custodies.

4.4 System Operation

4.4.1 Permeate Water Production. Based on the totalizer installed at the R1 residence, the RO unit produced approximately 481 gal of water from July 15, 2005, through June 28, 2006, an average of 40 gal/month (Figure 4-6). Water production reached 500 gal at the R1, R4, R5, R6, and R9 residences during the performance evaluation; the pre- and post-filters were replaced before water production resumed. Water production at the other four participating homes was not measured, but none reached the 500-gal level before the end of this performance evaluation period.

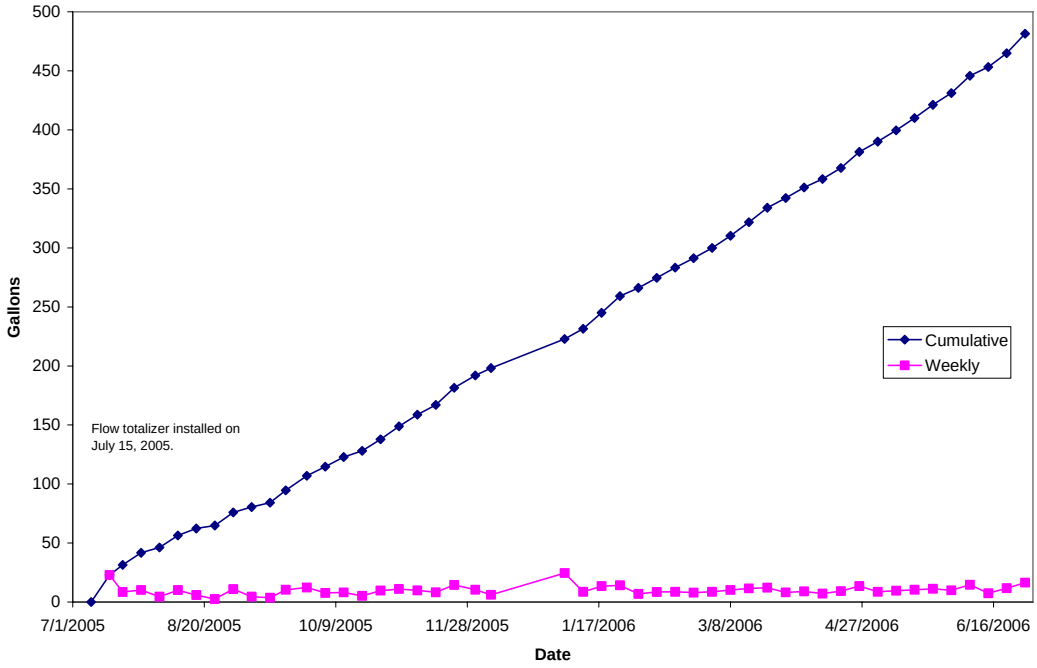

Figure 4-6. RO Totalizer Readings at R1 Residence

4.4.2 Reject Water Production. Due to the lack of a water meter on the reject water discharge line, the actual amount of reject water produced was not tracked. However, based on the 2.7:1 ratio, it was estimated that 818 gal of water was discharged to the septic system while producing 481 gal of permeate water at the R1 residence. Reject water samples were collected monthly at the R1 residence by the homeowner from a sampling tap on the reject water discharge line leading from the RO unit to the home septic system.

4.4.3 System/Operation Reliability and Simplicity. Operational problems were encountered during the first month of system operation. On July 26, 2005, the RO taps of two residences experienced low water flow and the respective undersink storage tanks had to be replaced in order to solve the problem. The undersink storage tank at one of these residences had to be replaced again on August 8, 2005, for the same problem. While under warranty, Kinetico technicians were on-site from August 10 to 11, 2005, to address this and other problems. On June 22, 2006, the low flow problem was encountered at two more residences and the undersink storage tanks at both of these residences had to be replaced and a check valve at one of the residence had to be replaced. Table 4-5 summarizes the problems encountered and corrective actions taken.

Table 4-5. Summary of Kinetico Service Report

Time	Problem Encountered	Corrective Action Taken	Residences
07/26/05 08/08/05	Low flowrate at faucet	Undersink storage tank replaced	R2 & R3
08/10/05	Water pulsing from faucet	Faucet upgraded to include new high flow gasket	R1-R9
08/10/05	Incorrect outlet elbow installed	Correct flow control elbow installed	R1
08/10/05	Water quality monitor malfunction	Sensor replaced	R9
08/10/05	Loose wire on TDS monitor indicator light	TDS monitor replaced	R6
6/22/06	Low flowrate at faucet	Replaced undersink storage tanks and a check valve	R1 & R6

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

Pre- and Post-Treatment Requirements. Softening of raw water was required before treatment by the RO unit to prevent scaling of the RO membranes. Water softeners were placed upstream of the RO units.

System Automation. The Model 2060s softeners were regenerated automatically after 625 gal of water treated. Hydraulic signals within the RO units controlled the operational sequences, such as pressurization and depressurization of the membranes and flushing of the membranes following the system shut down. The unit shut down automatically once 500 gal of water had been treated. A Puremometer™ indicator visibly indicated the remaining filter capacity.

Operator Skill Requirements. The POE water softeners and POU RO units were designed for residential use; therefore, the skill requirements to operate both systems were minimal. There was no need for the homeowners to inspect the systems on a daily basis. The operation of the systems did not appear to require additional skills beyond adding salt to the water softeners and replacing pre- and post-filters of the RO units. Operations of the POE/POU systems were handled well by all homeowners.

Preventative Maintenance Activities. Preventative maintenance activities were minimal for the water softeners and RO units. The water softener used an inline filter to remove particles from raw water and would require periodical replacement. The frequency of the filter replacement was determined by water usage and content of solids. The amount of salt in the brine tank needed to be checked and salt added as needed. The pre- and post-cartridge filters for the RO unit required changing every 500 gal, as the unit would shut down when it reaches the 500-gal production level. During the performance evaluation study, the RO units at five residences reached the 500-gal mark and replacement of the pre- and post-cartridge filters was required to resume normal operation.

Chemical Handling and Inventory Requirements. Salt was used for the regeneration of the water softeners. The homeowners needed to check and maintain salt levels in the brine tanks and contact Kinetico for salt delivery. On August 30, 2005, 2,450 lb of salt was delivered to the site and stored in the well house.

4.5 System Performance

The performance of the RO units was evaluated based on analyses of water samples collected from the POE/POU systems.

4.5.1 Treatment Plant Sampling. A total of 20 locations were sampled at the site, including locations at the wellhead (IN), after the water softener at each of the nine residences (WS1-WS9), after the RO unit at each of the nine residences (RO1-RO9), and at the reject water discharge line at the R1 residence (RW1). Water samples were collected monthly on 12 occasions during the one-year study period. Sample collection was discontinued at the WS3 and RO3 locations after October 19, 2005, due to vacancy of the R3 residence.

Table 4-6 summarizes the analytical results of arsenic, nitrate, uranium, vanadium, and TDS, and Figures 4-7 to 4-11 are plots of the results of these constituents across the treatment train. Note that the concentrations plotted for "after water softener" and "after RO unit" are the average of the respective results for the nine homes except for uranium and vanadium, which were measured at the R1 residence only.

Field arsenic speciation was performed at the R1 residence on four occasions, and the results are summarized in Table 4-7. Also, pH and temperature were measured on-site at the wellhead (IN) and in the R1 residence at the WS1 and RO1 locations on nine occasions, and the results are plotted in Figure 4-12.

Results of other water quality parameters measured are provided in Table 4-8. Appendix A contains a complete set of analytical results for the one year performance evaluation. The results of the water samples collected throughout the POE/POU systems are discussed as follows.

Arsenic. Total As concentrations in raw water ranged from 53.0 to 64.3 µg/L and averaged 57.8 µg/L (Table 4-6). Based on arsenic speciation results of the soluble fraction (Table 4-7), As(V) was the predominating species, ranging from 49.5 to 64.8 µg/L and averaging 56.3 µg/L. Only a trace amount of As(III) existed, ranging from 0.5 to 2.7 µg/L and averaging 1.5 µg/L. The arsenic concentrations measured during the one year performance evaluation were consistent with those in the raw water sample collected on December 1, 2004 (Table 4-1).

Total arsenic concentrations after the water softeners ranged from 48.1 to 97.2 µg/L (with one outlier of <0.1 µg/L occurring at the R7 Residence [WS7] on November 16, 2005) and averaged 57.2 µg/L, which were at similar levels as those in raw water (Figure 4-7). As expected, the softeners did not remove any arsenic. Total arsenic concentrations after the RO units were <1.0 µg/L for all samples, except for four occurrences measured at 8.7 µg/L at the R7 Residence on July 20, 2005, 1.2 µg/L at the R1 Residence on August 24, 2005, 5.1 µg/L at the R4 Residence on July 20, 2005, and 1.2 µg/L at the R1 Residence on August 24, 2005. Based on the average arsenic concentration in raw water, the RO units achieved over 99% arsenic removal.

Nitrate. Nitrate concentrations at the wellhead and after water softeners exceeded the MCL of 10 mg/L, averaging at 10.2 and 10.3 mg/L (as N), respectively (Table 4-6). Nitrate was consistently removed by the RO units during the performance evaluation with concentrations in RO permeate ranging from <0.05 to 3.7 mg/L (as N) and averaging 1.0 mg/L (as N), representing 90% removal (Figure 4-8).

Table 4-6. Summary of Arsenic, Nitrate, Uranium, Vanadium, and TDS Results at Sunset Ranch Development

Parameter	Sampling Location	Unit	Number of Samples	Concentration			
				Minimum	Maximum	Average	Standard Deviation
As (total)	IN	µg/L	12	53.0	64.3	57.8	3.4
	WS	µg/L	100	48.1	97.2	57.2	8.6
	RO	µg/L	100	<0.1	8.7	0.4	1.0
Nitrate (as N)	IN	mg/L	12	5.81	13.6	10.2	2.1
	WS	mg/L	100	0.62	13.6	10.3	2.0
	RO	mg/L	100	0.03	3.7	1.0	0.7
U (total)	IN	µg/L	12	23.4	31.0	27.4	2.4
	WS	µg/L	22	19.5	31.9	27.2	3.5
	RO	µg/L	22	<0.1	<0.1	<0.1	-
V (total)	IN	µg/L	12	29.1	39.0	32.4	2.5
	WS	µg/L	22	29.9	38.9	33.1	2.1
	RO	µg/L	22	<0.1	1.3	0.2	0.4
TDS	IN	mg/L	12	648	730	685	26.7
	WS	mg/L	100	492	946	704	49.0
	RO	mg/L	100	<1.0	98	26.2	21.0

One-half of detection limit used for non-detect samples for calculations.
Note: Uranium and vanadium measured at R1 residence only.

