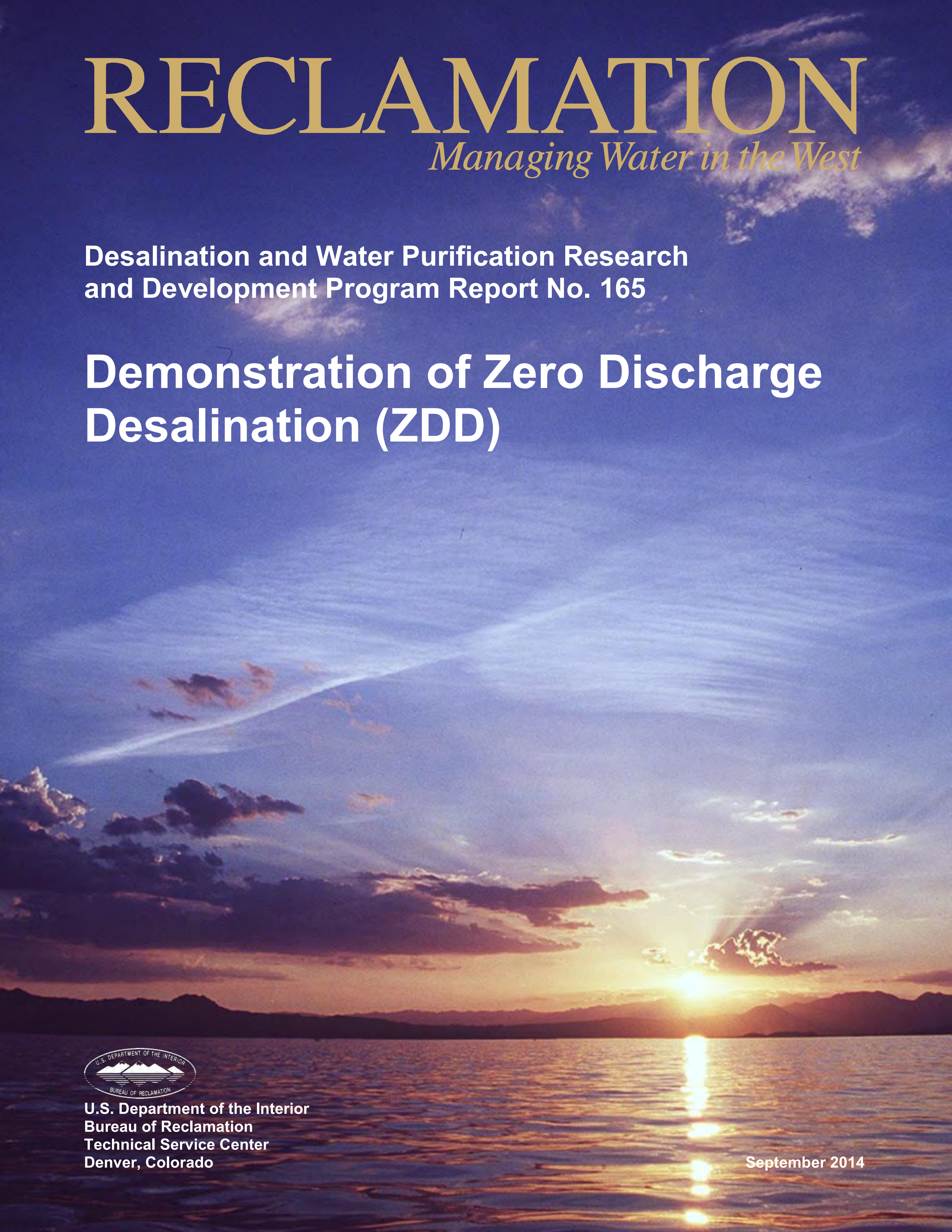

RECLAMATION

*Managing Water in the West*

Desalination and Water Purification Research
and Development Program Report No. 165

# Demonstration of Zero Discharge Desalination (ZDD)

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

September 2014

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Zero Discharge Desalination (ZDD) is a high recovery desalination process capable of extracting up to 98% of the water from brackish groundwater that has high levels of calcium sulfate, silica, and other problematic dissolved constituents. ZDD is comprised of a primary desalination process, typically reverse osmosis (RO) or nanofiltration (NF), and a secondary process called electrodialysis metatheses (EDM).

This report summarizes the results obtained from a multi-year research effort demonstrating Zero Discharge Desalination (ZDD). This effort was a collaborative project between The University of Texas at El Paso's Center for Inland Desalination Systems (CIDS) and Veolia Water Technologies (Veolia). Livingston Associates provided operational support and technical assistance. ZDD was demonstrated at the Brackish Groundwater National Desalination Research Facility (BGNDRF) in Alamogordo, New Mexico, and piloted in Colorado and California. High recovery (96-98% overall recovery) was demonstrated at each site and data for evaluating capital and operational and maintenance costs were gathered for use in cost models.

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## Desalination and Water Purification Research and Development Program Report No. 165

# Demonstration of Zero Discharge Desalination (ZDD)

### Prepared for the Bureau of Reclamation
### Under Agreement No. R10AP81212

*By*

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**Bureau of Reclamation**
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**Denver, Colorado**

**September 2014**

# MISSION STATEMENTS

## Disclaimer

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# Acronyms and Abbreviations

| | |
|---|---|
| AACE | American Association of Cost Engineers |
| AEM | anion-exchange membrane |
| AFY | acre feet per year |
| AMTA | American Membrane Technology Association |
| BGNDRF | Brackish Groundwater National Desalination Research Facility |
| BWRO | Brackish water reverse osmosis |
| CapEx | Capital Cost (Expense) |
| CapEx | Capital Cost |
| CCD™ | Closed circuit desalination |
| CEM | cation-exchange membrane |
| CERRO™ | Concentrate Enhanced Recovery Reverse Osmosis (), |
| CIDS | Center for Inland Desalination Systems |
| CIP | Clean In Place |
| DI | deionized |
| DWI | deep well injection |
| DWPR | Desalination and Water Purification Research |
| ED | electrodialysis |
| EDM | electrodialysis metathesis |
| EDR | electrodialysis reversal |
| E-Rinse | electrode rinse |
| EDM | electrode rinse stream |
| EWM | Enviro Water Minerals Company |
| F | Faraday's constant |
| GAO | Government Accountability Office |
| Hall | Hall Environmental Analysis Laboratory |
| HDPE | High density polyethylene |
| HEEPM™ | High Efficiency Electro-Pressure Membrane |
| HERO™ | High Efficiency Reverse Osmosis |
| I/O | input/output |
| IC | ion chromatography |
| ICP-OES | inductively coupled plasma atomic emission spectroscopy |
| IWA | International Water Association (co-publisher of WERF 5T10 report) |
| MEGA | MEGA Group |
| NF | nanofiltration |
| NTU | Nephelometric Turbidity Unit |
| O&M | operations and maintenance |
| OpEx | operational cost (expense) |
| Panoche | Panoche Irrigation District of California () |
| PLC | programmable logic controller |
| quad | Repeating set in an EDM stack with four membranes and four spacers |
| Reclamation | Bureau of Reclamation |
| RO | Reverse osmosis |
| RTN | Relative transport number |
| Sandia | Sandia National Laboratories |
| SARI | Santa Ana Regional Interceptor |
| SCADA | Supervisory control and data acquisition |
| SMCL | secondary maximum contaminant level |
| SPARRO | slurry precipitation and recycle reverse osmosis |
| Stack | EDM system comprised of electrodes, membranes, spacers, and connectors |
| TDS | total dissolved solids |
| USC | University of South Carolina |
| UTEP | The University of Texas at El Paso |
| VAC | volts alternating current |
| VDC | volts direct current |
| Veolia | Veolia Water Technologies |
| VSEP™ | Vibratory shear enhanced process ( |
| WERF | Water Environment Research Foundation (co-publisher of WERF 5T10) |
| ZDD | Zero Discharge Desalination |
| ZLD | Zero Liquid Desalination |

# Chemical Abbreviations

| | |
|---|---|
| $CaCl_2$ | calcium chloride, |
| $CaCO_3$ | calcium carbonate |
| $Ca_3(PO_4)_2$ | calcium phosphate |
| $CaSO_4$ | calcium sulfate |
| $CO_2$ | carbon dioxide, |
| $HCO_3$ | bicarbonate |
| KCl | potassium chloride |
| $Mg(OH)_2$ | magnesium hydroxide |
| Na/Ca | Ratio of concentration of sodium to calcium (in meq/L) |
| NaCl | sodium chloride |
| NaOH | sodium hydroxide, |
| $Na_2SO_4$ | sodium sulfate, |

# Measurements

| | |
|---|---|
| $/kgal | dollars per thousand gallons |
| A | amps |
| $A/m^2$ | amperes per square meter |
| $cm^2$ | square centimeters () |
| cm/s | centimeters per second |
| eq/L | equivalent per liter |
| ft | feet |
| ft/sec | feet per second |
| GFD | gallon per square foot per day |
| GPD | gallon of daily capacity |
| gph | gallon per hour |
| gpm | gallon per minute |
| kgal | 1000 gallons |
| kWh | kilowatt hour |
| kWh/kgal | kilowatt hours per thousand gallons |
| L | liter |
| lb | pound |
| lb/hr | pounds per hour |
| M | moles per liter |
| **$mA/cm^2$** | milliampere per square centimeter |
| Meq/L | milliequivalents of solute per litre of solvent |
| MGD | million gallons per day |
| mg/L | milligrams per liter |
| mS/cm | millisiemens per centimeter [mS/cm] |
| $mT/m^3$ | metric tons per cubic meter [ |
| mT/d | metric tons per day |
| m/yr | meters per year (). |
| psi | pounds per square inch |
| V | volts |

$\mu$S/cm = microsiemen per centimeter

# Metric Conversions

The metric equivalents for non-metric units used in the text are as follows:

| Unit | Metric Equivalent |
|---|---|
| 1 gallon | 3.785 liters |
| 1 gallon per minute | 3.785 liters per minute |
| 1 gallon per square foot of membrane area per day | 40.74 liters per square meter per day |
| 1 inch | 2.54 centimeters |
| 1 million gallons per day | 3,785 cubic meters per day |
| 1 pound per square inch | 6.895 kilopascals |
| 1 square foot | 0.093 square meters |
| °F (temperature measurement) | (°F–32) × 0.556 = °C |
| 1 °F (temperature change or difference) | 0.556 °C |

# 1. Executive Summary

Zero Discharge Desalination (ZDD) is a high recovery desalination process capable of extracting up to 98 percent of the water from brackish groundwater that has high levels of calcium sulfate, silica, and other problematic dissolved constituents. ZDD is comprised of a primary desalination process, typically reverse osmosis (RO) or nanofiltration (NF), and a secondary process called electrodialysis metatheses (EDM).

This report summarizes the results obtained from a multi-year research effort demonstrating ZDD. This effort was a collaborative project between the University of Texas (UTEP) at El Paso's Center for Inland Desalination Systems Texas (CIDS), and Veolia Water Technologies (Veolia). Livingston Associates provided operational support and technical assistance. ZDD was demonstrated at the Brackish Groundwater National Desalination Research Facility (BGNDRF) in the city of Alamogordo, New Mexico, and piloted in Colorado and California. High recovery (96-98 percent overall recovery) was demonstrated at each site and data for evaluating capital, and operational and maintenance (O&M) costs were gathered for use in cost models.

Veolia performed a cost analysis of ZDD and four other technologies in Alamogordo. ZDD with 98 percent recovery is estimated to have a treatment cost of $3.30-3.40 per 1,000 gallons of product water. This ZDD cost is based on a 4 million gallon per day (MGD) desalination facility and includes amortized capital and annual operating expenses for the ZDD and an 18 acre evaporation pond for disposal of all waste (excludes the cost of final solids disposal). Traditional brackish water reverse osmosis (BWRO) (without softening) is estimated to cost $1.25 to 3.50/1000 gallons of product water, but is limited to 80 percent overall recovery and depends strongly on the cost of concentrate disposal method and plant size. The cost of production for a BWRO plant with 80 percent recovery and thermal Zero Liquid Desalination (ZLD) for disposal of its concentrate is estimated to be at least $4.70 per 1,000 gallons.

The cost of ZDD can be further reduced if magnesium hydroxide is recovered from the mixed chloride stream as a salable product. If credit is taken for the value of the magnesium hydroxide, $Mg(OH)_2$, the cost of a 4 MGD ZDD system drops by 16 - 24 percent, bringing the cost of ZDD down to $2.55-2.80 per 1,000 gallons. This cost includes all salt recovery equipment (including clarifiers and evaporation ponds) and final waste disposal of the gypsum solids. Improved EDM system energy efficiency is expected to further reduce the cost of ZDD by an additional 10 to 20 percent.

Future work should focus on demonstrating a cost effective method for sodium chloride recovery such as evaporation on a larger scale, but it appears to be the most attractive method for achieving a truly zero liquid discharge desalination system for Alamogordo. ZDD has been proven to achieve 98 percent recovery and shows potential to achieve ZLD when solar salt recovery is implemented.

# 2. Introduction

Increasing population, decreasing water supply (volume and quality), and droughts are leading to increased competition between users of freshwater (municipal, irrigation, power, etc.), for both surface water (lakes, rivers) and groundwater. Much of the semiarid southwest has experienced drought in recent years. As annual precipitation decreases, there is less water available in streams, rivers, lakes, and other surface facilities. Many municipalities and industries are considering non-fresh water sources, as this may be the only way to grow.

Many fast growing locations have inadequate freshwater supplies. Desalination can augment the water supply for areas, but conventional approaches like RO are usually limited to 70 - 80 percent recovery. This means that large volumes of desalination waste (called brine) would have to be disposed of using evaporation ponds or deep well injection (DWI). Additionally, acceptable brine disposal options are often limited in these areas, presenting a major obstacle to implementing membrane-based desalination technology. For example, the population that depends on the water resources in the Tularosa Basin in southern New Mexico is subject to water scarcity. The groundwater of the Tularosa Basin is nearly saturated in calcium sulfate. Even when scale inhibitors are used, conventional BWRO can only recover up to 75-85 percent of the source water, so the volume of concentrate requiring disposal remains a considerable problem. An effective concentrate management solution is key to the design and operation of inland brackish desalination systems.

Local and regional water supplies are becoming more stressed due to overuse and drought. In a 2003 Government Accountability Office (GAO) report, 36 States (out of 47 States participating) reported that they anticipate water shortages under normal conditions in the next 10 years (GAO, 2003). In a drought, the number increases to 46. Michigan, California, and New Mexico did not participate in the 2003 study. As annual precipitation decreases, there is less water available in streams, rivers, lakes, and other surface facilities. Many municipalities and industries are considering non-fresh water sources, as this may be the only way to assure they maintain a sustainable water supply.

By 2025, nearly one-third of the population of the developing world will face severe water scarcity, according to the International Water Management Institute (Keller et al., 2000). Many locations that have inadequate freshwater supplies are fast-growing regions, including the American Southwest, Florida, and Asia, and many municipalities will eventually need desalination to supplement their limited supplies of fresh water (Davis and Rayman, 2007). Additionally, acceptable brine disposal options are often limited in these areas, presenting a major obstacle to implementing membrane-based desalination technology. The population that depends on the water resources in the Tularosa Basin in southern New Mexico is subject to water scarcity, and desalination yields of the existing water supply have been limited (Brady et al. 2005). The groundwater of the Tularosa Basin is almost 100 percent saturated in calcium sulfate. Even when scale inhibitors are used, conventional BWRO can only recover approximately 75 percent of the source water, so the volume of concentrate requiring disposal remains a substantial problem. An effective concentrate management system is a key to the design and operation of inland brackish desalination systems.

ZDD a form of high recovery desalination, has been shown to provide substantially higher recovery than BWRO alone. ZDD has been demonstrated at pilot scales in New Mexico, Colorado, and Texas by UTEP researchers with funding from the Bureau of Reclamation's (Reclamation) Desalination and Water Purification Research (DWPR) Program, Sandia National Laboratories, the Texas Emerging Technology Fund, and other researchers have tested ZDD in California and Florida with other funding (Bond et al., 2011, 2015). ZDD achieves high recovery by converting the dissolved calcium sulfate to a solid byproduct without the need for energy-intensive evaporation that is characteristic of thermal ZLD processes.

UTEP and Veolia have demonstrated the ZDD technology at the BGNDRF with a blend of two wells that simulates Alamogordo's brackish raw water source, called the "Snake Tank" wells. ZDD is best-suited for desalinating brackish groundwater that has high levels of calcium sulfate like the BGNDRF and Snake Tank wells' groundwater. This is because calcium sulfate will limit desalination recovery to 70-75 percent. About 2 percent of the initial volume of brackish water remains in the ZDD concentrate streams.

## 2.1 Project Objectives and Goals

The primary goal of this project was to move towards commercialization and regulatory acceptance of the ZDD process. This project was done in support of Reclamation goals to (1) augment the supply of drinking water in the United States and (2) develop an approach to desalination that minimizes the environmental impact of desalination.

Another important aspect of this project was the focus on technology transfer to ensure the transfer of knowledge and work toward the commercialization of the ZDD technology by working with water utility(ies) to train them on the ZDD process and to document the operation of ZDD equipment with a user manual.

The demonstration results provided a baseline for design of a ZDD system for Alamogordo as well as other municipalities that have or will face similar challenges in achieving high desalination yields on their source waters.

Specific research goals addressed by this project are:

- Reduce the environmental impacts of desalination:
    - Evaluate potential for implementing ZDD technology in several water chemistries (laboratory studies)
    - Evaluate commercial potential for salable byproducts produced in ZDD process (calcium sulfate, sodium sulfate, etc.)
    - Evaluate potential for NF desalination, which could reduce overall cost by reducing the amount of energy required for both RO and EDM
    - Evaluate actual waste disposal costs and concerns for solid waste stream disposal to landfills
    - Establish cost/benefit analysis of recovering sodium chloride (NaCl) versus purchase
    - Evaluate the potential for incorporation of renewable energy into the ZDD process for direct power and/or solar drying of waste products

This project's objective was to demonstrate technology that has the potential to reduce the cost of desalination with the aim to develop cost-effective approaches for concentrate management that minimize potential environmental impacts.

## 2.2 Project Approach

This project was a demonstration of the commercial readiness of the ZDD technology. The following activities were conducted:

Phase 1:

- Preliminary study to evaluate NF membranes
- Design and procure equipment

Phase 2:

- Install and operate Phase 2 equipment at BGNDRF
- Install and operate Phase 1 equipment in Colorado
- Support pilot testing in California (with Phase 2 EDM equipment)
- Salt recovery laboratory studies
- Write final report

A 20 gallons per minute (gpm) ZDD system was installed at the BGNDRF in Alamogordo. The brackish feedwater was a mixture of two wells chosen to simulate the composition of groundwater from the Snake Tank wells that are available to Alamogordo. After being commissioned, the 20 gpm ZDD system was operated for five weeks at NF permeate flows ranging from 14 - 25 gpm. This system used 4-inch NF270 membranes and one full-size (commercially available)

EDM stack. The system was only shut down on weekends or when project personnel didn't have access to the site. System recovery was 98 percent, and good product water quality (total dissolved solids [TDS] below 800 mg/L) was achieved. The NF270 membranes performed better than expected in terms of permeate quality and allowed most of the silica to pass to the permeate. This means that a silica removal system will not be required for further evaluations in Alamogordo or in the full-scale design. Details from the pilot study are included in Chapter 4 of this report.

In Phase 2 the ZDD was demonstrated at the BGNDRF for extended periods of time. This equipment was designed to produce 40 gpm of product water at 98 percent recovery and used full size, commercially available NF membranes (8 inches) and two EDM stacks. The system was operated on a daily basis until nighttime temperatures were well above freezing and then continuously for multiple day runs during the week. The longest, mostly continuous, run was 145 hours (137 hours without interruption for clean in place (CIP) and maintenance shutdowns). Similar to Phase 1, 98 percent recovery with good product water quality was achieved. Problems with controls and stack design and construction were identified. Corrections were made to provide reliable conductivity measurements, eliminate internal leaks in the EDM stacks, and improvements were made for controls upgrades for future demonstration activities and full scale designs. Details are included in Chapter 4 of this report.

BGNDRF, UTEP, and Veolia participated with two other project teams to pilot ZDD technology in Colorado and California. HDR, Inc. led an effort evaluating ZLD techniques for Colorado (Brandhuber et al., 2014). The 20 gpm ZDD equipment was piloted in La Junta, Colorado and in Brighton, Colorado. Up to 98 percent recovery with good product water quality was demonstrated at both sites; however, equipment problems, operator errors, and other issues were encountered. Lessons learned from Colorado have led to better training, documentation, and operations of pilot equipment. Details can be found in the Water Environment Research Foundation (WERF) 5T10 report (written and co-published by WERF and International Water Association [IWA]) and in Chapters 5 and 6 of this report.

UTEP and Veolia provided equipment, labor, and supplies for this effort. The success of this pilot led to the design of the demonstration equipment for Phase 2 and future studies. During Phase 2, additional sites in Colorado and California were identified as side projects to expand the scope of the DWPR-funded project.

# 3. Review of Concentrate Management Technologies

Brackish groundwater often has enough calcium and sulfate ions to limit the amount of fresh water that can be recovered by desalination. The simplest way to prevent precipitation of calcium sulfate, $CaSO_4$, is to operate the desalination process under conditions that do not allow supersaturation at any point in the process. That could be done by limiting the yield of desalted water, but the high cost of obtaining raw water is an incentive to push for the highest practical yields. The degree of supersaturation is usually highest at the membrane surface in RO and at the heat-exchange surface in evaporative processes. Some increase in turbulence can be achieved by a modification in the design of the permeator or the evaporator, but substantial increases would likely require increased circulation, which means additional pumps and pumping energy, both of which are economically unattractive. In conventional RO without mineral recovery, the formation of $CaSO_4$ scale can be alleviated by adding scale inhibitors to the feed stream.

Several high recovery desalination techniques are available at various levels of development. Other researchers have summarized thorough evaluations of high recovery desalination and thermal ZLD approaches (Bond et al., 2015; Bond, et al., 2011; Brandhuber et al., 2014; Juby et al., 2008; and Mickley, 2008). A summary of several approaches is provided in the following sections. A comparison of these and ZDD is provided in Table 1. ZDD offers very high recovery, and with salt recovery implemented can achieve ZLD with substantially less energy than thermal ZLD approaches.

Table 1.—Comparison of ZLD, ZDD, and High Recovery Approaches

| Technique | Expected Recovery | Capital Cost | Operating Cost | Revenue Potential |
|---|---|---|---|---|
| Deep Well Injection | 80% | Low-Moderate | Low-Moderate | Low |
| Evaporation ponds | 80% | Moderate | Moderate | Low |
| Volume Reduction | 90-95% | Moderate-High | Moderate-High | Low |
| Volume Reduction + Salt Recovery | 90-98% | Moderate-High | Moderate-High | High* |
| ZDD | 95-100% | Moderate-High | Moderate-High | High* |
| ZLD (thermal) | Up to 100% | High | High | Low |

*Market conditions dictate sale price and sale ability of recovered salts.

## 3.1. Thermal Zero Liquid Discharge

An approach used by industry for management of liquid wastes, namely ZLD, typically consists of thermal brine concentration and crystallization technologies. However, the substantial capital and operating costs that are inherent in ZLD processes often prevent them from becoming feasible solutions for RO desalination facilities. For example, capital costs of $30-100 per gallon of daily capacity (GPD) for brine concentrators and crystallizers have been reported for RO brine with 6,000-18,000 milligrams per liter (mg/L) TDS (Juby, et al., 2008). Electrical unit consumption on the order of 75-95 kilowatt hours per thousand gallons (kWh/kgal) is typical for thermal ZLD systems such as brine concentrators and evaporators (Mickley, 2008). Thermal ZLD is not reasonable for dealing with the large volume of desalination concentrate from municipal desalination facilities unless some form of volume reduction is included. ZDD accomplishes similar volume-reduction goals of a thermal ZLD system, but differs in that it uses substantially less energy and is able to separate the salts in the water into potentially salable byproducts.

## 3.2 Evaporation Ponds

Another ZLD strategy uses solar evaporation ponds. However, evaporation ponds are also expensive, usually requiring double liners to prevent leakage. Additionally, evaporation ponds require large land areas, which are not available in many populated inland communities, and the evaporated water is a lost resource. ZDD accomplishes similar volume-reduction goals of a solar evaporation pond system, but differs in that it requires substantially less pond area and is able to separate the salts in the water into potentially salable byproducts.

## 3.3 Deep Well Injection

DWI, where feasible, can be a cost effective method for inland desalination communities. El Paso Water Utilities, El Paso, Texas, owns and operates a 27.5 MGD desalination plant that has up to 3 MGD of concentrate pumped to a disposal site about 20 miles northwest of El Paso. The target formation for the concentrate requires no additional pressure for disposal. Some sites may not have DWI as an option because of local regulations or lack of suitable geological formations for disposal. High salinity concentrate likely would not be disposed of using DWI because of scale formation in the pipelines or disposal wells.

## 3.4 High Recovery Desalination and Salt Recovery

Manufacturers and researchers have described and tested techniques using modified RO, ED, and combinations of processes to achieve high recovery desalination from brackish and other source waters. Alternatives to the ZDD technology are summarized in the following two sections.

## 3.4.1 Volume Reduction Technologies

Volume reduction techniques generally use RO, NF, or electrodialysis (ED) as the primary desalination technique and add another RO or ED stage to further reduce the concentrate volume prior to final disposal. Two techniques, namely Closed Circuit Desalination (CCD™) and Concentrate Enhanced Recovery Reverse Osmosis (CERRO™), employ a semi-batch process that takes advantage of slow silica scale formation kinetics.

High Efficiency Electro-Pressure Membrane (HEEPM™) by EET Corporation uses a combination of RO and high efficiency ED to achieve high recovery from brackish feedwater (EET Corporation, 2011 and Mickley, 2008). Pre-treatment to remove sparingly soluble salts is included in this process, which likely helps the performance of the ED system. It is interesting to note that the recovery is not affected much by the type of water for the estimates made for RO concentrate at 8,000 mg/L TDS. In his evaluation of HEEPM™, (Mickley, 2008) includes two RO concentrates, one with high levels of calcium, magnesium, and sulfate, and one with mostly sodium, chloride, and bicarbonate. The HEEPM™ recovery is 95.1 percent for the high scaling feed and 95.2 percent for the lower scaling feed.

Vibratory shear enhanced process (VSEP™) by New Logic uses vibration to mitigate problems from sparingly soluble salts. Flat RO membranes are used and are enclosed in a housing that is vibrated (Mickley, 2008). The combination of high shear at the membrane surface and vibrating action allows for recoveries as high as 80-85 percent without need for pre-treatment chemicals (Mickley, 2008).

High Efficiency Reverse Osmosis (HERO™) by Aquatech and GE is a commercially available process that has been successfully installed in at least 20 non-municipal sites around the world (Mickley, 2008). The process uses a combination of lime softening or ion exchange to remove calcium and carbonate, pH adjustment to mitigate silica scale formation, and staged RO to achieve high recovery. GE states that recovery above 90 percent is achievable (GE, 2013 a and b) and Aquatech suggests recovery “beyond 95 percent” is achievable (Aquatech, 2014). Mickley states that there is a tradeoff between lower energy cost and higher chemical cost with HERO™ (Mickley, 2008). The Aquatech and GE websites provide additional information on the HERO™ technology.

CCD™ by Desalitech uses a novel operation of RO to achieve high recovery up to 98 percent (Desalitech, 2013). The technology functions in a semi-batch mode. Feedwater enters the CCD, outfitted with the proper RO or NF membranes necessary for desalination, and permeate and concentrate are produced. The concentrate is recycled to the feed until a recovery (TDS) setpoint is achieved and the remaining fluid is drained from the process. Substantial energy savings are possible, up to 35-50 percent are reported by Desalitech (Desalitech, 2013) for brackish water as compared to brackish RO with high recovery (typically two or three-stage RO).

AquaSel™ by GE combines electrodialysis reversal (EDR) with precipitation to treat RO concentrate and has demonstrated 99 percent recovery for a soda manufacturing process (GWI, 2012). GE is quoted as saying they are focusing on smaller (25-100 gpm) systems with moderate salinity (2,000 - 4,000 mg/L TDS) for its initial clients (GWI, 2012). The RO concentrate contained 838 mg/L TDS and was comprised mainly of bicarbonate, sulfate, and sodium chloride (GE Power & Water, 2013).

CERRO™ from UTEP (invented by Dr. Anthony Tarquin) operates similarly to the CCD™ technology, in that it is a single-pass, multi-membrane, batch-treatment system with periodic flushing. The two systems differ in the membrane array used and in how they are piped and controlled. CERRO has been tested at the pilot scale in El Paso and Alamogordo as part of research sponsored by Reclamation's DWPR, WateReuse, and the Texas Water Development Board. El Paso Water Utilities was recently awarded a Reclamation WaterSMART grant to evaluate 70 gpm CERRO systems for wellhead RO systems (Reclamation, 2014).

### 3.4.2 Volume Reduction with Salt Recovery Technologies

Several techniques have been tested, and sometimes patented, that include volume reduction with salt recovery. Selective salt recovery from desalination concentrate may provide a revenue stream that offsets the cost of desalination. Many of these are chemically intensive and somewhat complex.

SAL-PROC™ by Geo-Processors is a multi-component system that includes precipitation, desalination by RO, brine concentrators, crystallization, and evaporation ponds. The potential for $5 million in annual revenue for recovered magnesium hydroxide, calcium carbonate, and other mixed salts from 2.5 MGD of concentrate was reported by Mickley (2008).

Selective Salt Recovery from Reverse Osmosis Brine Using Interstage Ion Exchange from the University of New Mexico (invented by Kerry Howe, Josh Goldman, and Bruce Thomson) uses a combination of RO, NF, ion exchange, and chemical precipitation to achieve both high efficiency desalination and recovery of salts from desalination concentrate. The desalination portion functions similar to ZDD except that it uses ion exchange resin columns instead of ion exchange membranes. The technique has been evaluated at laboratory and pilot scale in Colorado and is patented (8,557,119).

In addition to the processes listed, at least two engineering firms have evaluated and piloted high recovery techniques:

- Carollo Engineering performed laboratory studies and desktop estimates for several combinations including softening, RO, slurry precipitation and recycle reverse osmosis (SPARRO), forward osmosis, brine concentrators and SAL-PROC with different final disposal methods, including the Santa Ana Regional Interceptor (SARI) brine line, evaporation ponds, and landfill (Juby et al., 2008). The various techniques were estimated to be able to recover 93-99.75 percent from a brine with 8,000 mg/L TDS.

- Enviro Water Minerals Company (EWM) has piloted a technique that includes softening and alkalinity removal as pre-treatment prior to RO/NF and ED for desalination of El Paso Water Utilities' Kay Bailey Hutchison Desalination Plant (EWM, 2014). In addition, EWM recovers minerals at various points including magnesium chloride, calcium chloride, sodium sulfate, and sodium sulfate. EWM is awaiting approval from the Texas Commission on Environmental Quality to proceed with a design of a full-scale plant.

# 4. Zero Discharge Desalination

ZDD is comprised of a primary RO or NF desalination process and EDM. In contrast to conventional ED, the EDM has four membrane and solution compartments in a repeating unit. Two feed streams enter to the EDM, including the concentrate from the primary desalination (called EDM feed) and NaCl. The salts in the feed and the NaCl change partners and form two concentrated byproduct streams, one rich in sodium sulfate (the Mixed Na stream) and one rich in calcium chloride (the Mixed Cl stream). The salt-depleted EDM product (called EDM diluate) is then either returned to the feed or blended with the desalted product of the primary process. The EDM concentrate streams contain the remaining 2 percent of volume and all of the salts removed in the ZDD process. Combining these streams results in the precipitation of calcium sulfate and release of the NaCl, which can be recovered and returned to the EDM. Recovering NaCl will achieve even higher recovery, can reduce overall cost of the process, and reduce the environmental impact of the desalination process.

## 4.1 ZDD Technology Development and Funding History

ZDD was developed by Dr. Thomas A. Davis while at the University of South Carolina (USC). Two U.S. patents (7,459,088 and 7,083,730) protect the technology for both brackish water and seawater desalination. Patent 7,083,730 also describes techniques for salt recovery from several process streams. ZDD differs from other high recovery techniques in that it does not require pre-treatment to remove hardness and usually only employs moderate pH adjustment (to pH 6.8-7.0), antiscalants, and cartridge filters for pre-treatment.

Reclamation support of the ZDD technology began in 2002 with a proposal by Dr. Davis on behalf of USC in response to a solicitation No.02-FC-81-0757 by Reclamation. The research project entitled “Zero-Discharge Desalination of Seawater” was highly successful, and a small company, ZDD, Inc., was formed to commercialize the technology. Results of lab-scale experiments with seawater from the Atlantic Ocean demonstrated that the use of ED to treat the concentrate from RO produced an ED concentrate stream with about 20 percent NaCl. The ED had special membranes with selectivity for transport of monovalent cations and anions. The ED concentrate was processed in an evaporative crystallizer to produce NaCl of high purity. Bromide ions were selectively concentrated by the ED, and the mother liquor from the NaCl crystallization contained enough bromide to justify recovery in a large-scale desalination plant. The ED diluate was treated by NF to reject divalent ions and returned to the RO feed to increase yield of fresh water. The ED diluate contained the magnesium ions from the RO concentrate with a much higher concentration than in seawater. Treating that stream with sodium hydroxide, NaOH, precipitated $Mg(OH)_2$ of high purity and potential commercial value.

Based on the success of the laboratory work, Reclamation funded construction of a pilot plant to demonstrate the seawater technology. Partway through the construction of the pilot plant, it became apparent that a suitable seawater intake was not available, so the pilot project was redirected. Reclamation identified a need to treat irrigation drainage contaminated with selenium and agreed to allow the pilot plant to be reconfigured to treat that water. During the 2-year interval between completion of the lab program and initiation of the pilot plant construction, Sandia National Laboratories (Sandia) funded laboratory research at USC on concentrate management for water containing high levels of $CaSO_4$, specifically groundwater in the vicinity of Alamogordo, and that research showed that $CaSO_4$ could be recovered as a solid byproduct. Removal of the $CaSO_4$ and recycle of the $CaSO_4$-depleted solution to the RO feed allowed substantial improvement in the yield of RO permeate. Similarities between the $CaSO_4$ content of Alamogordo water and irrigation drainage in the Panoche Irrigation District of California (Panoche) made it apparent that the same $CaSO_4$-removal should be applicable to both.

The ZDD process proved successful at Panoche. Treatment of the RO concentrate by EDM, produced two highly concentrated streams, one containing calcium chloride, $CaCl_2$, and the other containing sodium sulfate, $Na_2SO_4$. Mixing those two concentrated streams precipitated solid $CaSO_4$. As anticipated, the selenate anions followed the sulfate through the anion-exchange membrane (AEM) of the EDM and appeared in the $Na_2SO_4$–rich concentrate stream but did not precipitate with the $CaSO_4$. Thus the selenate was confined to a highly concentrated supernatant from the precipitation step.

Sandia continued to recognize the applicability of the ZDD process to the $CaSO_4$-rich groundwater of the Tularosa Basin, the aquifer from which Alamogordo would have to draw water, and Sandia contracted with ZDD, Inc., to build a pilot plant to treat water from the Tularosa basin. The ZDD pilot plant, comprising RO, EDM, and a second ED stack for NaCl recovery, was housed in a 24-foot cargo trailer. Reclamation facilitated efforts to demonstrate the ZDD process, and the process was up and running during the opening ceremony of the BGNDRF in August, 2007. Sandia operated the pilot plant at the BGNDRF for about two years and subsequently donated it to UTEP. UTEP refitted the ZDD pilot plant to include data acquisition, feed decarbonation, and other useful features and named it MDU2. The testing showed that the ZDD technology is capable of increasing the desalination yield from a typical level of 75 percent in a conventional BWRO system up to 84 percent without a silica removal system.

Veolia obtained the license for the ZDD technology in February, 2009, and continued piloting efforts at the BGNDRF until 2010. The tests were conducted both with and without the use of a proprietary silica removal system. The testing showed that the ZDD technology is capable of increasing the desalination yield from a typical level of 75 percent in a conventional BWRO system up to as high as 97 percent with the use of the silica removal system. High recovery processes are essential due to waste disposal costs, fixed water supply, and environmental concerns associated with brine. The ZDD was able to achieve this criterion while reducing the operational and capital cost compared to a conventional system.

Veolia piloted ZDD for the treatment of wastewater at Hilmar Cheese Company in Hilmar, California, in 2010 using both a small scale ZDD system (1-2 gpm product) and a full scale EDM system to treat various waste streams. The waste water contained high levels of calcium, bicarbonate, phosphate and silica (Biagini et al. 2011). High recovery was demonstrated (96-98 percent) and, if implemented, would provide a treated effluent that would be in compliance with surface discharge.

Black and Veatch has evaluated EDM, the key component of ZDD, in Florida and California. Both projects were aimed at comparing ZLD approaches available for utilities. A bench-scale EDM unit fitted with ASTOM Corporation's neosepta ion exchange membranes was leased to Black and Veatch in 2009 for testing in Florida. A full scale pilot demonstration EDM system fitted with MEGA Group RALEX® ion exchange membranes was provided for testing in California in the Fall 2013 through Spring 2014. UTEP and Veolia provided technical assistance and training for both projects. In Florida, four process trains were evaluated with EDM as the final concentrate volume reduction process. High recovery (87-97 percent) was demonstrated and the cost of treatment was deemed reasonable for brackish water with less than 5,000 mg/L TDS (Bond et al., 2011). In California, the EDM was used to treat the RO concentrate from the Beverly Hills Water Treatment Facility, Beverly Hills, California. High recovery was demonstrated (91-92 percent) and several full scale cost evaluations were developed to assess the cost of treatment using EDM (Bond, et al., 2015). If implemented, EDM could raise overall plant recovery from 80 percent to 97-99 percent.

## 4.2 Process Description

The ZDD process typically includes filtration, RO and/or NF, EDM, chemical feed systems, and a deionizer (DI) water system. A salt recovery system can be installed to recover NaCl, which is needed in the ZDD process, as well as other useful salts such as $Mg(OH)_2$, $Na_2SO_4$, and $CaSO_4$. Each major process is discussed briefly in this section and detailed descriptions of the equipment tested at each site are included later in this report, as references, or in appendices.

## 4.3 Process Configurations

Three types of ZDD systems were evaluated during this project: greenfield, bolt-on, and EDM-only. The greenfield configuration was tested at BGNDRF and La Junta; the bolt-on configuration was tested in Brighton; and the EDM-only configuration was briefly tested in La Junta and piloted at Beverly Hills, California. The choice of configuration depended on the water being treated by ZDD and the product water quality requirements.

The first ZDD system evaluated simulates a greenfield site (i.e., no existing desalination equipment) and involves a brackish water that is fed to a NF or RO to produce a permeate quality that meets primary drinking water standards. The concentrate from this NF is fed to an EDM system where offending dissolved constituents such as calcium sulfate are removed. This is shown in Figure 1. This configuration also shows how an existing plant could install different membranes in their existing system and install a new EDM to achieve high recovery. RO membranes have high silica rejection, so a silica purge, silica treatment system, or use of silica-permeable membranes are needed where moderate to high levels of silica are present in the groundwater.

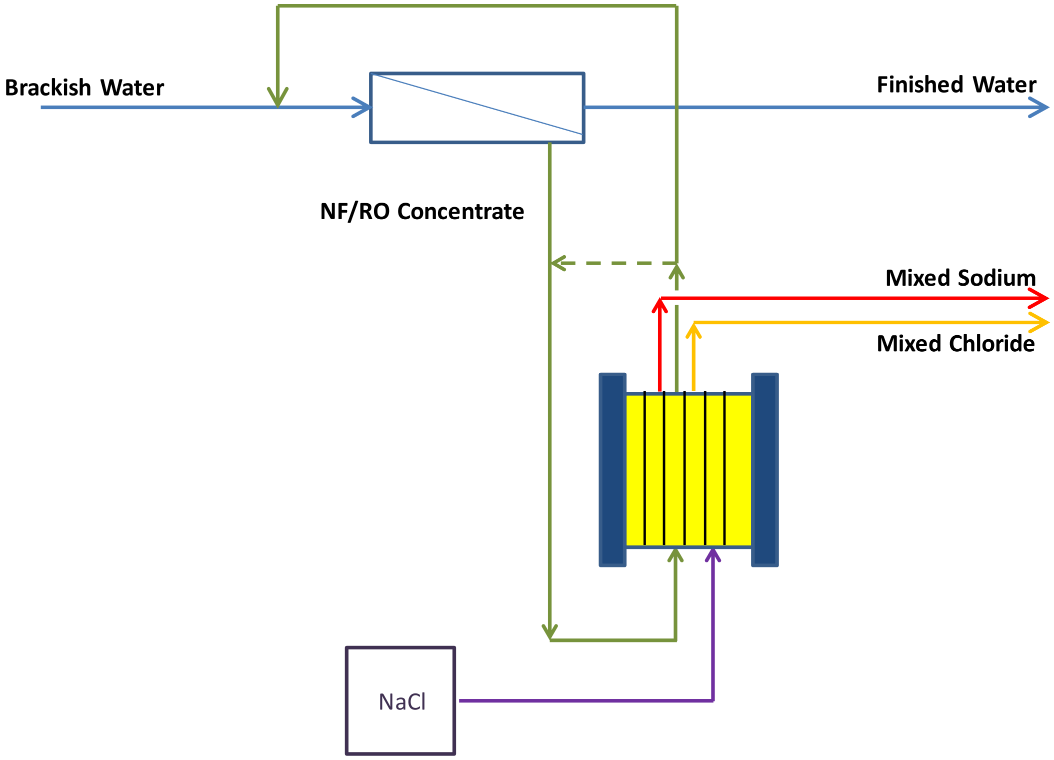


**Figure 1.—Greenfield ZDD flow diagram (simplified).**

The second type of ZDD system tested simulates a bolt-on approach and involves ZDD desalinating the concentrate from an existing desalination plant. This is shown in Figure 2. EDM is placed at the front of the treatment scheme, because ED operates more efficiently at higher concentration. Additionally, the EDM removes $CaSO_4$ and other dissolved constituents to a level that allows the NF system to operate efficiently and with a lesser chance for scale formation. A silica purge stream is necessary at sites with high silica in their RO concentrate. If

NF270 membranes are used to desalinate EDM diluate, the rate of silica purge is expected to be 10 percent of the waste, or less than 0.2 percent of the initial feed to the existing plant RO. If RO is used, the waste volume could be 5-10 percent of the initial feed.

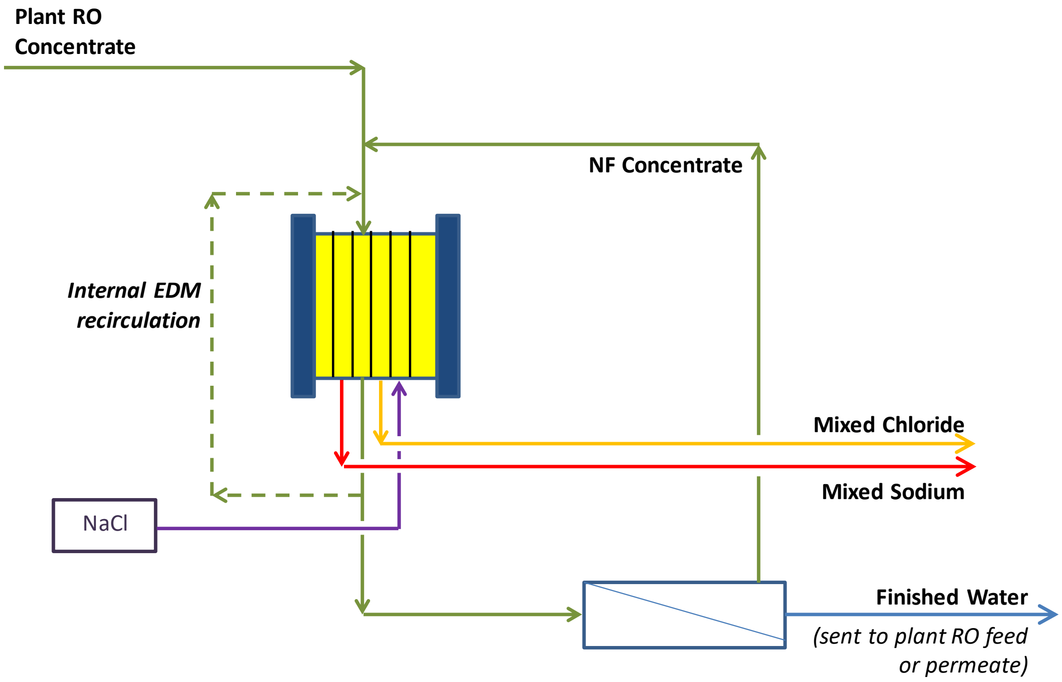


**Figure 2.—Bolt-on ZDD flow diagram (simplified).**

Some brackish water and plant RO concentrate has a low enough concentration that RO/NF systems are not required in the ZDD process. In this case, the EDM desalinates the feed water or RO/NF concentrate directly and the diluate can either be mixed with the existing plant's feed or permeate. This process is shown in Figure 3.

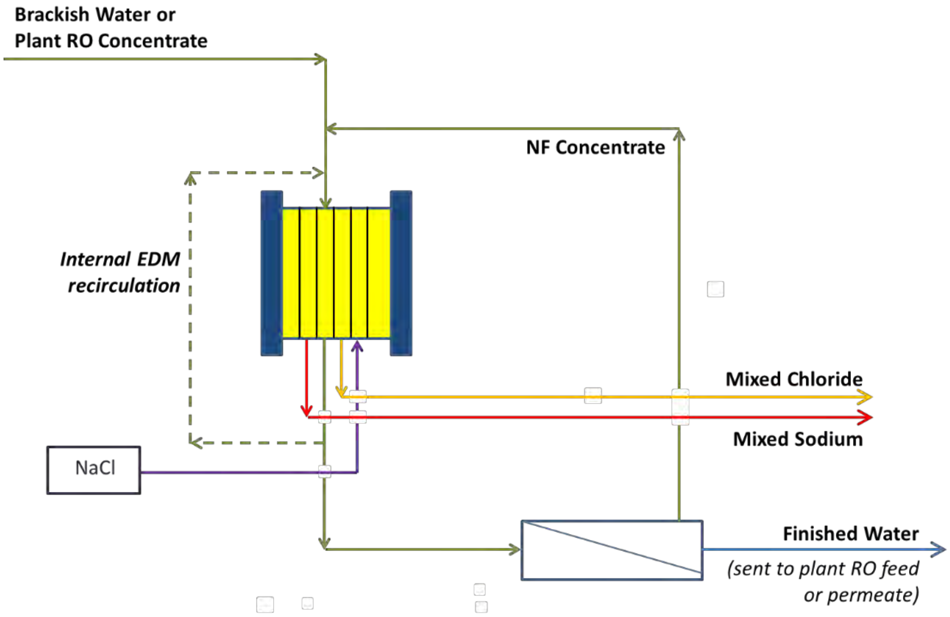


**Figure 3.—EDM only ZDD flow diagram (simplified).**

# 4.4 Pre-Treatment

Pressure driven membrane processes such as RO and NF require pretreatment for particles. Cartridge filters were installed on the raw (untreated) feed water and the NF feed water systems to protect the NF membranes; 20-micron and 10-micron cartridge filters were installed on the raw feed and NF feed, respectively.

Bicarbonate alkalinity was reduced by the addition of sulfuric acid to the raw feed at all sites. During the Phase 1 activities at the BGNDRF, a degasifying tower was also used. The addition of sulfuric acid to the raw feed water forms carbonic acid. When the acidified water passes through a degasifying tower, carbon dioxide, $CO_2$, is released to the environment and alkalinity is partially reduced in the NF feed. During Phase 2 and in both sites in Colorado, only acid addition was employed to reduce the amount of bicarbonate alkalinity in the NF feed. Hydrex 4101 antiscalant was added to the NF feed at a dosage of 2-3 mg/L at all sites.

# 4.5 Reverse Osmosis and Nanofiltration

The concept of RO was first studied by Fick in 1855 (Glater, 1998) but pressure-driven RO membranes were not developed and tested until the mid-1950s by researchers at the University of California, Los Angeles, California; University of Florida, Gainesville, Florida; and the U.S. Office of Saline Water, Washington, D.C. (Glater, 1998). RO and NF membrane manufacturers now produce many types of membranes, and different designs are optimized for productivity (high flux), lower energy, high salt rejection, fouling resistance, or other useful properties.

RO and NF produce two streams of water, namely permeate and concentrate. The concentrate contains all of the salts removed by the membrane. Typical brackish RO/NF systems can operate at 75-85 percent recovery and are limited by the sparingly soluble salts such as $CaSO_4$, calcium carbonate ($CaCO_3$), and silica. The amount of salts in the concentrate is related to the recovery of the RO/NF—higher recovery systems will have higher concentrations. Disposal or treatment of the concentrate can be a limitation to the installation of RO or NF.

Both RO and NF use pressure to produce permeate from a brackish water source using semi-permeable membranes installed in pressure vessels. RO is able to produce high quality product water. However, it requires higher pressure than NF and can be susceptible to fouling and scaling. Rejection of multi-valent and large molecules in brackish feedwater is similar for RO and NF membranes, but NF membranes have lower rejection of monovalent and uncharged molecules. NF can produce good quality permeate that meets primary drinking water standards and can require substantially lower feed pressure than RO. Table 2 compares the predicted product water and energy consumption for several RO and NF membranes produced by Dow Filmtec. Each of the designs uses the average water quality from Phase 2 operations at the BGNDRF and assumes 1 MGD of permeate. Three brackish water membranes and two nanofiltration membranes were compared with similar staging. Of these, the BW30HR-440i membrane is predicted to produce the best quality permeate and require the most energy for the RO. The NF90-400/34i is predicted to have similar water qualitya as the XLE-440i membranes, but requires 9 percent less energy. The NF270-400 membranes require the least amount of energy, but also have the highest salinity permeate (note that Phase 2 demonstrated better performance with the same membranes).

Table 2.—Comparison of Dow Filmtec Membranes to Produce 1 MGD Permeate from Average Snake Tank Brackish Water

| Membrane | BW30HR-440i | ECO-440i | XLE-440i | NF90-400/34i | NF270-400 |
|---|---|---|---|---|---|
| Staging | 12 x 6 (6M) | 12 x 6 (6M) | 14 x 7 (6M) | 14 x 7 (6M) | 14 x 7 (6M) |
| Average Permeate Flux (gfd) | 18.16 | 16.52 | 14.16 | 15.57 | 15.57 |
| Feed Pressure (psi) | 218 | 137 | 118 | 107 | 101 |
| Permeate Back Pressure (psi) | 0 | 0 | 0 | 15 | 30 |
| Recovery | 76% | 76% | 76% | 76% | 75% |
| RO Energy (kWh/kgal) | 2.59 | 1.64 | 1.41 | 1.28 | 1.22 |
| Permeate TDS (mg/L) | 27 | 30 | 125 | 162 | 841 |

The brackish water in Alamogordo is nearly saturated in $CaSO_4$ and has moderate silica. Because ZDD operates at 98 percent recovery, silica must be removed, or otherwise dealt with, to protect the RO/NF system in ZDD. Dow Filmtec's NF270 membranes were used at the BGNDRF site, because they allow for nearly all of the silica in the brackish feedwater to pass to the product water. This eliminates the silica scale problem and produces water suitable for Alamogordo's customers (less than 800 mg/L TDS). A combination of Dow Filmtec's NF270 and NF90 membranes were employed at both La Junta and Brighton, because their water quality requirements were more restrictive.

## 4.6 Electrodialysis Metathesis

ED has been around nearly as long as RO, with its discovery in 1890, and first installation for the desalination of seawater in the 1960s (Xu, 2005). While ED is a proven method for desalination, it is not as widespread as RO. A recent study estimated that ED accounted for 3.53 percent of the world's desalination capacity while RO accounted for 59.85 percent in 2012 (Ghaffour, Missimer, & Amy, 2013).

ED "stacks" are comprised of alternating cation membranes and AEMs as shown in Figure 4. Commercial stacks include hundreds of cell pairs. An aqueous solution, such as brackish water, is fed into alternating feed compartments. As an electrical potential is applied, anions move towards the positively charged anode and cations move towards the negatively charged cathode. Cations, shown moving to the left in Figure 4, will pass through the cation-exchange membrane (CEM) but will be blocked by the AEM. Similarly, anions will pass thorough the AEM but will be blocked by the cation exchange membrane. This leads to changes in the salt content of alternating streams: one is a diluted stream (called diluate) and the other is a concentrated stream (called concentrate).

Oxidation and reduction reactions occur and gasses are generated at each of the electrodes. These reactions are summarized in Figure 5. Dashed lines in 5a) represent the concentration in the diluting compartment (center of the figure) and concentrate compartments (left on AEM, and right of cation-exchange membrane, CEM). Although not shown in Figure 4, an electrode rinse (E-Rinse) stream flows across each electrode to provide a path for current to flow from the electrodes into the rest of the stack, as well as to cool both electrodes and sweep gases out of the stack. Gases generated in the E-Rinse compartments are vented to the atmosphere.

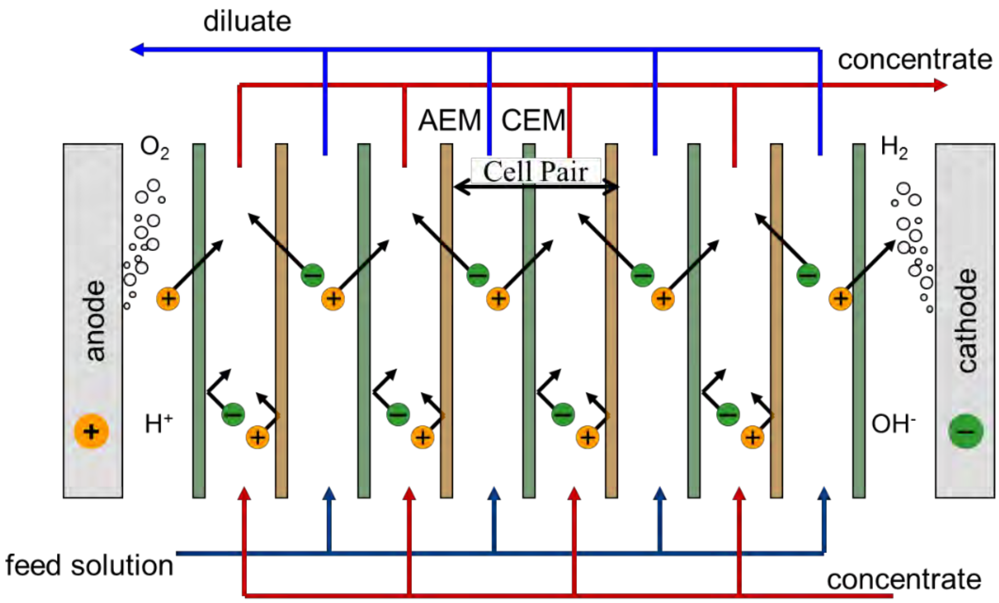
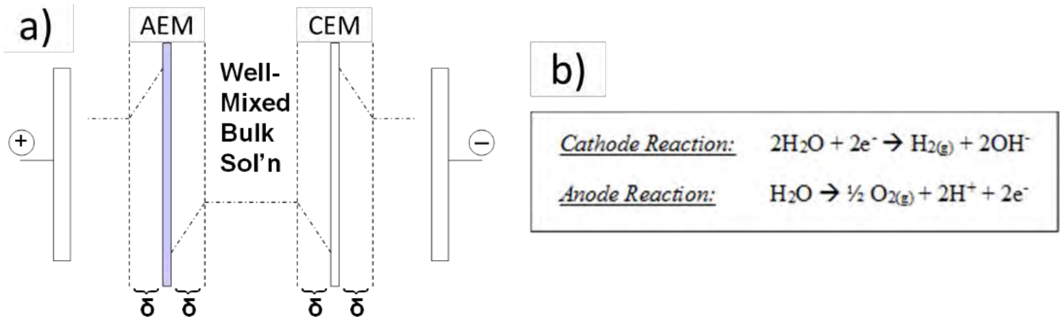


**Figure 4.—Flow of ions in electrodialysis.**
(CEM = cation-exchange membrane, AEM= anion-exchange membrane)
(modified from Strathmann, 2004 and Murray, 1995)



*Cathode Reaction:* $2H_2O + 2e^- \rightarrow H_{2(g)} + 2OH^-$

*Anode Reaction:* $H_2O \rightarrow \frac{1}{2} O_{2(g)} + 2H^+ + 2e^-$

**Figure 5.—Concentration polarization in electrodialysis showing a) concentration profile and b) electrode reactions.**

Similar to RO and NF, concentration polarization occurs at the boundary layers in the solutions next to the membranes. In ED, concentration boundary layers are on both sides of every ion-exchange membrane. These concentration boundary layers exist because the electric current is carried through the membrane by only one ion type (anion or cation), but in solution the current is carried by both ion types. Consider the AEM in Figure 5. Only a portion of the current is carried by anions migrating through the boundary layer toward the anode, but essentially all of the current is carried by anions migrating through the AEM. Cations migrating through the boundary layer toward the cathode cause depletion of the solution next to the membrane. That depletion is made up by ion pair diffusing toward the membrane, and the driving force for that diffusion is the difference between the salt concentrations in the bulk solution and at the interface. As the current density increases, the rate of removal of anions through the membrane increases, and the concentration gradient increases. The salt concentration at the interface approaches zero at some current density, because the rate of diffusion cannot keep up with the rate of removal. That condition corresponds to the limiting current density. For potassium chloride, KCl, the mobility of $Cl^-$ ion is the same as the mobility of $K^+$ ions, so zero concentration is attained at both membranes simultaneously. For NaCl, the $Na^+$ ions are less mobile than the $Cl^-$ ion, so the zero concentration occurs at the cation-membrane at lower current density than at the AEM. When there are not enough ions available in the solution at the interface, the difference is made up by dissociation of water into $H^+$ and $OH^-$ ions.

Figure 6 shows the relationship between current density and applied voltage in ED. In the Region I, called the ohmic region, an increase in voltage leads to a proportional increase in current density. In Region II, called the plateau region, there is a much lower increase in current density with increasing voltage. In Region III, called the overlimiting region, current density does increase with increasing voltage; however, at this point water splitting is occurring (other unknown phenomena also occur in this region (Strathmann, 2004). Applying too much voltage can damage the ED equipment and cause operational problems. The limiting current density can be determined by the intersection of the lines for the ohmic and plateau regions (labeled $i_{lim}$ in Figure 6).

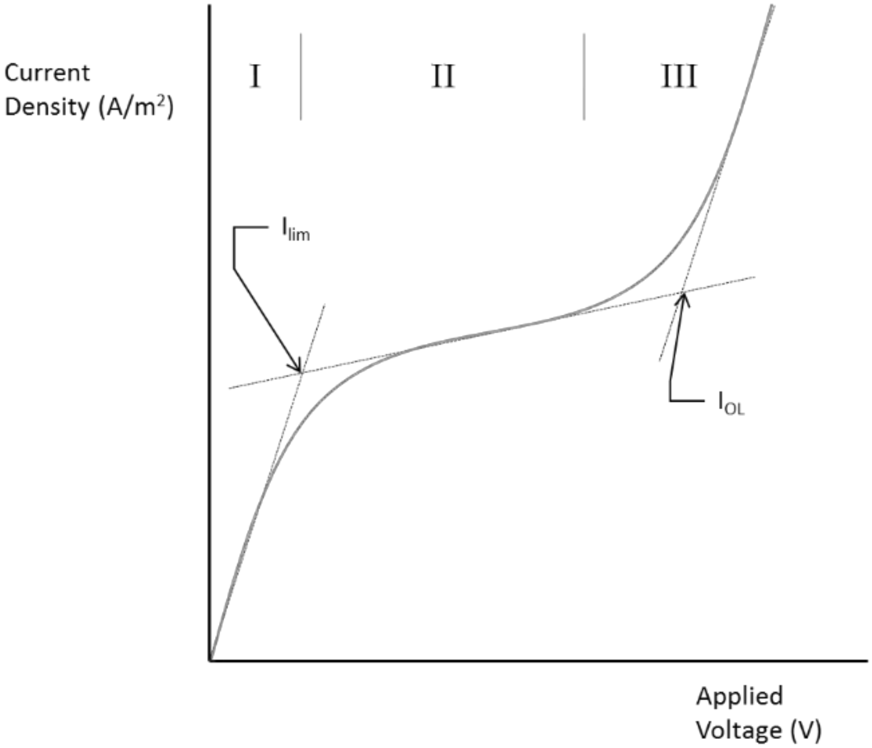


**Figure 6.—Limiting current density in electrodialysis.**

This method is described by Krol et al (1999). Other methods calculate the point where all ions have been depleted from the boundary layer (labeled $i_{OL}$ in Figure 6) (Bond et al., 2011and Bard and Faulkner, 2001). At $i_{OL}$, complete concentration polarization has occurred (Bard and Faulkner, 2001). While an ED system can be operated beyond the $i_{lim}$, ED is less efficient (with respect to desalination) beyond the $i_{lim}$, because additional voltage will not lead to a useful increase in ion removal. Additionally, the closer an ED system is operated to the overlimiting region (III in Figure 6), the more likely water splitting and equipment damage will occur.

Current density in general, and limiting current density in particular, is affected by operating conditions, stream concentrations, and hydraulic properties of the stack (Bond et al., 2015). Increased concentration supports increased current density (Krol et al., 1999) and increased stream velocity also leads to increased current density (Kanavova et al., 2013). As temperatures decrease, the effective cell resistance increases, and the current density also declines (Leitz, 1974). Figure 7 shows how decreasing temperature leads to higher cell pair resistance in ED.

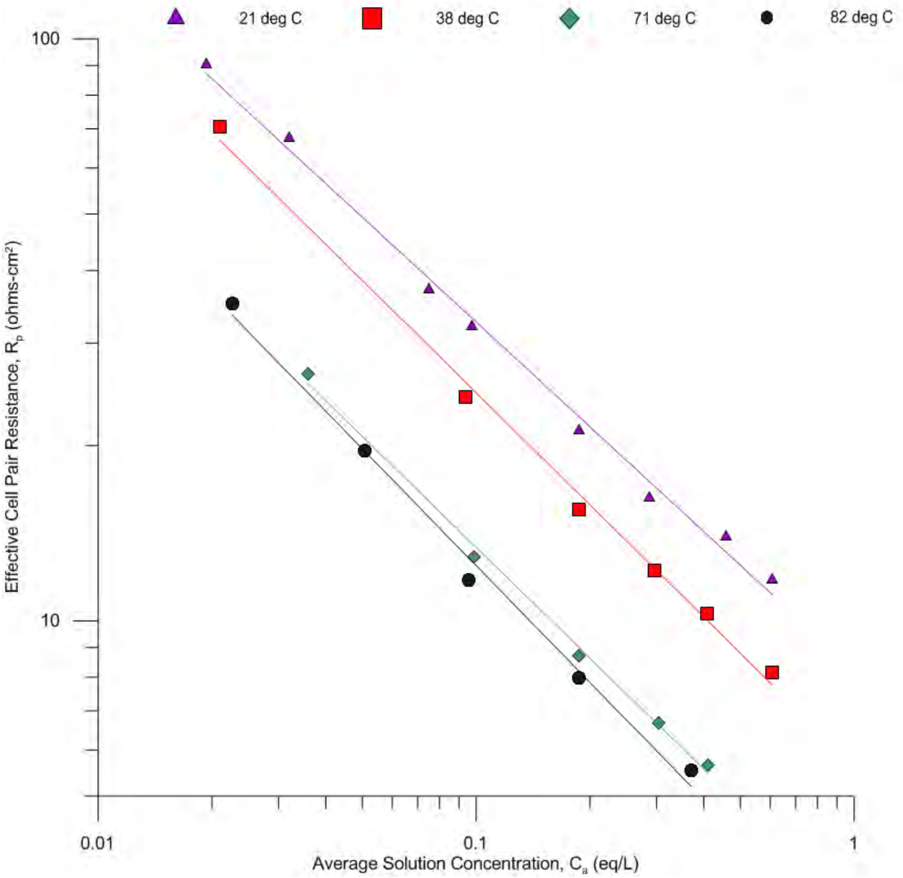


**Figure 7.—Decreased temperature leads to increased ED resistance.**
(Modified from Leitz, 1974)

Brackish water contains many dissolved salts that, when concentrated, would precipitate in ED concentrate compartments. Electrodialysis reversal (EDR) mitigates this problem by regularly changing the polarity of the applied voltage, which dissolves nascent scale that had formed in compartments that were previously concentrating (Katz, 1979). Figure 8 shows the relative solubility of several common dissolved salts in brackish water and desalination concentrate. In general, chloride salts and sodium salts are very soluble. However, sodium sulfate and sodium carbonate have steep declines in solubility with decreasing temperature and sodium bicarbonate has a relatively low solubility.

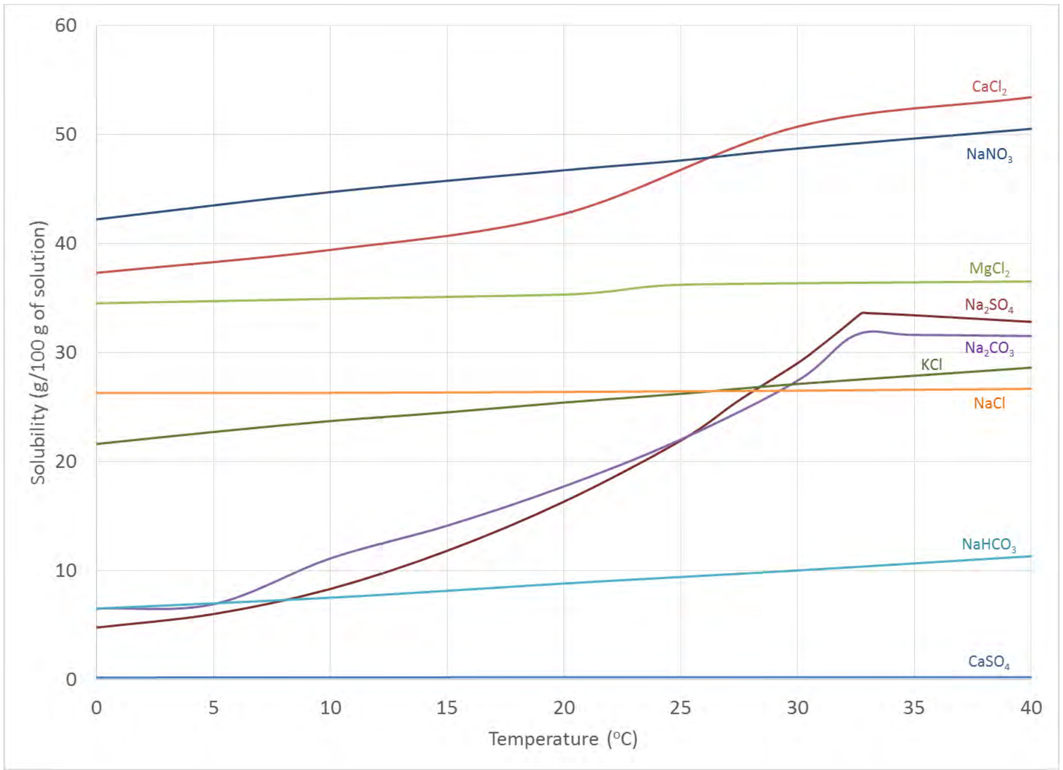


**Figure 8.—Solubility of dissolved salts (Siedell, 1907).**

Similar to ED, an electrodialysis metathesis (EDM) stack is comprised of alternating cation membranes and AEMs. However, instead of a single diluting and single concentrating stream, EDM has two diluting streams and two concentrating streams. The combination of the four streams and associated membranes is called a quad. Commercial EDM stacks include 100 or more quads.

Figure 9 shows a single quad in detail and how that quad is incorporated in the rest of the EDM stack. Brackish water or desalination concentrate is fed to the EDM feed compartments. The applied voltage causes the cations to move to the right (towards the cathode) and anions to the left (towards the anode). Cations from the EDM feed combine with chloride from the NaCl to produce a mixed chloride salt concentrate stream (called Mixed Cl). Anions from the EDM feed combine with sodium from the NaCl to produce a mixed sodium salt concentrate stream (called Mixed Na). This metathesis, or changing of partners, produces highly soluble sodium and chloride salts such as calcium chloride and sodium sulfate from sparingly soluble salts. NaCl is added to the EDM at a rate equivalent to the amount of ions removed from the EDM feed. EDM acts like a kidney in the ZDD process by removing troublesome salts from the RO/NF concentrate. The desalinated EDM product (called diluate) can be returned to the RO/NF feed or blended directly with the RO/NF permeate, thus allowing for higher overall water recovery.

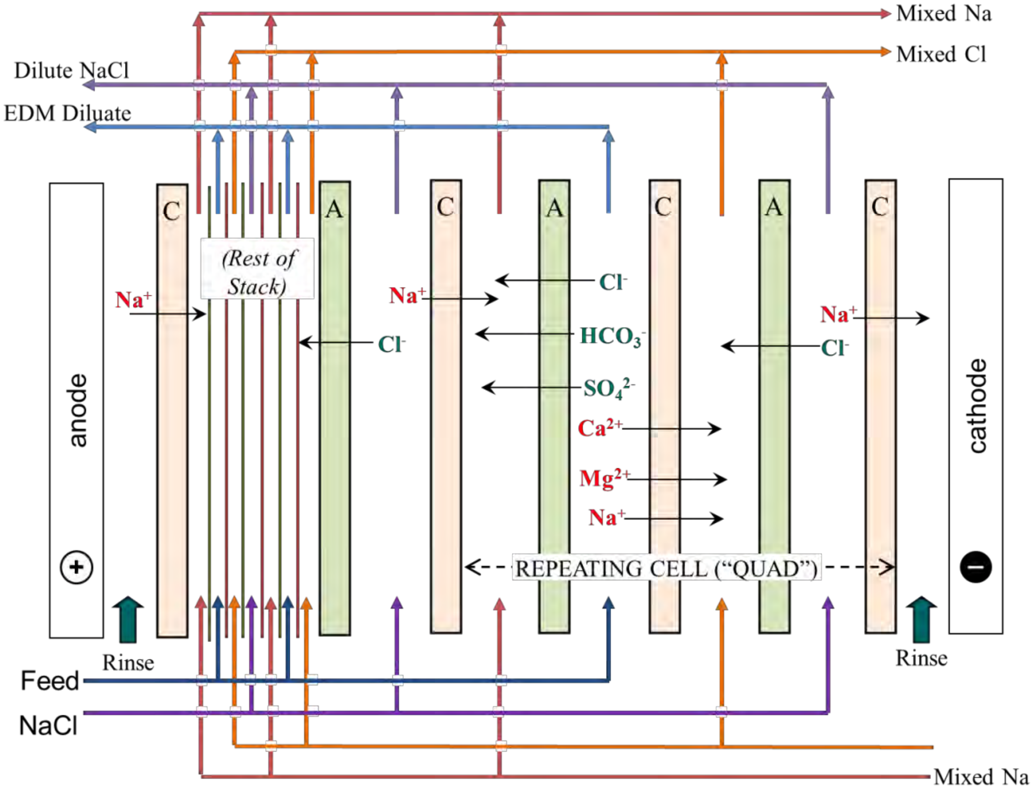


**Figure 9.—Flow of ions in electrodialysis metathesis.**
(C=cation-exchange membrane, A=anion-exchange membrane)

The first description of EDM appeared in U.S. Patent 2,721,171, which was issued in 1955 and assigned to DuPont. This patent described production of $H_2SO_4$ and NaOH from $Na_2SO_4$ (Monet and Wilfred, 1957). Winger described the use of EDM to generate NaOH from lime and NaCl (Winger, 1957). J. R. Ochoa et al. used an electrolytic cell with a single set of membranes in an EDM arrangement to convert a salt to an acid (Ochoa et al., 1993). Alheritiere et al. (1998) described the use of EDM to convert magnesium chloride and sodium sulfate to magnesium sulfate and sodium chloride. A more recent patent, U.S. Patent 6,712,946, describes the use of EDM to produce 2-keto-L-gulonic acid from its calcium salt (Genders and Hartsough, 2004). In this, HCl is fed to the other depleting compartments, and $CaCl_2$ is a byproduct. There is no indication that any of the aforementioned examples of EDM was ever practiced on a scale larger than laboratory scale. Indeed, it is apparent that the ZDD process is the first commercial process to use EDM.

Before the ZDD process created a demand for large EDM stacks, the largest EDM stacks were laboratory scale with about 200 square centimeters ($cm^2$) of exposed membrane in each solution compartment. For the first pilot plant funded by Reclamation in 2004, Tokuyama Corp designed and built an EDM stack comprising 20 repeating quads with 500 $cm^2$ of exposed membrane in each solution compartment. For the 20-40 gpm demonstrations funded by Reclamation in 2011-2013, MEGA designed and built an EDM stack with 100 repeating quads with 4,200 $cm^2$ of exposed membrane in each solution compartment. Further research will use expanded stacks from MEGA with 120 quads.

## 4.7 DI Water System

Deionized (DI) water (or RO permeate) is used in the ZDD process to prepare NaCl and E-Rinse ($Na_2SO_4$) solutions as well as to dilute the Mixed Na and Mixed Cl streams to prevent precipitation and minimize back diffusion of ions. It is also used to flush the EDM system during shutdown operations. Virtually all of the DI water used in the ZDD process is captured in the waste streams from the EDM's Mixed Na and Mixed Cl streams. If excessive DI water is used to dilute the concentrate streams, there will be a larger volume of waste measured in the Mixed Na and Mixed Cl outflows. DI water used to prepare the NaCl solution is not considered a loss, because water is transported with the sodium and chloride ions (called water of hydration) that migrate into the Mixed Na and Mixed Cl streams. Finally, there are minimal water losses in the E-Rinse stream, so the DI water used to prepare the initial solution is not considered a significant loss.

## 4.8 Salt Recovery

Cost analysis of the ZDD process indicates that the purchase of NaCl represents a substantial portion of the operating cost of the process (87 percent of the chemical cost and 33 percent of the total cost of production). The EDM waste streams contain all of the salts removed by the NF/RO and EDM systems and offer the potential for salt recovery. When these two concentrate streams are combined, calcium sulfate precipitates and can be recovered as a solid product. The remaining liquid contains NaCl (and other chloride salts). By employing NaCl recovery, ZDD can achieve water recoveries as high as 99 percent and reduce NaCl purchases by 50 percent to 90 percent, depending on the method of salt recovery.

The NaCl that is introduced as the NaCl feed appears as $Na^+$ ions in the Mixed Na stream and as $Cl^-$ ions in the Mixed Cl stream. Moreover, when these two streams are combined to precipitate $CaSO_4$, the NaCl is released and appears in the supernatant, the liquid that remains after the solid $CaSO_4$ settles. (It should be noted that calcium sulfate actually precipitates as the dihydrate $CaSO_4 \cdot 2H_2O$, commonly called gypsum, but the shortened version, $CaSO_4$, will be used in most of the text for brevity.) The following reaction shows how the primary constituents of the Mixed Cl ($CaCl_2$) and Mixed Na ($Na_2SO_4$) streams will combine to form $CaSO_4$ and release NaCl:

$$CaCl_2 + Na_2SO_4 + 2H_2O \rightarrow CaSO_4 \cdot 2H_2O + NaCl$$

When the entire volumes of the EDM Mixed Na and Mixed Cl streams are combined to precipitate $CaSO_4$, essentially all of the NaCl fed to the EDM stack appears in the supernatant. The challenge is to recover that NaCl from the supernatant at a concentration and level of purity that would allow its reuse in the EDM stack. The use of NaCl recovered from the supernatant is dictated by the composition of the source water. For the discussion that follows here, the exemplary source water is the average of the Snake Tank wells that are to supply the desalination plant planned by the Alamogordo.

Table 3 shows the major ions in the source water based on the average of analyses of the three wells supplied by Alamogordo. Data in Table 3 indicate that there is more sulfate than calcium in the well water. However, if the magnesium is replaced with calcium, which can be achieved by adding lime to precipitate $Mg(OH)_2$, then the proportions of calcium and sulfate would be nearly the same, and almost all of the volume of both concentrate streams could be fed to the precipitation process, and all of the supernatant is available for recovery of NaCl. Therefore, except for small amounts of solutions that would be discarded to achieve process control, all of the NaCl that enters the EDM is potentially recoverable.

Table 3.—Snake Tank Water Quality (average of 3 wells)

| Ion | Mg/L | Meq/L |
|---|---|---|
| K | 4.7 | 0.1 |
| Na | 164.3 | 7.1 |
| Mg | 87.7 | 7.2 |
| Ca | 413.3 | 20.6 |
| $HCO_3$ | 131.8 | 2.2 |
| Cl | 132.7 | 3.7 |
| $SO_4$ | 1,433 | 29.8 |
| TDS | 2,500 | |

NaCl can be recovered using ED with monovalent-selective membranes or other approaches. Research was performed using three techniques during this project, all of which produced NaCl of suitable quality for use in EDM (see Section 3.1 and Appendix E for a cost comparison and Chapter 9 for a detailed description of each process and research performed during this project).

# 5. Demonstration Testing Locations

ZDD was tested in several different configurations at four different sites during this project. The primary focus of this project is Alamogordo, New Mexico, but, as mentioned previously, the project team participated in studies led by HDR, Inc. in Colorado and Black and Veatch in California.

## 5.1 Alamogordo, New Mexico

The city of Alamogordo is in the initial steps of permitting and building a desalination facility. They have plans to eventually install a 3-6 MGD desalination plant and are designing a temporary 1 MGD peaking plant to replace the loss of an important surface water supply, Bonito Lake (approximately ten miles north of the village of Ruidoso, New Mexico, off of State Highway 37), while it is being rehabilitated following a forest fire in 2012. Water scarcity is a reality in the city, and the groundwater there has challenging characteristics. The City has rights to 4,000 acre-feet per year (AFY) (3.6 MGD) of brackish water annually. In a drought year, the city is allowed to withdraw up to 5,000 AFY, but the total amount of brackish water extracted cannot exceed 20,000 AFY over a five-year period.

Some of the major challenges that the city of Alamogordo is facing are:

- The city of Alamogordo's 40-year Water Development Plan states that the need for new water supplies is urgent (Livingston Associates, P.C. and John Shomaker and Associates, Inc., 2006).
- Historically, more than 70 percent of the city of Alamogordo's water supply is derived from surface water that is affected by drought, which creates a variable supply that is often not favorable (Livingston Associates, P.C. and John Shomaker and Associates, Inc., 2006).
- The brackish source water in Alamogordo, primarily originating from the Tularosa Underground Water Basin, is nearly saturated in calcium sulfate, and also contains high levels of TDS and silica, which significantly limits the potential desalination yields (~75 percent). The resulting issues are twofold: nearly 30 percent of an already scarce water supply could be wasted if the water were desalted by conventional technology, and without an alternative technology that can provide higher yields, the city of Alamogordo will need to identify and implement an acceptable brine disposal solution.

The BGNDRF is an ideal location to demonstrate the ZDD technology. Preliminary work (supported by Reclamation and Sandia) was successfully performed at BGNDRF, so this location provided a very logical base case in which to pilot ZDD. The facility has four wells, which can be blended to produce brackish water similar to the water available at Alamogordo's Snake Tank wells, which are the source for the city's future desalination plant.

## 5.2 La Junta and Brighton, Colorado

According to the American Membrane Technology Association (AMTA) database, the State of Colorado currently has 87 desalination facilities (AMTA, 2014). Nine of these facilities are for municipalities and there were 10 proposed municipal facilities as of 2007 (Brandhuber et al., 2007). Most desalination facilities discharge their concentrate to sewers or surface water discharge in Colorado, and there is only one permitted deep-well injection site (Archuleta et al., 2014). Many water utilities are looking towards brackish water for future demand and desire long-term solutions for concentrate management. HDR, Inc. led an effort to evaluate concentrate management strategies, including ZLD, for the State of Colorado (Brandhuber et al., 2014).

One portion of this project included pilot testing ZDD at the two Colorado sites, La Junta and Brighton, with existing RO facilities. Piloting at these sites offered the chance to train new operators and evaluate ZDD for the desalination of different feed water quality and product water quality requirements.

## 5.3 Beverly Hills, California

AMTA's database shows nearly 300 desalination facilities in California (AMTA, 2014) with 45 being for municipalities (Archuleta et al., 2014). California desalination plants use a variety of methods for disposal of its concentrate including surface and sewer disposal, DWI, land application, and recycling. Some facilities have access to a "brine line" that allows for disposal into the Pacific Ocean after treatment (Juby et al., 2008). Similar to New Mexico, Colorado, and other States, the State of California is interested in more sustainable concentrate management approaches. With funding from the California Energy Commission, Black and Veatch led an effort to evaluate EDM, the main part of ZDD. The PI, Rick Bond, has also evaluated EDM for treatment of brackish water in Florida (Bond et al., 2015).

Piloting at the Beverly Hills RO Plant allowed for training of other Black and Veatch personnel and for further evaluation of other water quality and treatment schemes.

## 5.4 Water Quality Analysis for Testing Sites

Selected feedwater quality data is presented in Table 4. ZDD is most efficient in areas with relatively high proportions of divalent ions such as calcium, magnesium, and sulfate. The water at the BGNDRF had the highest proportion of all of these ions, with around 60 percent of the cations present as calcium and magnesium and around 70 percent of the anions present as sulfate (concentrations in meq/L). Of the sites tested in Colorado, La Junta is a better fit than Brighton because of the relatively high proportion of calcium and sulfate.

Table 4.—Selected Feedwater Quality Data from ZDD Testing Sites

| **Site**<br>***Source*** | **Beverly Hills, CA**<br>***Conc*** | **Brighton, CO**<br>***Conc*** | **La Junta, CO**<br>***BW*** | **BGNDRF-Yr1**<br>***BW*** | **BGNDRF-Yr2**<br>***BW*** |
|---|---|---|---|---|---|
| Ca | 157 | 553 | 173 | 250 | 288 |
| Mg | 119 | 116 | 63 | 94 | 121 |
| Na | 537 | 555 | 115 | 370 | 379 |
| K | 16 | 15 | 3.8 | 4.5 | 2.6 |
| $SO_4$ | 470 | 870 | 581 | 1,300 | 1,281 |
| Cl | 511 | 638 | 44 | 290 | 342 |
| $HCO_3$ | 791 | 1,138 | 263 | 205 | 248 |
| $NO_3$ | 0.4 | 210 | 4.3 | 1.6 | N/A |
| $SiO_2$ | 118 | 99 | 16 | 24 | 19.8 |
| pH | 7.6 | 7.6 | 7.8 | 7.4 | 7.6 |
| TDS | 3,190 | 4,065 | 1,115 | 2,300 | 2,910 |
| Conductivity (µS/cm) | 4,126 | 5,666 | 1,639 | 2,857 | 3,739 |
| % of Ca, Mg to cations* | 43% | 60% | 67% | 56% | 61% |
| % $SO_4$ to anions* | 25% | 31% | 90% | 70% | 67% |

All in mg/L unless otherwise noted.
*Calculation is made using concentrations in meq/L.
Beverly Hills data from (Bond, et al., 2015 (in progress))
BW=brackish water, Conc=RO concentrate, N/A=not analyzed

# 6. Alamogordo Results and Discussion

Research in Alamogordo was performed in two phases with two sets of equipment. This section describes the feed water quality, the equipment used, and the results of the testing.

## 6.1 Feed Water Quality

The BGNDRF has four brackish water sources available for desalination technology evaluations. This project used a blend of Wells 1 and 4 (about 40 percent of Well 1 and 60 percent of Well 4) in order to simulate the chemistry of water from the Snake Tank wells available to the city of Alamogordo (Livingston Associates; Reclamation, 2013). Table 5 compares the well chemistry at both locations. Most of the contribution to the salinity of the Snake Tank water is from calcium, magnesium and sulfate. The targeted mix aimed to match the average sulfate concentration of the Snake Tank wells and was monitored using conductivity. Compared to the Snake Tank wells, the brackish wells at the BGNDRF have more bicarbonate, sodium, and chloride, relative to the overall TDS, and this difference resulted in higher TDS when the waters from Wells 1 and 4 were blended to achieve the sulfate target. Acid and a de-gas column was used to reduce alkalinity to a level close to the Snake Tank water during Phase 1 and acid alone for Phase 2.

Table 5.—Comparison of Alamogordo Snake Tank and BGNDRF Brackish Water Chemistry

| | Snake Tank Wells | | | | BGNDRF |
|---|---|---|---|---|---|
| **Well/Source Name** | **4** | **5** | **8** | **Average** | **Well 1+4 Targeted Mix** |
| K | 5.9 | 4.3 | 3.9 | 4.7 | 3.5 |
| Na | 320 | 85 | 88 | 164 | 382 |
| Mg | 66 | 98 | 99 | 88 | 143 |
| Ca | 390 | 410 | 440 | 413 | 334 |
| Fe | 0.63 | 0.14 | 0.27 | 0.35 | 0.24 |
| Mn | 0.44 | 0.021 | 0.029 | 0.16 | 0.012 |
| Ba | 0.02 | ND | ND | 0.02 | 0.02 |
| Sr | N/A | 7.15 | 7.4 | 7.3 | 5.3 |
| $HCO_3$ | 78.08 | 146.4 | 170.8 | 132 | 228 |
| F | 0.59 | 0.69 | 0.59 | 0.62 | 0.99 |
| Cl | 68 | 170 | 160 | 133 | 410 |
| $SO_4$ | 1600 | 1400 | 1300 | 1433 | 1455 |
| $SiO_2$ | 23 | 31 | 30 | 28 | 21 |

| | Snake Tank Wells | | | | BGNDRF |
|---|---|---|---|---|---|
| **Well/Source Name** | **4** | **5** | **8** | **Average** | **Well 1+4 Targeted Mix** |
| TDS | 2700 | 2400 | 2400 | 2500 | 3019 |
| Cond. (µS/cm) | 3200 | 2800 | 2900 | 2967 | 3560 |
| pH | 7.56 | 7.43 | 7.74 | 7.58 | 7.9 |
| Turbidity (NTU) | 2.1 | ND | 0.67 | 1.39 | 1.12 |

(concentrations in mg/L as ion unless otherwise noted)

µS/cm = microsiemen per centimeter
NTU = Nephelometric Turbidity Unit

# 6.2 Equipment Description

## 6.2.1 Phase 1 NF Membrane Evaluation

The ZDD equipment used in Phase 1 is capable of producing 20-25 gpm of permeate and is comprised of NF (housed in a 40-foot container, owned by UTEP) and EDM (housed in a 20-foot container, owned by Veolia). Figure 10 includes pictures of the containers and equipment and Figure 11 shows the process flows for the equipment. The NF was a 4x2x1 array with four Dow Filmtec NF270 4-inch-by-40-inch membranes in each pressure vessel. The NF270 membranes were chosen for their low silica rejection. Hydrex 4101 antiscalant was dosed at 3 mg/L to the NF system. The BGNDRF source water has higher alkalinity than the Snake Tank water, so alkalinity was reduced by adding sulfuric acid to the feed water before de-gassing. The EDM system includes the EDM stack, pumps, chemical dosing systems, and DI tanks. The EDM stack is designed to include 100 quads. NaCl is the only regular EDM chemical input. The only waste streams in the ZDD process are the mixed sodium and chloride salts. The permeate used to produce DI water remains in the system and is not considered a waste.

