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Environmental Technology Verification Report

Removal of Arsenic in Drinking Water

Basin Water
High Efficiency Ion Exchange Treatment System

Prepared by

NSF International

Under a Cooperative Agreement with
U.S. Environmental Protection Agency

THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**ION EXCHANGE USED IN DRINKING WATER TREATMENT SYSTEMS**
APPLICATION:	**REMOVAL OF ARSENIC**
TECHNOLOGY NAME:	**BASIN WATER HIGH EFFICIENCY ION EXCHANGE TREATMENT SYSTEM**
COMPANY:	**BASIN WATER**
ADDRESS:	**8731 PRESTIGE COURT** **RANCHO CUCAMONGA, CA 91730**
PHONE:	**(951) 233-9605**
FAX:	**(949) 631-8108**
WEB SITE:	**www.basinwater.com**
EMAIL:	**lwrowe@basinwater.com**

The U.S. Environmental Protection Agency (EPA) supports the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by accelerating the acceptance and use of improved and more cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the design, distribution, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations, stakeholder groups (consisting of buyers, vendor organizations, and permitters), and with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

NSF International (NSF) in cooperation with the EPA operates the Drinking Water Systems (DWS) Center, one of six technology areas under the ETV Program. The DWS Center recently evaluated the performance of an ion exchange (IX) system used in drinking water treatment applications. This verification statement provides a summary of the test results for the Basin Water High Efficiency Ion Exchange Treatment System (Basin Water System). MWH, an NSF-qualified field testing organization (FTO), performed the verification testing. The verification report contains a comprehensive description of the test.

ABSTRACT

Verification testing of the Basin Water System was conducted over a 54-day period between April 4, 2005, and May 28, 2005. The test was conducted at the Elsinore Valley Municipal Water District (EVMWD) Corydon Street Well in Lake Elsinore, California. The source water was a raw groundwater supply with chlorine added at 0.10-0.50 milligrams per liter (mg/L) as an oxidant to convert arsenite (As [III]) to arsenate (As [V]). Based on the manufacturer's recommendation, the system was operated during the Verification Test at 850 bed volumes before regeneration. The average total arsenic and vanadium (both naturally occurring) in the raw water were 15 micrograms per liter (µg/L) and 107 µg/L, respectively, during the Verification Test. The Basin Water System reduced the arsenic levels to below the detection limit (1.0 µg/L) in all 24-hour composite samples and all grab samples, with the exception of one grab sample with a level of 1.1 µg/L. The Basin Water System reduced the vanadium levels to below the detection limit (3.0 µg/L) in all 24-hour composite samples and all grab samples, with the exception of one grab sample with a vanadium level of 4.9 µg/L in the effluent water.

TECHNOLOGY DESCRIPTION

The following technology description was provided by the manufacturer and has not been verified.

The equipment tested in the ETV test was the Basin Water System. The system was a self contained, multi-bed, mobile unit. The Basin Water System utilized multiple IX vessels in a parallel mode of operation. The system contained two prefilters (5 micron, 30 inches in length) in parallel and six IX vessels. There were four vessels in service, at different stages of exhaustion, and two vessels out of service at any one time while the IX unit was in operation. The two vessels out of service were in the regeneration cycle with one vessel ready to return to service when the next vessel online was ready to go into regeneration cycle. The resin used in the vessels was a strong base anion (SBA) resin. Each vessel is 16 inches in diameter and contained 5 cubic feet (ft^3) of resin.

At all times the system was in operation, the Basin Water System utilized one of two treatment systems for the waste brine generated from the regeneration process: brine precipitation unit (BPU) and brine readsorption unit (BRA). The BPU utilized ferric chloride to coagulate the arsenic and vanadium and precipitate it out from the waste brine, while the BRA utilized an iron based adsorptive media to remove the arsenic and vanadium from the waste brine.

VERIFICATION TEST DESCRIPTION

Test Site

The test site selected for the verification testing of the Basin Water System was EVMWD's Corydon Street Well, located in Lake Elsinore, California. Drilled in 1983, the EVMWD's well off Corydon Street is one of many wells that supply potable water to consumers in a rural area of southern California.

The Corydon Street Well normally operates at 1.2-1.5 mg/L free chlorine, which could be potentially damaging to the IX resin. Therefore, a raw water line upstream of the well's chlorinate point was selected for the verification testing. Because As (III) is present in the water, low levels of chlorine (0.10-0.50 mg/L of total chlorine) were dosed between the raw water sampling location and the prefilters to the IX vessels to convert As (III) to As (V). This setup allowed the water entering the IX treatment system (influent water) to maintain low levels of the desired total chlorine residual. The feed water used during the verification testing had an average total chlorine residual of 0.30 mg/L.

Over the 54 days on-site at the Corydon Street Well, the system was in operation for 48 days: 29 days for Initial Plant Characterization, five days in operation during data review, and 14 days for the Verification

Test. There were three plant shutdowns (April 7, May 12, and May 14, 2005) accounting for the balance of the testing period. Each shutdown was associated with construction in the area and was not a direct result of the Basin Water System.

Methods and Procedures

Water quality was monitored from three water streams: raw water, chlorinated and filtered raw water (influent), and treated water (effluent). Measurements of free and total chlorine, pH, temperature, and conductivity were collected on-site through grab samples, using equipment set up inside the mobile Basin Water System at the EVMWD Corydon Street Well. MWH Laboratories in Monrovia, California, were also sent samples to analyze for the following: arsenic (total [24-hour composite and grab samples] and dissolved and As [III] grab samples); vanadium (24-hour composite and grab samples); and calcium, chloride, hardness, alkalinity, total dissolved solids (TDS), total suspended solids (TSS), manganese, iron, magnesium, dissolved silica, fluoride, sulfate, and nitrate (24-hour composite samples). Grab samples were also collected for N-nitrosodimethylamine (NDMA), as requested by the utility. Previous research suggests that in some IX resins, NDMA could form when a water plant uses chloramines. All laboratory samples were delivered the same day as collection in coolers filled with ice. They were analyzed using either *Standard Methods for the Examination of Water and Wastewater, 20th edition* or EPA-approved methods. Complete descriptions of the verification test, results, and quality assurance/quality control (QA/QC) procedures are included in the verification report.

VERIFICATION OF PERFORMANCE

System Operation

The Basin Water System used multiple IX vessels operating in parallel to remove arsenic and vanadium from the water. The IX resin beds were staggered such that all beds online were operated at different, but evenly spaced points on their respective breakthrough curves. When a vessel reached the selected absorption limit set point (the point at which the bed would no longer provide beneficial target ion removal), the bed was removed from service for regeneration. The IX resin was regenerated using a sodium chloride (brine) solution. Following regeneration, the IX resin was then rinsed using effluent water from the treatment process prior to returning to service, to maintain the desired number of beds in service. As part of the waste minimization features of the Basin Water System, cleaner portions of the rinse water were recovered to the salt tank to make up the next batch of brine for the next regeneration cycle. The entire regeneration, rinsing, and exhaustion process was automatically performed by the programmable logic controller (PLC). Regeneration of the IX vessels was performed while the Basin Water System was online and did not interrupt the production of treated water. Individual IX vessels were regenerated and rinsed while the remaining vessels were online producing treated water.

The computer automation of the exhaustion, regeneration, rinse, and waste treatment using both BPU and BRA cycles required minimal human attention, and therefore made the system easy to operate. Automated alarms (system pressure, raw water flow rate, brine flow rate, brine tank level, etc.) further enhanced the system to alert the operator of any problems or changes in operating conditions outside the system's set points, as determined by the manufacturer. However, not all alarms worked flawlessly. Occasionally alarms (such as low and high-level tank alerts) would go off, and the appropriate actions would not automatically occur. In addition, inline sensors (pH and conductivity) could not be removed for calibration without the treatment system being taken off-line.

When changes in onsite conditions triggered a system shutdown, the IX and waste treatment systems would automatically go through shutdown procedures and wait in standby mode until the system pressure and raw water flow rates resumed to the preset points. This automatic system start-up had the option for manual override, but due to the remote nature of the test site, the system was operated in automatic mode.

All alarm and operating conditions were logged by the PLC for the operator to review upon returning to the test site.

Water Quality Results

The raw water at the test site had average total arsenic and vanadium levels of 15 µg/L and 107 µg/L, respectively. From the statistical analysis of the daily, 24-hour composite data presented in the following table, the Basin Water System consistently removed the raw water arsenic and vanadium to non-detectable levels of <1.0 µg/L and <3.0 µg/L, respectively.

Table VS-1: 24-Hour Composite Raw, Influent, and Effluent Water Verification Test Total Arsenic and Vanadium (May 12 through May 28, 2005)

	Arsenic (µg/L)			Vanadium (µg/L)		
	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water
Average	15	15	<1.0	107	105	<3.0
Minimum	14	14	<1.0	99	97	<3.0
Maximum	16	16	<1.0	110	110	<3.0
Number of Samples	13	14	14	13	14	14
Standard Deviation	0.49	0.62	NC	4.9	5.6	NC
95% Confidence Interval	(15-15)	(15-15)	NC	(106-108)	(104-106)	NC

NC = Not Calculated.

In addition to removing arsenic and vanadium from the raw water, the BasinWater System had an impact on other water quality parameters, as expected for an IX system. On average as compared to the raw water, the Basin Water System removed 18% alkalinity and 47% nitrate, and removed sulfate to below the detection limit. The average chloride level increased 67%. All other parameters had little to no change between the raw water and effluent water quality. TSS, iron, and magnesium each had non-detectable levels in the raw water, influent water, and effluent water throughout the verification testing.

Consumables and Waste Generation

The analyses of the solid waste generated from both the BPU and the BRA brine treatment systems are presented in the verification report. During the Initial Plant Characterization No. 1 when the bed volumes were set at 1,100, the percentage of waste brine was 0.06-0.08% of the treated water flow. When the bed volumes were reduced to 850 for the Verification Test, the percentage of waste brine was 0.08-0.09% of the treated water flow.

The waste generated from the BPU was found to be classified as nonhazardous based on the results of the California waste analysis methods of Total Threshold Limit Concentration (TTLC), Soluble Threshold Limit Concentration (STLC), and the federal waste analysis method of Toxicity Characteristic Leachate Procedure (TCLP). The total mass of arsenic in the waste was 233 milligrams per kilogram (mg/kg) of waste generated, with a TTLC limit of 500 mg/kg for hazardous waste. The results of the TCLP were <1.0 mg/L, with a limit of 5.0 mg/L. The total arsenic leachate from the STLC analysis was 2.8 mg/L, with a limit of 5.0 mg/L. Therefore, based on both the state and federal waste analyses, the waste generated from the BPU would be classified as nonhazardous (based on arsenic residuals).

The waste generated from the BRA was also found to be nonhazardous, with a TTLC of <3 mg/kg, a TCLP of <0.1 mg/L, and a STLC of 2.8 mg/L for total arsenic. Additional BPU and BRA metals analyses are provided in the verification report.

Quality Assurance/Quality Control

NSF provided technical and quality assurance oversight of the verification testing as described in the verification report, including an audit of nearly 100% of the data. NSF personnel also conducted a technical systems audit during testing to ensure the testing was in compliance with the test plan. A complete description of the QA/QC procedures is provided in the verification report.

Original Signed by *Sally Gutierrez*	*10/3/05*	*Original Signed by* *Robert Ferguson*	*10/5/05*
Sally Gutierrez	Date	Robert Ferguson	Date

Sally Gutierrez
Director
National Risk Management Research Laboratory
Office of Research and Development
United States Environmental Protection Agency

Robert Ferguson
Vice President
Water Systems
NSF International

NOTICE: Verifications are based on an evaluation of technology performance under specific, predetermined criteria and the appropriate quality assurance procedures. EPA and NSF make no expressed or implied warranties as to the performance of the technology and do not certify that a technology will always operate as verified. The end-user is solely responsible for complying with any and all applicable federal, state, and local requirements. Mention of corporate names, trade names, or commercial products does not constitute endorsement or recommendation for use of specific products. This report is not an NSF Certification of the specific product mentioned herein.

Availability of Supporting Documents

Copies of the *ETV Protocol for Equipment Verification Testing for Arsenic Removal* dated September 2003, the *ETV Protocol for Equipment Verification Testing for Removal of Inorganic Constituents* dated April 2002, the verification statement, and the verification report (NSF Report # 05/21/EPADWCTR) are available from the following sources:
(NOTE: Appendices are not included in the verification report. Appendices are available from NSF upon request.)

1. ETV Drinking Water Systems Center Manager (order hard copy)
   NSF International
   P.O. Box 130140
   Ann Arbor, Michigan 48113-0140
2. NSF web site: http://www.nsf.org/etv (electronic copy)
3. EPA web site: http://www.epa.gov/etv (electronic copy)

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Basin Water
High Efficiency Ion Exchange Treatment System

Prepared for:

NSF International
Ann Arbor, Michigan 48105

Prepared by:

MWH
Los Angeles, California 91017

Under a cooperative agreement with the U.S. Environmental Protection Agency

Jeffrey Q. Adams, Project Officer
National Risk Management Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

Notice

The U.S. Environmental Protection Agency (EPA) through its Office of Research and Development has financially supported and collaborated with NSF International (NSF) under Cooperative Agreement No. R-82833301. This verification effort was supported by the Drinking Water Systems (DWS) Center, operating under the Environmental Technology Verification (ETV) Program. This document has been peer reviewed, reviewed by NSF and EPA, and recommended for public release.

Foreword

The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

Sally Gutierrez, Director
National Risk Management Research Laboratory

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Abbreviations and Acronyms

ASTM	American Society of Testing and Materials
As (III)	arsenite
As (V)	arsenate
BPU	brine processing unit
BRA	brine readsorption unit
BV	bed volume
°C	degree Celsius
Cl-As (V)	chloride-arsenate
°F	degree Fahrenheit
d	day(s)
DQO	data quality objective
DRC	dynamic reaction cell
DWS	Drinking Water Systems
EBCT	empty bed contact time
EDTA	ethylenediaminetetraacetic acid
EPA	Environmental Protection Agency
ETV	Environmental Technology Verification
EVMWD	Elsinore Valley Municipal Water District
ft^3	cubic feet
FTO	field testing organization
g	gram
gpm	gallon per minute
H	hydrogen ion
HMI	human to machine interface
hr	hour
ICP/MS	Inductively Coupled Plasma Mass Spectrometry
IX	ion exchange
lb	pound
L	liter
LCS	laboratory control sample
LFM	laboratory fortified matrix
lpm	liter per minute
LSI	Langelier Saturation Index
M	molar
MB	method blank
MCL	maximum contaminant limit
Meq	milliequivalent
min	minute
mL	milliliter
mg	milligram
MRL	minimum reporting limit
NDMA	N-nitrosodimethylamine
NaCl	sodium chloride (salt)
NaOH	sodium hydroxide

NELAC	National Environmental Laboratory Accreditation Conference
NIST	National Institute of Standards and Technology
NSF	NSF International (formerly known as the National Sanitation Foundation)
NSS	nitrate over sulfate selective resin
O&M	operation and maintenance
PE	performance evaluation
PLC	Programmable Logic Controller
ppd	pounds per day
psi	pounds per square inch
psig	pound per square inch gauge
PSTP	Product Specific Test Plan
PT	proficiency testing
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
RCl	chloride-form strong base anion resin
RCRA	Resource Conservation and Recovery Act
SBA	strong base anion
SCADA	Supervisory Control and Data Acquisition
SDWA	Safe Drinking Water Act
SFR	service flow rate
SM	Standard Methods
STLC	soluble threshold limited concentration
T	temperature
TCLP	Toxicity Characteristic Leachate Procedure
TDS	total dissolved solids
TSS	total suspended solids
TTLC	Total Threshold Limit Concentration
μg	microgram

ACKNOWLEDGMENTS

The FTO, MWH, was responsible for all elements in the testing sequence, including collection of samples, calibration and verification of instruments, data collection and analysis, data management, data interpretation, and the preparation of this report.

MWH
626 Wilshire Boulevard, Suite 850
Los Angeles, California 91017
Contact Person: Kristie Witter

The laboratory selected for analytical work for this study was:

MWH Laboratories
750 Royal Oaks Lane, Suite 100
Monrovia, California 91016
Contact Person: Andrew Eaton, Ph.D.

The manufacturer of the equipment was:

Basin Water
5200 River Avenue
Newport Beach, California 92663
Contact Person: Larry Rowe

MWH wishes to thank NSF International, especially Mr. Bruce Bartley, Project Manager, and Ms. Kristie Wilhelm and Ms. Angela Beach, Project Coordinators, for providing guidance and program management. MWH also wishes to thank the Elsinore Valley Municipal Water District for providing the site for verification testing including providing assistance in connecting to the water system and all necessary utilities (water, sewer, and electrical).

NSF wishes to thank Mr. Dale Scherger, Environmental Consultant, Scherger Associates, for providing technical guidance.

Finally, NSF and MWH thank Basin Water for their technical support and for supplying the equipment necessary for the ETV.

Chapter 1
Introduction

1.1 ETV Purpose and Program Operation

The U.S. Environmental Protection Agency (EPA) has created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by accelerating the acceptance and use of improved and more cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the design, distribution, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations; with stakeholder groups consisting of buyers, vendor organizations, and permitters; and with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans responsive to the needs of stakeholders, conducting field demonstrations, collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

The EPA has partnered with NSF International (NSF) under the ETV Drinking Water Systems (DWS) Center to verify the performance of small drinking water systems that serve small communities. A goal of verification testing is to enhance and facilitate the acceptance of small drinking water treatment equipment by state drinking water regulatory officials and consulting engineers, while reducing the need for testing of equipment at each location where the equipment's use is contemplated. NSF meets this goal by working with manufacturers and NSF-qualified Field Testing Organizations (FTOs) to conduct verification testing under the approved protocols. It is important to note that verification of the equipment does not mean the equipment is "certified" by NSF or "accepted" by EPA. Rather, it recognizes that the performance of the equipment has been determined and verified by these organizations for those conditions tested by the FTO.

The DWS Center evaluated the performance of the Basin Water High Efficiency Ion Exchange Treatment System (Basin Water System), which is used in drinking water treatment system applications. The verification test evaluated the ability of the ion exchange (IX) system to remove arsenic from drinking water under specific feed water quality and conditions. This document provides the verification test results for the Basin Water System.

1.2 Testing Participants and Responsibilities

The ETV testing of the Basin Water System was a cooperative effort between the following participants:

NSF International
MWH

Basin Water
MWH Laboratories
Elsinore Valley Municipal Water District (EVMWD)
U.S. Environmental Protection Agency

The following is a brief description of each of the ETV participants and their roles and responsibilities.

1.2.1 NSF International

NSF is an independent, not-for-profit testing and certification organization dedicated to public health and safety and to the protection of the environment. Founded in 1946 and located in Ann Arbor, Michigan, NSF has been instrumental in the development of consensus standards for the protection of public health and the environment. NSF also provides testing and certification services to ensure products bearing the NSF Name, Logo and/or Mark meet those standards. The EPA partnered with NSF to verify the performance of drinking water treatment systems through the EPA's ETV Program.

NSF provided technical oversight of the verification testing. An audit of the field analytical data gathering and recording procedures was conducted. NSF also provided review of the Product Specific Test Plan (PSTP) as well as this report.

Contact Information:
NSF International
789 N. Dixboro Road
Ann Arbor, Michigan 48105
Phone: (734) 769-8010
Fax: (734) 769-0109
Contact: Bruce Bartley, Project Manager
Email: bartley@nsf.org

1.2.2 Field Testing Organization

MWH, an environmental engineering consulting firm, conducted the verification testing of the Basin Water System. MWH is an NSF-qualified FTO for the ETV DWS Center.

The FTO was responsible for conducting the verification testing for 54 calendar days. The FTO provided all needed logistical support, established a communications network, and scheduled and coordinated activities of all participants. The FTO prepared the PSTP; oversaw the operation of equipment; managed, evaluated, interpreted and reported on the data generated by the field operations; and evaluated and reported on the performance of the technology.

FTO employees conducted the on-site analyses and data recording during the testing. Oversight of the daily tests was provided by the FTO's project engineer and project manager.

Contact Information:
MWH
626 Wilshire Boulevard, Suite 850
Los Angeles, California 91017
Phone: (213) 316-7013
Fax: (213) 316-7048
Contact Person: Kristie Witter
Email: Kristie.Witter@MWHGlobal.com

1.2.3 Manufacturer

The treatment system was manufactured by Basin Water, a water treatment equipment manufacturer and supplier. The manufacturer was responsible for supplying a field-ready system equipped with all necessary components, including treatment equipment, instrumentation and controls, and an operations and maintenance (O&M) manual. The manufacturer was responsible for providing logistical and technical support, as needed, as well as providing technical assistance to the FTO during operation and monitoring of the equipment undergoing field verification testing.

Contact Information:
Basin Water
8731 Prestige Court
Rancho Cucamonga, California 91730
Phone: (909) 233-9605
Fax: (909) 631-8108
Contact Person: Larry Rowe, Vice President for Governmental Affairs
Email: lrowe@basinwater.com

1.2.4 Analytical Laboratory

The specific responsibilities of the water quality analytical staff, MWH Laboratories, were to provide the following: all off-site water quality analyses prescribed in the PSTP according to the Quality Assurance/Quality Control (QA/QC) and the protocols contained therein, reports including analytical results to the data manager, and detailed information on the analytical procedures implemented.

Contact Information:
MWH Laboratories
750 Royal Oaks, Suite 100
Monrovia, California 91016
Phone: (626) 386-1100
Fax: (626) 386-1101
Contact Person: Andrew Eaton, Ph.D.
Email: Andrew.Eaton@MWHGlobal.com

1.2.5 Elsinore Valley Water District

EVMWD supported the ETV by providing access to the Corydon Street Well, raw water, treated water blow-off structure, and electrical source; modification to the wellhead to connect to the well; and support throughout the project.

1.2.6 U.S. Environmental Protection Agency

The EPA, through its Office of Research and Development, has financially supported and collaborated with NSF under Cooperative Agreement No. R-82833301. This verification effort was supported by the DWS Center operating under the ETV Program. This document has been peer reviewed, reviewed by NSF and EPA, and recommended for public release.

1.3 Verification Testing Site

The test site selected for the verification testing of the Basin Water System was EVMWD's Corydon Street Well, located 50 feet south of Corydon and 200 feet west of Mission Trails in Lake Elsinore, California. Drilled in 1983, the EVMWD's well off Corydon Street is one of many wells that supply potable water to consumers in a rural area of southern California. The following sections provide additional information on the test site, including source water characteristics and discharge method.

Photograph 1: Test site at the Corydon Street Well.

1.3.1 Source Water

The Corydon Street Well normally operates at 1.2-1.5 mg/L free chlorine, which could be potentially damaging to the IX resin. Therefore, a raw water line upstream of the well's chlorinate point was selected for the verification testing. However, As (III) is present in the water, and therefore, a low level of chlorine (0.10-0.50 mg/L of total chlorine) was dosed between the raw water sampling location and the prefilters to the IX vessels to convert As (III) to As (V). This setup allowed the water entering the system (influent water) to maintain low levels of the desired total chlorine residual. The feed water used during the verification testing had an average total chlorine residual of 0.30 mg/L. The chlorine source was dosed by an LMI Milton Roy PX pump. A summary of the historical water quality at the Corydon Street Well is presented in Table 1-1.

Table 1-1. Historical Water Quality Data for Corydon Street Well (2004)

			Collection Date							
Parameters	Method	Units	3/25/04	4/22/04	5/20/04	6/17/04	7/22/04	Min[1]	Max[1]	Ave[1]
Conductivity	Lab Meter	µmhos/cm	506	475	478	479	481	475	506	484
pH	SM 4500H+ B	pH Units	9.1	9.1	9.1	9.1	9.2	9.1	9.2	9.1
Alkalinity	SM 2320B	mg/L	91.0	89.2	86.1	84.6	87.6	84.6	91.0	87.7
Chloride	EPA 300.0	mg/L	77	72	75	72	74	72	77	74
Fluoride	SM 4500F C	mg/L	0.40	0.41	0.41	0.42	0.41	0.40	0.42	0.41
Nitrate	EPA 300.0	mg/L	6.3	1.4	1.4	1.4	1.4	1.4	6.3	2.4
Sulfate	EPA 300.0	mg/L	38	34	36	35	36	34	38	36
Calcium	EPA 200.7	mg/L	6.1	6.3	6.1	6.1	6.1	6.1	6.3	6.1
Hardness	SM 3120B	mg/L	19.0	19.4	18.8	18.8	18.6	18.6	19.4	18.9
Magnesium	EPA 200.7	mg/L	<0.10	0.89	0.87	0.86	0.83	<0.10	0.89	0.71
LSI	SM 2330B	None	0.36	0.48	0.45	0.44	0.55	0.36	0.55	0.46
Total As[2]	EPA 200.8	µg/L	19	13	20	16	15	13	20	17
As (III)	EPA 200.8	µg/L	16	19	16	15	12.5	12.5	19	16
As (V)	EPA 200.8	µg/L	2.5	1.0	3.8	2.8	2.2	1.0	3.8	2.5
Iron	EPA 200.7	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Manganese	EPA 200.8	mg/L	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Silica	EPA 200.7	mg/L	12	12	12	12	13	12	13	12
Vanadium	EPA 200.8	µg/L	93	110	98	120	89	89	120	102
TDS	SM 2540C	mg/L	300	290	300	280	290	280	300	292
Total Suspended Solids (TSS)	EPA 160.2	mg/L	<10	<10	<10	<10	<10	<10	<10	<10

[1] Min = Minimum value; Max = Maximum value; Ave = Average value.

1.3.2 Raw Water Supply

The raw water was delivered to the site from the discharge manifold of the Corydon Street Well at an available pressure of approximately 65 pounds per square inch (psi). The water was pumped from the well into Loop 1434 pressure zone. Previous testing at the site has shown constant pressure of approximately 65 psi. No booster pumps were required for the verification testing.

Due to construction in the area of the well site, EVMWD experienced power failures at the site that caused the well to shutdown. When this occured, a run-signal from the well to the Basin Water System enabled the Basin Water System to start-up automatically once the well was put back into service.

1.3.3 Treated Water (Effluent) Discharge

All treated water was sent to a blow-off drain for disposal. The treated water produced from the system was not anticipated to adversely affect the environment. The blow-off drain had sufficient capacity to accept the treated water flow rate (approximately 37.5 gallons per minute [gpm]) for the duration of the study. All residuals generated from the study were stored on-site until analysis could confirm proper disposal method. Basin Water disposed of the treated waste brine liquid waste through Remedy Environmental Services in Anaheim, California. Basin Water disposed of the solid waste generated during the verification testing through Clean Harbors, a certified solids waste disposal company.

1.3.4 Discharge Permits

No discharge permits were necessary for this verification study.

Chapter 2
Equipment Description and Operating Processes

2.1 Equipment Description

The equipment tested in the ETV test was the Basin Water System. The system was a self-contained, multi-bed, mobile unit that utilized multiple IX vessels in a parallel mode of operation, as shown in Photograph 2. The system contained two prefilters (5 micron, 30 inches in length) in parallel and ten IX vessels. At any given time while the IX unit was in operation, there were four vessels in service at different stages of exhaustion and two vessels in standby, either in regeneration or recently regenerated and waiting to go back into service. The manufacturer elected not to use four vessels during verification testing. The resin used in the vessels was a strong base anion (SBA) resin. Each vessel was 16 inches in diameter and housed 5 cubic feet (ft^3) of resin.

Photograph 2: Interior of Basin Water high efficiency ion exchange system.

In the adsorption phase, the raw water entered the prefilters, then the IX beds, and was discharged as treated water (see Figure 2-1). When a vessel reached the selected absorption limit set point (the manufacturer's estimate of the point at which the bed would not longer provide beneficial target ion removal), the bed was taken out of service for regeneration. After a regeneration cycle, the brine was treated in either the brine processing unit (BPU) using ferric chloride precipitation or the brine readsorption unit (BRA), an iron based adsorptive media, which is discussed in Section 2.3.

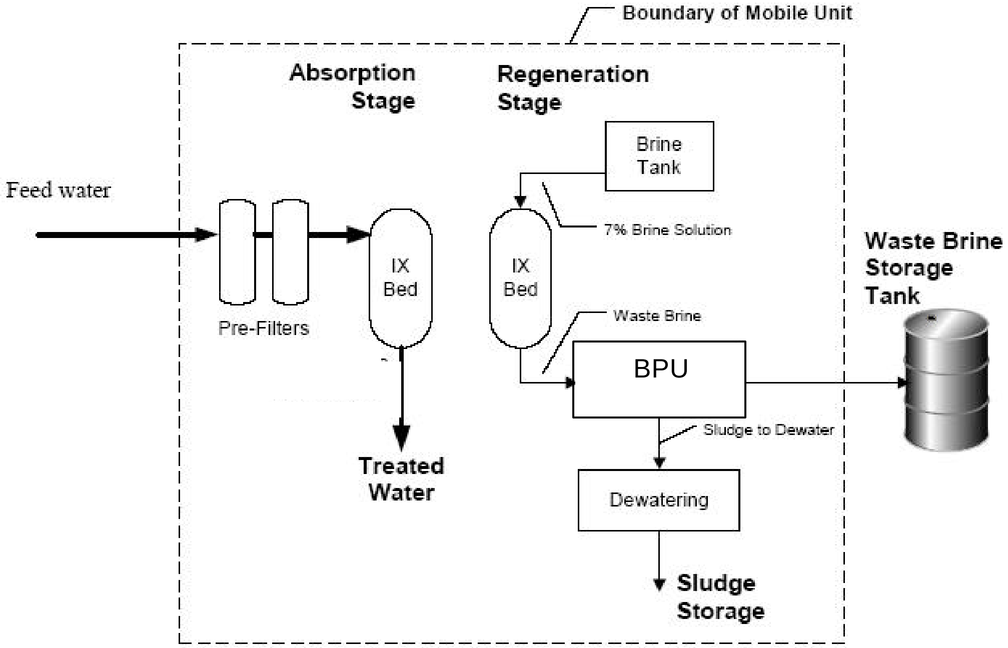


Figure 2-1: Basin Water High Efficiency Ion Exchange Treatment System detailed process flow.

2.2 Engineering and Scientific Concepts

When a specific ion comes in contact with an IX resin, a simple exchange takes place between the target ion (in this case arsenic and vanadium) and a chloride ion on the resin. This is called the exhaustion cycle of the IX process. In addition to being easily attracted to resin sites, arsenic and vanadium can easily be removed from the resin with a strong salt solution (regeneration cycle).

This operation (exhaustion and regeneration cycles) implies the production of a sludge and a waste brine stream. After the regeneration step, the waste brine stream from the Basin Water System flowed immediately into either the BPU or the BRA, where it was treated with either a ferric chloride solution or an iron-based adsorptive media. After treatment of the waste brine, the sludge was dewatered, and the nonhazardous waste brine was stored until hauled off site for disposal. The precipitation process reduced the arsenic level in the brine to a level where it was characterized as nonhazardous (<5 mg/L total arsenic). This allowed the brine to be disposed of at a standard brine-handling facility, such as Remedy Environmental Service in Anaheim. For every 1,000 bed volumes (BV) of water processed, only 1.3 BV of waste brine was produced by the Basin Water System. It should be noted that the volume of waste brine produced is manufacturer and site specific.

With the Basin Water System, the online vessels operated at staggered points in the exhaustion/regeneration cycle. Thus, if four vessels were online, the first vessel would be at 0-10% of the exhaustion cycle, while vessels two, three, and four would be at 20-30%, 40-50% and

60-70%, respectively. The dampening, or dilution, effect created by staggered operation allowed for more consistent (or steady-state) effluent water quality.

Total chlorine may be detrimental to the IX resin, but low doses (0.10-0.50 mg/L of total chlorine) are considered safe (i.e., not believed to cause long-term damage). Low doses of chlorine were required at this site to oxidize arsenite (As [III]) to arsenate (As [V]); otherwise the arsenic left in the arsenic (III) state would pass through the IX resin beds to the effluent water.

Oxidized and filtered raw water was passed through a bed of chloride-form SBA resin (RCl), and the chloride-arsenate (Cl^--As [V]) IX reaction, Eq. (2.1), yielded resin in the As (V) form (R_2HAsO_4). When the column capacity for arsenic was exhausted, the arsenic "broke through" into the effluent water. The reaction was easily reversed, and regeneration, as shown in Eq. (2.2), returned the resin to the chloride form, ready for another exhaustion cycle:

$$2\ RCl + HAsO_24^- = R_2HAsO_4 + 2\ Cl^- \qquad (2.1)$$

$$R_2HAsO^4 + 2NaCl = 2\ RCl + Na_2HAsO_4 \qquad (2.2)$$

Although the Cl^--As (V) IX reaction appears simple, several issues must be addressed when implementing the process for drinking water treatment. Among the important factors that would be expected to influence verification testing were:

(1) Effect of competing ions such as sulfate and bicarbonate,
(2) Multiple contaminants such as arsenic and vanadium,
(3) Low pH of the column effluent early in the run, and
(4) Waste brine reuse and treatment.

As mentioned, preoxidation to convert As (III) to As (V) was necessary (Frank and Clifford, 1986), but pH adjustment was not necessary because the chloride-arsenate exchange reaction took place readily in the ambient pH range of the Corydon Street Well.

2.2.1 Effect of Sulfate on Arsenic Removal

Because arsenic and vanadium are trace species, their concentrations do not greatly influence the run length to arsenic breakthrough. However, because sulfate, a common ion, is preferred over arsenic, vanadium, nitrate, chloride, bicarbonate, and most other common anions, its concentration largely determines the run length to arsenic breakthrough. For example, in a low-sulfate (5 mg/L) water in McFarland, California, arsenic run length exceeded 3,500 BV. In contrast, the arsenic run length of a McFarland, California, water spiked with 220 mg/L sulfate was only 250 BV. (These data are provided for informational purposes only and were not verified.) Thus, in testing the Basin Water System for arsenic removal, considerable attention was paid to the background sulfate concentration at the Corydon Street Well, which measured on average 41 mg/L during verification testing.

Not only does increasing sulfate concentration lead to shorter arsenic and vanadium removal runs, it can lead to chromatographic peaking or "dumping" of arsenic and/or vanadium. For example, arsenic process effluent concentration peaks in the range of 1.3-6 times the raw water arsenic concentration would not be unusual following arsenic breakthrough. These peaks were avoided by stopping a run at or before arsenic breakthrough for the Basin Water System. Another way of coping with the potential peaking of arsenic or any other contaminant less preferred than sulfate was to exhaust several columns in parallel and in different stages of exhaustion (as with the Basin Water System). Thus, if one column ran beyond breakthrough, its effluent peak would be diluted by the effluents from the other columns.

There are two types of IX systems that exhaust multiple columns in parallel: fixed bed and rotating carousel. The Basin Water System was a fixed bed design that did not rotate. With the carousel design, IX beds are mounted on a slowly rotating carousel; the physical rotation of the carousel moves the beds slowly through the required sequence of operations, which include adsorption, regeneration and displacement.

2.2.2 Effect of Multiple Contaminants

Sub-maximum contaminant limit (MCL) levels (<10 mg nitrate as N) of nitrate were present along with arsenic or vanadium as a drinking water contaminant. For the study, the IX system removed nitrate, arsenic, and vanadium. However, nitrate will generally break through before arsenic, vanadium, and even sulfate. Additionally, a nitrate peak will appear in the effluent of the column if it is allowed to run to arsenic and/or vanadium breakthrough. To avoid the nitrate peak in the event it would exceed the nitrate MCL, the column may be stopped at a design set point for nitrate rather than arsenic breakthrough. This will lead to shorter run lengths, but will avoid exceeding the nitrate MCL even for a short time. Another approach to avoiding the nitrate peak is to exhaust multiple (fixed or moving) beds in parallel. Even if one of the beds is subject to a nitrate peak, effluents from the other beds will dilute and smooth out the peak. The Basin Water System did not experience nitrate peaking during the verification testing, due to low levels of nitrate at the verification site (between 6-16 mg/L) and the use of multiple beds in staggered-parallel operation.

2.2.3 Low Column Effluent pH in the Early Stages of Exhaustion

When an RCl is used to treat natural water, as in the arsenic and vanadium IX process, the column effluent pH during the first 50-300 BV can be significantly reduced compared with the influent pH. For example, column effluent pH values as low as 5.0 can be observed (Clifford, 1990). The pH is reduced by the conversion of bicarbonate to carbonate within the resin (Horng and Clifford, 1997). This conversion occurs with the resulting expulsion of a proton (hydrogen ion, [H^+ ion]), which increases the H^+ ion concentration and lowers the pH. The bicarbonate to carbonate reaction occurs because all standard SBA resins prefer divalent ions (e.g., carbonate) to monovalent (such as bicarbonate) at the typical total dissolved solid (TDS) levels found in drinking water supplies. An exception to this preference for divalent ions occurs with nitrate-selective, or nitrate over sulfate selective (NSS) resins, which are designed to prefer monovalent nitrate to divalent sulfate. The NSS resins do not exhibit the pH-lowering effect.

The extent of the pH lowering depends primarily on the characteristics of the resin and the bicarbonate concentration in the raw water. Because seriously acidic pH values must be avoided when delivering treated water into a distribution system, the pH of the IX system during verification testing for arsenic and vanadium removal was measured and recorded.

As in the case with potential arsenic, vanadium and nitrate peaking, the low pH values observed during the early stages of a single column anion exchanger run can be avoided by exhausting multiple columns in parallel. This way, the low-pH column effluent from one of the columns was blended with the other column effluents to produce a neutral pH water. This was the configuration of the Basin Water System.

2.2.4 Spent Brine Reuse and Treatment

Spent arsenic-contaminated IX brine can be directly reused for regeneration of the spent resin (Clifford and Ghurye, 1998). Brine reuse can substantially cut down on the volume of brine discharged and the salt (NaCl) consumption by the process. The Basin Water System reduced the volume of waste brine through a continuous regeneration process. Brine was passed over one exhausted IX bed at a time until the brine reached a theoretical exchange capacity. The spent brine was then treated prior to disposal.

2.3 Description of the Unit Processes

The process flow of the Basin Water System is represented in Figure 2-2. Raw water was pumped into the Basin Water System utilizing the available pressure from the well pump. The raw water was chlorinated and filtered prior to entering the IX columns. Chlorination was used because As (III) was present in the raw water. Filters were recommended for this (and most) sites to remove sand or other solids from the raw water prior to entering the IX columns.

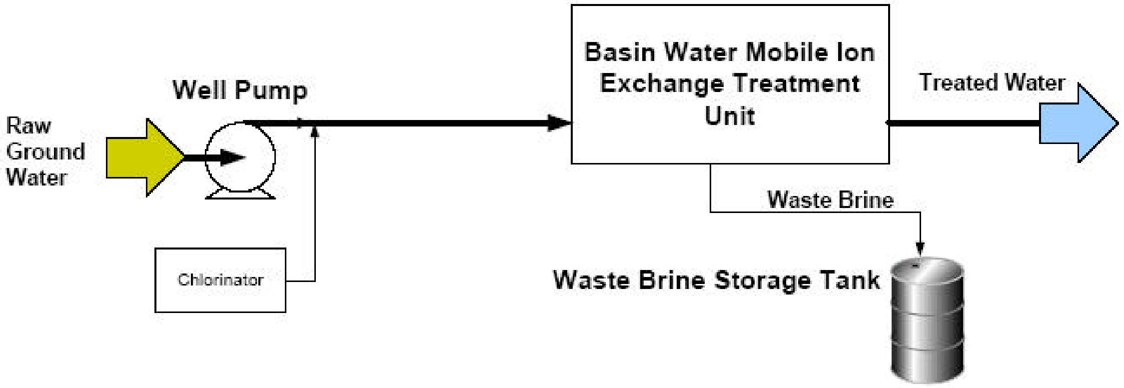


Figure 2-2: Simplified Basin Water High Efficiency Ion Exchange Treatment System process flow.

The raw water was chlorinated to a level of 0.10-0.50 mg/L total chlorine using a 0.5% sodium hypochlorite solution. The chlorine was fed through a 2 gallon per hour Milton Roy (LMI series AA) pump with adjustable stroke and frequency to ensure the influent water was within the desired design criteria of 0.10-0.50 mg/L of total chlorine. Dilution of the chlorine solution was made on-site using distilled water. The dilution ratios were recorded in the on-site logbook.

The Basin Water System used multiple IX vessels operating in parallel to remove arsenic and vanadium from the water. The IX resin beds were staggered such that all beds online were operated at different, but evenly spaced points on their respective breakthrough curves. When a vessel reached the selected absorption limit set point, defined for this system as a specific number of bed volumes processed, the bed was removed from service for regeneration. The manufacturer specified the number of bed volumes that triggered regeneration based on treated water results from the start-up and shakedown period. The IX resin was regenerated using a sodium chloride solution. Following regeneration, the resin was rinsed using effluent water from the treatment process prior to returning the bed to service. As part of the waste minimization features of the Basin Water System, cleaner portions of the rinse water were recovered to the salt tank to reduce the volume of liquid waste generated.

The entire regeneration, rinsing, and exhaustion process was automatically performed by the programmable logic controller (PLC). Individual IX vessels of the Basin Water System were regenerated and rinsed while the remaining vessels were online producing treated water. Four vessels were always online, while the other two were on standby following regeneration.

The waste brine produced by the regeneration and rinse cycles was sent to the brine treatment unit, which had two methods for treating the waste brine: the BRA, which used adsorption onto iron based media, or the BPU, which used ferric chloride precipitation. Both the adsorptive media method and the ferric chloride precipitation method of brine treatment were evaluated for removal efficiency of metals from the waste brine. The two brine treatment processes were evaluated independently (i.e., not a comparison evaluation) for effectiveness at reducing arsenic levels to below hazardous levels (i.e., less than 5.0 mg/L) in the liquid waste. Both the liquid and solid waste generated were analyzed upon completion of the verification testing for those parameters found in Table 3-7 (discussed in further detail in Chapter 3). The brine treatment method was deemed effective if successful in reducing the liquid waste to below hazardous levels for those parameters listed in Table 3-7. The on-site field engineer selected which brine treatment unit was in operation at any specific time.

The BRA used BW-33-60, an iron oxide absorptive media. This system utilized a 120-gallon batch treatment system with timed mixing of the iron oxide media with the waste liquid brine. Upon completion of the timed mixing set, the BRA system allowed the iron oxide adsorptive media to settle, and the treated waste liquid brine was decanted off and sent to a liquid waste storage tank. The media was characterized upon completion of the ETV.

The BPU system was an iron co-precipitation process. This process treated 240 gallons per batch using sulfuric acid (93% solution), caustic soda (50% solution), and ferric chloride (39.4% solution).

The raw water (pre-chlorinated water) was sampled outside of the testing unit by the raw water intake. The influent (chlorinated raw water) sample line was located inside the Basin Water trailer. There were two effluent sample lines. The effluent sample line inside the trailer was used for the 24-hour composite samples. The effluent sample line outside the trailer by the effluent blow off drain was used for grab samples. All sample lines were 1/8-inch flexible plastic. These lines were not standard for the Basin Water System, but were installed as part of the verification testing. The sample lines were allowed to purge (run) for one minute prior to collecting each sample.

The brine was sampled from the salt saturator, shown with the top removed in Photograph 3. Samples were collected once per week (two samples total) during the verification testing for TDS, chloride, sodium, and conductivity to calculate the brine concentration.

Photograph 3: Brine saturator.

The Basin Water System had a computerized data management system, as shown in Photograph 4. The following items are logged through the data management system: pressure (influent and effluent water, and regeneration cycle), pH (influent and effluent water), process flow, and conductivity (influent and effluent water).

Photograph 4: Data computer and control system.

The influent flow meter and the influent and effluent inline pressure, pH, and conductivity meters are shown in Photograph 5.

Photograph 5: Inline pressure, flow, pH and conductivity meters.

The brine flow control system is shown in Photograph 6.

Photograph 6: Brine flow control system.

The influent prefilters located in the rear of the Basin Water System are shown in Photograph 7.

Photograph 7: Influent pre-filters.

The untreated brine flowed directly into one of two waste brine treatment processes: the 240-gallon BPU tank or the 120-gallon BRA tank. Basin Water added a 1/8-inch ball valve on the untreated waste brine line to allow the brine to be sampled prior to treatment. A continuous sample of untreated brine was collected during the regeneration cycle to make a composite for each batch of untreated brine. Samples of the brine were collected before and after treatment for six brine treatment batches. Treated waste brine was sampled three times from each treatment process. BPU-treated brine was sampled from a sample tap on the treated brine line to the treated brine storage tank. BRA-treated brine was sampled from the top of each treatment tank. The iron oxide absorptive media treatment tank was accessible through an opening. Samples were collected from the top of each tank once the system indicated through the human machine interface (HMI) that the batch treatment process was completed.

2.4 Description of Physical Construction/Components

This section summarizes the devices in the Basin Water System:

- Footprint: The footprint of the Basin Water System was eight feet wide by 27 feet long, not including storage of treated waste brine or waste solids.
- Treated brine waste tank: The treated brine waste tank was located next to the Basin Water System. This 6,500-gallon, eight foot-diameter polypropylene tank was used to store the treated waste brine from both the precipitation and adsorption waste brine treatment methods.
- Solid waste tank: The solid waste was stored on-site in a 55-gallon drum with a sealing top.
- Brine treatment units: Two brine treatment units were tested. The BPU, using precipitation with ferric chloride, was located within the treatment unit. The BRA, using absorptive media, was located adjacent to the IX system.
- Salt tank: This tank was located within the Basin Water System. It was manually filled daily.
- Bag filters: There were two bag filters with a capacity of 100 gpm each (see Photograph 6). They were in parallel flow configuration, with one in operation at a time. These filters were 30 inches long and designed to remove particles down to 5 micron.

2.5 Chemical Consumption and Production of Waste Material

2.5.1 Chemical Consumption

NaCl, ferric chloride, acid, and caustic were consumed during the ETV for the Basin Water System.

- NaCl was required for regeneration of the IX resin once the exhaustion cycle was completed.
- Ferric chloride was used for the precipitation of arsenic.
- Acid was used to drop the pH of the waste brine.
- Caustic was required after precipitation to increase brine effluent pH to noncorrosive levels.

A 0.5% sodium hypochlorite solution was fed between the raw water sampling point and the influent sampling point (prior to the prefilters) and was monitored at the influent sampling point. The sodium hypochlorite was fed at a range of 0.10-0.50 mg/L (total chlorine) through a 2-gallon per hour Milton Roy (LMI series AA) pump. The sodium hypochlorite level was monitored daily through free and total chlorine analyses. Levels of sodium hypochlorite in the feed tank and any adjustments necessary to the Milton Roy pump were recorded in the on-site logbook.

2.5.2 Waste Production and Physical and Chemical Nature of Wastes

The precipitation process enabled the separation of the waste effluent into two categories of waste: solids (sludge) and liquid. The sludge and liquid were separated through decanting, which left nonhazardous levels of arsenic (<5 mg/L) in the liquid waste brine. The brine was then disposed of at a standard brine handling facility, such as the Remedy Environmental Services in Anaheim, California. The brine waste represented less than 0.1% of the amount of water treated. It was stored in a 6,500-gallon tank (with containment) on-site until analysis could confirm proper disposal method.

The solid waste volume was minimal. Disposal was arranged through an experienced waste management company, Clean Harbors in California. The solid waste was classified as hazardous. This waste was stored and disposed of appropriately.

2.6 Licensing Requirements

There were no special licensing requirements to operate the Basin Water System.

Chapter 3
Methods and Procedures

3.1 Quantitative and Qualitative Evaluation Criteria

The objectives of the ETV were to evaluate the equipment in the following areas:

1. Performance relative to Basin Water's stated range of equipment capabilities;
2. The impact on performance of variations in feed water quality (such as TDS, sulfate, hardness, temperature, pH, alkalinity and iron);
3. The logistical, human, and economic resources necessary to operate the equipment; and
4. The reliability, ruggedness, range of usefulness, and ease of operation of the equipment.