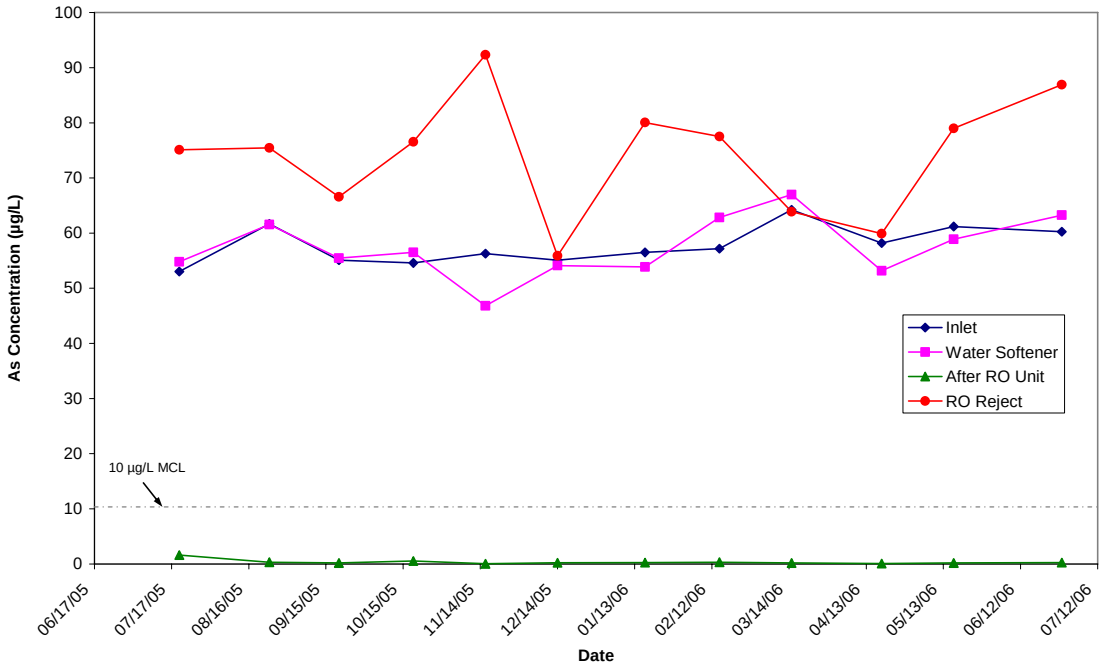

Figure 4-7. Total Arsenic Concentrations at Sunset Ranch Development

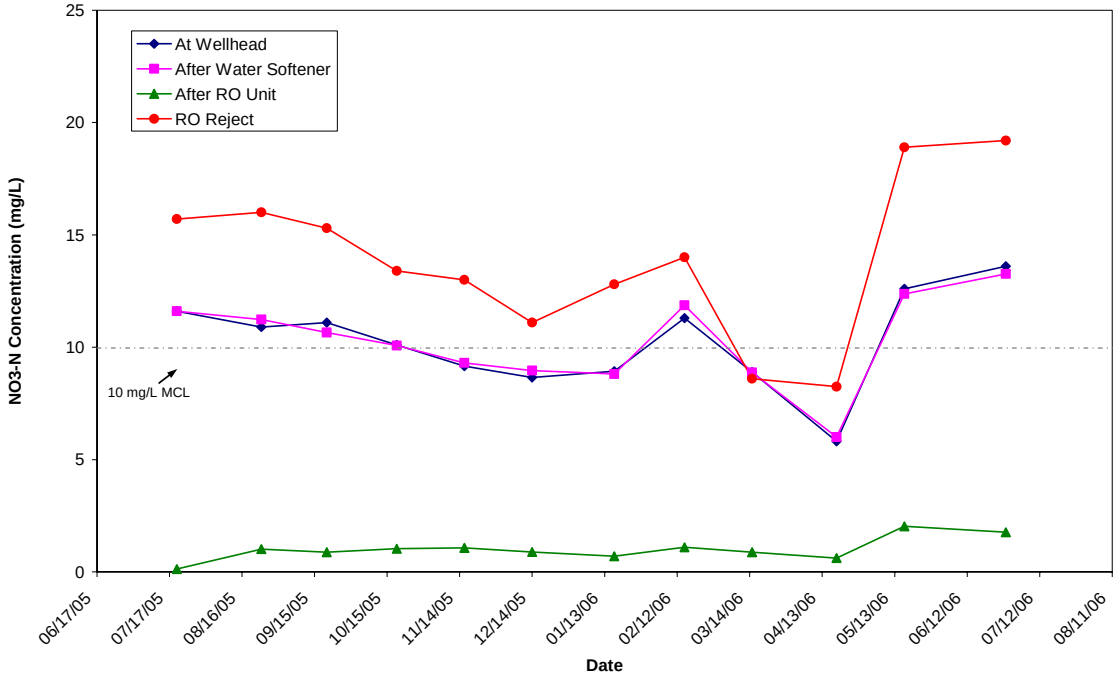

Figure 4-8. Nitrate Concentrations at Sunset Ranch Development

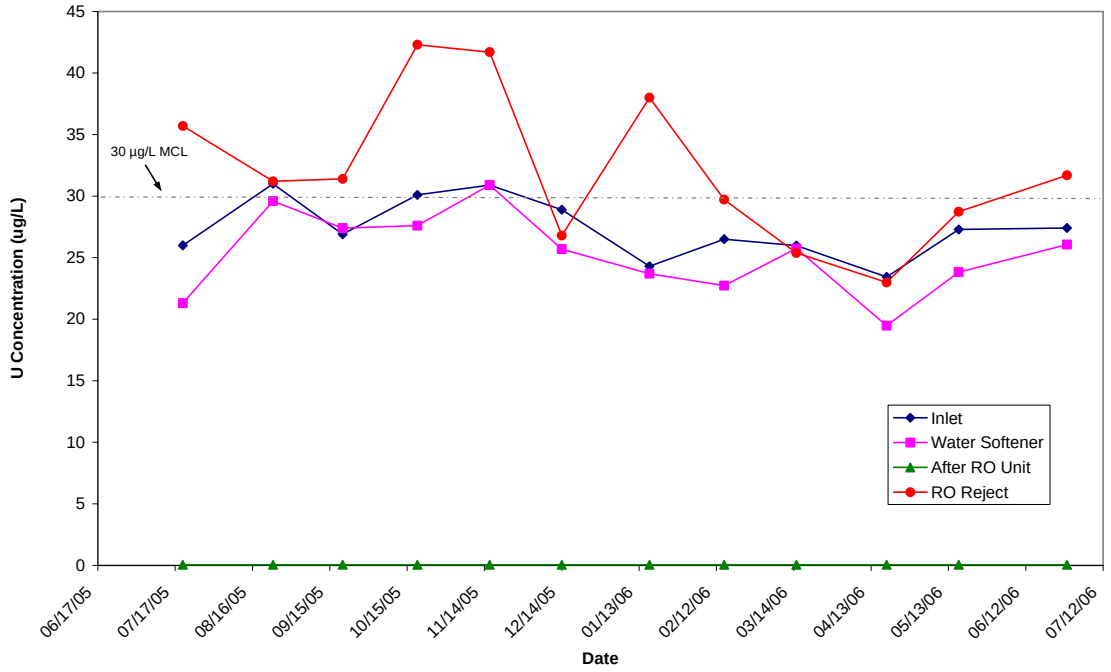

Figure 4-9. Uranium Concentrations at R1 Residence

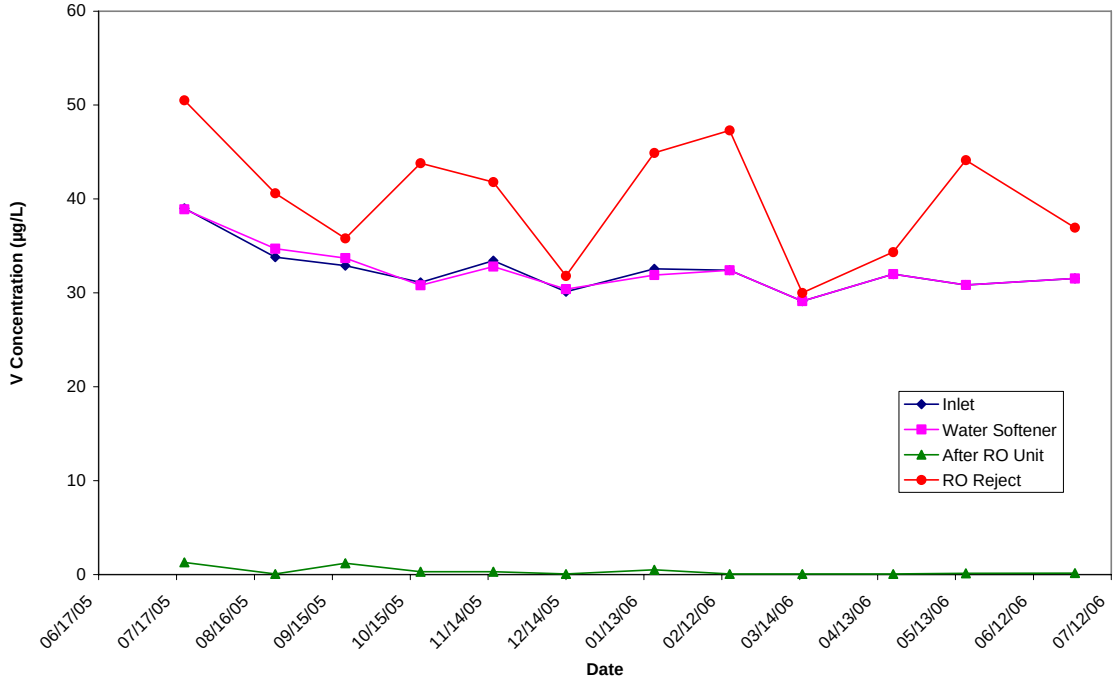

Figure 4-10. Vanadium Concentrations at R1 Residence

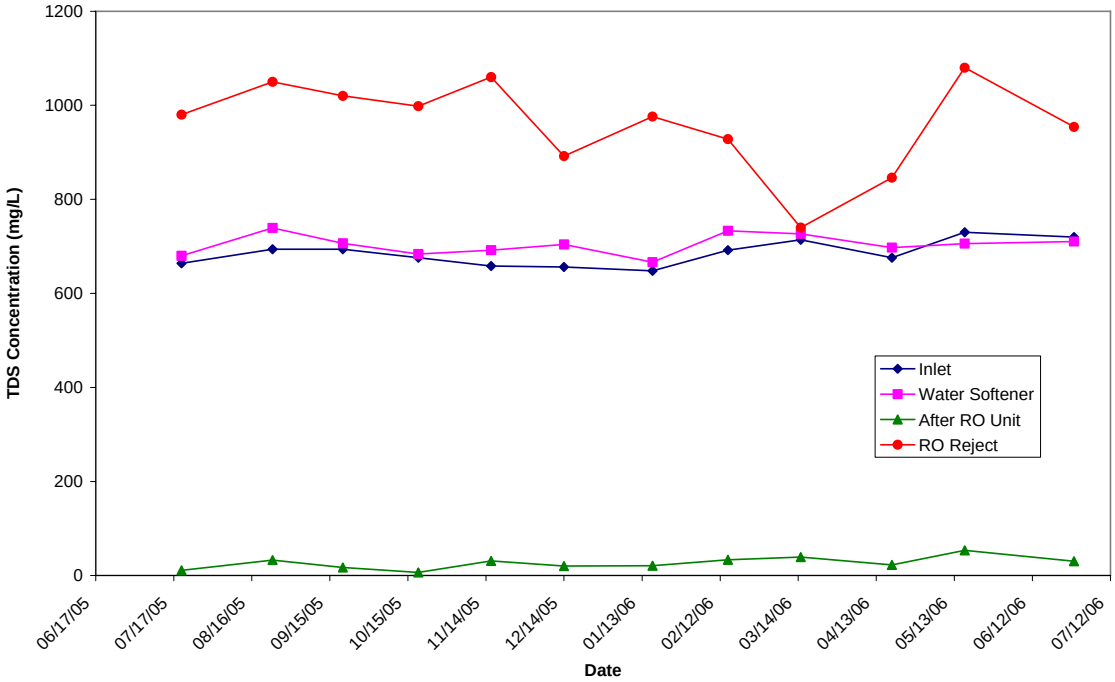

Figure 4-11. TDS Concentrations at Sunset Ranch Development

Table 4-7. Speciation Sampling Results at R1 Residence

Parameter	Unit	09/20/05			12/14/05		
		IN	WS1	RO1	IN	WS1	RO1
As (total)	µg/L	58.8	54.7	0.9	55.1	53.2	0.2
As (soluble)	µg/L	59.1	59.3	0.7	51.1	51.3	0.2
As (particulate)	µg/L	<0.1	<0.1	0.2	4.0	1.9	<0.1
As (III)	µg/L	2.7	3.0	0.8	1.7	1.3	0.2
As (V)	µg/L	56.4	56.3	<0.1	49.5	50.0	<0.1
Fe (total)	µg/L	<25	<25	<25	370	<25	<25
Fe (soluble)	µg/L	<25	<25	<25	<25	<25	<25
Mn (total)	µg/L	0.2	<0.1	0.8	0.6	0.1	0.2
Mn (soluble)	µg/L	0.2	<0.1	0.8	0.5	<0.1	0.2
U (total)	µg/L	26.9	26.2	<0.1	28.9	25.7	<0.1
U (soluble)	µg/L	27.2	26.6	<0.1	28.0	25.5	<0.1
V (total)	µg/L	29.1	29.8	<0.1	30.1	30.4	<0.1
V (soluble)	µg/L	31.5	30.4	<0.1	30.0	30.6	<0.1

Parameter	Unit	03/15/06			06/28/06		
		IN	WS1	RO1	IN	WS1	RO1
As (total)	µg/L	64.3	63.7	0.2	60.3	54.2	0.3
As (soluble)	µg/L	55.6	58.9	0.3	65.3	64.6	0.2
As (particulate)	µg/L	8.7	4.8	<0.1	<0.1	<0.1	<0.1
As (III)	µg/L	1.2	1.0	0.2	0.5	0.7	0.2
As (V)	µg/L	54.4	57.9	<0.1	64.8	63.9	<0.1
Fe (total)	µg/L	<25	<25	<25	<25	<25	<25
Fe (soluble)	µg/L	<25	<25	<25	<25	<25	<25
Mn (total)	µg/L	0.4	0.2	0.2	0.3	0.2	0.9
Mn (soluble)	µg/L	1.1	0.1	<0.1	0.8	0.2	0.7
U (total)	µg/L	26.0	25.7	<0.1	27.4	26.1	<0.1
U (soluble)	µg/L	25.6	25.2	<0.1	26.5	24.4	<0.1
V (total)	µg/L	29.1	29.9	<0.1	31.5	30.8	0.1
V (soluble)	µg/L	29.4	31.2	<0.1	30.6	28.5	0.2

Uranium and Vanadium. Uranium concentrations ranged from 23.4 and 31.0 µg/L in raw water and from 19.5 to 31.9 µg/L after softening (at the R1 Residence), which exceeded the MCL of 30 µg/L (Table 4-6). Uranium existed in the soluble form (Table 4-7) and was completely removed by the RO unit at the R1 Residence to below 0.1 µg/L for all sampling events (Figure 4-9).

Average vanadium concentrations in raw water and after the water softener at the R1 Residence were 32.4 and 33.1 µg/L, respectively. Vanadium concentrations in RO permeate ranged from <0.1 to 1.3 µg/L and averaged 0.2 µg/L (Table 4-6). Vanadium existed in soluble form (Table 4-7), and more than 99% of vanadium was removed from raw water (Figure 4-10).

TDS. When evaluating the performance of the RO units, a critical parameter is their ability to remove TDS from raw water. TDS concentrations averaged 685 and 704 mg/L in raw water and after softening, respectively (Table 4-6). The average TDS concentration after the RO units was 26.2 mg/L. On average, the RO units achieved 96% TDS removal (Figure 4-11).

***Iron and Manganese*.** Total iron concentrations in raw water ranged from <25 to 568 µg/L and averaged 112 µg/L (Table 4-8). In the WS and RO samples, total iron concentrations were <25 µg/L for all samples, except for two measurements (i.e., 56.4 µg/L at the WS6 location on August 24, 2005, and 45.9 µg/L at the WS4 location on November 16, 2005). The average manganese concentration in raw water averaged 0.6 µg/L. In the WS samples, total manganese concentrations ranged from <0.1 to 1.3 µg/L and averaged 0.1 µg/L. Total manganese concentrations in RO permeate water ranged from <0.1 to 28.2 µg/L and averaged 1.5 µg/L, indicating leaching of manganese from the RO units, possibly the pre- and/or post-cartridge filters.

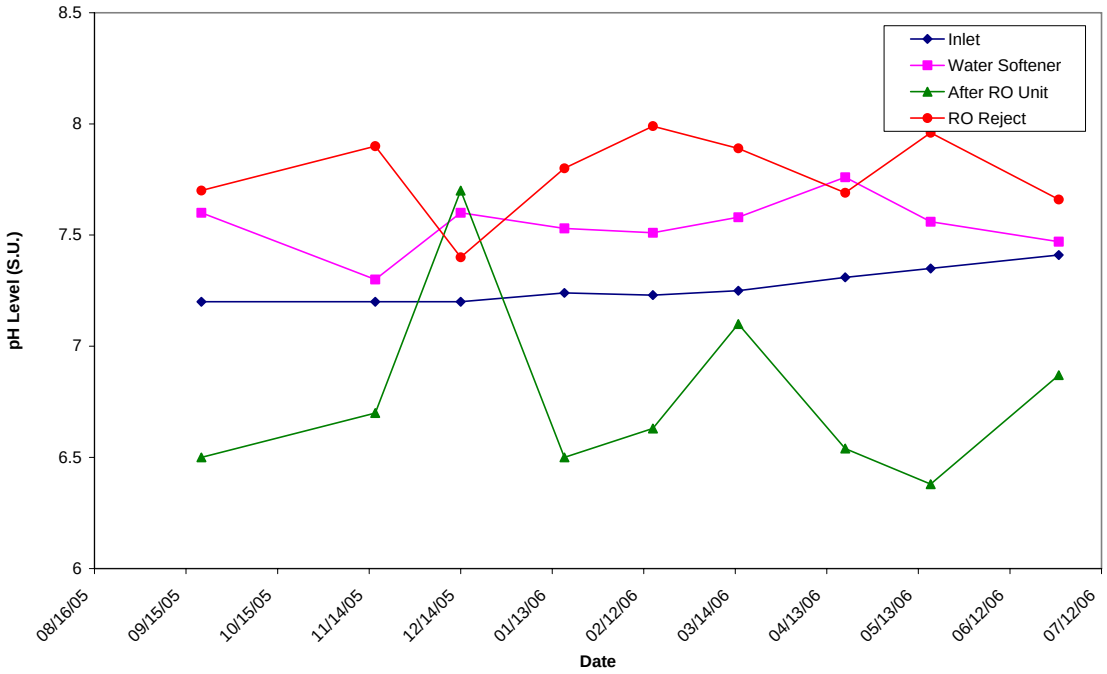

