FINAL REPORT

Demonstration of Regenerable, Large-scale Ion Exchange System Using WBA Resin in Rialto, CA

ESTCP Project ER-201168

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14. ABSTRACT
The objective of this demonstration was to test and validate weak base ion exchange (WBA IX) technology using established performance objectives in order to obtain permitting and certification from the California Department of Public Health (CDPH) as an approved perchlorate treatment technology. WBA IX is a process developed by ARA and Purolite and is comprised of three unit operations: pretreatment (pH and alkalinity reduction), ion exchange with two packed-bed vessels configured in series (multi-barrier perchlorate removal), and post treatment (restoration of pH and alkalinity). This specific 1,000 gallon per minute system was constructed by Applied Research Associates, Inc. (ARA) to treat groundwater at the Rialto No. 3 well site in the Rialto-Colton, CA area under Environmental Strategic Technology Certification Program (ESTCP) Project No. ER-0312, "Perchlorate Removal, Destruction, and Field Monitoring Demonstration."

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Acronyms

A&E – Architecture and Engineering
AF – Acre Feet
AFCEE – Air Force Center of Environmental Excellence
AMCOM – Army Aviation and Missile Command
ARA – Applied Research Associates, Inc.

BV – Bed Volumes

CDPH – California Department of Public Health

DoD – Department of Defense
DLR— Detection Limit for Reporting

ESTCP – Environmental Security Technology Certification Program

FWC – Fontana Water Company

gpm – gallons per minute

HASP – Health and Safety Plan

I&C – Instrumentation and Control
IEBL – Inland Empire Brine Line
ISEP – Ion Separation
IX – Ion Exchange

MCL – Maximum Contamination Level
meq – Milliequivalents

NDMA – N-nitrosodimethylamine
NPDES – National Pollutant Discharge Elimination System

O&M – Operation and Maintenance

O/I – Operator Interface
OSHA – Occupational Safety and Health Administration

P2 – Pollution Prevention
PEO – Program Executive Office
psig – pounds per square inch, gauge
PLC – Programmable Logic Controller
PM – Program Manager
ppb – parts per billion
ppm – parts per million
PPE – Personal Protective Equipment

QA – Quality Assurance
QA/QC – Quality Assurance/Quality Control
QAPP – Quality Assurance Project Plan

RfD – Reference Dose

SBA – Strong Base Anion
SBVMWD – San Bernardino Valley Municipal Water District
SSC – Site Safety Coordinator

TPM – Technical Program Manager

WBA – Weak Base Anion

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EXECUTIVE SUMMARY

DEMONSTRATION OBJECTIVES

The objective of this demonstration was to test and validate weak base anion resin ion exchange (WBA IX) technology using established performance objectives in order to obtain permitting and certification from the California Department of Public Health (CDPH) as an approved perchlorate treatment technology. This 1,000 gallon per minute system was constructed by Applied Research Associates, Inc. (ARA) to treat groundwater at the Rialto No. 3 well site in the Rialto-Colton, CA area under Environmental Security Technology Certification Program (ESTCP) Project No. ER-0312, "Perchlorate Removal, Destruction, and Field Monitoring Demonstration." Because perchlorate concentrations at Rialto No. 3 are elevated, this site is considered to be an extremely impaired source as defined by the CDPH 97-005 Policy Memorandum. To accomplish this, ARA worked with water utility and regional CDPH representatives to obtain all of the necessary permits to conduct the test and demonstrate performance. The quantitative performance objectives are: meeting perchlorate regulatory standards; demonstrate post-treatment capability; minimize process waste, demonstrate spent regenerant treatment; minimize perchlorate bleed from regenerated vessels; demonstrate treatment flow rates; validate operating costs; and future system scalability. Additionally, qualitative performance objectives included demonstrating the ability to model resin treatment capacity for drinking water applications and demonstrate effective system control during operation.

TECHNOLOGY DESCRIPTION

The WBA IX process developed by ARA and Purolite is comprised of three unit operations: pretreatment (pH and alkalinity reduction), ion exchange with two packed-bed vessels configured in series (multi-barrier perchlorate removal), and post treatment (restoration of pH and alkalinity).

Pretreatment prevents neutralization of WBA resin functional groups during ion exchange. Sulfuric acid is metered into the contaminated source water, reducing the pH to levels below the pKa of the WBA resin (i.e. conditions at which 50% of the functional groups are protonated). During pH reduction, alkalinity present in groundwater is converted to carbonic acid. Carbonic acid in equilibrium with dissolved carbon dioxide (CO_2) which remains in solution at operating pressures. Excess dissolved CO_2 is removed to reduce post-treatment costs using Liqui-Cell membranes designed for degassing liquids. WBA IX treatment is conducted in two, packed-bed ion exchange vessels configured in series.

After ion exchange treatment, the post treatment system restores alkalinity and pH of the treated water. Dilute sodium carbonate (soda ash) solution is metered into the treated water to raise pH and alkalinity. The alkalinity of the final product water is controlled by the amount of dissolved

CO_2 that remains after pretreatment. The pH and alkalinity are controlled to achieve product water that is neither scaling nor corrosive. This is determined by calculating the Langelier Saturation Index (LSI) for treated water samples.

After perchlorate breaks through the lead WBA vessel, the vessels are reconfigured so that the spent vessel (lead) is taken offline while the second vessel remains online. This enables treatment to continue while the spent vessel is regenerated. Regeneration is accomplished by increasing the pH of the spent resin to neutralize WBA resin functional groups. Water is circulated through the resin bed for a fixed time period. Sufficient caustic (NaOH) is added to the water to neutralize the WBA resin functional groups and achieve a pH of 12.0. The resin is rinsed using perchlorate-free water to remove residual perchlorate. Wastewater produced during regeneration is treated to remove perchlorate. This is performed using a small volume of strong base anion (SBA) scavenger resin. After the scavenger process, the perchlorate-free regenerating solution is discharged and the spent scavenger resin incinerated.

After rinsing, the WBA resin is restored to the ionized or protonated form by decreasing the pH of the resin. During protonation, water is circulated through the resin bed for a fixed time period. Sufficient acid is added to protonate the ion exchange sites and achieve a pH equal to or less than 4.0. After protonation, the resin is rinsed again and returned to service as the lag vessel. The spent protonating solution may be recovered, reused, or neutralized and discharged.

DEMONSTRATION RESULTS

The total value of the subcontract to design, install, and build the Rialto 3 demonstration system was $1.958M. Design and equipment costs accounted for $1.492M with installation costs of $0.466M. Observed costs for the demonstration were higher than anticipated due to fluctuating chemical costs, shortened operational periods, and intermittent operational difficulties. The normalized treatment cost for the demonstration system was $229 per acre-foot water treated.

During the Rialto 3 demonstration, a total of 14,950 BV (39.15MG) of groundwater was treated over four (4) test periods. The perchlorate concentration of all treated water samples was below the detection limit for reporting (DLR) of 4.0 parts per billion (ppb). During start up, NDEA and NPIP were detected at < 5 BV of water treated, but did not appear after this point. All testing was performed at flow rate of 800 gpm (2.29 gpm/cu ft), which was the highest possible flow rate due to equipment and pressure limitations. The first and second test periods were designed to be short cycle tests (1,339 BV and 2,261 BV) where the lead vessel was regenerated after only 7 days online and well before perchlorate breakthrough. These tests were designed to improve resin performance by executing more regenerations per vessel to condition the virgin resin. The third test period was designed to operate the system to approximately 50% of resin capacity (4,081 BV), while the fourth test period was designed to operate the system to perchlorate breakthrough. Test period 4 treated 7,269 BV, but perchlorate breakthrough was not achieved due to operational delays and budgetary constraints. Based on previous ESTCP field demonstrations and models using Rialto No. 3 groundwater characteristics, the lead vessel will treat ≥ 9,000 BV's of water before significant perchlorate breakthrough is observed.

Resin was regenerated at the end of the first three test periods. No detectable perchlorate bleed was observed when the regenerated vessel was placed back online as the lag vessel. The spent regenerant volume was limited to 0.07% of the total water treated during testing which resulted in concentrating the perchlorate to over 35,000 ppb. The SBA scavenger process effectively lowered perchlorate in the spent regenerant to non-detectable levels (< 2.5 ppb).

TECHNOLOGY IMPLEMENTATION

Implementation of this technology is straightforward. Commercial, large-scale, ion exchange equipment for WBA resin technology is commonplace. The pretreatment section of the system consists of pH control unit operations with two-stage static mixing which is straight forward to design and engineer. Reducing the alkalinity/stripping of carbon dioxide from the groundwater feed can be accomplished using membrane treatment systems or stripping towers. Both methods are straightforward and are commercially available. The post treatment system used to restore alkalinity and pH of the treated groundwater consists of a package soda ash delivery system combined with static mixers; both are commercially available. Treatment of residuals by the SBA scavenger ion exchange process is a proven technology.

Parameters that directly affect implementation of the WBA IX technology are groundwater alkalinity, perchlorate groundwater concentration, and treated water alkalinity. The amount of acid required to achieve operating pH is directly proportional to feed water alkalinity. Perchlorate concentration directly affects the amount of scavenger resin required, which can also increase cost. The amount of acid used in pretreatment and the desired alkalinity of the treated water affects soda ash requirements for neutralization, which, in turn, affects neutralization cost. The cost of each of these drivers is affected by fluctuating market prices.

Perchlorate concentration below 1 ppm has little effect on treatment capacity and resin regeneration costs. As a result, the WBA IX process becomes more economical than direct SBA IX as perchlorate concentration increases.

1.0 Introduction

1.1. Background

The Department of Defense (DoD) has used perchlorate (ClO_4^-) as an oxidizer in ordnance items and rocket motors since the 1940s. This very water soluble and environmentally persistent compound now contaminates drinking water for tens of millions of people in the United States. The cost for DoD to achieve compliance with this drinking water limit could be billions of dollars. The current approach is treatment by ion exchange for drinking water applications. Existing ion exchange technologies in use today include regenerable and single-use processes. Regenerable ion exchange processes use salt as the regenerating agent, such as the Calgon ISEP® process and other, more conventional, lead-lag processes. These non-selective regenerable systems require frequent regeneration and generate large volumes of salt brine containing high concentrations of nitrate, sulfate and perchlorate. This waste stream is becoming more difficult to dispose and the operation and maintenance (O&M) cost from frequent regenerations is high. Single-use ion exchange processes use strong base anion resins. After perchlorate loading capacity is reached, the single-use resins must be removed from the ion exchange vessels and incinerated resulting in high disposal and replacement costs.

Applied Research Associates, Inc., (ARA) was selected by the Environmental Security Technology Certification Program (ESTCP) to evaluate and demonstrate a regenerable ion exchange process for removing perchlorate from groundwater. The regenerable process that Applied Research Associates, Inc. (ARA) co-developed with The Purolite Company uses perchlorate-selective, weak-base-anion (WBA) resin. This process has the potential to significantly reduce operation and maintenance costs and reduce process waste compared to existing single-use and brine regenerable ion exchange processes.

1.2. Objective of the Demonstration

The objective of this demonstration was to test and validate weak base ion exchange (WBA IX) technology using established performance objectives in order to obtain permitting and certification from the California Department of Public Health (CDPH) as an approved perchlorate treatment technology. The 1,000 gallon per minute system constructed at the Rialto No. 3 well site by Applied Research Associates, Inc. (ARA) to treat perchlorate in groundwater was completed under Environmental Strategic Technology Certification Program (ESTCP) Project No. ER-0312, “Perchlorate Removal, Destruction, and Field Monitoring Demonstration.” Elevated groundwater perchlorate concentrations at Rialto No. 3 cause the site to be considered as an extremely impaired source as defined by the CDPH 97-005 Policy Memorandum. Based on previous pilot demonstrations, it was anticipated that O&M costs would be < $150/acre-ft.

1.3. Regulatory Drivers

Perchlorate is water soluble and persistent in the environment. This is of human health concern because perchlorate has been shown to inhibit the uptake of iodide by the thyroid gland, potentially impacting thyroid hormone production. On January 26, 2006, the U.S. EPA adopted a reference dose (RfD) for perchlorate of 0.0007 mg/kg-day.[1] This RfD equates to a Drinking Water Equivalent Level (DWEL) of 24.5 micrograms per liter (or 24.5 ppb). On January 8, 2009, the United States Environmental Protection Agency (EPA) updated the Interim Drinking Water Health Advisory for exposure to perchlorate from 24.5 µg/L (or ppb) in drinking water to 15 ppb. This adjustment was made to account for perchlorate exposure from food in addition to drinking water. Following EPA's lead, on April 22, 2009, the Office of the Under Secretary of Defense reduced the preliminary remediation goal from 24 ppb to 15 ppb or the State regulatory goal, whichever is least. In California, the drinking water public health goal (PHG) for perchlorate is 6 ppb.

The anticipated outcome of this demonstration is obtaining a modified or revised drinking water permit that includes WBA resin ion exchange as a treatment process for drinking water treatment applications. To accomplish this, ARA worked closely with water utility and regional CDPH representatives to develop a sampling and analysis plan that provided the data necessary to obtain permit modification. Acquiring the permit modification by the regional CDPH officials will facilitate permit modification in the future for other water utilities in this region (or in other regions) and facilitate technology implementation.

[1] U.S. EPA. Assessment Guidance for Perchlorate Memorandum dated January 26, 2006 http://epa.gov/newsroom/perchlorate.pdf

2.0 Technology

2.1. Technology Description

2.1.1. WBA Resin Chemistry

ARA and Purolite developed the regenerable ion exchange process to take advantage of the pH-dependent nature of WBA resins. At low pH, WBA functional groups on the resin have a positive charge (i.e., R-NH3+), allowing anion exchange to occur. However, at high pH, the functional groups lose a proton and become uncharged (i.e., R-NH2) and no longer attract the counter anion. It is this loss of a proton which enables the efficient and complete regeneration of the functional groups. The pH dependent nature of WBA resins enables efficient regeneration, minimizing the amount of regeneration chemicals consumed, which results in an economical process. Equations representing the pH-dependent chemistry of WBA functional groups are shown in Figure 2-1.

WBA resin in free-base form ($R\text{-}NH_2$) is ionized ($R\text{-}NH_3^+$) by protonating with acid (H^+):

$$R\text{-}NH_2 + H^+ \rightarrow R\text{-}NH_3^+$$

Protonated resin removes anions (A^-) from aqueous streams:

$$R\text{-}NH_3^+ + A^- \rightarrow R\text{-}NH_3\text{-}A$$

Spent resin ($R\text{-}NH_3\text{-}A$) is regenerated by neutralizing with caustic (NaOH), which liberates anions and returns resin to the free-base form:

$$R\text{-}NH_3\text{-}A + Na^+OH^- \rightarrow R\text{-}NH_2 + HOH + Na^+A^-$$

Figure 2-1. Weak Base Anion Resin Chemistry

2.1.2. WBA Ion Exchange Process

The WBA ion exchange process has two primary modes: operation and regeneration. During operation, perchlorate is removed from the contaminated water. Once the resin has reached its exchange capacity for perchlorate, it is considered "spent" and the resin must be regenerated before it can be returned to the operational mode. These modes are described below.

2.1.2.1. WBA Ion Exchange Operation

Because of the pH dependent nature of WBA resins, pH must be controlled during the ion exchange treatment process. The general ion exchange process developed by ARA and Purolite is comprised of three unit operations: pretreatment (pH and alkalinity reduction), ion exchange with two columns configured in series (multi-barrier perchlorate removal), and post treatment (restoration of pH and alkalinity). A general flow diagram of this process is shown in Figure 2-2.

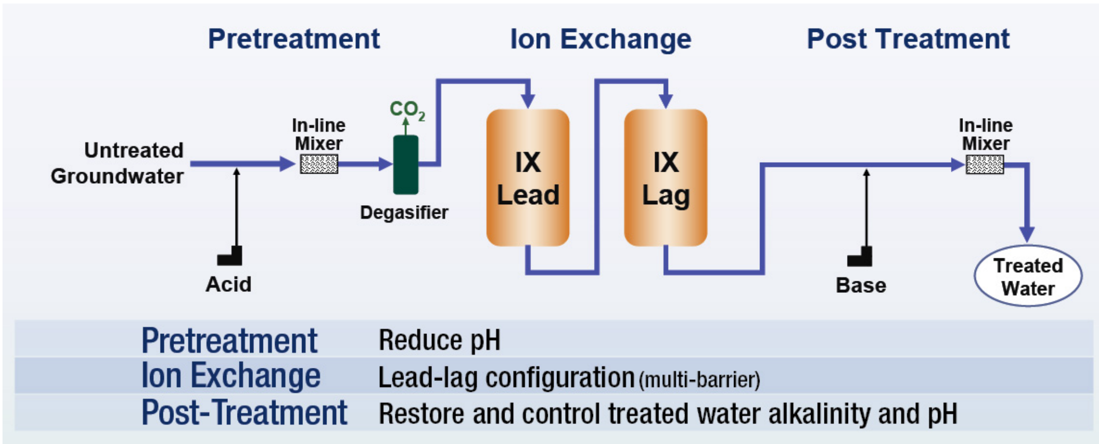

Figure 2-2. General Process Flow Diagram

The purpose of pretreatment is to prevent neutralization of WBA resin functional groups during ion exchange. This is accomplished by adding acid to the contaminated source water and reducing the pH. Specifically, the pH is reduced to below the pKa of the WBA resin (i.e. conditions at which 50% of the functional groups are protonated). During pH reduction, carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) alkalinity present in groundwater is converted to carbonic acid. Carbonic acid is in equilibrium with dissolved carbon dioxide (CO_2), which remains in solution at operating pressure and enables pretreatment and ion exchange to be accomplished using a single pumping operation. Ion exchange treatment is conducted in packed bed ion exchange vessels configured in series.

Post treatment returns the treated water to acceptable levels of alkalinity and pH. The pH is controlled in the post-treatment neutralization process by the addition of base (i.e., sodium hydroxide or sodium carbonate). Alkalinity in the product water is controlled by the amount of dissolved CO_2 removed prior to or during neutralization. Conditions for pH and alkalinity are controlled to achieve product water that is neither scaling nor corrosive. This is determined by measuring pH, temperature, alkalinity, hardness, and total dissolved solids in the product water and calculating the Langlier Saturation Index (LSI).

2.1.2.2. WBA Ion Exchange Regeneration

When regeneration becomes necessary, the ion exchange vessels are configured so that the spent vessel (lead) is offline and the second vessel (lag) remains online. In this configuration, treatment continues while the spent vessel is regenerated. Regeneration is accomplished by increasing the pH of the spent resin to neutralize weak base functional groups. Another objective of regeneration is to minimize the volume of water generated for disposal. A predetermined volume of water is circulated through the resin bed for a fixed duration. Sufficient caustic (i.e. NaOH) is added to the water to neutralize the resin exchange sites and maintain pH above 12.0 throughout regeneration. Wastewater produced during regeneration is treated to remove perchlorate. This can be done by use of a small volume of scavenger resin, or by biodegradation. When using the scavenger process, the perchlorate-free regenerating solution can then be discharged and the scavenger resin incinerated once capacity is reached. Schematics showing the batch regeneration process and scavenger process are shown in Figure 2-3. A rinse using perchlorate-free water is conducted to remove residual perchlorate from the resin.

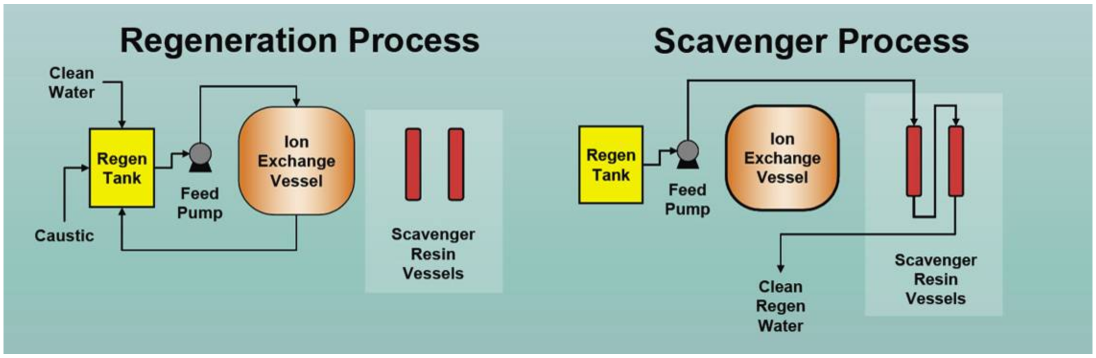

Figure 2-3. Regeneration & Scavenging Processes

Once rinsing is complete, the WBA resin is restored to the ionized or protonated form by decreasing the pH of the resin. During protonation, water is circulated through the resin bed for a fixed duration. Sufficient acid is added to protonate the ion exchange sites and maintain pH equal to or less than 4.0. After protonation is complete, a rinse is conducted and the vessel is returned to service as the second treatment vessel in series (lag position). The spent protonating solution may be recovered, reused, or neutralized and discharged.

2.1.3. Expected Applications

The expected applications for WBA resin ion exchange includes removal of perchlorate, nitrate, and other oxyanions from contaminated source waters. This includes drinking water treatment applications, especially waters that have relatively high contamination (10’s to 100’s ppb) where a regenerable process is more cost effective than a single-use ion exchange process. Another expected application for the WBA process is for use in treating industrial wastewaters containing higher concentrations of perchlorate. In addition to treating perchlorate and nitrate, the WBA resin ion exchange process may also be effective in removing anions of concern in the environment including selenium, chromium, and radionuclides.

2.2. Technology Development

Two pilot demonstrations of the WBA resin technology have been successfully completed. The first pilot demonstration was performing groundwater remediation at Redstone Arsenal, AL. The second pilot demonstration was conducting drinking water treatment at Fontana, CA. Both demonstrations were conducted and reported under ESTCP Project No. ER-0312, "Perchlorate Removal, Destruction, and Field Monitoring Demonstration."

2.2.1. Groundwater Remediation – Redstone Arsenal, AL

Groundwater remediation was conducted at Redstone Arsenal, located near Huntsville, Alabama. The demonstration was performed over a period of 15 weeks during which treatment rates of 12, 18, and 24 bed volumes per hour (1.5, 2.25, and 3.0 gpm/ft^3 of resin, respectively) were evaluated. Well RS498, a six-inch extraction well, was selected as the groundwater source for the demonstration. Anion concentrations of the well were as follows: 1500 to 2200 ppb perchlorate; 4 ppm nitrate; 3 ppm sulfate; 4 ppm chloride, and 150 ppm bicarbonate. Performance of the WBA IX technology was assessed by collecting and analyzing groundwater samples before and after treatment. Five resin regeneration tests were performed to characterize regeneration efficiency. The spent regenerating solutions from these tests were used in perchlorate destruction and scavenging evaluations.

Results of the demonstration at Redstone Arsenal confirmed that perchlorate was reduced in the contaminated groundwater from >1500 ppb to well below the method detection limit (4 ppb) using EPA Method 314.0. Regeneration of WBA resin was effectively and efficiently accomplished. The volume of spent regenerating solution was limited to less than 0.05% of the volume of water treated. Two treatment processes for the spent regenerating solution were demonstrated including biodegradation and a zero-discharge approach using strong base anion (SBA) scavenger resin. Both processes were effective in destroying or removing perchlorate to below the method detection limit. The regenerable WBA resin technology proved to be up to 50 times more efficient than brine-regenerable processes using SBA resins. In addition, O&M costs were projected to be less than $100 per acre-ft.

2.2.2. Drinking Water Treatment – Fontana, CA

As a result of the successful demonstration at Redstone Arsenal, a second demonstration for drinking water treatment in California was conducted at Plant F17 in Fontana, CA. Well F17-C water contained 8 ppb perchlorate; 11 ppm chloride; 31 ppm nitrate; 14 ppm sulfate; and 150 ppm bicarbonate. Six test periods were conducted during this demonstration. The minimum treatment rate was 24 bed volumes (BV) per hour (3 gpm/ft^3). Four test periods were long cycle breakthrough tests (1, 2, 5, and 6). During regeneration of the spent column, the lag column remained online and treated water in a single column. The remaining two test periods (3 and 4) were short-cycle tests. In short-cycle tests, columns were regenerated after approximately one week on-line and before breakthrough. These short-cycle tests were conducted to maximize the number of regenerations per column and minimize the duration of the demonstration. The short-cycle tests were also used to evaluate perchlorate removal efficiency at higher specific flow rates (4 gpm/ft^3). Regeneration of spent resin and treatment of the spent regenerating solution using the zero-discharge scavenger process were conducted on-site.

The treatment capacity determined from this demonstration was 9,700 bed volumes. The treated water was below the method report limit for perchlorate (< 0.10 ppb) using IC/MS/MS. Nitrosamines were analyzed using EPA Method 521. NDMA was 2.6 ppt with a detection limit of 2 ppt. All other nitrosamines analyzed (including NDEA, NDBA, NDPA, NMEA, NMOR, NPIP, and NPYR) were below the detection limit. The residual alkalinity of the treated water was controlled by varying the pH and using a combination of air/membrane stripping and calcite contacting. Treated water had a Langelier Saturation Index (LSI) near zero, which indicated that it had neither corrosive nor scaling tendencies. Five resin regenerations were accomplished using 3 bed volumes of regenerant solution, or approximately 0.03% of the treated water. The spent regenerating solution was successfully treated using the zero-discharge scavenger resin approach to remove perchlorate to below method reports limits. The scavenger approach cost less than $5 per acre-foot to implement based on conditions at the Fontana demonstration site.

2.3. Advantages and Limitations of the WBA IX Technology

2.3.1. Technology Comparisons

Three technologies are currently used commercially for remediating perchlorate-contaminated groundwater: 1) biodegradation, 2) ion exchange using SBA regenerable resins, and 3) ion exchange using non-regenerable or disposable SBA resins. The WBA resin technology takes advantage of the performance, favorable public perception, and regulatory acceptance of ion exchange while minimizing the liabilities of current ion exchange systems. These liabilities include: 1) high cost of perchlorate-selective resins currently in use, 2) large volume of residuals generated by regenerable systems, 3) difficulty and high cost of treating residuals, and 4) resin replacement and incineration costs for non-regenerable systems.

2.3.2. Technology Advantages and Limitations

Weak base, perchlorate-selective resins do not have the treatment capacity of strong base, perchlorate-selective, single-use resins. Even so, overall cost savings may be substantial since the WBA resins can be economically regenerated. Pretreatment and post treatment steps required for the WBA resin process do add process complexity compared to single-use ion exchange systems; however, the complexity is not greater than other commercial, regenerable ion exchange technologies. Pretreatment and post treatment unit operations are very straight-forward pH control processes.

Water quality parameters including alkalinity, hardness, perchlorate concentration, sulfate concentration, and treated water alkalinity affect cost and performance. The amount of acid required to achieve operating pH is directly proportional to feed water alkalinity and; therefore, pretreatment cost. Perchlorate concentration dictates the resin treatment capacity and regeneration frequency which affects regeneration cost. In addition, perchlorate concentration and regeneration frequency impact the amount of spent regenerating solution and treatment cost. Hardness and desired alkalinity of treated water affect the caustic requirement for neutralization, which affects neutralization cost. Competing ions such as nitrate will also impact treatment performance by driving a need for more frequent regenerations. Competing ion concentration is a limiting factor for all ion exchange technologies.

3.0 Performance Objectives

The objective of this effort was to demonstrate a large-scale (1,000 gpm) drinking water treatment system for perchlorate removal using the WBA process. This treatment system was designed specifically for treating drinking water from Rialto No. 3. Due to the level of perchlorate concentration and presence other contaminants, this particular well is considered an extremely impaired source as defined by the CDPH 97-005 Policy Memorandum.

During the demonstration, data was collected to evaluate perchlorate removal performance, regeneration efficiency, ease of operation, and operation and maintenance (O&M) costs. Based on data from the previous pilot demonstrations, it was anticipated that O&M costs would be < $150/acre-ft. Upon completion of demonstration testing, there is an option for ownership of the treatment system to be transferred to the City of Rialto.

Performance of the WBA system was evaluated by collecting and analyzing samples for perchlorate during ion exchange, regeneration, and treatment of residuals. Analytical results were used to assess and predict treatment performance of the WBA resin at the conditions tested. Operational data including flow rate, system pressure, pH, and consumption of chemicals and power were recorded and analyzed to validate operating performance and predict O&M costs. Specific quantitative and qualitative performance objectives for this demonstration are summarized in Table 3-1. Subsequent sections provide details for each performance objective identified.