To address these objectives, the ETV employed the quantitative and qualitative factors listed in Table 3-1 in evaluating the IX equipment performance. In this ETV study, the primary application of the IX system was arsenic and vanadium removal.

Table 3-1. Quantitative and Qualitative Evaluation Criteria

Quantitative Factors	Qualitative Factors
• Finished water quality	• Ease of operation
• Maintenance requirements	• Safety
• Required level of operator attention	• Susceptibility to environmental conditions
• Spatial requirements	• Ruggedness
• Waste disposal	• Impact of operator experience on successful operation
• Power consumption	• Portability of equipment
• Influent flow requirement	• Modular nature of equipment (ease of capacity expansion)
• Discharge requirement	
• Chemical composition and disposal of waste	
• Chemical consumption	
• Length of operating cycle	

3.2 Key Treated Water Quality Parameters

3.2.1 Key Groundwater Quality Parameters the Equipment is Designed to Address

The operating range of the Basin Water System is summarized in Table 3-2.

Table 3-2. Operating Range of Basin Water High Efficiency Ion Exchange Treatment System

Parameter	Range
Arsenic	Less than 100 μg/L[1]
Vanadium	Less than 150 μg/L
Total Dissolved Solids	Less than 650 mg/L
Sulfate	Less than 250 mg/L
Nitrate	Less than 25 mg/L
Chloride	Less than 250 mg/L
Bicarbonate Alkalinity	Less than 250 mg/L
pH	6.0 - 11.0

[1] For verification testing, the range of arsenic was anticipated to be <50 μg/L.

3.2.2 Key Treated Water Quality Parameters for Evaluating Equipment Performance

Key treated water quality parameters that were employed for evaluation of the Basin Water System equipment are listed in Table 3-3. In addition to these key parameters, N-nitrosodimethylamine (NDMA) was sampled from the raw water and the treated water effluent during the Initial Plant Characterization testing. Researchers suspect that NDMA is a possible human carcinogen and may be formed during the drinking water treatment chlorination process, especially if chloramines are used. Suspects for precursors to NDMA are coagulant aid polymers and SBA exchange resins containing quaternary amines.

Table 3-3. Key Treated Water Quality Parameters

- pH
- Hardness
- Alkalinity
- Chlorine (free and total)
- Chloride
- Dissolved Silica
- Fluoride
- Arsenic (total)
- As (III)
- As (V) (calculated)
- Arsenic-dissolved
- Iron
- Conductivity
- Nitrate
- Manganese
- Sulfate
- TDS
- TSS
- Vanadium
- Temperature
- Langelier Saturation Index (LSI)

3.3 Equations and Definitions of Operational Parameters

3.3.1 Equations

Mass Balance: Calculation of the mass balance was performed during the Initial Plant Characterization in order to verify the steady state of the system and arsenic removal through the IX columns, using Equation 3-1.

$$V_i C_i = V_e C_e + V_b C_b \tag{3-1}$$

where: V_i = influent water volume to the IX columns (gallons)
V_e = effluent water volume (gallons)
V_b = brine and washwater volume (gallons)
C_i = influent water concentration of arsenic (µg/L)
C_e = effluent concentration of arsenic (µg/L)
C_b = brine concentration of arsenic (µg/L)

It should be noted that the mass balance of arsenic for the Basin Water System might have been influenced by the following factors:

- Brine (wastewater) flow and concentration may have been affected by washwater/rinse water during the regeneration cycle that was collected with the waste brine;
- Electrical outages on-site that lead to plant shutdowns and intermittent flows; and
- Effluent concentrations (C_e) were consistently non-detect (<1.0 µg/L), but for calculation of the mass balance a value of 1 µg/L was used.

3.3.2 Definitions

The following are definitions of terms used in the evaluation:

Adsorption: The step in the IX process that removes arsenate from water by chemical or physical attraction to a medium such as an IX resin. It is also referred to as the service step or the exhaustion step. Note: In this document, the term adsorption is used in its general sense as a process for removing contaminants from a liquid by adsorbing them on a solid adsorbent by processes including IX, adsorption, and ligand exchange.

Anion: A negatively charged ion. The major anions of concern are divalent arsenate ($HAsO_4^{2-}$), monovalent arsenate ($H_2AsO_4^-$), nitrate (NO_3^-), sulfate (SO_4^{2-}), chloride (Cl^-), and bicarbonate (HCO_3^-).

Anion Exchange Resin: A polymeric matrix, usually polystyrene cross-linked with divinylbenzene, containing fixed positively charged functional groups that hold exchangeable anions by electrostatic attraction. During an anion-exchange reaction, a harmless ion such as chloride is exchanged for a target contaminant ion such as arsenate ($HAsO_4^{2-}$).

Attrition: Breakage and wear of IX resin beads.

Backwashing: The upward flow of water through an IX bed to clean it of foreign material and reduce the compaction of the resin bed. Usually the bed is fluidized by the upward flow of water.

Bed: The IX material contained in a column or vessel of an operating unit.

Bed Depth: The height of the resin material in the column after the exchanger has settled into a packed-bed condition.

Bed Expansion: The effect produced during backwashing. When the bed is fluidized, the resin particles become separated and rise in the column.

Bed Volumes (BV) or Bed Volumes Treated: A dimensionless ratio that refers to the volume of water that can be treated by a bed of resin. BV = volume of water treated/volume of resin including voids.

Breakthrough: The portion of the effluent history curve that exhibits a rapid increase in effluent concentration of a substance, which signals that adsorption of the substance is near completion, and further operation of the column will not be productive. During plant operation, the adsorption cycle is terminated prior to breakthrough of the ion of interest. The breakthrough point can be defined in several ways, such as the point on the breakthrough curve where the concentration of the target contaminant reaches the MCL or a predetermined fraction of the MCL, or where the inflection point in the breakthrough curve occurs. Breakthrough can be gradual or sharp depending on several factors, including the isotherm shape, the resin particle size, mass transfer considerations, channeling in the bed, and so forth.

Brine Recycle: The reuse of spent brine with or without treatment to remove the target contaminant, arsenic. Direct brine reuse, or brine recycling without treatment to remove arsenic, is possible during arsenic IX because arsenate is removed as a divalent ion ($HAsO_4^{2-}$) undergoes electroselectivity reversal and is not attracted to the resin when it is in contact with high-concentration brine.

Capacity: Generally, the advertised IX capacity expressed in milliequivalents per milliliter or equivalents per liter; the number of equivalents of exchangeable ions from the water that would be contained in one liter of an IX material. The volume is measured when the material is wet and fully saturated with adsorbed water.

Channeling: Random paths of relatively lower flow resistance in the resin bed resulting from improper operating procedures, including failure to remove particulate matter, improper backwashing, insufficient flow velocity, and so forth. Channeling, which can occur during exhaustion or regeneration, results in diminished mass transfer between the water and the resin.

Chromatography: The separation of ions, molecular species, or complexes into highly purified fractions by means of IX materials or adsorbents.

Chromatographic Peaking: The phenomenon that causes the effluent concentration of an ion to be higher than the influent concentration for a short time during the effluent history. Chromatographic peaking is also referred to as "dumping," and it occurs immediately following the breakthrough of each ion. All ions in the column influent are subject to peaking except the most preferred ion, which is usually sulfate. During chromatographic peaking, significant amounts of the adsorbed ion are "dumped" from the resin bed into the process effluent water.

Column Operation: The most common method of employing IX materials, in which the liquid to be treated passes through a fixed bed of IX resin held within a cylindrical vessel or column.

Composite Sample: A sample that has been collected from a continuous flow sample port over a predetermined period. For example, a one-gallon sample taken for a 24-hour composite period would be collected in the appropriate sample container and preservative (if required) at a flow rate of 2.6 ml per minute.

Cycle: A complete series of operational steps. For instance, a complete cycle of arsenate IX would involve the complete adsorption step, followed by backwash, regeneration, slow rinse, fast rinse, and return to adsorption service.

Dumping: The phenomenon that causes the effluent concentration of an ion to be higher than the influent concentration for a short time during the effluent history. Dumping is also referred to as "chromatographic peaking," and it occurs immediately following the breakthrough of an ion. All ions in the column influent are subject to peaking except the most-preferred ion, which is usually sulfate. During chromatographic peaking, significant amounts of the adsorbed ion are "dumped" from the resin bed into the effluent water.

Effluent: Column effluent is the treated water leaving an IX column. Process effluent is synonymous with treated water, which can be the result of blending several column effluents together to smooth out water quality variations resulting from a single column. Process effluent can also contain bypass water that has not been treated by IX. The regenerant emerging from the column after regeneration is referred to as the eluent, eluate or spent regenerant.

Effluent History Curve: An x-y plot showing the relationship between time or BV of water passed through a bed of IX resin (on the x-axis) and the effluent concentration (on the y-axis). Effluent concentration may be expressed as milliequivalents/L, mg/L, or the ratio $C_{Effluent}/C_{Influent}$. Contaminant breakthrough occurs when the effluent history curve begins to rise sharply. The run is terminated at the breakthrough point when the effluent concentration reaches the MCL or some predetermined fraction of the MCL. Prior to contaminant breakthrough, the measurable amount of contaminant in the effluent history curve is referred to as leakage. As long as the leakage is below the predetermined MCL, it is tolerable.

Elution: The stripping of adsorbed ions from the IX resin by the regenerant solution, which is usually highly concentrated (e.g., 1-2 molar NaCl [6-12% NaCl]).

Electroselectivity Reversal: The reversal of selectivity, which occurs when the ionic strength of the aqueous solution is changed between natural water (low ionic strength [e.g., 0.005 M]) and brine solution (high ionic strength [e.g., 1.0 M]). Divalent ions such as sulfate and arsenate undergo selectivity reversal during regeneration. These are easily stripped from the resin during regeneration, even though they are strongly attracted to the resin during exhaustion, which occurs in low ionic strength water.

Empty Bed Contact Time (EBCT): The time it would take for water to pass through the volume of the column occupied by the resin bed if the resin were not present, hence "Empty Bed" Contact Time. It is calculated as the volumetric flow rate divided by the resin BV. For example, if the flow rate is 350 gpm and one BV is 700 gallons, the EBCT is 2 minutes (i.e., 2 min per BV or 0.5 BV per min, or 30 BV per hr).

Equivalent: Short for gram equivalent weight, the molecular weight of an ion divided by its ionic charge. One equivalent of ions contains Avogadro's number (6.023×10^{23}) of ionic charges. For example one equivalent (i.e., one gram equivalent weight = 139.9/2 = 69.95 grams) of divalent arsenate ($HAsO_4^{2-}$) anions contains 6.023×10^{23} negative charges. Equivalents rather than grams of ions are used in IX calculations because one equivalent of chloride (35.5/2 = 17.75 grams) is replaced by exactly one equivalent of arsenate (69.95 grams).

Exhaustion: That portion of the operating cycle during which the resin adsorbs (actually, removes by IX) the contaminant from the raw water. The resin is spent or exhausted at the end of the exhaustion step.

Fouling: Any deposit or concentration of foreign material on or in an IX material that interferes with the chemical and physical processes. Typical foulants are lubricating oil from pumps, clays, silts, bacteria, algae, and so forth. Fouling can cause reduced efficiency, channeling, loss of resin during backwashing, and many other plant malfunctions.

Freeboard: The space provided above the resin bed in a vessel or column to accommodate the expansion of the resin bed during the backwash cycle.

Gauge Pressure (psig): The pressure read from a gauge that measures the difference between the pressure of the fluid and the pressure of the atmosphere.

Headloss: The loss of liquid pressure head resulting from the passage of water through a bed of IX material.

Hydraulic Loading Rate: Also referred to as the approach velocity (v_0) or the volume of water passing through a given area of resin within a given time. Hydraulic loading rate is usually expressed in terms of gallons per minute per square foot of bed cross sectional area. Hydraulic loading rate is not the same as the service flow rate (SFR), which is expressed as volumetric flow rate divided by resin BV (e.g., gal/min-ft^3). For arsenic IX processes, these values are typically as follows: v_0 = 10-15 gal/min-ft^2; SFR = 3-5 gal/min-ft^3.

Influent Water: The influent water is the arsenic-contaminated water entering an IX column after pretreatment (chlorination and prefiltration).

Interstitial Volume: The space between the particles of an IX material in a column or an operating unit (see Void Volume).

Leakage: The presence of the target contaminant (in this case, arsenate) in the treated water exiting from an IX column before its breakthrough has occurred, giving the impression that the contaminant has "leaked" through the resin bed. Leakage is different from breakthrough.

Milliequivalent (meq): Short for one milligram equivalent weight; one thousandth of an equivalent (i.e., 6.023 x 10^{20} ionic charges).

Operating Cycle: A single completion of all steps in the exhaustion-regeneration process consisting of adsorption, backwash, regeneration, fast rinse, slow rinse, and standby.

Preferred Ion: The one of at least two different ions having equal concentrations that will be adsorbed on the resin to the greatest extent.

Raw Water: Water from the well that has not been treated, either through the pretreatment process or the IX treatment process.

Recontamination: A potential problem in IX systems consisting of removing a contaminant from one point in a water supply and then adding the same and/or other contaminant into the supply at a different point. For example, by incomplete rinsing of resin beds, arsenate, nitrate, chloride, bicarbonate, sulfate, and sodium can be added to the supply. Also, by running beds beyond their bed life, arsenate ion can be “dumped” from the bed into the treated water.

Regenerant: The solution (6-12% NaCl for arsenate removal) used to convert an IX material from its exhausted state to the desired regenerated form for reuse.

Regeneration: Conversion of the spent resin back to the presaturant condition by elution of the contaminants after completion of the exhaustion and backwashing steps. In arsenate treatment, the regeneration is performed by passing a sodium chloride brine slowly through the bed in either a co- or countercurrent direction.

Regeneration Level: The amount of regenerant chemical used per unit volume of IX resin bed, commonly expressed as lb/ft^3 or equivalents Cl^-/equivalent resin. Also see Salt Loading. The lower the regeneration level, the more efficient the process.

Resin: Synthetic organic IX materials, usually in bead form, with a large number (= $6x10^{23}$ sites/L resin) of charged IX sites within the hydrated solid. The typical SBA resins used in arsenate anion removal from water are divinylbenzene cross-linked polystyrene polymers with positively charged quaternary amine functional groups.

Resin BV: The volume of IX resin material in a bed including voids between particles. The volume of the resin in the bed, referred to as one BV, is expressed in cubic feet, gallons, or liters.

Rinse: The passage of water through an IX bed to wash out excess regenerant and residual contaminants. The slow rinse or displacement rinse is generally less than 3 BV and is performed at the same rate as the regenerant flow rate (0.5-1 gal/min-ft^3). The fast rinse is generally less than 20 BV and is performed at the service (exhaustion) flow rate (3-5 gal/min-ft^3).

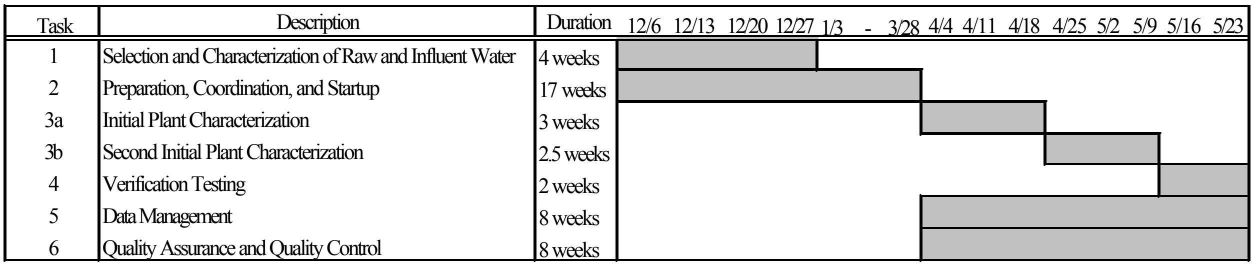
Run: A run is defined as one complete cycle: exhaustion, regeneration, and rinse. It will take approximately 17 hours.

Run Length: The number of BV or the exhaustion time (hrs) until the breakthrough point of the contaminant ion of interest (in this case, arsenic). For arsenic removal, the Run Length to Arsenic Breakthrough will be evaluated.

Salt Loading: Salt loading is the amount of regenerant applied to a resin during the regeneration step. It can be expressed in terms of pounds of NaCl per cubic foot of resin, grams of salt/L of resin, equivalents of salt/L of resin or, more conveniently, in terms of BV of brine (volumes brine/volumes resin) having a specified concentration of NaCl. Salt loading and regeneration level are equivalent terms.

3.4 Testing Schedule

The ETV testing schedule is presented in Figure 3-1. Verification testing activities took place over a total period of approximately 25 weeks beginning December 2004, and ending in May 2005. Initial Plant Characterization activities occurred in April and early May 2005. The Verification Test occurred from May 12 to May 28, 2005. The six tasks of the verification testing are described in further detail in Section 3.7.



Task	Description	Duration
1	Selection and Characterization of Raw and Influent Water	4 weeks
2	Preparation, Coordination, and Startup	17 weeks
3a	Initial Plant Characterization	3 weeks
3b	Second Initial Plant Characterization	2.5 weeks
4	Verification Testing	2 weeks
5	Data Management	8 weeks
6	Quality Assurance and Quality Control	8 weeks

*Dates denote beginning of each full week.

Figure 3-1: Verification testing schedule.

Verification testing activities included equipment setup, initial operation, verification operation, sampling, and analysis. A setup period was conducted to test equipment for proper function and to reach a steady state of operation. Setup served as the shakedown period to determine appropriate operating parameters.

3.5 Field Operations Procedures

Testing of the Basin Water System was conducted by MWH, an NSF-qualified FTO. Water quality analytical work carried out as part of the verification testing, was conducted by MWH Laboratories. Field analytical work was performed by MWH field personnel using field laboratory equipment and procedures for pH, temperature, conductivity, chlorine, and on-site speciation of arsenic.

The verification unit was operated 24 hours a day, seven days a week with staff on-site each day to operate the verification unit and collect water quality data during one 8-hour shift. Tasks performed by the operations staff are described in detail below.

3.6 Environmental Technology Verification Testing Plan

The following section provides a brief overview of the tasks included in the Basin Water System verification testing at the Corydon Street Well in Lake Elsinore, California. The verification tasks included:

Task 1: Selection and Characterization of the Raw Water
Task 2: Preparation, Coordination, and Start-Up
Task 3: Initial Plant Characterization
Task 4: Verification Testing
Task 5: Data Management
Task 6: Quality Assurance and Quality Control

Verification testing activities included equipment setup, initial operation, verification operation, and sampling and analysis. Initial operations were conducted so that equipment could be tested to be sure it was functioning as intended. An overview of each task is provided below with detailed information following this section of the report.

3.6.1 Task 1: Selection and Characterization of the Raw Water

The objective of Task 1 was to obtain a chemical and physical characterization of the raw water. The EVMWD's Corydon Street Ground Water Well was selected for verification testing because of its representative arsenic, vanadium, sulfate, nitrate, and TDS concentrations.

3.6.2 Task 2: Preparation, Coordination, and Start-Up

Task 2 activities were conducted to test that equipment was functioning as intended and to bring the system into a steady state of operation. Initial operations allowed the manufacturer to refine the operating procedures and to make operation adjustments, as needed, to successfully treat the influent water.

Upon completion of start-up (i.e., the system had reached steady state operations), an orientation meeting was held at the verification test site. The manufacturer met with the FTO personnel to explain the process and the detailed plant design and provide training to the FTO staff.

3.6.3 Task 3: Initial Plant Characterization

The objective of this task was to provide a preliminary evaluation of the quality of water produced by the IX system at the specified operational conditions. The Initial Plant Characterization was conducted for three complete exhaustion and regeneration cycles over a period of 18 days. Mass balance for arsenic was conducted on the IX system to verify the removal of arsenic.

3.6.4 Task 4: Verification Testing

The objective of this task was to evaluate the performance of the Basin Water System at the specified operational conditions set once the Initial Plant Characterization was found to be satisfactory to the manufacturer, Basin Water. System performance was evaluated relative to the removal of arsenic and vanadium. For verification testing purposes, the equipment was operated 24 hours per day, seven days per week, for 313.35 hours total over a period of 17 days. The IX system performance was evaluated at one set of operating conditions for the evaluation period. The effluent water quality was monitored and evaluated in relation to the raw and influent water quality and operational conditions.

The following is an overview of the equipment operational and production characteristics evaluated for each task of the verification testing:

- Influent water pressure and flow rate,
- Effluent water pressure and flow rate,
- Brine consumption,
- Power consumption, and
- Chemical consumption (acid, caustic, ferric chloride, sodium hypochlorite, and adsorptive media).

3.6.5 Task 5: Data Management

The objective of this task was to establish effective field protocols for data management at the field operations site and data transmission between the FTO and NSF during verification testing. Prior to the beginning of field testing, the spreadsheet design was developed by the FTO, and reviewed and approved by NSF. This ensured that the required data were collected during the testing and that results could be effectively transmitted to NSF for review.

3.6.6 Task 6: Quality Assurance Project Plan

The objective of this task was to assure accurate measurement of operational and water quality parameters during IX equipment verification testing. An important aspect of verification testing was the Quality Assurance Project Plan (QAPP).

3.7 Task 1: Selection and Characterization of the Raw Water

The manufacturer chose a groundwater location to test the IX system. The water from the Corydon Street Well at Lake Elsinore met the requirements of the ETV protocol.

3.7.1 Experimental Objective

The objective of Task 1 was to demonstrate the appropriate water conditions for the IX system at the test site. Complete chemical and physical characterization of the raw water was obtained during this task.

3.7.2 Work Plan

All water quality parameters corresponded to the expectations listed in the ETV protocol.

3.7.3 Schedule

The water characterization was performed prior to the start of the project.

3.7.4 Evaluation Criteria

The raw water was evaluated to verify that the capabilities of the equipment would be challenged, but not beyond the range of water quality suitable for the IX system.

3.8 Task 2: Preparation, Coordination, and Start-Up

Meetings of the manufacturer and the FTO were held regarding the tasks and scheduling of tasks. The manufacturer and the FTO were both present during the plant start-up to train the testing personnel in plant operation and maintenance.

3.8.1 Experimental Objectives

The objectives of the preparation, coordination, and start-up activities were to train the FTO to operate the plant, provide an opportunity for the manufacturer and the FTO personnel to reach a common understanding of the objectives and execution of the testing plan, and allow the manufacturer to bring the IX system into a steady state of operation. The meetings provided an opportunity to clarify any areas of concern by either party. Special attention was given to critical equipment such as alarms, controls, and safety devices. Additionally, emergency shutdown procedures were carefully reviewed.

3.8.2 Work Plan

The treatment objectives included the following:

- The effluent water arsenic and vanadium concentrations would always be less than 4 µg/L and 15 µg/L, respectively.
- The effluent water pH would be within the specified design range (6.0-11.0).
- The volume of wastewater, including brine and rinses, discharged from the process would be equal to or less than the manufacturer's objectives (0.1% of processed water).
- The regenerant salt consumption would meet the manufacturer's objectives [2.145 pounds per 1,000 gallons (lbs/1000 gal)].

3.8.3 Steady State Operation

Prior to the Initial Plant Characterization (Task 3), the IX system was brought into steady state operation by the manufacturer. For the Basin Water System with multiple parallel columns operating simultaneously, this applied to each operating column in the system. With a flow of approximately 37.5 gpm and four beds in operation at any time, the flow through one bed was 9.38 gpm. Each bed has a volume of 40.74 gallons and an absorption capacity set point of 1,050 BVs. Thus, the time for one bed to reach its capacity set point was:

- 1,050 BV x 40.74 gal/BV / 9.38 gpm = 4560.4 min/absorption cycle or 76.01 hours (hrs) per cycle.
- Since four beds were in service and the time between regeneration cycles was evenly divided among the in-service beds, the time between beds being removed and brined and new beds added was 1,140.1 min, or 19.00 hrs.
- Since there were two additional beds that were not active at any time, but all the beds had to be equalized, the total time for steady state was: 6 beds x 19.00 hrs x 3 cycles = 342 hrs or 14.25 days.

The regeneration time was relatively short and did not contribute to the equalization time. The 14.25 days required to reach equalization was conducted by Basin Water during Task 2 prior to the Initial Plant Characterization (Task 3).

3.9 Task 3: Initial Plant Characterization

Upon completion of Task 2, the Initial Plant Characterization was conducted by the FTO, and the base line performance data were recorded. During this task, a preliminary assessment of plant performance was made. Initially the plant did not meet the performance objects as set by the manufacturer specification. Performance of the IX system deteriorated over the span of the Initial Plant Characterization, and arsenic breakthrough was observed in the effluent at an increasing rate (i.e., arsenic in the effluent increased over time). Additionally, a mass balance of the raw water and waste brine indicated that initially the system was not regenerating completely.

These preliminary test results were reported to the manufacturer, who chose to make NSF-approved changes in operating procedures prior to the Verification Test. Adjustments were made to the absorption capacity set point (reduced to 850 BV), salt addition during regeneration (increased to 0.7 BV), and salt contact time during regeneration (increased to 5 minutes) prior to the actual Verification Test. Due to the initial performance and adjustments to the IX systems set points, the Initial Plant Characterization period was repeated until each column had undergone two complete exhaustion cycles. The second Initial Plant Characterization took 7.69 days to perform two complete exhaustion cycles. The second Initial Plant Characterization with the new plant settings was able to meet the manufacture's claim on arsenic removal. The performance data obtained during these preliminary tests provided baseline data for comparison with the Verification Test performance.

3.9.1 Experimental Objectives

The objectives of this task were to establish the initial plant performance characteristics and to permit NSF and the manufacturer to make approved changes in the PSTP prior to the Verification Test. Mass balances were performed as part of this task in order to evaluate the effectiveness of the regeneration of the IX columns. The approved preliminary data were used as baseline data for comparison with future plant performance.

3.9.2 Work Plan

Some of the water quality parameters described in this task were measured on-site by the FTO. These analyses included pH, conductivity, chlorine, temperature, and arsenic speciation. Analyses of the remaining water quality parameters were performed by MWH Laboratories, a state-certified laboratory. The methods used for measurement of water quality parameters are identified in Table 3-4. A number of the analytical methods utilized in this study for on-site monitoring of raw, influent, and effluent water qualities are further described in Task 6, Quality Assurance Project Plan.

For the water quality parameters submitted to MWH Laboratories, water samples were collected in appropriate containers (containing necessary preservatives as applicable) prepared by MWH Laboratories. These samples were then preserved, stored, shipped, and analyzed in accordance with appropriate procedures and holding times.

3.9.3 Analytical Schedule

The Initial Plant Characterization test was performed after the preparation, coordination, and start-up step (see Task 2), which included the manufacturer's time to reach a steady state operation. Table 3-4 presents the water quality parameters, frequency, and total number of samples that were collected during the first Initial Plant Characterization. Each parameter was analyzed per the methods listed in Table 3-4. To the extent possible, analyses for inorganic water quality parameters were performed on water sample aliquots obtained simultaneously from the same sampling location, in order to ensure the maximum degree of comparability between water quality analytes.

The collection of Initial Plant Characterization data was completed over the course of two sessions. The first Initial Plant Characterization was completed over three complete exhaustion and regeneration cycles (April 4–23, 2005), which was approximately 15 days. The second Initial Plant Characterization was completed over two complete exhaustion and regeneration cycles (April 29 – May 9, 2005), which was approximately eight days. The second Initial Plant Characterization's analytical sampling schedule was less rigorous than the first. During the second Initial Plant Characterization, sulfate, nitrate, chloride, calcium, magnesium, alkalinity, fluoride, TDS, TSS, iron, manganese, hardness, and dissolved silica, were sampled only once.

In order to perform the mass balance, the precipitation treatment method was not used during the first three days of the plant characterization tests. Twenty-four-hour composite samples were collected from the influent, effluent, and untreated waste brine and sent to MWH Laboratories with a request for 24- to 48-hour turnaround times. The data were evaluated, and a mass balance was performed. These data were provided to NSF and Basin Water prior to beginning the Verification Test. It should be noted that the waste brine also included the wastewater from the rinse process, which affected the mass balance by diluting the brine waste. It was not possible to segregate the waste brine from the waste rinse water in the Basin Water System.

Additionally, the following operating data were recorded once daily during the Initial Plant Characterization:

- Controller set points for each bed including: start time, finish time, and volume to exhaustion; flow rate, mass of salt and volume of regenerant used for each regeneration; and volume of chemicals (or adsorptive media) required for brine treatment.
- Pressure readings for the columns and pre-filter device.
- Number of vessels in exhaustion, regeneration, and standby.
- Visual observations of piping leaks and scaling and fouling problems.

Table 3-4. Initial Plant Characterization

Parameter	Frequency[1]	Facility	Standard Method[2]	EPA Method[3]	Hach Method
Arsenic [As (III)][4]	2/week on raw, influent and effluent water	Laboratory		200.8	
Dissolved Arsenic	2/week on raw, influent and effluent water	Laboratory		200.8	
Total Arsenic	1 composite per day on the raw, influent, and effluent water	Laboratory		200.8	
Sulfate	1 composite per day on the raw, influent, and effluent water	Laboratory		300.0	
Nitrate	1 composite per day on the raw, influent, and effluent water	Laboratory		300.0	
Chloride	1 composite per day on the raw, influent, and effluent water	Laboratory		300.0	
Calcium	1 composite per week on the raw, influent, and effluent water	Laboratory		200.7	
Magnesium	1 composite per week on the raw, influent, and effluent water	Laboratory		200.7	
Alkalinity	1 composite per day on the raw, influent, and effluent water	Laboratory	2320B		
Fluoride	1 composite per week on the raw, influent, and effluent water	Laboratory	4500-F C		
pH	Continuous monitoring of column influent and effluent water, and 1/day on-site verification of system influent and effluent	On-site	4500-H^+ B		
TDS	1 composite per week on the raw, influent, and effluent water	Laboratory	2540 C		
TSS	1 composite per week on the raw, influent, and effluent water	Laboratory	2540 D		
Iron	1 composite per week on the raw, influent, and effluent water	Laboratory		200.7	
Manganese	1 composite per week on the raw, influent, and effluent water	Laboratory		200.8	
Vanadium	1 composite per day on the raw, influent, and effluent water	Laboratory		200.8	
Hardness[5]	1 composite per week on the raw, influent, and effluent water	Laboratory	2340B		
Dissolved Silica	1 composite per week on the raw, influent, and effluent water	Laboratory		200.7	
Total Chlorine	1/day on raw, influent, and effluent water	On-site			8167
Free Chlorine	1/day on raw, influent, and effluent water	On-site			8021
Conductivity	Continuous monitoring of column influent and effluent water, and 1/day on-site verification of system influent and effluent		2510B		
NDMA[6]	1 grab sample on the raw water line, and 2 grab samples on the effluent (one chlorinated; one without chlorinated raw water)			1625	

[1] The verification plant was staffed seven days per week.

[2] Standard Methods 20th Edition.

[3] "Methods for the Determination of Metals in Environmental Samples-Supplement I", EPA/600/R-94/111, May 1994. Available at (NTIS) PB95-125472.

[4] Arsenic samples were speciated in the field using arsenic speciation resin columns provided by NSF.

[5] Calculated using calcium and magnesium concentrations from one composite sample per day on the raw, influent, and effluent water.

[6] NDMA samples collected per EVMWD's request.

3.9.4 Evaluation Criteria and Minimum Reporting Criteria

- The following data are presented in Chapter 4:
    - ⇒ A temporal plot of target inorganic constituents (arsenic and vanadium) in the raw, influent, and effluent water over the period of operation.
    - ⇒ Temporal plots of all other inorganic water quality parameters in the raw, influent, and effluent water over the period of operation.
    - ⇒ A table with twice-weekly values of percent removal of target inorganic constituents (arsenic [total, As (III), As (V) and dissolved] and vanadium) and other pertinent water quality parameters (vanadium) for the period of operation.
    - ⇒ Mass balances through the IX system for total arsenic were conducted. The mass balance equation presented in Section 3.3.1 was used for the calculation.
    - ⇒ Raw, influent and effluent water concentrations of any measured water quality parameters are provided in tabular form for the period of operation.
    - ⇒ Power consumption over the period of operation presented in a tabular format.
    - ⇒ A table of daily chemical consumption (salt, hypochlorite, ferric chloride, caustic soda, sulfuric acid) for the period of operation.

3.10 Task 4: Verification Testing

This task, which included the actual Verification Test, was the core of the verification testing plan. During this task, the Basin Water System was operated 24 hours per day, seven days per week, for a total of 313 hours over a 17-day period to collect data on equipment performance and water quality for the purpose of performance verification.

3.10.1 Experimental Objectives

The objectives of the verification testing runs were to:

- Observe and record the plant operating conditions and equipment performance;
- Determine the raw, influent, and effluent water quality;
- Characterize the effectiveness of the brine treatment processes; and
- Establish the arsenic and vanadium removal performance of the plant.

3.10.2 Work Plan

The plant was operated using the set point conditions determined in the Initial Plant Characterization test. Table 3-5 lists the operating and performance data collected during the verification testing runs.

Table 3-5. Operating and Performance Data

Operational Parameter for the Entire Plant	Monitoring Frequency
Instantaneous effluent water flow rate, gpm	Twice daily
Cumulative effluent water flow rate, gal	Twice daily
Cumulative waste water flow, gal	Daily
Brine consumption, gal	Daily
NaCl consumption, lbs and lbs/1000 gal effluent water	Daily
Volume of arsenic-contaminated sludge, gal	Once, at the end of testing
Solids conc. of arsenic-contaminated sludge, wt% solids	Once, at the end of testing
Mass of arsenic-contaminated sludge, lbs	Once, at the end of testing
Number of columns exhausted	Daily
Number of columns regenerated	Daily
Electrical energy consumption, kwhr	Daily
Equipment malfunctions, description of each malfunction and its result on plant performance	As they occur
Operational Parameter for Each Column in a Fixed-Bed Plant	**Monitoring Frequency**
Instantaneous column influent flow rate, gpm	Twice daily
Pressure drop, psig	Twice daily
Cumulative column influent flow, gal	Daily
Exhaustion start and stop times, time of day	Each exhaustion
Regeneration start and stop times, time of day	Each regeneration
Displacement rinse start and stop times, time of day	Each rinse
Brine consumption, gal	Each regeneration
Brine flow rate, gpm	Daily
NaCl consumption, lbs	Each regeneration

3.10.3 Analytical Schedule

Water Quality Characterization

Water quality data were collected from the raw, influent, and effluent water, as shown in Table 3-6, during the Verification Test. The sampling frequency and analytical methods are also presented in Table 3-6.

Water Quality Sample Collection

Water quality samples that were shipped to the state-certified analytical laboratory for analysis were collected in appropriate containers (containing preservatives, as applicable) prepared by the state-certified analytical laboratory. These samples were preserved, stored, shipped, and analyzed in accordance with appropriate procedures and holding times, as specified by the analytical laboratory. Note that unless otherwise stated, samples shown in Table 3-6 are grab samples. For those samples shown as "composite samples," a single sample was collected over a 24-hour period. Composite samples were collected in 2.5- or 5.0-gallon cube containers and then poured into their appropriate sample bottles provide by the analytical laboratory. Composite samples were stored (both during collection and after) on ice in a cooler on-site. Composite samples were collected through the continuous running of the sample line into the sample container at a rate not to exceed the volume of the sample container.

In addition to samples collected on-site, the HMI logged the following flow parameters: flow (effluent, brine, rinse), pressure (raw water, column influent and effluent water), pH (influent and effluent water), conductivity (influent and effluent water), and brine tank level.

Table 3-6. Verification Testing Analytical Methods and Sampling Frequency

Parameter	Frequency[1]	Facility	Standard Method[2]	EPA Method[3]	Hach Method
Arsenic [As (III)][4]	2/week (grab) on the raw, influent, and effluent water	Laboratory		200.8	
Dissolved Arsenic	2/week (grab) on the raw, influent, and effluent water	Laboratory		200.8	
Total Arsenic	1 composite sample per day on the raw, influent, and effluent water; 4/day (grab) on the effluent water; and 1/day (grab) on the raw and the influent water	Laboratory		200.8	
Sulfate	1 composite sample per day on the raw, influent, and effluent water	Laboratory		300.0	
Nitrate	1 composite sample per day on the raw, influent, and effluent water	Laboratory		300.0	
Chloride	1 composite sample per day on the raw, influent, and effluent water	Laboratory		300.0	
Calcium	1 composite sample per day on the raw, influent, and effluent water	Laboratory		200.7	
Magnesium	1 composite sample per day on the raw, influent, and effluent water	Laboratory		200.7	
Alkalinity	1 composite sample per day on the raw, influent, and effluent water	Laboratory	2320B		
Fluoride	1 composite sample per day on the raw, influent, and effluent water	Laboratory	4500-F C		
pH	Continuous monitoring of influent and effluent water; and 1/day (grab) on-site verification of raw, influent, and effluent water.	On-site	4500-H^+ B		
TDS	1 composite sample per day on the raw, influent, and effluent water	Laboratory	2540 C		
TSS	1 composite sample per day on the raw, influent, and effluent water	Laboratory	2540 D		
Iron	1 composite sample per day on the raw, influent, and effluent water	Laboratory		200.7	
Manganese	1 composite sample per day on the raw, influent, and effluent water	Laboratory		200.8	
Vanadium	1 composite sample per day on the raw water, influent, and effluent water; 4/day (grab) on the effluent water; and 1/day (grab) on the raw and the influent water	Laboratory		200.8	
Hardness[5]	1 composite sample per day on the raw, influent, and effluent water	Laboratory	2340B		
Dissolved Silica	1 composite sample per day on the raw, influent, and effluent water	Laboratory		200.7	
Total Chlorine	2/day (grab) on the raw, influent, and effluent water	On-site			8167
Free Chlorine	2/day (grab) on the raw, influent, and effluent water	On-site			8021
Conductivity	Continuous monitoring of effluent water from each column (recorded 1/day), and 1/day (grab) on-site analysis of raw, influent, and effluent water	On-site	2510B		
NDMA[6]	Once at end of verification test	Laboratory		1625	

[1] The verification plant was staffed seven days per week.

[2] Standard Methods 20th Edition.

[3] "Methods for the Determination of Metals in Environmental Samples-Supplement I", EPA/600/R-94/111, May 1994. Available at (NTIS) PB95-125472.

[4] Arsenic samples were speciated in the field using arsenic speciation resin columns provided by NSF.

[5] Calculated using calcium and magnesium concentrations from one composite sample per day on the raw, influent, and effluent water.

[6] NDMA samples collected per EVMWD's request/ suggestions to testing plan.

Characterization of Waste Brine

Waste brine samples were submitted to a state-certified laboratory for analysis from three waste sources: non-treated liquid waste brine, treated liquid waste brine, and waste solids from brine treatment process. The liquid waste samples were analyzed for conductivity and pH. Additionally, each of the three samples were submitted to a state-certified laboratory for analysis of the eight metals regulated under the Resource Conservation and Recovery Act (RCRA) (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver), as well as antimony, beryllium, cobalt, copper, molybdenum, nickel, thallium, vanadium, and zinc, as identified in Table 3-7. Solid waste samples from the BPU and BRA were also submitted for Toxicity Characteristic Leaching Procedure (TCLP), Total Threshold Limit Concentration (TTLC), and Soluble Threshold Limit Concentration (STLC). Duplicate samples of solid waste from both waste treatment processes were submitted for analysis. There was no field testing of the waste streams due to the possible classification of non-RCRA hazardous waste.

Once treatment was completed for the precipitation method, the treated waste brine was decanted off leaving a portion of the treated brine in the batch treatment tank as "seed" for the next batch treatment cycle. The treated waste brine was then pumped to a holding tank until hauled off-site for disposal.

Table 3-7. Sampling Frequency for Characterization of Waste Brine

Parameter	Sample Location	Sampling Frequency	Analytical Method	Reporting Limit (mg/L)
Conductivity	Untreated brine (liquid)	6 samples	2510B	NA
	Treated brine (liquid) from precipitation method	3 samples		
	Treated brine (liquid) from adsorption method	3 samples		
	Combined treated brine (liquid)[1]	1 sample		
pH	Untreated brine (liquid)	6 samples	4500-H+ B	NA
	Treated brine (liquid) from precipitation method	3 samples		
	Treated brine (liquid) from adsorption method	3 samples		
	Combined treated brine (liquid)[1]	1 sample		
Antimony	Untreated brine (liquid)	6 samples	EPA 6010B	0.01
	Treated brine (liquid) from precipitation method	3 samples		
	Treated brine (liquid) from adsorption method	3 samples		
	Solids from precipitation method	2 samples		
	Solids from adsorptive media	2 samples		
	Combined treated brine (liquid)[1]	1 sample		
Arsenic	Untreated brine (liquid)	6 samples	EPA 6010B	0.005
	Treated brine (liquid) from precipitation method	3 samples		
	Treated brine (liquid) from adsorption method	3 samples		
	Solids from precipitation method	2 samples		
	Solids from adsorptive media	2 samples		
	Combined treated brine (liquid)[1]	1 sample		
Barium	Untreated brine (liquid)	6 samples	EPA 6010B	0.01
	Treated brine (liquid) from precipitation method	3 samples		
	Treated brine (liquid) from adsorption method	3 samples		
	Solids from precipitation method	2 samples		
	Solids from adsorptive media	2 samples		
	Combined treated brine (liquid)[1]	1 sample		

Table 3-7. Sampling Frequency for Characterization of Waste Brine (continued)

Parameter	Sample Location	Sampling Frequency	Analytical Method	Reporting Limit (mg/L)
Beryllium	Untreated brine (liquid)	6 samples	EPA 6010B	0.004
	Treated brine (liquid) from precipitation method	3 samples		
	Treated brine (liquid) from adsorption method	3 samples		
	Solids from precipitation method	2 samples		
	Solids from adsorptive media	2 samples		
	Combined treated brine (liquid)[1]	1 sample		
Cadmium	Untreated brine (liquid)	6 samples	EPA 6010B	0.005
	Treated brine (liquid) from precipitation method	3 samples		
	Treated brine (liquid) from adsorption method	3 samples		
	Solids from precipitation method	2 samples		
	Solids from adsorptive media	2 samples		
	Combined treated brine (liquid)[1]	1 sample		
Chromium	Untreated brine (liquid)	6 samples	EPA 6010B	0.005
	Treated brine (liquid) from precipitation method	3 samples		
	Treated brine (liquid) from adsorption method	3 samples		
	Solids from precipitation method	2 samples		
	Solids from adsorptive media	2 samples		
	Combined treated brine (liquid)[1]	1 sample		
Cobalt	Untreated brine (liquid)	6 samples	EPA 6010B	0.01
	Treated brine (liquid) from precipitation method	3 samples		
	Treated brine (liquid) from adsorption method	3 samples		
	Solids from precipitation method	2 samples		
	Solids from adsorptive media	2 samples		
	Combined treated brine (liquid)[1]	1 sample		
Copper	Untreated brine (liquid)	6 samples	EPA 6010B	0.01
	Treated brine (liquid) from precipitation method	3 samples		
	Treated brine (liquid) from adsorption method	3 samples		
	Solids from precipitation method	2 samples		
	Solids from adsorptive media	2 samples		
	Combined treated brine (liquid)[1]	1 sample		
Lead	Untreated brine (liquid)	6 samples	EPA 6010B	0.005
	Treated brine (liquid) from precipitation method	3 samples		
	Treated brine (liquid) from adsorption method	3 samples		
	Solids from precipitation method	2 samples		
	Solids from adsorptive media	2 samples		
	Combined treated brine (liquid)[1]	1 sample		
Mercury	Untreated brine (liquid)	6 samples	EPA 7470A	0.0002
	Treated brine (liquid) from precipitation method	3 samples		
	Treated brine (liquid) from adsorption method	3 samples		
	Solids from precipitation method	2 samples		
	Solids from adsorptive media	2 samples		
	Combined treated brine (liquid)[1]	1 sample		
Molybdenum	Untreated brine (liquid)	6 samples	EPA 6010B	0.02
	Treated brine (liquid) from precipitation method	3 samples		
	Treated brine (liquid) from adsorption method	3 samples		
	Solids from precipitation method	2 samples		
	Solids from adsorptive media	2 samples		
	Combined treated brine (liquid)[1]	1 sample		

Table 3-7. Sampling Frequency for Characterization of Waste Brine (continued)

Parameter	Sample Location	Sampling Frequency	Analytical Method	Reporting Limit (mg/L)
Nickel	Untreated brine (liquid)	6 samples	EPA 6010B	0.01
	Treated brine (liquid) from precipitation method	3 samples		
	Treated brine (liquid) from adsorption method	3 samples		
	Solids from precipitation method	2 samples		
	Solids from adsorptive media	2 samples		
	Combined treated brine (liquid)[1]	1 sample		
Selenium	Untreated brine (liquid)	6 samples	EPA 6010B	0.005
	Treated brine (liquid) from precipitation method	3 samples		
	Treated brine (liquid) from adsorption method	3 samples		
	Solids from precipitation method	2 samples		
	Solids from adsorptive media	2 samples		
	Combined treated brine (liquid)[1]	1 sample		
Silver	Untreated brine (liquid)	6 samples	EPA 6010B	0.01
	Treated brine (liquid) from precipitation method	3 samples		
	Treated brine (liquid) from adsorption method	3 samples		
	Solids from precipitation method	2 samples		
	Solids from adsorptive media	2 samples		
	Combined treated brine (liquid)[1]	1 sample		
TSS	Untreated brine (liquid)	6 samples	SM 2540D	NA
	Treated brine (liquid) from precipitation method	3 samples		
	Treated brine (liquid) from adsorption method	3 samples		
	Solids from precipitation method	2 samples		
	Solids from adsorptive media	2 samples		
	Combined treated brine (liquid)[1]	1 sample		
Thallium	Untreated brine (liquid)	6 samples	EPA 6010B	0.005
	Treated brine (liquid) from precipitation method	3 samples		
	Treated brine (liquid) from adsorption method	3 samples		
	Solids from precipitation method	2 samples		
	Solids from adsorptive media	2 samples		
	Combined treated brine (liquid)[1]	1 sample		
Vanadium	Untreated brine (liquid)	6 samples	EPA 6010B	0.01
	Treated brine (liquid) from precipitation method	3 samples		
	Treated brine (liquid) from adsorption method	3 samples		
	Solids from precipitation method	2 samples		
	Solids from adsorptive media	2 samples		
	Combined treated brine (liquid)[1]	1 sample		
Zinc	Untreated brine (liquid)	6 samples	EPA 6010B	0.02
	Treated brine (liquid) from precipitation method	3 samples		
	Treated brine (liquid) from adsorption method	3 samples		
	Solids from precipitation method	2 samples		
	Solids from adsorptive media	2 samples		
	Combined treated brine (liquid)[1]	1 sample		

[1] Combined treated brine analysis was performed for characterization prior to disposal.

NA = Not Applicable.

3.10.4 Evaluation Criteria

Performance of the IX system was evaluated in the context of the manufacturer's statement of performance objectives with respect to: (1) treatment equipment performance, (2) finished water quality, and (3) arsenic and vanadium removal performance.

Treatment Equipment Performance

The goal of this subtask was to operate the plant within the mechanical and electrical constraints for a minimum of three complete exhaustion cycles during the verification testing runs. This included the following criteria: capacity in terms of total daily treated water production, liquid waste brine discharges, solid waste production, NaCl consumption, electrical consumption, and other relevant equipment performance criteria.

Arsenic and Vanadium Removal Performance

The Verification Test was performed to demonstrate the system's ability to remove arsenic and vanadium to below 4 µg/L and 15 µg/L, respectively (in 95% of effluent water samples).