Figure 4-12. pH Levels at R1 Residence

***pH*.** pH values averaged 7.3 for raw water and 7.6 after softening at the R1 residence. pH values of the RO permeate water at the R1 residence averaged 6.6 with two probable outliers at 7.7 and 7.1 (Figure 4-12). The RO units reduced the alkalinity values from 295 mg/L (as $CaCO_3$) in raw water to 12.4 mg/L (as $CaCO_3$) in RO permeate, causing a drop in the pH levels.

Other Water Quality Parameters. As shown in Table 4-8 and Figure 4-13, silica concentrations in raw water ranged between 59.8 and 95.9 mg/L (as SiO_2) and averaged 66.5 mg/L (as SiO_2). Silica concentrations after softening averaged 66.6 mg/L (as SiO_2), which was above the vendor-suggested maximum value of 10 mg/L in the influent to the RO units. Silica concentrations in RO permeate water ranged from 0.8 to 8.2 mg/L (as SiO_2) and averaged 2.8 mg/L (as SiO_2), indicating effective removal by the RO units.

Fluoride in raw water was consistently removed to ≤0.1 mg/L by the RO units except for the measurement of 0.7 mg/L at R3 on October 19, 2005, and 0.2 mg/L at R1 on April 19, 2006. Sulfate concentrations in RO permeate water ranged from <1.0 to 2.2 mg/L and averaged 0.6 mg/L. Total hardness in raw water ranged from 216 to 251 mg/L (as $CaCO_3$) and averaged 238 mg/L (as $CaCO_3$).

Table 4-8. Summary of Water Quality Parameter Measurements at Sunset Ranch Development

Parameter	Sampling Location	Unit	Count	Minimum	Maximum	Average	Standard Deviation
Fe (total)	IN	µg/L	12	<25	568	112	173
	WS	µg/L	100	<25	56.4	13.3	5.5
	RO	µg/L	100	<25	<25	<25	-
Mn (total)	IN	µg/L	12	0.1	1.9	0.6	2.5
	WS	µg/L	100	<0.1	1.3	0.1	0.2
	RO	µg/L	100	<0.1	28.2	1.5	3.6
Alkalinity	IN	mg/L	12	283	317	295	11.7
	WS	mg/L	100	264	326	294	11.4
	RO	mg/L	100	1.0	63.0	12.4	8.2
Fluoride	IN	mg/L	12	0.6	5.2	1.2	1.3
	WS	mg/L	98	<0.1	4.3	0.8	0.5
	RO	mg/L	100	<0.1	0.7	0.1	0.1
Sulfate	IN	mg/L	12	151	210	167	17.5
	WS	mg/L	100	140	226	168	19.1
	RO	mg/L	100	<1.0	2.2	0.6	0.2
Orthophosphate (as PO_4)	IN	mg/L	3	<0.05	<0.05	<0.05	-
	WS	mg/L	27	<0.05	<0.05	<0.05	-
	RO	mg/L	27	<0.05	<0.05	<0.05	-
Total Phosphorous (as PO_4)	IN	mg/L	9	<0.03	<0.03	-	-
	WS	mg/L	73	<0.03	0.1	0.0	0.0
	RO	mg/L	73	<0.03	0.4	0.0	0.0
Silica (as SiO_2)	IN	mg/L	12	59.8	95.9	66.5	9.6
	WS	mg/L	100	58.5	108	66.6	9.5
	RO	mg/L	100	0.8	8.2	2.8	1.3
pH	IN	S.U.	9	7.2	7.8	7.3	0.1
	WS	S.U.	9	7.3	7.7	7.6	0.1
	RO	S.U.	7	6.4	6.9	6.6	0.2
Turbidity	IN	NTU	12	<0.1	7.2	1.4	1.9
	WS	NTU	100	<0.1	2.1	0.5	0.4
	RO	NTU	100	<0.1	1.2	0.3	0.2
Total Hardness	IN	mg/L	12	216	251	238	9.9
	WS	mg/L	95	0.2	21.4	1.7	2.5
	RO	mg/L	100	0.0	5.6	0.5	0.6
Ca Hardness (as $CaCO_3$)	IN	mg/L	12	169	194	185	7.1
	WS	mg/L	100	<0.25	189.6	8.0	31.2
	RO	mg/L	100	<0.25	2.8	0.3	0.3
Mg Hardness (as CaCO3)	IN	mg/L	12	45.9	62.6	52.5	6.0
	WS	mg/L	100	<0.1	94.9	3.4	13.8
	RO	mg/L	100	<0.1	2.75	0.1	0.3

One-half of detection limit used for non-detect samples for calculations.
pH values were only measured at the R1 residence.