Table 3-1. Performance Objectives

Performance Objective	Data Requirements	Success Criteria	Results
Quantitative Performance Objectives			
1. Meet perchlorate regulatory standard	Perchlorate concentration in treated water	< DLR (4 ppb)	< 1.5 ppb (average= 0.61 ppb)
2. Demonstrate post treatment capability	Treated water characteristics including pH, total dissolved solids, alkalinity, hardness, and temperature to be used for calculating Langelier Saturation Index (LSI).	0 < LSI < 1.0 (i.e., non-corrosive & non-scaling)	No samples met requirement
3. Minimize process waste	Volume of spent solutions collected during regeneration and volume of water treated prior to regeneration	≤ 0.07 vol% residual	≤ 0.07 vol% residual
4. Demonstrate treatment of spent regenerating streams	Perchlorate concentration in treated spent regenerant following treatment using strong base anion resin (scavenging)	≤ 100 ppb perchlorate	≤ 2.5 ppb perchlorate
5. Determine perchlorate bleed from regenerated vessel	Perchlorate concentration in regenerated vessel effluent following a regeneration cycle)	< DLR (4 ppb)	All samples ≤ 0.27 ppb perchlorate
6. Treatment flow rate	Log of operational flow rate (gpm) during ion exchange	≥ 2.5 gpm/ft^3	≤ 2.5 gpm/ft^3 (2.29 gpm/ft^3)
7. Validate and report operating cost	Consumable chemicals, waste disposal, electrical requirements, labor requirements, and miscellaneous supply costs	< $150 /acre-ft	Actual= $266/acre-ft Theoretical= $229/acre-ft
8. System scalability	Actual regeneration time required for offline vessel; anticipated regeneration frequency.	System can support two additional ion exchange treatment trains and expand to 3000 gpm	System will support two additional trains
Qualitative Performance Objectives			
9. Model/predict WBA resin capacity for drinking water application	Perchlorate, nitrate, sulfate, and chloride concentrations in groundwater and in treated water exiting lead vessel	Provide a treatment capacity, in bed volumes, before regeneration is required	≥ 9,000 BVs
10. System control during treatment and regeneration cycles	Feedback from field technician on ability to use programmable logic control system to effectively monitor and control system operations such as flow, pressure, and pH during demonstration treatment and regeneration	A single field technician able to effectively take measurements and control system. System control features and interlocks operate as designed. System startup following shutdown initiates as designed.	Normal operations one operator req'd; during regeneration, two operators req'd

3.1. Performance Objective: Meet Perchlorate Regulatory Standard

The current regulatory standard for perchlorate issued by CDPH is a Public Health Goal of 6 ppb (effective October 18, 2007). In order for the WBA technology to be successful and ultimately issued a drinking water supply permit, it is imperative that perchlorate concentration in the treated water is below the regulatory standard.

3.1.1. Data Requirements

Data required to evaluate this performance objective includes perchlorate concentration in the fully treated water. Treated water samples were collected at defined frequencies, described in Section 5.6, throughout the demonstration. The sampling location, date, time, volume of water treated at sample collection and name of the individual collecting the sample was recorded in a logbook at the site. Collected samples were analyzed using EPA approved methods EPA 314.0 (IC) and EPA 331.0 (LC-IC-MS-MS).

3.1.2. Success Criteria

This performance objective was considered successful if perchlorate concentration in the treated water (following the lag column) remained less than the DLR of 4 ppb during normal operations. Any deviation from this goal throughout the demonstration resulted in a careful analysis of the events leading to the deviation, identification of probable causes, corrective actions, and preventative measures.

3.1.3. Results

This performance objective was considered successful throughout the demonstration and the technology worked as expected. All fully treated water samples analyzed for perchlorate during each test period were less than the DLR of 4 ppb. During the demonstration, there were numerous unexpected shutdowns due to water supply problems with Rialto No. 3, or from other perturbations. The WBA IX system was restarted on each occasion with no treated water perchlorate concentrations exceeding the DLR of 4 ppb.

3.2. Performance Objective: Demonstrate Post Treatment Capability

Post treatment, described in Section 2.1.2.1, is required to adjust pH and alkalinity of the fully treated water to acceptable levels with regard to corrosiveness or scaling tendencies prior to distribution. The Langelier Saturation Index (LSI) was used as the measure of post treatment success. This calculated number was used to predict the calcium carbonate stability of water; that is, whether a water sample will precipitate, dissolve, or be in equilibrium with calcium carbonate.

3.2.1. Data Requirements

The data required to calculate LSI includes alkalinity (mg/L as $CaCO_3$), pH, total dissolved solids (mg/L TDS), calcium hardness (mg/L as $CaCO_3$), and water temperature (°C). Select samples of fully treated water were analyzed by a certified laboratory and the resulting data was used to determine the pH at which the water sampled is saturated with calcium carbonate (pHs). The LSI was calculated by the certified analytical laboratory. LSI is calculated as the difference between the actual pH of the fully treated water sample and the calcium carbonate saturation pH. The calculation is shown below:

$$LSI = pH - pH_S$$
$$pH_S = (9.3 + A + B) - (C + D)$$
where:
$$A = (Log_{10}[TDS] - 1) / 10$$
$$B = -13.12 \times Log_{10}(°C + 273) + 34.55$$
$$C = Log_{10}[Ca^{+2} \text{ as } CaCO_3] - 0.4$$
$$D = Log_{10}[\text{alkalinity as } CaCO_3]$$

3.2.2. Success Criteria

This performance objective was considered successful if 95% of the fully treated water samples analyzed by a certified laboratory had a calculated LSI value between 0 and 1.

3.2.3. Results

This performance objective was not met. Eighteen samples were taken throughout the demonstration and none met the performance objective of having a value $0 < LSI < 1.0$. While this may appear to be a failure of the objective, the problems responsible are mechanical in nature and are easily remedied. Scaling issues were frequently observed in the soda ash mix tank, suction strainers, and the injector of the soda ash static mixer, preventing the required amount of soda ash to be dosed into the treated water. This scaling can be eliminated (or minimized) by installing media canisters to soften the recycled treated water prior to dilution of the soda ash in the dissolver tank of the package soda ash system. Also, the soda ash static mixer was sized specifically for the WBA system, but did not effectively mix the dilute soda ash. Mixing the soda ash with treated water would improve greatly by implementing a two-stage mixing process identical to that used to pre-dilute and mix sulfuric acid in the pretreatment step of the system. Additionally, the static mixer must be placed further upstream from the pH probes to allow more reaction time prior to pH measurement and sampling for LSI.

3.3. Performance Objective: Minimize Process Waste

Minimization of process waste is a key benefit of the WBA process which was validated. For this application, process waste is defined as the amount of spent regenerating solution generated that must be disposed offsite. The amount was reported as a percentage of the total groundwater treated. This value was calculated after each treatment cycle during the demonstration. Each treatment cycle consists of two steps as defined in Figure 3-3 (NOTE: in this figure, GW stands for groundwater and TGW stands for treated groundwater). At the conclusion of the demonstration, the total volume of spent regenerating solution disposed off site was calculated and compared to the total volume of groundwater treated.

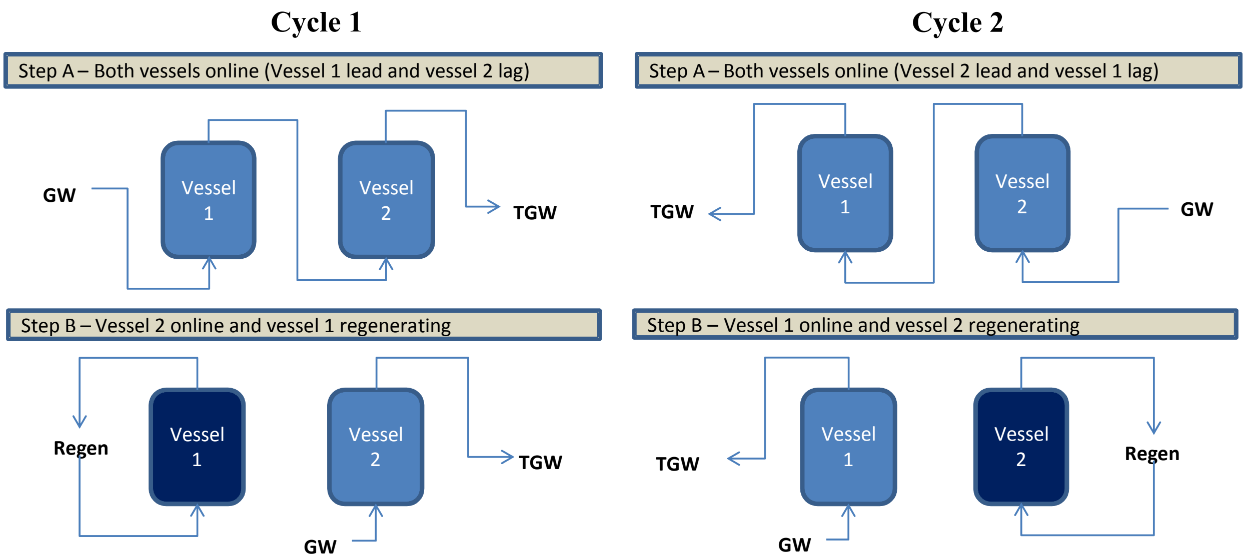

Figure 3-1. The WBA Treatment Cycle

3.3.1. Data Requirements

The data required to evaluate this performance objective includes the volume of treated groundwater produced during each cycle, and the total volume of water disposed offsite as wastewater, or spent regenerant. The total volume of water treated during each cycle was quantified and recorded using a magnetic flow sensor and a totalizer that was programmed into the process control system/PLC. This data was transmitted to a data acquisition system (DAQ) that recorded system parameters, including instantaneous flow rate and totalized flow, at a systematic interval (i.e. every 5 minutes) for the length of the demonstration. The volume of wastewater generated was quantified at the time of disposal using the manifest of the disposal company responsible for disposing the waste.

3.3.2. Success Criteria

This performance objective was considered successful if waste disposed is less than 0.07% of the groundwater treated.

3.3.3. Results

This performance objective was met based on data obtained during Test Periods 1-3. The percentage of waste disposed of during these test periods was determined to be 0.07% based on amounts of water treated and regeneration waste disposed of during those test periods. Data from Test Period 4 was not factored into this performance objective because the system was offline and the demonstration discontinued prior to completion.

3.4. Performance Objective: Treatment of Spent Regenerating Stream

Prior to disposal of spent regenerating solution, perchlorate was removed using a scavenger resin approach. The scavenger approach consisted of passing spent regenerating solution through two ion exchange vessels arranged in series, each containing 52.5 ft^3 of Purolite A530E strong base anion (SBA) resin. Perchlorate that concentrated in the spent regenerating solution was removed by this process prior to disposal.

3.4.1. Data Requirements

The data required to evaluate this performance objective was the perchlorate concentration of the composite, treated spent regenerating solution. This sample was collected following each scavenging operation using the sample valves located on the scavenger vessel valve manifold assembly. Perchlorate was analyzed by ion chromatography using method EPA 314.0 or EPA 331.0.

3.4.2. Success Criteria

This performance objective was considered successful if the perchlorate concentration of the composite, treated spent regenerating solution from the lag scavenger vessel remained below the reporting limit of the analytical method. The composite water was stored in a 10,500 gallon wastewater holding tank. A circulation pump was used to mix the tank contents. Following regeneration, and prior to disposal, the composite of the treated wastewater was collected and analyzed.

3.4.3. Results

This performance objective was successful. All samples obtained during scavenging of the regeneration waste during Test Periods 1-3 were found to be ≤ 2.5 ppb. Data from Test Period 4 was not factored into this performance objective because the system was offline and the demonstration discontinued prior to completion.

3.5. Performance Objective: Perchlorate Bleed from Regenerated Vessel

It is important to ensure that a regenerated vessel does not exhibit perchlorate bleed when placed back in service. A rinse step at the conclusion of resin regeneration has been used to eliminate perchlorate bleed. The goal of this performance objective was to verify the effectiveness of the rinse process.

3.5.1. Data Requirements

To investigate the adequacy of the rinse step in eliminating perchlorate bleed, a freshly regenerated vessel was sampled and analyzed for perchlorate using EPA 314.0 or EPA 331.0. Initial samples were taken within 300 BV's of the vessel being placed back online. Additional samples were taken after the vessels had been online between 1,000 and 2,500 BV's. Perchlorate data from both ARA and certified laboratory samples were evaluated to determine whether any perchlorate bleed was observed after the newly regenerated vessels were placed back online.

3.5.2. Success Criteria

This performance objective was considered successful if the perchlorate concentrations of the samples collected were below 4 ppb.

3.5.3. Results

This performance objective was successful. All samples collected and measured using both EPA 314.0 and 331.0 were below 0.27 ppb. The final rinsing step adequately minimized bleed from the regenerated vessel.

3.6. Performance Objective: Treatment Flow Rate

In order to be a viable drinking water treatment process, the treatment flow rate must adequate and comparable to existing treatment systems. This performance objective was evaluated in units of gallons per minute per cubic foot of resin (gpm/ft^3).

3.6.1. Data Requirements

The data required to evaluate this performance objective was system flow rate which was monitored using a magnetic flow sensor. This flow rate in turn was monitored by the PLC and transmitted to the DAQ for storage. In addition, the total volume of resin loaded in each ion exchange vessel was 350 ft^3 per vessel.

3.6.2. Success Criteria

This performance objective was considered successful if an average treatment rate of 2.5 gpm/ft^3 is maintained throughout the demonstration (i.e., greater than 875 gpm).

3.6.3. Results

Although the WBA IX system did not maintain the desired treatment flow rate of 2.5 gpm/ft^3 (875 gpm), the average flow throughout the demonstration was consistently 2.29 gpm/ft^3 (800 gpm). Lower flow rates were a result of increased pressure drop across the Liqui-Cell membranes used in the pretreatment system. When flow rates were increased to levels above 800 gpm, the system would operate for short periods of time before the high pressure interlock safety was activated (> 90 psig), causing the system to shut down. This problem can easily be overcome by installing a means for performing cleaning procedures on the membranes and by adding an additional pair of membranes. This is discussed further in Section 6.6.1.

3.7. Performance Objective: Operating Costs

Operating costs are critical in determining if the WBA process is competitive compared to existing perchlorate treatment systems. Activities and materials that contribute to O&M costs will be documented and reported in dollars per acre-ft of water treated.

3.7.1. Data Requirements

Operating costs were calculated based on actual consumption rates observed during the demonstration. Estimates of electrical costs and labor costs for a full-scale system were included in O&M costs. Costs associated with all sub-categories identified in the table below were documented and tracked throughout the demonstration. At the conclusion of the demonstration, this data was analyzed and totaled to provide the estimated O&M cost for operating the WBA IX system. All assumptions used to calculate the treatment costs were documented in the analysis. Table 3-2 identifies the categories that were tracked to determine O&M cost.

Table 3-2. Cost Categories for determining O&M Treatment Cost ($/acre-ft)

Tracked Cost Categories	**Details**
Consumable Materials	Consumption of all raw materials will tracked throughout the demonstration to enable cost prediction
-Acid	
-Caustic	
-Soda Ash	
-Resin Replacement (WBA & SBA)	
Waste Disposal	Cost for transporting and disposing all wastes will be tracked
-Treated spent regenerant solutions	
Untracked Cost Categories	**Details**
Utilities	Utility usage will be estimated based on equipment ratings and duty cycle
-Electricity	
Labor	Labor requirements will be estimated based on observed demonstration site activities
-Operator Labor	

3.7.2. Success Criteria

This performance objective was considered successful if O&M costs were validated to be less than $150/acre-ft.

3.7.3. Results

Actual O&M costs for operating the WBA IX system were much higher than anticipated. At the time of the demonstration, market prices of consumable chemicals, SBA resin, and WBA resin were higher than previous cost estimates. Due to intermittent operational difficulties, steady state operation was never reached to enable operators to optimize chemical consumption. In addition, it was originally estimated that groundwater perchlorate concentrations would climb to levels $\geq$ 50 ppb by the time the WBA IX system was originally proposed to come online (2009-2010). During the 2011 demonstration, groundwater perchlorate concentrations never reached predicted levels and the WBA resin was never operated at design capacity, making operational costs for the full scale system difficult to validate. Observed overall O&M costs based on tracked and untracked costs were >$398/acre-ft. In order to get a more realistic number, costs were normalized based on treatment of $\geq$ 9,000 BVs at design capacity (1,000 gpm). Average market pricing of consumable chemicals was also used for these calculations. Subsequently, O&M costs dropped to $229.00/acre-ft of water treated. These results are discussed further in Section 7.0, "Cost Assessment."

3.8. Performance Objective: System Scalability

There is an economy of scale associated with the regeneration components of the WBA system. The Rialto Well 3 system was designed to allow for additional ion exchange treatment trains to be installed without requiring additional equipment to be purchased (i.e., regeneration tanks, pumps, etc.).

3.8.1. Data Requirements

The regeneration process is designed to regenerate a single vessel at a time. For the regeneration system to support additional treatment trains, the frequency of regeneration must be such that there is no interference in drinking water treatment (i.e. a vessel can be completely regenerated before another vessel requires regeneration). Data including frequency of regeneration per vessel and total, real-time duration of regeneration was documented in logbooks. Quantities and frequency of replenishment of regeneration chemicals was also documented. These data points were used to validate that additional ion exchange trains can be added with little or no modification to the existing regeneration equipment.

3.8.2. Success Criteria

This objective was considered successful if the demonstration data indicated that the regeneration system could support two additional ion exchange treatment trains, which would expand the system from 1,000 gpm to 3,000 gpm.

3.8.3. Results

During this demonstration, this performance objective was successfully met. Although the first regeneration required approximately 72 hours due to several mechanical and programming issues, the second and third were achieved in less than 48 hours. Because breakthrough concentrations were not achieved in this demonstration, a model was used to calculate capacity. Using that model with the current flow rate capacity of 800 gpm (or the design flow rate of 1,000 gpm) and Rialto No. 3 groundwater characteristics, the lead vessel should treat 9,000 BV's, which equates to run times of between 16 and 21 days before the regeneration of the lead vessel is required. Based on those numbers, the existing onsite equipment easily supports two additional ion exchange treatment trains.

3.9. Performance Objective: Predict WBA Resin Capacity

The purpose of this performance objective was to collect the necessary water quality data to estimate and predict the treatment capacity of the WBA resin in drinking water applications with similar groundwater characteristics. For this purpose, treatment capacity is defined as the totalized volume of water treated before regeneration of the lead vessel is required.

3.9.1. Data Requirements

Initially, it is important to regenerate the resin frequently in order to reach a performance homeostasis and calculate an accurate estimate of capacity (several operation-regeneration cycles are needed to overcome virgin-resin effects with exchanging anions). Perchlorate breakthrough will not be achieved for the first two test periods, which are purposely shorter in order to accomplish frequent regenerations for both resin beds. Once these short test periods are completed, efforts will be made to “bracket” perchlorate breakthrough in the lead vessel during subsequent 14 day test periods. Sampling frequency was conducted daily during estimated periods of breakthrough. Data tables and plots showing volume of water treated versus perchlorate concentration was generated in an effort to characterize perchlorate breakthrough during the demonstration.

The data requirements include perchlorate concentration in effluent from the lead vessel, and the total volume of water treated by lead vessel at the time of sampling. The volume of water treated will be monitored using a magnetic flow sensor, totalized by the PLC, and stored by the DAQ for the length of the demonstration. The predicted treatment capacity can be calculated based on the most appropriate perchlorate breakthrough concentration. For this performance objective, perchlorate breakthrough will be defined as the point in time when the perchlorate concentration of the lead vessel effluent equals 50% of the perchlorate concentration of the Rialto No. 3 groundwater perchlorate concentration (17 ppb).

To ensure ability to compare source waters and predict capacity, characteristics of the untreated groundwater including pH, alkalinity, and concentrations of perchlorate, nitrate, sulfate, and chloride were also determined and recorded.

3.9.2. Success Criteria

The criterion for success of this performance objective was to develop a calculation or model capable of predicting the volume of water treated before perchlorate breakthrough occurs based on groundwater characteristics including perchlorate, nitrate, sulfate, chloride concentrations, and alkalinity.

3.9.3. Results

During this demonstration, the breakthrough capacity of the resin was not observed. During the fourth test period, an inconsistent supply of water from Rialto No. 3 and budget constraints halted the demonstration before breakthrough in the lead vessel was accomplished. This inconsistent operation of the system provided atypical results based on previous demonstrations. Although this capacity was not reached, it is much higher than observed. The current capacity can be calculated using a more recent model for the D4170 WBA resin constructed from previous ESTCP field demonstrations. Using the current WBA IX flow rate capacity of 800 gpm and observed Rialto No. 3 groundwater characteristics, this model supports the earlier estimates that the lead vessel will treat ≥ 9,000 BV’s before regeneration is required.

3.10. Performance Objective: System Control During Treatment and Regeneration Cycles

The Rialto No. 3 WBA system was automated to minimize operator effort and time requirements. The system also has the flexibility to manually modify system parameters such as flow rates, pH set points, time cycles, etc. The system includes a secure, fully enclosed control room that houses the equipment for monitoring and controlling the WBA system. Key operation screens and parameters including pH, flow rates, tank levels, valve conditions (i.e. open or closed), etc., are viewable on the operator interface (O/I). All recorded system data was stored on the DAQ for the duration of the demonstration. The effectiveness and ease of use of the WBA demonstration system using the automated monitoring and control system during ion exchange and regeneration operations will be investigated.

3.10.1. Data Requirements

Checklists and protocols were used to guide and streamline system inspection and data collection for each site visit. The time required for completing checklists to accomplish system inspection and data collection was documented each visit. Any tasks that could not be accomplished by a single technician were documented in the site log book and analyzed for alternatives that simplified the process.

3.10.2. Success Criteria

Success criterion for this performance objective was defined as the ability of a single field technician/system operator to effectively monitor and control the system during ion exchange and regeneration operations cycles. Success was based on the ability of a single operator to complete a system inspection checklist; view and record monitoring information in log books, including pH, flow rate, tank/vessel level, etc.; and have the ability to adjust control set points in the PLC from the O/I, if necessary.

3.10.3. Results

During normal operations, the performance objective was met. The use of the touch screen by a single operator for monitoring and controlling/adjusting system control parameters was very straightforward. Completing checklists and sampling was also handled by a single operator. It is only when the system is having problems, either during treatment or regeneration, that the system requires two or more operators. Because the system is operated from the PLC touch screen in the control room, it is difficult for a single operator to observe what the system is actually doing during trouble shooting.

4.0 Site Description

4.1. Site Location and History

The City of Rialto, California is located in San Bernardino County at the southern base of the San Gabriel Mountains with topography ranging from a low of 1,120 feet to a high of 1,520 feet above sea level. The 22 square mile City is bounded by San Bernardino and Colton on the East and Southeast and by Fontana and unincorporated Bloomington on the West and Southwest.

The northern two-thirds of the City of Rialto overlies the Rialto-Colton Groundwater basin. The City of Rialto currently depends on groundwater from this basin and other nearby groundwater basins for approximately 90% of its annual water supply. Groundwater in the basin flows southeast from the northwest near the former Rialto Ammunition Storage Point (RASP) site, toward the Santa Ana River.

The RASP property was used for munitions storage by the United States Army during World War II. Following inactivation of the RASP in late 1945, and over several years, the property was leased, subdivided, and sold to commercial activities. One resulting activity is the Mid-Valley Sanitary Landfill (MVSL), which has been operated by the County of San Bernardino since 1958. This property consists of approximately 448 acres of which 222 acres are in use for waste disposal activities. In 1990, the County purchased the northeast area of its current property, which contained storage bunkers that were known to have housed explosives, chemicals, propellant, oxidizers, and fireworks. The County demolished these bunkers in 1998-1999 and a portion of this area is currently used by a sand and gravel business in accordance with an agreement between the County and the business. In 1997, the County sampled 23 monitoring wells in the MVSL monitoring system for perchlorate. Only one well had a detectable concentration of perchlorate and it was less than five parts per billion. In 2001, perchlorate concentration of one of the MVSL monitoring wells increased significantly to 250 ppb. As a result, the County increased its monitoring for perchlorate in existing monitoring wells. The County also initiated an assessment of the possible perchlorate sources on its property by analyzing soil samples and process water samples generated by the sand and gravel business. The County found that the northeast area of its property purchased in 1990 may be a source of perchlorate contamination in the groundwater.

The municipal well Rialto No. 3 is located near the City of Rialto's municipal airport and is owned and operated by the City of Rialto. This well is down gradient of the MVSL property owned by the County and has been impacted by perchlorate and volatile organic carbon (VOC) contamination. This well has historically represented approximately 15% of the City's demand and is considered an important facility for the City's water system. In 2003-2004, the Santa Ana Regional Water Quality Control Board (RWQCB) issued cleanup and abatement orders that required the County to cleanup and abate perchlorate discharges at and from its property as well as provide replacement water.

Presently at Rialto No. 3, the County has in place a 2,000 gpm, single-use ion exchange system for perchlorate treatment. This treatment system is intended to intercept, contain, and treat groundwater contaminated with perchlorate and provide the replacement water necessary to fulfill the RWQCB cleanup and abatement order(s). Treatment system upgrades have been completed including installation of two additional extraction wells to enhance plume containment; adding a 100,000 gallon drinking water reservoir to store water before it is treated by the permitted treatment system; adding ultraviolet (UV) disinfection to disinfect groundwater before it is introduced to the ion exchange vessels; and adding granulated activated carbon (GAC) vessels to remove volatile organic carbon that has been detected in upstream monitoring wells. The WBA demonstration system treated water upstream of the UV and GAC systems.

4.2. Site Geology/Hydrogeology

Groundwater in the Rialto-Colton basin occurs within alluvial sediments at depths ranging from more than 400 feet below ground surface (bgs) near Rialto No. 3 to less than 100 feet bgs closer to the mountain front. Groundwater elevation data collected by the U.S. Geological Survey (USGS) indicates that groundwater in the northern and central portions of the basin flows to the south and southeast under a hydraulic gradient of about 0.3 to 1.2 percent. Upgradient of Rialto No. 3, groundwater elevation data obtained historically for monitoring wells located near the Mid-Valley Sanitary Landfill indicate steeper hydraulic gradients ranging from of 1.0 to 1.7 percent (GLA, March 2006).

Investigations and literature reviews conducted by the County indicate the presence of three laterally-continuous aquifers within the USGS's "middle hydrologic unit" in the Rialto-Colton Basin. These laterally continuous aquifers include an upper unconfined aquifer which is currently dry, an intermediate partially confined aquifer, and a deep regional confined aquifer that provides much of the groundwater that is pumped in the area by municipal supply wells. The three aquifers are separated by low-permeability aquitards that generally range in thickness from only a few feet to over 30 feet. The groundwater velocity is estimated to be approximately 0.5 to 5 feet per day.

4.3. Contaminant Distribution

A groundwater monitoring program is in place to monitor the lateral and vertical extent of perchlorate and VOC contamination upstream of Rialto No. 3. The monitoring program consists of quarterly groundwater sampling of monitoring wells located in the contamination plume impacting Rialto No. 3, also known as the Western Plume. Wells sampled to fulfill the monitoring program include: seven near-field monitoring wells (M-1, M-2, M-3, M-4, M-5, M-6, and N-14); eight plume-wide monitoring wells (F-6A, N-7, N-8, N-10, N-11, N-12, N-13, and N-15); nine piezometer monitoring stations (F-3, F-6, N-1, N-2, N-3, N-4, N-5, N-6, and N-9); and three west-side cluster monitoring wells (N-16, N-17, and N-18). The location of the MVSL property, the approximate limit of the Western Plume, the location of wells sampled for the groundwater monitoring program, and the location of Rialto No. 3 is shown in Figure 4-1. This map was included in the Spring 2008 monitoring results reported by GeoLogic Associates, a consultant supporting the County of San Bernardino.

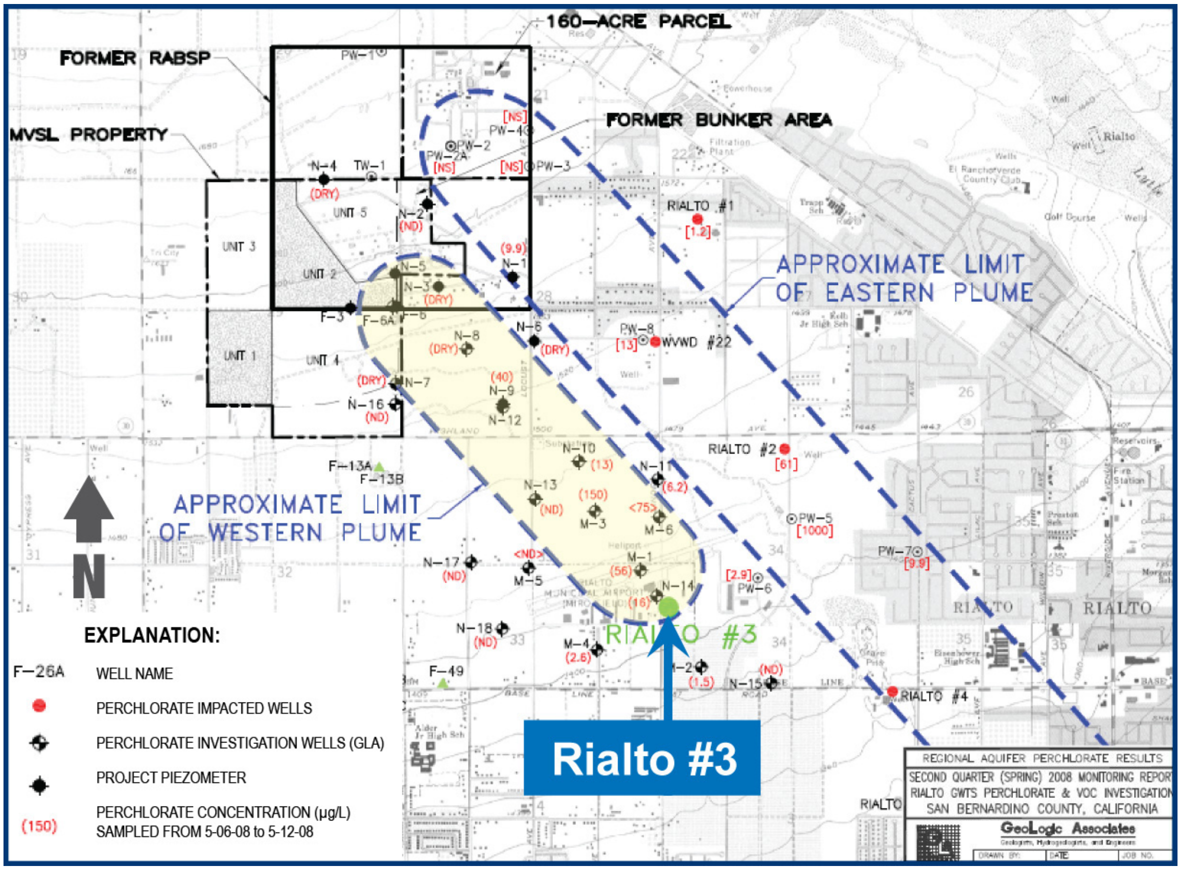

Figure 4-1. Locations of Wells in the Western Plume in Relation to Rialto No. 3

5.0 Test Design

5.1. Conceptual Experimental Design

This section provides a broad overview of the experimental design to be used to evaluate the technology based on performance objectives. Specific details of the experimental design including sample collection, quality controls and procedures, and data evaluation are provided in the following sections.