The assessment of arsenic removal performance was not dependent on the form of arsenic fed to the plant. Regardless of whether As (III) or As (V) or a mixture of the two was fed, the performance requirements were determined by the measurement of total arsenic in the effluent water.

3.11 Task 5: Data Management

The data management system used in the verification testing involved the use of both computer spreadsheets and manual recording (on-site logbook) of operational parameters for the water treatment equipment on a daily basis. All field activities were thoroughly documented. Field documentation included field notebooks, photographs, field data sheets, and chain-of-custody forms. The following guidelines were followed:

- Field notes were kept in a bound logbook;
- Field logbook was used to record all water treatment equipment operating data;
- Each page was sequentially numbered;
- Each page was labeled with the project name and number;
- Completed pages were signed and dated by the individual responsible for the entries; and
- Errors had one line drawn through them, and this line was initialed and dated.

All photographs were logged in the field logbook. These entries included the time, date, and subject of the photograph, and identified the photographer.

Original field sheets and chain-of-custody forms accompanied all samples shipped to the analytical laboratory. Copies of field sheets and chain-of-custody forms for all samples are included in Appendix C.

3.11.1 Experimental Objectives

The objective of this task was to establish a viable procedure for the recording and transmission of field testing data such that the FTO provided sufficient and reliable operational data for verification purposes.

3.11.2 Work Plan

FTO operators recorded data and calculations by hand in laboratory notebooks. Daily measurements were recorded on specially prepared data log sheets as appropriate. The original notebooks were stored on-site. Electronic copies were forwarded to the project manager of the FTO at least once per week during the testing period. Operating logs included a description of the IX equipment (description of test runs, names of visitors, description of any problems or issues, etc.), in addition to experimental calculations and other items.

A database for the project was set up using custom-designed spreadsheets. The spreadsheets were capable of storing and manipulating each monitored water quality and operational parameter from each task, sampling location, and sampling time. All data from the laboratory reports and data log sheets were entered into the appropriate spreadsheet. Data entry was conducted on-site by the designated field testing operators. All recorded calculations were also checked at this time. Following data entry, the spreadsheets were printed out, and the printouts were checked against the handwritten data sheets. Any corrections were noted on the hard copies and corrected on the screen, and a corrected version of the spreadsheet was printed out. Each step of the verification process was initialed by the field testing operator performing the entry or verification step. Backup of the computer databases to diskette was performed on a weekly basis.

Data from MWH Laboratories were received and reviewed by the field-testing operator. These data were entered into the data spreadsheets, corrected, and verified in the same manner as the field data. As available, electronic data storage and retrieval capabilities were employed in order to maximize data collection and minimize labor hours required for monitoring.

Data tracking included each of the following tasks:

- Data were tracked using the same system of run numbers as samples were collected and sent to state-certified analytical laboratories (MWH Laboratories).
- Data from the analytical laboratories were received and reviewed by the FTO.
- These data were entered into the data spreadsheets, corrected, and verified in the same manner as the field data.

3.12 Task 6: Quality Assurance Project Plan

QA/QC of the operation of the Basin Water System and the measured water quality parameters were maintained during verification testing through a QAPP as described in this section. A number of individuals were responsible for monitoring equipment and operating parameters, and for sampling and analysis QA/QC throughout the verification testing. Primary responsibility for ensuring that both equipment operation and sampling and analysis activities complied with the QA/QC requirements rested with the FTO and the analytical laboratory.

QA/QC activities for the analytical laboratory that analyzed samples sent off-site were the responsibility of that analytical laboratory's supervisor. If problems arose or any data appeared unusual, they were thoroughly documented and corrective actions were implemented as specified in Chapter 4.

3.12.1 Experimental Objectives

The objective of this task was to maintain strict QA/QC methods and procedures during verification testing. Maintenance of strict QA/QC procedures was important so that if a question arose when analyzing or interpreting data collected for a given experiment, it would be possible to verify exact conditions at the time of testing. The elements of the Quality Assurance Project Plan included:

- Data correctness
- Methodology for use of blanks
- Performance evaluation samples
- Duplicate samples
- Calculation of indicators of data quality
- Data reporting
- Measurement of precision and accuracy
- Corrective action plan.

3.12.2 Work Plan

Equipment flow rates and associated signals were verified and recorded on a routine daily basis. A daily walk-through during testing verified that each piece of equipment or instrumentation was operating properly. Particular care was taken to verify that water, brine, and flow rates were correct. Inline monitoring equipment, such as flow meters and conductivity meters, were checked to verify that the readouts matched with the actual measurements (i.e., flow rate, specific conductance) and that the signals being recorded were correct.

QA/QC Verifications
The effluent water pH meter was checked and calibrated daily. Additionally, the following parameters were verified daily by weight or by volume:

- NaCl, ferric chloride, sodium hypochlorite, acid and caustic consumption rates,
- Saturated brine flow rate, and
- Brine flow rate.

Other QA/QC checks included:

- Inline conductivity meters (calibrated prior to beginning verification testing [after the shakedown period] and daily during verification testing), and

- Tubing (verification of condition of all tubing and connections, and replacement if necessary).

3.12.3 Data Correctness

Data correctness refers to data quality, for which there are five indicators:

- Representativeness,
- Statistical uncertainty,
- Precision,
- Accuracy, and
- Completeness.

3.12.3.1 Representativeness

Representativeness refers to the degree to which the data accurately and precisely represent the conditions or characteristics of the parameter represented by the data. As specified by the ETV Protocol, representativeness of water quality samples for the ETV test was ensured by executing consistent sample collection procedures, including:

- Sample locations,
- Timing of sample collection,
- Sampling procedures,
- Sample preservation,
- Sample packaging, and
- Sample transport.

<u>Sample Locations</u>
Sample locations for all water quality parameters were specified in Section 2.3. Specifically, sample locations for the IX system include the raw water, influent, effluent, untreated brine, treated brine, and the solids from the waste brine treatment process.

<u>Timing of Sample Collection</u>
In an IX verification study, the timing of sample collection was not as critical as in, for example, a granular media filtration verification study in which the filter run time can influence the quality of water produced by the filter. For the IX verification test, there was no filter maturation time, stable period of filter operation, or turbidity breakthrough period. To the extent possible, analyses for inorganic water quality parameters were performed on water sample aliquots obtained simultaneously from the same sampling location, in order to ensure the maximum degree of comparability between water quality analytes.

<u>Sampling Procedures, Sample Preservation, Packaging, and Transport</u>
Sampling procedures for each water quality parameter are described below; additional information may be found in Tables 3-4 and 3-6. The samples were collected in bottles prepared by MWH Laboratories with the appropriate preservative for the analyte. For the 24-hour composite samples, 2.5- or 5-gallon cube containers were used and stored (both during and after

sample collection) on ice in a cooler. Field analyses were performed using portable field analytical equipment.

Once collected, all samples were stored and transported to MWH Laboratories in coolers packed with ice. Samples were analyzed within the Standard Methods or EPA recommended holding times, if not analyzed on-site (i.e., pH, conductivity, free and total chlorine, temperature, and arsenic speciation). The following parameters were sampled during verification testing:

<u>Alkalinity</u>
Samples were collected and analyzed off-site by the analytical laboratory using SM 2320B, within the 14-day holding period. Samples were not agitated or exposed to the atmosphere for prolonged periods of time. No preservative was used for alkalinity samples.

<u>Arsenic (As [III] and Dissolved)</u>
Samples were collected on-site and speciated using the procedures and resin columns provided by NSF (see Appendix C). The samples were collected in polyethylene bottles provided by MWH Laboratories and preserved in accordance with the ETV required procedures. The samples were analyzed using EPA Method 200.8 within the six-month holding period of the preserved samples.

<u>Arsenic (Total)</u>
Samples were collected headspace free into polyethylene bottles provided by the analytical laboratory, capped tightly, and transported daily to the analytical laboratory. The sample bottles from the laboratory included the preservative HNO_3 for a holding period of up to six months. The samples were analyzed using EPA Method 200.8 within the holding period of the preserved samples.

<u>Calcium</u>
Samples were collected headspace free into polyethylene bottles provided by the analytical laboratory, capped tightly, and transported daily to the analytical laboratory. The sample bottles from the laboratory included the preservative HNO_3 for a holding period of up to six months. All calcium samples were analyzed using EPA Method 200.7 within the holding period of the preserved samples.

<u>Chloride</u>
Samples were collected headspace free into polyethylene bottles provided by the analytical laboratory, capped tightly, and transported daily to the analytical laboratory. All chloride samples were analyzed using EPA Method 300.0 within the holding period of 28 days.

<u>Chlorine (Free and Total)</u>
Samples were collected and analyzed on-site immediately using Hach Method 8021 for free chlorine and Hach Method 8167 for total chlorine per the analysis instructions in Appendix C. Instructions for on-site calibration of the chlorine analyzer are also provided in Appendix C. Calibrations were conducted weekly.

Conductivity

Samples were collected and analyzed on-site immediately using SM 2510B. Sample agitation and prolonged exposure to air were avoided. The conductivity meter was calibrated daily on-site using a three-point calibration method and standard solutions manufactured by Hach at 180, 1000, and 1990 µmho/cm.

Fluoride

Samples were collected headspace free into polyethylene bottles provided by the analytical laboratory, capped tightly, and transported daily to the analytical laboratory. The sample bottles from the laboratory did not include a preservative, and when refrigerated, had a holding period of up to 28 days. All fluoride samples were analyzed using SM 4500F C within the allowable holding period.

Hardness

Samples were collected and analyzed on-site immediately using SM 2340B, with a six-month holding period using HNO_3 as a preservative. Samples were not agitated or exposed to the atmosphere for prolonged periods of time.

Iron

Samples were collected headspace free into polyethylene bottles provided by the analytical laboratory, capped tightly, and shipped daily to the analytical laboratory. The sample bottles from the laboratory included the preservative HNO_3 for a holding period of up to six months. All iron samples were analyzed using EPA Method 200.7 within the holding period of the preserved samples.

Magnesium

Samples were collected headspace free into polyethylene bottles provided by the analytical laboratory, capped tightly, and shipped daily to the analytical laboratory. The sample bottles from the laboratory included the preservative HNO_3 for a holding period of up to six months. All magnesium samples were analyzed using EPA Method 200.7 within the holding period of the preserved samples.

Manganese

Samples were collected headspace free into polyethylene bottles provided by the analytical laboratory, capped tightly, and shipped daily to the analytical laboratory. The sample bottles from the laboratory included the preservative HNO_3 for a holding period of up to six months. All manganese samples were analyzed using EPA Method 200.8 within the holding period of the preserved samples.

NDMA

Samples were collected headspace free in two one-litter bottles, each preserved with 1 milliliter thio (8%) provided by the analytical laboratory, capped tightly, and stored refrigerated. All NDMA samples were analyzed using EPA Method 1625 within the holding period of seven days of the preserved samples.

Nitrate

Samples were collected headspace free into polyethylene bottles provided by the analytical laboratory, capped tightly, and stored refrigerated. The bottles from the laboratory did not include a preservative. All nitrate samples were analyzed using EPA Method 300.0 within the holding period of 48 hours.

pH

Samples were collected and analyzed on-site immediately using SM 4500-H^+B, and the temperature at which the pH reading was made was recorded. Sample agitation and prolonged exposure to air were avoided. The pH probe was calibrated daily on-site using a three-point calibration method and standard solutions manufactured by Hach at 4,0, 7.0, and 10.0. The pH probe was stored in the appropriate solution defined in the instrument manual.

Silica (Dissolved)

Samples were collected headspace free into polyethylene bottles provided by the analytical laboratory, capped tightly, and shipped daily to the analytical laboratory. The sample bottles from the laboratory included the preservative HNO_3 for a holding period of up to six months. All silica samples were analyzed using EPA Method 200.7 within the holding period of the preserved samples.

Sulfate

Samples were collected headspace free into polyethylene bottles provided by the analytical laboratory, capped tightly, and shipped daily to the analytical laboratory. All sulfate samples were analyzed using EPA Method 300.0 within the 28-day holding period of the preserved samples.

TDS

Plastic sample bottles were used, as provided by the analytical laboratory. Analyses were made as soon as possible (within the seven-day holding period) due to impracticality of preserving samples, as specified in SM 2540. Samples were refrigerated until the time of analysis.

Temperature

Readings for temperature were conducted in accordance with Standard Method 2550. Raw water temperatures were obtained daily. The thermometer was a precision thermometer certified by the National Institute of Standards and Technology (NIST).

TSS

Plastic sample bottles were used, as provided by the analytical laboratory. Analyses were made as soon as possible (within the seven-day holding period) due to impracticality of preserving samples, as specified in SM 2540 D. Samples were refrigerated until the time of analysis.

Vanadium

Samples were collected headspace free into polyethylene bottles provided by the analytical laboratory, capped tightly, and shipped daily to the analytical laboratory. The sample bottles from the laboratory included the preservative HNO_3 for a holding period of up to six months. All vanadium samples were analyzed using EPA Method 200.8 within the holding period of the preserved samples.

Representativeness of Operational Parameters
As specified by the ETV protocol, representativeness for operational parameters entailed collecting a sufficient quantity of data during operation to be able to detect a change in operations. As specified by the ETV protocol, detecting a ±10 percent change in an operating parameter, such as pressure, was sufficient. Operational parameters including flow and pressure were recorded twice per day, which the ETV protocol specified as sufficient for tracking changes in operational conditions that exceed this 10 percent range.

Effluent Flow Rate
Effluent flow rate of the Basin Water System was verified daily using a calibrated container and stopwatch method to manually verify the flow rate. While no adjustments to the HMI flow rate display was possible, the manual "check" could verify if the HMI flow rate display was accurate.

3.12.3.2 Statistical analysis

Arsenic data developed from grab samples collected according to the Analytical Schedule in Task 4 of this test plan were analyzed for statistical uncertainty. The FTO calculated 95% confidence intervals for the arsenic data obtained during verification testing as described in the *EPA/NSF Protocol for Equipment Verification Testing for Arsenic Removal*.

The statistics developed were helpful in demonstrating the degree of reliability with which the water treatment equipment could attain quality goals under the treatment conditions tested. The results of the statistical analysis were used to determine if the performance of the equipment was equal to or better than that given in the statement of performance objectives.

3.12.3.3 Methodology for Measurement of Precision and Accuracy

Precision and Accuracy for Water Quality Parameters
Table 3-8 summarizes the methodology used for the measurement of precision and accuracy for each water quality analysis performed during verification testing. Arsenic speciation columns were QA/QC checked by NSF and were provided by NSF for the verification testing. The sampling location for each duplicate sample alternated from raw water, influent, and effluent. One duplicate was taken from each of the following: untreated brine, treated brine, and the solids from the waste brine.

Precision and Accuracy for Operational Parameters
The operational parameters in the ETV test included flow rates and pressures. Effluent flow rate was verified daily using a bucket test with calibrated containers and a stopwatch. The duration of the bucket test was 15 seconds.

Table 3-8. Methodology for Measurement of Precision and Accuracy

Parameter	Minimum Reporting Limit (MRL)	On-site Duplicate Frequency	Acceptable Precision	Accuracy
Arsenic (Total)[1] (report to nearest 1.0 µg/L)	1.0 µg/L	20 measurements per week in duplicate (32% of samples)	30%	See procedures of MWH Laboratories (see Table 3-10)
pH (report to nearest 0.1 pH unit)	0-14 pH units	7 measurements per week in duplicate (19% of samples)	10%	Daily 3-point calibration with certified pH buffers in range of measurements (4.0, 7.0 and 10.0)
Calcium (report to nearest 0.1 mg/L)	1.0 mg/L	4 measurements per week in duplicate (19% of samples)	30%	See procedures of MWH Laboratories (see Table 3-10)
Magnesium (report to nearest 0.1 mg/L)	0.1 mg/L	4 measurements per week in duplicate (19% of samples)	20%	See procedures of MWH Laboratories (see Table 3-10)
Chloride (report to nearest 0.1 mg/L)	1 mg/L	4 measurements per week in duplicate (19% of samples)	20%	See procedures of MWH Laboratories (see Table 3-10)
Free and Total Chlorine (report to nearest 0.1 mg/L)	1 mg/L	10 measurements per week in duplicate (12% of samples)	20%	Weekly verification using known standards at three concentration levels (see Appendix C)
Iron (report to nearest 0.5 mg/L)	0.2 mg/L	4 sample per week in duplicate (19% of samples)	30%	See procedures of MWH Laboratories (see Table 3-10)
Manganese (report to nearest 0.5 mg/L)	0.015 mg/L	4 sample per week in duplicate (19% of samples)	30%	See procedures of MWH Laboratories (see Table 3-10)
Sulfate (report to nearest 1 mg/L)	2 mg/L	4 sample per week in duplicate (19% of samples)	20%	See procedures of MWH Laboratories (see Table 3-10)
Nitrate (report to nearest 1 mg/L)	1 mg/L	4 sample per week in duplicate (19% of samples)	30%	See procedures of MWH Laboratories (see Table 3-10)
Vanadium (report to nearest 1 µg/L)	10 µg/L	20 sample per week in duplicate (32% of samples)	30%	See procedures of MWH Laboratories (see Table 3-10)
Dissolved Silica (report to nearest 0.1 mg/L)	0.05 mg/L	4 sample per week in duplicate (19% of samples)	30%	See procedures of MWH Laboratories (see Table 3-10)
Fluoride (report to nearest 0.1 mg/L)	0.1 mg/L	4 sample per week in duplicate (19% of samples)	20%	See procedures of MWH Laboratories (see Table 3-10)
Alkalinity (report to nearest 1 mg/L as $CaCO_3$)	2 mg/L	4 sample per week in duplicate (19% of samples)	30%	See procedures of MWH Laboratories (see Table 3-10)
Hardness[2] (report to nearest 1 mg/L as $CaCO_3$)	5 mg/L	4 sample per week in duplicate (19% of samples)	30%	See procedures of MWH Laboratories (see Table 3-10)

Table 3-8. Methodology for Measurement of Precision and Accuracy (continued)

Parameter	Minimum Reporting Limit (MRL)	On-site Duplicate Frequency	Acceptable Precision	Accuracy
TDS (report to nearest 1 mg/L)	10 mg/L	4 sample per week in duplicate (19% of samples)	30%	See procedures of MWH Laboratories (see Table 3-10)
TSS (report to nearest 1 mg/L)	10 mg/L	4 sample per week in duplicate (19% of samples)	30%	See procedures of MWH Laboratories (see Table 3-10)
NDMA[3] (report to nearest 1 ng/L)	2 ng/L	1 sample	30%	See procedures of MWH Laboratories (see Table 3-10)
Conductivity (report to nearest 0.1 µmho/cm)	4 µmho/cm	7 samples per week in duplicate (33% of samples)	10%	Daily calibration using known standards at three concentration levels. Acceptable accuracy was ±10%.

[1] As (III) and dissolved arsenic samples were prepared on-site using arsenic speciation procedures developed by Battelle for the EPA (Edwards et al.) (see Appendix B).

[2] Calculated using calcium and magnesium concentrations.

[3] A total of three samples for NDMA analysis were collected during the Initial Plant Characterization testing.

Method Blanks

The methodology for use of method blanks is summarized in Table 3-9.

Field Blanks

Field blanks were submitted with each set of samples submitted to MWH Laboratories for each parameter collected. One field blank was collected for each parameter submitted for analysis.

Table 3-9. Methodology for Use of Method Blanks

Method	Methodology for Blanks
Arsenic, TDS, alkalinity, calcium, magnesium, hardness, and other inorganic constituents for laboratory analysis	Blanks were used in accordance with the procedures of MWH Laboratories[1].
pH	Purchased certified pH buffers were used - no use of blanks.
Conductivity	No use of blanks.
Free and Total Chlorine	A reagent-grade ultra-pure water was kept in stock at the verification site for use as a blank prior to analyzing each free or total chlorine sample.

[1] See Table 3-10.

Spiked Samples

Spiked samples were utilized at MWH Laboratories as presented in Table 3-10. Spiked samples were not applicable for the analyses performed on-site at the treatment system for conductivity or pH, but were performed for total and free chlorine at a frequency of 10%.

Table 3-10. Laboratory Water Quality Analyses Indicators

Parameter	Laboratory Fortified Matrix (LFM), i.e., spike sample	LFM Duplicate	LFM Acceptance Limits (% Recovery)	Method Blank (MB)	MB Acceptance Limits	Lab Control Sample (LCS), i.e., standards	LCS Acceptance Limits
Total Arsenic	10% (1 per 10 samples)	10%	100 ±30	5% (1 per 20 samples or less)	<MRL[1]	5% (1 per 20 samples or less)	100 ±15
TDS	10%	10%	<5% RPD	5%	<MRL[1]	5%	100 ±15
Vanadium	10%	10%	100 ±30	5%	<MRL[1]	5%	100 ±15
Dissolved Silica	10%	10%	100 ±30	5%	<MRL[1]	5%	100 ±15
Iron	10%	10%	100 ±30	5%	<MRL[1]	5%	100 ±15
Calcium	10%	10%	100 ±30	5%	<MRL[1]	5%	100 ±15
Magnesium	10%	10%	100 ±30	5%	<MRL[1]	5%	100 ±15
Manganese	10%	10%	100 ±30	5%	<MRL[1]	5%	100 ±15
Sulfate	10%	10%	100 ±20	10%	<MRL[1]	10%	100 ±10
Alkalinity	10%	10%	100 ±30	5%	<MRL[1]	5%	100 ±15
Hardness	10%	10%	100 ±30	5%	<MRL[1]	5%	100 ±15
Chloride	10%	10%	100 ±20	10%	<MRL[1]	10%	100 ±10
Fluoride	10%	10%	100 ±30	5%	<MRL[1]	5%	100 ±15
Nitrate	10%	10%	100 ±30	5%	<MRL[1]	5%	100 ±15
NDMA	10%	10%	100 ±30	5%	<MRL[1]	5%	100 ±15

[1] MRL is the minimum reporting limit (See Table 3-8).

Proficiency Testing Samples

Proficiency testing (PT) samples were analyzed in accordance with the procedures of the MWH Laboratories, which performed the laboratory analyses. External PT samples (single blind) are analyzed approximately twice a year for each analysis for which the National Environmental Laboratory Accreditation Conference (NELAC) requires PT samples. An example of a recent MWH Laboratories PT is included in Appendix D. Additionally a laboratory control sample (typically second source) is analyzed with each analytical batch.

3.12.3.4 Completeness

Completeness refers to the number of valid, acceptable samples collected from a measurement process compared to the number of samples expected to be obtained. The completeness objective for data generated during the Verification Test was based on the number of samples collected and analyzed for each parameter and/or method. Table 3-11 illustrates the completeness objectives for performance parameter and/or method based on the sample frequency:

Table 3-11. Completeness Objective Based on Sample Frequency

Number of Samples Per Parameter and/or Method	Percent Completeness
0-10	80%
11-50	90%
>50	95%

3.12.4 Calculation of Indictors of Data Quality

Calculation of Precision

As specified in Standard Method 1030 C, precision is specified by the standard deviation of the results of replicate analyses. The overall precision of a study includes the random errors involved in sampling as well as the errors in sample preparation and analysis.

$$\text{Precision} = \text{Standard Deviation} = \sqrt{[\sum_{i=1}^{n} (\overline{x}_i - \overline{x})^2 \div (n - 1)]}$$

where: $\overline{x}$ = sample mean

$\overline{x}_i$ = ith data point in the data set

n = number of data points in the data set

Precision refers to the degree of mutual agreement among individual measurements and provides an estimate of random error. Analytical precision is a measure of how far an individual measurement may be from the mean of replicate measurements. The standard deviation and relative standard deviation recorded from sample analyses were recorded as a means to quantify sample precision. The percent relative standard deviation was calculated in the following manner:

$$\%\text{Relative Standard Deviation} = S(100)/X_{\text{average}}$$

where S = Standard Deviation

X_{average} = the arithmetic mean of the recovery values

For acceptable analytical precision under verification testing, the percent relative standard deviation for drinking water samples must be less than the acceptance limits, as indicated in Table 3-8 and Table 3-10. If the data generated during the ETV test did not meet the data quality objectives defined in the QA/QC section, additional testing and sampling was conducted.

Calculation of Accuracy

Accuracy is quantified as the percent recovery of a parameter in a sample to which a known quantity of that parameter was added. An example of an accuracy determination in this ETV was the analysis of an arsenic proficiency sample and comparison of the measured arsenic to the known level of arsenic in the sample.

$$\text{Accuracy} = \text{Percent Recovery} = 100 \times [1 - (X_{\text{known}} - X_{\text{measured}}) \div X_{\text{known}}]$$

where X_{known} = known concentration of measured parameter

X_{measured} = measured concentration of parameter

Statistical Uncertainty

For the water quality parameters monitored, 95% confidence intervals were calculated for data sets of eight values or more. The count, average, minimum, and maximum values were tabulated for all data sets. The following equation was used for confidence interval calculation:

$$\text{Confidence Interval} = \overline{X} \pm [t_{n-1,1-(\alpha/2)} \times (S/\sqrt{n})]$$

where:
$\overline{X}$ = sample mean
S = sample standard deviation
n = number of independent measurements included in the data set
t = Student's t distribution value with n-1 degrees of freedom
α = significance level, defined for 95 percent confidence as: 1 - 0.95 = 0.05

According to the 95% confidence interval approach, the α term is defined to have the value of 0.05, thus simplifying the equation for the 95% confidence interval in the following manner:

$$95\%\ \text{Confidence Interval} = \overline{X} \pm [t_{n-1,0.975} \times (S/\sqrt{n})]$$

With input of the analytical results for pertinent water quality parameters into the 95% confidence interval equation, the output appears as the sample mean value plus or minus the second term. The results of this statistical calculation are also presented as a range of values falling within the 95% confidence interval. For example, the result of the confidence interval calculation provides the following information: 520 +/- 38.4 mg/L, with a 95% confidence interval range described as (481.6, 558.4).

Calculation of Completeness

Completeness is defined as the following for all measurements:

$$\%C = (V/T) \times 100$$

where:
%C = percent completeness
V = number of measurements judged valid
T = total number of measurements

3.12.5 Corrective Action Plan

The corrective action plan followed during the ETV test for water quality parameters is summarized in Table 3-12.

Table 3-12. Corrective Action Plan

Parameter	Acceptance Criteria	Sequence of Steps for Corrective Action
Any Duplicate Analysis	See Tables 3-8 and 3-10	• Re-sampled duplicates. • Checked instrument calibration; recalibrated instrument.
Any Method Blank	See Tables 3-9 and 3-10	• Lab analyses: performed procedures specific to each analysis as determined by MWH Laboratories. • On-site analysis: performed procedures specific to on-site analyses.
Any Performance Evaluation (PE) or Proficiency Sample	Within recovery specified for each PE or proficiency sample	• Checked and verified all steps in sample collection and analysis. • Re-do PE or proficiency sampling and analysis.
pH and Conductivity	≤10% difference from previous day	• Checked for change in column influent source or supply. • Checked instrument calibration. • Recalibrated instrument.
Alkalinity, Hardness, Calcium, Magnesium, TDS, As (III), As (V), As(Total), Sulfate, Nitrate, Chloride, Fluoride, Iron, Manganese, Vanadium, Dissolved Silica, Free Chlorine and Total Chlorine	≤20% difference from previous reading	• Verified change in column influent source or supply.

3.13 Operation and Maintenance

The manufacturer's O&M documentation for the Basin Water System was reviewed by the project engineers and the verification plant operations staff prior to the verification testing. The O&M manual for the Basin Water System may be found in Appendix A. In addition, the following aspects of operability are addressed in Chapter 4:

- Fluctuation of flow rates and pressures through the IX unit – the time interval at which resetting is needed (i.e., how long could chemical feed pumps hold on a set value for the chemical feed rate?).
- Were devices present to aid the operator with flow control adjustment?
- Was chemical feed paced with raw water flow?
- Did the system have an indicator if sediment prefilter was changed ahead of scheduled quarterly maintenance?
- How successful was a SCADA system (i.e., complete automation and computer control) with data acquisition as a means of operating an arsenic and vanadium removal IX plant?

- How did one ensure that arsenic or vanadium had not broken through the column without actually making a continuous online arsenic measurement, which is impractical?
- How did the operator ensure that the regenerant brine had actually been fed to the spent resin column?
- What was the preferred means of measuring or estimating brine consumption?
- How many times could the brine be reused without treatment?
- How did one automate the precipitation of arsenic from the spent brine?
- Did the reuse of the brine cause any precipitation problems?
- How did a plant operator check on the condition and depth of the IX media?
- Was there any easily measured parameter, such as pH or conductivity, that would signal the breakthrough of arsenic from a column?
- How often was it necessary to reset the brine flow rate?

This report addresses the above questions. The issues of operability were dealt with in the portion of the reports written in response to Tasks 3 and 4 of the verification testing plan and may be found in Chapter 4.

Chapter 4
Results and Discussion

4.1 Introduction

Verification testing of the Basin Water System performed at the EVMWD Corydon Street Well in Lake Elsinore, California, occurred over a 54-day period that began on April 4, 2005, and concluded on May 28, 2005. The system ran continuously with the exception of 13 system shutdowns due to construction in the nearby area and electrical modifications to the site. Of the 13 shutdowns, three were considered major shutdowns (i.e., lasting eight hours or longer). These shutdowns occurred on April 7, May 12, and May 14, 2005.

Over the 54-day test period, the system was in operation and treating water for 48 days: 29 days for two Initial Plant Characterizations (Task 3), five days for data review between the two Initial Plant Characterizations and the Verification Test, and 14 days for the Verification Test (Task 4). Results and discussion of the operation of the Basin Water System, brine treatment efficiency (both BRA and BPU systems), finished water quality, and data management are presented in this chapter as the following six tasks:

Task 1: Selection and Characterization of the Raw Water
Task 2: Preparation, Coordination, and Start-Up
Task 3: Initial Plant Characterization
Task 4: Verification Testing
Task 5: Data Management
Task 6: Quality Assurance Project Plan

The field data (operational and water quality) were maintained in a field logbook per Section 3.11 (Task 5) and may be found in Appendix C. The corresponding off-site laboratory data may be found in Appendix D.

4.2 Task 1: Selection and Characterization of the Raw Water

The experimental objective, work plan, schedule, and evaluation criteria for Task 1 were previously presented in Section 3.7. Historical data were collected (see Table 4-1) and reviewed, and the site was determined to have appropriate conditions for the Basin Water System verification testing based on the operational parameters presented in Chapter 3 (see Table 3-2). The data provided in Table 4-1 is for informational purposes only to characterize the raw water quality and was not verified by NSF.

The average total arsenic, As (III), and As (V) concentrations in the raw water (based on the historical data available) are 17 μg/L, 16 μg/L, and 2.5 μg/L, respectively. The average historical vanadium level in the raw water was 102 μg/L.

Table 4-1. Historical Water Quality Data for Corydon Street Well (2004)

			Collection Date							
Parameters	Method	Units	3/25/04	4/22/04	5/20/04	6/17/04	7/22/04	Min	Max	Ave
Conductivity	Lab Meter	µmhos/cm	506	475	478	479	481	475	506	484
pH	SM 4500H+ B	pH Units	9.1	9.1	9.1	9.1	9.2	9.1	9.2	9.1
Alkalinity	SM 2320B	mg/L	91.0	89.2	86.1	84.6	87.6	84.6	91.0	87.7
Chloride	EPA 300.0	mg/L	77	72	75	72	74	72	77	74
Fluoride	SM 4500F C	mg/L	0.40	0.41	0.41	0.42	0.41	0.40	0.42	0.41
Nitrate	EPA 300.0	mg/L	6.3	1.4	1.4	1.4	1.4	1.4	6.3	2.4
Sulfate	EPA 300.0	mg/L	38	34	36	35	36	34	38	36
Calcium	EPA 200.7	mg/L	6.1	6.3	6.1	6.1	6.1	6.1	6.3	6.1
Hardness	SM 3120B	mg/L	19.0	19.4	18.8	18.8	18.6	18.6	19.4	18.9
Magnesium	EPA 200.7	mg/L	<0.10	0.89	0.87	0.86	0.83	<0.10	0.89	0.71
LSI	SM 2330B	None	0.36	0.48	0.45	0.44	0.55	0.36	0.55	0.46
Total As	EPA 200.8	µg/L	19	13	20	16	15	13	20	17
As (III)	EPA 200.8	µg/L	16	19	16	15	12.5	12.5	19	16
As (V)	EPA 200.8	µg/L	2.5	1.0	3.8	2.8	2.2	1.0	3.8	2.5
Iron	EPA 200.7	mg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Manganese	EPA 200.8	mg/L	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
Silica	EPA 200.7	mg/L	12	12	12	12	13	12	13	12
Vanadium	EPA 200.8	µg/L	93	110	98	120	89	89	120	102
TDS	SM 2540C	mg/L	300	290	300	280	290	280	300	292
TSS	EPA 160.2	mg/L	<10	<10	<10	<10	<10	<10	<10	<10

4.3 Task 2: Preparation, Coordination, and Start-Up

The experimental objectives, work plan, schedule, and evaluation criteria for Task 2 were previously presented in Section 3.8. Basin Water performed start-up activities on-site from March 3-April 4, 2005. There are no data to present from Task 2.

4.4 Task 3: Initial Plant Characterization

The experimental objectives, work plan, schedule, and evaluation criteria for Task 3 were previously presented in Section 3.9. Water quality data were collected on the raw water, influent water, and effluent water at the frequencies provided in Table 3-4.

There were two Initial Plant Characterizations conducted as part of the ETV at the direction of Basin Water. These are discussed in sections 4.4.1 and 4.4.2. The second Initial Plant Characterization was initiated based on the percent arsenic removals and arsenic breakthrough observed in the effluent of concentrations greater than 4 µg/L during the first Initial Plant Characterization.

The on-site and laboratory data for the two Initial Plant Characterizations are provided in this section. Twenty-four-hour composite samples were collected daily for total arsenic, vanadium, alkalinity, calcium, chloride, fluoride, total hardness, magnesium, nitrate, and sulfate. The 24-hour composite samples were analyzed twice per week for iron, manganese, dissolved silica, TDS, and TSS.

During the Initial Plant Characterization task, the system required salt, sodium hypochlorite, acid, and caustic. Discussion of operational data, including chemical and power consumption during the Initial Plant Characterization (Task 3) as well as the Verification Testing (Task 4) is provided in Section 4.5.4. A number of special studies were conducted on speciation of the arsenic concentration during both the Initial Plant Characterizations and the Verification Test; the results of these special tests are presented in Section 4.5.2.

4.4.1 Initial Plant Characterization No. 1

On April 4, 2005, the manufacturer turned the ETV site and IX system over to the FTO to characterize the raw water, influent water, and effluent water for a minimum of three complete exhaustion cycles of each IX vessel online over a period of approximately 19 days. During this 19-day period, 16 days were sampled for arsenic and vanadium. On one of the 19 days (April 7, 2005), the system was shutdown due to construction in the area. On two of the 19 days (April 18-19, 2005), the IX system was in operation but no samples were collected. During these two days, the site was not staffed while the available data were under review. In addition, other parameters were not sampled during the last three days while the FTO was waiting for laboratory results and notice to proceed with the Verification Test. The Initial Plant Characterization No. 1 concluded with the last 24-hour composite sample beginning on April 22, 2005, and collected on April 23, 2005. All composite sample data presented in the following figures and tables are shown as the ending date that the 24-hour composite was collected.

The IX system operating conditions were set at the flow rate, pressures, and regeneration rate determined during the start-up activities (March 3-April 4, 2005) by Basin Water. The total flow rate was targeted at approximately 37.5 gpm with four beds in operation at any time. The flow rate through each bed was uniform, giving a flow rate of approximately 9.38 gpm per vessel. The absorption capacity set point for the first Initial Plant Characterization was established at 1,100 BV.

The pressure and flow rate for the Basin Water system had very little variation throughout the characterization test. The average pressure drop across the system over the 19 days of the first characterization test was approximately 10.3 psi with an average effluent flow rate of 38.0 gpm. Operating data collected during the Initial Plant Characterization No. 1 are presented in Section 4.5.5 with the Verification Test data (Table 4-27).

4.4.1.1 Total Arsenic and Vanadium

The Initial Plant Characterization No. 1 did not meet the performance expectations of the manufacturer, because total arsenic breakthrough began to occur earlier than anticipated (i.e., prior to 1,100 BV). Total arsenic and vanadium data collected during Initial Plant Characterization No. 1 are presented in Figures 4-1 and 4-2, and the corresponding data are provided in Table 4-2. Due to a system shutdown on April 7, 2005, no composite samples were collected on April 8, 2005. In addition, no composite samples were collected on April 19-20, 2005, while the testing data were under review by NSF and the FTO.

The manufacturer's goal was for 95% of the total arsenic effluent water samples to have concentrations less than 4 µg/L and 95% of the vanadium samples to have concentrations less than 15 µg/L. On the sixth day of the first Initial Plant Characterization (April 11, 2005), the effluent total arsenic level was 4.5 µg/L. For the 16 days when samples were collected, eight of the 16 (50%) total arsenic samples were greater than 4 µg/L, while one of the 14 (7%) vanadium samples were greater than 15 µg/L. During the Initial Plant Characterization, the average raw, influent and effluent water total arsenic concentrations were 16 µg/L, 15 µg/L, and 4.7 µg/L, respectively. The vanadium concentrations were 109 µg/L, 111 µg/L, and 6.4 µg/L, respectively.

The vanadium data appear to have outlying data points for the raw and the influent water on April 5, 2005, and for the influent water on April 9, 2005. On these dates, data points indicate vanadium levels were below the detection limit (<3.0 µg/L) with higher levels of vanadium in the effluent. All other vanadium data points appear within the anticipated range for the analytical technology. The outlying data points are possibly due to labeling errors (either in the field or the laboratory) and are not included in the statistical analyses of the data.

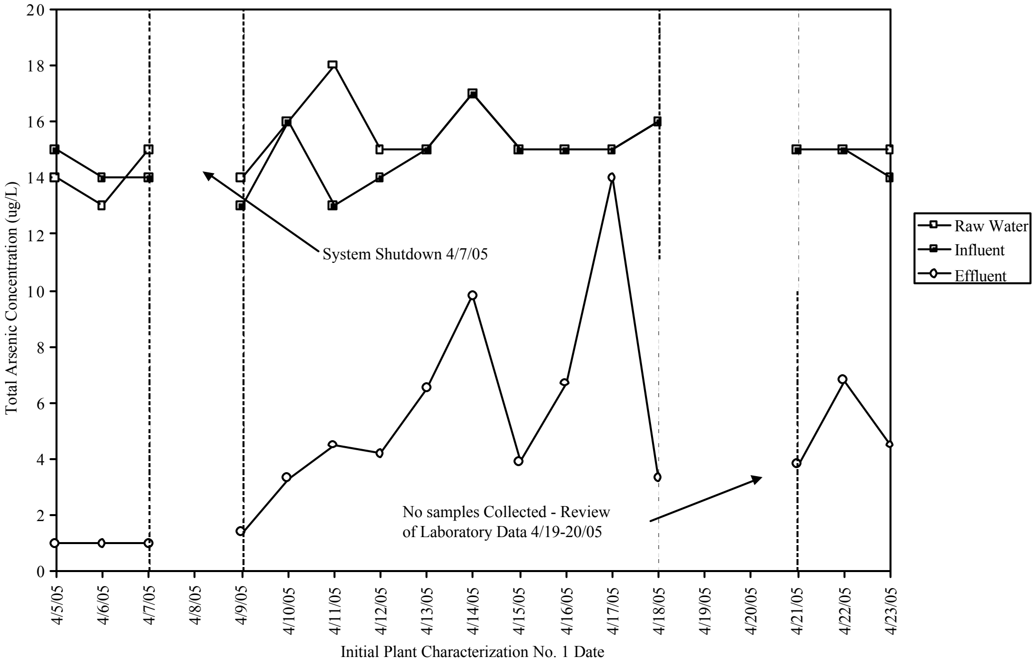


Figure 4-1: Temporal plot of Initial Plant Characterization No. 1 raw, influent, and effluent water total arsenic.

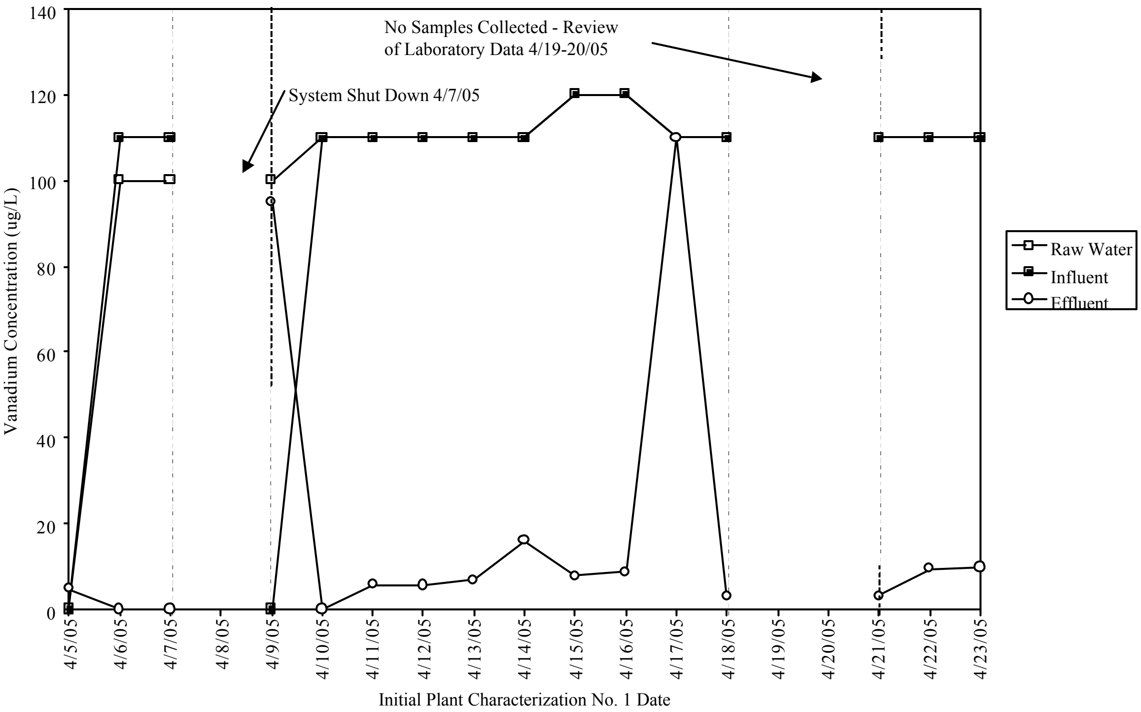


Figure 4-2: Temporal plot of Initial Plant Characterization No. 1 raw, influent, and effluent water vanadium.

Table 4-2. Initial Plant Characterization No. 1: Raw, Influent, and Effluent Water Total Arsenic and Vanadium

	Total Arsenic (µg/L)			Vanadium (µg/L)		
Date	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water
4/5/05	14	15	<1.0	<3.0[1]	<3.0[1]	4.8
4/6/05	18	19	<1.0	100	110	<3.0
4/7/05	15	14	1.0	100	110	<3.0
4/8/05	NA	NA	NA	NA	NA	NA
4/9/05	14	13	1.4	100	<3.0[1]	95[1]
4/10/05	16	16	3.3	110	110	<3.0
4/11/05	18	13	4.5	110	110	5.7
4/12/05	15	14	4.2	110	110	5.6
4/13/05	15	15	6.5	110	110	6.9
4/14/05	17	17	9.8	110	110	16
4/15/05	15	15	3.9	120	120	7.8
4/16/05	15	15	6.7	120	120	8.7
4/17/05	15	15	14	110	110	110[1]
4/18/05	16	16	3.3	110	110	3.1
4/19/05	NA	NA	NA	NA	NA	NA
4/20/05	NA	NA	NA	NA	NA	NA
4/21/05	16	15	3.8	110	110	3.2
4/22/05	15	15	6.8	110	110	9.5
4/23/05	15	14	4.5	110	110	9.8
Average	16	15	4.7	109	111	6.4
Minimum	14	13	<1.0	100	110	<3.0
Maximum	18	19	14	120	120	16
Number of Samples	16	16	16	15	14	14
Standard Deviation	1.2	1.5	3.5	5.9	3.6	3.7
95% Confidence Interval	(15-16)	(15-15)	(4.2-5.3)	(108-110)	(111-112)	(5.7-7.2)

[1] Data are considered aberrant and are not included in the statistical analysis.

NA = Not Available.

4.4.1.2 Inorganic Constituents

In addition to the target parameters (total arsenic and vanadium), raw, influent, and effluent water samples were collected daily for alkalinity, calcium, chloride, fluoride, magnesium, sulfate, nitrate, and total hardness. Samples were collected twice weekly for dissolved silica, TDS, TSS, iron, and manganese.

Daily 24-Hour Composite Inorganic Parameters

The daily 24-hour composite inorganic parameters collected during the Initial Plant Characterization No. 1 are presented in Figures 4-3 through Figure 4-10 with the corresponding data provided in Table 4-3. The results of the daily 24-hour composite samples for inorganic parameters indicated the treatment system removed very low levels of inorganic constituents from the raw water, including on average 11% alkalinity and 28% nitrate. Sulfate concentrations were reduced to less than the detection limit. However, in the case of chloride, the treatment system contributed 35 to 59% more chloride than observed in the raw water.

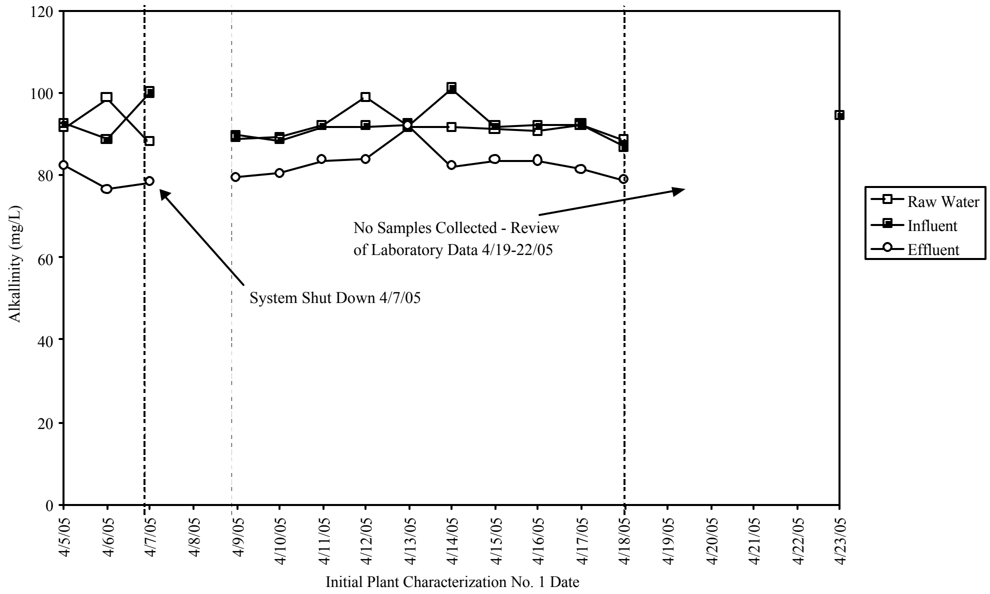


Figure 4-3: Temporal plot of Initial Plant Characterization No. 1 of daily raw, influent, and effluent water alkalinity.