**Figure 10.—Phase 1 ZDD system installed in Alamogordo (20 gpm).**

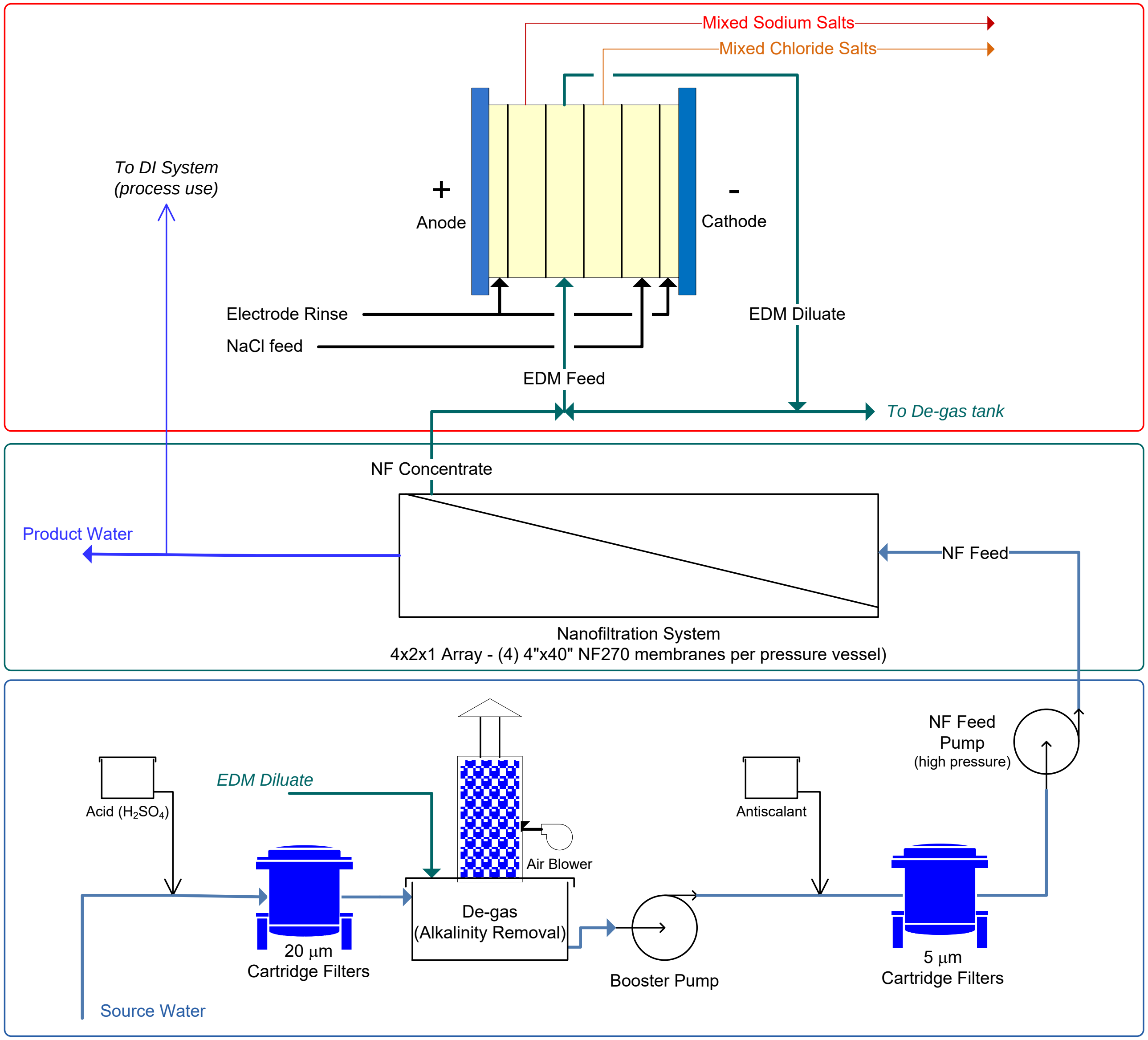


**Figure 11.—Phase 1 equipment flow diagram.**

### 6.2.2 Phase 2 Demonstration Activities

The ZDD equipment used in Phase 2 is capable of producing 20-40 gpm of permeate and is comprised of a NF and an EDM, each housed in a 40-foot container. Figure 12 includes pictures of the containers and equipment installed during Phase 2 in Alamgordo and Figure 13 shows the process flows for the equipment. The NF array was a 4x4 array with four Dow Filmtec NF270 8-inch-by-40-inch membranes in each pressure vessel. Hydrex 4101 antiscalant was dosed at 2-3 mg/L to the NF system. Alkalinity was reduced by adding sulfuric acid to the feed water before the 20-micron cartridge filter. The EDM system includes two EDM stacks, pumps, chemical dosing systems, and DI tanks. The stacks are designed to include 100 quads. NaCl is the only regular EDM chemical input. The only waste streams in the ZDD process are the mixed sodium and chloride salts. The NF permeate used to produce RO permeate remains in the system and is not considered a waste.

**Figure 12.—Phase 2 ZDD System Installed in Alamogordo (40 gpm). Showing a) containers, NaCl tanks, and sulfuric acid tanks; b) NF system; c) EDM standpipes and pumps; and d) EDM stacks.**

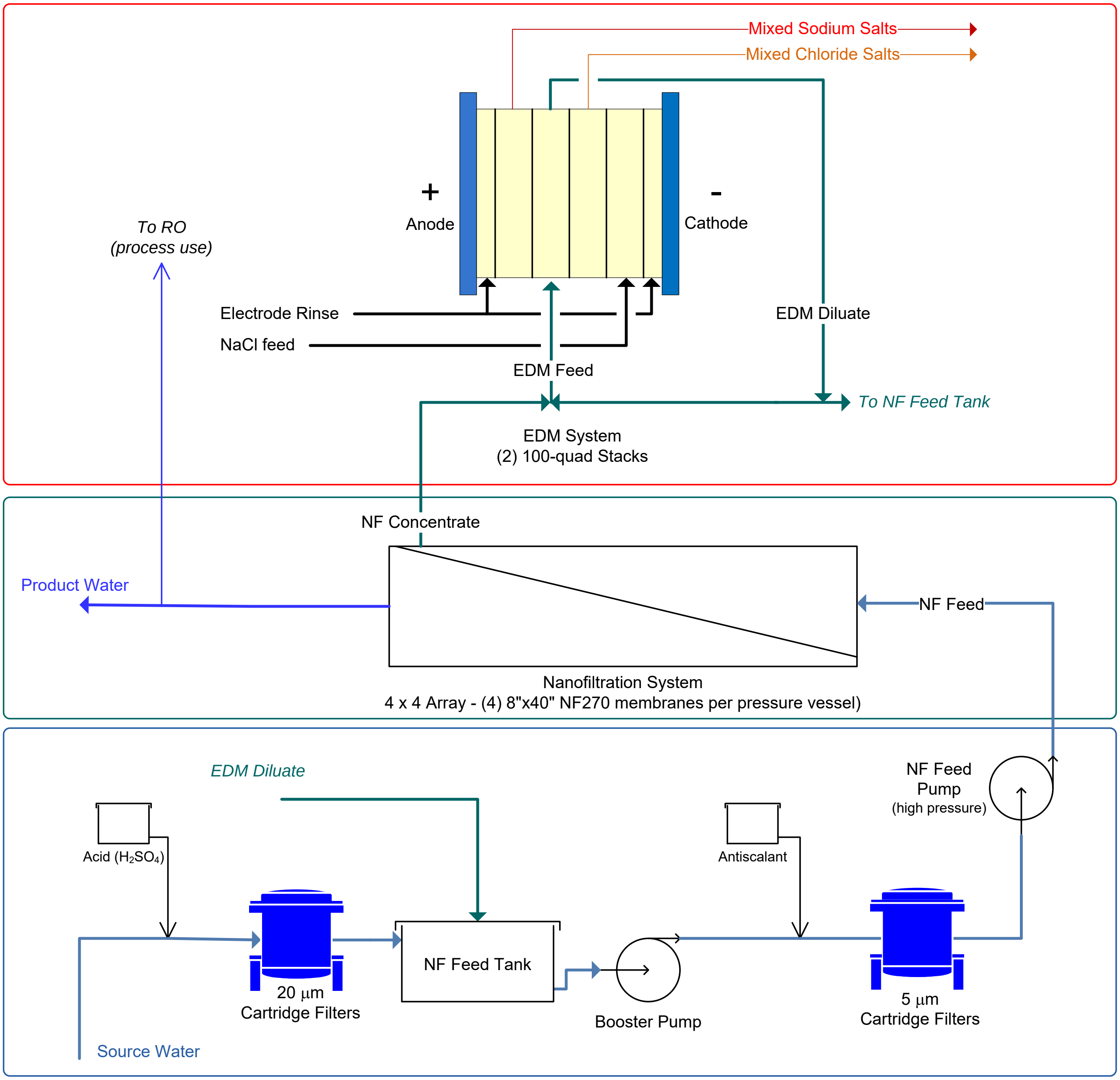


**Figure 13.—Phase 2 flow diagram.**

## 6.3 Phase 1 Operations

A 20 GPD ZDD system was installed at the BGNDRF. The brackish feedwater was a mixture of two wells. Pilot system commissioning activities began in January 2011, but the system was shut down from February 1-7 because of a winter storm that caused sub-zero temperatures and rolling blackouts in much of New Mexico and Texas.

Commissioning restarted in late February 2011. Severe scaling in one of the EDM stack compartments required a shutdown and inspection of the EDM stack. The stack had been installed at location in CA prior to being shipped to Alamogordo and some membranes were removed in between operations. The stack was not reassembled correctly, and this allowed the Mixed Cl stream and E-Rinse (i.e., sodium sulfate) streams to mix and resulted in the formation of calcium sulfate. Six severely fouled quads were removed from the stack, and the system was rebuilt. Another potential problem was thought to be from sulfate in the solar salt used in the EDM process. The solar salt was replaced with pelletized NaCl (water softener salt) purchased at the local home improvement store. No further scaling issues were experienced during Phase 1.

After being commissioned, the ZDD system was operated for five weeks at flow rates ranging from 14-25 gpm. The system was only shut down on weekends when project personnel didn’t have access to the site. System recovery was 98 percent and product water quality of TDS below 800 mg/L was achieved.

Table 6 summarizes the operational data (average values for the entire period with standard deviation shown in parentheses) and field water quality analyses for Phase 1 operations in Alamogordo. As the NF permeate flow was increased from 14 to 20 gpm, the proportion of the NF reject flow to the EDM feed-diluate recirculating flow increased. This is because the EDM feed-diluate flow was kept constant at around 25 gpm. More voltage would be required to achieve the same ion removal with a fixed recirculation rate. The conductivity was relatively constant for the 14 gpm and 20 gpm runs, but increased dramatically during the 25 gpm run (especially on the final day). This increase is possibly due to internal leakage or back diffusion from the concentrate streams to the feed streams in the EDM. Visible leakage was noted near the center divider during Phase 1 operations. There is some indication that the NaCl stream was contaminated with sulfate and possibly calcium and bicarbonate. The NaCl stream was sampled and sulfate was analyzed in the field regularly; sulfate increased from levels below 200 mg/L to as high as 1,325 mg/L at the end of each run. Similar internal leakage is described in the Phase 2 operation (see Section 4.2). Online data can be found in Appendix A1 and logsheet data in Appendix B1.

Table 6.—Alamogordo Phase 1 Operational Data and Field Water Quality Analyses

| **NF Permeate Flow** | | **14-gpm Avg (SD)** | **20-gpm Avg (SD)** | **25-gpm Avg (SD)** |
|---|---|---|---|---|
| NF Removal (NF feed→NF permeate) | | | | |
| conductivity | % | 60.1 (2.7) | 66.2 (1.6) | 68.8 (0.8) |
| total hardness | % | 86.2 (2.8) | 90.3 (1.3) | 91.8 (2.1) |
| alkalinity | % | 14.9 (6.2) | 21.6 (12.2) | 21.8 (17.3) |
| sulfate | % | 98.5 (0.3) | 98.9 (0.2) | 99.2 (0.2) |
| silica | % | -4.6 (22) | 2.2 (11.9) | -3.5 (10.2) |
| NF Permeate | µS/cm | 955 (201) | 916 (120) | 912 (77) |

| NF Permeate Flow | | 14-gpm Avg (SD) | 20-gpm Avg (SD) | 25-gpm Avg (SD) |
|---|---|---|---|---|
| EDM feed-diluate flow | gpm | 24.8 (0.9) | 24.9 (1.1) | 23.6 (0.5) |
| EDM feed pressure | psi | 10.2 (0.7) | 13.5 (0.8) | 14.9 (0.4) |
| EDM recycle ratio | range | 1.7-1.9 | 1.0-1.2 | 0.6-0.7 |
| Brackish SW conductivity | µS/cm | 3,012 (326) | 3,020 (215) | 2,917 (56) |
| EDM Stack Voltage | $V_{DC}$ | 100 (14) | 138 (13) | 180 (0.3) |
| EDM Stack Current | amp | 35 (2.4) | 51 (2.5) | 64 (1.9) |
| ZDD Recovery | % | 98.0 (0.1) | 98.2 (0.2) | 98.3 (0.05) |
| EDM Removal (NF Reject→EDM Diluate) | | | | |
| conductivity | % | 68.5 (2.7) | 56.3 (2.8) | 46.7 (7.8) |
| sulfate | % | 80.1 (7.1) | 68.7 (3.2) | 51.9 (13) |
| ZDD Removal (SW→NF Permeate) | % | 68.6 (3.3) | 69.7 (2) | 68.7 (2.1) |
| Longest Continuous Run | Date<br>Hours | 3/15-3/25<br>239 | 3/25-4/1*<br>166* | 4/5-4/8<br>76 |

*The system was operated for a total of 188 hours at 20-gpm NF permeate flow.
Avg = Average
SD = Standard Deviation
$V_{DC}$ = volts direct current

A set of samples was taken on April 5, 2011, and sent for analysis by Hall Environmental Analysis Laboratory (Hall) in Albuquerque, New Mexico. The results are summarized in Table 7. The original results from Hall indicated poor ion balance for the Mixed Cl and Mixed Na streams. UTEP results are provided for these and are an average of three samples of Mixed Cl and six samples of Mixed Na (gathered in 5-gallon buckets).

Table 7.—Phase 1 Water Quality Analysis Summary

| | Source | NF Feed | NF Perm | NF Conc | EDM Feed | EDM Diluate | Mixed Cl | Mixed Na |
|---|---|---|---|---|---|---|---|---|
| F | 1.7 | 1.4 | 0.9 | 2.5 | 1.8 | 0.8 | ND | 61.3 |
| Cl | 290 | 210 | 260 | 160 | 140 | 100 | 74,767 | 12,694 |
| $SO_4$ | 1,300 | 1,300 | 9.50 | 3,600 | 2,600 | 1,300 | 927 | 110,161 |
| Ca | 250 | 220 | 19 | NT | 380 | 160 | 13,838 | 412 |
| Mg | 94 | 94 | 7.50 | NT | 190 | 86 | 7,623 | 75 |
| Na | 370 | 350 | 150 | NT | 580 | 350 | 18,588 | 61,172 |
| $SiO_2$ | 24.0 | 27.0 | 23.0 | NT | 33.0 | 33.0 | 5.7 | 11.4 |
| pH | 7.4 | 7.0 | 7.0 | 7.0 | 6.9 | 6.6 | 1.8 | 7.9 |
| $HCO_3$ | 205 | 110 | 70 | 135 | 128 | 43 | NT | 4,931 |
| Cond. | 2,857 | 2,724 | 872 | 5,021 | 4,271 | 2,404 | 124,800 | 109,000 |
| TDS | 2,300 | 2,180 | 471 | 4,980 | 3,840 | 1,940 | 160,553 | 184,387 |

| | Source | NF Feed | NF Perm | NF Conc | EDM Feed | EDM Diluate | Mixed Cl | Mixed Na |
|---|---|---|---|---|---|---|---|---|

Concentrations in mg/L, conductivity in μS/cm

The EDM specific energy (kilowatt hour [kWh] per unit of treated water) was estimated for the three NF permeate production flows during Phase 1. Figure 14 includes the energy required for desalination and excludes the circulating pumps (EDM stack power is about 70 percent of the total EDM system energy requirement). A factor of 82 percent is assumed for converting alternating current voltage (VAC) to direct current voltage (VDC) voltage. Figure 14 displays the range of values obtained at three recycle ratios. The recycle ratio is the ratio of the EDM diluate flow returned to the EDM feed divided by the NF concentrate flow (Bond et al., 2015). A recycle ratio of one would indicate that the EDM feed is comprised of equal parts EDM diluate and NF concentrate. As the NF permeate flow increased, so did the NF concentrate flow. Since the EDM recirculating rate was kept constant, the recycle ratio decreased, and more energy was required to remove the ions in the NF concentrate.

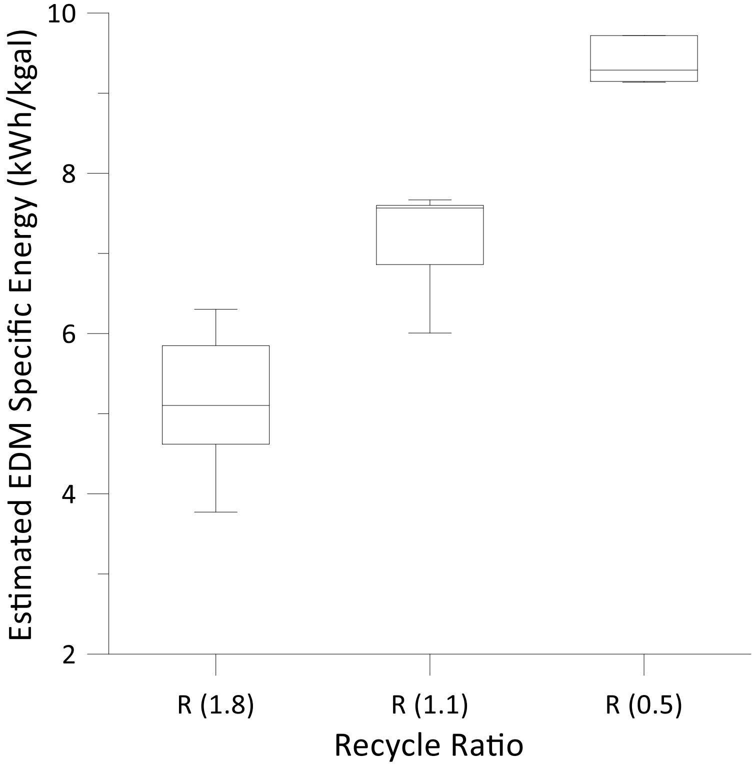


**Figure 14.—Estimated EDM stack specific energy at Alamogordo (Phase 1).**

## 6.4 Phase 2 Operations

### 6.4.1 Preliminary Experiments (Before 4/22/13)

The Phase 2 demonstration equipment arrived in January 2013, and Veolia engineers spent January and February making piping connections, improving processes, and implementing controls for both systems. Several problems were encountered early in the start-up. The equipment was shipped from the integrator, which installed the NF and EDM equipment inside the 40 foot containers, without draining all fluid from the piping. Several online probes and sections of pipe froze and had to be replaced. The NF feed pump arrived damaged from the factory and was repaired and re-installed by local Grundfos technicians. The NF membranes were initially installed incorrectly. The membranes were removed and installed correctly on March 7, 2013.

The system was not operated overnight until nighttime temperatures were high enough to minimize freezing potential and the control system had proper automatic shutdowns and allowed remote viewing and control. Several short experiments were performed between March 20 and 22. Longer experiments took place during March 22-28 and April 8-11. Automated shutdowns, automated DI addition to EDM streams, and remote control and viewing were not in place until April 5. The E-Rinse flow meter stopped working on March 28 (which caused an automatic shutdown). Later operations used E-Rinse pressure to ensure flow (if E-Rinse pressure was less than 3 pounds per square inch (psi), it would trigger an automatic shutdown).

Miscommunication led to higher-than-necessary voltage being applied until April 17. The team intended to apply 1.2-1.3 volts/quad to each stack. The team mistakenly thought the stacks contained 125 quads (instead of the correct 100 quads), so the actual voltage was closer to 1.6 volts/quad. It is likely that the EDM systems were operated at or beyond the limiting current density and water splitting occurred. One way to identify whether water splitting is occurring is to monitor the difference in pH between the Mixed Na and Mixed Cl streams. When water splitting is occurring, the pH of the Mixed Cl stream will decrease and the pH of the Mixed Na stream will increase (see Figure 34).

Grab samples and data were taken at least once per day to check online probe calibration, verify operational setpoints, and act as a backup for loss of online data. Conductivity, pH, specific gravity, and temperature were measured in the field.

Figure 15 summarizes the conductivity, pH, temperature, and specific gravity measurements taken during the preliminary experiments. The online conductivity data before April is not representative of actual conductivity. The programmable logic controller (PLC) code was not fixed to include proper scaling until the first week of April due to personnel availability. The Mixed Cl and Mixed Na online conductivity probes' data are not valid for this most of this time period as well. The conductivity probes had interference from stray current. The probes were initially installed in the feed piping, and it is possible to have current travel from the stack to the probes through the liquid streams. This stray current tended to cause the transmitter to drift and/or not calibrate properly. Logsheet data can be found in Appendix A2 and online data can be found in Appendix B2 of this report.

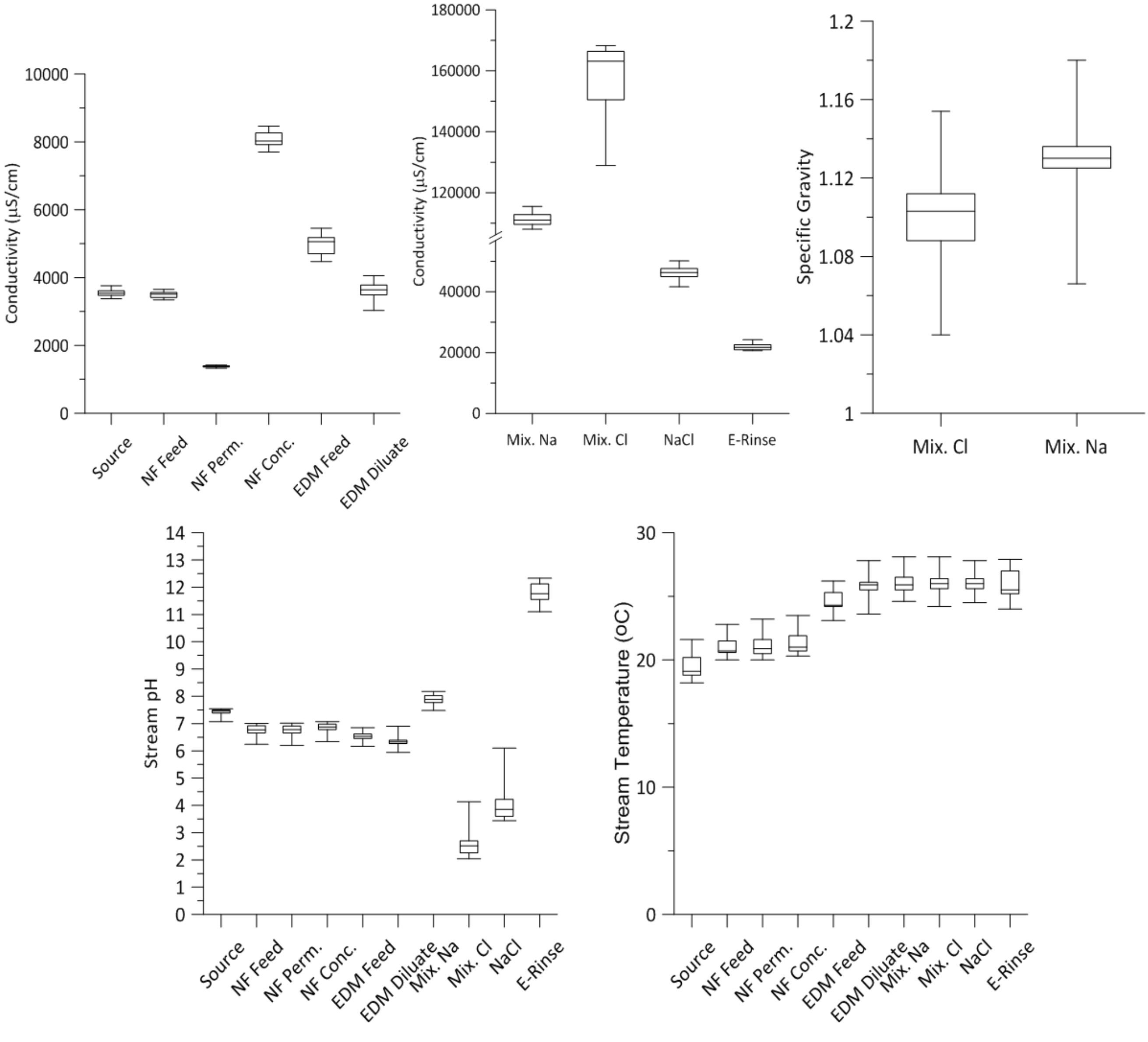


Figure 15.—Grab sample data (preliminary experiments).

The NF and EDM systems operated smoothly with no signs of scale formation until April 11. The datalogger did not record data for April 8-11. Logsheet data does have several data for this period. The system was shut down after there was indication of scale formation (EDM pressures increased and EDM conductivity reduction decreased). A leak test identified major internal leakage, so the stacks were taken apart. One stack (called EDM-1) had a spacer in the incorrect configuration (see Figure 16). The spacer was in D2 (EDM diluate) position, allowing mixing of EDM diluate to the NaCl. The red staining in Figure 16 is typical for the anion membrane in the D2 compartment and is thought to be from iron and/or biological fouling. The other stack (called EDM-2) had a bent spacer due to a piece of membrane leftover from the manufacturer (see Figure 17). Additionally, the center dividers in each stack had holes and were folded. This bent membrane piece allowed mixing of C1 (Mixed Cl) and C2 (Mixed Na) streams. Substantial scale was found at the center of each stack and near the spacers with problems (see **Figure *18*** ). The scale shown is believed to be caused by misalignment of the black divider. This allowed mixing of all streams. The five quads closest to the anode of EDM-2 were stuck together but seemed to be functional enough for operation.

**Figure 16.—EDM-2 Stack with corrected D1 (NaCl outlet) spacer installation.**

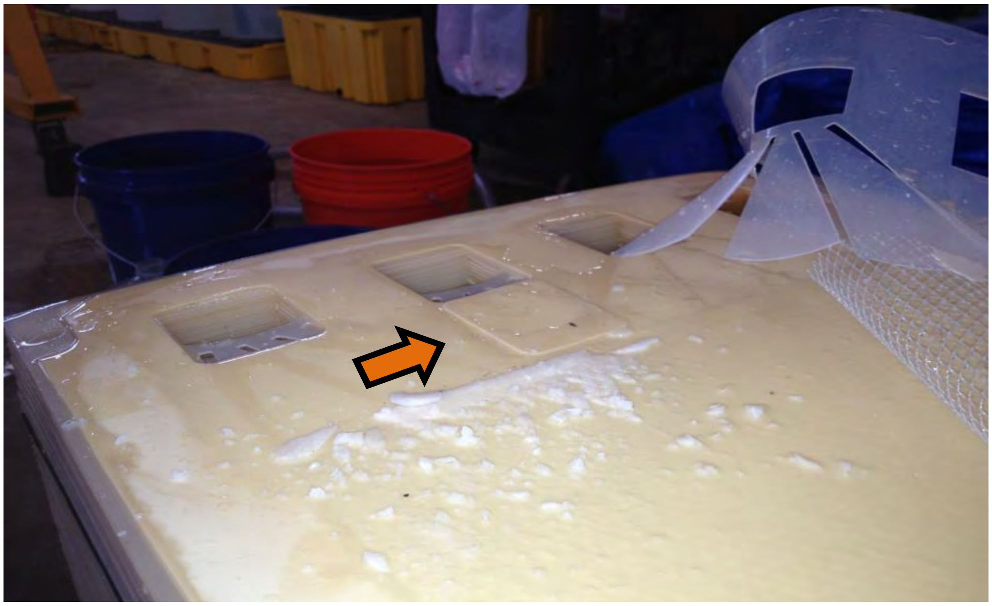


**Figure 17.—EDM-1 Stack with membrane piece from manufacturer.**

**Figure 18.—EDM-2 center membrane (top) and center divider (bottom).**

The ZDD system was re-started on April 17 and two daytime runs were used to test operations. An overnight run with no malfunctions occurred on April 19-20, and the system was considered fixed.

The relationship between conductivity and solution concentration is not reliable for high strength solutions such as the Mixed Na and Mixed Cl streams in the EDM system, because the change in conductivity (related to the change in concentration) diminishes at elevated concentrations of all electrolytes. For this reason, grab samples were taken and the specific gravity and conductivity were measured. Dilution water (RO permeate) was added automatically on a schedule to maintain a specific gravity of 1.13 in the Mixed Na stream. This setpoint was chosen to mitigate sodium sulfate precipitation; a concern in March and April when nighttime temperatures were at or below freezing and the Mixed Na streams were at or below 25 degrees Celsius (see Figure 8 for sodium sulfate solubility vs temperature).

It is important to note that, while there was a larger variation in the NF concentrate, EDM feed, and EDM diluate streams, the NF permeate remained relatively consistent (see

Figure 15 and Appendix B2). The ZDD system reduced the conductivity of the NF reject by an average of 61 percent during this time period. All of the field sample analyses are summarized in

Figure 15. Colder overnight temperatures and a desire to minimize both sodium sulfate and sodium bicarbonate scale formation in the Mixed Na stream led to increased dilution of the Mixed Na stream. This resulted in lower ZDD recovery, ranging from
95.8 percent-97.7 percent.

### 6.4.2 Experiment 1a and 1b (4/22/13-4/26/13)

The system was operated for two periods during April 22-26. The datalogger failed to record data; however, logsheets from in-person and remote login checks are available to describe operations. Appendix B2 includes data from these sources. The system operated fairly stably from April 22 to 24, but the EDM diluate conductivity was increasing and EDM pressures were increasing slightly. A burning smell on April 24 led to a rapid shutdown and inspection of the stacks. During shutdown, the EDM feed stream turned a reddish-brown color. The stream was rinsed with DI water and the problem did not reappear upon restarting.

EDM-2 had been dripping, and dried salts formed at the bottom of the stack that resembled stalactites towards the cathode and on the cathode side of the center of the stack (Figure 19).

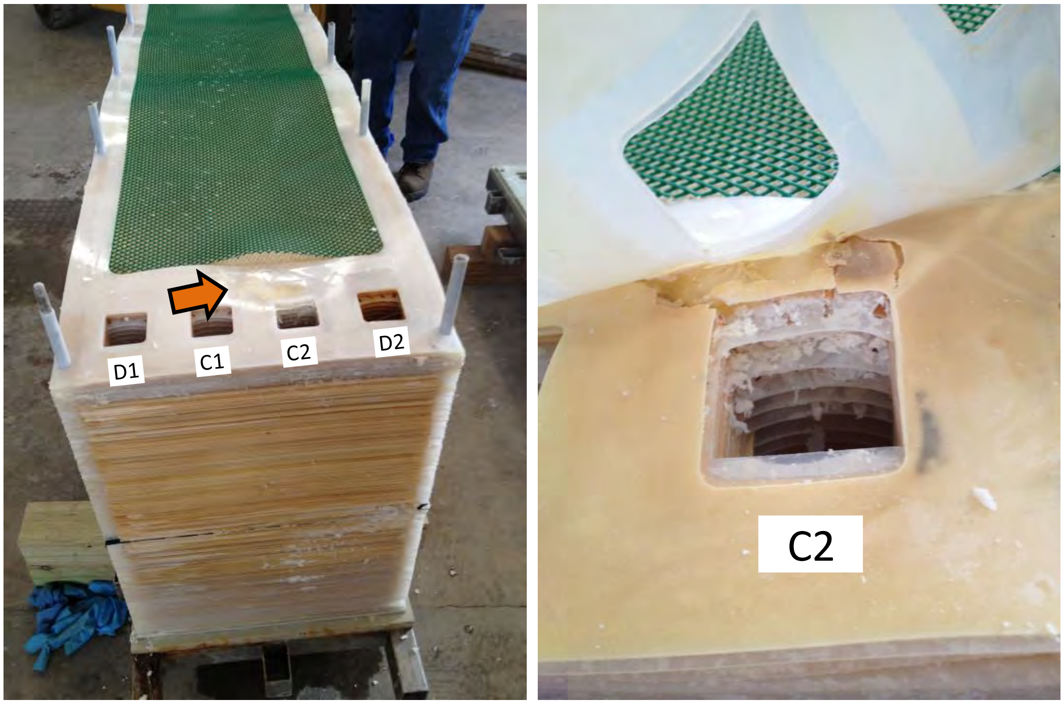


**Figure 19.—EDM-2 stack showing melted anode spacers and adjacent damaged membranes (C2 is mixed Na).**

Upon removal, the five quads in EDM-2 closest to the anode were found to be much more damaged than what was seen during the previous inspection. The manufacturer, MEGA, limits the applied voltage to less than 2 volts/quad. The team thought that 1.75 volts/quad was necessary to achieve the desired water quality objectives at the time. However, in hindsight, too much voltage was applied on April 23-24 (the stack was operated well above the limiting current density). This, combined with the salt growths outside the stack, allowed shunt currents to travel down the membranes to the manifolds. This shunt current allowed localized heat increases that melted the membranes and spacers.

The system was restarted with a single EDM stack (EDM-1) and a lower NF permeate production rate setpoint (20-gpm). The system was stable for nearly 24 hours and was shut down on Friday, April 26. The BGNDRF is not usually open on weekends and personnel were not available for weekend operation.

The grab sample analyses are summarized in Figure 20. The E-Rinse had a low pH on the final day of operation; this is either an analytical error or could be an indication of contamination of the electrolyte stream. The sample analyzed at UTEP also had a lower pH. Samples taken between April 20-26 had elevated bicarbonate and the samples on April 25 and 26 had higher sodium as well. The stack resistance and the permeate quality were stable for the entire run (see Appendix B2 of this report).

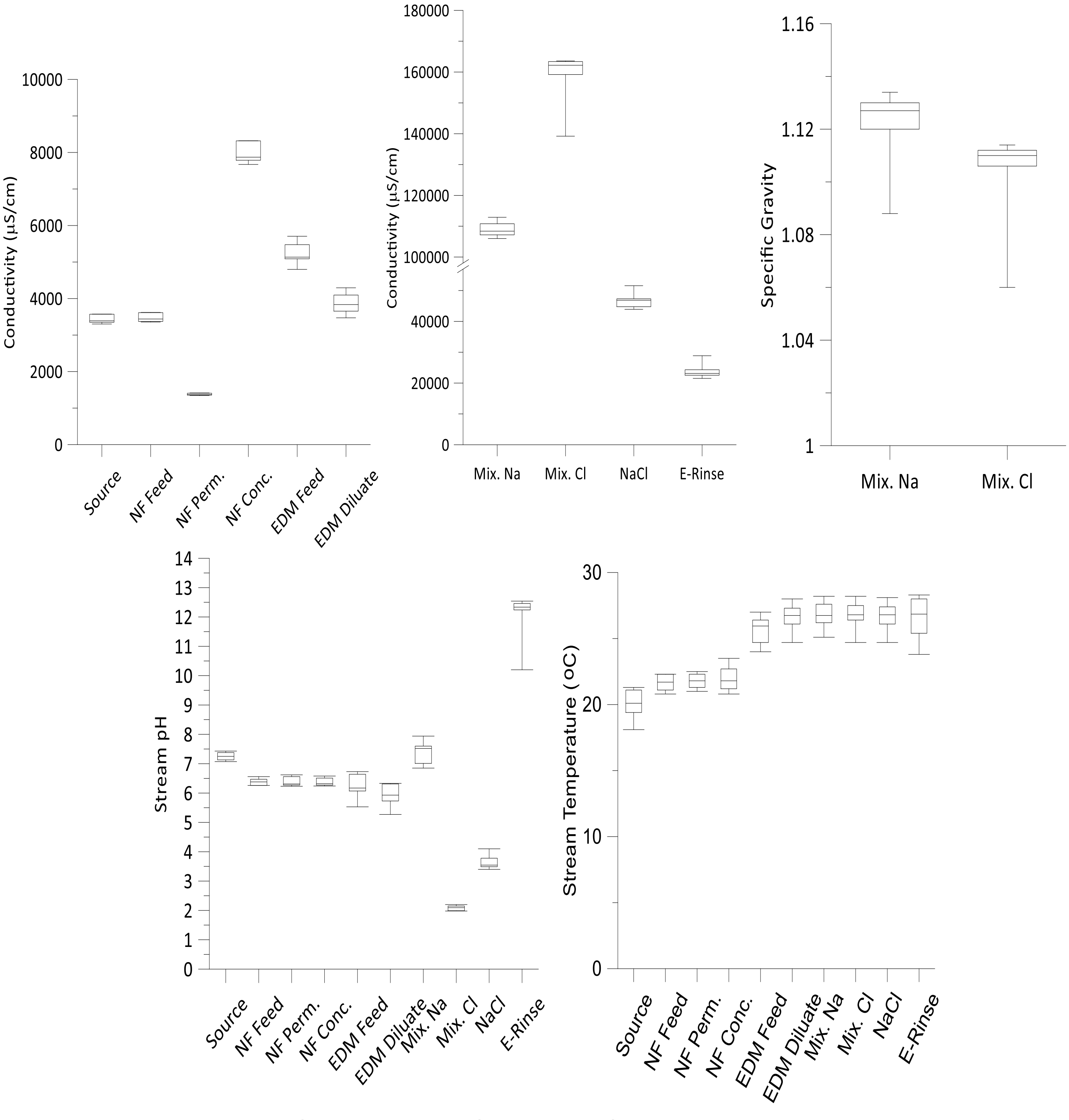


**Figure 20.—Grab sample data (Experiment 1).**

## 6.4.3 Experiment 2 (4/30/13-5/2/13)

The system was restarted with a single EDM stack and 20 gpm of NF permeate flow on April 3 and operated continuously for 58 hours. The antiscalant tank went empty at some point, and there was not enough sulfuric acid remaining to operate after May 2.

Isolation transformers were installed on the power supply for the Mixed Cl and Mixed Na conductivity transmitters. This seemed to allow for proper calibration of the conductivity probes and reliable conductivity data were obtained for the first time by the online data logger.

New 5-micron and 20-micron cartridge filters were installed on the source water and NF feed lines as well as CIP for iron, sulfate, and carbonate scale. However, the NF seemed permanently scaled and new membranes were ordered. The source of the iron in the NF and EDM was unclear at the time. Pictures taken on May 3 of the cartridge filters suggest there was some iron (or red particles) in the BGNDRF source water (Figure 21). Analytical results did not indicate regular presence of iron in the source water or NF streams; however, analyses by inductively coupled plasma atomic emission spectroscopy (ICP-OES) require filtration, so it is possible the iron was filtered out.

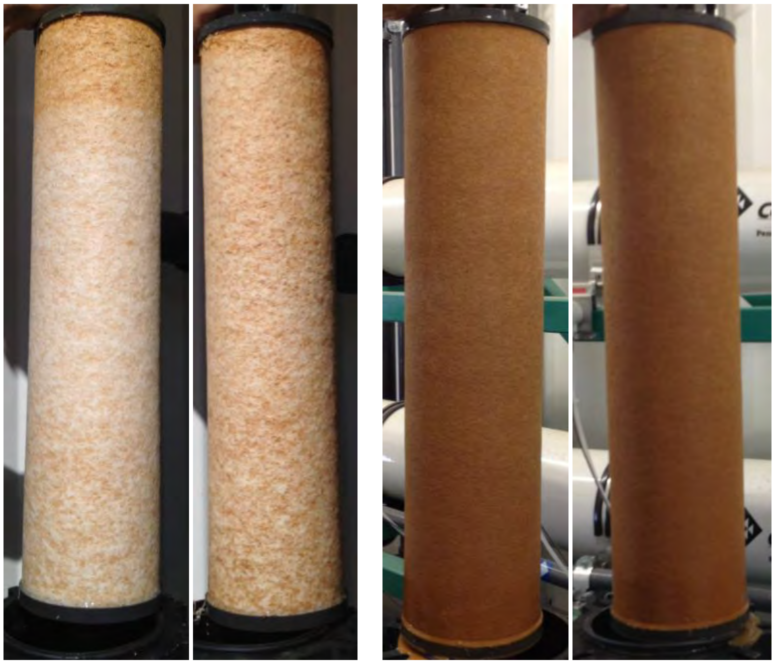


**Figure 21.—NF cartridge filters on May 3. Left: 20-micron filters on source water. Right: 5-micron filters on NF feed.**

Grab sample analyses are summarized in Figure 22 and online data are summarized in in Appendix B2 of this report.

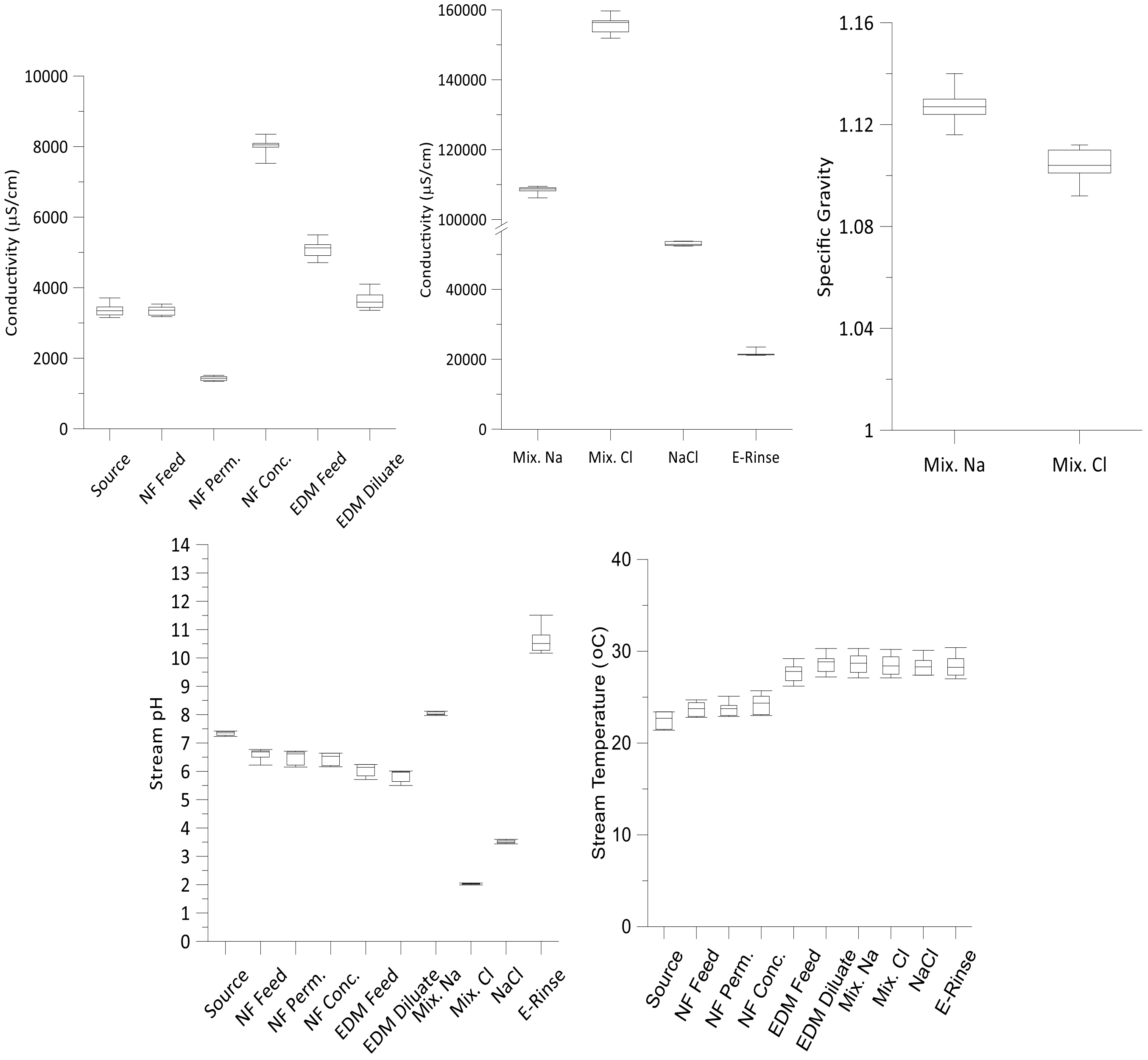


**Figure 22.—Grab sample data (Experiment 2).**

## 6.4.4 NF Membrane Replacement (5/23/13)

The original NF270 membranes were removed and replaced with new membranes on May 23. The membrane elements showed signs of particulate fouling by what was suspected to be iron. Additionally, there was scale outside several of the elements and in the end caps of the pressure vessels (Figure 23).

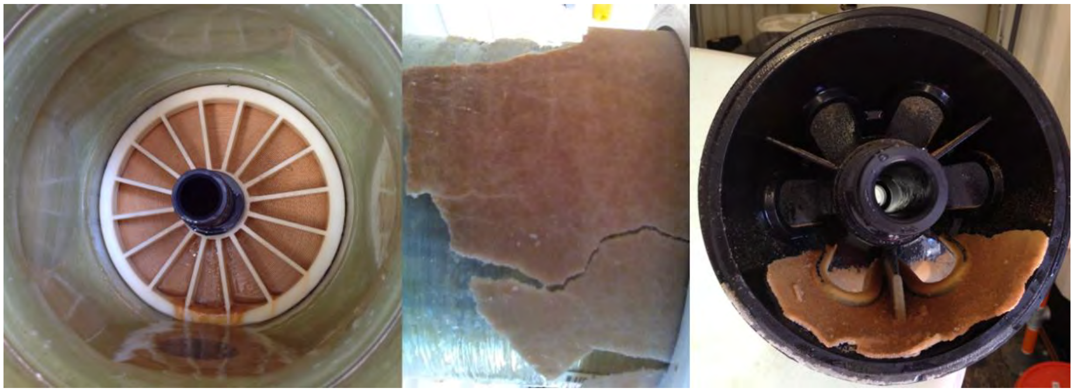


**Figure 23.—Original NF270 membranes removed on May 23.**

Samples were not gathered for analysis, but the scale was suspected to be a mixture of calcium sulfate (from the loss of antiscalant) and iron particulates (later determined to be from corrosion in the acid feed line).

## 6.4.5 Experiment 3 (5/29/13-6/4/13)

The system was tested on May 29 and June 3 to determine whether controls, the new acid, and new NF membranes were working properly. Operators were not available to keep the system operating overnight on June 3 so the system was shut down. The system was operated continuously for nearly 21 hours between June 4 and 5. The new sulfuric acid was more concentrated (93 percent) than the original strength (50 percent). This, combined with the controls, led to a much wider pH span measured by the pH meter in the acidified source water pipe (see Appendix B2).

The grab sample analyses are summarized in Figure 24, and the online data are summarized in Appendix B2 of this report. Similar to earlier experiments, there was more variation in the EDM feed, EDM diluate, and NF concentrate than in the NF permeate. The overnight run started on June 4 was more stable than the earlier runs, in terms of all streams' conductivities. The Mixed Na probe began to read incorrectly and would not calibrate properly beginning on June 4.

The system was shut down on June 5 so that replacement membranes could be installed in EDM-2 and EDM-1 could be inspected. Several issues were found in both stacks and are summarized below. EDM-1 had 91 quads and EDM-2 had 94 quads; both stacks were reinstalled in the EDM container.

- A hole was found in the top of the cation membrane between the EDM feed and Mixed Cl compartments in the second quad of EDM-1 on the cathode end of the stack. This hole allowed mixing and a substantial amount of scale was found on the cathode and on the anode side of the membranes in the first two quads. The quad closest to the cathode was removed; the remaining membranes were cleaned and four membranes were replaced.

- The center divider was damaged and six quads that were stuck together were removed (see Figure 25). Two quads on each side of the center divider were stuck together but were separated and left in the stack.

- Five quads were removed from EDM-2 (the original five quads that were found melted on April 25). Similar to EDM-1, the center divider was damaged and four quads (two on each side of the center divider) were stuck together. The membranes and spacers were separated and remained in the stack.

- New center dividers were made using 6 mil high density polyethylene (HDPE) purchased at the local hardware store.

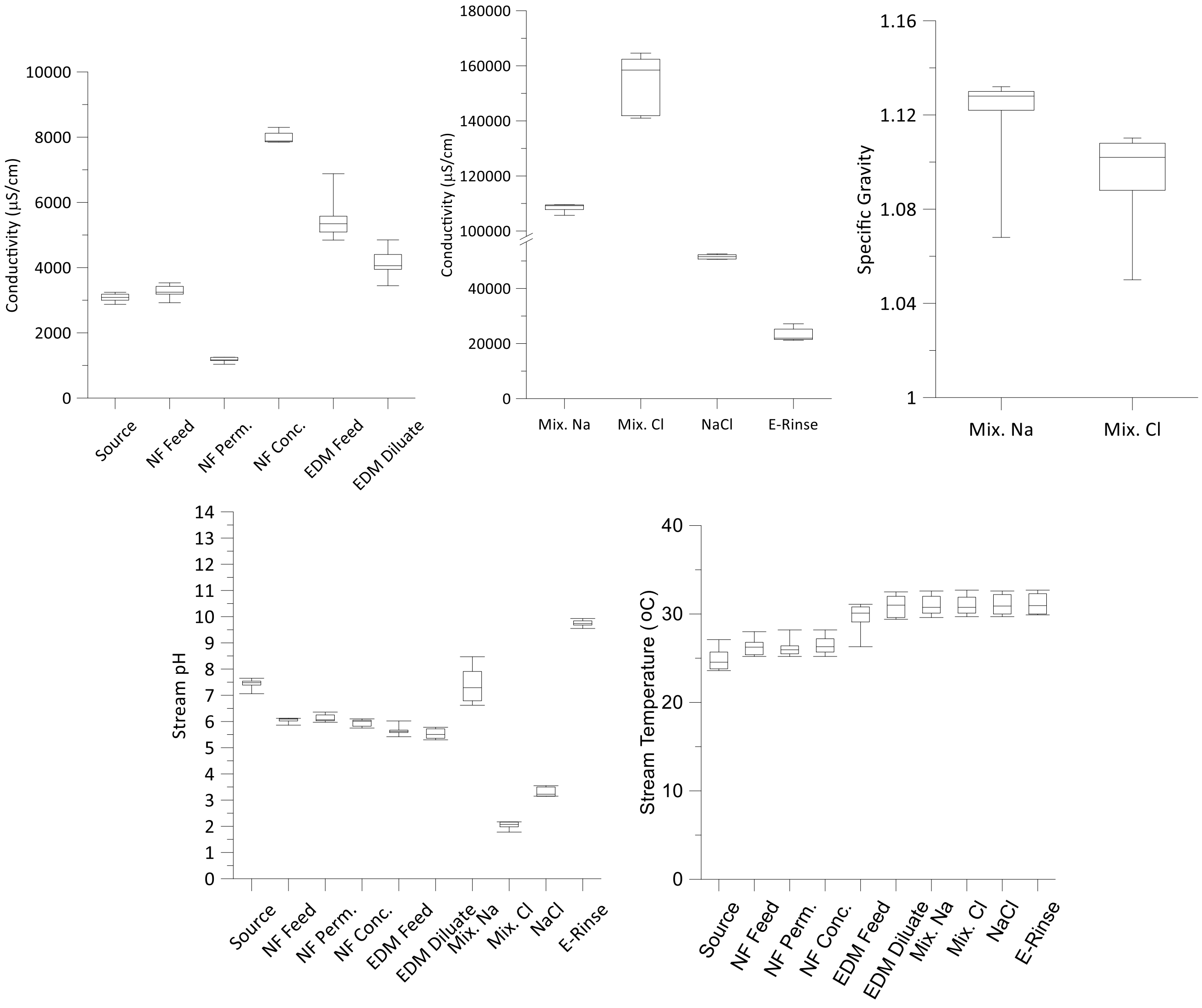


**Figure 24.—Grab sample data (Experiment 3).**

The system was shut down on June 5 so that replacement membranes could be installed in EDM-2, and so EDM-1 could be inspected. Several issues were found in both stacks and are summarized below. EDM-1 had 91 quads and EDM-2 had 94 quads; both stacks were reinstalled in the EDM container.

- A hole was found in the top of the cation membrane between the EDM feed and Mixed Cl compartments in the second quad of EDM-1 on the cathode end of the stack. This hole allowed mixing and a substantial amount of scale was found on the cathode and on the anode side of the membranes in the first two quads. The quad closest to the cathode was removed; the remaining membranes were cleaned and four membranes were replaced.

- The center divider was damaged and six quads that were stuck together were removed (see Figure 25). Two quads on each side of the center divider were stuck together, but were separated and left in the stack.
- Five quads were removed from EDM-2 (the original five quads that were found melted on April 25). Similar to EDM-1, the center divider was damaged and four quads (two on each side of the center divider) were stuck together. The membranes and spacers were separated and remained in the stack.
- New center dividers were made using 6-mil HDPE purchased at the local hardware store.

**Figure 25.—EDM-2 precipitation and damage from mixing at center of stack.**

### 6.4.6 Experiment 4 (6/17/13-6/21/13)

The system was offline for most of the week of June 10 for additional control modifications and was restarted on June 17. The system was shut down on June 17 for a remote update to the controls and restarted again on June 18. The data logger did not record data for part of the day on June 19, but log sheet data and grab samples filled in the gaps. The system ran continuously for 79 hours.

The NF permeate production was intentionally reduced to 35 gpm on June 19 to reduce the percentage of NF reject to EDM feed to 50 percent or lower. This percentage was identified as an operational setpoint during Phase 1. This change also reduced the average flux from 18 gallons per square foot per day (GFD) to 15.75 GFD.

The EDM's operations were fairly stable throughout the week. The flows, pressures, and stack resistance were constant and showed no signs of scale formation. Towards the end of the week the EDM feed and NF feed and concentrate streams showed signs of iron. The NF feed tank and EDM feed systems were drained and refilled while operational to reduce the level of iron visible.

The grab sample analyses are summarized in Figure 26 and the online data are summarized in Appendix B2 of this report. The EDM stack resistance increased when the particles were visible, and this increase in stack resistance caused the EDM diluate conductivity to increase due to the consequent decrease in stack current. That said, the NF permeate conductivity remained stable for most of the week. Lower voltage was applied and the difference in pH between the Mixed Na and Mixed Cl was lower than in earlier experiments. The pH of the NaCl was also higher than the earlier experiments. Subsequent water quality analyses suggest that the NaCl stream could have been contaminated with sulfate and bicarbonate, $HCO_3$, from the Mixed Na stream. Beginning on June 14, NaCl stream's bicarbonate alkalinity went from being below detection levels to 91-220 mg/L as $HCO_3$ (see Figure 32 and Appendix C2). Sulfate also increased at this time. Unfortunately, these analyses were not available for operators and no changes were made to the system.

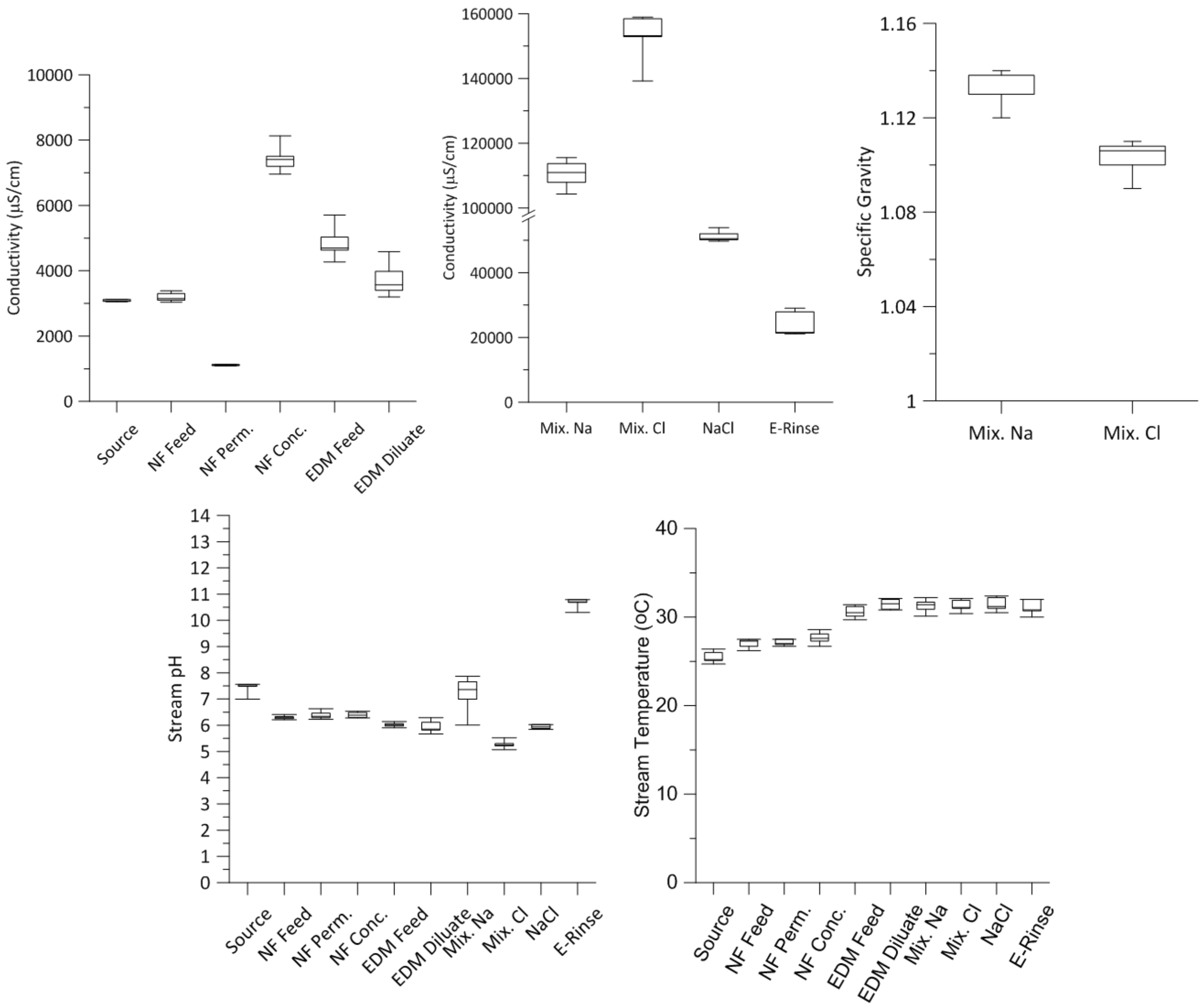


**Figure 26.—Grab sample data (Experiment 4).**

## 6.4.7 Experiment 5 (6/24/13-6/28/13)

The system was restarted on June 24 and operated for 24 hours. The system was shut down, and a CIP was performed to remove iron in the EDM feed and NF systems. The CIP was moderately successful, but the improvement was temporary. The system was restarted on June 26 and operated continuously (with occasional purges of the EDM feed and NF feed tanks to remove visible iron) for 54 hours.

The grab sample analyses are summarized in Figure 27 and the online data are summarized in Appendix B2 of this report. The NF system was stable for the week’s operation, but the EDM showed signs of potential scale. The pressures increased throughout the week. As mentioned previously, there may have been contamination in the NaCl stream that caused bicarbonate and sulfate to be transferred to the Mixed Cl stream. The combination of iron particles in the EDM feed and bicarbonate and sulfate in the NaCl stream likely led to blockages inside the EDM feed and Mixed Cl streams. These blockages would cause increased pressure and reduced flow.

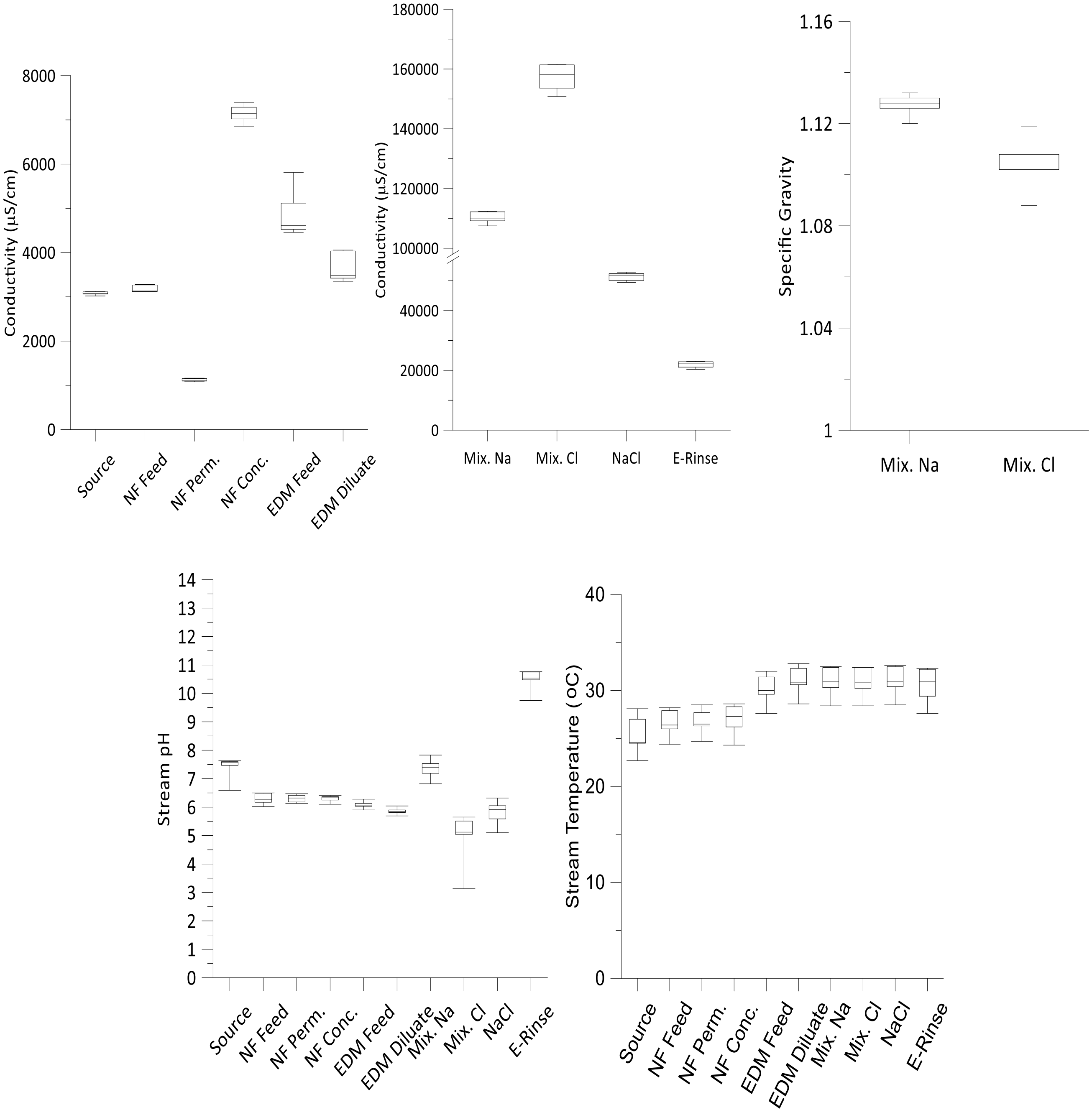


**Figure 27.—Grab sample data (Experiment 5).**

## 6.4.8 Experiment 6 (7/8/13-7/14/13)

The final experiment at BGNDRF began on July 8 and, except for two short shut downs, operated continuously for a total of 137 hours (75 hours from July 8 through 11, and 62 hours from July 11 through 14). The system was shut down on July 11 for a CIP on the EDM and a brief (less than one hour) shutdown on July 12 to fix a leak on the E-Rinse piping and install one micron cartridge filters on the NF feed to remove suspected iron particles.

The one micron cartridge filters on the NF feed nearly eliminated the visible iron in the EDM feed and NF feed tanks. However, the EDM resistance continued to increase, especially in EDM-1. The higher resistance before July 12 is believed to be caused by iron and possibly internal leakage. The higher resistance on July 12 is believed to be caused by lower conductivity in the E-Rinse and internal leakage. The final days' operation had a marked decrease in the Mixed Cl flow and an increase in conductivity in the EDM feed and diluate, E-Rinse, and all NF streams. These problems were likely caused by internal leakage and precipitation in the Mixed Chloride stream.

The EDM stacks were removed and inspected after the system was shut down. The EDM-1 stack had a substantial amount of scale at the center of the stack. Both stacks had similarly damaged or misaligned center dividers again. New center dividers were made using a thicker HDPE sheet and installed in EDM-1 (the local supplier didn't have enough material for both stacks). New dividers made from the 6-mil plastic sheets were made and installed in EDM-2.

The grab sample analyses are summarized in Figure 28 and the online data are summarized in Appendix B2 of this report. Similar to all previous experiments, even with reasonably large variation in the EDM salt removal, the NF permeate quality was relatively stable.

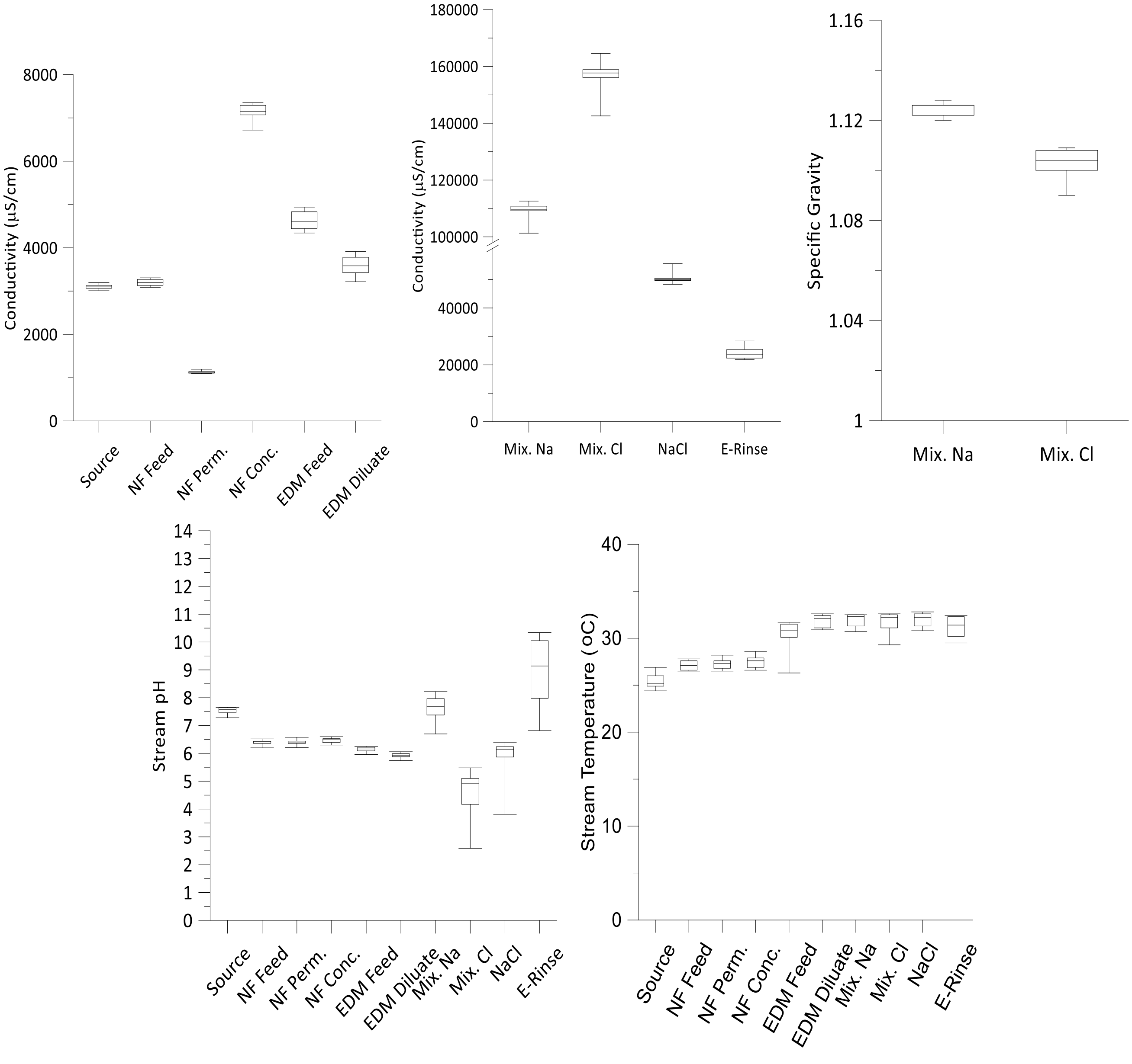


**Figure 28.—Grab sample data (Experiment 6).**

## 6.4.9 Summary of Phase 2 Results

Alamogordo’s water is made up mostly of calcium, magnesium, and sulfate. On an equivalent basis, the sulfate is nearly equal to the sum of the calcium and magnesium. The brackish water, finished water (NF permeate), and EDM concentrate streams’ chemical makeup (Mixed Na and Mixed Cl) is shown using Stiff Diagrams in Figure 29. Stiff Diagrams are one way to visualize the composition of water. Distance to the left of the origin on the left represents the concentration of cations (milliequivalents of solute per litre of solvent [meq/L]), and distance to the right represents concentration of anions. The vertical position has no significance. One can see how the Mixed Na stream is composed primarily of sodium and sulfate and the Mixed Cl is composed primarily of chloride salts of calcium, magnesium, and sodium in nearly equal concentrations.

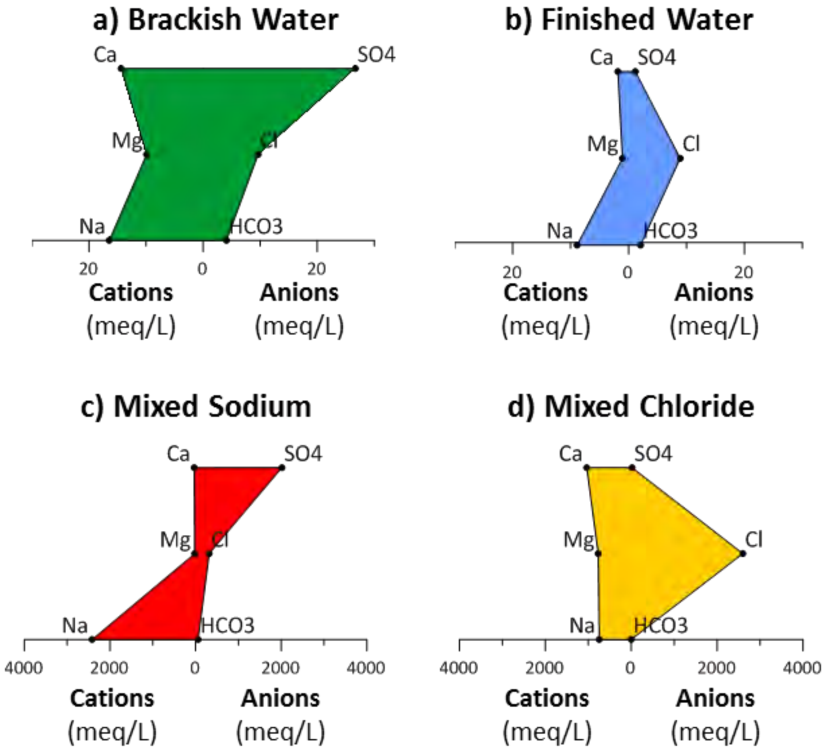


**Figure 29.—Average Alamogordo Phase 2 water quality for ZDD inlet (a) and outlet streams (b-d).**

The variability in the incoming and exiting streams to the ZDD demonstration system are shown in Figure 30. Since the brackish water feed is a mixture of two wells, some variation is expected in both the brackish feed and NF permeate, although the variation is not large. Also, after nearly 10 quads of membranes were removed, it seemed that there was not enough membrane area in the EDM stacks to achieve the water quality targets, so the BGNDRF Well 1/Well 2 blend was adjusted to achieve a lower conductivity setpoint (around 3,100 µS/cm instead of around 3,500 µS/cm). There is a fairly wide range of values for the major constituents of the Mixed Na and Mixed Cl streams. The lower values correspond with earlier runs where steady state conditions had not yet been reached. It can take 8 to 12 hours for the Mixed Na and Mixed Cl streams to reach their steady state composition. The high points, especially the outliers, on the Mixed Na graph represent either early runs where the setpoint was not properly controlled or the final days of operation when the conductivity setpoint was increased or eliminated.

Samples were taken nearly every day of operation for all ZDD streams and analyzed at UTEP's water quality laboratory. Several quality assurance and quality control (QA/QC) methods were in place to ensure that results would be trustworthy. This included using sample blanks, known standards, and rigorous calibration procedures during the analyses steps. After the samples were analyzed, the output was checked for ion balance, and confirmation of TDS by gravimetric and sum of ions, and ion ratios. If one or more of the QA/QC checks failed, a sample was re-analyzed. Less than 10 percent of the remaining samples were excluded from statistical analysis because they failed more than one of the QA/QC checks after being re-analyzed.

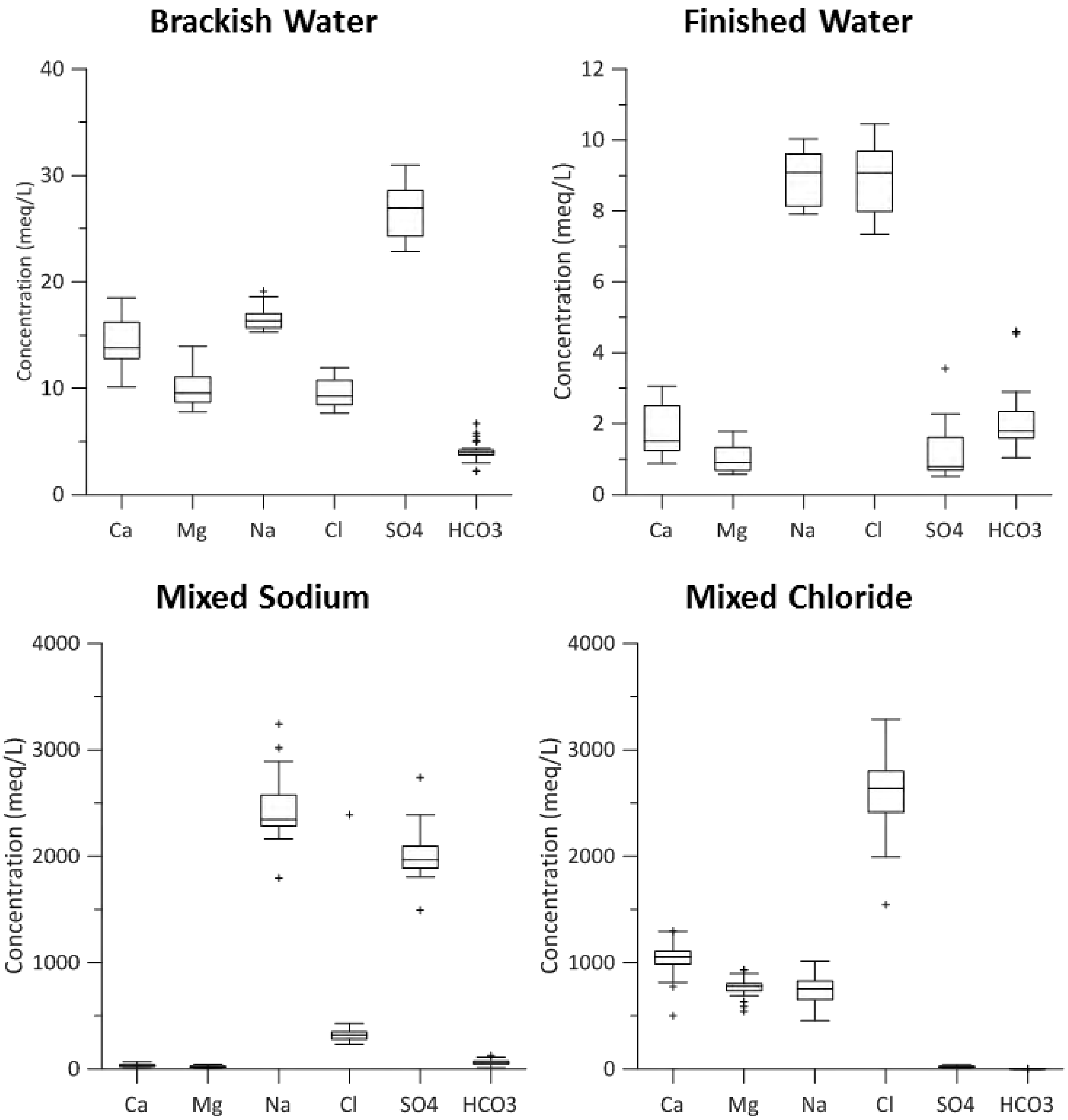


**Figure 30.—Variability in Alamogordo Phase 2 Water Quality for ZDD inlet and outlet streams.**

Table 8 summarizes the average, standard, and number of samples analyzed for all of the Phase 2 water quality analyses. The NF permeate TDS was, on average, less than the 850 mg/L target. After new membranes were installed and the brackish water feed TDS decreased in May, the TDS remained below 800 mg/L TDS. It is important to note that the Snake Tank well water has a TDS at or below 2,700 mg/L, so the later setpoint could be viewed as more representative. All sample analyses are provided in Appendix C2.

As mentioned in the experiment summaries, scale was found on several occasions when the EDM stacks were opened. Early on, this scale is thought to have been caused solely by problems with stack construction. After mid-April, scale was typically only found near the center of the stack. The EDM stacks are built in a way that makes them two stacks hydraulically (two sets of inlets and outlets for each stream) and one stack electrically (one set of electrodes). At the center of the stack are two dividers that are intended to prevent mixing from the two sides of the stack but allow ions to flow between the two sides. This configuration is meant to mitigate shunt currents. The center dividers were found to be problematic during both Phase 1 and Phase 2 at Alamogordo. In Figure 31, a NaCl compartment (anode side) and a Mixed Na compartment (cathode side) are on either side of the dividers (shown with gray dashed lines). If the integrity of the dividers is compromised, mixing between the Mixed Na and NaCl streams will occur. This would allow sulfate and bicarbonate to contaminate the Mixed Cl stream by first entering the NaCl stream and then migrating through the AEMs into the Mixed Cl stream. Figure 32 shows the increase in both bicarbonate and sulfate in the NaCl stream over time. Figure 33 shows the increase of bicarbonate and sulfate in the Mixed Cl stream.

The pH of both the Mixed Cl and NaCl streams is typically low (around pH 4.0 or lower), so increased pH levels in these streams can be a proxy for indication of contamination. Figure 34 shows the increase in these streams' pH measurements over time. As the system was being operated, the pH in both the NaCl and Mixed Cl streams increase until the system was shut down. During most of these shutdown periods, the center dividers were replaced. The center dividers were not replaced between June 8 and July 14, and the contamination seems to have been worst during this period of time..

Table 8.—Phase 2 Alamogordo Water Quality Summary (mg/L)

Avg=Average, SD=standard deviation

| | **TDS*** | | **$HCO_3$** | | **Ca** | | **Mg** | | **Na** | | **Cl** | | **$SO_4$** | | **$SiO_2$** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Avg (SD)** | **N** | **Avg (SD)** | **N** | **Avg (SD)** | **N** | **Avg (SD)** | **N** | **Avg (SD)** | **N** | **Avg (SD)** | **N** | **Avg (SD)** | **N** | **Avg (SD)** | **N** |
| RO (DI) | 364 (188) | 32 | 54 (40.7) | 29 | 2 (2.3) | 28 | 1 (3.4) | 28 | 21 (22.6) | 28 | 22 (33.4) | 29 | 4 (7.4) | 29 | 1.9 (2.8) | 32 |
| raw | 2,910 (524) | 38 | 248 (47.6) | 37 | 288 (40.1) | 35 | 121 (17.1) | 33 | 379 (21.4) | 34 | 342 (45.5) | 34 | 1,281 (111.8) | 34 | 19.8 (1.6) | 39 |
| NF Feed | 3,045 (480) | 34 | 147 (41.8) | 33 | 276 (49.3) | 32 | 130 (49.8) | 32 | 402 (23.1) | 31 | 275 (49.2) | 32 | 1,557 (592.2) | 31 | 22.8 (2) | 34 |
| NF Perm | 767 (262.9) | 36 | 124 (44.6) | 37 | 37 (13.4) | 34 | 13 (4.8) | 34 | 204 (17) | 34 | 316 (33.6) | 34 | 56 (32.9) | 35 | 20.2 (4.2) | 38 |
| NF conc | 8,344 (676) | 33 | 212 (76.4) | 32 | 674 (183.3) | 30 | 442 (135) | 29 | 940 (71.8) | 29 | 279 (550) | 30 | 4,717 (510.8) | 29 | 25.3 (2.2) | 33 |
| EDM feed | 4,686 (641.7) | 40 | 106 (45.2) | 40 | 413 (79.1) | 37 | 202 (47) | 36 | 612 (107.3) | 36 | 117 (16.7) | 37 | 2,697 (407.4) | 33 | 26.4 (2.4) | 41 |
| EDM dil | 3,212 (601.9) | 39 | 76 (40.7) | 38 | 242 (55.9) | 36 | 127 (33.5) | 35 | 502 (120.8) | 35 | 98 (12.8) | 36 | 1,892 (392.6) | 33 | 26 (4.6) | 38 |
| Mixed Na | 164,776 (15,608) | 36 | 3,493 (1369.2) | 32 | 663 (265.6) | 33 | 266 (118.1) | 33 | 55,941 (6,538) | 33 | 13,487 (12,878) | 33 | 96816 (11,159) | 32 | 8.9 (1.6) | 35 |
| Mixed Cl | 175,122 (23,222) | 36 | 32 (44.2) | 36 | 20,721 (3,138) | 33 | 9350 (1041) | 32 | 17,130 (2,545) | 32 | 92,100 (12,225) | 31 | 968 (397.7) | 32 | 5.1 (3.5) | 35 |
| NaCl | 32,007 (2,763) | 34 | 67 (72.4) | 34 | 64 (36.7) | 30 | 34 (18.7) | 30 | 12,249 (1,561) | 30 | 18,317 (2,576) | 31 | 1,000 (739.3) | 31 | 6.5 (2.5) | 33 |
| E-rinse | 20,245 (2,591) | 35 | 420 (418.3) | 32 | 29 (15.9) | 32 | 5 (4.5) | 27 | 6,526 (7,964) | 30 | 197 (96.7) | 32 | 11,989 (1,899) | 31 | 3.2 (2.9) | 35 |

*TDS: Samples were not filtered before placement in oven.

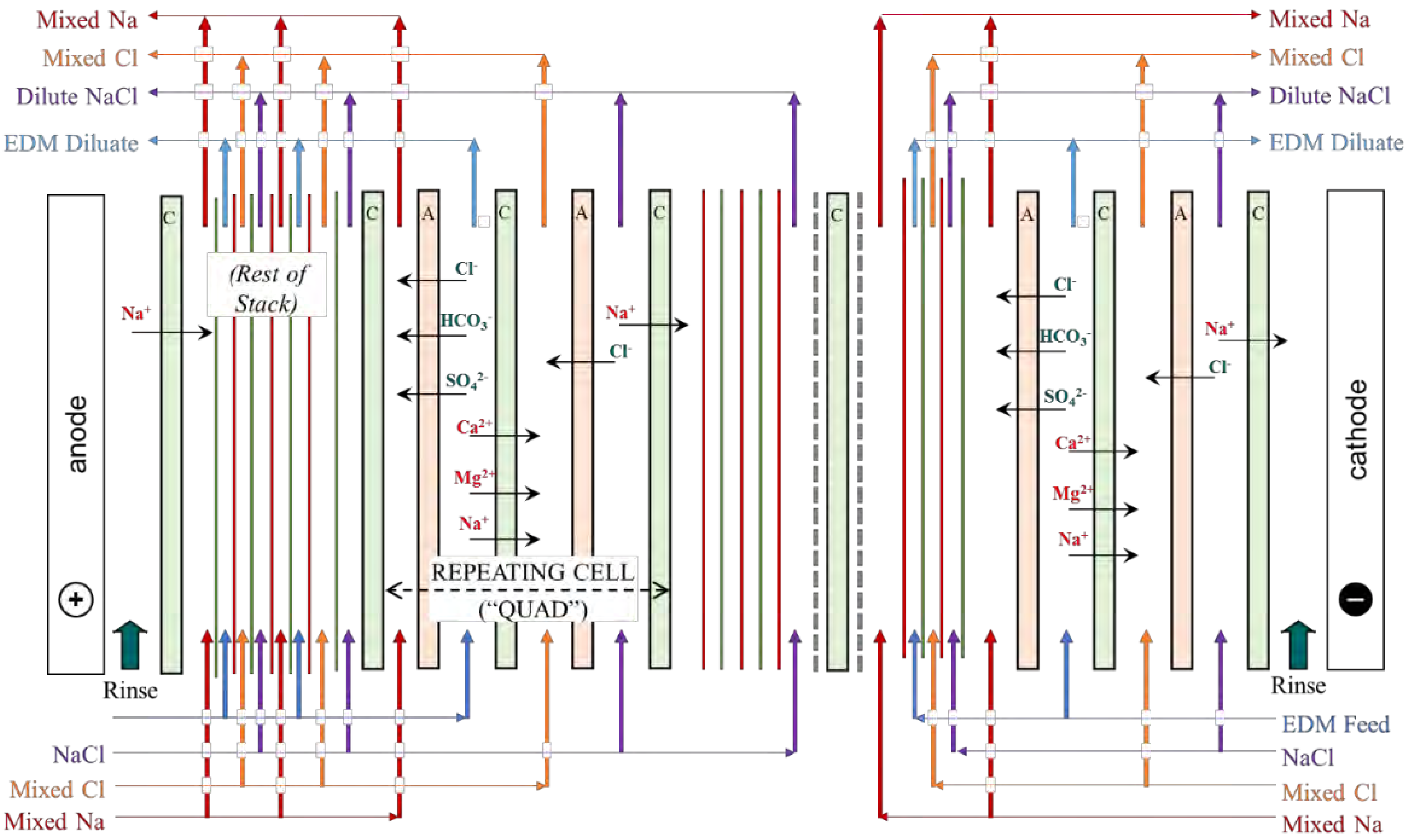


Figure 31.—EDM stack construction at center and electrodes.

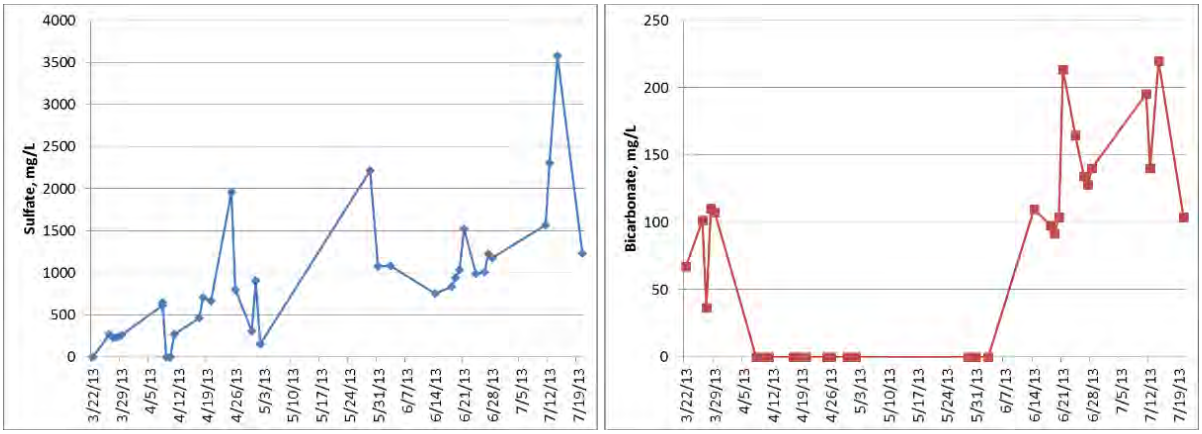


Figure 32.—Bicarbonate and sulfate contamination in NaCl.

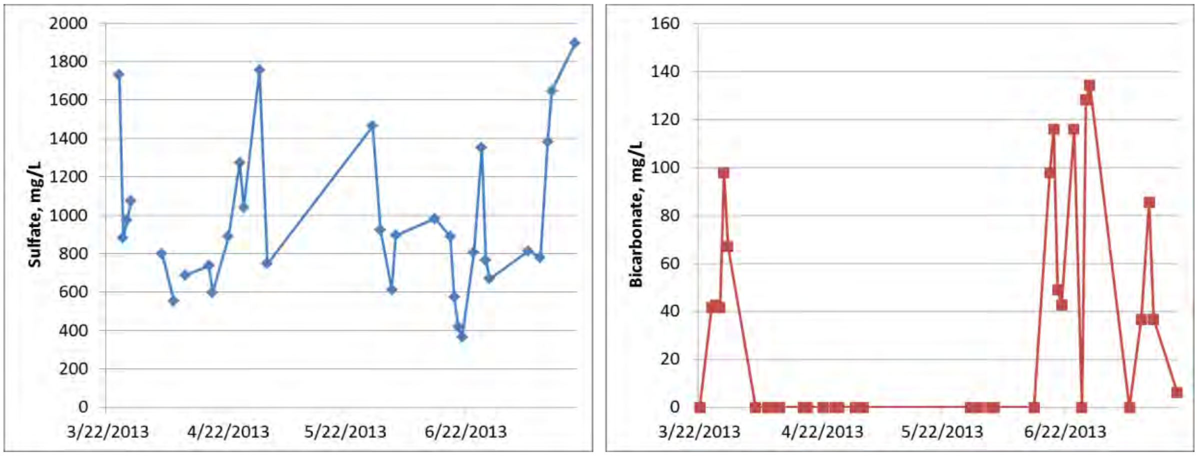


Figure 33.—Bicarbonate and sulfate increase over time - Mixed Cl.