5.2. Baseline Characterization Activities

A water monitoring program has been in effect for Rialto No. 3 and monitoring wells since 2006. A report is generated quarterly summarizing the analytical results. The results from 6/22/10 of the raw water from Rialto Well No. 3 are shown below in Table 5-1.

Table 5-1. Analytical Results – Historical Summary Data for Well No. 3 Rialto

ANALYTE	UNITS	AVG. VALUE
Anions		
Nitrate-Nitrogen	mg/L	4.64
Perchlorate	µg/L	15.14
Sulfate	mg/L	13.36
Volatile Organic Compounds (EPA 524.2)		
Bromochloromethane	µg/L	0.19
Bromodichloromethane	µg/L	0.42
Bromoform	µg/L	0.36
Chloromethane	µg/L	0.26
Dibromochloromethane	µg/L	1.09
Trichloroethene	µg/L	0.36
Total Trihalomethanes	µg/L	3.83
Bacteriological		
Heterotrophic Plate Count	CFU/mL	29.9

5.2.1. Available Characterization Data

The County of San Bernardino executes a groundwater monitoring program monthly, quarterly, and annually. During this program, approximately 26 groundwater monitoring wells or piezometers are sampled to characterize the groundwater and contamination plume. Relative to the location of Rialto No. 3, these wells and piezometers are positioned near-field, plume-wide, and on the west side. Samples are analyzed for one or more of the various constituents including perchlorate, volatile organic carbon compounds, alkalinity, bicarbonate, carbonate, chloride, hardness (calculation), hydroxide, nitrate, sulfate, total dissolved solids, and metals. Wells from which water could not be sampled (i.e. the well is dry) are identified in the data report.

Data collected from the most up to date groundwater monitoring report were reviewed prior to initiating the demonstration for any anomalies and to facilitate characterization of the groundwater properties approaching Rialto No. 3. Of most interest for this demonstration were the near-field wells located directly upstream from Rialto No. 3. These wells include N-14, M-1, and M-3, which are approximately 325 ft, 900 ft, and 2,440 ft directly upstream from Rialto No. 3, respectively.

5.2.2. Groundwater Sampling

In addition to having the available plume characterization data, groundwater from Rialto No. 3 was sampled and analyzed prior to startup of the WBA demonstration system. Groundwater from Rialto No. 3 was analyzed for perchlorate, nitrate, sulfate, chloride, and general mineral and physical properties used to determine scaling potential. These water quality characteristics were used not only to assist in determining operational parameters, but also to establish the baseline for evaluating performance objectives identified in Section 3.0. Throughout the demonstration, Rialto No. 3 was sampled several times each month and analyzed by either ARA or by a certified laboratory.

5.3. Treatability or Laboratory Study Results

Treatability and laboratory studies were previously performed under ESTCP Project No. ER-0312, "Perchlorate Removal, Destruction, and Field Monitoring Demonstration."

5.4. Design and Layout of Technology Components

5.4.1. WBA Demonstration System

The WBA ion exchange process is comprised of four major operations: pretreatment, ion exchange, post treatment, and regeneration. Pretreatment consists of acid addition to decrease pH of the untreated feed water in order to maintain functional groups on the WBA resin in the ionized or protonated form. Carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) alkalinity present in the groundwater is converted to carbonic acid in equilibrium with CO_2. Approximately 90 percent of the dissolved CO_2 is removed by a Liqui-Cel membrane degasifier system. Ion exchange is conducted using two packed-bed ion exchange vessels in lead-lag configuration. At system pressure, any undissolved CO_2 remains in solution. Post treatment consists of pH control using soda ash to return treated water to acceptable levels of alkalinity and pH. Regeneration of spent resin is accomplished by circulating a high pH solution through the offline vessel to neutralize the functional groups, followed by rinsing, protonation using acid, and a final rinse. Each of these major operations is illustrated in subsequent sections. A flow diagram of the general process is shown in Figure 5-1. A drawing package containing the original Rialto No. 3 site development plan, WBA system layouts, and WBA system PID's are attached as Appendix B. Equipment specifications are attached as Appendix C.

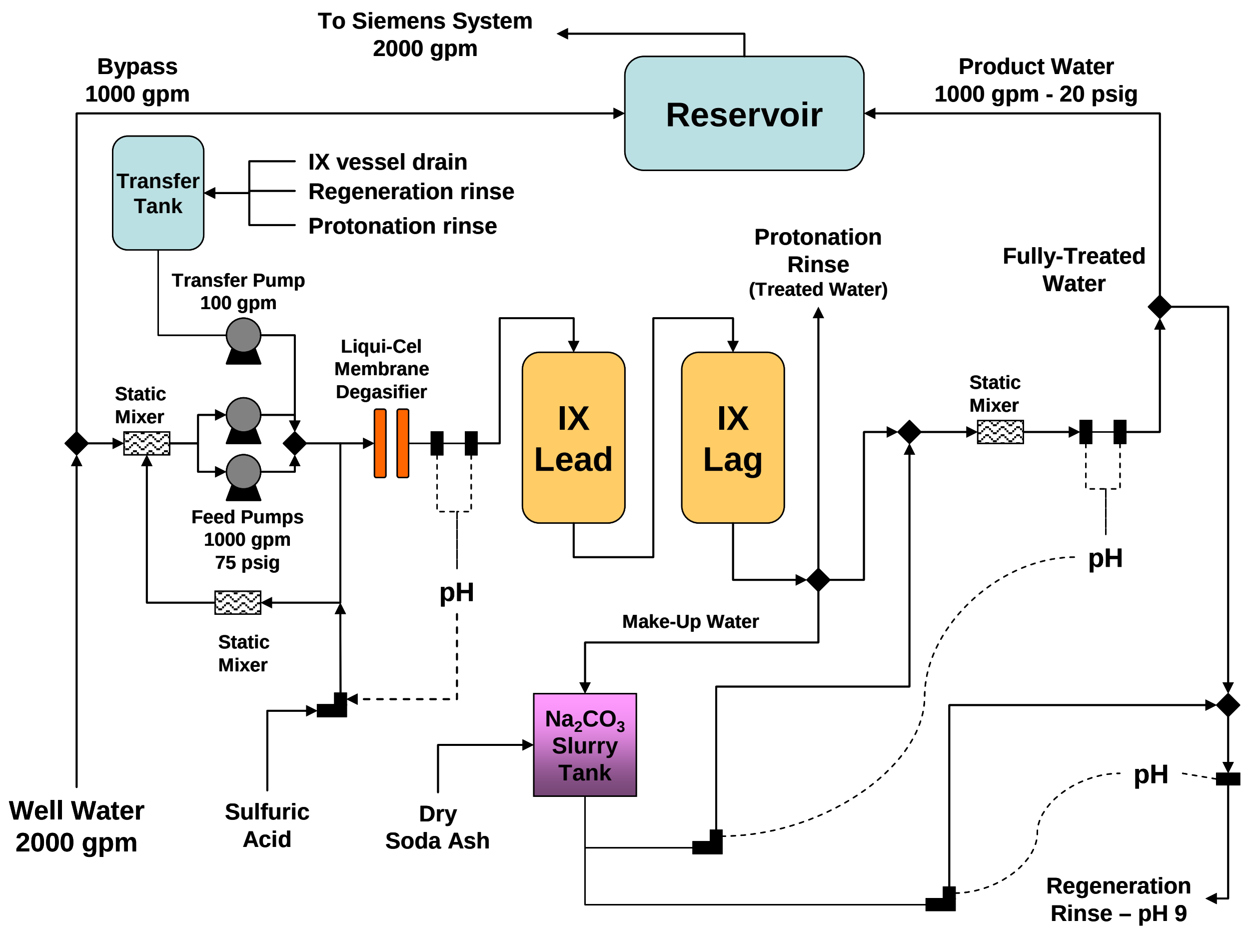

Figure 5-1. Flow Schematic of the WBA Treatment System

5.4.1.1. Pretreatment (Reduce pH)

The objective for pretreatment was to reduce pH in the groundwater prior to ion exchange. Reducing the pH of the groundwater ensured that functional groups on the WBA resin remained protonated or ionized and capable of perchlorate exchange. The operational pH was maintained at 4.0-4.5 by addition of NSF certified 96-98% sulfuric acid. Two–step mixing of the sulfuric acid into the feed water was performed to ensure complete mixing while reducing groundwater pH. In the first step, a dosing pump injected acid into a slipstream of feed water downstream of the system feed pumps. This line contained a static mixer which provided the initial mixing of the acid. This slipstream was then redirected to an injection location on the suction side of the feed pumps where it passed through another static mixer. This configuration ensured the optimal/complete mixing of feed water and acid before water reached the membrane degasifier system and ion exchange vessels, and protecting the main feed pumps.

At operational pH, carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) alkalinity present in the groundwater converted to carbonic acid in equilibrium with dissolved CO_2. To save chemical costs on the downstream, neutralization process (post-treatment), excess dissolved CO_2 was removed from the feed water using the membrane degasifying system. The Liqui-Cel membrane degassing system stripped 85-90% of the dissolved CO_2 from the feed water. A liquid-ring vacuum pump provided the vacuum required for operation of the membrane system.

Integrated redundant pH probes monitored feed water pH downstream of the membrane degassing system. WBA system interlocks were controlled by one pH probe, although the PLC monitored both probes to ensure accurate and precise pH control was maintained. If signals from the pH probes deviated from one another by the predetermined amount, then alarms and interlocks initiated system shutdown.

5.4.1.2. Ion Exchange

Perchlorate removal was accomplished using two, packed bed ion exchange vessels operated in a series, lead-lag configuration. These vessels have a diameter of 108 inches (9 ft), with a cylindrical height of 92.5 inches (7.7 ft). The materials of construction for these vessels were SA 516-70 lined with an NSF-approved vinyl ester material that was resistant to acid and caustic solutions. The packed-bed configuration minimized the volumes of regenerating and rinse solutions generated during regeneration procedures. Operational service for the vessels was designed to be upflow with a design treatment rate of 3 gpm/ft^3 of resin (24 BV/hr), establishing a minimum resin capacity of 333 ft^3 per vessel (in the free-base form). Each vessel was loaded with 350 ft^3 of Purolite D-4170 resin and 40 ft^3 of Purolite IP4 inert resin. A vessel diameter of 9 feet results in a linear flow rate of 17 gpm/ft^2 with a pressure drop of 13.5 psig at 1100 gpm. Based on a treatment capacity of 10,000 bed volumes and with perchlorate concentration less than or equal to 200 ppb in the groundwater, the regeneration frequency was estimated to be every 17 days when operated 24 hours per day. The CDPH 97-005 Policy Memorandum requires “multi-barrier” treatment (i.e., lead-lag, two-stage vessel configuration) for perchlorate removal when using ion exchange. Ion exchange treatment systems have been permitted for intermittent operation with a single vessel on-line while the redundant vessel is being regenerated or the resin is replaced.

5.4.1.3. Post Treatment (Restore pH)

Post treatment of the treated water restores pH and alkalinity to acceptable levels. Soda ash was used to restore alkalinity and pH, resulting in near-neutral water with respect to scaling or corrosion tendencies. The post-treatment soda ash system has the flexibility to produce soda ash solutions that vary in concentration from 1 to 10% dry soda ash.

The packaged soda ash system was engineered and fabricated by Merrick Industries, Inc. The system includes components for storage of dry soda ash and for preparation and delivery of soda ash solution. Bags of dry soda ash were emptied into a bag dump station equipped with a dust control system (reverse pulse jet dust collector and blower assembly). The dry soda ash was conveyed to a storage hopper (39.5 ft^3) using a flexible screw conveyer. Soda ash solutions were prepared in a 100 gallon dissolver tank. This was accomplished by simultaneously feeding dry soda ash from the storage hopper and a slip stream of treated water into the dissolver tank at pre-determined and pre-calibrated rates to attain the desired concentration of soda ash solution in the tank. The soda ash concentration has the flexibility to be adjusted, as needed, to meet system requirements. Soda ash concentration was maintained volumetrically and independent of the usage rate.

Two positive displacement pumps with pulsation dampeners were used to deliver soda ash solution to neutralize the 800-1000 gpm treated water stream. A static mixer element was used at the injection point to ensure complete mixing of the soda ash solution. Flow rates were adjustable by changing the stroke length of the pumps.

Redundant pH probes monitored the fully treated water pH downstream of the static mixing element. WBA system interlocks were controlled by a single pH probe. However, the PLC monitored both probes to ensure that accurate pH control was maintained. If signals from the pH probes deviated from one another by the predetermined amount, then alarms, interlocks, or shutdown were initiated.

5.4.1.4. Regeneration

Major components of the regeneration system consist of: 1) a drain/transfer pump to initially drain the offline, ion exchange vessel; 2) a transfer vessel and pump to recycle rinse water and vessel drain water; 3) a sulfuric acid (96-98%) storage tank and feed pump; 4) a sodium hydroxide (25%) storage tank and feed pump; 5) a regeneration tank; 6) a protonation tank; 7) pH probes and associated controls for use with the regeneration system; 8) a 500-gpm regeneration/protonation pump; and 9) a scavenger ion exchange system to treat spent regenerating solution before discharge.

Regeneration of spent WBA resin included two key operations: 1) neutralization of the functional groups to “release” anions (regeneration) and rinsing and 2) ionization of functional groups to restore ion exchange functionality (protonation) and rinsing. Key steps of this entire operation are shown as flow diagrams in Figures 5-2 and 5-3. During regeneration, a spent, offline, ion exchange vessel was drained and the water was pumped to the front of the system for treatment by the online vessel (Step 1). Regeneration solution (a pre-determined amount of sodium hydroxide in a fixed volume of water) was circulated at a minimum of 500 gpm, up-flow, through the spent ion exchange vessel (Step 2). After attaining set time and pH criteria, circulation was discontinued. The spent regenerating solution was pumped from the offline vessel, through the scavenger vessels, and into the waste holding tank (Step 3). The initial pH 9 rinse was collected in the regeneration tank and held for the next regeneration (Step 4). A final rinse of 16-20 hours flowed to the transfer tank for retreatment (Step 5 – not shown).

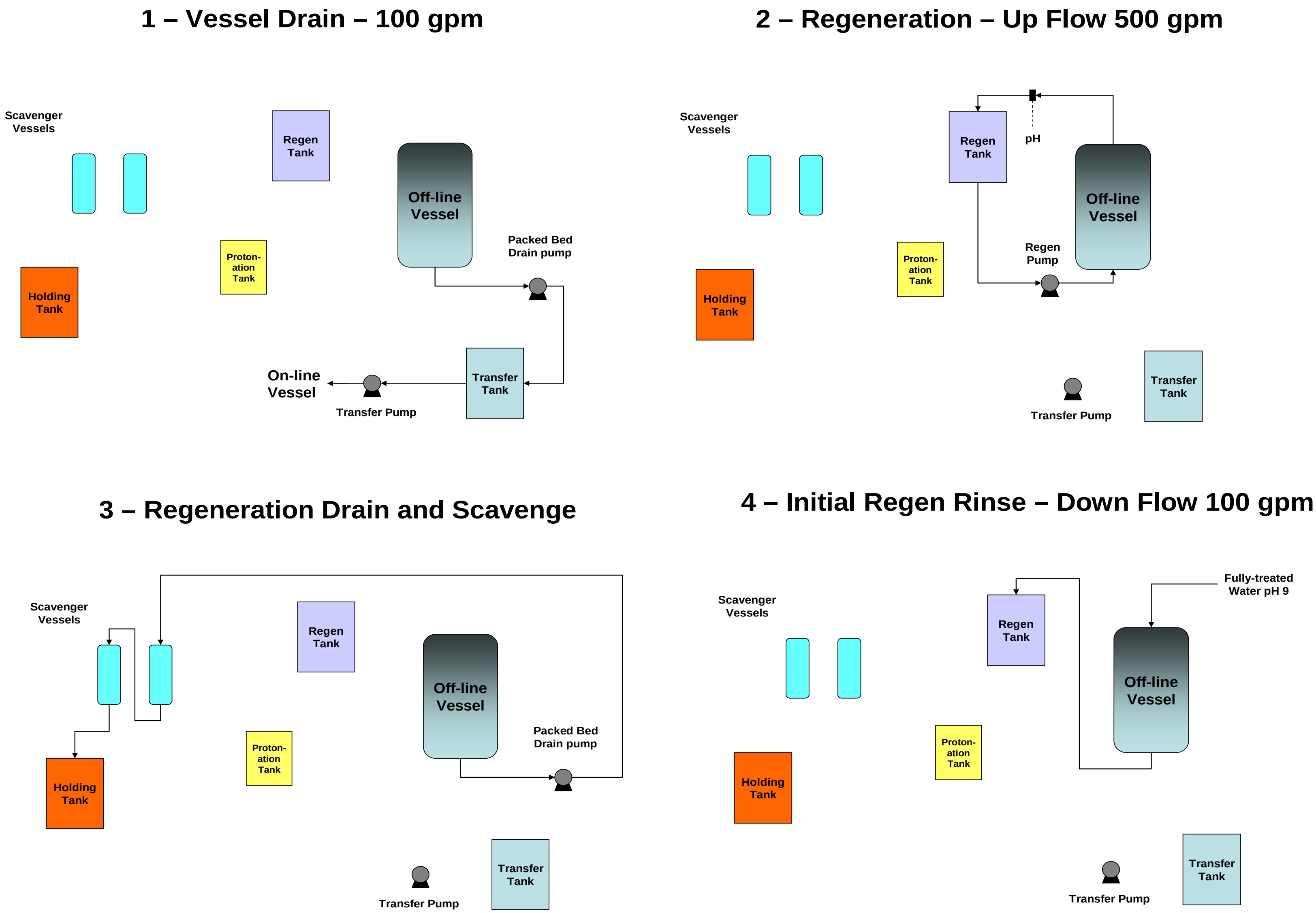

Figure 5-2. Regeneration Steps

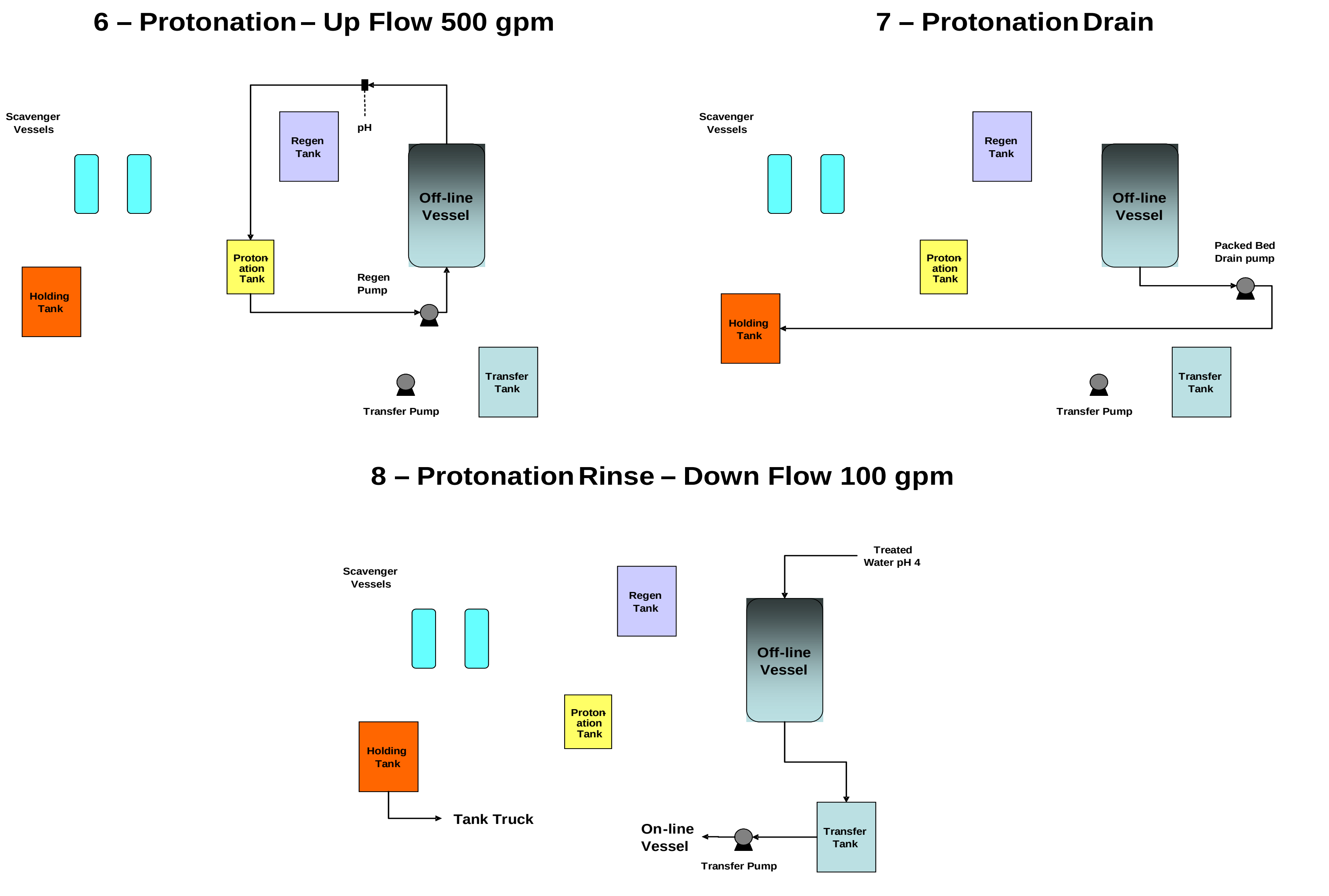

Figure 5-3. Protonation Steps

Following the pH 9 rinse, the resin in the offline vessel was protonated. To accomplish this, a protonation solution (a pre-determined amount of sulfuric acid in a fixed volume of water) was circulated at a minimum of 500 gpm, up-flow, through the ion exchange vessel (Step 6). After attaining the pH criteria for the specified time, circulation of the protonation solution was discontinued and the ion exchange vessel and protonation tank were drained to the waste holding tank (Step 7). The vessel was rinsed with treated water for a set time (Step 8) prior to returning the vessel to online operation in the lag position.

5.4.2. Integration with Extraction Well Rialto No. 3

The demonstration system was integrated with Rialto No. 3 as a "pre-treatment" system to the existing, single-use ion exchange system as shown in Figure 5.4. This enabled the demonstration of the WBA treatment system to take place while still allowing the City of Rialto to simultaneous produce up to 2,000 gpm of drinking water through their existing, permitted treatment system. During the demonstration, flow from Rialto No. 3 was split to provide up to 1,000 gpm to the WBA process and up to 1,000 gpm to the 100,000 gallon feed reservoir. During periods when the WBA system was offline, all well water flowed unrestricted to the feed reservoir. Suction head pressure for the WBA system was observed to be 8-10 psig.

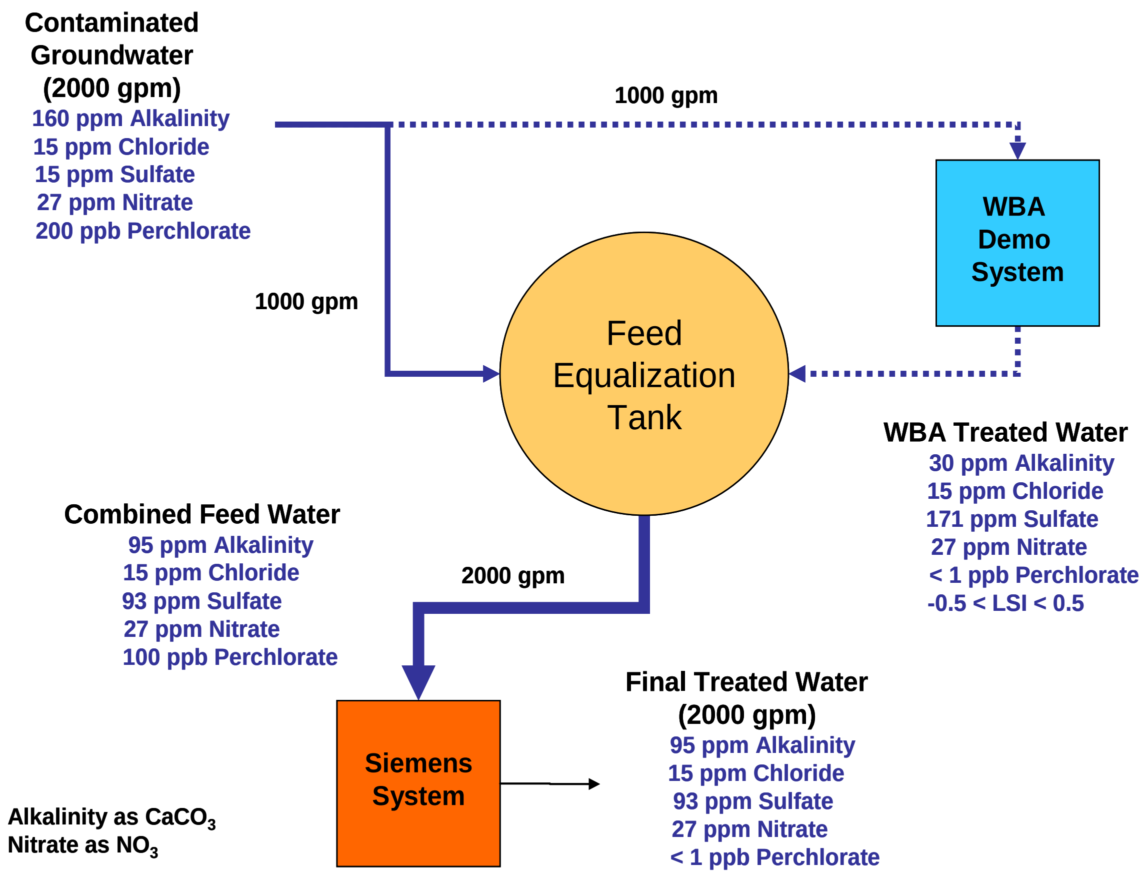

Figure 5-4. WBA System Integration with Rialto No. 3

5.4.3. Integration with Infiltration Basin and Feed Reservoir

Piping and valves were installed to direct water produced by the WBA treatment system to either of the two following discharge points: 1) an infiltration basin with a capacity of approximately 900,000 gallons; or 2) a 100,000 gallon feed reservoir which serves as the source of water for the existing treatment system at Rialto No. 3, which operates under a drinking water supply permit issued by CDPH.

Water produced from the demonstration system during functional testing, start-up testing, and troubleshooting operations was be discharged directly to the infiltration basin. During these tests, the system operated for short periods of time and/or at reduced flow rates as limited by the infiltration basin capacity.

During the actual demonstration, water was directed to the 100,000 gallon feed reservoir after completion of an extensive review of WBA operating procedures and approval by CDPH. Water from the reservoir was treated by the existing permitted system that included UV sterilization, ion exchange, carbon treatment, and disinfection. After disinfection the water entered normal distribution.

5.5. Field Testing

5.5.1. Functional Testing

All vessels, tanks, pumps, pipes and valves, and sensors and controls were inspected for structural integrity and function. Leak testing of tanks, pumps, and valves were performed by filling tanks with potable water or groundwater and inspecting the system for leaks while operating individual pumps and valves. Equipment items (i.e., pumps, air compressor, etc.) and instrumentation (i.e, pH probes, level sensors, etc.) were functionally/operationally tested and calibrated. Water used for leak testing was drained into the infiltration basin.

Functional testing was previously completed during the fall of 2010 under ESTCP Project No. ER-0312, “Perchlorate Removal, Destruction, and Field Monitoring Demonstration.”

5.5.2. Startup Testing

Following functional testing, the system was operated under scenarios which tested system operation and control. All system alarms and interlocks in the PLC logic were tested to ensure that the system operated as designed in a controlled and reliable manner.

Startup testing was previously completed during the fall of 2010 under ESTCP Project No. ER-0312, “Perchlorate Removal, Destruction, and Field Monitoring Demonstration.”

5.5.3. System Disinfection

Prior to delivering water from the WBA demonstration system to the 100,000 gallon reservoir feeding the existing perchlorate treatment system, the vessels, tanks, and pipes were disinfected. A subcontractor was hired to disinfect the system according to AWWA standard C653-03 “Disinfection of Water Treatment Plants.” Disinfection was previously completed during the fall of 2010 under ESTCP Project No. ER-0312. Due to the length of time the system had been in standby awaiting for various approvals (approximately 6-7 months), Bac-T analyses were performed to determine whether further disinfection was required prior to the beginning of the demonstration. All analytical results came back negative and no further disinfection was required.

5.5.4. System Demonstration

5.5.4.1. Test Matrix

Due to unexpected delays, testing was reduced to four (4) test periods. These delays came in the form of delayed approval by the City of Rialto for amending the current treatment permit, the time required for CDPH to review the permit amendment, and delays in a resin change out (May-July 2011) for the existing SBA system. ARA returned to the site on July 12, 2011 and performed a week of system re-preparation and re-checkout. Demonstration and system start up took place on July 18, 2011. The demonstration continued until December 08, 2011 when it was terminated due to budgetary constraints. A Gantt chart showing the actual schedule is shown below in Figure 5-5.

