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Arsenic Removal from Drinking Water by Point of Use Reverse Osmosis EPA Demonstration Project at Sunset Ranch Development in Homedale, ID Six-Month Evaluation Report

by

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Sally Gutierrez, Director
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ABSTRACT

The treatment system at Sunset Ranch Development in Homedale, ID, consisted of one Point of Use (POU) reverse osmosis (RO) unit each at 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 and nine POU RO units were provided by Kinetico. Each POU RO unit consisted of a 20-µm pre-filter, a RO module with a 1.7-in-diameter by 11-in-tall, 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 the 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 242 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.

Arsenic speciation results indicated that As(V) was the predominant species in raw water, ranging from 49.5 to 56.4 µg/L. Only a trace amount of As(III) existed, ranging from 1.7 to 2.9 and averaging 2.2 µg/L. As expected, the softeners did not remove any arsenic, but reduced the water hardness from 232–247 mg/L (as $CaCO_3$) to an average of 0.5 mg/L (as $CaCO_3$). Total arsenic concentrations in the permeate water were less than 0.1 µg/L for all samples except for two at 5.1 and 8.7 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 10.1 mg/L (as N) in raw water to an average of 0.8 mg/L (as N) in the permeate water, representing a 94% reduction. Uranium was removed from 24.3 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 97% for total dissolved solids (TDS). pH values also were reduced to 6.5-6.7, due to the reduction of alkalinity by the RO units.

Regeneration brine waste from the softener and reject water from the RO units were discharged to the septic tank at each residence. The RO reject water contained 56 to 92 µg/L of arsenic, 11 to 16 mg/L (as N) of nitrate, 27 to 42 µg/L of uranium, and 892 to 1,060 mg/L of TDS. The mass balance across the RO unit was calculated for total arsenic and nitrate for each sampling event. During the first six months, the mass balance ranged from 66% to 114% for total arsenic and from 83% to 99% for nitrate.

Operational problems encountered during the reporting period included water pulsing from the faucet, incorrect outlet elbow installation, water quality monitor malfunction, and a loose wire on the TDS monitor indicator light. These problems were corrected promptly by the vendor and have not re-occurred; 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. O&M cost per household during a six-month period was near $144 or $24/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 treatment-level certified operator.

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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
DO	dissolved oxygen
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
MDWCA	Mutual Domestic Water Consumers Association
MEI	Magnesium Elektron, Inc.
Mg	magnesium
mg/L	milligrams per liter
µg/L	micrograms per liter
µm	micrometer
Mn	manganese
mV	millivolts
Na	sodium
NA	not applicable
ND	not detected
NRMRL	National Risk Management Research Laboratory
NO_2	nitrite
NO	nitrate

NSF	NSF International
NTU	nephlemetric turbidity units
O&M	operation and maintenance
OIT	Oregon Institute of Technology
ORD	Office of Research and Development
ORP	oxidation-reduction potential
PO_4	orthophosphate
POC	point of contact
POE	point of entry
POU	point of use
psi	pounds per square inch
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RO	reverse osmosis
RPD	relative percent difference
SDWA	Safe Drinking Water Act
SiO_2	silica
SO_4	sulfate
STMGID	South Truckee Meadows General Improvement District
STS	Severn Trent Services
TDS	total dissolved solids
TO	Task Order
TOC	total organic carbon
U	uranium
V	vanadium
VOC	volatile organic compound

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The authors wish to extend their sincere appreciation to the president and homeowners of the Sunset Ranch Development in Homedale, ID. They assisted in monitoring the system's performance and collected samples regularly from nine point-of-use reverse osmosis units throughout this study period. This performance evaluation study would not have been possible without their support and dedication.

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 sites from a list of 115 sites to be the host sites for the demonstration studies.

In September 2002, EPA solicited proposals from engineering firms and vendors for cost-effective arsenic removal treatment technologies for the 17 host sites. EPA received 70 technical proposals for the 17 host sites, with each site receiving from one to six proposals. In April 2003, an independent technical panel reviewed the proposals and provided its recommendations to EPA on the technologies that it determined were acceptable for the demonstration at each site. Because of funding limitations and other technical reasons, only 12 of the 17 sites were selected for the Round 1 demonstration program. Using the information provided by the review panel, EPA, in cooperation with the host sites and the drinking water programs of the respective states, selected one technical proposal for each site. As of July 2006, 11 of the 12 systems have been operational and the performance evaluations of two systems have been 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 (including 3 AM systems at the Oregon Institute of Technology [OIT] site), 13 coagulation/ filtration systems, 2 ion exchange (IX) systems, 17 POU units (including 9 residential RO units at the Sunset Ranch Development site and 8 AM units at the OIT site), and 1 system modification. Table 1-1 summarizes the locations, technologies, vendors, system flowrates, and key source water quality parameters (including arsenic, iron, and pH) at the 40 demonstration sites. An overview of the technology selection and system design for the 12 Round 1 sites has been provided in an EPA report (Wang et al., 2004). The capital costs of the 12 Round 1 systems have been discussed in a separate EPA report (Chen et al., 2004). Both reports are posted on the EPA's Web site at http://www.epa.gov/ORD/NRMRL/arsenic/resource.htm.

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.
- Determine the capital and O&M costs of the technologies.
- Characterize process residuals produced by the technologies.

This report summarizes the results gathered during the first six months of Kinetico's POU RO system operation from July 15, 2005, through January 17, 2006, at the Sunset Ranch Development in Homedale, ID. The types of data collected included system operational data, water quality data, and capital and preliminary O&M cost data.

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
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 Public Water System	AM (G2)	ADI	70[d]	39	<25	7.7
Goffstown, NH	Orchard Highlands	AM (E33)	AdEdge	10	33	<25	6.9
Rollinsford, NH	Rollinsford	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	Felton	C/F (Macrolite)	Kinetico	375	30[a]	48	8.2
Queen Anne's County, MD	Queen Anne's County	AM (E33)	STS	300	19[a]	270[b]	7.3
Buckeye Lake, OH	Buckeye Lake Head Start Building	AM (ARM 200)	Kinetico	10	15[a]	1,312[b]	7.6
Springfield, OH	Chateau Estates Mobile Home Park	AM (E33)	AdEdge	150	25[a]	1,615[b]	7.3
Great Lakes/Interior Plains							
Brown City, MI	Brown City	AM (E33)	STS	640	14[a]	127[b]	7.3
Pentwater, MI	Village of Pentwater	C/F (Macrolite)	Kinetico	400	13[a]	466[b]	6.9
Sandusky, MI	City of Sandusky	C/F (Aeralater)	USFilter	340	16[a]	1,387[b]	6.9
Delavan, WI	Vintage on the Ponds	C/F (Macrolite)	Kinetico	40	20[a]	1,499[b]	7.5
Greenville, WI	Town of Greenville	C/F (Macrolite)	Kinetico	375	17	7827[b]	7.3
Climax, MN	City of Climax	C/F (Macrolite)	Kinetico	140	39[a]	546[b]	7.4
Sabin, MN	City of Sabin	C/F (Macrolite)	Kinetico	250	34	1,470[b]	7.3
Sauk Centre, MN	Big Sauk Lake Mobile Home Park	C/F (Macrolite)	Kinetico	20	25[a]	3,078[b]	7.1
Stewart, MN	City of Stewart	C/F&AM (E33)	AdEdge	250	42[a]	1,344[b]	7.7
Lidgerwood, ND	Lidgerwood	System Modification	Kinetico	250	146[a]	1,325[b]	7.2
Midwest/Southwest							
Lyman, NE	Village of Lyman	C/F (Macrolite)	Kinetico	350	20	<25	7.5
Arnaudville, LA	United Water Systems	C/F (Macrolite)	Kinetico	385	35[a]	2,068[b]	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 MDWCA	AM (E33)	STS	320	23[a]	39	7.7
Nambe Pueblo, NM	Nambe Pueblo	AM (E33)	AdEdge	145	33	<25	8.5
Taos, NM	Town of Taos	AM (E33)	STS	450	14	59	9.5
Rimrock, AZ	Rimrock	AM (E33)	AdEdge	90[e]	50	170	7.2
Sells, AZ	Tohono O'odham Nation	AM (E33)	AdEdge	50	32	<25	8.2
Valley Vista, AZ	Valley Vista	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)	Kenetico	250	44	<25	7.4
Homedale, ID	Sunset Ranch Development	POU RO[(c)]	Kinetico	75 gpd	52	134	7.5
Okanogan, WA	City of Okanogan	C/F (Electromedia II)	Filtronics	750	18	69[(b)]	8.0
Klamath Falls, OR	Oregon Institute of Technology	AM (Adsorbsia/ARM 200/ArsenX)	Kinetico	60/60/30	33	<25	7.9
Vale, OR	City of Vale	IX (A520)	Kinetico	525	17	<25	7.5
Reno, NV	STMGID	AM (GFH)	USFilter	350	39	<25	7.4
Susanville, CA	Richmond School District	AM (A/I Complex)	ATS	12	37[(a)]	125	7.5
Lake Isabella, CA	Upper Bodfish Well CH2-A	AM (HIX)	VEETech	50	35	125	7.5
Tehachapi, CA	Golden Hills Community Service District	AM (Isolux)	MEI	150	15	<25	6.9