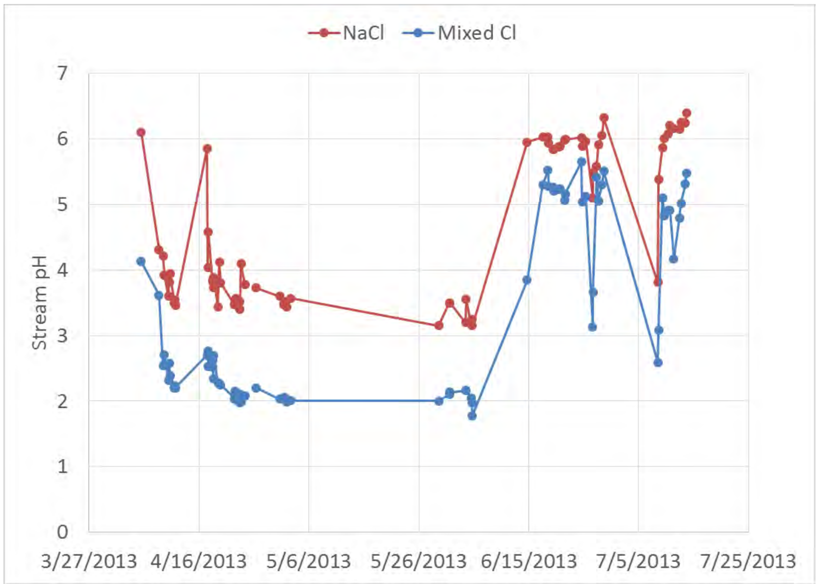


Figure 34.—pH increase over time – Mixed Cl and NaCl.

The anion membranes between the NaCl and Mixed Cl compartments were found to be much thicker than the other anion membranes in the stacks (see Figure 35). This swelling is likely the cause of the decreased flow in the Mixed Cl stream during the final experiment. A portion of the swollen membrane was soaked in a 500 molar NaCl solution and the solution was collected and analyzed by ion chromatography (IC) to see if calcium sulfate was released by the NaCl. NaCl increases the solubility of calcium sulfate, the expected cause of the membrane swelling. The IC analyses of the NaCl solution used to extract precipitate from the membrane are summarized in Table 9.

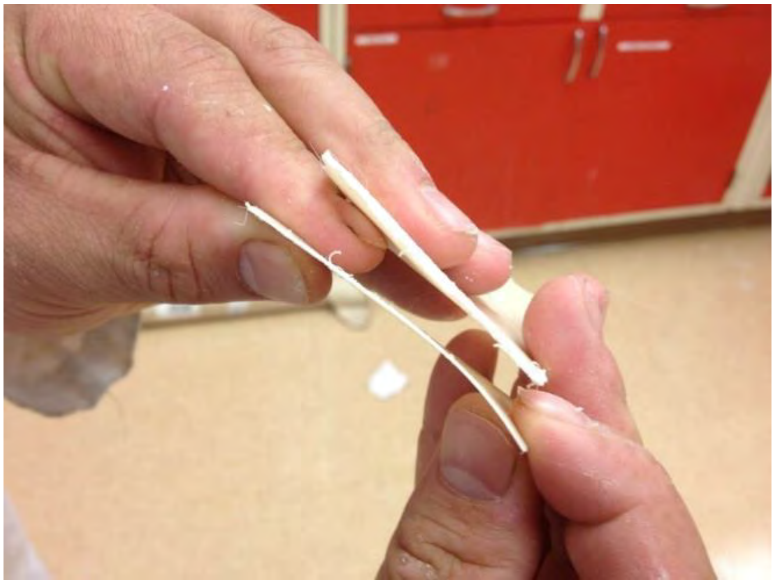


**Figure 35.—Comparison of normal and swollen AEMs.**

Table 9.—Anion Membrane Soak – NaCl Solution IC Results

| | mg/L | meq/L |
|---|---|---|
| Ca | 1,829 | 91 |
| Na | 65,621 | 2,853 |
| Cl | 93,154 | 2,662 |
| $SO_4$ | 5,173 | 108 |

Two quads of EDM membranes were shipped to MEGA for analysis of scale and fouling of the membranes at the conclusion of the Brighton study. The results are included here for continuity of the discussion regarding NaCl contamination. The project team was interested in determining whether the swollen AEMs were a primary cause of increased EDM stack resistance. MEGA's report is included as Appendix D2. The primary findings were:

- The AEMs in between the Na Cl and Mixed Cl (A1 and A1' in MEGA report) had high resistance that decreased after cleaning with acid.

- Cleaning also improved the AEM between the EDM feed and Mixed Na compartment (A2, A2’ in MEGA report)

Analysis of the A1 and A1’ membranes by burning the membrane and analyzing the ash for inorganic content. This procedure showed high levels of calcium and sulfate, as well as higher than expected phosphate and silica. MEGA suggests that $CaSO_4 \cdot 2H_2O$ (and calcium phosphate [$Ca_3(PO_4)_2$]) precipitated inside the membrane:

- MEGA recommended replacing the swollen AEMs.

Analyses by both UTEP and MEGA suggest that calcium sulfate, carbonate, and possibly calcium phosphate are present in or on the anion membranes. A likely mechanism for the swelling of this particular membrane in the quad is that:

1. Sulfate ions that contaminate the NaCl solution migrate through the AEM and encounter calcium ions that have accumulated in the concentrating boundary layers of the Mixed Cl compartments.

2. Because of incomplete Donnan exclusion due to high solution concentration is the Mixed Cl, calcium ions enter the AEM and react with the sulfate ions that are present in high concentration.

3. The precipitate forms a path for more calcium ions to invade the AEM and form more precipitate.

4. Accumulation of precipitate in the membrane causes it to become thicker.

Conductivity is known to have a non-linear relationship with concentration, and the ratio is specific to the composition of the fluid being measured. For this reason, specific gravity measurements were taken regularly to ensure that solubility limits for salts that have a steep decline with decreasing temperature (i.e. sodium sulfate, sodium carbonate, and, to a lesser degree, sodium bicarbonate – see Figure 8). Once a relationship is known (and the proper conductivity probes are installed in the proper location), a conductivity setpoint can be employed for maintaining the desired concentration in the Mixed Na and Mixed Cl streams. Figure 36 shows the relationship and reasonable linear fits for the regime in which the EDM stack was operated in Phase 2.

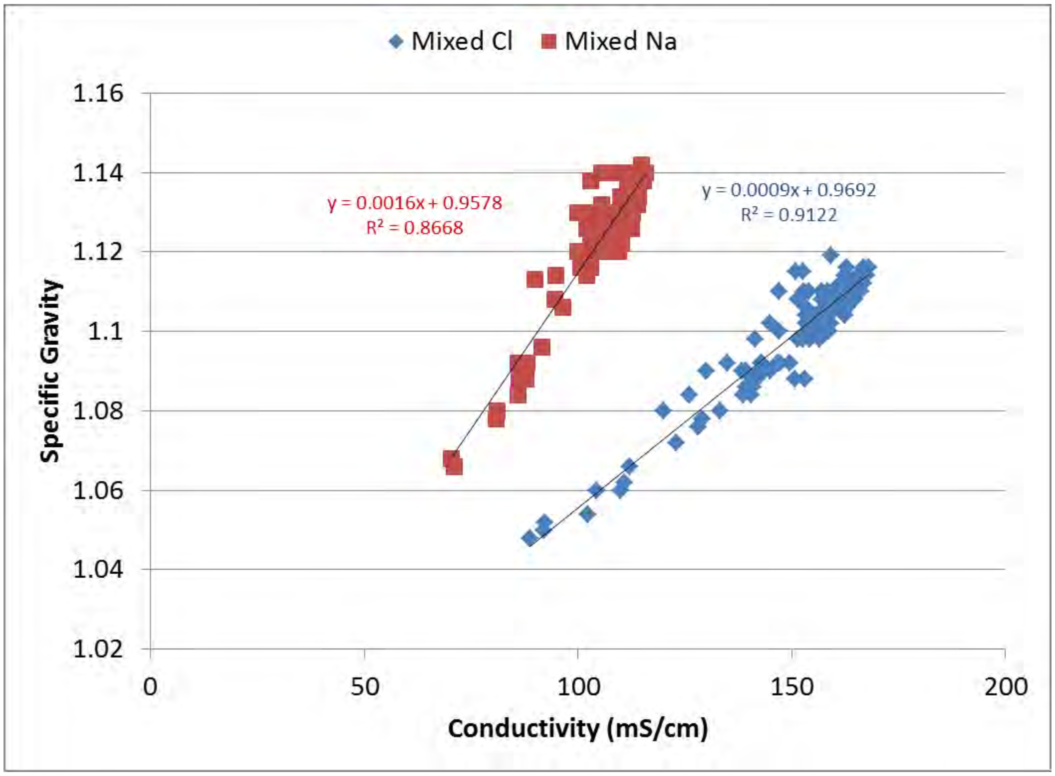


**Figure 36.—Relationship between conductivity and specific gravity (Alamogordo – Phase 2) .**

Table 10.—Summary of Alamogordo Phase 2 Operational Data

| **Experiment** | | **0** | **1a** | **1b** | **2** | **3** | **4** | |
|---|---|---|---|---|---|---|---|---|
| **Dates** | | **Bef. 4/22** | **4/22-4/24** | **4/25-4/26** | **4/30-5/2** | **5/29-6/5** | **6/17-6/21** | **6/** |
| **# EDM stacks** | | **2** | **2** | **1** | **1** | **1** | **2** | |
| | | **Average (Range)** | **Average (Range)** | **Average (Range)** | **Average (Range)** | **Average (Range)** | **Average (Range)** | **A (I** |
| NF Feed Pressure | gpm | 103.7 | 106.7 | 63.3 | 68.5 | 60.5 | 87.6 | |
| | | (98-109) | (103-112) | (62-64) | (65-70) | (59-62) | (82-99) | ( |
| NF Permeate flow | psi | 40.2 | 40.3 | 21.2 | 21.6 | 22.3 | 36.8 | |
| | | (38.7-43.2) | (39.1-42.2) | (20.4-21.9) | (20.1-22.3) | (21-25.6) | (34.5-40.6) | (33 |
| NF Pressure Drop | psi | 37.5 | 37.0 | 18.7 | 33.8 | 18.5 | 33.1 | |
| | | (36-41) | (36-39) | (18-19) | (19-62) | (18-20) | (30-42) | ( |
| EDM Feed flow | gpm | 56.6 | 55.1 | 26.7 | 26.4 | 31.8 | 56.4 | |
| | | (51.2-60.4) | (51.1-59.9) | (25.3-27.6) | (24.4-27.8) | (30.2-33.5) | (54.4-59.6) | (53 |
| EDM Feed pressure | psi | 17.8 | 15.6 | 11.7 | 13.1 | 24.6 | 18.6 | |
| | | (13.9-21.5) | (15.1-18) | (11.4-12) | (12.3-13.7) | (22.4-27) | (18.1-19.1) | (19 |
| Mixed Cl flow | gpm | 66.4 | 63.2 | 32.0 | 31.9 | 37.5 | 69.9 | |
| | | (57.5-76.3) | (57.2-68.2) | (30.9-33) | (31-32.7) | (35.3-40.2) | (67.2-75.3) | (64 |
| Mixed Cl pressure | psi | 18.1 | 15.9 | 11.7 | 13.5 | 25.0 | 18.9 | |
| | | (13.9-21.8) | (15-18.5) | (11.4-12.1) | (12.6-14.2) | (22.6-27.9) | (18-19.4) | (19 |
| Mixed Na flow | gpm | 68.8 | 64.4 | 31.3 | 31.2 | 35.8 | 73.4 | |
| | | (43.4-76) | (61-68) | (30-33) | (30-34) | (28-42) | (69-77) | ( |
| Mixed Na pressure | psi | 18.1 | 15.7 | 12.0 | 13.4 | 24.8 | 18.9 | |
| | | (13.9-21.9) | (15.1-18.3) | (11.9-12.1) | (12.3-14.3) | (22.8-26.8) | (17.9-19.7) | (19 |
| Mixed NaCl flow | gpm | 76.4 | 71.9 | 31.0 | 33.7 | 42.0 | 74.1 | |
| | | (66-84) | (65-76) | (30-32) | (33-35) | (40-45) | (64-77) | ( |
| Mixed NaCl pressure | psi | 18.1 | 15.6 | 11.8 | 13.5 | 24.9 | 18.7 | |
| | | (14-21.8) | (15-18.4) | (11.6-12.1) | (12.6-13.9) | (22.7-27.2) | (18.1-19.5) | (19 |
| E-Rinse Flow | gpm | 7.5 | *Flow meter not functional* | | | | 11.6 | |
| | | (0-12.8) | | | | | (11-12.1) | (10 |
| E-Rinse Pressure | psi | 11.8 | 11.1 | 12.2 | 13.6 | 20.2 | 12.8 | |
| | | (10-13.4) | (10.7-11.8) | (12-12.4) | (12.8-14.3) | (19.3-20.8) | (12-13.7) | (13 |
| EDM-1 voltage | volts | 160.0 | 163.0 | 156.0 | 154.0 | 142.0 | 124 | |
| | | (150-175) | (155-170) | (156-156) | (150-160) | (124-150) | (111-137) | (1 |
| EDM-1 current | amps | 61.0 | 62.0 | 52.0 | 54.0 | 50.0 | 48 | |
| | | (36-68) | (45-67) | (39-57) | (47-59) | (34-58) | (43-53) | ( |
| EDM-2 voltage | volts | 151.0 | 160.0 | | | | 122 | |
| | | (140-165) | (155-166) | | | | (111-130) | (1 |
| EDM-2 current | amps | 49.0 | 48.0 | | | | 49 | |
| | | (31-61) | (37-51) | | | | (42-53) | ( |
| NaCl Consumption (est) | lb/day | Unreliable | 1072 | 491 | 521 | 422 | 868 | |
| NF Recovery | % | 58.6 | 58.0 | 59.2 | 61.5 | 58.4 | 56.6 | |
| | | (57.3-60.1) | (57.2-58.6) | (58.6-59.6) | (59.7-64.1) | (57-61.7) | (55.2-58.7) | (54 |

| **Experiment** | | **0** | **1a** | **1b** | **2** | **3** | **4** | |
|---|---|---|---|---|---|---|---|---|
| **Dates** | | **Bef. 4/22** | **4/22-4/24** | **4/25-4/26** | **4/30-5/2** | **5/29-6/5** | **6/17-6/21** | **6/** |
| **# EDM stacks** | | **2** | **2** | **1** | **1** | **1** | **2** | |
| | | **Average (Range)** | **Average (Range)** | **Average (Range)** | **Average (Range)** | **Average (Range)** | **Average (Range)** | **A (** |
| NF rejection | % | 60.5 | 60.4 | 60.4 | 57.4 | 63.9 | 64.9 | |
| | | (57.6-61.8) | (58.3-62.1) | (58.3-62.1) | (56.1-58.5) | (63.2-64.7) | (63.3-66.5) | (63 |
| EDM removal- per pass | % | 28.1 | 26.9 | 26.9 | 28.5 | 24.5 | 24.2 | |
| | | (25.5-32.3) | (24.1-31.4) | (24.1-31.4) | (25.4-35.5) | (19.8-29.5) | (19.7-26.9) | (20 |
| EDM removal-overall | % | 55.6 | 52.4 | 52.4 | 54.5 | 48.4 | 50.9 | |
| | | (51.8-61.1) | (48.4-55.1) | (48.4-55.1) | (50.9-57.9) | (41.6-56.3) | (43.7-54.1) | (43 |
| ZDD removal-overall | % | 61.0 | 59.8 | 59.8 | 57.6 | 61.8 | 64 | |
| | | (59.2-62.7) | (58.5-60.7) | (58.5-60.7) | (56.2-60.1) | (60.4-63.9) | (63-64.5) | (62 |
| ZDD Recovery | % | 96.6 | 96.3 | 97.2 | 97.1 | 97.5 | 97.7 | |
| | | (95.8-97.7) | (96.1-96.5) | (97-97.5) | (96.7-97.5) | (97.5-97.9) | (97.2-98.2) | (96 |
| Longest continuous Run | Date | 4/19-4/20 | 4/22-4/24 | 4/25-4/26 | 4/30-5/2 | 6/4-5 | 6/18-21 | 6 |
| | Hours | 24.4 | 49.3 | 23.4 | 58.1 | 20.8 | 79.1 | |

*The combined total run for 7/8-14 was 137 hours (excludes 8 hours of shutdowns). There was a 7-hour shut down on 7/11 to CIP the EDM feed stream and a 1-hour shutdown on 7/12 to install new cartridge filters for the NF feed and fix a leak on the E-Rinse.

# 6.3 Evaluation of Current Density, Current Efficiency, Power Consumption – Alamogordo

## 6.3.1 Current Density

Operating beyond the limiting current density is inefficient and can lead to damage of membranes and equipment. A set of experiments was run in early April in an attempt to identify the limiting current density. Voltage and current data were gathered at three cell velocities in a single EDM stack. Unfortunately, conductivity data was not gathered at this time.

Figure 37 shows the current density versus voltage plots. The operational limiting current density is the intersection between the ohmic (blue line/dots) and plateau (red line/dots) lines and was calculated algebraically from the data gathered. A relationship between velocity and limiting current density was obtained so that the limiting current density could be calculated for the duration of the Phase 2 operations.

At the beginning of the Phase 2 operations, the operators thought that they had two 120-quad EDM stacks. This led to operating above the operational limiting current density (shown with blue dashed line in Figure 38). When operating beyond the limiting current density, ions are depleted from the boundary layer near the ion exchange membranes, and the only way to support increasing current is for water to split into hydrogen and hydroxyl ions. This causes a decreased pH in the Mixed Cl stream from $H^+$ ions and an increased pH in the Mixed Na stream from $OH^-$ ions. The difference between the pH measurements in these two streams can be an indicator of water splitting. In Figure 38, this effect is visible in the earlier runs. The later runs were operated closer to the limiting current density, but in many cases still above the setpoint. While the pH difference does not show the effect of over-current, it is likely explained by the NaCl and Mixed Cl contamination described earlier (presence of bicarbonate in Mixed Cl stream buffered the pH so the difference was lower than expected).

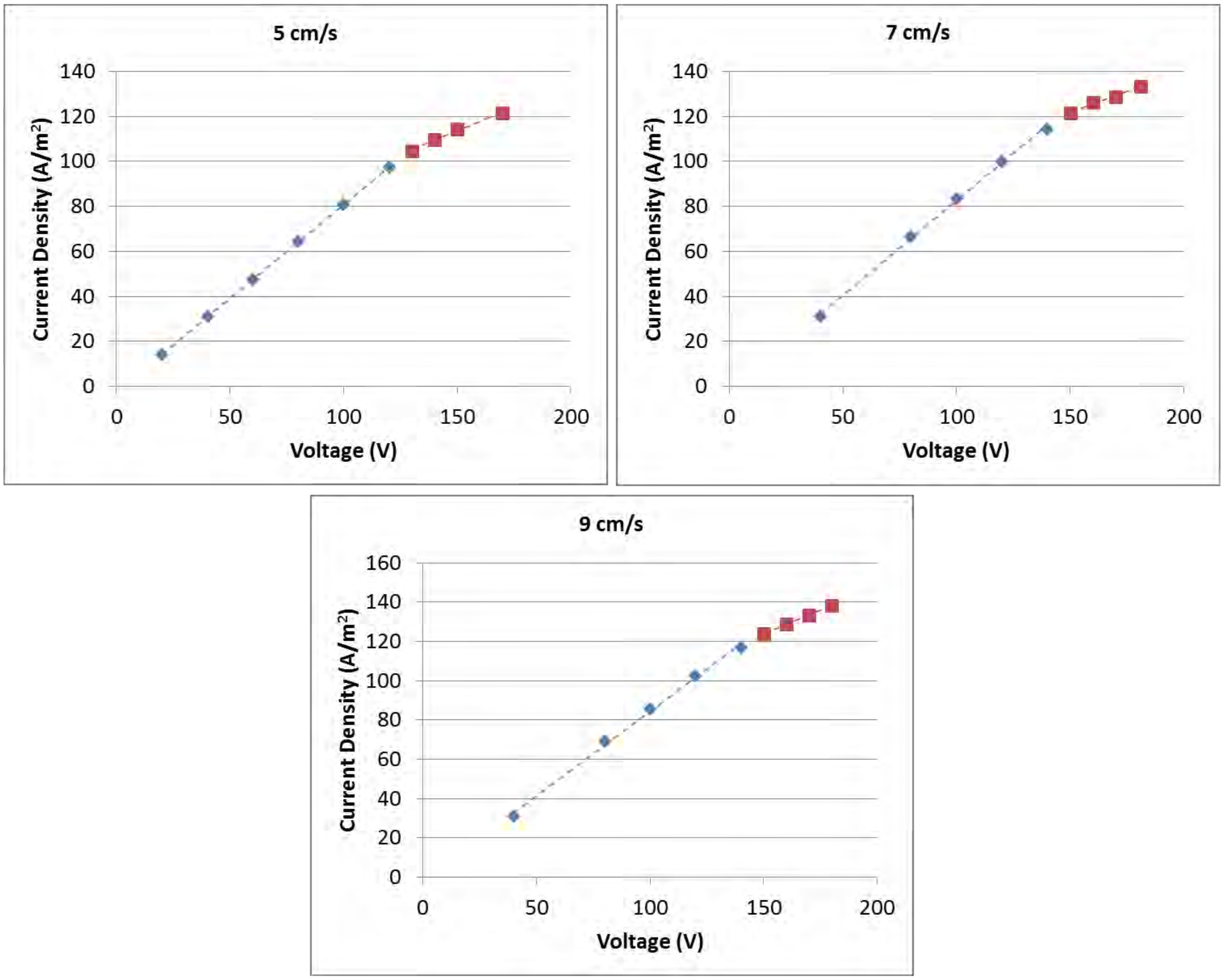


Figure 37.—Limiting Current Density – Alamogordo Phase 2.

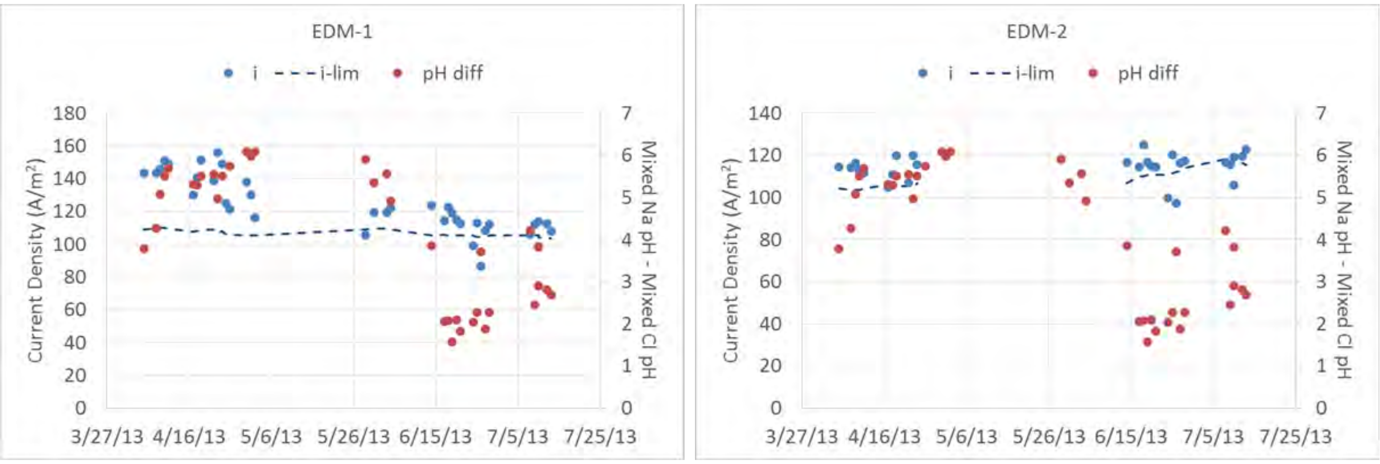


Figure 38.—Limiting current density and effects on EDM concentrate stream pH (Alamogordo Phase 2).

## 6.3.2 EDM Stack Performance Monitoring

One way to monitor EDM performance in the field is to track the EDM stack resistance (applied voltage divided by current). When stack resistance increases, it can be an indicator of membrane fouling or other problems within the stack. Increasing stack resistance can also be used to understand changes in diluate quality and temperature. The EDM feed-diluate compartment has the lowest concentration, so will be the determining factor for stack resistance: lower concentrations will increase the resistance. Also, there is increased resistance with reduced temperatures (see Figure 7).

Stack resistance did increase throughout some of the runs during Phase 2. However, the cause did not seem to be low dilate conductivity or low temperature. As described in Experiments 2, 5, and 6, iron particles were present in the NF concentrate and EDM feed streams. The source of iron was initially unknown and is thought to be the cause of the increased EDM stack resistance. When the particles were visible, the resistance seemed to increase. Several CIPs were performed and new 1-micron cartridge filters were eventually installed on the NF feed. This lessened the resistance increase (see data inside box in Figure 39).

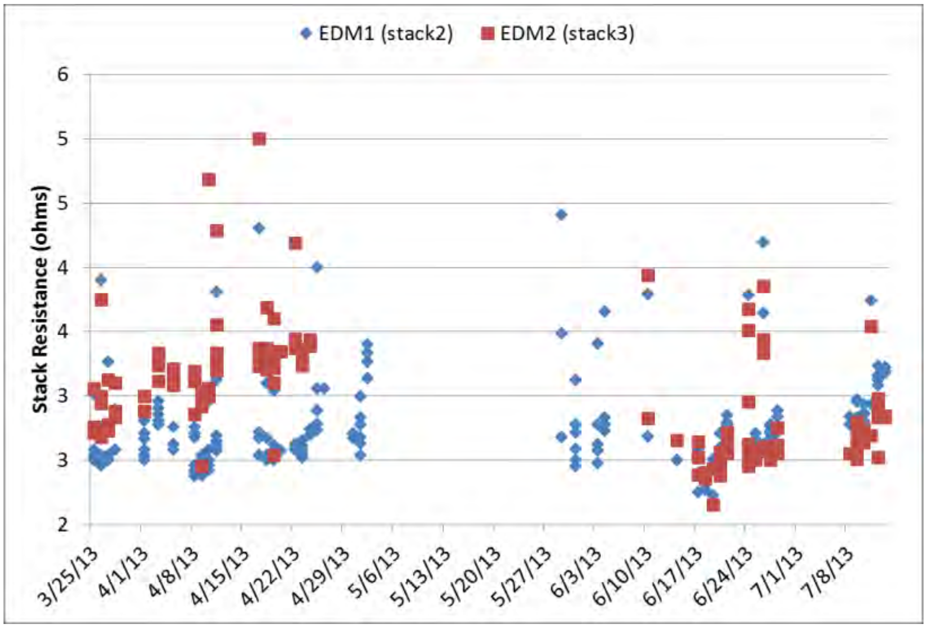


**Figure 39.—EDM stack resistance – Phase 2.**

The final reasons for reduced performance, as measured by ion removal in the EDM, could be explained by internal leakage, back diffusion of ions from the EDM concentrate streams to the EDM feed, and inadequate membrane area. Internal leaks were present throughout the study and are thought to be an important cause of scale formation at the center of the stack and reduced performance. Since nearly 10 quads were removed in each stack by the end of the study, reduced performance was also likely caused by a combination of inadequate area and operator misunderstanding.

The predicted membrane area and quads needed for desired EDM performance can be calculated using the following equation,

$$EDM\ Area\ (m^2) = \frac{Q_{feed} \cdot \left(C_{feed} - C_{diluate}\right) \cdot F}{i \cdot \eta}$$

Where:

$Q_{feed}$ = EDM feed flow rate, L/s
$C_{feed}$, $C_{diluate}$ = Concentration of EDM feed and diluate, equivalent per liter (eq/L)
F = Faraday's Constant, 96,485 A-s/eq
i = Current density, amperes per square meter (A/$m^2$)
$\eta$ = Current efficiency, %

Current efficiency was assumed to be 80 percent in the design by Veolia; however, it is good to calculate the actual value for a full scale design. The current efficiency can be calculated in several ways, but is essentially is a ratio of the charge (calculated from concentration) that leaves or enter a stream in the EDM. Each method is summarized. The first method is a ratio of the ions that are removed from the EDM feed to the current supplied:

$$\eta_{feed} = \frac{F \cdot Q_{feed} \cdot \left(C_{feed} - C_{diluate}\right)}{A \cdot N_{quads}}$$

Where:

A = Measured EDM Stack current, amps
$N_{quads}$ = Number of quads in EDM stack

The next method for estimating current efficiency is a ratio of the ions supplied by the NaCl stream to the current supplied:

$$\eta_{NaCl} = \frac{F \cdot M_{NaCl}}{A \cdot N_{quads}}$$

Where $M_{NaCl}$ is the flow of NaCl into the EDM stack, eq/sec. This is calculated from the daily NaCl consumption.

The final method for estimating the current efficiency involves a ratio of the ions in the EDM concentrate overflow streams to the current supplied:

$$n_{M.Na\ or\ M.Cl} = \frac{F \cdot Q_{OF} \cdot C_{M.Na\ or\ M.Cl}}{A \cdot N_{quads}}$$

Where:

> $Q_{OF}$ is the waste flow rate of the Mixed Na or Mixed Cl stream, L/sec
> $C_{M,Na\ or\ M.Cl}$ is the concentrate of the Mixed Na or Mixed Cl stream, eq/L

Each of these methods is limited by the quality of the data gathered in the field. The NaCl consumption and EDM concentrate overflow rates were highly variable and open to operator errors during measurement. However, enough data was gathered to compare the various methods. The average current efficiency values for the Phase 2 operations in Alamogordo are summarized in Table 11 and Figure 40. The average current efficiency using these four methods is 80 percent and is in line with Veolia's design.

Table 11.—Average Current Efficiency (Alamogordo-Phase 2)

| Method | Average Current Efficiency |
|---|---|
| EDM Feed | 72% |
| NaCl | 84% |
| Mixed Cl | 76% |
| Mixed Na | 90% |
| Average | 80% |

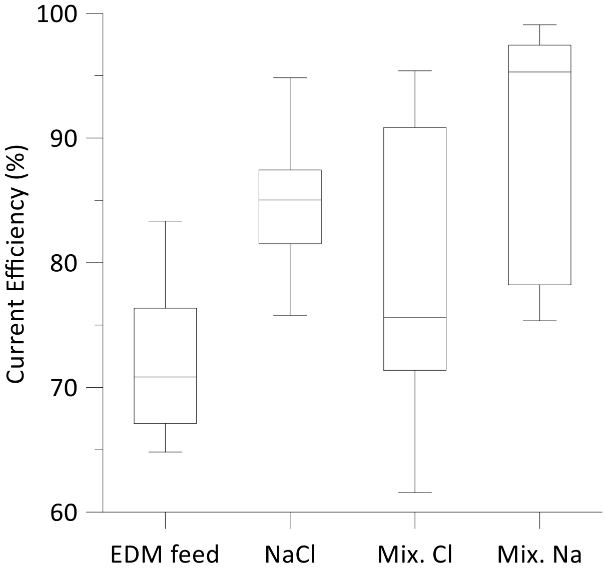


**Figure 40.—Alamogordo current efficiency (Phase 2).**

### 6.3.3 Energy Consumption

The goal of Phase 2 was to operate with fixed operating setpoints for long durations. This would allow for comparison to Phase 1 and provide information for sizing the full scale system for Alamogordo's desalination plant. The EDM specific energy was estimated for all logsheet data points for Phase 2 using the same assumptions as made in Phase 1. Figure 41 compares the EDM stack resistance for both stacks with the estimated specific energy. As mentioned in earlier sections, operators applied more voltage than necessary; this is reflected in the higher specific energy (data in April and May). The recycle ratio was slightly lower in the earlier runs as well (0.91 vs 1.02). The combination of applying lower voltage and increasing the recycle ratio led to lower specific energy consumption by the EDM. The average specific energy for the early and late runs is comparable to what was observed during 1 activities (see Figure 42).

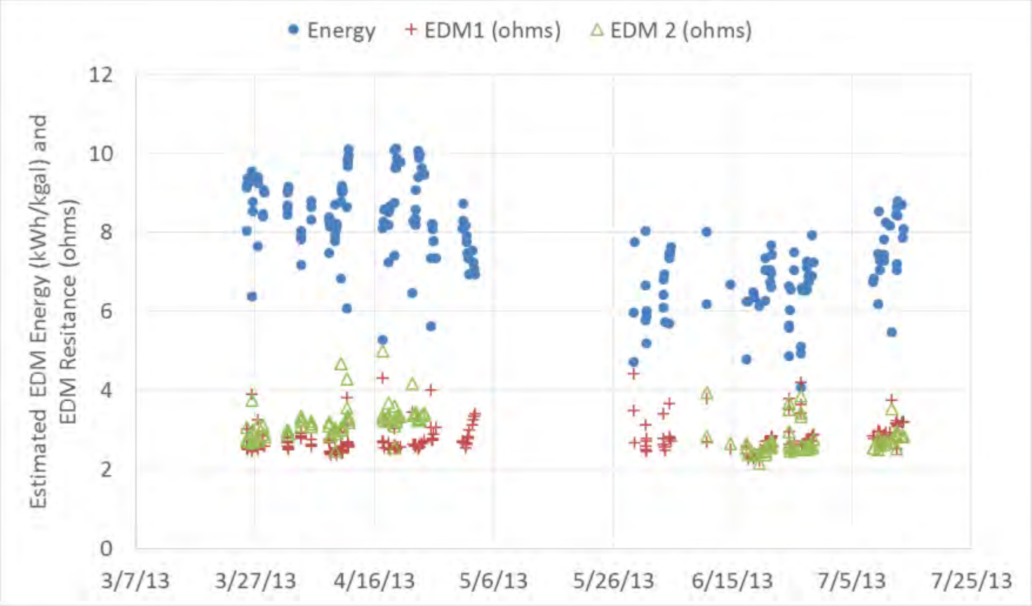


Figure 41.—EDM stack resistance and estimated specific energy (Phase 2).

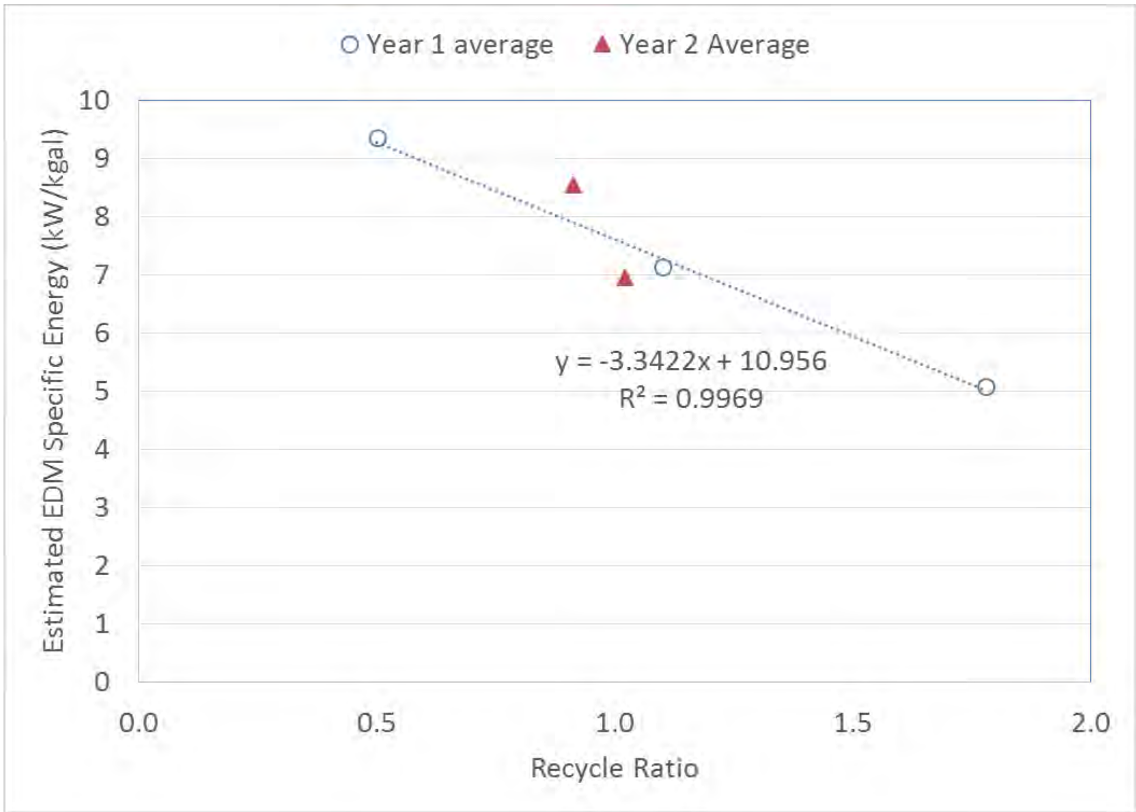


**Figure 42.—Comparison of Phase 1 and Phase 2 specific energy.**

Data from the Phase 2 demonstration activities were used to design a full-scale ZDD system for Alamogordo. Slight changes from what was used and observed during the pilot were made to in some cases and are summarized in Table 12 (middle column) and in Section 4.2.

Table 12.—Comparison of Full Scale and Pilot Demonstration Operating Setpoints

| | Phase 2 | Full Scale (4 MGD) Design |
|---|---|---|
| NF/RO Staging | 4x4<br>(NF270-400) | Single Stage with 16 PVs<br>(1st three elements: XLE-440, last five: NF270-400) |
| NF/RO Recovery | 55% | 60% |
| NF Feed Pressure (psi) | 90 | 91 |
| EDM feed velocity (cm/s) | 5-9 | 6-7 |
| EDM Recycle Ratio | 0.8-1.1 | 1.2 |
| #Quads/EDM stack | 100 | 120 |
| EDM voltage/current | 135-150 volts<br>40-50 amps | 135-140 volts<br>44-46 amps |

| | Phase 2 | Full Scale (4 MGD) Design |
|---|---|---|
| EDM current density (A/m2) | 10.5-11.9 | 10.9 |
| EDM TDS reduction | 45% | 50% |
| Permeate TDS (mg/L) | <800 | <400 |

The data in Table 12, along with flow rates and other design information, were used to develop a cost model. A key piece of this model includes the energy consumption for each of the major equipment systems. Table 13 summarizes the output from the power analysis. The calculations are made assuming the plant is operational 365 days per year and produces 4 MGD of product water (includes 570 gpm bypass blend) with TDS less than 800 mg/L at 98 percent recovery. The EDM specific energy is based on operating at the limiting current density for 6.5 cm/s velocity, 46 amps. An equation was fit to the same data obtained in the limiting current density experiment and was used to determine the voltage, 140 volts.

Table 13.—Alamogordo Estimated Specific Energy (4 MGD Design)

| Process | kWh/kgal | % of total |
|---|---|---|
| NF energy | 1.93 | 22.3% |
| EDM energy | 6.61 | 76.4% |
| Other energy (e.g. process water, chemical pumps) | 0.11 | 1.3% |
| Total energy | 8.66 | |

# 7. La Junta Results and Discussion

As part of an effort to evaluate ZLD options available for Colorado utilities with existing or planned desalination facilities, HDR, Inc. led a pilot testing program that evaluated ZDD in the Colorado cities of La Junta and Brighton. A thorough report was written and co-published by WERF and IWA (Brandhuber et al., 2014), so only a brief description of the pilot and differences in (or additional) interpretation are described in this report. The WERF/IWA report is labeled WERF 5T10 in this report. Figure 43 shows a) NF container installed outside the La Junta Plant and b) EDM Container in background and NaCl Recovery Equipment in foreground, both installed inside the La Junta Plant

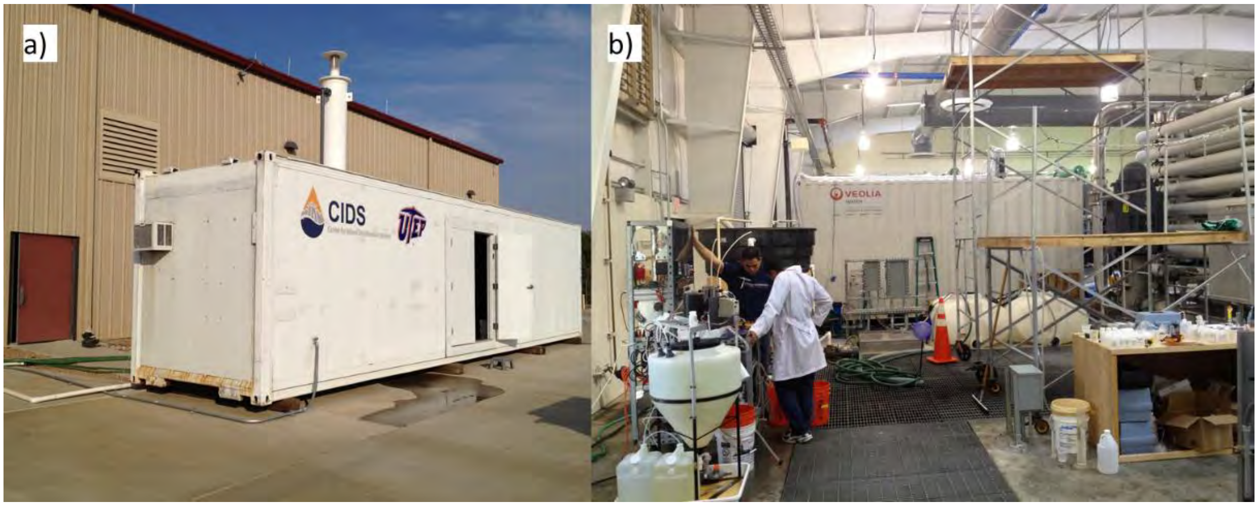


**Figure 43.—ZDD and NaCl recovery systems installed in La Junta (20-gpm).**

## 7.1 Equipment Description

The 20-gpm ZDD pilot system used in Alamogordo was shipped from Alamogordo to La Junta by Veolia and site work was performed by a combination of contractors, Veolia operators, and others. A new Veolia operator was trained and the system was modified during the summer of 2012. Four sets of experiments were performed in the fall of 2012 using the configuration in Figure 44 and a bench scale NaCl recovery system was tested in September 2012.

The NF staging and membranes were changed for the La Junta pilot. A 3x2x1(4M) array was chosen with NF90-4040 membranes in the first two stages (24 membrane elements) and the final stage had NF270-4040 membranes. The NF-90 membranes were chosen for their good salt rejection and low pressure (as compared to typical brackish water RO membranes). The NF270 membranes were chosen for their low silica rejection. Similar to Alamogordo, there was enough silica present in the brackish feed water that a strategy was required for mitigating scale formation in the ZDD system. While the La Junta brackish water feed has a lower salinity than what was treated in Alamogordo, the water quality target was more stringent; the project set a target of 100 mg/L TDS (Brandhuber et al., 2014), which is well below the secondary maximum contaminant level (SMCL) of 500 mg/L TDS. NF270 membranes could produce good quality drinking water, likely below the SMCL (see Table 14). A design with only NF270 membranes would have the lowest feed pressure requirements and would also allow for the most protection against silica scale formation. Hydrex 4101 antiscalant was dosed at 2-3 mg/L to the NF system. Acid was added to the Mixed Na stream to prevent precipitation by sodium bicarbonate and carbonate species.

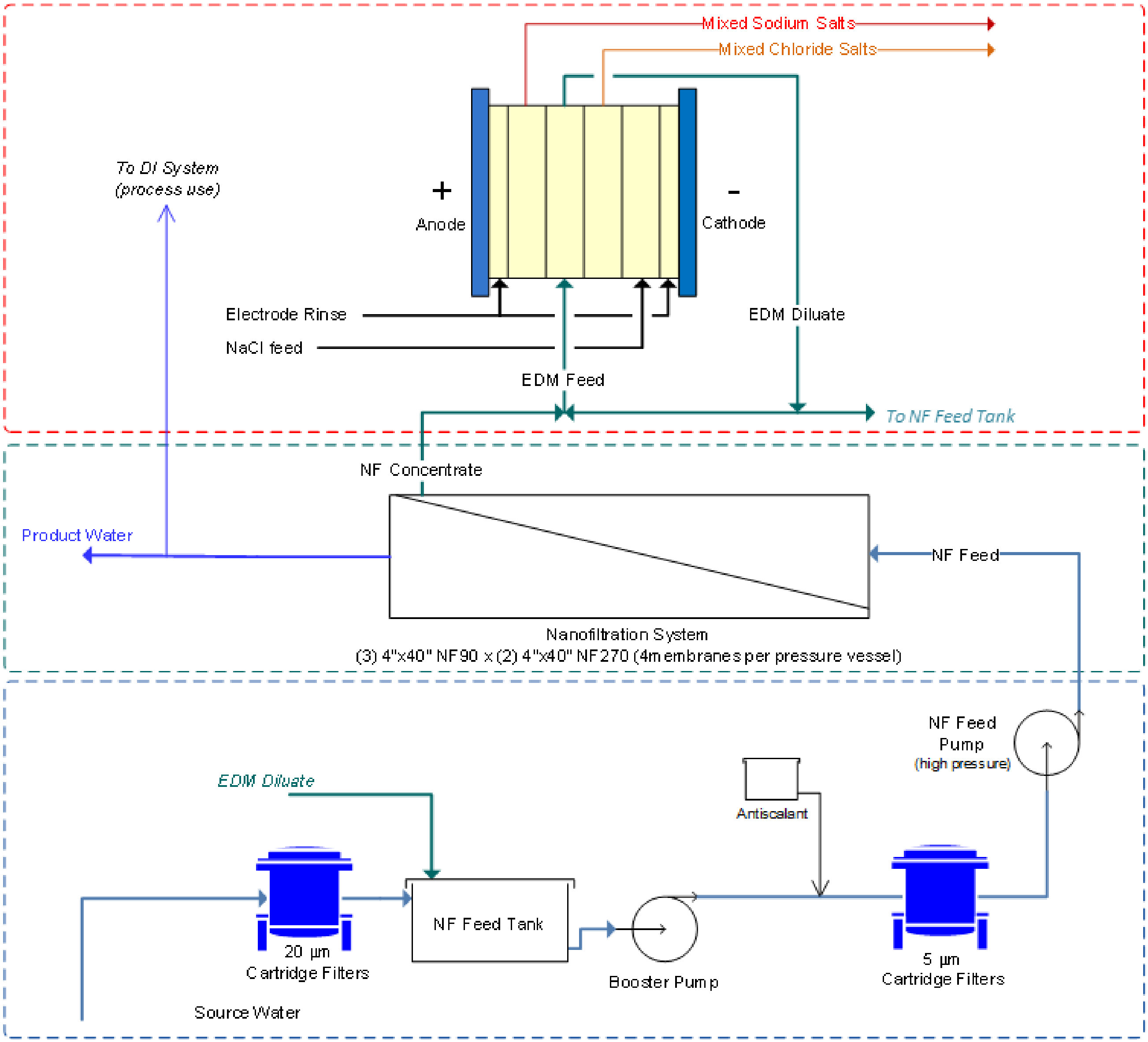


**Figure 44.—Equipment flow diagram (La Junta).**

Table 14.—Comparison of RO and NF Membranes for La Junta Desalination

| Membrane | BW30 | NF90/ NF270 | NF270 |
|---|---|---|---|
| Configuration | 3x2x1 (4M) | 3x2x1 (4M) | 3x2x1 (4M) |
| Average Permeate Flux (gfd) | 15.38 | 14.63 | 14.63 |
| Feed Pressure (psi) | 173.5 | 91.1 | 83.2 |
| Permeate Back Pressure (psi) | 0 | 0 | 15 |
| Recovery | 60% | 60% | 60% |
| RO Energy (kWh/kgal) | 2.62 | 1.38 | 1.26 |
| Permeate TDS (mg/L) | 7.7 | 99.3 | 356.3 |

# 7.2 Summary of Pilot Testing

The ZDD system recovery calculation in the WERF 5T10 report used a different method than what is used by UTEP. The WERF 5T10 equation used was:

$$Recovery(WERF\ 5T10) = 100\% \cdot \left(1 - \frac{Waste\ Flow}{Feed\ Flow}\right)$$

While this is a correct formula, there are several challenges specific to the ZDD pilot system tested at La Junta that make this formula less accurate. First, the feed flow was calculated using a totalizer reading from a flow meter that showed 1 to 2 gpm flow when there was zero flow. Also, the method used in the WERF 5T10 report estimated the feed flow rate assuming the totalizer value represented a full 24-hour day's flow. The combination of these factors leads to the estimated feed flow being less than the NF permeate flow (see Figure 45).

The next problem with the WERF 5T10 recovery calculation was that all DI water consumption was considered an additional waste flow; this double-counts the DI water usage. While understanding the DI water consumption was important for sizing of the DI water system, virtually all DI water used in the ZDD system was accounted for in the EDM waste flow streams. Water was transported along with ions from the NaCl and EDM feed streams into the EDM's Mixed Na and Mixed Cl streams called water of hydration. Therefore, any DI water used to prepare the NaCl solution would be in the recirculating stream or in the EDM waste streams (evaporation is considered to be negligible). Any DI water added to dilute the Mixed Na and Mixed Cl streams would also be present in the streams' overflow (waste) streams. These waste streams would have periods of relatively high flow when DI water was being added and periods of relatively low flow when DI wasn't being added. To mitigate double-counting, the operators in La Junta measured the overflow rates during relatively low flow periods when DI wasn't being added; however, a portion of this overflow was still from DI water added to the system and so a portion of the DI water added is still double-counted. The overflow measurements were taken once per day over a one minute period, which may not have been adequate to fully estimate the actual waste flow variation.

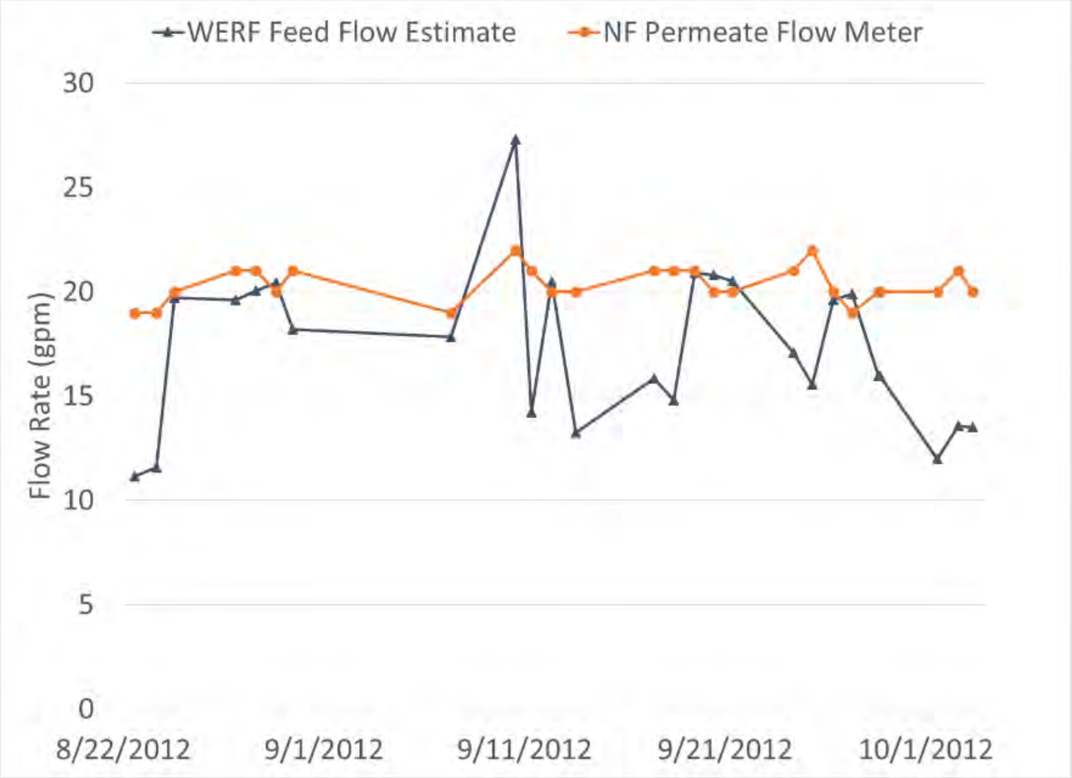


**Figure 45.—Comparison of feed flow estimates and NF permeate flow.**

The preferred ZDD recovery calculation method used by UTEP for reporting recovery is based the NF Permeate, Mixed Na, and Mixed Cl flows. The feed flow can be estimated by summing these flows. However, to use this method a longer collection time (at least one hour) is needed for capturing the Mixed Na and Mixed Cl flows so that each stream's waste flow is properly calculated. A longer collection period will allow for variations in dilution volume and changes in the ion removal (and water transfer) rate. The ZDD flow diagram and available flow meters or flow measuring points are shown in Figure 46.

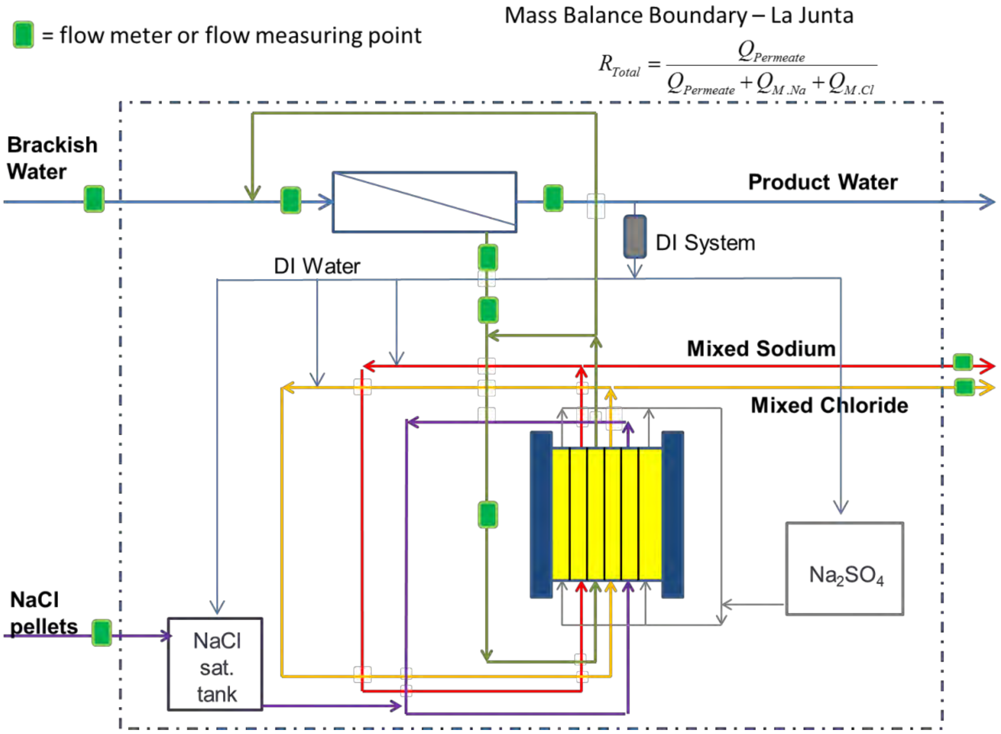


**Figure 46.—ZDD flow diagram showing mass balance measuring points.**

Since the measured overflow rates are likely underestimated, alternative methods for calculating ZDD recovery are summarized in the following equations. The first equation estimates the feed flow as the sum of the NF permeate flow (flow meter reading), average DI water use rate, and calculated Mixed Na and Mixed Cl overflow rates. The NF permeate, calculated DI, Mixed Na, and Mixed Cl flow values were taken directly from the logsheet data provided by HDR, Inc.

$$Rec1 = \frac{NF\ Permeate\ Flow}{NF\ Perm. Flow + DI + Mixed\ Cl, Na\ Waste\ Flows}$$

The second method eliminates the DI usage from the waste flows:

$$Rec2 = \frac{NF\ Permeate\ Flow}{NF\ Perm. Flow + Mixed\ Cl, Na\ Waste\ Flows}$$

The proportion of the EDM waste flows is expected to be predominantly from DI dilutions, so a third method ignores the overflow rates and solely uses the DI consumption for the waste flow:

$$Rec3 = \frac{NF\ Permeate\ Flow}{NF\ Perm. Flow + DI}$$

Since the first method (Rec1) underestimates the recovery and the second and third method (Rec2 and Rec3) overestimate the recovery, a better recovery is estimated by taking the average of all methods. Each of the recovery method results and the average of Rec1 and Rec2 are compared against the data obtained in the WERF 5T10 study in **Error! Reference source not found.** (includes 26 ays' worth of data). Average values for the Mixed Cl and Mixed Na waste flows were used for days when overflow rates were not recorded. The large variation in the WERF 5T10 method (UTEP calculations using method described in WERF 5T10 report) reflects the wide variation in the estimated feed flow. Values from each of the calculation methods that incorporate the total DI flow have low points throughout the La Junta pilot operations. These low points correspond to days where the system was shutdown, started up, or had high DI consumption after process upsets such as the loss of NaCl makeup.

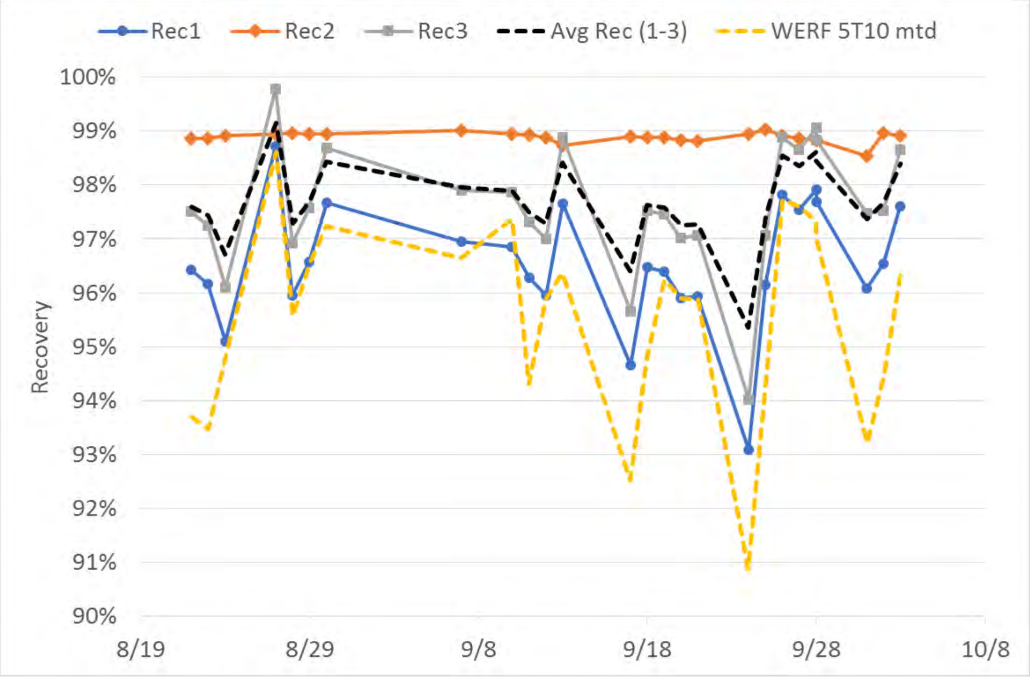


**Figure 47.—Comparison of recovery calculation method results (La Junta).**

Four time periods were summarized in table 3-3 of the WERF 5T10 report. Recovery using the method described in the WERF 5T10 report is compared against the recovery calculations summarized in Table 15 of this report. The average values (last column) are likely the most representative of the actual ZDD recovery, but are still considered to be somewhat conservative. DI water consumption was variable throughout the project and did not decrease with increasing conductivity setpoints for the Mixed Cl and Mixed Na streams (increased setpoints should lead to lower DI consumption for dilutions). DI water is used during startup and shutdown activities, for sample dilutions and washing, and was used for NaCl recovery experiments. Of these uses, the startup and shutdown activities should have consumed the most DI water and are not expected to be representative of a full scale system operating continuously. The pilot was shut down over weekends and other times when personnel were not available; a full-scale plant would have a more continuous operation and would, therefore, use less DI water.

Table 15.—Comparison of Recovery Results by Experiment (La Junta).

Rec=Recovery method

Avg (1-3 is the average of Rec1, Rec2, and Rec3

| Dates | # Quads | WERF 5T10[1] | Rec1 | Rec2 | Rec3 | Avg (1-3) |
|---|---|---|---|---|---|---|
| 8/21-8/30 | 100 | 96% | 97% | 99% | 98% | 98% |
| 9/6-9/13 | 80 | 96% | 97% | 99% | 98% | 98% |
| 9/17-9/25 | 80 | 94% | 96% | 99% | 97% | 97% |
| 9/26-10/3 | 80 | 96% | 97% | 99% | 98% | 98% |

[1] Calculations made by UTEP match WERF 5T10 report except 9/26-10/3 (WERF 5T10 table 3-3 reported value is 97%).

Rec=Recovery method

Avg (1-3 is the average of Rec1, Rec2, and Rec3

Internal leaks are suspected in the EDM stack because sulfate and bicarbonate were present in the NaCl and Mixed Cl samples taken on September 21, 2013, and September 28, 2013. Another indicator is the higher than normal pH in both the NaCl and Mixed Cl streams for most of the La Junta pilot. Typically, the Mixed Cl stream pH is less than 4 and can be less than 3 when too much voltage is applied to the EDM stack. The NaCl stream pH is typically less than 5. Figure 48 shows the measured pH of both streams. The pH of both streams was around pH 6-7 for most of the samples. Small holes were detected in some membranes and the center dividers when the stack was taken apart in both La Junta and Brighton. Finally, the EDM stack bolts were not regularly tightened so low stack compression could be another source of internal leakage. ED and EDM stacks must be properly tightened and aligned to prevent internal leaks.

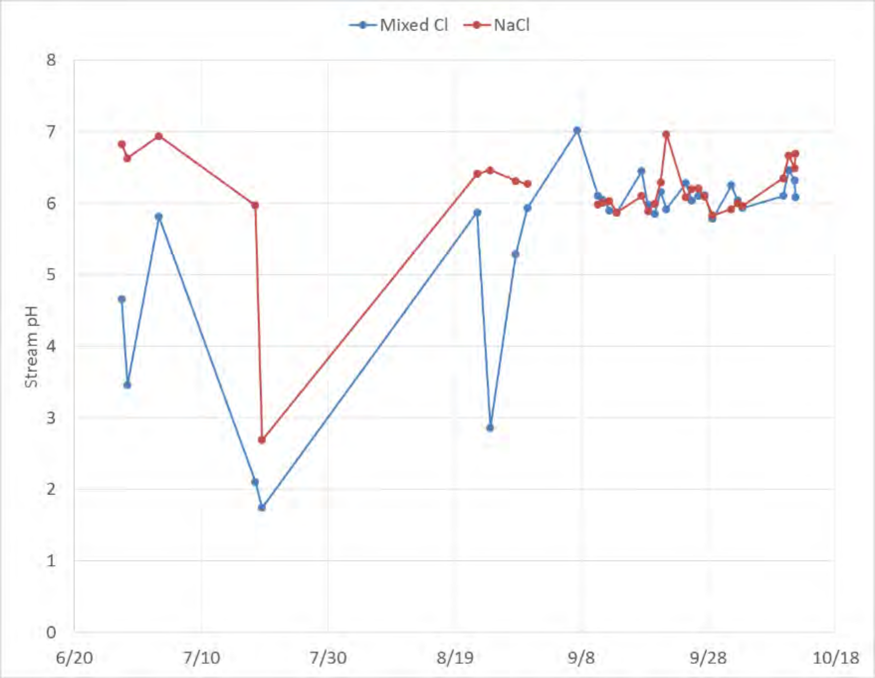


**Figure 48.—NaCl and Mixed Chloride pH at La Junta.**

One other type of operational problem occurred several times during the La Junta pilot. The pilot system's circulating NaCl stream conductivity dropped dramatically at least six times during the operations in August and September. This is because there was not enough NaCl in the saturator tank. Earlier piloting problems (scale formation) were attributed to NaCl contamination and to the fact that the overflow between the standpipe and saturator tank was routed to the drain instead of to the NaCl saturator tank. This caused excessive NaCl consumption. In addition, it is possible that the operators did not add enough NaCl pellets prior to departing for the night. After the loss of NaCl on August 29, the overflow was re-routed to the NaCl saturator tank. Unfortunately, this did not completely solve the problem as the NaCl conductivity dropped precipitously again on August 30, September 18, and September 19. All of these outages occurred during the night or early morning when operators were not onsite. The operators also did not have remote viewing or control access. When the conductivity dropped in the NaCl stream, there were no longer ions present to carry the current through the stack. This means the only current that could flow was by way of shunt currents. This caused the EDM feed and diluate conductivity to rise, because ions were not being removed from the NF system, but ions were still back diffusing from the EDM's Mixed Na and Mixed Cl streams. The impact of these NaCl losses led to a buildup of ions in the EDM and NF systems, as is evident from the EDM diluate conductivity increasing over time. Figure 49 and Figure 50 show the conductivity of the NaCl, NF Concentrate, and EDM feed streams along with the flow of the EDM feed pump.

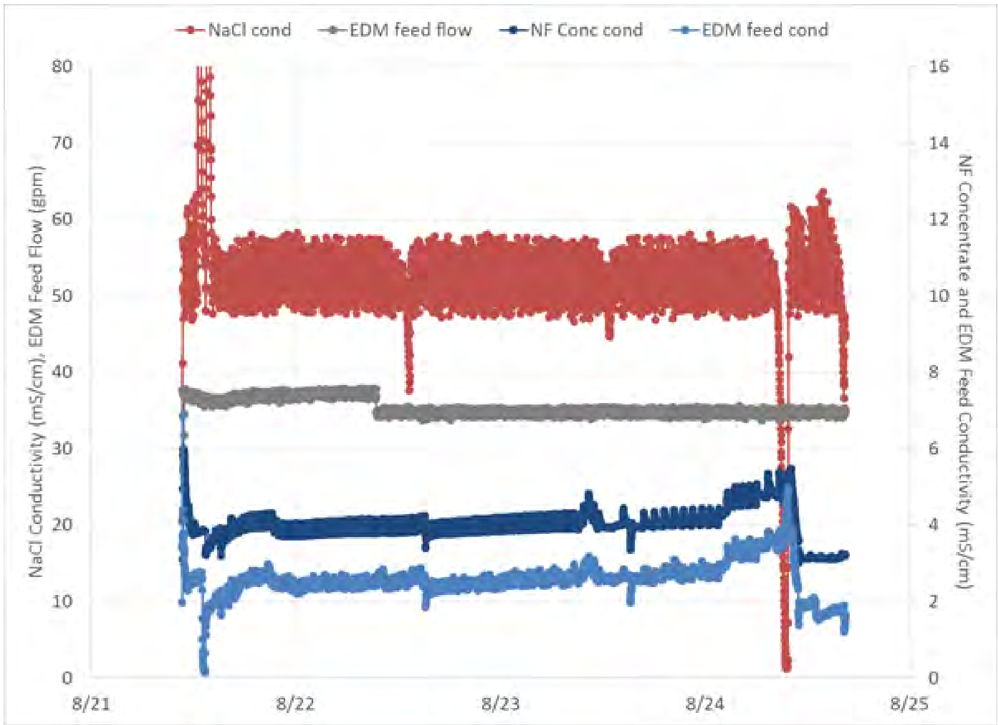


**Figure 49.—NaCl conductivity in La Junta (8/21 – 8/24).**

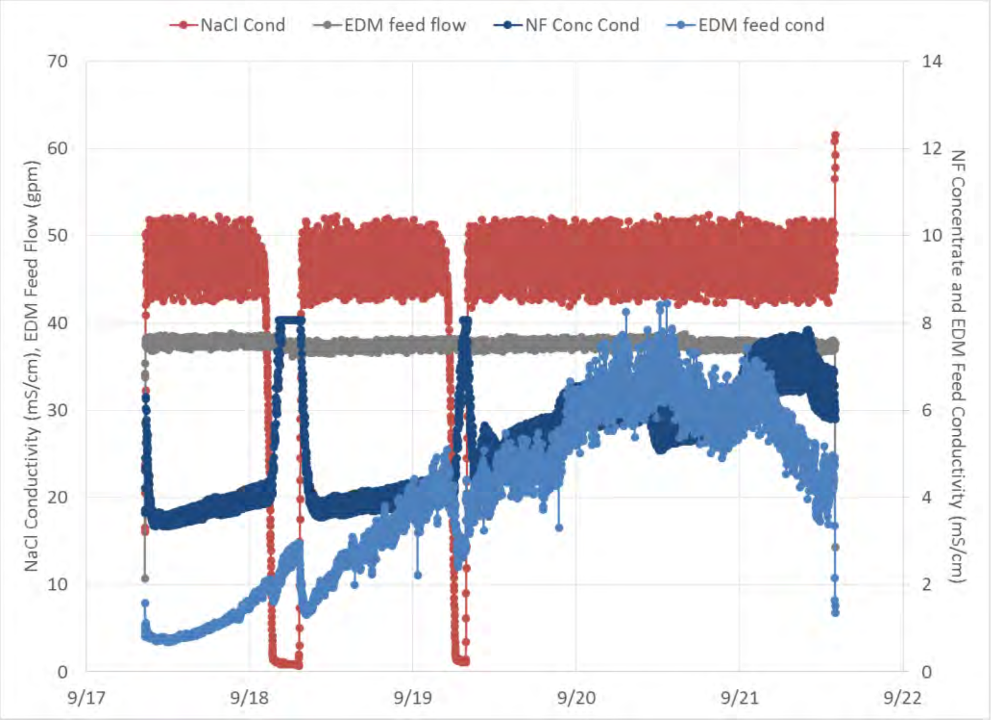


**Figure 50.—Loss of NaCl conductivity in La Junta (9/17 - 9/21).**

Late afternoon on August 30, the NF system shut down because the NF feed tank level was low. At about the same time, the EDM feed flow also dropped to zero.

All other pumps remained on and the stack power also remained on until operators returned on August 31. The lack of flow in the EDM feed compartment combined with the EDM's power supply remaining on led to a rapid and precipitous decline in conductivity in the EDM feed compartment. Also, temperatures in the EDM stack increased from 20-25ºC to the maximum that the temperature probes could read (45-50ºC). The MEGA membranes and spacers have a maximum temperature tolerance of 35-40ºC. Five quads of membranes and spacers were melted together after this occurred, and the membranes were subsequently removed from the stack. This stack was sent to Alamogordo and was used during Phase 2. Figure 52 shows the conductivity of the streams and flows and Figure 52the NF concentrate and EDM stream temperatures (bottom diagram).

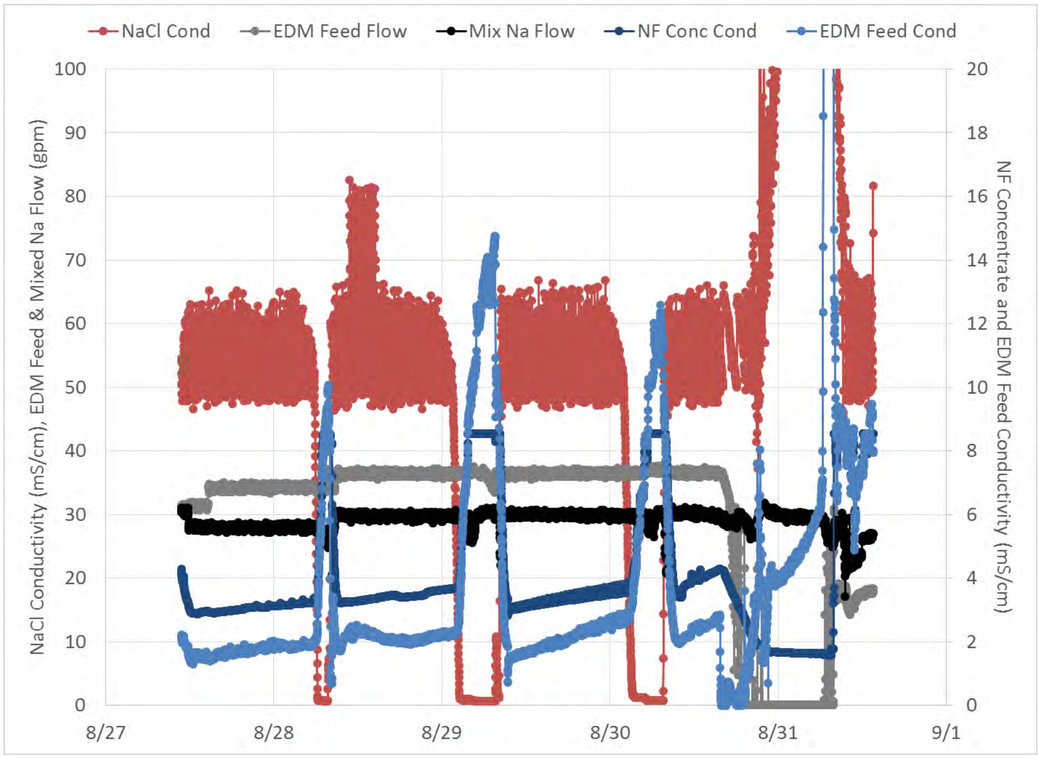


**Figure 51.—NaCl conductivity in La Junta (8/27 -8/31).**

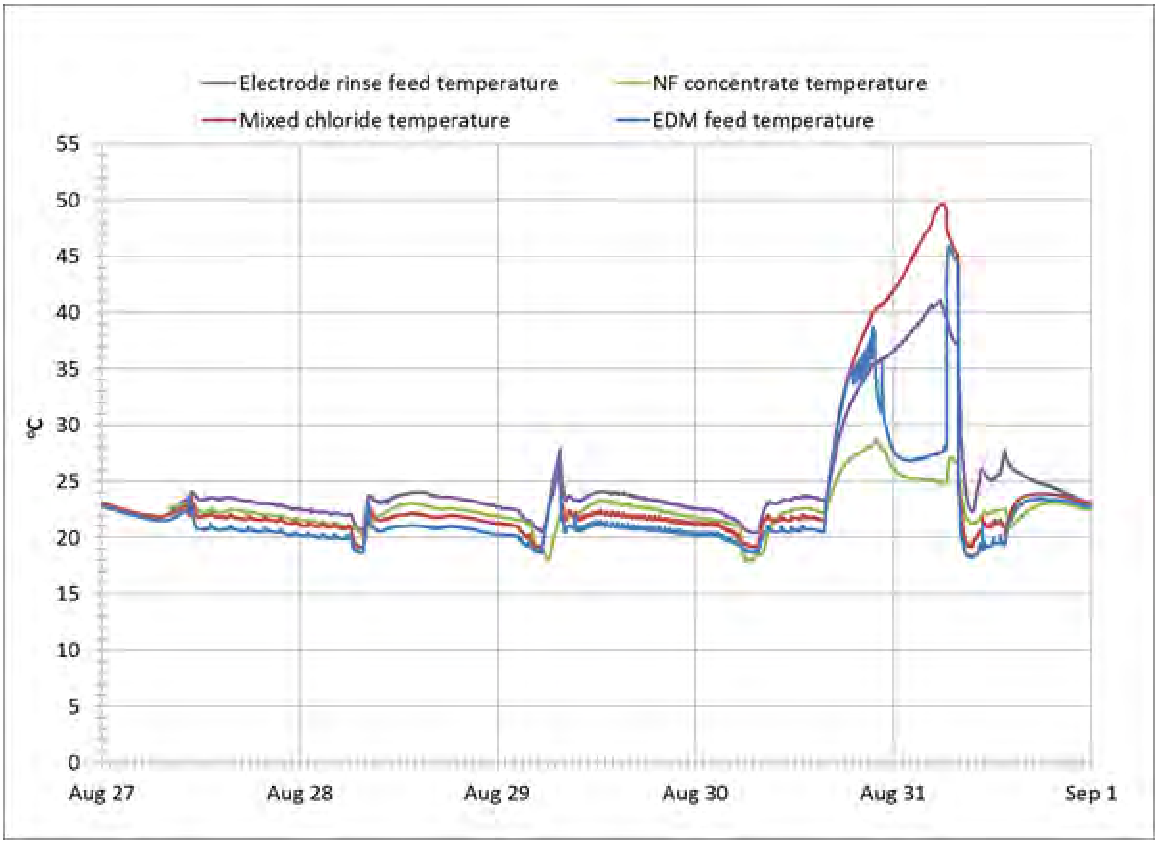


Figure 52.—EDM feed flow in La Junta (8/21 – 9/1).

## 7.3 Evaluation of Current Density, Current Efficiency, Power Consumption – La Junta

### 7.3.1 EDM Stack Performance Monitoring

The EDM stack resistance was relatively stable throughout the La Junta piloting in September. A similar miscommunication in the number of quads in the EDM stack as in Alamogordo (Phase 2) led to excessive voltage being applied to the 100-quad stack. The 80-quad stack was used for all of the September and October piloting in La Junta and the average resistance was 3.3 ohms. Figure 53 includes all of the EDM stack resistance points for the La Junta pilot.

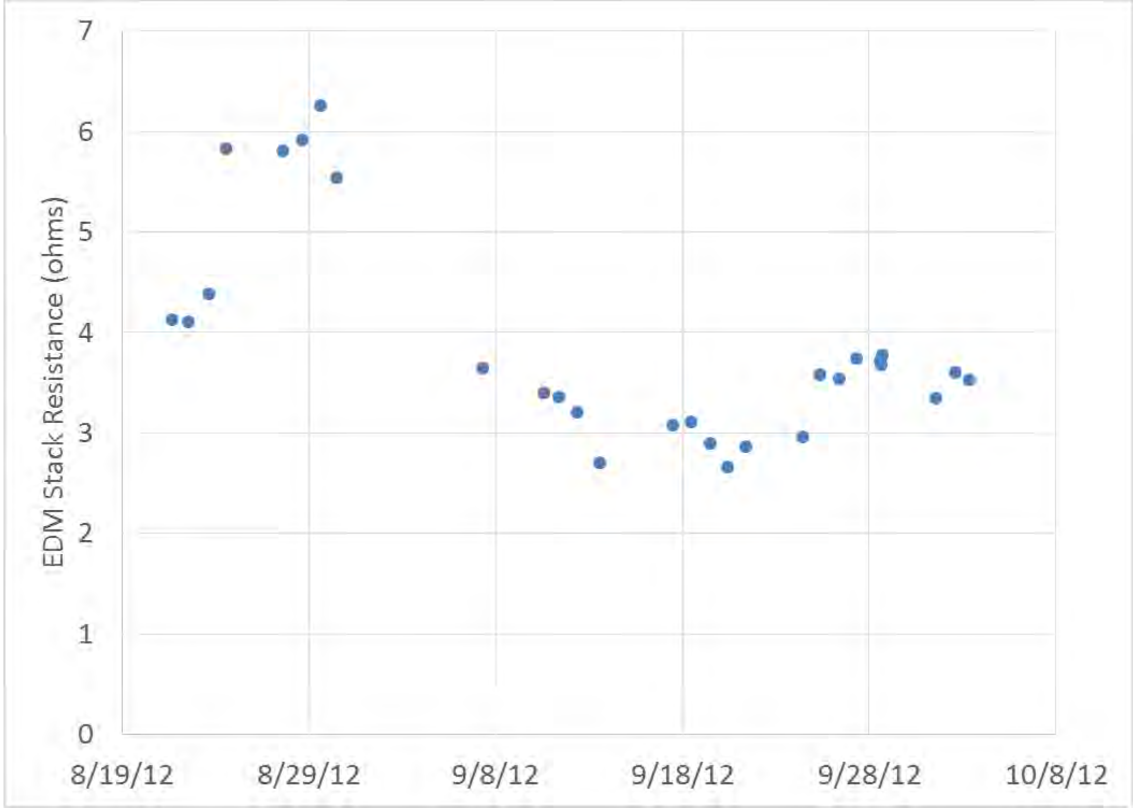


Figure 53.—EDM stack resistance (La Junta).

An attempt was made to calculate the mass balance and current efficiency for the two days with full water analyses. However, an accurate mass balance was not possible because of the problems with flow measurements and the lack of ability to accurately estimate the daily salt consumption. Also, the ion balance is off by 10 percent or more for several of the samples. There are other inconsistencies with the analyses (conductivity/TDS ratio suggests problems with one or both analyses for the EDM feed and diluate) that prevent estimations of the current efficiency. Finally, the way NaCl consumption is calculated is to sum up the number of bags added and divide by operational hours. Using this method is inaccurate because the amount of NaCl added varies from zero to as much as 10 bags in a period. A better method for NaCl consumption estimation was incorporated at the Brighton pilot.

A sample of membranes from the La Junta pilot was sent to MEGA for analysis of precipitates. One membrane was found to be damaged (tear or otherwise) upon inspection. Additionally, carbonate scale appeared to be present inside another membrane. MEGA's report is included as Appendix D1.

## 7.3.2 Power Consumption

Power meters were installed by Reclamation personnel on the pilot equipment trailers in La Junta to record power consumption during four periods in August and September. The data were reported in the WERF 5T10 report and are summarized in Table 16. The total energy consumption reported was quite high, at 13 to 15 kWh/kgal. As described in a footnote in the WERF 5T10 report, pilot equipment is not designed or sized to be energy efficient. In fact, the NF system pumps were grossly oversized for the flow and brackish water feed concentration at La Junta.

Table 16.—WERF 5T10 Report Energy Consumption

| | 8/21-8/23 | 9/6-9/7 | 9/10-9/12 | 9/19-9/21 |
|---|---|---|---|---|
| NF | 5.8 | 5.5 | 5.6 | 5.8 |
| EDM | 6.6 | 7.8 | 8.0 | 7.6 |
| Total | 12.3 | 13.3 | 13.6 | 13.4 |

The operating expenses are described later in this report for both the La Junta and Alamogordo sites. Briefly, the energy for the NF and EDM systems was estimated based on the pilot data and includes flow rate and pressure for the brackish feed, NF feed, EDM recirculating pumps, and the maximum VDC and current required by the EDM to achieve the water quality objectives (this point may be higher or lower than what was piloted and depends on the design of the full scale system).

The pilot brackish water pump, which pumps water from the NF feed tank through cartridge filters has a 5 horse power (hp) motor, or 400 percent higher than what is needed to pump 35 gpm at 30 psi. The NF feed pump had a 15 hp motor, 650 percent higher than what was required to boost the pressure from 30 psi to 90 psi. As shown in Table 14, Dow's ROSA program predicted the energy for desalination to be 1.38 kWh/kgal, which corresponds to a motor size of 1.65 kW (2.2 hp); this is the amount of energy required if no pressure is supplied to the feed of the high pressure pump. The reported NF unit energy consumption is likely overestimating by a factor of 2.5 to 3.

Similar to the NF, the EDM recirculating pumps were also oversized. Most of the energy required for the EDM container should come from the EDM power supplies, which was 3 to 4 kWh/kgal for most of the operations in La Junta. The values in Table 16 suggest that more power was used in the EDM system in September than in August, which is odd since more power was required by the EDM stack power supply for at least a portion of August. The estimated unit energy is shown in Figure 54. The energy, $kWh_{AC}$, is estimated using an 82.4 percent conversion factor for the various transformers employed in the EDM container to convert from the 480 VAC supplied to the EDM container to 100-150 VDC supplied to the EDM stack. The reported EDM unit energy consumption is overestimated by 30-70 percent.

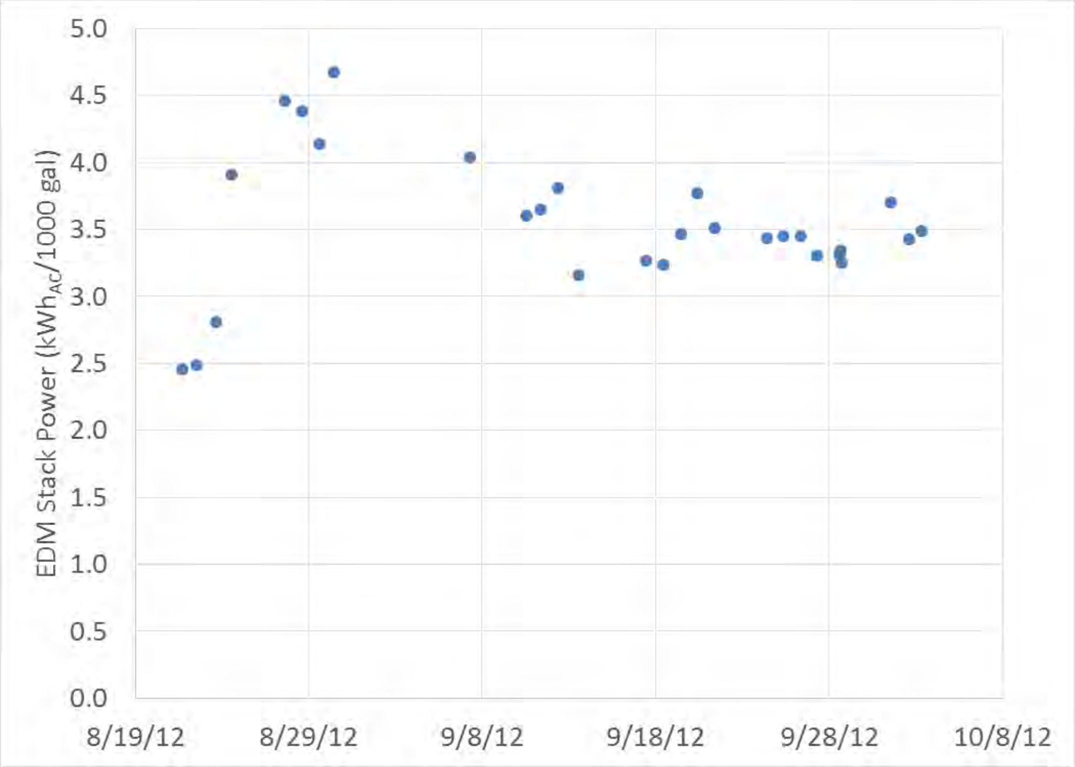


**Figure 54.—Estimated power EDM consumption (La Junta).**

An estimate was made for the unit energy consumption for the ZDD system components using the full scale flow rate of 6.6 MGD product water at the La Junta RO Plant. A full scale ZDD system would include:

- Brackish well water pumping: 4,670 gpm
- NF system (80 percent recovery with NF90/NF270 mixture piloted) capable of producing 4,130 gpm of permeate that would be blended with 603 gpm of brackish water
- Brackish feed pump: 467 gpm at 30 psi
- Three NF feed pumps: 1,690 gpm at 82 psi (5,097 gpm total NF feed flow at full flow)
- EDM system sized to reduce the concentration by 50 percent (from the NF reject to EDM diluate)
- 3,200 gpm recirculating rate for EDM feed, NaCl, Mixed Na, Mixed Cl pumps

- 800 gpm recirculating rate for E-rinse pump
- DC power supply needs: 120-140 VDC/40-45 amps
- Basis for operations is full production for 365 days per year

The maximum current from the La Junta pilot operations was 37 amps, but was likely low because of various operating problems and colder temperatures. The full scale system is expected to be able to operate at 40 amps or higher. This is an important design factor, as the number of EDM stacks required depends on the current density (current per unit of membrane area). The values for power consumption for the two ZDD designs are summarized in Table 17.

Table 17.—Estimated Full Scale Unit Energy Consumption (La Junta)

| | **100-Stack EDM Design (40 amps)** | | **90-Stack EDM Design (45 amps)** | |
|---|---|---|---|---|
| | **kWh/kgal** | **% of total** | **kWh/kgal** | **% of total** |
| NF energy | 2.06 | 36.5% | 2.06 | 37.8% |
| EDM energy | 3.53 | 62.4% | 3.35 | 61.2% |
| Other energy | 0.06 | 1.0% | 0.06 | 1.0% |
| Total energy | 5.65 | | 5.47 | |

# 8. Brighton Results and Discussion

The second pilot site for the WERF 5T10 project was in Brighton, where the "bolt-on" ZDD system was implemented (Figure 55). As with the La Junta pilot, data and analysis are provided in the WERF 5T10 report, so only additional or differences in analysis are described in this report.

**Figure 55.—ZDD system installed in Brighton (20-gpm).**

## 8.1 Equipment Description

The 20 gpm pilot system employed during Phase 1 in Alamogordo and La Junta was shipped and installed at the Brighton Water Treatment Plant. This plant includes a greensand treatment system for treating water with high iron and manganese and a RO plant for desalinating brackish groundwater.

The design for the bolt-on ZDD system involved blending the Brighton RO concentrate with NF concentrate from the pilot system. Sulfuric acid was added to the Brighton RO concentrate to reduce the alkalinity to less than 200 mg/L as $CaCO_3$ in the blended RO/NF feed to the EDM. The original design, prepared in May 2014, was designed to treat about 10 gpm of RO concentrate. (The WERF 5T10 report table 4-1 incorrectly notes this flowrate as the "ZDD Test Plan" flowrate, when in actuality it was an approximation based upon a model that does not consider the pilot pipe sizes.) However upon startup, it was evident that the feed piping to and from the EDM system could not accommodate 10 gpm of NF/RO reject. The standpipe inside the container would overflow, because the EDM diluate line was undersized to allow the gravity flow between the EDM and NF containers. The ZDD equipment was never designed with this configuration in mind. For this reason, the RO concentrate flow was reduced to 5 to 5.2 gpm, which corresponds with an EDM feed flow of 9-9.2 gpm. The EDM reduced the concentration by at least 50 percent, and its diluate was fed to an NF system. The NF contained a 2x1(4M) array with NF90-4040 membranes in the first stage and NF270-4040 membranes in the second stage. The NF concentrate, as mentioned before, was blended with the pH-adjusted Brighton RO concentrate. A small purge stream from the NF concentrate was required to maintain silica levels below 150 mg/L. Figure 56 shows the flow diagrams for the ZDD system tested at Brighton. Flow rates for the RO concentrate and silica purge were measured manually and verified using rotameters installed outdoors adjacent to the waste tanks. Sulfuric acid dosage was adjusted manually and verified using field analysis of pH and alkalinity reduction. Hydrex 4101 antiscalant was dosed at 2 to 3 mg/L to the NF system.