ID	Task Name	Duration	Start	Finish
1	**Rialto 3 WBA IX Demonstration**	**573 days**	**Fri 3/18/11**	**Mon 12/31/12**
2	Original Contract Award Date	0 days	Fri 3/18/11	Fri 3/18/11
3	Original Contract	367 days	Fri 3/18/11	Sun 3/18/12
4	Demonstration Plan (Draft)	0 days	Fri 4/29/11	Fri 4/29/11
5	CDPH Pretreatment Permit	38 days	Mon 4/18/11	Wed 5/25/11
6	Demonstration Plan (Final)	0 days	Mon 7/11/11	Mon 7/11/11
7	No Cost Extension Award	0 days	Fri 3/16/12	Fri 3/16/12
8	No Cost Contract Extension	209 days	Fri 3/16/12	Mon 12/31/12
9				
10	**WBA IX Demo Testing**	**232 days**	**Wed 7/13/11**	**Wed 2/29/12**
11	Startup Testing	5 days	Wed 7/13/11	Sun 7/17/11
12	Test Period 1	7 days	Mon 7/18/11	Sun 7/24/11
13	Regen 1	3 days	Mon 7/25/11	Wed 7/27/11
14	Test Period 2	8 days	Mon 7/25/11	Mon 8/1/11
15	Regen 2	2 days	Mon 8/1/11	Tue 8/2/11
16	Test Period 3	41 days	Mon 8/1/11	Sat 9/10/11
17	Regen 3	2 days	Sat 9/10/11	Sun 9/11/11
18	Test Period 4	90 days	Sat 9/10/11	Thu 12/8/11
19	End of Testing	0 days	Thu 12/8/11	Thu 12/8/11
20	Decommissioning	8 days	Wed 2/22/12	Wed 2/29/12
21				
22	**ESTCP Reporting**	**555 days**	**Fri 4/15/11**	**Tue 1/15/13**
23	Draft Final Report	0 days	Tue 5/15/12	Tue 5/15/12
24	Draft Cost & Performance Report	0 days	Fri 6/15/12	Fri 6/15/12
25	Final Report	0 days	Tue 7/17/12	Tue 7/17/12
26	Cost & Performance Report	0 days	Tue 7/31/12	Tue 7/31/12

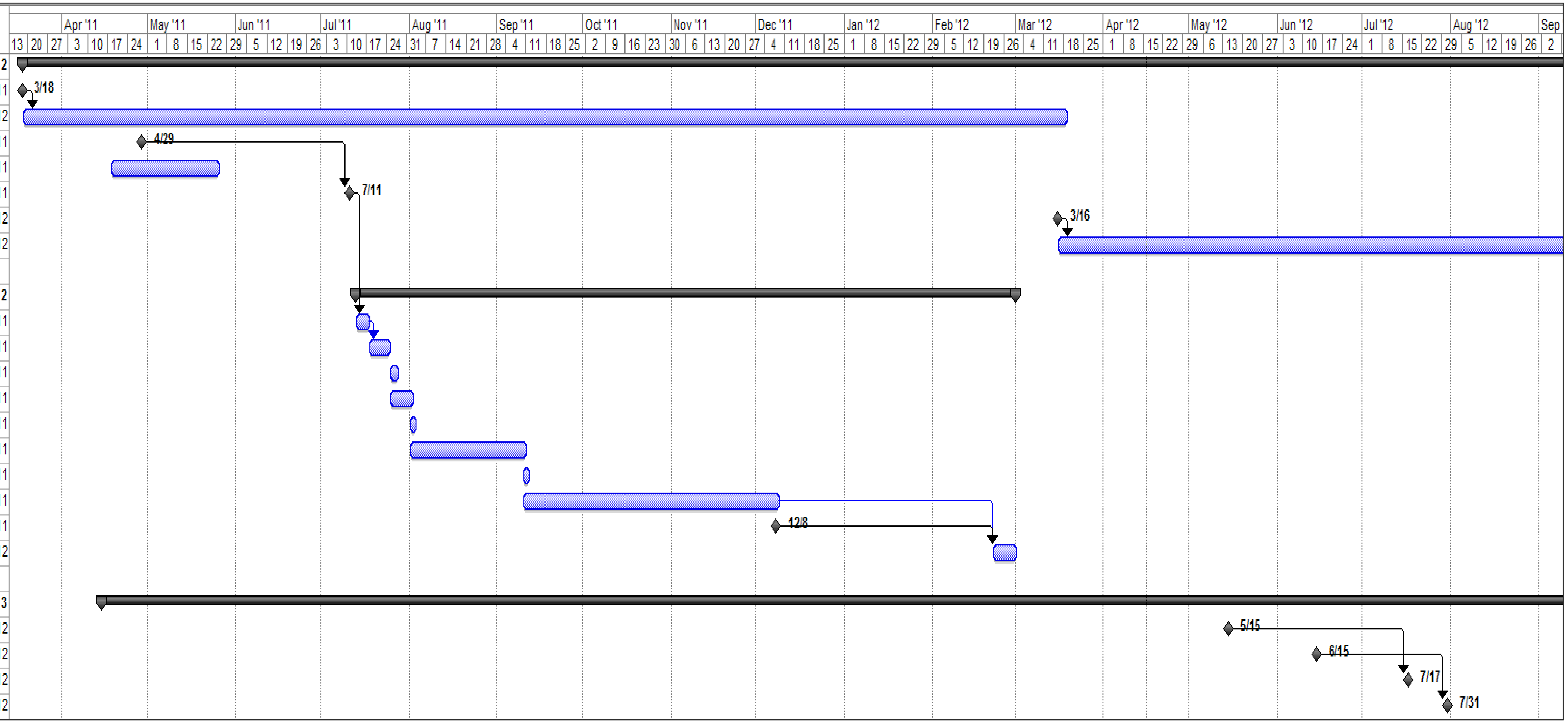

Figure 5-5. Rialto 3 WBA IX Testing

Delays and problems occurred throughout each test period that lengthened the overall time of the demonstration. These delays and problems presented themselves most often as difficulties obtaining groundwater from Rialto No. 3, but also with operation of the soda ash post treatment system. The test plan performed is shown in Table 5-2.

Table 5-2. WBA IX Test Matrix

Test Period	Lead Vessel	Actual Days of Operation	Lead Column			Gallons Treated (MG)
			BV Treated	ClO4 Conc. (ppb)	% Breakthrough	
1 [1]	WBA-301	3.1	1,339	1.2	13	3.51
2 [1]	WBA-302	5.5	2,261	1.4	16	5.92
3 [1]	WBA-301	9.3	4,081	2.8	31	10.69
4 [2]	WBA-302	16.5	7,269	4.4	49	19.03
TOTALS:		**34.4**	**14,950**			**39.15**

[1] *The low volume of BV's treated during the first three test periods were due to early termination of testing to meet project regeneration objectives*
[2] *The fourth test was terminated early due to operational problems*

During each test period, there were six operating modes for each ion exchange vessel: 1) IX operation/water treatment; 2) regeneration of the lead column; 3) scavenger treatment of regeneration waste; 4) regeneration rinse; 5) protonation; and 6) protonation rinse. Figure 5-5 is a diagram illustrating the order of these operating modes and provides a brief configuration description for the lead and lag vessels.

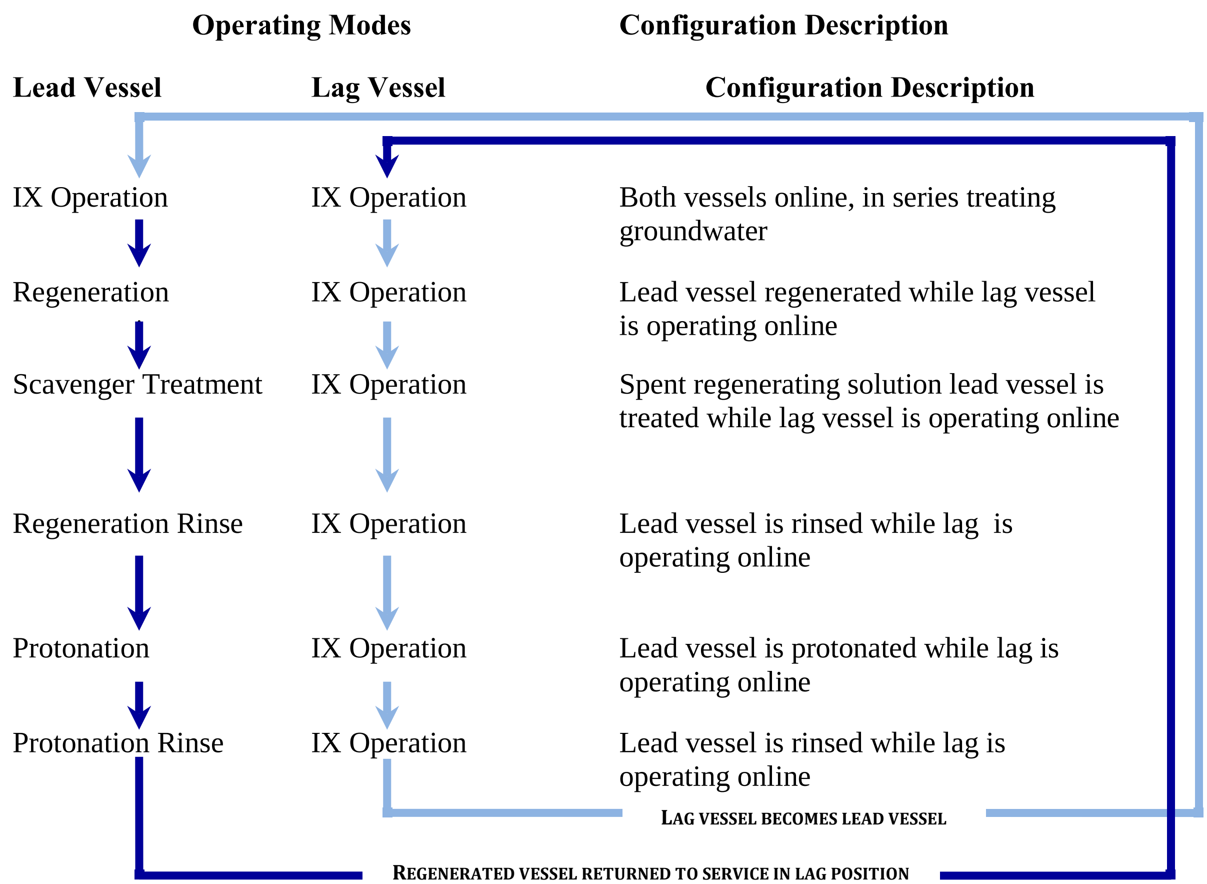

Figure 5-6. Configuration Description of Operational Steps

Each test period was defined as the point in time when flow was initiated through the newly regenerated vessel in the lead position until the vessel was taken offline for regeneration. Data from models based on the Fontana demonstration (ESTCP Project No. ER-0312) estimates that each WBA vessel will treat approximately 9,000 bed volumes of water from Rialto No. 3 prior to perchlorate breakthrough. The first two test periods were intentionally reduced in order to accomplish the operation-regeneration cycles in a short period of time. This was performed in an attempt to enable the resin to reach homeostatic performance, overcoming the performance influences caused by virgin-resin effects. The third test period was intended to operate the resin to near breakthrough conditions. For this demonstration, breakthrough was defined as the amount of BV's treated when the perchlorate concentration of the lead vessel effluent reaches 50% of the perchlorate concentration of the groundwater influent. The calculated BV's required for breakthrough was predicted to be 9,000 BV's. The fourth test period was intended to demonstrate breakthrough, but was not completed due to operational difficulties and budgetary constraints. As stated previously, during each test period there were several events that lengthened each test period. Spreadsheets outlining daily flows, totalizer readings, and comments for each test period during the demonstration are attached as Appendix D.

5.5.5. System Shutdown and Demobilization

The demonstration was ended on December 08, 2011 due to schedule and budget constraints. ARA returned to the site February 22, 2012 to begin demobilization. Both ion exchange vessels were regenerated offline manually. At completion of regeneration, both vessels were drained and the resin left at pH >12.0 to prevent any biological growth during long term storage. The Liqui-Cel membrane pretreatment system was isolated and completely drained. All chemical supply lines were back flushed to a sump and drained to the waste storage tank for disposal. Each of the chemical storage vessels and regeneration vessels were also drained to the waste storage tank, rinsed, re-drained to waste storage, and isolated. The A530E SBA resin used for scavenging perchlorate from the spent regenerant was removed from the scavenger vessels by a certified contractor (Baker/Purolite) and landfilled. All soda ash was removed from the package soda ash post treatment system and placed in containers for disposal. This soda ash and excess bags of soda ash were disposed of by a certified waste hauler (K-Vac Environmental, Rancho Cucamonga, CA). The soda ash dissolver tank was drained and rinsed thoroughly to the waste storage tank. The soda ash feed system was also disassembled and all equipment rinsed down with potable water into a sump and drained to waste storage. All liquids from the waste storage tank were neutralized and disposed of at the San Bernardino SARI line by the certified waste handler (K-Vac Environmental) under ARA's disposal permit.

All data collected on the DAQ was downloaded onto a thumb drive and secured. The data acquisition system and PLC were switched off and system power was de-energized at the breaker panels. All pH probes were thoroughly cleaned, rinsed with distilled water, and placed in individual storage containers filled with pH 7.0 buffer solutions. Spare parts and equipment to be left onsite were stored in boxes on shelves in the control building. The WBA resin ion exchange system will remain in standby mode until final disposition is determined by San Bernardino County and the City of Rialto.

5.6. Sampling Methods

All demonstration sampling was conducted by ARA personnel. A comprehensive sampling plan titled "Demonstration of Perchlorate Removal at Rialto No. 3 using 1000 gpm WBA Resin Technology-Performance Objective Plan" was submitted to CDPH April 2011 for pretreatment permit approval. This plan covers sampling, calibration of analytical equipment, quality assurance sampling, and sample documentation and has been attached as Appendix E. A summary of the analytes, methods, sample descriptions, and number of samples pulled during both the water treatment cycle and the regeneration cycle for each test period are shown below in Tables 5-3 and 5-4. The number of samples does not include duplicates or QA/QC samples collected and analyzed in accordance with the QAPP.

Table 5-3. Sampling Summary for WBA IX Demonstration During the Treatment Cycle

Test Period	Sample Description	ARA Laboratory		Weck Laboratories				
		ClO_4^- (EPA314.0)	Anions (EPA300.0)*	ClO_4^- (EPA314.0)	ClO_4^- (EPA331.0)	Anions (EPA300.0)*	LSI Group**	Biological
1	GW Feed	6	2	1		1	1	1
	Lead A	6	2	1	1			1
	Lag B	6	2					
	FTGW	6	2	1	1	1	1	1
2	GW Feed	6	2	4			1	2
	Lag A	6	2					1
	Lead B	6	2		2			1
	FTGW	6	2		2	1	2	2
3	GW Feed	14	5	4			1	
	Lead A	14	5		2	1		2
	Lag B	14	5		1			
	FTGW	14	5		6	4	5	2
4	GW Feed	24	9	1			1	
	Lag A	24	9		1			
	Lead B	24	9		7			3
	FTGW	24	9		13	6	5	3
	TOTALS:	**200**	**72**	**12**	**36**	**14**	**17**	**19**

*Anions include nitrate, sulfate, and chloride
**LSI Group includes pH, alkalinity, total dissolved solids, calcium, and temperature

Table 5-4. Sampling Summary for WBA IX Demonstration During the Regeneration Cycle

Test Period	Sample Description	ARA Laboratory		Weck Laboratories				
		ClO_4^- (EPA314.0)	Anions (EPA300.0)*	ClO_4^- (EPA314.0)	ClO_4^- (EPA331.0)	Anions (EPA300.0)*	LSI Group**	TDS
1	Regeneration	3	3	1		1	1	
	Regen Rinse	13	10		4	1	1	
	Lead Scavenger	1	1					
	Lag Scavenger	1	1		1	1	1	
	Protonation	1		1		1	1	
	Protonation Rinse	13	11		2	1	1	
2	Regeneration	3	3	1		1		
	Regen Rinse	12	12		3	1	1	
	Lead Scavenger	1	1					
	Lag Scavenger	1	1	1		1		1
	Protonation	3		1		1		1
	Protonation Rinse	8	8		3	1		1
3	Regeneration	3	3	1		1		1
	Regen Rinse	16	16		4	1	1	
	Lead Scavenger	1	1					
	Lag Scavenger	1	1	1		1		1
	Protonation	3		1		1	1	
	Protonation Rinse	8	8		2	1	1	
	TOTALS:	**92**	**80**	**8**	**19**	**15**	**9**	**5**

*Anions include nitrate, sulfate, and chloride

**LSI Group includes pH, alkalinity, total dissolved solids, calcium, and temperature

Table 5-5 lists the analytical methods along with specific containers, preservatives and maximum holding times used during the demonstration.

Table 5-5. Analytical Methods Used During the WBA IX Demonstration

Analyte	Method	Container	Preservative	Holding Time
Perchlorate, IC	EPA 314.0	HDPE	< 4 ^oC	28 days
Low-Level Perchlorate, LC/IC/MS/MS	EPA 331.0	HDPE	< 4 ^oC	28 days
Nitrate, as NO_3	EPA 300.0	HDPE	< 4 ^oC	2 days
Sulfate	EPA 300.0	HDPE	< 4 ^oC	28 days
Chloride	EPA 300.0	HDPE	< 4 ^oC	28 days
pH	EPA 150.1	HDPE	< 4 ^oC	15 minutes
Alkalinity (as $CaCO_3$)	SM 2320B	HDPE	< 4 ^oC	14 days
Total Dissolved Solids (TDS)	SM 2540C	HDPE	< 4 ^oC	7 days
Calcium, Total	EPA 200.7	HDPE	< 4 ^oC, Nitric Acid	6 months
Langelier Saturation Index/Corrosivity**	SM 2330B	HDPE	< 4 ^oC	14 days
Nitrosamines	EPA 521	Amber Glass	< 4 ^oC	365 days
Total Coliform/E. coli, P/A	SM 9223	Sterile Polyethylene	< 4 ^oC, Sodium Thiosulfate	30 hours
*All samples were in an aqueous matrix				
**LSI/Corrosivity includes pH, alkalinity, total dissolved solids, calcium, and temperature				

Samples were analyzed for perchlorate, other inorganic anions, and total dissolved solids at ARA's in-house laboratory. Select samples were split and shipped to Weck Laboratories for external analysis of perchlorate, inorganic anions, Langelier Saturation Index, and other general mineral and physical analyses. Biological testing required by CDPH was performed by Clinical Laboratories. The address of each laboratory is listed below:

In-House Analyses:
Applied Research Associates, Inc.
430 West 5th Street, Suite 700
Panama City, Florida, 32401
Phone: 850-914-3188

External Analyses:
Weck Laboratories, Inc.
14859 East Clark Avenue
City of Industry, CA 91745
Phone: 626-336-2139
NELAP #: 04229CA

Clinical Laboratory of San Bernardino, Inc.
21881 Grand Terrace Road
Grand Terrace, CA 92313
Phone: 909-825-7693
ELAP #: 1088

5.7. Sampling Results

5.7.1 Perchlorate Analysis

All fully treated water samples analyzed for perchlorate during each test period were less than the DLR of 4 ppb. During the demonstration, there were several unexpected shutdowns due to water supply problems with Rialto No. 3, or from other perturbations. The WBA IX system was restarted on each occasion with no treated water perchlorate concentrations exceeding the DLR of 4 ppb. ARA laboratory results are shown below in Figure 5-6. Both groundwater and treated groundwater samples were analyzed using EPA Method 314.0 (IC).

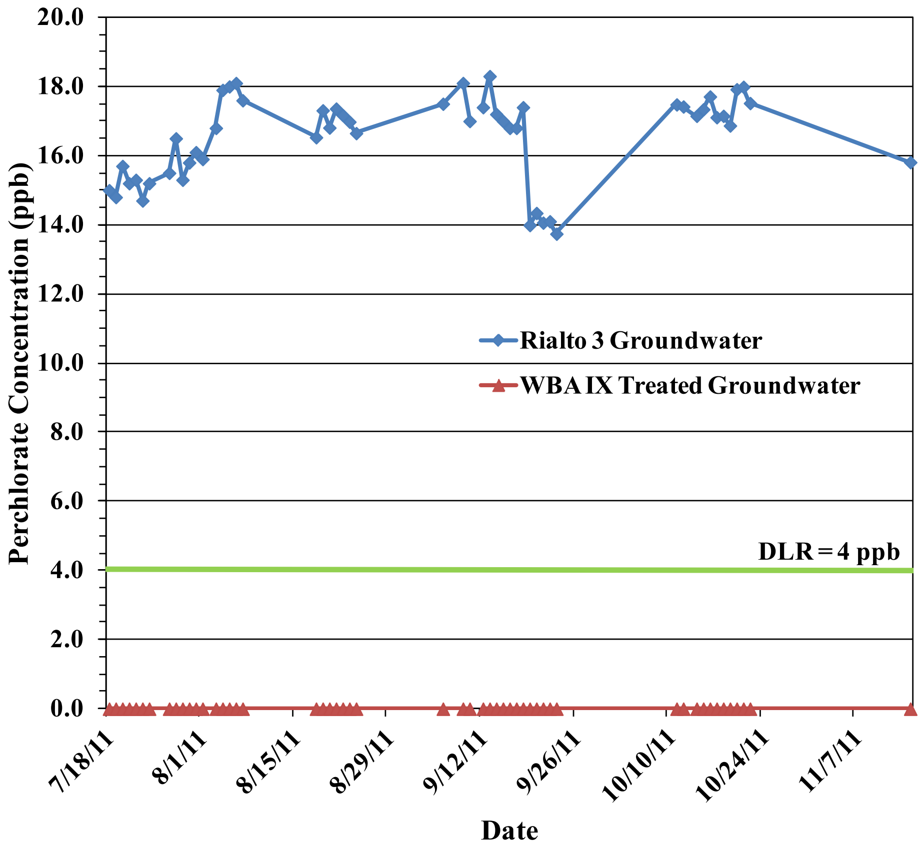

Figure 5-7. ARA Laboratory Perchlorate Results for Test Periods 1-4

Results from Weck Laboratories (City of Industry, CA) are shown below in Figure 5-7. These results confirm the ARA results above. All groundwater samples from Rialto No. 3 were analyzed using EPA 314.0 (IC), while all fully treated water samples were analyzed using EPA 331.0 (LC-IC-MS-MS).

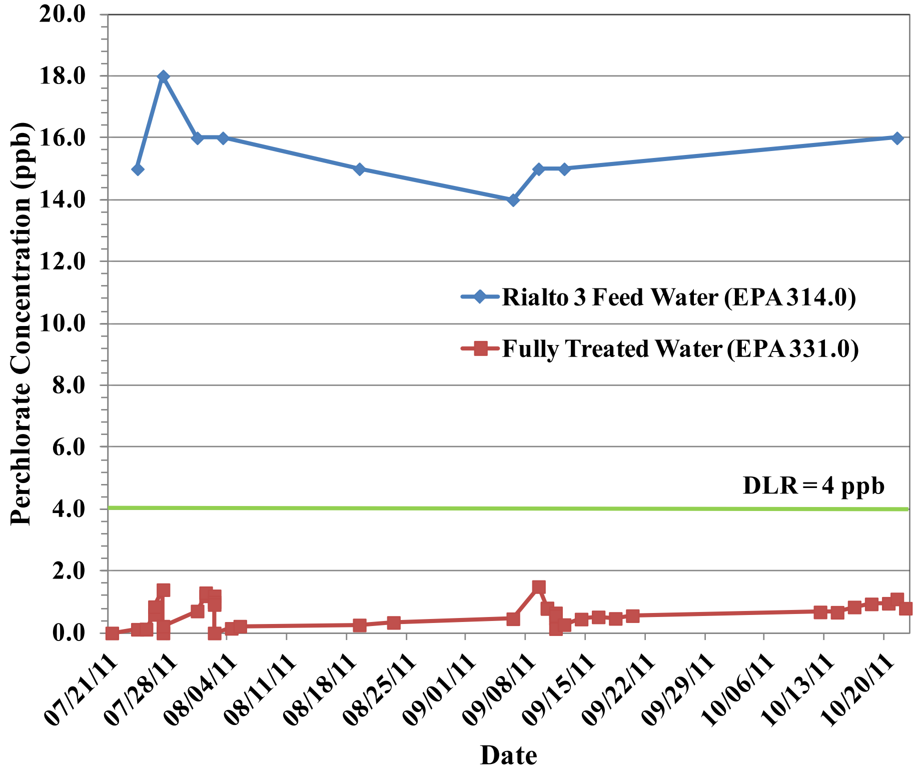

Figure 5-8. Certified Laboratory Perchlorate Results for Test Periods 1-4

5.7.2 Post Treatment—Langelier Saturation Index (LSI)

The performance objective for post treatment was to control and adjust pH and alkalinity of the fully treated water to acceptable levels with regard to corrosiveness or scaling tendencies prior to distribution. The Langelier Saturation Index (LSI) was used as the measure of post treatment success. This index is a calculated number used to predict the calcium carbonate ($CaCO_3$) stability of water; that is, whether a water sample will precipitate, dissolve, or be in equilibrium with calcium carbonate. The data required to calculate LSI includes alkalinity (mg/L as $CaCO_3$), pH, total dissolved solids (mg/L TDS), calcium hardness (mg/L as $CaCO_3$), and water temperature (°C). If water has an LSI of > 1.0, scale tends to form; conversely, if water has an LSI of -1.0, it is considered corrosive (i.e., dissolves $CaCO_3$). In practice, water between -0.5 and 0.5 tends to be neither scaling, nor corrosive. For this demonstration, the objective was considered successful if 95% or more of the samples were between and LSI of 0 and 1.0.

Samples of fully treated water were analyzed by Weck Laboratories and the resulting data was used to calculate the LSI for each sample. Of the eighteen samples taken during the demonstration, no samples measured at 20°C met our performance objective of having an LSI between 0 and 1.0. Only four samples (22%) measured at 60°C met that objective. Results are shown below in Figure 5-8.

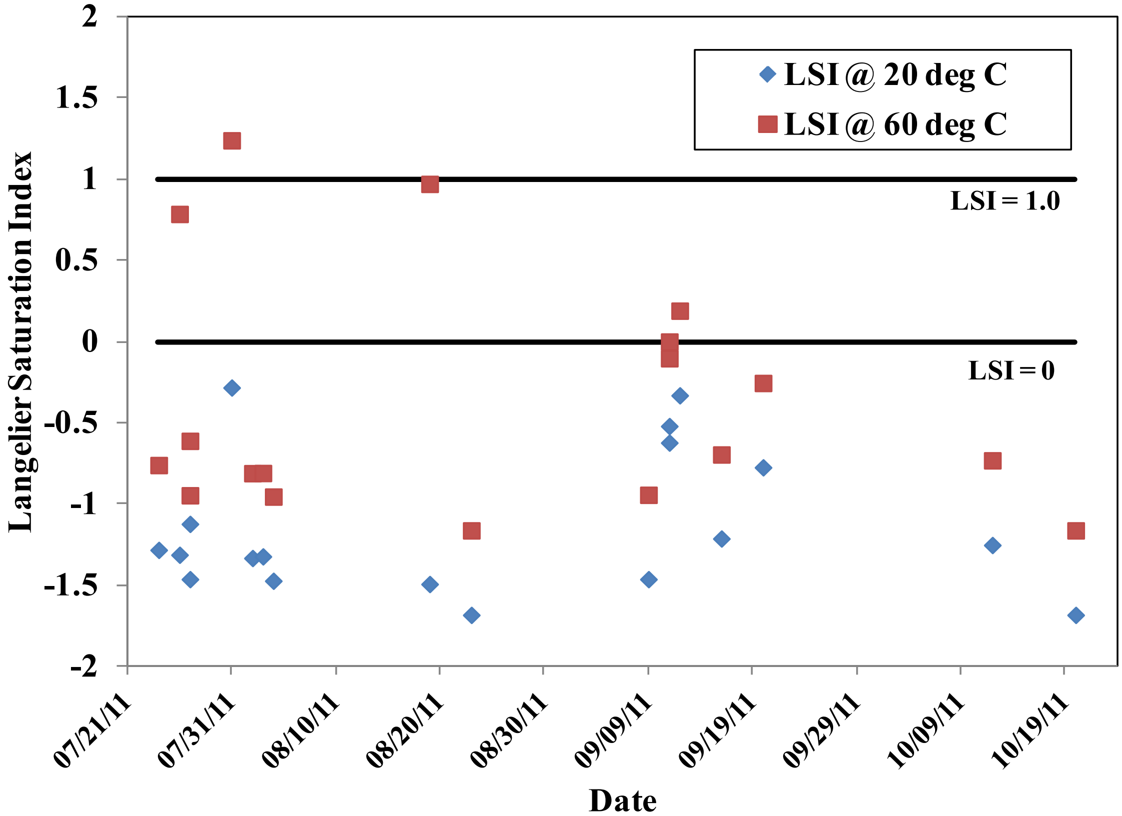

Figure 5-9. Langelier Saturation Index Results of WBA IX Treated Water For Test Periods 1-4

As discussed previously in Section 3.2.3., this failure is attributed to the operational difficulties experienced with the package soda ash system that was integrated into the WBA system to provide post-treatment capabilities. The soda ash system experienced large amounts of scaling in the dissolver tank, which often plugged the y-strainers on the suction side of the soda ash dosing pumps. This plugging prevented the required amount of dilute soda ash solution from being delivered to the inline static mixer injector. In addition, major scaling was observed throughout the equipment and piping associated with the soda ash system. This scaling was very problematic at the injector of the inline static mixer. When plugged with scale, the amounts of soda ash solution needed for raising pH and alkalinity of the treated water were not obtained.