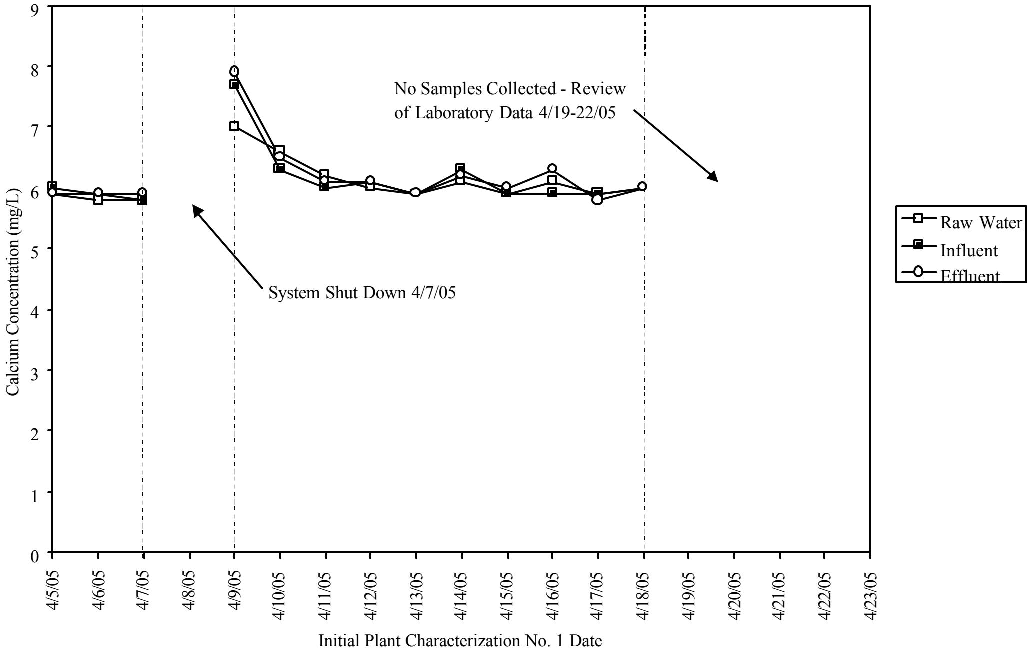


Figure 4-4: Temporal plot of Initial Plant Characterization No. 1 of daily raw, influent, and effluent water calcium.

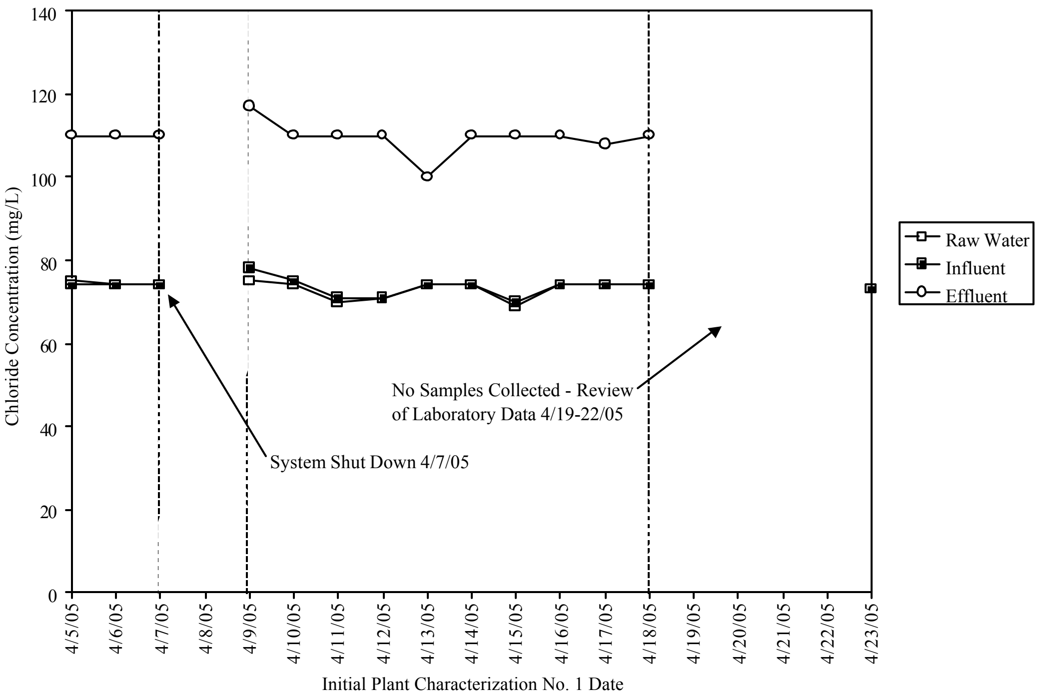


Figure 4-5: Temporal plot of Initial Plant Characterization No. 1 of daily raw, influent, and effluent water chloride.

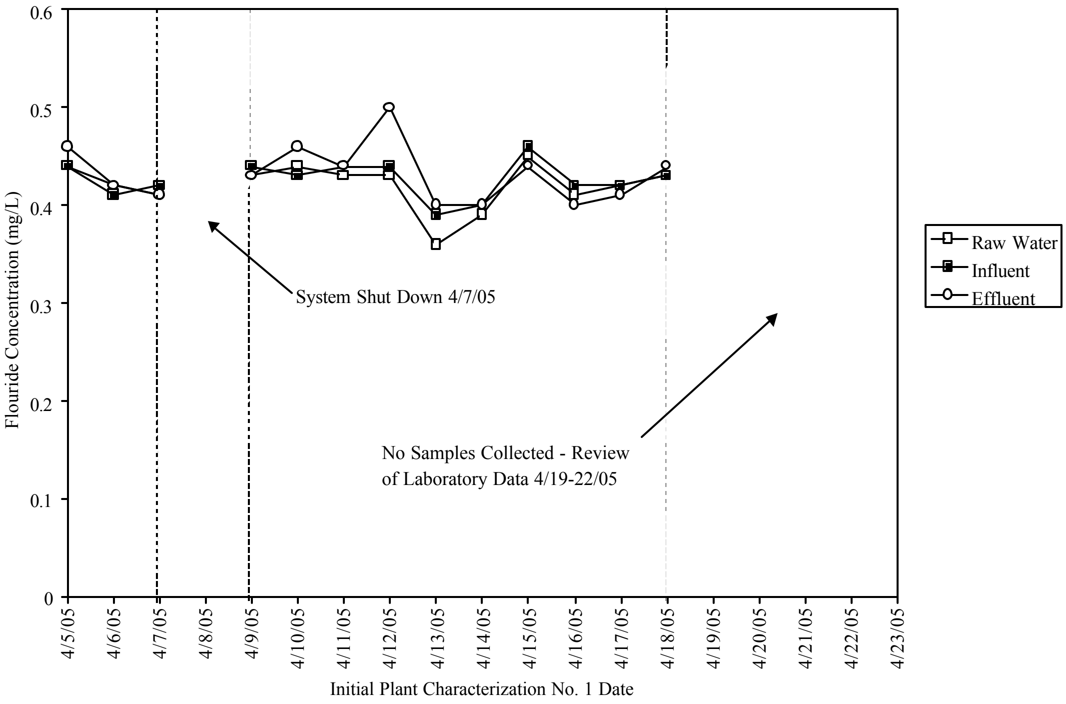


Figure 4-6: Temporal plot of Initial Plant Characterization No. 1 of daily raw, influent, and effluent water fluoride.

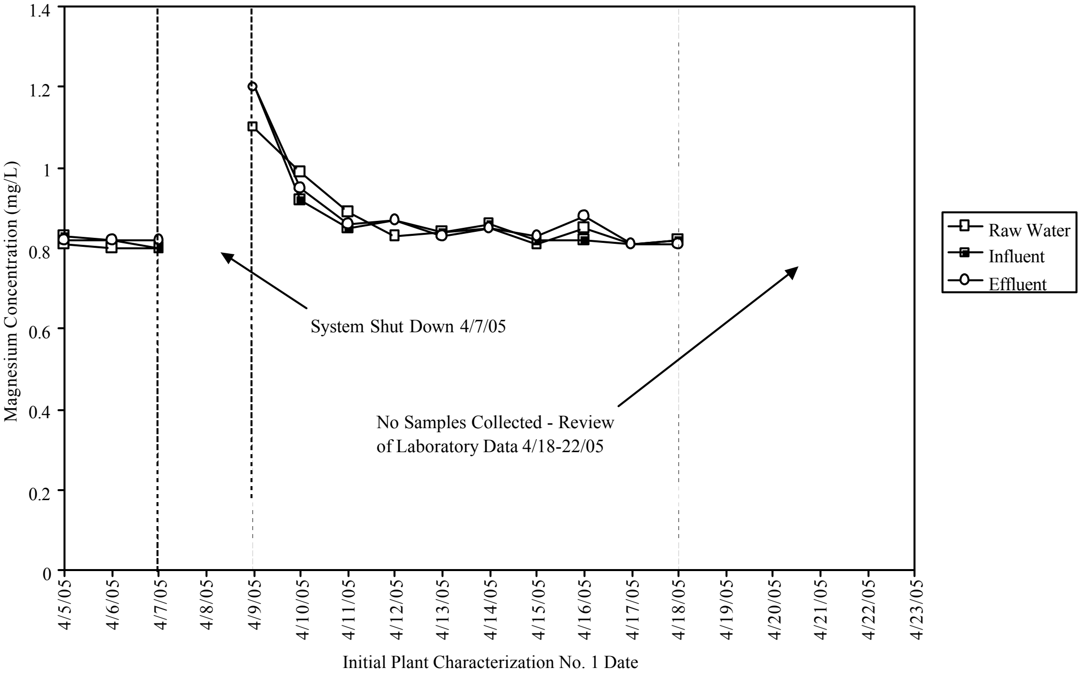


Figure 4-7: Temporal plot of Initial Plant Characterization No. 1 of daily raw, influent, and effluent water magnesium.

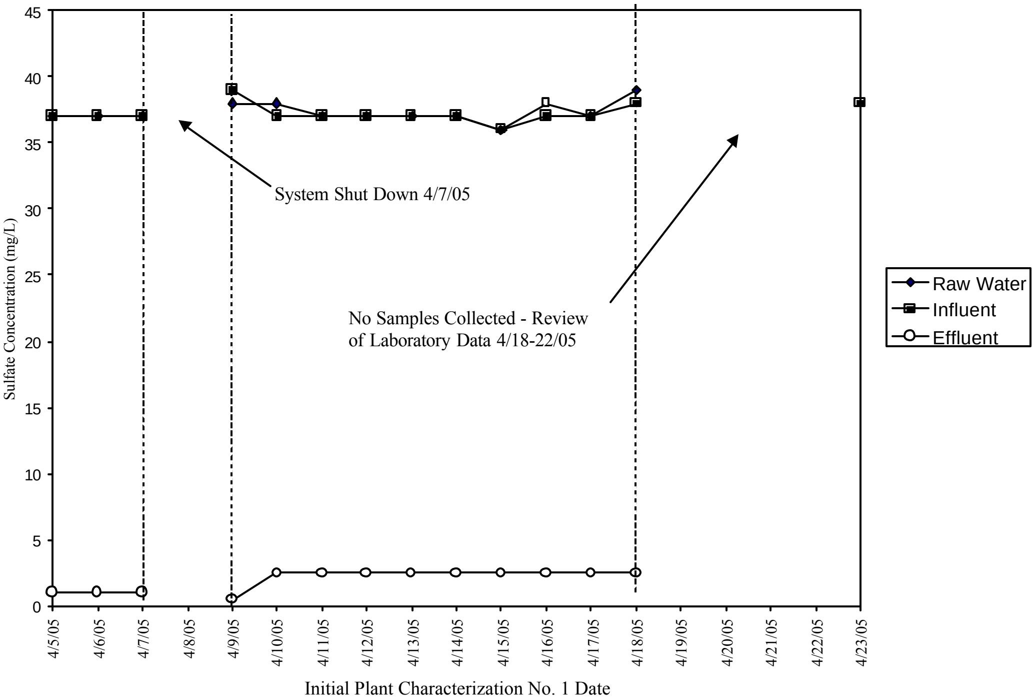


Figure 4-8: Temporal plot of Initial Plant Characterization No. 1 of daily raw, influent, and effluent water sulfate.

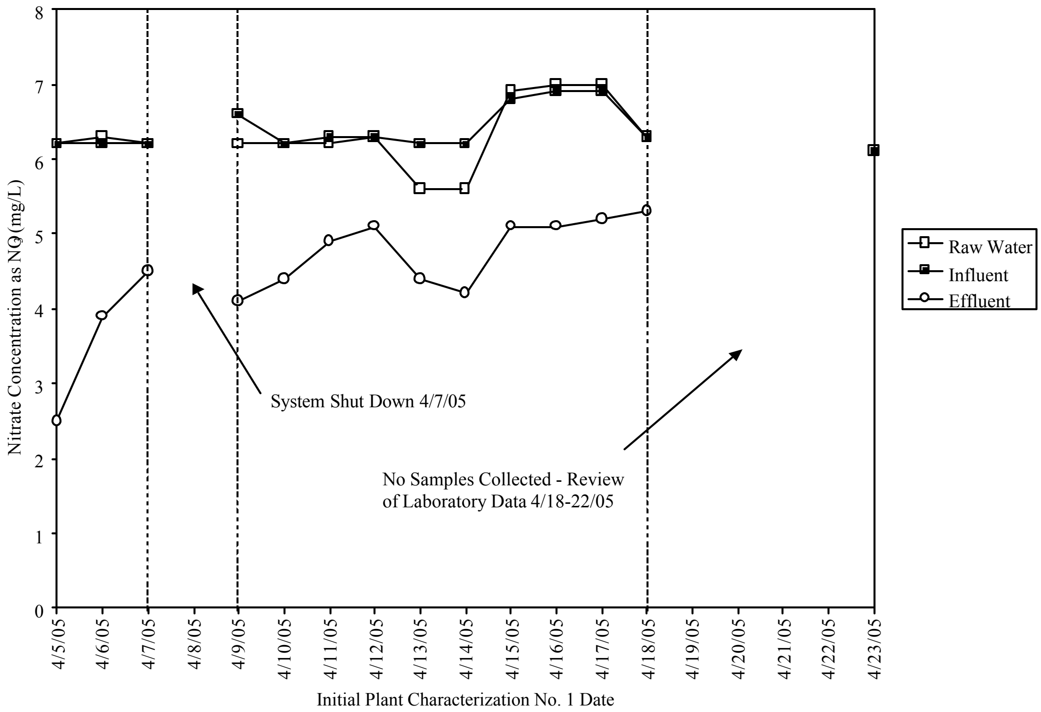


Figure 4-9: Temporal plot of Initial Plant Characterization No. 1 of daily raw, influent, and effluent water nitrate.

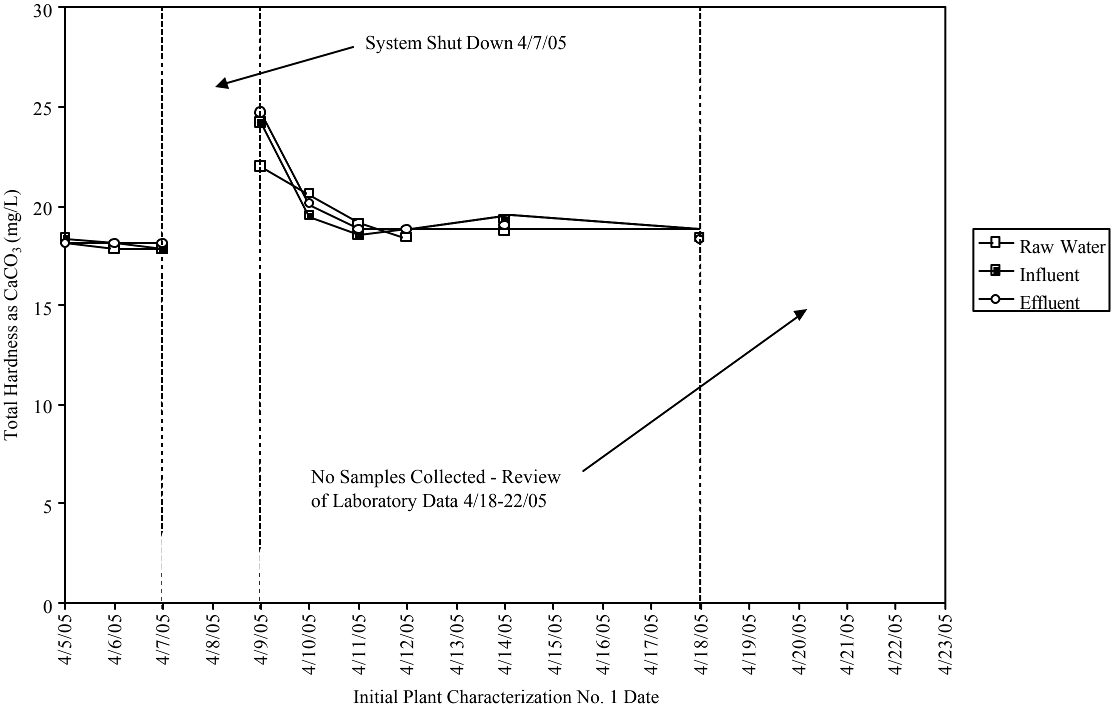


Figure 4-10: Temporal plot of Initial Plant Characterization No. 1 of daily raw, influent, and effluent water total hardness.

Table 4-3. Initial Plant Characterization No. 1 Daily Raw, Influent, and Effluent Water Alkalinity, Calcium, Chloride, Fluoride, Magnesium, Sulfate, Nitrate, and Hardness

	Alkalinity as $CaCO_3$ (mg/L)			Calcium (mg/L)		
Date	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water
4/5/05	91.4	92.5	82.3	5.9	6.0	5.9
4/6/05	98.6	88.6	76.6	5.8	5.9	5.9
4/7/05	88.0	100	78.2	5.8	5.8	5.9
4/8/05	NA	NA	NA	NA	NA	NA
4/9/05	88.9	89.7	79.5	7.0	7.7	7.9
4/10/05	89.2	88.5	80.4	6.6	6.3	6.5
4/11/05	92.0	91.8	83.7	6.2	6.0	6.1
4/12/05	98.8	91.9	83.8	6.0	6.1	6.1
4/13/05	91.7	92.2	91.8	5.9	5.9	5.9
4/14/05	91.5	101	82.2	6.1	6.3	6.2
4/15/05	91.0	91.9	83.6	5.9	5.9	6.0
4/16/05	90.8	92.0	83.5	6.1	5.9	6.3
4/17/05	92.0	92.2	81.3	5.9	5.9	5.8
4/18/05	88.5	86.9	78.7	6.0	6.0	6.0
4/19/05	NA	NA	NA	NA	NA	NA
4/20/05	NA	NA	NA	NA	NA	NA
4/21/05	NA	NA	NA	NA	NA	NA
4/22/05	NA	NA	NA	NA	NA	NA
4/23/05	NA	94.5	NA	NA	NA	NA
Average	91.7	92.4	82.0	6.1	6.1	6.2
Minimum	88.0	86.9	76.6	5.8	5.8	5.8
Maximum	98.8	101	91.8	7.0	7.7	7.9
Number of Samples	13	14	13	13	13	13
Standard Deviation	3.39	3.97	3.77	0.35	0.50	0.55
95% Confidence Interval	(91.0-92.4)	(91.6-93.2)	(81.2-82.8)	(6.0-6.2)	(6.0-6.2)	(6.1-6.3)

	Chloride (mg/L)			Fluoride (mg/L)		
Date	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water
4/5/05	75	74	110	0.44	0.44	0.46
4/6/05	74	74	110	0.42	0.41	0.42
4/7/05	74	74	110	0.41	0.42	0.41
4/8/05	NA	NA	NA	NA	NA	NA
4/9/05	75	78	117	0.43	0.44	0.43
4/10/05	74	75	110	0.44	0.43	0.46
4/11/05	70	71	110	0.43	0.44	0.44
4/12/05	71	71	110	0.43	0.44	0.50
4/13/05	74	74	100	0.36	0.39	0.40
4/14/05	74	74	110	0.39	0.40	0.40
4/15/05	69	70	110	0.45	0.46	0.44
4/16/05	74	74	110	0.41	0.42	0.40
4/17/05	74	74	108	0.42	0.42	0.41
4/18/05	74	74	110	0.43	0.43	0.44
4/19/05	NA	NA	NA	NA	NA	NA
4/20/05	NA	NA	NA	NA	NA	NA
4/21/05	NA	NA	NA	NA	NA	NA
4/22/05	NA	NA	NA	NA	NA	NA
4/23/05	NA	73	NA	NA	NA	NA
Average	73	74	110	0.42	0.43	0.43
Minimum	69	70	100	0.36	0.39	0.40
Maximum	75	78	117	0.45	0.46	0.50
Number of Samples	13	14	13	13	13	13
Standard Deviation	1.9	1.9	3.5	0.02	0.02	0.03
95% Confidence Interval	(73-74)	(73-74)	(109-110)	(0.41-0.43)	(0.42-0.43)	(0.43-0.44)

Table 4-3. Initial Plant Characterization No. 1 Daily Raw, Influent, and Effluent Water Alkalinity, Calcium, Chloride, Fluoride, Magnesium, Sulfate, Nitrate and Hardness (continued)

	Magnesium (mg/L)			Sulfate (mg/L)		
Date	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water[1]
4/5/05	0.81	0.83	0.82	37	37	<1.0
4/6/05	0.80	0.82	0.82	37	37	<1.0
4/7/05	0.80	0.80	0.82	37	37	<1.0
4/8/05	NA	NA	NA	NA	NA	NA
4/9/05	1.1	1.2	1.2	38	39	<0.50
4/10/05	0.99	0.92	0.95	38	37	<2.5
4/11/05	0.89	0.85	0.86	37	37	<2.5
4/12/05	0.83	0.87	0.87	37	37	<2.5
4/13/05	0.84	0.84	0.83	37	37	<2.5
4/14/05	0.85	0.86	0.85	37	37	<2.5
4/15/05	0.81	0.82	0.83	36	36	<2.5
4/16/05	0.85	0.82	0.88	38	37	<2.5
4/17/05	0.81	0.81	0.81	37	37	<2.5
4/18/05	0.82	0.82	0.81	39	38	<2.5
4/19/05	NA	NA	NA	NA	NA	NA
4/20/05	NA	NA	NA	NA	NA	NA
4/21/05	NA	NA	NA	NA	NA	NA
4/22/05	NA	NA	NA	NA	NA	NA
4/23/05	NA	NA	NA	NA	38	NA
Average	0.86	0.87	0.87	37	37	<2.5
Minimum	0.80	0.80	0.81	36	36	<0.050
Maximum	1.1	1.2	1.2	39	39	<2.5
Number of Samples	13	13	13	13	14	13
Standard Deviation	0.09	0.11	0.11	0.75	0.70	NA
95% Confidence Interval	(0.84-0.88)	(0.84-0.89)	(0.85-0.90)	(37-37)	(37-37)	NA

	Nitrate (mg/L)			Total Hardness as $CaCO_3$ (mg/L)		
Date	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water
4/5/05	6.2	6.2	2.5	18.1	18.4	18.1
4/6/05	6.3	6.2	3.9	17.8	18.1	18.1
4/7/05	6.2	6.2	4.5	17.8	17.8	18.1
4/8/05	NA	NA	NA	NA	NA	NA
4/9/05	6.2	6.6	4.1	22.0	24.2	24.7
4/10/05	6.2	6.2	4.4	20.6	19.5	20.1
4/11/05	6.2	6.3	4.9	19.1	18.5	18.8
4/12/05	6.3	6.3	5.1	18.4	18.8	18.8
4/13/05	5.6	6.2	4.4	NA	NA	NA
4/14/05	5.6	6.2	4.2	18.7	19.3	19.0
4/15/05	6.9	6.8	5.1	NA	NA	NA
4/16/05	7.0	6.9	5.1	NA	NA	NA
4/17/05	7.0	6.9	5.2	NA	NA	NA
4/18/05	6.3	6.3	5.3	18.4	18.4	18.3
4/19/05	NA	NA	NA	NA	NA	NA
4/20/05	NA	NA	NA	NA	NA	NA
4/21/05	NA	NA	NA	NA	NA	NA
4/22/05	NA	NA	NA	NA	NA	NA
4/23/05	NA	6.1	NA	NA	NA	NA

Table 4-3. Initial Plant Characterization No. 1 Daily Raw, Influent, and Effluent Water Alkalinity, Calcium, Chloride, Fluoride, Magnesium, Sulfate, Nitrate and Hardness (continued)

	Nitrate (mg/L)			Total Hardness as $CaCO_3$ (mg/L)		
	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water
Average	6.3	6.4	4.5	19.0	19.2	19.3
Minimum	5.6	6.1	2.5	17.8	17.8	18.1
Maximum	7.0	6.9	5.3	22.0	24.2	24.7
Number of Samples	13	14	13	9	9	9
Standard Deviation	0.44	0.29	0.76	1.42	1.94	2.11
95% Confidence Interval	(6.2-6.4)	(6.3-6.4)	(4.4-4.7)	(18.5-19.5)	(18.6-19.9)	(18.6-20.1)

[1] Detection limits for sulfate in effluent water are raised by the dilution factor. A dilution was made because of either a matrix interference such as high TDS, a high concentration of sulfate to bring calibration of the instrument in range, and/or a high concentration of another parameter detected in the same analysis.

NA = Not Available.

24-Hour Twice Weekly Composite Inorganic Parameters

Since the historical water quality data indicated low to non-detect concentrations of silica, TDS, TSS, iron, and manganese, these parameters were collected at a reduced frequency of twice per week. These data are presented in Table 4-4. The sample collection times were targeted to collect one sample towards the beginning and one sample towards the end of a regeneration cycle. There was little to no change in the inorganic parameters between the raw water and effluent water, with the exception of an average 4% reduction in TDS. All raw, influent, and effluent water samples for TSS, iron, and manganese were below the detection limit (10 mg/L, 0.020 mg/L, and 2.0 µg/L, respectively).

Table 4-4. Initial Plant Characterization No. 1 Twice Weekly Parameters for Raw, Influent, and Effluent Water Silica, TDS, TSS, Iron, and Manganese

	Dissolved Silica (mg/L)			TDS (mg/L)		
Date	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water
4/5/05	12	12	13	300	290	280
4/11/05	12	12	13	390	300	280
4/12/05	12	11	12	290	290	280
4/14/05	11	11	12	280	290	280
Average	12	12	13	290	293	280
Minimum	11	11	12	280	290	280
Maximum	12	12	13	300	300	280
Number of Samples	4	4	4	4	4	4

	TSS (mg/L)			Iron (mg/L)		
Date	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water
4/5/05	<10	<10	<10	<0.020	<0.020	<0.020
4/11/05	<10	<10	<10	<0.020	<0.020	<0.020
4/12/05	<10	<10	<10	<0.020	<0.020	<0.020
4/14/05	<10	<10	<10	<0.020	<0.020	<0.020
Average	<10	<10	<10	<0.020	<0.020	<0.020
Minimum	<10	<10	<10	<0.020	<0.020	<0.020
Maximum	<10	<10	<10	<0.020	<0.020	<0.020
Number of Samples	4	4	4	4	4	4

	Manganese (µg/L)		
Date	Raw Water	Influent Water	Effluent Water
4/5/05	<2.0	<2.0	<2.0
4/11/05	<2.0	<2.0	<2.0
4/12/05	<2.0	<2.0	<2.0
4/14/05	<2.0	<2.0	<2.0
Average	<2.0	<2.0	<2.0
Minimum	<2.0	<2.0	<2.0
Maximum	<2.0	<2.0	<2.0
Number of Samples	4	4	4

4.4.1.3 On-Site Laboratory Testing

On-site laboratory testing during Initial Plant Characterization No. 1 included pH, conductivity, free and total chlorine, and temperature, as presented in Tables 4-5 through 4-7. There was very little difference between the influent and effluent water for pH, conductivity, and temperature. The average chlorine residuals in the influent water were 0.10 mg/L and 0.12 mg/L for free and total chlorine, respectively. These measurements were within the target range of 0.10-0.50 mg/L.

Table 4-5: Initial Plant Characterization No. 1 pH and Conductivity

	pH			Conductivity (µmho/cm)		
Date	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water
4/4/05	9.04	9.02	8.65	564	535	543
4/5/05	9.25	9.21	8.64	537	529	541
4/6/05	9.17	9.19	8.89	503	515	508
4/8/05	8.92	8.86	9.16	595	596	581
4/9/05	9.21	9.21	8.99	530	528	542
4/10/05	9.13	9.18	9.05	527	526	529
4/11/05	8.95	9.05	9.10	512	537	543
4/12/05	8.98	9.04	9.01	527	527	547
4/13/05	9.08	9.11	9.10	521	524	523
4/14/05	8.97	9.11	9.05	533	520	522
4/15/05	9.17	9.16	8.70	540	543	556
4/16/05	9.11	9.17	8.69	533	517	532
4/17/05	9.16	9.16	8.76	520	520	530
4/18/05	9.12	9.14	9.04	526	527	530
4/20/05	9.11	9.10	9.02	541	545	550
4/21/05	9.11	9.10	9.07	540	545	551
4/22/05	9.24	9.23	9.21	536	534	525
Median/Average[1]	9.11	9.14	9.02	534	533	538
Minimum	8.92	8.86	8.64	503	515	508
Maximum	9.25	9.23	9.21	595	596	581
Number of Samples	17	17	17	17	17	17
Standard Deviation	NA	NA	NA	20.5	18.6	16.6
95% Confidence Interval	NA	NA	NA	(531-538)	(531-536)	(536-541)

[1] The median values of the pH analyses are presented. The averages were calculated for the conductivity analyses.

NA = Not Applicable.

Table 4-6. Initial Plant Characterization No. 1 Free and Total Chlorine

	Free Chlorine (mg/L)			Total Chlorine (mg/L)		
Date	Raw	Influent	Effluent	Raw	Influent	Effluent
4/4/05	0.00	0.04	0.02	0.00	0.08	0.00
4/5/05	0.04	0.14	0.02	0.04	0.17	0.14
4/6/05	0.01	0.02	0.06	0.02	0.10	0.03
4/8/05	0.02	0.10	0.03	0.03	0.10	0.01
4/9/05	0.03	0.10	0.02	0.01	0.13	0.03
4/10/05	0.01	0.12	0.02	0.01	0.13	0.02
4/11/05	0.03	0.04	0.01	0.03	0.02	0.02
4/12/05	0.01	0.04	0.02	0.02	0.04	NA
4/13/05	0.01	0.04	0.03	0.01	0.06	0.04
4/14/05	0.01	0.09	0.00	0.01	0.10	0.02
4/15/05	0.04	0.21	0.01	0.03	0.22	0.01
4/16/05	0.02	0.10	0.01	0.01	0.12	0.01
4/17/05	0.05	0.13	0.03	0.04	0.15	0.01
4/18/05	0.02	0.12	0.03	0.01	0.11	0.01
4/20/05	NA	0.20	NA	NA	0.21	NA
4/20/05	0.04	0.08	0.01	0.01	0.09	0.02
4/21/05	0.01	0.17	0.01	0.01	0.15	0.02
4/22/05	0.01	0.14	0.01	0.00	0.17	0.01
Average	0.02	0.10	0.02	0.02	0.12	0.03
Minimum	0.00	0.02	0.00	0.00	0.02	0.00
Maximum	0.05	0.21	0.06	0.04	0.22	0.14
Number of Samples	17	18	17	17	18	16
Standard Deviation	0.01	0.06	0.01	0.01	0.05	0.03
95% Confidence Interval	(0.02-0.02)	(0.10-0.11)	(0.02-0.02)	(0.02-0.02)	(0.11-0.13)	(0.02-0.03)

NA = Not Available.

Table 4-7. Initial Plant Characterization No. 1 On-Site Temperature

	Temperature (°C)		
Date	Raw Water	Influent Water	Effluent Water
4/15/05	27.0	27.0	27.0
4/16/05	27.0	27.0	27.0
4/17/05	27.0	27.0	27.0
4/18/05	25.0	25.0	25.0
4/19/05	NA	NA	NA
4/20/05	26.0	26.0	26.0
4/21/05	26.0	26.0	26.0
4/22/05	26.0	26.0	26.0
4/27/05	26.0	26.0	26.0
Average	26.3	26.3	26.3
Minimum	25.0	25.0	25.0
Maximum	27.0	27.0	27.0
Number of Samples	8	8	8
Standard Deviation	0.71	0.71	0.71
95% Confidence Interval	(26.0-26.5)	(26.0-26.5)	(26.0-26.5)

NA = Not Available.

4.4.1.4 Mass Balance of Total Arsenic

A mass balance through the Basin Water System for total arsenic was conducted for the Initial Plant Characterization No. 1. The mass balance was calculated based on the influent water, effluent water, and waste brine arsenic concentrations to ensure the arsenic was being removed from the resin during the regeneration cycles.

The equation used for the mass balance was previously presented in Equation 3-1: $V_iC_i = V_eC_e + V_bC_b$. In this equation, V_iC_i represents the influent water volume to the IX treatment system multiplied by the influent water total arsenic concentration. V_eC_e represents the effluent water volume from the IX treatment system multiplied by the effluent water total arsenic concentration. Lastly, V_bC_b represents the brine volume from the IX treatment system multiplied by the brine total arsenic concentration. In total, six data sets were collected to calculate the mass balance during the Initial Plant Characterization No. 1. The results are provided in Table 4-8. The influent and effluent total arsenic values for each of the dates presented in Table 4-8 were previously presented in Table 4-2. The brine total arsenic values were presented in Table 4-8 as C_b (brine concentration).

Throughout most of the Initial Plant Characterization, the total arsenic mass balance had a 1 to 45% difference between $V_eC_e + V_bC_b$ and V_iC_i, with the exception of the samples collected on April 4, 2005. On that date, the arsenic concentration in the brine was 0.36 g arsenic as compared to 1.31 to 2.22 g arsenic in the remaining five samples collected. The lower arsenic level in the waste brine led to an 82% difference in the mass balance. When this data point is included in the summed six data sets, the percent difference is 28%, as compared to a 17% difference when this data point is not included in the summed mass balance.

Table 4-8: Initial Plant Characterization No. 1 Arsenic Mass Balance

Date	VeCe	Cb	VbCb	ViCi	% Difference	Comments
4/4/05	0.21 g As	930 ug/L	0.36 g As	3.08 g As	-82	
4/5/05	0.19 g As	5300 ug/L	2.22 g As	2.63 g As	-8	
4/6/05	0.21 g As	3600 ug/L	1.48 g As	2.92 g As	-42	
4/20/05	0.83 g As	3200 ug/L	1.31 g As	3.33 g As	-35	
4/21/05	1.39 g As	4300 ug/L	1.78 g As	3.08 g As	+3	
4/22/05	0.92 g As	5100 ug/L	1.99 g As	2.88 g As	+1	
Total	3.75 g As	22,430 ug/L	9.15 g As	17.9 g As	-28	Includes all data points.
Total	3.55 g As	21,500 ug/L	8.78 g As	14.84 g As	-17	4/4/05 not included in total.

4.4.2 Initial Plant Characterization No. 2

Data from Initial Plant Characterization No. 1 were reviewed and discussed with the manufacturer. While the arsenic results showed that the treated water met the drinking water standard (≤10 µg/L), the results did not meet the manufacturer's goal of 95% of the total arsenic effluent water samples having a concentration less than 4 µg/L. The manufacturer returned to the site to make modifications to operational set points, and a Second Initial Plant Characterization was performed. Initial Plant Characterization No. 2 was conducted from April 29-May 9, 2005, for a total of two complete exhaustion and regeneration cycles (10 days). There were no major shutdowns during the second Initial Plant Characterization.

The only change made to the operation of the IX system was to adjust the regeneration rate from 1,100 BV to 850 BV. It was expected that increasing the frequency of regeneration (i.e., lowering the loading rate on the resin) should result in a lower total arsenic concentration in the blended water from the four operating vessels. All other operating parameters, such as pressure and flow rates, were held constant at the same conditions used during the first characterization. The target total flow rate was 37.5 gpm, with approximately 9.38 gpm per vessel.

The pressure and flow rate for the Basin Water system had very little variation throughout the second Initial Plant Characterization. The average pressure drop across the system over the 10 days of Initial Plant Characterization No. 2 was approximately 10.3 psi with an average effluent flow rate of 37.0 gpm from the treatment system. Operating data collected during the Initial Plant Characterization No. 2 are presented in Section 4.5.5 with the Verification Test data (Table 4-27).

Total arsenic and vanadium were sampled daily from 24-hour composite samples. Sulfate, nitrate, chloride, calcium, magnesium, alkalinity, fluoride, TDS, TSS, iron, manganese, hardness, and dissolved silica were collected once during the Initial Plant Characterization No. 2 on May 4, 2005, from the 24-hour composite sample. The sampling frequency for the non critical parameters was decreased during the Initial Plant Characterization No. 2 from that of the Initial Plant Characterization No. 1, because the purpose of repeating the Initial Plant Characterization test was to the evaluate the arsenic and vanadium breakthrough with a reduction of BVs.

4.4.2.1 Total Arsenic and Vanadium

The Initial Plant Characterization No. 2 met the performance expectations of the manufacturer. Total arsenic was consistently less than 4 µg/L, and vanadium was consistently less than 15 µg/L. The effluent water total arsenic was consistently below the detection limit of 1.0 µg/L until the last day of the Initial Plant Characterization, when the effluent water total arsenic was 1.6 µg/L. The vanadium concentration was less than the detection limit of 3.0 µg/L throughout the second Initial Plant Characterization. Total arsenic and vanadium data collected during Initial Plant Characterization No. 2 are presented in Figures 4-11 and 4-12, with the corresponding data presented in Table 4-9.

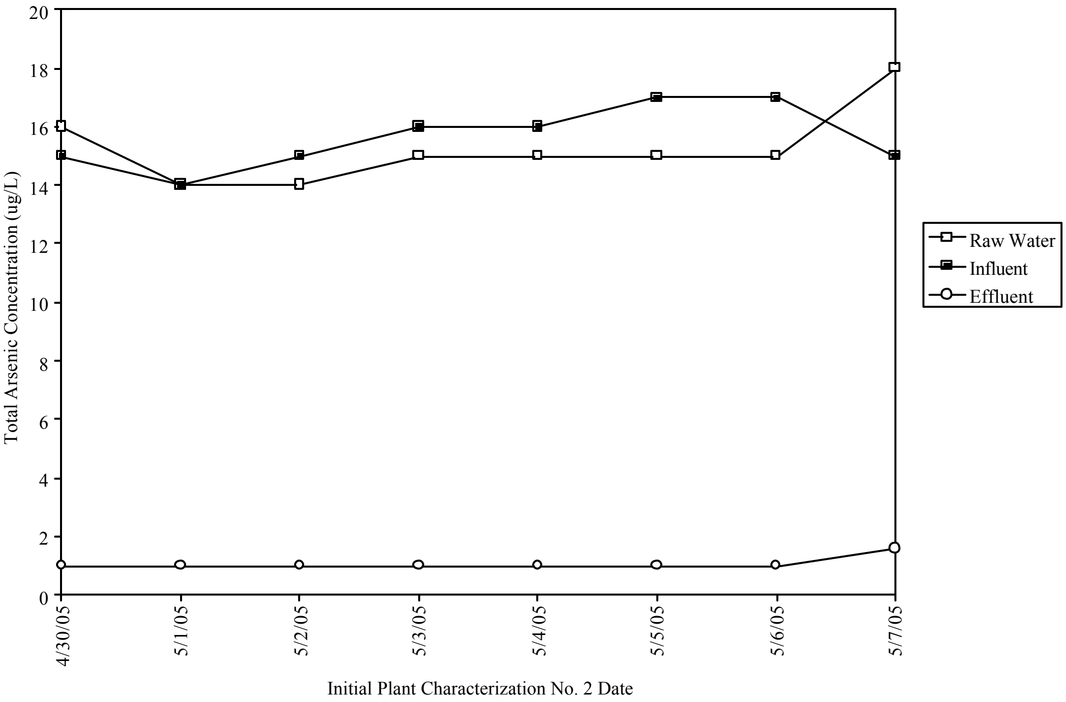


Figure 4-11: Temporal plot of Initial Plant Characterization No. 2 raw, influent, and effluent water total arsenic.

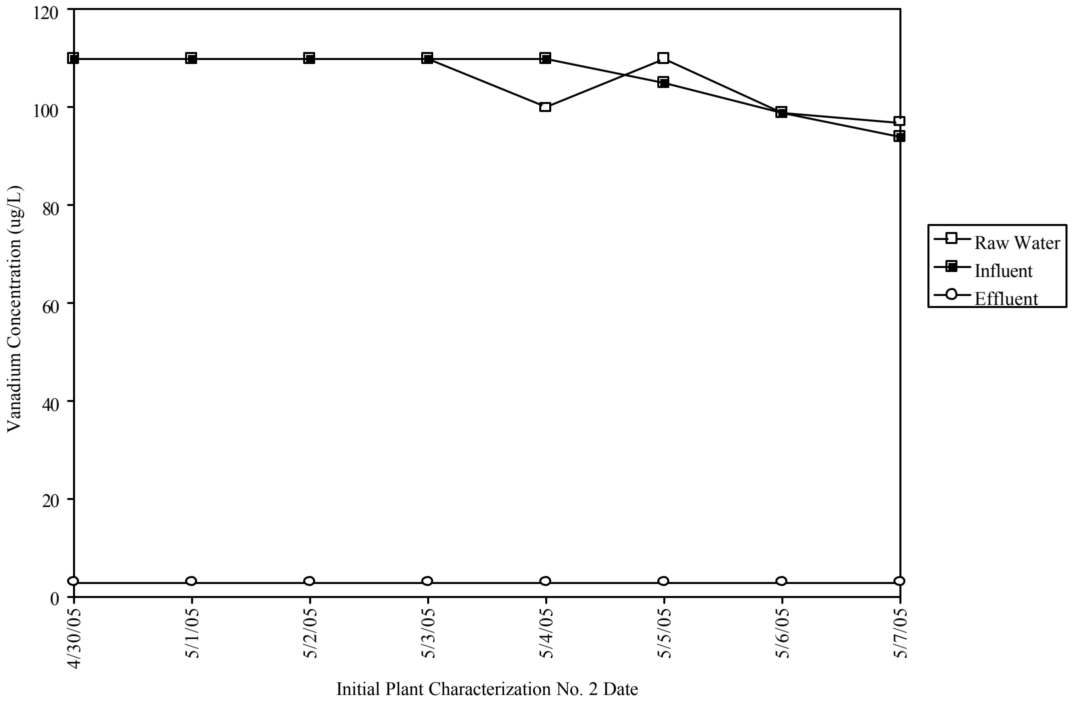


Figure 4-12: Temporal plot of Initial Plant Characterization No. 2 raw, influent, and effluent water vanadium.

Table 4-9. Initial Plant Characterization No. 2 Raw Water, Influent, and Effluent Water Total Arsenic and Vanadium

	Total Arsenic (µg/L)			Vanadium (µg/L)		
Date	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water
4/30/05	16	15	<1.0	110	110	<3.0
5/1/05	14	14	<1.0	110	110	<3.0
5/2/05	14	15	<1.0	110	110	<3.0
5/3/05	15	16	<1.0	110	110	<3.0
5/4/05	15	16	<1.0	100	110	<3.0
5/5/05	15	17	<1.0	110	105	<3.0
5/6/05	15	17	<1.0	99	99	<3.0
5/7/05	18	15	1.6	97	94	<3.0
5/8/05	NA	NA	NA	NA	NA	NA
5/9/05	NA	NA	NA	NA	NA	NA
Average	15	16	1.1	106	106	<3.0
Minimum	14	14	<1.0	97	94	<3.0
Maximum	18	17	1.6	110	110	<3.0
Number of Samples	8	8	8	8	8	8
Standard Deviation	1.3	1.1	0.21	5.9	6.3	NC
95% Confidence Interval	(15-16)	(15-16)	(<1.0-1.2)	(103-108)	(103-109)	NC

NA = Not Available.

NC = Not Calculated.

4.4.2.2 Inorganic Constituents

In addition to the target parameters (total arsenic and vanadium), raw, influent, and effluent water samples were collected for sulfate, nitrate, chloride, calcium, magnesium, alkalinity, fluoride, TDS, TSS, iron, manganese, hardness, and dissolved silica. The inorganic constituents collected during the Initial Plant Characterization No. 2 are provided in Table 4-10. There was little to no change in the inorganic parameters between the raw water and effluent water, with the exception of a 67% increase in chloride. Nitrate and fluoride were removed by 48 and 22%, respectively, and sulfate was removed to below the detection limit of 2.5 mg/L. Reducing the BVs from 1,100 (Initial Plant Characterization No. 1) to 850 BVs (Initial Plant Characterization No. 2) had little impact on the general water quality other than arsenic and vanadium removal.

Table 4-10. May 5, 2005 Initial Plant Characterization No. 2 Raw, Influent, and Effluent Water Inorganic Constituents

Parameter	Units	Raw Water	Influent Water	Effluent Water
Sulfate	mg/L	37	38	<2.5
Nitrate as NO_3	mg/L	6.1	6.2	3.2
Chloride	mg/L	72	73	120
Calcium	mg/L	5.8	6.3	5.8
Magnesium	mg/L	0.79	0.86	0.79
Alkalinity	mg/L	93.6	72.8	94.4
Fluoride	mg/L	0.63	0.56	0.49
TDS	mg/L	300	290	310
TSS	mg/L	<10	<10	<10
Iron	mg/L	<0.020	<0.020	<0.020
Manganese	ug/L	<2.0	<2.0	<2.0
Hardness	mg/L	17.7	19.3	17.7
Silica	mg/L	12	12	12

4.4.2.3 On-Site Laboratory Testing

On-site laboratory testing during Initial Plant Characterization No. 2 included pH, conductivity, free and total chlorine, and temperature, as presented in Tables 4-11 through 4-13. As with the previous characterization test, there was very little difference between the raw and effluent water for conductivity and temperature. There was a slight reduction in pH between both the raw and influent water compared to the effluent water. The average influent chlorine residuals were 0.21 mg/L and 0.25 mg/L for free and total chlorine, respectively. These averages were a little higher than the previous characterization test, but still within the target range of 0.10-0.50 mg/L.

Table 4-11. Initial Plant Characterization No. 2 pH and Conductivity

	pH			Conductivity		
Date	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water
4/29/05	9.08	9.10	8.13	545	536	561
4/30/05	9.10	9.09	7.85	545	546	560
5/1/05	9.08	9.12	8.82	538	540	544
5/2/05	9.08	9.10	8.26	533	530	544
5/3/05	9.07	9.06	8.71	528	534	540
5/4/05	9.09	9.09	8.67	532	534	541
5/5/05	8.64	8.33	7.83	508	527	551
5/6/05	9.13	9.11	8.72	548	543	549
5/7/05	9.09	9.10	8.03	537	532	558
5/8/05	9.09	9.08	8.58	518	518	528
5/9/05	9.09	9.10	7.93	534	534	541
Median/Average[1]	9.09	9.10	8.26	533	534	547
Minimum	8.64	8.33	7.83	508	518	528
Maximum	9.13	9.12	8.82	548	546	561
Number of Samples	11	11	11	11	11	11
Standard Deviation	NC	NC	NC	12.0	7.68	10.0
95% Confidence Interval	NC	NC	NC	(530-536)	(532-536)	(544-550)

[1] The median values of the pH analyses are presented. The averages were calculated for the conductivity analyses.

NC = Not Calculated.