MDWCA = Mutual Domestic Water Consumers Association; STMGID = South Truckee Meadows General Improvement District
AM = adsorptive media; C/F = coagulation/filtration; GFH = granular ferric hydroxide; IX = ion exchange; HIX = hybrid ion exchanger
ATS = Aquatic Treatment Systems; STS = Severn Trent Services; MEI = Magnesium Elektron, Inc.

(a) Arsenic exists mostly as As(III).
(b) Iron exists mostly as Fe(II).
(c) Consisted of nine residential units.
(d) System reconfigured from parallel to series operation due to lower flowrate of 40 gpm.
(e) System reconfigured from parallel to series operation due to lower flowrate of 30 gpm.

2.0 CONCLUSIONS

Nine residential POU RO units were installed at Sunset Ranch Development in Homedale, ID, on July 1, 2005, and were put into use on July 15, 2005. Water softening was performed as a pretreatment to prevent scaling of the RO membranes. Based on the information collected during the first six months of operation, the following preliminary conclusions were made relating to the overall project objectives.

Performance of the arsenic removal technology for use on small systems

- The RO units effectively reduced total arsenic from 56.1 µg/L (on average) in raw water to less than 0.1 µg/L in the permeate water for all but two samples (i.e., 5.1 and 8.7 µg/L), achieving over 99% removal efficiency for arsenic.
- The RO units effectively reduced nitrate from 8.7-11.6 mg/L (as N) in raw water to an average of 0.8 mg/L (as N) in the permeate water, achieving 92% removal for nitrate.
- Uranium was completely removed by the RO units to below 0.1 µg/L.
- The RO units also achieved 97% removal for total dissolved solids (TDS), 100% for iron, 99% for vanadium, and 96% for silica. pH values were reduced to 6.5-6.7 due to the reduction of alkalinity by the RO units.
- Although not effective at removing arsenic or nitrate, the water softeners reduced hardness in raw water from 232-247 mg/L (as $CaCO_3$) to an average of 0.5 mg/L (as $CaCO_3$) to meet the RO feed water quality requirements.

Process residuals produced by the technology

- The water softener regeneration wastewater and the RO reject water were discharged to the septic system at individual homes. The RO reject water contained 56 to 92 µg/L of arsenic, 11 to 16 mg/L (as N) of nitrate, 27 to 42 µg/L of uranium, and 892 to 1,060 mg/L of TDS.

Required system operation and maintenance

- The point of entry (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.
- Only one homeowner used 500 gal of treated water during this six month reporting period. For this homeowner with the largest water usage, the six month O&M cost for salt usage ($57.50) and filter replacement ($86.50) was $144, or $24 per month.

3.0 MATERIALS AND METHODS

3.1 General Project Approach

Following the pre-demonstration activities summarized in Table 3-1, the performance evaluation study of the POE/POU systems began on July 15, 2005. Table 3-2 summarizes the types of data collected and/or considered as part of the technology evaluation process. The overall system performance was evaluated based on its ability to consistently meet 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.

Table 3-1. Pre-Demonstration 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

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

Evaluation Objectives	Data Collection
Performance	-Ability to consistently meet 10 µg/L of arsenic and 10 mg/L of nitrate in effluent
Reliability	-Unscheduled downtime for system -Frequency and extent of repairs to include labor hours, problem description, description of materials, and cost of materials
O&M and Operator Skill Requirements	-Pre- and post-treatment requirements -Level of system automation for data collection and system operation -Task analysis of preventative maintenance to include labor hours per month and number and complexity of tasks -Chemical handling and inventory requirements -General knowledge needed of safety requirements and chemical processes
System Cost	-Capital cost for equipment and installation -O&M cost for salt supply and filter replacement
Residual Management	-Quantity of the residuals generated by the process -Characteristics of the aqueous and solid residuals

The system O&M and operator skill levels required were evaluated based on a combination of quantitative data and qualitative considerations, including any pre-treatment and/or post-treatment requirements, level of system automation, operator skill requirements, task analysis of the preventive maintenance activities, frequency of chemical handling and inventory requirements, and general knowledge needed for safety requirements and chemical processes. The staffing requirements to maintain the system operation were recorded on an Operator Labor Hour Log Sheet.

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. Monthly, homeowner R1 measured pH and temperature using a hand-held meter and recorded the data on an On-Site Water Quality Parameters Log Sheet.

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 treatments 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 and 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. Table 3-3 summarizes the sampling and analysis schedule for each sampling event. Specific sampling requirements for arsenic speciation, 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).

3.3.1 Source Water Sample Collection. During the initial site visit on December 1, 2004, one set of source water samples was collected from the wellhead for detailed water quality analyses (Table 3-3). The sample tap was flushed for several minutes before sampling; special care was taken to avoid agitation, which might cause unwanted oxidation. An arsenic speciation kit and sample bottles with appropriate preservatives were used for sample collection.

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. The samples were analyzed for the analytes listed for the monthly treatment system water samples. On-site arsenic speciation also was performed at the IN and R1 residence's WS and RO sampling locations on a quarterly basis. The samples were speciated and analyzed for the analytes listed for the quarterly treatment system water samples (Table 3-3).

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

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
Source Water	At Wellhead (IN)	1	Once	On-site: pH, temperature, DO, and ORP Off-site: As (total, soluble, particulate), 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	12/01/05
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 (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 (total U and V 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
	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, soluble, particulate), 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
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), 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

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

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.

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, 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, where to send the sample, 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. Samples for off-site analyses were packed carefully in the original coolers with wet ice and shipped to Battelle. Upon receipt, sample custodians verified that all samples indicated on the chain-of-custody forms were included and intact. Sample label identifications were checked against the chain-of-custody forms and the samples were logged into the laboratory sample receipt log. Discrepancies noted by the sample custodians were addressed with the plant operator by the Battelle Study Lead.

Samples for metal analyses were stored at Battelle's ICP-MS Laboratory. Samples for other water quality analyses were packed in coolers at Battelle and picked up by a courier from Battelle's subcontract laboratories, including American Analytical Laboratories (AAL) in Columbus, OH. 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, DHL, and TCCI Laboratories. Field measurements of pH were conducted by homeowner R1 using a WTW Multi 340i hand-held 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 reached.