5.7.3 Nitrosamine Analysis

Nitrosamine compounds have become an issue of concern to California regulators for ion exchange treatment systems. As a requirement for permitting this demonstration, CDPH recommended that nitrosamine sampling be performed at specific intervals. Groundwater and treated groundwater samples were obtained at < 5 BV's from the start of the first test period; treated water sample at the conclusion of the first test period (before regeneration); and a treated water sample < 5 BV's after the regenerated vessel (Vessel A) was returned to service. All samples were analyzed by Weck Laboratories using EPA Method 521. Analytes included

NDEA, NDMA, NDBA, NDPA, NMEA, NMOR, NPIP, and NPYR. The reportable limit for each of these analytes is 2 ng/L. NDEA and NPIP were observed at concentrations above the reportable limit at < 5 BV's after startup, but were non-detect throughout the remainder of the demonstration. According to Purolite, low-level nitrosamine formation can occur if resin is stored for extended periods of time prior to use. The WBA resin was loaded into the IX vessels several months prior to demonstration testing. Once placed into service, the nitrosamine concentration was quickly reduced to non-detectable levels. Results are shown in Table 5-6.

Table 5-6. Certified Laboratory Results of Nitrosamines

EPA Method 521 Nitrosamines (ng/L)	Sample Points			
	GW 07/18 @ 1029	FTGW 07/18 @ 1029	FTGW 07/24 @ 0810	Vessel A Rtn to Svc (<5BV) 07/27 @1117
N-Nitrosodiethylamine (NDEA)	ND	26	ND	ND
N-Nitrosodimethylamine (NDMA)	ND	ND	ND	ND
N-Nitrosodi-n-butylamine (NDBA)	ND	ND	ND	ND
N-Nitrosodi-n-propylamine (NDPA)	ND	ND	ND	ND
N-Nitrosomethylethylamine (NMEA)	ND	ND	ND	ND
N-Nitrosomorpholine (NMOR)	ND	ND	ND	ND
N-Nitrosopiperidine (NPIP)	ND	660	ND	ND
N-Nitrosopyrrolidine (NPYR)	ND	ND	ND	ND

6.0 Performance Assessment

The objective of this demonstration was to test and validate weak base ion exchange (WBA IX) technology using established performance objectives in order to obtain permitting and certification from the California Department of Public Health (CDPH) as an approved perchlorate treatment technology. Elevated groundwater perchlorate concentrations at Rialto No. 3 cause the site to be considered as an extremely impaired source as defined by the CDPH 97-005 Policy Memorandum. Based on previous pilot demonstrations, it was anticipated that O&M costs would be < $150/acre-ft.

Performance of the WBA system was evaluated by collecting and analyzing samples for perchlorate during ion exchange, regeneration, and treatment of residuals. Analytical results were used to assess and predict treatment performance of the WBA resin at the conditions tested. Operational data including flow rate, system pressure, pH, and consumption of chemicals were recorded and analyzed to validate operating performance and predict O&M costs.

6.1. Performance Objective: Meet Perchlorate Regulatory Standard

6.1.1. Results

This performance objective was considered successful throughout the demonstration. The data requirements, success criteria, and a brief description of the results for this performance objective were discussed earlier in Sections 3.1.1-3.1.3, and 5.7.1. All WBA IX treated water samples analyzed by both ARA and Weck Laboratories during this demonstration were less than the DLR of 4 ppb.

6.2. Performance Objective: Demonstrate Post Treatment Capabilities

6.2.1. Results

The performance objective for post treatment was to control and adjust pH and alkalinity of the fully treated water to acceptable levels (0 < LSI < 1.0) with regard to corrosiveness or scaling tendencies prior to distribution. As discussed previously in Sections 3.2.3. and 5.7.2., this performance objective was not met. While this may appear to be a failure of the objective, the problems responsible are mechanical in nature and are easily remedied. Scaling issues were frequently observed in the soda ash mix tank, suction strainers, and the injector of the soda ash static mixer, preventing the required amount of soda ash to be dosed into the treated water. This scaling can be eliminated (or minimized) by installing media canisters to soften the recycled treated water prior to dilution of the soda ash in the dissolver tank of the package soda ash system. Also, the soda ash static mixer was sized specifically for the WBA system, but did not effectively mix the dilute soda ash. Mixing the soda ash with treated water would improve greatly by implementing a two-stage mixing process identical to that used to pre-dilute and mix sulfuric acid in the pretreatment step of the system. Additionally, the static mixer must be placed further upstream from the pH probes to allow more reaction time prior to pH measurement and sampling for LSI.

6.3. Performance Objective: Minimize Process Waste

6.3.1. Results

One of the key benefits of the WBA process is the minimization of process waste created during the resin regeneration process. Process waste is defined as the ‘spent” regenerating solution that is generated by the regeneration process, scavenged, and pumped into the 10,500 gallon waste storage tank onsite (TK-701). A table of the key wastewater characteristics of this spent regenerating solution is shown below in Table 6-1. These characteristics were analyzed as a requirement for obtaining a disposal permit through the City of San Bernardino Municipal Water Department (SBMWD) Water Reclamation Plant (WRP) for use of the Inland Empire Brine Line (IEBL) Santa Ana Watershed Project Authority (SAWPA).

Table 6-1. Regeneration Waste Properties

Analysis	Units	Results
EPA 625--Semivolatile Organic Compounds	ug/L	All were ND
pH		11.8
BOD	mg/L	23
TSS	mg/L	280
TDS	mg/L	63,000
VSS	mg/L	14
Dissolved Organic Carbon	mg/L	21
Hardness as CaCO3, Total	mg/L	140
EPA 200.7--Metals		
Arsenic, Total	mg/L	0.024
Cadmium, Total	mg/L	ND
Calcium, Total	mg/L	52
Chromium, Total	mg/L	0.079
Copper, Total	mg/L	ND
Lead, Total	mg/L	ND
Magnesium, Total	mg/L	1.7
Nickel, Total	mg/L	ND
Silica as SiO2, Total	mg/L	21
Silver, Total	mg/L	ND
Zinc, Total	mg/L	ND
EPA 245.1--Mercury, Total	mg/L	ND
EPA 314.0--Perchlorate	ug/L	ND
EPA 324--Volatile Organics	ug/L	All were ND
EPA 608--Chlorinated Pesticides and/or PCB's	ug/L	All were ND
Oil & Grease	mg/L	ND
Sulfide, soluble	mg/L	ND
Sulfide, Total	mg/L	ND
Cyanide, Free (amenable)	mg/L	ND
Cyanide, Total	mg/L	ND
EPA 300.0--Anions		
Chloride	mg/L	1500
Nitrate	mg/L	610
Sulfate	mg/L	28,000

The amount of waste disposed during this demonstration of was calculated as a percentage of the total groundwater treated during each test period. The percentage of waste created was determined to be 0.07% of the total water treated during Test Periods 1-3. Note that because the typical online regeneration procedure could not be followed after Test Period 4, the data was not included in this determination. Data used to calculate this number is shown below in Table 6-2.

Table 6-2. Percent Waste Generated by the WBA IX

Disposal Date	Test Period	Vessel Regenerated	Water Treated (G)	Regen Waste Disposed (G)	% Regen Waste
9-Sep	1	A	3,505,780	5,000	0.14%
	2	B	5,919,575	4,800	0.08%
13-Sep	3	A	10,685,200	5,000	0.05%
		TOTALS:	20,110,555	14,800	**0.07%**

It must also be noted that during each test period, the resin was not loaded to capacity. The first two regenerations were conducted to minimize virgin resin effects and the third was conducted based on time limitations and budget constraints. Once the resin is permitted to treat closer to the 9,000 BV breakthrough capacity, the percentage regeneration waste will be much lower.

6.4. Performance Objective: Treatment of Spent Regenerating Stream

6.4.1. Results

The performance criterion for treating the spent regenerant was to remove perchlorate from the spent regenerant solutions to concentrations less than 100 ppb. As described earlier, perchlorate was removed from the spent regeneration waste prior to disposal using a scavenger resin approach. This process consisted of passing the spent regenerant through two ion exchange vessels that were configured in series. Each vessel contained approximately 52.5 ft^3 of Purolite A530E strong base anion (SBA) resin which is highly selective for perchlorate. Perchlorate was removed as the spent regenerating solution passed through the scavenger resin for storage in wastewater holding tank TK-701 (10,500 gallons). ARA laboratory results using EPA 314.0 show that the spent regenerant was successfully treated to levels below the detection limit (< 1.4 ppb). A summary of anion and TDS concentrations of both the spent regenerant and the treated regenerant for disposal are shown below in Table 6-3.

Table 6-3. Anion and TDS Concentrations in Spent Regenerant Before and After Scavenging with Purolite A530E SBA

Date	Test Period	Regen Solution	EPA 314.0 Perchlorate (ug/L)	Anions (mg/L)			TDS (mg/L)
				Cl^-	NO_3^-	SO_4	
07/25/11	1	Spent	7,737	170	3,951	17,000	40,000
		Treated	ND	605	108	18,000	35,000
08/01/11	2	Spent	16,648	274	5,699	20,000	61,000
		Treated	ND	1,205	534	24,000	58,000
09/10/11	3	Spent	35,951	334	6,555	22,000	80,000
		Treated	ND	680	5,051	24,000	82,000

6.5. Performance Objective: Perchlorate Bleed from Regenerated Vessel

6.5.1. Results

During the WBA IX regeneration process, a rinse step at the conclusion of resin regeneration was used to reduce and/or eliminate perchlorate bleed. To determine the effectiveness of the rinsing process, perchlorate data from samples analyzed by both ARA and the certified laboratory were evaluated to determine whether any perchlorate bleed was observed after the newly regenerated vessels were placed back online. Samples were obtained for this determination to bracket data from < 300 BV's of the vessel being placed back online until the next available sample point (<= 2500 BV's). All data shows that perchlorate bleed was below the performance objective of 4 ppb. Samples analyzed for perchlorate by ARA were below the detection limit (1.4 ppb) and are shown in Table 6-4. Similar samples analyzed by Weck Laboratories mirror ARA analyses (Table 6.5).

Table 6-4. ARA Laboratory Results of Regenerated Vessel Bleed

Test Period	Date of Regeneration	Regenerated Vessel	Treated Water Sample Date	Approx BVs Treated	Perchlorate Conc. (ppb)
1	07/25-07/27	A	7/27/2011	19	ND
			7/28/2011	326	ND
2	08/01-08/02	B	8/3/2011	291	ND
			8/4/2011	460	ND
3	09/10-09/11	A	9/12/2011	225	ND
			9/13/2011	533	ND

Table 6-5. Certified Laboratory Results of Regenerated Vessel Bleed

Test Period	Date of Regeneration	Regenerated Vessel	Treated Water Sample Date	Approx. BVs Treated	Perchlorate Conc. (ppb)
1	07/25-07/27	A	07/27/11	10	ND
			07/31/11	2260	0.22
2	08/01-08/02	B	08/03/11	300	ND
			08/05/11	1280	0.15
3	09/10-09/11	A	09/12/11	200	0.14
			09/14/11	1490	0.27

6.6. Performance Objective: Treatment Flow Rate

6.6.1. Results

During this demonstration the WBA IX system did not quite reach the treatment flow rate of 2.5 gpm/ft^3 (875 gpm). The average flow throughout the demonstration was 2.29 gpm/ft^3 (800 gpm). This was due to a large pressure drop observed across the Liqui-Cell membranes used in the pretreatment system. As flow rates increased above 800 gpm, pressures at the pump would rise above the high pressure safety interlock (90 psig), causing the system to shut down. This problem may be rectified by performing periodic cleaning of the membranes. According to Membrana (manufacturer of the membranes), any substantial biological growth or other particulates from the groundwater accumulating on the surface of the membranes will cause increased pressure drop across the membranes. Another solution would be adding another membrane pair to the existing manifold of three membrane pairs, which would allow the flow to be further spread across additional membrane surface area, lowering the pressure drop. These two changes would solve this issue.

6.7. Performance Objective: Operating Costs

6.7.1. Results

Operating costs are critical in determining if the WBA process is competitive compared to existing perchlorate treatment systems. Activities and materials that contribute to O&M costs were documented and reported in dollars per acre-ft of water treated. Operating costs were calculated based on actual consumption rates and costs that were observed during the demonstration. This performance objective will be discussed in detail in Section 7.0, Cost Assessment.

6.8. Performance Objective: System Scalability

6.8.1. Results

During this demonstration, this performance objective was successfully met. Although the first regeneration required approximately 72 hours due to mechanical and programming issues, the second and third were achieved in less than 48 hours. Due to Rialto No. 3 operational problems, getting a consistent source of ground water for the WBA IX from Rialto No. 3 was difficult. The demonstration was discontinued before a resin treatment capacity could be established. Instead, the capacity of the resin was calculated using a more recent model for the D4170 WBA resin constructed using previous demonstration data (ESTCP ER-0312). Based on the current WBA IX flow rate capacity (800 gpm, or 2.29 gpm/ft3) and Rialto No. 3 groundwater characteristics, the model supports the earlier estimates from the Fontana, CA pilot demonstration that the lead vessel will treat 9,000 BV's before regeneration is required. This provides 21 days of operation before regeneration of the lead vessel is required. Based on that number, the existing onsite equipment will easily support the two additional ion exchange treatment trains. Regeneration events could be staggered to provide adequate time for regeneration. Additionally, if changes are made to the system to enable operation at the design flow rate of 1000 gpm (2.86 gpm/ft^3) at the above predicted capacities, regeneration of the lead vessel of each train will be required every 16 days, which would still allow for the addition of two more ion exchange trains.

6.9. Performance Objective: Predict WBA Resin Capacity

6.9.1. Results

During the fourth test period, non-continuous supplies of water from Rialto No. 3 well and program constraints resulted in termination of the demonstration before breakthrough was attained. Sampling indicated that the resin was approaching breakthrough concentrations, or 8-9 ppb (50% of the groundwater feed perchlorate concentration). Three of the final samples indicated that the perchlorate was leveling off at 6 ppb at 6,900 BV's, but then the system experienced a 3 week shutdown due to a combination of problems with the Rialto No. 3 well site and problems with the soda ash system and static mixer/injector that required maintenance and repairs to be effected. When the system was repaired and restarted, sampling indicated that perchlorate concentration had dropped to 2.9 ppb at 7,300 BV's. This is shown below in Figure 6-1. Only two days of part time operation were accomplished before the Rialto No. well experienced more operational problems and program constraints halted the demonstration.

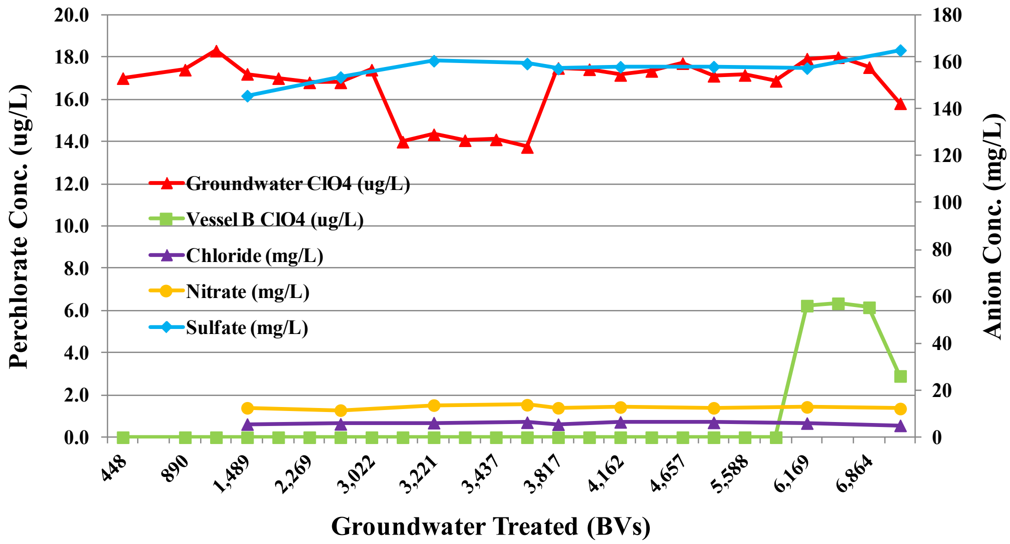

Figure 6-1. Test Period 4: Lead Vessel B Perchlorate and Anion Concentrations

In test period 4, perchlorate breakthrough was not achieved, and capacity of the resin (i.e., bed volumes to breakthrough) is actually greater than demonstrated. During the Phase 2 field demonstration at Redstone Arsenal in 2005 (ESTCP Project CU-0312) the WBA resin reached a capacity of 6,500 BVs at a treatment rate that varied from 2.25-3.00 gpm/ft^3 with much higher groundwater perchlorate concentrations (2200 ppb). In addition, during the Phase 3 field drinking water treatment demonstration at Fontana in 2006 (ESTCP Project ER-0312) a higher treatment capacity of 9,700 BVs at a rate of > 3.0 gpm/ft^3 was observed, although at a lower perchlorate influent concentration (8.0 ppb). Although the breakthrough capacity was not able to be demonstrated, the current capacity can be calculated using a model for the D4170 WBA resin constructed from those demonstrations. Using the Rialto treatment rate of 800 gpm (2.29 gpm/ft3) and the Rialto No. 3 groundwater characteristics, this model supports the earlier estimates that the lead vessel will treat 9,000 BV's before regeneration is required.

6.10. Performance Objective: System Control During Treatment and Regeneration Cycles

6.10.1. Results

During normal operations, the performance objective was met. The use of the touch screen by a single operator for monitoring and controlling/adjusting system control parameters was very straightforward. Completing checklists, sampling, and downloading data from the DAQ system was also handled by a single operator. During regeneration or mechanical troubleshooting, it is recommended that two or more operators be onsite. Because the system is operated from the PLC touch screen in the control room, it is difficult for a single operator to observe what the system is actually doing during trouble shooting or regeneration.

7.0 Cost Assessment

7.1. Cost Model

The purpose of this demonstration was not only to demonstrate the WBA IX technology, but to also to validate equipment, construction, and operation and maintenance (O&M) costs of the WBA IX process. To accomplish this, data for various cost elements of the WBA process were identified and collected, as shown below in Table 7-1. Data for each element was collected for the duration of the demonstration effort. Detailed descriptions of each cost element are provided in subsequent sections. This data was compared and integrated into previously derived WBA process cost models in order to establish a robust, realistic cost model for implementing the WBA IX technology. When modeling the implementation and operating costs of the WBA technology, care should be taken to apply the appropriate site specific elements to the model. For example, different methods may be employed to remove excess CO_2 generated during pretreatment of the influent water such as membranes, air stripping, or no treatment. The method selected will impact the equipment, electrical, and consumable costs.

Table 7-1. Cost Model Elements for the WBA IX Process

Cost Element	Tracked Data	Units
Design, Construction, and Installation	Design Engineering, Construction Mgmt, Equipment and Installation. Costs, including actual equipment costs, construction management, and installation costs	$/1,000 gpm treatment system
Consumable Materials	Consumables which were tracked and documented include: • Sulfuric acid • Sodium hydroxide • Sodium carbonate (soda ash) • Strong base anion resin for scavenging • Weak base anion resin for primary treatment • Gas separation membranes • Miscellaneous chemicals and supplies	$/acre-foot water treated
Waste Disposal	Disposal of treated spent regenerating solution (transport and disposal fee)	$/acre-foot water treated
	Untracked Elements	
Electricity	Total electrical consumption of the demonstration system was calculated based upon installed equipment, usage rates, and load factors	$/acre-foot water treated
Labor	Labor required for operating and maintaining system	$/acre-foot water treated

7.1.1. Cost Element: Construction and Installation

Equipment, construction management, and installation cost data were tracked from actual costs of the subcontract with Carollo Engineers for design and construction of the 1,000 gpm demonstration unit. Equipment costs were based on invoices from the Carollo subcontract and on invoices for equipment purchased by ARA. Total equipment purchases for the 1,000 gpm system totaled $1.958M, with system installation costs totaling $466K. To derive cost estimates for different sized systems, standard industry practice scaling factors may be used to derive cost estimates using the six-tenths power factor rule. According to this rule, if the cost of a given unit at one capacity is known, the cost of a similar unit with X times the capacity of the first is $X^{0.6}$ times the cost of the initial unit.

In addition, design, engineering, and management costs are much greater for a first-of-a-kind technology demonstration than for the construction and installation of additional similar systems. There are also unique costs for the management and reporting requirements of an ESTCP demonstration. For input into the cost model, design and engineering costs can be estimated based upon a factor of the actual delivered equipment costs. This factor is usually some percentage of the equipment costs.

7.1.2. Cost Element: Consumable Materials

7.1.2.1. Sulfuric Acid

Sulfuric acid (98 wt%) was used to lower the pH of the ground water during pretreatment and at the end of the regeneration process to restore the resin to the active ionized or protonated form. The size of the storage tank permitted procurement of sulfuric acid in full tank truck quantities. At the time of the 1,000 gpm system demonstration, market pricing of sulfuric acid for the California site was at an all-time high of $0.215/lb. A five year US average price which is more reflective of the current market pricing of sulfuric acid is approximately $0.12/lb for bulk chemical purchases. The acid storage tank level was monitored and recorded by the data acquisition system so that acid consumption could be calculated for any time period during the demonstration. During steady-state operation (between regeneration events), the daily acid consumption and acid consumption per acre-foot of treated water were calculated.

Acid required for WBA resin protonation during the regeneration process was determined separately. Acid needed for each regeneration-protonation cycle was measured using a digital flowmeter/totalizer that was monitored by the data acquisition system. Acid consumption per acre-foot of water was calculated based on the number of acre-feet of water treated before regeneration was required.

7.1.2.2. Sodium Hydroxide

Sodium hydroxide (25 wt% NaOH) caustic solution was used to regenerate the WBA resin. The size of the storage tank permitted procurement of 25% NaOH solution in full tank truck quantities. Current market pricing and market pricing of sodium hydroxide during the demonstration were $0.1675/lb for bulk chemical delivery. 50% NaOH is more economical, but

25% was selected to eliminate the potential for precipitation of solid NaOH during the winter months. The caustic storage tank level was monitored and recorded by the data acquisition system so that caustic consumption could be calculated for any time period during the demonstration. The volume of caustic required for each regeneration-protonation cycle was measured using a digital flowmeter/totalizer that was monitored by the data acquisition system. Caustic consumption per acre-foot of water was calculated based on the number of acre-feet of water treated before regeneration was required.

7.1.2.3. Soda Ash

Soda ash (Na_2CO_3) solution was used to restore the pH and alkalinity of the treated water to acceptable levels prior to discharge to the reservoir. Solid soda ash was used to prepare a 3% soda ash solution on-site. For the demonstration, soda ash was purchased in 50 pound bags delivered as 2,100 pound pallets at $0.3225/lb. This is not the most economical approach. Soda ash can also be delivered in 1,000-pound super-sacks, or by bulk, pneumatic truck. For this assessment, actual purchase price and consumption were used to determine soda ash costs.

The average soda ash consumption was calculated based on the number of 50-pound sacks consumed over an extended period of time (3-10 days). The consumption rate and cost per acre-foot of water treated were calculated from this usage rate.

7.1.2.4. Strong Base Anion Resin (Scavenger Resin)

The SBA resin scavenging system consists of two (2), 60 cubic foot ion exchange vessels configured in series. Each vessel was charged with approximately 52.5 cubic feet of resin. There are three reasons for this design: 1) to prevent the inadvertent discharge of perchlorate-contaminated effluent; 2) achieve maximum loading of SBA resin in the lead vessel; and 3) to determine when perchlorate breakthrough of the lead vessel occurs. Based on previous pilot test data, breakthrough of the lead vessel was designed to occur during the demonstration. Treated water from the lead vessel was sampled and analyzed during each regeneration event in order to determine when breakthrough occurs. Breakthrough is defined as when perchlorate concentration of treated water from the lead vessel equals 20-50% of the perchlorate concentration of the spent regenerating solution being treated.

The cost of SBA resin change-out includes transportation costs, resin replacement costs ($240.95/cu. ft.), and spent resin disposal costs. The average cost per acre-foot of water treated was calculated based on the total amount of water treated up to perchlorate breakthrough and the total cost of resin replacement. Actual perchlorate loading on the SBA resin was determined. SBA resin cost is the only cost element that is dependent on the perchlorate concentration of the groundwater being treated. Based on demonstration test results, the cost of scavenger resin was determined as a function of perchlorate concentration in the groundwater.

7.1.2.5. Weak Base Anion Resin

The WBA resin is anticipated to provide acceptable performance for several years. However, since it will have a limited lifetime, and it is relatively expensive, the cost of the WBA resin must be factored into overall treatment costs. Resin cost was determined by the current market replacement cost of the WBA resin. Replacement cost includes transportation and disposal of the old resin. Resin life is estimated to be ten years. The cost per acre-foot of water treated was calculated based on 700 cubic feet of resin (350 cubic feet per vessel) and the amount of water treated assuming system operation at the rated capacity (1,000 gpm) for 360 days per year. The current market price of the WBA resin is $478.23/cu ft.

7.1.2.6. Gas Separation Membranes

Liquid-cell gas membranes are used to reduce dissolved CO_2 (carbonic acid) in the ground water that is the result of the reaction between alkalinity in the water and the sulfuric acid used to maintain low pH in the WBA IX process. The WBA IX system can be operated without actively removing CO_2, but this would result in much higher consumption of soda ash necessary to restore treated water pH and alkalinity to levels acceptable for distribution as drinking water. Treatment cost per acre-foot of water treated was calculated both ways – with and without degassing. Liquid-cell membranes have a limited life expectancy. The current replacement price of an individual membrane is $10,140/ea. The cost per acre-foot of water treated was calculated based on operation at the rated capacity (1,000 gpm) for 360 days per year, and the replacement cost and life expectancy of the liquid-cell membranes. For input into the cost model, alternative, less expensive means of removing the CO_2 from groundwater may be considered (i.e., using a stripping tower prior to discharge of treated water to a reservoir). A stripping tower was not used for the Rialto demonstration due to the footprint and height restrictions at the site.

7.1.2.7. Miscellaneous Chemicals and Supplies

Other chemicals and supplies were consumed for routine maintenance and calibrations. These materials may include: bleach solution for disinfection components, pH buffers for calibrating pH probes, air filters for the membrane degasification system and air compressor, and oil for gearboxes. The approximate annual cost of miscellaneous chemicals and supplies was estimated to be $12,000 per year. The cost per acre-foot of water treated was calculated based on operation at the rated capacity (1,000 gpm) for 360 days per year.

7.1.3. Cost Element: Electricity

Because operation of the WBA system was intermittent throughout the demonstration, power consumption was estimated/calculated based on equipment rating, frequency of operation, and a factored load rating. Total electrical cost per acre-foot was calculated using $0.10/kilowatt-hour based on the volume of water treated and estimated kilowatt-hours consumed during demonstration testing. For input into the cost model, site specific requirements should be considered. For example, if booster pumps and membrane degassing are not required based upon site specific requirements, then total power consumption per acre-foot would be drastically reduced.

7.1.4. Cost Element: Labor

Operating labor was estimated based on ARA personnel hours during normal, steady-state operation and regeneration. Labor hours per acre-foot of water treated were calculated based on operation at the rated capacity (1,000 gpm) with 312 days of "normal" operation (1.5 labor hours per day) and 48 days of operation in "regeneration" mode (16 labor hours per regeneration). A labor rate of $75.00 per hour was used in all calculations. For use in the cost model, labor hours per acre-foot should be scaled accordingly. Doubling or halving the size of the system will not double or half the labor hours required for operation of the system and should be factored accordingly.

7.1.5. Cost Element: Waste Disposal

Ion exchange resin wastes are accounted for as part of WBA and SBA resin costs. The only additional waste produced during the demonstration was treated, spent regenerating solution. This solution contains no perchlorate. This waste was hauled by a local, commercial waste handler (K-Vac Environmental, Rancho Cucamonga, CA) to a local disposal facility/terminal in San Bernardino, CA. The pH requirement for disposal of this solution is 6.0-12.0. Adjustment of pH was sometimes required prior to pick up. The total cost of waste disposal included pH adjustment, pick-up and transportation, and the tipping fee at the terminal. Waste disposal cost per acre-foot of groundwater treated was calculated from the volume of wastewater produced per regeneration and the average regeneration frequency at the rated capacity (1,000 gpm) for 360 days per year. Actual hauling costs to the San Bernardino facility were $800.00 per 10,000 gallons of spent regenerant, in addition to disposal fees of $0.054 per gallon

7.2. Cost Drivers

There are five main cost drivers for the WBA IX system: 1) perchlorate concentration of the feed water; 2) alkalinity of the feed water; 3) alkalinity of the treated water; 4) regeneration frequency; and 5) WBA resin costs. Each cost driver has site-specific or equipment-specific characteristics that impact costs which are discussed in the following sections. Soda ash consumption is dependent on sulfuric acid usage. If excess acid is used for pH reduction, higher amounts of soda ash will be required to neutralize pH during post-treatment.

7.2.1. Perchlorate Concentration

Overall, the cost advantage of WBA IX technology relative to conventional SBA technology is greater as perchlorate concentration in the groundwater increases. However, scavenger resin consumption is directly proportional to perchlorate concentration. Since perchlorate is very concentrated in the spent regenerating solutions, much more perchlorate can be exchanged onto a strong-base scavenger resin than is removed by the primary ion exchange resin (weak base or strong base, single-use resin) used to directly treat the groundwater. The perchlorate-loading capacity of the perchlorate-selective SBA resin (meq/L) is directly proportional to the concentration of perchlorate in the spent regenerating solution. SBA resin used in single-use ion exchange systems to treat low perchlorate concentrations (10's of ppb) loads only a small fraction of the total available ion exchange sites with perchlorate. For instance, the highly selective Purolite A530E resin will load only ~30 milliequivalents (meq) of perchlorate from treating a typical groundwater source containing 20 ppb perchlorate, even though the total ion exchange capacity is greater than 600 meq. That is only 5% capacity before breakthrough is observed and the resin must be removed and incinerated. However, since the spent regenerating solution from the WBA process has 2,000-5,000 times more perchlorate and lower ratios of competing anions, A530E resin will load over 90% (550 meq) of the exchangeable sites with perchlorate. This efficient use of SBA resin in the scavenging process reduces resin consumption by over 95% compared to single-use systems used for groundwater treatment.