Table 4-12. Initial Plant Characterization No. 2 Free and Total Chlorine

	Free Chlorine (mg/L)			Total Chlorine (mg/L)		
Date	Raw	Influent	Effluent	Raw	Influent	Effluent
4/29/05	0.01	0.15	0.02	0.00	0.17	0.01
4/30/05	0.01	0.15	0.05	0.02	0.19	0.02
5/1/05	0.01	0.26	0.01	0.01	0.30	0.01
5/2/05	0.04	0.26	0.02	0.00	0.27	0.02
5/3/05	0.01	0.23	0.01	0.01	0.29	0.02
5/4/05	0.01	0.24	0.01	0.01	0.30	0.02
5/5/05	0.01	0.28	0.01	0.01	0.28	0.02
5/6/05	0.01	0.14	0.00	0.00	0.25	0.00
5/7/05	0.00	0.24	0.00	0.01	0.27	0.02
5/8/05	0.01	0.20	0.00	0.01	0.23	0.02
5/9/05	0.00	0.21	0.00	0.01	0.23	0.00
Average	0.01	0.21	0.01	0.01	0.25	0.01
Minimum	0.00	0.14	0.00	0.00	0.17	0.00
Maximum	0.04	0.28	0.05	0.02	0.30	0.02
Number of Samples	11	11	11	11	11	11
Standard Deviation	0.01	0.05	0.01	0.01	0.04	0.01
95% Confidence Interval	(0.01-0.01)	(0.20-0.23)	(0.01-0.02)	(0.01-0.01)	(0.24-0.26)	(0.01-0.02)

Table 4-13. Initial Plant Characterization No. 2 Temperature

	Temperature (°C)		
Date	Raw Water	Influent Water	Effluent Water
4/29/05	26.0	26.0	26.0
4/30/05	26.0	26.0	26.0
5/1/05	26.0	26.0	26.0
5/2/05	26.5	26.5	26.5
5/3/05	27.0	27.0	27.0
5/4/05	26.1	26.1	26.5
5/5/05	26.7	26.6	26.7
5/6/05	26.0	26.0	26.0
5/7/05	26.0	26.0	26.0
5/8/05	26.5	26.5	26.5
5/9/05	26.0	26.0	26.0
Average	26.3	26.2	26.3
Minimum	26.0	26.0	26.0
Maximum	27.0	27.0	27.0
Number of Samples	11	11	11
Standard Deviation	0.36	0.35	0.36
95% Confidence Interval	(26.2-26.3)	(26.2-26.3)	(26.2-26.4)

4.4.2.4 Mass Balance of Total Arsenic

A mass balance through the Basin Water System for total arsenic was conducted for the Initial Plant Characterization No. 2 using equation 3-1, previously presented and discussed in Section 4.4.1.4. In total, three data sets were collected during the Initial Plant Characterization No. 2. The results are provided in Table 4-14. The total arsenic influent and effluent values used for the calculation of the mass balance were previously presented in Table 4-9. The total arsenic brine concentrations (C_b) are presented in Table 4-14.

When mass balance data were summed (see totals in Table 4-14), the percent difference in the influent volume and concentration (V_iC_i) was 13% higher than the combined effluent and brine volume and concentration (V_eC_e and V_bC_b, respectively).

Table 4-14. Initial Plant Characterization No. 2 Arsenic Mass Balance

Date	VeCe	Cb	VbCb	ViCi	% Difference
5/4/05	0.20 g As	4600 ug/L	1.78 g As	3.21 g As	-38
5/5/05	0.19 g As	5400 ug/L	4.40 g As	3.32 g As	+38
5/6/05	0.20 g As	4300 ug/L	1.85 g As	3.34 g As	-39
Total	0.59 g As	14,300 ug/L	8.02 g As	9.86 g As	-13

4.5 Task 4: Verification Testing

The verification testing period for the Basin Water System was May 12-28, 2005. The experimental objectives, work plan, analytical schedule, and evaluation criteria were previously presented in Section 3.10. The objectives of the Verification Test were:

- Determine the raw, influent and effluent water quality (see Sections 4.5.1-4.5.2);
- Observe and record the plant operating conditions and equipment performance (see Section 4.5.4) with additional O&M observations discussed in Section 4.8; and
- Characterize the effectiveness of the brine treatment processes (BRA and BPU) (see Section 4.5.5).

4.5.1 Raw, Influent, and Effluent Water Quality

Water quality samples were collected throughout the Verification Test and analyzed by the MWH Laboratories. Daily 24-hour composite samples of the raw, influent, and effluent water were checked for the following parameters: total arsenic, vanadium, sulfate, nitrate, chloride, calcium, magnesium, alkalinity, fluoride, TDS, TSS, iron, manganese, hardness, and dissolved silica. Grab samples were collected four times per day for total arsenic and vanadium on the effluent water. Twice weekly parameters during the Verification Test included on-site speciation of arsenic (As [III] and As [V]) on the raw, influent, and effluent water.

Daily on-site testing included free and total chlorine (twice daily), conductivity (continuous online monitoring and daily grab samples), and turbidity (continuous online monitoring and daily grab samples). The results of the analytical data collected during the Verification Test are presented in this section. Results of the waste generated during the Verification Test (BRA and BPU waste) are presented in Section 4.5.5.

There were two short-term system shutdowns between May 12-15, 2005. These shutdowns were not due to problems with the Basin Water System, but rather caused by construction in the area of the Corydon Street Well. The shutdowns occurred on the following dates and for the noted approximate durations:

- May 12, 2005 at 4:11 PM until May 13, 2005 at 3:53 PM, approximately 24 hours; and
- May 14, 2005 at 7:07 PM until May 15, 2005 at 10:01 AM, approximately 15 hours.

4.5.1.1 Verification Testing Daily Laboratory Data

Daily 24-hour composite samples were collected from the raw, influent, and effluent water and analyzed for total arsenic and vanadium. Grab samples were also collected for total arsenic and vanadium to spot-check the effluent water quality and to collect one grab sample per day of the raw and influent water. Daily analyses were also conducted on the 24-hour composite samples from the raw, influent, and effluent water for alkalinity, chloride, fluoride, nitrate, dissolved silica, sulfate, TDS, TSS, calcium, iron, total hardness, magnesium, and manganese. The following sections present the data from these analyses.

Daily 24-Hour Composite Total Arsenic and Vanadium

The 24-hour composite data shown in Figures 4-13 and 4-14 and presented in Table 4-15 indicate that the Basin Water System removed total arsenic and vanadium in the raw water to non-detectable levels in each of the sample sets collected. The detection limits were 1.0 μg/L and 3.0 μg/L for total arsenic and vanadium, respectively.

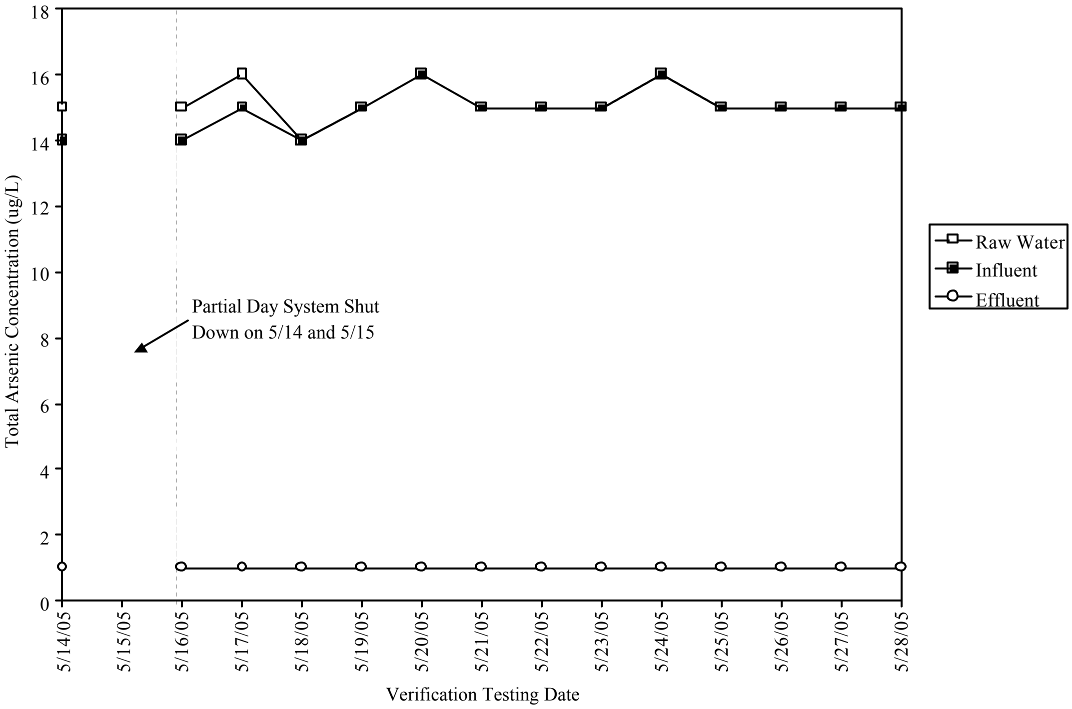


Figure 4-13: Temporal plot of verification testing 24-hour composite raw, influent, and effluent water total arsenic.

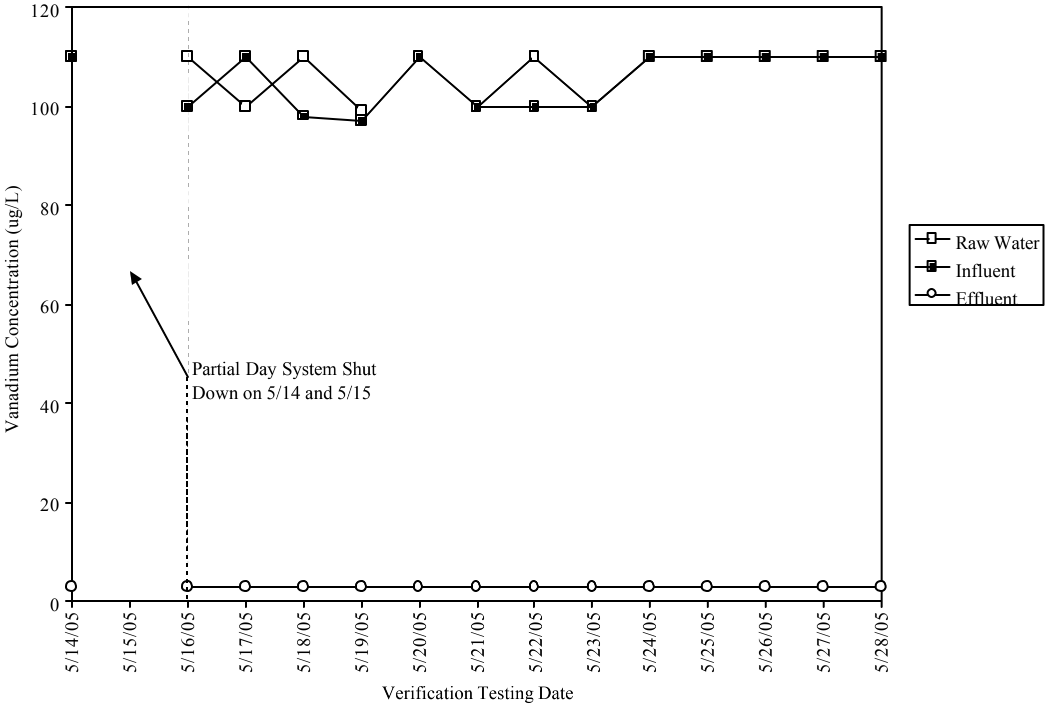


Figure 4-14: Temporal plot of verification testing 24-hour composite raw, influent, and effluent water vanadium.

Table 4-15. Verification Testing 24-Hour Composite Raw, Influent, and Effluent Water Total Arsenic and Vanadium

Date	Total Arsenic (µg/L) Raw Water	Total Arsenic (µg/L) Influent Water	Total Arsenic (µg/L) Effluent Water	Vanadium (µg/L) Raw Water	Vanadium (µg/L) Influent Water	Vanadium (µg/L) Effluent Water
5/14/2005	15	14	<1.0	110	110	<3.0
5/15/2005	NA	NA	NA	NA	NA	NA
5/16/2005	15	14	<1.0	110	100	<3.0
5/17/2005	16	15	<1.0	100	110	<3.0
5/18/2005	14	14	<1.0	110	98	<3.0
5/19/2005	15	15	<1.0	99	97	<3.0
5/20/2005	<1.0[1]	16	<1.0	<3.0[1]	110	<3.0
5/21/2005	15	15	<1.0	100	100	<3.0
5/22/2005	15	15	<1.0	110	100	<3.0
5/23/2005	15	15	<1.0	100	100	<3.0
5/24/2005	16	16	<1.0	110	110	<3.0
5/25/2005	15	15	<1.0	110	110	<3.0
5/26/2005	15	15	<1.0	110	110	<3.0
5/27/2005	15	15	<1.0	110	110	<3.0
5/28/2005	15	15	<1.0	110	110	<3.0
Average	15	15	<1.0	107	105	<3.0
Minimum	14	14	<1.0	99	97	<3.0
Maximum	16	16	<1.0	110	110	<3.0
Number of Samples	13	14	14	13	14	14
Standard Deviation	0.49	0.62	NC	4.9	5.6	NC
95% Confidence Interval	(15-15)	(15-15)	NC	(106-108)	(104-106)	NC

[1] Considered aberrant data point and removed from statistical analysis.
NA = Not Available.
NC = Not Calculated.

Grab Samples of Total Arsenic and Vanadium

Grab samples were collected once a day from the raw and influent water lines and four times per day from the effluent water line to analyze for total arsenic and vanadium. The grab sample data are presented in Figures 4-15 and 4-16, with the corresponding data in Table 4-16. The results of the grab sample analyses show that all total arsenic samples collected from the system effluent were at non-detectable levels (<1.0 µg/L) with the exception of one grab sample collected on May 26, 2005 with a result of 1.1 µg/L. All vanadium grab samples collected during the Verification Test were at non-detectable levels (<3.0 µg/L) with the exception of one sample collected on May 26, 2005 with a result of 4.9 µg/L.

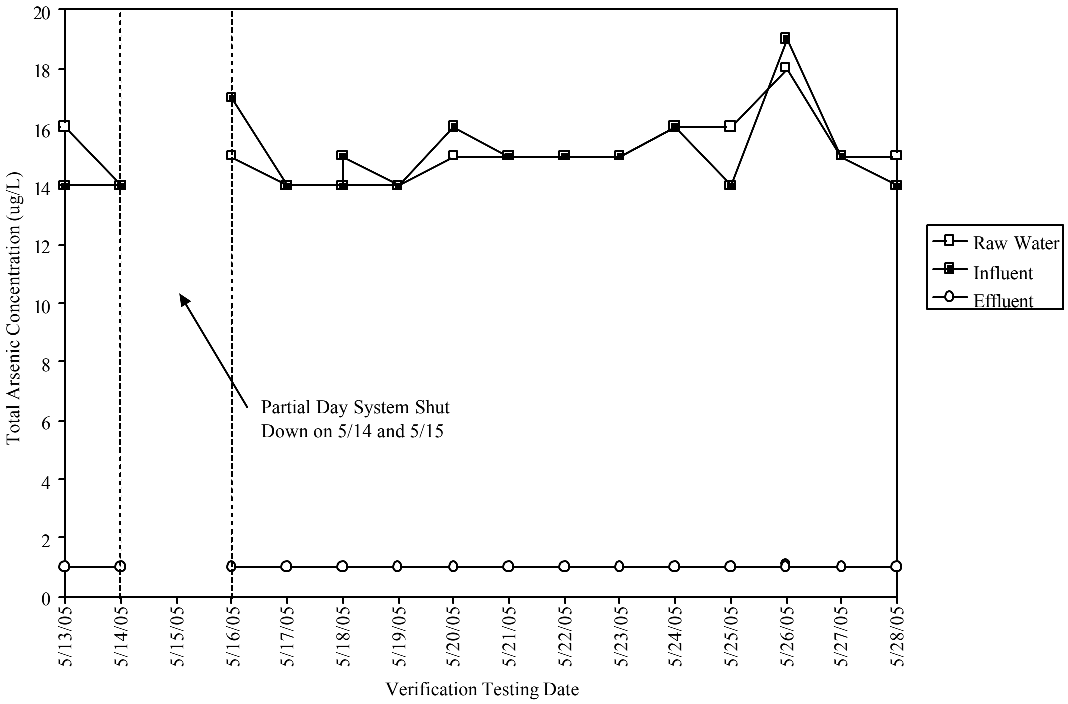


Figure 4-15: Temporal plot of verification testing raw, influent, and effluent water grab sample total arsenic.

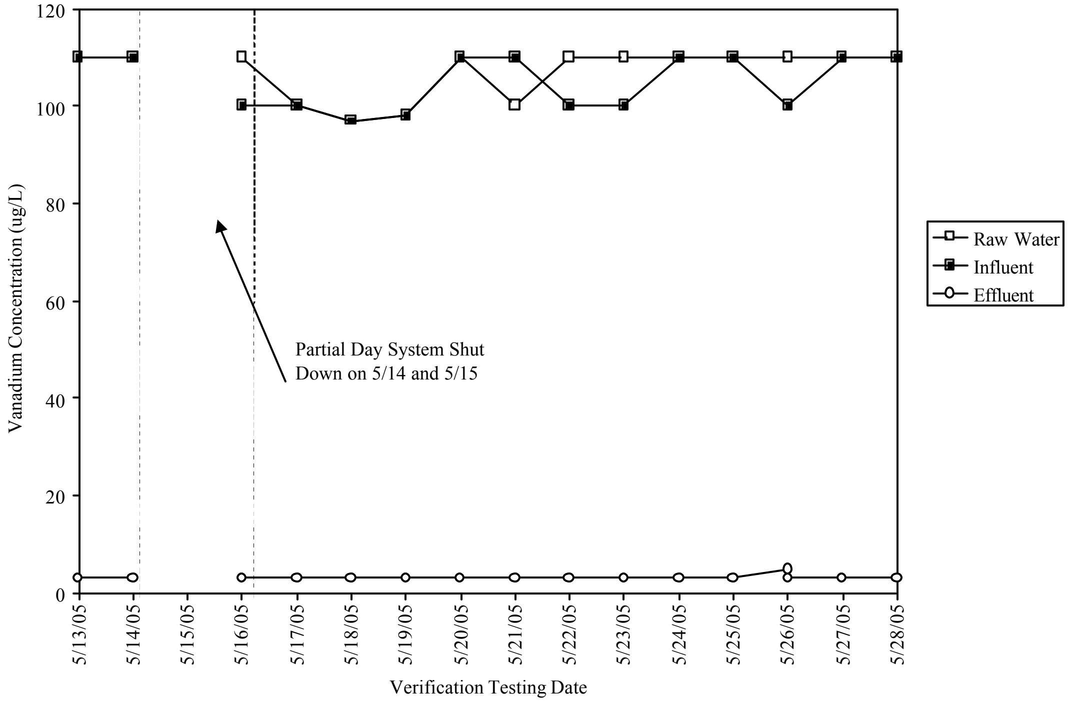


Figure 4-16: Temporal plot of verification testing raw, influent, and effluent water grab sample vanadium.

Table 4-16. Verification Testing Daily Grab Samples for Total Arsenic and Vanadium

		Total Arsenic (µg/L)			Vanadium (µg/L)		
Date	Grab Sample No.	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water
5/13/2005	1	16	14	<1.0	110	110	<3.0
	2			<1.0			<3.0
	3			<1.0			<3.0
	4			<1.0			<3.0
5/14/2005	1	14	14	<1.0	110	110	<3.0
	2			<1.0			<3.0
	3			<1.0			<3.0
	4			<1.0			<3.0
5/16/2005[1]	1	15	17	<1.0	110	100	<3.0
	2			<1.0			<3.0
	3			<1.0			<3.0
	4			<1.0			<3.0
5/17/2005	1	14	14	<1.0	100	100	<3.0
	2			<1.0			<3.0
	3			<1.0			<3.0
	4			<1.0			<3.0
5/18/2005	1	14	14	<1.0	97	97	<3.0
	2			<1.0			<3.0
	3[2]	14	15	<1.0	NA	NA	NA
	4			<1.0			<3.0
5/19/2005	1	14	14	<1.0	98	98	<3.0
	2			<1.0			<3.0
	3[3]			<1.0			<3.0
5/20/2005	1	15	16	<1.0	110	110	<3.0
	2			<1.0			<3.0
	3			<1.0			<3.0
	4			<1.0			<3.0
5/21/2005	1	15	15	<1.0	100	110	<3.0
	2			<1.0			<3.0
	3			<1.0			<3.0
	4			<1.0			<3.0
5/22/2005	1	15	15	<1.0	110	100	<3.0
	2			<1.0			<3.0
	3			<1.0			<3.0
	4			<1.0			<3.0
5/23/2005	1	15	15	<1.0	110	100	<3.0
	2			<1.0			<3.0
	3			<1.0			<3.0
	4			<1.0			<3.0
5/24/2005	1	16	16	<1.0	110	110	<3.0
	2			<1.0			<3.0
	3			<1.0			<3.0
	4			<1.0			<3.0
5/25/2005	1	16	14	<1.0	110	110	<3.0
	2			<1.0			<3.0
	3			<1.0			<3.0
	4			<1.0			<3.0

Table 4-16. Verification Testing Daily Grab Samples for Total Arsenic and Vanadium (continued)

		Total Arsenic (µg/L)			Vanadium (µg/L)		
Date	Grab Sample No.	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water
5/26/2005	1	18	19	<1.0	110	100	4.9
	2			1.1			<3.0
	3			<1.0			<3.0
	4			<1.0			<3.0
5/27/2005	1	15	15	<1.0	110	110	<3.0
	2			<1.0			<3.0
	3			<1.0			<3.0
	4			<1.0			<3.0
5/28/2005	1	15	14	<1.0	110	110	<3.0
Average		15	15	<1.0	107	105	<3.0
Minimum		14	14	<1.0	97	97	<3.0
Maximum		18	19	1.1	110	110	4.9
Number of Samples		16	16	56	15	15	54
Standard Deviation		1.1	1.4	0.01	5.2	5.6	0.26
95% Confidence Interval		(15-15)	(15-15)	(<0.1-<0.1)	(106-108)	(104-106)	(<3.0-<3.0)

[1] Data for 5/15/05 not available due to plant shutdown.

[2] Extra samples were collected on 5/18/05 due to the site audit. Regular samples were collected and then speciated for arsenic in the afternoon for NSF. NA = Additional vanadium samples were not collected on this day.

[3] Fourth grab sample for 5/19/05 not available due to plant shutdown.

Daily 24-Hour Composite Samples for Other Inorganic Parameters

Samples from the raw, influent, and effluent water were collected daily from the 24-hour composite samples to analyze for sulfate, nitrate, chloride, calcium, magnesium, alkalinity, fluoride, TDS, TSS, iron, manganese, hardness, and dissolved silica. The results for sulfate, nitrate, chloride, calcium, magnesium, alkalinity, fluoride, TDS, and hardness are graphically presented in Figures 4-17 through 4-25. Corresponding data for all of the parameters are provided in Table 4-17. Data were not graphically presented for TSS, iron, and manganese because these parameters were all at non-detectable levels for the raw, influent, and effluent water samples.

On average as compared to the raw water, the Basin Water System removed 18% alkalinity and 47% nitrate, and removed sulfate to below the detection limit. Chloride levels increased from 53% to 82% (67% on average). All other parameters had little to no change in the effluent water quality as compared to the raw water quality.

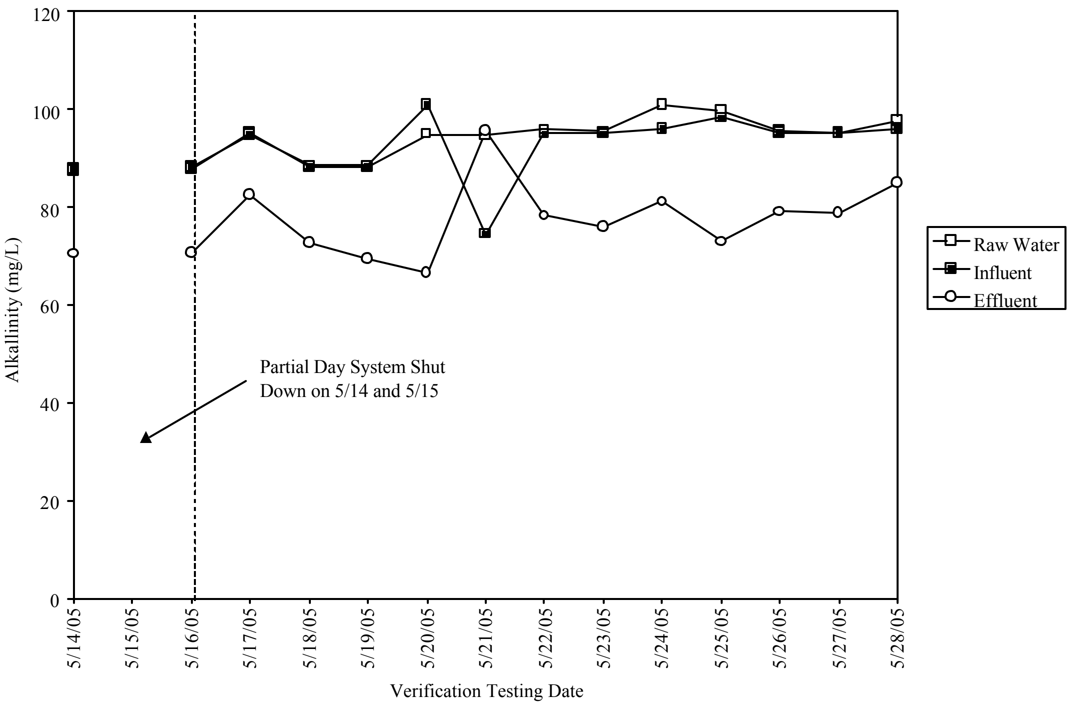


Figure 4-17: Temporal plot of verification testing raw, influent, and effluent water alkalinity.

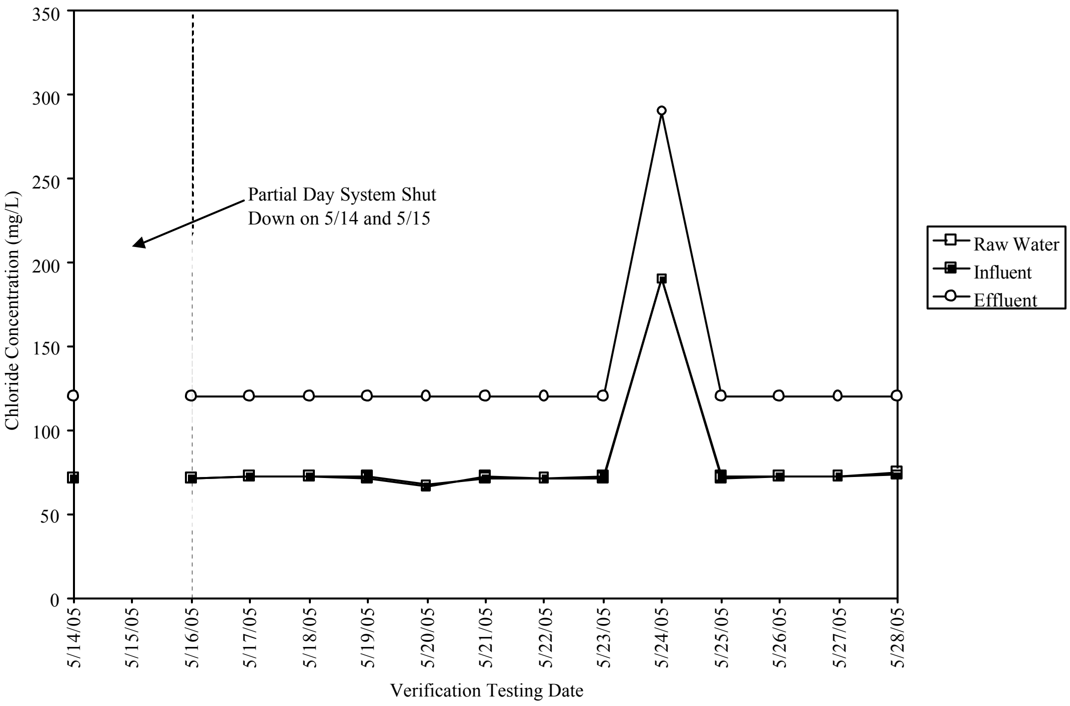


Figure 4-18: Temporal plot of verification testing raw, influent, and effluent water chloride.

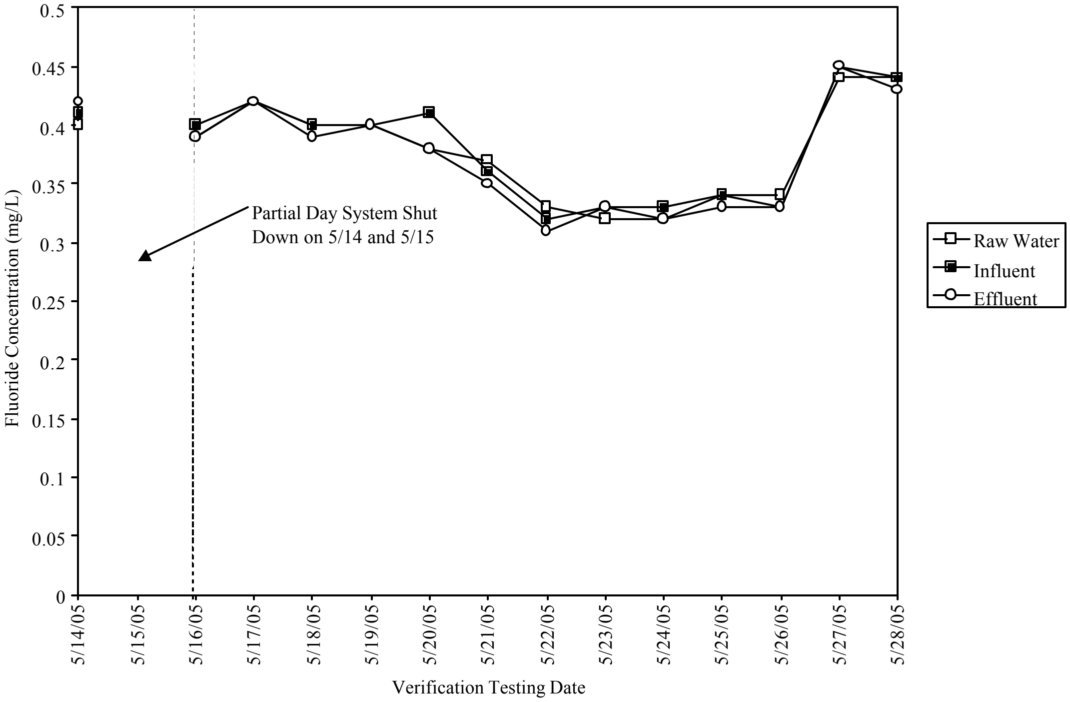


Figure 4-19: Temporal plot of verification testing raw, influent, and effluent water fluoride.

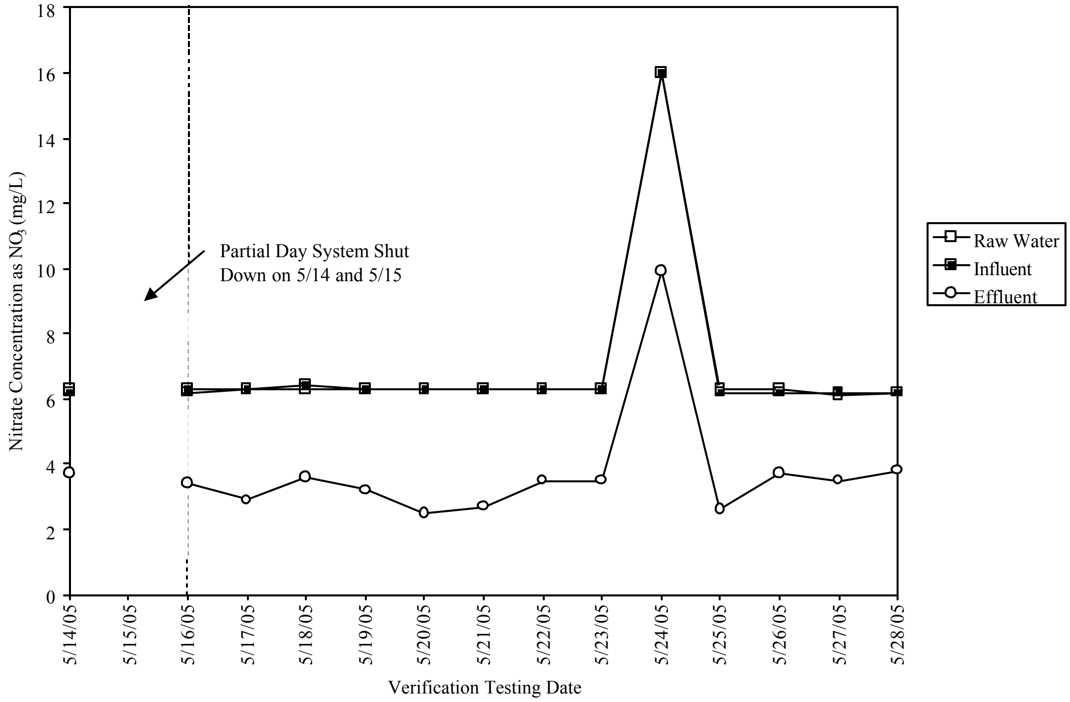


Figure 4-20: Temporal plot of verification testing raw, influent, and effluent water nitrate.

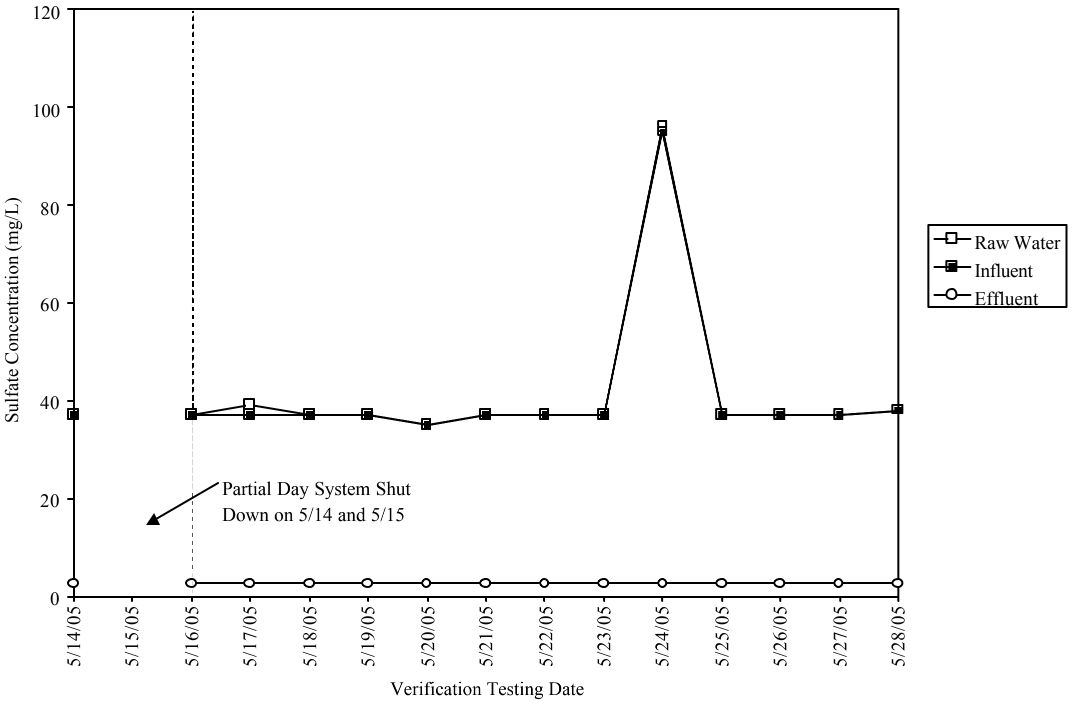


Figure 4-21: Temporal plot of verification testing raw, influent, and effluent water sulfate.

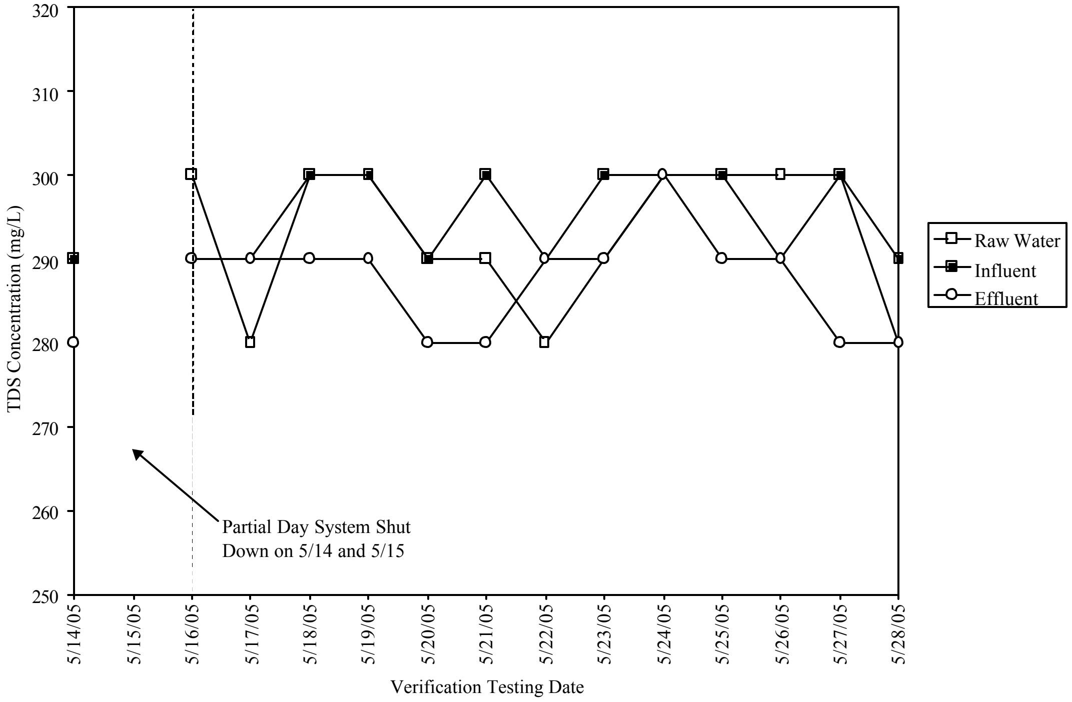


Figure 4-22: Temporal plot of verification testing raw, influent, and effluent water TDS.

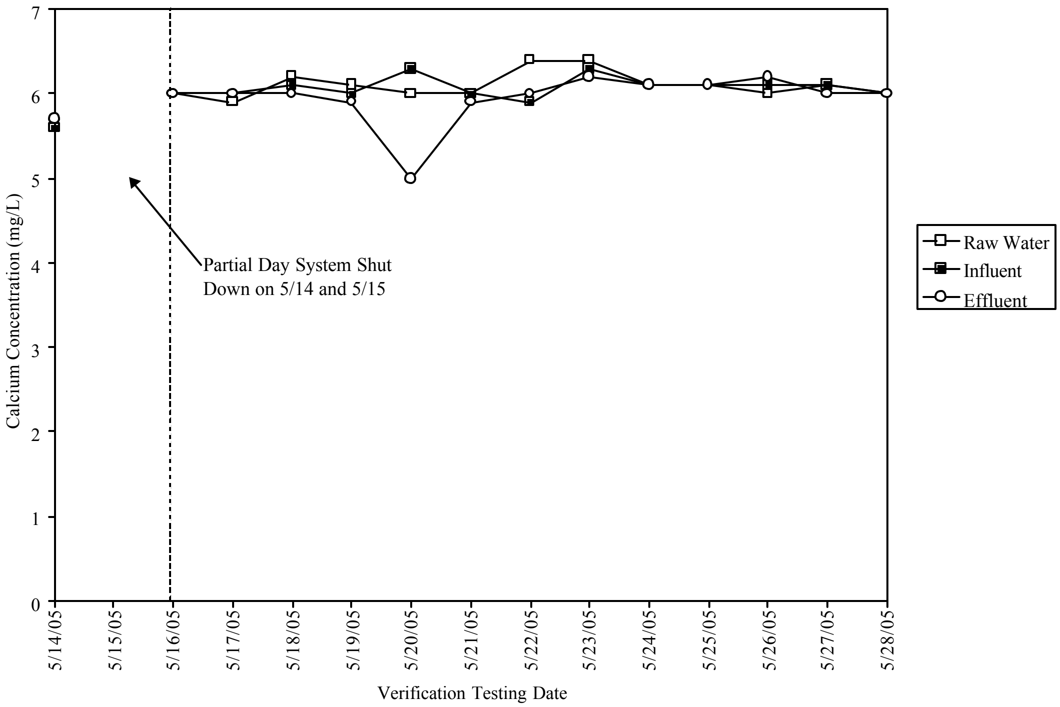


Figure 4-23: Temporal plot of verification testing raw, influent, and effluent water calcium.

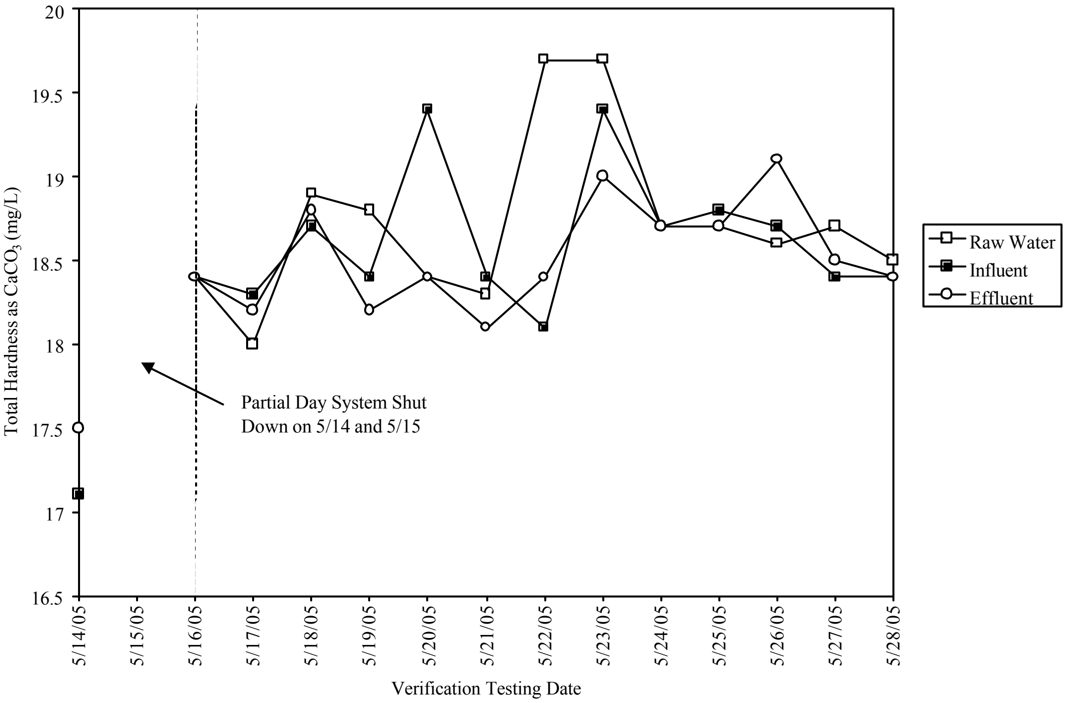


Figure 4-24: Temporal plot of verification testing raw, influent, and effluent water total hardness.

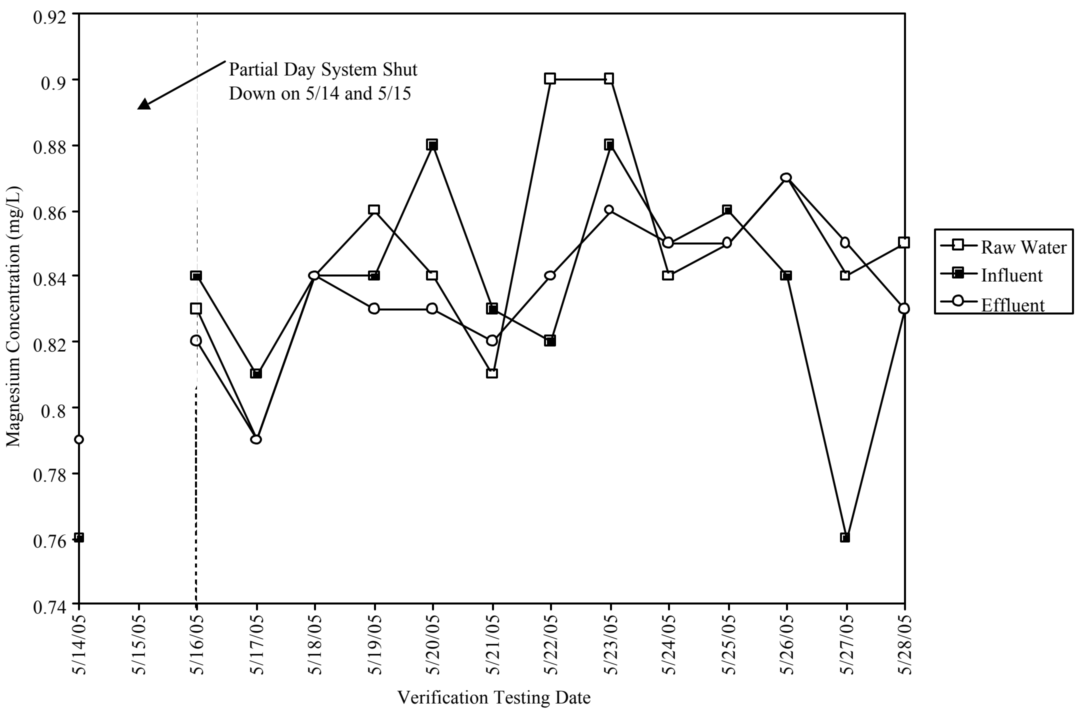


Figure 4-25: Temporal plot of verification testing raw, influent, and effluent water magnesium.