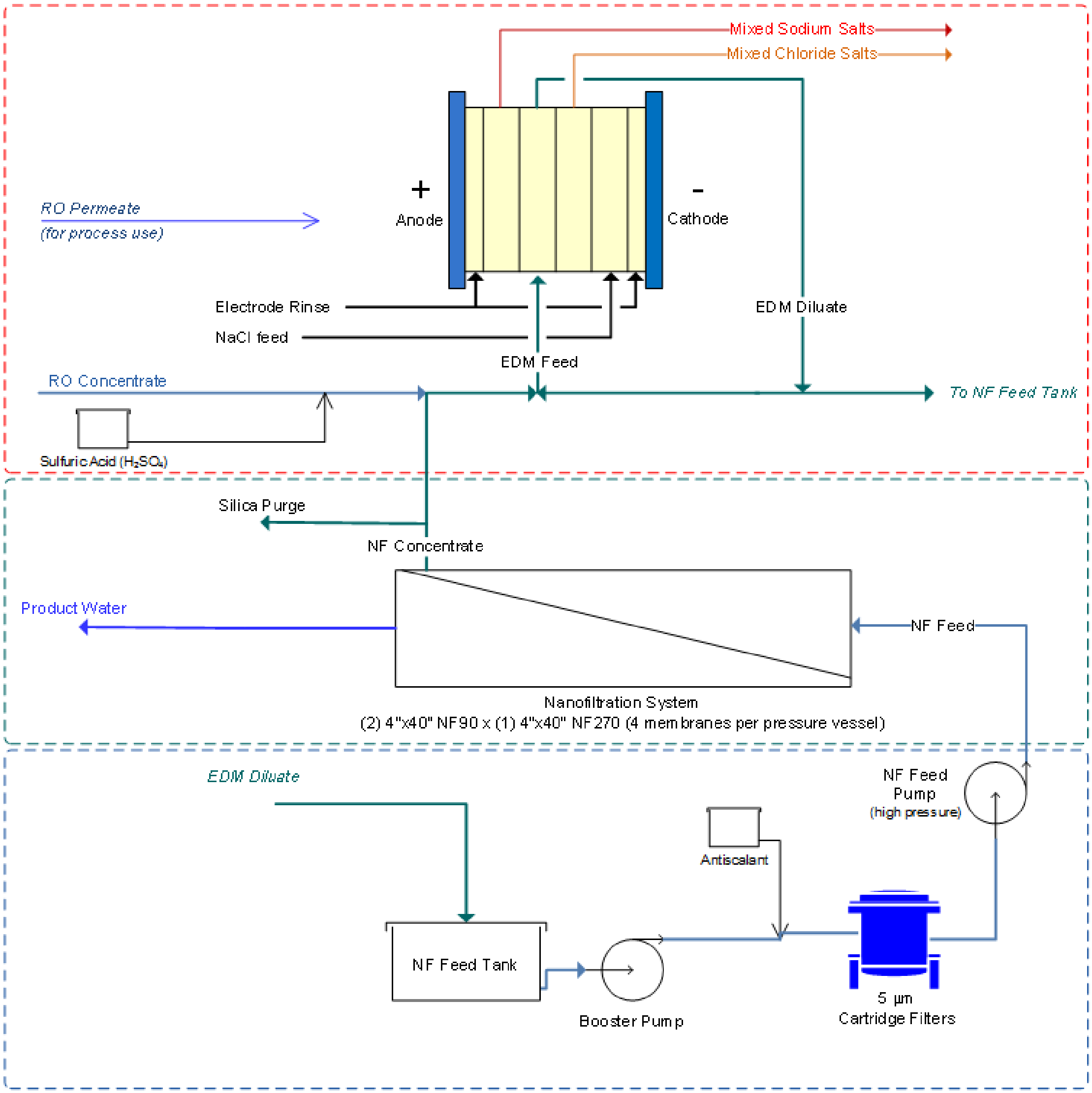


**Figure 56.—Equipment flow diagram (Brighton).**

The NF high pressure pump motor seized during commissioning and did not operate after September. Sufficient pressure and flow were available from the NF booster pump, so operations continued with the NF operated in manual mode. The NF system was designed to produce 20 gpm of permeate. By operating at 5 gpm of permeate, the online flow meters were out of range and did not provide adequate precision for flow adjustment (5 gpm displayed could easily be 4.5 gpm or 5.4 gpm). The operator estimated actual flows using a bucket and stop water and by comparison with other rotameters and online flow meters throughout the system. The combination of manual adjustment of RO concentrate and NF silica purge stream, low overnight temperatures, and a lack of additional operational support led to operating the system with an imbalance overnight. This means more RO concentrate was being added, which led to an intentional, but slight, overflow of the NF feed tank. This nighttime overflow was estimated to be 0.1-0.18 gpm.

## 8.2 Pilot System Upgrades and Commissioning

Prior to shipping the pilot equipment, multiple upgrades were performed to the pilot equipment:

- Conductivity probes on mixed salt streams were replaced with inductive conductivity probes (HACH 3726E2T).
- Improved interlocks were added between the EDM and NF systems to ensure automatic shutdown by the PLC for alarm conditions including high temperature, high pressure, and low flow; also a shutdown-enabled alarm was added for low EDM feed flow.
- Controls were upgraded so that additional data were automatically recorded and trended including EDM voltage and current as well as NF permeate and concentrate flow.
- The EDM stack flush system was upgraded to include a bladder tank to provide a more thorough flush of EDM stack upon shutdown.
- The E-Rinse pressure gauge and flow control valve were relocated to properly match the E-Rinse pressure to the other EDM stream pressures.

During commissioning, the Mixed Na and Mixed Cl conductivity probes were still unreliable. The operator moved their location from the standpipes to the overflow pipes. This allowed for isolation from suspected shunt current in the highly concentrated solutions (this lesson learned was also implemented in Alamogordo during Phase 2).

Several problems occurred during setup and commissioning, most of which were explained by internal EDM stack leaks, improper acid dosing location and rate, unexpected solubility problems in the Mixed Na stream, and equipment damage. Each of these is described later in this section.

Budgetary concerns caused Veolia to withdraw on-site personnel after August 2013, therefore UTEP operated Brighton after Alamogordo Phase 2 operations were completed. Veolia supported the project by shipping a replacement stack to Brighton, purchasing supplies for and providing an operator to install new center dividers in the EDM stack, purchasing NaCl and sulfuric acid, and providing technical guidance throughout the pilot operations.

## 8.3 Experiment 1 (9/30/13-10/13/13)

The first three days of operation were used to identify a safe conductivity setpoint for the Mixed Na stream, which had caused several shutdowns during commissioning. Additionally, the time was used to determine if the new center divider was working properly and preventing internal leaks. A low conductivity setpoint (45 millisiemens per centimeter [mS/cm]) was the starting setpoint. After safe operation for around 24 hours, the setpoint was increased to 50 mS/cm for another 24 hours. After this, the setpoint was increased to 60 mS/cm, where it remained for the duration of the experiment (except for one overnight run where outdoor temperatures dropped below freezing). No dilutions were used for the Mixed Cl stream initially; however, dilutions were implemented overnight on October 12 (conductivity setpoint of 100 mS/cm), because the outdoor temperature had dropped below freezing. Additionally, it was thought that having the two concentrate streams be more balanced in terms of conductivity and density would improve operations.

The ZDD system operated nearly continuously during this experiment. The Brighton RO Plant shutdown briefly (5.3 hours) on October 3 for maintenance and there were a few times during the first week where RO concentrate flow was lost temporarily when the plant switched RO trains. The ZDD system operated for a total of 298.6 hours during this experiment (excludes the 5.3 hour shutdown); 233.6 hours were continuous and without setpoint changes.

All EDM flow and pressure data show no indication of scale formation. EDM performance was more stable at the beginning of the experiment, but the diluate conductivity and EDM stack resistance rose as the system operated. The system feed flows and the NF system were controlled manually. This, combined with low overnight temperatures and increasing RO concentrate conductivity, are believed to be the cause of the reduced EDM performance. The ZDD system was shut down on October 13 because the Brighton water tanks were full and the city's demand had decreased.

## 8.4 Experiment 2 (10/15/13-10/19/13)

The ZDD system was restarted on October 15 and operated continuously without shutdown until October 19 because the Brighton RO Plant needed to shut down to allow its product water tank levels to drop. During the 93.4 hours, all EDM streams (except the E-Rinse) were stable and showed no signs of scale formation. The E-Rinse would lose pressure overnight. There were several leaks in the E-Rinse system, and DI water was added regularly to make up for the losses. Addition of DI water also warmed the stream. The combination of these effects is the reason for the variation in pressure (see Appendix B3).

The Mixed Na and Mixed Cl conductivity setpoints remained constant at 120 mS/cm and 65 mS/cm, respectively. All high concentration EDM streams had stable conductivity except for the E-Rinse. DI water was added regularly to make up for the lost volume from leaks. The setpoint was reduced on the final day because the operator mistakenly thought this would improve the crystallization problem. The EDM performance was more stable towards the end of the run, which is related to the RO concentrate conductivity decreasing and also better flow balancing in the NF and EDM systems.

## 8.5 Experiment 3 (10/22/13-10/26/13)

The ZDD system was restarted on October 22 and operated continuously without shutdown until October 26, because the Brighton RO Plant needed to shut down to allow its product tank levels to drop. During the 94.4 hours, all EDM streams (except the E-Rinse) were stable and showed no signs of scale formation. The E-Rinse pressure increased gradually as the run progressed. About half of the E-Rinse piping is located outdoors and is uninsulated. This exposure likely caused some of the sodium sulfate to crystalize and settle in the electrode compartments, which is thought to be the cause of the increased pressure (see Appendix B3).

The Mixed Na and Mixed Cl conductivity setpoints remained constant at the setpoints from Experiment 2 for the first three days of operation. In an attempt to reduce back diffusion from the concentrate streams as well as to balance the stream densities, the setpoints were reduced stepwise until the Mixed Cl was at 100 mS/cm and the Mixed Na was at 55 mS/cm. The EDM diluate quality remained fairly constant during the day but increased overnight. This decreased performance was thought to be caused by a combination of factors including electrode scaling (later inspection of the electrode showed substantial scale, presumably from sodium sulfate), low temperatures, and flow imbalances between the NF and EDM.

# 8.6 Summary of Brighton Pilot Operations

## 8.6.1 Early Problem Discussion

During setup and commissioning activities, the EDM stack was not able to operate continuously without scale forming in the Mixed Na compartment. The operator initially located the sulfuric acid addition point inside the EDM container to add acid directly to the Mixed Na stream. The thought was this would target the single stream that needed bicarbonate reduction directly and could reduce the volume of acid used. However, pH measurement in this stream became problematic, and the acid addition point was relocated to the original design point (addition to RO concentrate).

Before the acid injection point was changed, carbonate and/or bicarbonate scale formation was regular in the Mixed Na stream. CIPs were performed, but were ineffective at increasing run time. The EDM stack was removed and inspected in late May. Holes were found in the center divider. The divider was patched, but not replaced. During the next week, the Mixed Cl stream did not overflow, but the EDM stack leaked warm water. The stack was removed and inspected again and damaged membranes were removed; the damaged center dividers were still not replaced.

The acid injection point was relocated to the RO concentrate in mid-June. The system operated more stably, but the EDM stack resistance continued to climb. An attempt was made to dose acid to the NF feed instead. However, this did not solve the problem.

In mid-July, both the Mixed Na and Mixed Cl streams had scale formation problems. The cause of the scale formation (carbonate based on acid addition test) in the Mixed Cl stream was suspected to be from internal leaks in the EDM stack. A leak test confirmed substantial leaks in late July, and the stack was removed so that new center dividers could be installed. The new dividers allowed for better operation; however, the Mixed Na stream was still scaling. Prior to mid-July, field alkalinity analyses were not performed, and the handheld and online pH probes were not calibrated. The field alkalinity tests revealed that there was more bicarbonate in the EDM feed than the Veolia design had anticipated. Even though changes were made to reduce bicarbonate in the NF/RO reject fed to the EDM the Mixed Na stream still had scale formation issues. This scale was suspected to be from reduced sodium sulfate and sodium bicarbonate solubility related to the concentration of NaCl present in the Mixed Na stream and from internal leakage in the EDM stack. Marion and Farren studied the effect of NaCl concentration on sodium sulfate and sodium bicarbonate solubilities in different studies (Marion and Farren, 1999 and Marion, 2001). Figure 57 shows a) how increasing $Na_2SO_4$ concentration and decreasing temperature reduce the solubility of $NaHCO_3$, and b) how increasing NaCl concentration and decreasing temperature reduce the solubility of $Na_2SO_4$.

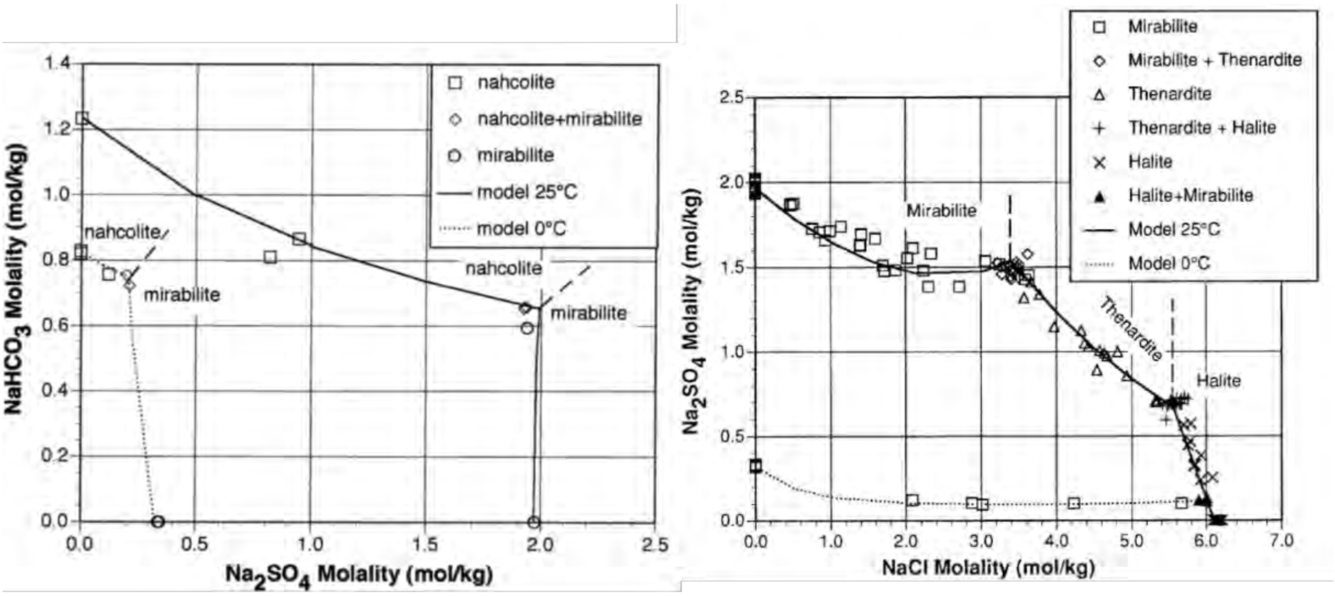


Figure 57.—Solubility and temperature relationships between a) $Na_2SO_4$-$NaHCO_3$ (Marion and Farren, 1999) and b) NaCl (Marion, 2001).

Operation of the ZDD system was relatively stable in August; however, the EDM stack resistance continued to increase. The E-Rinse stream showed signs of severe corrosion and did not allow for a successful handoff to the WERF 5T10 operators. The stack was inspected in early September and severe corrosion was found on the stainless steel cathodes. Inspection of the electrical connection identified the source of the corrosion and high stack resistance. Each electrode plate had an upper electrode and lower electrode with individual connections. The original electrical lug on the bottom cathode wire had been replaced in Alamogordo before the system was shipped to La Junta (and no changes were made before shipping to Brighton). This lug was made of aluminum and had a bolt to fasten the lug to the copper wire. This connection loosened over time, and less current flowed through the lower electrode. There was also evidence of arcing (see Figure 58). This bad connection is believed to have made the cathode act more like a sacrificial anode, and some of the stainless steel corroded.

Figure 59 shows the cathode end plate (top picture) during an inspection in late August; the bottom picture was taken during the inspection in early September. The lower cathode was very shiny and had no texture remaining. There were small holes showing pitting corrosion on several places on the lower anode, especially at the electrical connections.

**Figure 58.—Damaged EDM cathode electrical connection. Photo taken on 8/29/13,**

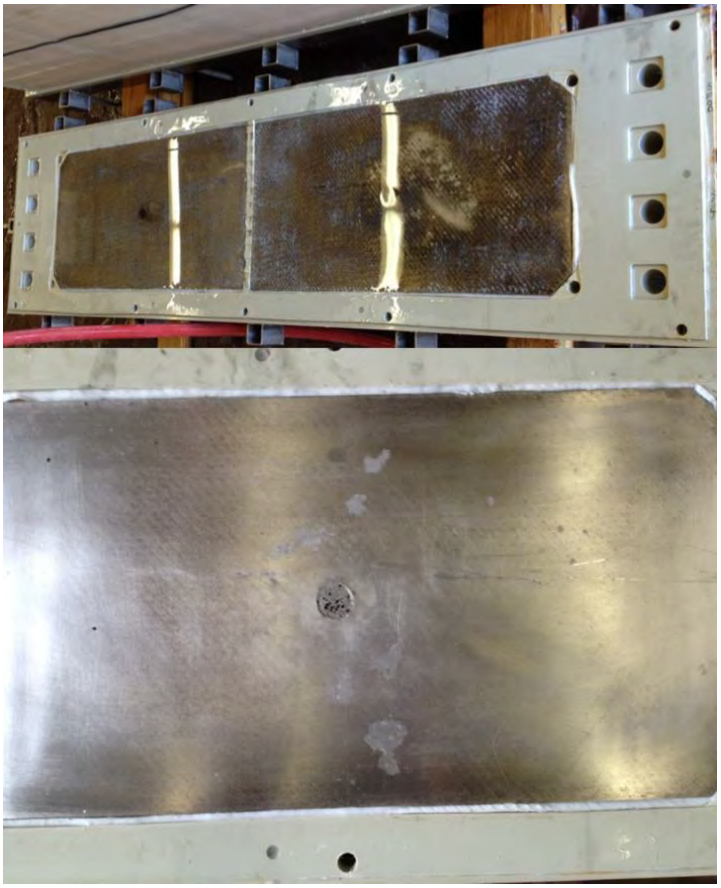


**Figure 59.—EDM cathode inspection. Photo taken on 9/9/13)**

### 8.6.2 Summary of Brighton Operations by UTEP (9/30/13-10/26/13)

Reliable operating setpoints were verified within the first days of a nearly two-week run. Except for overnight operations, the setpoints were followed throughout the three experiments.

As previously mentioned, the NF online flow meters were not precise (output whole numbers without decimals). Additionally, since the system was being operated in manual mode, no data was recorded. The actual permeate produced was estimated by subtracting the calculated Mixed Na and Mixed Cl flows from the EDM feed online flow meter. The NF concentrate flow was calculated by subtracting the silica purge flow from the NF concentrate flow (both measurements were taken from rotameters). The RO concentrate was piped to a storage tank, which was allowed to overflow to ensure adequate supply at all times to the pilot system. A submersible pump's outflow was modulated using a gate valve (red handle in Figure 60). Data from the three rotameters (Brighton RO concentrate, NF concentrate, and silica purge) located outside generally correlated with the EDM feed (called NF/RO reject) flow meter inside the EDM container. At night there was sometimes a discrepancy. The Mixed Na and Mixed Cl overflow streams were captured in 30-gallon tanks with markings at each gallon. The tanks were allowed to fill for at least an hour and the volume was recorded.

**Figure 60.—RO concentrate and NF concentrate flow metering (Brighton).**

The EDM system's datalogger recorded flow, pressure, conductivity for each of the streams (including the NF/RO reject), temperature of the EDM feed and E-Rinse, EDM applied voltage, and EDM current. The NF/RO reject pH was also recorded, but the data is not considered valid, since the probe would not calibrate properly. Table 18 summarizes the average value for various operating data points gathered during pilot operations at Brighton.

Table 18.—Summary of Brighton Operational Data

| **Data Point** | **Unit** | **Average (Range)** |
|---|---|---|
| NF Permeate Flow | gpm | 5 (N/A) |
| 1st Stage NF Permeate (rotameter) | gpm | 3.8 (3.8-3.9) |
| NF Reject (rotameter) | gpm | 4 (3.9-4.2) |
| RO Reject (rotameter) | gpm | 5.1 (4.8-5.2) |
| NF/RO reject | gpm | 9.2 (9-9.4) |
| EDM Feed | gpm | 31.4 (30.7-32.2) |
| M. Na | gpm | 26.7 (25.7-27.6) |
| M. Cl | gpm | 26.1 (25.4-26.6) |
| NaCl | gpm | 27.1 (24.5-27.8) |
| E-Rinse | gpm | 4.9 (4.6-5.2) |
| Silica Purge | gph | 3.5 (1.3-4) |
| *Estimated Flows* | | |
| *NF Feed Tank overflow* | *gpm* | *0.1 (0-0.2)* |
| *NF Permeate* | *gpm* | *4.6 (4.4-4.9)* |
| *NF Reject* | *gpm* | *4.1 (3.9-4.2)* |
| NF Feed | psi | 40.1 (32.8-43.7) |
| NF Permeate | psi | 2.1 (1.8-2.2) |
| NF Concentrate | psi | 25.7 (21-28.9) |
| EDM Feed | psi | 19 (17-147) |
| Mixed Na | psi | 17 (16.2-17.7) |
| Mixed Cl | psi | 17.1 (16.4-18.8) |
| NaCl | psi | 17.1 (16.5-17.7) |
| E-Rinse | psi | 17.3 (16.7-17.9) |
| NF Feed | °C | 21.9 (20.2-23.6) |
| NF Permeate | °C | 21.7 (20.5-22.8) |
| NF Concentrate | °C | 21.7 (20.7-22.9) |
| NF/RO Concentrate | °C | 20.1 (18.7-21.4) |
| EDM Feed | °C | 20.7 (19-22.3) |
| EDM Diluate | °C | 21.2 (19.2-22.9) |
| Mixed Na | °C | 21.3 (19.5-23) |
| Mixed Cl | °C | 21.5 (19.5-23.4) |

| Data Point | Unit | Average (Range) |
|---|---|---|
| E-Rinse | °C | 21.8 (17.8-24.7) |
| EDM Voltage | volts | 100 (79.2-120.4) |
| EDM Current | amps | 26.3 (23.7-28.3) |
| NF Recovery | % | 53.2 (51.2-55.1) |
| ZDD Recovery w/o NF purge | % | 89.8 (87.1-91.4) |
| ZDD Recovery w/NF purge | % | 88.1 (85.4-89.7) |
| ZDD Recovery (NF perm/RO Conc) | % | 91.6 (85.4-95.4) |
| Longest Continuous Run | | 298 hours (9/30/13-10/13/13) |

gph = gallon per hour

The ZDD recovery was calculated using three methods.

The first method is similar to Rec1 used in La Junta (called ZDD Recovery w/o NF Purge in Table 18) divides the calculated NF permeate by the sum of the calculated NF permeate and EDM concentrate streams.

The second method (called ZDD Recovery w/NF Purge in Table 18) assumes that the NF feed tank was overflowing continuously and adds the estimated flow to the denominator of the calculation:

$$\text{ZDD Recovery w/NF purge} = \frac{NF\ permeate\ (calculated)}{NF\ perm\ (calc) + \sum overflows + NF\ purge}$$

The third method (called ZDD Recovery (NF perm/RO Conc) in Table 18) simply divides the RO concentrate flow by the calculated NF permeate flow. Recoveries calculated by each of these methods varied by about 4 percent and the variation is caused by differences in the calculated NF permeate flow rate.

Again, the NF system was controlled manually, and the operator was not able to regularly balance all of the flows between systems and account for differences in concentration and temperature. Of course, a full scale system would be operated at constant flow using automated controls. The results of the Brighton pilot study indicate that recovery of 90 percent is achievable with this bolt-on approach. Samples were taken at least once per day and analyzed onsite to monitor performance of the NF and EDM systems. The results are summarized in Figure 61. The variation in the Mixed Na and Mixed Cl stream conductivity and specific gravity and Mixed Na alkalinity relate to the different conductivity setpoints employed throughout the study. The NF permeate was below 800 µS/cm before October 10 and around 900 µS/cm for the remainder of the pilot.

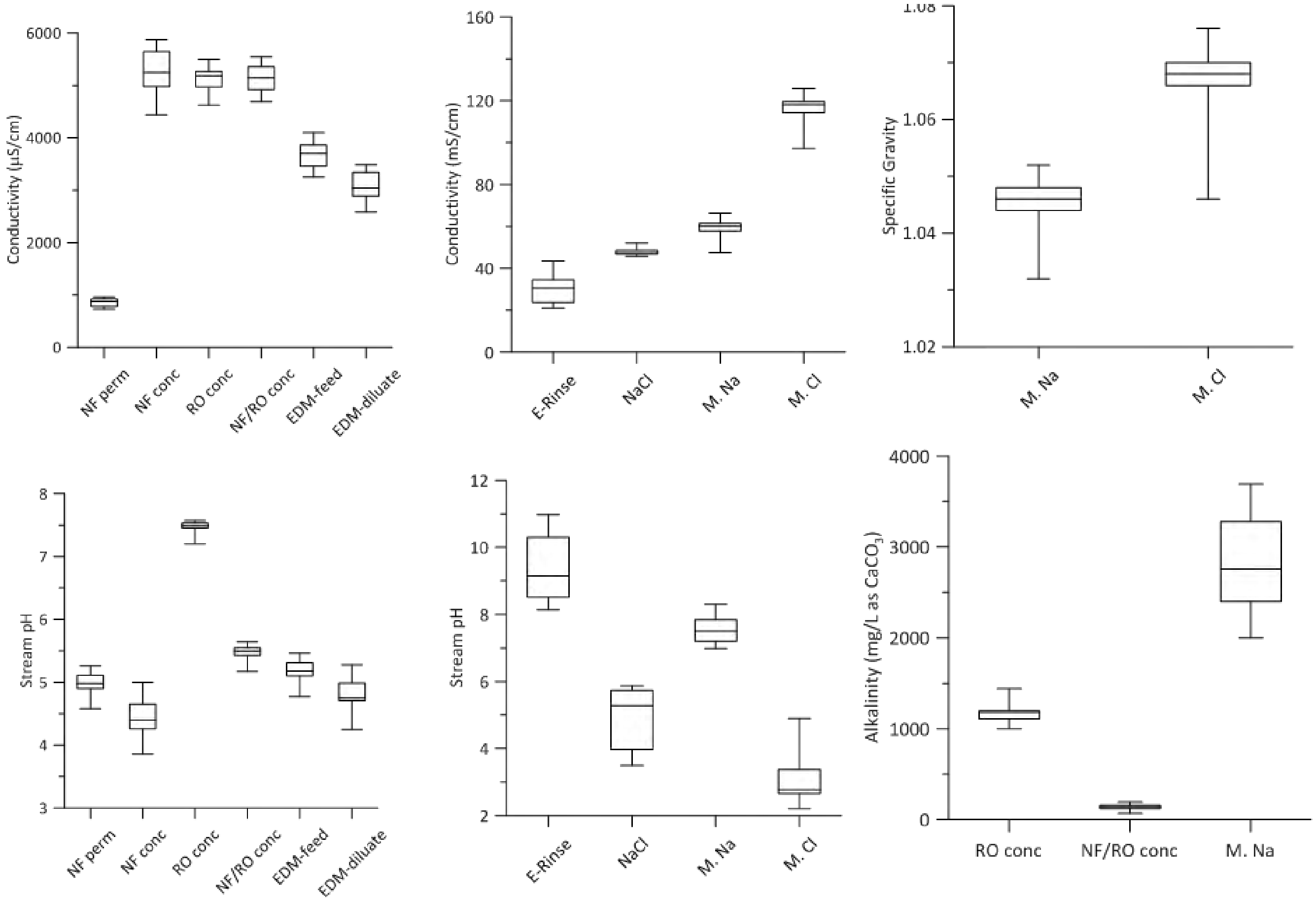


**Figure 61.—Brighton grab sample data.**

Samples were taken daily for most of the streams (RO concentrate, EDM feed and diluate, Mixed Cl, Mixed Na, and NF permeate) and at least weekly for the remaining streams. These samples were shipped to UTEP for analysis. The average data was summarized in Stiff Diagrams in Figure 62. From these, one can observe that the primary ions in the RO concentrate are calcium, sodium, chloride, sulfate, and bicarbonate. The EDM performed as expected transferring the cations into a stream with chloride salts (Mixed Cl) and the anions into the Mixed Na stream (see bottom figures in Figure 62).

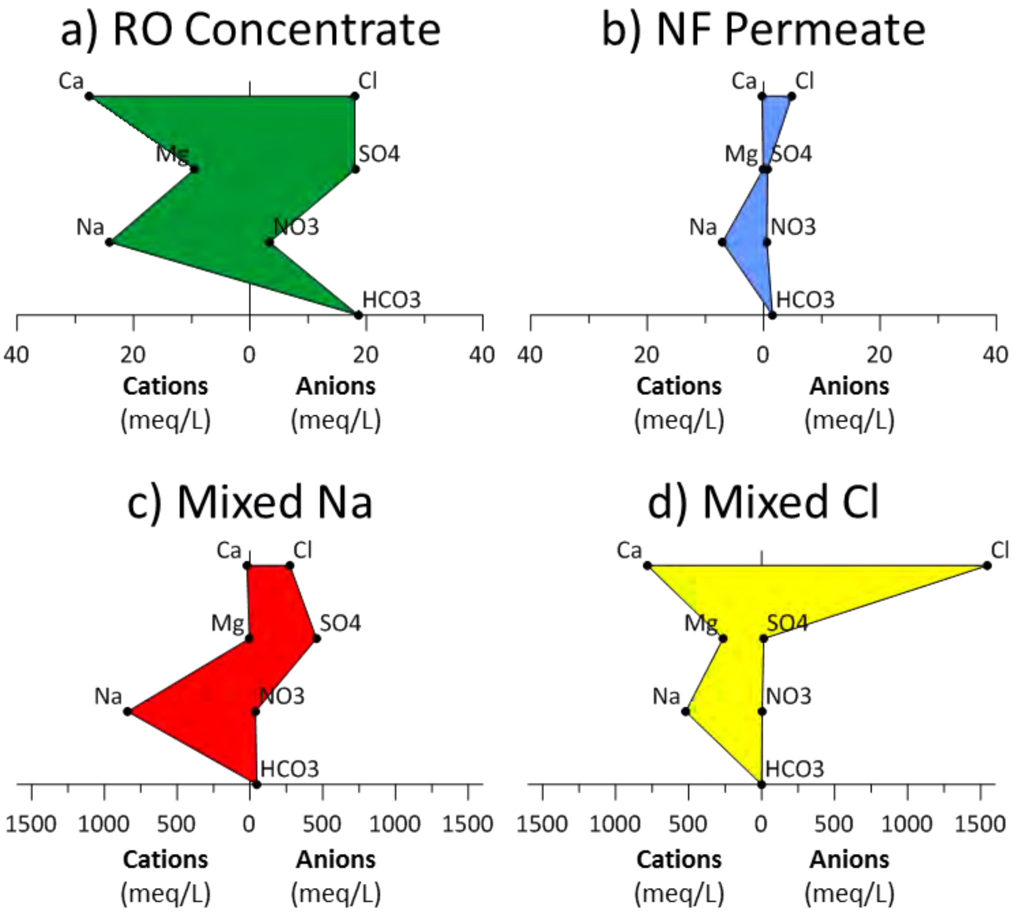


**Figure 62.—Average Brighton water quality for ZDD Inlet (a) and outlet streams (b-d).**

The variation for each of the main streams studied in Brighton is shown in Figure 63. As expected, the variation in the major ions in the Mixed Cl and Mixed Na streams is explained by the different conductivity setpoints. There is a larger variation and there also seem to be some outliers in the calcium data for the RO concentrate. This may be analytical error, since there isn't a similar degree of variability in the anions. The variability in the monovalent ions is similar to what was seen with conductivity variation for the NF permeate samples. In Figure 64, an upward trend in the RO concentrate is visible during the first run, along with the increase in conductivity of the NF permeate. During the second run, there is a consistent downward trend and a relatively flat trend with higher conductivity during the third run. Water quality for the remaining sample points is provided in Table 19 and Table 20.

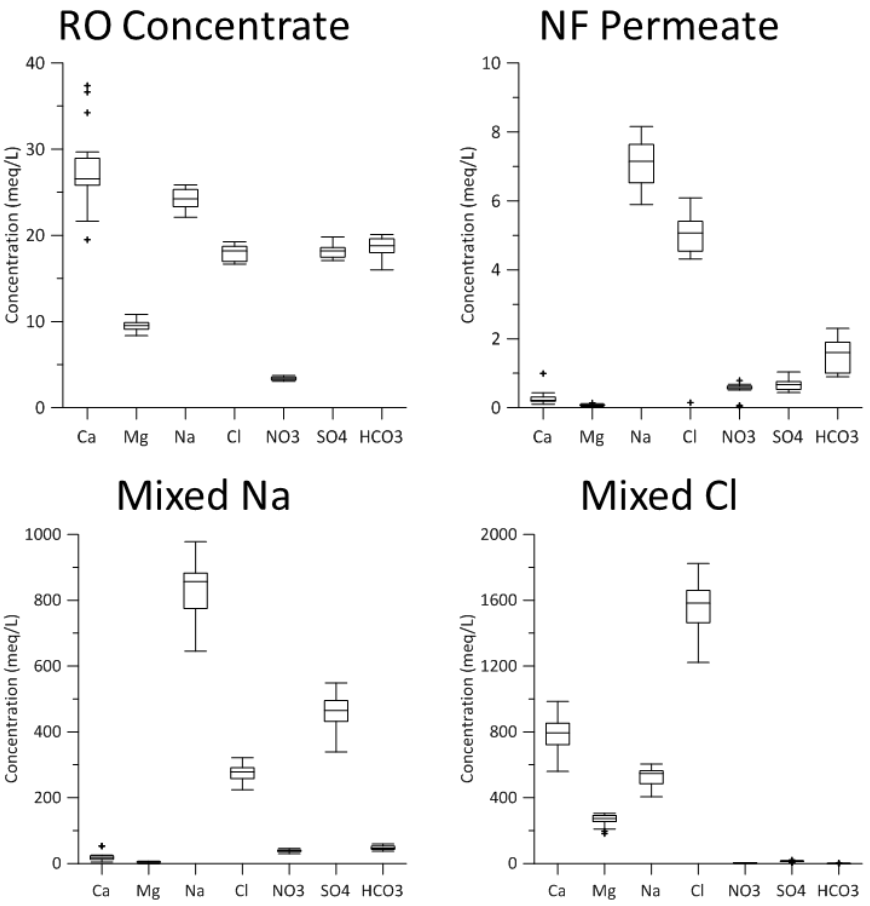


Figure 63.—Variability in Brighton water quality for ZDD inlet and outlet streams.

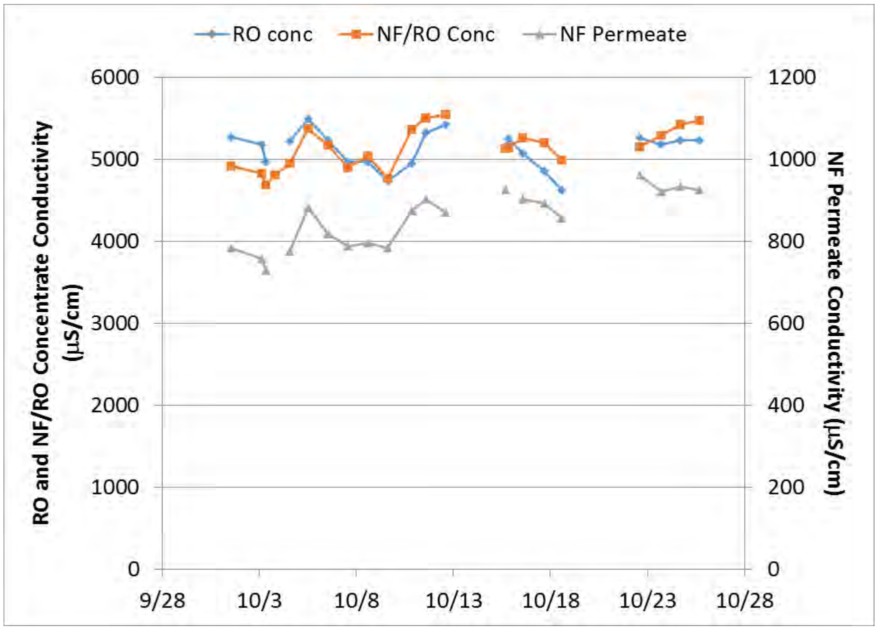


Figure 64.—ZDD inlet and outlet conductivity monitoring (Brighton).

Table 19.—Brighton IC Analyses (all in mg/L)

| | **Ca** | | **K** | | **Mg** | | **Na** | | **Cl** | | **F** | | NO**3** | | SO**4** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Avg (Std Dev)** | **N** | **Avg (Std Dev)** | **N** | **Avg (Std Dev)** | **N** | **Avg (Std Dev)** | **N** | **Avg (Std Dev)** | **N** | **Avg (Std Dev)** | **N** | **Avg (Std Dev)** | **N** | **Avg (Std Dev)** | **N** |
| Raw | 108.3 (3.66) | 3 | 3.6 (0.35) | 3 | 22.3 (3.52) | 3 | 118.8 (4.15) | 3 | 133.4 (3.32) | 3 | 1.9 (1.36) | 3 | 44.8 (3.25) | 3 | 176.9 (8.48) | 3 |
| RO Conc | 552.6 (82.7) | 20 | 14.9 (2.04) | 20 | 116.1 (7.27) | 20 | 555 (27.78) | 20 | 638.3 (30.77) | 20 | 7.9 (2.14) | 20 | 209.7 (13.09) | 20 | 870.3 (35.79) | 20 |
| NF/RO Conc | 449.5 (29.23) | 7 | 14.6 (2.73) | 7 | 99.8 (7.47) | 7 | 724.1 (75.32) | 7 | 374.6 (18.38) | 7 | 6.3 (2.34) | 7 | 119 (6.97) | 7 | 2,164 (214.5) | 7 |
| EDM Feed | 249.2 (27.21) | 20 | 9.1 (1.58) | 20 | 60.2 (6.85) | 20 | 594.2 (64.74) | 20 | 194.8 (12.86) | 20 | 3.3 (0.84) | 20 | 51 (3.61) | 20 | 1,599 (179.2) | 20 |
| EDM Dil | 152.2 (22.49) | 20 | 7.3 (1.3) | 20 | 40.4 (6.48) | 20 | 530.9 (67.54) | 20 | 117.2 (11.21) | 20 | 3.1 (0.9) | 20 | 21.9 (2.64) | 20 | 1351 (184.3) | 20 |
| Mix Cl | 15,636 (2578) | 20 | 273.2 (35.27) | 20 | 3,216 (430.32) | 20 | 11,974 (1403) | 20 | 54,795 (6,159) | 20 | 86.3 (38.36) | 20 | 212 (40.44) | 20 | 678.7 (146.2) | 20 |
| Mix Na | 397.4 (243.51) | 20 | 47.6 (8.14) | 20 | 52.3 (24.46) | 20 | 19,346 (1971) | 20 | 9,733 (950.2) | 20 | 96.7 (45.72) | 20 | 2,377 (245.3) | 20 | 21,974 (2,558) | 20 |
| E-Rinse | 119.8 (168.98) | 4 | 11.7 (6.31) | 4 | 3.8 (4.75) | 4 | 8,148 (3444) | 4 | 271.8 (118.6) | 4 | 17.8 (19.8) | 4 | 445.7 (454.3) | 4 | 14,729 (6,443) | 4 |
| NaCl | 209.6 (394.4) | 4 | 20 (5.08) | 4 | 14 (3.15) | 4 | 12,050 (397.16) | 4 | 18,257 (666.5) | 4 | 21.5 (22.54) | 4 | 47 (10.6) | 4 | 361.9 (205.2) | 4 |
| NF Conc | 330.1 (38.97) | 4 | 14.4 (3.72) | 4 | 83.8 (8.04) | 4 | 984.5 (133.14) | 4 | 45.3 (10.94) | 4 | 3.2 (2.39) | 4 | 5.6 (0.66) | 4 | 2,959 (355.6) | 4 |
| NF Perm | 5.36 (3.60) | 20 | 2.69 (0.33) | 20 | 0.96 (0.29) | 20 | 163.16 (15.26) | 20 | 171.27 (41.55) | 19 | 1.55 (0.46) | 20 | 34.18 (10.74) | 20 | 32.12 (7.62) | 18 |
| RO Perm | 8.53 (17.33) | 4 | 0.64 (0.67) | 4 | 1.91 (3.87) | 4 | 30.54 (46.24) | 4 | 5.92 (1.65) | 4 | 0.5 (0.27) | 4 | 5.56 (3.26) | 4 | 68.92 (146.77) | 4 |

Table 20.—Brighton General Water Quality Analyses

| | **pH** | | **TDS* (mg/L)** | | **Conductivity ($\mu$S/cm)** | | **$SiO_2$ (mg/L)** | | **Alkalinity (mg/L as $HCO_3$)** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Avg (Std Dev)** | **N** | **Avg (Std Dev)** | **N** | **Avg (Std Dev)** | **N** | **Avg (Std Dev)** | **N** | **Avg (Std Dev)** | **N** |
| Raw | 7.4 (0.11) | 4 | 817.5 (55) | 4 | 1,410 (66.19) | 4 | 20.8 (0.5) | 4 | 294.3 (17.52) | 4 |
| RO Conc | 7.6 (0.05) | 22 | 4,065 (211.6) | 22 | 5,666 (304.5) | 22 | 99.1 (5.23) | 22 | 1,138 (64.34) | 21 |
| NF/RO Conc | 5.7 (0.12) | 9 | 4,686 (428) | 9 | 5,643 (349.4) | 9 | 109.8 (6.67) | 9 | 167.4 (31.27) | 9 |
| EDM Feed | 5.5 (0.31) | 22 | 3,339 (332.5) | 22 | 4,142 (313.5) | 22 | 109.6 (6.37) | 22 | 109.5 (28.25) | 21 |
| EDM Dil | 5 (0.42) | 22 | 2,725 (341.7) | 22 | 3,442 (344.2) | 22 | 110.4 (6.13) | 22 | 79.6 (35.3) | 20 |
| Mix Cl | 3.1 (1.02) | 22 | 106,082 (10844) | 22 | 128,336 (11,995) | 22 | 10.1 (1.17) | 22 | 7.8 (20.9) | 22 |
| Mix Na | 7.7 (0.29) | 22 | 59,416 (5770) | 22 | 65,164 (5,443) | 22 | 11.2 (2.11) | 22 | 2,876 (371.4) | 22 |
| E-Rinse | 9.3 (0.94) | 6 | 30,308 (10763) | 6 | 30,810 (10,970) | 6 | 2.3 (1.03) | 6 | 244 (29.6) | 6 |
| NaCl | 4.6 (1.36) | 6 | 31,738 (1235) | 6 | 53,833 (2,917) | 6 | 5.2 (1.47) | 6 | 71.2 (78.9) | 6 |
| NF Conc | 4.4 (0.53) | 6 | 5,328 (705.6) | 6 | 6,053 (645) | 6 | 127.3 (8.91) | 6 | 37.6 (38.66) | 5 |
| NF Perm | 5.44 (0.52) | 22 | 547.1 (131.5) | 21 | 923.7 (75.86) | 22 | 99.64 (5.778) | 22 | 92.11 (26.91) | 20 |
| RO Perm | 5.96 (0.13) | 5 | 265 (197.96) | 5 | 62.92 (13.04) | 5 | 1.4 (0.55) | 5 | 82.96 (18.1) | 5 |

*TDS samples are not filtered before being placed in oven.

## 8.7 Evaluation of Current Density, Current Efficiency, Power Consumption – Brighton

Intentional experiments were not performed to identify the limiting current density at Brighton due to time limitations, but useful data can be obtained from the startup data. The EDM voltage was slowly increased during startup and the datalogger recorded all of the data that would be needed to determine the limiting current density for the flow rate used throughout the study. Data from five startups were graphed (Figure 65 is from 10/15/13). The intersection between the ohmic and limiting sections was calculated for each set of data and averaged. The limiting current density using the shoulder method was determined to be 59.6 A/m$^2$.

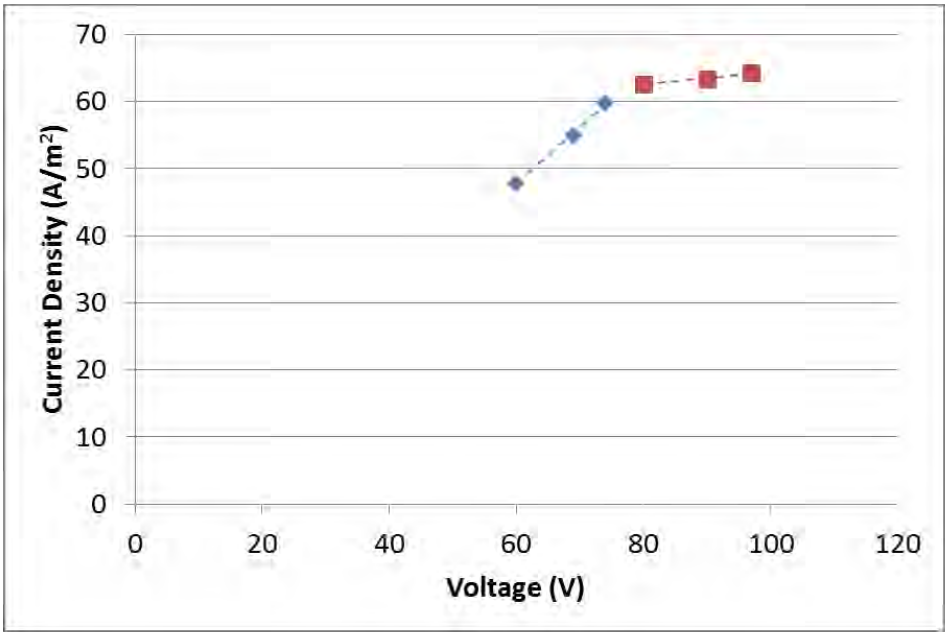


**Figure 65.—Typical limiting current density – Brighton (7 cm/s velocity).**

## 8.8 EDM Stack Performance Monitoring

During each of the runs EDM performance declined, as measured by stack resistance and EDM diluate conductivity. The cause seemed to be related to temperature, as ED systems perform better at warmer temperatures, but a direct correlation can't be shown with the data obtained. In some cases, decreasing temperature led to lower current efficiency, but in others, it did not. Instead of having a direct effect, the lower temperatures may have contributed indirectly. RO and NF membranes produce better quality permeate (and higher conductivity concentrate) at lower temperatures. The combination of lower temperature and overnight flow imbalances tended to lead to imbalances in ions entering and leaving the system. A mass balance using the measured or calculated flow rates and TDS analyses showed a gradual upward trend—suggesting that more ions were entering than leaving during the first run and that the performance was more stable during the final two runs. The current efficiency (calculated based on ions removed from the EDM feed and diluate), daily outdoor low temperature (at nearby Denver airport), mass balance, and EDM stack resistance are graphed in Figure 66. Since the second and third runs were shorter than the first it is unclear whether the stack resistance would have stabilized.

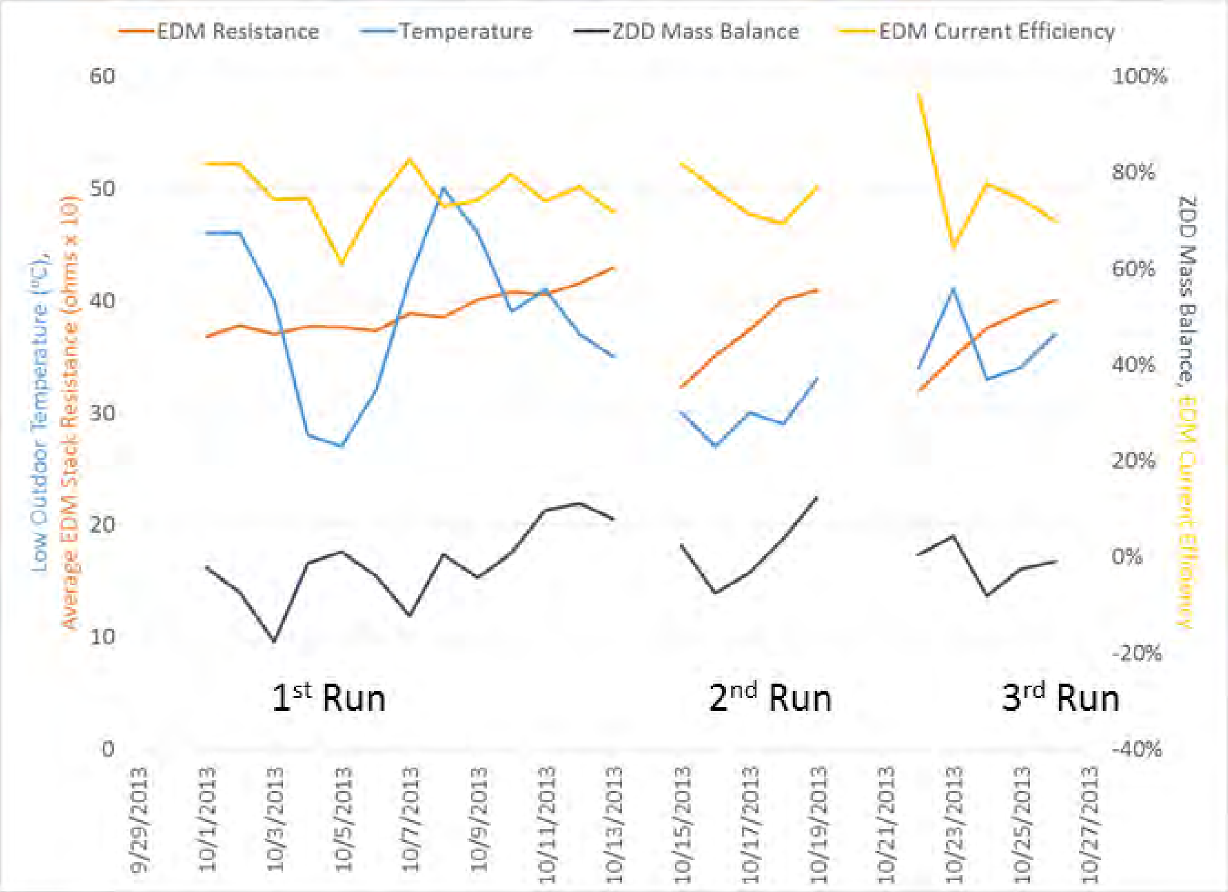


**Figure 66.—Brighton EDM performance and outdoor temperature data near Brighton (Denver International Airport (DIA), Denver, Colorado).**

The stack was operated beyond the limiting current density identified using the shoulder method. This led to an increased difference between the Mixed Cl and Mixed Na pH values, which is expected to be caused by water splitting (see Figure 67).

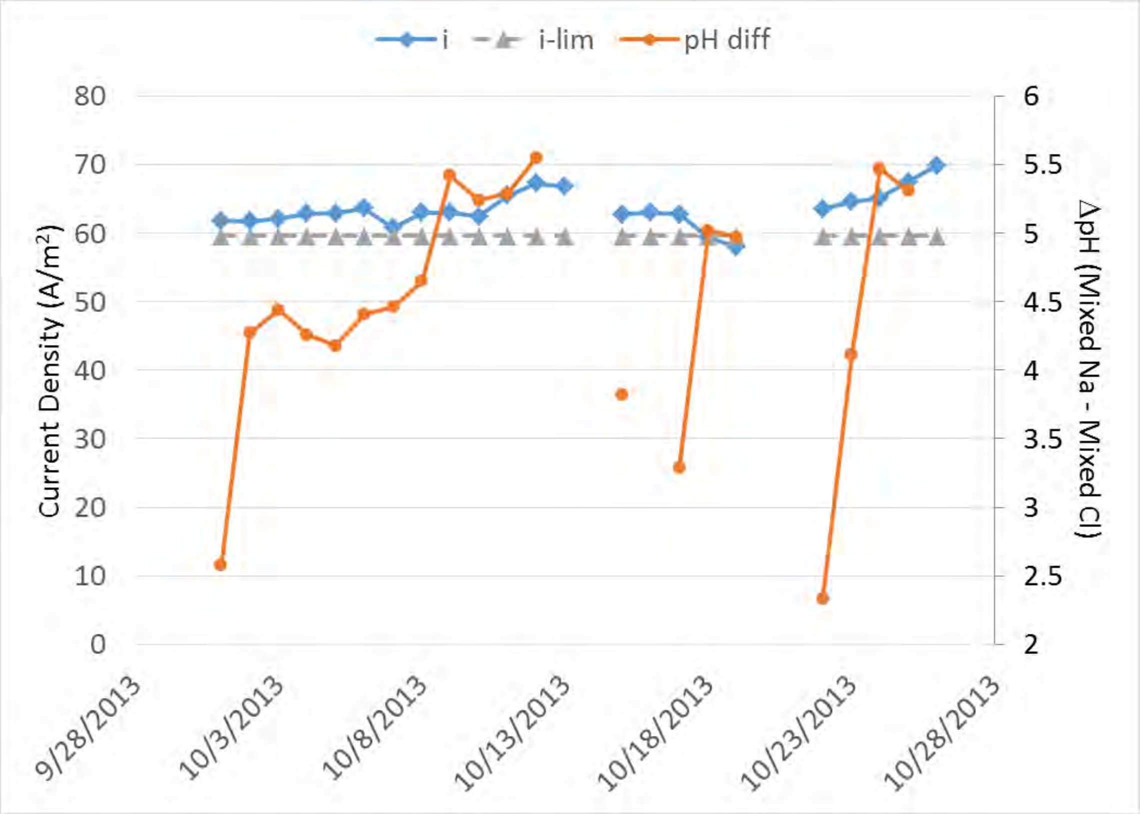


Figure 67.—Current density and pH difference (Brighton).

Using methodology similar to what was described for Phase 2 operations in Alamogordo, the current efficiency for the EDM stack was calculated using four methods for each day with reliable water quality, NaCl consumption, and flow rate data (22 sets of data for each method). Average data for the 22 sets are summarized in Table 21 and the range of the calculated results is shown in Figure 68. The individual method results and average of the method yields lower average current efficiency than what was calculated for Alamogordo. The lower current efficiencies were attributed to operation above the limiting current density, cold temperature effects, and possibly back diffusion.

Table 21.—Average Current Efficiency (Brighton).

| Method | Average Current Efficiency |
|---|---|
| EDM Feed | 76% |
| NaCl | 73% |
| Mixed Cl | 62% |
| Mixed Na | 71% |
| Average | 70% (74%-EDM feed & NaCl only) |

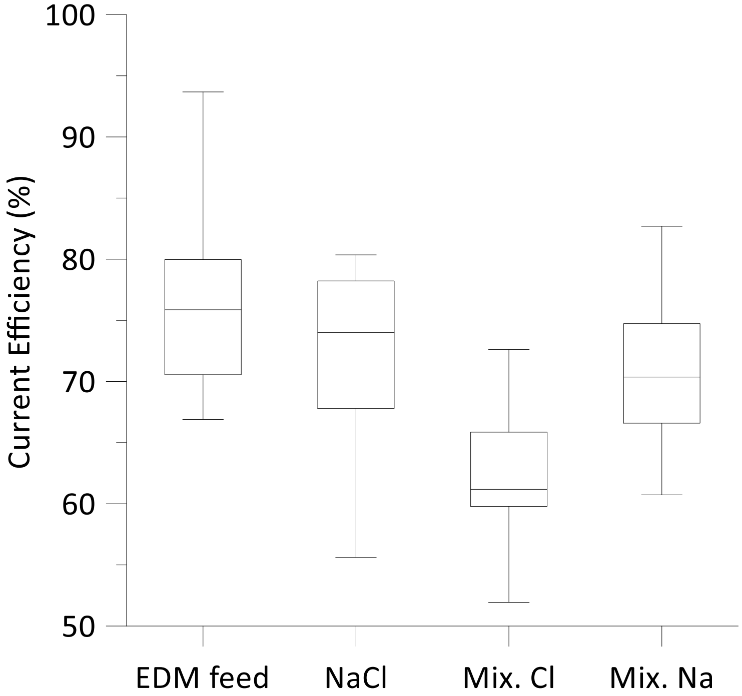


**Figure 68.—Brighton current efficiency.**

# 9. Beverly Hills Pilot

The EDM container used in Phase 2 operations in Alamogordo was shipped to the Beverly Hills Water Treatment Plant for a pilot project led by Black & Veatch and funded by the California Energy Commission (Bond et al., 2015). The experimental objectives differed somewhat from the ZDD demonstrations and pilots in Alamogordo and Colorado, but some observations can be made from the work performed by Black & Veatch. Some raw operating data and water analyses were shared with UTEP for inclusion in this report.

- The EDM stack used for the pilot studies at Beverly Hills still had the swollen AEMs between the NaCl and Mixed Cl compartments for the experiments performed in fall 2013. Two quads of membranes were shipped from Brighton to the manufacturer, MEGA, for analysis. Calcium sulfate and possibly calcium phosphate (from antiscalant) was present inside the anion exchange modules and MEGA recommended replacement. The swollen membranes were replaced in February 2014 in the one stack operated at Beverly Hills.

- The new center divider, installed after Alamogordo Phase 2 operations, seemed to correct problems with major internal leakages. The stack did not show signs of extensive scale formation during the project. Some internal leaks seemed to be present based on sulfate and bicarbonate being present in the NaCl and Mixed Cl streams. At the beginning of the Beverly Hills pilot, the amount of sulfate in both the Mixed Cl and NaCl streams was high. The source of the contamination was not identified or reported by the project team; however, it is possible that small leaks were still occurring at the center divider or elsewhere in the stack or that the RO system used to prepare process water was not performing adequately. Figure 69 shows the concentrations of sulfate and bicarbonate in mg/L (left) and the Na/Ca and $Cl/SO_4$ ratios (right; based on concentrations in meq/L).

- High recovery was demonstrated with the EDM system. The EDM recovery reported in the California Energy Commission report is calculated differently from the previous studies. EDM recovery is defined as the EDM diluate volume divided by the EDM feed (Beverly Hills RO concentrate). Total system recovery is defined as the EDM diluate flow rate divided by the sum of the EDM feed rate (RO concentrate) and DI water used for NaCl makeup and dilutions. The total system recovery method is expected to provide similar recovery as the method used in this report. Black & Veatch reported total system recovery of 91 to 92 percent, which would boost the Beverly Hills RO plant recovery to 98 percent or

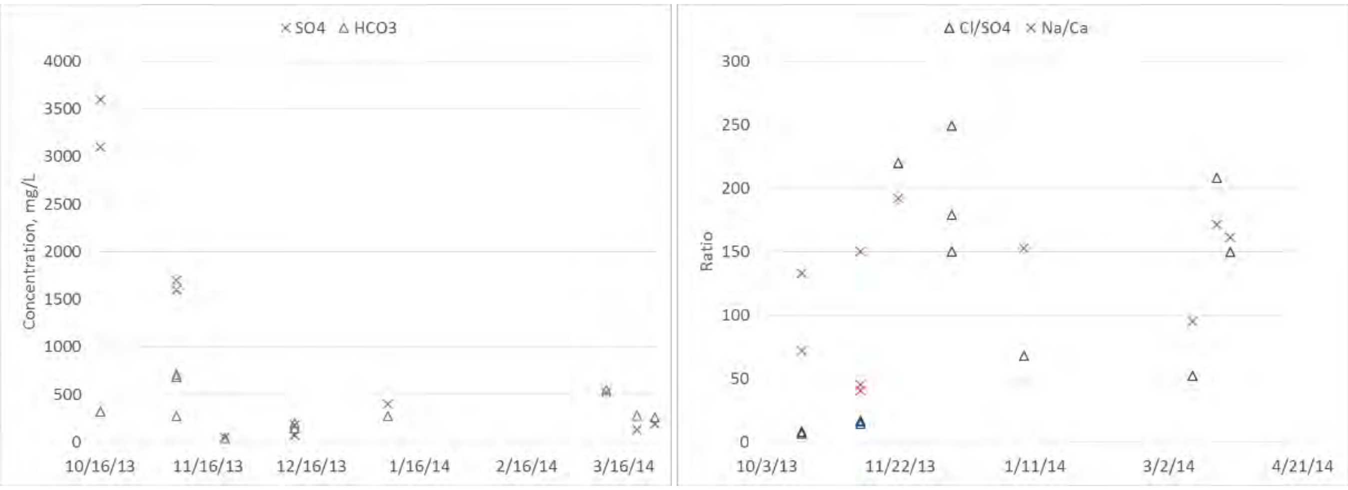


**Figure 69.—NaCl contamination – Beverly Hills pilot.**

higher. A substantial amount of DI water was used to dilute the Mixed Na Stream to prevent carbonate- and bicarbonate-based scale formation. If sulfuric acid were to be added to the RO concentrate stream to reduce bicarbonate levels, higher recovery is possible.

- Black & Veatch acknowledged that the complexity of EDM is higher than that of conventional water treatment and suggested that, "Concentrate treatment is inherently more complex than conventional water treatment, because concentrations of contaminants that must be removed are four to five times greater" (Bond et.al, 2015). Additionally, the report stated that EDM has two advantages. First, EDM is capable of achieving recovery comparable to thermal approaches while requiring substantially less energy. Second, EDM allows for beneficial recovery of saleable salts, which could reduce concentrate treatment costs.

- Black & Veatch developed an EDM cost model and performed calculations for three sites in California, including Beverly Hills, Santa Rosa, and Arcadia. Selected details from the model inputs and outputs are summarized in Table 22.

- EDM was described as a "promising solution for concentrate management" and Black & Veatch recommended that utilities test it on their water to best understand if EDM (or other technologies) will meet the needs of the utility with respect to cost, complexity, and sustainability (Bond et.al., 2015).

Table 22.—Black & Veatch EDM Study Summary (Bond et al., 2015)

| | **Units** | **Beverly Hills** | **Santa Rosa** | **Arcadia** |
|---|---|---|---|---|
| # of EDM Stages | | 1 | 3 | 1 |

| | **Units** | **Beverly Hills** | **Santa Rosa** | **Arcadia** |
|---|---|---|---|---|
| RO Concentrate flow | gpm | 300 | 550 | 270 |
| TDS | mg/L | 3,190 | 4,791 | 4,333 |
| Conductivity | mS/cm | 4.126 | 5.99 | 5.53 |
| % Ca, Mg to cations* | % | 42.6% | 38.9% | 72.7% |
| % $SO_4$ to anions* | % | 26.2% | 25.9% | 37.0% |
| Projected EDM Recovery | % | 95% | 89% | 93% |
| New Plant Recovery | % | 99% | 97% | 99% |
| RO Concentrate Treatment Cost | $/kgal | $2.28 | $4.48 | $2.61 |

$/kgal = dollars per thousand gallons

# 10. Cost Analysis

As part of the Reclamation's Alamogordo Phase 1 Study, a cost estimate was developed for a 3.6 MGD production ZDD system (Biagini et.al, 2012). These cost estimates were considered preliminary at that point due to the lack of long-term ZDD operating data. Cost information was updated as part of the Phase 2 Study using additional ZDD pilot operating data at BGNDRF, La Junta, Brighton, and Beverly Hills, California; project-specific equipment quotes for ZDD controls and ancillaries; and a new EDM skid design which minimizes onsite installation time.

Alamogordo is planning to build desalination capacity in stages, starting with a 1 MGD plant to replace the loss of its Bonito Lake surface water supply. This will be installed at a location that will allow Alamogordo to use the existing Bonito Lake pipeline with minimal cost to connect. Later, the city is planning a 4 to 5 MGD desalination plant to be located across the street from the BGNDRF. Cost estimates were updated for 1 MGD production based on the average Alamogordo Snake Tank water quality (see Table 5). Since the EDM and NF systems are modular, these costs were scaled-up to 4 MGD. Estimates for both are presented in this chapter, along with the conceptual drawings of the treatment process for Alamogordo.

## 10.1 Cost Development Approach

This report's objectives were to provide study or feasibility-level costs. The American Association of Cost Engineers (AACE) defines five categories of estimates that describe the accuracy range for cost estimates (see Table 23). It is expected that an estimate of this type would be a Class 4 estimate (accurate within -15 percent to +30 percent). Project-specific process and instrumentation diagrams were developed, and ancillaries were specified and selected based upon years of operating data at the pilot-scale. However, quotes for the EDM skid were based upon designs of similarly-sized ED systems from MEGA instead of mechanical design drawings specific to the EDM skids. Additional details on the selection of the estimated class are provided in the AACE International Recommended Practice document (AACE, 2000). Capital and operating costs could change, depending on the actual brackish water feed or on further optimization of the EDM to reduce NaCl and/or energy consumption.

Table 23.—AACE Cost Estimation Classification (AACE, 2000)

| Estimate Class | Level of Project Definition[1] | End Usage – Typical Purpose Of Estimate | Typical Budget Estimate Accuracy |
|---|---|---|---|
| Class 5 | 0 to 2% | Concept screening | -30% to +50% |
| Class 4 | 1 to 15% | Study or feasibility | -15% to +30% |
| Class 3 | 10 to 40% | Budget, amortization or control | -15% to +30% |
| Class 2 | 30 to 70% | Control or bid | -5% to +15% |
| Class 1 | 50 to 100% | Check estimates on bid | -5% to +15% |

[1] Expressed as % of complete definition.

Cost information was requested from vendors for the 1 MGD design:

- MEGA EDM stacks
- Veolia-Dayton for NF skids
- Bardac DC drive
- Bryneer salt make-up system
- Verderflex NaCl slurry pumps
- Prominent chemical dosing pumps
- Grundfos pumps (NF and EDM)

The economic analysis assumes the following multipliers:

- Install cost: 1.4 times equipment price

- 20-year present worth of operating costs: 11.47 times annual operating cost (or, 20 years at 6 percent)

Typical flow diagrams for a ZDD and BWRO system are shown in Figure 70 and Figure 71. Letters are placed at key positions where key design information is provided for economic analysis. Recovery is defined as product flow (G) and well water (A) in Figure 70 and Figure 71 for both designs. Key labels are included and are incorporated into the operational cost summary in **Error! Reference ource not found.**Table 24.

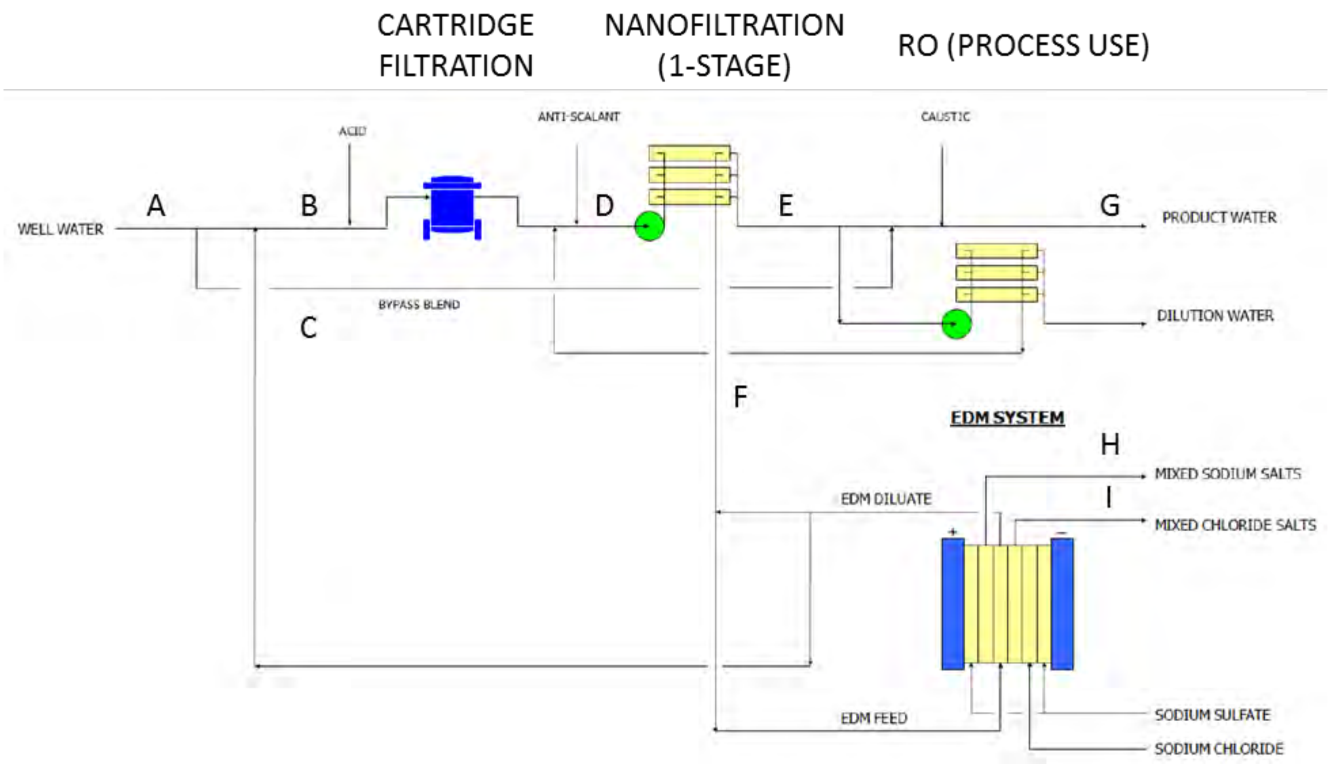


**Figure 70.—Process flow diagram of a ZDD system.**

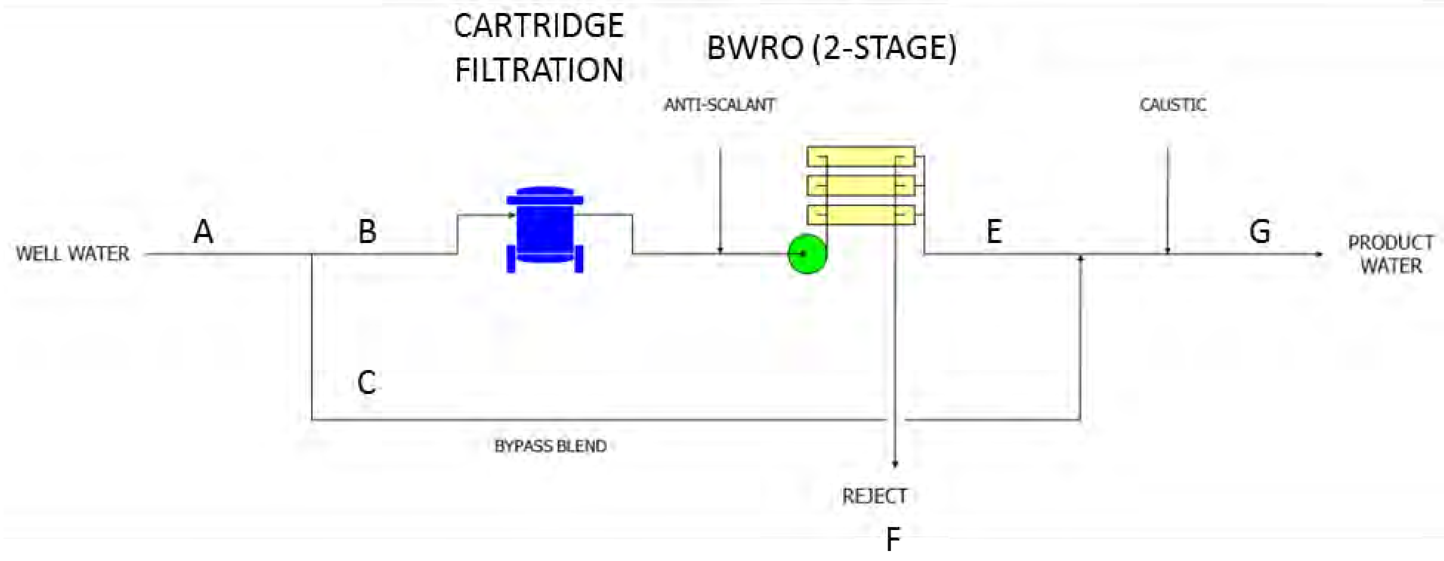


**Figure 71.—Process flow diagram of a BWRO system.**

Table 24.—Major Operational Cost Comparison by Product Flow Rate and System (Alamogordo)

| Location | 1 MGD | | 4 MGD | |
|---|---|---|---|---|
| | ZDD | BWRO | ZDD | BWRO |
| A (BW feed) | 709 gpm / 0 psi | 868 gpm / 0 psi | 2,835 gpm / 0 psi | 3,473 gpm / 0 psi |
| B (BW feed to ZDD/BWRO) | 561 gpm / 30 psi | 720 gpm / 30 psi | 2,263 gpm / 30 psi | 2,875 gpm / 30 psi |
| C (Bypass) | 148 gpm / 30 psi | 150 gpm / 30 psi | 572 gpm / 30 psi | 600 gpm / 30 psi |
| D (NF/RO feed) | 950 gpm / 90[1] psi | 720 gpm / 174 psi [1] | 3,800 gpm / 90 psi [1] | 2,875 gpm / 174 psi [1] |
| E (NF/RO permeate) | 570 gpm / 0 psi | 544 gpm / 0 psi | 2,280 gpm / 0 psi | 2,178 gpm / 0 psi |
| F (NF/RO concentrate) | 380 gpm | 176 gpm | 1520 gpm | 697 gpm |
| G (Product) | 694 gpm / 30 psi | 694 gpm / 30 psi | 2,778 gpm / 30 psi | 2,778 gpm / 30 psi |
| H + I (ZDD Waste) | 17.7 gpm / 25 psi | | 55.6 gpm / 25 psi | |
| PROCESS RO design | 25 gpm / 90 psi[2] | | 75 gpm / 90 psi [2] | |
| EDM pumps (total) | 835 gpm / 25 psi | | 3,339 gpm / 25 psi | |
| EDM E-rinse pumps (total) | 209 gpm / 25 psi | | 209 gpm / 25 psi | |
| EDM Power Supply | 24 @ 140 $V_{DC}$ /46 A | | 93 @ 140 $V_{DC}$ / 46 A | |
| EDM NaCl use | 12,205 lb/day | | 48,350 lb/day | |

[1] The pressure listed is the pressure estimated by Dow's ROSA program; however, the pressure in the cost model accounts for the pressure in the BW feed (NF feed pressure = ROSA value – BW feed)

[2] The cost model is based on the design flow, but actual flow (and energy) is expected to be lower

# 10.2 Technology Cost Estimates – Alamogordo

## 10.2.1 Treatment Process Descriptions – Alamogordo

ZDD with 98 percent recovery was compared against a conventional BWRO with 80 percent recovery. Both designs include a bypass blend intended to improve the stability of the RO/NF permeate. The ZDD system consists of an NF membrane system, an EDM system, and all ancillary feed tanks and pumps. The BWRO system consists of a RO membrane system and all ancillary feed tanks and pumps. Snake Tank brackish water is fed to each system. Sulfuric acid is added to reduce the pH to 7 on the ZDD system and both systems include antiscalant added to the NF or RO feed (2 mg/L). The product water flow is the same for each BWRO and ZDD system, but the amount of brackish groundwater differs because of the difference in recovery.

Both ZDD systems include a single stage NF with a blend of Dow Filmtec XLE-440 (first three) and NF270-400 (last five) membranes. The 1 MGD design includes a single skid with 16 pressure vessels and the 4 MGD design includes four skids, each with 16 pressure vessels. The mixture of the XLE and NF270 membranes allows for the flux and product water quality necessary for blending with the bypassed brackish water. A portion of the NF permeate is fed to a BWRO system for process water production. This water is used for dilutions and salt preparation for the EDM. The system is sized to equal the full waste flow (2 percent of the brackish water feed). Chemical costs include the initial sodium sulfate charge for the E-Rinse as well as daily consumption for sulfuric acid, antiscalant, and caustic (post treatment) for the NF and NaCl for the EDM. The NF concentrate is fed to the EDM system and the EDM diluate (and concentrate from the Process RO) is blended with acidified brackish water and fed to the NF. The NF is designed for 60 percent recovery, which reduces the risk of scale formation. The EDM is design to reduce the concentration of the NF concentrate by 50 percent and nearly all of the NF reject is returned to the NF system (>99.5 percent recovery).

The BWRO system includes a two-stage BWRO with Dow Filmtec BW30-400/34i membranes in a 12x6 array with 6 membranes in each pressure vessel. The 1 MGD design includes a single skid and the 4 MGD design includes four skids, each with 16 pressure vessels. There is an extra skid included with the 4 MGD design to allow for maintenance on the other skids. The BW30-400/34i membranes were chosen because of their relatively high flux as well as having a larger spacer. Chemical costs include antiscalant and caustic (post treatment). The BWRO is operated at 76 percent recovery, which is technically feasible for commercially available antiscalants; however, it is close to the limit on calcium sulfate solubility (concentrate is estimated to be at 320 percent of saturation).

### 10.2.2 Capital Cost Development – Alamogordo

As mentioned previously, BWRO and ZDD designs were developed for a 1 MGD ZDD system, and were modularly scaled-up to 4 MGD. The BWRO capital cost is simply based on a design cost of $2.23/GPD obtained from the Alamogordo Environmental Impact Study (SWCA, 2012). The ZDD includes an NF and EDM system. The 1 MGD NF system capital cost (CapEx) includes a Veolia NF package system containing:

- Single-stage NF unit, including 16 - 8 M vessels, each loaded with three XLE-440 membranes followed by five NF 270-400 membranes. Also included on this skid are a horizontal centrifugal high pressure pump and two 100 percent cartridge filters.

- NF feed pump skid, including two horizontal centrifugal pumps.
- NF permeate forwarding pump, including two 100 percent permeate forwarding pumps.
- NF CIP skid with tank, pump, heater, and cartridge filter.
- 48 Dow XLE-400 and 80 Dow NF270-400 membranes
- Sulfuric acid and antiscalant dosing pumps

The 1 MGD EDM system consists of 24 EDM stacks configured into skids of six quads per skid. Each EDM stack has 120 quads, stainless steel frame, membranes, spacers, and electrodes, all manufactured by MEGA. Each EDM stack has its own power supply (DC drive manufactured by BARDAC). All of the stack skids share a common feed pump and feed tank for each of the five compartments in the stack:

- EDM feed/NF concentrate tank (3,500-gallon), and one duty plus one standby 835 gpm pump
- E-Rinse ($Na_2SO_4$) tank (600-gallon), and one duty plus one standby 209 gpm pump
- Sodium chloride storage tank (2,500-gallon), and one duty plus one standby 850 gpm pump
- Mixed sodium tank (2,500-gallon), and one duty plus one standby 850 gpm pump
- Mixed chloride tank (2,500-gallon), and one duty plus one standby 850 gpm pump

The 4 MGD ZDD system includes four 1 MGD NF skids with one backup 1 MGD skid. The EDM includes 16 EDM skids with 93 stacks total. Tanks, controls, and other ancillary systems were scaled up for the 4 MGD design.

Each of the EDM recirculating/transfer pumps delivers a pressure of 25 psi to the stack, and provides enough residual pressure to return the streams to the storage tank, creating one large recycle loop from the tank, through the stack, and back to the tank. Automatic valves on each skid ensure even distribution among the stacks, based upon pressure readings for each stream. ED stacks are operated with equal pressure on each side of the membranes to mitigate internal leakage and prevent membrane damage. As with the pilot and demonstration systems, the

NaCl, Mixed Na, Mixed Cl, and E-Rinse pressures will be set to match the EDM feed pressure.

There are make-up tanks for sodium chloride and sodium sulfate solutions, which will deliver to site as dry products. The NaCl brine make-up system for the 1 MGD Alamogordo design is a Bryneer system of 42-ton capacity (84,000 lbs); the 4 MGD system will include four 42-ton capacity Bryneer systems.

There is also a degasifier fan and tower to remove hydrogen and oxygen gas produced at the EDM electrodes.

A secondary RO system provides process water to dilute the Mixed Na and Mixed Cl streams. The system is designed to equal the waste flow from the EDM (2 percent of the brackish water feed).

Instrumentation and controls include rotameters, flow switches, and pressure switches for every EDM stream on every stack, ancillary instruments for tanks and pumps, master control panel/SCADA, and skid remote input/output (I/O) panels.

Flush pumps, tank heaters, and CIP pumps are provided for both the EDM and NF systems.

Equipment to transfer water from the brackish wells to the NF feed pump are not included in the Veolia pricing estimate, since these costs vary widely on every site; however power required for this transfer is included in the operation and maintenance cost development (OpEx) evaluation. Additionally, the air compressor required for automatic valve actuation is not included.

### 10.2.3. Operation and Maintenance Cost Development – Alamogordo

Operating cost assumptions used for the ZDD and/or BWRO systems include the following:

- Power cost: $0.08/kWh flat rate
- EDM sodium chloride: $0.075 per pound (lb)
- Annual CIP for NF lasting one hour, includes operation of NF flush pump, CIP pump, CIP heater (same for BWRO and ZDD)
- Monthly CIP for EDM systems, lasting one hour per skid, includes operation of NF flush pump, CIP pump, CIP heater
- Antiscalant: 2 mg/L dosage: $2.95/lb (same for BWRO and ZDD)
- Sulfuric acid for reducing bicarbonate in feed: pH≤7.0, $0.20/lb

- Sodium sulfate for the E-Rinse: $0.08/lb
- Caustic post treatment: 5 mg/L dosage, $0.45/lb (same for BWRO and ZDD)
- NF and EDM CIP chemicals: <$0.01/1,000 gallons product (same for BWRO and ZDD)
- Source water cartridge filters replaced monthly for annual cost: $38,720 for the 1 MGD system and $69,750 for the 4 MGD (same for BWRO and ZDD)
- NF and RO membranes replaced every five years: $600/element
- EDM membranes and spacers will be replaced every 10 years: $354/quad
- EDM electrode replacement schedule includes replacing the anodes every two years and cathodes every five years.

The ZDD O&M costs are dominated by the EDM power cost (77 percent of annual power expenditure) and sodium chloride (91 percent of annual chemical cost; 42 percent of annual OpEx). The EDM design is conservative, and additional optimization is possible to improve the energy efficiency by increasing the current density (or decreasing stack resistance) or reducing the recirculating rate for the EDM pumps. Although not tested at pilot scale, cost savings may be realized if sodium chloride is recovered by any of the methods suggested in this report; this will be tested in future demonstration studies. While not included in the cost estimate, there is an expected avoided cost by way of power savings with ZDD since the brackish water pumps will pump less water to achieve the same amount of product water. This savings is estimated to be $31,000/year for the 1 MGD design and $124,000/year for the 4 MGD design. This only includes the power required to lift water from 1,000 feet. Additional savings may be realized if additional pressure is required by the well pumps or if booster pumps are required for transporting on the 32 mile pipeline from the Snake Tank Wells.

The major flows, pressures, EDM power supply, and NaCl consumption are summarized for the two design flow rates in Table 24. Process flow diagrams are included as Figure 70 and Figure 71. Key labels are included and are incorporated into the operational cost summary in **Error! Reference source not found.**Table 24. The recovery is calculated by dividing the product water by brackish feed water (G/A in Table 24).

## 10.2.4 ZDD & BWRO Residuals Cost Development – Alamogordo

All of the BWRO concentrate and only the EDM waste streams will require final disposal, likely using evaporation ponds or deep well injection. The residual streams from the ZDD consist of a total of 2 percent of the brackish feed, in the

form of two high-concentration streams called the Mixed Cl stream and Mixed Na streams. For the 1 MGD system, the combined ZDD waste flow is 17.7 gpm and the 4 MGD is 55.6 gpm (see H+I in Table 24**Error! Reference source not found.**). The BWRO concentrate is
176 gpm for the 1 MGD system and 697 gpm for the 4 MGD system (seeFaraday's constant (F) in Table 24). ZDD achieves a 92 percent reduction in waste volume compared to BWRO.

Four evaporation pond estimation methods were evaluated and averaged for the final disposal of BWRO and ZDD waste flows. Costs are in normalized to 2013 dollars and were updated using the Producer Price Index for capital equipment (Bureau of Labor Statistics, n.d.). The capital costs for the evaporation pond used for this model is the average of the values estimated using the Voutchkov method and the scaled versions from El Paso (design cost) and BGNDRF (actual cost). The method described by Mickley (Mickley and Associates, 2006) allows for multiple dike heights, so a four foot and 12 foot height model are included. The net evaporation rate for Alamogordo used in the model is 14.8 cm per month, based upon evaporation rates from nearby Holloman Air Force Base (Livingston Associates, P.C., 2003). The estimated cost for evaporation ponds for each system is summarized in Table 25.

Table 25.—Comparison of Evaporation Pond CapEx Estimation Costs ($ Million)

| | **1 MGD** | | **4 MGD** | |
|---|---|---|---|---|
| **System** | **BWRO** | **ZDD** | **BWRO** | **ZDD** |
| **Pond size (acres)[1]** | **69** | **8** | **252** | **25** |
| **Method:** | | | | |
| Voutchkov (ref) | $5.59 | $0.39 | $13.1 | $1.21 |
| Mickley (Mickley & Associates, 2006)<br>8-ft dike<br>12-ft dike | <br><br>$3.79<br>$4.45 | <br><br>$0.38<br>$0.54 | <br><br>$14.2<br>$15.9 | <br><br>$1.31<br>$1.65 |
| BGNDRF | $7.36 | $0.59 | $29.1 | $3.73 |
| EPWU (Gorder, 2009) | $5.14 | $0.41 | $20.3 | $1.29 |
| Average | $5.27 | $0.46 | $19.2 | $1.83 |

[1] Acreage includes adjustment for 8-ft dike height.

DWI can be an affordable concentrate disposal method in areas with the geology to support it and regulations to allow it. The CapEx is dependent on the style of construction (affected by regulations and geology), and the OpEx is affected by the geology (tight formations may require pressurization of the concentrate). It is estimated that a single disposal well is required for the 1 MGD and 4 MGD BWRO and ZDD designs based upon Mickley and Associates (2006), which states, as a generality, one well of 6 inch nominal internal pipe diameter can receive 1.27 MGD of flow at the recommended velocity of 10 feet per second (ft/sec) (Mickley and Associates, 2006). A well size of 4 inches was assumed for flows equal to or less than 0.25 MGD for the calculation using Mickley and Associates (2006), Voutchkov (2013, and M46 (AWWA, 2007) methods scale with concentrate flow. The well is assumed to be 2,500 feet deep and constructed similar to the wells in El Paso. Minimal pressure (50 psi) is estimated for the CapEx. Estimates for disposal using DWI were made using a similar approach as with the evaporation ponds and are summarized in Table 26. Four methods for DWI well costs were used and the results averaged. Costs are in 2013 dollars and were updated using the Producer Price Index for capital equipment (Bureau of Labor Statistics, n.d.).

Table 26.—Comparison of DWI CapEx Estimation Costs ($ Million)

| | **1 MGD** | | **4 MGD** | |
|---|---|---|---|---|
| **System** | **BWRO** | **ZDD** | **BWRO** | **ZDD** |
| EIS (SWCA, 2012) | $2.85 | $2.85 | $2.85 | $4.17 |
| Voutchkov (Voutchkov, 2013) | $1.46 | $1.13 | $2.50 | $1.17 |
| AWWA M46 (American Water Works Association, 2007) | $2.63 | $2.40 | $3.29 | $2.46 |
| Mickley (Mickley & Associates, 2006) | $3.79 | $3.79 | $4.22 | $3.79 |
| EPWU (Gorder, 2009) | $4.17 | $4.17 | $4.17 | $4.17 |
| Average | $2.98 | $2.87 | $3.41 | $2.89 |

## 10.3 Technology Cost Estimates – La Junta

### 10.3.1 Treatment Process Descriptions – La Junta

ZDD was piloted at La Junta as part of WERF Project 5T10. Operational data from this pilot were combined with lessons learned at other pilot studies, to create a full-scale design for a 6.6 MGD greenfield ZDD solution for La Junta. The ZDD system would consist of a NF membrane system, an EDM system, and all ancillary feed tanks and pumps.

Process flow diagrams are similar to those described earlier (Figure 70 and Figure 71. Key labels are included and are incorporated into the operational cost summary in Table 24). A portion (13 percent) of the brackish feed is bypassed for blending and sulfuric acid is added to the remainder. The NF feed is dosed with antiscalant (2 mg/L). The NF concentrate is fed to the EDM system, and the EDM diluate (and concentrate from the Process RO) is blended with acidified brackish well water and fed to the NF. The NF is designed for 80 percent overall recovery. The EDM is designed to reduce the concentration of the NF concentrate by 40 percent, and nearly all of the NF reject is returned to the NF system (98 percent overall recovery). The EDM produces two waste streams: a Mixed Sodium Salt and Mixed Chloride Salt stream.