In previous laboratory scavenger tests, Purolite A-530E resin was the most economical resin based on treatment capacity and replacement costs ($240.95 per cubic foot). SBA resin cost is the only cost driver/element that is dependent on the perchlorate concentration of the groundwater being treated. Figure 7-1 shows SBA resin cost as a function of groundwater perchlorate concentration. The scavenger resin costs for this demo were determined to be $10.11 per acre-foot based on an average groundwater perchlorate concentration of 16 mg/L.

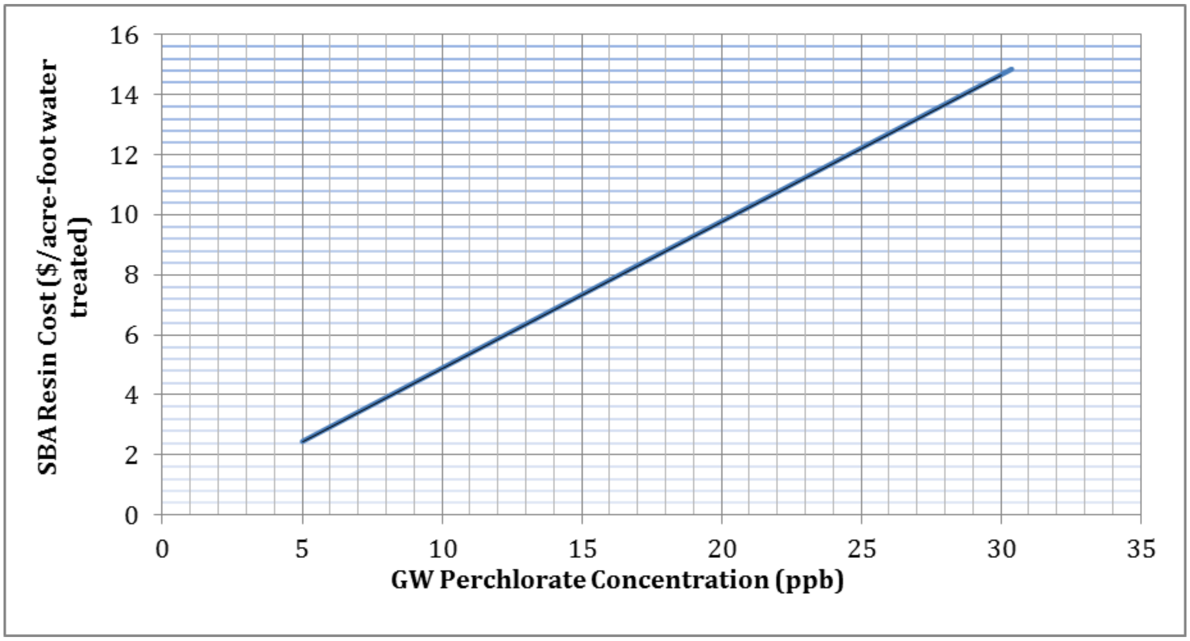

Figure 7-1. Scavenger SBA Resin Cost versus Perchlorate Concentration

7.2.2. Groundwater Alkalinity

The amount of acid required for pretreatment to attain the pH necessary for good performance is directly proportional to groundwater alkalinity. Acid cost was determined to be $3.96/acre-foot for every 10 mg/L of total alkalinity in the groundwater, based on sulfuric acid pricing of $0.12 per pound, delivered. The pilot demonstration at Fontana, CA resulted in an acid cost of $2.47/acre-foot for every 10 mg/L of alkalinity in the groundwater. This represents a 38% increase in acid use which was caused by inadequate mixing of acid prior to pH measurement. This is a design issue that can be rectified by relocation of the pH probes to permit additional mixing time.

7.2.3. Treated Water Alkalinity

Post treatment costs are directly proportional to the alkalinity required in the treated water to achieve a slightly negative LSI. The post treatment approach is dependent on the water quality at each site. The approach taken during the Rialto demonstration was to lower the pH using sulfuric acid, remove excess dissolved CO_2 using Liqui-Cel membranes, and use sodium carbonate (soda ash) solution to return alkalinity to the desired level. Post treatment cost (soda ash, electricity, membrane replacement) for this demonstration equated to $59/acre-foot based on an average of 54 ppm of residual alkalinity (as $CaCO_3$). Soda ash represents 80% of this cost and consumption was significantly higher than the theoretical requirement. This was due to the addition of excess acid during regeneration and pretreatment. Optimization of the regeneration, pretreatment, and post-treatment operations will significantly reduce both acid and soda ash consumption.

7.2.4. Resin Regeneration Frequency

Regeneration frequency and the related costs are dependent on resin treatment capacity, which is affected by competing anions present in a groundwater. For a given water composition, treatment capacity is relatively independent of perchlorate concentration below 100 ppb because the perchlorate isotherm is linear between 1 and 100 ppb. In other words, the quantity of the perchlorate anion that is exchanged is directly proportional to the concentration of perchlorate anion in untreated water.

7.2.5. WBA Resin Cost

Resin replacement cost is a major component of operating costs for several reasons. The commercial resin used in this demonstration (D4170) is produced by Purolite at $478.23 per cubic foot. While this resin is commercially produced, production rates are relatively low at this time. Higher production rates in the future may lead to reduced costs. Also, perchlorate treatment systems for drinking water require a “multi-barrier” or two-stage, lead-lag treatment configuration. This configuration, in effect, doubles the amount of resin necessary for a treatment process. The cost of resin replacement is $22.08 per acre-foot based on a 10-year service life.

7.3. Cost Analysis

The costs provided in Table 7.2 are normalized costs based on the current WBA IX configuration and the water quality at the Rialto 3 site. Observed costs were higher than projected due to problems identified and discussed in previous sections. Feed water pH ranged between 7.5 and 7.9 and the average alkalinity was 150 mg/L. Treated water pH was between 6.5 and 7.5 and the average alkalinity was 55 mg/L.

Table 7-2. Cost Analysis for the WBA IX Process

Cost Element	Assumptions	Costs
Design, Construction, and Installation	1,000 gpm system with multi-stage barrier treatment, boost pumps, membrane degasification, soda ash injection system for post treatment.	$1.958M
Consumable Materials	Consumables include: • Sulfuric acid • Sodium hydroxide • Sodium carbonate (soda ash) • Strong base anion resin for scavenging • Weak base anion resin for primary treatment • Gas separation membranes • Miscellaneous chemicals and supplies	 $42.79/AF $13.84/AF $38.19/AF $8.09/AF $22.08/AF $7.65/AF $7.54/AF
Waste disposal	Disposal of treated spent regenerating solution (transport and disposal fee)	$10.11/AF
	Untracked Elements	
Electricity	Total electrical consumption as configured for demo, including boost pumps and vacuum pumps for CO_2 degassing	$20.44/AF
Labor	Labor required for operating and maintaining system	$58.27/AF
	TOTAL:	**$229.00/AF**

7.3.1. Design/Construction/Installation

The design and management costs for a first-of-a-kind technology demonstration are much larger than would be expected for future implementations of this technology. When estimating design and engineering costs of future implementations of the WBA technology, a factor of the current delivered equipment costs, typically 30 percent (Peters, Timmerhaus, and West, 2002), should be used. Derived from 2008-2010 costs, Table 7-3 shows the total value of the subcontract with Carollo Engineering for design, construction, and installation of the Rialto 1,000 gpm system ($1.958M). Equipment costs for the demonstration unit totaled $1.492M, with system installation costs totaling $466K. The Rialto system capacity can be increased to 2,000 gpm by installing an additional train of lead/lag vessels at minimal cost as the post treatment system and regeneration system were designed for future expansion. In order to determine the price of systems larger than 2,000 gpm, standard industry scaling factors such as the six-tenths power factor rule may be used (Peters, Timmerhaus, and West, 2002). According to this rule, if the cost of a given unit at one unit of capacity is known, the cost of a similar unit with X times the capacity of the first is $X^{0.6}$ times the cost of the initial unit.

Table 7-3. Equipment Costs for the 1,000 gpm WBA IX System

Equipment	Cost ($)
Pretreatment:	
Feed Pumps (2 x 600 gpm)	$ 28,284
Membrana System (CO_2 degasification)	$ 80,375
Acid Storage Tank (6,000 gal)	$ 29,254
Acid Feed Pump (5-10 gpm)	$ 4,957
Heat Exchanger	$ 3,847
Ion Exchange:	
Vessels, Packed Bed, Coated Stainless (2 X 9ft diameter)	$ 292,003
Nozzles (1000, including gaskets)	$ 25,239
WBA Resin (Purolite D4170, 700 cu.ft)	$ 287,000
Inert Material (Purolite IP-4, 82 cu.ft.)	$ 10,250
Post Treatment:	
Merrick Soda Ash Delivery System	$ 57,505
Regeneration:	
Scavenger Vessels (2 X 68 cu.ft.)	$ 24,660
SBA Resin (Purolite A530E, 105 cu.ft.)	$ 19,425
Acid Transfer Pump (10 gpm)	$ 4,957
Caustic Transfer Pump (20 gpm)	$ 2,904
Regeneration/Protonation Circulation Pump (500 gpm)	$ 10,053
Tranfer Tank Pump (100 gpm)	$ 7,489
IX Vessel Drain Pump (100 gpm)	$ 7,489
Caustic Storage Tank (3000 gal)	$ 16,800
Regeneration Tank (4500 gal)	$ 18,781
Protonation Tank (1200 gal)	$ 7,694
Transfer Tank (500 gal)	$ 1,886
Control System/Electrical:	
Electrical Building	$ 22,628
VFD Panel	$ 17,619
Motor Starter Panel	$ 4,991
PLC Control Panel	$ 30,084
Local Electrical Panel	$ 8,318
Data Acquisition System	$ 5,300
pH Controllers (10 units)	$ 10,578
Lighting	$ 8,620
Air Compressor (20 cfm)	$ 5,926
Subtotal Equipment	**$ 1,054,916**
Other Misc. Costs:	
Design, Piping, Static Mixers, Waste Storage Tank, Lighting, Wiring, pH Probes, Control Valves, Safety Equipment (eye wash, safety showers), Coatings, Chemical Containment Areas, Fencing, Additional Seismic Requirements	**$ 437,084**
Total Design/Equipment Costs	**$ 1,492,000**
Installation Costs	**$ 466,010**
Total Subcontract Value	**$ 1,958,010**

7.3.2. Cost Element: Consumable Materials

Observed and normalized consumable material costs are shown in Table 7.4. Observed costs are actual costs observed during the demonstration period. Because of the difficulty of determining costs due to problems experienced during the demonstration, normalized costs were developed based on the design treatment capacity of 9,000 BVs (average alkalinity of 150 mg/L) at 1,000 gpm over a 16 day operating cycle. In some cases material costs are based on bulk rates and/or average pricing, not including fuel costs and other miscellaneous charges. Each consumable item is discussed in detail in subsequent sections.

Table 7-4. Consumable Material Costs for Operation of the WBA IX Process

Consumable Material	Actual Demonstration Cost, $/AF	Normalized Cost, $/AF
Sulfuric Acid, 98 wt %	$106.50	$42.79
Sodium Hydroxide, 25 wt%	$25.00	$13.84
Sodium Carbonate (Soda Ash)	$47.45	$38.19
Strong Base Anion Scavenger Resin, A530E [1]	--	$8.09
Weak Base Anion Resin, D4170 [1]	--	$22.08
Gas Separation Membranes [1]	--	$7.65
Misc. Chemicals & Supplies[2]	--	$7.54

[1]Actual costs were unable to be determined as these items' life cycle were longer than the demonstration
[2]This cost is based on a yearly budget of $12,000, which may vary from site to site

7.3.2.1. Sulfuric Acid

During this demonstration, acid consumption was 125 gallons per day (gpd), or 36 gallons/AF of treated water. Sulfuric acid market prices were higher than usual ($0.215/lb), which raised demonstration acid costs to $106.50/AF of treated water. Costs were based on actual volumes of water treated, actual flow rates, and recorded run times, which were considerably less due to the first two test periods being short cycles, and the third and fourth test periods being shortened due to intermittent operational difficulties experienced by the City of Rialto at the well site. This consumption rate is much higher (38%) than previous demonstrations due to mixing issues and non-steady state operation issues discussed in preceding sections. This sulfuric acid consumption rate is considered the maximum rate and must be adjusted based on groundwater alkalinity. Sulfuric acid cost can vary greatly; therefore, site-specific conditions should be used to model future implementations of this technology. Using the five-year US industry average of $0.12/lb, sulfuric acid costs drop to $42.79/AF of treated water. This is based on treating 9,000 BV of groundwater with 150 ppm alkalinity at design flow rates of 1,000 gpm over a 16 day cycle. Also, acid consumption drops to 103 gallons per day, or 23 gallons/AF of treated water.

7.3.2.2. Sodium Hydroxide

Actual caustic (25% NaOH) consumption over the demonstration period averaged 559 gallons per regeneration for each vessel (350 ft^3 of resin), or 35 gallons/AF treated water. Overall demonstration costs were $25.00/AF of treated water based on market costs of $0.1675/lb. However, each of the test periods (1-3) was shortened, either by design, or by time constraints caused by well site operational issues. Because of the shortened run times, the caustic consumption rates were much higher. Using the same system operating conditions as with sulfuric acid (9,000 BVs), a theoretical caustic consumption rate per regeneration was calculated based on the 1.4 equivalents per liter of resin plus a 5% excess which equates to 481 gallons of 25% NaOH. This drops caustic consumption to 8 gallons/AF of treated water and $13.84/AF of treated water. Sodium hydroxide costs can vary greatly, therefore, site-specific conditions should be used to model future implementations of this technology.

7.3.2.3. Sodium Carbonate (Soda Ash)

Actual soda ash consumption during the demonstration averaged ~500 pounds per day (10 x 50 lb. bags). This equates to a soda ash consumption rate of 147.15 lbs/AF of treated water at an average cost of $47.45/AF of treated water. This consumption rate is considerably higher than predicted, but was greatly affected by excess acid used during pretreatment and regeneration. Normalizing costs as before drops treatment consumption rates to 118.42 lbs/AF of treated water and $38.19/AF of treated water. Soda ash consumption could be reduced proportionately and costs greatly lowered by optimization of chemical usage during the regeneration process, making improvements to the membrane pretreatment system, and making improvements to the soda ash delivery system.

7.3.2.4. Strong Base Anion Resin for Scavenging

Current market resin replacement costs, installation costs, transportation costs, and disposal costs were used to determine the scavenger resin costs. Calculations were based on the total amount of water treated to achieve perchlorate breakthrough in the lead scavenger vessel. Because the scavenger vessels were not operated to breakthrough during this demonstration, a theoretical cost was calculated. The lead and lag scavenger vessels each contained 52.5 cu. ft. of Purolite A530E SBA resin (105 cu. ft. total). The SBA resin consumption was projected to be 0.0336 ft^3 per acre-foot of water treated. At current market pricing of $240.95/cu. ft. resin, the average cost of the SBA resin was $8.09 per acre-foot of water treated. As discussed in Section 7.2.3, SBA resin cost is the only cost element that is dependent upon the perchlorate concentration of the groundwater being treated. Calculations were based on an average perchlorate concentration of 16 ppb during this demonstration at the Rialto No. 3 well site.

7.3.2.5. Weak Base Anion Resin for Primary Treatment

Cost calculations for the WBA resin were based on a resin life expectancy of 10 years, operating at the rated capacity of 1,000 gpm for 360 days per year. As with scavenger resin costs, calculations take into consideration transportation costs, spent resin disposal, and resin installation using the current market cost for WBA resin. Each of the packed bed ion exchange vessels was loaded with 350 ft^3 WBA resin (700 ft^3 total). Based on current market pricing of \$478.23/ft^3, the consumption rate is 0.046 ft^3 of resin per acre-foot, or \$22.08 per acre-foot of water treated.

7.3.2.6. Gas Separation Membranes

The cost of the gas separation membranes is based on a life expectancy of 5 years and the system operating at the rated capacity of 1,000 gpm for 360 days per year. With three pairs of membranes (6 membranes total) and a replacement cost of \$10,140.00 each, the cost per acre-foot of water treated equates to \$7.65.

7.3.2.7. Miscellaneous Chemicals and Supplies

The annual cost for miscellaneous chemicals and materials is estimated to be \$12,000 per year. Based on the system operating at the rated capacity of 1,000 gpm for 360 days per year, the average cost per acre-foot of water treated was determined to be \$7.54. These costs are for supplies such as sump pumps, tools, electrical cords, disinfecting solutions, onsite pH analysis, etc.

7.3.3. Electricity

Electricity consumed during the demonstration was an untracked cost. Calculated power consumption was based on equipment ratings and duty cycles. The total amount of electricity consumed during the entire demonstration was approximately 24,548 kilowatt hours. Based on a rate of \$0.10 per kW-hr and a total of 120.12 acre-foot of water treated during the demonstration, total electricity cost was \$20.44 per acre-foot of water treated, or 204 kW-hr per acre-foot water treated. This number accounts for each of the three regenerations performed during the demonstration. Power consumption was dominated by the booster feed pumps (75% of total) and the liquid ring vacuum pump (19% of total). Depending on site-specific requirements, many applications may not require booster pumps or a liquid ring vacuum pump for membrane degassing as demonstrated in Rialto. Electrical costs representing the exclusion of various elements are calculated and shown in Table 7.5.

Table 7-5. WBA IX Process Electrical Costs

Electrical Elements	Total kW Required	Total kW-hr Used	Total Cost ($)	Cost ($) per acre-ft Water Treated
IX operations, as demonstrated	140	24548	$2,454.79	$20.44
IX operation, excl. regenerations	112	24289	$2,428.94	$20.22
IX operation, excl. booster & vacuum pumps	47	1600	$160.04	$1.33
IX operation, excl. regenerations, booster & vacuum pumps	19	1342	$134.19	$1.22

7.3.4. Labor

Labor hours were determined based on the normal operation and regeneration operation modes. From the demonstration, it was determined that under normal operating conditions, a single operator was needed on-site for approximately 1.5 hours per day. During regeneration cycles, it was determined that two (2) operators would need to be onsite intermittently for approximately 8 hours per day. With the system operating at the rated capacity of 1,000 gpm for 360 days per year at a $75.00/hr rate, labor costs were $58.27 per acre-foot of water treated. Labor costs per acre-foot of water treated may vary from site to site due to varying labor rates. Doubling or halving the size of the system will not double or half the labor hours required for operation of the system.

7.3.5. Waste Disposal

The only waste requiring disposal during the demonstration was the perchlorate-free, spent regenerating solution. Each regeneration cycle produced approximately 5,000 gallons of the solution. A 10,500 gallon waste tank, located onsite, allowed for two regenerations to be conducted before a certified waste hauler/environmental company would transport and dispose of this solution. The transportation costs for this process was $800 per 10,000 gallons of waste, with disposal fees of $0.054 per gallon. Assuming the system runs at capacity (1,000 gpm) for 360 days per year, and 24 regenerations are performed throughout the year, the waste disposal costs would be $10.11 per acre-foot of water treated.

8.0 Implementation Issues

8.1. Environmental Issues and Implementation

The City of Rialto has an existing permit for treating perchlorate using the single-use, SBA resin treatment process located at Rialto No. 3. In order to demonstrate the WBA system, ARA was required to go through a multi-step process to apply for an amendment to this permit. With the City's approval, an application for amending the permit, along with a Performance Objective Plan and an Operations Manual/Control Narrative, were submitted to CDPH. CDPH reviewed both documents and issued a permit amendment for the WBA system to be operated only as a pretreatment system to the existing treatment system. A treatment permit approving WBA technology as a primary treatment may be issued after review of the Final Report and completion of the permitting process. According to CDPH, implementation of this treatment technology at other sites will be approved on a case by case basis.

Additionally, the WBA system requires a permit for disposal of the waste produced during WBA resin regeneration. An application for a discharge permit was submitted to the San Bernardino Valley Municipal Water District (SBVMWD) in order to have a certified waste hauler dispose of this waste at the Inland Empire Brine Line (IEBL). Samples of the waste were analyzed by a certified laboratory for a list of pollutants and the results were submitted to SBVWMD. A site inspection was also conducted by an environmental technician from SBVWMD in order to create a process flow diagram for the permit. The permit was issued directly to ARA. If the City of Rialto chooses to operate the WBA system, they must re-apply for a permit that would be issued directly to the City.

8.2. End User Concerns and Issues

End-users for this technology include DoD facilities, formally used defense sites, and municipal drinking water systems that have been contaminated with perchlorate by past DoD operations. In addition to drinking water applications, the technology can be used for pump-and-treat perchlorate remediation and to facilitate remediation of co-contaminants (such as VOCs) by removal of perchlorate to enable discharge or re-injection. The technology can also be applied to the treatment of other types of wastewater generated by munitions manufacturing or demilitarization operations.

Implementation of this technology is straightforward. Commercial, large-scale, ion exchange equipment for WBA resin technology is commonplace. The pretreatment section of the system consists of pH control unit operations with two-stage static mixing which is straight forward to design and engineer. Reducing the alkalinity/stripping of carbon dioxide from the groundwater feed can be accomplished using membrane treatment systems or stripping towers. Both methods are straightforward and are commercially available. The post treatment system used to return alkalinity and raise the pH of the treated groundwater consists of a package soda ash delivery system combined with static mixers; both are commercially available. Treatment of residuals by an SBA resin scavenger ion exchange process is a proven technology.

The issues of primary concern for the end user concerning the WBA technology are: 1) operational complexity; 2) labor requirements; and 3) requirements for bulk chemicals onsite (i.e., acid, caustic, and soda ash).

8.2.1. Interfering Anions

The WBA resin has greater selectivity for perchlorate than other anions. However, the presence of competing anions such as chloride, nitrate, and/or sulfate will reduce the overall treatment capacity of the resin. WBA resin performance can be modeled based on site-specific groundwater characteristics.

8.2.2. Operational Complexity

The WBA IX system demonstrated at the Rialto No. 3 well site is an automated water treatment system. Automation of any technology brings a level of complexity to that technology. The programmable logic controller (PLC), operator interface (O/I), control software, and other associated electronics used to control the WBA system were off-the-shelf, and readily available. A computer engineer programmed the PLC system based on a predetermined control philosophy which allowed operators to control the system by means of input and monitoring screens at the O/I. In addition, the system could be operated in manual or automatic modes. Real-time data was also displayed on the monitoring screens. Operators must have a basic understanding of PLC systems, control logic, and the operating philosophy of the WBA system.

8.2.3. Labor Requirements

The WBA system, as designed in Rialto, CA, will require a single operator for approximately 1.5 hours per day. This operator can perform sampling, collect operational data, perform or monitor chemical re-supply, and basic maintenance. During the 48-hour regeneration cycles and major maintenance procedures, it is recommended that two (2) operators be available onsite intermittently for 8 hours per day. Once familiarity with the system has been established and operations streamlined, these requirements can be reduced.

8.2.4. Chemical Storage Requirements

Currently, bulk chemicals need to be stored onsite for the WBA system at the Rialto No. 3 site: sodium hydroxide (25%) in a 3,000 gallon poly tank (T-501); sulfuric acid (93%) in a 6,000 gallon poly tank (T-601); and 4 or 5 pallets (4 or 5 x 2,100 lb) of soda ash. The acid and caustic vessels are in sealed containment areas with sumps to protect against an accidental spill or release. Since soda ash is highly hygroscopic, it should be stored indoors or in a covered area to prevent moisture intrusion/hardening of the soda ash.

8.2.5. System Improvements

8.2.5.1. Pre-Treatment

In order to reduce the pressure drop experienced across the membranes and increase flow to the design capacity of 1,000 gpm, the membrane system must be modified. An additional membrane pair must be installed to reduce the flow through each membrane train. In addition, the membrane system must be modified to allow for periodic cleaning to be performed.

Rotameters used to balance the airflow through the membranes were oversized for this application. Smaller rotameters will enable operators to better control airflow (and CO_2 removal) across the membranes.

Also, the membrane vendor (Membrana) recommended that the membranes and associated equipment be covered to provide protection from direct sunlight. If the WBA system is used as a permanent treatment system, this will prolong the life cycle of the membranes.

8.2.5.2. Post-Treatment

The Merrick soda ash system was not designed for outdoor use. This system will require a cover to protect it from the elements. It is also recommended that softened water or RO water be used for dissolving solid soda ash in the dissolver tank of the Merrick soda ash system. If not, scale will form in the dissolver tank, soda ash feed pump strainers, piping, and in the injection quill of static mixer MX-401. Softening of the water will eliminate scale formation.

During this demonstration, LSI and pH of the treated water was difficult to control. To rectify this problem, two-stage mixing should be employed with the soda ash—identical to that employed in the pretreatment system with sulfuric acid. In this process, the soda ash would be premixed with a slipstream of recycled treated water in a smaller static mixer which would then be injected into the larger static mixer. To further assist mixing and increase residence time, the distance between the static mixer and the pH probes must be maximized.

8.3. Procurement Issues

This system is not considered a commercial off-the-shelf (COTS) system. Although the WBA system is composed of readily available commercial components, application of this technology to other sites will require additional engineering to meet site-specific requirements based on groundwater characteristics and onsite needs and/or restrictions.