Hardness in raw water consisted of approximately 78% of calcium hardness and 22% of magnesium hardness. Total hardness was reduced to an average of 1.7 mg/L (as $CaCO_3$) by the water softeners and further reduced to an average of 0.5 mg/L by the RO units.

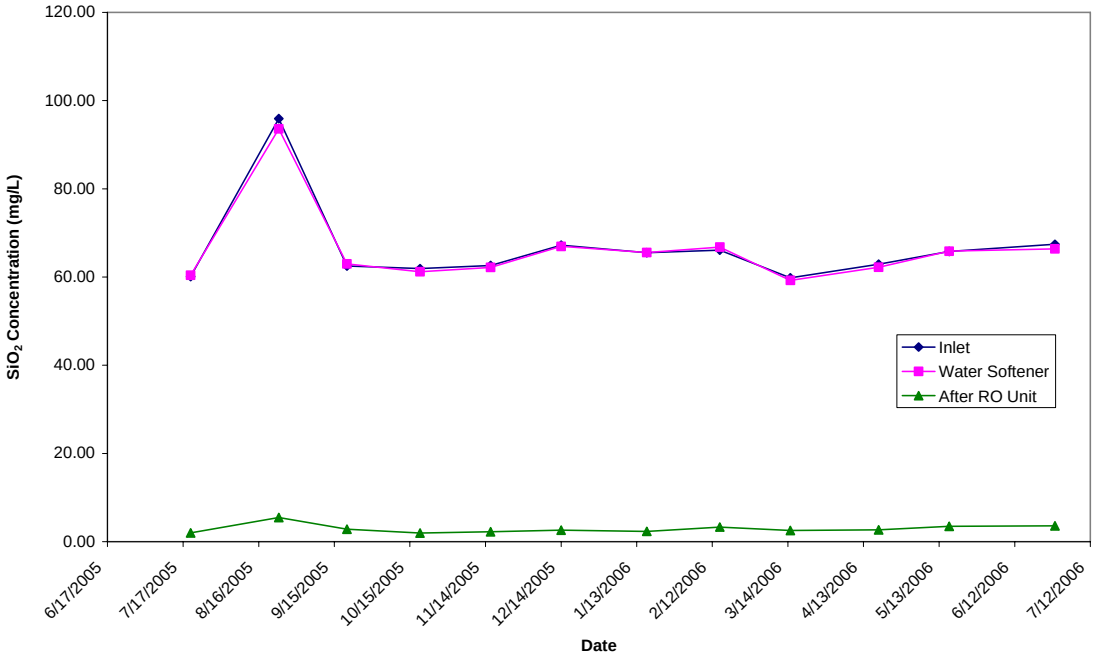

Figure 4-13. Total Silica Concentrations at Sunset Ranch Development

4.5.2 Reject Water Sampling. Reject water was collected monthly at the R1 residence. The analytical results from the reject water sampling are summarized in Table 4-9. As expected, the reject water contained higher concentrations of TDS, arsenic, uranium, and nitrate than raw water did. Calculations of mass balance for total arsenic and nitrate across the RO unit were done using the data presented in Tables 4-6 and 4-9 and the equation shown as follows:

$$C_f V_f = C_p V_p + C_r V_r$$

where C_f = feed water total arsenic or nitrate concentration
V_f = volume of feed water
C_p = permeate water total arsenic or nitrate concentration
V_p = volume of permeate water
C_r = reject water total arsenic or nitrate concentration
V_r = volume of reject water.

Calculations were done for each of the 12 sampling dates. The total arsenic mass balance data are tabulated in Table 4-10 and graphically presented in Figure 4-14. The total nitrate mass balance data are tabulated in Table 4-11 and graphically presented in Figure 4-15. During the one year performance evaluation, mass balance data in terms of the mass recovered in the permeate and reject water against the mass in the raw water ranged from 63% to 114% and averaged 83% for total arsenic and from 66% to 100% and averaged 89% for nitrate.

Table 4-9. Reject Water Sampling Results

Sampling Event		Sulfate	Nitrate (as N)	Turbidity	TDS	pH	Total Hardness[a]	Ca Hardness[a]	Mg Hardness[a]	As (total)	As (soluble)	Fe (total)	Fe (soluble)	Mn (total)	Mn (soluble)	U (total)	U (soluble)	V (total)	V (soluble)
No.	**Date**	**mg/L**	**mg/L**	**NTU**	**mg/L**	**S.U.**	**mg/L**	**mg/L**	**mg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**
1	07/20/05	217	15.7	0.5	980	7.9	1.6	1.1	0.5	75.1	-	<25	-	<0.1	-	35.7	-	50.5	-
2	08/24/05	214	16.0	6.0	1,050	7.7	1.0	0.9	<0.1	75.5	-	<25	-	0.1	-	31.2	-	40.6	-
3	09/20/05	176	15.3	0.4	1,020	7.7	-	-	-	66.6	88.3	<25	<25	<0.1	<0.1	31.4	40.1	35.8	44.3
4	10/19/05	252	13.4	0.9	998	8.1	-	-	-	76.5	78.8	<25	<25	<0.1	<0.1	42.3	42.1	43.8	42.6
5	11/16/05	265	13.0	0.4	1,060	7.9	-	-	-	92.3	87.5	<25	<25	<0.1	<0.1	41.7	41.2	41.8	41.6
6	12/14/05	211	11.1	1.5	892	7.4	-	-	-	55.9	55.8	<25	<25	<0.1	<0.1	26.8	26.3	31.8	32.8
7	01/17/06	229	12.8	0.8	976	7.8	-	-	-	80.1	79.2	<25	<25	<0.1	<0.1	38.0	37.6	44.9	45.3
8	02/15/06	266	14.0	1.2	928	8.0	-	-	-	77.5	73.2	<25	<25	<0.1	<0.1	29.7	27.3	47.3	43.6
9	03/15/06	167	8.6	1.6	740	7.9	-	-	-	63.9	58.9	<25	<25	0.1	<0.1	25.4	25.7	30.0	30.1
10	04/19/06	214	8.3	0.5	846	7.7	-	-	-	59.9	70.8	<25	<25	<0.1	<0.1	23.0	24.9	34.3	40.3
11	05/17/06	267	18.9	0.8	1,080	8.0	-	-	-	79.0	82.4	<25	<25	<0.1	<0.1	28.7	27.3	44.1	44.7
12	06/28/06	210	19.2	1.1	954	7.7	-	-	-	86.9	105	<25	<25	0.1	0.2	31.7	25.2	36.9	36.6

(a) as $CaCO_3$

Table 4-10. Monthly Total Arsenic Mass Balance

Date	Feed		Permeate		Reject		$C_pV_p + C_rV_r$	C_fV_f	Mass Balance
	C_f	V_f	C_p	V_p	C_r	V_r			
	µg/L	gal	µg/L	gal	µg/L	gal	Mg	mg	%
07/20/05	53.3	85.1	0.3	31.5	75.1	53.6	15.2	17.1	89
08/24/05	63.3	90.2	1.2	33.4	75.5	56.8	16.4	21.6	76
09/20/05	54.8	80.2	0.5	29.7	66.6	50.5	12.8	16.6	77
10/19/05	54.9	90.5	0.5	33.5	76.5	56.9	16.5	18.8	88
11/16/05	50.9	105	0.05	38.9	92.3	66.1	23.1	20.2	114
12/14/05	53.2	84.2	0.2	31.2	55.9	53.0	11.2	16.9	66
01/17/06	51.6	126	0.2	46.8	80.1	79.6	24.1	24.7	98
02/15/06	57.2	103	0.3	38.1	77.5	64.9	19.0	22.3	86
03/15/06	64.3	104	0.2	38.5	63.9	65.5	15.8	25.3	63
04/19/06	58.2	122	0.05	45.2	59.9	76.8	17.4	26.8	65
05/17/06	61.2	114	0.2	42.2	79.0	71.8	21.5	26.4	81
06/28/06	60.3	97	0.3	35.9	86.9	61.1	20.1	22.1	91

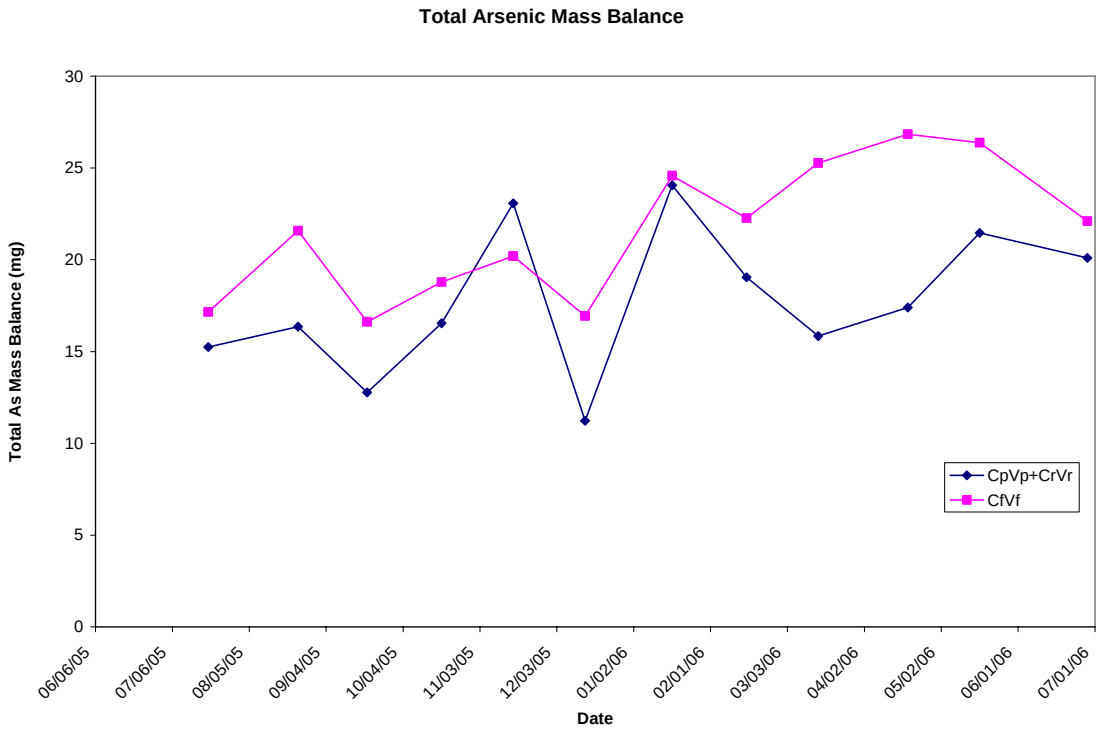

Figure 4-14. Monthly Total Arsenic Mass Balance at R1 Residence

Table 4-11. Monthly Nitrate (as N) Mass Balance

Date	Feed		Permeate		Reject		$C_pV_p + C_rV_r$	C_fV_f	Mass Balance
	C_f	V_f	C_p	V_p	C_r	V_r			
	mg/L	gal	mg/L	gal	Mg/L	gal	mg	mg	%
07/20/05	11.6	85.1	0.03	31.5	15.7	53.6	3,181	3,729	85
08/24/05	10.9	90.2	1.9	33.4	16.0	56.8	3,674	3,716	99
09/20/05	10.6	80.2	0.7	29.7	15.3	50.5	2,999	3,213	93
10/19/05	10.2	90.5	1.5	33.5	13.4	56.9	3,075	3,487	88
11/16/05	9.2	105	1.1	38.9	13.0	66.1	3,411	3,653	93
12/14/05	9.1	84.2	1.5	31.2	11.1	53.0	2,402	2,898	83
01/17/06	8.8	126	1.1	46.8	12.8	79.6	4,044	4,203	96
02/15/06	11.3	103	1.8	38.1	14.0	64.9	3,692	4,399	84
03/15/06	8.9	104	1.3	38.5	8.6	65.5	2,318	3,499	66
04/19/06	5.8	122	0.1	45.2	8.3	76.8	2,427	2,675	91
05/17/06	12.6	114	1.8	42.2	18.9	71.8	5,415	5,430	100
06/28/06	13.6	97	0.2	35.9	19.2	61.1	4,460	4,987	89