Table 4-17. Verification Testing 24-Hour Composite Data for Raw, Influent, and Effluent Water Inorganic Parameters

	Alkalinity (mg/L)			Chloride (mg/L)		
Date	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water
5/14/05	87.4	87.7	70.4	71	71	120
5/16/05	87.8	88.2	70.6	71	71	120
5/17/05	95.1	94.7	82.4	72	72	120
5/18/05	88.3	88.5	72.6	72	72	120
5/19/05	88.3	88.5	69.3	71	72	120
5/20/05	94.9	101	66.5	66	67	120
5/21/05	94.8	74.5	95.6	72	71	120
5/22/05	95.8	95.0	78.2	71	71	120
5/23/05	95.4	95.0	76.0	71	72	120
5/24/05	101	96.0	81.1	190	190	290
5/25/05	99.8	98.3	72.9	71	72	120
5/26/05	95.6	95.3	79.0	72	72	120
5/27/05	95.0	95.1	78.8	72	72	120
5/28/05	97.6	96.0	85.0	75	73	120
Average	94.1	92.4	77.0	80	80	132
Minimum	87.4	74.5	66.5	66	67	120
Maximum	101	101	95.6	190	190	290
Number of Samples	14	14	14	14	14	14
Standard Deviation	4.42	6.56	7.63	32	32	45
95% Confidence Interval	(93.2-94.6)	(91.1-93.7)	(75.5-78.5)	(74-86)	(74-86)	(123-141)

Table 4-17. Verification Testing 24-Hour Composite Data for Raw, Influent, and Effluent Water Inorganic Parameters (continued)

	Fluoride (mg/L)			Nitrate as NO_3 (mg/L)		
Date	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water
5/14/05	0.40	0.41	0.42	6.3	6.2	3.7
5/16/05	0.39	0.40	0.39	6.2	6.3	3.4
5/17/05	0.42	0.42	0.42	6.3	6.3	2.9
5/18/05	0.40	0.40	0.39	6.3	6.4	3.6
5/19/05	0.40	0.40	0.40	6.3	6.3	3.2
5/20/05	0.38	0.41	0.38	6.3	6.3	2.5
5/21/05	0.37	0.36	0.35	6.3	6.3	2.7
5/22/05	0.33	0.32	0.31	6.3	6.3	3.5
5/23/05	0.32	0.33	0.33	6.3	6.3	3.5
5/24/05	0.32	0.33	0.32	16	16	9.9
5/25/05	0.34	0.34	0.33	6.3	6.2	2.6
5/26/05	0.34	0.33	0.33	6.3	6.2	3.7
5/27/05	0.44	0.45	0.45	6.1	6.2	3.5
5/28/05	0.44	0.44	0.43	6.2	6.2	3.8
Average	0.38	0.38	0.38	7.0	7.0	3.8
Minimum	0.32	0.32	0.31	6.1	6.2	2.5
Maximum	0.44	0.45	0.45	16	16	9.9
Number of Samples	14	14	14	14	14	14
Standard Deviation	0.04	0.04	0.05	2.6	2.6	1.8
95% Confidence Interval	(0.37-0.39)	(0.37-0.39)	(0.37-0.38)	(6.5-7.5)	(6.5-7.5)	(3.4-4.1)

	Dissolved Silica (mg/L)			Sulfate (mg/L)		
Date	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water
5/14/05	12	12	13	37	37	<2.5
5/16/05	12	12	12	37	37	<2.5
5/17/05	12	12	13	39	37	<2.5
5/18/05	12	12	13	37	37	<2.5
5/19/05	12	12	12	37	37	<2.5
5/20/05	11	12	12	35	35	<2.5
5/21/05	11	12	12	37	37	<2.5
5/22/05	11	11	12	37	37	<2.5
5/23/05	11	11	12	37	37	<2.5
5/24/05	11	11	12	96	95	<2.5
5/25/05	11	11	12	37	37	<2.5
5/26/05	11	11	12	37	37	<2.5
5/27/05	12	12	12	37	37	<2.5
5/28/05	11	12	12	38	38	<2.5
Average	11	12	12	41	41	<2.5
Minimum	11	11	12	35	35	<2.5
Maximum	12	12	13	96	95	<2.5
Number of Samples	14	14	14	14	14	14
Standard Deviation	0.51	0.50	0.43	16	16	NC
95% Confidence Interval	(11-12)	(12-12)	(12-12)	(38-44)	(38-44)	NC

Table 4- 17. Verification Testing 24-Hour Composite Data for Raw, Influent, and Effluent Water Inorganic Parameters (continued)

	TDS (mg/L)			TSS (mg/L)		
Date	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water
5/14/05	290	290	280	<10	<10	<10
5/16/05	300	290	290	<10	<10	<10
5/17/05	280	290	290	<10	<10	<10
5/18/05	300	300	290	<10	<10	<10
5/19/05	300	300	290	<10	<10	<10
5/20/05	290	290	280	<10	<10	<10
5/21/05	290	300	280	<10	<10	<10
5/22/05	280	290	290	<10	<10	<10
5/23/05	290	300	290	<10	<10	<10
5/24/05	300	300	300[1]	<10	<10	<10
5/25/05	300[1]	300[1]	290[1]	<10	<10	<10
5/26/05	300	290	290	<10	<10	<10
5/27/05	300	300	280	<10	<10	<10
5/28/05	280	290	280	<10	<10	<10
Average	293	295	287	<10	<10	<10
Minimum	280	290	280	<10	<10	<10
Maximum	300	300	300	<10	<10	<10
Number of Samples	14	14	14	14	14	14
Standard Deviation	8.3	5.2	6.1	NC	NC	NC
95% Confidence Interval	(291-294)	(294-296)	(286-288)	NC	NC	NC

	Calcium (mg/L)			Iron (mg/L)		
Date	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water
5/14/05	5.7	5.6	5.7	<0.020	<0.020	<0.020
5/16/05	6.0	6.0	6.0	<0.020	<0.020	<0.020
5/17/05	5.9	6.0	6.0	<0.020	<0.020	<0.020
5/18/05	6.2	6.1	6.0	<0.020	<0.020	<0.020
5/19/05	6.1	6.0	5.9	<0.020	<0.020	<0.020
5/20/05	6.0	6.3	6.0	<0.020	<0.020	<0.020
5/21/05	6.0	6.0	5.9	<0.020	<0.020	<0.020
5/22/05	6.4	5.9	6.0	<0.020	<0.020	<0.020
5/23/05	6.4	6.3	6.2	<0.020	<0.020	<0.020
5/24/05	6.1	6.1	6.1	<0.020	<0.020	<0.020
5/25/05	6.1	6.1	6.1	<0.020	<0.020	<0.020
5/26/05	6.0	6.1	6.2	<0.020	<0.020	<0.020
5/27/05	6.1	6.1	6.0	<0.020	<0.020	<0.020
5/28/05	6.0	6.0	6.0	<0.020	<0.020	<0.020
Average	6.1	6.0	6.0	<0.020	<0.020	<0.020
Minimum	5.7	5.6	5.7	<0.020	<0.020	<0.020
Maximum	6.4	6.3	6.2	<0.020	<0.020	<0.020
Number of Samples	14	14	14	14	14	14
Standard Deviation	0.18	0.17	0.13	NC	NC	NC
95% Confidence Interval	(6.0-6.1)	(6.0-6.1)	(6.0-6.0)	NC	NC	NC

Table 4- 17. Verification Testing 24-Hour Composite Data for Raw, Influent, and Effluent Water Inorganic Parameters (continued)

	Total Hardness as $CaCO_3$ (mg/L)			Magnesium (mg/L)		
Date	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water
5/14/05	17.5	17.1	17.5	0.79	0.76	0.79
5/16/05	18.4	18.4	18.4	0.83	0.84	0.82
5/17/05	18.0	18.3	18.2	0.79	0.81	0.79
5/18/05	18.9	18.7	18.4	0.84	0.84	0.84
5/19/05	18.8	18.4	18.2	0.86	0.84	0.83
5/20/05	18.4	19.4	18.4	0.84	0.88	0.83
5/21/05	18.3	18.4	18.1	0.81	0.83	0.82
5/22/05	19.7	18.1	18.4	0.90	0.82	0.84
5/23/05	19.7	19.4	19.0	0.90	0.88	0.86
5/24/05	18.7	18.7	18.7	0.84	0.85	0.85
5/25/05	18.7	18.8	18.7	0.85	0.86	0.85
5/26/05	18.6	18.7	19.1	0.87	0.84	0.87
5/27/05	18.7	18.4	18.5	0.84	0.76	0.85
5/28/05	18.5	18.4	18.4	0.85	0.83	0.83
Average	18.6	18.5	18.4	0.84	0.83	0.83
Minimum	17.5	17.1	17.5	0.79	0.76	0.79
Maximum	19.7	19.4	19.1	0.90	0.88	0.87
Number of Samples	14	14	14	14	14	14
Standard Deviation	0.58	0.56	0.39	0.03	0.04	0.02
95% Confidence Interval	(18.5-18.7)	(18.4-18.6)	(18.4-18.5)	(0.84-0.85)	(0.82-0.84)	(0.83-0.84)

	Manganese (µg/L)		
Date	Raw Water	Influent Water	Effluent Water
5/14/05	<2.0	<2.0	<2.0
5/16/05	<2.0	<2.0	<2.0
5/17/05	<2.0	<2.0	<2.0
5/18/05	<2.0	<2.0	<2.0
5/19/05	<2.0	<2.0	<2.0
5/20/05	6.5	<2.0	7.0
5/21/05	<2.0	<2.0	<2.0
5/22/05	<2.0	<2.0	<2.0
5/23/05	<2.0	<2.0	<2.0
5/24/05	<2.0	<2.0	<2.0
5/25/05	<2.0	<2.0	<2.0
5/26/05	<2.0	<2.0	<2.0
5/27/05	<2.0	<2.0	<2.0
5/28/05	<2.0	<2.0	<2.0
Average	2.3	<2.0	2.4
Minimum	<2.0	<2.0	<2.0
Maximum	6.5	<2.0	7.0
Number of Samples	14	14	14
Standard Deviation	2.1	NC	2.1
95% Confidence Interval	(2.1-2.6)	NC	(2.1-2.6)

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[1] Target analyte detected in method blank for TDS was at or above method reporting limit. Concentration found in the sample was 10 times above the concentration found in the method blank.

NC = Not Calculated.

4.5.1.2 NDMA

At the request of the water utility, NDMA was added to the ETV test plan for the evaluation of the Basin Water System. NDMA is a potential by-product from IX systems and is classified as a carcinogen. It is believed that chlorinated water sources increase the potential for NDMA in the effluent of an IX facility. Therefore, additional samples were collected at the beginning and end of verification testing for NDMA. The first two samples were collected either with or without a chlorinated water source, as presented in Table 4-18.

On April 4, 2004, the effluent water was sampled without chlorine addition to the raw water supply. The result was a non-detectable level (<2.0 μg/L) of NDMA. Throughout the remainder of the test, chlorine was added to the raw water. The raw water was sampled on April 6, 2005, and the influent water was sampled on May 27, 2005, to analyze for NDMA; the NDMA levels were non-detectable in the raw and influent water, but 10-16 μg/L in the effluent.

Table 4-18. Raw, Influent, and Effluent Water NDMA

	NDMA (μg/L)			
Date	Raw Water	Influent Water	Effluent Water	Chlorinated Water Source
4/4/05	NA	NA	<2.0	No
4/6/05	<2.0	NA	16	Yes
5/27/05	NA	<2.0	10	Yes

NA = Not Available. NDMA was spot-checked throughout the verification testing.

4.5.1.3 LSI

The LSI was calculated with the following equation: $LSI = pH - pH_s$. Where pH is the measured pH of the water and pH_s is the pH at saturation (calcium carbonate).

$$pH_s = (9.3 + A + B) - (C + D)$$

Where: $A = (\text{Log}_{10}\,[\text{TDS}] - 1) / 10$
$B = -13.12 \times \text{Log}_{10}\,(^\circ\text{C} + 273) + 34.55$
$C = \text{Log}_{10}\,[Ca^{2+} \text{ as } CaCO_3] - 0.4$
$D = \text{Log}_{10}\,[\text{alkalinity as } CaCO_3]$

The LSI is an indictor of how corrosive or scaling water may be, and is primarily based on the TDS, calcium, water temperature, and alkalinity. Using the data provided from the daily analyses (Section 4.5.1.1), the LSI of the water was calculated for the raw, influent, and effluent water. The results of the calculated LSI, provided in Table 4-19, indicate that the raw and influent waters during the Initial Plant Characterizations and Verification Test were both at or near equilibrium[1] with slightly scaling tendencies, with the one exception of May 20, 2005, when both the raw and the influent LSI were less than zero (–0.90 and –0.53, respectively). The LSI of the effluent water from the Basin Water System during the Verification Test indicated a corrosive environment to slightly scaling environment, with values ranging from –1.25 to 0.05.

Throughout verification testing, the raw, influent, and effluent water were measured for temperature using an NIST thermometer. There is no temperature data available from April 4-15, because the NIST thermometer was not being available at the site. The primary purpose of measuring the temperature was to calculate the LSI of the water. For those dates when the thermometer was not available, a value of 26°C was assumed for use in the calculation.

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[1] Equilibrium LSI is zero and means neither corrosive or scaling tendencies are present.

Table 4-19. Raw, Influent, and Effluent Water LSI

	LSI		
Date	Raw Water	Influent Water	Effluent Water
Initial Plant Characterization No. 1 (4/4/05 – 4/22/05)			
4/5/05	0.25	0.25	-0.18
4/6/05	0.49	0.49	-0.22
4/7/05	0.36	0.44	0.04
4/9/05	0.20	0.18	0.44
4/10/05	0.46	0.44	0.14
4/11/05	0.37	0.40	0.24
4/12/05	0.21	0.28	0.29
4/13/05	0.20	0.28	0.23
4/14/05	0.31	0.40	0.29
4/15/05	0.18	0.33	0.23
4/16/05	0.42	0.40	-0.08
4/18/05	0.39	0.38	-0.06
Initial Plant Characterization No. 2 (4/29/05 – 5/09/05)			
5/5/05	0.31	0.24	-0.10
Verification Testing (5/12/05 – 5/28/05)			
5/14/05	0.27	0.26	-0.41
5/16/05	0.29	0.30	-0.65
5/17/05	0.31	0.30	-0.57
5/18/05	0.28	0.29	-0.61
5/19/05	0.31	0.30	-0.80
5/20/05	-0.90	-0.53	-1.25
5/21/05	0.15	0.01	-0.78
5/22/05	0.37	0.36	-0.85
5/23/05	0.37	0.37	-0.49
5/24/05	0.37	0.36	0.05
5/25/05	0.31	0.34	-0.10
5/26/05	0.33	0.32	-0.50
5/27/05	0.32	0.31	-0.09
5/28/05	0.34	0.33	-0.56
Verification Test Statistical Analysis			
Average	0.22	0.24	-0.54
Minimum	-0.90	-0.53	-1.25
Maximum	0.37	0.37	0.05
Number of Samples	14	14	14
Standard Deviation	0.33	0.24	0.34
95% Confidence Interval	(0.16-0.29)	(0.19-0.28)	(-0.61-(-)0.48)

4.5.1.4 Verification Testing On-Site Laboratory Data

In addition to laboratory data, on-site testing was conducted for pH, conductivity, free and total chlorine and temperature. The results of the on-site laboratory testing are provided in Tables 4-20-4-22. The on-site testing indicated that there was very little variability in the pH, conductivity, free chlorine, total chlorine, or temperature at the Corydon Street Well.

As presented in Table 4-20, the pH reduced slightly from 9.07 in both the raw and influent water to 8.27 in the effluent water. The conductivity increased from 534 µmho/cm in both the raw and influent water to 551 µmho/cm in the effluent water.

Table 4-20. Verification Testing On-Site Analytical Results of pH and Conductivity

	pH			Conductivity (µmho/cm)		
Date	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water
5/12/05	9.08	9.07	8.27	543	546	562
5/13/05	9.07	9.07	8.48	523	533	545
5/14/05	9.06	9.06	8.57	534	538	544
5/15/05	9.07	9.07	8.22	521	523	545
5/16/05	9.08	9.06	8.25	545	548	562
5/17/05	9.06	9.08	8.27	528	530	540
5/18/05	9.09	9.09	8.10	552	545	583
5/19/05	7.82	8.15	7.64	543	527	563
5/20/05	8.93	8.90	8.02	548	545	565
5/21/05	9.07	9.10	7.97	529	532	553
5/22/05	9.08	9.09	8.34	527	524	542
5/23/05	9.08	9.09	8.88	551	551	561
5/24/05	9.03	9.06	8.32	517	518	529
5/25/05	9.07	9.05	8.31	528	528	542
5/26/05	9.08	9.07	8.75	525	526	532
5/27/05	9.07	9.07	8.23	528	530	547
5/28/05	9.06	9.07	8.56	534	538	548
Median/Average[1]	9.07	9.07	8.27	534	534	551
Minimum	7.82	8.15	7.64	517	518	529
Maximum	9.09	9.10	8.88	552	551	583
Number of Samples	17	17	17	17	17	17
Standard Deviation	NC	NC	NC	11.0	9.89	13.7
95% Confidence Interval	NC	NC	NC	(532-536)	(533-536)	(549-553)

[1] The median values of the pH analyses are presented. The averages were calculated for the conductivity analyses.

NC = Not Calculated.

The free and total chlorine results are presented in Table 4-21. The target chlorine residual in the influent water was 0.10-0.50 mg/L. From the results presented, the average influent water free and total chlorine residuals were 0.24 and 0.30 mg/L, respectively.

Table 4-21. Verification Test On-Site Analytical Results of Free and Total Chlorine

	Free Chlorine (mg/L)			Total Chlorine (mg/L)		
Date	Raw	Influent	Effluent	Raw	Influent	Effluent
5/12/05	0.05	0.20	0.01	0.01	0.24	0.01
5/13/05	0.01	0.24	0.01	0.01	0.29	0.01
5/14/05	0.01	0.30	0.00	0.02	0.34	0.03
5/15/05	0.01	0.28	0.00	0.02	0.34	0.04
5/16/05	0.01	0.26	0.01	0.02	0.34	0.01
5/17/05	0.05	0.30	0.01	0.01	0.35	0.02
5/18/05	0.03	0.30	0.02	0.04	0.34	0.02
5/19/05	0.02	0.14	0.01	0.06	0.25	0.02
5/20/05	0.01	0.20	0.01	0.03	0.21	0.00
5/21/05	0.03	0.28	0.01	0.03	0.31	0.03
5/22/05	0.02	0.27	0.02	0.03	0.34	0.01
5/23/05	0.04	0.27	0.05	0.04	0.28	0.01
5/24/05	0.02	0.26	0.01	0.04	0.33	0.01
5/25/05	0.03	0.28	0.01	0.02	0.33	0.01
5/26/05	0.02	0.20	0.02	0.02	0.29	0.02
5/27/05	0.02	0.21	0.01	0.03	0.30	0.01
5/28/05	0.01	0.17	0.00	0.02	0.30	0.01
Average	0.02	0.24	0.01	0.03	0.30	0.02
Minimum	0.01	0.14	0.00	0.01	0.21	0.00
Maximum	0.05	0.30	0.05	0.06	0.35	0.04
Number of Samples	17	17	17	17	17	17
Standard Deviation	0.01	0.05	0.01	0.01	0.04	0.01
95% Confidence Interval	(0.02-0.03)	(0.24-0.25)	(0.01-0.01)	(0.02-0.03)	(0.30-0.31)	(0.01-0.02)

As shown by the data provided in Table 4-22, there was very little change in the water temperature of approximately 27°C during the Verification Test, as indicated by a low range of standard deviation values of 0.69-0.83 in the raw, influent, and effluent water.

Table 4-22. Verification Test On-Site Temperature

	Temperature (°C)		
Date	Raw Water	Influent Water	Effluent Water
5/12/05	27.0	27.0	27.0
5/13/05	27.0	27.0	27.0
5/14/05	27.0	27.0	27.0
5/15/05	27.0	27.0	27.0
5/16/05	26.0	26.0	26.0
5/17/05	26.0	26.0	26.0
5/18/05	26.5	26.0	26.5
5/19/05	28.0	28.0	27.5
5/20/05	25.0	25.0	24.0
5/21/05	27.5	27.5	27.5
5/22/05	27.0	27.0	27.0
5/23/05	27.0	27.0	27.0
5/24/05	27.0	27.0	27.0
5/25/05	27.0	27.0	27.0
5/26/05	26.0	26.0	26.0
5/27/05	27.0	27.0	27.0
5/28/05	27.0	27.0	27.0
Average	26.8	26.7	26.7
Minimum	25.0	25.0	24.0
Maximum	28.0	28.0	27.5
Number of Samples	17	17	17
Standard Deviation	0.69	0.71	0.83
95% Confidence Interval	(26.7-26.9)	(26.6-26.8)	(26.5-26.8)

4.5.2 Arsenic Speciation Results and Special Studies

Arsenic speciation data collected from April 6-May 5 during the Initial Plant Characterization task and from May 16-28 during the Verification Test are presented in Table 4-23 and illustrated in Figures 4-26-4-28. The dissolved arsenic data, presented in Table 4-24, confirm that all or most of the arsenic was in the dissolved form. Arsenic (V) concentrations were calculated by subtracting the As (III) concentration from the dissolved arsenic concentration. Arsenic speciation was performed in the field using the Edwards et al. preservation method, as required and presented in the ETV Protocol. The samples were then analyzed by MWH Laboratories using EPA Method 200.8.

Although the arsenic species data collected during the Initial Plant Characterization task are erratic, the arsenic species data during the Verification Test are consistent with the historical data (Table 4-1) where the dominant species is As (III). The raw water samples collected during the Verification Test contained more As (III) than As (V), except for the sample collected on May 25, 2005, that may have resulted from a sample mix-up. Sample collection errors or transposition of samples during laboratory analysis could also explain the apparently erratic As (III) and As (V) results during the two Initial Plant Characterization periods.

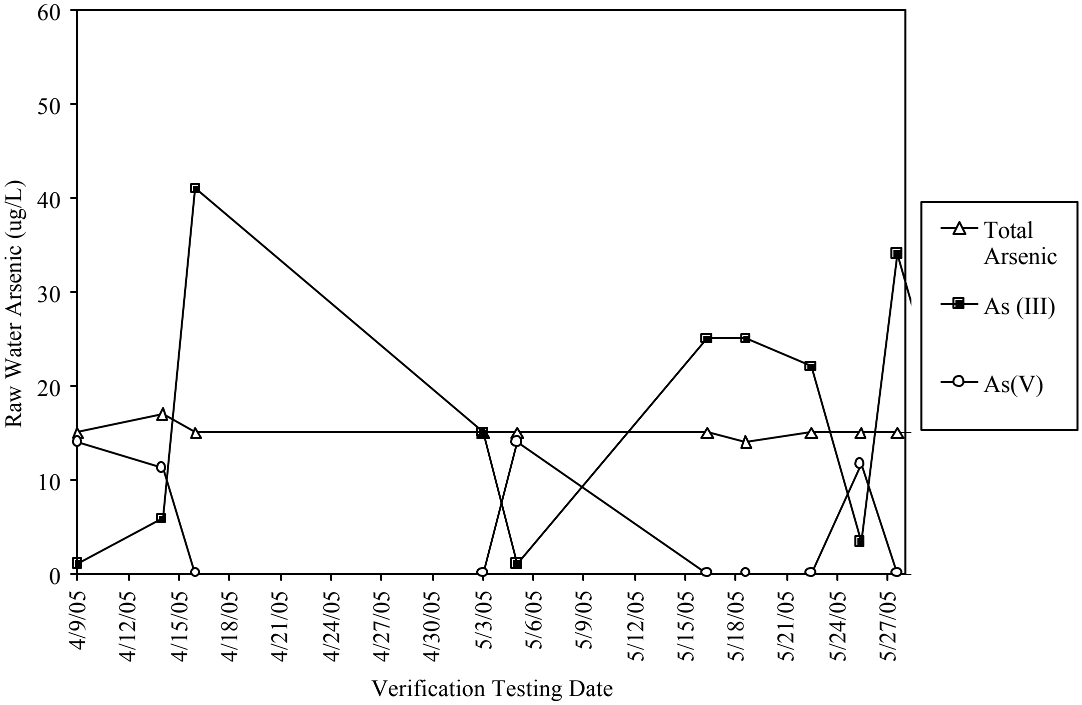

Figure 4-26: Speciated arsenic raw water results for Initial Plant Characterization through verification testing.

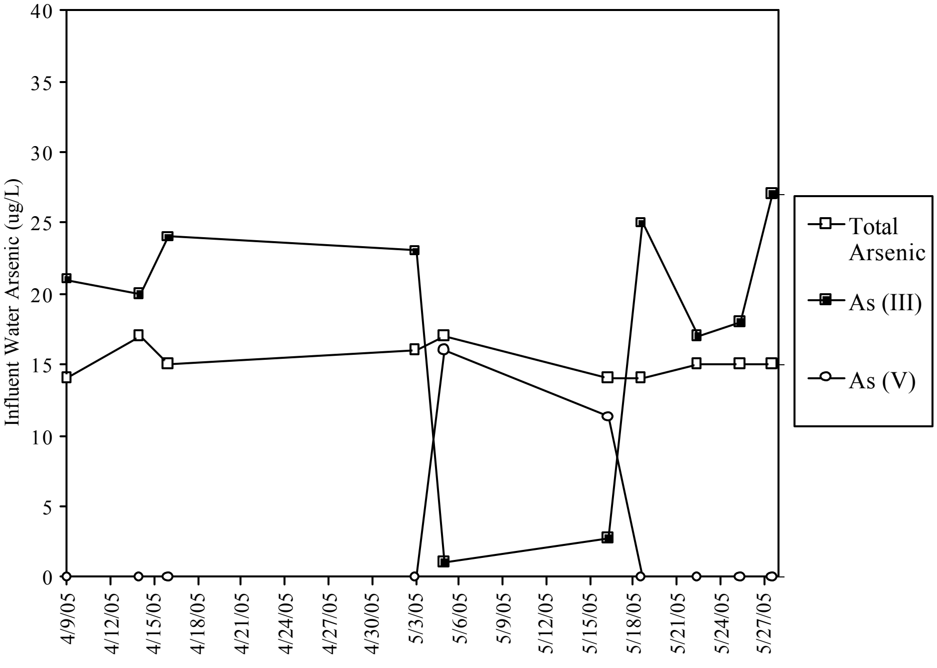

Figure 4-27: Speciated arsenic influent water results for Initial Plant Characterization through verification testing.

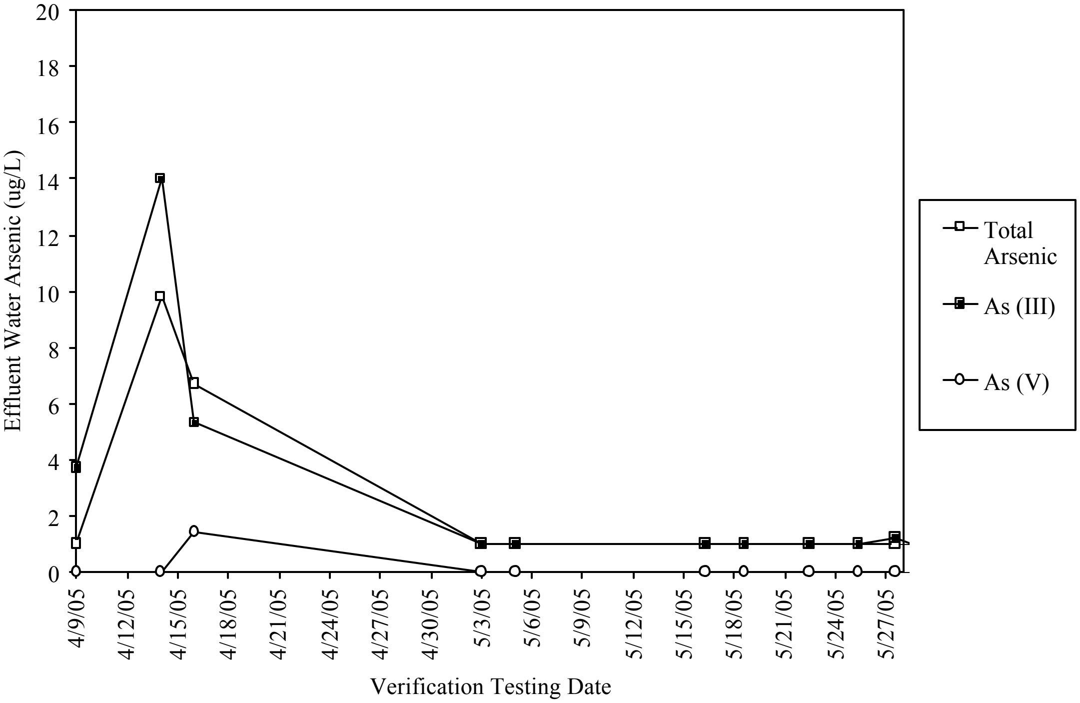

Figure 4-28: Speciated arsenic effluent water results for Initial Plant Characterization through verification testing.

Table 4-23. Total Arsenic, As (III), and As (V) from the Initial Plant Characterization and the Verification Testing

	Total Arsenic (µg/L)			As (III) (µg/L)			As (V) (µg/L) (calculated)		
Date	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water
Initial Plant Characterization No. 1 (04/04/05 - 04/23/05)									
4/6/05	18	19	<1.0	1.5	25	<1.0	12	<1.0	<1.0
4/9/05	14	13	1.4	<1.0	21	3.7	16	<1.0	<1.0
4/14/05	17	17	9.8	5.8	20	14	14	<1.0	<1.0
4/16/05	15	15	6.7	41	24	5.3	<1.0	<1.0	2.4
Initial Plant Characterization No. 2 (04/29/05 - 05/09/05)									
5/3/05	15	16	<1.0	15	23	<1.0	<1.0	<1.0	<1.0
5/5/05	18	17	<1.0	<1.0	<1.0	<1.0	21	21	<1.0
Verification Testing (05/12/05 - 05/28/05)									
5/16/05	15	17	<1.0	25	2.7	<1.0	<1.0	20	<1.0
5/18/05	14	15	<1.0	25	25	<1.0	<1.0	<1.0	<1.0
5/22/05	15	15	<1.0	22	17	<1.0	<1.0	3.0	<1.0
5/25/05	16	14	<1.0	3.3	18	<1.0	17	<1.0	<1.0
5/26/05	18	19	<1.0	1.4	1.0	<1.0	20	19	<1.0
5/27/05	15	15	<1.0	34	27	1.2	<1.0	<1.0	<1.0
5/28/05	15	14	<1.0	28	27	<1.0	<1.0	<1.0	<1.0
Verification Test Statistical Analysis									
Average	15	16	<1.0	20	17	<1.0	6.0	6.6	<1.0
Minimum	14	14	<1.0	1.4	1.0	<1.0	<1.0	<1.0	<1.0
Maximum	18	19	<1.0	34	27	1.2	20	20	<1.0
Number of Samples	7	7	7	7	7	7	7	7	7

Table 4-24: Dissolved Arsenic Results from the Initial Plant Characterization and the Verification Testing

	Dissolved Arsenic (µg/L)		
Date	Raw Water	Influent Water	Effluent Water
Initial Plant Characterization No. 1 (04/04/05 - 04/23/05)			
4/6/05	13	14	<1.0
4/9/05	17	18	2.1
4/14/05	20	18	12
4/16/05	19	18	7.7
Initial Plant Characterization No. 2 (04/29/05 - 05/09/05)			
5/3/05	18	19	<1.0
5/5/05	22	22	<1.0
Verification Testing (05/12/05 - 05/28/05)			
5/16/05	22	23	<1.0
5/18/05	17	16	<1.0
5/22/05	20	20	<1.0
5/25/05	20	14	<1.0
5/26/05	21	20	1.1
5/27/05	20	20	<1.0
5/28/05	19	20	<1.0
Verification Test Statistical Analysis			
Average	20	19	<1.0
Minimum	17	14	<1.0
Maximum	22	23	1.1
Number of Samples	7	7	7

The total arsenic concentration was consistently lower than the As (III) concentration in the raw water. MWH and NSF performed additional investigations in an attempt to identify any contributing factors to these unusual data.

One investigation considered whether an alternative preservation methodology, the Gallagher et al. method, would provide a more accurate estimate of the amount of As (III) in the water. Although this method is normally used for water with high iron concentrations, it was used during this investigation to try to confirm the arsenic results reported from the Edwards et al. method. The Gallagher et al. method involves using one 250-ml, amber poly bottle (per sample location [i.e., raw, influent, and effluent]) that is preserved with 10.8 ml of 2M acetic acid and 3.35 ml 0.1M ethylenediaminetetraacetic acid (EDTA). This prevents precipitation of iron and loss of arsenic sorbing onto any iron, which would oxidize upon exposure to air, and prevents oxidation of As (III). Research by Clifford et al. (Samanta et al., 2005) indicates that this is more effective than sulfuric acid at preserving arsenic speciation. Once samples are preserved, they can be speciated in the lab using any appropriate separation method.

MWH Laboratories used a technique where samples were filtered through a proprietary resin column and analyzed using the EPA Method 200.8 (Inductively Coupled Plasma Mass Spectrometry [ICP/MS] method with dynamic reaction cell [DRC]). The arsenic that passed through the resin column was As (III) and the remaining arsenic was As (V). The Edwards et al. method and the Gallagher et al. method results are provided in Table 4-25 for comparative purposes. The data suggest that the Gallagher et al. preservation method reported As (III) in the raw and feed water that was approximately ten times less than the results using the Edwards et al. method.

Table 4-25. Comparison of Edwards et al. and EDTA/Acetic Acid Preservation Methods for Arsenic Speciation

	Edwards et al. Method As (III) (µg/L)			Gallagher et al. Method As (III) (µg/L)		
Date	Raw Water	Influent Water	Effluent Water	Raw Water	Influent Water	Effluent Water
5/18/05	25	25	<1.0	1.5	2.9	<1.0
5/25/05	3.3	18	<1.0	1.7	1.8	<1.0
5/26/05	21	20	1.1	1.4	1.0	<1.0
5/27/05	34	27	1.2	1.5	1.6	<1.0
Average	21	23	1.1	1.5	1.8	<1.0
Minimum	3.3	18	<1.0	1.4	1.0	<1.0
Maximum	34	27	1.2	1.7	2.9	<1.0
Number of Samples	4	4	4	4	4	4

A second investigation into the unusual arsenic speciation results examined whether the resin column and the preservatives used in the sample bottles with the Edwards et al. method were a possible source of arsenic contamination. The resin columns used for the Edwards et al. method were QA/QC checked by NSF prior to use in the field. Table 4-26 presents sample results of deionized water that was preserved using the Edwards et al. method. The arsenic results were all non-detectable (<1.0 µg/L), indicating that the resin speciation columns and preservatives were not contributing arsenic to the samples.

A third investigation examined whether the chlorine injected into the raw water source could contribute arsenic into the samples. The chlorine solution was analyzed but the result indicated that non-detectable levels of arsenic (<1.0 µg/L) were present.

A fourth and final investigation examined whether the ultra pure nitric acid and ultra pure sulfuric acid used to preserve the samples could influence the arsenic results. The Edwards et al. method requires a nitric acid preservative for the total arsenic sample and the As (III) sample, and sulfuric acid for the filtered sample. The filtered sample with sulfuric acid was passed through a resin column that removed As (V), according to the method.

The effect of nitric and sulfuric acid preservatives were evaluated on the raw and influent water and reported in Table 4-26. The samples preserved with nitric acid had a total arsenic concentration of 15 µg/L for both the raw and influent water, and values of 6.4 and 15 µg/L dissolved arsenic for the raw and influent samples, respectively. Both the raw and influent water preserved with sulfuric acid had results of 20 µg/L for total and dissolved arsenic. This method requires the preserved total arsenic samples to have a pH less than 2.0 to prevent a bias. The pH of the samples were not verified in the field; however, the samples were tested at MWH Laboratories, and each sample's pH was less than 2.0.

Table 4-26. Edwards et al. Method for Additional Speciation Studies

		Edwards et al. Method		
Date	Sample	Total As (ug/L)	Dissolved As (ug/L)	As (III) (ug/L)
5/5/05	Deionized (DI) Water	<1.0	<1.0	<1.0
5/17/05	0.5% Chlorine Solution	<1.0	NA	NA
5/27/05	Raw Water Preserved with Nitric Acid	15	6.4	NA
5/27/05	Raw Water Preserved with Sulfuric Acid	20	20	NA
5/27/05	Influent Preserved with Sulfuric Acid	20	20	NA
5/27/05	Influent Preserved with Nitric Acid	15	15	NA

NA = Not Available

While the exact reason is unknown, these results suggest that there is a bias in the arsenic concentration depending on the acid preservative used. Since the preservatives were checked through the use of DI blanks and all results were non-detect, the data suggest the combination of the preservative and the water quality may be one contributing factor to variable arsenic results. Regardless of the erratic and unusual arsenic speciation results, the data were sufficient to suggest that As (III) was the dominant form of arsenic in the raw water, thus requiring pretreatment of raw water to oxidize As (III) to As (V). The actual amount of total arsenic or As (III) in the raw water may not be known due to the influence of the acid preservatives on either the water chemistry at this specific site and/or its influence on the ICP/MS method used by the laboratory to analyze the samples. However, the effluent As (III) results suggest that sufficient oxidant was provided to the raw water (sodium hypochlorite at 0.10-0.50 mg/L) to convert the As (III) to As (V). The results were all non-detect with the exception of two effluent As (III) samples of 1.1 µg/L and 1.2 µg/L, collected on May 26 and 27, 2005, respectively (see Table 4-25).

The chlorine residual data provided further proof that the water chemistry at the site may have influenced the speciation results. After liquid hypochlorite was added to the raw water, the residual chlorine ranged from 0.18–0.28 mg/L, and yet the pH did not decline, with a mean raw water pH of 9.05 and mean influent pH of 9.05. This would suggest that the raw water contained a buffering capacity to hypochlorous acid. This unexplained capacity of the water to resist change in pH from the addition of hypochlorous acid might also have contributed to the variance observed in the acid preservatives and arsenic speciation results.

The arsenic speciation studies concluded that most of the arsenic present at the Corydon Street Well was in the As (III) state and that after oxidation by chlorination, the system could remove the arsenic to non-detectable levels (<1 µg/L).

4.5.3 Online Continuous Monitoring Data during Verification Testing

In addition to laboratory and on-site analytical data, the Basin Water System recorded pH, conductivity, flow rates, and brine tank levels continuously through the PLC. Two example snapshot screens from the PLC are presented in Figures 4-29 and 4-30 from April 4-10, 2005, with additional information provided in Appendix E. The information recorded by the PLC was used to compare data with field analyses and operation parameters measured on-site.

The manufacturer calibrated the online pH, conductivity, and flow meters prior to beginning the test. However, it was not possible to calibrate them during the test without bringing the treatment system off-line. Comparing the PLC data to the daily-calibrated hand-held pH and conductivity meters indicated that online pH measurements were not comparable, but the conductivity measures did appear comparable. The instantaneous flow rate varied from the bucket and stopwatch test, but did provide a close estimate of the system flow rate.

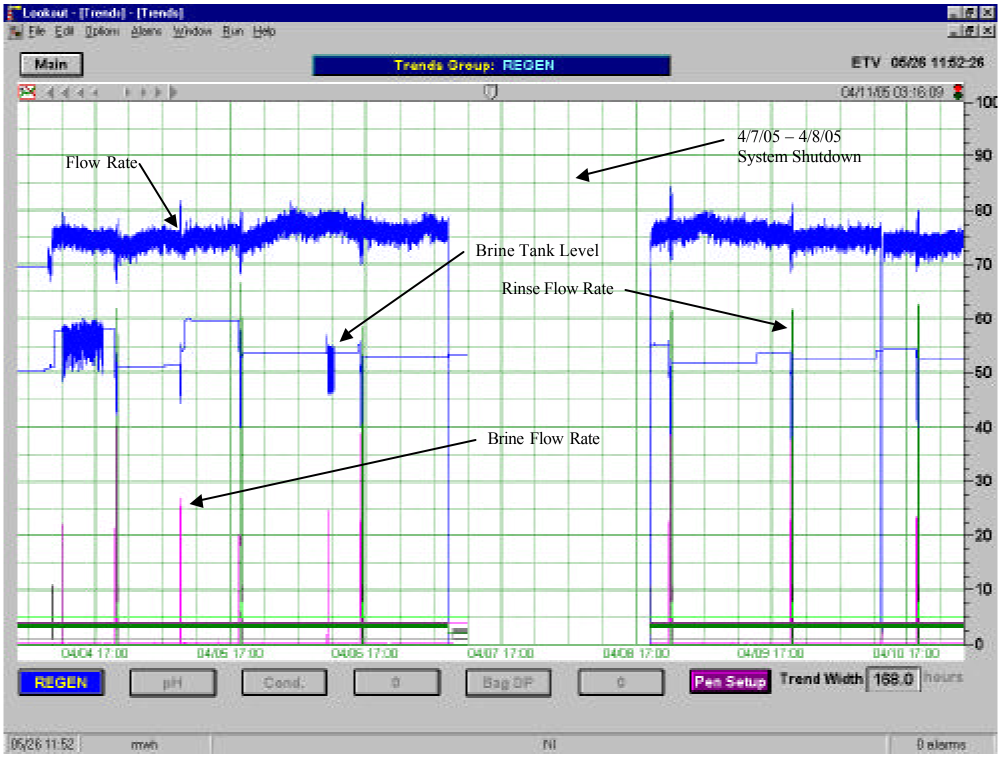

Figure 4-29: Trend screen during regeneration cycle of 4/4/05-4/10/05 of Initial Plant Characterization No. 1.

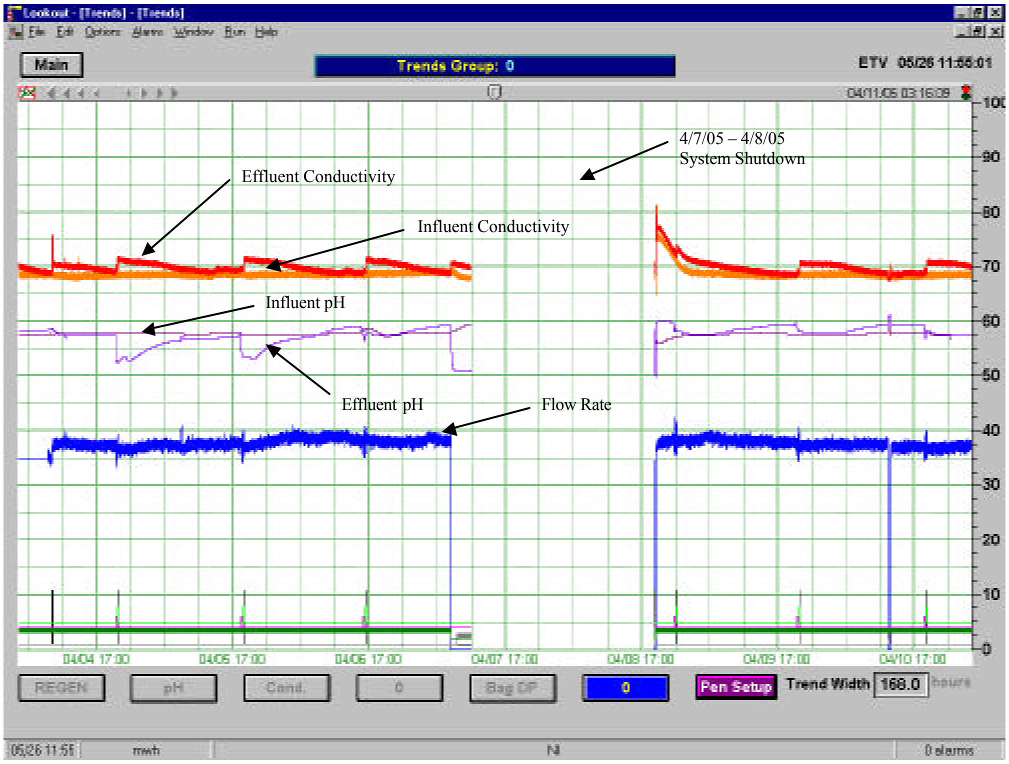

Figure 4-30: Trend screen during exhaustion cycle of 4/4/05-4/10/05 of Initial Plant Characterization No. 1.

4.5.4 Verification Testing Operational Data

The purpose of this task was to evaluate the general operational performance of the Basin Water System. Operational information regarding this task was collected throughout the verification testing according to the frequency presented in Chapter 3 (see Table 3-6). Operation data collected during verification testing included:

- The raw, influent, and effluent water pressure;
- Water flow and waste generation rates;
- Brine solution strength;
- Number of columns exhausted/regenerated per day; and
- Power consumption.

Each of these operation parameters is discussed in this section with the exception of waste generation. The waste flow rate and solids volumes generated during verification testing are presented in Section 4.5.5.

Pressure and Flow Rate

There was very little variation in the pressure and flow rate of the Basin Water System throughout verification testing. The results of the daily pressure and flow rate readings are provided in Table 4-27. The average pressure drop across the system during the Verification Test was approximately 10.5 psi with an average effluent flow rate of 36.6 gpm from the treatment system. It was noted that the flow meter on the unit typically gave flow rates about

16% higher than the bucket and stopwatch measurement used to check the flow rate on a daily basis. The bucket and stopwatch data show that the average flow rate during the Verification Test was 32 gpm. While this difference may not be considered large, it does affect the regeneration bed volume calculations and other calculations that depend on the flow rate. The regeneration flow rates were based on the flow meters and not the automated flow rates.

Table 4-27. Raw, Influent, and Effluent Water Pressure and Influent and Effluent Flow Rate

	Pressure			Flow Rate[1]		
Date	Raw Water (psi)	Influent Water (psi)	Effluent Water (psi)	Influent Water (gpm)	Calculated Influent Water (gpm)	Calculated Effluent Water (gpm)
Initial Plant Characterization No. 1 (04/04/05 – 04/23/05)						
4/4/05	46.6	45.4	36.6	37.7	NA	NA
4/4/05	45.4	46.7	36.6	NA	NA	NA
4/5/05	47.6	46.0	36.6	38.0	34.5	34.5
4/5/05	47.4	45.7	36.4	37.4	NA	NA
4/6/05	48.0	46.6	38.1	37.7	38.3	38.3
4/6/05	48.0	46.3	38.1	NA	NA	NA
4/8/05	46.6	44.7	36.7	38.2	40.0	40.2
4/8/05	47.2	45.5	37.3	38.0	NA	NA
4/9/05	46.7	45.0	36.4	37.2	38.6	38.6
4/9/05	46.9	44.9	36.5	36.5	NA	NA
4/10/05	47.0	45.4	37.1	37.5	37.6	37.4
4/10/05	47.4	45.5	37.2	37.9	NA	NA
4/11/05	46.7	44.9	36.2	37.8	37.8	38.0
4/11/05	NA	45.4	37.4	36.9	NA	NA
4/12/05	46.7	NA	36.6	37.1	34.3	34.9
4/12/05	47	NA	36.3	37.6	NA	NA
4/13/05	45.3	43.4	35.3	36.8	39.6	38.6
4/13/05	45.8	43.9	35.7	37.4	NA	NA
4/14/05	47.1	45.3	37.2	39.1	37.9	37.8
4/14/05	47.0	44.7	36.3	39.7	NA	NA
4/15/05	47.0	45.3	36.7	39.1	39.4	39.3
4/15/05	49.1	47.3	38.6	39.4	NA	NA
4/16/05	48.0	46.2	37.6	38.6	40.0	39.9
4/16/05	47.2	45.6	36.9	38.3	NA	NA
4/17/05	47.3	45.8	36.1	38.9	38.9	38.9
4/17/05	47.2	45.4	36.0	38.2	NA	NA
4/18/05	47.2	45.6	37.5	37.4	38.1	38.8
4/18/05	49.3	47.6	38.4	36.8	NA	NA
4/20/05	47.4	45.6	37.3	37.9	37.5	37.1
4/20/05	47.7	45.8	37.6	38.8	NA	NA
4/21/05	46.9	45.3	37.2	37.7	37.7	37.6

Table 4-27. Raw, Influent and Effluent Water Pressure and Influent and Effluent Flow Rate (continued)

	Pressure			Flow Rate		
Date	Raw Water (psi)	Influent Water (psi)	Effluent Water (psi)	Influent Water (gpm)	Calculated Influent Water (gpm)	Calculated Effluent Water (gpm)
Initial Plant Characterization No. 1 (04/04/05 – 04/23/05)						
4/21/05	45.9	43.9	35.3	38.1	NA	NA
4/22/05	46.0	44.1	35.7	37.4	37.7	37.6
4/22/05	46.9	45.1	36.4	36.9	NA	NA
4/23/05	47.9	46.2	37.1	38.3	37.1	38.0
4/23/05	48.0	46.2	37.1	37.8	NA	NA
4/27/05	45.5	43.6	36.2	35.5	38.0	37.7
Initial Plant Characterization No. 2 (04/29/05 – 05/09/05)						
4/29/05	47.4	45.6	37.9	36.7	37.2	37.1
4/29/05	46.2	44.2	35.9	38.6	36.6	36.6
4/30/05	47.5	45.8	38.1	36.6	37.8	37.8
4/30/05	46.3	44.3	36.0	38.5	38.0	38.0
5/1/05	47.5	45.9	37.8	37.6	37.7	37.7
5/1/05	46.7	44.8	36.7	38.7	36.9	36.9
5/2/05	47.6	46.1	37.6	36.3	36.3	36.2
5/2/05	45.7	43.7	34.8	37.4	36.4	36.4
5/3/05	45.8	44.0	36.0	35.2	36.8	36.8
5/3/05	44.7	42.8	34.5	37.1	36.1	36.1
5/4/05	45.6	43.9	36.6	35.6	35.8	35.7
5/4/05	45.3	45.0	34.4	33.3	36.1	35.9
5/5/05	46.0	43.9	34.9	39.5	36.0	35.9
5/5/05	46.0	44.1	35.0	37.7	33.5	33.5
5/6/05	48.7	47.0	38.2	37.4	39.4	39.3
5/6/05	49.5	47.8	38.5	38.3	37.8	37.8
5/7/05	47.5	45.9	37.1	36.7	39.9	39.4
5/7/05	46.3	44.3	34.9	37.9	37.4	37.4
5/8/05	48.1	46.4	38.0	37.5	38.1	38.0
5/8/05	47.1	45.4	36.3	38.1	37.6	37.6
5/9/05	46.9	45.2	37.2	36.9	37.7	37.6
5/9/05	45.6	43.5	34.9	38.0	37.2	37.2
Verification Testing (05/12/05 – 05/28/05)						
5/12/05	46.2	44.4	36.3	35.0	37.6	37.5
5/12/05	45.5	43.8	34.8	37.9	35.9	35.9
5/13/05	48.2	46.4	37.3	38.1	41.7	41.7
5/13/05	48.4	46.5	37.5	37.7	37.5	37.5
5/14/05	45.8	43.9	35.0	36.1	37.3	37.3
5/14/05	44.4	46.1	36.8	36.3	35.9	35.9
5/15/05	47.8	46.2	37.3	37.4	37.4	37.2

Table 4-27. Raw, Influent and Effluent Water Pressure and Influent and Effluent Flow Rate (continued)

		Pressure			Flow Rate	
Date	Raw Water (psi)	Influent Water (psi)	Effluent Water (psi)	Influent Water (gpm)	Calculated Influent Water (gpm)	Calculated Effluent Water(gpm)
Verification Testing (05/12/05 – 05/28/05)						
5/15/05	47.5	45.8	36.7	37.7	37.7	37.7
5/16/05	44.9	42.9	35.2	36.7	37.4	37.3
5/16/05	46.9	45.1	36.7	38.0	36.3	36.3
5/17/05	44.7	43.0	35.3	34.0	36.9	36.8
5/17/05	45.8	43.8	36.0	37.0	36.6	36.4
5/18/05	46.0	44.0	36.0	35.7	36.1	36.0
5/18/05	50.4	48.7	38.6	40.6	37.1	37.1
5/19/05	46.4	44.4	35.4	36.4	36.3	44.1
5/19/05	45.8	43.8	36.1	36.3	44.3	13.6
5/20/05	46.8	44.8	36.8	37.7	38.7	38.6
5/20/05	47.2	45.2	36.9	37.8	23.3	23.1
5/21/05	47.1	45.3	36.6	37.6	40.3	40.3
5/21/05	47.2	45.3	36.8	38.2	37.6	37.4
5/22/05	48.4	46.4	37.6	37.7	37.4	37.3
5/22/05	49.2	47.6	38.8	38.2	46.7	37.7
5/23/05	48.9	47.1	37.3	37.7	35.1	37.9
5/23/05	48.4	46.4	36.3	38.2	37.5	37.5
5/24/05	48.0	48.0	37.3	37.8	39.1	39.0
5/24/05	47.0	44.7	36.1	38.0	38.1	38.1
5/25/05	47.8	45.7	37.4	37.8	37.8	37.7
5/25/05	47.2	45.2	36.1	38.1	38.0	38.0
5/26/05	48.2	46.1	37.6	36.8	37.9	37.8
5/26/05	47.4	45.2	36.8	36.5	37.6	37.3
5/27/05	48.2	46.2	37.7	36.2	36.4	36.4
5/27/05	47.2	45.2	35.5	37.6	36.5	36.5
5/28/05	48.4	46.3	37.9	37.0	36.6	36.6
5/28/05	47.7	45.6	35.9	38.6	37.4	37.4
Verification Test Statistical Analysis						
Average	47.2	45.4	36.7	37.3	37.5	36.6
Minimum	44.4	42.9	34.8	34.0	23.3	13.6
Maximum	50.4	48.7	38.8	40.6	46.7	44.1
Number of Samples	34	34	34	34	34	34
Standard Deviation	1.34	1.35	0.98	1.17	3.41	5.03
95% Confidence Interval	(47.1-47.3)	(45.4-45.5)	(36.6-36.7)	(37.2-37.4)	(37.3-37.7)	(36.2-36.9)

[1] The reported flow rates may be biased high based on manual calibration results – see Section 4.7.4 and Table 4-49.