Laboratory quality assurance/quality control (QA/QC) of all methods followed the guidelines provided in the QAPP (Battelle, 2004). Data quality in terms of precision, accuracy, method detection limit (MDL), and completeness met the criteria established in the QAPP (i.e., relative percent difference [RPD] of 20%, percent recovery of 80-120%, 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 separately.

4.0 RESULTS AND DISCUSSION

This section describes the existing facility and arsenic treatment technology installed at Sunset Ranch Development in Homedale, ID; it presents the results of the first six months (from July 15, 2005, to January 17, 2006) of the performance evaluation of the POU RO units and discusses the system reliability, O&M requirements, and system cost.

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 ten homes, is located approximately three miles west of Homedale, on Route 19 at Northside Road. Nine homes are participating in the EPA demonstration; one homeowner has 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.

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

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.

4.1.1 Source Water Quality. Source water samples were collected from the well on December 1, 2004, by a Battelle staff member who traveled to the site to attend an introductory meeting. The sample tap was flushed for 15 min prior to sample collection. The source water was speciated on-site for total arsenic (As), soluble As (including As[III] and As[V]), and particulate As. Special care was taken to avoid agitaion, which could cause unwanted oxidation of the water. After collection, the samples were packed in a cooler with double-bagged wet ice for overnight shipment to Battelle.

The analytical results from the source water sampling event are presented in Table 4-1 and compared to the data submitted by the facility to EPA for the demonstration site selection and to data 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 (Table 4-1). Based on the December 1, 2004, sampling results obtained by Battelle, the total arsenic concentration in the raw source water was 51.6 μg/L with most present as As(V) (46.8 μg/L). A small amount of arsenic also existed as As(III) (2.9 μg/L) and particulate As (i.e., 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.

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 the undersink RO unit.
NA = not available.
ND = not detectable.
TOC = total organic carbon.
TDS = total dissolved solids.

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 MCL's of 10 mg/L and 30 μg/L.

Other Water Quality Parameters. Total dissolved solids (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), 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 (30.3-31.2 μg/L). Because relatively high concentrations of vanadium were measured, its concentrations were monitored monthly during the one-year performance evaluation study.

Hardness ranged from 298 to 310 mg/L (as $CaCO_3$) in the source water samples collected by Battelle and Kinetico. Softening of this water prior to the RO system was recommended by the vendor to prevent scaling of the RO membrane.

4.1.2 Treated Water Quality. As noted above, although there is no centralized treatment system in place at Sunset Ranch Development, several homeowners have installed a softener and/or a RO unit. A sample was collected from the kitchen tap after the water had been treated by a softener and a RO unit at the R1 residence on December 1, 2004. The total arsenic and nitrate concentrations in the treated water sample were less than 0.1 μg/L and 1.1 mg/L (as N), 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 employ septic tank systems for waste disposal. No centralized waste disposal system is in place. Regeneration wastewater from the softeners and the 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 4-4 presents a process flowchart, including sample locations, frequency, and analytes.

4.2.1 Water Softener. A Kinetico's Model 2060s water softener consisted of two 8-in-diameter by 40-in-tall polyethylene wrapped resin tanks and one 12-in-diameter by 40-in-tall or 18-in-diameter by 35-in-tall brine tank (Figure 4-5). Each resin tank contained 0.7 ft^3 of non-solvent cation 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

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)

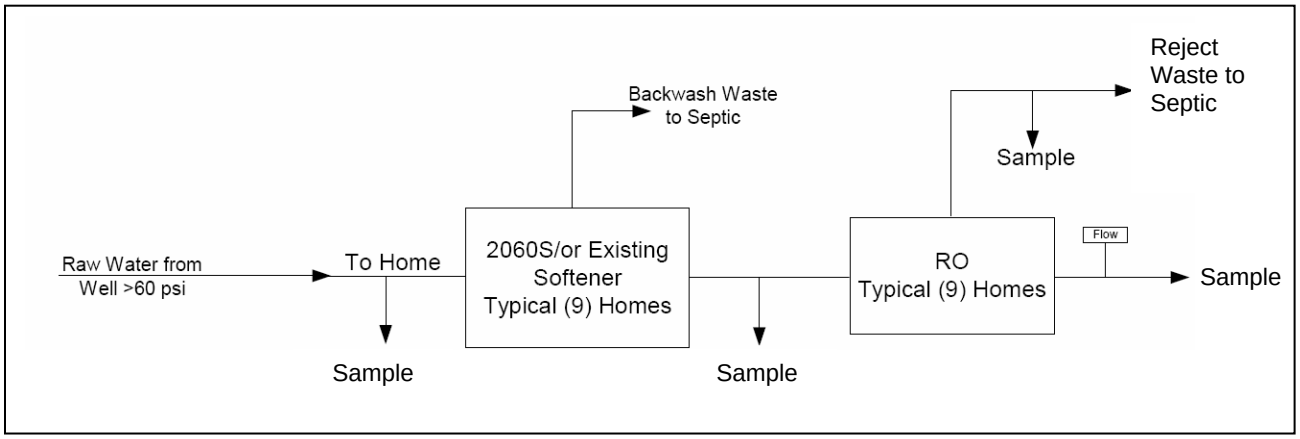

Figure 4-3. Schematic of Kinetico's POE Water Softener and POU RO Unit

took 45 min to complete. The two pre-existing 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 is 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.

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 pre-filter cartridge, a RO module, a storage tank, and a post-filter cartridge (Figure 4-6).

- **Pre-Filter Cartridge** – Prior to entering the RO module, water passed through a 20-μm pre-filter to remove particles.

- **RO Module** – After passing through the pre-filter, water was forced through a 1.7-in-diameter by 11-in-tall thin film composite, semi-permeable membrane element where most soluble minerals and chemicals were removed. The RO unit could produce up to 35.5 gpd of permeate water. While yielding permeate water, the RO unit also produced reject water, which included water rejected by the RO membrane and rinse water used to rinse the RO