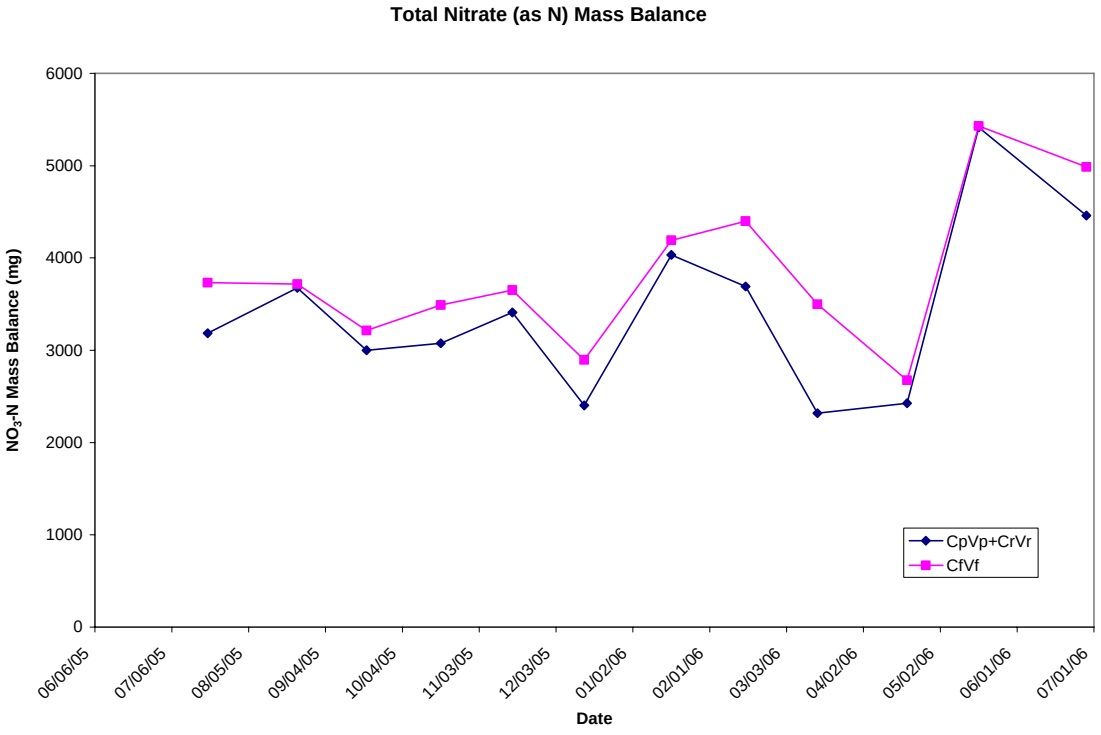

Figure 4-15. Monthly Nitrate (as N) Mass Balance at R1 Residence

4.6 System Cost

4.6.1 Capital Cost. The capital investment for purchasing and installing six water softeners and nine RO units was $31,877.50 (see Table 4-12) as provided by the vendor in a cost proposal to Battelle dated April 8, 2005. The equipment cost was $21,732.50 (or 68% of the total capital investment), which included cost for nine RO units, six water softeners, initial salt fill, additional sample tap and a water meter, and freight. Each water softener unit cost $1,585 and each RO unit cost $1,025.

Table 4-12. Summary of Capital Investment

Description	Quantity	Unit Cost	Cost	% of Capital Investment Cost
Equipment Costs				
RO Plus Deluxe Systems	9	$1,025	$9,225	–
Model 2060s Water Softeners	6	$1,585	$9,510	–
Initial Salt Fill (9 units 250 lb each)	2,250	$0.23	$518	–
Additional Sample Taps and Water Meter	1	–	$355	–
Freight	1	–	$2,125	–
Equipment Total	–	–	**$21,733**	**68%**
Installation Costs				
Material	1	–	$650	
Softener Installation	6	$810	$4,860	–
RO Installation	9	$195	$1,755	–
Vendor Travel (days)	6	$480	$2,880	–
Installation Total	–	–	**$10,145**	**32%**
Total Capital Investment	–	–	**$31,878**	**100%**

The installation cost included the cost for the material and labor to install nine RO units and six water softeners by the vendor (Section 4.3.2). The installation cost was $10,145, or 32% of the total capital investment. The installation of each water softener and RO unit cost $810 and $195, respectively (excluding material and vendor travel).

For home installation of a water softener and an RO unit, total equipment ($2,610) and installation ($1,005) cost amounted to $3,615. If the cost of materials and vendor travel was added, the total cost for each household system was nearly $4,000. Based on a 10-year life for both softener and RO unit and a 7% interest rate, the annualized cost is $570 (i.e., multiplying $4,000 by a capital recovery factor [CRF] of 0.142378).

4.6.2 Operation and Maintenance Cost. The O&M cost for the water softener consisted of salt usage and system maintenance. The O&M cost for the RO unit consisted of pre- and post-filter replacement, RO element replacement, and system maintenance. The yearly service contract with the vendor for salt was $115 for a one year supply. Pre- and post-cartridge filter replacement at 500 gal of treated water was quoted at $86.50.

Only five homeowners used 500 gal of treated water during the performance evaluation period. For these homeowners with the largest water usage, the one year O&M cost for salt usage ($115) and filter replacement ($86.50) was $201.50 or $17 per month. The systems were under warranty for one year; therefore, no maintenance cost was incurred during the performance evaluation period.

Table 4-13. Summary of O&M Cost

Cost Category	Value	Assumption
Salt Replenishment for Water Softener		
Salt Cost ($)	$115	Vendor quote
Salt Consumption Rate (lb/1,000 gal)	5.77	Vendor quote
Salt Unit Cost ($/lb)	$0.12	Vendor quote
Salt Cost ($/1,000 gal)	$0.69	Vendor quote
Cartridge Filter Replacement		
Pre- and Post-Cartridge Filter Replacement	$86.50	Replacement required every 500 gal

5.0 REFERENCES

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APPENDIX A

ANALYTICAL DATA TABLES

Table 1. Analytical Results from Monthly Sampling at Homedale, ID

Sampling Date		Month 1: 07/20/05																	
Sampling Residence		Wellhead	R1		R1		R3		R4		R5		R6		R7		R8		R9	
Sampling Location		IN	WS1	RO1	WS2	RO2	WS3	RO3	WS4	RO4	WS5	RO5	WS6	RO6	WS7	RO7	WS8	RO8	WS9	RO9
Parameter	Unit																			
Alkalinity (as $CaCO_3$)	mg/L	290	286	8	286	11	295	17	286	11	286	11	286	10	282	14	277	12	286	8
Fluoride	mg/L	0.8	0.8	<0.1	0.8	<0.1	0.8	<0.1	0.8	<0.1	0.8	<0.1	0.8	<0.1	0.8	<0.1	0.8	<0.1	0.8	<0.1
Sulfate	mg/L	151	152	<1	152	<1	147	<1	153	<1	152	<1	151	<1	153	<1	154	<1	154	<1
Nitrate (as N)	mg/L	11.6	11.6	<0.05	11.6	0.1	11.3	0.4	11.7	0.1	11.6	<0.05	11.6	<0.05	11.6	0.4	11.7	0.1	11.7	<0.05
Orthophosphate (as PO_4)	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silica (as SiO_2)	mg/L	60.1	59.4	1.8	60.7	2.3	59.2	2.0	59.0	1.8	60.5	1.6	60.7	1.4	-	2.9	61.3	2.7	62.4	1.4
Turbidity	NTU	<0.1	<0.1	0.5	<0.1	0.2	0.2	0.6	<0.1	0.4	0.8	<0.1	<0.1	<0.1	<0.1	0.2	0.1	<0.1	0.5	<0.1
TDS	mg/L	664	672	8	678	10	672	16	706	4	676	2	708	10	656	22	652	14	698	14
pH	S.U.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	ºC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness (as $CaCO_3$)	mg/L	232	0.6	0.3	<0.35	0.4	<0.35	0.6	1.8	0.5	<0.35	0.3	2.2	<0.35	239	1.1	0.5	<0.35	<0.35	<0.35
Ca Hardness (as $CaCO_3$)	mg/L	185	0.5	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	0.6	<0.25	190[(a)]	<0.25	<0.25	<0.25	<0.25	<0.25
Mg Hardness (as $CaCO_3$)	mg/L	47.5	0.2	0.1	<0.1	0.1	<0.1	0.3	1.5	0.2	<0.1	<0.1	1.6	<0.1	49.8[(a)]	0.8	0.3	<0.1	<0.1	<0.1
Total As	µg/L	53.0	53.3	0.3	53.8	0.2	52.1	0.2	52.2	5.1	52.8	<0.1	52.0	<0.1	66.8	8.7	59.1	<0.1	51.4	<0.1
Total Fe	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Total Mn	µg/L	0.3	<0.1	3.1	<0.1	3.9	<0.1	3.6	<0.1	7.1	<0.1	4.4	<0.1	6.2	0.2	11.6	<0.1	1.6	<0.1	1.4
Total U	µg/L	26.0	21.3	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total V	µg/L	39.0	38.9	1.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

IN = wellhead
WS = after water softener
RO = after RO unit
(a) Softener might have run out of salt.