9.0 References

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Appendix A: Points of Contact

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Site Liaison	Mr. Nick Somogyi	Bryan A. Stirrat & Associates (BAS) 1360 Valley Vista Dr . Diamond Bar, Ca 91765	909-860-7777 909-396-1768 fax NSomogyi@bas.com
DW Treatment Operator	Mr. John M. Thompson (Mike)	Grade T4 Drinking Water Treatment Operator (Lic. No. 22694) 1922 W Sycamore St San Bernardino, CA 92407	909-435-6017 cell jthompson1909@verizon.net
CDPH Liaison	Mr. Sean McCarthy	CDPH 464 W 4th Street, Suite 437 San Bernardino, CA 92401	909-388-2602 Sean.McCarthy@cdph.ca.gov

Appendix B

Rialto No. 3 WBA IX Demonstration System

Equipment Specifications

ESTCP PROJECT: ER-1168
ARA PROJECT: 001060

Name	Tag #	Manufacturer	Model	Capacity	Set Point	Description	Function	Type of Control	Control Sensor(s)	Interlock(s)	Parameters to monitor
Heat exchanger	HE-201	WCR	WCR-6x72-BEU			WCR shell and tube heat exchanger: 6" nominal X 72" tube length. 4 pass, type BEU. All shell side and tube side wetted parts are 316L stainless steel. 3/4" OD X 0.049 wall u-tubes. ASME stamped for 150 psig @ 250F	Groundwater slipstream is used to cool water recycled for LRV pump (P-201). Flow of slipstreamed controlled manually (30 gpm) using GV-203. Slipstream is returned to suction side of feed pumps (P-101A/B).	None	None	None	FI-203 (flow of slipstream)
Lag scavenger vessel	ST-701A	Baker Corp	KW2000HPV			Liquid phase filter vessel, 48" D, 96" H, 75 psi, 68 cu.ft., 150F, high pH internal coating	Vessel containing 45 cu.ft. of strong base anion resin (A530E) for treating spent regen solution.	Manual	Manually configure valves. However, the regen cycle for pumping regen is automatic.	Are there any lock valves?	
Lead scavenger vessel	ST-701B	Baker Corp	KW2000HPV			Liquid phase filter vessel, 48" D, 96" H, 75 psi, 68 cu.ft., 150F, high pH internal coating	Vessel containing 45 cu.ft. of strong base anion resin (A530E) for treating spent regen solution.	Manual	Manually configure valves. However, the regen cycle for pumping regen is automatic.	Are there any lock valves?	
WBA ion exchange vessel	WBA-301	AATECH				Vessel 9 FT. X 7FT. 7 IN. FT. SSH; Vessel Lining VYNYLESTER by SOCCO					
WBA ion exchange vessel	WBA-302	AATECH				Vessel 9 FT. X 7FT. 7 IN. FT. SSH; Vessel Lining VYNYLESTER by SOCCO					
Liqui-Cel membrane contactors	201-A, B, C, D, E, F	Liqui-cel	G533			14"X28" membrane contactor. X50 fiber, epoxy potting, PVC vessel with nylon end caps, 2" ANSI gas side connections, 4" ANSI liquid side connections. Gas ports in line		Manual			
Secondary acid mixer	MX-101	Komax	54989	N/A	N/A	8 IN. Inline mixer, CPVC Construction	Mixes stream from primary acid mixer with groundwater.	None	None	None	None
Primary acid mixer	MX-102	Komax	54988	N/A	N/A	1" in-line mixer. SS injection quill.	Mixes 93% sulfuric acid from metering pump MP-601 with a slipstream of groundwater. MP-601 addition is controlled by AT-201A (pH following membrane system). Flow rate of slipstream is manually controlled at 30 gpm using GV-101.	None	None	None	None
Caustic metering pump	MP-501	Nipton	547-S-N5	30 gph	30 gph	Caustic transfer Pump 30GPH at 100PSI. 1/2 HP, 1ph, 115V, TEFC MOTOR	Meter caustic for regeneration rinse	Manual			
Acid metering pump	MP-601	NEPTUNE /Pumping Solutions	535-A-N4-FA-SCR50	10 gph	5.33 gph??	Final acid feed pump 10 GPH at 150 PSI, Alloy 20 PVDF wetted parts, 115V, 3 1 PH, 60 HZ with SCR drive	Pump conc. acid from TK-601 to reduce pH of the groundwater. Pumps through an initial stage mixer (MX-102) mixed with a stream of groundwater (stream volume manually controlled using GV-101) and added to the suction side of the feed pumps (P-101A/B) at MX-101.	Automatic	AT-201A/B		
Feed pump	P-101A	Grundfos	CRN90-3	600 gpm	VFD driven so total flow is 1000 gpm	Ion Exchanger feed pumps, 600 GPM at 90 PSI, Vertical multistage centrifugal pump, 316 SS construction, 460v, 3ph, 60 hz.	Pump groundwater to demo system. 1000 gpm total. VFD	Automatic	FT101 - PSH-201	BFC-101 Control valve Flow rate too low or high (FALL-101 & FAHH-101)	

Name	Tag #	Manufacturer	Model	Capacity	Set Point	Description	Function	Type of Control	Control Sensor(s)	Interlock(s)	Parameters to monitor
Feed pump	P-101B	Grundfos	CRN90-3	600 gpm	VFD driven so total flow is 1000 gpm	Ion Exchanger feed pumps, 600 GPM at 90 PSI, Vertical multistage centrifugal pump, 316 SS construction, 460v, 3ph, 60 hz.	Pump groundwater to demo system. 1000 gpm total. VFD	Automatic	FT101 - PSH-201		
Transfer pump	P-102	Grundfos	CRN15-5	100 gpm	100 gpm	Transfer pump, 100 GPM at 90 PSI, Vertical multistage centrifugal pump, 316 SS construction, 460v, 3ph, 60 hz.	Pump from transfer tank to front of system (injection side of feed pumps prior to FT-101)	Automatic	Controlled by level sensors in transfer tank TK-101: LSL-101, LSH-102, and LSHH-102.		
Liquid ring vacuum pump	P-201	Nash Elmo	2BV5161			Vacuum ring pump, 327 CFM at 150 in. HG ABS, 25 HP, 460V, 3PH, 60 HZ	"Sweeps" carbon dioxide out of membrane system.	Always on??	None	Don't see a way for this pump to be shut off automatically in a shutdown event…??	FI-203 monitors flow rate of fluid entering shell side of HX. Manually control rate using GV-203 (30 gpm). TI-201 monitors temperature of water exiting tube side of the HX before LVP. PI-202 monitors pressure of sweep from membranes entering LVP. What is purpose of PS-201?
Drain pump	P-301	Grundfos	CRN15-3	100 gpm	100 gpm	Drain Pump 100 GPM at 90 PSI, 316 SS construction, __ HP, 460V, 3PH, 60 HZ, TEFC motor, Vertical multi-stage centrifugal		Automatic			
Caustic transfer pump	P-501	Iwaki	100LFZE-1	10 gpm	10 gpm	Caustic transfer Pump 10 GPM at 60 ft. 1/3 HP, 115V, TEFC MOTOR	Pump fixed volume of caustic from caustic storage tank (T-501) to Regen tank (T-502)	Automatic			
Regeneration/Protonation Pump	P-502	F.H. Pumps	SUMMIT MODEL CC, SIZE 3X4-8	500 gpm	500 gpm	SUMMIT MODEL CC, SIZE 3X4-8 316 SS WITH SILICON CARBIDE/SILICON. CARBIDE/VITON/316 SS MECHANICAL SEAL CLOSE COUPLED TO A 20HP/3600RPM 230-460V/3PH/60CY TEFC MOTOR	Circulate regenerating solution from tank TK-502 through IX vessel. Circulate protonating solution from TK-602 through IX vessel.	Automatic	Activated during regeneration by control system		
Acid transfer pump	P-601	Iwaki	100LFZE-1	10 gpm	10 gpm	Acid transfer Pump 10 GPM at 60 ft. 1/3 HP, 115V, TEFC MOTOR	Pump fixed volume of acid from acid storage tank (TK-601) to Protonation tank (TK-602)	Automatic			
Protonation drain pump	P-602	Grundfos	CRN5-4	30 gpm	30 gpm	Protonation drain pump 30 GPM at 30 PSI, ___ HP 460V, 3PH, 60 HZ, TEFC motor, 316 SS construction	Drains protonating solution from IX vessel(s) to waste holding tank (TK-701)	Automatic	Regeneration sequence		
Waste circulation pump	P-701	Grundfos	CRN15-2	100 gpm	100 gpm	Circulation Pump 100 GPM at 30 PSI, 316 SS construction, __ HP, 460V, 3PH, 60 HZ, TEFC motor, Vertical multi-stage centrifugal	Circulates contents in the waste tanks. Will pump out waste tanks.	Manual	None	None	
Pretreatment pH	AE/AIT 201A	Enders Hauser		0-14	4	pH sensor with transmitter 0-14 pH, 4-20 ma signal	Measure pH of the pretreated water	Automatic	This electrode controls acid metering pump MP-601.	If pH is outside of predetermined range, alarm and/or shutdown. If pH deviates from redundant electrode by a predetermined amount, alarm and/or shutdown.	
Pretreatment pH	AE/AIT 201B	Enders Hauser		0-14	4	pH sensor with transmitter 0-14 pH, 4-20 ma signal	Redundant measure of the pH of pretreated water	Automatic	Used to compare to AE/AT 201A		

Name	Tag #	Manufacturer	Model	Capacity	Set Point	Description	Function	Type of Control	Control Sensor(s)	Interlock(s)	Parameters to monitor
Regeneration/Protonation pH	AE/AIT-301A	Enders Hauser		0-14	Variable depending on operation	1/4 in. PG Ball valve, 316 SS, single piece, FNPT	Measures pH of the regenerating solution and protonating solution. If the pH of either solution is not within the specification at a fixed time, more caustic or acid is added (i.e. regeneration pH < 12.5 after XX time, additional caustic added)	Automatic	This sensor controls caustic transfer pump (P-501) to add additional caustic if needed and controls acid transfer pump (P-601) to add more acid if needed.		
Regeneration/Protonation pH	AE/AIT-301B	Enders Hauser		0-14	Variable depending on operation	1/4 in. PG Ball valve, 316 SS, single piece, FNPT	Redundant measure of the pH of regenerating solution and protonating solution.	Automatic	Used to compare to AE/AT 201B		
Protonation pH	AE/AIT/302	Enders Hauser			≥12.5	1/4 in. PG Ball valve, 316 SS, single piece, FNPT					
Regeneration pH	AE/AIT/303	Enders Hauser			≤4						
Regeneration Rinse pH	AE/AIT-402A	Enders Hauser			≥12	pH sensor with transmitter 0-14 pH with 4-20 ma signal to PLC	Measures pH of regeneration rinse solution. The caustic metering pump used to adjust pH (MP-501) must be manually controlled.				
Regeneration Rinse pH	AE/AIT-402B	Enders Hauser			≥12	pH sensor with transmitter 0-14 pH with 4-20 ma signal to PLC	Redundant measure of pH of the regenerating rinse solution.				
Fully treated water pH	AE/AIT-401A	Enders Hauser			7-8	pH sensor with transmitter 0-14 pH with 4-20 ma signal to PLC					
Fully treated water pH	AE/AIT-401B	Enders Hauser			7-8	pH sensor with transmitter 0-14 pH with 4-20 ma signal to PLC					
Waste pH	AE/AIT/701	Enders Hauser		0-14	None	pH sensor with transmitter, 0-14 pH, 4-20 ma signal	Measures pH of the waste circulating in the waste tanks (TK-701 A/B) using pump P-701.	Manual	None	None	pH
Groundwater Butterfly valve	BFC-101	Bray	30-0800-11010-110	N/A	N/A	8 in. BF Valve, wafer style, nylon coated disc, EPDM seat with Double Acting actuator, 100 PSI pressure	Controls flow of groundwater from Rialto No. 3 to the WBA system.	Automatic		Normally open. Closed for all shutdown events.	
System flow rate	FE/FIT-101	Signet	3-2551-P1-12	1200 gpm	1000 gpm	Magnetic flow sensor, 1200 GPM, 8 in. pipe,	Monitors system flow rate. Controls VFD feed pumps to achieve desired flow rate.	Automatic	FIT-101	Triggers alarms and shutdowns if out of range.	FE-101.; FQ-101; FALL-101; FAHH-101
Drain pump flow rate	FE/FIT-301	Signet	3-2551-1O-12		100 gpm	Flow meter and sensor with display and 4-20 ma reading, sensor, flow transmitter, flow integral mounting, magnetic type	?? Is there any control to this pump to reduce flow based on level sensors in transfer tank?				
Regeneration rinse flow rate	FE/FIT-401	Signet	3-2551-TO-12			Magnetic type flow sensor , 3 IN. PIPE					
Protonation rinse flow rate	FE/FIT-402	Signet	3-2551-TO-12			Magnetic type flow sensor , 3 IN. PIPE					
Caustic tranfer pump flow rate	FE/FIT-501	Signet Signet	3-5600 3-2551-TO-12			Flow Batch controller monitor, 24V power supply, for 1 in. pipe, 10 gpm flow rate Magnetic type flow sensor polypropylene					
Protonation/Regeneration pump flow rate	FE/FIT-502	Signet	3-2551-P1-12			6 in. flow transmitter and sensor magnetic type					
Acid transfer pump flow rate	FE/FIT-601	Signet Signet	3-5600 3-2551-TO-12			Flow Batch controller monitor, 24V power supply, 1 in. pipe, 10 gpm 1 IN. PIPE Magnetic type flow sensor polypropylene, 10 GPM					
Slip stream flow for acid injection	FI-101	??	??	??	30 gpm - manually using GV-101	??	Monitors flow of a slip stream of groundwater water to accomplish acid injection	Manual	None - Manually adjust GV-101	None	None

Name	Tag #	Manufacturer	Model	Capacity	Set Point	Description	Function	Type of Control	Control Sensor(s)	Interlock(s)	Parameters to monitor
Air flow meter	FI-201A	Blue-White	F-452250GHN			Air flow meter, vacuum flow, 240 cfm, 2 in. FNPT	Measure air flow sweeping through one pair of membranes (201-A & 201-B). Air flow can be manually adjusted using GV-201A.	Manual	None	None	
Air flow meter	FI-201B	Blue-White	F-452250GHN			Air flow meter, vacuum flow, 240 cfm, 2 in. FNPT	Measure air flow sweeping through one pair of membranes (201-C & 201-D). Air flow can be manually adjusted using GV-201B.	Manual	None	None	
Air flow meter	FI-201C	Blue-White	F-452250GHN			Air flow meter, vacuum flow, 240 cfm, 2 in. FNPT	Measure air flow sweeping through one pair of membranes (201-E & 201-F). Air flow can be manually adjusted using GV-201C.	Manual	None	None	
Air flow meter	FI-202	BLUE-WHITE	F-452250GHN		N/A	Air flow meter, vacuum flow, 240 cfm, 2 in. FNPT	Measure air flow sweeping through membrane system.	None	None	None	None
Flow to HX for LRV pump	FI-203	Blue-white	F451004LHN-24	0-40 gpm	30 gpm - manually using GV-203	Feed water flow meter 0-40 GPM In line type, 1 1/2 IN. FNPT	Supplies water to the shell side of the HX cooling water to the LRV pump.	Manual	None - Manually adjust GV-203	None	FI-203; TI-201
Feed pump outlet pressure	PI-101A	Ashcroft	351009SWL04L150 PSI	150 psi	None	Pump outlet pressure gauges, 0-150 PSI, 3 1/2 in. dial. 316 SS construction wetted parts, glycerin liquid filled, 1/2 in. MNPT LM	Monitor outlet pressure of feed pump P-101A.	None		Software alarm if pressure is too low/too high??	
Feed pump outlet pressure	PI-101B	Ashcroft	351009SWL04L150 PSI	151 psi	None	Pump outlet pressure gauges, 0-150 PSI, 3 1/2 in. dial. 316 SS construction wetted parts, glycerin liquid filled, 1/2 in. MNPT LM	Monitor outlet pressure of feed pump P-101B.	None		Software alarm if pressure is too low/too high??	
Transfer pump outlet pressure	PI-102	Ashcroft	351009SWL04L100 PSI	100 psi	None	Pump outlet pressure gauges, 0-100 PSI, 4 in. dial. 316 SS construction wetted parts, glycerin liquid filled, 1/2 in. MNPT LM	Monitors outlet pressure of the transfer pump P-102.	None			
Pressure air sweep entering LRV pump	PI-202	Ashcroft	351009SWL04L30 in./0 in. Hg	30 in. to 0 in. Hg	None	Vacuum pressure gauge, 316 SS, liquid filled, 1/2 in. lower mount	Monitors vacuum pressure exiting membrane system and entering LRV pump.	Manual	None - Adjust vacuum??	None	
Drain pump outlet pressure	PI-301	Ashcroft	351009SWL04L150 PSI			Drain pump outlet pressure gauges, 0-150 PSI, 3 1/2 in. dial. 316 SS construction wetted parts, glycerine liquid filled, 1/2 in. MNPT LM					
Caustic transfer pump outlet pressure	PI-501	PLAST OMATIC, RYAN HERCO/PENVALVE	5342-030			Pressure indicator, 0/100psi, bottom mount, oil-filled gauge with CPVC guard seal & Teflon diaphragm, Plastomatic					
Protonation/Regeneration pump outlet pressure	PI-502	PLAST OMATIC, RYAN HERCO/PENVALVE	5342-030			Pressure indicator, 0/100psi, bottom mount, oil-filled gauge with PVDF guard seal & Teflon diaphragm, Plastomatic					
Acid transfer pump outlet pressure	PI-601	PLAST OMATIC, RYAN HERCO/PENVALVE	5342-030			Pressure indicator, 0/100psi, bottom mount, oil-filled gauge with PVDF guard seal & Teflon diaphragm, Plastomatic					
Acid metering pump outlet pressure	PI-602	PLAST OMATIC, RYAN HERCO/PENVALVE	5342-030			Pressure indicator, 0/100psi, bottom mount, oil-filled gauge with PVDF guard seal & Teflon diaphragm, Plastomatic					
Protonation drain pump outlet pressure	PI-603	PLAST OMATIC, RYAN HERCO/PENVALVE	5342-030			Pressure indicator, 0/100psi, bottom mount, oil-filled gauge with PVDF guard seal & Teflon diaphragm, Plastomatic					
Circulation pump outlet pressure	PI-701	Ashcroft	351009SWL04L100 PSI			Circulation pump outlet pressure gauges, 0-100 PSI, 43 1/2in. dial. 316 SS construction wetted parts, glycerin liquid filled, 1/2 in. MNPT LM					
Temperature of water entering LRV pump	TI-201	Ashcroft	20CL60R025 0/250F	0 to 200°F	None	Temperature indicator, 2 IN. DIAL ,0-200 deg.F, 1/4 IN. NPT	Monitors temperature of water exiting tube side of HX and entering LRV pump.	Manual	None	None	FI-203
Discharge separator tank-membrane system	T-201	Membrana	separator 2BV5161				Tank integrated with outlet port of LRV pump to allow separation of gas and liquid. Gas is vented and liquid is drained into a holding tank and recycled for cooling the LRV pump.	None	None	None	None

Name	Tag #	Manufacturer	Model	Capacity	Set Point	Description	Function	Type of Control	Control Sensor(s)	Interlock(s)	Parameters to monitor
LRV Pump holding tank	T-202	US Plastic	5318	55 gal	N/A	closed-head tank, 55 gal, 22-1/4" X 43-1/8"	Tank for collecting liquid from discharge separator tank and recycling through heat exchanger to LRV pump	None	None	None	Manually check level to ensure additional water is not needed.
Transfer Tank	TK-101	Schneider		500 gallons	Low, high, HighHigh	500 GAL. Transfer tank, 48 in. x 74 in. with 18 in. manway, flat bottom, domed top	Receives effluent from ion exchange draining prior to regeneration (pumped at ~ 80 gpm by P-301)); and final regeneration rinse and protonation rinse (introduced at a fixed rate of ~80 gpm based on manually adjusted flows from GV-401 and GV-402, respectively). Level sensors in the tank control P-102 (on/off) to ensure that liquid is pumped at a constant rate (100 gpm) to the front of the system and tank does not overflow.	Automatic - Level sensors	Level sensors in tank: LSL-101, LSH-102, and LSHH-102 control P-102		
Waste holding tank	TK-701A	Baker Corp	6500 gal	6500 gal	N/A	6500 gal Poly tank	Rented storage tank to hold regeneration waste prior to disposal.	Manual	None	None	FE/FIT-301 - To quantify amount of waste added to the tank during regeneration waste to scavenger followed by waste and protonation drain to waste.
Waste holding tank	TK-701B	Baker Corp	6500 gal	6500 gal	N/A	6500 gal Poly tank	Rented storage tank to hold regeneration waste prior to disposal.	Manual	None	None	FE/FIT-301 - To quantify amount of waste added to the tank during regeneration waste to scavenger followed by waste and protonation drain to waste.

Appendix C

Rialto No. 3 WBA IX Demonstration

Test Period Treatment Data

ESTCP PROJECT: ER-1168
ARA PROJECT: 001060

Test Period 1

Start Date/Time	Finish Date/Time	Time Duration (hrs)	Runtime (days)	Flow Setpt (GPM)	Water Totalizer (G) Initial	Water Totalizer (G) Final	Water Processed (G)	Calc BV/day	Actual BV/day	Comments
7/18/11 10:19	7/18/11 12:05	1.77	0.07	800	114476	191435	76959	440	29	flow to basin
7/18/11 14:57	7/18/11 18:51	3.90	0.15	800	191435	364202	172767	440	66	flow to basin
7/19/11 9:05	7/19/11 9:39	0.57	0.02	800	364202	389125	24923	440	10	flow to basin
7/19/11 9:39	7/19/11 14:40	5.02	0.21	800	389125	628300	239175	440	91	flow to reservoir
7/20/11 7:54	7/20/11 9:03	1.15	0.05	800	628394	683852	55458	440	21	flow to basin
7/20/11 10:15	7/20/11 11:03	0.80	0.03	800	683852	720905	37053	440	14	flow to basin
7/20/11 14:14	7/20/11 14:54	0.67	0.03	800	720905	750178	29273	440	11	flow to basin
7/20/11 14:56	7/21/11 2:52	11.93	0.15	800	750178	925917	175739	440	67	reservoir at 800/600/400 gpm, then back to 600
7/21/11 7:27	7/21/11 8:43	1.27	0.00	600	1160843	1162824	1981	330	1	flow to basin
7/21/11 8:43	7/21/11 14:00	5.28	0.22	600	1162824	1350279	187455	330	72	flow to reservoir
7/21/11 14:00	7/21/11 16:00	2.00	0.09	700	1350279	1440730	90451	385	35	flow to reservoir
7/21/11 16:00	7/21/11 21:36	5.60	0.18	800	1440730	1643991	203261	440	78	flow to reservoir
7/22/11 10:46	7/22/11 15:56	5.17	0.22	800	1643991	1892375	248384	440	95	flow to reservoir
7/22/11 16:12	7/23/11 8:22	16.17	0.68	800	1892375	2673949	781574	440	299	flow to reservoir
7/23/11 8:22	7/24/11 7:35	23.22	0.96	800	2673949	3785585	1111636	440	425	flow to reservoir
7/24/11 7:35	7/24/11 9:10	1.58	0.06	800	3785585	3855276	69691	440	27	flow to reservoir
		TOTAL:	3.1			TOTAL:	3,505,780	6,765	1,339	

Test Period 2

Start Date/Time	Finish Date/Time	Time Duration (hrs)	Runtime (days)	Flow Setpt (GPM)	Water Totalizer (G) Initial	Water Totalizer (G) Final	Water Processed (G)	Calc BV/day	Actual BV/day	Comments
7/24/11 9:10	7/24/11 9:20	0.17	0.00	800	0	4781	4781	440	2	flow to reservoir, regen
7/24/11 9:20	7/24/11 19:33	10.22	0.02	800	4781	32877	28096	440	11	flow to reservoir
7/24/11 19:33	7/24/11 19:45	0.20	0.00	800	32877	34122	1245	440	0	flow to reservoir; CR3 shut down @ 1945
7/25/11 8:05	7/26/11 7:50	23.75	0.99	800	34122	1175290	1141168	440	436	flow to reservoir, continue regen
7/26/11 7:50	7/27/11 14:28	30.63	1.21	800	1175290	2573102	1397812	440	534	flow to reservoir, finish regen
7/27/11 14:28	7/28/11 10:13	19.75	0.07	500	2573102	2624061	50959	275	19	flow to reservoir @ reduced flow
7/28/11 10:13	7/29/11 10:19	24.10	1.00	500	2624061	3345310	721249	275	275	Increased flow from 500 GPM to 800 GPM @ 17:23
7/29/11 10:19	7/30/11 8:45	22.43	0.67	800	3345310	4120126	774816	440	296	
7/30/11 8:45	7/31/11 22:20	37.58	1.18	800	4120126	5473755	1353629	440	517	
7/31/11 22:20	8/1/11 8:05	9.75	0.39	800	5473755	5919575	445820	440	170	
		TOTAL:	5.5			TOTAL:	5,919,575	4070	2261	

Test Period 3

Start Date/Time	Finish Date/Time	Time Duration (hrs)	Runtime (days)	Flow Setpt (GPM)	Water Totalizer (G) Initial	Water Totalizer (G) Final	Water Processed (G)	Calc BV/day	Actual BV/day	Comments
8/1/11 8:05	8/2/11 7:00	22.92	0.88	800	0	1018578	1018578	440	389	Started regen vessel B
8/2/11 7:00	8/3/11 12:08	29.13	0.55	800	1018578	1655286	636708	440	243	Completed regen vessel B; PM--pH LoLo; system shutdown overnt
8/3/11 12:08	8/4/11 11:46	23.63	0.89	800	1655286	2685225	1029939	440	393	Restart system @ 1153; low P alarm @ 1447
8/4/11 11:46	8/5/11 11:45	23.98	0.16	800	2685225	2872876	187651	440	72	Lo-lo pH @ 0912; restart; low P alarm @ 1507
8/5/11 11:45	8/6/11 12:10	24.42	0.41	800	2872876	3348069	475193	440	182	Restart @ 1055; hi P alarm @ 2138
8/6/11 12:10	8/7/11 10:00	21.83	0.91	800	3348069	4395590	1047521	440	400	Restart @ 1145
8/7/11 10:00	8/8/11 6:03	20.05	0.83	800	4395590	5356549	960959	440	367	System dwn-broken soda ash lines
8/8/11 6:03	8/18/11 18:40	252.62	0.00	800	5356549	5356549	0	4632	0	Repairs complete--attempted restart 08/10 @ 2000; chk vlv CV-101B brkn--system down
8/18/11 18:40	8/19/11 11:00	16.33	0.61	800	5356549	6060744	704195	440	269	Lo-lo pH 0600 08/19; restart
8/19/11 11:00	8/20/11 8:40	21.67	0.54	800	6060744	6683412	622668	440	238	Lo-lo pH 2328 08/19; restart
8/20/11 8:40	8/21/11 16:15	31.58	0.93	800	6683412	7758528	1075116	440	411	Lo-Lo pH 0600-0700; restart
8/21/11 16:15	8/22/11 9:45	17.50	0.73	800	7758528	8594662	836134	440	319	
8/22/11 9:45	8/23/11 10:04	24.32	0.23	800	8594662	8859579	264917	440	101	HI P shutdwn 1440 08/22; restart 08/23
8/23/11 10:04	8/24/11 7:40	21.60	0.22	800	8859579	9108527	248948	440	95	Rialto 3 down 1440 08/23; restart 08/24
8/24/11 7:40	8/25/11 7:17	23.62	0.28	800	9108527	9436239	327712	440	125	Rialto 3 down @ 1340 08/24; restart @ 1615
8/25/11 7:17	8/26/11 7:00	23.72	0.00	800	9436239	9436239	0	440	0	pH LoLo @ 1750 08/24; restart not successful--soda ash lines plugged solid; shutdown until MT available to fix
8/26/11 7:00	8/27/11 7:00	24.00	0.00	800	9436239	9436239	0	440	0	
8/27/11 7:00	8/28/11 7:00	24.00	0.00	800	9436239	9436239	0	440	0	
8/28/11 7:00	8/29/11 7:00	24.00	0.00	800	9436239	9436239	0	440	0	Rialto 3 down--DOW resin probs
8/29/11 7:00	8/30/11 7:00	24.00	0.00	800	9436239	9436239	0	440	0	Rialto 3 down--DOW resin probs
8/30/11 7:00	8/31/11 7:00	24.00	0.00	800	9436239	9436239	0	440	0	Rialto 3 down--DOW resin probs
8/31/11 7:00	9/1/11 7:00	24.00	0.00	800	9436239	9436239	0	440	0	Rialto 3 down--DOW resin probs; repairs complete; cleaning tank
9/1/11 7:00	9/2/11 7:00	24.00	0.00	800	9436239	9436239	0	440	0	
9/2/11 7:00	9/3/11 7:00	24.00	0.00	800	9436239	9436239	0	440	0	
9/3/11 7:00	9/4/11 7:00	24.00	0.00	800	9436239	9436239	0	440	0	
9/4/11 7:00	9/5/11 7:00	24.00	0.00	800	9436239	9436239	0	440	0	
9/5/11 7:00	9/6/11 7:50	24.83	0.08	800	9436239	9527271	91032	440	35	Restart system @ 1123; pH feed water HiHi shutdown @ 1253 09/05
9/6/11 7:50	9/7/11 7:00	23.17	0.80	800	9527271	10447451	920180	440	351	Restart system @ 0736; Rialto 3 down--low P shutdown (PSH-201) @ 1256 09/06; restart system @1705
9/7/11 7:00	9/8/11 7:00	24.00	0.00	800	10447451	10447451	0	440	0	Rialto 3 down--low P shutdown (PSH-201) @ 0745 09/07; cannot restart
9/8/11 7:00	9/9/11 12:01	29.02	0.00	800	10447451	10447451	0	440	0	Rialto 3 offline--bag filters plugged early AM 09/08; restart @ 1201 09/09
9/9/11 12:01	9/10/11 10:05	22.07	0.21	800	10447451	10685200	237749	440	91	Rialto 3 down--low P shutdown (PSH-201) @ 1600 09/09; restart 0830 09/10
		TOTAL:	9.3			TOTAL:	10,685,200	17,833	4,081	