The ZDD system includes a two-stage NF where Stage 1 consists of 30 pressure vessels with six Dow NF 90-400 modules and Stage 2 consists of 15 pressure vessels with a blend of Dow NF 90-400 (first three) and NF270-400 (last three) membranes. Four skids are provided, each capable of producing 2.2 MGD. An extra skid is included to allow for maintenance on the other skids. The mixture of the NF90 and NF270 membranes allows for the necessary flux and product water quality for blending with the bypassed brackish water. The NF270 modules were selected for their ability to pass silica into the product water, thereby bypassing the EDM loop and acting as a silica purge. A portion of the NF permeate is fed to a small BWRO system for process water production, used for dilutions and salt preparation for the EDM. Chemical costs include the initial sodium sulfate charge for the E-Rinse and NaCl for the EDM, as well as daily consumption for sulfuric acid, antiscalant, and caustic (post treatment) for the NF.

## 10.3.2 Capital Cost (CapEx) Development – La Junta

ZDD designs were developed for a 6.6 MGD system. The ZDD includes an NF and EDM system. The NF system CapExt includes four Veolia NF package systems containing:

- Two-stage NF unit including 45 – 6M vessels. Stage 1 consists of 30 vessels loaded with Dow NF90-400 modules. Stage 2 consists of 15 vessels, each loaded with three Dow NF90-400 modules in the lead position followed by three NF 270-400 membranes.
- Cartridge filter skids, three including one standby.
- NF feed pumps, four horizontal centrifugal pumps, including one standby.
- Two product water pumps.
- NF CIP skid with tank, pump, heater, cartridge filter.
- 225 Dow NF90-400 and 45 Dow NF270-400 membranes.
- Sulfuric acid and antiscalant dosing pumps.

The EDM system consists of ninety (90) EDM stacks configured into skids of six stacks per skid. Each EDM stack has 120 quads, stainless steel frame, membranes, spacers, and electrodes, all manufactured by MEGA. Each EDM stack has its own power supply (DC drive manufactured by BARDAC). All of the stack skids share a common feed pump and feed tank for each of the five process streams to the stack:

- EDM feed/NF concentrate tank (4,000-gallon) and one duty plus one standby 900 gpm pump

- E-Rinse ($Na_2SO_4$) tank (600-gallon) and one duty plus one standby 225 gpm pump
- Sodium chloride storage tank (2,500-gallon) and one duty plus one standby 900 gpm pump
- Mixed Sodium tank (2,500-gallon) and one duty plus one standby 900 gpm pump
- Mixed Chloride tank (2,500-gallon) and one duty plus one standby 900 gpm pump

Each of the EDM recirculating/transfer pumps deliver a pressure of 25 psi to the stack, and provide enough residual pressure to return the streams to the storage tank, creating one large recycle loop from the tank, through the stack, and back to the tank. Automatic valves on each skid ensure even distribution among the stacks, based upon pressure readings for each stream. ED stacks are operated with equal pressure on each side of the membranes to mitigate internal leakage and prevent membrane damage. As with the pilot and demonstration systems, the NaCl, Mixed Na, Mixed Cl, and E-Rinse pressures will be set to match the EDM feed pressure.

There are make-up tanks for sodium chloride and sodium sulfate solutions; these products will deliver to site as dry products. The NaCl brine make-up system design is for three 80 ton Bryneer system.

There is also a degasifier blower and tower to remove hydrogen and oxygen gas produced at the EDM electrodes.

A secondary RO system provides 75 gpm of process water to dilute the Mixed Na and Mixed Cl streams. The system is designed to match the waste flow from the EDM (2 percent of the brackish water feed).

Instrumentation and controls include: rotameters, flow switches, and pressure switches for every EDM stream on every stack; ancillary instruments for tanks and pumps; master control panel/SCADA; and EDM skid remote I/O panels.

Flush pumps, tank heaters, and CIP pumps are provided for both the EDM and NF.

Equipment to transfer water from the brackish wells to the NF feed pump are not included in the Veolia pricing estimate, since these costs vary widely on every site. Further, the air compressor required for automatic valve actuation is not included.

### 10.3.3 Operation and Maintenance Cost Development

Operating cost assumptions used for the ZDD and/or BWRO systems includes the following (same as for Alamogordo):

- Power cost: \$0.08/kWh flat rate
- EDM sodium chloride: \$0.075/lb
- Annual CIP for NF lasting one hour, includes operation of NF flush pump, CIP pump, CIP heater (same for BWRO and ZDD)
- Monthly CIP for EDM systems, lasting one hour per skid, includes operation of EDM flush pump, CIP pump, and CIP heater
- Antiscalant: 2 mg/L dosage: \$2.95/lb
- Sulfuric acid for reducing bicarbonate in feed: pH≤7.0, \$0.20/lb
- Sodium sulfate for the E-Rinse: \$0.08/lb
- Caustic post treatment: 5 mg/L dosage: \$0.45/lb
- NF & EDM CIP chemicals: <\$0.01/1000 gallons product
- Source water cartridge filters replaced every month for annual cost: \$115,000
- NF and RO membranes replaced every five years: \$600/element
- EDM membranes and spacers will be replaced every 10 years: \$354/quad
- EDM electrode replacement schedule includes replacing the anodes every two years and cathodes every five years

The ZDD O&M costs are more evenly distributed than the Alamogordo design because more of the work is being done by the NF system, which is designed for 80 percent recovery. The higher recovery (80 percent vs 60 percent) leads to a higher relative specific energy for the NF and lower relative specific energy by the EDM. Another important difference is the EDM power supplies are operating at a lower voltage and current than the Alamogordo design. The current density is assumed to be 10 percent higher than what was piloted and differs from what was provided to the WERF authors for inclusion in their report. As stated in that report, the EDM stack was not operated at 80 amps (Brandhuber et. al, 2014) and it is possible that this is infeasible for many reasons. This revised lower current density means that more EDM stacks are included in this design than what was provided to the WERF authors for inclusion in their report. The EDM power cost is 31 percent of annual power expenditure, NF feed pumps power cost is 32 percent of annual power expenditure, and the NaCl cost is 46 percent of annual chemical expenditure. The EDM design is conservative, so it is possible that additional optimization could improve the energy efficiency by increasing the current density (or decreasing stack resistance) or reducing the recirculating rate for the EDM pumps. Cost savings may be realized if sodium chloride is recovered by any of the methods suggested in this report. NaCl recovery using lime treatment of the Mixed Cl and ED fitted with monovalent selective membranes was tested at La Junta.

The major flows, pressures, EDM power supply, and NaCl consumption are summarized for the design flow rates in Table 27. The letters refer to the locations in Figure 70 and Figure 71.The recovery is calculated by dividing the product water by brackish feed water (G/A in Table 27).

Table 27.—Major Operational Cost Comparison by Product Flow Rate and System (La Junta, 6.6 MGD)

| **Location** | **ZDD** | **BWRO** | **Dual RO**[2] |
|---|---|---|---|
| **System Recovery** | **98%** | **80%** | **92%** |
| A (BW feed) | 4,670 gpm / 30 psi | 5486 gpm | 4,987 gpm |
| B (BW feed to ZDD/BWRO) | 4,067 gpm / 30 psi | 4,514 gpm / 225 psi | 4,583 gpm |
| C (Bypass) | 603 gpm / 30 psi | 972 gpm | 404 gpm |
| D (NF/RO feed) | 5,097 gpm / 112 psi [1] | 4,514 gpm / 225 psi | 1st RO: 4,583 gpm<br>2nd RO: 916 gpm |
| E (NF/RO permeate) | 4,077 gpm / 0 psi | 3611 gpm | 1st RO: 3,667 gpm<br>2nd RO: 513 gpm |
| F (NF/RO concentrate) | 1,019 gpm | 903 gpm | 403 gpm |
| G (product) | 4,583 gpm / 30 psi | 4,583 / 30 psi | 4583 gpm |
| H + I (ZDD waste) | 72.8 gpm / 25 psi | | |
| PROCESS RO design (feed) | 97 gpm / 90 psi [2] | | |
| EDM pumps (total) | 3,600 gpm / 25 psi | | |
| EDM E-rinse pumps (total) | 900 gpm / 25 psi | | |
| EDM Power Supply | 90 @ 110 $V_{DC}$ / 37 amps | | |
| EDM NaCl use | 42,327 lb/day | | |

[1] The pressure listed is the pressure estimated by Dow's ROSA program; however, the pressure in the cost model accounts for the pressure in the brackish water feed (NF feed pressure = ROSA value – BW feed).

[2] WERF report figures were scaled from 5.2 MGD permeate flow to 6.6 MGD permeate flow.

## 10.3.4 ZDD and BWRO Residuals Cost Development – La Junta

The EDM and BWRO waste streams will require final disposal via evaporation ponds. The residual streams from the ZDD consist of 2 percent of the brackish feed, in the form of two high-concentration streams called the Mixed Cl stream and Mixed Na stream. The residual stream from the BWRO consists of 20 percent of the brackish feed.

Four evaporation pond cost estimation methods were evaluated for the brine disposal. Costs are in 2013 dollars and were updated using the Producer Price Index for capital equipment (Bureau of Labor Statistics, n.d.). The capital costs for the evaporation pond used for this model is the average of the values estimated using the Voutchkov method, Mickley method with a 4-foot dike height for comparison with the WERF 5T10 evaluation, and the scaled versions from El Paso (design cost) and BGNDRF (actual cost). The net evaporation rate for La Junta used in the model is 32.4 inches per year (6.9 centimeter per month), based upon the WERF 5T10 report (Brandhuber et al., 2014). The estimated cost for evaporation ponds for each system is summarized in Table 28.

Table 28.—Comparison of Evaporation Pond CapEx Estimation Methods (La Junta, 6.6 MGD full capacity)

| System | ZDD | BWRO | Dual RO, 91.2% Recovery [3] |
|---|---|---|---|
| **Required Evaporative Area (acres)** | **56** | **682** | **240** |
| **Capital Cost Using** | | | |
| Voutchkov (ref) | $4.9 M | $41.0 M | -- |
| Mickley (ref)[2] | $5.9 M | $68.1 M | $15.8M[4] |
| BGNDRF[2] | $9.2 M | $103 M | -- |
| EPWU (ref) | $2.1 M | $33.3 M | -- |
| Average | $5.5 M | $61.3 M | -- |

[1] Both the BWRO and ZDD evaporation ponds assume an 8-foot dike height.
[2] Excluded from average for BWRO.
[3] From WERF 5T10 Report, assumes a 4-foot dike height.

## 10.3.5 Comparison of BWRO and ZDD Cost Estimates – La Junta

The capital cost estimate for the BWRO and ZDD systems is summarized in Figure 72. At this flow rate and with evaporation ponds as the only available brine disposal method, ZDD is less expensive than conventional BWRO. The Dual BWRO costs for a 6.6 MGD system were estimated by scaling the costs included in the WERF report from 5.2 to 6.6 MGD. Also, the WERF report used the average flow for designing the evaporation ponds (Brandhuber et. al., 2014). While this is a reasonable assumption, our report uses the design flow for all systems, so the WERF 5T10 reported installation cost ($6,400,000 for 96.3 gpm of concentrate) was used to scale up the full Dual RO concentrate flow (403 gpm).

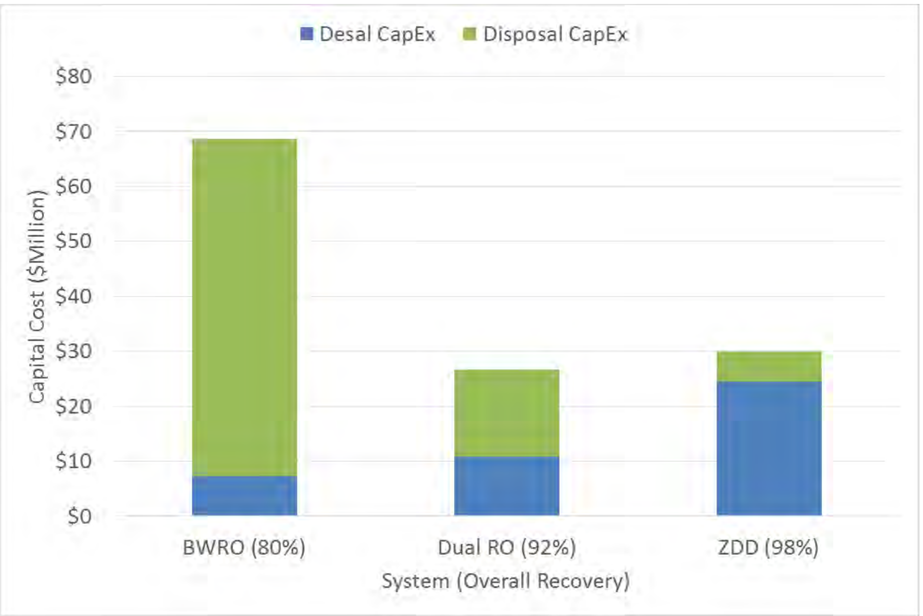


**Figure 72.—Capital cost estimates for ZDD, BWRO, and Dual RO (6.6 MGD).**

The total cost of water produced by the BWRO, ZDD, and Dual RO is summarized in Figure 73. The estimated annual capital cost for the ZDD system, which includes ZDD equipment and Evaporation Pond installation, accounts for 38 percent of the total cost of water production for ZDD and 73 percent of the total cost of water by BWRO. The capital cost of ZDD is very competitive with the Dual RO system, as the unit cost is within 33 percent of the Dual RO design and the main difference is membrane replacement cost. It is possible that both the RO and EDM membranes could last longer than the budgeted five year timeframe. It is important to note that the Dual RO would still require 278 acres of evaporation ponds, and ZDD would only require 94 acres. As mentioned earlier, the ZDD primary OpEx cost drivers are the NaCl and EDM power consumption. Future optimization and research will aim to reduce the cost of both of these.

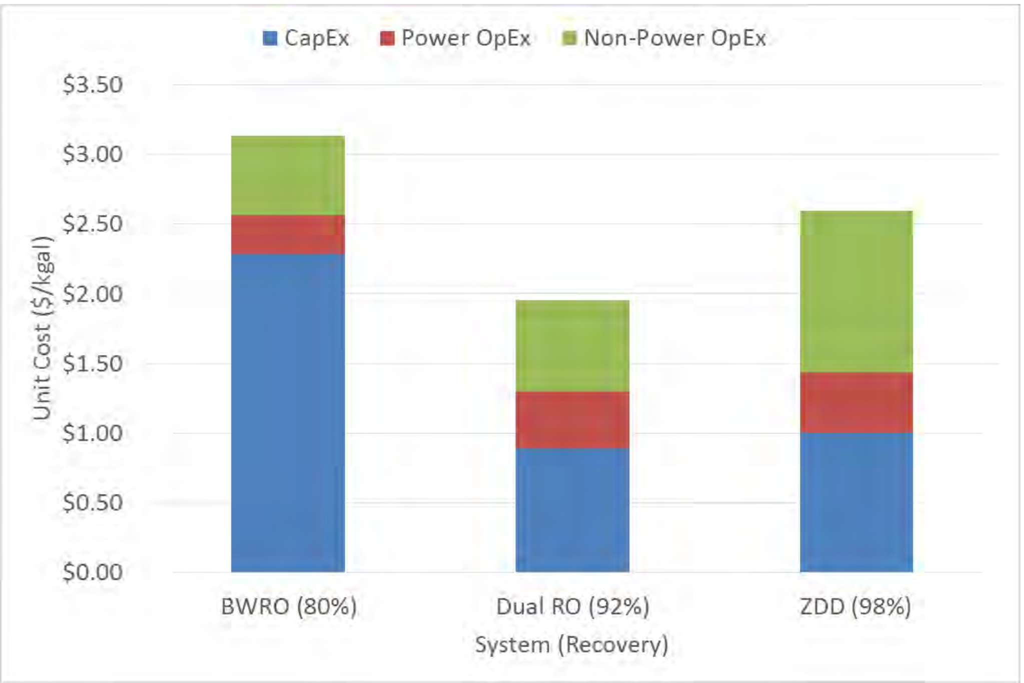


Figure 73.—Unit cost estimates for ZDD, BWRO, and Dual RO (6.6 MGD).

# 11. Salt Recovery

## 11.1 NaCl Purity Requirements

Experiments were performed to determine the level of purity required for the NaCl feed to the EDM stack. The results, described elsewhere in this report, indicated that the ion ratios of Na/Ca and Cl/$SO_4$ need to be at least 12 to prevent precipitation of $CaSO_4$ in the Mixed Cl and Mixed Na solution compartments of the EDM. Higher ratios will definitely reduce the chances of formation of $CaSO_4$ precipitation in the concentrate streams. The supernatant from the precipitation of $CaSO_4$, which typically has 1.5 M NaCl and Na/Ca and Cl/$SO_4$ ion ratios of 15, might be marginally acceptable for use as the NaCl supply, but it does not meet the criterion of a 3 M solution. If a 1.5 M NaCl solution were fed into the EDM stack, the rate of NaCl transport through the membranes would be about twice the rate of water transport, so the salt concentration in the NaCl solution compartments would be depleted. However, this shortcoming does not preclude the use of supernatant in the salt supply; it just means that the NaCl concentration of the solution would have to be boosted by the addition of NaCl crystals. If crystals of NaCl were added to the supernatant to boost its concentration to 3 M, the value of the Na/Ca and Cl/$SO_4$ ratios would double to about 30. Essentially half of the NaCl required for the EDM would be supplied by the supernatant, and half would be supplied by purchased salt.

The importance of salt purity is illustrated in Figure 74 where the cations in the salt stream include $Na^+$ and $Ca^{2+}$, and the anions include $Cl^-$ and $SO_4^{2-}$. If it is assumed that the membranes on either side of the NaCl compartment have equal permeability for monovalent and divalent ions, the undesirable $Ca^{2+}$ ions will migrate into the Mixed Na stream along with the desirable $Na^+$ ions. $Ca^{2+}$ ions that enter the Mixed Na compartment will encounter a high concentration of $SO_4^{2-}$ ions. If the rate of entry of $Ca^{2+}$ ions is sufficient to exceed the solubility of $CaSO_4$, the condition will exist for precipitation of $CaSO_4$ in the Mixed Na solution compartments. Assuming that the NaCl stream is the only source of $Ca^{2+}$ ions entering the Mixed Na compartment, one could determine experimentally what ratio of $Na^+$ to $Ca^{2+}$ ions would be sufficient to avoid a condition of supersaturation of $CaSO_4$ in the Mixed Na compartments. Indeed, after consideration of the utility of this ratio, it was decided to adopt the Na/Ca ratio as a criterion for assessing the quality of the NaCl supply. Similarly, $Cl^-$ ions and $SO_4^{2-}$ ions are transported through the AEM into the Mixed Cl compartment, and excessive transport of $SO_4^{2-}$ ions leads to precipitation of $CaSO_4$ in that compartment. Therefore, the Cl/$SO_4$ ratio is also a useful criterion for measuring salt quality. Both ratios are based on measured or calculated concentrations of the ions in equivalents per unit volume.

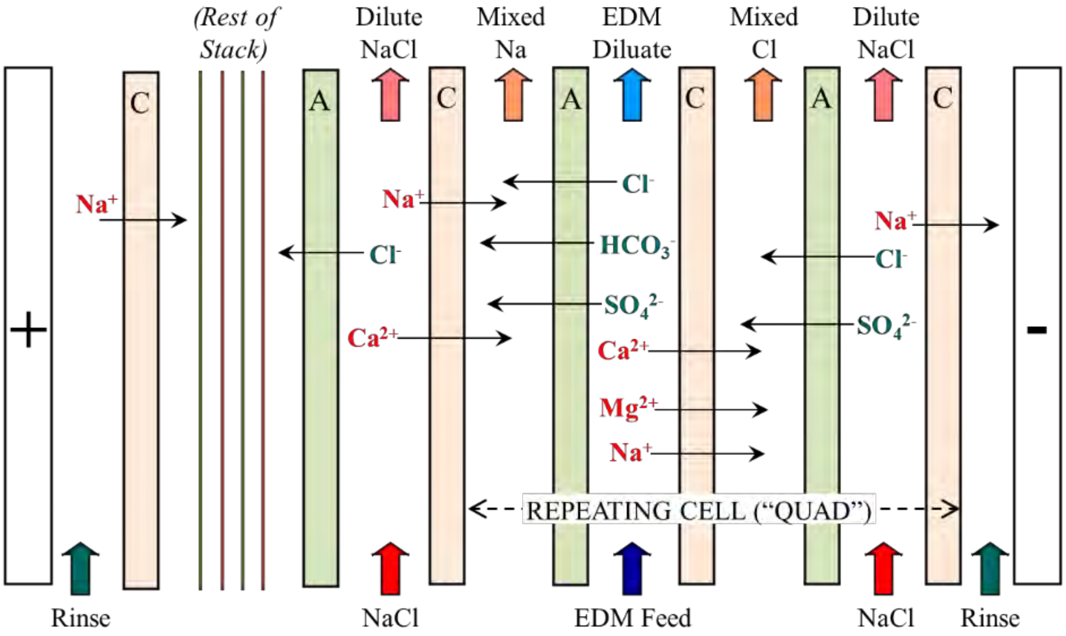


**Figure 74.—Transport of ions through ion-exchange membranes in EDM stack.**

It is extremely useful to have an understanding of how the solubility of $CaSO_4$ is affected by the presence of NaCl in solution. Figure 75 shows solubility data reported by Ostroff and Metler (1966). The data show that the presence of NaCl causes a substantial increase in the solubility of $CaSO_4$. The solubility of $CaSO_4$ is 2 g/kg of $H_2O$ in pure water, and it increases to a maximum of 7.7 g/kg of $H_2O$ in 2.7 molar NaCl. Dashed lines in Figure 75 indicate the concentration of NaCl in the supernatant of the precipitation tank and the concentration of NaCl that is needed for the salt supply to the EDM stack. The 1.5 M supernatant concentration is based on typical experimental data obtained when Mixed Cl and Mixed Na streams were combined in stoichiometric proportions to precipitate $CaSO_4$. The 3 M requirement is based on data obtained for the amount of water transported through the membranes along with the $Na^+$ and $Cl^-$ ions.

As mentioned earlier, the Snake Tank wells that have been selected for the supply of groundwater to the planned desalination plant in Alamogordo have an excess of sulfate compared to calcium (see Table 3). Since the NF membranes reject divalent anions and cations almost equally well, this same excess of sulfate occurs in the NF reject stream and in the concentrate streams produced by the EDM. This means that some of the Mixed Na stream would need to be diverted to achieve stoichiometric proportions with the Mixed Cl stream in the precipitation of $CaSO_4$.

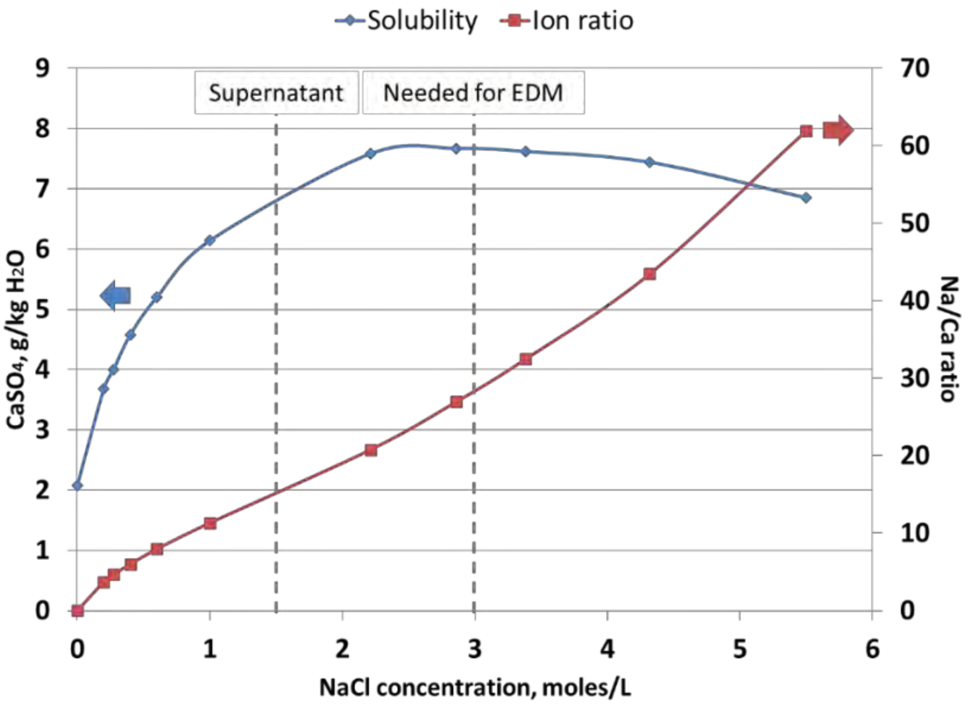


**Figure 75.—$CaSO_4$ solubility in NaCl solution at 28˚C and calculated ion ratios in saturated $CaSO_4$ solution.**

However, the total equivalents of calcium and magnesium in the groundwater almost match the sulfate level. Therefore, if the $Mg^{2+}$ ions were to be replaced with $Ca^{2+}$ ions, then essentially all of the two concentrate streams from the EDM could be combined to make stoichiometric proportions for precipitation of $CaSO_4$.

$$Mg^{2+} + Ca(OH)_2 \rightarrow Mg(OH)_2 + Ca^{2+}$$

This chemical reaction is aided by the fact that $Ca(OH)_2$ is slightly soluble (1.73 g/L) whereas $Mg(OH)_2$ has very low solubility (0.009 g/L). It is also aided by the fact that the Mixed Cl stream has negligible amounts of sulfate and carbonate, which would react with the calcium ions released from the lime.

Another motivation for removing the magnesium is that the presence of magnesium increases the solubility of $CaSO_4$. The graphs in Figure 76 show that both NaCl and $MgCl_2$ cause the solubility of $CaSO_4$ to increase, and the effects are additive.

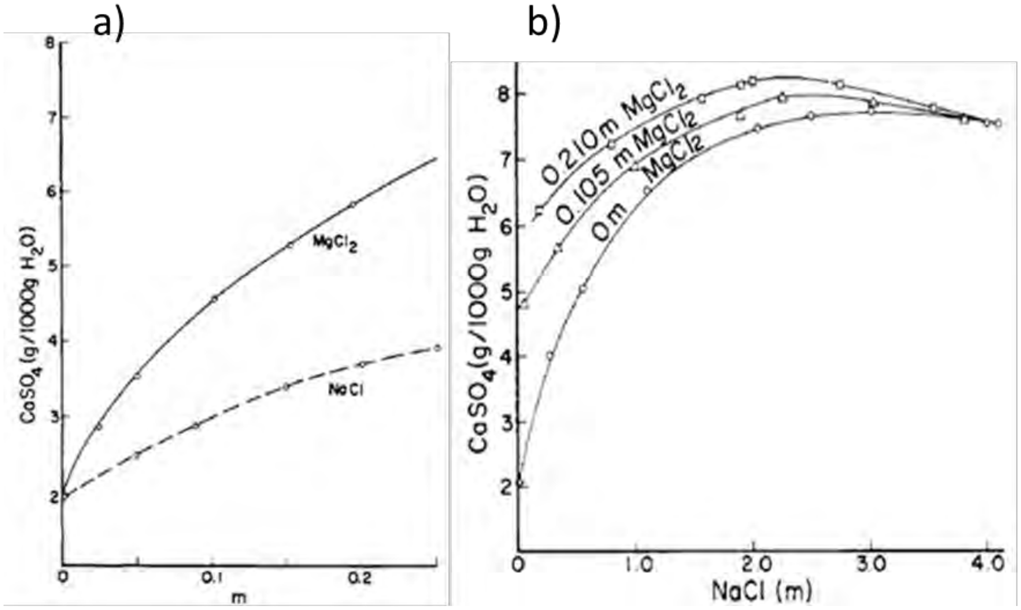


**Figure 76.— a) Gypsum solubility in NaCl and MgCl$_2$ solutions and (b) Gypsum solubility in NaCl solutions with increasing concentrations of MgCl$_2$ (Ostroff & Metler, 1966)**

## 11.2 Feasibility of Supernatant Use in EDM for NaCl Supply

To demonstrate that the use of supernatant is technically feasible, a lab-scale EDM stack containing the same MEGA membranes that were in the demonstration stacks was operated in the pilot area of BGNDRF for one week during Phase 2. The Mixed Cl and Mixed Na streams from the 40 gpm demonstration system were collected, magnesium ions were removed from the Mixed Cl stream by adding Ca(OH)$_2$ to precipitate Mg(OH)$_2$, and approximate stoichiometric proportions of the two concentrate streams were combined to precipitate CaSO$_4$ (previous sample analyses and ratios with conductivity were used to approximate the calcium and sulfate in the streams). Three batches of supernatant were prepared using this method, and samples were analyzed. Two sets of samples of the mixture of supernatant and NaCl pellets (same brand used in the demonstration system) were also analyzed. The average of each of these batches, along with the recirculating NaCl streams in the bench scale and demonstration scale systems are summarized in Table 29. The average supernatant from that precipitation was determined to have a NaCl concentration of 1.65 M. The NaCl concentration was boosted to 3 M by addition of the same NaCl crystals that were used in the 40 gpm demonstration plant.

Table 29.—Summary of Prepared NaCl Solutions and Circulating NaCl Streams (all in meq/L)

| | Ca | Mg | Na | Cl | $SO_4$ | $HCO_3$ | Na/Ca | $Cl/SO_4$ |
|---|---|---|---|---|---|---|---|---|
| Supernatant (average of 3) | 121 | 7.4 | 1,565 | 1,602 | 136 | 8.7 | 14.7 | 12.6 |
| Supernatant + NaCl (average of 2) | 121 | 14.6 | 4,880 | 4,696 | 205 | 8.0 | 40.8 | 26.8 |
| NaCl to EDM (bench - beginning) | 3.4 | 1.0 | 238 | 230 | 15.0 | 2.3 | 70.8 | 15.4 |
| NaCl to EDM (bench - end) | 7.3 | 3.6 | 474 | 468 | 24.4 | 3.2 | 65.2 | 19.2 |
| NaCl to EDM (demo - low $Cl/SO_4$) | 2.6 | 2.0 | 540 | 534 | 15.7 | 1.8 | 209.3 | 34.1 |
| NaCl to EDM (demo - high $Cl/SO_4$) | 8.6 | 6.7 | 597 | 494 | 74.6 | 3.6 | 69.7 | 6.6 |

The system was intended to be operated at a current density similar to the demonstration scale EDM stacks, but the density ended up being lower than expected because of a miscommunication about the available surface area in the full scale EDM stacks. Even though the current density was lower at the bench scale (bench scale: 65-70 A/m$^2$, demonstration stacks: 110 A/m$^2$), the EDM performance was similar in terms of concentrations. Since the bench-scale system is not automatically controlled, it was not operated overnight or for extended periods of time. At the end of each day's operation, a portion of the Mixed Na and Mixed Cl streams were captured before the concentrate compartments were rinsed with DI water. The captured Mixed Na and Mixed Cl would be used to start up the experiment on the following day. The NaCl concentration would go down over time and the infusion pump would be turned on when the conductivity was below 50 mS/cm. The EDM stream pressures were controlled manually by opening or closing a valve downstream of each of the pumps. The valves on the Mixed Na, Mixed Cl, NaCl, and E-Rinse streams were adjusted to match the pressure in the EDM feed (similar to how the demonstration equipment is controlled automatically). Pressure drop across the EDM stack increased slightly over time; however, this is related to iron particulates in the EDM feed stream. A 1 micron cartridge filter was installed on the EDM feed and as it clogged, the EDM feed pressure (and therefore the other stream pressures) increased. Figure 77 includes conductivity, pressure, voltage, and current data obtained during the six day study.

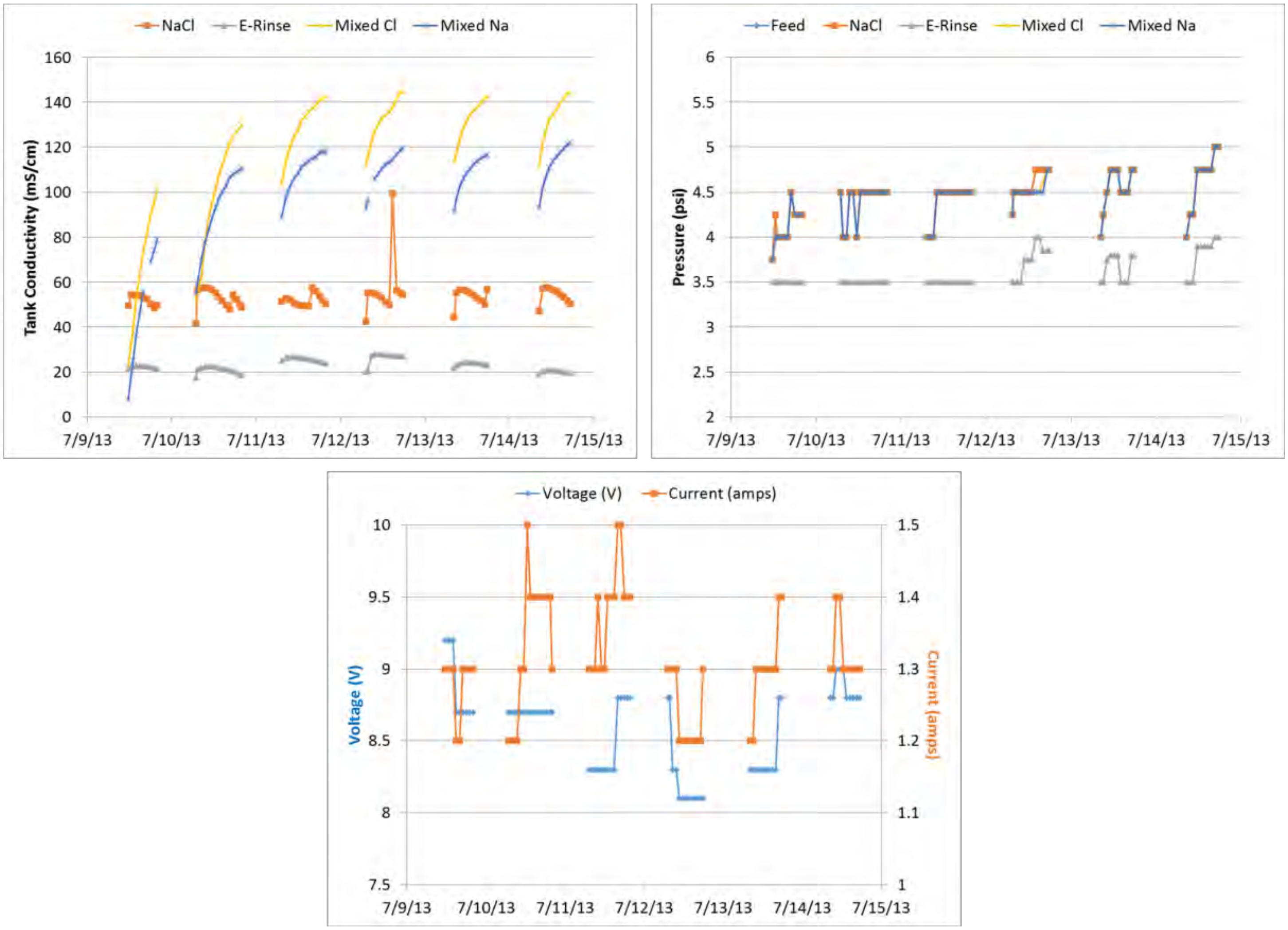


**Figure 77.—Operations data from Supernatant Study at BGNDRF.**

There was no evidence of precipitation in the concentrate streams or of membrane swelling during the six days of operation. The results of this experiment offered conclusive evidence that the supernatant can be used to dissolve NaCl crystals for the salt supply to the EDM stack, and the benefit is that the consumption of purchased salt is reduced. Moreover, the use of the supernatant for this purpose consumes about half of the volume of supernatant produced and pushes the overall yield of fresh water from 98 percent to 99 percent.

# 11.3 Feasibility of Using Evaporation Pond to Recover NaCl

Full-scale implementation to use supernatant in the NaCl supply would require a process for the precipitation of $CaSO_4$. That process was performed in the laboratory and in the ZDD pilot in La Junta by combining the two concentrate streams (after treating the Mixed Cl stream with $Ca(OH)_2$) in a conical-bottom plastic tank equipped with an agitator. The Mixed Cl and Mixed Na streams were introduced to a zone that contained the previously formed $CaSO_4$ precipitate, which provided seed crystals for the precipitation of $Ca^{2+}$ and $SO_4^{2-}$ ions being introduced with the concentrate solutions. The agitation was confined to the bottom of the tank so that supernatant could disengage from the crystals. Because the crystals were allowed to grow, they became large enough to remain in the lower zone of the tank. Supernatant was decanted from the top of the tank. This operation is illustrated in Figure 78. For a commercial-scale ZDD process it is envisioned that a conventional clarifier similar to what is used for lime softening would be employed. Figure 79 shows the anticipated configuration of an appropriate clarifier.

The $CaSO_4$ crystals from the clarifier would be removed continuously and sent to a belt filter or centrifuge where the liquid would be drained from the crystals. The centrate or drained supernatant would be returned to the mixing zone of the clarifier, and that liquid would ultimately appear in the overflow of the clarifier. It would likely be necessary for the crystals to be washed with groundwater to remove excess NaCl if the $CaSO_4$ crystals are to be sold. Washing would not be necessary if the $CaSO_4$ is to be placed in a landfill. The rinse water, which might represent 1 percent of the groundwater pumped from the wells, could be combined with the NaCl feed to the EDM, as illustrated in Figure 80.

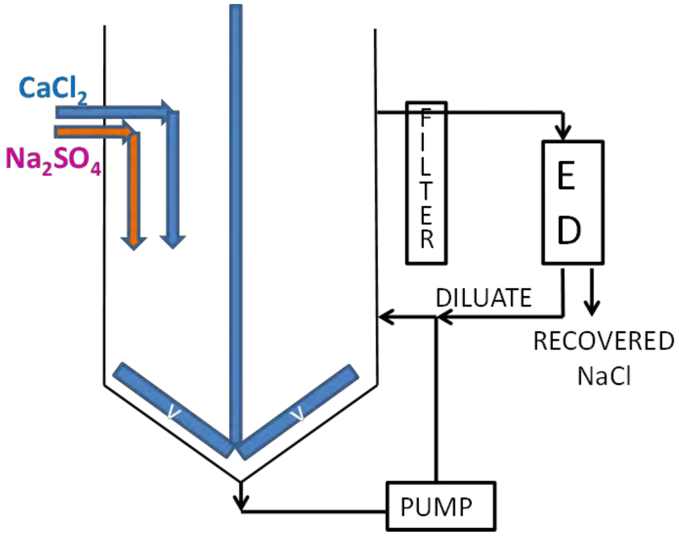


Figure 78.—Setup for lab ED of supernatant.

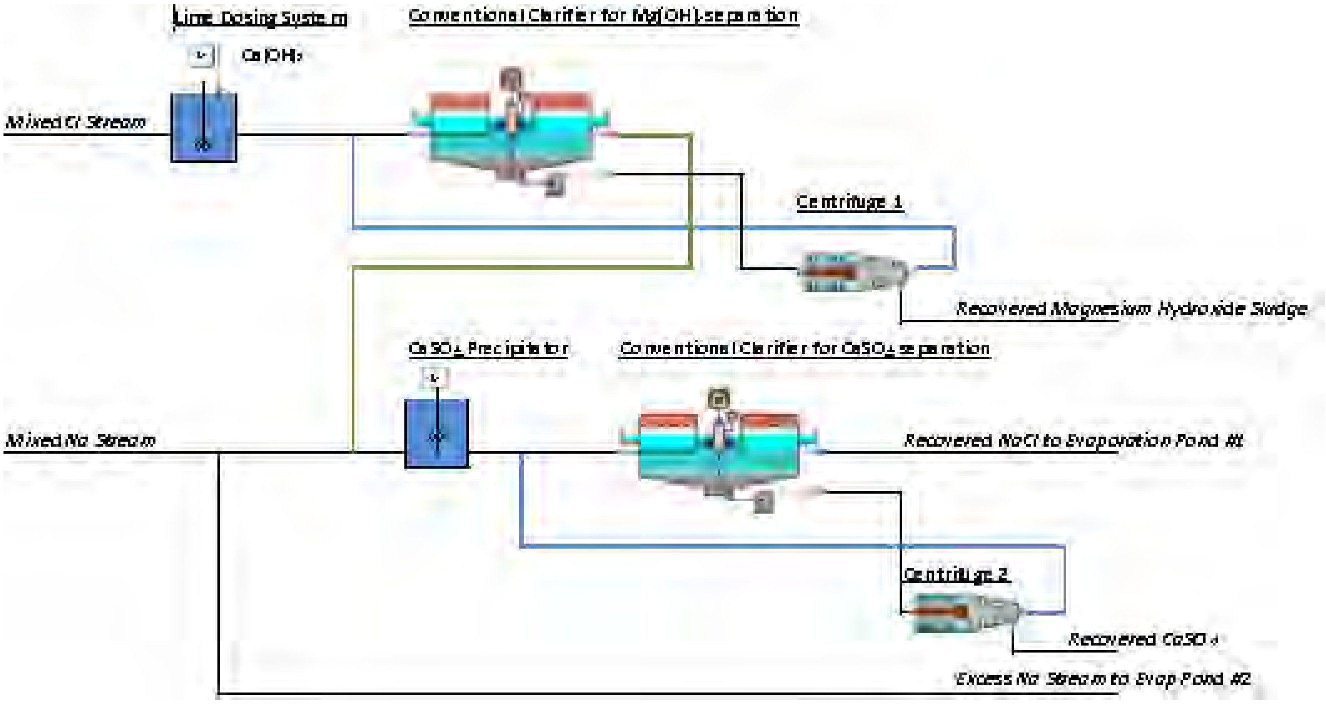


**Figure 79.—Full scale salt (NaCl, $CaSO_4$, $Mg(OH)_2$) recovery diagram.**

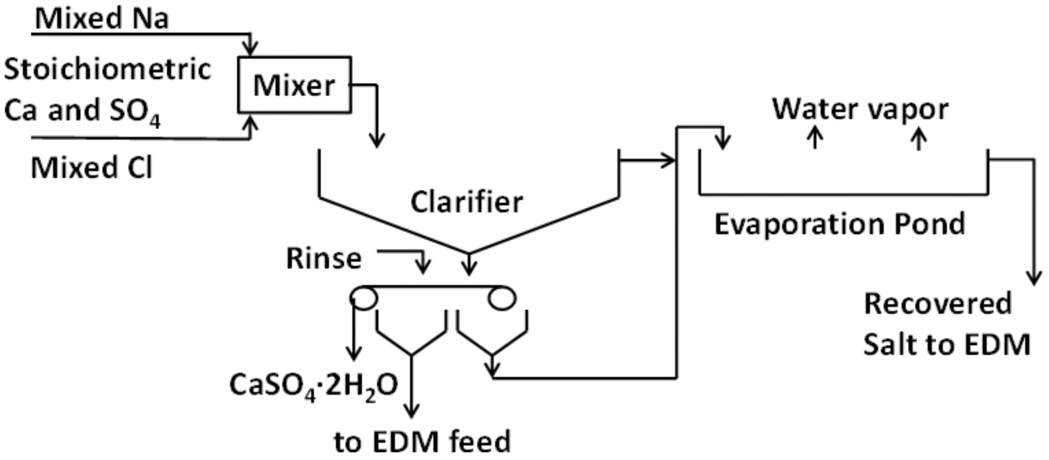


**Figure 80.—Recovery of NaCl from EDM concentrate streams by precipitation and evaporation.**

Returning to Figure 75, one can observe that the equilibrium values of the ion ratios (Na/Ca and Cl/$SO_4$) will continue to rise as the concentration of NaCl in the solution increases. That increase in NaCl concentration could be achieved by evaporation of water from the supernatant, and that evaporation would be most economically performed in an evaporation pond. If the NaCl concentration is raised to 3 M in the evaporation and the calcium and sulfate are fed to the pond in stoichiometric proportions, then the ion ratio would be about 28, which should be adequate for direct use in the EDM stack. However, since some NaCl still needs to be purchased, the blended purity is expected to have a ratio greater than 50. Experience with operation of the pilot and demonstration plants confirmed that an ion ratio of 28 in the NaCl stream was quite sufficient to avoid precipitation problems in the EDM stack. Figure 81 shows the various ratios and pH measurements for Phase 2 operations at the BGNDRF. Managing the evaporation pond for NaCl recovery would be somewhat more complicated than managing a pond in which all of both concentrated streams are disposed. It would be necessary to monitor the $Ca^{2+}$ and $SO_4^{2-}$ ion concentrations of the water in the salt-recovery pond and divert an appropriate amount of one of the concentrate streams into another pond to maintain nearly equal concentrations of the $Ca^{2+}$ and $SO_4^{2-}$ ions. Such imbalances could happen due to changes in the proportions of water drawn from wells with different water chemistries.

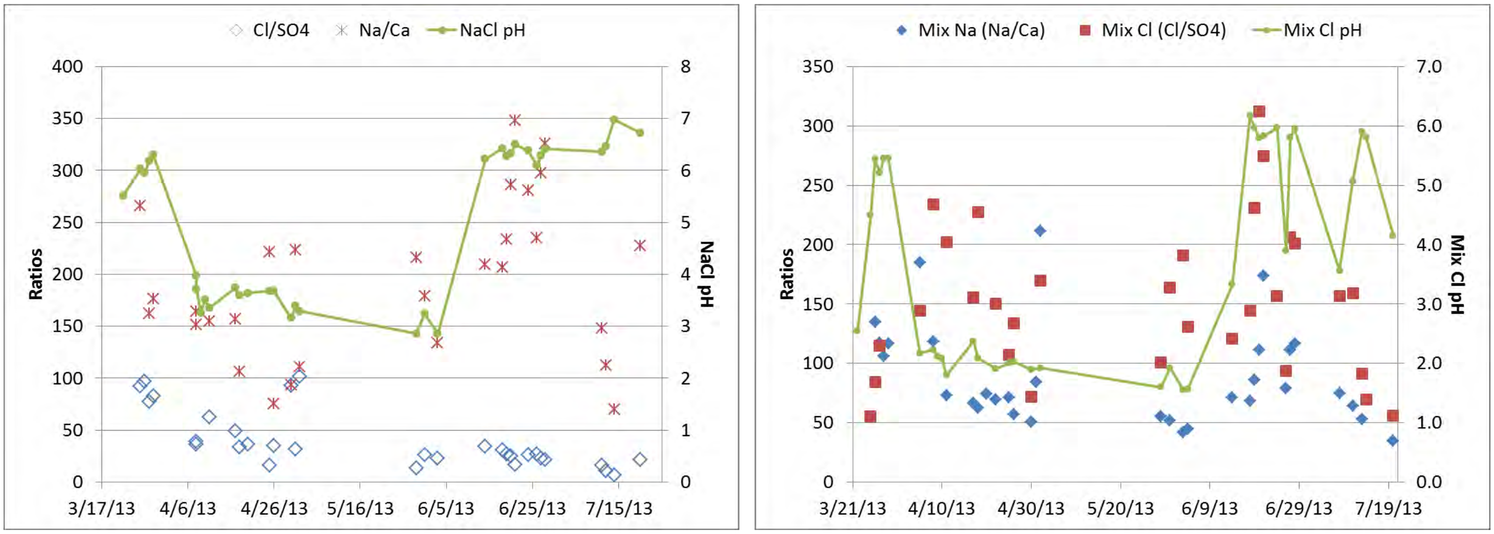


**Figure 81.—Comparison of Na/Ca and Cl/SO ratios and stream pH during Phase 2 Operations at BGNDRF. Left: NaCl stream ratios & pH; Right: Mixed Na & Mixed Cl ratios, Mixed Cl pH**

A laboratory experiment (seef) was performed to demonstrate that evaporation would indeed lead to the production of NaCl solution of adequate purity for use in the EDM stack. The Mixed Cl and Mixed Na solutions from the 40 gpm demonstration plant at BGNDRF were analyzed, and stoichiometric proportions of those solutions, with respect to calcium and sulfate, were combined in a 2 liter (L) beaker and stirred. The precipitate was recovered by filtration. The filtrate (supernatant) was boiled slowly to concentrate the NaCl. As water was removed by evaporation, the solution became supersaturated with $CaSO_4$, and precipitation occurred. The evaporated solution was 4.6 M, nearly saturated in NaCl, and the ion ratios were Na/Ca=185 and $Cl/SO_4$=16. The square root of the product of the ion ratios is 54.4, a value very close to the curve for ion ratio in Figure 75 for the final salt concentration. The distribution of the calcium and sulfate originally in the Mixed Cl and Mixed Na solutions introduced to the experiment was as follows: 73 percent was removed in the precipitation tank, 25 percent was removed in the evaporation tank, and 2 percent remained in the recovered NaCl solution.

It is obvious that the experiment was started with an excess of the Mixed Na solution; however, considering that only 2 percent of the calcium and sulfate remained in the evaporated liquid, the difference was likely due to imprecision in the original analyses. This underscored the need for periodic adjustment of the mixing proportions based on analysis of the solution in the evaporation pond.

The results of the experiment described in Figure 82 indicate that the solution of NaCl produced in an evaporation pond would be of sufficient quality to provide the supply of NaCl to the EDM stack. The next question relates to the quantity of NaCl that could be available from the evaporation pond. The composition of water in the wells of Alamogordo will be used as an example. Data in Table 3 indicate that there is more sulfate than calcium in the well water, so just as in the experiment described in Figure 82, a larger portion of Mixed Cl solution would be needed to achieve stoichiometric proportions of calcium and sulfate. However, if the magnesium is replaced with calcium, which can be achieved by adding lime to precipitate $Mg(OH)_2$, then the proportions of calcium and sulfate would be nearly the same, and almost all of the volume of both concentrate streams could be fed to the precipitation chamber, and all of the supernatant could be sent to the evaporation pond. Therefore, except for small amounts of solutions that would be discarded in a second evaporation pond and the solution that was not separated by the centrifuge, all of the NaCl that enters the EDM would enter the evaporation pond for recovery. To provide a margin for loss, it will be assumed that 90 to 95 percent of the available NaCl in the Snake Tank source water is recovered.

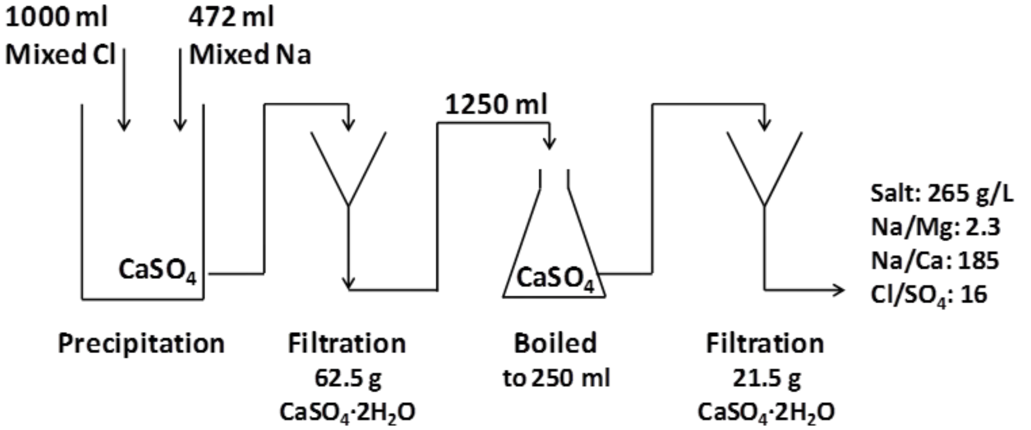


**Figure 82.—Evaporation experiment using EDM concentrates from BGNDRF 40 gpm demonstration plant.**

The quantities of $CaSO_4$ involved can be estimated for the case of the Snake Tank Wells that will supply the water for the desalination plant to be built in Alamogordo. Examination of the analyses in Table 3 reveals that sulfate represents 85 percent of the anions in the feed. Removal of that $SO_4$ as a solid byproduct would result in the production of water of high quality. Assuming total conversion of sulfate to calcium sulfate dihydrate ($CaSO_4{\cdot}2H_2O$) would result in the daily production of metric 32 metric tons per day (mT/d) of solids from a 4 MGD desalination plant. Data from the experiment described in Figure 82 indicate that about 73 percent of the solids would precipitate quickly when the two concentrate streams are combined, and 25 percent would precipitate gradually in an evaporation pond used for recovery of NaCl for return to the EDM. The net annual evaporation rate for the Holloman Air Force Base, which is close to the site for Alamogordo's desalination plant, is 70 in/yr (Livingson Associates, 2003). Using the monthly average net evaporation rate in at Alamogordo, 14.8 cm per month, an evaporation pond with 7.7 acres would be needed to concentrate the salt solution. A smaller pond (3 acres would also be needed for excess Mixed Na solution and other waste streams. Assuming dense gypsum crystals at the bottom of the pond (1 metric tons per cubic meter [$mT/m^3$]), the accumulation from the 25 percent would be 0.093 meters per year (m/yr). If the life of the evaporation pond is assumed to be 20 years, the pond would need to be 1.85 meters deeper than an evaporation pond with no precipitation. After its 20-year life, the pond would be removed from service, allowed to evaporate to dryness, and covered with an impervious film and soil.

Construction of the evaporation ponds and clarifiers represents a capital cost. Assuming that the rate of flow of supernatant into the evaporation pond is 2 percent of the well water in a 4 MGD desalination plant and that half of the water would be evaporated to raise the salt content from 1.5 moles per liter (M) to 3 M, the evaporation rate would be 40,000 GPD. Capital equipment would include the evaporation pond, two clarifiers (one for lime addition, one for $CaSO_4$ precipitation and recovery), and pumps and piping for transferring fluid between processes. Operating costs would include lime. The cost for this method is estimated to be $0.022/lb of NaCl recovered, which would reduce the NaCl purchases by 53 percent. Assumptions for the cost for implementation of this strategy include:

- 7.7 acre evaporation pond for NaCl recovery, 3 acre evaporation pond for excess Mixed Na waste. Capital Cost of $80,000/acre is based on average of four methods described in the Chapter 8 (see Table 25).
- Clarifiers for Mixed Cl treatment with lime and $CaSO_4$ recovery. Capital cost of $14,427/gpm treated is based on the capital cost for a 500 gpm system treating produced water (Hamilton Engineering Inc., 2009).
- Belt filter capital cost estimated at $71,532 is based on 500 dry pounds per hour (lb/hr) (U.S. Environmental Protection Agency [EPA], 2000).
- Annual operating cost includes the purchase of lime is based on $0.04/lb.
- Annual electrical cost for clarifiers is based on 15 kWh/kgal.

A less expensive alternative (in terms of capital cost) exists for recovery of NaCl in an evaporation pond. If there is no market for the $CaSO_4 \cdot 2H_2O$ that is precipitated and washed as shown in Figure 80, the clarifier and belt press equipment could be eliminated, and the precipitation could be done in a mixing channel at the entrance to the evaporation pond. After magnesium is removed from the Mixed Cl stream by lime addition, the Mixed Cl and Mixed Na streams are combined, agitated and discharged into a concrete-lined channel with a weir that overflows to the evaporation pond. This alternative would require an evaporation pond of the same size as the one used to evaporate water from the supernatant of the process shown in Figure 80. Most of the 75 percent of the $CaSO_4$ that would have been collected on the filtration belt (or centrifuge) would now accumulate in the channel. When the channel is filled with solids, the slurry would be diverted to another channel, and the $CaSO_4$ in the first channel would be dewatered, excavated and transported to a landfill. Assuming that a contractor would perform the excavation and hauling monthly, a channel 40 meters long and 20 meters wide would fill to a depth of 1.7 meters, which is enough material to fill twenty five 35 metric ton dump trucks. The cost for this method is estimated to be $0.024/lb of NaCl recovered, which would reduce the NaCl purchases by 50 percent. Assumptions for the cost for implementation of this strategy include:

- Same cost for evaporation ponds as using $CaSO_4$ recovery method
- One clarifier for lime precipitation using the same price as the $CaSO_4$ method
- Annual $CaSO_4$ disposal cost based on a dumping fee of $10/m/T and a contractor charge of $5,000 per month
- Annual lime and electricity cost is the same as for the $CaSO_4$ + lime recovery method

## 11.4 High Purity NaCl Recovery Using Electrodialysis and Recovery of $Mg(OH)_2$

Before the potential cost savings of evaporation became evident, the NaCl recovery efforts were focused on the use of ED to recover NaCl from the supernatant. ED is used on a large scale to recover NaCl from seawater in Japan where there are no natural salt deposits and where abundant rainfall makes evaporation ponds ineffective. To prevent precipitation of $CaSO_4$ in the concentrate streams of the ED stacks, companies in Japan developed ion-exchange membranes that were selectively permeable to monovalent ions and limited the transport of divalent ions into the recovered salt. Figure 83 illustrates the selective transport of monovalent ions in ED. Monovalent selective ion exchange membranes are able to allow passage of mostly $Na^+$ and $Cl^-$ ions and block most of the troublesome ions such as $Ca^{2+}$ and $SO_4^{2-}$.

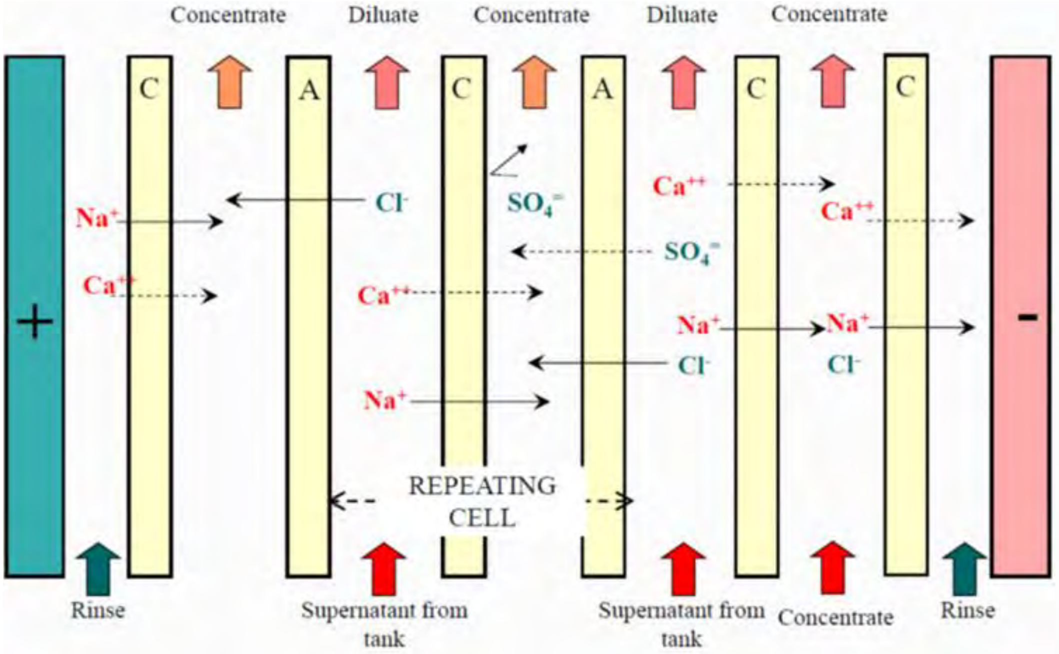


Figure 83.—Selective transport of monovalent ions in electrodialysis.

An extensive experimental program was carried out to study the use of ED to recover NaCl from the supernatant of the process where $CaSO_4$ precipitates when the Mixed Cl and Mixed Na concentrate streams from the EDM are combined. ED has the advantage that it can concentrate salts to very high levels. ED has been used in Japan to recover NaCl from seawater (3.5 percent NaCl) and concentrate it to high levels (20 percent) in the commercial production of edible salt (Strathmann, 2004). To avoid the precipitation of $CaSO_4$ in the concentrated salt solution, the major manufacturers of ED membranes in Japan developed monovalent-ion-selective membranes that block the transport of divalent ions. The monovalent-anion-selective membranes are extremely effective in allowing the passage of Cl ions and blocking $SO_4^{2-}$ ions. This high selectivity for rejecting sulfate in ED is fortuitous, because there are really no other practical methods for removing sulfate from a concentrated NaCl solution. The monovalent-cation-selective membranes are adequately effective for rejecting $Ca^{2+}$ and $Mg^{2+}$ ions and passing $Na^+$ ions. Fortunately there are other methods for removing divalent cations if further purification were required. Adding $Na_2CO_3$ or using chelating resins would provide means of removing divalent cations from the concentrated NaCl solution.

With the prospect available for employing an inexpensive base to recover a valuable byproduct and solve a stoichiometry problem, a study using salt values from (National Lime Association, 2000) was devised to determine the practicality of adding $Ca(OH)_2$ ($80/ton) to the Mixed Cl stream to precipitate $Mg(OH)_2$ ($600/ton). Preliminary experiments showed that feeding a slurry of lime to the Mixed Cl stream was effective, but calculations indicated that the water to make a 10 percent lime slurry would dilute the Mixed Cl stream by more than 20 percent. Therefore, experimental efforts were focused on the use of powdered hydrated lime, which is easily handled with commercial equipment (Figure 84).

**Figure 84.—Hydrated lime injection system (Con-V-Air Solutions, n.d.).**

In the precipitation experiments a solution with composition simulating the Mixed Cl from the Phase 1 Alamogordo pilot plant was placed in a beaker fitted with a magnetic stirrer and a pH probe, and measured amounts of powdered $Ca(OH)_2$ were added. The pH was recorded after it stabilized after each incremental addition. The graph in Figure 85 shows the pH versus amount of lime added. The pH remained nearly constant, because $Ca(OH)_2$ was dissolving, and the OH- ions were reacting with $Mg^{2+}$ ions. When the $Mg^{2+}$ ions had been consumed, further dissolution caused an increase in pH until the solution was saturated with $Ca(OH)_2$. After the second plateau was reached, all of the lime remained in suspension.

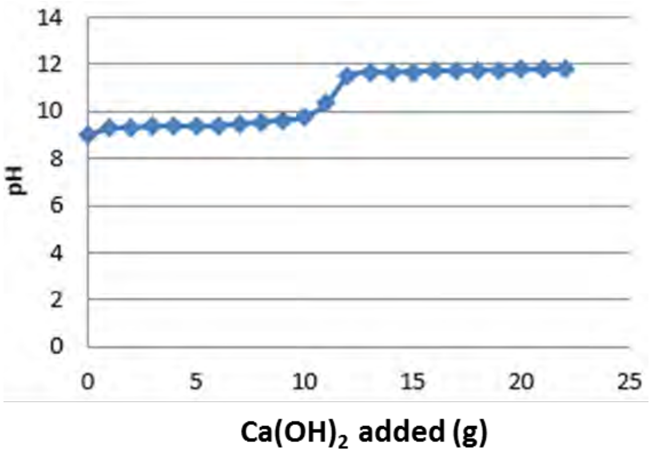


**Figure 85.—Addition of $Ca(OH)_2$ powder into simulated Mixed Cl solution.**

In a second experiment, the addition of lime was stopped as soon as the pH increased (Figure 86) to avoid accumulation of undissolved lime. A sample of the supernatant analyzed by ion chromatography (IC) revealed that the magnesium level was below detection limits. For a determination of the quality of the $Mg(OH)_2$, duplicate samples of the precipitate were washed with DI water and dissolved in 37.1 percent HCl acid, and the composition of the solution was analyzed by the IC. The analysis of the solution from the dissolved precipitate, shown in table 2, reveals the high quality of the precipitated $Mg(OH)_2$. A small amount of $CaSO_4$ was the only noteworthy contaminant. Based on the cations, the purity is 97.31 and 98.17 for the two samples. If the precipitation shown in Figure 86 had been stopped before the last addition of lime, it is likely that the 99 percent target could have been achieved.

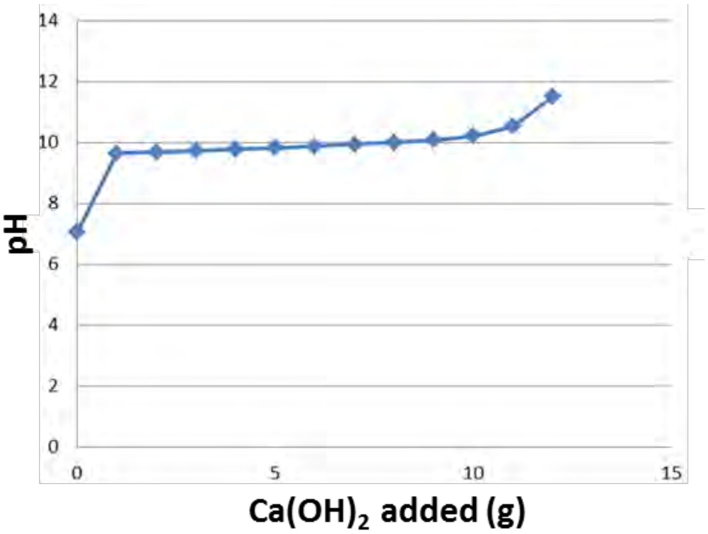


**Figure 86.—Stopping the addition of Ca(OH)2 powder at the endpoint of the plateau eliminates undissolved lime in the $Mg(OH)_2$ product.**

Alibaba advertises 92 percent as high purity with a retail price range of $400 to 600 per metric ton (Alibaba, n.d. a), and advertises 99 percent purity with a retail price range of $800-850 per metric ton (Alibaba, n.d. b).The magnesium content of 88 mg/L in the Snake Tank wells would produce 3262 kg/day of $Mg(OH)_2$ from a 4 MGD desalination plant. At $600 per metric ton, monthly sales exceeding $50,000 could induce a contractor to invest in the operation of a demonstration of the precipitation in Alamogordo's 1 MGD plant to see if a high-purity product and a premium price could be obtained. There are markets for $Mg(OH)_2$ slurry as well as the dried product.

All of the laboratory ED experiments used as feed the supernatant from the precipitation of $CaSO_4$ and specifically used the apparatus illustrated in Figure 78. The ED stack was assembled with nine cell pairs comprising Neosepta ACS monovalent-anion-selective and CMX-S monovalent-cation-selective membranes. The diluate flowed once through the ED stack and back into the precipitation tank. The concentrate stream was recirculated through the ED stack at a flow rate that resulted in balanced pressures between the diluate and concentrate. There was no solution fed to the concentrate streams; the water in the concentrate was entirely derived from molecules of water that were transported through the membranes along with the ions. In a typical experiment the concentrate tank would be filled initially with DI water, and the concentrate built up gradually over time. The ED would be operated during the day and shut down for evenings and weekends. Because the precipitation tank had a large capacity relative to the ED, the introduction of Mixed Cl and Mixed Na streams to the tank was intermittent and led to depletion of the salt in the feed tank. Figure 87 shows the concentrations of ions in the diluate and concentrate based on measurements of solution conductivity. With this mode of operation, the NaCl level of the concentrate was pushed as high as 4.36 M (22 percent NaCl by weight), which is far above the 3 M level needed to feed the EDM stack. At that level of NaCl concentration the current efficiency was 64 percent. The graduate student who was performing the ED experiments infused DI water to dilute the concentrate to 2.7 M (the last two data points on Figure 87), slightly below the target of 3 M, and he reported in his thesis that the current efficiency improved to 84 percent (Yetayew, 2013). Evidently, back diffusion of ions is enhanced when the ED is pushed to its limits, and reducing the driving force for back diffusion provides a substantial improvement in current efficiency. Since DI water would be used to dilute the recovered salt before it is returned to the EDM, it makes sense to perform that dilution in the ED stack and benefit from the improved current efficiency.

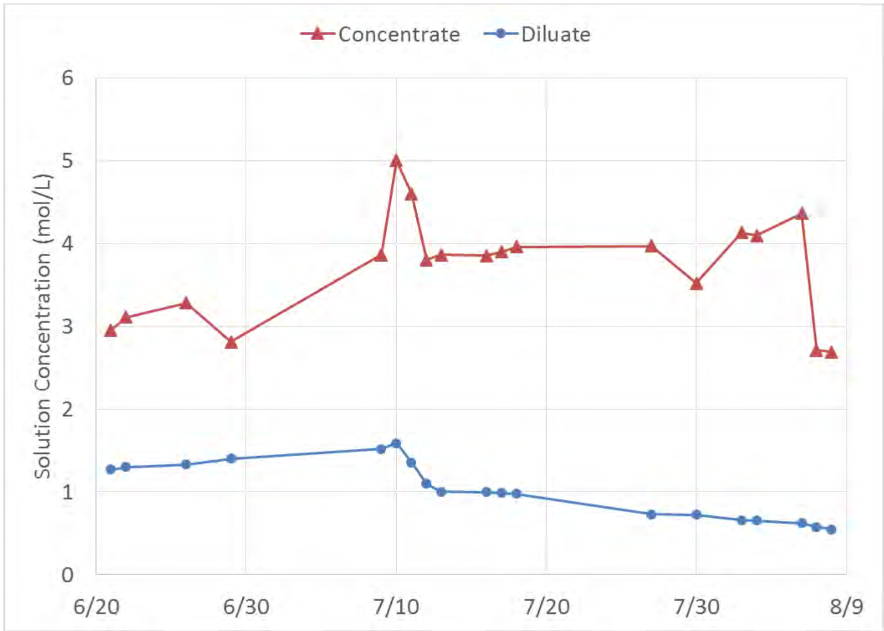


**Figure 87.—Molar concentrations (based on conductivity measurements) of NaCl in diluate and concentrate of ED stack.**

The experiments described above were performed in a feed-and-bleed mode of operation in which the $CaCl_2$-rich concentrate and the $Na_2SO_4$-rich concentrate from the EDM were added continuously to the bottom of the precipitation chamber so that they contacted the previously precipitated $CaSO_4$, and the supernatant was drawn off continuously for treatment by ED. In the feed-and-bleed mode, the solution being treated by the ED has a constant concentration, and that concentration is low. An alternative is to operate the ED in batch mode wherein the initial concentration is 1.5 M and the final concentration is the low value. The data in Figure 88 show the implications of operation in the batch or feed-and-bleed modes. The longer of the two vertical dashed lines in Figure 88 shows the expected concentration of NaCl (1.5 eq/L) in the supernatant when the Mixed Cl and Mixed Na concentrates from the EDM are combined. (The 1.5 eq/L is given as an example based on pilot plant experience. Larger values of NaCl concentration in the supernatant are possible.) The shorter dashed line shows the concentration of NaCl (0.215 eq/L) after 90 percent of the NaCl is recovered by ED. In the batch mode of operation the Na/Ca ratio in the ED feed would begin at 15 and drop to 4 at the end of the batch. The solution being fed to the ED in the feed-and-bleed mode would have a constant Na/Ca ratio of 4, so the recovered NaCl solution would have a Na/Ca ratio less than half of that achievable with batch ED.

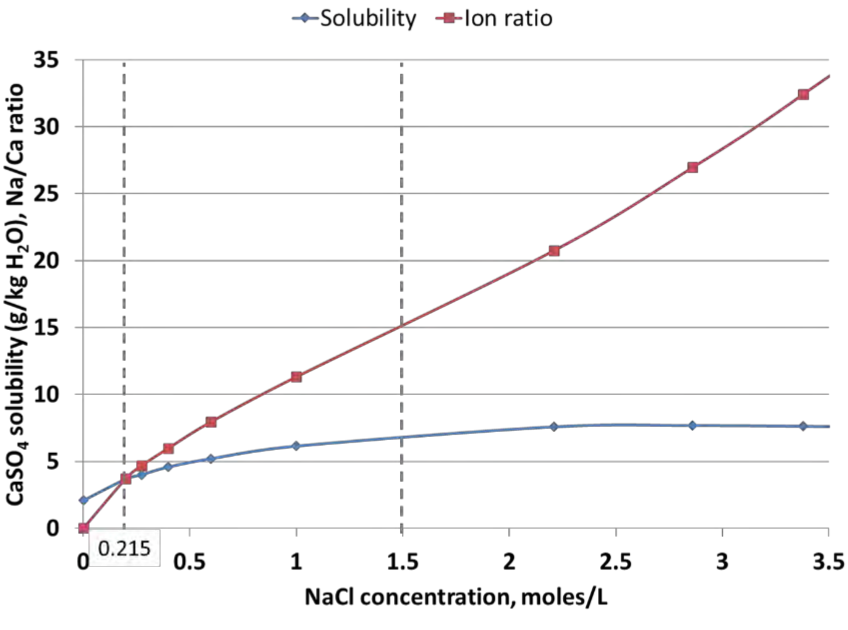


**Figure 88.—on ratios in feed-and-bleed mode of ED operation.**

Batch treatment requires less electrical energy than feed-and-bleed treatment, because the higher concentration of salt in the depleting compartments of the ED at the beginning of the batch provides lower electrical resistance, so the voltage applied to the ED stack can be lower at the beginning of the batch than at the end. With feed-and-bleed operation, the required voltage would be the same as the voltage at the end of a batch operation, because the NaCl concentration fed to the ED would have a constant value of 0.215 eq/L.

In the procedure for batch ED, a batch of supernatant and previously precipitated $CaSO_4$ are agitated to promote contact between the calcium and sulfate ions in solution with the solid $CaSO_4$. The precipitate is allowed to settle somewhat in order to form a clear supernatant containing NaCl and saturated with $CaSO_4$. The supernatant passes through a filter to remove particles of $CaSO_4$ that might remain suspended in the solution. Then the supernatant flows through the ED stack and back into the agitated precipitate in the bottom of the tank.

Because the supernatant solution enters the ED saturated with $CaSO_4$, removal of NaCl causes the diluate to be somewhat supersaturated with $CaSO_4$. However, the slow kinetics of precipitation of $CaSO_4$ and the short residence time of the solution in the ED stack favor a delay in precipitation until the diluate enters the precipitation chamber where it comes into contact with the previously form precipitate that provides sites for crystallization of $CaSO_4{\cdot}2H_2O$. The point of entry of the diluate is preferably in the bottom region of the precipitation chamber where it can have maximum contact with the previously formed precipitate. ED treatment of the batch of supernatant continues until a target concentration of NaCl is reached in the supernatant or until the Na/Ca ratio or the $Cl/SO_4$ ratio in the recovered NaCl solution drops to a target level.

Controlling the composition of the batch solution being treated by ED is important to quality control for the recovered NaCl. Since the monovalent-anion-selective membranes exclude sulfate ions more effectively than monovalent-cation-selective membranes exclude calcium ions, the removal rate of calcium ions from the feed solution exceeds the removal rate of sulfate ions when the calcium and sulfate are present in equal ionic concentrations. If it is assumed that an optimum condition is to have equal amounts of calcium and sulfate in the feed solution to the ED, it would be necessary to provide supplemental calcium ions to the solution in order to avoid an imbalance in the proportions of calcium and sulfate ions. Control of the solution composition can be accomplished by measuring the concentration of calcium ions or the concentration of sulfate ions or both. With information on the solubility of $CaSO_4$ as a function of NaCl concentration and analytical information about the calcium or sulfate concentration or both, a control algorithm provides a signal to control an infusion pump that infuses the Mixed Cl concentrate stream produced by the EDM and thus achieve the desired addition rate of calcium to match the rate of calcium removal through the cation-exchange membranes of the ED. The Orion™ 2120XP calcium hardness analyzer (Thermo Scientific, 2013) could be used to measure the calcium level of the solution in real time. It is not necessary to maintain calcium and sulfate concentrations at equal levels throughout the batch. If specifications require a reduction in the sulfate level of the recovered NaCl, the control algorithm can be set to maintain the calcium level higher than the sulfate level.

Experiments were performed in December 2012 and January 2013 to determine the quality of NaCl that could be achieved with batch ED treatment of the supernatant. The results are shown in Table 30 and Figure 89. The total duration of this series of experiments was 25 hours.

Table 30.—Ion Ratios and Relative Transport during Batch ED of Supernatant Prepared with Simulated Alamogordo EDM Concentrate Streams

| Sample | Day | Ion Ratio | | Relative Transport | |
|---|---|---|---|---|---|
| | | Na/Ca | $Cl/SO_4$ | Na/Ca | $Cl/SO_4$ |
| Feed-12-17-2013-end | 1 | 28.2 | 6.2 | - | - |
| Feed-12-18-2013-end | 2 | 26.3 | 5.8 | - | - |
| Feed-12-19-2013-end | 3 | 26.7 | 5.4 | - | - |
| Feed-12-20-2013-end | 4 | 28.0 | 5.2 | - | - |
| Feed-12-21-2013-end | 5 | 26.6 | 4.6 | - | - |
| Feed-01-16-2013-end | 6 | 27.8 | 4.3 | - | - |
| Feed-01-17-2013-end | 7 | 27.4 | 4.0 | - | - |
| Feed-01-24-2013-end | 8 | 28.4 | 3.8 | - | - |
| Concentrate-12-17-2013-end | 1 | 59.9 | 132.4 | 2.1 | 21.3 |
| Concentrate-12-18-2013-end | 2 | 68.0 | 165.5 | 2.6 | 28.8 |
| Concentrate-12-19-2013-end | 3 | 70.9 | 156.4 | 2.7 | 29.0 |
| Concentrate-12-20-2013-end | 4 | 69.1 | 122.8 | 2.5 | 23.4 |
| Concentrate-12-21-2013-end | 5 | 70.2 | 125.5 | 2.6 | 27.3 |
| Concentrate-01-16-2013-end | 6 | 64.5 | 67.3 | 2.3 | 15.6 |
| Concentrate-01-17-2013-end | 7 | 67.8 | 91.0 | 2.5 | 22.7 |
| Concentrate-01-24-2013-end | 8 | 58.2 | 34.6 | 2.1 | 9.1 |

The data in Figure 89 indicate that the concentration of $Na^+$, $Cl^-$, and $Ca^{2+}$ in the feed tank decreased while $Mg^{2+}$ and $SO_4^{2-}$ ions remained unchanged. No explanation was found for the jump in concentrations on Day 6. The quality of the recovered NaCl was excellent up to the last day. Ion ratios for Na/Ca were consistently in the range of 60 - 70. Ion ratios for $Cl/SO_4$ began very high and decreased somewhat. It was fortuitous that there was an excess of $SO_4^{2-}$ ions in the feed tank, because the monovalent AEM provides excellent rejection of sulfate.

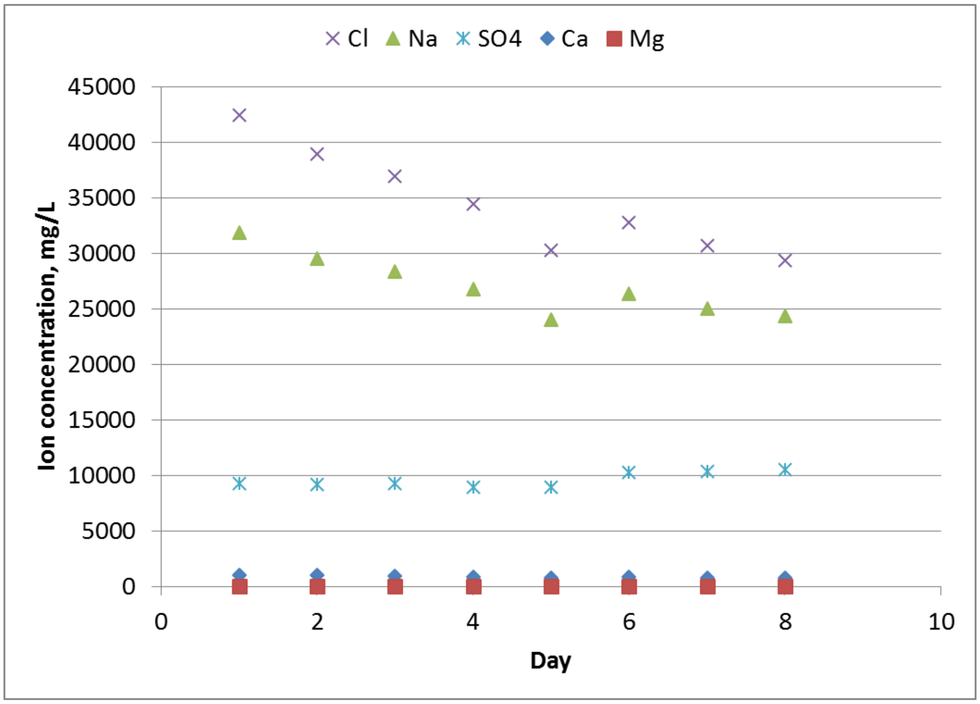


**Figure 89.—Composition of solution in feed tank during batch ED experiments.**

The selectivity of these membranes is usually described by a term called the relative transport number (RTN) with is defined as:

$$RTN_{Cl/SO_4} = \frac{[Cl]_c}{[SO_4]_c} / \frac{[Cl]_d}{[SO_4]_d}$$

So the RTN can be calculated simply by dividing the ion ratio in the ED concentrate by the ion ratio of the ED feed. Calculated values for RTN shown in Table 30 indicate that $RTN_{Cl/SO4}$ for the ACS membrane is an order of magnitude higher than $RTN_{Na/Ca}$ for the CMX-S membrane

On January 24, the flow rate of diluate was decreasing, so the experiment was terminated, and the ED stack was disassembled. White precipitate, presumed to be $CaSO_4 \cdot 2H_2O$, was observed in the depleting compartments.

The crystallization of $CaSO_4$ could be prevented by reversing the polarity of the electrodes in the ED stack, in the EDR process. Reversal of the polarity causes the electrical current to flow in the opposite direction, and the compartments that had been depleting compartments become concentrating compartments. When nascent crystals of $CaSO_4$ in the concentrating compartments are exposed to increasing NaCl concentrations, the increased solubility will cause $CaSO_4$ crystals to dissolve. The dissolution will add some calcium and sulfate ions to the recovered salt, but those amounts will be small. The main purpose of the current reversal is to eliminate nascent crystals so that they do not become sites for further crystal growth, which could happen if the ED stack is used to treat multiple batches of supernatant without current reversal.

The values of $RTN_{Na/Ca}$ shown in Table 30 were lower than expected. The monovalent-cation-selective membrane used in these experiments was Neosepta CMX-S. Another monovalent-cation-selective membrane Neosepta CMS had been used in the EDM stack in the early pilot-scale work, and CMS was found to be the most fragile membrane in the EDM stack. Switching to CMX-S membranes definitely resulted in improved membrane life. A decision was made to do some comparative experiments with an ED stack containing CMS and ACS membranes.

Because the CMS membranes were in short supply, the ED stack was assembled with only 6 cell pairs and hence a potential of only 6 V was applied. This substantially lower voltage resulted into a lower current flow in the system (17 mA/cm$^2$ vs 50 mA/cm$^2$ in the December experiments). The analytical data and calculated values of ion ratios and RTN are shown in Table 31. The RTN values for Cl/$SO_4$ in the ACS membrane were nearly the same as in the previous experiments, but the RTN values for Na/Ca in CMS were doubled the values for CMX-S. The CMS membranes block more calcium ions than the CMX-S membranes did and produce NaCl solution with higher purity for the EDM process.

Table 31.—Ion Ratios during Batch ED of Supernatant with Neosepta CMS and ACS Membranes at Low Current Density

| Sample | Ion Ratio | | Relative Transport | | Current Density |
|---|---|---|---|---|---|
| | Na/Ca | Cl/$SO_4$ | Na/Ca | Cl/$SO_4$ | mA/cm$^2$ |
| Feed 02-11-2013-end | 29.95 | 3.61 | | | |
| Feed 02-12-2013-end | 29.53 | 3.52 | | | |
| Feed 02-13-2013-end | 27.53 | 3.36 | | | |
| Concentrate 02-11-2013-end | 156 | 109 | 5.22 | 30.11 | 16.65 |
| Concentrate 02-12-2013-end | 174 | 145 | 5.88 | 41.03 | 16.95 |
| Concentrate 02-13-2013-end | 188 | 167 | 6.83 | 49.79 | 17.2 |

The same ED stack with ACS and CMS membranes was operated with sufficient applied voltage to achieve the current densities that were attained in the December experiment. Raising the current density caused an improvement in the quality and the concentration of the recovered NaCl solution. The conductivity of the ED concentrate indicated a 5.9 M concentration, and the ion ratios were about 300 for Na/Ca and 200 for Cl/$SO_4$ (see Table 32). This is the highest quality of NaCl recovered by ED and is of similar quality of salt that has been purchased for use in the EDM. These data indicate that the RTN values for both membranes improved at the high current density.

Table 32.—Ion Ratios During Batch ED of Supernatant with Neosepta CMS and ACS Membranes at High Current Density

| Sample | Ion Ratio | | Relative Transport | | Current Density |
|---|---|---|---|---|---|
| | Na/Ca | Cl/$SO_4$ | Na/Ca | Cl/$SO_4$ | mA/$cm^2$ |
| Feed 02-21-2013-end | 28 | 3 | | | |
| Feed 03-05-2013-end | 27 | 3 | | | |
| Concentrate 02-21-2013-end | 369 | 208 | 13 | 68 | 57.8 |
| Concentrate 03-05-2013-end | 302 | 190 | 11 | 66 | 51.2 |

**mA/$cm^2$** = milliampere per square centimeter

Implementation of NaCl recovery using ED with the mixing channel approach (i.e., single clarifier) could involve the purchase of an ED with 680 $m^2$ of exposed membrane. The installed cost for a very large ED system fitted with monovalent selective membranes is \$1,800/$m^2$ (private communication from Daniel Bar of Ameridia). Since the ED for NaCl recovery would be a smaller scale system, a multiplier of 1.5 is used to scale up the capital cost. Experimental data suggest that the power cost for recovering NaCl by ED would be 2.4 cents per pound. The cost for this strategy is estimated to cost between \$0.036-0.038 per pound of NaCl recovered, which would reduce the NaCl purchases by 33 to 35 percent. If $Mg(OH)_2$ is sold at half the market rate of \$800 per metric tons. annual operating costs could be reduced by nearly \$375,000. If a utility doesn't want to invest in the capital equipment (clarifiers, belt presses, etc), it is possible that a private company would make the investment to sell $Mg(OH)_2$ and the city could reduce its operating cost.

## 11.5 Voltage Drop in ED Stacks

In lab-scale ED, a large portion of the voltage applied to the electrodes is consumed in the electrode reactions and in the E-Rinse solution compartments. To obtain a true value of the voltage drop attributable to the cell pairs, it is necessary to subtract the voltage associated with the electrodes. Experiments were performed with the ED electrodes separated by a single cation-exchange membrane to determine the voltage that should be subtracted. Data for those experiments are plotted in Figure 90. The individual curves are associated with different concentrations of $Na_2SO_4$ in the E-Rinse. The data were well described by the equation:

$$V = 2.943 + 0.1205 \times I + 8.434 \times I/K$$

Where:
V is the applied potential (volts [V])
I is the current (amps [A])
K is the conductivity (mS/cm) of the rinse solution

The conductivity of the E-Rinse solutions was routinely measured during the ED experiments, so there were sufficient data to determine the portion of the applied voltage that should be attributed to the electrodes.

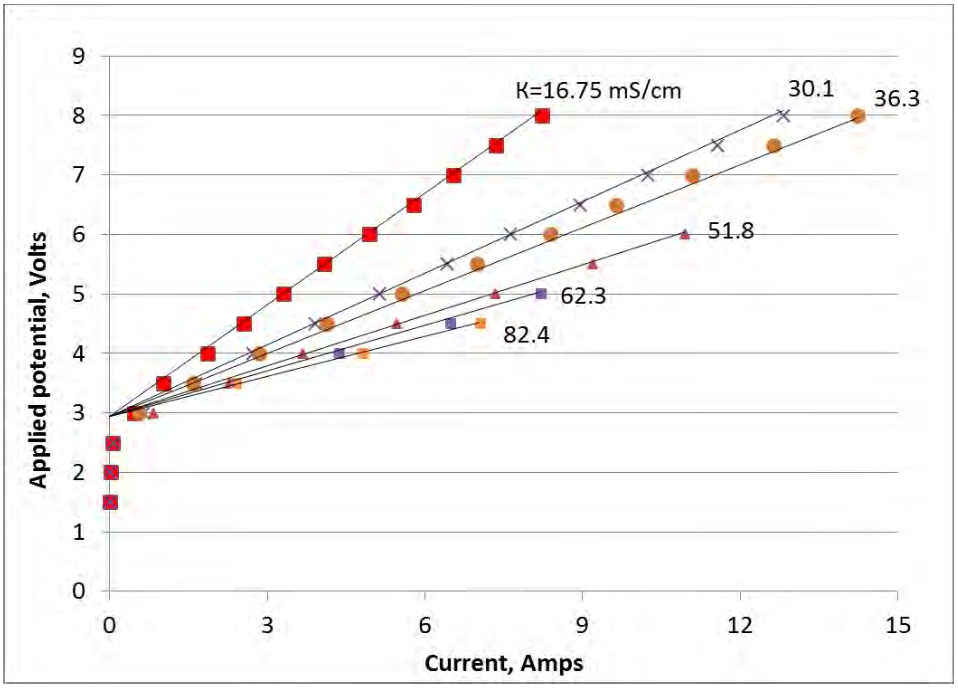


**Figure 90.—Voltage drop in TS-2 stack with electrodes and a CMB membrane.**

In a typical ED experiment, the measurements of the current and applied voltage are routinely performed at the end of an experiment simply by reducing the applied voltage incrementally and recording the voltage and current. Figure 91 shows the voltage measured when the ED was being shut down on December 21, 2012. In this experiment, the potential applied to the ED stack was 13 V, and 4.32 V is attributed to the electrodes. The power consumed by the ED was (13-4.32) V x 10.68 A = 89 W. Calculation of power consumption by the ED is shown in Table 33 for three laboratory experiments with an assumed current efficiency of 0.8 and power cost of 10 cents per kWh.