Table 1. Analytical Results from Monthly Sampling at Homedale, ID (Continued)

Sampling Date		Month 2: 08/24/05																	
Sampling Residence		Wellhead	R1		R2		R3		R4		R5		R6		R7		R8		R9	
Sampling Location / Parameter	Unit	IN	WS1	RO1	WS2	RO2	WS3	RO3	WS4	RO4	WS5	RO5	WS6	RO6	WS7	RO7	WS8	RO8	WS9	RO9
Alkalinity (as $CaCO_3$)	mg/L	286	286	25	286	11	273	9	286	17	277	11	277	11	286	12	282	17	264	6
Fluoride	mg/L	0.8	0.8	<0.1	0.8	<0.1	0.8	<0.1	0.8	<0.1	0.7	<0.1	0.8	<0.1	0.8	<0.1	0.8	<0.1	0.8	<0.1
Sulfate	mg/L	153	140	2.2	152	1.3	152	<1	152	<1	155	<1	155	<1	151	<1	150	1.3	153	<1
Nitrate (as N)	mg/L	10.9	10.9	1.9	11.6	1.7	11.6	<0.05	11.7	1.2	10.8	1.2	10.9	0.4	10.9	0.3	11.2	1.8	11.5	0.6
Orthophosphate (as PO_4)	mg/L	<0.05	<0.05	0.2	<0.05	<0.05	<0.05	<0.05	<0.05	0.4	<0.05	<0.05	<0.05	0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silica (as SiO_2)	mg/L	95.9	91.0	8.2	92.5	5.7	91.4	3.5	91.8	6.1	92.7	5.4	93.6	5.2	91.2	4.4	90.1	6.7	108.0	4.0
Turbidity	NTU	<0.1	0.1	<0.1	0.1	<0.1	0.2	0.2	0.1	<0.1	0.8	<0.1	0.2	0.1	<0.1	<0.1	0.6	0.3	0.2	<0.1
TDS	mg/L	694	724	48	732	34	714	6	712	26	700	20	698	18	710	28	842	86	822	30
pH	S.U.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	ºC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness (as $CaCO_3$)	mg/L	247	1.0	0.4	1.2	<0.35	1.1	0.8	1.1	<0.35	0.9	<0.35	1.0	<0.35	1.1	0.8	0.8	0.6	0.8	<0.35
Ca Hardness (as $CaCO_3$)	mg/L	187	1.0	0.3	1.1	<0.25	0.9	0.4	1.0	<0.25	0.8	<0.25	0.9	<0.25	1.0	0.5	0.8	0.3	0.7	<0.25
Mg Hardness (as $CaCO_3$)	mg/L	59.9	0.1	0.1	0.1	<0.1	0.2	0.4	0.2	<0.1	0.1	<0.1	0.1	<0.1	0.1	0.3	0.1	0.3	0.1	<0.1
Total As	µg/L	61.7	63.3	1.2	62.4	0.1	62.9	0.2	61.6	0.4	58.5	0.1	60.8	<0.1	61.1	0.3	61.0	0.4	62.7	0.2
Total Fe	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	56.4	<25	<25	<25	<25	<25	<25	<25
Total Mn	µg/L	0.4	0.2	1.6	0.2	0.9	0.2	5.2	0.2	0.7	0.1	0.8	0.5	0.9	0.2	7.4	0.2	1.2	0.2	0.4
Total U	µg/L	31.0	29.6	<0.1	29.9	<0.1	29.5	<0.1	29.4	<0.1	31.9	<0.1	31.4	<0.1	30.3	<0.1	29.8	<0.1	30.4	<0.1
Total V	µg/L	33.8	34.7	<0.1	34.7	<0.1	34.1	<0.1	34.1	<0.1	32.9	<0.1	33.8	<0.1	34.2	<0.1	34.1	<0.1	34.5	<0.1

IN = wellhead
WS = after water softener
RO = after RO unit

Table 1. Analytical Results from Monthly Sampling at Homedale, ID (Continued)

Sampling Date		Month 3: 09/20/05																	
Sampling Residence		Wellhead	R1		R2		R3		R4		R5		R6		R7		R8		R9	
Sampling Location		IN	WS1	RO1	WS2	RO2	WS3	RO3	WS4	RO4	WS5	RO5	WS6	RO6	WS7	RO7	WS8	RO8	WS9	RO9
Parameter	Unit																			
Alkalinity (as $CaCO_3$)	mg/L	308	312	11	290	12	286	9	290	14	277	11	286	9	308	13	295	11	299	10
Fluoride	mg/L	0.8	0.8	<0.1	0.8	<0.1	0.8	<0.1	0.8	<0.1	0.8	<0.1	0.8	<0.1	0.8	<0.1	0.8	<0.1	0.8	<0.1
Sulfate	mg/L	152	152	<1	153	<1	152	<1	153	<1	152	<1	158	<1	155	<1	155	<1	155	<1
Nitrate (as N)	mg/L	11.1	10.6	0.7	11.2	1.6	11.4	<0.05	10.6	0.5	11.1	1.6	11.4	0.9	10.5	0.4	11.0	1.0	10.7	1.2
Orthophosphate (as PO_4)	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silica (as SiO_2)	mg/L	62.5	62.6	3.1	62.9	2.7	63.3	2.3	63.4	3.1	62.5	3.2	62.6	1.6	62.3	1.4	63.1	2.7	64.1	2.1
Turbidity	NTU	0.3	0.3	0.2	<0.1	0.3	2.1	<0.1	0.2	<0.1	1.2	0.6	0.3	0.1	0.3	0.3	1.5	0.1	0.1	<0.1
TDS	mg/L	694	692	10	698	16	700	14	694	22	704	8	730	34	712	6	720	28	708	16
pH	S.U.	7.2	7.6	6.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	ºC	16.6	18.8	21.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness (as $CaCO_3$)	mg/L	242	1.4	0.4	1.6	<0.35	0.5	5.6	1.7	<0.35	1.5	<0.35	0.8	<0.35	8.9	0.5	0.7	<0.35	0.5	<0.35
Ca Hardness (as $CaCO_3$)	mg/L	190	1.3	0.3	1.4	<0.25	0.4	2.8	1.3	<0.25	1.3	<0.25	0.6	<0.25	7.3	<0.25	0.6	<0.25	0.4	<0.25
Mg Hardness (as $CaCO_3$)	mg/L	52.4	0.1	<0.1	0.2	<0.1	0.1	2.8	0.4	<0.1	0.2	<0.1	0.2	<0.1	1.6	0.3	0.1	<0.1	0.1	<0.1
Total As	µg/L	55.1	54.8	0.5	56.4	<0.1	53.9	<0.1	56.3	0.2	60.2	0.3	52.4	<0.1	54.9	0.2	55.5	<0.1	54.7	<0.1
Total Fe	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Total Mn	µg/L	0.3	<0.1	0.6	<0.1	0.5	<0.1	28.2	<0.1	0.4	<0.1	0.4	<0.1	0.4	1.0	8.4	<0.1	0.4	<0.1	0.1
Total U	µg/L	26.9	27.4	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total V	µg/L	32.9	33.7	1.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

IN = wellhead
WS = after water softener
RO = after RO unit

Table 1. Analytical Results from Monthly Sampling at Homedale, ID (Continued)

Sampling Date		Month 4: 10/19/05																	
Sampling Residence		Wellhead	R1		R2		R3		R4		R5		R6		R7		R8		R9	
Sampling Location		IN	WS1	RO1	WS2	RO2	WS3	RO3	WS4	RO4	WS5	RO5	WS6	RO6	WS7	RO7	WS8	RO8	WS9	RO9
Parameter	Unit																			
Alkalinity (as $CaCO_3$)	mg/L	290	295	8	290	11	290	14	290	8	290	9	264	1	286	8	290	14	286	55
Fluoride	mg/L	0.8	0.7	0.1	0.7	0.1	0.8	0.7	0.8	<0.1	0.7	<0.1	0.8	<0.1	0.7	<0.1	0.7	0.1	0.8	<0.1
Sulfate	mg/L	171	165	<1	168	<1	165	<1	166	<1	177	<1	170	1	166	<1	189	<1	170	<1
Nitrate (as N)	mg/L	10.1	10.2	1.5	10.3	2.0	9.9	0.1	10.1	0.8	10.0	1.1	10.2	1.2	10.0	0.4	10.0	1.5	9.9	0.8
Total P	mg/L	<0.03	<0.03	<0.03	0.03	<0.03	0.05	0.04	0.03	<0.03	0.04	<0.03	<0.03	<0.03	0.04	0.1	0.1	<0.03	0.04	<0.03
Silica (as SiO_2)	mg/L	61.9	62.2	2.4	62.4	3.5	61.8	0.8	61.2	1.3	60.7	2.1	60.4	1.4	60.8	1.5	60.6	3.3	60.5	1.3
Turbidity	NTU	0.9	0.5	0.2	0.3	0.2	0.8	0.4	0.4	0.6	0.5	0.2	0.5	0.2	0.3	0.3	0.4	0.5	0.7	0.5
TDS	mg/L	676	706	2	682	24	650	<1	656	<1	690	2	680	<1	692	12	674	16	724	<1
pH	S.U.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	ºC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness (as $CaCO_3$)	mg/L	247	0.9	<0.35	1.2	0.8	241	1.2	220	0.8	1.6	<0.35	1.5	0.4	1.9	1.6	1.3	0.4	1.2	<0.35
Ca Hardness (as $CaCO_3$)	mg/L	194	0.8	<0.25	1.1	0.7	186	0.9	138	0.6	1.5	<0.25	1.3	0.4	1.9	1.3	1.2	0.4	1.1	<0.25
Mg Hardness (as $CaCO_3$)	mg/L	53.3	<0.1	<0.1	<0.1	<0.1	55.3	0.2	82.1	0.1	0.1	<0.1	0.2	<0.1	<0.1	0.3	<0.1	<0.1	<0.1	<0.1
Total As	µg/L	54.6	54.9	0.5	57.4	0.7	58.6	0.5	56.0	0.5	56.3	0.5	53.5	0.4	55.5	0.6	58.2	0.6	58.0	0.4
Total Fe	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Total Mn	µg/L	0.2	<0.1	0.6	<0.1	0.2	0.5	7.4	0.7	0.2	<0.1	0.3	<0.1	0.3	<0.1	9.2	<0.1	0.2	<0.1	<0.1
Total U	µg/L	30.1	27.6	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total V	µg/L	31.1	30.8	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

IN = wellhead
WS = after water softener
RO = after RO unit

Table 1. Analytical Results from Monthly Sampling at Homedale, ID (Continued)

Sampling Date		Month 5: 11/16/05																
Sampling Residence		Wellhead	R1		R2		R4		R5		R6		R7		R8		R9	
Sampling Location / Parameter	Unit	IN	WS1	RO1	WS2	RO2	WS4	RO4	WS5	RO5	WS6	RO6	WS7	RO7	WS8	RO8	WS9	RO9
Alkalinity (as $CaCO_3$)	mg/L	286	295	11	304	12	286	6	290	6	286	3	295	13	286	22	295	7
Fluoride	mg/L	0.7	0.7	<0.1	0.7	<0.1	0.7	<0.1	0.7	<0.1	0.7	<0.1	0.7	<0.1	0.7	<0.1	0.7	<0.1
Sulfate	mg/L	188	191	<1	190	<1	188	<1	191	<1	195	<1	192	<1	191	<1	193	<1
Nitrate (as N)	mg/L	9.2	9.2	1.1	9.2	1.3	9.2	0.8	9.5	0.9	9.3	1.1	9.4	0.3	9.3	2.2	9.3	1.0
Total P	mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Silica (as SiO_2)	mg/L	62.6	63.2	2.7	61.6	2.7	62.4	1.2	62.3	2.4	61.5	2.0	61.9	1.4	62.4	3.6	62.0	1.8
Turbidity	NTU	1.1	0.3	<0.1	<0.1	<0.1	0.1	<0.1	0.4	<0.1	0.2	<0.1	<0.1	<0.1	0.2	<0.1	0.3	<0.1
TDS	mg/L	658	698	98	658	36	740	8	492	<1	764	32	722	<1	784	74	678	<1
pH	S.U.	7.2	7.3	6.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	ºC	22.1	13.2	18.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness (as $CaCO_3$)	mg/L	240	1.3	0.4	1.2	<0.35	2.1	0.5	1.1	<0.35	1.5	<0.35	<0.35	0.8	1.0	0.3	1.3	<0.35
Ca Hardness (as $CaCO_3$)	mg/L	193	1.3	0.3	1.1	<0.25	1.8	0.4	1.0	<0.25	1.4	<0.25	<0.25	0.6	1.0	0.3	1.2	<0.25
Mg Hardness (as $CaCO_3$)	mg/L	46.9	0.1	<0.1	0.1	<0.1	0.3	0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.2	<0.1	<0.1	0.1	<0.1
Total As	µg/L	56.3	50.9	<0.1	53.9	<0.1	53.7	<0.1	51.6	<0.1	48.1	<0.1	<0.1	<0.1	50.9	<0.1	48.4	<0.1
Total Fe	µg/L	229	<25	<25	<25	<25	45.9	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Total Mn	µg/L	1.9	<0.1	0.1	<0.1	<0.1	<0.1	0.2	<0.1	0.1	<0.1	<0.1	<0.1	7.4	<0.1	0.1	<0.1	<0.1
Total U	µg/L	30.9	30.9	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total V	µg/L	33.4	32.8	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-

IN = wellhead.
WS = after water softener.
RO = RO permeate.