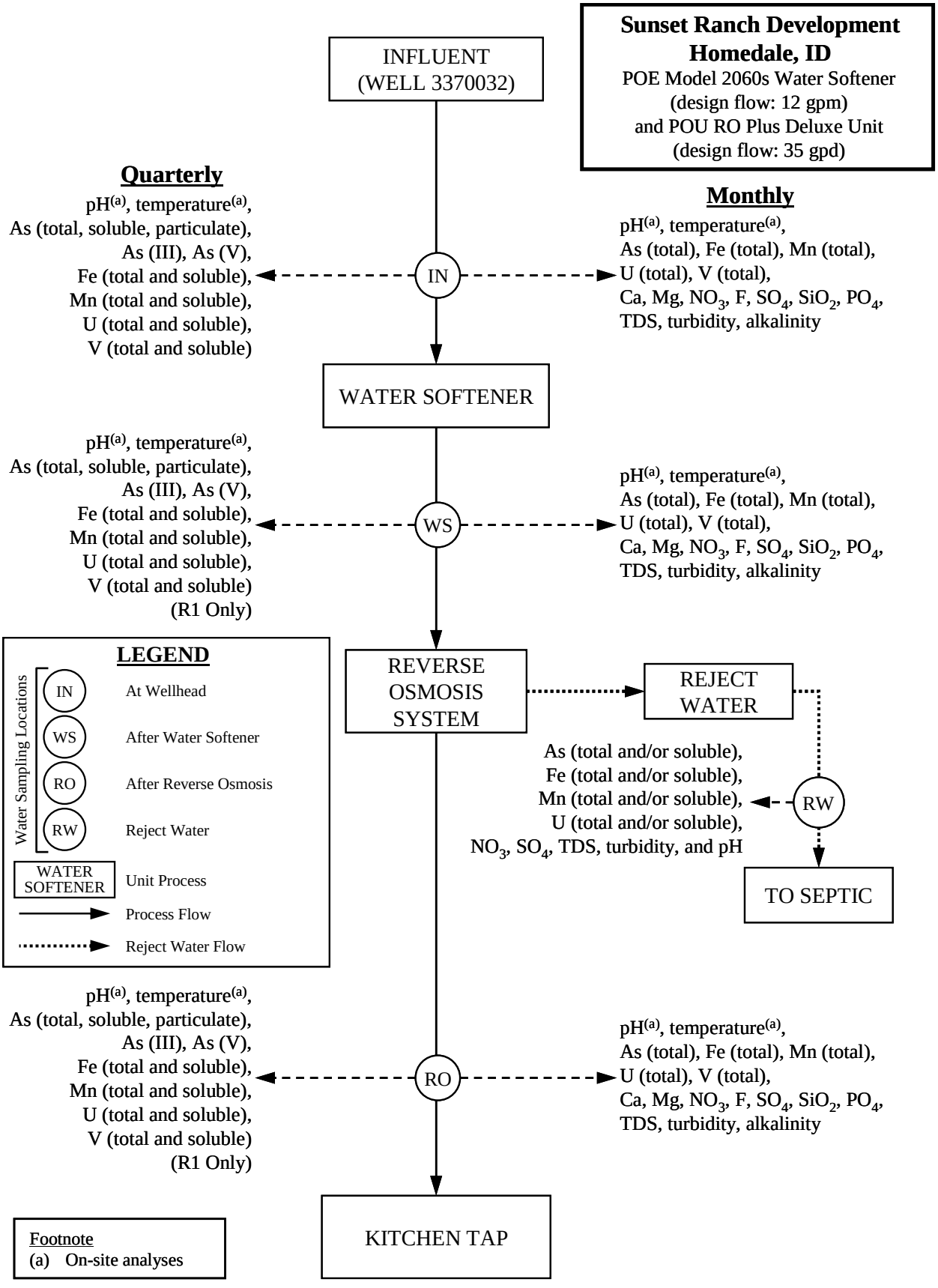

Figure 4-4. Process Flow Diagram and Sampling Locations for Sunset Ranch Development

Figure 4-5. Kinetico Model 2060s Water Softener

membrane. The reject water represented approximately 63% of the volume reaching the RO unit was discharged to the home septic system. 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.

- **Post-Filter** – The water then flowed from the storage tank 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. The water production will resume 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,

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

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 the 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.

Figure 4-6. Under-the-Sink RO Plus Deluxe Unit

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 faucets 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 hand-held 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 242 gal of water from July 15, 2005, through January 17, 2006, an average of 40 gal/month (Figure 4-7). At the R9 residence, the water production reached 500 gal on January 9, 2006, and the pre- and post-filters were replaced on January 11, 2006, before water production resumed. Water production at the other seven participating homes were not tracked, but had not reached the 500-gal level before the end of this six-month study period.

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 (ºF)	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

4.4.2 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 411 gal of water has discharged to the septic system while producing 242 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.

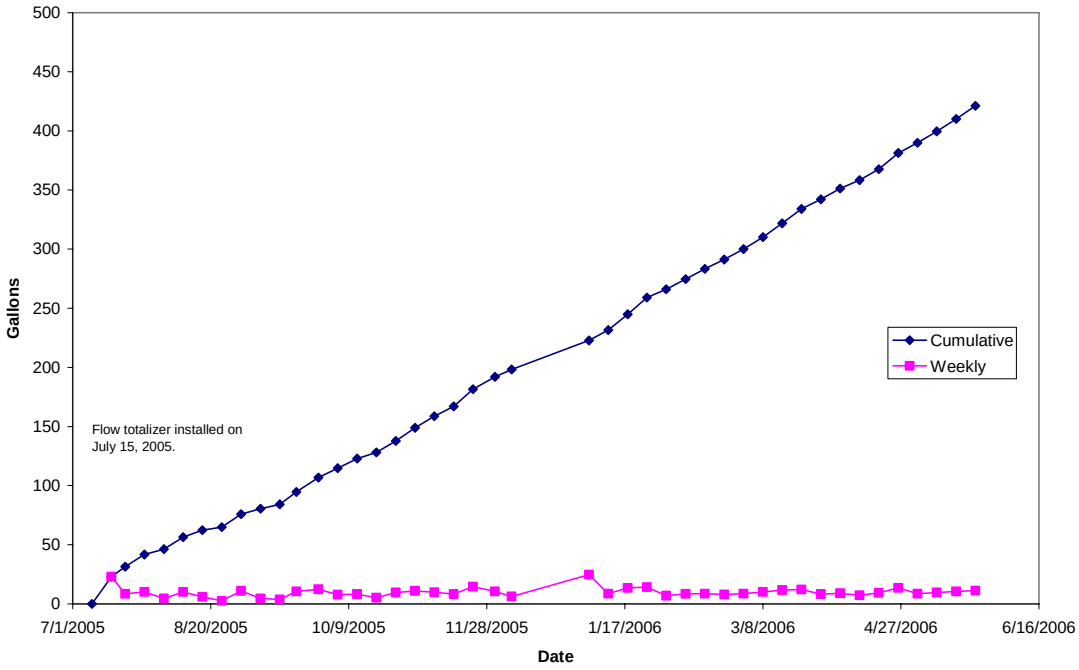

Figure 4-7. RO Totalizer Readings at R1 Residence

4.4.3 System/Operation Reliability and Simplicity. Operational problems were encountered during the first month of system operation. On July 26, 2005, the undersink storage tanks at two residences were replaced due to low water flow at the respective RO taps. The undersink storage tank at one of these residences had to be replaced again on August 8, 2005, for the same problem. Under warranty, Kinetico technicians were on-site from August 10 to 11, 2005, to address this and other problems. Table 4-5 summarizes the problems encountered and corrective actions taken. No additional operational problems were encountered.

Table 4-5. Summary of Kinetico Service Report

Problem	Corrective Action Taken	Residences
Water Pulsing from Faucet	Faucet upgraded to include new high flow gasket	R1-R9
Incorrect Outlet Elbow Installed	Correct flow control elbow installed	R1
Water Quality Monitor Malfunction	Sensor replaced	R9
Loose Wire on TDS Monitor Indicator Light	TDS monitor replaced	R6
Low Flow from a Previously Replaced Undersink Storage Tank	Faulty check valve replaced	R2 & R3

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. Preventive maintenance activities were minimal for Kinetico's water softeners and RO units. The water softeners 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 units required changing every 500 gal, as the units would shut down when reaching the 500-gal production level. On January 11, 2006, the RO unit at one residence 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 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 seven occasions during the first six months of system operation. 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 4-8 to 4-12 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 two occasions, and the results are summarized in Table 4-7. Also, pH (Figure 4-13) and temperature were measured on-site at the wellhead (IN) and in the R1 residence at the WS1 and RO1 locations.