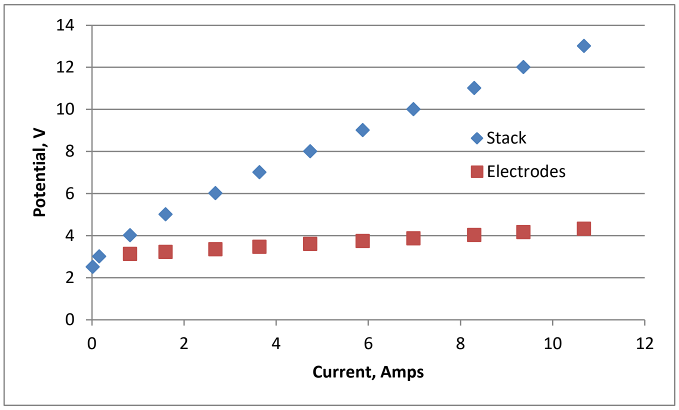


**Figure 91.—Measured potential and current of the ED stack as it was being shut down on 12/21/2012.**

Table 33.—Energy Consumption for NaCl Recovery by ED

| Date | Applied to Stack | | E-Rinse Conc. | Electrodes | Power | Cell Pairs | Power Cost |
|---|---|---|---|---|---|---|---|
| | Volts | Amps | mS/cm | Volts | Watts | | ₵/lb |
| 12/21/12 | 13 | 10.19 | 98 | 4.26 | 89 | 10 | 2.28 |
| 2/13/13 | 6 | 3.44 | 53 | 3.52 | 9 | 6 | 1.08 |
| 3/5/13 | 10 | 10.24 | 76 | 4.29 | 58 | 6 | 2.48 |

Note: Current efficiency = 80%, power cost = 10 cents per kWh

# 12. Conclusions and Recommendations

## 12.1 Technical Performance and Cost Evaluation

Outside of this project, Black and Veatch has evaluated EDM in Florida (Bond et.al., 2011) and most recently in Beverly Hills (Bond et.al., 2015). UTEP and Veolia participated by providing equipment, training, and support for the research sponsored by the California Energy Commission. High recovery with acceptable water quality for blending was achieved. The reported total EDM recovery of water from the RO concentrate was 91 to 92 percent, which would improve the overall recovery of the Beverly Hills RO plant from 80 percent to 97-98 percent. Details can be found in the WERF 5T10 report and in Section 9 of this report.

The capital costs for the BWRO and ZDD systems with deep well injection are summarized in Figure 92. The capital cost for the ZDD system is similar to the BWRO system capital costs, but the relative proportion for the concentrate disposal is quite different between ZDD and BWRO. The capital cost of BWRO with evaporation ponds is greater than ZDD due to the large evaporation ponds required for BWRO. If a utility does not have land available for large evaporation ponds, and, therefore, considers deep well injection (DWI), the capital cost for ZDD with a small evaporation pond is 13 percent higher than BWRO. Since the EDM concentrate streams are above 100,000 mg/L TDS, it is unlikely that they would be disposed of using DWI since the concentration may not be allowed to be disposed of using this method.

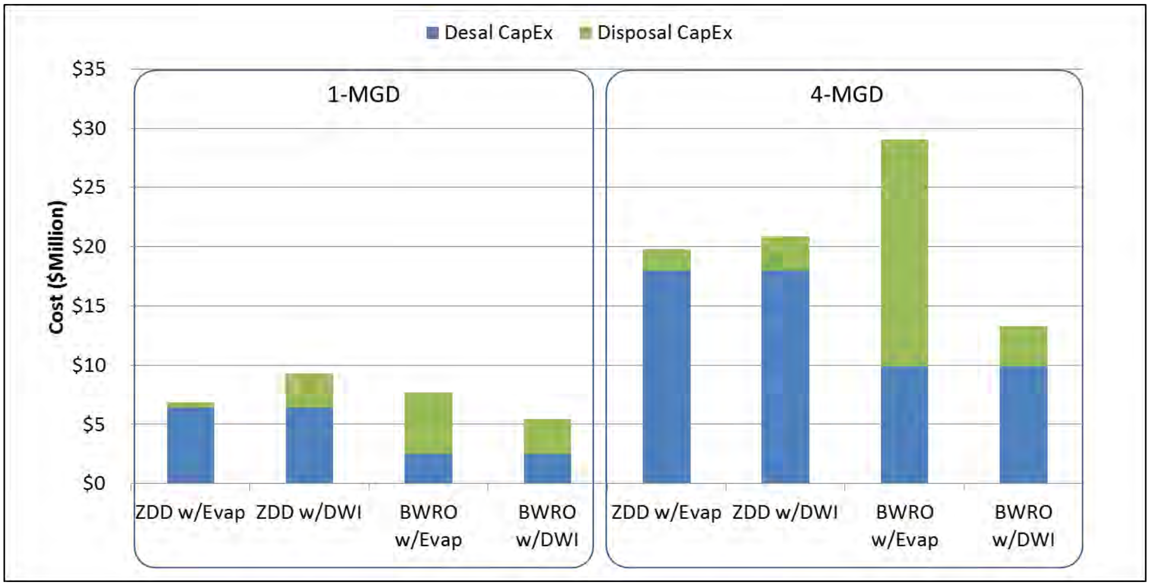


**Figure 92.—Capital cost estimates for ZLD, ZDD and BWRO for 1 MGD and 4 MGD designs.**

This BWRO unit cost range is likely low because our analysis excludes the cost of labor. An example of an existing full-scale BWRO facility is El Paso Water Utilities' Desalination Plant (concentrate disposal with deep well injection) which reports to be around $1.53 per kgal for its 27.5 MGD facility. While site-specific details can play a larger role, in general, the unit cost to produce 1-4 MGD should be higher than the unit cost to produce 27.5 MGD because of economies of scale. ZDD, at 98 percent recovery, maximizes the amount of water available for consumption while minimizing the environmental and economic cost of concentrate disposal.

The total cost of water produced is summarized in Figure 93. As expected, there is a decrease in the unit cost of water as the production increases due to there being some effect of economies of scale. The estimated capital cost for the ZDD system accounts for 35 to 37 percent of the total cost of water production for ZDD and nearly 63 to 77 percent of the total cost of water by BWRO. The ZDD primary operations and maintenance (OpEx) cost drivers are the NaCl and EDM power consumption. Future optimization and research will aim to reduce the cost of both of these. Using methods proven to be feasible at a bench scale (see Section 11), it is reasonable to expect that up to 90 to 95 percent of the NaCl already in the EDM waste streams can be recovered and used in the EDM, which would reduce the cost of NaCl purchased by up to 50 percent, reduce the amount of deliveries by more than 70 percent, and reduce or eliminate the capital cost of the larger evaporation pond (the combined size for the NaCl recovery evaporation ponds is 10.7 acres vs 18.2 acres for ZDD without NaCl recovery). Improved energy efficiency of the EDM system could also lead to reduced capital cost, because fewer EDM stacks would need to be purchased. Further optimization will minimize recirculating flow to each stack, improve current density and efficiency, and minimize back diffusion from the concentrate streams. Finally, while not included in Figure 93, ZDD will reduce the amount of power used by the Snake Tank wellfield because less volume will be required to produce the same amount of energy. ZDD would reduce the wellfield pumping cost by at least 30 percent (assuming 1000-ft depth for wells). If additional pressure is needed to transport the water from the wellfield to the desalination plant, additional energy savings will be realized if a ZDD system is installed.

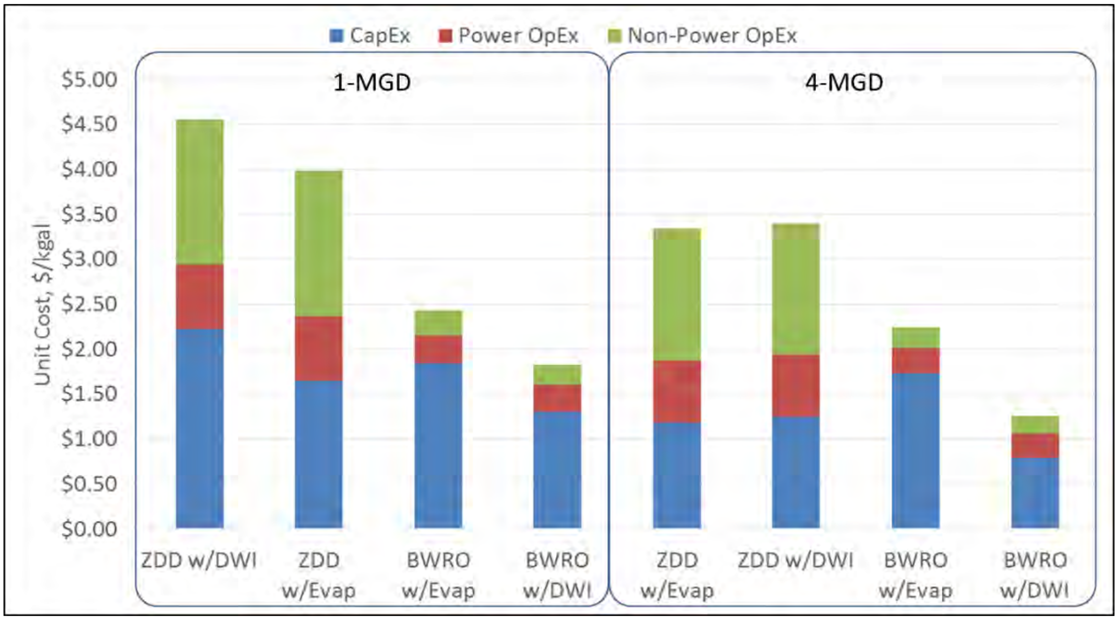


**Figure 93.—Production cost estimates for ZLD, ZDD and BWRO for 1 MGD and 4 MGD designs.**

Conceptual costs for NaCl recovery were estimated for four methods of production, ranging from low capital cost to high capital cost. There is increasing purity expected with increasing cost. All three methods use lime to remove magnesium from the Mixed Cl stream using a clarifier, but the potential revenue for $Mg(OH)_2$ ($375,000 per year) is not included. In Method A (see Table 34) the Mixed Cl stream is combined with the Mixed Na stream stoichiometrically to precipitate calcium sulfate in a clarifier that overflows to an evaporation pond. The remaining fluid, called the supernatant, would be allowed to concentrate in the evaporation pond and then be used directly as the NaCl supply for the EDM. The second method (B in Table 34) would use a mixing channel in place of the $CaSO_4$ clarifier, but all other aspects are the same (the anticipated recovery is expected to be lower than the clarifier method). The final methods (C and in Table 34) would employ an ED system fitted with monovalent-selective ion exchange membranes to recover a high purity NaCl solution from the mixing channel (C) or clarifier effluent (D). Both C and D assume that the process is expected to recover 10 percent less than the clarifier methods. The data in the first column of Table 34 are for the case in which all of the NaCl is purchased. All of the methods have been evaluated at a laboratory scale and are deemed feasible. If a NaCl recovery method is implemented, the annual NaCl purchase cost is expected to be reduced by as much as 28 percent based on a NaCl purchase price of $0.075/lb. If a buyer could be identified for the $Mg(OH)_2$, the revenue would cover the annual cost of NaCl recovery. Detailed calculations are provided in Appendix E.

Table 34.—Conceptual NaCl Recovery Costs (4 MGD, Alamogordo)

| | | **4 MGD** | **A** | **B** | **C** | **D** |
|---|---|---|---|---|---|---|
| NaCl needed | lb/day | 48,350 | -- | -- | -- | |
| NaCl produced | lb/day | -- | 35,910 | 35,910 | 32,319 | 32,319 |
| % NaCl recovered | -- | -- | 90% | 90% | 81% | 81% |
| CapEx of equipment | $/yr | -- | $159,377 | $88,942 | $248,686 | $319,122 |
| OpEx | $/yr | | $159,126 | $267,010 | $267,087 | $159,203 |
| NaCl purchased | lb/day | -- | 12,440 | 12,440 | 16,031 | 16,031 |
| Blended NaCl purity | $Cl/SO_4$ | -- | 75 | 75 | 194 | 194 |
| Solar salt (99.1%) | $Cl/SO_4$ | 232 | -- | -- | -- | -- |
| Morton (99.5%) | $Cl/SO_4$ | 128 | -- | -- | -- | -- |
| Unit cost | $/lb | $0.075 | $0.022 | $0.024 | $0.038 | $0.036 |
| Annual NaCl cost ($1000) | | $1,324 | $633 | $661 | $885 | $859 |

Incorporation of NaCl recovery would lead to a considerable decrease in the overall cost of desalination by ZDD. Operating costs would decrease using any of the methods described, but the lower cost methods show potential to reduce the overall unit cost of treatment by nearly 30 percent. Figure 94 compares the unit cost of a 4 MGD system with evaporation ponds and the same system with the four NaCl recovery methods summarized in Table 34.

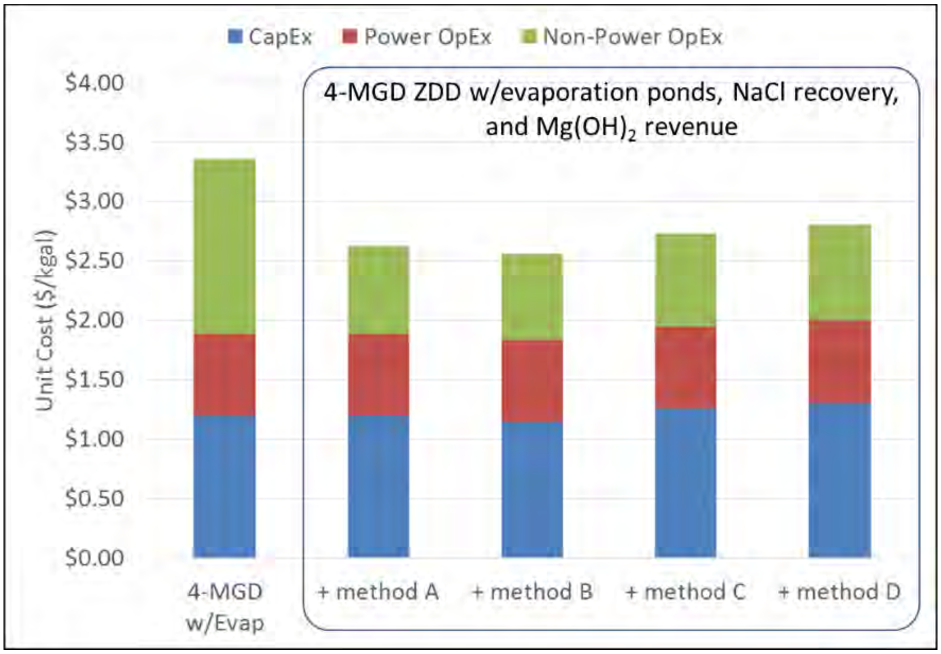


**Figure 94.—Comparison of 4 MGD ZDD System with and without NaCl Recovery (Alamogordo).**

## 12.2 Problems Encountered & Solutions

Developing and demonstrating a new technology is challenging, and problems can and do arise, offering opportunities for improvement. Several challenges were encountered during the piloting and demonstration activities. The most important challenges and the solutions identified are summarized here.

Many of the problems encountered in Colorado and some in Alamogordo can be attributed to inadequate instrumentation and controls and/or lack of remote viewing and control access to the equipment. Specific issues encountered include:

- Improper (or lack of) automated shutdown of equipment. Alarm conditions such as low flow, high pressure, and high temperature were intended to shut down the 20-gpm equipment. Additionally, the interlock, which would shut down the NF if the EDM shut down (and vice versa), between the NF and EDM containers was not working as intended. After the La Junta pilot, the project team found problems in the code that were modified before the system was restarted in Brighton.

- An additional conductivity alarm setpoint will be added for automated shutdown based on low conductivity measured in any of the EDM streams. This will protect the EDM stack from loss of chemical feed or DI valves getting stuck in the open position.

- The Mixed Na and Mixed Cl conductivity probes did not read or calibrate properly, likely because of stray current in the streams. The probes were relocated in both of these concentrate streams (in both the Brighton and Alamogordo locations), and the relocated probes provided accurate signals. This design change will be implemented at the full scale.

- Remote access and control is crucial for long-term operation; however, piloting budgets don’t always allow for all of the necessary instrumentation and interfaces for remote access. The 20 gpm pilot does have remote viewing capability, so the operators must make modifications in person if problems occur. The 40 gpm pilot has remote viewing and control capability.

Training new operators was another challenge for the project team. This is part of commercialization, and many lessons were learned at the project sties. A training manual, such as EDM stack tightening, daily sampling, and operational checklists and alarm/shutdown setpoints, was written and used for Brighton, and that manual was the basis for training operators in Beverly Hills. Adherence to the procedures in the manual seemed to reduce the number and frequency of equipment problems. This manual will be the basis for full scale training operators at full scale and other pilot demonstrations sites. It will be updated as new lessons are learned and better practices identified.

The EDM stacks are constructed with center dividers intended to reduce shunt currents by blocking direct current flow between the electrodes through the solution manifolds. These dividers were the source of internal leakage that caused scale formation and reduced electrical efficiency. The solution compartments on each side of the divide are NaCl and Mixed Na. When these streams mixed, sulfate that entered the NaCl solution compartment was subsequently transported from the NaCl compartment into the Mixed Cl compartment. This is believed to be the cause of membrane swelling and led to loss of flow and increased pressure in the EDM stacks in Alamogordo and in early Beverly Hills activities. New dividers made of thicker HDPE material were constructed by project personnel after the Alamogordo Phase 2 activities were completed. The swollen membranes were replaced in January 2014 in Beverly Hills. The new dividers appeared to eliminate major internal leaks, as scale formation was no longer evident in Brighton and Beverly Hills. To further mitigate this problem, a minor stack modification is being evaluated that could eliminate the scale formation problem even if slight leaks occur. Additionally, MEGA is evaluating different center divider designs that could reduce or eliminate leakage at the center of the stack. Future work will implement solutions identified.

## 12.3 Recommendations and Future Research

ZDD has shown potential to greatly improve desalination recovery and provide good quality drinking water or blend water at four sites with different water quality. Multiple configurations have been evaluated and most of the operating parameters necessary for full scale design have been identified, tested, and validated. Future research is needed to better optimize the EDM system for improved electrical efficiency and to better understand the interaction between salts and solubility in the Mixed Na stream. Finally, the NaCl recovery options tested at the bench scale should be tested at the pilot scale for verification and eventual implementation at the full scale. Each of these opportunities is described here briefly.

Future research will include better characterization of the upper operating limits for solubility in the Mixed Na stream to provide utilities with better information for conductivity setpoints at various temperatures. All anions in the brackish water feed will end up in the Mixed Na stream at very high concentrations. This is not a problem for chloride and sulfate, as sodium chloride and sodium sulfate are both highly soluble at normal operating temperatures (i.e. 25 ºC or higher). However, bicarbonate (and carbonate) can be a problem. Sodium carbonate is similar to sodium sulfate, both in terms of solubility and in terms of its solubility-temperature relationship. Both salts have steep declines in solubility at low temperatures. This is not expected to be a problem at the full scale, where the equipment will be inside a building (pilot systems were in uninsulated containers with exposed piping subject to cold outdoor temperatures in fall and spring). Sodium bicarbonate is much less soluble than the other salts in the Mixed Na stream. Crystallization of sodium bicarbonate can be mitigated by adding acid directly to the Mixed Na stream or by reducing bicarbonate alkalinity in the brackish water feed by adding acid and possibly removing $CO_2$ with an aeration tower.

More research is needed to identify the true limiting current density for safe operations (conservative setpoints have been identified). Most of the scientific literature for limiting current density is based on a two compartment ED system and there is a gap in understanding and interpreting the effect of limiting current density in EDM. This project's work in New Mexico and Colorado, combined with Black & Veatch's efforts in Florida and California, have provided the necessary operational and empirical information to identify conservative setpoints for operation. Careful laboratory experiments aimed at describing the effects of cell velocity, solution chemistry and concentration, as well as NaCl and E-Rinse concentration are needed to fully optimize the EDM and minimize energy consumption.

NaCl recovery has been demonstrated to be feasible and limits for the level of impurities for safe use have been identified. Additional research is needed to determine what level of impurities will cause swelling of the ion exchange membranes between the NaCl and EDM concentrate compartments. Research will also look at whether this effect is limited to a single type of membrane. Full-scale demonstration of NaCl recovery processes, including operating a full-scale EDM system with recovered NaCl should also be performed.

Finally, continuous operation for extended periods of time by utility engineers and water operators will be a primary focus of any future efforts to demonstrate and commercialize this technology.

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# APPENDIX A
# GRAB SAMPLE DATA

**Appendix A1 – Alamogordo, Year 1**

**Appendix A2 – Alamogordo, Year 2**

**Appendix A3 – Brighton, Colorado**

*(Note: La Junta, Colorado, data can be found in* (11) *and Beverly Hills data can be found in* (7)*)*

# APPENDIX A1
# ALAMOGORDO,
# YEAR 1 LOG SHEET DATA

# Appendix A1-1.—Alamogordo Year 1 Grab Sample Data

| **pH** | 3/15/11 | 3/16/11 | 3/17/11 | 3/18/11 | 3/21/11 | 3/22/11 |
|---|---|---|---|---|---|---|
| FEED WATER | 7.76 | 6.86 | 5.73 | 7.53 | 7.67 | 7.55 |
| NF FEED | 7.45 | 7.44 | 7.04 | 7.51 | 7.58 | 7.5 |
| NF PERMEATE | 7.55 | 7.63 | 7.3 | 7.5 | 7.55 | 7.4 |
| NF REJECT | 4.95 | 7.45 | 7.3 | 7.24 | 7.12 | 7.3 |
| EDM FEED | 5.28 | 7.45 | 7.15 | 7.09 | 6.95 | 7.03 |
| EDM DILUATE | 5.4 | 7.3 | 7 | 6.83 | 6.62 | 6.75 |
| EDM MIXED CHLORIDE SALTS | 2.41 | 4.7 | 5.8 | 5.8 | 3.11 | 5.38 |
| EDM MIXED SODIUM SALTS | 6.42 | 8.2 | 8.11 | 8.3 | 7.62 | 8.06 |
| SODIUM CHLORIDE STREAM | 3.01 | 6.97 | 7.17 | 6.83 | 4.02 | 6.42 |
| **Temperature (C)** | 3/15/11 | 3/16/11 | 3/17/11 | 3/18/11 | 3/21/11 | 3/22/11 |
| FEED WATER | 23.2 | 22.9 | 23.8 | 25.8 | 22.9 | 22.3 |
| NF FEED | 23.6 | 23.2 | 23.8 | 26.4 | 23.5 | 22.4 |
| NF PERMEATE | 23.5 | 23.3 | 23.8 | 26.5 | 23.8 | 22.4 |
| NF REJECT | 23.1 | 23.7 | 23.9 | 26.9 | 23.7 | 22.5 |
| EDM FEED | 24.1 | 24.1 | 24.6 | 27.6 | 25 | 23.1 |
| EDM DILUATE | 24.4 | 24.6 | 24.9 | 27.8 | 24.7 | 23.4 |
| EDM MIXED CHLORIDE SALTS | 24.7 | 24.9 | 24.3 | 27.7 | 25.0 | 23.7 |
| EDM MIXED SODIUM SALTS | 24.2 | 25.1 | 24.5 | 27.6 | 25.2 | 23.8 |
| SODIUM CHLORIDE STREAM | 24.6 | 24.7 | 24.9 | 28.1 | 25.2 | 23.3 |
| **Conductivity (μS/cm)** | 3/15/11 | 3/16/11 | 3/17/11 | 3/18/11 | 3/21/11 | 3/22/11 |
| FEED WATER | 3012 | 3448 | 3409 | 2704 | 2675 | 3248 |
| NF FEED | 2286 | 2815 | 2788 | 2137 | 2067 | 2790 |
| NF PERMEATE | 901.1 | 1220 | 1206 | 769.3 | 755.7 | 1144 |
| NF REJECT | 4211 | 4689 | 4786 | 3746 | 3488 | 4685 |
| EDM FEED | 2400 | 2479 | 2740 | 2180 | 2160 | 2883 |
| EDM DILUATE | 1409 | 1298 | 1579 | 1119 | 1111 | 1660 |
| EDM MIXED CHLORIDE SALTS | 50900 | 76650 | 77240 | 89450 | 122000 | 137900 |
| EDM MIXED SODIUM SALTS | 67600 | 82900 | 82170 | 91700 | 108100 | 113900 |
| SODIUM CHLORIDE STREAM | 50270 | 50930 | 47100 | 46270 | 55810 | 55920 |
| **Total Hardness (mg/L as $CaCO_3$)** | 3/15/11 | 3/16/11 | 3/17/11 | 3/18/11 | 3/21/11 | 3/22/11 |
| FEED WATER | 1020 | 1230 | 1240 | 850 | 800 | 1290 |
| NF FEED | 745 | 1045 | 970 | 630 | 580 | 960 |
| NF PERMEATE | 98 | 160 | 164 | 64 | 62 | 166 |
| DI WATER | 0.1 | 0 | 0 | 0 | 0.1 | 0 |
| NF REJECT | 1820 | 2290 | 2330 | 1490 | 1450 | 2230 |
| **Ca Hardness (mg/L as $CaCO_3$)** | 3/15/11 | 3/16/11 | 3/17/11 | 3/18/11 | 3/21/11 | 3/22/11 |
| FEED WATER | 605 | 745 | 770 | 500 | 510 | 730 |
| NF FEED |  | 610 | 555 | 370 | 360 | 600 |
| NF PERMEATE | 6.5 | 12 | 10.5 | 4.8 | 4.2 | 9.9 |
| DI WATER | 20 | 0 | 0 | 0 | 0.1 | 0 |
| NF REJECT | 1090 | 1290 | 1380 | 840 | 870 | 1200 |
| **Mg Hardness (mg/L as $CaCO_3$)** | 3/15/11 | 3/16/11 | 3/17/11 | 3/18/11 | 3/21/11 | 3/22/11 |
| FEED WATER | 415 | 485 | 470 | 350 | 290 | 560 |
| NF FEED |  | 435 | 415 | 260 | 220 | 360 |
| NF PERMEATE | 92 | 148 | 154 | 59 | 58 | 156 |
| DI WATER | -20 | 0 | 0 | 0 | 0 | 0 |
| NF REJECT | 730 | 1000 | 950 | 650 | 580 | 1030 |

# Appendix A1-1.—Alamogordo Year 1 Grab Sample Data

| **pH** | 3/23/11 | 3/24/11 | 3/25/11 | 3/28/11 | 3/29/11 | 3/31/11 |
|---|---|---|---|---|---|---|
| FEED WATER | 7.61 | 7.58 | 7.46 | 7.66 | 7.29 | 7.53 |
| NF FEED | 7.26 | 7.29 | 7.24 | 7.29 | 7 | 7.16 |
| NF PERMEATE | 7.24 | 7.25 | 7.22 | 7.24 | 7.02 | 7.15 |
| NF REJECT | 7.25 | 6.99 | 7.1 | 7.1 | 6.96 | 6.97 |
| EDM FEED | 6.77 | 6.89 | 6.99 | 6.9 | 6.82 | 6.9 |
| EDM DILUATE | 6.32 | 6.5 | 6.75 | 6.61 | 6.48 | 6.61 |
| EDM MIXED CHLORIDE SALTS | 5.26 | 1.96 | 2.26 | 1.95 | 1.83 | 1.66 |
| EDM MIXED SODIUM SALTS | 8.27 | 8.38 | 8.33 | 8.48 | 8.39 | 8.54 |
| SODIUM CHLORIDE STREAM | 6.72 | 3.37 | 4.39 | 3.29 | 3.28 | 2.92 |
| **Temperature (C)** | 3/23/11 | 3/24/11 | 3/25/11 | 3/28/11 | 3/29/11 | 3/31/11 |
| FEED WATER | 21.5 | 21.1 | 21.6 | 21.6 | 21.3 | 21.1 |
| NF FEED | 22.0 | 21.9 | 21.2 | 22.1 | 21.8 | 21.5 |
| NF PERMEATE | 21.9 | 21.8 | 21.2 | 22.4 | 21.8 | 21.6 |
| NF REJECT | 22.7 | 21.8 | 21..4 | 22.4 | 22.1 | 21.9 |
| EDM FEED | 23.1 | 22.8 | 22.7 | 23.6 | 23.4 | 22.9 |
| EDM DILUATE | 23.1 | 23 | 23 | 24.5 | 23.9 | 23.4 |
| EDM MIXED CHLORIDE SALTS | 23.1 | 23.2 | 22.5 | 23.9 | 23.7 | 23.5 |
| EDM MIXED SODIUM SALTS | 23.1 | 23.1 | 22.8 | 23.7 | 23.8 | 23.4 |
| SODIUM CHLORIDE STREAM | 23.2 | 23.3 | 23.3 | 24.2 | 24.1 | 23.6 |
| **Conductivity (μS/cm)** | 3/23/11 | 3/24/11 | 3/25/11 | 3/28/11 | 3/29/11 | 3/31/11 |
| FEED WATER | 2659 | 2939 | 3101 | 2886 | 3337 | 2775 |
| NF FEED | 1981 | 2168 | 2837 | 2561 | 3038 | 2468 |
| NF PERMEATE | 804.7 | 840 | 1006 | 827.1 | 1081 | 816 |
| NF REJECT | 3881 | 3976 | 5202 | 4776 | 5459 | 4620 |
| EDM FEED | 2195 | 2580 | 3713 | 3502 | 3940 | 3545 |
| EDM DILUATE | 1090 | 1298 | 2280 | 2004 | 2377 | 1890 |
| EDM MIXED CHLORIDE SALTS | 135900 | 112600 | 113000 | 129100 | 119800 | 126200 |
| EDM MIXED SODIUM SALTS | 111500 | 96390 | 93570 | 113800 | 111100 | 112500 |
| SODIUM CHLORIDE STREAM | 52440 | 55960 | 52400 | 63050 | 58700 | 62150 |
| **Total Hardness (mg/L as $CaCO_3$)** | 3/23/11 | 3/24/11 | 3/25/11 | 3/28/11 | 3/29/11 | 3/31/11 |
| FEED WATER | 760 | 920 | 1070 | 910 | 1230 | 870 |
| NF FEED | 590 | 670 | 955 | 805 | 1045 | 765 |
| NF PERMEATE | 90 | 76 | 100 | 70 | 114 | 60 |
| DI WATER | 0 | 0 | 0 | 0 | 0.2 | 0 |
| NF REJECT | 1500 | 1700 | 2210 | 1800 | 2500 | 1840 |
| **Ca Hardness (mg/L as $CaCO_3$)** | 3/23/11 | 3/24/11 | 3/25/11 | 3/28/11 | 3/29/11 | 3/31/11 |
| FEED WATER | 530 | 590 | 650 | 640 | 695 | 535 |
| NF FEED | 350 | 415 | 535 | 460 | 560 | 440 |
| NF PERMEATE | 5.1 | 5.4 | 6.8 | 4.4 | 7.5 | 4.2 |
| DI WATER | 0 | 0 | 0 | 0 | 0 | 0 |
| NF REJECT | 880 | 960 | 1340 | 1130 | 1455 | 1030 |
| **Mg Hardness (mg/L as $CaCO_3$)** | 3/23/11 | 3/24/11 | 3/25/11 | 3/28/11 | 3/29/11 | 3/31/11 |
| FEED WATER | 230 | 330 | 420 | 270 | 535 | 335 |
| NF FEED | 240 | 255 | 420 | 345 | 485 | 325 |
| NF PERMEATE | 85 | 71 | 93 | 65.6 | 106.5 | 55.8 |
| DI WATER | 0 | 0 | 0 | 0 | 0.2 | 0 |
| NF REJECT | 620 | 740 | 870 | 670 | 1045 | 810 |

# Appendix A1-1.—Alamogordo Year 1 Grab Sample Data

| **pH** | 4/4/11 | 4/5/11 | 4/6/11 | 4/7/11 | 4/8/11 |
|---|---|---|---|---|---|
| FEED WATER | 7.98 | 7.44 | 7.25 | 7.54 | 7.54 |
| NF FEED | 7.62 | 7.04 | 6.98 | 6.79 | 6.92 |
| NF PERMEATE | 7.85 | 6.99 | 6.96 | 6.69 | 6.83 |
| NF REJECT | 7.01 | 7.02 | 6.91 | 6.74 | 6.75 |
| EDM FEED | 6.97 | 6.93 | 6.78 | 6.65 | 6.82 |
| EDM DILUATE | 7.12 | 6.64 | 6.38 | 6.3 | 6.59 |
| EDM MIXED CHLORIDE SALTS | 1.29 | 1.84 | 1.79 | 1.64 | 2.22 |
| EDM MIXED SODIUM SALTS | 7.8 | 7.93 | 7.18 | 7.93 | 7.06 |
| SODIUM CHLORIDE STREAM | 5.51 | 3.13 | 3 | 2.89 | 3.23 |
| **Temperature (C)** | 4/4/11 | 4/5/11 | 4/6/11 | 4/7/11 | 4/8/11 |
| FEED WATER | 21.1 | 21.7 | 22.4 | 23.5 | 23.6 |
| NF FEED | 21.4 | 22.2 | 23.1 | 24.1 | 24.7 |
| NF PERMEATE | 21.3 | 22.2 | 22.9 | 24.3 | 24.9 |
| NF REJECT | 21.4 | 22.4 | 23.3 | 24.2 | 24.9 |
| EDM FEED | 22.5 | 23.3 | 24.4 | 24.8 | 25.4 |
| EDM DILUATE | 22.9 | 24.3 | 24.8 | 25.3 | 26 |
| EDM MIXED CHLORIDE SALTS | 22.4 | 24.1 | 25.0 | 25.5 | 26.3 |
| EDM MIXED SODIUM SALTS | 22.6 | 24.1 | 25.0 | 25.6 | 26.2 |
| SODIUM CHLORIDE STREAM | 23.1 | 24.4 | 25.3 | 25.2 | 26.1 |
| **Conductivity (μS/cm)** | 4/4/11 | 4/5/11 | 4/6/11 | 4/7/11 | 4/8/11 |
| FEED WATER | 3000 | 2857 | 2902 | 2918 | 2991 |
| NF FEED | 2632 | 2724 | 2818 | 2762 | 3403 |
| NF PERMEATE | 851.5 | 871.7 | 890.2 | 861.7 | 1026 |
| NF REJECT | 4552 | 5021 | 5259 | 5152 | 6453 |
| EDM FEED | 3751 | 4271 | 4429 | 4407 | 5767 |
| EDM DILUATE | 2191 | 2404 | 2591 | 2645 | 4181 |
| EDM MIXED CHLORIDE SALTS |  | 124800 | 104600 | 110700 | 114100 |
| EDM MIXED SODIUM SALTS |  | 109000 | 105600 | 102500 | 108900 |
| SODIUM CHLORIDE STREAM |  | 61280 | 59580 | 61690 | 55290 |
| **Total Hardness (mg/L as $CaCO_3$)** | 4/4/11 | 4/5/11 | 4/6/11 | 4/7/11 | 4/8/11 |
| FEED WATER | 930 | 960 | 800 | 840 | 1180 |
| NF FEED | 790 | 845 | 885 | 850 | 1145 |
| NF PERMEATE | 82 | 94 | 74 | 58 | 76 |
| DI WATER | 0.2 | 0 | 0 | 0 | 0 |
| NF REJECT | 1830 | 1960 | 2240 | 2140 | 2780 |
| **Ca Hardness (mg/L as $CaCO_3$)** | 4/4/11 | 4/5/11 | 4/6/11 | 4/7/11 | 4/8/11 |
| FEED WATER | 575 | 585 | 570 | 595 | 585 |
| NF FEED | 445 | 500 | 545 | 480 | 645 |
| NF PERMEATE | 4.8 | 4.9 | 4.2 | 4 | 3.5 |
| DI WATER | 0 | 0 | 0 | 0 | 0 |
| NF REJECT | 1110 | 1245 | 1250 | 1170 | 1650 |
| **Mg Hardness (mg/L as $CaCO_3$)** | 4/4/11 | 4/5/11 | 4/6/11 | 4/7/11 | 4/8/11 |
| FEED WATER | 355 | 375 | 230 | 245 | 595 |
| NF FEED | 345 | 345 | 340 | 370 | 500 |
| NF PERMEATE | 77.2 | 89.1 | 69.8 | 54 | 72.5 |
| DI WATER | 0.2 | 0 | 0 | 0 | 0 |
| NF REJECT | 720 | 715 | 990 | 970 | 1130 |

# Appendix A1-1.—Alamogordo Year 1 Grab Sample Data

| **T. Alkalinity (mg/L as $CaCO_3$)** | 3/15/11 | 3/16/11 | 3/17/11 | 3/18/11 | 3/21/11 | 3/22/11 |
|---|---|---|---|---|---|---|
| FEED WATER | 120 | 130 | 35 | 210 | 210 | 215 |
| NF FEED | 55 | 130 | 95 | 110 | 95 | 110 |
| NF PERMEATE | 85 | 100 | 90 | 90 | 85 | 90 |
| NF REJECT | 100 | 145 | 115 | 110 | 110 | 135 |
| **Sulfates (mg/L)** | 3/15/11 | 3/16/11 | 3/17/11 | 3/18/11 | 3/21/11 | 3/22/11 |
| FEED WATER | 1150 | 1250 | 1150 | 1000 | 900 | 1000 |
| NF FEED | 1000 | 1050 | 800 | 700 | 650 | 1000 |
| NF PERMEATE | 14 | 16 | 16 | 12 | 10 | 14 |
| EDM FEED | 1250 | 1000 | 850 | 950 | 900 | 1100 |
| EDM DILUATE | 450 | 450 | 650 | 350 | 300 | 650 |
| MIXED CL | 350 | 50 | 650 | 825 | 1500 | 1325 |
| NACL | 600 | 125 | 150 | 400 | 1,150 | 425 |
| **Silica (mg/L)** | 3/15/11 | 3/16/11 | 3/17/11 | 3/18/11 | 3/21/11 | 3/22/11 |
| FEED WATER | 18.6 | 24.8 | 22.7 | 22.3 | 14.3 | 22.1 |
| NF FEED | 13.1 | 25.9 | 22.8 | 24.6 | 20.7 | 22 |
| NF PERMEATE | 19.9 | 20.8 | 21.4 | 20.9 | 22.5 | 23 |
| NF REJECT | 25.7 | 25.1 | 23.9 | 27.6 | 20.9 | 24.4 |
| EDM FEED | 25.4 | 28.4 | 25.5 | 25.5 | 27.9 | 23.8 |
| EDM DILUATE | 28.8 | 25 | 24.3 | 25.5 | 26.1 | 25.1 |

| **T. Alkalinity (mg/L as $CaCO_3$)** | 3/23/11 | 3/24/11 | 3/25/11 | 3/28/11 | 3/29/11 | 3/31/11 |
|---|---|---|---|---|---|---|
| FEED WATER | 220 | 230 | 195 | 210 | 200 | 200 |
| NF FEED | 70 | 75 | 85 | 95 | 70 | 85 |
| NF PERMEATE | 75 | 65 | 80 | 60 | 55 | 60 |
| NF REJECT | 105 | 95 | 125 | 110 | 100 | 125 |
| **Sulfates (mg/L)** | 3/23/11 | 3/24/11 | 3/25/11 | 3/28/11 | 3/29/11 | 3/31/11 |
| FEED WATER | 950 | 1150 | 1450 | 1300 | 1300 | 1150 |
| NF FEED | 800 | 900 | 1200 | 1250 | 1200 | 900 |
| NF PERMEATE | 9 | 11 | 15 | 11 | 13 | 8 |
| EDM FEED | 1100 | 1700 | 2150 | 1900 | 2050 | 1850 |
| EDM DILUATE | 500 | 450 | 1150 | 900 | 1150 | 850 |
| MIXED CL | 2450 | 1700 | 1800 | 1250 | 1450 | 475 |
| NACL | 1,000 | 500 | 500 | 250 | 600 | 625 |
| **Silica (mg/L)** | 3/23/11 | 3/24/11 | 3/25/11 | 3/28/11 | 3/29/11 | 3/31/11 |
| FEED WATER | 23.6 | 22.3 | 16.7 | 15.9 | 19 | 20.9 |
| NF FEED | 23.5 | 23.1 | 23.7 | 19.1 | 21.5 | 24.2 |
| NF PERMEATE | 26.1 | 23.4 | 23.2 | 22.2 | 21.5 | 21.7 |
| NF REJECT | 22.1 | 17.5 | 27.8 | 27.9 | 25.7 | 24.8 |
| EDM FEED | 24.9 | 23.3 | 21.3 | 26.9 | 25.2 | 27.9 |
| EDM DILUATE | 23.7 | 22.3 | 20.2 | 24.6 | 25.9 | 29.2 |

# Appendix A1-1.—Alamogordo Year 1 Grab Sample Data

| **T. Alkalinity (mg/L as $CaCO_3$)** | 4/4/11 | 4/5/11 | 4/6/11 | 4/7/11 | 4/8/11 |
|---|---|---|---|---|---|
| FEED WATER | 210 | 205 | 210 | 210 | 200 |
| NF FEED | 70 | 110 | 100 | 95 | 95 |
| NF PERMEATE | 60 | 70 | 65 | 95 | 80 |
| NF REJECT | 90 | 135 | 135 | 105 | 120 |
| **Sulfates (mg/L)** | 4/4/11 | 4/5/11 | 4/6/11 | 4/7/11 | 4/8/11 |
| FEED WATER | 1100 | 1300 | 1000 | 850 | 850 |
| NF FEED | 850 | 1400 | 1400 | 1150 | 1850 |
| NF PERMEATE | 12 | 7 | 10 | 12 | 15 |
| EDM FEED | 2100 | 2500 | 2400 | 2300 | 3600 |
| EDM DILUATE | 1000 | 1200 | 1450 | 1100 | 2200 |
| MIXED CL | 2250 | 1000 | 900 | 1325 | 950 |
| NACL | 25 | 200 | 500 | 875 | 1,325 |
| **Silica (mg/L)** | 4/4/11 | 4/5/11 | 4/6/11 | 4/7/11 | 4/8/11 |
| FEED WATER | 11.1 | 18.3 | 22.4 | 20.1 | 22.3 |
| NF FEED | 19.7 | 20.5 | 20.1 | 24.1 | 23.6 |
| NF PERMEATE | 16.8 | 22.4 | 23.1 | 23.2 | 22.1 |
| NF REJECT | 23.9 | 23 | 28 | 25.1 | 25.1 |
| EDM FEED | 25.8 | 23.1 | 26.4 | 18.7 | 24.3 |
| EDM DILUATE | 25.7 | 26.5 | 24 | 26.6 | 25.9 |

## Appendix A1-2.—Alamogordo Year 1 Log Sheet Data

| **EDM STACK** | 3/15/11 | 3/16/11 | 3/17/11 | 3/18/11 | 3/21/11 | 3/22/11 |
|---|---|---|---|---|---|---|
| Stack Voltage (VDC) | 79.7 | 101.3 | 90.8 | 90.7 | 100.4 | 100.5 |
| Stack Amperage (amps) | 32.6 | 37.4 | 35.7 | 32.7 | 31.7 | 38.2 |
| **NaCl added (lb)** | 400 | 400 | 400 | 400 | 200 | 200 |
| Totalized Permeate (gal) | 17742 | 19492 | 20177 | 20399 | 20168 | 20026 |
| Totalized Permeate (1000 gal) | 17.742 | 19.492 | 20.177 | 20.399 | 20.168 | 20.026 |
| totalized DI Water (gal) | 30887 | 32289 | 33,298 | 34193 | 35,787 | 36160 |
| Total DI water used (gal) | 1225.0 | 1402 | 1009 | 895 | 1594 | 373 |
| DI used by Mixed Cl salts (gal) | 710.4 | 483.6 | 422.4 | 74.4 | 14.4 | 0 |
| DI used by Mixed Na salts (gal) | 379.50 | 309.00 | 202.50 | 0.00 | 0.00 | 0.00 |
| DI used for salt preparation, etc. | 135.10 | 609.40 | 384.10 | 820.60 | 1579.60 | 373.00 |
| Total Concentrate flows (gal) | 399.47 | 399.47 | 399.47 | 399.47 | 399.47 | 452.73 |
| **Operational Data** | | | | | | |
| RO Concentrate Flow Rate (gpm) | 7 | 7 | 7.2 | 6.7 | 6.8 | 7.2 |
| RO Concentrate Conductivity (µS/cm) | 4694 | 4848 | 4911 | 4415 | 4220 | 4815 |
| RO Concentrate pH | 7.58 | 7.34 | 7.26 | 7.33 | 7.25 | 7.29 |
| EDM Feed Conductivity (mS/cm) | 6.3 | 5.8 | 6.7 | 5 | 4.8 | 6.8 |
| EDM Feed Flow Rate (gpm) | 25.6 | 25.1 | 25.7 | 25.6 | 25.2 | 24.1 |
| EDM Feed Pressure (psi) | 9.5 | 9.9 | 9.5 | 9.6 | 10.2 | 10.7 |
| EDM Feed Temperature ($^{o}$C) | 26.2 | 25.5 | 25.3 | 29.1 | 25.9 | 24.1 |
| Mixed Sodium Salt Conductivity (mS/cm) | 30.9 | 42.3 | 41.7 | 49.4 | 65.9 | 69.2 |
| Mixed Sodium Salt Feed Flow Rate (gpm) | 22.6 | 22.7 | 23.5 | 22.8 | 20.1 | 19.2 |
| Mixed Sodium Salt Feed Pressure (psi) | 10.4 | 11.2 | 10.3 | 10.5 | 11.1 | 11.7 |
| Mixed Chloride Salt Conductivity (mS/cm) | 35.5 | 49.3 | 49.7 | 62.7 | 94.1 | 80.8 |
| Mixed Chloride Salt Feed Flow Rate (gpm) | 25.3 | 24.3 | 25.4 | 25.3 | 24.6 | 24 |
| Mixed Chloride Salt Feed Pressure (psi) | 10.4 | 11.4 | 10.3 | 10.4 | 11.2 | 11.8 |
| Mixed Chloride Salt Feed Temp ($^{o}$C) | 26.8 | 26.4 | 26.2 | 30 | 26.8 | 25 |
| Sodium Chloride Conductivity (mS/cm) | 30.8 | 27.8 | 28.1 | 30.2 | 33 | 34.2 |
| Sodium Chloride Feed Flow Rate (gpm) | 21.3 | 20.4 | 21.4 | 21 | 20.5 | 19.6 |
| Sodium Chloride Feed Pressure (psi) | 10.6 | 11.4 | 10.4 | 10.8 | 11.6 | 12 |
| Electrode Rinse Conductivity (mS/cm) | 13 | 11.8 | 16.2 | 15.2 | 19.9 | 17.8 |
| Electrode Rinse Feed Flow Rate (gpm) | 4.4 | 4.4 | 4.4 | 4.4 | 4.3 | 4.4 |
| Electrode Rinse Feed Pressure (psi) | 35.8 | 35.5 | 36.1 | 35.6 | 35.5 | 35.9 |
| Electrode Rinse Feed Temperature ($^{o}$C) | 25.2 | 26.4 | 26.3 | 29.3 | 26.4 | 23.9 |

# Appendix A1-2.—Alamogordo Year 1 Log Sheet Data

| **EDM STACK** | 3/23/11 | 3/24/11 | 3/25/11 | 3/28/11 | 3/29/11 | 3/31/11 |
|---|---|---|---|---|---|---|
| Stack Voltage (VDC) | 119.9 | 119.6 | 119.9 | 135.3 | 135.0 | 150.1 |
| Stack Amperage (amps) | 33.6 | 36.3 | 49.3 | 49.9 | 55.4 | 49.6 |
| **NaCl added (lb)** | 0 | 200 | 320 | 480 | 480 | 480 |
| Totalized Permeate (gal) | 20039 | 20036 | 29118 | 29085 | 29085 | 29091 |
| Totalized Permeate (1000 gal) | 20.039 | 20.036 | 29.118 | 29.085 | 29.085 | 29.091 |
| totalized DI Water (gal) | 36,342 | 36547 | 36879 | 38317 | 38785 | 39684 |
| Total DI water used (gal) | 182 | 205 | 332 | 1438 | 468 | 899 |
| DI used by Mixed Cl salts (gal) | 0 | 78 | 243.6 | 243.6 | 230.4 | 199.2 |
| DI used by Mixed Na salts (gal) | 0.00 | 31.50 | 72.00 | 72.00 | 18.00 | 30.00 |
| DI used for salt preparation, etc. | 182.00 | 95.50 | 16.40 | 1122.40 | 219.60 | 669.80 |
| Total Concentrate flows (gal) | 391.86 | 433.71 | 498.39 | 498.39 | 595.40 | 547.85 |
| **Operational Data** | | | | | | |
| RO Concentrate Flow Rate (gpm) | 7.1 | 7.1 | 9.1 | 9.7 | 9.9 | 10.9 |
| RO Concentrate Conductivity (μS/cm) | 4159 | 4657 | 5662 | 5276 | 5990 | 5031 |
| RO Concentrate pH | 7.18 | 7.19 | 7.3 | 7.15 | 7.18 | 7.17 |
| EDM Feed Conductivity (mS/cm) | 4.3 | 5.9 | 9.9 | 8.7 | 10.8 | 7.1 |
| EDM Feed Flow Rate (gpm) | 23.9 | 23.2 | 26.4 | 25.3 | 25.1 | 24.2 |
| EDM Feed Pressure (psi) | 10.9 | 11.5 | 12.7 | 13.2 | 13 | 14 |
| EDM Feed Temperature ($^{o}$C) | 22.6 | 22.7 | 22.5 | 22.3 | 22.9 | 22.9 |
| Mixed Sodium Salt Conductivity (mS/cm) | 67.6 | 57 | 59.1 | 61.8 | 48 | 54.2 |
| Mixed Sodium Salt Feed Flow Rate (gpm) | 19.7 | 19 | 18.3 | 18.3 | 18.1 | 18 |
| Mixed Sodium Salt Feed Pressure (psi) | 11.9 | 12.3 | 12.4 | 13.8 | 13.1 | 14.2 |
| Mixed Chloride Salt Conductivity (mS/cm) | 81.3 | 72.9 | 70.4 | 68 | 71.8 | 68.6 |
| Mixed Chloride Salt Feed Flow Rate (gpm) | 23.9 | 23 | 22.9 | 22 | 22.6 | 21.5 |
| Mixed Chloride Salt Feed Pressure (psi) | 11.9 | 12.6 | 12.8 | 13.8 | 13.4 | 14.2 |
| Mixed Chloride Salt Feed Temp ($^{o}$C) | 23.7 | 23.9 | 23.6 | 24.1 | 24.5 | 24.4 |
| Sodium Chloride Conductivity (mS/cm) | 33.8 | 32.9 | 35.3 | 34.6 | 35.3 | 32.7 |
| Sodium Chloride Feed Flow Rate (gpm) | 19.7 | 18.5 | 17.9 | 17.1 | 17 | 16.2 |
| Sodium Chloride Feed Pressure (psi) | 12.1 | 13.3 | 13.5 | 14.4 | 14 | 14.9 |
| Electrode Rinse Conductivity (mS/cm) | 24 | 22.3 | 24.1 | 20.3 | 23.9 | 20 |
| Electrode Rinse Feed Flow Rate (gpm) | 4.3 | 4.5 | 4.3 | 4.6 | 4.6 | 4.6 |
| Electrode Rinse Feed Pressure (psi) | 35.9 | 36.2 | 35.6 | 36.3 | 35.7 | 36.1 |
| Electrode Rinse Feed Temperature ($^{o}$C) | 23.5 | 24.6 | 24.6 | 25.2 | 26.1 | 25.5 |

# Appendix A1-2.—Alamogordo Year 1 Log Sheet Data

| **EDM STACK** | 4/4/11 | 4/5/11 | 4/6/11 | 4/7/11 | 4/8/11 |
|---|---|---|---|---|---|
| Stack Voltage (VDC) | 150.0 | 180.3 | 179.8 | 180.4 | 180.3 |
| Stack Amperage (amps) | 50.3 | 62.4 | 64.5 | 62.3 | 66.3 |
| **NaCl added (lb)** | 480 | 480 | 480 | 320 | 0 |
| Totalized Permeate (gal) | 41074 | 18893 | 33732 | 35341 | 35299 |
| Totalized Permeate (1000 gal) | 41.074 | 18.893 | 33.732 | 35.341 | 35.299 |
| totalized DI Water (gal) | 41074 | 41664 | 42460 | 43063 | 43699 |
| Total DI water used (gal) | 1390 | 590 | 796 | 603 | 636 |
| DI used by Mixed Cl salts (gal) | 0 | 129.6 | 108 | 60 | 88.5 |
| DI used by Mixed Na salts (gal) | 0.00 | 37.50 | 289.20 | 453.60 | 378.00 |
| DI used for salt preparation, etc. | 1390.00 | 422.90 | 398.80 | 89.40 | 169.50 |
| Total Concentrate flows (gal) | 593.50 | 599.21 | 616.33 | 593.50 | 608.72 |
| **Operational Data** | | | | | |
| RO Concentrate Flow Rate (gpm) | 11.4 | 12.6 | 12.6 | 12.5 | 12.8 |
| RO Concentrate Conductivity (µS/cm) | 5176 | 5456 | 5740 | 5569 | 6874 |
| RO Concentrate pH | 7.11 | 6.93 | 6.79 | 6.72 | 6.7 |
| EDM Feed Conductivity (mS/cm) | 9.7 | 5.3 | 5.6 | 5.4 | 9 |
| EDM Feed Flow Rate (gpm) | 23.5 | 24.3 | 23.5 | 23.2 | 23.4 |
| EDM Feed Pressure (psi) | 14.7 | 14.5 | 14.8 | 15 | 15.4 |
| EDM Feed Temperature ($^{o}$C) | 21.7 | 22.6 | 23.7 | 25.7 | 26.3 |
| Mixed Sodium Salt Conductivity (mS/cm) | 49.9 | 54.5 | 51.9 | 54.8 | 54.3 |
| Mixed Sodium Salt Feed Flow Rate (gpm) | 16.7 | 16.9 | 16.5 | 16.7 | 15.9 |
| Mixed Sodium Salt Feed Pressure (psi) | 15.2 | 14.8 | 14.7 | 15 | 15.6 |
| Mixed Chloride Salt Conductivity (mS/cm) | 68.3 | 65.3 | 67.2 | 56.1 | 66.4 |
| Mixed Chloride Salt Feed Flow Rate (gpm) | 19 | 20.7 | 20.3 | 20.6 | 18.9 |
| Mixed Chloride Salt Feed Pressure (psi) | 15.6 | 14.8 | 14.8 | 15 | 16 |
| Mixed Chloride Salt Feed Temp ($^{o}$C) | 23.2 | 24.6 | 25.9 | 27.6 | 28.5 |
| Sodium Chloride Conductivity (mS/cm) | 31.7 | 34.5 | 32.5 | 34 | 33.3 |
| Sodium Chloride Feed Flow Rate (gpm) | 14.7 | 15.5 | 15 | 15.3 | 14.3 |
| Sodium Chloride Feed Pressure (psi) | 16.6 | 15.4 | 15.8 | 16.1 | 16.4 |
| Electrode Rinse Conductivity (mS/cm) | 24.6 | 22.3 | 19.9 | 20.8 | 23.9 |
| Electrode Rinse Feed Flow Rate (gpm) | 4.6 | 4.6 | 4.7 | 5 | 4.7 |
| Electrode Rinse Feed Pressure (psi) | 31.6 | 36.3 | 35.8 | 35.7 | 35.5 |
| Electrode Rinse Feed Temperature ($^{o}$C) | 27.9 | 28.9 | 31.5 | 29 | 34.3 |

# APPENDIX A2
# ALAMOGORDO,
# YEAR 2 GRAB SAMPLE DATA

EDM System Data

| Item | EDM SYSTEM | Tag | units | 3/28/13 16:56 | 3/29/13 10:14 |
|---|---|---|---|---|---|
| 1 | EDM-1 Feed Flow | rotameter | gpm | 31 | 31 |
| 2 | EDM-2 Feed Flow | rotameter | gpm | 26 | 26 |
| 3 | EDM Total Feed Flow | FIT-2111 | gpm | 58.3 | 55.1 |
| 4 | EDM Feed Pressure | PIT-2111 | psi | 18.6 | 18.6 |
| 5 | EDM Feed Conductivity | AIT-2111 | mS/cm | 4.802 | 4.536 |
| 6 | EDM Feed Temperature | TIT-2111 | $^oF$ | 76.7 | 76.2 |
| 7 | EDM Diluate Conductivity | AIT-2110 | mS/cm | 3.295 | 3.14 |
| 8 | EDM Diluate Temperature | TIT-2110 | $^oF$ | 79.6 | 78.8 |
| 9 | EDM-1 Mixed Na Flow | rotameter | gpm | 41 | 40 |
| 10 | EDM-2 Mixed Na Flow | rotameter | gpm | 35 | 35 |
| 11 | EDM Total Mixed Na Flow | FIT-2113 | gpm | 76 | 75 |
| 12 | EDM Mixed Na Pressure | PIT-2113 | psi | 19.5 | 19.5 |
| 13 | EDM Mixed Na Conductivity | AIT-2113 | mS/cm | 2.876 | 25.288 |
| 14 | EDM Mixed Na Temperature | TIT-2113 | $^oF$ | 78.9 | 78.1 |
| 15 | EDM-1 Mixed Cl Flow | rotameter | gpm | 40 | 41 |
| 16 | EDM-2 Mixed Cl Flow | rotameter | gpm | 34 | 34 |
| 17 | EDM Total Mixed Cl Flow | FIT-2115 | gpm | 75.9 | 74.8 |
| 18 | EDM Mixed Cl Pressure | PIT-2115 | psi | 19.5 | 19.3 |
| 19 | EDM Mixed Cl Conductivity | AIT-2115 | mS/cm | 77.021 | 91.576 |
| 20 | EDM Mixed Cl Temperature | TIT-2115 | $^oF$ | 79.4 | 78.7 |
| 21 | EDM-1 NaCl Flow | rotameter | gpm | 36 | 35 |
| 22 | EDM-2 NaCl Flow | rotameter | gpm | 33 | 33 |
| 23 | EDM Total NaCl Flow | FIT-2117 | gpm | 69 | 68 |
| 24 | EDM NaCl Pressure | PIT-2117 | psi | 19.6 | 18.7 |
| 25 | EDM NaCl Conductivity | AIT-2117 | mS/cm | 45.842 | 47.532 |
| 26 | EDM NaCl Temperature | TIT-2117 | $^oF$ | 79.1 | 78.4 |
| 27 | EDM Total E-Rinse Flow | FIT-2124 | gpm | 0 | 9.5 |
| 28 | EDM E-Rinse Pressure | PIT-2124 | psi | 11.9 | 11.9 |
| 29 | EDM E-Rinse Conductivity | AIT-2124 | mS/cm | 23.209 | 22.743 |
| 30 | EDM E-Rinse Temperature | TIT-2124 | $^oF$ | 80.1 | 78.1 |

Appendix A2: Alamogordo Year 2 Logsheet Data
EDM System Data

| Item | 4/1/13 9:28 | 4/1/13 11:15 | 4/1/13 13:22 | 4/2/13 14:38 | 4/3/13 16:40 | 4/5/13 10:06 |
|---|---|---|---|---|---|---|
| 1 | 29 | 31 | 31 | 31 | 32 | 32 |
| 2 | 28 | 26 | 26 | 26 | 25 | 25 |
| 3 | 55 | 57.6 | 56.9 | 57.6 | 51.2 | 54.7 |
| 4 | 20.1 | 18.5 | 18.5 | 18.5 | 18.8 | 18.1 |
| 5 | 4.891 | 4.468 | 4.494 | 4.487 | 4.248 | 4.331 |
| 6 | 73.4 | 77.8 | 79.5 | 79.8 | 75.9 | 76.8 |
| 7 | 3.518 | 3.034 | 3.062 | 3.091 | 2.887 | 2.941 |
| 8 | 75 | 80.3 | 82.2 | 82.6 | 77.6 | 78.8 |
| 9 | 40 | 40 | 40 | 40 | 36 | 36 |
| 10 | 35 | 3.4 | 35 | 35 | 30 | 31 |
| 11 | 75 | 43.4 | 75 | 75 | 66 | 67 |
| 12 | 21.1 | 19.4 | 19.3 | 19.2 | 19.4 | 18.5 |
| 13 | 37.97 | 87.714 | 22.328 | 22.134 | 47.099 | 4.642 |
| 14 | 74.3 | 80.3 | 81.6 | 81.9 | 77.1 | 78.3 |
| 15 | 37 | 35 | 38 | 38 | 37 | 35 |
| 16 | 31 | 29 | 32 | 33 | 29 | 27 |
| 17 | 72 | 66 | 64.8 | 69.5 | 67.4 | 65.2 |
| 18 | 20.9 | 18.8 | 19.2 | 19.2 | 19.4 | 18.5 |
| 19 | 58.393 | 36.977 | 78.435 | 74.271 | 63.795 | 90.901 |
| 20 | 75.1 | 79.6 | 82.2 | 82.5 | 77.8 | 79 |
| 21 | 41 | 39 | 39 | 39 | 40 | 40 |
| 22 | 38 | 35 | 35 | 35 | 35 | 35 |
| 23 | 79 | 74 | 74 | 74 | 75 | 75 |
| 24 | 20.9 | 18.9 | 19 | 18.9 | 19.3 | 18.4 |
| 25 | 45.911 | 50.985 | 42.178 | 48.827 | 47.389 | 46.857 |
| 26 | 74.9 | 80 | 81.9 | 82.2 | 77.6 | 78.8 |
| 27 | 10.2 | 9.3 | 10.2 | 10.1 | 9.2 | 12.3 |
| 28 | 12.2 | 12 | 12.1 | 12.2 | 12.2 | 11.9 |
| 29 | 23.178 | 23.329 | 23.081 | 23.553 | 17.612 | 22.69 |
| 30 | 72.6 | 79.4 | 82.4 | 82.9 | 75.8 | 76.9 |

Appendix A2: Alamogordo Year 2 Logsheet Data
EDM System Data

| Item | 4/5/13 11:48 | 4/8/13 10:51 | 4/8/13 14:42 | 4/8/13 17:05 | 4/9/13 10:49 | 4/9/13 16:35 |
|---|---|---|---|---|---|---|
| 1 | 33 | 33 | 33 | 34 | 34 | 34 |
| 2 | 25 | 24 | 24 | 24 | 24 | 24 |
| 3 | 56.9 | 55.2 | 59.2 | 53.7 | 56.3 | 58 |
| 4 | 18.3 | 18.5 | 19.1 | 19.1 | 20.4 | 20.5 |
| 5 | 4.351 | 4.152 | 4.703 | 4.772 | 4.778 | 5.314 |
| 6 | 78.1 | 78.8 | 80.9 | 81.3 | 77.7 | 78.4 |
| 7 | 2.959 | 2.768 | 3.285 | 3.34 | 3.469 | 3.812 |
| 8 | 80.4 | 80.9 | 83.3 | 83.8 | 79.9 | 80.7 |
| 9 | 39 | 38 | 41 | 42 | 42 | 44 |
| 10 | 30 | 30 | 31 | 31 | 31 | 32 |
| 11 | 69 | 68 | 72 | 73 | 73 | 76 |
| 12 | 18.3 | 18.6 | 19.6 | 19.7 | 21.4 | 21.1 |
| 13 | 4.574 | 4.702 | 2.082 | 2.022 | 2.144 | 1.952 |
| 14 | 79.6 | 80.3 | 82.7 | 83.2 | 79.2 | 79.9 |
| 15 | 38 | 35 | 41 | 42 | 42 | 44 |
| 16 | 29 | 29 | 29 | 30 | 30 | 32 |
| 17 | 63.8 | 68.2 | 64.3 | 71.1 | 76.3 | 67.6 |
| 18 | 18.6 | 19.3 | 19.4 | 19.6 | 21.2 | 20.9 |
| 19 | 82.929 | 88.842 | 43.882 | 38.831 | 52.395 | 39.833 |
| 20 | 80.4 | 81 | 83.3 | 83.9 | 79.9 | 80.6 |
| 21 | 39 | 42 | 42 | 44 | 45 | 45 |
| 22 | 37 | 38 | 37 | 39 | 37 | 37 |
| 23 | 76 | 80 | 79 | 83 | 82 | 82 |
| 24 | 18.4 | 18.7 | 19.6 | 19.5 | 20.6 | 20.7 |
| 25 | 45.49 | 47.38 | 46.299 | 55.103 | 47.09 | 45.79 |
| 26 | 80.1 | 80.7 | 83.1 | 83.6 | 79.7 | 80.3 |
| 27 | 12.3 | 11.5 | 11.3 | 12.1 | 11.5 | 12 |
| 28 | 11.9 | 11.9 | 12.2 | 12.1 | 12.8 | 12.9 |
| 29 | 23.397 | 21.988 | 22.436 | 22.028 | 22.089 | 21.642 |
| 30 | 79.9 | 79 | 83.1 | 83.7 | 76.7 | 78.3 |

Appendix A2: Alamogordo Year 2 Logsheet Data

EDM System Data

| **Item** | **4/10/13 11:16** | **4/10/13 16:30** | **4/11/13 11:55** | **4/11/13 13:42** | **4/11/13 16:00** | **4/11/13 17:03** |
|---|---|---|---|---|---|---|
| 1 | 34 | 34 | 34 | 34 | 33 | 33 |
| 2 | 24 | 24 | 25 | 25 | 24 | 25 |
| 3 | 55.8 | 56.7 | 57.5 | 58.1 | 55 | 55.4 |
| 4 | 20.7 | 20.5 | 21 | 21.1 | 21.3 | 21.5 |
| 5 | 5.192 | 5.703 | 4.905 | 5.134 | 5.441 | 5.446 |
| 6 | 77.8 | 78.3 | 77.2 | 77.8 | 78.7 | 78.8 |
| 7 | 3.578 | 3.904 | 3.324 | 3.376 | 3.588 | 3.665 |
| 8 | 80.2 | 80.9 | 79.8 | 80.6 | 81.5 | 81.8 |
| 9 | 43 | 43 | 41 | 41 | 43 | 42 |
| 10 | 31 | 32 | 31 | 31 | 33 | 32 |
| 11 | 74 | 75 | 72 | 72 | 76 | 74 |
| 12 | 21.5 | 21.4 | 21.9 | 21 | 21.1 | 21.6 |
| 13 | 1.96 | 1.935 | 2.012 | 1.89 | 1.969 | 1.892 |
| 14 | 79.6 | 80 | 79.1 | 79.7 | 80.8 | 81.1 |
| 15 | 44 | 44 | 43 | 44 | 44 | 44 |
| 16 | 31 | 30 | 31 | 32 | 33 | 33 |
| 17 | 69.4 | 73.3 | 72 | 74 | 71 | 70.3 |
| 18 | 21.8 | 21.4 | 21.4 | 21.7 | 21.2 | 21.2 |
| 19 | 38.175 | 33.917 | 43.077 | 35.427 | 30.651 | 31.589 |
| 20 | 80.3 | 80.7 | 79.8 | 80.5 | 81.5 | 81.8 |
| 21 | 45 | 45 | 43 | 45 | 44 | 43 |
| 22 | 37 | 37 | 36 | 38 | 37 | 37 |
| 23 | 82 | 82 | 79 | 83 | 81 | 80 |
| 24 | 20.5 | 21.5 | 21.4 | 21.4 | 21.8 | 21.5 |
| 25 | 46.034 | 49.059 | 47.937 | 42.579 | 46.011 | 45.676 |
| 26 | 79.9 | 80.4 | 79.5 | 80.2 | 81.2 | 81.5 |
| 27 | 11.5 | 10.4 | 10.4 | 11.5 | 11.3 | 11 |
| 28 | 12.8 | 13 | 13.1 | 13.3 | 13.4 | 13.4 |
| 29 | 22.407 | 20.696 | 22.249 | 22.118 | 19.979 | 21.11 |
| 30 | 78.9 | 79.9 | 79.4 | 81.1 | 82.2 | 82.5 |

Appendix A2: Alamogordo Year 2 Logsheet Data
EDM System Data

| Item | 4/17/13 10:45 | 4/17/13 14:54 | 4/17/13 16:15 | 4/18/13 10:30 | 4/18/13 13:03 | 4/18/13 16:16 |
|---|---|---|---|---|---|---|
| 1 | 31 | 31 | 31 | 31 | 31 | 31 |
| 2 | 27 | 27 | 27 | 27 | 27 | 27 |
| 3 | 53.3 | 56.7 | 56.8 | 59.4 | 59.2 | 60.4 |
| 4 | 14.1 | 13.9 | 14.1 | 14.6 | 14.8 | 14.5 |
| 5 | 4.258 | 4.338 | 4.453 | 4.672 | 4675 | 4822 |
| 6 | 78.5 | 80.8 | 80.1 | 75.6 | 77.1 | 77.7 |
| 7 | 2.995 | 3.07 | 3.195 | 3.476 | 3.464 | 3.629 |
| 8 | 80.6 | 83.2 | 82.2 | 77.5 | 79 | 80 |
| 9 | 32 | 32 | 32 | 33 | 34 | 34 |
| 10 | 30 | 30 | 29 | 29 | 28 | 30 |
| 11 | 62 | 62 | 61 | 62 | 62 | 64 |
| 12 | 14 | 13.9 | 14.1 | 14.5 | 14.4 | 14.6 |
| 13 | 5.441 | 5.449 | 44.014 | 68.785 | 61.5 | 61.626 |
| 14 | 80 | 82.4 | 81.6 | 76.9 | 78.7 | 79.4 |
| 15 | 30 | 33 | 33 | 33 | 33 | 33 |
| 16 | 27 | 30 | 29 | 29 | 29 | 29 |
| 17 | 60.3 | 57.9 | 57.5 | 62.5 | 62 | 59.1 |
| 18 | 13.9 | 13.9 | 14.5 | 15 | 14.7 | 14.7 |
| 19 | 147.415 | 165.757 | 147.836 | 127.936 | 164.4 | 168.289 |
| 20 | 80.6 | 83.1 | 82.2 | 77.6 | 79.3 | 80.1 |
| 21 | 34 | 36 | 36 | 39 | 38 | 39 |
| 22 | 32 | 34 | 34 | 37 | 36 | 37 |
| 23 | 66 | 70 | 70 | 76 | 74 | 76 |
| 24 | 14 | 14 | 14.7 | 14.4 | 14.7 | 14.4 |
| 25 | 47.556 | 50.533 | 58.378 | 53.525 | 48.154 | 48.558 |
| 26 | 80.3 | 82.8 | 82.1 | 77.2 | 78.9 | 79.8 |
| 27 | 11.9 | 12.8 | 0 | 0 | 0 | 0 |
| 28 | 10 | 10.3 | 10.3 | 10.5 | 10.6 | 10.9 |
| 29 | 20.398 | 22.408 | 20.891 | 21.777 | 21.941 | 22.271 |
| 30 | 79.6 | 83.2 | 82 | 75.7 | 78.3 | 79.8 |

Appendix A2: Alamogordo Year 2 Logsheet Data
EDM System Data

| Item | 4/19/13 10:41 | 4/19/13 13:57 | 4/19/13 17:50 | 4/19/13 21:50 | 4/20/13 8:27 | 4/22/13 11:24 |
|---|---|---|---|---|---|---|
| 1 | 32 | 31 | 31 | 31 | 31 | 32 |
| 2 | 27 | 26 | 26 | 26 | 26 | 26 |
| 3 | 59 | 55.5 | 55.3 | 56.6 | 56.8 | 57 |
| 4 | 14.5 | 14.7 | 14.6 | 14.8 | 14.7 | 15.3 |
| 5 | 4.826 | 4.835 | 4.81 | 4.99 | 5265 | 4.57 |
| 6 | 75.6 | 77.3 | 77.9 | 77.2 | 76.2 | 78.6 |
| 7 | 3.554 | 3.551 | 3.547 | 3.744 | 4.012 | 3.384 |
| 8 | 77.8 | 79.9 | 80.5 | 79.8 | 78.7 | 80.8 |
| 9 | 36 | 36 | 36 | 36 | 37 | 36 |
| 10 | 31 | 30 | 30 | 30 | 31 | 28 |
| 11 | 67 | 66 | 66 | 66 | 68 | 64 |
| 12 | 14.7 | 14.6 | 14.9 | 14.7 | 14.9 | 15.6 |
| 13 | 69.887 | 72.585 | 76.667 | 78.785 | 76.3202 | 54.411 |
| 14 | 77.2 | 79.2 | 79.6 | 79.1 | 78.1 | 80.1 |
| 15 | 35 | 36 | 36 | 36 | 37 | 35 |
| 16 | 30 | 31 | 31 | 31 | 31 | 28 |
| 17 | 57.7 | 59 | 62.3 | 60.3 | 64.4 | 57.2 |
| 18 | 14.5 | 14.3 | 14.6 | 14.9 | 14.9 | 15.9 |
| 19 | 175.395 | 166.434 | 166.883 | 158.21 | 161.506 | 114.3 |
| 20 | 77.9 | 79.8 | 80.4 | 79.7 | 78.7 | 80.8 |
| 21 | 39 | 39 | 39 | 39 | 39 | 41 |
| 22 | 37 | 37 | 37 | 37 | 37 | 34 |
| 23 | 76 | 76 | 76 | 76 | 76 | 75 |
| 24 | 14.9 | 14.8 | 15 | 14.9 | 14.9 | 15.2 |
| 25 | 50.045 | 52.326 | 48.832 | 45.666 | 49.629 | 45.843 |
| 26 | 77.5 | 79.5 | 80.1 | 79.4 | 78.3 | 80.6 |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 10.8 | 10.8 | 10.7 | 10.8 | 10.9 | 10.7 |
| 29 | 23.101 | 24.974 | 24.622 | 22.834 | 23.376 | 23.461 |
| 30 | 76.9 | 79.6 | 80.1 | 78.2 | 78.1 | 81.7 |

Appendix A2: Alamogordo Year 2 Logsheet Data
EDM System Data

| Item | 4/22/13 13:34 | 4/22/13 16:18 | 4/22/13 21:45 | 4/23/13 8:27 | 4/23/13 11:00 | 4/23/13 15:22 |
|---|---|---|---|---|---|---|
| 1 | 32 | 33 | 32 | 32 | 28 | 27 |
| 2 | 26 | 27 | 26 | 26 | 25 | 25 |
| 3 | 58 | 59.9 | 57.1 | 54.3 | 52.9 | 51.4 |
| 4 | 15.2 | 15.4 | 15.7 | 15.7 | 15.1 | 15.1 |
| 5 | 4.635 | 4.806 | 5.06 | 5.539 | 5.486 | 5.436 |
| 6 | 79.5 | 80 | 78.7 | 78.9 | 79.8 | 81 |
| 7 | 3.471 | 3.607 | 3.758 | 4.049 | 3.879 | 3.881 |
| 8 | 81.9 | 82.5 | 78.7 | 81.4 | 82.5 | 84 |
| 9 | 36 | 37 | 37 | 37 | 33 | 33 |
| 10 | 28 | 29 | 29 | 29 | 28 | 29 |
| 11 | 64 | 66 | 66 | 66 | 61 | 62 |
| 12 | 15.5 | 15.5 | 15.4 | 15.4 | 15.2 | 15.1 |
| 13 | 48.047 | 44.151 | 57.981 | 50.225 | 48.129 | 41.159 |
| 14 | 81 | 81.9 | 80.4 | 80.7 | 81.8 | 83.2 |
| 15 | 35 | 35 | 37 | 37 | 36 | 35 |
| 16 | 28 | 29 | 29 | 30 | 31 | 30 |
| 17 | 61.6 | 60.2 | 64.7 | 67.8 | 63.7 | 61.6 |
| 18 | 15.6 | 15.6 | 15.9 | 15.7 | 15.1 | 15 |
| 19 | 106.453 | 124.852 | 138.275 | 148.59 | 152.376 | 122.776 |
| 20 | 81.8 | 82.5 | 76 | 69.1 | 65.7 | 78.7 |
| 21 | 41 | 40 | 40 | 41 | 35 | 35 |
| 22 | 34 | 34 | 35 | 35 | 30 | 30 |
| 23 | 75 | 74 | 75 | 76 | 65 | 65 |
| 24 | 15.3 | 15.2 | 15.7 | 15.7 | 15 | 15.1 |
| 25 | 47.251 | 53.126 | 50.642 | 46.35 | 44.718 | 54.911 |
| 26 | 81.5 | 82.2 | 80.8 | 81 | 82.2 | 83.7 |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 10.7 | 10.9 | 11.1 | 11.2 | 11.2 | 11.1 |
| 29 | 23.708 | 23.688 | 24.123 | 23.271 | 23.261 | 26.263 |
| 30 | 83.3 | 84.3 | 80.9 | 81.1 | 82.5 | 84.9 |

Appendix A2: Alamogordo Year 2 Logsheet Data

EDM System Data

| Item | 4/23/13 22:30 | 4/24/13 8:16 | 4/25/13 16:52 | 4/25/13 21:45 | 4/26/13 8:25 | 4/30/13 16:00 |
|---|---|---|---|---|---|---|
| 1 | 27 | 31 | 27 | 28 | 28 | 27 |
| 2 | 25 | 28 | 0 | 0 | 0 | 0 |
| 3 | 51.1 | 54.2 | 25.3 | 27.1 | 27.6 | 24.4 |
| 4 | 15.2 | 18 | 11.4 | 11.8 | 12 | 12.3 |
| 5 | 5.578 | 5.674 | 4.851 | 4.829 | 4.811 | 4.865 |
| 6 | 79.5 | 77.9 | 79.9 | 78.7 | 76.2 | 83.6 |
| 7 | 4.072 | 4.332 | 3.37 | 3.449 | 3.47 | 3.296 |
| 8 | 82.2 | 80.3 | 82.3 | 81.1 | 78.3 | 86.2 |
| 9 | 34 | 38 | 30 | 31 | 33 | 31 |
| 10 | 29 | 30 | 0 | 0 | 0 | 0 |
| 11 | 63 | 68 | 30 | 31 | 33 | 31 |
| 12 | 15.2 | 18.3 | 11.9 | 11.9 | 12.1 | 12.3 |
| 13 | 45.772 | 107.644 | 107.064 | 106.504 | 106.79 | 108.521 |
| 14 | 81.4 | 79.5 | 81.6 | 80.4 | 77.7 | 85.5 |
| 15 | 35 | 38 | 32 | 32 | 30 | 30 |
| 16 | 30 | 32 | 0 | 0 | 0 | 0 |
| 17 | 63.6 | 68.2 | 30.9 | 32.1 | 33 | 31.2 |
| 18 | 15.4 | 18.5 | 11.4 | 11.5 | 12.1 | 12.6 |
| 19 | 143.2 | 1639.18 | 1660.94 | 1681.75 | 1547.48 | 151.409 |
| 20 | 67.4 | -4 | -4 | -4 | -4 | 86.3 |
| 21 | 35 | 40 | 30 | 31 | 32 | 33 |
| 22 | 32 | 35 | 0 | 0 | 0 | 0 |
| 23 | 67 | 75 | 30 | 31 | 32 | 33 |
| 24 | 15.2 | 18.4 | 11.6 | 11.6 | 12.1 | 12.6 |
| 25 | 43.347 | 43.983 | 52.592 | 50.878 | 50.957 | 55.762 |
| 26 | 81.8 | 78.9 | 82 | 80.8 | 78 | 85.9 |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 11.2 | 11.8 | 12 | 12.1 | 12.4 | 12.8 |
| 29 | 27.4 | 25.191 | 21.674 | 21.584 | 21.518 | 20.95 |
| 30 | 81.1 | 78.9 | 82 | 79 | 76.1 | 86.6 |

Appendix A2: Alamogordo Year 2 Logsheet Data

EDM System Data

| Item | 4/30/13 21:51 | 5/1/13 8:53 | 5/1/13 13:35 | 5/1/13 16:41 | 5/1/13 21:20 | 5/2/13 7:56 |
|---|---|---|---|---|---|---|
| 1 | 27 | 28 | 27 | 27 | 27 | 28 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 27.1 | 26.6 | 26.8 | 26.1 | 26.8 | 27.8 |
| 4 | 12.8 | 13 | 13 | 13.1 | 13.2 | 13.6 |
| 5 | 5.144 | 5.489 | 5.108 | 4.932 | 4.888 | 5.599 |
| 6 | 82.1 | 80.1 | 82.1 | 85.2 | 83.1 | 79.2 |
| 7 | 3.555 | 4.047 | 3.622 | 3.569 | 3.54 | 4.299 |
| 8 | 84.8 | 82.4 | 84.8 | 87.7 | 85.4 | 81.2 |
| 9 | 31 | 31 | 30 | 32 | 30 | 30 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 31 | 31 | 30 | 32 | 30 | 30 |
| 12 | 13.4 | 13.1 | 13.5 | 13.5 | 12.9 | 13.4 |
| 13 | 106.331 | 105.592 | 104.483 | 104.516 | 115.759 | 110.73 |
| 14 | 84.1 | 81.7 | 84.1 | 87 | 84.7 | 80.4 |
| 15 | 31 | 33 | 33 | 31 | 31 | 32 |
| 16 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | 32.7 | 32.6 | 32.5 | 32.4 | 32.5 | 31.5 |
| 18 | 13.2 | 13.4 | 13.2 | 13.5 | 13.5 | 13.4 |
| 19 | 160.687 | 150.749 | 158.307 | 163.858 | 152.579 | 147.23 |
| 20 | 84.7 | 82.4 | 84.8 | 87.8 | 85.4 | 81.2 |
| 21 | 33 | 34 | 35 | 33 | 34 | 34 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 33 | 34 | 35 | 33 | 34 | 34 |
| 24 | 13.4 | 13.4 | 13.6 | 13.5 | 13.4 | 13.5 |
| 25 | 53.143 | 50.966 | 50.783 | 51.834 | 51.481 | 50.216 |
| 26 | 84.5 | 82.2 | 84.5 | 87.4 | 85.1 | 81 |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 13.2 | 13.6 | 13.3 | 13.4 | 13.5 | 13.8 |
| 29 | 21.92 | 2.809 | 21.372 | 21.947 | 22.007 | 21.507 |
| 30 | 82.2 | 80.8 | 86.5 | 88.1 | 83.2 | 77.5 |

Appendix A2: Alamogordo Year 2 Logsheet Data
EDM System Data

| Item | 5/2/13 14:37 | 5/2/13 21:46 | 5/29/13 13:50 | 5/31/13 13:32 | 5/31/13 15:20 | 6/3/13 11:33 |
|---|---|---|---|---|---|---|
| 1 | 27 | 27 | 32 | 32 | 33 | 33 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 25.3 | 26.3 | 31.4 | 33 | 30.4 | 33.5 |
| 4 | 13.6 | 13.7 | 23.3 | 22.4 | 22.6 | 27 |
| 5 | 4.731 | 4.98 | 4.735 | 5.128 | 5.888 | 5.336 |
| 6 | 81 | 78.1 | 90.1 | 84.3 | 85 | 84.4 |
| 7 | 3.446 | 3.726 | 3.412 | 3.975 | 4.806 | 4.184 |
| 8 | 83.1 | 80.2 | 92.2 | 86.2 | 87.1 | 86.1 |
| 9 | 34 | 32 | 28 | 29 | 30 | 40 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 34 | 32 | 28 | 29 | 30 | 40 |
| 12 | 14.3 | 14.3 | 23.5 | 22.8 | 23.1 | 26.8 |
| 13 | 106.017 | 106.972 | 102.069 | 82.05 | 81.34 | 73.546 |
| 14 | 82.4 | 79.5 | 91.6 | 85.6 | 86.4 | 86.6 |
| 15 | 31 | 31 | 40 | 39 | 38 | 42 |
| 16 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | 31 | 31 | 40.2 | 36.1 | 36.7 | 38 |
| 18 | 14.2 | 14.2 | 23.1 | 22.6 | 22.9 | 27.9 |
| 19 | 158.041 | 154.467 | 148.588 | 152.436 | 156.688 | 123.665 |
| 20 | 83.1 | 80.2 | 92.3 | 86.5 | 87.3 | 86.5 |
| 21 | 34 | 33 | 40 | 41 | 41 | 45 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 34 | 33 | 40 | 41 | 41 | 45 |
| 24 | 13.9 | 13.8 | 23.8 | 22.7 | 23.2 | 26.8 |
| 25 | 51.458 | 53.745 | 52.834 | 49.968 | 50.744 | 50.667 |
| 26 | 82.9 | 79.9 | 91.9 | 86.1 | 86.8 | 86.3 |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 14.1 | 14.3 | 19.3 | 19.4 | 19.3 | 20.7 |
| 29 | 21.859 | 21.186 | 22.554 | 22.221 | 21.812 | 22.074 |
| 30 | 82.8 | 76.7 | 90.3 | 86.5 | 87.7 | 86.7 |

Appendix A2: Alamogordo Year 2 Logsheet Data
EDM System Data

| Item | 6/3/13 14:46 | 6/4/13 11:10 | 6/4/13 14:55 | 6/4/13 16:50 | 6/10/13 0:00 | 6/14/13 15:35 |
|---|---|---|---|---|---|---|
| 1 | 32 | 32 | 33 | 32 | 24 | 25 |
| 2 | 0 | 0 | 0 | 0 | 29 | 28 |
| 3 | 30.2 | 31.5 | 31.2 | 32.8 | 50.3 | 51.5 |
| 4 | 26.9 | 24.6 | 25 | 25 | 14.3 | 14.6 |
| 5 | 5.469 | 5.076 | 5.117 | 5.135 | 4.771 | 4.26 |
| 6 | 86 | 84.9 | 86.6 | 87.1 | 86.6 | 87.4 |
| 7 | 4.29 | 3.851 | 3.939 | 3.954 | 3.3 | 2.833 |
| 8 | 87.9 | 86.7 | 88.6 | 89.1 | 88.2 | 89.4 |
| 9 | 42 | 41 | 39 | 37 | 26 | 30 |
| 10 | 0 | 0 | 0 | 0 | 22 | 32 |
| 11 | 42 | 41 | 39 | 37 | 48 | 62 |
| 12 | 26.7 | 25.6 | 24.8 | 25.1 | 15 | 14.6 |
| 13 | 112.128 | 107.087 | 100.407 | 104.942 | 6.482 | 26.625 |
| 14 | 88.4 | 87.3 | 89.2 | 89.6 | 88.9 | 89.8 |
| 15 | 41 | 41 | 40 | 38 | 25 | 29 |
| 16 | 0 | 0 | 0 | 0 | 30 | 32 |
| 17 | 40 | 38.1 | 35.3 | 35.6 | 61.3 | 62.5 |
| 18 | 27.7 | 24.5 | 25.4 | 26.1 | 14.2 | 14.4 |
| 19 | 158.744 | 138.194 | 160.881 | 162.308 | 9.391 | 104.309 |
| 20 | 88.4 | 87.2 | 89.1 | 89.6 | 88.7 | 89.5 |
| 21 | 42 | 45 | 41 | 41 | 26 | 30 |
| 22 | 0 | 0 | 0 | 0 | 30 | 32 |
| 23 | 42 | 45 | 41 | 41 | 56 | 62 |
| 24 | 27.2 | 25.1 | 24.6 | 25.6 | 14.8 | 14.6 |
| 25 | 50.71 | 50.489 | 54.842 | 53.837 | 46.179 | 48.953 |
| 26 | 88.1 | 56.9 | 88.8 | 89.3 | 88.6 | 89.4 |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 20.8 | 20.5 | 20.6 | 20.7 | 10.7 | 11.2 |
| 29 | 21.796 | 21.389 | 21.812 | 21.85 | 18.954 | 22.131 |
| 30 | 89.1 | 86.9 | 89.7 | 90.3 | 88.3 | 87.6 |