Table 1. Analytical Results from Monthly Sampling at Homedale, ID (Continued)

Sampling Date		Month 6: 12/14/05																
Sampling Residence		Wellhead	R1		R2		R4		R5		R6		R7		R8		R9	
Sampling Location		IN	WS1	RO1	WS2	RO2	WS4	RO4	WS5	RO5	WS6	RO6	WS7	RO7	WS8	RO8	WS9	RO9
Parameter	Unit																	
Alkalinity (as $CaCO_3$)	mg/L	290	295	17	295	11	304	7	295	9	295	3	290	4	295	8	290	11
Fluoride	mg/L	0.6	0.6	<0.1	0.6	<0.1	0.6	<0.1	0.6	<0.1	0.6	<0.1	0.6	<0.1	0.6	<0.1	0.6	<0.1
Sulfate	mg/L	160	160	<1	161	<1	162	<1	161	<1	161	<1	161	<1	164	<1	162	<1
Nitrate (as N)	mg/L	8.7	9.1	1.5	9.2	1.5	9.1	0.6	8.8	1.0	8.7	0.6	8.7	0.2	8.7	0.5	9.4	1.3
Total P	mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.03	<0.03	0.04	<0.03	<0.03	<0.03	0.03	<0.03	0.03	<0.03
Silica (as SiO_2)	mg/L	67.2	67.5	4.6	69.0	3.5	69.9	1.1	68.2	2.7	64.1	1.3	65.7	1.4	63.8	2.8	67.3	3.3
Turbidity	NTU	2.3	0.5	0.2	0.5	0.2	1.4	0.4	0.7	0.5	0.5	0.3	0.6	0.4	0.4	0.7	0.4	0.6
TDS	mg/L	656	700	26	698	18	696	6	726	8	700	<1	700	12	702	18	710	74
pH	S.U.	7.2	7.6	7.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	ºC	25.1	12.7	16.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness (as $CaCO_3$)	mg/L	233	1.3	<0.35	1.0	<0.35	10.3	<0.35	1.3	0.4	1.8	0.5	1.2	0.5	0.9	0.4	1.3	0.4
Ca Hardness (as $CaCO_3$)	mg/L	184	1.2	<0.25	0.9	<0.25	5.8	<0.25	1.2	0.4	1.6	0.5	1.1	0.4	0.9	0.3	1.1	0.4
Mg Hardness (as $CaCO_3$)	mg/L	48.8	<0.1	<0.1	<0.1	<0.1	4.5	<0.1	0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1
Total As	µg/L	55.1	53.2	0.2	54.9	0.2	54.5	0.1	52.4	0.3	55.1	0.2	54.8	0.2	55.4	0.3	52.6	0.2
Total Fe	µg/L	252	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Total Mn	µg/L	0.6	0.1	0.2	<0.1	0.1	0.1	0.2	<0.1	0.1	<0.1	<0.1	<0.1	3.0	<0.1	0.3	<0.1	0.1
Total U	µg/L	28.9	25.7	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total V	µg/L	30.1	30.4	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-

IN = wellhead
WS = after water softener
RO = after RO unit

Table 1. Analytical Results from Monthly Sampling at Homedale, ID (Continued)

Sampling Date		Month 7: 01/17/06															
Sampling Residence		Wellhead	R1		R2		R4		R5		R6		R7		R8		R9	
Sampling Location		IN	WS1	RO1	WS2	RO2	WS4	RO4	WS5	RO5	WS6	RO6	WS7	RO7	WS8	RO8	WS9	RO9
Parameter	Unit																	
Alkalinity (as $CaCO_3$)	mg/L	308	308	12	304	11	312	6	312	8	304	2	308	3	304	9	308	15
Fluoride	mg/L	0.6	0.6	<0.1	0.6	<0.1	0.6	<0.1	0.6	<0.1	0.6	<0.1	0.6	<0.1	0.6	<0.1	0.6	<0.1
Sulfate	mg/L	172	169	<1	168	<1	169	<1	160	<1	171	<1	169	<1	171	<1	169	<1
Nitrate (as N)	mg/L	8.9	8.8	1.1	8.8	1.5	8.8	1.1	8.8	0.9	8.7	0.3	8.9	0.1	8.8	0.6	8.8	<0.05
Total P	mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.04
Silica (as SiO_2)	mg/L	65.5	66.1	3.2	66.7	3.4	65.5	1.9	65.7	2.4	63.5	1.5	66.7	1.1	64.8	2.6	65.2	2.7
Turbidity	NTU	0.4	0.3	0.2	0.4	0.1	0.6	0.3	0.5	0.5	0.3	0.1	0.5	0.1	0.2	0.4	0.3	0.6
TDS	mg/L	648	706	28	660	48	716	25	614	26	666	2	664	<1	624	2	680	36
pH	S.U.	7.2	7.5	6.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	ºC	25.3	14.3	19.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness (as $CaCO_3$)	mg/L	228	0.8	<0.35	0.6	<0.35	1.9	<0.35	0.9	<0.35	173	0.4	0.9	0.5	0.5	<0.35	0.9	0.6
Ca Hardness (as $CaCO_3$)	mg/L	182	0.7	<0.25	0.6	<0.25	1.5	<0.25	0.7	<0.25	78.5	0.4	0.8	0.4	0.4	<0.25	0.7	0.3
Mg Hardness (as $CaCO_3$)	mg/L	45.9	0.1	<0.1	0.1	<0.1	0.4	<0.1	0.1	<0.1	94.9	<0.1	0.2	0.1	<0.1	<0.1	0.1	0.2
Total As	µg/L	56.5	51.6	0.2	53.7	0.3	54.4	0.2	54.1	0.2	56.0	0.4	52.3	0.1	52.8	0.3	56.0	0.3
Total Fe	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Total Mn	µg/L	0.5	<0.1	0.2	<0.1	0.1	<0.1	0.3	<0.1	0.2	1.3	0.1	<0.1	6.5	<0.1	0.2	<0.1	3.5
Total U	µg/L	24.3	23.7	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total V	µg/L	32.6	31.9	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-

IN = wellhead
WS = after water softener
RO = after RO unit

Table 1. Analytical Results from Monthly Sampling at Homedale, ID (Continued)

Sampling Date		Month 8: 02/15/06															
Sampling Residence		Wellhead	R1		R2		R4		R5		R6		R7		R8		R9	
Sampling Location		IN	WS1	RO1	WS2	RO2	WS4	RO4	WS5	RO5	WS6	RO6	WS7	RO7	WS8	RO8	WS9	RO9
Parameter	Unit																	
Alkalinity (as $CaCO_3$)	mg/L	283	320	18	308	13	299	10	295	17	283	6	299	7	295	11	287	19
Fluoride	mg/L	1.3	1.3	<0.1	0.9	<0.1	<0.1	<0.1	0.9	<0.1	0.9	<0.1	0.9	<0.1	0.9	<0.1	0.9	<0.1
Sulfate	mg/L	210	211	<1	219	<1	217	<1	220	<1	222	<1	226	<1	224	<1	222	<1
Nitrate (as N)	mg/L	11.3	11.7	1.8	11.6	1.7	11.6	1.5	11.8	1.2	12.0	1.0	11.9	0.2	12.1	1.3	12.2	0.1
Total P (as PO_4)	mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.1	0.4
Silica (as SiO_2)	mg/L	66.1	66.4	4.1	65.7	3.0	66.9	2.2	66.5	2.3	67.0	1.6	67.9	1.6	67.7	2.9	66.2	3.3
Turbidity	NTU	7.2	1.0	0.2	1.0	0.3	1.8	0.5	0.5	0.3	0.6	0.2	0.5	0.3	0.7	1.0	1.3	0.9
TDS	mg/L	692	716	36	946	36	696	30	688	36	716	28	706	26	668	46	728	30
pH	S.U.	7.2	7.5	6.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	ºC	24.3	12.2	18.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness (as $CaCO_3$)	mg/L	232	1.5	<0.7	1.7	<0.7	2.6	<0.7	1.2	<0.7	1.8	<0.7	1.3	<0.7	1.1	<0.7	1.2	<0.7
Ca Hardness (as $CaCO_3$)	mg/L	182	1.4	<0.6	1.5	<0.6	2.2	<0.6	1.1	<0.6	1.6	<0.6	1.2	<0.6	1.0	<0.6	1.0	<0.6
Mg Hardness (as $CaCO_3$)	mg/L	49.8	<0.1	<0.1	0.2	<0.1	0.4	<0.1	<0.1	<0.1	0.2	<0.1	0.1	<0.1	<0.1	<0.1	0.2	<0.1
Total As	µg/L	57.2	63.9	0.3	67.1	0.2	69.9	0.1	60.5	0.3	66.0	0.1	60.5	0.1	61.8	0.3	52.7	1.2
Total Fe	µg/L	568	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Total Mn	µg/L	0.9	<0.1	0.1	<0.1	0.1	<0.1	0.2	<0.1	0.1	<0.1	<0.1	<0.1	1.9	<0.1	<0.1	0.1	0.5
Total U	µg/L	26.5	22.7	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total V	µg/L	32.4	35.2	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-

IN = wellhead
WS = after water softener
RO = after RO unit

Table 1. Analytical Results from Monthly Sampling at Homedale, ID (Continued)