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	7	53.0	61.7	56.1	2.7
	WS	µg/L	60	48.1	66.8	54.6	8.1
	RO	µg/L	60	<0.1	8.7	0.5	1.3
Nitrate (as N)	IN	mg/L	7	8.7	11.6	10.1	1.2
	WS	mg/L	60	8.7	11.7	10.2	1.1
	RO	mg/L	60	<0.05	2.2	0.8	0.6
U (total)	IN	µg/L	7	24.3	31.0	28.3	2.6
	WS	µg/L	16	21.3	31.9	28.4	3.0
	RO	µg/L	16	<0.1	<0.1	<0.1	0.0
V (total)	IN	µg/L	7	30.1	39.0	33.3	2.8
	WS	µg/L	16	30.4	38.9	33.7	1.9
	RO	µg/L	16	<0.1	1.3	0.3	0.5
TDS	IN	mg/L	7	648	694	670	18.5
	WS	mg/L	60	492	842	696	46.8
	RO	mg/L	60	<1.0	0.5	19.7	21.2

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

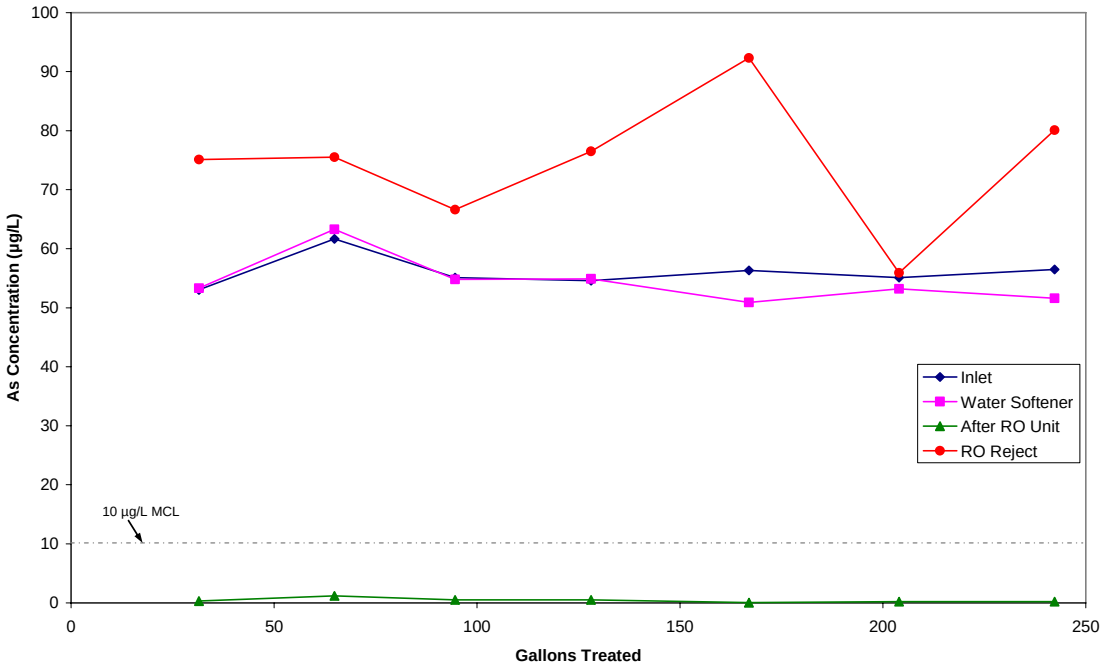

Figure 4-8. Total Arsenic Concentrations at Sunset Ranch Development

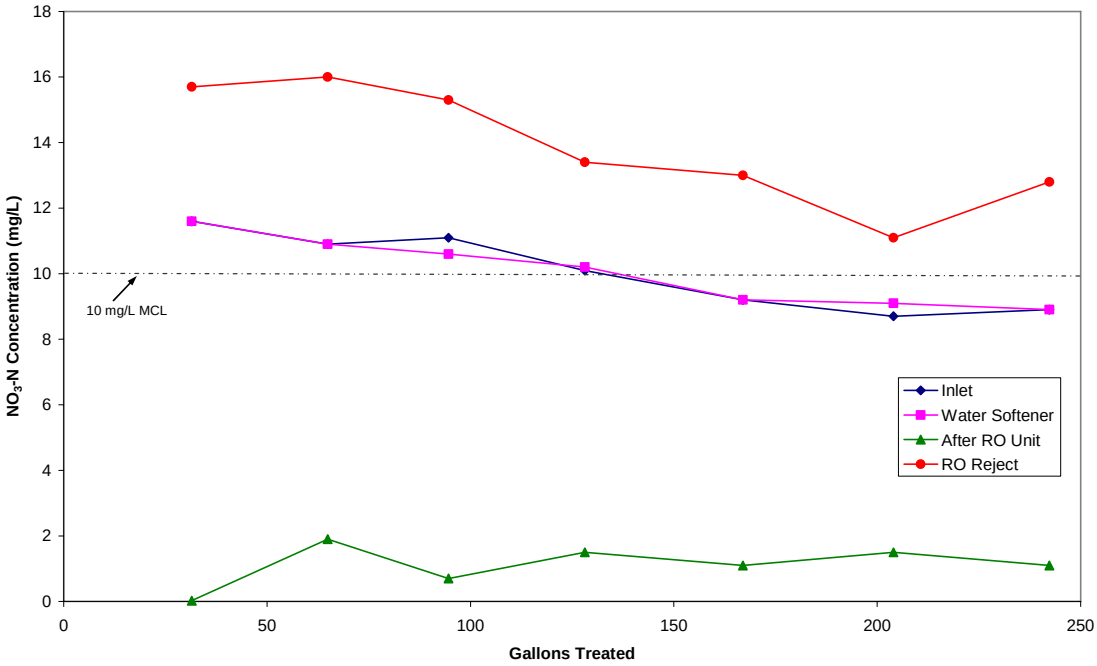

Figure 4-9. Nitrate Concentrations at Sunset Ranch Development

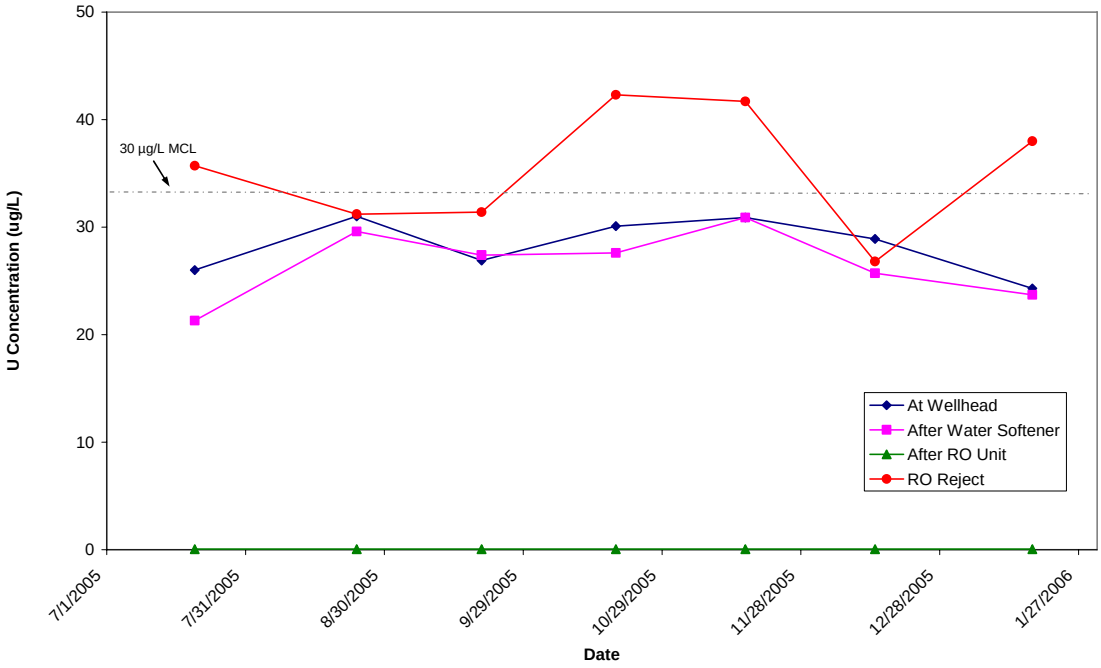

Figure 4-10. Uranium Concentrations at R1 Residence

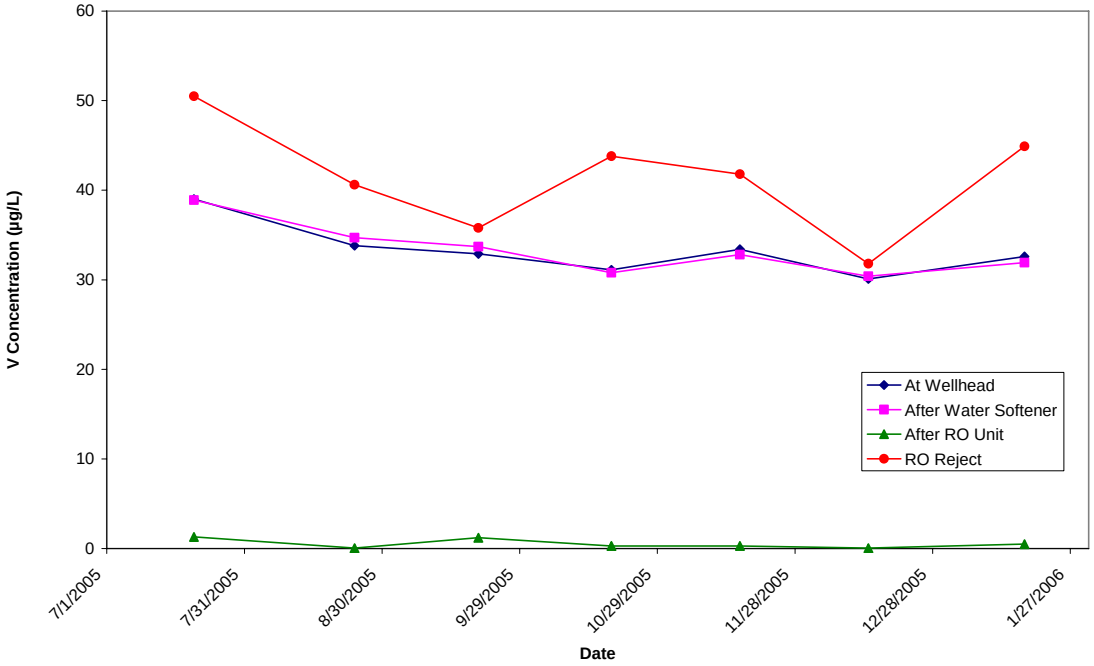

Figure 4-11. Vanadium Concentrations at R1 Residence

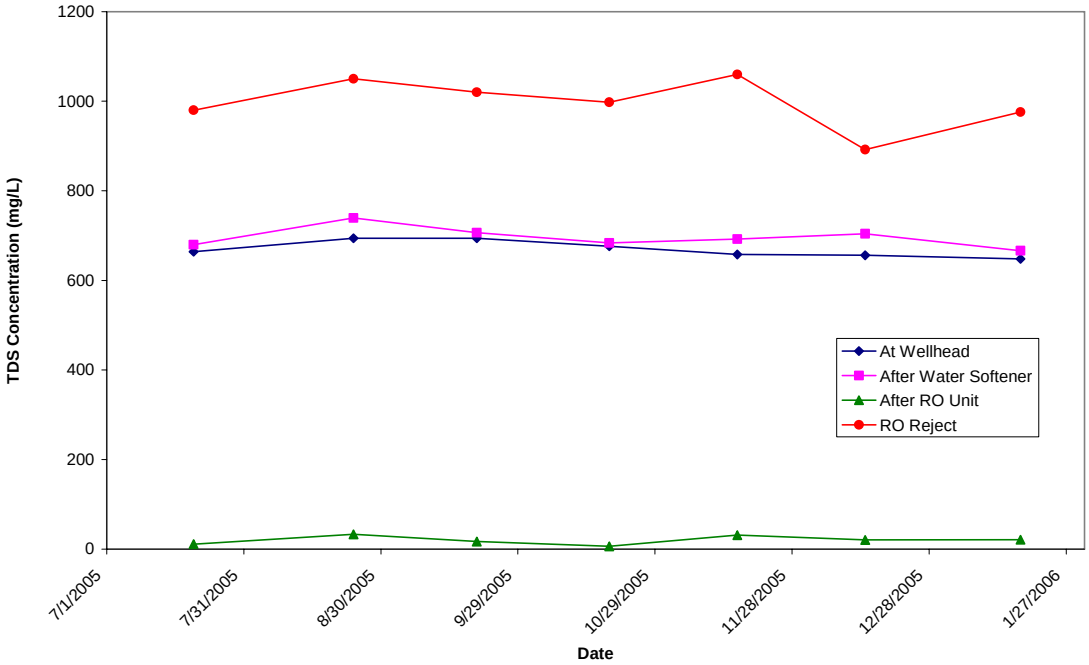

Figure 4-12. TDS Concentrations at Sunset Ranch Development

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

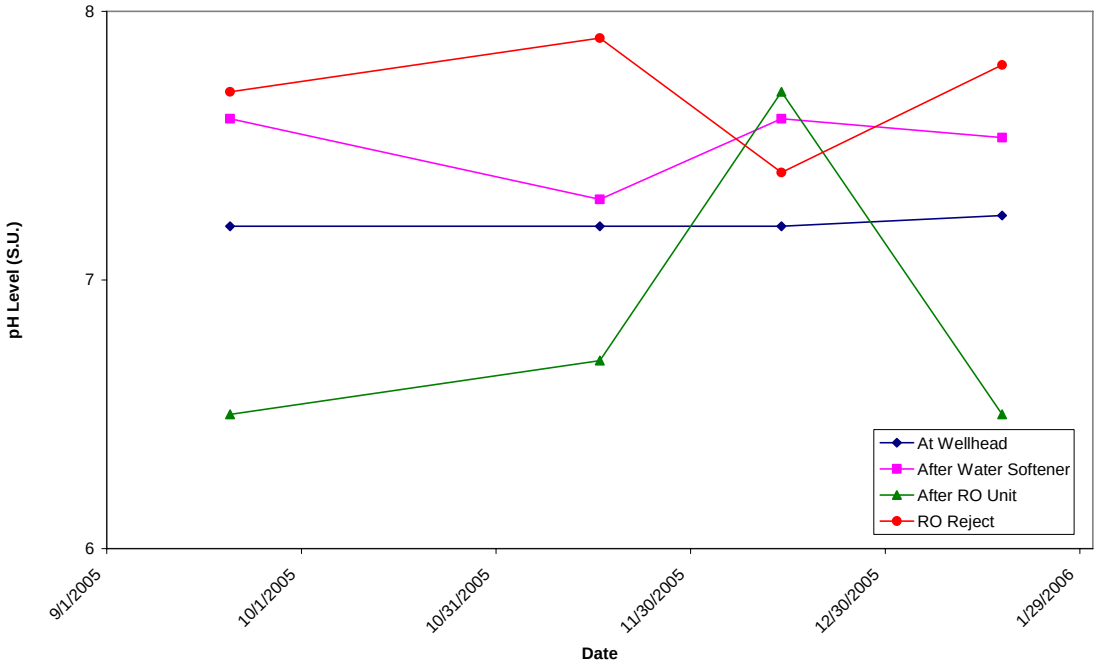

Figure 4-13. pH Levels at R1 Residence

Results of other water quality parameters measured are provided in Table 4-8. Appendix A contains a complete set of analytical results through the first six months of system operation. 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 61.7 µg/L and averaged 56.1 µg/L (Table 4-6). Based on arsenic speciation results obtained on September 20 and December 14, 2005, As(V) was the predominating species, ranging from 49.5 to 56.4 µg/L and averaging 52.9 µg/L. Only a trace amount of As(III) existed, ranging from 1.7 to 2.7 µg/L and averaging 2.2 µg/L (Table 4-7). The arsenic concentrations measured during the six-month period 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 66.8 µg/L, with one outlier of <0.1 µg/L, and averaged 54.6 µg/L, which were at the same levels as those in raw water (Figure 4-8). As expected, the softeners did not remove any arsenic. Total arsenic concentrations after the RO units were <0.1 µg/L for all samples, except for two measurements at 5.1 and 8.7 µg/L. Based on the average arsenic concentration in raw water, the RO units achieved over 99% arsenic removal. After 242 gal of water production at the R1 residence, the RO unit continued to perform well, with arsenic reported at 0.2 µg/L.