NA = Not Available.

Brine Solution Strength

The fresh brine was sampled once during the first Initial Plant Characterization and twice during the Verification Test to evaluate the percentage of brine used during the regeneration process. The results of the sampling are provided in Table 4-28 and indicate that there is variability in the brine strength used for the regeneration cycle, with chloride levels ranging from 67,000 to 230,000 mg/L.

Table 4-28. Brine Solution Strength

Date	Chloride (mg/L)	Sodium (mg/L)	TDS (mg/L)	Conductivity (μmho/cm)
4/17/05	67000	41000	108000	NA
5/12/05	230000	98000	319000	177000
5/18/05	200000	97000	313000	180000

NA = Not Available.

Number of columns exhausted/regenerated per day

The number of columns exhausted and regenerated per day was consistent throughout verification testing. Four IX columns were online at all times, with one column in regeneration and one in standby. Table 4-29 presents the start and finish times and dates when each column was in an exhaustion (water treatment) cycle.

Table 4-29: Exhaustion Start and Finish Times and Dates

Cycle. No.	Column 5		Column 6		Column 7	
	Start	Finish	Start	Finish	Start	Finish
1	4/2/05 10:26 PM	4/5/05 6:21 PM	4/3/05 9:40 PM	4/6/05 4:14 PM	4/4/05 9:08 AM	4/8/05 11:04 PM
2	4/8/05 11:33 PM	4/12/05 5:33 PM	4/9/05 9:05 PM	4/13/05 3:39 PM	4/10/05 7:32 PM	4/14/05 1:15 PM
3	4/14/05 1:43 PM	4/18/05 3:20 AM	4/15/05 12:47 PM	4/19/05 1:24 AM	4/16/05 9:11 AM	4/19/05 11:37 PM
4	4/20/05 12:05 AM	4/23/05 2:52 PM	4/20/05 9:39PM	4/24/05 11:57 AM	4/21/05 7:39 PM	4/25/05 9:42 AM
5	4/25/05 10:10 AM	4/28/05 4:51 PM	4/26/05 7:48 AM	4/29/05 9:50 AM	4/27/05 6:26 AM	4/30/05 2:39 AM
6	4/30/05 3:13 AM	5/2/05 11:35 PM	4/30/05 8:10 PM	5/3/05 5:06 PM	5/1/05 1:14 PM	5/4/05 10:53 AM
7	5/4/05 11:28 AM	5/8/05 5:15 AM	5/5/05 5:20 AM	5/8/05 10:12 PM	5/5/05 9:39 PM	5/9/05 3:13 PM
8	5/9/05 3:46 PM	5/15/05 10:01 AM	5/11/05 3:56 PM	5/16/05 2:50 AM	5/12/05 9:16 AM	5/17/05 8:13 PM
9	5/16/05 8:47 PM	5/19/05 9:32 AM	5/17/05 2:07 PM	5/20/05 2:55 AM	5/19/05 7:44 AM	5/20/05 7:47 PM
10	5/21/05 8:21 PM	5/23/05 3:32 PM	5/21/05 1:11 PM	5/24/05 7:47 AM	5/22/05 5:52 AM	5/25/05 12:22 AM
11	5/25/05 12:57 AM	NA	5/24/05 5:45 PM	NA	5/26/05 1:20 PM	NA

Cycle No.	Column 8		Column 9		Column 10	
	Start	Finish	Start	Finish	Start	Finish
1	4/4/05 8:45 PM	4/9/05 8:37 PM	4/5/05 7:21 PM	4/10/05 7:05 PM	4/1/05 8:09 PM	4/4/05 8:15 PM
2	4/11/05 7:47 PM	4/15/05 12:22 PM	4/12/05 5:57 PM	4/16/05 8:45 AM	4/6/05 4:47 PM	4/11/05 7:20 PM
3	4/17/05 6:29 AM	4/20/05 9:12 PM	4/18/05 3:46 AM	4/21/05 7:13 PM	4/13/05 4:07 PM	4/17/05 6:03 AM
4	4/22/05 5:41 PM	4/26/05 7:20 AM	4/23/05 3:18 PM	4/27/05 5:59 AM	4/19/05 1:52 AM	4/22/05 5:16 PM
5	4/28/05 4:46 AM	4/30/05 7:36 PM	4/28/05 5:24 PM	5/1/05 12:41 PM	4/24/05 12:26 PM	4/28/05 4:20 AM
6	5/2/05 6:47 AM	5/5/05 4:44 AM	5/3/05 12:07 AM	5/5/05 9:07 PM	4/29/05 10:25 AM	5/2/05 6:16 AM
7	5/7/05 1:23 PM	5/10/05 7:49 AM	5/8/05 5:47 AM	5/12/05 8:43 AM	5/3/05 12:07 AM	5/6/05 1:48 PM
8	5/14/05 2:04 AM	5/17/05 1:43 PM	5/15/05 10:30 AM	5/18/05 7:11 AM	5/8/05 10:45 PM	5/14/05 1:33 AM
9	5/19/05 12:07 AM	5/21/05 12:36 PM	5/19/05 10:05 AM	5/22/05 5:20 AM	5/16/05 3:24 AM	5/19/05 12:09 AM
10	5/22/05 11:19 PM	5/25/05 5:12 PM	5/23/05 4:04 PM	5/26/05 12:46 PM	5/20/05 2:55 AM	5/22/05 10:49 PM
11	5/27/05 11:01 AM	NA	NA	NA	5/24/05 8:21 AM	5/27/05 6:13 AM

NA = Not Available.

Power Consumption

The Basin Water System is a hydraulically driven system that required approximately 42 KW-Hrs total during the Initial Plant Characterizations and the Verification Test for a total of 48 days (0.88 KW-Hrs per day). The average daily power consumption during the first characterization test (regeneration set at 1,100 BV) was 0.84 KW-Hrs per day. The average consumption during the second Initial Plant Characterization and the Verification Test was slightly higher at 0.92 KW-Hrs per day and 0.88 KW-Hrs per day, respectively. The cumulative daily power totalizer readings are presented in Table 4-30.

Table 4-30. Cumulative Power Totalizer Reading During Verification Testing

Date	Power Totalizer (KW-Hrs)
Initial Plant Characterization No. 1 (04/04/05 – 04/23/05)	
4/4/05	0
4/5/05	5
4/6/05	5
4/7/05	6
4/8/05	6
4/9/05	6
4/10/05	7
4/11/05	8
4/12/05	8
4/13/05	9
4/14/05	10
4/15/05	10
4/16/05	11
4/17/05	12
4/18/05	12
4/20/05	14
4/21/05	14
4/22/05	15
4/23/05	16
Initial Plant Characterization No. 2 (04/29/05 – 05/09/05)	
4/27/05	18
4/29/05	20
4/30/05	21
5/1/05	21
5/2/05	22
5/3/05	23
5/4/05	23
5/5/05	24
5/6/05	25
5/7/05	25
5/8/05	26
5/9/05	27
Verification Testing (05/12/05 – 05/28/05)	
5/12/05	29
5/13/05	29
5/14/05	30
5/15/05	31
5/16/05	31
5/17/05	32
5/18/05	33
5/19/05	33
5/20/05	33
5/21/05	34
5/22/05	36
5/23/05	38
5/24/05	38
5/25/05	39
5/26/05	40
5/27/05	41
5/28/05	42

Chemical Consumption

The chemicals consumed during the Initial Plant Characterizations and the Verification Test included sodium hypochlorite for preoxidation, sodium chloride (salt) for the regeneration of the IX resin, and sulfuric acid, caustic soda, and ferric chloride for the brine treatment process. The daily chemical consumption information is provided in Table 4-31. On average throughout both Initial Plant Characterizations and the Verification Test, the Basin Water system consumed 0.11 pounds per day (ppd) of sodium hypochlorite for preoxidation, 107 ppd of sodium chloride for regeneration, and 4.10 ppd sulfuric acid, 1.83 ppd caustic soda, and 1.63 ppd ferric chloride for the brine treatment process.

Table 4-31. Daily Chemical Consumption

Date	Sodium Hypochlorite Consumption (lbs)	Sodium Chloride Consumption (lbs)	Sulfuric Acid Consumption (lbs)	Caustic Soda Consumption (lbs)	Ferric Chloride Consumption (lbs)
4/4/05	NA	85.5	NA	NA	NA
4/5/05	0.18	97.0	NA	NA	NA
4/6/05	0.08	101.0	NA	NA	NA
4/8/05	NA	83.1	1.43	0.96	0.54
4/9/05	0.13	83.9	0.71	1.49	0.59
4/10/05	NA	87.4	1.43	0.85	0.52
4/11/05	NA	84.6	1.43	1.06	0.49
4/12/05	NA	73.3	1.90	1.06	0.52
4/13/05	0.05	81.5	1.43	1.28	0.56
4/14/05	0.06	84.2	2.75	1.92	1.77
4/15/05	0.06	83.5	3.86	2.42	0.50
4/16/05	0.17	86.6	4.64	3.11	1.26
4/17/05	0.01	89.7	3.86	2.42	1.26
4/18/05	0.08	83.9	4.64	2.42	1.26
4/19/05	NA	86.1	3.09	3.11	1.51
4/20/05	0.09	88.2	3.09	1.38	1.26
4/21/05	0.10	83.5	2.32	1.04	1.26
4/22/05	0.09	81.4	4.64	3.11	1.26
4/23/05	0.10	83.9	4.64	2.76	1.26
4/29/05	0.09	102.0	6.95	3.97	2.65
4/30/05	0.11	197.3	4.64	2.07	1.51
5/1/05	0.08	94.5	4.64	1.38	1.77
5/2/05	0.09	189.5	8.50	2.76	3.03
5/3/05	0.15	95.8	5.41	1.38	1.77
5/4/05	0.09	104.5	3.86	1.38	1.77
5/5/05	NA	200.0	3.86	3.11	3.53
5/6/05	0.10	NA	4.64	1.04	1.51
5/7/05	0.18	18.5	3.09	1.73	3.03
5/8/05	0.10	189.7	3.86	1.73	1.77

Table 4-31. Chemical Consumption (continued)

Date	Sodium Hypochlorite Consumption (lbs)	Sodium Chloride Consumption (lbs)	Sulfuric Acid Consumption (lbs)	Caustic Soda Consumption (lbs)	Ferric Chloride Consumption (lbs)
5/9/05	0.08	95.8	3.86	1.38	1.51
5/12/05	0.10	95.9	NA	NA	NA
5/13/05[1]	NA	NA	NA	NA	NA
5/14/05	0.12	97.3	3.86	1.38	2.02
5/15/05	0.07	83.7	2.32	1.04	3.28
5/16/05	0.12	93.5	3.86	0.35	1.77
5/17/05	0.12	96.5	10.05	2.76	3.03
5/18/05	0.11	94.0	4.64	1.38	1.77
5/19/05	0.10	190.9	4.64	1.04	1.26
5/20/05	0.17	195.5	NA	NA	NA
5/21/05	0.13	98.5	6.18	1.73	1.77
5/22/05	0.14	188.1	3.09	1.04	1.26
5/23/05	0.12	98.3	4.64	1.73	1.51
5/24/05	0.14	97.6	NA	NA	NA
5/25/05	0.14	193.2	NA	NA	NA
5/26/05	0.15	94.4	9.27	2.76	3.03
5/27/05	0.12	92.5	NA	NA	NA
Daily Average	0.11	107	4.10	1.83	1.63

[1] Data not available because there was not a regeneration cycle on this day; a shutdown occurred on 5/12-5/13/05.
NA = Not Available.

4.5.5 Brine Treatment Operation and Waste Generation

The Basin Water System generated two waste streams: solid waste (from BPU and BRA) and liquid waste. Each of these waste streams is discussed in additional detail in Section 4.5.5.1 and 4.5.5.2.

The BRA utilized one 55-gallon drum (2 cubic feet) of an iron-based adsorptive media (BW-33-60). The brine circulated between a holding tank and the 55-gallon drum of adsorptive media for 10 hours prior to discharging to the waste storage tank. The settling time prior to discharge to the waste tank was two hours. The treated brine was clear, indicating the brine/adsorptive media were not difficult to separate. The results of the analysis of the treated waste brine are presented and discussed in Section 4.5.5.2

The BPU system operated in batch precipitation mode. As the waste brine was pumped into the reaction tank, ferric chloride was added at a rate of 0.041 pounds of ferric chloride per gallon of waste brine. The mixing was instantaneous, and no additional mixing mechanism was applied. Acid was then added to the reaction tank, followed by 30 minutes of slow mixing. Caustic was then added followed by 30 minutes of additional slow mixing. Upon completion of chemical additions and mixing, the reaction tank was allowed to settle for three hours. After one hour the sludge reached what appeared to be the final settled volume.

The optimal pH (as defined by the manufacturer) during the BPU reaction was 6.0 during the acid addition phase and 7.3 during the caustic addition phase. However, the pH meter in the BPU was not calibrated as part of the verification test, and the optimal pH for the acid and caustic addition phases were not consistently achieved. The pH of the brine was sometimes less than 6.0 during the acid addition phase and greater than 7.3 during the caustic addition phase. These differences may have been attributed to the location of the pH meter or the mixing conditions.

4.5.5.1 Waste Brine Efficiency

As discussed in Section 2.5.2, the manufacturer indicated the waste brine represented less than 0.1% of the treated water. Table 4-32 presents the percentage of waste brine to treated water, or waste brine efficiency. During the Initial Plant Characterization No. 1 when the bed volumes were set at 1,100, the percentage of waste brine was 0.06-0.08% of the treated water flow. When the bed volumes were reduced to 850 for the Verification Test, the percentage of waste brine was 0.08-0.09% of the treated water flow. These calculations are based on the flow rate measured by the flow meter. As noted in Section 4.5.4 and Section 4.7.4 and presented in Table 4-49, the manual flow measurements showed that the flow meter may have read about 16% high. If this was the case, the actual regeneration set points were 950 BV and 730 BV versus the reported set points of 1,100 BV and 850 BV. The percentage of waste brine to treated water would be slightly above 0.1% of the treated water flow, if the treated water volumes shown in Table 4-32 were adjusted for the flow rate measured by the manual method.

Table 4-32. Waste Brine Efficiency

Date	Brine (gallons)	Effluent Water (gallons)	Bed Volumes[1]	Percentage of Brine to Treated Water
Initial Plant Characterization No. 1 (04/04/05 - 04/23/05)				
4/4/2005	28.50	44814	1100	0.06%
4/5/2005	32.32	44814	1100	0.07%
4/6/2005	33.66	44814	1100	0.08%
4/8/2005	27.69	44814	1100	0.06%
4/9/2005	27.95	44814	1100	0.06%
4/10/2005	29.12	44814	1100	0.06%
4/11/2005	28.20	44814	1100	0.06%
4/12/2005	24.42	44814	1100	0.05%
4/13/2005	27.17	44814	1100	0.06%
4/14/2005	28.08	44814	1100	0.06%
4/15/2005	27.82	44814	1100	0.06%
4/16/2005	28.86	44814	1100	0.06%
4/17/2005	29.90	44814	1100	0.07%
4/18/2005	27.95	44814	1100	0.06%
4/19/2005	28.70	44814	1100	0.06%
4/20/2005	29.40	44814	1100	0.07%
4/21/2005	27.82	44814	1100	0.06%
4/22/2005	27.12	44814	1100	0.06%

Table 4-32. Waste Brine Efficiency (continued)

Date	Brine (gallons)	Effluent Water (gallons)	Bed Volumes[1]	Percentage of Brine to Treated Water
Initial Plant Characterization No. 1 (04/04/05 - 04/23/05)				
4/23/2005	27.95	44814	1100	0.06%
Initial Plant Characterization No. 2 (04/29/05 - 05/09/05)				
4/29/2005	34.00	34629	850	0.10%
4/30/2005	65.76	69258	850	0.09%
5/1/2005	31.50	34629	850	0.09%
5/2/2005	63.17	69258	850	0.09%
5/3/2005	31.93	34629	850	0.09%
5/4/2005	34.83	34629	850	0.10%
5/5/2005	66.65	69258	850	0.10%
5/6/2005	NA	34629	850	NA
5/7/2005	6.18	34629	850	0.02%
5/8/2005	63.22	69258	850	0.09%
5/9/2005	31.93	34629	850	0.09%
Verification Test (05/12/05 - 05/28/05)				
5/12/2005	31.95	34629	850	0.09%
5/13/051	NA	34629	850	NA
5/14/2005	32.21	34629	850	0.09%
5/15/2005	27.82	34629	850	0.08%
5/16/2005	31.00	34629	850	0.09%
5/17/2005	32.16	34629	850	0.09%
5/18/2005	31.33	34629	850	0.09%
5/19/2005	63.63	69258	850	0.09%
5/20/2005	64.75	69258	850	0.09%
5/21/2005	32.60	34629	850	0.09%
5/22/2005	62.29	69258	850	0.09%
5/23/2005	32.55	34629	850	0.09%
5/24/2005	32.32	34629	850	0.09%
5/25/2005	64.19	69258	850	0.09%
5/26/2005	31.37	34629	850	0.09%
5/27/2005	30.74	34629	850	0.09%

[1] The reported volumes may be biased high based on manual calibration results – see Section 4.7.4 and Table 4-49.

NA = Not Available.

4.5.5.2 Untreated and Treated Waste Brine

During the Verification Test, six samples of untreated and treated waste brine were collected for analysis of the parameters listed in Table 3-7. The results of the analyses are presented in Table 4-33. These results indicate that both the BPU and the BRA were effective at removing arsenic from the waste brine.

Table 4-33. Untreated and Treated Liquid Waste Brine

Date	Sample	Conductivity[1] mmho/cm	pH[2]	Total As[3] ug/L	Antimony[4] mg/L	Barium[4] mg/L	Beryllium[4] mg/L	Cadmium[4] mg/L
5/16/05	Untreated Brine	99700	9.7	3800	<0.025	0.200	<0.025	<0.012
5/16/05	Treated Brine (Preciptation)	97200	8.0	1100	<0.100	<0.200	<0.100	<0.050
5/17/05	Untreated Brine	106000	9.7	4700	<0.100	0.230	<0.100	<0.050
5/17/05	Treated Brine (Preciptation)	99200	8.1	<100	<0.100	<0.200	<0.100	<0.050
5/18/05	Untreated Brine	105000	9.7	4100	<0.050	0.380	<0.050	<0.025
5/18/05	Treated Brine (Preciptation)	101000	7.9	140	<0.050	<0.100	<0.050	<0.025
5/25/05	Untreated Brine	96500	9.7	4800	<0.100	0.420	<0.100	<0.050
5/25/05	Treated Brine (Adsorption)	48600	9.8	1100	<0.100	<0.200	<0.100	<0.050
5/26/05	Untreated Brine	111000	9.6	1200	<0.100	<0.200	<0.100	<0.050
5/26/05	Treated Brine (Adsorption)	81100	9.8	1100	<0.100	<0.200	<0.100	<0.050
5/28/05	Untreated Brine	108000	9.8	2700	<0.050	0.350	<0.050	<0.025
5/28/05	Treated Brine (Adsorption)	72200	9.9	1500	<0.050	0.290	<0.050	<0.025
Untreated Brine	Average	104000	9.7	3600	<0.100	0.300	<0.100	<0.050
	Minimum	96500	9.6	1200	<0.025	<0.200	<0.025	<0.012
	Maximum	111000	9.8	4800	<0.100	0.420	<0.100	<0.050
	Number of Samples	6	6	6	6	6	6	6
Treated Brine (Preciptation)	Average	99100	8.0	450	<0.100	<0.200	<0.100	<0.050
	Minimum	97200	7.9	<100	<0.050	<0.100	<0.050	<0.025
	Maximum	101000	8.1	1100	<0.100	<0.200	<0.100	<0.050
	Number of Samples	3	3	3	3	3	3	3
Treated Brine (Adsorption)	Average	67300	9.8	1200	<0.100	0.230	<0.100	<0.050
	Minimum	48600	9.8	1100	<0.050	<0.200	<0.050	<0.025
	Maximum	81100	9.9	1500	<0.100	0.290	<0.100	<0.050
	Number of Samples	3	3	3	3	3	3	3

Date	Sample	Chromium[4] mg/L	Cobalt[4] mg/L	Copper[4] mg/L	Lead[4] mg/L	Mercury[5] mg/L	Molybdenum[4] mg/L	Nickel[4] mg/L
5/16/05	Untreated Brine	<0.025	<0.050	<0.050	<0.012	<0.00020	1.400	<0.125
5/16/05	Treated Brine (Preciptation)	0.100	<0.200	<0.200	<0.050	<0.00020	4.700	<0.500
5/17/05	Untreated Brine	0.100	<0.200	<0.200	<0.050	<0.00020	4.500	<0.500
5/17/05	Treated Brine (Preciptation)	<0.100	<0.200	<0.200	<0.050	<0.00020	3.500	<0.500
5/18/05	Untreated Brine	<0.050	<0.100	<0.100	<0.025	<0.00020	3.500	<0.250
5/18/05	Treated Brine (Preciptation)	<0.050	<0.100	<0.100	<0.025	<0.00020	3.200	<0.250
5/25/05	Untreated Brine	<0.100	<0.200	<0.200	<0.050	<0.00020	4.400	<0.500
5/25/05	Treated Brine (Adsorption)	0.470	<0.200	<0.200	<0.050	<0.00020	1.200	<0.500
5/26/05	Untreated Brine	0.580	<0.200	<0.200	<0.050	<0.00020	1.300	<0.500
5/26/05	Treated Brine (Adsorption)	0.490	<0.200	<0.200	<0.050	<0.00020	0.840	<0.500
5/28/05	Untreated Brine	<0.050	<0.100	<0.100	<0.025	<0.00020	3.900	<0.250
5/28/05	Treated Brine (Adsorption)	0.150	<0.100	<0.100	<0.025	<0.00020	1.900	<0.250
Untreated Brine	Average	0.150	<0.200	<0.200	<0.050	<0.00020	3.200	<0.500
	Minimum	<0.025	<0.050	<0.050	<0.012	<0.00020	1.300	<0.125
	Maximum	0.580	<0.200	<0.200	<0.050	<0.00020	4.500	<0.500
	Number of Samples	6	6	6	6	6	6	6
Treated Brine (Preciptation)	Average	0.083	<0.200	<0.200	<0.050	<0.00020	3.800	<0.500
	Minimum	<0.050	<0.100	<0.100	<0.025	<0.00020	3.200	<0.250
	Maximum	0.100	<0.200	<0.200	<0.050	<0.00020	4.700	<0.500
	Number of Samples	3	3	3	3	3	3	3
Treated Brine (Adsorption)	Average	0.370	<0.200	<0.200	<0.050	<0.00020	1.300	<0.500
	Minimum	0.150	<0.100	<0.100	<0.025	<0.00020	0.840	<0.250
	Maximum	0.490	<0.200	<0.200	<0.050	<0.00020	1.900	<0.500
	Number of Samples	3	3	3	3	3	3	3

Table 4-33. Untreated and Treated Liquid Waste Brine (continued)

Date	Sample	Selenium[4] mg/L	Silver[4] mg/L	TSS[6] mg/L	Thallium[4] mg/L	Vanadium[4] mg/L	Zinc[4] mg/L
5/16/05	Untreated Brine	<0.500	<0.012	<10	<0.025	14.000	<0.125
5/16/05	Treated Brine (Preciptation)	0.820	<0.050	340	<0.100	1.001	<0.500
5/17/05	Untreated Brine	0.610	<0.050	76	<0.100	4.024	<0.500
5/17/05	Treated Brine (Preciptation)	0.690	<0.050	190	<0.100	0.360	<0.500
5/18/05	Untreated Brine	0.570	<0.025	26	<0.050	3.940	<0.250
5/18/05	Treated Brine (Preciptation)	<0.500	0.030	24	<0.050	0.890	<0.250
5/25/05	Untreated Brine	0.550	<0.050	70	<0.100	3.954	<0.500
5/25/05	Treated Brine (Adsorption)	<0.500	<0.050	<10	<0.100	9.900	<0.500
5/26/05	Untreated Brine	<0.500	<0.050	47	<0.100	11.000	<0.500
5/26/05	Treated Brine (Adsorption)	0.690	<0.050	<10	<0.100	9.200	<0.500
5/28/05	Untreated Brine	0.580	<0.025	43	<0.050	4.113	<0.250
5/28/05	Treated Brine (Adsorption)	0.470	<0.025	<10	<0.050	1.996	<0.250
Untreated Brine	Average	0.550	<0.050	45	<0.100	6.839	<0.500
	Minimum	<0.500	<0.012	<10	<0.025	3.940	<0.125
	Maximum	0.610	<0.050	76	<0.100	14.000	<0.500
	Number of Samples	6	6	6	6	6	6
Treated Brine (Preciptation)	Average	0.670	0.040	180	<0.100	0.750	<0.500
	Minimum	<0.500	0.030	24	<0.050	0.360	<0.250
	Maximum	0.820	<0.050	340	<0.100	1.001	<0.500
	Number of Samples	3	3	3	3	3	3
Treated Brine (Adsorption)	Average	0.550	<0.050	<10	<0.100	7.032	<0.500
	Minimum	0.470	<0.025	<10	<0.050	1.996	<0.250
	Maximum	0.690	<0.050	<10	<0.100	9.900	<0.500

[1] Conductivity was measured using SW9050 analytical method instead of method 2510B, as stated in Table 3-7.

[2] pH was measured using E 150 analytical method instead of method 4500-H+ B, as stated in Table 3-7.

[3] Arsenic was measured using EPA 200.8 analytical method except on 05/24/05 for untreated brine, when EPA method 200.7 was used.

[4] EPA 200.8 analytical method was used instead of EPA 6010B method, as stated in Table 3-7.

[5] Mercury was measured using EPA 245.1 analytical method instead of EPA 7470A method, as stated Table 3-7.

[6] TSS was measured using EPA 160.2 analytical method instead of SM 2540D method, as stated Table 3-7.

The combined (BPU and BRA) treated waste was analyzed prior to disposal to characterize the liquid waste for appropriate disposal. The results of the liquid brine waste analysis are presented in Table 4-34.

Table 4-34: Combined BRA and BPU Waste Brine Analysis

Parameter	Units	Results
Antimony	µg/L	<50
Total Arsenic	µg/L	580
Barium	µg/L	100
Beryllium	µg/L	<50
Cadmium	µg/L	<25
Cobalt	µg/L	<100
Chromium, Total	µg/L	56
Copper	µg/L	<100
Conductivity	umho/cm	94,500
Mercury	µg/L	<0.20
Molybdenum	µg/L	3400
Nickel	µg/L	<250
Lead	µg/L	<25
pH	pH units	9.2
Selenium	µg/L	690
Silver	µg/L	<25
Thallium	µg/L	<50
TSS	mg/L	<10
Vanadium	µg/L	5800
Zinc	µg/L	<250

4.5.5.3 Solid Waste

The analysis of the solid waste generated from both the BPU and the BRA brine treatment systems is presented in Table 4-35. The waste generated from the BPU on May 19, 2005, was found to be classified as nonhazardous based on the results of the California waste analysis methods of TTLC, STLC, and the federal waste analysis method of TCLP based on the total arsenic. The total mass of arsenic in the waste was 233 milligrams per kilogram (mg/kg) of waste generated, with a TTLC limit of 500 mg/kg for hazardous waste. The result of the TCLP was <1.0 mg/L total arsenic, with a hazardous limit of 5.0 mg/L. The total arsenic leachate from the STLC analysis was 2.8 mg/L, with a limit of 5.0 mg/L for hazardous waste. The waste generated from the BRA on June 2, 2005, was also found to be classified as nonhazardous based on the results of the California waste analysis methods of TTLC, STLC, and the federal waste analysis method of TCLP based on the total arsenic. The total mass of arsenic in the waste was <3 mg/kg of waste generated, with a TTLC limit of 500 mg/kg for hazardous waste. The result of the TCLP was <1.0 mg/L total arsenic, with a hazardous limit of 5.0 mg/L. The total arsenic leachate from the STLC analysis was <0.5 mg/L, with a limit of 5.0 mg/L for hazardous waste.

Precision results are also presented in Table 4-35 for solid samples collected on both May 19, 2005, and June 2, 2005. These results show the variation possible in the TTLC samples collected. There was very little variation between the sample and duplicate collected on May 19 (approximately 4%), while there was great variation in those samples and duplicates collected on June 2 (approximately 51%). Most duplicate samples collected for the TCLP and STLC samples were <10%.

Table 4-35: Solid Waste Analysis

		Solids (Precipitation)	Duplicate Solids (Precipitation)	Percent Precision	Solids (Adsorption)	Duplicate Solids (Adsorption)	Percent Precision	Threshold Levels
Sample Date			5/19/05			6/2/05		
TTLC								
Antimony	mg/Kg	<10	<10	0%	<10	<20	47%	500
Total As[1]	mg/Kg	233	199	11%	<3	<7	57%	500
Barium	mg/Kg	21	20	3%	1.31	3	55%	10,000
Beryllium	mg/Kg	0.5	<0.5	0%	<0.5	<1	47%	75
Cadmium	mg/Kg	<1	<1	0%	<1	<2	47%	100
Chromium	mg/Kg	16	16	0%	46.9	100	51%	2,500
Cobalt	mg/Kg	<2	<2	0%	11.2	24	51%	8,000
Copper	mg/Kg	10	9	7%	<2	<5	61%	2,500
Lead	mg/Kg	9	<5	40%	25.4	53	50%	1,000
Mercury[2]	mg/Kg	<0.05	<0.05	0%	<0.05	<0.1	47%	20
Molybdenum	mg/Kg	80	76	4%	10.2	<20	46%	3,500
Nickel	mg/Kg	<5	<5	0%	37.8	83	53%	2,000
Selenium[3]	mg/Kg	<3	<3	0%	<3	<7	57%	100
Silver	mg/Kg	<1	<1	0%	<1	<2	47%	500
Thallium[3]	mg/Kg	<0.4	<0.4	0%	<0.4	<0.9	54%	700
Vanadium	mg/Kg	1980	1910	3%	<1	<2	47%	2,400
Zinc	mg/Kg	19	19	0%	23.1	50	52%	5,000
TCLP								
Total As	mg/L	<0.1	<0.1	0%	<0.1	<0.1	0%	5.0
Barium	mg/L	<1	<1	0%	<1	<1	0%	100.0
Cadmium	mg/L	<0.01	<0.01	0%	<0.01	<0.01	0%	1.0
Chromium	mg/L	<0.01	<0.01	0%	<0.01	<0.01	0%	5.0
Lead	mg/L	<0.05	<0.05	0%	<0.05	<0.05	0%	5.0
Mercury	mg/L	<0.01	<0.01	0%	<0.01	<0.01	0%	0.2
Selenium	mg/L	0.1	0.1	0%	<0.1	<0.1	0%	1.0
Silver	mg/L	<0.01	<0.01	0%	<0.01	<0.01	0%	5.0
STLC								
Antimony	mg/L	<0.5	<0.5	0%	<0.5	<0.5	0%	15
Total As	mg/L	2.8	2.9	2%	<0.5	<0.5	0%	5.0
Barium	mg/L	0.6	0.7	11%	<0.5	<0.5	0%	100
Beryllium	mg/L	<0.05	<0.05	0%	<0.05	<0.05	0%	0.75
Cadmium	mg/L	<0.05	<0.05	0%	<0.05	<0.05	0%	1.0
Chromium	mg/L	0.6	0.70	11%	0.2	0.22	7%	560
Cobalt	mg/L	<0.1	<0.1	0%	<0.1	<0.1	0%	80
Copper	mg/L	0.63	0.70	7%	<0.05	<0.05	0%	25
Lead	mg/L	<0.5	<0.5	0%	<0.5	<0.5	0%	5.0
Mercury	mg/L	<0.01	<0.01	0%	<0.01	<0.01	0%	0.2

Table 4-35: Solid Waste Analysis (continued)

		Solids (Precipitation)	Duplicate Solids (Precipitation)	Percent Precision	Solids (Adsorption)	Duplicate Solids (Adsorption)	Percent Precision	Threshold Levels
Sample Date			5/19/05			6/2/05		
STLC								
Molybdenum	mg/L	3.7	4.3	11%	0.3	0.32	5%	350
Nickel	mg/L	0.3	0.3	0%	<0.2	<0.2	0%	20
Selenium	mg/L	<0.5	<0.5	0%	<0.5	<0.5	0%	1.0
Silver	mg/L	<0.05	<0.05	0%	<0.05	<0.05	0%	5
Thallium	mg/L	0.6	<0.5	13%	<0.5	<0.5	0%	7.0
Vanadium	mg/L	76	84	7%	<0.05	<0.05	0%	24
Zinc	mg/L	1.0	1.1	7%	<0.1	0.11	7%	250
Total Solids	%	20	20	0%	45	43	3%	NA

[1] EPA 6020 method was used to test total arsenic instead of EPA 6010B method, as stated in Table 3-7.
[2] EPA 7471A method was used to test mercury instead of EPA 7470A method, as stated in Table 3-7.
[3] EPA 6020 method was used to test selenium and thallium instead of EPA 6010B method, as stated in Table 3-7.
NA = Not Applicable.

4.6 Task 5: Data Management

The objective of this task was to establish an effective field protocol for data management at the field operations site and for data transmission between the FTO and NSF during verification testing. Prior to the beginning of the field testing, the database or spreadsheet design was developed by the FTO and received and approved by NSF. This ensured that the required data were collected during the testing, and that results could be effectively transmitted to NSF for review. The FTO followed all data handling procedures that were presented in Chapter 3.

4.7 Task 6: Quality Assurance Project Plan

An important aspect of verification testing is the Quality Assurance Project Plan (QAPP) developed for QA/QC, as described in Section 3.12. The objective of this task was to assure accurate measurement of operational and water quality parameters during IX equipment verification testing. The primary areas of evaluation were precision, accuracy, statistical uncertainty, and completeness. Statistical uncertainty was calculated on data sets containing eight or more data points and is presented in tables in Chapter 4 as the 95% confidence interval.

Each day the tubing, fittings, and general condition of the Basin Water System were inspected to verify that there were no leaks or needed repairs. No leaks in tubing were reported.

4.7.1 Precision

Precision refers to the degree of mutual agreement among individual measurements, as discussed in Section 3.12.3.3. The percent acceptable precision among duplicate samples was previously presented in Table 3-8. The calculated precision for each analytical parameter is presented in the following tables.

4.7.1.1 Laboratory Duplicate Precision

The total alkalinity precision analyses for duplicates collected from the 24-hour composite samples are presented in Table 4-36. In total, there were 21 duplicates collected for total alkalinity. All samples were within the acceptable precision of 30%.

Table 4-36. Total Alkalinity Precision Analysis

Date	Sample Location	Alkalinity (mg/L of $CaCO_3$)	Duplicate Alkalinity (mg/L of $CaCO_3$)	Percent Precision
4/5/05	Raw Water	91.4	104	9%
4/6/05	Influent Water	88.6	87.8	1%
4/7/05	Effluent Water	78.2	78.8	1%
4/9/05	Effluent Water	79.5	78.6	1%
4/10/05	Influent Water	88.5	90.0	1%
4/11/05	Effluent Water	83.7	85.8	2%
4/12/05	Raw Water	98.8	92.9	4%
4/13/05	Raw Water	91.7	99.5	6%
4/14/05	Effluent Water	82.2	83.5	1%
4/15/05	Raw Water	91.0	92.6	1%
4/16/05	Influent Water	92.0	91.9	0%
4/17/05	Effluent Water	81.3	81.5	0%
4/18/05	Raw Water	88.5	80.6	7%
5/14/05	Influent Water	87.7	88.2	0%
5/17/05	Influent Water	94.7	95.7	1%
5/19/05	Raw Water	88.3	88.0	0%
5/20/05	Influent Water	101	94.8	4%
5/22/05	Raw Water	95.8	95.2	0%
5/24/05	Effluent Water	81.1	77.5	3%
5/26/05	Influent Water	95.3	94.9	0%
5/27/05	Effluent Water	78.8	77.9	1%
			Acceptable Precision	30%

The total arsenic precision analyses for duplicates collected from the 24-hour composite samples are presented in Table 4-37. Of the 94 duplicate sets collected for arsenic, all samples were within the acceptable precision of 30%, with the exception of two on April 17, 2005, and one May 20, 2005. The two duplicate sets on April 17, 2005, that were outside the acceptable range were evaluated for possible mislabeling (e.g., effluent sample labeled as a raw or influent sample). Both sets of data appear to fall within this possible scenario. The sample arsenic result on May 20, 2005, with a percent precision of 126% is considered aberrant.

Table 4-37. Total Arsenic Precision Analysis

Date	Sample Location	Sample Arsenic (µg/L)	Duplicate Arsenic (µg/L)	Percent Precision
Initial Plant Characterization No. 1 (04/04/05 – 04/23/05)				
4/5/05	Raw Water	14	14	0%
	Influent Water	15	15	0%
	Effluent Water	<1.0	<1.0	0%
4/6/05	Raw Water	18	18	0%
	Influent Water	19	14	21%
	Effluent Water	<1.0	<1.0	0%
4/7/05	Raw Water	15	15	0%
	Influent Water	14	14	0%
	Effluent Water	<1.0	<1.0	0%
4/9/05[1]	Raw Water	14	14	0%
	Influent Water	13	13	0%
	Effluent Water	1.4	1.6	9%
4/10/05	Raw Water	16	14	9%
	Influent Water	16	14	9%
	Effluent Water	3.3	3.7	8%
4/11/05	Raw Water	18	13	23%
	Influent Water	13	16	15%
	Effluent Water	4.5	4.3	3%
4/12/05	Raw Water	15	16	5%
	Influent Water	14	14	0%
	Effluent Water	4.2	4.2	0%
4/13/05	Raw Water	15	14	5%
	Influent Water	15	15	0%
	Effluent Water	6.5	7.7	12%
4/14/05	Raw Water	17	15	9%
	Influent Water	17	16	4%
	Effluent Water	9.8	9.9	1%
4/15/05	Raw Water	15	15	0%
	Influent Water	15	16	5%
	Effluent Water	3.9	3.7	4%
4/16/05	Raw Water	15	15	0%
	Influent Water	15	15	0%
	Effluent Water	6.7	6.2	5%
4/17/05	Raw Water	15	6.4	57%
	Influent Water	15	15	0%
	Effluent Water	14	6.2	55%

Table 4-37. Total Arsenic Precision Analysis (continued)

Date	Sample Location	Sample Arsenic (µg/L)	Duplicate Arsenic (µg/L)	Percent Precision
4/18/05	Raw Water	16	15	5%
	Influent Water	16	15	5%
	Effluent Water	3.3	2.7	14%
4/21/05[1]	Raw Water	16	15	5%
	Influent Water	15	15	0%
	Effluent Water	3.8	4.0	4%
4/22/05	Raw Water	15	15	0%
	Influent Water	15	16	5%
	Effluent Water	6.8	7.5	7%
4/23/05	Raw Water	15	14	5%
	Influent Water	14	15	5%
	Effluent Water	4.5	4.7	3%
Initial Plant Characterization No. 2 (04/29/05 – 05/9/05)				
4/30/05[2]	Influent Water	15	14	5%
5/1/05	Effluent Water	<1.0	<1.0	0%
5/2/05	Raw Water	14	16	9%
5/3/05	Raw Water	15	15	0%
5/4/05	Influent Water	16	15	5%
5/5/05	Effluent Water	<1.0	<1.0	0%
5/6/05	Raw Water	15	14	5%
5/7/05	Influent Water	15	16	5%
Verification Testing (05/12/05 – 05/28/05)				
5/14/05[3]	Raw Water	15	14	5%
	Influent Water	14	15	5%
	Effluent Water	<1.0	<1.0	0%
5/16/05[1]	Raw Water	15	14	5%
	Influent Water	14	15	5%
	Effluent Water	<1.0	<1.0	0%
5/17/05	Raw Water	16	15	5%
	Influent Water	15	15	0%
	Effluent Water	<1.0	<1.0	0%
5/18/05	Raw Water	14	14	0%
	Influent Water	14	14	0%
	Effluent Water	<1.0	<1.0	0%
5/19/05	Raw Water	15	14	5%
	Influent Water	15	15	0%
	Effluent Water	<1.0	<1.0	0%

Table 4-37. Total Arsenic Precision Analysis (continued)

Date	Sample Location	Sample Arsenic (μg/L)	Duplicate Arsenic (μg/L)	Percent Precision
5/20/05	Raw Water	<1.0	15	124%
	Influent Water	16	15	5%
	Effluent Water	<1.0	<1.0	0%
5/21/05	Raw Water	15	14	5%
	Influent Water	15	15	0%
	Effluent Water	<1.0	<1.0	0%
5/22/05	Raw Water	15	15	0%
	Influent Water	15	15	0%
	Effluent Water	<1.0	<1.0	0%
5/23/05	Raw Water	15	15	0%
	Influent Water	15	15	0%
	Effluent Water	<1.0	<1.0	0%
5/25/05[4]	Raw Water	15	15	0%
	Influent Water	15	15	0%
	Effluent Water	<1.0	<1.0	0%
5/26/05	Influent Water	15	15	0%
	Effluent Water	<1.0	<1.0	0%
5/27/05	Raw Water	15	15	0%
	Influent Water	15	15	0%
	Effluent Water	<1.0	<1.0	0%
5/28/05	Raw Water	15	15	0%
	Influent Water	15	15	0%
	Effluent Water	<1.0	<1.0	0%
			Acceptable Precision	30%

[1] Missing data on 4/8, 4/19-4/20, and 5/15 due to plant shutdown.
[2] Data not available 4/24-4/29 while awaiting approval from NSF to continue testing.
[3] Missing data from 5/8-5/13 due to switch over from Initial Plant Characterization to the Verification Test.
[4] Grab samples not collected on 5/24.

The vanadium precision analyses for duplicates collected from the 24-hour composite samples are presented in Table 4-38. Of the 62 duplicate samples collected, four duplicate sets of vanadium results were outside the acceptable precision of 30% and were evaluated for possible mislabeling. All four of the data sets (April 5: raw water, April 9: effluent water, April 17: effluent water, and May 20: raw water) appear to fall within this possible scenario.