## Appendix A2: Alamogordo Year 2 Logsheet Data
## EDM System Data

| Item | 6/17/13 13:47 | 6/18/13 11:15 | 6/18/13 14:15 | 6/18/13 17:23 | 6/19/13 10:21 | 6/19/13 14:26 |
|---|---|---|---|---|---|---|
| 1 | 26 | 25 | 25 | 25 | 25 | 25 |
| 2 | 32 | 32 | 32 | 32 | 33 | 33 |
| 3 | 57.6 | 54.4 | 56.7 | 54.7 | 56.2 | 56.2 |
| 4 | 18.1 | 18.1 | 18.2 | 18.1 | 18.6 | 18.7 |
| 5 | 4.752 | 4.758 | 4.676 | 4.664 | 5.768 | 4.674 |
| 6 | 86.5 | 85.6 | 87 | 89.5 | 85.3 | 86.9 |
| 7 | 3.492 | 3.442 | 3.394 | 3.387 | 4.548 | 3.566 |
| 8 | 88.3 | 387.3 | 88.8 | 89.6 | 87.1 | 88.5 |
| 9 | 35 | 35 | 35 | 34 | 36 | 35 |
| 10 | 39 | 39 | 39 | 37 | 41 | 40 |
| 11 | 74 | 74 | 74 | 71 | 77 | 75 |
| 12 | 17.9 | 18.8 | 18.5 | 18.3 | 18.4 | 18.8 |
| 13 | 40.421 | 35.356 | 34.717 | 32.407 | 49.729 | 35.894 |
| 14 | 88.7 | 87.8 | 89.3 | 90.1 | 87.6 | 89.2 |
| 15 | 30 | 31 | 33 | 32 | 32 | 32 |
| 16 | 36 | 36 | 37 | 35 | 38 | 37 |
| 17 | 70.8 | 69.5 | 67.4 | 67.2 | 68.2 | 72.7 |
| 18 | 18 | 18.7 | 18.9 | 18.2 | 19.1 | 18.9 |
| 19 | 148.937 | 95.903 | 132.379 | 136.586 | 144.53 | 142.211 |
| 20 | 88.5 | 87.6 | 89.1 | 89.9 | 87.4 | 88.9 |
| 21 | 30 | 35 | 35 | 37 | 37 | 37 |
| 22 | 34 | 37 | 37 | 40 | 40 | 40 |
| 23 | 64 | 72 | 72 | 77 | 77 | 77 |
| 24 | 18.2 | 18.2 | 18.7 | 18.1 | 18.4 | 19 |
| 25 | 42.585 | 50.451 | 50.063 | 52.332 | 51.192 | 50.782 |
| 26 | 88.5 | 87.5 | 89.1 | 89.8 | 87.3 | 88.8 |
| 27 | 12.1 | 12.1 | 11.6 | 11.9 | 11.7 | 11.6 |
| 28 | 12 | 12.1 | 12.2 | 12.2 | 12.6 | 12.7 |
| 29 | 22.343 | 22.185 | 21.778 | 22.079 | 21.663 | 22.029 |
| 30 | 87.6 | 86.1 | 88.3 | 89 | 86.7 | 88.3 |

## Appendix A2: Alamogordo Year 2 Logsheet Data

### EDM System Data

| **Item** | **6/20/13 10:06** | **6/20/13 14:29** | **6/21/13 8:25** | **6/21/13 11:13** | **6/21/13 14:51** | **6/24/13 13:30** |
|---|---|---|---|---|---|---|
| 1 | 25 | 25 | 25 | 25 | 25 | 25 |
| 2 | 33 | 33 | 33 | 33 | 33 | 33 |
| 3 | 59.6 | 58.7 | 56.2 | 55.2 | 54.9 | 59.2 |
| 4 | 18.9 | 19 | 19 | 19 | 19.1 | 20.2 |
| 5 | 5.109 | 4.398 | 4.721 | 4.755 | 4.311 | 4.49 |
| 6 | 85.7 | 87.6 | 85.7 | 86 | 88 | 89.4 |
| 7 | 4.004 | 3.265 | 3.607 | 3.668 | 3.186 | 3.357 |
| 8 | 87.2 | 89.4 | 87.4 | 87.7 | 89.8 | 91 |
| 9 | 34 | 33 | 35 | 32 | 34 | 34 |
| 10 | 39 | 37 | 41 | 37 | 40 | 40 |
| 11 | 73 | 70 | 76 | 69 | 74 | 74 |
| 12 | 19.4 | 19.3 | 19.3 | 19.7 | 19.5 | 20.3 |
| 13 | 49.858 | 35.769 | 42.63 | 38.186 | 31.172 | 32.505 |
| 14 | 87.8 | 90 | 87.9 | 88.2 | 90.4 | 91.5 |
| 15 | 31 | 31 | 32 | 32 | 31 | 30 |
| 16 | 37 | 37 | 39 | 39 | 37 | 36 |
| 17 | 70.4 | 75.3 | 69.8 | 67.9 | 69.6 | 68.1 |
| 18 | 19.2 | 19.4 | 19.2 | 19.3 | 19.4 | 19.9 |
| 19 | 135.681 | 118.477 | 112.16 | 114.691 | 106.671 | 124.011 |
| 20 | 87.6 | 89.8 | 87.7 | 88.1 | 90.2 | 91.3 |
| 21 | 36 | 35 | 36 | 36 | 35 | 35 |
| 22 | 40 | 40 | 40 | 40 | 38 | 40 |
| 23 | 76 | 75 | 76 | 76 | 73 | 75 |
| 24 | 19 | 18.7 | 19.5 | 19 | 19.2 | 20.1 |
| 25 | 49.695 | 54.81 | 51.352 | 56.412 | 50.983 | 51.535 |
| 26 | 87.5 | 89.7 | 87.7 | 88 | 90.1 | 91.2 |
| 27 | 11 | 11.7 | 11 | 11.7 | 11.6 | 11.9 |
| 28 | 13.2 | 13.1 | 13.4 | 13.6 | 13.7 | 13.7 |
| 29 | 21.769 | 22.24 | 21.85 | 21.641 | 22.497 | 22.498 |
| 30 | 86.3 | 88.8 | 86.6 | 87 | 89.3 | 89.8 |

## Appendix A2: Alamogordo Year 2 Logsheet Data
## EDM System Data

| Item | 6/24/13 16:37 | 6/25/13 8:15 | 6/26/13 14:22 | 6/26/13 16:15 | 6/27/13 8:25 | 6/27/13 16:47 |
|---|---|---|---|---|---|---|
| 1 | 25 | 24 | 24 | 24 | 24 | 25 |
| 2 | 33 | 34 | 35 | 35 | 35 | 36 |
| 3 | 56.1 | 59.8 | 58.6 | 53.3 | 53.1 | 60.9 |
| 4 | 20.1 | 20.9 | 19.1 | 19.3 | 19.4 | 20.9 |
| 5 | 4.513 | 5.072 | 4.481 | 4.529 | 4.122 | 4.717 |
| 6 | 88.1 | 85.3 | 84.5 | 85.2 | 81.6 | 87.5 |
| 7 | 3.373 | 3.966 | 3.328 | 3.423 | 3.152 | 3.663 |
| 8 | 89.9 | 86.9 | 86.2 | 86.9 | 83 | 89.2 |
| 9 | 34 | 33 | 31 | 31 | 31 | 32 |
| 10 | 39 | 40 | 40 | 39 | 40 | 42 |
| 11 | 73 | 73 | 71 | 70 | 71 | 74 |
| 12 | 20.6 | 21.3 | 19.5 | 19.5 | 19.4 | 21 |
| 13 | 34.074 | 44.841 | 5.657 | 5.59 | 7.869 | 4.114 |
| 14 | 90.5 | 87.4 | 86.8 | 87.5 | 83.5 | 89.8 |
| 15 | 30 | 30 | 29 | 29 | 28 | 29 |
| 16 | 36 | 38 | 38 | 36 | 36 | 40 |
| 17 | 71.47 | 72.8 | 65.9 | 67.7 | 67.1 | 65.7 |
| 18 | 20.5 | 21.3 | 19.4 | 19.5 | 19.7 | 21.9 |
| 19 | 121.419 | 108.339 | 10.3 | 10.493 | 10.037 | 87.526 |
| 20 | 90.2 | 87.2 | 86.3 | 87.3 | 83.3 | 89.6 |
| 21 | 35 | 36 | 34 | 34 | 33 | 34 |
| 22 | 40 | 42 | 42 | 40 | 40 | 42 |
| 23 | 75 | 78 | 76 | 74 | 73 | 76 |
| 24 | 20.1 | 21.4 | 19.5 | 19.2 | 19.1 | 21.2 |
| 25 | 53.22 | 50.84 | 51.347 | 51.109 | 50.888 | 53.988 |
| 26 | 90.1 | 87.1 | 86.5 | 87.2 | 83.2 | 89.5 |
| 27 | 11.1 | 10.2 | 11.3 | 10.4 | 11.4 | 11.7 |
| 28 | 13.9 | 14.2 | 13.3 | 13.3 | 13.3 | 13.8 |
| 29 | 20.757 | 22.041 | 22.216 | 21.925 | 23.074 | 22.153 |
| 30 | 89.3 | 85.1 | 86.1 | 87 | 81.3 | 89.2 |

Appendix A2: Alamogordo Year 2 Logsheet Data
EDM System Data

| **Item** | **6/28/13 7:45** | **6/28/13 15:30** | **7/8/13 11:45** | **7/8/13 15:50** | **7/9/13 8:30** | **7/9/13 15:25** |
|---|---|---|---|---|---|---|
| 1 | 25 | 25 | 25 | 25 | 25 | 25 |
| 2 | 37 | 37 | 41 | 44 | 44 | 43 |
| 3 | 59.6 | 60.4 | 57.5 | 59.1 | 56.7 | 60 |
| 4 | 21.3 | 21.7 | 20.8 | 23.1 | 24.4 | 23.5 |
| 5 | 5.064 | 4.529 | 4.372 | 4.478 | 5.019 | 4.612 |
| 6 | 85.7 | 88 | 88.6 | 88.5 | 86.2 | 87.9 |
| 7 | 4.035 | 3.49 | 3.184 | 3.422 | 3.962 | 3.522 |
| 8 | 87.3 | 89.8 | 90.2 | 90.2 | 87.9 | 89.7 |
| 9 | 34 | 33 | 29 | 31 | 34 | 33 |
| 10 | 43 | 42 | 40 | 43 | 46 | 46 |
| 11 | 77 | 75 | 69 | 74 | 80 | 79 |
| 12 | 22 | 22.4 | 20.9 | 23.5 | 24.4 | 23.5 |
| 13 | 6.586 | 4.524 | 107.072 | 113.791 | 112.982 | 116.086 |
| 14 | 87.9 | 90.4 | 89.1 | 90.8 | 87.6 | 90.6 |
| 15 | 29 | 29 | 27 | 29 | 29 | 29 |
| 16 | 40 | 40 | 36 | 41 | 42 | 41 |
| 17 | 64.9 | 69.2 | 61.8 | 60.5 | 62.5 | 58.2 |
| 18 | 22.1 | 22.4 | 21.1 | 23.9 | 24.4 | 23.8 |
| 19 | 83.575 | 79.38 | 135.86 | 155.386 | 151.505 | 154.289 |
| 20 | 87.6 | 90.2 | 89.4 | 90.5 | 87.3 | 90.3 |
| 21 | 35 | 34 | 34 | 35 | 35 | 34 |
| 22 | 45 | 43 | 43 | 45 | 45 | 45 |
| 23 | 80 | 77 | 77 | 80 | 80 | 79 |
| 24 | 21.5 | 22.2 | 21 | 23.2 | 24.2 | 23.4 |
| 25 | 51.804 | 51.962 | 49.62 | 50.366 | 56.187 | 50.274 |
| 26 | 87.6 | 90.1 | 90.5 | 90.6 | 88.2 | 90.1 |
| 27 | 11.5 | 10.4 | 11.9 | 11.3 | 11.2 | 9.8 |
| 28 | 14.2 | 14.3 | 13.8 | 14.4 | 15.2 | 15.2 |
| 29 | 22.63 | 22.48 | 22.03 | 22.073 | 22.366 | 22.5 |
| 30 | 85.8 | 89.3 | 89.2 | 89.5 | 86.4 | 89.5 |

Appendix A2: Alamogordo Year 2 Logsheet Data
EDM System Data

| Item | 7/10/13 8:14 | 7/10/13 15:50 | 7/11/13 8:26 | 7/11/13 17:11 | 7/12/13 9:35 | 7/12/13 17:00 |
|---|---|---|---|---|---|---|
| 1 | 25 | 25 | 24 | 23 | 23 | 24 |
| 2 | 44 | 43 | 42 | 37 | 40 | 41 |
| 3 | 61.1 | 62.6 | 61.9 | 55.7 | 54.4 | 58.9 |
| 4 | 25.8 | 25.3 | 26.1 | 23.2 | 25.4 | 25.8 |
| 5 | 4.739 | 4.512 | 4.698 | 4.283 | 4.834 | 4.979 |
| 6 | 86.5 | 88.4 | 87.3 | 84.7 | 86.7 | 88.1 |
| 7 | 3.7 | 3.42 | 3.601 | 3.104 | 3.779 | 3.89 |
| 8 | 88.2 | 90.4 | 89.1 | 86.1 | 88.5 | 90.1 |
| 9 | 33 | 32 | 32 | 26 | 31 | 33 |
| 10 | 46 | 45 | 45 | 34 | 44 | 45 |
| 11 | 79 | 77 | 77 | 60 | 75 | 78 |
| 12 | 25.9 | 25.4 | 26.9 | 24 | 26 | 26.2 |
| 13 | 111.462 | 109.754 | 14.51 | 59.952 | 110.689 | 110.215 |
| 14 | 87.9 | 91.3 | 88.7 | 86.5 | 88.3 | 90.7 |
| 15 | 27 | 26 | 25 | 24 | 24 | 26 |
| 16 | 40 | 37 | 36 | 34 | 36 | 38 |
| 17 | 61.4 | 54.3 | 54.8 | 53.3 | 56.9 | 52.4 |
| 18 | 26.2 | 25.1 | 25.9 | 23.5 | 25.6 | 26.1 |
| 19 | 160.345 | 155.008 | 157.954 | 72.414 | 163.23 | 158.909 |
| 20 | 87.4 | 91 | 88.1 | 86.2 | 87.9 | 90.5 |
| 21 | 36 | 34 | 34 | 31 | 30 | 33 |
| 22 | 47 | 45 | 46 | 40 | 42 | 43 |
| 23 | 83 | 79 | 80 | 71 | 72 | 76 |
| 24 | 26.2 | 25.4 | 25.9 | 23.8 | 25.5 | 26.1 |
| 25 | 50.234 | 49.27 | 49.715 | 49.742 | 53.212 | 50.133 |
| 26 | 88.5 | 90.7 | 89.4 | 86.5 | 88.8 | 90.5 |
| 27 | 8.6 | 9.5 | 9 | 10.6 | 10.4 | 0 |
| 28 | 16.2 | 16.1 | 16.6 | 15.8 | 16.6 | 16.3 |
| 29 | 23.02 | 22.095 | 23.013 | 22.031 | 22.261 | 23.54 |
| 30 | 86.8 | 89.9 | 87.6 | 84.9 | 87.5 | 89.5 |

Appendix A2: Alamogordo Year 2 Logsheet Data
EDM System Data

| Item | 7/13/13 8:40 | 7/13/13 16:25 | 7/14/13 7:53 |
|---|---|---|---|
| 1 | 23 | 23 | 22 |
| 2 | 39 | 39 | 38 |
| 3 | 55 | 60.5 | 60.6 |
| 4 | 25.7 | 25.2 | 27.2 |
| 5 | 5.07 | 4.73 | 6.662 |
| 6 | 86.2 | 89.8 | 85.7 |
| 7 | 4.003 | 3.846 | 5.929 |
| 8 | 88 | 87.9 | 87.4 |
| 9 | 31 | 31 | 29 |
| 10 | 43 | 42 | 42 |
| 11 | 74 | 73 | 71 |
| 12 | 26.4 | 25.1 | 27.5 |
| 13 | 111.88 | 109.63 | 110.773 |
| 14 | 87.4 | 90.7 | 86.8 |
| 15 | 22 | 22 | 19 |
| 16 | 31 | 32 | 29 |
| 17 | 49 | 54 | 48 |
| 18 | 26.8 | 25.8 | 27.8 |
| 19 | 160.561 | 158.008 | 152.118 |
| 20 | 87.1 | 90.4 | 86.3 |
| 21 | 30 | 29 | 28 |
| 22 | 40 | 40 | 38 |
| 23 | 70 | 69 | 66 |
| 24 | 26.4 | 26 | 27.9 |
| 25 | 48.552 | 52.455 | 52.447 |
| 26 | 88.3 | 90.2 | 87.7 |
| 27 | 0 | 0 | 0 |
| 28 | 17 | 17.4 | 18.5 |
| 29 | 24.68 | 27.03 | 28.965 |
| 30 | 86.4 | 89.5 | 85.3 |

Appendix A2: Alamogordo Year 2 Logsheet Data
(Mix Na Mix Cl Specific Gravity)

| **date** | **Mixed Cl** | | **Mixed Na** | |
|---|---|---|---|---|
| | sp gr | cond | sp gr | cond |
| 3/28/2013 14:30 | 1.09 | | 1.17 | |
| 3/28/2013 17:20 | 1.09 | | 1.18 | |
| 3/29/2013 10:00 | 1.094 | | 1.139 | |
| 3/29/2013 15:38 | 1.083 | | 1.116 | |
| 3/29/2013 15:58 | 1.09 | | 1.168 | |
| 4/1/2013 11:03 | 1.04 | | 1.083 | |
| 4/1/2013 11:30 | 1.06 | | 1.113 | 90 |
| 4/1/2013 12:00 | 1.08 | 120 | 1.13 | 100 |
| 4/1/2013 12:12 | 1.084 | 126 | 1.138 | 103 |
| 4/1/2013 12:22 | | | 1.14 | 105.5 |
| 4/1/2013 12:32 | 1.09 | 130 | 1.13 | 100 |
| 4/1/2013 12:52 | 1.092 | 135 | 1.14 | 105.5 |
| 4/1/2013 13:02 | | | 1.13 | 102 |
| 4/1/2013 13:12 | 1.098 | 141.5 | 1.14 | 106.5 |
| 4/1/2013 13:16 | | | 1.13 | |
| 4/1/2013 13:32 | 1.102 | 145 | 1.14 | 107 |
| 4/1/2013 13:52 | 1.1102 | 147 | 1.14 | 107.5 |
| 4/1/2013 14:12 | 1.11 | | 1.14 | 107 |
| 4/1/2013 14:32 | 1.115 | 151 | 1.14 | 107 |
| 4/1/2013 14:52 | 1.115 | 152.6 | | |
| 4/1/2013 15:12 | 1.1152 | | | |
| 4/1/2013 15:17 | 1.1152 | | 1.132 | 105.5 |
| 4/1/2013 15:34 | 1.154 | | 1.134 | |
| 4/1/2013 15:57 | | | 1.126 | |
| 4/5/2013 10:00 | 1.062 | 111 | 1.092 | 88 |
| 4/5/2013 10:50 | 1.088 | 141 | 1.13 | 111.5 |
| 4/5/2013 11:17 | 1.092 | 149.5 | 1.134 | 112.6 |
| 4/5/2013 11:37 | 1.098 | 154.2 | 1.14 | 114.8 |
| 4/5/2013 11:46 | | | 1.096 | 91.5 |
| 4/8/2013 10:45 | 1.054 | 102.2 | 1.084 | 86.03 |
| 4/8/2013 11:15 | 1.078 | 129 | 1.1152 | 102 |

## Appendix A2: Alamogordo Year 2 Logsheet Data
## (Mix Na Mix Cl Specific Gravity)

| **date** | **Mixed Cl** | | **Mixed Na** | |
|---|---|---|---|---|
| | sp gr | cond | sp gr | cond |
| 4/8/2013 11:40 | | | 1.125 | 110 |
| 4/8/2013 11:50 | 1.09 | 143.5 | 1.132 | 112.5 |
| 4/8/2013 12:35 | 1.098 | | 1.13 | |
| 4/8/2013 12:52 | 1.11 | 157 | 1.13 | 110 |
| 4/8/2013 13:27 | 1.11 | 160.8 | 1.14 | 115.8 |
| 4/8/2013 13:58 | 1.11 | 162.2 | 1.132 | 111.5 |
| 4/8/2013 14:24 | | | 1.13 | 112.5 |
| 4/8/2013 14:40 | 1.11 | 164.2 | 1.14 | 115.3 |
| 4/8/2013 14:45 | | | 1.13 | 111.3 |
| 4/8/2013 15:06 | 1.11 | 165 | 1.13 | 111.1 |
| 4/8/2013 15:52 | | | 1.128 | 110.4 |
| 4/8/2013 16:15 | 1.112 | 166.7 | 1.128 | 111.6 |
| 4/9/2013 9:05 | 1.06 | 104.4 | 1.078 | 80.76 |
| 4/9/2013 9:53 | | | 1.12 | 105.1 |
| 4/9/2013 10:15 | | | 1.134 | 111 |
| 4/9/2013 10:21 | 1.09 | 144.9 | | |
| 4/9/2013 11:04 | | | 1.128 | 108.2 |
| 4/9/2013 11:15 | 1.104 | 157 | | |
| 4/9/2013 11:52 | 1.108 | 161.6 | | |
| 4/9/2013 12:10 | 1.11 | 160.8 | 1.128 | 108.9 |
| 4/9/2013 13:35 | 1.112 | 165.5 | 1.14 | 114.2 |
| 4/9/2013 14:23 | | | 1.128 | 109.7 |
| 4/9/2013 14:40 | 1.114 | 166.7 | | |
| 4/9/2013 15:40 | 1.114 | 167.3 | 1.138 | 113.1 |
| 4/9/2013 16:45 | 1.114 | 167.3 | 1.136 | 111.6 |
| 4/10/2013 9:22 | 1.066 | 112 | 1.092 | 87.2 |
| 4/10/2013 9:53 | | | 1.12 | 104.1 |
| 4/10/2013 10:25 | | | 1.142 | 114.9 |
| 4/10/2013 10:38 | 1.098 | 151.5 | 1.126 | 109.1 |
| 4/10/2013 11:07 | | | 1.132 | 110.9 |
| 4/10/2013 12:28 | 1.112 | 163.9 | 1.14 | 114.8 |

Appendix A2: Alamogordo Year 2 Logsheet Data
(Mix Na Mix Cl Specific Gravity)

| date | Mixed Cl | | Mixed Na | |
|---|---|---|---|---|
| | sp gr | cond | sp gr | cond |
| 4/10/2013 13:28 | 1.112 | 165.9 | 1.13 | 109 |
| 4/10/2013 15:25 | 1.116 | 166.9 | 1.138 | 113.5 |
| 4/10/2013 16:30 | 1.116 | 168 | 1.13 | 110.5 |
| 4/11/2013 10:20 | 1.052 | 92.2 | 1.068 | 70.37 |
| 4/11/2013 10:57 | | | 1.114 | 94.71 |
| 4/11/2013 11:01 | 1.076 | 128.2 | | |
| 4/11/2013 11:42 | 1.092 | 146.8 | 1.138 | 113.3 |
| 4/11/2013 11:46 | | | 1.128 | 108.7 |
| 4/11/2013 13:21 | 1.11 | 162.2 | 1.13 | |
| 4/11/2013 14:41 | 1.114 | 165.7 | 1.138 | 115.3 |
| 4/11/2013 16:18 | 1.114 | 167.6 | 1.13 | 111.3 |
| 4/17/2013 9:10 | 1.048 | 88.66 | 1.066 | 71.1 |
| 4/17/2013 9:35 | | | 1.088 | 87.9 |
| 4/17/2013 10:11 | 1.08 | 133.2 | 1.116 | 103 |
| 4/17/2013 10:28 | 1.086 | 140.2 | 1.13 | 110 |
| 4/17/2013 10:53 | 1.092 | 147.2 | 1.128 | 110.7 |
| 4/17/2013 11:41 | 1.102 | 156.6 | 1.13 | 111 |
| 4/17/2013 12:45 | 1.116 | 162.9 | | |
| 4/17/2013 14:10 | 1.11 | 164.8 | 1.128 | 111.3 |
| 4/17/2013 14:50 | 1.11 | 165.3 | 1.132 | 113.8 |
| 4/17/2013 15:10 | 1.112 | 166.4 | | |
| 4/17/2013 16:30 | 1.098 | 152.6 | 1.128 | 111.5 |
| 4/18/2013 9:10 | | | 1.066 | 71.1 |
| 4/18/2013 9:50 | 1.072 | 123.1 | 1.106 | 96.4 |
| 4/18/2013 10:21 | 1.084 | 138.5 | 1.128 | 110.1 |
| 4/18/2013 11:16 | 1.088 | 153.1 | 1.13 | 111.1 |
| 4/18/2013 12:36 | 1.106 | 161 | 1.124 | 108 |
| 4/18/2013 13:20 | 1.11 | 162.8 | 1.122 | 107 |
| 4/18/2013 16:20 | 1.11 | 166.1 | 1.126 | 110 |
| 4/19/2013 9:10 | | 100.5 | 1.08 | 81.1 |
| 4/19/2013 9:55 | | | 1.12 | 105.5 |

## Appendix A2: Alamogordo Year 2 Logsheet Data
## (Mix Na Mix Cl Specific Gravity)

| **date** | **Mixed Cl** | | **Mixed Na** | |
|---|---|---|---|---|
| | sp gr | cond | sp gr | cond |
| 4/19/2013 10:08 | 1.084 | 140.4 | 1.13 | 110 |
| 4/19/2013 11:10 | 1.098 | 156.5 | 1.134 | 114.2 |
| 4/19/2013 13:50 | 1.11 | 163.7 | 1.134 | 113.1 |
| 4/19/2013 17:20 | 1.112 | 165 | 1.132 | 112 |
| 4/19/2013 17:50 | 1.114 | 165.3 | 1.13 | 109.7 |
| 4/19/2013 21:40 | 1.108 | 160 | 1.132 | 110.8 |
| 4/20/2013 8:30 | 1.11 | 160 | 1.128 | 107.8 |
| 4/22/2013 10:10 | 1.06 | 110 | 1.088 | 86.1 |
| 4/22/2013 10:40 | | | 1.114 | 102 |
| 4/22/2013 11:02 | 1.086 | 139.2 | 1.128 | 108.2 |
| 4/22/2013 13:55 | 1.108 | 161.5 | 1.132 | 111.5 |
| 4/22/2013 16:36 | 1.11 | 163.6 | 1.13 | 111 |
| 4/22/2013 21:11 | 1.11 | 163 | 1.132 | 110 |
| 4/23/2013 7:46 | 1.106 | 158.5 | 1.13 | 110 |
| 4/23/2013 9:36 | 1.112 | 161.4 | 1.13 | 109.1 |
| 4/23/2013 11:25 | 1.112 | 163.1 | 1.132 | 110.2 |
| 4/23/2013 15:45 | 1.112 | 163 | 1.13 | 109.8 |
| 4/23/2013 22:13 | | | 1.12 | 108 |
| 4/23/2013 22:35 | | | 1.12 | 100 |
| 4/24/2013 8:38 | 1.114 | 162.5 | 1.12 | 103.1 |
| 4/25/2013 12:21 | | | 1.092 | 86 |
| 4/25/2013 13:15 | | | 1.124 | 103 |
| 4/25/2013 15:01 | | | 1.124 | 103 |
| 4/25/2013 16:32 | 1.108 | 159.3 | 1.128 | 107.5 |
| 4/25/2013 17:00 | | | 1.134 | 110 |
| 4/25/2013 21:20 | 1.112 | 163 | 1.126 | 105.6 |
| 4/26/2013 8:55 | 1.104 | 155.2 | 1.124 | 104.3 |
| 4/30/2013 14:14 | | | 1.108 | 94.6 |
| 4/30/2013 14:39 | | | 1.124 | 103.5 |
| 4/30/2013 14:56 | | | 1.13 | 107.5 |
| 4/30/2013 15:17 | 1.092 | 142.7 | 1.14 | 110.9 |

## Appendix A2: Alamogordo Year 2 Logsheet Data
## (Mix Na Mix Cl Specific Gravity)

| **date** | **Mixed Cl** | | **Mixed Na** | |
|---|---|---|---|---|
| | sp gr | cond | sp gr | cond |
| 4/30/2013 16:30 | 1.11 | 152.9 | 1.13 | 109.1 |
| 4/30/2013 21:34 | 1.112 | 162 | 1.128 | 106.4 |
| 5/1/2013 9:36 | 1.108 | 160.7 | 1.13 | 109.5 |
| 5/1/2013 13:53 | 1.106 | 157.8 | 1.128 | 109.5 |
| 5/1/2013 17:00 | 1.104 | 158.1 | 1.126 | 109.2 |
| 5/1/2013 21:47 | 1.101 | 157.2 | 1.12 | 105.2 |
| 5/1/2013 21:57 | | | 1.124 | 107.1 |
| 5/2/2013 14:53 | 1.1 | 153.7 | 1.126 | 106.2 |
| 5/2/2013 21:34 | 1.102 | 153.4 | 1.116 | 100.7 |
| 5/29/2013 14:18 | 1.1 | 154.6 | 1.132 | 110.4 |
| 5/31/2013 9:48 | 1.05 | 92.04 | 1.068 | 70.28 |
| 5/31/2013 11:00 | | | 1.126 | 102.1 |
| 5/31/2013 12:30 | | | 1.128 | |
| 5/31/2013 13:36 | 1.1102 | 154 | 1.13 | 107.2 |
| 5/31/2013 15:38 | 1.106 | 160 | 1.122 | 105.6 |
| 6/3/2013 11:50 | 1.088 | 141.9 | 1.13 | 109.5 |
| 6/3/2013 14:57 | 1.102 | 159.2 | 1.13 | 107.6 |
| 6/4/2013 11:25 | 1.086 | 141 | 1.126 | 107.8 |
| 6/4/2013 14:55 | 1.104 | 162.4 | 1.12 | 105.1 |
| 6/4/2013 17:00 | 1.108 | 164.6 | 1.128 | |
| 6/14/2013 15:45 | 1.09 | 138.4 | 1.132 | 111.4 |
| 6/17/2013 11:20 | | | 1.132 | 111 |
| 6/17/2013 11:37 | | | 1.14 | 114 |
| 6/17/2013 11:40 | 1.092 | 143 | 1.13 | 111 |
| 6/17/2013 11:55 | | | 1.13 | |
| 6/17/2013 12:55 | 1.1 | 147 | 1.132 | 110 |
| 6/17/2013 14:15 | 1.104 | 155.7 | 1.136 | 112.8 |
| 6/18/2013 11:02 | 1.09 | 139.2 | 1.13 | 108.1 |
| 6/18/2013 14:30 | 1.106 | 153.2 | 1.138 | 113.7 |
| 6/19/2013 10:50 | 1.11 | 159.7 | 1.138 | 114.3 |
| 6/19/2013 14:40 | 1.106 | 158.9 | 1.13 | 112.7 |

## Appendix A2: Alamogordo Year 2 Logsheet Data
## (Mix Na Mix Cl Specific Gravity)

| **date** | **Mixed Cl** | | **Mixed Na** | |
|---|---|---|---|---|
| | sp gr | cond | sp gr | cond |
| 6/20/2013 10:33 | 1.104 | 153.3 | 1.12 | 105.3 |
| 6/20/2013 15:05 | 1.108 | 157.3 | 1.12 | 104.8 |
| 6/21/2013 10:56 | 1.108 | 151.5 | 1.13 | 107.9 |
| 6/21/2013 15:05 | 1.11 | 158.4 | 1.14 | 115.5 |
| 6/24/2013 13:45 | 1.088 | 150.8 | 1.12 | 107.8 |
| 6/24/2013 16:35 | 1.102 | 157.3 | 1.128 | 111.8 |
| 6/25/2013 8:30 | 1.119 | 159.1 | 1.128 | 109.7 |
| 6/26/2013 14:38 | 1.1 | 153.6 | 1.126 | 109.2 |
| 6/26/2013 16:30 | 1.104 | 158.2 | 1.13 | 112.2 |
| 6/27/2013 8:30 | 1.106 | 159.9 | 1.122 | 107.5 |
| 6/27/2013 12:08 | 1.108 | 159 | 1.132 | 111 |
| 6/27/2013 17:00 | 1.11 | 161.8 | 1.128 | 111.1 |
| 6/27/2013 19:45 | 1.108 | 160 | 1.132 | 112.2 |
| 6/28/2013 8:06 | 1.108 | 161.4 | 1.126 | 110.1 |
| 6/28/2013 15:45 | 1.108 | 159.3 | 1.128 | 112.4 |
| 7/8/2013 12:00 | 1.09 | 142.6 | 1.122 | 108.3 |
| 7/8/2013 16:05 | 1.1 | 158.6 | 1.126 | 110.8 |
| 7/9/2013 8:43 | 1.104 | 158.9 | 1.122 | 110.3 |
| 7/9/2013 15:40 | 1.1 | 158.6 | 1.126 | 112.5 |
| 7/10/2013 8:33 | 1.102 | 157.7 | 1.126 | 110 |
| 7/10/2013 16:05 | 1.102 | 157.7 | 1.128 | 111.6 |
| 7/11/2013 8:49 | 1.104 | 156.4 | 1.126 | 109.4 |
| 7/12/2013 9:30 | 1.109 | 164.6 | 1.124 | 109.7 |
| 7/12/2013 17:15 | 1.106 | 163 | 1.12 | 109.4 |
| 7/13/2013 8:48 | 1.108 | 157 | 1.128 | 105.5 |
| 7/13/2013 16:48 | 1.108 | 158.8 | 1.124 | 108.3 |

| Item | Location | Tag | units | 3/28/2013 16:40 | 3/29/2013 10:08 | 4/1/2013 9:25 | 4/1/2013 11:15 |
|---|---|---|---|---|---|---|---|
| 1 | 20-µm Cartridge filters | (gauges) | psi | 0/0 | 0/0 | 0/0 | 0/0 |
| 2 | 5-µm Cartridge filters-inlet | PIT-2007 | psi | 48 | 48.1 | 48.1 | 47.5 |
| 3 | 5-µm Cartridge filters-outlet | PIT-2007B | psi | 46 | 46.1 | 46.2 | 46.2 |
| 4 | High pressure pump feed Pressure | (gauge) | psi | 46 | 46 | 46 | 46 |
| 5 | NF Feed Pressure | PIT-2008 | psi | 107 | 107 | 109 | 106 |
| 6 | NF Reject Pressure | PIT-2008R | psi | 68 | 67 | 68 | 66 |
| 7 | NF Permeate Pressure | PIT-2009 | psi | 0.7 | 0.6 | 0.7 | 0.6 |
| 8 | Feed Flow | FIT-2001 | gpm | 51.6 | 49.7 | 53.8 | 47.6 |
| 9 | Feed pH | AIT-2003 |  | 7.15 | 7.08 | 6.54 | 6.59 |
| 10 | Tank Level | LIT-2003 | in | 20.68 | 20.653 | 20.736 | 20.542 |
| 11 | NF Feed pH | AIT-2008A |  | 7.17 | 7.05 | 6.63 | 6.65 |
| 12 | NF Feed Cond | AIT-2008 | µS/cm | 3,666 | 3,571 | 3,494 | 3,368 |
| 13 | NF Feed Temp | TIT-2008 | $^{o}$F | 68.21 | 68.39 | 68.58 | 70.38 |
| 14 | NF Permeate Flow | FIT-2009P | gpm | 43.2 | 40.86 | 42.33 | 41.6 |
| 15 | NF Permeate Conductivity | AIT-2009P | µS/cm | 1,412 | 1,325 | 1,322 | 1,297 |
| 16 | NF Reject Flow | FIT-2009R | gpm | 28.66 | 29.16 | 28.63 | 28.69 |
| 17 | NF Reject Conductivity | AIT-2009R1 | µS/cm | 8,609 | 7,803 | 8,081 | 7,804 |
| 18 | NF Reject pH | AIT-2009R2 |  | 7.36 | 7.29 | 6.91 | 6.93 |
| 19 | NF Reject Temp | TIT-2009R2 | $^{o}$F | 67.78 | 67.97 | 67.95 | 69.83 |
| 20 | Product Flow | FIT-2011 | gpm | 60.5 | 63.8 | 64.1 | 62.7 |

Appendix A2: Alamogordo Year 2 Logsheet Data
NF System Data

| Item | 4/1/2015 13:22 | 4/3/2013 16:35 | 4/5/2013 10:00 | 4/5/2013 11:45 | 4/8/2013 10:47 | 4/8/2013 14:31 | 4/8/2013 17:05 | 4/9/2013 10:28 |
|---|---|---|---|---|---|---|---|---|
| 1 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 |
| 2 | 47.8 | 48.1 | 48.5 | 48.4 | 48.3 | 48 | 48.3 | 48.3 |
| 3 | 46 | 46.5 | 46.7 | 46.6 | 46.4 | 46.3 | 46.8 | 46.8 |
| 4 | 45 | 46 | 46 | 46 | 45 | 45 | 45 | 45 |
| 5 | 106 | 103 | 101 | 102 | 103 | 100 | 98 | 98 |
| 6 | 66 | 65 | 63 | 64 | 64 | 63 | 62 | 62 |
| 7 | 0.6 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 8 | 46.7 | 47.6 | 42.5 | 43.1 | 49.5 | 42 | 43.5 | 43.5 |
| 9 | 6.64 | 6.62 | 6.51 | 6.54 | 6.53 | 6.54 | 6.57 | 6.57 |
| 10 | 20.653 | 20.597 | 20.542 | 20.542 | 20.736 | 20.68 | 20.597 | 20.597 |
| 11 | 6.66 | 6.66 | 6.6 | 6.6 | 6.5 | 6.5 | 6.53 | 6.53 |
| 12 | 3,366 | 3,316 | 3,369 | 3,383 | 3,341 | 3,466 | 3489.3 | 3,489 |
| 13 | 71.03 | 69.93 | 69.99 | 70.6 | 71.7 | 72.78 | 73.35 | 73.35 |
| 14 | 41.96 | 40.1 | 38.67 | 40.58 | 39.59 | 39.59 | 39.85 | 39.85 |
| 15 | 1,323 | 1,256 | 1,316 | 70 | 72 | 1,385 | 1360.9 | 1,361 |
| 16 | 28.53 | 27.52 | 28.22 | 27.59 | 27.75 | 27.92 | 27.99 | 27.99 |
| 17 | 7,819 | 7,645 | 7,326 | 7,643 | 7,543 | 7,801 | 7899.6 | 7,900 |
| 18 | 6.91 | 6.86 | 6.85 | 6.82 | 6.75 | 6.78 | 6.81 | 6.81 |
| 19 | 70.65 | 69.19 | 69.38 | 70.13 | 71.24 | 72.38 | 72.9 | 72.9 |
| 20 | 61.5 | 62 | 61.8 | 65 | 59.4 | 65.5 | 61.9 | 61.9 |

| Item | 4/9/2013 16:40 | 4/10/2013 11:22 | 4/10/2013 16:35 | 4/11/2013 11:59 | 4/11/2013 13:43 | 4/11/2013 16:11 | 4/11/2013 17:04 |
|---|---|---|---|---|---|---|---|
| 1 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 |
| 2 | 48.5 | 48.3 | 48.3 | 48.3 | 48.5 | 48.3 | 48.4 |
| 3 | 46.8 | 46.6 | 46.5 | 46.8 | 46.7 | 46.8 | 46.8 |
| 4 | 47 | 47 | 46 | 47 | 46 | 46 | 46 |
| 5 | 100 | 103 | 104 | 105 | 106 | 104 | 106 |
| 6 | 64 | 67 | 67 | 67 | 68 | 68 | 69 |
| 7 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 8 | 54.5 | 51.6 | 42 | 57 | 47.6 | 44.2 | 55 |
| 9 | 6.49 | 6.37 | 6.46 | 6.47 | 6.73 | 6.65 | 6.57 |
| 10 | 20.68 | 20.68 | 20.761 | 20.763 | 20.678 | 20.602 | 20.681 |
| 11 | 6.51 | 6.42 | 6.55 | 6.49 | 6.64 | 6.48 | 6.45 |
| 12 | 3,445 | 3,571 | 3,674 | 3,518 | 3,481 | 3,566 | 3,602 |
| 13 | 71 | 70.08 | 70.45 | 69.24 | 69.29 | 70.15 | 70.02 |
| 14 | 39.06 | 40.62 | 39.78 | 39.51 | 39.87 | 39.42 | 39.18 |
| 15 | 1,339 | 1,400 | 1,411 | 1,371 | 1,353 | 1,377 | 1,392 |
| 16 | 27.89 | 28.13 | 29.06 | 28.99 | 28.66 | 28.42 | 28.79 |
| 17 | 7,823 | 7,946 | 8,210 | 7,863 | 7,806 | 8,070 | 8,055 |
| 18 | 6.69 | 6.84 | 6.82 | 6.82 | 6.85 | 6.68 | 6.76 |
| 19 | 70.19 | 69.81 | 69.61 | 68.75 | 68.9 | 69.59 | 69.7 |
| 20 | 61.4 | 61.1 | 62.7 | 60.7 | 64.7 | 61.4 | |

| Item | 4/17/2013 10:40 | 4/17/2013 14:25 | 4/17/2013 16:20 | 4/18/2013 10:10 | 4/18/2013 13:00 | 4/18/2013 16:16 | 4/19/2013 10:45 | 4/19/2013 14:01 | 4/19/2013 17:40 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 |
| 2 | 48.3 | 48.4 | 48 | 48.5 | 48.1 | 48.3 | 48.3 | 48.2 | 48.1 |
| 3 | 46.8 | 46.9 | 46.5 | 46.9 | 47 | 46.3 | 46.6 | 46.5 | 46.5 |
| 4 | 46 | 46 | 45 | 48 | 46 | 46 | 46 | 46 | 46 |
| 5 | 100 | 98 | 100 | 103 | 104 | 104 | 107 | 107 | 106 |
| 6 | 64 | 62 | 64 | 66 | 67 | 67 | 69 | 70 | 68 |
| 7 | 0.6 | 0.6 | 0.5 | 0.6 | 0.5 | 0.6 | 0.5 | 0.5 | 0.5 |
| 8 | 47.2 | 48.3 | 44.2 | 53.1 | 52.2 | 47.5 | 51.5 | 47.9 | 46.6 |
| 9 | 6.57 | 6.8 | 6.7 | 6.16 | 6.25 | 6.86 | 6.37 | 6.23 | 6.21 |
| 10 | 20.547 | 20.736 | 20.542 | 20.68 | 20.81 | 20.739 | 20.763 | 20.655 | 20.543 |
| 11 | 6.47 | 6.5 | 6.6 | 6.34 | 6.33 | 6.58 | 6.26 | 6.27 | 6.31 |
| 12 | 3338.6 | 3314.9 | 3382 | 3429.4 | 3386.5 | 3407.1 | 3525.1 | 3563.6 | 3558 |
| 13 | 71.59 | 73.2 | 73.19 | 69.36 | 70.35 | 70.63 | 68.68 | 69.63 | 69.96 |
| 14 | 39.48 | 39.87 | 40.87 | 39.79 | 40.3 | 40.19 | 40.1 | 39.3 | 39.98 |
| 15 | 1388.3 | 1363.5 | 1367 | 1361 | 1316 | 1336.6 | 1388.2 | 1391.8 | 1393.3 |
| 16 | 28.16 | 28.09 | 27.42 | 28.4 | 28.2 | 28.42 | 28.83 | 29.26 | 29.03 |
| 17 | 7467.8 | 7501.8 | 7600.8 | 7670 | 7682.1 | 7700.8 | 7867.7 | 8063.4 | 8017.9 |
| 18 | 6.7 | 6.76 | 6.91 | 6.83 | 6.64 | 6.86 | 6.64 | 6.55 | 6.52 |
| 19 | 71.13 | 72.67 | 72.57 | 68.86 | 69.76 | 70.03 | 68.23 | 69.11 | 69.56 |
| 20 | 55.4 | 53.9 | 50.6 | 54.6 | 51.8 | 53.7 | 51 |  | 54.5 |

| Item | 4/19/2013 21:45 | 4/20/2013 8:25 | 4/22/2013 11:24 | 4/22/2013 13:38 | 4/22/2013 16:14 | 4/22/2013 21:40 | 4/23/2013 8:14 | 4/23/2013 11:05 |
|---|---|---|---|---|---|---|---|---|
| 1 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 |
| 2 | 48.6 | 48.1 | 48.4 | 48.3 | 48.3 | 47.8 | 48.4 | 47.9 |
| 3 | 46.8 | 46.4 | 46.4 | 46.6 | 46.5 | 46.2 | 46.5 | 46.5 |
| 4 | 46 | 46 | 46 | 45 | 45 | 46 | 46 | 45 |
| 5 | 106 | 109 | 104 | 103 | 104 | 107 | 107 | 108 |
| 6 | 69 | 72 | 68 | 67 | 67 | 70 | 70 | 70 |
| 7 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.5 | 0.6 | 0.5 |
| 8 | 47.4 | 54.6 | 48.1 | 56.2 | 57.5 | 48.7 | 43.5 | 56.1 |
| 9 | 6.36 | 6.25 | 6.69 | 6.13 | 6.29 | 6.98 | 6.58 | 6.5 |
| 10 | 20.73 | 20.68 | 20.736 | 20.761 | 20.736 | 20.736 | 20.658 | 20.764 |
| 11 | 6.26 | 6.24 | 6.54 | 6.27 | 6.3 | 6.46 | 5.97 | 6.17 |
| 12 | 3605.1 | 3651.9 | 3333.2 | 3350.4 | 3418.7 | 3408 | 3601.3 | 3612.4 |
| 13 | 69.52 | 68.67 | 71.23 | 71.8 | 72.08 | 71.46 | 71.53 | 72.66 |
| 14 | 39.9 | 39.71 | 39.68 | 40.42 | 39.22 | 40.46 | 40.7 | 39.14 |
| 15 | 1398.4 | 1423.5 | 1367.7 | 1340.2 | 1354.6 | 1363.6 | 1389 | 1426.4 |
| 16 | 28.89 | 28.95 | 28.76 | 28.52 | 28.72 | 28.96 | 29.3 | 29.23 |
| 17 | 7984.3 | 8080.7 | 7531.5 | 7627.4 | 7671.1 | 7702.3 | 8024.3 | 8070.3 |
| 18 | 6.55 | 6.6 | 6.96 | 6.67 | 6.57 | 6.84 | 6.24 | 6.33 |
| 19 | 68.91 | 68.46 | 70.87 | 71.27 | 71.76 | 70.97 | 71.02 | 72.06 |
| 20 | 51.6 | 52.5 | 56.1 | 52.3 | 53.3 | 51.7 | 58.3 | 50.8 |

| Item | 4/23/2013 15:30 | 4/23/2013 22:27 | 4/24/2013 8:20 | 4/25/2013 16:57 | 4/25/2013 21:45 | 4/26/2013 8:32 | 4/30/2013 16:10 | 4/30/2013 21:47 |
|---|---|---|---|---|---|---|---|---|
| 1 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 |
| 2 | 48 | 48.1 | 47.9 | 51.5 | 51.5 | 51.6 | 51.2 | 51.4 |
| 3 | 46.2 | 46.1 | 46 | 50.8 | 50.7 | 51 | 50.7 | 50.6 |
| 4 | 45 | 45 | 46 | 50 | 50 | 50 | 49 | 50 |
| 5 | 106 | 109 | 112 | 64 | 64 | 62 | 65 | 67 |
| 6 | 70 | 72 | 73 | 45 | 45 | 44 | 46 | 47 |
| 7 | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 | 0.1 | 0.4 | 0.4 |
| 8 | 45.4 | 41.8 | 57.1 | 20.9 | 21.3 | 19.8 | 27.4 | 15.6 |
| 9 | 6.54 | 7.58 | 6.47 | 6.72 | 6.87 | 5.44 | 6.58 | 6.52 |
| 10 | 20.597 | 20.648 | 20.373 | 20.902 | 20.927 | 20.819 | 20.93 | 20.93 |
| 11 | 6.15 | 7.14 | 6.21 | 6.18 | 6.19 | 6.1 | 6.07 | 6.12 |
| 12 | 3596.3 | 3614.4 | 3635.9 | 3417.4 | 3342 | 3360.4 | 3404.1 | 3550.7 |
| 13 | 73.45 | 72.58 | 71.23 | 72.96 | 72.4 | 70.84 | 75.73 | 75.02 |
| 14 | 40.31 | 42.2 | 40.39 | 21.87 | 21.45 | 20.41 | 22.19 | 21.94 |
| 15 | 1415.2 | 1472.6 | 1397.4 | 1072 | 1175.8 | 943.77 | 952.97 | 1116.2 |
| 16 | 29.2 | 30.07 | 30.04 | 15.03 | 14.53 | 14.4 | 14.56 | 14.83 |
| 17 | 8046.7 | 7949.02 | 8124.6 | 7754.5 | 7558 | 7451.7 | 7710.7 | 7962.9 |
| 18 | 6.29 | 7.24 | 6.31 | 6.18 | 6.12 | 6.33 | 6.17 | 6.04 |
| 19 | 72.91 | 71.78 | 70.5 | 72.37 | 71.63 | 69.92 | 75.46 | 74.3 |
| 20 | 48.7 | 52.7 | 51.1 | 51.9 | 52.1 | 51.4 | 54.2 | 54.3 |

| Item | 5/1/2013 9:00 | 5/1/2013 13:35 | 5/1/2013 16:45 | 5/1/2013 21:25 | 5/2/2013 14:45 | 5/2/2013 21:42 | 5/29/2013 13:54 | 5/31/2013 13:37 | 5/31/2013 15:22 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 |
| 2 | 51.2 | 51.5 | 51.4 | 51.3 | 51.5 | 51.5 | 50.7 | 51.0 | 51.1 |
| 3 | 50.6 | 50.6 | 50.4 | 50.7 | 50.9 | 51.7 | 50.3 | 50.7 | 50.7 |
| 4 | 50 | 49 | 49 | 50 | 50 | 50 | 49.0 | 49.0 | 49.0 |
| 5 | 70 | 69 | 69 | 70 | 68 | 70 | 60.0 | 59.0 | 61.0 |
| 6 | 46 | 42 | 40 | 37 | 12 | 8 | 42.0 | 41.0 | 43.0 |
| 7 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.5 | 0.4 | 0.4 |
| 8 | 44.6 | 43.4 | 40 | 32 | 37.6 | 20.1 | 37.9 | 39.1 | 38.3 |
| 9 | 6.49 | 6.83 | 6.61 | 6.3 | 6.88 | 7.64 | 5.5 | 6.9 | 6.2 |
| 10 | 20.902 | 20.73 | 20.847 | 20.926 | 20.846 | 20.819 | 20.905 | 21.063 | 21.013 |
| 11 | 6.09 | 6.5 | 6.28 | 6.55 | 6.48 | 7.22 | 6.0 | 5.7 | 5.8 |
| 12 | 3574.5 | 3473.4 | 3345.9 | 3231.4 | 3286.7 | 3322.3 | 2959.7 | 3292.8 | 3524.8 |
| 13 | 73.99 | 75.79 | 77.06 | 75.85 | 74.63 | 72.4 | 83.5 | 77.6 | 78.4 |
| 14 | 21.87 | 22.26 | 21.72 | 22.01 | 20.29 | 20.13 | 25.6 | 21.6 | 21.0 |
| 15 | 1118.8 | 1167.3 | 1140.2 | 1124 | 757.65 | 964.2 | 1067.8 | 1228.8 | 1293.3 |
| 16 | 14.5 | 13.76 | 12.72 | 12.35 | 12.52 | 12.96 | 15.9 | 16.0 | 15.9 |
| 17 | 8149 | 7824.4 | 7751.4 | 7522.4 | 6030.4 | 5817.2 | 6439.3 | 7081.0 | 7111.9 |
| 18 | 6.1 | 6.61 | 6.48 | 6.55 | 6.65 | 7.29 | 5.8 | 6.0 | 5.8 |
| 19 | 73.38 | 75.26 | 76.66 | 75 | 73.4 | 71.56 | 82.9 | 77.2 | 77.9 |
| 20 | 56 | 55.9 | 54 |  | 51.4 | 51.5 | 54.1 | 0.0 | 55.3 |

| Item | 6/3/2013 0:00 | 6/3/2013 14:50 | 6/4/2013 11:15 | 6/18/2013 14:21 | 6/18/2013 17:23 | 6/19/2013 10:22 | 6/19/2013 14:30 | 6/20/2013 | 6/20/2013 14:54 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 |
| 2 | 51.0 | 51.1 | 50.8 | 47.7 | 47.7 | 47.3 | 48.8 | 48.9 | 48.9 |
| 3 | 50.4 | 50.6 | 50.4 | 46.5 | 46.5 | 46.2 | 47.8 | 47.9 | 47.9 |
| 4 | 50.0 | 50.0 | 50.0 | 45.0 | 45.0 | 45.0 | 46.0 | 46.0 | 46.0 |
| 5 | 60.0 | 61.0 | 62.0 | 93.0 | 92.0 | 99.0 | 83.0 | 85.0 | 83.0 |
| 6 | 42.0 | 42.0 | 42.0 | 58.0 | 50.0 | 63.0 | 52.0 | 54.0 | 52.0 |
| 7 | 0.4 | 0.4 | 0.4 | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 |
| 8 | 44.9 | 36.0 | 30.4 |  | 52.2 | 45.5 | 42.9 | 40.6 | 43.4 |
| 9 | 6.2 | 6.3 | 7.0 | 7.1 | 6.7 | 7.2 | 6.9 | 7.2 | 5.8 |
| 10 | 20.901 | 21.013 | 20.934 | 20.846 | 20.736 | 20.517 | 20.763 | 20.763 | 20.761 |
| 11 | 6.0 | 6.1 | 6.0 | 6.2 | 6.1 | 6.3 | 6.1 | 6.2 | 6.3 |
| 12 | 3405.5 | 3389.5 | 3179.7 | 3089.8 | 3091.6 | 3371.5 | 3143.7 | 3277.8 | 3105.4 |
| 13 | 79.3 | 79.7 | 79.4 | 81.8 | 82.2 | 80.5 | 81.9 | 81.1 | 82.0 |
| 14 | 21.4 | 21.3 | 22.9 | 40.0 | 40.6 | 39.8 | 34.5 | 35.0 | 35.7 |
| 15 | 1281.0 | 1294.8 | 1167.1 | 1109.0 | 1106.4 | 1168.2 | 1125.9 | 1170.9 | 1141.6 |
| 16 | 15.8 | 15.4 | 16.0 | 28.3 | 28.6 | 30.0 | 27.4 | 28.3 | 27.5 |
| 17 | 7619.0 | 7746.3 | 7594.1 | 7226.5 | 7150.2 | 7971.4 | 6920.1 | 7284.9 | 6826.9 |
| 18 | 5.9 | 6.0 | 6.0 | 6.3 | 6.5 | 6.4 | 6.4 | 6.4 | 6.3 |
| 19 | 78.2 | 79.1 | 78.5 | 81.4 | 81.9 | 80.0 | 81.5 | 80.7 | 81.7 |
| 20 | 59.0 | 61.5 | 60.9 | 64.7 |  | 66.6 | 0.0 | 0.0 | 65.9 |

| Item | 6/21/2013 9:28 | 6/21/2013 11:10 | 6/21/2013 14:54 | 6/24/2013 13:30 | 6/24/2013 16:30 | 6/25/2013 8:16 | 6/26/2013 14:30 | 6/26/2013 16:21 | 6/27/2013 8:27 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 |
| 2 | 48.7 | 48.6 | 48.7 | 48.7 | 48.7 | 48.7 | 48.9 | 48.8 | 48.7 |
| 3 | 47.9 | 47.8 | 48.0 | 47.6 | 47.9 | 47.7 | 48.0 | 48.2 | 47.9 |
| 4 | 47.0 | 47.0 | 47.0 | 46.0 | 48.0 | 48.0 | 47.0 | 47.0 | 48.0 |
| 5 | 86.0 | 85.0 | 82.0 | 81.0 | 83.0 | 86.0 | 85.0 | 84.0 | 89.0 |
| 6 | 55.0 | 54.0 | 52.0 | 51.0 | 52.0 | 55.0 | 54.0 | 53.0 | 57.0 |
| 7 | 0.4 | 0.4 | 0.5 | 0.4 | 0.4 | 0.4 | 0.5 | 0.4 | 0.3 |
| 8 | 45.0 | 43.4 | 41.0 | 45.3 | 45.4 | 43.0 | 44.3 | 40.5 | 41.2 |
| 9 | 3.8 | 5.7 | 7.1 | 7.1 | 5.7 | 6.5 | 6.6 | 7.0 | 7.1 |
| 10 | 20.763 | 20.730 | 20.822 | 20.819 | 20.818 | 20.761 | 20.763 | 20.653 | 20.756 |
| 11 | 6.3 | 6.2 | 6.1 | 6.1 | 6.1 | 6.2 | 6.1 | 6.1 | 6.2 |
| 12 | 3168.0 | 3166.7 | 3043.9 | 3130.2 | 3187.0 | 3272.0 | 3120.5 | 3150.6 | 3258.0 |
| 13 | 80.9 | 81.2 | 82.0 | 84.0 | 82.5 | 80.7 | 79.7 | 80.2 | 77.6 |
| 14 | 35.6 | 35.5 | 34.7 | 35.0 | 34.9 | 33.9 | 34.6 | 35.4 | 35.1 |
| 15 | 1124.5 | 1133.4 | 1125.0 | 1156.5 | 1137.6 | 1163.1 | 1085.2 | 1112.2 | 1077.7 |
| 16 | 27.8 | 28.0 | 27.9 | 27.4 | 27.7 | 28.4 | 28.6 | 28.1 | 29.0 |
| 17 | 7070.3 | 7074.9 | 6734.6 | 6885.0 | 6880.9 | 7246.7 | 6829.2 | 6802.1 | 7177.5 |
| 18 | 6.3 | 6.4 | 6.3 | 6.4 | 6.4 | 6.4 | 6.5 | 6.5 | 6.3 |
| 19 | 80.0 | 80.6 | 81.9 | 83.6 | 82.1 | 80.0 | 79.0 | 79.9 | 77.1 |
| 20 | 63.2 | 61.4 | 65.5 | 66.3 | 63.4 | 65.4 | 51.8 | 50.4 | 52.4 |

| Item | 6/27/2013 16:56 | 6/28/2013 7:55 | 6/28/2013 15:35 | 7/8/2013 11:50 | 7/8/2013 15:54 | 7/9/2013 8:32 | 7/9/2013 15:30 | 7/10/2013 8:19 | 7/10/2013 15:54 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | | |
| 2 | 48.7 | 48.9 | 48.8 | 48.7 | 48.9 | 48.6 | 48.7 | 48.7 | 48.3 |
| 3 | 48.0 | 47.7 | 48.0 | 47.9 | 48.0 | 47.4 | 47.7 | 47.8 | 47.4 |
| 4 | 47.0 | 47.0 | 47.0 | 47.0 | 47.0 | 47.0 | 47.0 | 47.0 | 47.0 |
| 5 | 85.0 | 87.0 | 85.0 | 81.0 | 83.0 | 86.0 | 84.0 | 86.0 | 86.0 |
| 6 | 54.0 | 56.0 | 54.0 | 51.0 | 53.0 | 55.0 | 54.0 | 55.0 | 56.0 |
| 7 | 0.5 | 0.5 | 0.4 | 0.5 | 0.4 | 0.3 | 0.4 | 0.4 | 0.4 |
| 8 | 44.8 | 41.7 | 45.2 | 40.7 | 43.1 | 40.0 | 41.0 | 42.9 | 45.2 |
| 9 | 5.1 | 5.6 | 7.1 | 6.1 | 6.2 | 6.2 | 5.9 | 6.3 | 6.9 |
| 10 | 20.768 | 20.603 | 20.763 | 20.7 | 20.8 | 20.8 | 20.9 | 20.8 | 20.9 |
| 11 | 6.3 | 6.5 | 6.5 | 6.4 | 6.5 | 6.4 | 6.4 | 6.4 | 6.4 |
| 12 | 3159.1 | 3274.9 | 3109.0 | 3131.3 | 3146.5 | 3327.5 | 3142.3 | 3146.3 | 3242.5 |
| 13 | 81.8 | 80.9 | 82.4 | 84.0 | 83.2 | 81.2 | 82.1 | 81.6 | 82.4 |
| 14 | 34.8 | 35.2 | 35.3 | 35.4 | 34.7 | 34.7 | 34.6 | 35.0 | 34.9 |
| 15 | 15.4 | 1133.9 | 1103.4 | 1127.6 | 1122.9 | 1167.9 | 1111.0 | 1083.9 | 1154.0 |
| 16 | 28.4 | 28.8 | 28.2 | 28.1 | 27.8 | 28.8 | 28.4 | 28.9 | 29.0 |
| 17 | 7006.7 | 7227.9 | 6849.2 | 6828.1 | 6908.0 | 7210.9 | 6868.1 | 6927.3 | 7074.2 |
| 18 | 6.2 | 6.6 | 6.5 | 6.5 | 6.5 | 6.6 | 6.6 | 6.6 | 6.6 |
| 19 | 81.4 | 80.3 | 82.0 | 83.4 | 82.9 | 80.5 | 81.7 | 80.9 | 81.7 |
| 20 | 54.0 | 50.5 | 51.9 | 0.0 | 70.5 | 63.3 | 58.3 | 60.3 | 61.3 |

| Item | 7/11/2013 8:34 | 7/11/2013 17:10 | 7/12/2013 9:35 | 7/12/2013 17:07 | 7/13/2013 8:42 | 7/13/2013 16:30 | 7/14/2013 8:00 |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | 48.8 | 48.5 | 48.7 | 48.6 | 48.5 | 48.4 | 48.6 |
| 3 | 47.9 | 47.5 | 47.5 | 47.5 | 47.4 | 47.2 | 47.2 |
| 4 | 47.0 | 47.0 | 47.0 | 47.0 | 48.0 | 48.0 | 48.0 |
| 5 | 87.0 | 86.0 | 87.0 | 88.0 | 90.0 | 89.0 | 91.0 |
| 6 | 56.0 | 55.0 | 56.0 | 57.0 | 58.0 | 58.0 | 58.0 |
| 7 | 0.5 | 0.4 | 0.3 | 0.5 | 0.3 | 0.4 | 0.4 |
| 8 | 40.3 | 45.6 | 42.0 | 42.7 | 42.1 | 41.9 | 59.9 |
| 9 | 7.1 | 2.9 | 5.9 | 7.1 | 7.1 | 7.1 | 6.8 |
| 10 | 20.8 | 20.8 | 20.8 | 20.9 | 20.9 | 20.8 | 20.7 |
| 11 | 6.4 | 6.6 | 6.5 | 6.5 | 6.4 | 6.3 | 6.5 |
| 12 | 3199.3 | 3128.7 | 3244.1 | 3275.9 | 3319.1 | 3333.4 | 3183.6 |
| 13 | 81.9 | 80.6 | 81.3 | 81.9 | 81.8 | 82.0 | 78.6 |
| 14 | 34.5 | 35.4 | 34.4 | 34.8 | 35.5 | 34.6 | 35.1 |
| 15 | 1120.7 | 1108.7 | 1122.0 | 1163.0 | 1116.4 | 1112.5 | 1246.9 |
| 16 | 28.6 | 28.4 | 29.3 | 29.2 | 29.4 | 29.5 | 29.8 |
| 17 | 6926.0 | 6678.7 | 7032.4 | 7147.9 | 7234.0 | 7219.5 | 6823.7 |
| 18 | 6.5 | 7.4 | 6.5 | 6.6 | 6.6 | 6.6 | 6.7 |
| 19 | 81.4 | 80.0 | 80.6 | 81.3 | 80.2 | 81.5 | 78.5 |
| 20 | 58.4 | 54.1 | 61.4 | 61.9 | 59.8 | 48.6 | 57.2 |

Appendix A2: Alamogordo Year 2 Logsheet Data

NaCl Usage Data

| | Tank A | | | | | |
|---|---|---|---|---|---|---|
| | **Water Level** | **Salt Level** | **Bags salt added** | **Δ salt height (in)** | **Salt used (lb)** | **in use?** |
| 4/9/2013 8:20 | 11.75 | 27.75 | 0 | | | yes |
| 4/9/2013 9:42 | 10 | 29.25 | 0 | 1.5 | 48.73 | yes |
| 4/9/2013 10:56 | 11.75 | 30 | 0 | 0.75 | 24.36 | yes |
| 4/9/2013 15:00 | 15.5 | 34.5 | 0 | 4.5 | 146.19 | yes |
| 4/9/2013 16:00 | 15 | 35.5 | 0 | 1 | 32.49 | yes |
| 4/9/2013 17:27 | 18 | 36.875 | 0 | 1.375 | 44.67 | yes |
| 4/10/2013 8:30 | 15.5 | 36.625 | 0 | -0.25 | -8.12 | yes |
| 4/10/2013 10:45 | 17.125 | 39.25 | 0 | 2.625 | 85.28 | yes |
| 4/10/2013 11:05 | 9.75 | 12.625 | 20 | | | yes |
| 4/10/2013 13:10 | 13.625 | 19 | 0 | 6.375 | 207.10 | yes |
| 4/10/2013 13:20 | 10.75 | 19 | 0 | 0 | 0.00 | yes |
| 4/10/2013 15:20 | 14.25 | 21 | 0 | 2 | 64.97 | yes |
| 4/10/2013 15:50 | 12.25 | 21.5 | 0 | 0.5 | 16.24 | yes |
| 4/10/2013 16:48 | 13.75 | 22.375 | 0 | 0.875 | 28.43 | yes |
| 4/11/2013 9:50 | 13.75 | 23 | 0 | 0.625 | 20.30 | yes |
| 4/11/2013 12:00 | 13.75 | 24.5 | 0 | 1.5 | 48.73 | yes |
| 4/11/2013 15:15 | 16 | 27 | 0 | 2.5 | 81.22 | yes |
| 4/11/2013 17:10 | 15.75 | 27.625 | 0 | 0.625 | 20.30 | yes |
| 4/17/2013 8:52 | unknown | 31.625 | | 4 | 129.95 | no |
| 4/17/2013 10:35 | | | | | | no |
| 4/17/2013 16:15 | | | | 0 | 0.00 | no |
| 4/18/2013 8:43 | 27 | 35 | | | | yes |
| 4/18/2013 9:00 | 15 | 17.25 | | -17.75 | | yes |
| 4/18/2013 11:08 | 9.625 | 17.75 | | 0.5 | 16.24 | yes |
| 4/18/2013 16:53 | 17.5 | 26.5 | | 8.75 | 284.25 | yes |
| 4/19/2013 8:30 | 17.5 | 26 | | | | yes |
| 4/19/2013 11:10 | 9 | 29.25 | | 3.25 | 105.58 | yes |
| 4/19/2013 16:15 | 14 | 34.5 | | 5.25 | 170.55 | yes |
| 4/19/2013 16:30 | 8.5 | 15.625 | | -18.875 | -613.18 | yes |
| 4/19/2013 21:22 | 11.5 | 23.25 | | 7.625 | 247.71 | no |
| 4/20/2013 9:15 | 8.5 | 23.25 | | 0 | 0.00 | no |
| 4/22/2013 9:30 | | 25 | | | 0.00 | yes |
| 4/22/2013 10:24 | 15.25 | 27 | | 2 | 64.97 | yes |
| 4/22/2013 14:25 | 9.75 | 32 | | 5 | 162.43 | yes |
| 4/22/2013 16:00 | 8.75 | 16 | 14 | | 0.00 | yes |
| 4/22/2013 21:51 | 10 | 20.5 | | 4.5 | 146.19 | yes |
| 4/23/2013 7:54 | 8.75 | 32.875 | 0 | 12.375 | 402.02 | yes |
| 4/23/2013 10:35 | 10.25 | 36.5 | 0 | 3.625 | 117.76 | yes |
| 4/23/2013 13:15 | 14.75 | 39 | 0 | 2.5 | 81.22 | yes |
| 4/23/2013 13:35 | 13.5 | 39 | 0 | 0 | 0.00 | yes |
| 4/23/2013 15:50 | 16.5 | 41.5 | 0 | 2.5 | 81.22 | yes |

Appendix A2: Alamogordo Year 2 Logsheet Data

NaCl Usage Data

| | Tank A | | | | | |
|---|---|---|---|---|---|---|
| | **Water Level** | **Salt Level** | **Bags salt added** | **Δ salt height (in)** | **Salt used (lb)** | **in use?** |
| 4/23/2013 16:35 | 14.5 | 41.75 | 0 | 0.25 | 8.12 | |
| 4/23/2013 4:45 | 11.5 | 41.75 | 0 | 0 | 0.00 | no |
| 4/23/2013 22:25 | 14 | 44.375 | 0 | 2.625 | 85.28 | no |
| 4/24/2013 7:15 | 17.625 | 50.5 | 0 | 6.125 | 198.98 | no |
| 4/24/2013 8:52 | 20 | 52.5 | 0 | 2 | 64.97 | no |
| 4/24/2013 9:35 | 9.75 | 14 | 30 | | 0.00 | no |
| 4/25/2013 10:50 | 9.5 | 18.375 | 0 | 4.375 | 142.13 | no |
| 4/25/2013 16:30 | 14.375 | 21.625 | 0 | 3.25 | 105.58 | no |
| 4/25/2013 21:30 | 16 | 24 | 0 | 2.375 | 77.15 | no |
| 4/26/2013 8:15 | 17.5 | 27.25 | 0 | 3.25 | 105.58 | no |
| 4/30/2013 14:10 | 20.75 | 29.125 | 0 | 1.875 | 60.91 | no |
| 4/30/2013 16:40 | 23 | 30.5 | 13 | 1.375 | 44.67 | no |
| 4/30/2013 16:40 | 11.75 | 13 | 0 | | 0.00 | no |
| 4/30/2013 21:25 | 14 | 15.625 | 0 | 2.625 | 85.28 | no |
| 5/1/2013 6:45 | 16.625 | 18.75 | 0 | 3.125 | 101.52 | no |
| 5/1/2013 14:02 | 17.75 | 21.75 | 1 | 3 | 97.46 | no |
| 5/1/2013 17:00 | 18.25 | 22.25 | 2 | 0.5 | 16.24 | no |
| 5/1/2013 21:52 | 15.25 | 24 | 3 | 5.25 | 170.55 | no |
| 5/2/2013 9:54 | 11 | 27 | 1 | 8.25 | 268.01 | |
| 5/2/2013 15:30 | 11.75 | 29 | 2 | 2 | 64.97 | |
| 5/2/2013 20:00 | 8.375 | 30.375 | 3 | 1.375 | 44.67 | |
| 5/13/2013 8:00 | 8.75 | 32 | 4 | 1.625 | 52.79 | |
| 5/13/2013 11:50 | | 32 | | 0 | 0.00 | no |
| 5/29/2013 9:35 | | 33 | | 1 | 32.49 | no |
| 5/29/2013 14:20 | | 34.75 | | 1.75 | 56.85 | no |
| 5/31/2013 8:55 | | 35.25 | | 0.5 | 16.24 | no |
| 5/31/2013 15:42 | | 38.25 | | 3 | 97.46 | no |
| 6/3/2013 9:15 | | 40 | 20 | 1.75 | 56.85 | no |
| 6/3/2013 10:00 | | 41.5 | | 1.5 | 48.73 | no |
| 6/3/2013 15:06 | | 43.25 | | 3.25 | 105.58 | no |
| 6/3/2013 15:40 | | 18 | | | 0.00 | no |
| 6/4/2013 8:45 | | 18.75 | | 0.75 | 24.36 | no |
| 6/4/2013 11:30 | | 19.5 | | 1.5 | 48.73 | no |
| 6/4/2013 15:15 | | 21.25 | | 2.5 | 81.22 | no |
| 6/4/2013 17:10 | | 22.25 | | 1 | 32.49 | no |
| 6/14/2013 16:10 | | 39 | | 16.75 | 544.15 | no |
| 6/17/2013 9:30 | | 27.75 | | -11.25 | -365.47 | no |
| 6/17/2013 14:16 | | 31.75 | | | 0.00 | no |
| 6/17/2013 16:45 | | 33.75 | | 2 | 64.97 | no |
| 6/18/2013 8:50 | | 34.5 | | 0.75 | 24.36 | no |
| 6/18/2013 11:20 | | 37.25 | | 2.75 | 89.34 | no |

## Appendix A2: Alamogordo Year 2 Logsheet Data
## NaCl Usage Data

**Tank A**

| | Water Level | Salt Level | Bags salt added | Δ salt height (in) | Salt used (lb) | in use? |
|---|---|---|---|---|---|---|
| 6/18/2013 14:41 | | 39.75 | | 2.5 | 81.22 | no |
| 6/18/2013 15:10 | | 39.75 | | 2.5 | 81.22 | no |
| 6/18/2013 15:10 | | 14.625 | | | 0.00 | no |
| 6/19/2013 11:00 | | 31.25 | | 16.625 | 540.08 | no |
| 6/19/2013 14:46 | | 34.5 | | 3.25 | 105.58 | no |
| 6/19/2013 16:00 | | 35.25 | | 0.75 | 24.36 | no |
| 6/19/2013 16:00 | | 16 | | | 0.00 | no |
| 6/20/2013 10:40 | | 28.5 | | 12.5 | 406.08 | no |
| 6/20/2013 15:10 | | 32 | | 3.5 | 113.70 | no |
| 6/20/2013 15:31 | | 14 | | | 0.00 | |
| 6/21/2013 8:13 | | 25.75 | | 11.75 | 381.71 | no |
| 6/21/2013 11:20 | | 28 | | 2.25 | 73.09 | |
| 6/21/2013 15:10 | | 31.5 | | 3.5 | 113.70 | no |
| 6/24/2013 10:05 | | 32.75 | | 1.25 | 40.61 | no |
| 6/24/2013 12:00 | | 36 | | 3.25 | 105.58 | no |
| 6/24/2013 14:38 | | 36.625 | | 3.875 | 125.88 | no |
| 6/24/2013 14:38 | | 14.625 | | | 0.00 | |
| 6/25/2013 8:34 | | 27.75 | | 13.125 | 426.38 | no |
| 6/26/2013 10:15 | | 29.25 | | 1.5 | 48.73 | no |
| 6/26/2013 14:43 | | 33.5 | | 4.25 | 138.07 | no |
| 6/26/2013 15:11 | | 33.75 | | 0.25 | 8.12 | no |
| 6/26/2013 15:30 | | 13.5 | | | 0.00 | |
| 6/26/2013 16:35 | | 14.25 | | 0.75 | 24.36 | yes |
| 6/27/2013 8:46 | | 25.785 | | 11.535 | 374.73 | yes |
| 6/27/2013 17:12 | | 32 | | 6.215 | 201.90 | yes |
| 6/28/2013 8:10 | | 43 | | 11 | 357.35 | yes |
| 6/28/2013 15:53 | | 48 | | 5 | 162.43 | yes |
| 7/8/2013 9:05 | | 48.5 | | 0.5 | 16.24 | yes |
| 7/8/2013 12:03 | | 51.75 | | 3.25 | 105.58 | yes |
| 7/8/2013 16:10 | | 55 | | 6.5 | 211.16 | yes |
| 7/8/2013 16:30 | | 34 | | | 0.00 | |
| 7/9/2013 8:55 | | 46 | | 12 | 389.84 | |
| 7/9/2013 15:45 | | 50 | | 4 | 129.95 | |
| 7/9/2013 16:30 | | 45 | | | 0.00 | |
| 7/9/2013 19:05 | | 45.5 | | 0.5 | 16.24 | yes |
| 7/9/2013 20:15 | | 46.375 | | 1.375 | 44.67 | yes |
| 7/10/2013 8:40 | | 55 | | 8.625 | 280.19 | yes |
| 7/10/2013 13:54 | | 55 | | 8.625 | 280.19 | yes |
| 7/10/2013 14:15 | | 13.625 | | | 0.00 | yes |
| 7/10/2013 16:09 | | 16.5 | | 2.875 | 93.40 | yes |
| 7/11/2013 8:54 | | 33.375 | | 16.875 | 548.21 | yes |

## Appendix A2: Alamogordo Year 2 Logsheet Data
## NaCl Usage Data

**Tank A**

| | Water Level | Salt Level | Bags salt added | Δ salt height (in) | Salt used (lb) | in use? |
|---|---|---|---|---|---|---|
| 7/11/2013 16:49 | | 37 | | 3.625 | 117.76 | yes |
| 7/11/2013 17:00 | | 25 | | | 0.00 | yes |
| 7/11/2013 20:05 | | 28.5 | | 3.5 | 113.70 | yes |
| 7/12/2013 8:45 | | 42 | | 13.5 | 438.56 | yes |
| 7/12/2013 16:30 | | 48 | | 6 | 194.92 | yes |
| 7/12/2013 16:52 | | 13 | | | 0.00 | yes |
| 7/13/2013 8:33 | | 31.5 | | 18.5 | 601.00 | yes |
| 7/13/2013 9:12 | | 12.125 | | | 0.00 | yes |
| 7/13/2013 17:20 | | 21 | | 8.875 | 288.32 | yes |
| 7/14/2013 8:00 | | 35.5 | | 14.5 | 471.05 | yes |

## Appendix A2: Alamogordo Year 2 Logsheet Data
## NaCl Usage Data

**Tank B**

| **Water Level** | **Salt Level** | **Bags salt added** | **Δ salt height (in)** | **Salt used (lb)** | **in use?** |
|---|---|---|---|---|---|
| 12.5 | 24 | 0 | | | yes |
| 11 | 24.5 | 0 | 0.5 | 16.24 | yes |
| 12.5 | 24.5 | 0 | 0 | 0.00 | yes |
| 16.75 | 26.5 | 0 | 2 | 64.97 | yes |
| 16.75 | 27 | 0 | 0.5 | 16.24 | yes |
| 16.75 | 27.25 | 0 | 0.25 | 8.12 | yes |
| 17.5 | 27.25 | 0 | 0 | 0.00 | yes |
| 19.5 | 27.75 | 0 | 0.5 | 16.24 | yes |
| 10.25 | 21.5 | 5 | | | yes |
| 13.75 | 21.625 | 0 | 0.125 | 4.06 | yes |
| 10.875 | 21.625 | 0 | 0 | 0.00 | yes |
| 14.5 | 22.25 | 0 | 0.625 | 20.30 | yes |
| 12.25 | 22.5 | 0 | 0.25 | 8.12 | yes |
| 14 | 23.125 | 0 | 0.625 | 20.30 | yes |
| 14 | 23 | 0 | -0.125 | -4.06 | yes |
| 13.5 | 24.5 | 0 | 1.5 | 48.73 | yes |
| 15.75 | 26.75 | 0 | 2.25 | 73.09 | yes |
| 15.625 | 28.5 | 0 | 1.75 | 56.85 | yes |
| 19.25 | 29 | 0 | 0.5 | 16.24 | yes |
| 28 | 31.5 | | | 0.00 | yes |
| unknown | 38.5 | 0 | 7 | 227.40 | yes |
| 29.5 | 40 | | | | |
| 15 | 17.25 | | -22.75 | | |
| 32.5 | 19 | | 1.75 | 56.85 | |
| | | | | 0.00 | |
| 14 | 21.25 | | | 0.00 | |
| 14 | 21.25 | | 0 | 0.00 | no |
| 14 | 21.25 | | 0 | 0.00 | no |
| 11 | 17 | | -4.25 | -138.07 | no |
| 11 | 17 | | 0 | 0.00 | yes |
| below salt | 25.75 | | 8.75 | 284.25 | yes |
| | 27 | | | 0.00 | no |
| 15.5 | 28 | | 1 | 32.49 | no |
| 10 | 30 | | 2 | 64.97 | no |
| 8.75 | 16 | 12 | | 0.00 | no |
| 10 | 19 | | 3 | 97.46 | no |
| 11.5 | 20 | | 1 | 32.49 | no |
| 13.75 | 20 | | 0 | 0.00 | no |
| 18.5 | 21 | | 1 | 32.49 | no |
| 15.5 | 21 | | 0 | 0.00 | no |
| 19.5 | 22.75 | | 1.75 | 56.85 | no |

# Appendix A2: Alamogordo Year 2 Logsheet Data
## NaCl Usage Data

**Tank B**

| **Water Level** | **Salt Level** | **Bags salt added** | **Δ salt height (in)** | **Salt used (lb)** | **in use?** |
|---|---|---|---|---|---|
| 16 | 16 | 6 | -6.75 | -219.28 | |
| 14.25 | 16 | | 0 | 0.00 | yes |
| 18.375 | 20.875 | 0 | 4.875 | 158.37 | yes |
| 22 | 25.75 | 0 | 4.875 | 158.37 | yes |
| 24.75 | 26.5 | 0 | 0.75 | 24.36 | yes |
| 9.5 | 26.75 | 0 | 0.25 | 8.12 | yes |
| 9.5 | 26.625 | 0 | | 0.00 | yes |
| 13.75 | 27.25 | 0 | 0.625 | 20.30 | yes |
| 16 | 29.875 | 0 | 2.625 | 85.28 | yes |
| 16.5 | 31.25 | 0 | 1.375 | 44.67 | yes |
| 20 | 32.5 | 0 | 1.25 | 40.61 | yes |
| 22.25 | 33.5 | 14 | 1 | 32.49 | yes |
| 14 | 16.625 | 0 | | 0.00 | yes |
| 13.75 | 17.375 | 0 | 0.75 | 24.36 | yes |
| 15.5 | 19.875 | 0 | 2.5 | 81.22 | yes |
| 17.5 | 22.75 | 1 | 2.875 | 93.40 | yes |
| 15.75 | 24 | 2 | 1.25 | 40.61 | yes |
| 14.75 | 25.5 | 3 | 5.625 | 182.74 | yes |
| 10.25 | 30 | | 10.125 | 328.92 | |
| 11.5 | 31.75 | | 1.75 | 56.85 | |
| 8.625 | 33.375 | | 1.625 | 52.79 | |
| 8.5 | 33.75 | | 0.375 | 12.18 | |
| | 33.75 | | 0 | 0.00 | yes |
| | 34.25 | | 0.5 | 16.24 | yes |
| | 34.75 | | 0.5 | 16.24 | yes |
| | 34.75 | | 0 | 0.00 | yes |
| | 35.5 | | 0.75 | 24.36 | yes |
| | 35.5 | | 0 | 0.00 | yes |
| | 35.75 | | 0.25 | 8.12 | yes |
| | 35.75 | | 0.25 | 8.12 | yes |
| | 18 | | | 0.00 | yes |
| | 19 | | 1 | 32.49 | yes |
| | 19 | | 1 | 32.49 | yes |
| | 19.5 | | 0.5 | 16.24 | yes |
| | 19.25 | | | 0.00 | yes |
| | 26.75 | | 7.5 | 243.65 | yes |
| | 26.5 | | -0.25 | -8.12 | yes |
| | 28.75 | | 2.25 | 73.09 | yes |
| | 29.5 | | 0.75 | 24.36 | yes |
| | 29.75 | | 0.25 | 8.12 | yes |
| | 30 | | 0.25 | 8.12 | yes |

## Appendix A2: Alamogordo Year 2 Logsheet Data

## NaCl Usage Data

**Tank B**

| **Water Level** | **Salt Level** | **Bags salt added** | **Δ salt height (in)** | **Salt used (lb)** | **in use?** |
|---|---|---|---|---|---|
| | 32 | | 2 | 64.97 | yes |
| | 31.75 | | 1.75 | 56.85 | yes |
| | 14.75 | | | 0.00 | yes |
| | 22.25 | | 7.5 | 243.65 | yes |
| | 23.5 | | 1.25 | 40.61 | yes |
| | 23.75 | | 0.25 | 8.12 | yes |
| | 14 | | | 0.00 | yes |
| | 21.25 | | 7.25 | 235.53 | yes |
| | 23 | | 1.75 | 56.85 | yes |
| | 16 | | | 0.00 | |
| | 23 | | 7 | 227.40 | yes |
| | 24 | | 1 | 32.49 | yes |
| | 24.75 | | 0.75 | 24.36 | yes |
| | 25.25 | | 0.5 | 16.24 | yes |
| | 26 | | 0.75 | 24.36 | yes |
| | 26.25 | | 1 | 32.49 | yes |
| | 14.5 | | | 0.00 | |
| | 21 | | 6.5 | 211.16 | yes |
| | 21.75 | | 0.75 | 24.36 | yes |
| | 22.75 | | 1 | 32.49 | yes |
| | 23 | | 0.25 | 8.12 | yes |
| | 14.75 | | | 0.00 | |
| | 15 | | 0.25 | 8.12 | no |
| | 20 | | 5 | 162.43 | no |
| | 23.5 | | 3.5 | 113.70 | no |
| | 28.75 | | 5.25 | 170.55 | no |
| | 31.75 | | 3 | 97.46 | no |
| | 32.5 | | 0.75 | 24.36 | no |
| | 31.75 | | | 0.00 | no |
| | 34 | | 1.5 | 48.73 | no |
| | 34.5 | | 0.5 | 16.24 | no |
| | 40.75 | | 6.25 | 203.04 | no |
| | 44 | | 3.25 | 105.58 | no |
| | 32 | | | 0.00 | no |
| | 33.25 | | 1.25 | 40.61 | no |
| | 33.75 | | 1.75 | 56.85 | no |
| | 38.25 | | 4.5 | 146.19 | no |
| | 42 | | 8.25 | 268.01 | no |
| | 42 | | | 0.00 | no |
| | 43 | | 1 | 32.49 | no |
| | 43 | | 0 | 0.00 | no |

Appendix A2: Alamogordo Year 2 Logsheet Data

NaCl Usage Data

**Tank B**

| Water Level | Salt Level | Bags salt added | Δ salt height (in) | Salt used (lb) | in use? |
|---|---|---|---|---|---|
| | 43 | | 0 | 0.00 | no |
| | 43 | | 0 | 0.00 | no |
| | 43 | | 0 | 0.00 | no |
| | 43 | | 0 | 0.00 | no |
| | 43 | | 0 | 0.00 | no |
| | 43 | | 0 | 0.00 | no |
| | 43 | | 0 | 0.00 | no |
| | 43 | | 0 | 0.00 | no |
| | 43 | | 0 | 0.00 | no |
| | 43 | | 0 | 0.00 | no |

Appendix A2: Alamogordo Year 2 Logsheet Data
NaCl Usage Data

### Tank Filling - For calculating lb/inch

| | | **# 40-lb bags** | **tank height** | **lb/inch** | **avg lb/inch** |
|---|---|---|---|---|---|
| 4/8/2013 | Tank A | 18 | 21 | 34.3 | 34.0 |
| | Tank B | 23 | 27.25 | 33.8 | |
| 4/18/2013 | Tank A | 14 | 17.75 | 31.5 | 31.6 |
| | Tank B | 18 | 22.75 | 31.6 | |
| 4/19/2013 | Tank A | 16 | 18.875 | 33.9 | 35.8 |
| | Tank B | 4 | 4.25 | 37.6 | |
| 6/3/2013 | tank A | 20 | 25.25 | 31.7 | 32.7 |
| | tank B | 15 | 17.75 | 33.8 | |
| 6/17/2013 | tank A | 9 | 12.125 | 29.7 | |
| 6/18/2013 | tank A | 20 | 26.375 | 30.3 | 31.6 |
| | tank B | 14 | 17 | 32.9 | |
| 6/19/2013 | tank A | 16 | 19.25 | 33.2 | 33.0 |
| | tank B | 8 | 9.75 | 32.8 | |
| 6/20/2013 | tank A | 14 | 18 | 31.1 | 32.7 |
| | tank B | 6 | 7 | 34.3 | |
| 6/24/2013 | tank A | 18 | 22 | 32.7 | 31.7 |
| | tank B | 9 | 11.75 | 30.6 | |
| 6/26/2013 | tank A | 16 | 20.25 | 31.6 | 32.8 |
| | tank B | 7 | 8.25 | 33.9 | |
| 7/8/2013 | tank A | 16 | 21 | 30.5 | |
| 7/9/2013 | tank A | 5 | 6 | 33.3 | 33.3 |
| | tank B | 10 | 12 | 33.3 | |
| 7/10/2013 | tank A | 34 | 41.375 | 32.9 | |
| 7/11/2013 | tank A | 10 | 12 | 33.3 | |
| 7/12/2013 | tank A | 29 | 35 | 33.1 | |
| 7/13/2013 | tank A | 15 | 19.375 | 31.0 | |
| | | avg lb/inch - entire | 32.5 | | |