Nitrate. Nitrate concentrations at the wellhead and after water softeners exceeded the MCL of 10 mg/L, averaging at 10.1 and 10.2 mg/L (as N), respectively (Table 4-6). Nitrate was consistently removed by the RO unit throughout the first six months of operation (Figure 4-9). Nitrate concentrations in RO permeate ranged from <0.05 to 2.2 mg/L (as N) and averaged 0.8 mg/L (as N), representing 92% removal. After 242 gal of water production at the R1 residence, nitrate continued to be removed to levels as low as 1.1 mg/L (as N).

Uranium and Vanadium. Uranium concentrations ranged from 24.3 and 31.0 µg/L in raw water and from 21.3 to 31.9 µg/L after softening, 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 units to below 0.1 µg/L throughout the first six months (Figure 4-10).

Average vanadium concentrations in raw water and after water softeners were 33.3 and 33.7 µg/L, respectively; and vanadium concentrations in RO permeate ranged from <0.1 to 1.3 µg/L and averaged 0.3 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 4-11).

After 242 gal of water production at the R1 residence, samples indicated <0.1 µg/L of uranium and 0.5 µg/L of vanadium.

TDS. When evaluating the performance of the RO units, a critical parameter is their ability to remove TDS from raw water. TDS concentrations averaged 670 and 696 mg/L in raw water and after softening, respectively (Table 4-6). The average TDS concentration after the RO units was 19.7 mg/L. On average, the RO units achieved 97% TDS removal (Figure 4-12).

Iron and Manganese. Total iron concentrations in raw water ranged from <25 to 252 µg/L and averaged 78 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 was 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

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

Parameter	Sampling Location	Unit	Sample Count	Concentration			Standard Deviation
				Minimum	Maximum	Average	
Fe (total)	IN	µg/L	7	<25	252	78	111
	WS	µg/L	60	<25	56	14	7.1
	RO	µg/L	60	<25	<25	<25	-
Mn (total)	IN	µg/L	7	0.2	1.9	0.6	0.6
	WS	µg/L	60	<0.1	1.3	0.1	0.2
	RO	µg/L	60	<0.1	28.2	2.4	4.4
Alkalinity (as $CaCO_3$)	IN	mg/L	7	286	308	294	9.7
	WS	mg/L	60	264	312	291	10.7
	RO	mg/L	60	1.0	55.0	11.1	7.3
Fluoride	IN	mg/L	7	0.6	0.8	0.7	0.1
	WS	mg/L	60	0.6	0.8	0.7	0.1
	RO	mg/L	60	<0.1	0.7	0.1	0.1
Sulfate	IN	mg/L	7	151	188	163	13.8
	WS	mg/L	60	140	195	163	13.7
	RO	mg/L	60	<1.0	2.2	0.6	0.3
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	-
Phosphorous (total) (as PO_4)	IN	mg/L	4	<0.03	<0.03	<0.03	-
	WS	mg/L	33	<0.03	0.1	<0.03	-
	RO	mg/L	33	<0.03	0.1	<0.03	-
Silica (as SiO_2)	IN	mg/L	7	60.1	95.9	68.0	12.5
	WS	mg/L	59	59.0	108	67.8	11.5
	RO	mg/L	59	0.8	8.2	2.7	1.5
Turbidity	IN	NTU	7	<0.1	2.3	0.7	0.8
	WS	NTU	60	<0.1	2.1	0.4	0.4
	RO	NTU	60	<0.1	0.7	0.2	0.2
Total Hardness (as $CaCO_3$)	IN	mg/L	7	228	247	238	7.5
	WS	mg/L	60	0.2	241	15.9	55.1
	RO	mg/L	60	0.0	5.6	0.5	0.7
Ca Hardness (as $CaCO_3$)	IN	mg/L	7	182	193	187	4.5
	WS	mg/L	60	<0.25	189	10.9	38.8
	RO	mg/L	60	<0.25	2.8	0.3	0.4
Mg Hardness (as $CaCO_3$)	IN	mg/L	7	45.9	59.9	50.7	4.9
	WS	mg/L	60	<0.1	94.9	5.0	18.3
	RO	mg/L	60	<0.1	2.8	0.2	0.4

One-half of detection limit used for non-detect samples for calculations.

averaged 2.4 µg/L, indicating that leaching of manganese from the RO units, possibly the pre- and/or post-cartridge filters.

pH. pH values averaged 7.2 for raw water and 7.5 after softening at the R1 residence. pH values of the RO permeate water at the R1 residence were 6.5, 6.7, a probable outlier of 7.7, and 6.5 (Figure 4-13). The RO units reduced the alkalinity values from 294 mg/L (as $CaCO_3$) in raw water to 11.1 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 4-14, silica concentrations in raw water ranged between 60.1 and 95.9 mg/L (as SiO_2) and averaged 68.0 mg/L (as SiO_2). Silica concentrations after softening averaged 67.8 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 2.7 mg/L (as SiO_2), indicating effective removal by the RO units (Figure 4-14).

Fluoride and sulfate were consistently removed by the RO units (below 0.1 and 1.0 mg/L, respectively) throughout the first six months of operation. Total hardness in raw water ranged from 228 to 247 g/L (as $CaCO_3$), consisting of approximately 78% of calcium hardness and 12% of magnesium hardness. Total hardness was reduced to an average of 15.9 mg/L (as $CaCO_3$) by the water softeners and further reduced to an average of 0.5 mg/L by the RO units.

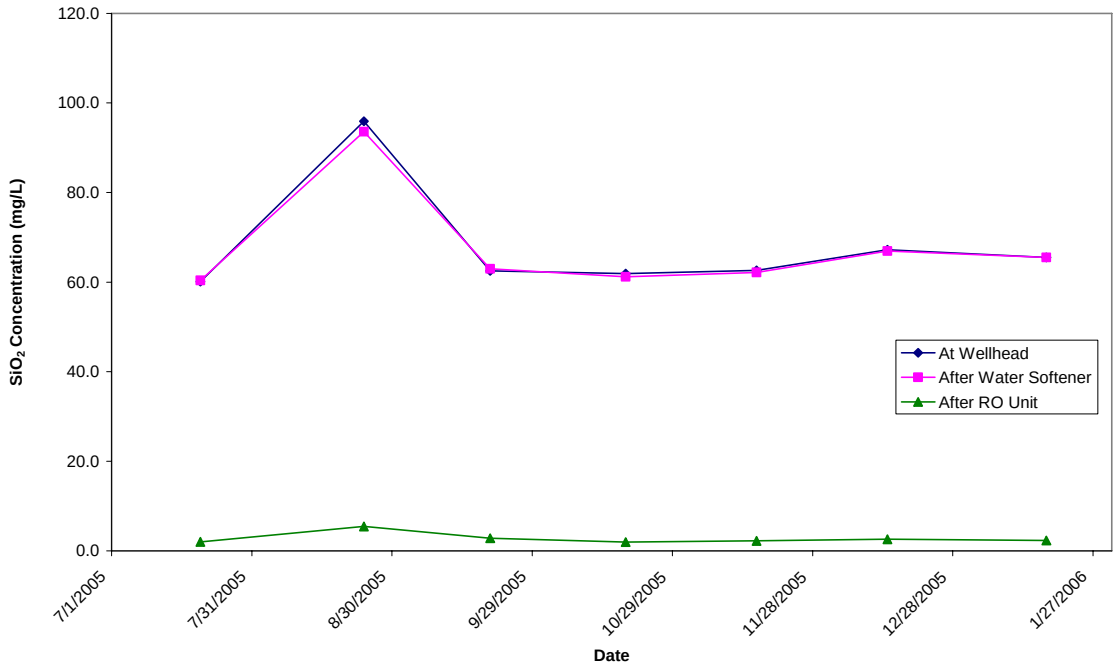

Figure 4-14. Total Silica Concentrations at Sunset Ranch Development

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.