Sampling Date		Month 9: 03/15/06															
Sampling Residence		Wellhead	R1		R2		R4		R5		R6		R7		R8		R9	
Sampling Location		IN	WS1	RO1	WS2	RO2	WS4	RO4	WS5	RO5	WS6	RO6	WS7	RO7	WS8	RO8	WS9	RO9
Parameter	Unit																	
Alkalinity (as $CaCO_3$)	mg/L	305	305	17	305	63	326	13	309	21	297	10	301	10	297	17	301	10
Fluoride	mg/L	0.8	0.8	<0.1	0.8	<0.1	1.0	<0.1	0.8	<0.1	0.8	<0.1	0.8	<0.1	0.8	<0.1	0.8	<0.1
Sulfate	mg/L	168	168	<1	172	<1	176	<1	167	<1	169	<1	171	<1	172	<1	169	<1
Nitrate (as N)	mg/L	8.9	8.8	1.3	9.0	1.7	9.0	1.4	8.9	<0.05	8.8	<0.05	8.8	0.2	8.9	1.6	8.8	0.9
Total P (as PO_4)	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	0.1	<0.01	<0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.03
Silica (as SiO_2)	mg/L	59.8	59.2	3.6	59.2	3.6	60.0	2.2	59.8	29.0	58.5	1.6	59.2	1.3	58.7	2.8	59.1	2.3
Turbidity	mg/L	0.9	0.6	0.4	0.6	0.5	1.0	0.5	0.4	0.3	0.3	0.5	0.4	0.4	0.7	1.2	0.7	1.0
TDS	NTU	714	692	44	744	36	834	28	742	26	710	98	740	14	746	38	606	30
pH	mg/L	7.3	7.6	7.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	S.U.	21.2	11.7	17.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness (as $CaCO_3$)	ºC	216	1.5	<0.35	1.2	<0.35	109	2.3	1.3	0.8	1.5	<0.35	1.2	<0.35	1.1	<0.35	1.4	<0.35
Ca Hardness (as $CaCO_3$)	mg/L	169	1.4	<0.25	1.1	<0.25	82.0	1.6	1.2	0.5	1.4	<0.25	1.1	<0.25	1.0	<0.25	1.3	<0.25
Mg Hardness (as $CaCO_3$)	mg/L	46.5	<0.1	<0.1	<0.1	<0.1	26.9	0.7	0.1	0.3	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1
Total As	mg/L	64.3	63.7	0.2	62.3	0.2	97.2	0.1	63.2	0.1	60.8	<0.1	60.4	0.2	64.4	0.2	63.9	0.2
Total Fe	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Total Mn	µg/L	0.4	0.2	0.2	0.1	0.2	0.5	0.3	<0.1	1.0	<0.1	1.0	<0.1	0.2	<0.1	<0.1	<0.1	0.4
Total U	µg/L	26.0	25.7	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total V	µg/L	29.1	29.9	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-

IN = wellhead
WS = after water softener
RO = after RO unit

Table 1. Analytical Results from Monthly Sampling at Homedale, ID (Continued)

Sampling Date		Month 10: 04/19/2006															
Sampling Residence		Wellhead	R1		R2		R4		R5		R6		R7		R8		R9	
Sampling Location		IN	WS1	RO1	WS2	RO2	WS4	RO4	WS5	RO5	WS6	RO6	WS7	RO7	WS8	RO8	WS9	RO9
Parameter	Unit																	
Alkalinity (as $CaCO_3$)	mg/L	317	313	19	308	9	308	9	308	17	313	9	313	8	317	11	308	12
Fluoride	mg/L	5.2	4.3	0.2	4	<0.1	0.4	<0.1	0.8	<0.1	0.8	<0.1	0.8	<0.1	7.9	<0.1	10.4	0.1
Sulfate	mg/L	155	166	<1	169	<1	16	<1	171	<1	169	<1	161	<1	174	<1	173	<1
Nitrate (as N)	mg/L	5.8	6.3	0.1	6.8	0.9	0.6	0.9	6.4	0.3	6.5	0.1	6.2	0.5	7.4	1.0	7.9	1.1
Total P (as PO_4)	mg/L	0.1	0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.1	<0.01	<0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silica (as SiO_2)	mg/L	62.9	62.3	4.7	61.9	2.1	62	1.7	61.8	3.9	62.5	1.9	62.7	1.4	61.9	2.6	62.6	3.1
Turbidity	mg/L	1.6	0.3	0.1	0.7	0.5	0.3	0.2	0.2	0.2	0.2	0.1	0.3	0.2	0.3	0.1	0.2	0.4
TDS	NTU	676	706	44	728	28	680	20	692	30	694	10	716	14	692	20	672	14
pH	mg/L	7.3	7.8	6.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	S.U.	20.8	14.0	19.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness (as $CaCO_3$)	ºC	238	1.6	0.4	1.2	0.4	5.1	1.0	1.1	0.4	1.6	0.4	1.2	0.4	0.9	0.4	1.5	0.4
Ca Hardness (as $CaCO_3$)	mg/L	176	1.5	<0.25	1.1	<0.25	3.9	0.5	1.0	<0.25	1.4	<0.25	1.1	<0.25	0.8	<0.25	1.2	<0.25
Mg Hardness (as $CaCO_3$)	mg/L	62.6	0.1	<0.1	0.1	<0.1	1.2	0.5	0.1	<0.1	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	0.3	<0.1
Total As	mg/L	58.2	53.0	<0.1	53.2	<0.1	53.6	<0.1	53.6	0.1	54.8	<0.1	53.9	<0.1	51.8	<0.1	51.5	<0.1
Total Fe	µg/L	200	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Total Mn	µg/L	1.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total U	µg/L	23.4	19.5	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total V	µg/L	32.0	31.8	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-

IN = wellhead
WS = after water softener
RO = after RO unit

Table 1. Analytical Results from Monthly Sampling at Homedale, ID (Continued)

Sampling Date		Month 11: 05/17/06															
Sampling Residence		Wellhead	R1		R2		R4		R5		R6		R7		R8		R9	
Sampling Location		IN	WS1	RO1	WS2	RO2	WS4	RO4	WS5	RO5	WS6	RO6	WS7	RO7	WS8	RO8	WS9	RO9
Parameter	Unit																	
Alkalinity (as $CaCO_3$)	mg/L	288	292	16	291	20	283	18	291	13	287	5	291	8	291	18	283	13
Fluoride	mg/L	0.8	0.7	<0.1	0.7	<0.1	0.7	<0.1	0.7	<0.1	0.6	<0.1	0.7	<0.1	0.7	<0.1	0.7	<0.1
Sulfate	mg/L	164	170	<1	166	1	165	<1	164	1	168	<1	165	<1	166	1	166	1
Nitrate (as N)	mg/L	12.6	12.7	1.8	12.7	3.7	12.1	1.6	12.3	1.5	12	1.3	12.5	1.9	12.1	2.7	12.6	1.9
Total P (as PO_4)	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silica (as SiO_2)	mg/L	65.8	66.5	4.7	64.7	3.6	64.3	3.0	65.8	3.4	68.7	2.5	66.2	2.6	65.4	4.5	65.2	3.7
Turbidity	mg/L	1.2	0.3	0.2	0.2	0.6	0.3	0.4	0.3	0.4	0.2	0.2	0.2	0.3	0.7	0.7	0.3	0.3
TDS	NTU	730	700	66	738	68	728	50	732	42	698	44	676	52	670	60	706	46
pH	mg/L	7.4	7.6	6.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	S.U.	17.4	19.1	23.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness (as $CaCO_3$)	ºC	243	2.0	0.4	1.8	0.4	21.4	0.4	1.8	0.4	2.1	0.4	2.4	0.4	2.2	0.4	2.9	0.4
Ca Hardness (as $CaCO_3$)	mg/L	187	1.8	<0.25	1.7	<0.25	13.9	<0.25	1.7	<0.25	1.9	<0.25	2.2	<0.25	2.1	<0.25	2.8	<0.25
Mg Hardness (as $CaCO_3$)	mg/L	55.3	<0.1	<0.1	<0.1	<0.1	7.5	<0.1	0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1
Total As	mg/L	61.2	62.0	0.2	60.5	0.3	59.5	<0.1	62.7	0.4	62.8	<0.1	54.4	0.2	58.0	0.2	51.0	0.2
Total Fe	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Total Mn	µg/L	0.1	<0.1	0.1	<0.1	<0.1	0.1	0.1	<0.1	0.4	<0.1	0.3	<0.1	0.3	<0.1	<0.1	<0.1	0.1
Total U	µg/L	27.3	23.8	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total V	µg/L	30.8	31.0	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-

IN = wellhead
WS = after water softener
RO = after RO unit

Table 1. Analytical Results from Monthly Sampling at Homedale, ID (Continued)

Sampling Date		Month 12: 06/28/06																
Sampling Residence		Wellhead	R1		R2		R4		R5		R6		R7		R8		R9	
Sampling Location		IN	WS1	RO1	WS2	RO2	WS4	RO4	WS5	RO5	WS6	RO6	WS7	RO7	WS8	RO8	WS9	RO9
Parameter	Unit																	
Alkalinity (as $CaCO_3$)	mg/L	283	283	27	288	14	292	15	292	12	292	7	288	9	292	15	288	7
Fluoride	mg/L	0.9	0.9	<0.1	0.9	<0.1	0.3	<0.1	0.8	<0.1	0.8	<0.1	0.8	<0.1	0.8	<0.1	0.9	<0.1
Sulfate	mg/L	155	156	<1	156	<1	155	<1	154	<1	155	<1	154	<1	150	<1	153	<1
Nitrate (as N)	mg/L	13.6	13.4	0.2	13.4	2.5	13.1	2.1	13.2	1.8	13.4	2.3	13.2	2.3	12.8	2.0	13.6	1.0
Total P (as PO_4)	mg/L	<0.01	<0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silica (as SiO_2)	mg/L	67.4	66.2	5.2	65.6	4.1	66.2	3.8	65.1	2.9	66.8	3.4	66.7	3.1	67.1	4.2	67.3	2.1
Turbidity	mg/L	0.9	0.3	0.3	0.3	0.5	0.6	0.4	0.5	0.4	0.5	0.3	0.3	0.2	1.0	0.7	0.6	0.3
TDS	NTU	720	752	42	694	40	698	30	722	36	706	28	728	26	696	24	686	16
pH	mg/L	7.4	7.5	6.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	S.U.	17.0	21.1	22.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Hardness (as $CaCO_3$)	ºC	251	1.5	0.4	1.1	0.3	1.5	0.3	1.2	0.3	1.3	0.3	1.1	0.3	1.1	0.3	1.1	0.3
Ca Hardness (as $CaCO_3$)	mg/L	190	1.4	<0.25	1.1	<0.25	1.3	<0.25	1.1	<0.25	1.2	<0.25	1.0	<0.25	1.0	<0.25	1.0	<0.25
Mg Hardness (as $CaCO_3$)	mg/L	61.3	0.1	0.1	0.1	<0.04	0.2	<0.04	0.1	<0.04	0.1	<0.04	0.1	<0.04	0.0	<0.04	0.1	<0.04
Total As	mg/L	60.3	54.2	0.3	66.6	0.2	65.1	0.2	64.8	0.3	61.8	0.2	62.3	0.2	63.5	0.3	67.8	0.2
Total Fe	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Total Mn	µg/L	0.3	0.2	0.9	0.1	0.1	0.1	<0.1	<0.1	0.2	0.1	0.3	<0.1	0.1	0.1	<0.1	0.1	0.1
Total U	µg/L	27.4	26.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	26.0	<0.1
Total V	µg/L	31.5	30.8	0.1	-	-	-	-	-	-	-	-	-	-	-	-	30.9	0.1

IN = wellhead
WS = after water softener
RO = after RO unit