Table 4-38. Vanadium Precision Analysis

Date	Sample Location	Sample Vanadium (µg/L)	Duplicate Vanadium (µg/L)	Percent Precision
Initial Plant Characterization No. 1 (04/04/05 – 04/23/05)				
4/5/05	Raw Water	<3.0	100	133%
4/6/05	Influent Water	110	110	0%
4/7/05	Effluent Water	<3.0	<3.0	0%
4/9/05[1]	Effluent Water	95	<3.0	133%
4/10/05	Influent Water	110	110	0%
	Raw Water	110	110	0%
	Effluent Water	5.7	5.8	1%
4/11/05	Raw Water	110	110	0%
4/12/05	Raw Water	110	110	0%
4/13/05	Raw Water	110	110	0%
4/14/05	Effluent Water	16	16	0%
4/15/05	Raw Water	120	120	0%
4/16/05	Influent Water	120	120	0%
4/17/05	Effluent Water	110	8.5	121%
4/18/05	Raw Water	110	110	0%
4/21/05[1]	Effluent Water	3.2	3.2	0%
4/22/05	Raw Water	110	110	0%
4/23/05	Effluent Water	9.8	9.6	1%
Initial Plant Characterization No. 2 (04/29/05 – 05/9/05)				
4/30/05[2]	Influent Water	110	110	0%
5/1/05	Effluent Water	<3.0	<3.0	0%
5/2/05	Raw Water	110	110	0%
5/3/05	Raw Water	110	110	0%
5/4/05	Influent Water	110	100	7%
5/5/05	Effluent Water	<3.0	<3.0	0%
5/6/05	Raw Water	99	110	7%
5/7/05	Influent Water	94	96	1%
Verification Testing (05/12/05 – 05/28/05)				
5/14/05[3]	Raw Water	110	110	0%
	Influent Water	110	110	0%
	Effluent Water	<3.0	<3.0	0%
5/16/05[1]	Raw Water	110	100	7%
5/17/05	Raw Water	100	110	7%
	Influent Water	110	110	0%
	Effluent Water	<3.0	<3.0	0%

Table 4-38. Vanadium Precision Analysis (continued)

Date	Sample Location	Sample Vanadium (µg/L)	Duplicate Vanadium (µg/L)	Percent Precision
5/18/05	Raw Water	110	99	7%
5/18/05	Influent Water	98	97	1%
	Effluent Water	<3.0	<3.0	0%
5/19/05	Raw Water	99	96	2%
	Influent Water	97	96	1%
	Effluent Water	<3.0	<3.0	0%
5/20/05	Raw Water	<3.0	110	134%
	Influent Water	110	110	0%
	Effluent Water	<3.0	<3.0	0%
5/21/05	Raw Water	100	100	0%
	Influent Water	100	100	0%
	Effluent Water	<3.0	<3.0	0%
5/22/05	Raw Water	110	100	7%
	Influent Water	100	100	0%
	Effluent Water	<3.0	<3.0	0%
5/23/05	Raw Water	100	100	0%
	Influent Water	100	100	0%
	Effluent Water	<3.0	<3.0	0%
5/25/05[4]	Raw Water	110	110	0%
	Influent Water	110	110	0%
	Effluent Water	<3.0	<3.0	0%
5/26/05	Influent Water	110	110	0%
	Effluent Water	<3.0	<3.0	0%
5/27/05	Raw Water	110	110	0%
	Influent Water	110	110	0%
	Effluent Water	<3.0	<3.0	0%
5/28/05	Raw Water	110	110	0%
	Influent Water	110	110	0%
	Effluent Water	<3.0	<3.0	0%
			Acceptable Precision	30%

[1] Missing data on 4/8/05, 4/19-4/20, and 5/15 due to plant shutdown.

[2] Data not available 4/24-4/29 while awaiting approval from NSF to continue testing.

[3] Missing data from 5/8-5/13 due to switch over from Initial Plant Characterization to the Verification Test.

[4] Grab samples not collected on 5/24/05.

Table 4-39 presents the calcium, iron, total hardness, magnesium, and manganese precision analyses. All of the duplicate data sets were within the acceptable precision range of 30% for each parameter.

Table 4-39. Calcium, Iron, Total Hardness, Magnesium, and Manganese Precision Analysis

Date	Sample Location	Sample Calcium (mg/L)	Duplicate Calcium (mg/L)	Percent Precision	Sample Iron (mg/L)	Duplicate Iron (mg/L)	Percent Precision
4/5/05	Raw Water	5.9	5.8	1%	<0.020	<0.020	0%
4/11/05	Effluent Water	6.1	6.0	1%	<0.020	<0.020	0%
4/12/05	Raw Water	6.0	5.9	1%	<0.020	<0.020	0%
4/14/05	Effluent Water	6.2	6.2	0%	<0.020	<0.020	0%
5/14/05	Influent Water	5.6	6.0	5%	<0.020	<0.020	0%
5/17/05	Influent Water	6.0	6.0	0%	<0.020	<0.020	0%
5/19/05	Raw Water	6.1	5.8	4%	<0.020	<0.020	0%
5/20/05	Influent Water	6.3	6.0	3%	<0.020	<0.020	0%
5/22/05	Raw Water	6.4	6.0	5%	<0.020	<0.020	0%
5/24/05	Effluent Water	6.1	6.7	7%	<0.020	<0.020	0%
5/26/05	Influent Water	6.1	6.2	1%	<0.020	<0.020	0%
5/27/05	Effluent Water	6.0	6.0	0%	<0.020	<0.020	0%
			Acceptable Precision	30%	Acceptable Precision		30%

Date	Sample Location	Sample Hardness (mg/L)	Duplicate Hardness (mg/L)	Percent Precision	Sample Magnesium (mg/L)	Duplicate Magnesium (mg/L)	Percent Precision
4/5/05	Raw Water	18.1	17.8	1%	0.81	0.81	0%
4/11/05	Effluent Water	18.8	18.5	1%	0.86	0.85	1%
4/12/05	Raw Water	18.4	18.2	1%	0.83	0.83	0%
4/14/05	Effluent Water	19.0	19.0	0%	0.85	0.85	0%
5/14/05	Influent Water	17.1	18.4	5%	0.76	0.84	7%
5/17/05	Influent Water	18.3	18.2	0%	0.81	0.79	2%
5/19/05	Raw Water	18.8	17.9	3%	0.86	0.82	3%
5/20/05	Influent Water	19.4	18.4	4%	0.88	0.84	3%
5/22/05	Raw Water	19.7	18.4	5%	0.90	0.82	7%
5/24/05	Effluent Water	18.7	20.2	5%	0.85	0.84	1%
5/26/05	Influent Water	18.7	19.0	1%	0.84	0.85	1%
5/27/05	Effluent Water	18.5	18.4	0%	0.85	0.84	1%
		Acceptable Precision		30%	Acceptable Precision		30%

Table 4-39. Calcium, Iron, Total Hardness, Magnesium, and Manganese Precision Analysis (continued)

Date	Sample Location	Sample Manganese (mg/L)	Duplicate Manganese (mg/L)	Percent Precision
4/5 /05	Raw Water	<2.0	<2.0	0%
4/11/05	Effluent Water	<2.0	<2.0	0%
4/12/05	Raw Water	<2.0	<2.0	0%
4/14/05	Effluent Water	<2.0	<2.0	0%
5/14/05	Influent Water	<2.0	<2.0	0%
5/17/05	Influent Water	<2.0	<2.0	0%
5/19/05	Raw Water	<2.0	<2.0	0%
5/20/05	Influent Water	<2.0	<2.0	0%
5/22/05	Raw Water	<2.0	<2.0	0%
5/24/05	Effluent Water	<2.0	<2.0	0%
5/26/05	Influent Water	<2.0	<2.0	0%
5/27/05	Effluent Water	<2.0	<2.0	0%
			Acceptable Precision	30%

Table 4-40 presents the dissolved silica, TDS, fluoride, and TSS precision analyses. All of the duplicate data sets were within the acceptable precision range for each parameter.

Table 4-40. Silica, TDS, TSS, and Fluoride Precision Analysis

Date	Sample Location	Sample Dissolved Silica (mg/L)	Duplicate Dissolved Silica (mg/L)	Percent Precision	Sample TDS (mg/L)	Duplicate TDS (mg/L)	Percent Precision
4/5/05	Raw Water	12	12	0%	300	300	0%
4/11/05	Effluent Water	13	13	0%	280	280	0%
4/12/05	Raw Water	12	11	6%	290	290	0%
4/14/05	Effluent Water	12	12	0%	280	280	0%
5/14/05	Influent Water	12	12	0%	290	290	0%
5/17/05	Influent Water	12	12	0%	290	290	0%
5/19/05	Raw Water	12	12	0%	300	290	2%
5/20/05	Influent Water	12	11	6%	290	290	0%
5/22/05	Raw Water	11	12	6%	280	290	2%
5/24/05	Effluent Water	12	12	0%	300	290	2%
5/26/05	Influent Water	11	11	0%	290	290	0%
5/27/05	Effluent Water	12	12	0%	280	280	0%
		Acceptable Precision		30%	Acceptable Precision		30%

Table 4-40. Silica, TDS, TSS, and Fluoride Precision Analysis (continued)

Date	Sample Location	Sample Fluoride (mg/L)	Duplicate Fluoride (mg/L)	Percent Precision	Sample TSS (mg/L)	Duplicate TSS (mg/L)	Percent Precision
4/5/05	Raw Water	0.44	0.45	2%	<10	<10	0%
4/11/05	Effluent Water	0.44	0.44	0%	<10	<10	0%
4/12/05	Raw Water	0.43	0.44	2%	<10	<10	0%
4/13/05[1]	Raw Water	0.36	0.39	6%	NA	NA	NA
4/1405	Effluent Water	0.40	0.40	0%	<10	<10	0%
5/14/05	Influent Water	0.41	0.42	2%	<10	<10	0%
5/17/05	Influent Water	0.42	0.41	2%	<10	<10	0%
5/19/05	Raw Water	0.40	0.45	8%	<10	<10	0%
5/20/05	Influent Water	0.41	0.44	5%	<10	<10	0%
5/22/05	Raw Water	0.33	0.32	2%	<10	<10	0%
5/24/05	Effluent Water	0.32	0.40	16%	<10	<10	0%
5/26/05	Influent Water	0.33	0.31	4%	<10	<10	0%
5/27/05	Effluent Water	0.45	0.45	0%	<10	<10	0%
		Acceptable Precision		20%	Acceptable Precision		30%

[1] Fluoride duplicate sample collected on 4/13 was an additional sample collected during the Initial Plant Characterization task; therefore, a TSS duplicate sample was not collected.

Table 4-41 presents the chloride, sulfate, and nitrate precision analyses. With the exception of three sample sets, all of the duplicate data sets were within the acceptable precision range. The sulfate duplicate set on April 9, 2005, had a percent precision of 47% due to a difference in the minimum detection limits of the samples. The duplicate sets for chloride and nitrate on May 24, 2005, had percent precisions of 59 and 60%, respectively, with an acceptable percent precision range of 0 to 20% for chloride and 0-30% for nitrate.

Table 4-41. Chloride, Sulfate, and Nitrate Precision Analysis

Date	Sample Location	Sample Chloride (mg/L)	Duplicate Chloride (mg/L)	Percent Precision	Sample Sulfate (mg/L)	Duplicate Sulfate (mg/L)	Percent Precision
4/5/05	Raw Water	75	74	1%	37	37	0%
4/6/05	Influent Water	74	75	1%	37	37	0%
4/7/05	Effluent Water	110	110	0%	<1.0	<1.0	0%
4/9/05	Effluent Water	117	117	0%	<1.0	<0.50	47%
4/10/05	Influent Water	75	74	1%	37	37	0%
4/11/05	Effluent Water	110	110	0%	<2.5	<2.5	0%
4/12/05	Raw Water	71	70	1%	37	37	0%
4/13/05	Raw Water	74	75	1%	37	37	0%
4/14/05	Effluent Water	110	110	0%	<2.5	<2.5	0%

Table 4-41. Chloride, Sulfate, and Nitrate Precision Analysis (continued)

Date	Sample Location	Sample Chloride (mg/L)	Duplicate Chloride (mg/L)	Percent Precision	Sample Sulfate (mg/L)	Duplicate Sulfate (mg/L)	Percent Precision
4/15/05	Raw Water	69	69	0%	36	36	0%
4/16/05	Influent Water	74	74	0%	37	37	0%
4/17/05	Effluent Water	108	110	1%	<2.5	<2.5	0%
4/18/05	Raw Water	74	74	0%	39	38	2%
5/14/05	Influent Water	71	71	0%	37	37	0%
5/17/05	Influent Water	72	72	0%	37	37	0%
5/19/05	Raw Water	71	72	1%	37	37	0%
5/20/05	Influent Water	67	71	4%	35	37	4%
5/22/05	Raw Water	71	71	0%	37	37	0%
5/24/05	Effluent Water	290	120	59%	<2.5	<2.5	0%
5/26/05	Influent Water	72	72	0%	37	37	0%
5/27/05	Effluent Water	120	120	0%	<2.5	<2.5	0%
	Acceptable Precision			20%	Acceptable Precision		20%

Date	Sample Location	Sample Nitrate (mg/L)	Duplicate Nitrate (mg/L)	Percent Precision
4/5/05	Raw Water	6.2	6.2	0%
4/6/05	Influent Water	6.2	6.2	0%
4/7/05	Effluent Water	4.5	4.5	0%
4/9/05	Effluent Water	4.1	4.2	2%
4/10/05	Influent Water	6.2	6.2	0%
4/11/05	Effluent Water	4.9	4.9	0%
4/12/05	Raw Water	6.3	6.3	0%
4/13/05	Raw Water	5.6	5.7	1%
4/14/05	Effluent Water	4.2	4.1	2%
4/15/05	Raw Water	6.9	6.8	1%
4/16/05	Influent Water	6.9	6.9	0%
4/17/05	Effluent Water	5.2	5.2	0%
4/18/05	Raw Water	6.3	6.3	0%
5/14/05	Influent Water	6.2	6.4	2%
5/17/05	Influent Water	6.3	6.3	0%
5/19/05	Raw Water	6.3	6.3	0%
5/20/05	Influent Water	6.3	6.2	1%
5/22/05	Raw Water	6.3	6.3	0%
5/24/05	Effluent Water	9.9	4.0	60%
5/26/05	Influent Water	6.2	6.2	0%
5/27/05	Effluent Water	3.5	3.5	0%
		Acceptable Precision		30%

Table 4-42 presents the precision data for the one set of duplicate samples collected on May 19, 2005 from the treated brine and the untreated brine. The high precision levels are due to a difference in the minimum detection limits of the samples. Another likely explanation for the high precision levels could be variability in the waste (i.e., non-homogeneous samples). Precision levels for detectable data ranged from 0-70%.

Table 4-42. Treated and Untreated Liquid Waste Brine Precision Analysis

Parameter	Units	Sample Treated Brine	Duplicate Treated Brine	Percent Precision	Sample Untreated Brine	Duplicate Untreated Brine	Percent Precision
Conductivity	umho/cm	101000	101000	0%	105000	105000	0%
pH	units	7.9	8.1	1.8%	9.7	9.7	0%
Total Arsenic	µg/L	140	140	0%	4100	3500	11%
Antimony	µg/L	<50	<20	60%	<50	<20	60%
Barium	µg/L	<100	43	56%	380	140	65%
Beryllium	µg/L	<50	<20	60%	<50	<20	60%
Cadmium	µg/L	<25	<10	61%	<25	<10	61%
Chromium	µg/L	<50	<20	60%	<50	22	55%
Cobalt	µg/L	<100	<40	60%	<100	<40	60%
Copper	µg/L	<100	<40	60%	<100	73	22%
Lead	µg/L	<25	<10	61%	<25	<10	61%
Mercury	µg/L	<0.20	0.327	34%	<0.20	<0.20	0%
Molybdenum	µg/L	3200	3200	0%	3500	3000	11%
Nickel	µg/L	<250	<100	61%	<250	<100	61%
Selenium	µg/L	<500	660	20%	570	420	21%
Silver	µg/L	30	<10	70%	<25	<10	61%
TSS	mg/L	24	43	40%	26	56	52%
Thallium	µg/L	<50	<20	60%	<50	<20	60%
Vanadium	µg/L	890	830	4.9%	3940	3831	2.0%
Zinc	µg/L	<250	<100	61%	<250	<100	61%

4.7.1.2 On-Site Analytical Precision

Duplicate samples were collected and the on-site analytical precision was calculated for free and total chlorine, conductivity, and pH. The precision analyses of these parameters are presented in Tables 4-43 through 4-45.

As presented in Table 4-43, there were 31 total chlorine duplicate sets, with 14 sets above the acceptable precision value of 20%. The low number of sample sets that fell within the acceptable precision level may be attributed to the volatile nature of chlorine and/or the very low levels of chlorine being analyzed. The similar scenario was observed for free chlorine, with 14 of the 30 sample duplicates exceeding the acceptable precision of 20%.

Table 4-43. Free and Total Chlorine Precision Analysis

Date	Sample Location	Sample Total Chlorine (mg/L)	Duplicate Total Chlorine (mg/L)	Percent Precision	Sample Free Chlorine (mg/L)	Duplicate Free Chlorine (mg/L)	Percent Precision
4/5/05	Influent Water	0.17	0.13	19%	0.14	0.02	106%
4/6/05	Effluent Water	0.03	0.05	35%	0.06	0.04	28%
4/9/05	Influent Water	0.13	0.13	0%	0.10	0.13	18%
4/10/05	Effluent Water	0.02	0.02	0%	0.02	0.02	0%
4/12/05	Influent Water	0.02	0.07	79%	0.01	0.04	85%
4/15/05	Influent Water	0.22	0.17	18%	0.21	0.14	28%
4/16/05	Effluent Water	0.01	0.01	0%	0.01	0.01	0%
4/17/05	Raw Water	0.04	0.01	85%	0.05	0.02	61%
4/20/05	Effluent Water	0.02	0.00	141%	0.01	0.00	141%
4/22/05	Influent Water	0.17	0.13	19%	0.14	0.13	5%
4/29/05	Influent Water	0.17	0.15	9%	0.15	0.16	5%
4/30/05	Effluent Water	0.02	0.01	47%	0.05	0.01	94%
5/1/05	Raw Water	0.01	0.00	141%	0.01	0.01	0%
5/2/05	Raw Water	0.00	0.01	141%	0.04	0.02	47%
5/4/05	Effluent Water	0.02	0.02	0%	0.01	0.02	47%
5/6/05	Influent Water	0.25	0.25	0%	0.14	0.17	14%
5/9/05	Raw Water	0.01	0.00	141%	0.00	0.00	0%
5/12/05	Raw Water	0.01	0.01	0%	0.05	0.01	94%
5/13/05	Influent Water	0.29	0.29	0%	0.24	0.25	3%
5/14/05	Effluent Water	0.03	0.00	141%	0.00	0.00	0%
5/15/05	Raw Water	0.02	0.01	47%	0.01	0.01	0%
5/16/05	Influent Water	0.34	0.34	0%	0.26	0.27	3%
5/17/05	Effluent Water	0.02	0.02	0%	0.01	NA	NA
5/21/05	Raw Water	0.03	0.02	28%	0.03	0.04	20%
5/22/05	Influent Water	0.34	0.35	2%	0.27	0.26	3%
5/23/05	Effluent Water	0.01	0.03	71%	0.05	0.07	24%
5/24/05	Raw Water	0.04	0.02	47%	0.02	0.03	28%
5/25/05	Influent Water	0.33	0.33	0%	0.28	0.25	8%
5/26/05	Effluent Water	0.02	0.02	0%	0.02	0.01	47%
5/27/05	Raw Water	0.03	0.01	71%	0.02	0.02	0%
5/28/05	Influent Water	0.30	0.28	5%	0.17	0.23	21%
		Acceptable Precision		20%	Acceptable Precision		20%

NA = Not Available.

Conductivity was measured on-site using Standard Method 2510B. The percent precision results are presented in Table 4-44. All 40 duplicate sample sets were within the acceptable precision range of 10%.

Table 4-44. Conductivity Precision Analysis

Date	Sample Location	Sample Conductivity (μmho/cm)	Duplicate Conductivity (μmho/cm)	Percent Precision
4/5/05	Influent Water	529	541	2%
4/6/05	Effluent Water	508	508	0%
4/8/05	Raw Water	595	572	3%
4/9/05	Influent Water	528	529	0%
4/10/05	Effluent Water	529	540	1%
4/11/05	Raw Water	512	522	1%
4/13/05	Influent Water	527	519	1%
4/15/05	Influent Water	543	540	0%
4/16/05	Effluent Water	532	533	0%
4/17/05	Raw Water	520	526	1%
4/18/05	Influent Water	527	526	0%
4/20/05	Effluent Water	550	548	0%
4/21/05	Raw Water	540	542	0%
4/22/05	Influent Water	534	536	0%
4/29/05	Influent Water	536	533	0%
4/30/05	Effluent Water	560	562	0%
5/1/05	Raw Water	538	535	0%
5/2/05	Raw Water	533	528	1%
5/3/05	Influent Water	534	536	0%
5/4/05	Effluent Water	541	543	0%
5/5/05	Raw Water	508	507	0%
5/6/05	Influent Water	543	542	0%
5/7/05	Effluent Water	558	551	1%
5/8/05	Raw Water	518	516	0%
5/9/05	Raw Water	534	534	0%
5/12/05	Raw Water	543	541	0%
5/13/05	Influent Water	533	533	0%
5/14/05	Effluent Water	544	547	0%
5/15/05	Raw Water	521	523	0%
5/16/05	Influent Water	548	549	0%
5/17/05	Effluent Water	540	539	0%
5/18/05	Raw Water	552	545	1%
5/21/05	Raw Water	529	531	0%
5/22/05	Influent Water	524	524	0%
5/23/05	Effluent Water	561	562	0%
5/24/05	Raw Water	517	513	1%
5/25/05	Influent Water	528	532	1%
5/26/05	Effluent Water	532	535	0%
5/27/05	Raw Water	528	531	0%

Table 4-44. Conductivity Precision Analysis (continued)

Date	Sample Location	Sample Conductivity (µmho/cm)	Duplicate Conductivity (µmho/cm)	Percent Precision
5/28/05	Influent Water	538	540	0%
			Acceptable Precision	10%

In total, 30 duplicate pH samples were collected for precision analysis. The results of the precision analyses for on-site pH data are presented in Table 4-45. All of the duplicate sets were within the acceptable precision range of 10%.

Table 4-45. Precision Analysis of On-Site pH

Date	Sample Location	Sample pH	Duplicate pH	Percent Precision
4/5/05	Influent Water	9.21	8.64	5%
4/6/05	Effluent Water	8.89	8.89	0%
4/9/05	Influent Water	9.21	9.12	1%
4/10/05	Effluent Water	9.05	9.05	0%
4/13/05	Influent Water	8.98	9.08	1%
4/16/05	Effluent Water	8.69	8.68	0%
4/17/05	Raw Water	9.16	9.19	0%
4/20/05	Effluent Water	9.02	9.03	0%
4/22/05	Influent Water	9.23	9.19	0%
4/29/05	Influent Water	9.10	9.11	0%
4/30/05	Effluent Water	7.85	8.02	2%
5/1/05	Raw Water	9.08	9.10	0%
5/2/05	Raw Water	9.08	9.05	0%
5/4/05	Effluent Water	8.67	8.66	0%
5/6/05	Influent Water	9.11	9.11	0%
5/9/05	Raw Water	9.09	9.11	0%
5/12/05	Raw Water	9.08	9.08	0%
5/13/05	Influent Water	9.07	9.07	0%
5/14/05	Effluent Water	8.57	8.59	0%
5/15/05	Raw Water	9.07	9.04	0%
5/16/05	Influent Water	9.06	9.07	0%
5/17/05	Effluent Water	8.27	8.26	0%
5/21/05	Raw Water	9.07	9.08	0%
5/22/05	Influent Water	9.09	9.08	0%
5/23/05	Effluent Water	8.88	8.72	1%
5/24/05	Raw Water	9.03	9.06	0%
5/25/05	Influent Water	9.05	9.09	0%
5/26/05	Effluent Water	8.75	8.76	0%
5/27/05	Raw Water	9.07	9.07	0%
5/28/05	Influent Water	9.07	9.06	0%
			Acceptable Precision	10%

4.7.2 Accuracy

Arsenic Speciation and Analysis

Total arsenic samples were collected daily and analyzed using EPA Method 200.8. Additional arsenic samples were collected twice per week for As (III) and dissolved arsenic. The field speciation columns for the dissolved arsenic and As (III) samples were provided by NSF. QA/QC evaluations of the speciation columns using known concentrations of As (III) and As (V) were conducted by the NSF laboratory prior to verification testing; this QA/QC documentation is provided in Appendix B. Additional speciation studies were previously discussed in Section 4.5.2. There is currently no explanation for the inconsistent speciation results observed during the test. However, the arsenic present at the test site appeared to be in the As (III) state, and the Basin Water System consistently removed the arsenic to non-detectable levels (<1 µg/L).

Other Laboratory Parameters

Accuracy checks performed by MWH Laboratories for all samples analyzed by MWH Laboratories were within the specified acceptance limits outlined in Table 3-10.

pH Meter

The pH meter was calibrated daily using certified pH solutions (4.0, 7.0, and 10.0) purchased from Hach. Analyses were made daily according to Standard Method 4500-H^+B.

Pressure Gauges

Basin Water indicated that the pressure gauges installed were factory-calibrated. No additional accuracy checks were performed.

Temperature

Temperature was measured with a NIST-certified thermometer. Because temperature was measured daily using a NIST-certified thermometer, no accuracy checks were necessary.

Conductivity Meter

The handheld conductivity meter was used according to Standard Method 2510 B. A three-point calibration with certified conductivity solutions (184, 1000, and 1990 umoh/cm) was made each day the meter was in use.

Chlorine Meter

Three times during the testing the chlorine meter was checked for accuracy using known spike samples provided by Hach with the Hach 8167 method for total chlorine and Hach 8021 method for free chlorine. The accuracy of the free and total chlorine spikes is discussed in additional detail in Section 4.7.3 with corresponding data provided in Table 4-45. All results were within the acceptable accuracy range.

Flow Monitoring

The Basin Water System was equipped with panel-mounted flow meters to read the influent and effluent flow rates. The effluent flow rate was also checked daily using the bucket and stopwatch method. The flow meters appeared to be accurate according to this method of calibration, with an average accuracy of 86% for the effluent flow rate. The flow meters were not designed to allow adjustment or calibration, so the differences (when present) were recorded; however, no adjustments could be made to "calibrate" the flow meters.

4.7.3 Spikes

All spikes were performed and analyzed at MWH Laboratories, with the exception of chlorine. Field spikes were measured using a handheld chlorine analyzer. The results are presented in Table 4-46.

Table 4-46. Chlorine Spike Results

Date	Spike (mg/L)	Total Chlorine (mg/L)	Percent Accuracy	Free Chlorine (mg/L)	Percent Accuracy
4/8/05	0.27	0.25	93%	0.18	67%
	0.53	0.57	108%	0.42	79%
	0.80	0.79	99%	0.74	93%
4/13/05	0.27	0.25	93%	0.16	59%
	0.53	0.47	89%	0.47	89%
	0.80	0.77	96%	0.68	85%
4/14/05	0.27	0.25	93%	0.21	78%
	0.53	0.54	102%	0.49	92%
	0.80	0.80	100%	0.77	96%
4/18/05	0.27	0.22	81%	0.22	81%
	0.53	0.46	87%	0.45	85%
	0.80	0.70	88%	0.69	86%
4/29/05	0.27	0.22	81%	0.22	81%
	0.53	0.46	87%	0.47	89%
	0.80	0.76	95%	0.75	94%
5/2/05	0.27	0.24	89%	0.18	67%
	0.53	0.49	92%	0.48	91%
	0.80	0.75	94%	0.76	95%
5/9/05	0.27	0.27	100%	0.28	104%
	0.53	0.51	96%	0.49	92%
	0.80	0.75	94%	0.73	91%
5/16/05	0.27	0.32	119%	0.26	96%
	0.53	0.56	106%	0.40	75%
	0.80	0.74	93%	0.73	91%
5/23/05	0.27	0.26	96%	0.22	81%
	0.53	0.53	100%	0.49	92%
	0.80	0.81	101%	0.74	93%

4.7.4 Calibrations

Calibrations of the pH meter and conductivity meter and manual checks of the flow rate using the bucket and stop watch method were completed daily. The results of the daily calibrations are presented in Tables 4-47 through 4-49. The results indicate a 99-100% degree of accuracy with each pH buffer solution used for the pH calibrations, 99-102% degree of accuracy of the conductivity meter, and approximately 86% accuracy of the flow meter.

Table 4-47. Daily Calibration of pH Meter

Date	Measurement with 4.01 Buffer	Percent Accuracy	Measurement with 7.00 Buffer	Percent Accuracy	Measurement with 10.01 Buffer	Percent Accuracy
4/15/05	3.97	99%	7.03	100%	9.99	100%
4/16/05	3.83	96%	7.00	100%	10.03	100%
4/17/05	3.77	94%	6.97	100%	10.01	100%
4/18/05	3.74	93%	6.97	100%	10.08	101%
4/20/05[1]	4.00	100%	7.02	100%	10.07	101%
4/21/05	3.99	100%	7.02	100%	10.07	101%
4/22/05	4.00	100%	7.01	100%	10.04	100%
4/29/05	4.00	100%	7.01	100%	10.05	100%
4/30/05	4.01	100%	7.01	100%	10.06	100%
5/1/05	4.00	100%	7.02	100%	10.08	101%
5/2/05	4.00	100%	7.01	100%	10.05	100%
5/3/05	4.01	100%	7.00	100%	10.03	100%
5/4/05	4.00	100%	7.02	100%	10.06	100%
5/5/05	4.00	100%	7.00	100%	10.07	101%
5/6/05	4.00	100%	7.02	100%	10.07	101%
5/7/05	4.01	100%	7.01	100%	10.04	100%
5/8/05	4.01	100%	7.00	100%	10.01	100%
5/9/05	4.01	100%	7.01	100%	10.04	100%
5/12/05	4.01	100%	7.00	100%	9.99	100%
5/13/05	4.02	100%	6.99	100%	9.96	100%
5/14/05	4.02	100%	6.99	100%	9.98	100%
5/15/05	4.02	100%	6.99	100%	9.98	100%
5/16/05	4.01	100%	7.01	100%	10.03	100%
5/17/05	4.01	100%	7.00	100%	10.02	100%
5/18/05	4.00	100%	7.01	100%	10.05	100%
5/19/05	4.00	100%	7.01	100%	10.05	100%
5/20/05	4.01	100%	7.01	100%	10.00	100%
5/21/05	4.01	100%	6.99	100%	10.00	100%
5/22/05	4.01	100%	7.00	100%	10.00	100%
5/23/05	4.01	100%	6.99	100%	9.98	100%
5/24/05	4.01	100%	6.99	100%	9.99	100%
5/25/05	4.01	100%	7.00	100%	10.00	100%

Table 4-47. Daily Calibration of pH Meter (continued)

Date	Measurement with 4.01 Buffer	Percent Accuracy	Measurement with 7.00 Buffer	Percent Accuracy	Measurement with 10.01 Buffer	Percent Accuracy
5/26/05	4.01	100%	7.01	100%	10.04	100%
5/27/05	4.01	100%	6.99	100%	9.99	100%
5/28/05	4.01	100%	7.00	100%	10.00	100%
Average	3.99	99%	7.00	100%	10.03	100%
Minimum	3.74	93%	6.97	100%	9.96	100%
Maximum	4.02	100%	7.03	100%	10.08	101%

[1] Data not available on 4/19/05 due to plant-shutdown.

Table 4-48. Daily Calibration of Conductivity Meter

Date	With 180 µmho/cm Sol.	Percent Accuracy	With 1000 µmho/cm Sol.	Percent Accuracy	With 1990 µmho/cm Sol.	Percent Accuracy
First Conductivity Reading						
4/15/05	186.2	103%	1002	100%	1940	97%
4/16/05	187.2	104%	1034	103%	NA	NA
4/17/05	NA	NA	1015	102%	NA	NA
4/20/05	180.0	100%	1000	100%	2000	101%
4/21/05	182.8	102%	1002	100%	1975	99%
4/22/05	183.1	102%	1020	102%	1975	99%
4/29/05	182.5	101%	1010	101%	1989	100%
4/30/05	179.0	99%	998	100%	1977	99%
5/1/05	177.4	99%	1008	101%	1975	99%
5/2/05	182.7	102%	1003	100%	2020	102%
5/3/05	183.0	102%	992	99%	1976	99%
5/4/05	173.4	96%	1006	101%	1996	100%
5/5/05	180.7	100%	985	99%	1997	100%
5/6/05	188.1	105%	1016	102%	1811	91%
5/7/05	190.0	106%	1023	102%	1969	99%
5/8/05	185.6	103%	1023	102%	2000	101%
5/9/05	175.5	98%	975	98%	1980	99%
5/12/05	180.2	100%	995	100%	1963	99%
5/13/05	185.0	103%	1032	103%	1978	99%
5/14/05	180.5	100%	1000	100%	1973	99%
5/15/05	195.2	108%	1040	104%	1958	98%
5/16/05	177.6	99%	968	97%	1969	99%
5/17/05	185.3	103%	1035	104%	1989	100%
5/18/05	181.5	101%	1005	101%	2000	101%
5/19/05	182.3	101%	1000	100%	1995	100%
5/20/05	181.9	101%	1003	100%	1999	100%
5/21/05	178.9	99%	1016	102%	2010	101%
5/22/05	183.9	102%	1013	101%	1979	99%

Table 4-48. Daily Calibration of Conductivity Meter (continued)

Date	With 180 µmho/cm Sol.	Percent Accuracy	With 1000 µmho/cm Sol.	Percent Accuracy	With 1990 µmho/cm Sol.	Percent Accuracy
5/23/05	163.3	91%	959	96%	1990	100%
5/24/05	227.0	126%	844	84%	1984	100%
5/25/05	182.5	101%	961	96%	2020	102%
5/26/05	180.0	100%	981	98%	1996	100%
5/27/05	188.2	105%	1013	101%	1934	97%
5/28/05	179.0	99%	1009	101%	1958	98%
Average	183.3	102%	1000	100%	1977	99%
Minimum	163.3	91%	844	84%	1811	91%
Maximum	227.0	126%	1040	104%	2020	102%
Second Conductivity Reading						
4/15/05	NA	NA	NA	NA	NA	NA
4/16/05	NA	NA	NA	NA	NA	NA
4/17/05	NA	NA	NA	NA	NA	NA
4/20/05	180.1	100%	998	100%	1997	100%
4/21/05	178.9	99%	1000	100%	1998	100%
4/22/05	179.1	100%	996	100%	1990	100%
4/29/05	178.2	99%	996	100%	1986	100%
4/30/05	179.3	100%	997	100%	1984	100%
5/1/05	180.0	100%	1000	100%	1992	100%
5/2/05	178.2	99%	1000	100%	1983	100%
5/3/05	178.0	99%	999	100%	1990	100%
5/4/05	179.9	100%	998	100%	1984	100%
5/6/05	179.4	100%	1001	100%	1978	99%
5/7/05	179.2	100%	999	100%	1992	100%
5/8/05	178.3	99%	999	100%	1980	99%
5/9/05	179.0	99%	996	100%	1979	99%
5/12/05	178.5	99%	1000	100%	1994	100%
5/13/05	178.4	99%	996	100%	1997	100%
5/14/05	177.5	99%	1000	100%	1981	100%
5/15/05	177.7	99%	993	99%	1988	100%
5/16/05	180.4	100%	997	100%	2000	101%
5/17/05	180.0	100%	995	100%	1989	100%
5/18/05	178.5	99%	995	100%	2010	101%
5/19/05	180.0	100%	999	100%	1998	100%
5/20/05	180.3	100%	1005	101%	1991	100%
5/21/05	179.6	100%	1007	101%	1990	100%
5/22/05	178.0	99%	998	100%	1985	100%
5/23/05	180.1	100%	998	100%	1980	99%
5/24/05	184.2	102%	988	99%	1971	99%

Table 4-48. Daily Calibration of Conductivity Meter (continued)

Date	With 180 µmho/cm Sol.	Percent Accuracy	With 1000 µmho/cm Sol.	Percent Accuracy	With 1990 µmho/cm Sol.	Percent Accuracy
5/25/05	179.2	100%	1001	100%	1988	100%
5/26/05	180.6	100%	1000	100%	1986	100%
5/27/05	178.3	99%	1006	101%	1996	100%
5/28/05	180.0	100%	994	99%	1999	100%
Average	179.3	100%	998	100%	1989	100%
Minimum	177.5	99%	988	99%	1971	99%
Maximum	184.2	102%	1007	101%	2010	101%

NA = Not Available.

Flow rate calibration readings from April 22–May 28, 2005, are presented in Table 4-49. The effluent flow rate values were based on the measurements from the flow meter gage and its recorded readings from the PLC screen. Once a reading was recorded, a manual check using the bucket and stopwatch test, measuring volume per time, was conducted to test the accuracy of the HMI flow meter.

Table 4-49. Flow Rate Calibration Checks

Date	Collection Time[1]	Effluent Flow Rate Reading (gpm)	Measured Flow Rate (gpm)	% Accuracy of HMI Flow Meter
4/22/05	AM	37.6	32.0	85%
4/27/05	PM	37.7	30.8	82%
4/29/05	AM	37.1	32.0	86%
4/29/05	PM	36.6	32.0	87%
4/30/05	AM	37.8	32.0	85%
4/30/05	PM	38.0	32.0	84%
5/1/05	AM	37.7	32.0	85%
5/1/05	PM	36.9	32.0	87%
5/2/05	AM	36.2	32.0	88%
5/2/05	PM	36.4	32.0	88%
5/3/05	AM	36.8	29.3	80%
5/3/05	PM	36.1	29.3	81%
5/4/05	AM	35.7	30.2	85%
5/4/05	PM	35.9	30.2	84%
5/6/05	AM	39.3	32.0	81%
5/6/05	PM	37.8	32.0	85%
5/7/05	AM	39.4	32.0	81%
5/7/05	PM	37.4	32.0	86%
5/8/05	AM	38.0	32.0	84%
5/8/05	PM	37.6	32.0	85%
5/9/05	AM	37.6	32.0	85%
5/9/05	PM	37.2	32.0	86%

Table 4-49. Flow Rate Calibration Checks (continued)

Date	Collection Time[1]	Effluent Flow Rate Reading (gpm)	Measured Flow Rate (gpm)	% Accuracy of HMI Flow Meter
5/13/05	AM	41.7	32.0	77%
5/13/05	PM	37.5	32.0	85%
5/14/05	AM	37.3	32.0	86%
5/14/05	PM	35.9	32.0	89%
5/15/05	AM	37.2	32.0	86%
5/15/05	PM	37.7	32.0	85%
5/16/05	AM	37.3	30.5	82%
5/16/05	PM	36.3	30.5	84%
5/17/05	AM	36.8	32.0	87%
5/17/05	PM	36.4	32.0	88%
5/20/05	AM	38.6	32.0	83%
5/20/05	PM	23.1	32.0	139%
5/21/05	AM	40.3	31.1	77%
5/21/05	PM	37.4	31.1	83%
5/22/05	AM	37.3	32.0	86%
5/22/05	PM	37.7	32.0	85%
5/23/05	AM	37.9	32.0	84%
5/23/05	PM	37.5	32.0	85%
5/24/05	AM	39.0	32.0	82%
5/24/05	PM	38.1	32.0	84%
5/25/05	AM	37.7	32.0	85%
5/25/05	PM	38.0	32.0	84%
5/26/05	AM	37.8	32.0	85%
5/26/05	PM	37.3	32.0	86%
5/27/05	AM	36.4	35.0	96%
5/27/05	PM	36.5	35.0	96%
5/28/05	AM	36.6	32.0	87%
5/28/05	PM	37.4	32.0	86%

[1] AM/PM refers to morning (AM) and afternoon (PM) calibration checks.

4.7.5 Completeness

Calculation of data completeness was made for on-site water quality measurements and MWH Laboratories water quality measurements, as discussed in Section 3.12.3.4 and presented in Table 3-11. During the test, duplicate samples were collected in a rotating manner (i.e., duplicates were taken of the raw water during one round of duplicate analysis, then influent water, and finally effluent water). Based on the completeness goals defined in Table 3-11 and the completeness results presented in Table 4-50, all parameters were within the stated completeness goals.

Table 4-50. Completeness

	Proposed		Actual		Completeness (%)		Completeness Goal	
Parameter	Results	Duplicates	Results	Duplicates	Results	Duplicates	Results	Duplicates
As (III)	24	0	36	NA	>100%	NA	90%	100%
Dissolved As	24	0	39	NA	>100%	NA	90%	100%
Total As	168	80	202	92	>100%	>100%	95%	95%
Sulfate	84	22	85	21	>100%	95%	95%	90%
Nitrate	84	22	84	20	100%	91%	95%	90%
Chloride	84	22	85	21	>100%	95%	95%	90%
Calcium	48	10	78	11	>100%	>100%	95%	90%
Magnesium	48	10	78	11	>100%	>100%	95%	90%
Alkalinity	84	22	85	21	>100%	95%	95%	90%
Fluoride	48	10	84	13	>100%	>100%	95%	90%
TDS	48	10	57	12	>100%	>100%	95%	90%
TSS	48	10	57	12	>100%	>100%	95%	90%
Iron	48	10	51	11	>100%	>100%	95%	90%
Manganese	48	10	51	11	>100%	>100%	95%	90%
Vanadium	168	54	196	59	>100%	>100%	95%	95%
Hardness	48	10	66	11	>100%	>100%	95%	90%
Dissolved Silica	48	10	57	12	>100%	>100%	95%	90%
pH	64	20	135	30	>100%	>100%	95%	90%
Conductivity	64	24	135	39	>100%	>100%	95%	90%
Free Chlorine	126	16	186	16	>100%	>100%	95%	90%

NA = Not Available.

4.8 Operations and Maintenance

The following section discusses the FTO's experience with the operation and maintenance of the Basin Water System.

4.8.1 Fluctuation in Flow Rate

The Basin Water System is an automated system that may be a staffed or un-staffed system (with periodic visits to check chemical feed levels and overall system performance). The influent and effluent flow rates and pressures are continuously recorded through the system's PLC, which logs any fluctuations. If necessary, the flow may be adjusted through settings on the PLC. During verification testing these settings were preset by Basin Water and not adjusted.

4.8.2 Chemical Feed Systems

For purposes of verification testing (which had set system flow rates), the chlorine feed rate was set during the Initial Plant Characterization phase at 0.10-0.50 mg/L and not adjusted during the testing.

Sulfuric acid, sodium hydroxide, ferric chloride, and salt were fed by batch processes associated with the regeneration phase and were not dependent upon the system flow rate. Sulfuric acid and sodium hydroxide were dosed to reach a certain brine pH and were dependent on the initial brine pH and buffering capacity. The ferric chloride and salt had a preset volume per batch. If the system flow rates were to vary, the chemical feed rates would only vary based on an increase or decrease in the number of batches per day. The brine flow rate (volume per day) was set based on the number of IX bed volumes to exhaustion. The bed volumes were adjusted from 1,100 to 850 BVs between the first and second Initial Plant Characterization. The brine was sent through two IX vessels before it was sent to either the BRA or BPU for treatment.

4.8.3 Sediment Prefilters

The sediment prefilters were monitored through the differential pressure across the filters. This differential pressure was logged daily through the PLC. During verification testing, the filters did not require changing (i.e., did not exceed the set differential pressure [12 psi] as set by Basin Water).

4.8.4 Resin Depth

The depth of the resin in each IX vessel could not be measured or monitored during verification testing, because there was not a site glass or other means to measure the depth of resin in each vessel.

4.8.5 Arsenic and/or Vanadium Breakthrough

With the exception of off-site laboratory testing of arsenic and vanadium, there was no means to monitor if arsenic and/or vanadium had broken through the IX resin. Online monitoring of pH and conductivity were not indicator parameters if either ion had broken through the resin.

4.8.6 Brine Reuse, Feed, and Treatment

The on-site field engineer could monitor if brine had been fed to the IX vessels through the PLC, which recorded each step (salt addition, salt dilution, and rinse) of the regeneration. The information recorded included the particular liquid's flow rate and duration. The brine consumption could be monitored in a number of ways, such as through the PLC, but the simplest method was through calculating the flow rate of the brine and the time the brine pump was in operation. The operator could detect an improperly regenerated IX vessel by observing the information recorded on the PLC. The regeneration step was set to utilize a certain volume of brine, dilution water, and rinse water. A deviation from the set volume of brine, dilution water, or rinse water would be recorded on the PLC and would indicate that IX vessel was not properly regenerated.

No observable issues were noted in the ability to precipitate arsenic and vanadium from the waste brine due to recycling of the brine. The BPU and the BRA were both automated treatment systems that were placed on set points by Basin Water during the Initial Plant Characterization. The only maintenance required was for the high-level indicator and waste pump on the BRA recirculation tank, which failed during the verification testing.

4.9 NSF Field Inspection

On May 19, 2005, NSF conducted a field inspection of the verification test and found the practices in place on-site to be in accordance with the PSTP that was approved prior to beginning the testing.

Chapter 5
References

The following references were used in the preparation of this report:

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U.S. EPA/NSF International, *EPA/NSF ETV Protocol for Equipment Verification Testing for Arsenic Removal*, September 2003.

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Chapter 6
Vendor Comments

Basin Water submitted the following comments concerning the ETV test and report. These statements were not validated in the verification test and are the opinion of Basin Water:

"The Basin Water pre-packaged ion exchange system has been specifically designed for wellhead installation and has numerous advantages both from an operational and economic standpoint. In recognition of its unique design and high efficiency, it has been granted patent # 6,706,195 by the US Patent and Trademark Office. The Title of this patent is "High Efficiency Ion Exchange for Removing Arsenic from Water."

Ion Exchange

The use of ion exchange for arsenic removal has been studied for many years and its performance is well known. Ion exchange has been designated as a Best Available Technology (B.A.T.) by the U.S. Environmental Protection Agency. Some of the advantages of ion exchange for arsenic removal are:

1. Not sensitive to pH.
2. Not affected by silica / phosphate.
3. Will also remove vanadium with minimal loss of capacity.
4. Can consistently remove arsenic to non-detect levels.

The negative aspect to using ion exchange has always been related to disposal of brine wastes produced during the regeneration process.

Traditional ion exchange plants consist of three large vessels, two in operation and one in regeneration. A standard ion exchange treatment plant will produce anywhere from 3 – 10% waste, which usually cannot be disposed of in a domestic sewer because of the high salt content. The disposal of these large quantities of brine waste makes wellhead installation of traditional ion exchange plants very difficult and expensive. It is precisely for this reason that ion exchange was discounted as a viable technology for arsenic removal.

Basin Water Ion Exchange System

The Basin Water IX System has incorporated the advantage of ion exchange technology into a package, which is extremely well suited to either wellhead or centralized treatment facilities. This multibed system operates continuously and has the following advantages over traditional ion exchange systems:

1. Very low waste rates – Typically less than 0.25%.
2. Consistent Effluent Quality – The staggered, multibed system allows for very consistent effluent water quality.
3. Low power requirements – Operates off of well head pressure.

4. Reliability – Multiple beds provide redundancy not available with traditional ion exchange systems.
5. Operational flexibility – Can operate from 0 to 100% of well capacity while accommodating the frequent starting and stopping of the well(s).
6. Small foot print – A 1,000 GPM system can fit onto a site as small as 1,100 ft^2.
7. Mobility – An entire system can be delivered and installed in 7 to 10 working days.

Comments on Elsinore EPA – ETV Testing

Both MWH and EPA/NSF did a great job in organizing the ETV test and the processing of all data collected. It is worth noting that this test utilized one of the Basin Water mobile units (T-2), which is a 10-bed system with a maximum capacity of 110 GPM. Since this test operated at 35 GPM instead of its full capacity, only 4 out of the 10 ion exchange beds were used.

The net result of this was a less consistent effluent water quality since there where far fewer beds in service to damp out changing water quality. A typical Basin Water 1,000 GPM system has 16 beds with 13 in absorption at all times. This plurality of vessels produces very consistent effluent water quality and a negligible change in pH through the system. For example, a 1,000 gpm arsenic removal system operating at the Baldy Mesa Water District in High Desert of Southern California had a pH change of less than 0.2 units with a very similar water quality.

It is also worth noting that the amount of waste produced by a Basin Water system is completely dependent on the source water quality. The test system at Elsinore Valley operated at 850 bed volumes, as predicted by Basin Water's proprietary computer simulation model. Basin Water has seen different water qualities, which result in bed lifes ranging from 300 – 10,000 bed volumes. Basin Water has deployed an arsenic treatment system in Arizona that operates at 10,000 bed volumes and has a waste rate of 0.01%. This translates to only 100 gallons of waste per one million gallons treated, or a net recovery of 99.99%. This reduced waste rate has the added benefit of creating additional water supply for anyone choosing a Basin Water IX System over traditional ion exchange conserving a precious natural resource.

Conclusions

Basin Water wishes to thank EPA/NSF for the opportunity to demonstrate the efficiency and operational characteristics of the Basin Water "High Efficiency Arsenic Treatment System". Basin Water also wishes to thank the MWH project team for the diligent and professional manner in which they conducted this test and operated the Basin Water Demonstration Unit.

It is Basin Water's belief that by optimizing the use of ion exchange for arsenic treatment we have created the opportunity for the economic and conserved water benefits to be passed on to the end user."