Table 4-9. Reject Water Sampling Results

Sampling Event	Date	Sulfate	Nitrate (as N)	Turbidity	TDS	pH	Total Hardness (as $CaCO_3$)	Ca Hardness (as $CaCO_3$)	Mg Hardness (as $CaCO_3$)	As (total)	As (soluble)	As (particulate)	Fe (total)	Fe (soluble)	Mn (total)	Mn (soluble)	U (total)	U (soluble)	V (total)	V (soluble)
		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	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	<0.1	<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	<0.1	<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	4.8	<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	<0.1	<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	0.8	<25	<25	<0.1	<0.1	38.0	37.6	44.9	45.3

4.5.3 Mass Balance Calculations. The mass balance for total arsenic and nitrate across the RO unit was conducted based on the data collected from the R1 residence. The equation used for the calculations is 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.

The total arsenic and nitrate mass balance was calculated for each sampling date. During the first six months of system operation, the mass balance ranged from 66% to 114% for total arsenic and from 83% to 99% for nitrate. The total arsenic mass balance data are tabulated in Table 4-10 and graphically presented in Figure 4-15. The total nitrate mass balance data are tabulated in Table 4-11 and graphically presented in Figure 4-16.

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

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

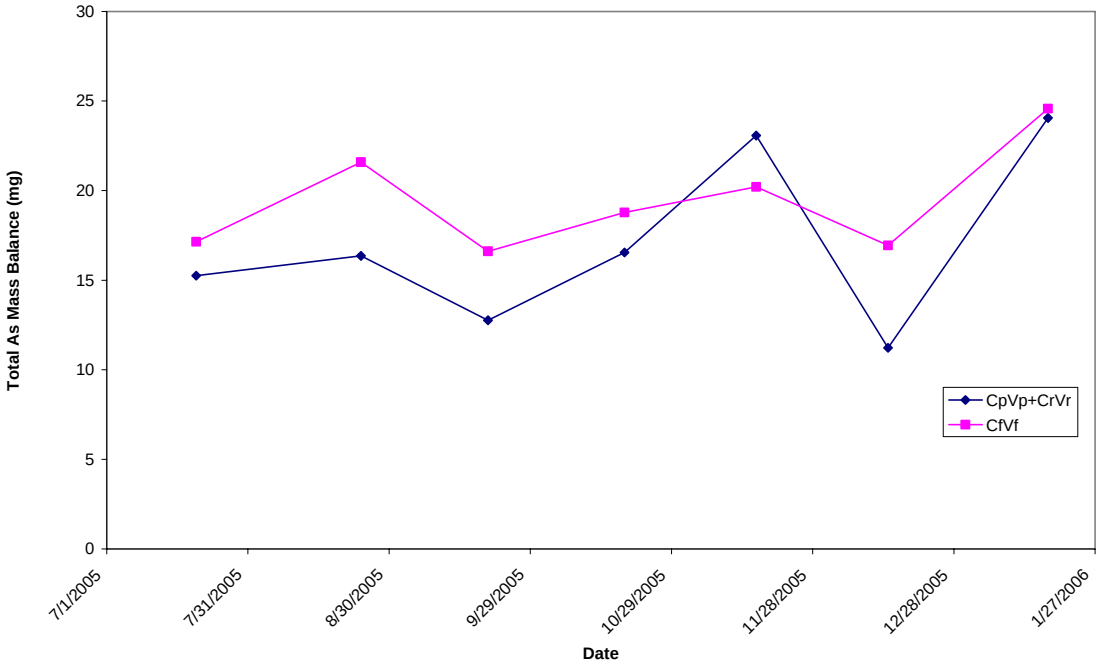

Figure 4-15. Monthly Total Arsenic Mass Balance at R1 Residence

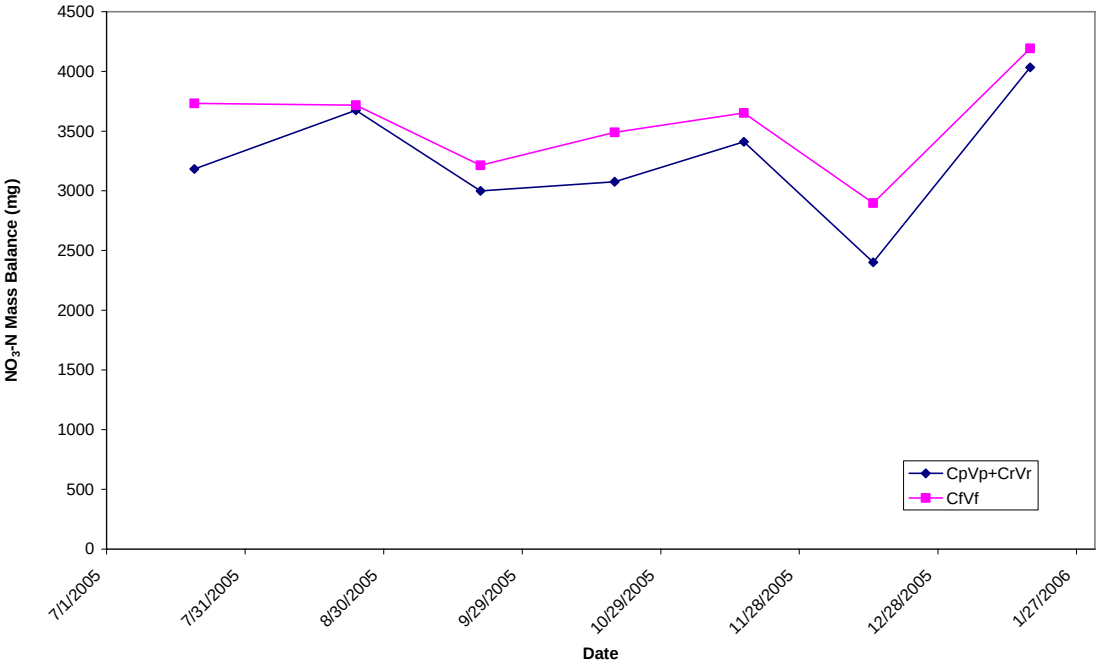

Figure 4-16. Monthly Nitrate (as N) Mass Balance at R1 Residence

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 Kinetico 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 taps 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	$517.50	–
Additional Sample Taps and Water Meter	1	–	$355	–
Freight	1	–	$2,125	–
Equipment Total	–	–	**$21,732.50**	**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	–	–	**$31,877.50**	**100%**

The installation cost included the cost for the material and labor to install nine RO units and six water softeners by Kinetico (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 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.

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 $57.50 for a six month delivery. Pre- and post-cartridge filter replacement at 500 gal of treated water was quoted at $86.50.

Only one homeowner used 500 gal of treated water during this six month reporting period. For this homeowner with the largest water usage, the six month O&M cost for salt usage ($57.50) and filter replacement ($86.50) was $144 or $24 per month. The systems were under warranty for one year; therefore, no maintenance cost was incurred during this six-month evaluation period.

Table 4-13. Summary of O&M Cost

Cost Category	Value	Assumption
Salt Replenishment for Water Softener		
Salt Cost ($)	$57.50	Vendor quote for 6-month salt delivery
Salt Consumption Rate (lbs/1,000 gal)	5.77	Vendor quote
Salt Unit Cost ($/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		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	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
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