Test Period 4

Start	Finish	Time Duration	Runtime	Flow Setpt (GPM)	Water Totalizer FQIT-101		Water Processed (G)	Calc	Actual	Comments
Date/Time	Date/Time	(hrs)	(days)		Initial	Final		BV/day	BV/day	
9/10/11 10:05	9/11/11 10:38	24.55	1.02	800	0	1,173,400	1,173,400	440	448	Start regen TP 4/vessel A @ 1005
9/11/11 10:38	9/12/11 9:00	22.37	0.93	800	1,173,400	2,242,300	1,068,900	440	408	
9/12/11 9:00	9/13/11 14:10	29.17	0.08	800	2,242,300	2,331,180	88,880	440	34	Rialto 3 down--low P shutdown (PSH-201) @ 0955 09/12; restart @ 1320 09/13
9/13/11 14:10	9/14/11 10:00	19.83	0.37	800	2,331,180	2,762,500	431,320	440	165	Rialto 3 down--pH LoLo @ 2200 09/14; restart @ 0836 09/14
9/14/11 10:00	9/15/11 9:45	23.75	0.99	800	2,762,500	3,897,660	1,135,160	440	434	
9/15/11 9:45	9/16/11 8:45	23.00	0.81	800	3,897,660	4,830,200	932,540	440	356	
9/16/11 8:45	9/17/11 7:55	23.17	0.96	800	4,830,200	5,940,300	1,110,100	440	424	
9/17/11 7:55	9/18/11 12:30	28.58	1.14	800	5,940,300	7,249,116	1,308,816	440	500	Hi P alarm shutdown @ 1230 09/17: restart @ 1255 09/17
9/18/11 12:30	9/19/11 8:00	19.50	0.57	800	7,249,116	7,911,182	662,066	440	253	Rialto 3 offline--low P shutdown (PSH-201) @ 1348 09/18; restart @ 1830 09/18
9/19/11 8:00	9/20/11 9:35	25.58	0.22	800	7,911,182	8,161,902	250,720	440	96	Rialto 3 offline--low P shutdown (PSH-201) @ 1224 09/19; restart @ 0846 09/20
9/20/11 9:35	9/21/11 9:12	23.62	0.23	800	8,161,902	8,431,768	269,866	440	103	Rialto 3 offline--low P shutdown (PSH-201) @ XXXX 09/20; restart @ 0912 09/21
9/21/11 9:12	9/22/11 7:15	22.05	0.23	800	8,431,768	8,696,951	265,183	440	101	Rialto 3 offline--low P shutdown (PSH-201) @ 1454 09/21; restart @ 0715 09/22
9/22/11 7:15	9/23/11 14:05	30.83	0.26	800	8,696,951	8,997,974	301,023	440	115	Rialto 3 offline--low P shutdown (PSH-201) @ 1323 09/22; restart @ 1353 09/23
9/23/11 14:05	9/24/11 7:05	17.00	0.01	800	8,997,974	9,012,217	14,243	440	5	Rialto 3 offline--low P shutdown (PSH-201) @ 1442 09/24; could not restart
9/24/11 7:05	9/25/11 0:00	16.92	0.00	800	9,012,217	9,012,217	0	440	0	Rialto 3 offline--high P diff/electrical problems
9/25/11 0:00	9/26/11 0:00	24.00	0.00	800	9,012,217	9,012,217	0	440	0	Rialto 3 offline--pump motor repairs
9/26/11 0:00	9/27/11 0:00	24.00	0.00	800	9,012,217	9,012,217	0	440	0	Rialto 3 offline--pump motor repairs
9/27/11 0:00	9/28/11 0:00	24.00	0.00	800	9,012,217	9,012,217	0	440	0	Rialto 3 offline--pump motor repairs
9/28/11 0:00	9/29/11 0:00	24.00	0.00	800	9,012,217	9,012,217	0	440	0	Rialto 3 offline--pump motor repairs
9/29/11 0:00	9/30/11 0:00	24.00	0.00	800	9,012,217	9,012,217	0	440	0	Rialto 3 offline--pump motor repairs
9/30/11 0:00	10/1/11 0:00	24.00	0.00	800	9,012,217	9,012,217	0	440	0	Rialto 3 offline--pump motor repairs
10/1/11 0:00	10/2/11 0:00	24.00	0.00	800	9,012,217	9,012,217	0	440	0	Rialto 3 offline--pump motor repairs
10/2/11 0:00	10/3/11 0:00	24.00	0.00	800	9,012,217	9,012,217	0	440	0	Rialto 3 offline--pump motor repairs
10/3/11 0:00	10/4/11 0:00	24.00	0.00	800	9,012,217	9,012,217	0	440	0	WBA IX offline--foreign materials in Siemens resin; no restart allowed
10/4/11 0:00	10/5/11 0:00	24.00	0.00	800	9,012,217	9,012,217	0	440	0	WBA IX offline--foreign materials in Siemens resin; no restart allowed
10/5/11 0:00	10/6/11 0:00	24.00	0.00	800	9,012,217	9,012,217	0	440	0	WBA IX offline--foreign materials in Siemens resin; no restart allowed
10/6/11 0:00	10/7/11 0:00	24.00	0.00	800	9,012,217	9,012,217	0	440	0	WBA IX offline--foreign materials in Siemens resin; no restart allowed
10/7/11 0:00	10/8/11 0:00	24.00	0.00	800	9,012,217	9,012,217	0	440	0	WBA IX offline--foreign materials in Siemens resin; no restart allowed
10/8/11 0:00	10/9/11 0:00	24.00	0.00	800	9,012,217	9,012,217	0	440	0	WBA IX offline--foreign materials in Siemens resin; no restart allowed
10/9/11 0:00	10/10/11 0:00	24.00	0.00	800	9,012,217	9,012,217	0	440	0	WBA IX offline--foreign materials in Siemens resin; no restart allowed
10/10/11 0:00	10/11/11 13:30	37.50	0.00	800	9,012,217	9,012,217	0	440	0	WBA IX offline--foreign materials in Siemens resin; no restart allowed
10/11/11 13:30	10/12/11 9:15	19.75	0.85	800	9,012,217	9,992,194	979,977	440	374	Startup 10/11 @ 1330
10/12/11 9:15	10/13/11 16:20	31.08	0.78	800	9,992,194	10,887,172	894,978	440	342	Rialto 3 offline--low P shutdown (PSH-201) @ 1441 10/12; restart @ 2251 10/12
10/13/11 16:20	10/14/11 10:03	17.72	0.01	800	10,887,172	10,896,365	9,193	440	4	Rialto 3 offline--low P shutdown (PSH-201) @ 1236 10/13; restart @ 1003 10/14
10/14/11 10:03	10/15/11 11:12	25.15	0.24	800	10,896,365	11,175,254	278,889	440	107	Rialto 3 offline--low P shutdown (PSH-201) @ 1534 10/14; restart @ 1105 10/15
10/15/11 11:12	10/16/11 15:02	27.83	0.88	800	11,175,254	12,192,411	1,017,157	440	389	Rialto 3 offline--high P shutdown (Line Over Pressure) @ 1153 10/15; restart @ 1812 10/15
10/16/11 15:02	10/17/11 9:58	18.93	0.79	800	12,192,411	13,104,107	911,696	440	348	
10/17/11 9:58	10/18/11 18:40	32.70	1.32	800	13,104,107	14,628,409	1,524,302	440	582	Rialto 3 offline--low flow (FT-101 IX Feed Low Low) @ 1101 (Siemens unannounced maintenance); restart @ 1148 10/17
10/18/11 18:40	10/19/11 9:25	14.75	0.28	800	14,628,409	14,955,079	326,670	440	125	10/19 0128 Treated Water pH LoLo--strainer clogged; restart @ 0910 10/19
10/19/11 9:25	10/20/11 16:20	30.92	1.04	800	14,955,079	16,149,404	1,194,325	440	456	
10/20/11 16:20	10/21/11 15:45	23.42	0.95	800	16,149,404	17,248,926	1,099,522	440	420	10/21 1510 treated water pH LoLo--soda ash out; restart 1605 10/21
10/21/11 15:45	10/22/11 7:05	15.33	0.63	800	17,248,926	17,970,806	721,880	440	276	Shutdown--soda ash pumps leaking
10/22/11 7:05	10/23/11 7:00	23.92	0.00	800	17,970,806	17,970,806	0	440	0	Troubleshooting soda ash pumps
10/23/11 7:00	10/24/11 7:00	24.00	0.00	800	17,970,806	17,970,806	0	440	0	Troubleshooting soda ash pumps
10/24/11 7:00	10/25/11 7:00	24.00	0.00	800	17,970,806	17,970,806	0	440	0	Troubleshooting soda ash pumps
10/25/11 7:00	10/26/11 7:00	24.00	0.00	800	17,970,806	17,970,806	0	440	0	Soda ash static mixer/injector damaged during troubleshooting
10/26/11 7:00	10/27/11 7:00	24.00	0.00	800	17,970,806	17,970,806	0	440	0	
10/27/11 7:00	10/28/11 7:00	24.00	0.00	800	17,970,806	17,970,806	0	440	0	
10/28/11 7:00	10/29/11 7:00	24.00	0.00	800	17,970,806	17,970,806	0	440	0	
10/29/11 7:00	10/30/11 7:00	24.00	0.00	800	17,970,806	17,970,806	0	440	0	
10/30/11 7:00	10/31/11 7:00	24.00	0.00	800	17,970,806	17,970,806	0	440	0	
10/31/11 7:00	11/1/11 7:00	24.00	0.00	800	17,970,806	17,970,806	0	440	0	
11/1/11 7:00	11/2/11 7:00	24.00	0.00	800	17,970,806	17,970,806	0	440	0	
11/2/11 7:00	11/3/11 7:00	24.00	0.00	800	17,970,806	17,970,806	0	440	0	
11/3/11 7:00	11/4/11 7:00	24.00	0.00	800	17,970,806	17,970,806	0	440	0	
11/4/11 7:00	11/5/11 7:00	24.00	0.00	800	17,970,806	17,970,806	0	440	0	
11/5/11 7:00	11/6/11 7:00	24.00	0.00	800	17,970,806	17,970,806	0	440	0	
11/6/11 7:00	11/7/11 7:00	24.00	0.00	800	17,970,806	17,970,806	0	440	0	
11/7/11 7:00	11/8/11 7:00	24.00	0.00	800	17,970,806	17,970,806	0	440	0	
11/8/11 7:00	11/9/11 7:00	24.00	0.00	800	17,970,806	17,970,806	0	440	0	
11/9/11 7:00	11/10/11 7:00	24.00	0.00	800	17,970,806	17,970,806	0	440	0	
11/10/11 7:00	11/11/11 7:00	24.00	0.00	800	17,970,806	17,970,806	0	440	0	Static mixer repaired; reservoirs are full--CR#3 offline/unable to startup
11/11/11 7:00	11/12/11 7:00	24.00	0.00	800	17,970,806	17,970,806	0	440	0	CR#3 offline/unable to startup
11/12/11 7:00	11/13/11 7:00	24.00	0.00	800	17,970,806	17,970,806	0	440	0	CR#3 offline/unable to startup
11/13/11 7:00	11/14/11 12:25	29.42	0.01	800	17,970,806	17,983,284	12,478	440	5	Startup/ph LoLo--soda ash feed off/restart 11/17 PM
11/14/11 12:25	11/15/11 8:45	20.33	0.74	800	17,983,284	18,839,194	855,910	440	327	
11/15/11 8:45	11/16/11 7:00	22.25	0.17	800	18,839,194	19,030,498	191,304	440	73	CR3 offline @ 0945 11/15 for testing; restart @ 1045; CR3 offline @ XXXX--UV lamps out
11/16/11 7:00	11/30/11 0:00	329.00	0.00	800	19,030,498	19,030,498	0	440	0	CR3 offline; unable to restart
11/30/11 0:00	12/5/11 7:00	127.00	0.00	800	19,030,498	19,030,498	0	440	0	CR3 offline; restart system @ XXXX
12/5/11 7:00	12/6/11 7:00	24.00	0.00	800	19,030,498	19,030,498	0	440	0	
12/6/11 7:00	12/7/11 7:00	24.00	0.00	800	19,030,498	19,030,498	0	440	0	
12/7/11 7:00	12/8/11 7:00	24.00	0.00	800	19,030,498	19,030,498	0	440	0	End of Demo
		TOTAL:	16.5			TOTAL:	19,030,498	18,041	6,589	

July 2010

Start	Finish	Time Duration (hrs)	Runtime (days)	Flow Setpt (GPM)	Water Totalizer		Water Processed (G)	Comments
Date/Time	Date/Time				Initial	Final		
7/18/11 10:19	7/18/11 12:05	1.8	0.1	800	114,476	191,435	76,959	basin
7/18/11 14:57	7/18/11 18:51	3.9	0.1	800	191,435	364,202	172,767	basin
7/19/11 9:05	7/19/11 9:39	0.6	0.0	800	364,202	389,125	24,923	basin
7/19/11 9:39	7/19/11 14:40	5.0	0.2	800	389,125	628,300	239,175	reservoir
7/20/11 7:54	7/20/11 9:03	1.1	0.0	800	628,394	683,852	55,458	basin
7/20/11 10:15	7/20/11 11:03	0.8	0.0	800	683,852	720,905	37,053	basin
7/20/11 14:14	7/20/11 14:54	0.7	0.0	800	720,905	750,178	29,273	basin
7/20/11 14:56	7/21/11 2:52	11.9	0.2	800	750,178	925,917	175,739	reservoir at 800/600/400 gpm, then back to 600
7/21/11 7:27	7/21/11 8:43	1.3	0.0	600	1,160,843	1,162,824	1,981	basin
7/21/11 8:43	7/21/11 14:00	5.3	0.2	600	1,162,824	1,350,279	187,455	reservoir
7/21/11 14:00	7/21/11 16:00	2.0	0.1	700	1,350,279	1,440,730	90,451	reservoir
7/21/11 16:00	7/21/11 21:36	5.6	0.2	800	1,440,730	1,643,991	203,261	reservoir
7/22/11 10:46	7/22/11 15:56	5.2	0.2	800	1,643,991	1,892,375	248,384	reservoir
7/22/11 16:12	7/23/11 8:22	16.2	0.7	800	1,892,375	2,673,949	781,574	reservoir
7/23/11 8:22	7/24/11 7:35	23.2	1.0	800	2,673,949	3,785,585	1,111,636	reservoir
7/24/11 7:35	7/24/11 9:10	1.6	0.1	800	3,785,585	3,855,276	69,691	reservoir
7/24/11 9:10	7/24/11 9:20	0.2	0.0	800	0	4,781	4,781	reservoir, regen
7/24/11 9:20	7/24/11 19:33	10.2	0.0	800	4,781	32,877	28,096	reservoir
7/24/11 19:33	7/24/11 19:45	0.2	0.0	800	32,877	34,122	1,245	reservoir; city well shut down @ 1945
7/25/11 8:05	7/26/11 7:50	23.8	1.0	800	34,122	1,175,290	1,141,168	reservoir, continue regen
7/26/11 7:50	7/27/11 14:28	30.6	1.2	800	1,175,290	2,573,102	1,397,812	reservoir, finish regen
7/27/11 14:28	7/28/11 10:13	19.7	0.1	500	2,573,102	2,624,061	50,959	Reservoir @ reduced flow
7/28/11 10:13	7/29/11 10:19	24.1	1.0	500	2,624,061	3,345,310	721,249	Raised flow from 500 GPM to 800 GPM @ 17:23
7/29/11 10:19	7/30/11 8:45	22.4	0.7	800	3,345,310	4,120,126	774,816	Reservoir
7/30/11 8:45	7/31/11 22:20	37.6	1.2	800	4,120,126	5,473,755	1,353,629	Reservoir
7/31/11 22:20	8/1/11 8:05	9.8	0.4	800	5,473,755	5,919,575	445,820	Reservoir
		TOTAL:	8.6				9,425,355	

August 2010

Start	Finish	Time Duration (hrs)	Runtime (days)	Flow Setpt (GPM)	Water Totalizer		Water Processed (G)	Comments
Date/Time	Date/Time				Initial	Final		
8/1/11 8:05	8/2/11 7:00	22.9	0.9	800	0	1,018,578	1,018,578	Started regen vessel B; vessel A lead
8/2/11 7:00	8/3/11 12:08	29.1	0.6	800	1,018,578	1,655,286	636,708	Completed regen vessel B; PM--pH LoLo; system shutdown overnt
8/3/11 12:08	8/4/11 11:46	23.6	0.9	800	1,655,286	2,685,225	1,029,939	Restart system @ 1153; low P alarm @ 1447
8/4/11 11:46	8/5/11 11:45	24.0	0.2	800	2,685,225	2,872,876	187,651	Lo-lo pH @ 0912; restart; low P alarm @ 1507
8/5/11 11:45	8/6/11 12:10	24.4	0.4	800	2,872,876	3,348,069	475,193	Restart @ 1055; hi P alarm @ 2138
8/6/11 12:10	8/7/11 10:00	21.8	0.9	800	3,348,069	4,395,590	1,047,521	Restart @ 1145
8/7/11 10:00	8/8/11 6:03	20.1	0.8	800	4,395,590	5,356,549	960,959	System dwn-broken soda ash lines
8/8/11 6:03	8/18/11 16:40	250.6	0.0	800	5,356,549	5,356,549	0	Repairs complete--attempted restart 08/10 @ 2000; chk vlv CV-101B brkn--system down
8/18/11 16:40	8/19/11 11:00	18.3	0.6	800	5,356,549	6,060,744	704,195	Lo-lo pH 0600 08/19; restart
8/19/11 11:00	8/20/11 8:40	21.7	0.5	800	6,060,744	6,683,412	622,668	Lo-lo pH 2328 08/19; restart
8/20/11 8:40	8/21/11 16:10	31.5	0.9	800	6,683,412	7,758,528	1,075,116	Lo-Lo pH 0600-0700; restart
8/21/11 16:10	8/22/11 9:50	17.7	0.7	800	7,758,528	8,594,662	836,134	
8/22/11 9:50	8/23/11 9:25	23.6	0.2	800	8,594,662	8,859,579	264,917	Hi P shutdwn 1440 08/22; restart 08/23
8/23/11 9:25	8/24/11 7:00	21.6	0.2	800	8,859,579	9,108,527	248,948	Rialto 3 down 1440 08/23; restart 08/24
8/24/11 7:00	8/25/11 7:00	24.0	0.3	800	9,108,527	9,443,950	335,423	Rialto 3 down @ 1340 08/24; restart @ 1615
8/25/11 7:00	8/31/11 7:00	144.0	0.0	800	9,443,950	9,443,950	0	pH LoLo @ 1750 08/24; restart not successful--soda ash lines plugged solid; shutdown until MT available to fix
		TOTAL:	8.2		TOTAL		9,443,950	

September 2010

Start Date/Time	Finish Date/Time	Time Duration (hrs)	Runtime (days)	Flow Setpt (GPM)	Water Totalizer Initial	Water Totalizer Final	Water Processed (G)	Comments
9/1/11 7:00	9/2/11 7:00	24.0	0.0	800	9,436,239	9,436,239	0	Rialto 3 offline/soda ash repairs
9/2/11 7:00	9/3/11 7:00	24.0	0.0	800	9,436,239	9,436,239	0	
9/3/11 7:00	9/4/11 7:00	24.0	0.0	800	9,436,239	9,436,239	0	
9/4/11 7:00	9/5/11 7:00	24.0	0.0	800	9,436,239	9,436,239	0	
9/5/11 7:00	9/6/11 7:50	24.8	0.1	800	9,436,239	9,527,271	91,032	Restart system @ 1123; pH feed water HiHi shutdown @ 1253 09/05
9/6/11 7:50	9/7/11 7:00	23.2	0.8	800	9,527,271	10,447,451	920,180	Restart system @ 0736; Rialto 3 offline--low P shutdown (PSH-201) @ 1256 09/06; restart system @1705
9/7/11 7:00	9/8/11 7:00	24.0	0.0	800	10,447,451	10,447,451	0	Rialto 3 offline--low P shutdown (PSH-201) @ 0745 09/07; could not restart
9/8/11 7:00	9/9/11 12:01	29.0	0.0	800	10,447,451	10,447,451	0	Rialto 3 offline--bag filters plugged early AM 09/08; restart @ 1201 09/09
9/9/11 12:01	9/10/11 9:38	21.6	0.2	800	10,447,451	10,664,000	216,549	Rialto 3 offline--low P shutdown (PSH-201) @ 1600 09/09; restart 0830 09/10
9/10/11 9:38	9/10/11 10:05	0.5	0.0	800	10,664,000	10,685,200	21,200	Start regen vessel A @ 1005
9/10/11 10:05	9/11/11 10:38	24.6	1.0	800	0	1,173,400	1,173,400	Start Test Period 4
9/11/11 10:38	9/12/11 9:00	22.4	0.9	800	1,173,400	2,242,300	1,068,900	
9/12/11 9:00	9/13/11 14:10	29.2	0.1	800	2,242,300	2,331,180	88,880	Rialto 3 offline--low P shutdown (PSH-201) @ 0955 09/12; restart @ 1320 09/13
9/13/11 14:10	9/14/11 10:00	19.8	0.4	800	2,331,180	2,762,500	431,320	pH LoLo @ 2200 09/13; restart @ 0836 09/14
9/14/11 10:00	9/15/11 9:45	23.8	1.0	800	2,762,500	3,897,660	1,135,160	
9/15/11 9:45	9/16/11 8:45	23.0	0.8	800	3,897,660	4,830,200	932,540	Hi P alarm shutdown @ 1124 09/15; restart system @ 1456
9/16/11 8:45	9/17/11 7:55	23.2	1.0	800	4,830,200	5,940,300	1,110,100	
9/17/11 7:55	9/18/11 12:30	28.6	1.1	800	5,940,300	7,227,982	1,287,682	Hi P alarm shutdown @ 1657 09/17: restart @ 1728
9/18/11 12:30	9/19/11 8:00	19.5	0.6	800	7,227,982	7,911,182	683,200	Rialto 3 offline--low P shutdown (PSH-201) @ 1348 09/18; restart @ 1830 09/18
9/19/11 8:00	9/20/11 9:35	25.6	0.2	800	7,911,182	8,161,902	250,720	Rialto 3 offline--low P shutdown (PSH-201) @ 1224 09/19; restart @ 0846 09/20
9/20/11 9:35	9/21/11 9:12	23.6	0.2	800	8,161,902	8,431,768	269,866	Rialto 3 offline--low P shutdown (PSH-201) @ 1502 09/20; restart @ 0912 09/21
9/21/11 9:12	9/22/11 7:15	22.1	0.2	800	8,431,768	8,696,951	265,183	Rialto 3 offline--low P shutdown (PSH-201) @ 1454 09/21; restart @ 0715 09/22
9/22/11 7:15	9/23/11 14:05	30.8	0.3	800	8,696,951	8,997,974	301,023	Rialto 3 offline--low P shutdown (PSH-201) @ 1323 09/22; restart @ 1353 09/23
9/23/11 14:05	9/24/11 0:00	9.9	0.0	800	8,997,974	9,012,217	14,243	Rialto 3 offline--low P shutdown (PSH-201) @ 1442 09/23; could not restart
9/24/11 0:00	9/25/11 0:00	24.0	0.0	800	9,012,217	9,012,217	0	Rialto 3 offline--high P diff/electrical problems
9/25/11 0:00	9/26/11 0:00	24.0	0.0	800	9,012,217	9,012,217	0	Rialto 3 offline--pump motor repairs
9/26/11 0:00	9/27/11 0:00	24.0	0.0	800	9,012,217	9,012,217	0	Rialto 3 offline--pump motor repairs
9/27/11 0:00	9/28/11 0:00	24.0	0.0	800	9,012,217	9,012,217	0	Rialto 3 offline--pump motor repairs
9/28/11 0:00	9/29/11 0:00	24.0	0.0	800	9,012,217	9,012,217	0	Rialto 3 offline--pump motor repairs
9/29/11 0:00	9/30/11 0:00	24.0	0.0	800	9,012,217	9,012,217	0	Rialto 3 offline--pump motor repairs
9/30/11 0:00	10/1/11 0:00	24.0	0.0	800	9,012,217	9,012,217	0	Rialto 3 offline--pump motor repairs
		TOTAL:	**8.9**		**TOTAL**		**10,261,178**	

October 2010

Start	Finish	Time Duration	Runtime	Flow Setpt (GPM)	Water Totalizer		Water Processed (G)	Comments
Date/Time	Date/Time	(hrs)	(days)		Initial	Final		
10/1/11 0:00	10/2/11 0:00	24.00	0.0	800	9,012,217	9,012,217	0	Rialto 3 offline--pump motor repairs
10/2/11 0:00	10/3/11 0:00	24.00	0.0	800	9,012,217	9,012,217	0	Rialto 3 offline--pump motor repairs
10/3/11 0:00	10/4/11 0:00	24.00	0.0	800	9,012,217	9,012,217	0	WBA IX system offline--not permitted to restart due to foreign materials in Siemens resin beds
10/4/11 0:00	10/5/11 0:00	24.00	0.0	800	9,012,217	9,012,217	0	WBA IX system offline--not permitted to restart due to foreign materials in Siemens resin beds
10/5/11 0:00	10/6/11 0:00	24.00	0.0	800	9,012,217	9,012,217	0	WBA IX system offline--not permitted to restart due to foreign materials in Siemens resin beds
10/6/11 0:00	10/7/11 0:00	24.00	0.0	800	9,012,217	9,012,217	0	WBA IX system offline--not permitted to restart due to foreign materials in Siemens resin beds
10/7/11 0:00	10/8/11 0:00	24.00	0.0	800	9,012,217	9,012,217	0	WBA IX system offline--not permitted to restart due to foreign materials in Siemens resin beds
10/8/11 0:00	10/9/11 0:00	24.00	0.0	800	9,012,217	9,012,217	0	WBA IX system offline--not permitted to restart due to foreign materials in Siemens resin beds
10/9/11 0:00	10/10/11 0:00	24.00	0.0	800	9,012,217	9,012,217	0	WBA IX system offline--not permitted to restart due to foreign materials in Siemens resin beds
10/10/11 0:00	10/11/11 1:30	25.50	0.0	800	9,012,217	9,012,217	0	WBA IX system offline--not permitted to restart due to foreign materials in Siemens resin beds
10/11/11 1:30	10/12/11 9:15	31.75	0.9	800	9,012,217	9,992,194	979,977	Start up system 10/11 @ 1330
10/12/11 9:15	10/13/11 16:20	31.08	0.8	800	9,992,194	10,887,172	894,978	Rialto 3 offline--low P shutdown (PSH-201) @ 1441 10/12; restart @ 2251 10/12
10/13/11 16:20	10/14/11 10:03	17.72	0.0	800	10,887,172	10,896,365	9,193	Rialto 3 offline--low P shutdown (PSH-201) @ 1236 10/13; restart @ 1003 10/14
10/14/11 10:03	10/15/11 11:12	25.15	0.2	800	10,896,365	11,175,254	278,889	Rialto 3 offline--low P shutdown (PSH-201) @ 1534 10/14; restart @ 1105 10/15
10/15/11 11:12	10/16/11 15:02	27.83	0.9	800	11,175,254	12,192,411	1,017,157	Rialto 3 offline--high P shutdown (Line Over Pressure) @ 1153 10/15; restart @ 1812 10/15
10/16/11 15:02	10/17/11 9:58	18.93	0.8	800	12,192,411	13,104,107	911,696	
10/17/11 9:58	10/18/11 18:40	32.70	1.3	800	13,104,107	14,628,409	1,524,302	Rialto 3 offline--low flow (FT-101 IX Feed Low Low) @ 1101 (County/Siemens unscheduled maintenance); restart @ 1148 10/17
10/18/11 18:40	10/19/11 9:25	14.75	0.3	800	14,628,409	14,955,079	326,670	0128 10/19 Treated Water pH LoLo--strainer clogged; restart @ 0910 10/19
10/19/11 9:25	10/20/11 16:20	30.92	1.0	800	14,955,079	16,149,404	1,194,325	
10/20/11 16:20	10/21/11 15:45	23.42	1.0	800	16,149,404	17,248,926	1,099,522	10/21 1510 treated water pH LoLo--soda ash out; restart 1605 10/21
10/21/11 15:45	10/22/11 7:05	15.33	0.6	800	17,248,926	17,970,806	721,880	Shutdown--soda ash pumps leaking
10/22/11 7:05	10/23/11 7:00	23.92	0.0	800	17,970,806	17,970,806	0	Troubleshooting soda ash pumps
10/23/11 7:00	10/24/11 7:00	24.00	0.0	800	17,970,806	17,970,806	0	Troubleshooting soda ash pumps
10/24/11 7:00	10/25/11 7:00	24.00	0.0	800	17,970,806	17,970,806	0	Troubleshooting soda ash pumps
10/25/11 7:00	10/26/11 7:00	24.00	0.0	800	17,970,806	17,970,806	0	Soda ash static mixer/injector damaged during troubleshooting
10/26/11 7:00	10/27/11 7:00	24.00	0.0	800	17,970,806	17,970,806	0	Down
10/27/11 7:00	10/28/11 7:00	24.00	0.0	800	17,970,806	17,970,806	0	Down
10/28/11 7:00	10/29/11 7:00	24.00	0.0	800	17,970,806	17,970,806	0	Down
10/29/11 7:00	10/30/11 7:00	24.00	0.0	800	17,970,806	17,970,806	0	Down
10/30/11 7:00	10/31/11 7:00	24.00	0.0	800	17,970,806	17,970,806	0	Down
10/31/11 7:00	11/1/11 0:00	17.00	0.0	800	17,970,806	17,970,806	0	Down
		TOTAL:	7.8		TOTAL		8,958,589	

November 2010

Start	Finish	Time Duration	Runtime	Flow Setpt (GPM)	Water Totalizer		Water Processed (G)	Comments
Date/Time	Date/Time	(hrs)	(days)		Initial	Final		
11/1/11 7:00	11/2/11 7:00	24.0	0.0	800	17,970,806	17,970,806	0	Broken soda ash static mixer
11/2/11 7:00	11/3/11 7:00	24.0	0.0	800	17,970,806	17,970,806	0	Broken soda ash static mixer
11/3/11 7:00	11/4/11 7:00	24.0	0.0	800	17,970,806	17,970,806	0	Broken soda ash static mixer
11/4/11 7:00	11/5/11 7:00	24.0	0.0	800	17,970,806	17,970,806	0	Broken soda ash static mixer
11/5/11 7:00	11/6/11 7:00	24.0	0.0	800	17,970,806	17,970,806	0	Broken soda ash static mixer
11/6/11 7:00	11/7/11 7:00	24.0	0.0	800	17,970,806	17,970,806	0	Broken soda ash static mixer
11/7/11 7:00	11/8/11 7:00	24.0	0.0	800	17,970,806	17,970,806	0	Broken soda ash static mixer
11/8/11 7:00	11/9/11 7:00	24.0	0.0	800	17,970,806	17,970,806	0	Broken soda ash static mixer
11/9/11 7:00	11/10/11 7:00	24.0	0.0	800	17,970,806	17,970,806	0	Broken soda ash static mixer
11/10/11 7:00	11/11/11 7:00	24.0	0.0	800	17,970,806	17,970,806	0	Static mixer repaired; reservoirs are full--CR#3 offline/unable to startup
11/11/11 7:00	11/12/11 7:00	24.0	0.0	800	17,970,806	17,970,806	0	CR#3 offline/unable to startup
11/12/11 7:00	11/13/11 7:00	24.0	0.0	800	17,970,806	17,970,806	0	CR#3 offline/unable to startup
11/13/11 7:00	11/14/11 12:25	29.4	0.0	800	17,970,806	17,983,284	12,478	Startup 11/14 @ 1225; forgot to turn on soda ash--offline @ 1304; restart @ 1624
11/14/11 12:25	11/15/11 8:45	20.3	0.7	800	17,983,284	18,839,194	855,910	
11/15/11 8:45	11/16/11 7:00	22.2	0.2	800	18,839,194	19,030,498	191,304	CR3 offline @ 0945 11/15 for testing; restart @ 1045; CR3 offline @ 1335--UV lamps out
11/16/11 7:00	11/30/11 7:00	336.0	0.0	800	19,030,498	19,030,498	0	CR3 offline; unable to restart
		TOTAL:	0.9		TOTAL		1,059,692	

December 2010

Start	Finish	Time Duration	Runtime	Flow Setpt (GPM)	Water Totalizer		Water Processed (G)	Comments
Date/Time	Date/Time	(hrs)	(days)		Initial	Final		
12/1/11 7:00	12/2/11 7:00	24.0	0.0	800	18,839,194	18,839,194	0	CR3 offline; UV lamp problems
12/2/11 7:00	12/3/11 7:00	24.0	0.0	800	18,839,194	18,839,194	0	CR3 offline
12/3/11 7:00	12/4/11 7:00	24.0	0.0	800	18,839,194	18,839,194	0	CR3 offline
12/4/11 7:00	12/5/11 7:00	24.0	0.0	800	18,839,194	18,839,194	0	CR3 offline
12/5/11 7:00	12/6/11 7:00	24.0	0.0	800	18,839,194	18,839,194	0	CR3 offline
12/6/11 7:00	12/7/11 7:00	24.0	0.0	800	18,839,194	18,839,194	0	CR3 offline
12/7/11 7:00	12/8/11 7:00	24.0	0.0	800	18,839,194	18,839,194	0	End of Demo
		TOTAL:	0.0		TOTAL		0	