## Appendix A2: Alamogordo Year 2 Logsheet Data
## NaCl Usage Data

**Tank Filling - For calculating lb/inch**

| # 40-lb bags | tank height | lb/inch | avg lb/inch |
|---|---|---|---|

Appendix A2: Alamogordo Year 2 Logsheet Data
NaCl Usage Data

**Tank Filling - For calculating lb/inch**

| # 40-lb bags | tank height | lb/inch | avg lb/inch |
|---|---|---|---|

## NaCl Usage Data

**Tank Filling - For calculating lb/inch**

| # 40-lb bags | tank height | lb/inch | avg lb/inch |
|---|---|---|---|

| **Mixed Cl** | **inches** | **duration (min)** | **Mixed Cl volume (gal)** | **dilutions?** | **flow (gpm)** |
|---|---|---|---|---|---|
| **3/29/2013** | 6.5 | 60 | 32.5 | no | 0.54 |
| **3/29/2013** | 4.625 | 48 | 23.125 | yes | 0.48 |
| **3/29/2013** | 7 | 48 | 35 | yes | 0.73 |
| **3/29/2013** | 11.75 | 75 | 58.75 | no | 0.78 |
| **4/1/2013** | 6.375 | 60 | 31.875 | yes | 0.53 |
| **4/1/2013** | 11.625 | 90 | 58.125 | yes | 0.65 |
| **4/5/2013** | 6 | 60 | 30 | no | 0.50 |
| **4/5/2013** | 6.375 | 60 | 31.875 | no | 0.53 |
| **4/8/2013** | 11 | 120 | 55 | no | 0.46 |
| **4/9/2013** | 6.375 | 60 | 31.875 | no | 0.53 |
| **4/9/2013** | 6.25 | 60 | 31.25 | yes | 0.52 |
| **4/10/2013** | 5.625 | 60 | 28.125 | no | 0.47 |
| **4/10/2013** | 6.5 | 60 | 32.5 | yes | 0.54 |
| **4/10/2013** | 6.875 | 60 | 34.375 | no | 0.57 |
| **4/11/2013** | 9.75 | 60 | 48.75 | no | 0.81 |
| **4/11/2013** | 9.75 | 62 | 48.75 | no | 0.79 |
| **4/11/2013** | | | | | |
| **4/17/2013** | 9.625 | 63 | 48.125 | no | 0.76 |
| **4/17/2013** | 10.125 | 62 | 50.625 | no | 0.82 |
| **4/17/2013** | 18 | 121 | 90 | no | 0.74 |
| **4/18/2013** | 10.5 | 60 | 52.5 | no | 0.88 |
| **4/18/2013** | 11 | 61 | 55 | with NaCl | 0.90 |
| **4/18/2013** | 10.875 | 61 | 54.375 | no | 0.89 |
| **4/19/2013** | 11.375 | 61 | 56.875 | no | 0.93 |
| **4/19/2013** | 11.375 | 70 | 56.875 | with NaCl | 0.81 |
| **4/19/2013** | 10.125 | 62 | 50.625 | with NaCl | 0.82 |
| **4/22/2013** | 16 | 108 | 80 | w/NaCl | 0.74 |
| **4/22/2013** | 9 | 56 | 45 | w/NaCl | 0.80 |
| **4/23/2013** | 15 | 80 | 75 | w/NaCl | 0.94 |
| **4/23/2013** | 11.5 | 70 | 57.5 | w/o NaCl | 0.82 |
| **4/23/2013** | 4.75 | 31 | 23.75 | w/o NaCl | 0.77 |
| **4/24/2013** | 20.125 | 118 | 100.625 | w/ NaCl | 0.85 |
| **4/25/2013** | | | | | |
| **4/25/2013** | 3.5 | 62 | 17.5 | w/ NaCl | 0.28 |
| **4/26/2013** | 2.5 | 63 | 12.5 | w/o NaCl | 0.20 |
| **4/30/2013** | 3.625 | 66 | 18.125 | w/o NaCl | 0.27 |
| **4/30/2013** | 16.5 | 294 | 82.5 | w/ NaCl | 0.28 |
| **5/1/2013** | 3.625 | 64 | 18.125 | w/ NaCl | 0.28 |
| **5/1/2013** | 5.375 | 117 | 26.875 | w/ NaCl | 0.23 |
| **5/2/2013** | 13.75 | 256 | 68.75 | w/ NaCl | 0.27 |
| **5/2/2013** | | | | | |
| **5/31/2013** | 3.5 | 69 | 17.5 | no | 0.25 |

| **Mixed Cl** | **inches** | **duration (min)** | **Mixed Cl volume (gal)** | **dilutions?** | **flow (gpm)** |
|---|---|---|---|---|---|
| **5/31/2013** | 5.25 | 110 | 26.25 | no | 0.24 |
| **6/3/2013** | 2.875 | 62 | 14.375 | no | 0.23 |
| **6/3/2013** | 3.625 | 102 | 18.125 | no | 0.18 |
| **6/4/2013** | 7.625 | 136 | 38.125 | no | 0.28 |
| **6/4/2013** | 8.625 | 174 | 43.125 | no | 0.25 |
| **6/4/2013** | 3.125 | 64 | 15.625 | no | 0.24 |
| **6/4/2013** | 4.5 | 86 | 22.5 | no | 0.26 |
| **6/17/2013** | 3.75 | 78 | 18.75 | no | 0.24 |
| **6/17/2013** | 5.875 | 95 | 29.375 | no | 0.31 |
| **6/18/2013** | 10.25 | 114 | 51.25 | no | 0.45 |
| **6/18/2013** | 9.25 | 121 | 46.25 | no | 0.38 |
| **6/18/2013** | 4.25 | 69 | 21.25 | no | 0.31 |
| **6/19/2013** | 8.875 | 250 | 44.375 | no | 0.18 |
| **6/20/2013** | 12.375 | 167 | 61.875 | no | 0.37 |
| **6/20/2013** | 16.125 | 297 | 80.625 | no | 0.27 |
| **6/20/2013** | | | | no | |
| **6/24/2013** | 5.5 | 71 | 27.5 | no | 0.39 |
| **6/24/2013** | 8.375 | 122 | 41.875 | no | 0.34 |
| **6/26/2013** | 3.75 | 107 | 18.75 | no | 0.18 |
| **6/26/2013** | 7 | 73 | 35 | no | 0.48 |
| **6/26/2013** | 6.75 | 60 | 33.75 | no | 0.56 |
| **6/26/2013** | 4.75 | 55 | 23.75 | no | 0.43 |
| **6/26/2013** | 5.875 | 65 | 29.375 | no | 0.45 |
| **7/8/2013** | 4.25 | 120 | 21.25 | no | 0.18 |
| **7/8/2013** | | | | no | |
| **7/8/2013** | | | | no | |
| **7/9/2013** | 5.875 | 63 | 29.375 | no | 0.47 |
| **7/9/2013** | 10.125 | 113 | 50.625 | no | 0.45 |
| **7/10/2013** | 6.625 | 67 | 33.125 | no | 0.49 |
| **7/10/2013** | 6 | 60 | 30 | no | 0.50 |
| **7/10/2013** | | | | no | |
| **7/12/2013** | 3.125 | 40 | 15.625 | no | 0.39 |
| **7/12/2013** | 6.625 | 76 | 33.125 | no | 0.44 |
| **7/12/2013** | 3 | 40 | 15 | no | 0.38 |
| **7/12/2013** | 4.25 | 62 | 21.25 | no | 0.34 |
| **7/13/2013** | 6.625 | 80 | 33.125 | no | 0.41 |
| **7/13/2013** | 8.625 | 103 | 43.125 | no | 0.42 |
| **7/13/2013** | 7.875 | 100 | 39.375 | no | 0.39 |
| **7/13/2013** | 4.875 | 60 | 24.375 | no | 0.41 |

| inches | duration | Mixed Na volume | dilutions? | M. Na flow |
|---|---|---|---|---|
| 6 | 60 | 30 | no | 0.50 |
| 4.625 | 48 | 23.125 | yes | 0.48 |
| 8 | 41 | 40 | yes | 0.98 |
| 6 | 60 | 30 | no | 0.50 |
| 11 | 75 | 55 | yes | 0.73 |
| 9 | 60 | 45 | yes | 0.75 |
| 5.625 | 60 | 28.125 | no | 0.47 |
| 11.75 | 60 | 58.75 | yes | 0.98 |
| 7.625 | 60 | 38.125 | yes | 0.64 |
| 8.875 | 60 | 44.375 | no | 0.74 |
| 7.875 | 60 | 39.375 | yes | 0.66 |
| 9 | 60 | 45 | no | 0.75 |
| 8.625 | 60 | 43.125 | yes | 0.72 |
| 8.25 | 60 | 41.25 | yes | 0.69 |
| 9.625 | 68 | 48.125 | yes | 0.71 |
| 9.625 | 60 | 48.125 | yes | 0.80 |
| 9.25 | 63 | 46.25 | yes | 0.73 |
| 8.625 | 60 | 43.125 | yes | 0.72 |
| 9.5 | 60 | 47.5 | yes | 0.79 |
| 10.625 | 60 | 53.125 | yes | 0.89 |
| 9 | 62 | 45 | yes | 0.73 |
| 7.75 | 60 | 38.75 | yes | 0.65 |
| | | | | |
| 8.375 | 60 | 41.875 | yes | 0.70 |
| 15.75 | 106 | 78.75 | yes | 0.74 |
| 12 | 76 | 60 | yes | 0.79 |
| 15.125 | 108 | 75.625 | yes | 0.70 |
| 8.5 | 63 | 42.5 | yes | 0.67 |
| 10.875 | 75 | 54.375 | yes | 0.73 |
| 7.625 | 49 | 38.125 | yes | 0.78 |
| 11.5 | 83 | 57.5 | yes | 0.69 |
| | | | | |
| 5.625 | 70 | 28.125 | yes | 0.40 |
| 4 | 62 | 20 | yes | 0.32 |
| 4.75 | 63 | 23.75 | yes | 0.38 |
| | | | | |
| 22.75 | 296 | 113.75 | yes | 0.38 |
| 4.25 | 73 | 21.25 | yes | 0.29 |
| 4.875 | 64 | 24.375 | yes | 0.38 |
| 10.375 | 108 | 51.875 | yes | 0.48 |
| 6.75 | 98 | 33.75 | yes | 0.34 |

| inches | duration | Mixed Na volume | dilutions? | M. Na flow |
|---|---|---|---|---|
| 5 | 73 | 25 | yes | 0.34 |
| 3.625 | 62 | 18.125 | yes | 0.29 |
| 5.5 | 102 | 27.5 | yes | 0.27 |
| | | | yes | |
| 12.375 | 174 | 61.875 | yes | 0.36 |
| 4.125 | 64 | 20.625 | yes | 0.32 |
| 6.5 | 86 | 32.5 | yes | 0.38 |
| 18 | 135 | 90 | yes | 0.67 |
| 12 | 95 | 60 | yes | 0.63 |
| | | | yes | |
| 16.125 | 138 | 80.625 | yes | 0.58 |
| 9.25 | 66 | 46.25 | yes | 0.70 |
| 9.25 | 133 | 46.25 | yes | 0.35 |
| 9.125 | 70 | 45.625 | yes | 0.65 |
| 4.5 | 36 | 22.5 | yes | 0.63 |
| 10.75 | 93 | 53.75 | yes | 0.58 |
| 7.75 | 61 | 38.75 | yes | 0.64 |
| | | | yes | |
| 6.75 | 59 | 33.75 | yes | 0.57 |
| 8.625 | 73 | 43.125 | yes | 0.59 |
| 7.5 | 60 | 37.5 | yes | 0.63 |
| 6.125 | 55 | 30.625 | yes | 0.56 |
| | | | yes | |
| 11.125 | 100 | 55.625 | yes | 0.56 |
| 7.125 | 60 | 35.625 | yes | 0.59 |
| 9.5 | 83 | 47.5 | yes | 0.57 |
| 20 | 176 | 100 | yes | 0.57 |
| | | | yes | |
| 7.5 | 67 | 37.5 | yes | 0.56 |
| 6.25 | 60 | 31.25 | yes | 0.52 |
| 21.375 | 187 | 106.875 | yes | 0.57 |
| 4.75 | 45 | 23.75 | yes | 0.53 |
| 4.625 | 40 | 23.125 | yes | 0.58 |
| | | | yes | |
| | | | yes | |
| | | | yes | |
| 11.625 | 103 | 58.125 | yes | 0.56 |
| 10.125 | 100 | 50.625 | yes | 0.51 |
| 7 | 60 | 35 | yes | 0.58 |

Appendix A2: Alamogordo Year 2 Logsheet Data

Remote Data - Single Stack Data

| | **EDM SYSTEM** | | **Day/Time (MST)-->** | 4/25/2013 10:00pm | 4/26/2013 |
|---|---|---|---|---|---|
| | Location | Tag | units | 10:00 PM | 5:30 AM |
| RO Unit | NF Feed pH | AIT-2008A | | 6.3 | 6.2 |
| | NF Permeate Flow | FIT-2009P | gpm | 21.1 | 21 |
| | NF Permeate Conductivity | AIT-2009P | µS/cm | 1345 | 1061 |
| | NF Reject Flow | FIT-2009R | gpm | 14.6 | 14.9 |
| | NF Reject Conductivity | AIT-2009R1 | µS/cm | 7530 | 7674 |
| EDM Units | EDM-1 reference | | volt | 159 | 159 |
| | EDM-1 current | | amps | 54 | 54 |
| Tank 1 | EDM Total Feed Flow | FIT-2111 | gpm | 25 | 24 |
| | EDM Feed Pressure | PIT-2111 | psi | 7.8 | 7.9 |
| | EDM Feed Conductivity | AIT-2111 | µS/cm | 4892 | 5099 |
| | EDM Feed Temperature | TIT-2111 | °F | 76 | 74 |
| | EDM Diluate Conductivity | AIT-2110 | | | |
| | EDM Diluate Temperature | | | | |
| | EDM Total Mixed Na Flow | FIT-2113 | gpm | 0 | 0 |
| | EDM Mixed Na Pressure | PIT-2113 | psi | | 7.9 |
| | EDM Mixed Na Conductivity | AIT-2113 | µS/cm | 106900 | 108400 |
| | EDM Mixed Na Temperature | TIT-2113 | °F | 78 | 76 |
| Tank 2 | EDM Total Mixed Cl Flow | FIT-2115 | gpm | 27 | 27 |
| | EDM Mixed Cl Pressure | PIT-2115 | psi | 8.1 | 8.1 |
| | EDM Mixed Cl Conductivity | AIT-2115 | µS/cm | -200 | -200 |
| | EDM Mixed Cl Temperature | TIT-2115 | °F | 78 | 76 |
| | EDM Total NaCl Flow | FIT-2117 | gpm | 0 | 0 |
| | EDM NaCl Pressure | PIT-2117 | psi | 7.7 | 8.05 |
| | EDM NaCl Conductivity | AIT-2116 | µS/cm | 49000 | 50000 |
| | EDM NaCl Temperature | TIT-2117 | °F | 78 | 76 |
| DI System | EDM Total E-Rinse Flow | FIT-2124 | gpm | 0 | 0 |
| | EDM E-Rinse Pressure | PIT-2124 | psi | 8 | 8.2 |
| | EDM E-Rinse Conductivity | AIT-2123 | µS/cm | 20000 | 21000 |
| | EDM E-Rinse Temperature | TIT-2124 | °F | 76 | 72 |
| | High level switch on TK-2141 | LSHH-2141 | gray/red | gray | gray |

Appendix A2: Alamogordo Year 2 Logsheet Data

Remote Data - Single Stack Data

| | **EDM SYSTEM**<br>Location | 5/1/2013<br>11:12 PM | 5/1/2013<br>11:18 PM | 5/1/2013<br>11:21 PM | 6/3/2013 actual<br>5:00 PM | 6/3/2013 HMI<br>5:00 PM |
|---|---|---|---|---|---|---|
| | NF Feed pH | 6.6 | 6.7 | 6.6 | | |
| | NF Permeate Flow | 22.5 | 24.5 | 23 | | |
| RO Unit | NF Permeate Conductivity | 1076 | 1056 | 1274 | | |
| | NF Reject Flow | 12.1 | 12.6 | 12.3 | | |
| | NF Reject Conductivity | 7522 | 7754 | 7631 | | |
| EDM Units | EDM-1 reference | | | 154 | 124 | 127 |
| | EDM-1 current | | | 52 | 52 | 53 |
| | EDM Total Feed Flow | | | 24 | 32 | 30 |
| | EDM Feed Pressure | | | 8.7 | 27.3 | 17.9 |
| | EDM Feed Conductivity | | | 5073 | 6306 | 6268 |
| | EDM Feed Temperature | | | 80 | 86.5 | 86 |
| Tank 1 | EDM Diluate Conductivity | | | | 5416 | 4286 |
| | EDM Diluate Temperature | | | | 88.3 | - |
| | EDM Total Mixed Na Flow | | | 0 | 0 | 0 |
| | EDM Mixed Na Pressure | | | 8.7 | 28.4 | 18.1 |
| | EDM Mixed Na Conductivity | | | 110000 | 107.926 | 107700 |
| | EDM Mixed Na Temperature | | | 82 | 88.9 | 88 |
| | EDM Total Mixed Cl Flow | | | 27 | 36.9 | 40 |
| | EDM Mixed Cl Pressure | | | 9.2 | 27.1 | 18.8 |
| | EDM Mixed Cl Conductivity | | | 151600 | 161.6 | 161100 |
| Tank 2 | EDM Mixed Cl Temperature | | | 82 | 88.8 | 88 |
| | EDM Total NaCl Flow | | | 0 | 0 | 0 |
| | EDM NaCl Pressure | | | 8.7 | 27.6 | 18.1 |
| | EDM NaCl Conductivity | | | 49000 | 50925 | 53000 |
| | EDM NaCl Temperature | | | 82 | 88.6 | 88 |
| | EDM Total E-Rinse Flow | | | 0 | 0 | 0 |
| DI System | EDM E-Rinse Pressure | | | 8.9 | 21.2 | 14 |
| | EDM E-Rinse Conductivity | | | 21000 | 20.906 | 20000 |
| | EDM E-Rinse Temperature | | | 80 | 89.7 | 89 |
| | High level switch on TK-2141 | | | gray | | grey |

| | **EDM SYSTEM** | 6/4/2013 actual | 6/4/2013 HMI | 6/4/2013 | 6/4/2013 | 6/4/2013 |
|---|---|---|---|---|---|---|
| | Location | 4:00 PM | 4:00 PM | 7:30 PM | 9:00 PM | 10:30PM |
| | NF Feed pH | 6.03 | 5.9 | 5.9 | 6 | 6 |
| RO Unit | NF Permeate Flow | 22.87 | 22.8 | 23.2 | 23.1 | 22.7 |
| | NF Permeate Conductivity | 1140.6 | 1129 | 1109 | 1089 | 1085 |
| | NF Reject Flow | 16.44 | 15.9 | 16.2 | 16.4 | 16 |
| | NF Reject Conductivity | 7683.6 | 7673 | 7653 | 7664 | 7695 |
| EDM Units | EDM-1 reference | 150 | 153 | 153 | 153 | 153 |
| | EDM-1 current | 54 | 55 | 56 | 55 | 55 |
| | EDM Total Feed Flow | 29.4 | 29 | 30 | 31 | 28 |
| | EDM Feed Pressure | 24.9 | 16.6 | 16.7 | 17.2 | 17.4 |
| | EDM Feed Conductivity | 5138 | 5108 | 5176 | 5159 | 5274 |
| | EDM Feed Temperature | 87 | 86 | 86 | 85 | 85 |
| Tank 1 | EDM Diluate Conductivity | 3944 | 2428 | 2472 | 2491 | 2611 |
| | EDM Diluate Temperature | 89 | - | | | |
| | EDM Total Mixed Na Flow | 0 | 0 | 0 | 0 | 0 |
| | EDM Mixed Na Pressure | 25.5 | 16.6 | 17 | 17.4 | 17.3 |
| | EDM Mixed Na Conductivity | 103700 | 106200 | 114700 | 91700 | 34000 |
| | EDM Mixed Na Temperature | 89.6 | 89 | 88 | 88 | 87 |
| | EDM Total Mixed Cl Flow | 38.9 | 37 | 36 | 39 | 35 |
| | EDM Mixed Cl Pressure | 25 | 17.1 | 17.3 | 17.5 | 17.7 |
| | EDM Mixed Cl Conductivity | 162300 | 161900 | 162700 | 163900 | 164400 |
| Tank 2 | EDM Mixed Cl Temperature | 89.5 | 88 | 89 | 88 | 87 |
| | EDM Total NaCl Flow | 0 | 0 | 0 | 0 | 0 |
| | EDM NaCl Pressure | 25.6 | 17 | 17.5 | 17 | 18.1 |
| | EDM NaCl Conductivity | 50543 | 56000 | 49000 | 49000 | 49000 |
| | EDM NaCl Temperature | 89.2 | 88 | 88 | 88 | 87 |
| DI System | EDM Total E-Rinse Flow | 0 | 0 | 0 | 0 | 0 |
| | EDM E-Rinse Pressure | 20.7 | 13.8 | 13.9 | 14 | 14.1 |
| | EDM E-Rinse Conductivity | 21321 | 20000 | 20000 | 21000 | 20000 |
| | EDM E-Rinse Temperature | 90.3 | 90 | 89 | 87 | 86 |
| | High level switch on TK-2141 | | grey | grey | grey | gray |

# Appendix A2: Alamogordo Year 2 Logsheet Data

## Remote Data - Single Stack Data

| | **EDM SYSTEM** | 6/5/2013 | 6/5/2013 | 6/17/2013 |
|---|---|---|---|---|
| | Location | 12:05 AM | 5:30am | 8:06 PM |
| | NF Feed pH | 6 | 5.9 | 6.2 |
| RO Unit | NF Permeate Flow | 22.1 | 22.7 | 40.4 |
| | NF Permeate Conductivity | 1075 | 821 | 1099 |
| | NF Reject Flow | 16.2 | 16.2 | 28.9 |
| | NF Reject Conductivity | 7715 | 7048 | 7263 |
| EDM Units | EDM-1 reference | 153 | 153 | 121 |
| | EDM-1 current | 55 | 50 | 52 |
| | EDM Total Feed Flow | 30 | 29 | 126 |
| | EDM Feed Pressure | 17.5 | 17.9 | 53 |
| | EDM Feed Conductivity | 5355 | 4915 | 4755 |
| | EDM Feed Temperature | 85 | 83 | 86 |
| Tank 1 | EDM Diluate Conductivity | 2653 | 2163 | 3470 |
| | EDM Diluate Temperature | | | |
| | EDM Total Mixed Na Flow | 0 | 0 | 0 |
| | EDM Mixed Na Pressure | 17.5-18.2 | 17.7 - 18.6 | 18.1 |
| | EDM Mixed Na Conductivity | 31400 | 17700 | 35500 |
| | EDM Mixed Na Temperature | 87 | 85 | 88 |
| | EDM Total Mixed Cl Flow | 35 | 0 | 68 |
| | EDM Mixed Cl Pressure | 17.5 | 1.6 | 18.8 |
| | EDM Mixed Cl Conductivity | 165300 | 162900 | 134200 |
| Tank 2 | EDM Mixed Cl Temperature | 87 | 85 | 88 |
| | EDM Total NaCl Flow | 0 | 0 | 0 |
| | EDM NaCl Pressure | 17.4 | 1.4 | 18.6 |
| | EDM NaCl Conductivity | 56000 | 51000 | 50000 |
| | EDM NaCl Temperature | 87 | 84 | 88 |
| DI System | EDM Total E-Rinse Flow | 0 | 0 | 11 |
| | EDM E-Rinse Pressure | 14.2 | 2.2 | 12.2 |
| | EDM E-Rinse Conductivity | 21000 | 20000 | 21000 |
| | EDM E-Rinse Temperature | 86 | 82 | 87 |
| | High level switch on TK-2141 | grey | | gray |

Appendix A2: Alamogordo Year 2 Logsheet Data
Remote Data - 2-Stack Data

| | **EDM SYSTEM** | **Day/Time (MST)-->** | | **4/22/2013** | **4/22/2013** |
|---|---|---|---|---|---|
| | Location | Tag | units | 4:30 PM | 9:00 PM |
| RO Unit | NF Feed pH | AIT-2008A | | 6.7 | 6.6 |
| | NF Permeate Flow | FIT-2009P | gpm | 40.3 | 40.2 |
| | NF Permeate Conductivity | AIT-2009P | µS/cm | 1364 | 1371 |
| | NF Reject Flow | FIT-2009R | gpm | 28.6 | 28.7 |
| | NF Reject Conductivity | AIT-2009R1 | µS/cm | 7534 | 7637 |
| EDM Units | EDM-1 reference | | volt | 159 | 159 |
| | EDM-1 current | | amps | 61 | 61 |
| | EDM-2 reference | | volt | 155 | 155 |
| | EDM-2 current | | amps | 47 | 47 |
| Tank 1 | EDM Total Feed Flow | FIT-2111 | gpm | 58 | 56 |
| | EDM Feed Pressure | PIT-2111 | psi | 10.2 | 10.3 |
| | EDM Feed Conductivity | AIT-2111 | µS/cm | 4767 | 4867 |
| | EDM Feed Temperature | TIT-2111 | °F | 78 | 77 |
| | EDM Diluate Conductivity | AIT-2110 | µS/cm | | |
| | EDM Total Mixed Na Flow | FIT-2113 | gpm | 0 | 0 |
| | EDM Mixed Na Pressure | PIT-2113 | psi | 10.2 | 10.3 |
| | EDM Mixed Na Conductivity | AIT-2113 | µS/cm | 44900 | 56700 |
| Tank 1 | EDM Mixed Na Temperature | TIT-2113 | °F | 80 | 79 |
| | EDM Total Mixed Cl Flow | FIT-2115 | gpm | 60 | 59 |
| | EDM Mixed Cl Pressure | PIT-2115 | psi | 10.4 | 10.2 |
| | EDM Mixed Cl Conductivity | AIT-2115 | mS/cm | 126500 | 138700 |
| | EDM Mixed Cl Temperature | TIT-2115 | °F | 80 | 79 |
| | EDM Total NaCl Flow | FIT-2117 | gpm | 0 | 0 |
| | EDM NaCl Pressure | PIT-2117 | psi | 10.3 | 10.2 |
| | EDM NaCl Conductivity | AIT-2116 | mS/cm | 53000 | 50000 |
| | EDM NaCl Temperature | TIT-2117 | °F | 83 | 79 |
| DI System | EDM Total E-Rinse Flow | FIT-2124 | gpm | 0 | 0 |
| | EDM E-Rinse Pressure | PIT-2124 | psi | 7.2 | 7.3 |
| | EDM E-Rinse Conductivity | AIT-2123 | mS/cm | 22000 | 22000 |
| | EDM E-Rinse Temperature | TIT-2124 | °F | 83 | 80 |
| | High level switch on TK-2141 | LSHH-2141 | gray/red | gray | gray |

Appendix A2: Alamogordo Year 2 Logsheet Data
Remote Data - 2-Stack Data

| | **EDM SYSTEM** | **4/22/2013** | **4/23/2013** | **4/23/2013** | **4/23/2013** |
|---|---|---|---|---|---|
| | Location | 10:30 PM | 3:00 AM | 6:00 AM | 11:00 PM |
| RO Unit | NF Feed pH | 5.9 | 6 | 6 | 7.1 |
| | NF Permeate Flow | 39.7 | 41.8 | 41.1 | 38.8 |
| | NF Permeate Conductivity | 1355 | 1362 | 1352 | 1471 |
| | NF Reject Flow | 28.6 | 28.4 | 29.1 | 29.6 |
| | NF Reject Conductivity | 7777 | 7856 | 7839 | 7981 |
| EDM Units | EDM-1 reference | 168 | 168 | 168 | 174 |
| | EDM-1 current | 63 | 64 | 64 | 64 |
| | EDM-2 reference | 160 | 160 | 160 | 165 |
| | EDM-2 current | 48 | 49 | 49 | 49 |
| Tank 1 | EDM Total Feed Flow | 54 | 53 | 52 | 49 |
| | EDM Feed Pressure | 10.3 | 10.4 | 10.4 | 10.1 |
| | EDM Feed Conductivity | 5017 | 5213 | 5282 | 2617 |
| | EDM Feed Temperature | 77 | 77 | 77 | 77 |
| | EDM Diluate Conductivity | | | | |
| | EDM Total Mixed Na Flow | 0 | 0 | 0 | 0 |
| | EDM Mixed Na Pressure | 10.6 | 10.4 | 10.4 | 10.3 |
| | EDM Mixed Na Conductivity | 55300 | 53500 | 55300 | 53000 |
| Tank 1 | EDM Mixed Na Temperature | 80 | 80 | 79 | 80 |
| | EDM Total Mixed Cl Flow | 63 | 61 | 66 | 61 |
| | EDM Mixed Cl Pressure | 10.4 | 10.7 | 10.7 | 10.2 |
| | EDM Mixed Cl Conductivity | 137900 | 133000 | 153100 | 127800 |
| | EDM Mixed Cl Temperature | 80 | 79 | 79 | 80 |
| | EDM Total NaCl Flow | 0 | 0 | 0 | 0 |
| | EDM NaCl Pressure | 10.4 | 10.6 | 10.7 | 10.3 |
| | EDM NaCl Conductivity | 52000 | 48000 | 45000 | 47000 |
| | EDM NaCl Temperature | 80 | 79 | 79 | 80 |
| DI System | EDM Total E-Rinse Flow | 0 | 0 | 0 | 0 |
| | EDM E-Rinse Pressure | 7.4 | 7.4 | 7.4 | 7.4 |
| | EDM E-Rinse Conductivity | 22000 | 22000 | 22000 | 27000 |
| | EDM E-Rinse Temperature | 80 | 79 | 79 | 79 |
| | High level switch on TK-2141 | gray | gray | gray | gray |

Appendix A2: Alamogordo Year 2 Logsheet Data
Remote Data - 2-Stack Data

| | **EDM SYSTEM** | **4/24/2013** | **4/24/2013** | **6/18/2013** | **6/18/2013** |
|---|---|---|---|---|---|
| | Location | 2:30 AM | 3:40 AM | 8:06 PM | 10:00 PM |
| RO Unit | NF Feed pH | 7.1 | 7.1 | 6.2 | 6.1 |
| | NF Permeate Flow | 41.2 | 40.9 | 40.4 | 39.7 |
| | NF Permeate Conductivity | 1492 | 1489 | 1099 | 89 |
| | NF Reject Flow | 29.5 | 29.9 | 28.9 | 29.4 |
| | NF Reject Conductivity | 8019 | 8087 | 7263 | 7345 |
| EDM Units | EDM-1 reference | 174 | 174 | 121 | 126 |
| | EDM-1 current | 64 | 63 | 52 | 54 |
| | EDM-2 reference | 165 | 165 | 126 | 121 |
| | EDM-2 current | 48 | 48 | 53 | 52 |
| Tank 1 | EDM Total Feed Flow | 52 | 53 | | 54 |
| | EDM Feed Pressure | 10.2 | 10.2 | | 18.2 |
| | EDM Feed Conductivity | 2844 | 5770 | 4755 | 4833 |
| | EDM Feed Temperature | 76 | 76 | 86 | 86 |
| | EDM Diluate Conductivity | | | 3470 | 3571 |
| | EDM Total Mixed Na Flow | 0 | 0 | 0 | 0 |
| | EDM Mixed Na Pressure | 10.5 | 11 | 18.1 | 18.4 |
| | EDM Mixed Na Conductivity | 68600 | 72000 | 35500 | 37700 |
| Tank 1 | EDM Mixed Na Temperature | 79 | 79 | 88 | 88 |
| | EDM Total Mixed Cl Flow | 62 | 0 | 68 | 74 |
| | EDM Mixed Cl Pressure | 10.1 | 10.2 | 18.8 | 18.2 |
| | EDM Mixed Cl Conductivity | 19600 | 199600 | 134200 | 135300 |
| | EDM Mixed Cl Temperature | 79 | 79 | 88 | 88 |
| | EDM Total NaCl Flow | 0 | 0 | 0 | 0 |
| | EDM NaCl Pressure | 10.5 | 10.1 | 18.6 | 18.9 |
| | EDM NaCl Conductivity | 42000 | 45000 | 50000 | 49000 |
| | EDM NaCl Temperature | 79 | 79 | 88 | 88 |
| DI System | EDM Total E-Rinse Flow | 0 | 0 | 11 | 9 |
| | EDM E-Rinse Pressure | 10.5 | 10.3 | 12.2 | 12.2 |
| | EDM E-Rinse Conductivity | | 28000 | 21000 | 19000 |
| | EDM E-Rinse Temperature | | 78 | 87 | 86 |
| | High level switch on TK-2141 | | gray | gray | grey |

| | **EDM SYSTEM** | **6/19/2013** | **6/19/2013** | **6/19/2013** | **6/19/2013** |
|---|---|---|---|---|---|
| | Location | 12:35 AM | 5:34 AM | 7:52 PM | 9:47 PM |
| RO Unit | NF Feed pH | 6.1 | 6.1 | 6.2 | 6.2 |
| | NF Permeate Flow | 40.3 | 39.5 | 35.5 | 34.8 |
| | NF Permeate Conductivity | 1106 | 1106 | 1112 | 1116 |
| | NF Reject Flow | 29.1 | 29.2 | 27.6 | 27.6 |
| | NF Reject Conductivity | 7346 | 7403 | 7164 | 7131 |
| EDM Units | EDM-1 reference | 121 | 121 | 121 | 121 |
| | EDM-1 current | 52 | 51 | 48 | 48 |
| | EDM-2 reference | 126 | 126 | 113 | 113 |
| | EDM-2 current | 54 | 54 | 47 | 47 |
| Tank 1 | EDM Total Feed Flow | 51 | 56 | 54 | 54 |
| | EDM Feed Pressure | 18.2 | 18.5 | 18.6 | 18.7 |
| | EDM Feed Conductivity | 4898 | 5022 | 4778 | 4865 |
| | EDM Feed Temperature | 85 | 85 | 86 | 85 |
| | EDM Diluate Conductivity | 3644 | 3754 | 3671 | 3750 |
| | EDM Total Mixed Na Flow | 0 | 0 | 0 | 0 |
| | EDM Mixed Na Pressure | 18.6 | 19.3 | 18.6 | 18.9 |
| | EDM Mixed Na Conductivity | 38000 | 45900 | 40300 | 42200 |
| Tank 1 | EDM Mixed Na Temperature | 88 | 88 | 88 | 19 |
| | EDM Total Mixed Cl Flow | 66 | 74 | 71 | 71 |
| | EDM Mixed Cl Pressure | 18.2 | 19.1 | 18.7 | 19 |
| | EDM Mixed Cl Conductivity | 135800 | 135000 | 146400 | 150300 |
| | EDM Mixed Cl Temperature | 87 | 87 | 88 | 87 |
| | EDM Total NaCl Flow | 0 | 0 | 0 | 0 |
| | EDM NaCl Pressure | 18.7 | 18.8 | 18.8 | 19.1 |
| | EDM NaCl Conductivity | 50000 | 50000 | 50000 | 50000 |
| | EDM NaCl Temperature | 87 | 87 | 88 | 87 |
| DI System | EDM Total E-Rinse Flow | 11 | 11 | 11 | 11 |
| | EDM E-Rinse Pressure | 12.3 | 12.4 | 12.8 | 12.8 |
| | EDM E-Rinse Conductivity | 20000 | 20000 | 21000 | 20000 |
| | EDM E-Rinse Temperature | 86 | 86 | 87 | 86 |
| | High level switch on TK-2141 | grey | gray | gray | gray |

Appendix A2: Alamogordo Year 2 Logsheet Data

Remote Data - 2-Stack Data

| | **EDM SYSTEM** | **6/19/2013** | **6/20/2013** | 6/20/2013 | 6/20/2013 |
|---|---|---|---|---|---|
| | Location | 11:58 PM | 6:28 PM | 8:15 PM | 8:20 PM |
| RO Unit | NF Feed pH | 6.3 | 6.1 | 6.2 | 6.1 |
| | NF Permeate Flow | 34.8 | 35 | 34.7 | 39.9 |
| | NF Permeate Conductivity | 1116 | 1081 | 1058 | 1037 |
| | NF Reject Flow | 27.9 | 27.4 | 27.5 | 28.9 |
| | NF Reject Conductivity | 7155 | 6659 | 6696 | 6968 |
| EDM Units | EDM-1 reference | 121 | 133 | 133 | 133 |
| | EDM-1 current | 48 | 48 | 47 | 49 |
| | EDM-2 reference | 113 | 124 | 124 | 124 |
| | EDM-2 current | 47 | 47 | 47 | 49 |
| Tank 1 | EDM Total Feed Flow | 56 | 55 | 55 | 54 |
| | EDM Feed Pressure | 18.6 | 18.5 | 18.5 | 19 |
| | EDM Feed Conductivity | 4894 | 4276 | 4273 | 4573 |
| | EDM Feed Temperature | 85 | 87 | 86 | 86 |
| | EDM Diluate Conductivity | 3796 | 3169 | 3156 | 3399 |
| | EDM Total Mixed Na Flow | 0 | 0 | 0 | 0 |
| | EDM Mixed Na Pressure | 19 | 18.5 | 18.3 | 19.5 |
| | EDM Mixed Na Conductivity | 50000 | 33800 | 35000 | 38500 |
| Tank 1 | EDM Mixed Na Temperature | 87 | 89 | 89 | 88 |
| | EDM Total Mixed Cl Flow | 66 | 68 | 68 | 67 |
| | EDM Mixed Cl Pressure | 19.2 | 18.9 | 18.6 | 19.2 |
| | EDM Mixed Cl Conductivity | 144700 | 121400 | 118500 | 126200 |
| | EDM Mixed Cl Temperature | 87 | 89 | 88 | 88 |
| | EDM Total NaCl Flow | 0 | 0 | 0 | 0 |
| | EDM NaCl Pressure | 19 | 18.5 | 18.6 | 18.8 |
| | EDM NaCl Conductivity | 50000 | 49000 | 50000 | 49000 |
| | EDM NaCl Temperature | 87 | 89 | 88 | 88 |
| DI System | EDM Total E-Rinse Flow | 11 | 11 | 11 | 11 |
| | EDM E-Rinse Pressure | 12.8 | 13 | 13.1 | 13.2 |
| | EDM E-Rinse Conductivity | 21000 | 21000 | 20000 | 21000 |
| | EDM E-Rinse Temperature | 86 | 89 | 88 | 88 |
| | High level switch on TK-2141 | gray | gray | gray | gray |

Appendix A2: Alamogordo Year 2 Logsheet Data
Remote Data - 2-Stack Data

| | **EDM SYSTEM** | 6/20/2013 | 6/20/2013 | 6/20/2013 | 6/21/2013 | 6/24/2013 |
|---|---|---|---|---|---|---|
| | Location | 9:04 PM | 9:54 PM | 11:03 PM | 2:24 AM | 7:51 PM |
| RO Unit | NF Feed pH | 6.2 | 6.1 | 6.1 | 6.2 | 6.2 |
| | NF Permeate Flow | 39.7 | 35.1 | 34.6 | 34.9 | 34.9 |
| | NF Permeate Conductivity | 1068 | 1061 | 1062 | 1048 | 1126 |
| | NF Reject Flow | 29.4 | 27.4 | 27.6 | 27.6 | 27.6 |
| | NF Reject Conductivity | 7355 | 6738 | 6694 | 6775 | 6876 |
| EDM Units | EDM-1 reference | 133 | 133 | 133 | 133 | 128 |
| | EDM-1 current | 52 | 47 | 47 | 47 | 47 |
| | EDM-2 reference | 124 | 124 | 124 | 124 | 126 |
| | EDM-2 current | 52 | 47 | 47 | 47 | 49 |
| Tank 1 | EDM Total Feed Flow | 56 | 55 | 57 | 57 | 55 |
| | EDM Feed Pressure | 18.9 | 18.5 | 18.7 | 18.7 | 20.2 |
| | EDM Feed Conductivity | 5028 | 4363 | 4331 | 4369 | 4483 |
| | EDM Feed Temperature | 3826 | 86 | 85 | 85 | 86 |
| | EDM Diluate Conductivity | 3830 | 3240 | 3255 | 3300 | 3368 |
| | EDM Total Mixed Na Flow | 0 | 0 | 0 | 0 | 0 |
| | EDM Mixed Na Pressure | 19 | 19.1 | 18.7 | 18.7 | 21 |
| | EDM Mixed Na Conductivity | 42800 | 38600 | 40900 | 42400 | 36100 |
| Tank 1 | EDM Mixed Na Temperature | 88 | 88 | 88 | 87 | 89 |
| | EDM Total Mixed Cl Flow | 67 | 65 | 64 | 65 | 67 |
| | EDM Mixed Cl Pressure | 18.7 | 18.7 | 18.9 | 19.1 | 20.2 |
| | EDM Mixed Cl Conductivity | 126200 | 118200 | 120000 | 118500 | 113600 |
| | EDM Mixed Cl Temperature | 88 | 88 | 87 | 87 | 89 |
| | EDM Total NaCl Flow | 0 | 0 | 0 | 0 | 0 |
| | EDM NaCl Pressure | 18.8 | 19.1 | 18.9 | 19.1 | 20.6 |
| | EDM NaCl Conductivity | 49000 | 50000 | 49000 | 48000 | 49000 |
| | EDM NaCl Temperature | 88 | 88 | 87 | 87 | 88 |
| DI System | EDM Total E-Rinse Flow | 11 | 11 | 11 | 11 | 11 |
| | EDM E-Rinse Pressure | 13.3 | 13.3 | 13.3 | 13.4 | 13.9 |
| | EDM E-Rinse Conductivity | 21000 | 21000 | 21000 | 21000 | 21000 |
| | EDM E-Rinse Temperature | 87 | 87 | 87 | 86 | 88 |
| | High level switch on TK-2141 | gray | gray | gray | gray | gray |

Appendix A2: Alamogordo Year 2 Logsheet Data
Remote Data - 2-Stack Data

| | **EDM SYSTEM** | 6/25/2013 | 6/25/2013 | 6/26/2013 | 6/26/2013 | 6/27/2013 |
|---|---|---|---|---|---|---|
| | Location | 12:15 AM | 6:25 AM | 7:23 PM | 9:42 PM | 12:00 AM |
| RO Unit | NF Feed pH | 6.1 | 6 | 6.3 | 6.3 | 6.3 |
| | NF Permeate Flow | 34.9 | 35.2 | 34.5 | 34.5 | 34.8 |
| | NF Permeate Conductivity | 1130 | 1141 | 1092 | 1048 | 984 |
| | NF Reject Flow | 28 | 28.2 | 28.7 | 28.4 | 28.2 |
| | NF Reject Conductivity | 7037 | 7126 | 7039 | 6935 | 6844 |
| EDM Units | EDM-1 reference | 128 | 128 | 118 | 118 | 118 |
| | EDM-1 current | 47 | 48 | 44 | 44 | 42 |
| | EDM-2 reference | 126 | 126 | 127 | 127 | 127 |
| | EDM-2 current | 50 | 51 | 51 | 50 | 49 |
| Tank 1 | EDM Total Feed Flow | 55 | 54 | 55 | 55 | 56 |
| | EDM Feed Pressure | 20.6 | 20.7 | 18.8 | 18.8 | 19.1 |
| | EDM Feed Conductivity | 4803 | 5014 | 4737 | 4781 | 4708 |
| | EDM Feed Temperature | 85 | 84 | 84 | 83 | 83 |
| | EDM Diluate Conductivity | 3686 | 3923 | 3643 | 3705 | 3655 |
| | EDM Total Mixed Na Flow | 0 | 0 | 0 | 0 | 0 |
| | EDM Mixed Na Pressure | 20.6 | 20.6 | 19.5 | 19.2 | 18.9 |
| | EDM Mixed Na Conductivity | 42500 | 45900 | 5700 | 6300 | 6800 |
| Tank 1 | EDM Mixed Na Temperature | 87 | 86 | 87 | 85 | 85 |
| | EDM Total Mixed Cl Flow | 67 | 65 | 65 | 64 | 65 |
| | EDM Mixed Cl Pressure | 20.3 | 21 | 19.4 | 19.1 | 19.8 |
| | EDM Mixed Cl Conductivity | 114600 | 108900 | 10300 | 10100 | 10000 |
| | EDM Mixed Cl Temperature | 87 | 86 | 86 | 85 | 85 |
| | EDM Total NaCl Flow | 0 | 0 | 0 | 0 | 0 |
| | EDM NaCl Pressure | 20.6 | 20.9 | 19 | 18.9 | 19.4 |
| | EDM NaCl Conductivity | 49000 | 49000 | 49000 | 49000 | 50000 |
| | EDM NaCl Temperature | 87 | 86 | 86 | 85 | 85 |
| DI System | EDM Total E-Rinse Flow | 11 | 11 | 11 | 11 | 11 |
| | EDM E-Rinse Pressure | 14 | 14.1 | 13.1 | 13.2 | 13.1 |
| | EDM E-Rinse Conductivity | 21000 | 21000 | 21000 | 21000 | 21000 |
| | EDM E-Rinse Temperature | 85 | 84 | 86 | 84 | 83 |
| | High level switch on TK-2141 | gray | gray | gray | gray | gray |

## Appendix A2: Alamogordo Year 2 Logsheet Data
## Remote Data - 2-Stack Data

| | **EDM SYSTEM** |
|---|---|
| | Location |
| RO Unit | NF Feed pH |
| | NF Permeate Flow |
| | NF Permeate Conductivity |
| | NF Reject Flow |
| | NF Reject Conductivity |
| EDM Units | EDM-1 reference |
| | EDM-1 current |
| | EDM-2 reference |
| | EDM-2 current |
| Tank 1 | EDM Total Feed Flow |
| | EDM Feed Pressure |
| | EDM Feed Conductivity |
| | EDM Feed Temperature |
| | EDM Diluate Conductivity |
| | EDM Total Mixed Na Flow |
| | EDM Mixed Na Pressure |
| | EDM Mixed Na Conductivity |
| Tank 1 | EDM Mixed Na Temperature |
| | EDM Total Mixed Cl Flow |
| | EDM Mixed Cl Pressure |
| | EDM Mixed Cl Conductivity |
| | EDM Mixed Cl Temperature |
| | EDM Total NaCl Flow |
| | EDM NaCl Pressure |
| | EDM NaCl Conductivity |
| | EDM NaCl Temperature |
| DI System | EDM Total E-Rinse Flow |
| | EDM E-Rinse Pressure |
| | EDM E-Rinse Conductivity |
| | EDM E-Rinse Temperature |
| | High level switch on TK-2141 |

6/27/13 mass balance - 12:15 am

| | flow | cond |
|---|---|---|
| perm | 35.5 | 970 |
| reject | 28.2 | 6803 |
| NF feed | 63.7 | 3043 |
| Σ in | 193839.1 | |
| Σ out | 226279.6 | |
| difference | 15% | |
| | | |
| SW | *37.2* | 2619.855 |
| EDM dil | 26.5 | 3637 |
| NF feed | 63.7 | 3043 |

I think that we might lose the tank tonight

Appendix A2: Alamogordo Year 2 Logsheet Data
Remote Data - 2-Stack Data

| | **EDM SYSTEM** | 6/27/2013 | 6/27/2013 | | | |
|---|---|---|---|---|---|---|
| | Location | 3:00 AM | 3:12 AM | | | |
| RO Unit | NF Feed pH | 6.2 | 6.2 | | | |
| | NF Permeate Flow | 35 | 34.8 | 6/27/13 mass balance - 3:14 am | | |
| | NF Permeate Conductivity | 882 | 899 | | flow | cond |
| | NF Reject Flow | 28.4 | 28.4 | perm | 35.2 | 872 |
| | NF Reject Conductivity | 6576 | 6508 | reject | 28 | 6447 |
| EDM Units | EDM-1 reference | 118 | 118 | NF feed | 63.2 | 2809 |
| | EDM-1 current | 41 | 40 | Σ in | 177528.8 | |
| | EDM-2 reference | 127 | 127 | Σ out | 211210.4 | |
| | EDM-2 current | 47 | 47 | difference | 17% | |
| Tank 1 | EDM Total Feed Flow | 53 | 44 | | | |
| | EDM Feed Pressure | 19.3 | 14.2 | SW | *47.2* | 2618.831 |
| | EDM Feed Conductivity | 4527 | 4590 | EDM dil | 16 | 3370 |
| | EDM Feed Temperature | 82 | 82 | NF feed | 63.2 | 2809 |
| | EDM Diluate Conductivity | 3487 | 3387 | | | |
| | EDM Total Mixed Na Flow | 0 | 0 | I think that we might lose the tank | | |
| | EDM Mixed Na Pressure | 19.6 | 14.6 | | | |
| | EDM Mixed Na Conductivity | 6800 | 6800 | | | |
| Tank 1 | EDM Mixed Na Temperature | 84 | 84 | | | |
| | EDM Total Mixed Cl Flow | 65 | 50 | | | |
| | EDM Mixed Cl Pressure | 19.7 | 14.2 | | | |
| | EDM Mixed Cl Conductivity | 9900 | 9600 | | | |
| | EDM Mixed Cl Temperature | 84 | 84 | | | |
| | EDM Total NaCl Flow | 0 | 0 | | | |
| | EDM NaCl Pressure | 19.4 | 14.2 | | | |
| | EDM NaCl Conductivity | 51000 | 51000 | | | |
| | EDM NaCl Temperature | 84 | 84 | | | |
| DI System | EDM Total E-Rinse Flow | 11 | 11 | | | |
| | EDM E-Rinse Pressure | 13.3 | 11.8 | | | |
| | EDM E-Rinse Conductivity | 21000 | 21000 | | | |
| | EDM E-Rinse Temperature | 82 | 82 | | | |
| | High level switch on TK-2141 | gray | gray | | | |

Appendix A2: Alamogordo Year 2 Logsheet Data

Remote Data - 2-Stack Data

| | **EDM SYSTEM** | 6/27/2013 | | | |
|---|---|---|---|---|---|
| | Location | 5:32 AM | | | |
| RO Unit | NF Feed pH | 6.1 | | | |
| | NF Permeate Flow | 34.8 | 6/27/13 mass balance - 5:39 am | | |
| | NF Permeate Conductivity | 811 | | flow | cond |
| | NF Reject Flow | 27.8 | perm | 35 | 821 |
| | NF Reject Conductivity | 6234 | reject | 28 | 6237 |
| EDM Units | EDM-1 reference | 118 | NF feed | 63 | 2724 |
| | EDM-1 current | 38 | Σ in | 171612 | |
| | EDM-2 reference | 127 | Σ out | 203371 | |
| | EDM-2 current | 44 | difference | 17% | |
| Tank 1 | EDM Total Feed Flow | 47 | | | |
| | EDM Feed Pressure | 14.3 | SW | *47* | 2553.447 |
| | EDM Feed Conductivity | 4418 | EDM dil | 16 | 3225 |
| | EDM Feed Temperature | 80 | NF feed | 63 | 2724 |
| | EDM Diluate Conductivity | 3230 | | | |
| | EDM Total Mixed Na Flow | 0 | | | |
| | EDM Mixed Na Pressure | 14 | | | |
| | EDM Mixed Na Conductivity | 6800 | | | |
| Tank 1 | EDM Mixed Na Temperature | 82 | | | |
| | EDM Total Mixed Cl Flow | 50 | | | |
| | EDM Mixed Cl Pressure | 14.5 | | | |
| | EDM Mixed Cl Conductivity | 9700 | | | |
| | EDM Mixed Cl Temperature | 82 | | | |
| | EDM Total NaCl Flow | 0 | | | |
| | EDM NaCl Pressure | 14.4 | | | |
| | EDM NaCl Conductivity | 51000 | | | |
| | EDM NaCl Temperature | 82 | | | |
| DI System | EDM Total E-Rinse Flow | 11 | | | |
| | EDM E-Rinse Pressure | 11.7 | | | |
| | EDM E-Rinse Conductivity | 20000 | | | |
| | EDM E-Rinse Temperature | 80 | | | |
| | High level switch on TK-2141 | gray | | | |

Appendix A2: Alamogordo Year 2 Logsheet Data
Remote Data - 2-Stack Data

|  | **EDM SYSTEM** |  |  |  | 6/27/2013 | 6/27/2013 |
|---|---|---|---|---|---|---|
|  | Location |  |  |  | 6:52 PM | 10:16 PM |
| RO Unit | NF Feed pH |  |  |  | 6.2 | 6.3 |
|  | NF Permeate Flow | 6/27/13 mass balance - 7:24 am |  |  | 35.1 | 35.3 |
|  | NF Permeate Conductivity |  | flow | cond | 1064 | 1088 |
|  | NF Reject Flow | perm | 35 | 954 | 28.2 | 28.6 |
|  | NF Reject Conductivity | reject | 28 | 6563 | 6970 | 6975 |
| EDM Units | EDM-1 reference | NF feed | 63 | 2962 | 128 | 128 |
|  | EDM-1 current | Σ in | 186606 |  | 46 | 46 |
|  | EDM-2 reference | Σ out | 217154 |  | 126 | 126 |
|  | EDM-2 current | difference | 15% |  | 50 | 49 |
| Tank 1 | EDM Total Feed Flow |  |  |  | 54 | 56 |
|  | EDM Feed Pressure | SW | *47* | 2752.298 | 21 | 21.3 |
|  | EDM Feed Conductivity | EDM dil | 16 | 3578 | 4725 | 4835 |
|  | EDM Feed Temperature | NF feed | 63 | 2962 | 87 | 85 |
|  | EDM Diluate Conductivity |  |  |  | 3697 | 3802 |
|  | EDM Total Mixed Na Flow |  |  |  | 0 | 0 |
|  | EDM Mixed Na Pressure |  |  |  | 21.1 | 21.3 |
|  | EDM Mixed Na Conductivity |  |  |  | 4400 | 4800 |
| Tank 1 | EDM Mixed Na Temperature |  |  |  | 89 | 88 |
|  | EDM Total Mixed Cl Flow |  |  |  | 64 | 65 |
|  | EDM Mixed Cl Pressure |  |  |  | 21.3 | 21.8 |
|  | EDM Mixed Cl Conductivity |  |  |  | 88100 | 86400 |
|  | EDM Mixed Cl Temperature |  |  |  | 89 | 87 |
|  | EDM Total NaCl Flow |  |  |  | 0 | 0 |
|  | EDM NaCl Pressure |  |  |  | 21.3 | 21.1 |
|  | EDM NaCl Conductivity |  |  |  | 49000 | 49000 |
|  | EDM NaCl Temperature |  |  |  | 89 | 87 |
| DI System | EDM Total E-Rinse Flow |  |  |  | 11 | 11 |
|  | EDM E-Rinse Pressure |  |  |  | 13.6 | 13.8 |
|  | EDM E-Rinse Conductivity |  |  |  | 21000 | 21000 |
|  | EDM E-Rinse Temperature |  |  |  | 88 | 87 |
|  | High level switch on TK-2141 |  |  |  | gray | gray |

Appendix A2: Alamogordo Year 2 Logsheet Data
Remote Data - 2-Stack Data

| | **EDM SYSTEM** | 7/8/2013 | 7/8/2013 | 7/9/2013 | 7/9/2013 | 7/9/2013 |
|---|---|---|---|---|---|---|
| | Location | 8:37 PM | 10:38 | 2:04 | 10:15 PM | 11:30 PM |
| RO Unit | NF Feed pH | 6.5 | 6.4 | 6.4 | 6.4 | 6.4 |
| | NF Permeate Flow | 35.4 | 35.3 | 35.3 | 34.9 | 35.1 |
| | NF Permeate Conductivity | 1126 | 1133 | 1113 | 1111 | 1089 |
| | NF Reject Flow | 28.5 | 28.8 | 28.6 | 28.4 | 28.5 |
| | NF Reject Conductivity | 7131 | 7152 | 7234 | 6880 | 6972 |
| EDM Units | EDM-1 reference | 128 | 128 | 128 | 135 | 136 |
| | EDM-1 current | 47 | 47 | 47 | 47 | 48 |
| | EDM-2 reference | 126 | 126 | 126 | 133 | 133 |
| | EDM-2 current | 50 | 50 | 51 | 50 | 51 |
| Tank 1 | EDM Total Feed Flow | 58 | 60 | 59 | 58 | 56 |
| | EDM Feed Pressure | 23.6 | 23.7 | 23.7 | 25.2 | 25 |
| | EDM Feed Conductivity | 4794 | 4887 | 4998 | 4646 | 4663 |
| | EDM Feed Temperature | 86 | 86 | 86 | 87 | 86 |
| | EDM Diluate Conductivity | 3735 | 3820 | 3940 | 3579 | 3618 |
| | EDM Total Mixed Na Flow | 0 | 0 | 0 | 0 | 0 |
| | EDM Mixed Na Pressure | 24.2 | 24.1 | 24.4 | 25 | 25.2 |
| | EDM Mixed Na Conductivity | 113900 | 115400 | 116100 | 110700 | 112200 |
| Tank 1 | EDM Mixed Na Temperature | 89 | 88 | 88 | 89 | 89 |
| | EDM Total Mixed Cl Flow | 63 | 61 | 56 | 58 | 61 |
| | EDM Mixed Cl Pressure | 23.7 | 24.4 | 24 | 25.7 | 25.5 |
| | EDM Mixed Cl Conductivity | 149800 | 150000 | 150400 | 158100 | 158400 |
| | EDM Mixed Cl Temperature | 89 | 88 | 87 | 89 | 89 |
| | EDM Total NaCl Flow | 0 | 0 | 0 | 0 | 0 |
| | EDM NaCl Pressure | 24.2 | 24.1 | 24.5 | 25.8 | 25.1 |
| | EDM NaCl Conductivity | 48000 | 48000 | 51000 | 49000 | 52000 |
| | EDM NaCl Temperature | 89 | 88 | 87 | 89 | 89 |
| DI System | EDM Total E-Rinse Flow | 10 | 11 | 10 | 10 | 10 |
| | EDM E-Rinse Pressure | 14.6 | 14.7 | 14.9 | 15.6 | 15.6 |
| | EDM E-Rinse Conductivity | 20000 | 21000 | 21000 | 21000 | 21000 |
| | EDM E-Rinse Temperature | 87 | 87 | 86 | 87 | 87 |
| | High level switch on TK-2141 | gray | gray | gray | gray | gray |

## Appendix A2: Alamogordo Year 2 Logsheet Data
### Remote Data - 2-Stack Data

| | **EDM SYSTEM** | 7/10/2013 | 7/10/2013 | 7/11/2013 | 7/11/2013 | 7/12/2013 |
|---|---|---|---|---|---|---|
| | Location | 8:40 PM | 10:50 PM | 2:01 | 9:21 PM | 12:13 AM |
| RO Unit | NF Feed pH | 6.3 | 6.4 | 6.4 | 6.4 | 6.4 |
| | NF Permeate Flow | 34.7 | 34.6 | 34.5 | 34.8 | 35 |
| | NF Permeate Conductivity | 1112 | 1119 | 1099 | 1110 | 1130 |
| | NF Reject Flow | 28.4 | 28.5 | 28.4 | 28.9 | 29 |
| | NF Reject Conductivity | 6883 | 6880 | 6880 | 6850 | 6982 |
| EDM Units | EDM-1 reference | 144 | 144 | 144 | 134 | 134 |
| | EDM-1 current | 49 | 49 | 48 | 47 | 47 |
| | EDM-2 reference | 141 | 141 | 141 | 136 | 136 |
| | EDM-2 current | 52 | 52 | 52 | 51 | 51 |
| Tank 1 | EDM Total Feed Flow | 59 | 58 | 59 | 58 | 56 |
| | EDM Feed Pressure | 25.8 | 25.9 | 26 | 25 | 23 |
| | EDM Feed Conductivity | 4513 | 4546 | 4505 | 4462 | 4826 |
| | EDM Feed Temperature | 87 | 87 | 87 | 86 | 85 |
| | EDM Diluate Conductivity | 3413 | 3446 | 3436 | 3355 | 3709 |
| | EDM Total Mixed Na Flow | 0 | 0 | 0 | 0 | 0 |
| | EDM Mixed Na Pressure | 25.7 | 26.4 | 26.3 | 25.6 | 23.8 |
| | EDM Mixed Na Conductivity | 111000 | 111500 | 111800 | 110200 | 110400 |
| Tank 1 | EDM Mixed Na Temperature | 89 | 89 | 89 | 88 | 88 |
| | EDM Total Mixed Cl Flow | 59 | 55 | 51 | 53 | 50 |
| | EDM Mixed Cl Pressure | 26.1 | 25.8 | 25.8 | 25.6 | 22.9 |
| | EDM Mixed Cl Conductivity | 155400 | 155700 | 156200 | 156600 | 162700 |
| | EDM Mixed Cl Temperature | 89 | 89 | 89 | 88 | 87 |
| | EDM Total NaCl Flow | 0 | 0 | 0 | 0 | 0 |
| | EDM NaCl Pressure | 26.3 | 26.2 | 26.1 | 25 | 23.2 |
| | EDM NaCl Conductivity | 49000 | 48000 | 51000 | 47000 | 49000 |
| | EDM NaCl Temperature | 89 | 89 | 89 | 88 | 87 |
| DI System | EDM Total E-Rinse Flow | 10 | 10 | 10 | 10 | 10 |
| | EDM E-Rinse Pressure | 16.2 | 16.4 | 16.4 | 16.1 | 15.8 |
| | EDM E-Rinse Conductivity | 21000 | 22000 | 21000 | 17000 | 16000 |
| | EDM E-Rinse Temperature | 88 | 88 | 88 | 87 | 86 |
| | High level switch on TK-2141 | gray | gray | gray | gray | gray |

## Appendix A2: Alamogordo Year 2 Logsheet Data
### Remote Data - 2-Stack Data

| | **EDM SYSTEM** | 7/12/2013 | 7/12/2013 | 7/13/2013 | 7/13/2013 | 7/13/2013 |
|---|---|---|---|---|---|---|
| | Location | 7:30 PM | 9:30 PM | 1:30 | 7:44 | 6:21 PM |
| RO Unit | NF Feed pH | 6.5 | 6.4 | 6.4 | 6.4 | 6.4 |
| | NF Permeate Flow | 35.1 | 35.2 | 34.4 | 34.9 | 34.7 |
| | NF Permeate Conductivity | 1140 | 1147 | 1154 | 1155 | 1112 |
| | NF Reject Flow | 29 | 28.9 | 29.6 | 29.4 | 29.6 |
| | NF Reject Conductivity | 7128 | 7148 | 1154 | 1155 | 7293 |
| EDM Units | EDM-1 reference | 154 | 154 | 154 | | 154 |
| | EDM-1 current | 49 | 48 | 48 | | 46 |
| | EDM-2 reference | 151 | 151 | 151 | | 146 |
| | EDM-2 current | 54 | 54 | 54 | | 52 |
| Tank 1 | EDM Total Feed Flow | 56 | 58 | 57 | | 55 |
| | EDM Feed Pressure | 24.6 | 25.1 | 25.4 | | 25.4 |
| | EDM Feed Conductivity | 4943 | 4978 | 5043 | | 4821 |
| | EDM Feed Temperature | 86 | 86 | 85 | | 87 |
| | EDM Diluate Conductivity | 3872 | 3907 | 3986 | | 3974 |
| | EDM Total Mixed Na Flow | 0 | 0 | 0 | | 0 |
| | EDM Mixed Na Pressure | 25 | 25 | 25.7 | | 26.1 |
| | EDM Mixed Na Conductivity | 111800 | 109500 | 110700 | | 110800 |
| Tank 1 | EDM Mixed Na Temperature | 89 | 89 | 88 | | 90 |
| | EDM Total Mixed Cl Flow | 53 | 52 | 47 | | 44 |
| | EDM Mixed Cl Pressure | 25.1 | 25.5 | 25.9 | | 26.2 |
| | EDM Mixed Cl Conductivity | 158900 | 159200 | 160000 | | 15850 |
| | EDM Mixed Cl Temperature | 89 | 88 | 88 | | 89 |
| | EDM Total NaCl Flow | 0 | 0 | 0 | | 0 |
| | EDM NaCl Pressure | 24.6 | 25.2 | 25.5 | | 25.4 |
| | EDM NaCl Conductivity | 47000 | 47000 | 159900 | | 47000 |
| | EDM NaCl Temperature | 89 | 88 | 87 | | 89 |
| DI System | EDM Total E-Rinse Flow | 0 | 0 | 0 | | 0 |
| | EDM E-Rinse Pressure | 16.1 | 16.1 | 16.4 | | 17.5 |
| | EDM E-Rinse Conductivity | 22000 | 23000 | 22000 | | 25000 |
| | EDM E-Rinse Temperature | 88 | 87 | 86 | | 89 |
| | High level switch on TK-2141 | gray | gray | gray | | gray |

| | **EDM SYSTEM** | 7/13/2013 | 7/14/2013 | | | |
|---|---|---|---|---|---|---|
| | Location | 9:24 PM | 1:31 | | | |
| RO Unit | NF Feed pH | 6.3 | 6.3 | | | |
| | NF Permeate Flow | 34.4 | 34.8 | 7/14/13 mass balance - 1:36 am | | |
| | NF Permeate Conductivity | 1126 | 1137 | | flow | cond |
| | NF Reject Flow | 29.9 | 30.2 | perm | 34.8 | 1137 |
| | NF Reject Conductivity | 7518 | 8024 | reject | 30.2 | 8024 |
| EDM Units | EDM-1 reference | 154 | 154 | NF feed | 65 | 3680 |
| | EDM-1 current | 45 | 44 | Σ in | 239200 | |
| | EDM-2 reference | 146 | 146 | Σ out | 281892.4 | |
| | EDM-2 current | 52 | 52 | difference | 16% | |
| Tank 1 | EDM Total Feed Flow | 54 | 60 | | | |
| | EDM Feed Pressure | 25.7 | 26.1 | SW | *37.2* | 2652.446 |
| | EDM Feed Conductivity | 5260 | 5840 | EDM dil | 27.8 | 5055 |
| | EDM Feed Temperature | 86 | 86 | NF feed | 65 | 3680 |
| | EDM Diluate Conductivity | 4440 | 5055 | | | |
| | EDM Total Mixed Na Flow | 0 | 0 | | | |
| | EDM Mixed Na Pressure | 25.8 | 26.6 | | | |
| | EDM Mixed Na Conductivity | 109900 | 111700 | | | |
| Tank 1 | EDM Mixed Na Temperature | 89 | 88 | | | |
| | EDM Total Mixed Cl Flow | 42 | 41 | | | |
| | EDM Mixed Cl Pressure | 26.2 | 26.8 | | | |
| | EDM Mixed Cl Conductivity | 158800 | 149800 | | | |
| | EDM Mixed Cl Temperature | 89 | 88 | | | |
| | EDM Total NaCl Flow | 0 | 0 | | | |
| | EDM NaCl Pressure | 26.6 | 27 | | | |
| | EDM NaCl Conductivity | 51000 | 149800 | | | |
| | EDM NaCl Temperature | 89 | 88 | | | |
| DI System | EDM Total E-Rinse Flow | 0 | 0 | | | |
| | EDM E-Rinse Pressure | 17.6 | 17.9 | | | |
| | EDM E-Rinse Conductivity | 27000 | 27000 | | | |
| | EDM E-Rinse Temperature | 87 | 86 | | | |
| | High level switch on TK-2141 | gray | gray | | | |

# Appendix A2: Alamogordo Year 2 Logsheet Data
## Voltage Current Data

| | | | EDM1 | | | EDM2 | |
|---|---|---|---|---|---|---|---|
| **Date** | **Time** | **volts** | **amps** | **#quads** | **volts** | **amps** | **#quads** |
| 3/25/2013 | 13:07 | 160 | 53 | 100 | 150 | 49 | 95 |
| 3/25/13 | 14:13 | 160 | 62 | 100 | 149 | 54 | 95 |
| 3/25/13 | 15:58 | 160 | 63 | 100 | 149 | 54 | 95 |
| 3/25/13 | 17:00 | 160 | 64 | 100 | 149 | 55 | 95 |
| 3/26/13 | 10:00 | 160 | 41 | 100 | 150 | 40 | 95 |
| 3/26/13 | 10:45 | 160 | 63 | 100 | 150 | 56 | 95 |
| 3/26/13 | 11:25 | 160 | 63 | 100 | 150 | 55 | 95 |
| 3/26/13 | 12:45 | 160 | 65 | 100 | 150 | 56 | 95 |
| 3/26/13 | 13:15 | 160 | 63 | 100 | 150 | 55 | 95 |
| 3/26/13 | 13:55 | 160 | 58 | 100 | 150 | 50 | 95 |
| 3/26/13 | 14:32 | 160 | 60 | 100 | 150 | 51 | 95 |
| 3/27/13 | 9:26 | 160 | 49 | 100 | 150 | 48 | 95 |
| 3/27/13 | 10:31 | 160 | 63 | 100 | 150 | 54 | 95 |
| 3/27/13 | 11:11 | 160 | 64 | 100 | 150 | 54 | 95 |
| 3/27/13 | 11:43 | 160 | 64 | 100 | 150 | 55 | 95 |
| 3/27/13 | 11:46 | 160 | 64 | 100 | 150 | 55 | 95 |
| 3/28/13 | 8:07 | 162 | 56 | 100 | 152 | 49 | 95 |
| 3/28/13 | 8:16 | 162 | 57 | 100 | 152 | 49 | 95 |
| 3/28/13 | 10:13 | 160 | 62 | 100 | 150 | 53 | 95 |
| 3/28/13 | 14:40 | 160 | 62 | 100 | 150 | 52 | 95 |
| 4/1/13 | 9:15 | 160 | 57 | 100 | 150 | 50 | 95 |
| 4/1/13 | 10:08 | 160 | 59 | 100 | 150 | 50 | 95 |
| 4/1/13 | 11:15 | 160 | 60 | 100 | 150 | 50 | 95 |
| 4/1/13 | 12:00 | 160 | 62 | 100 | 150 | 52 | 95 |
| 4/1/13 | 13:05 | 160 | 63 | 100 | 150 | 52 | 95 |
| 4/1/13 | 14:24 | 160 | 64 | 100 | 150 | 52 | 95 |
| 4/3/13 | 16:33 | 160 | 54 | 100 | 150 | 45 | 95 |
| 4/3/13 | 16:47 | 160 | 55 | 100 | 150 | 45 | 95 |
| 4/3/13 | 17:01 | 160 | 56 | 100 | 149 | 46 | 95 |
| 4/3/13 | 17:03 | 150 | 54 | 100 | 140 | 43 | 95 |
| 4/3/13 | 17:20 | 160 | 57 | 100 | 140 | 45 | 95 |
| 4/5/13 | 9:54 | 160 | 58 | 100 | 151 | 47 | 95 |
| 4/5/13 | 11:00 | 160 | 61 | 100 | 151 | 48 | 95 |
| 4/5/13 | 11:36 | 160 | 62 | 100 | 151 | 49 | 95 |
| 4/8/13 | 9:50 | 160 | 59 | 100 | 150 | 47 | 95 |
| 4/8/13 | 10:46 | 160 | 58 | 100 | 150 | 47 | 95 |
| 4/8/13 | 10:55 | 150 | 56 | 100 | 140 | 45 | 95 |
| 4/8/13 | 12:45 | 150 | 61 | 100 | 140 | 49 | 95 |
| 4/8/13 | 14:20 | 150 | 62 | 100 | 140 | 49 | 95 |
| 4/8/13 | 14:55 | 150 | 63 | 100 | 140 | 49 | 95 |
| 4/8/13 | 16:48 | 150 | 63 | 100 | 140 | 49 | 95 |
| 4/9/13 | 8:18 | 150 | 61 | 100 | 140 | 57 | 95 |

## Appendix A2: Alamogordo Year 2 Logsheet Data

## Voltage Current Data

| | | **EDM1** | | | **EDM2** | | |
|---|---|---|---|---|---|---|---|
| **Date** | **Time** | **volts** | **amps** | **#quads** | **volts** | **amps** | **#quads** |
| 4/9/13 | 9:42 | 150 | 59 | 100 | 140 | 46 | 95 |
| 4/9/13 | 10:28 | 150 | 60 | 100 | 140 | 47 | 95 |
| 4/9/13 | 11:27 | 150 | 61 | 100 | 140 | 48 | 95 |
| 4/9/13 | 12:27 | 150 | 62 | 100 | 140 | 48 | 95 |
| 4/9/13 | 14:50 | 150 | 62 | 100 | 140 | 48 | 95 |
| 4/9/13 | 16:43 | 150 | 63 | 100 | 140 | 48 | 95 |
| 4/10/13 | 8:21 | 160 | 54 | 100 | 150 | 32 | 95 |
| 4/10/13 | 9:54 | 160 | 62 | 100 | 150 | 49 | 95 |
| 4/10/13 | 11:15 | 160 | 64 | 100 | 150 | 50 | 95 |
| 4/10/13 | 12:31 | 160 | 65 | 100 | 150 | 50 | 95 |
| 4/10/13 | 13:44 | 160 | 65 | 100 | 150 | 50 | 95 |
| 4/10/13 | 14:27 | 160 | 66 | 100 | 150 | 50 | 95 |
| 4/10/13 | 15:25 | 160 | 65 | 100 | 150 | 49 | 95 |
| 4/10/13 | 16:40 | 160 | 66 | 100 | 150 | 49 | 95 |
| 4/11/13 | 9:40 | 160 | 42 | 100 | 150 | 35 | 95 |
| 4/11/13 | 9:50 | 175 | 56 | 100 | 160 | 45 | 95 |
| 4/11/13 | 11:25 | 175 | 65 | 100 | 160 | 48 | 95 |
| 4/11/13 | 12:04 | 175 | 66 | 100 | 160 | 49 | 95 |
| 4/11/13 | 12:50 | 175 | 66 | 100 | 160 | 49 | 95 |
| 4/11/13 | 13:38 | 175 | 66 | 100 | 160 | 48 | 95 |
| 4/11/13 | 14:41 | 175 | 67 | 100 | 160 | 49 | 95 |
| 4/11/13 | 16:00 | 175 | 67 | 100 | 160 | 49 | 95 |
| 4/11/13 | 17:08 | 175 | 68 | 100 | 160 | 50 | 95 |
| 4/17/13 | 8:30 | 155 | 36 | 100 | 155 | 31 | 95 |
| 4/17/13 | 10:05 | 155 | 57 | 100 | 155 | 46 | 95 |
| 4/17/13 | 10:30 | 155 | 58 | 100 | 155 | 47 | 95 |
| 4/17/13 | 15:05 | 155 | 61 | 100 | 155 | 48 | 95 |
| 4/17/13 | 15:05 | 155 | 61 | 98 | 155 | 48 | 95 |
| 4/18/13 | 8:38 | 155 | 50 | 98 | 155 | 42 | 95 |
| 4/18/13 | 9:20 | 155 | 58 | 98 | 155 | 46 | 95 |
| 4/18/13 | 9:56 | 155 | 61 | 98 | 155 | 47 | 95 |
| 4/18/13 | 12:12 | 155 | 61 | 98 | 154 | 48 | 95 |
| 4/18/13 | 13:30 | 155 | 62 | 98 | 154 | 48 | 95 |
| 4/18/13 | 16:42 | 155 | 62 | 98 | 155 | 48 | 95 |
| 4/19/13 | 8:27 | 155 | 51 | 98 | 155 | 43 | 95 |
| 4/19/13 | 9:27 | 155 | 61 | 98 | 155 | 50 | 95 |
| 4/19/13 | 9:27 | 165 | 63 | 98 | 155 | 61 | 95 |
| 4/19/13 | 10:29 | 165 | 64 | 98 | 165 | 51 | 95 |
| 4/19/13 | 14:51 | 165 | 65 | 98 | 165 | 50 | 95 |
| 4/19/13 | 16:38 | 165 | 65 | 98 | 164 | 51 | 95 |
| 4/19/13 | 16:38 | 170 | 68 | 98 | 164 | 51 | 95 |
| 4/19/13 | 18:01 | 170 | 67 | 98 | 164 | 49 | 95 |

## Appendix A2: Alamogordo Year 2 Logsheet Data
## Voltage Current Data

| | | | EDM1 | | | EDM2 | |
|---|---|---|---|---|---|---|---|
| **Date** | **Time** | **volts** | **amps** | **#quads** | **volts** | **amps** | **#quads** |
| 4/19/13 | 21:15 | 170 | 66 | 98 | 164 | 49 | 95 |
| 4/19/13 | 22:00 | 170 | 66 | 98 | 164 | 49 | 95 |
| 4/20/13 | 8:21 | 170 | 66 | 98 | 164 | 49 | 95 |
| 4/22/13 | 9:05 | 155 | 45 | 98 | 155 | 37 | 95 |
| 4/22/13 | 11:30 | 155 | 59 | 98 | 155 | 46 | 95 |
| 4/22/13 | 13:27 | 155 | 59 | 98 | 155 | 46 | 95 |
| 4/22/13 | 16:33 | 155 | 60 | 98 | 155 | 46 | 95 |
| 4/22/13 | 21:11 | 155 | 59 | 98 | 155 | 45 | 95 |
| 4/22/13 | 22:00 | 155 | 60 | 98 | 155 | 46 | 95 |
| 4/22/13 | 22:05 | 160 | 61 | 98 | 155 | 46 | 95 |
| 4/22/13 | 22:10 | 164 | 63 | 98 | 160 | 47 | 95 |
| 4/23/13 | 8:30 | 164 | 65 | 98 | 160 | 49 | 95 |
| 4/23/13 | 8:38 | 170 | 67 | 98 | 165 | 51 | 95 |
| 4/23/13 | 9:36 | 170 | 66 | 98 | 165 | 50 | 95 |
| 4/23/13 | 10:55 | 170 | 65 | 98 | 165 | 51 | 95 |
| 4/23/13 | 12:41 | 170 | 66 | 98 | 165 | 51 | 95 |
| 4/23/13 | 15:20 | 170 | 66 | 98 | 165 | 51 | 95 |
| 4/23/13 | 22:34 | 170 | 64 | 98 | 165 | 49 | 95 |
| 4/24/13 | 7:24 | 170 | 63 | 98 | 165 | 48 | 95 |
| 4/24/13 | 8:30 | 170 | 62 | 98 | 166 | 49 | 95 |
| 4/25/13 | 10:50 | 156 | 39 | 98 | | | |
| 4/25/13 | 11:50 | 156 | 51 | 98 | | | |
| 4/25/13 | 15:13 | 156 | 57 | 98 | | | |
| 4/25/13 | 16:19 | 156 | 57 | 98 | | | |
| 4/25/13 | 16:51 | 156 | 56 | 98 | | | |
| 4/25/13 | 21:35 | 156 | 54 | 98 | | | |
| 4/25/13 | 21:52 | 156 | 54 | 98 | | | |
| 4/26/13 | 8:20 | 156 | 51 | 98 | | | |
| 4/30/13 | 16:37 | 154 | 57 | 98 | | | |
| 4/30/13 | 21:29 | 155 | 58 | 98 | | | |
| 4/30/13 | 21:38 | 160 | 59 | 98 | | | |
| 5/1/13 | 7:00 | 150 | 59 | 98 | | | |
| 5/1/13 | 8:48 | 150 | 56 | 98 | | | |
| 5/1/13 | 11:55 | 150 | 57 | 98 | | | |
| 5/1/13 | 13:55 | 150 | 54 | 98 | | | |
| 5/1/13 | 16:04 | 150 | 54 | 98 | | | |
| 5/1/13 | 16:30 | 150 | 53 | 98 | | | |
| 5/1/13 | 21:16 | 150 | 50 | 98 | | | |
| 5/2/13 | 9:47 | 160 | 51 | 98 | | | |
| 5/2/13 | 14:37 | 160 | 49 | 98 | | | |
| 5/2/13 | 15:38 | 160 | 48 | 98 | | | |
| 5/2/13 | 21:41 | 160 | 47 | 98 | | | |

## Appendix A2: Alamogordo Year 2 Logsheet Data
## Voltage Current Data

| | | | EDM1 | | | EDM2 | |
|---|---|---|---|---|---|---|---|
| **Date** | **Time** | **volts** | **amps** | **#quads** | **volts** | **amps** | **#quads** |
| 5/3/13 | | | | | | | |
| 5/29/13 | 9:31 | 150 | 34 | 98 | | | |
| 5/29/13 | 9:41 | 150 | 43 | 98 | | | |
| 5/29/13 | 14:15 | 150 | 56 | 98 | | | |
| 5/31/13 | 8:52 | 150 | 48 | 98 | | | |
| 5/31/13 | 11:38 | 150 | 58 | 98 | | | |
| 5/31/13 | 11:39 | 125 | 50 | 98 | | | |
| 5/31/13 | 12:20 | 125 | 45 | 98 | | | |
| 5/31/13 | 12:21 | 133 | 49 | 98 | | | |
| 5/31/13 | 15:22 | 125 | 51 | 98 | | | |
| 6/3/13 | 9:00 | 150 | 44 | 98 | | | |
| 6/3/13 | 10:00 | 139 | 50 | 98 | | | |
| 6/3/13 | 11:37 | 139 | 53 | 98 | | | |
| 6/3/13 | 14:50 | 139 | 54 | 98 | | | |
| 6/3/13 | 16:53 | 124 | 50 | 98 | | | |
| 6/4/13 | 8:45 | 150 | 41 | 98 | | | |
| 6/4/13 | 11:10 | 150 | 53 | 98 | | | |
| 6/4/13 | 11:30 | 150 | 54 | 98 | | | |
| 6/4/13 | 14:53 | 150 | 54 | 98 | | | |
| 6/4/13 | 16:47 | 150 | 55 | 98 | | | |
| 6/10/13 | 16:00 | 129 | 34 | 91 | 130 | 33 | 94 |
| 6/10/13 | 16:30 | 129 | 48 | 91 | 130 | 46 | 94 |
| 6/14/13 | 15:32 | 130 | 52 | 91 | 130 | 49 | 94 |
| 6/17/13 | 9:12 | 111 | 43 | 91 | 111 | 42 | 94 |
| 6/17/13 | 9:26 | 120 | 50 | 91 | 126 | 50 | 94 |
| 6/17/13 | 13:45 | 115 | 51 | 91 | 124 | 52 | 94 |
| 6/18/13 | 11:02 | 118 | 52 | 91 | 125 | 53 | 94 |
| 6/18/13 | 14:14 | 118 | 51 | 91 | 125 | 52 | 94 |
| 6/19/13 | 10:12 | 118 | 53 | 91 | 112 | 52 | 94 |
| 6/19/13 | 14:26 | 118 | 47 | 91 | 112 | 46 | 94 |
| 6/20/13 | 10:00 | 118 | 47 | 91 | 112 | 47 | 94 |
| 6/20/13 | 11:00 | 130 | 50 | 91 | 123 | 50 | 94 |
| 6/20/13 | 11:23 | 130 | 48 | 91 | 123 | 48 | 94 |
| 6/20/13 | 15:09 | 130 | 48 | 91 | 123 | 48 | 94 |
| 6/21/13 | 8:05 | 130 | 48 | 91 | 123 | 48 | 94 |
| 6/21/13 | 9:00 | 125 | 46 | 91 | 125 | 47 | 94 |
| 6/21/13 | 10:42 | 125 | 47 | 91 | 125 | 49 | 94 |
| 6/21/13 | 11:53 | 125 | 45 | 91 | 125 | 46 | 94 |
| 6/21/13 | 12:52 | 137 | 49 | 91 | 130 | 50 | 94 |
| 6/21/13 | 14:51 | 137 | 48 | 91 | 130 | 48 | 94 |
| 6/24/13 | 9:16 | 125 | 33 | 91 | 125 | 34 | 94 |
| 6/24/13 | 9:30 | 130 | 37 | 91 | 130 | 37 | 94 |

## Appendix A2: Alamogordo Year 2 Logsheet Data

## Voltage Current Data

| | | | EDM1 | | | EDM2 | |
|---|---|---|---|---|---|---|---|
| **Date** | **Time** | **volts** | **amps** | **#quads** | **volts** | **amps** | **#quads** |
| 6/24/13 | 10:30 | 130 | 44 | 91 | 130 | 44 | 94 |
| 6/24/13 | 11:20 | 113 | 43 | 91 | 113 | 43 | 94 |
| 6/24/13 | 13:45 | 113 | 46 | 91 | 113 | 46 | 94 |
| 6/24/13 | 16:30 | 120 | 47 | 91 | 120 | 47 | 94 |
| 6/25/13 | 8:10 | 125 | 47 | 91 | 125 | 50 | 94 |
| 6/25/13 | 8:36 | 130 | 48 | 91 | 131 | 51 | 94 |
| 6/26/13 | 10:13 | 130 | 31 | 91 | 131 | 34 | 94 |
| 6/26/13 | 10:18 | 113 | 31 | 91 | 110 | 32 | 94 |
| 6/26/13 | 10:21 | 113 | 33 | 91 | 130 | 39 | 94 |
| 6/26/13 | 14:22 | 113 | 43 | 91 | 130 | 50 | 94 |
| 6/26/13 | 16:32 | 115 | 44 | 91 | 126 | 49 | 94 |
| 6/27/13 | 8:20 | 115 | 43 | 91 | 126 | 50 | 94 |
| 6/27/13 | 11:20 | 120 | 44 | 91 | 125 | 48 | 94 |
| 6/27/13 | 11:40 | 130 | 48 | 91 | 125 | 50 | 94 |
| 6/27/13 | 12:13 | 130 | 47 | 91 | 125 | 49 | 94 |
| 6/27/13 | 16:21 | 125 | 45 | 91 | 125 | 48 | 94 |
| 6/27/13 | 16:46 | 125 | 46 | 91 | 125 | 49 | 94 |
| 6/27/13 | 18:03 | 125 | 45 | 91 | 125 | 48 | 94 |
| 6/28/13 | 7:45 | 125 | 46 | 91 | 125 | 49 | 94 |
| 6/28/13 | 8:20 | 142 | 50 | 91 | 131 | 50 | 94 |
| 6/28/13 | 15:30 | 130 | 45 | 91 | 135 | 49 | 94 |
| 7/8/13 | 11:45 | 125 | 44 | 91 | 125 | 49 | 94 |
| 7/8/13 | 16:00 | 125 | 45 | 91 | 125 | 49 | 94 |
| 7/9/13 | 8:20 | 136 | 50 | 91 | 123 | 49 | 94 |
| 7/9/13 | 10:35 | 125 | 42 | 91 | 123 | 44 | 94 |
| 7/9/13 | 12:00 | 136 | 49 | 91 | 149 | 54 | 94 |
| 7/9/13 | 14:50 | 136 | 46 | 91 | 125 | 47 | 94 |
| 7/9/13 | 15:25 | 136 | 48 | 91 | 125 | 48 | 94 |
| 7/9/13 | 20:15 | 132 | 47 | 91 | 132 | 49 | 94 |
| 7/10/13 | 8:38 | 132 | 46 | 91 | 132 | 49 | 94 |
| 7/10/13 | 10:13 | 140 | 49 | 91 | 132 | 50 | 94 |
| 7/10/13 | 10:46 | 132 | 47 | 91 | 132 | 50 | 94 |
| 7/10/13 | 15:44 | 144 | 49 | 91 | 140 | 51 | 94 |
| 7/11/13 | 8:24 | 141 | 48 | 91 | 140 | 52 | 94 |
| 7/11/13 | 16:35 | 131 | 35 | 91 | 131 | 37 | 94 |
| 7/12/13 | 9:52 | 155 | 49 | 91 | 142 | 49 | 94 |
| 7/12/13 | 11:30 | 124 | 49 | 91 | 126 | 50 | 94 |
| 7/12/13 | 13:56 | 152 | 47 | 91 | 152 | 51 | 94 |
| 7/12/13 | 13:56 | 135 | 43 | 91 | 135 | 47 | 94 |
| 7/12/13 | 16:28 | 148 | 48 | 91 | 145 | 51 | 94 |
| 7/12/13 | 17:20 | 150 | 48 | 91 | 150 | 53 | 94 |
| 7/13/13 | 8:31 | 150 | 47 | 91 | 150 | 53 | 94 |

# Appendix A2: Alamogordo Year 2 Logsheet Data

## Voltage Current Data

| | | | EDM1 | | | EDM2 | |
|---|---|---|---|---|---|---|---|
| **Date** | **Time** | **volts** | **amps** | **#quads** | **volts** | **amps** | **#quads** |
| 7/13/13 | 11:50 | 140 | 44 | 91 | 145 | 51 | 94 |
| 7/13/13 | 16:25 | 145 | 45 | 91 | 145 | 51 | 94 |
| 7/13/13 | 16:43 | 145 | 45 | 91 | 145 | 51 | 94 |

Table A2-1.—Grab Samples - Conductivity

| | Source | NF Feed | NF Perm | NF Conc | EDM Feed | EDM Diluate | Mix Na | Mix Cl | NaCl | E-Rinse | RO/DI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Date/Time** | **µS/cm** | **µS/cm** | **µS/cm** | **µS/cm** | **µS/cm** | **µS/cm** | **mS/cm** | **mS/cm** | **mS/cm** | **mS/cm** | **µS/cm** |
| 3/28/2013 17:03 | 3478 | 3396 | 1327 | 7993 | 4494 | 3124 | 115.5 | 128.9 | 41.6 | 20.7 | 100 |
| 4/5/2013 10:25 | 3538 | 3343 | 1362 | 7795 | 4474 | 3030 | 108 | 133.9 | 47.6 | 22.66 | 68.9 |
| 4/8/2013 16:40 | 3567 | 3514 | 1374 | 8007 | 4942 | 3493 | 115 | 166.4 | 50.11 | 21.72 | 127.5 |
| 4/9/2013 10:33 | 3490 | 3449 | 1372 | 7999 | 4997 | 3578 | 109.6 | 150 | 49.46 | 21.88 | 158.8 |
| 4/9/2013 16:37 | 3493 | 3536 | 1355 | 8265 | 5343 | 3980 | 111.6 | 167.3 | 48.12 | 21.3 | 120.9 |
| 4/10/2013 11:17 | 3598 | 3562 | 1385 | 8271 | 5152 | 3731 | 109.4 | 158.5 | 46.7 | 21.84 | 64.85 |
| 4/10/2013 13:30 | 3615 | 3614 | 1397 | 8312 | 5267 | 3889 | 114 | 165.8 | 47.08 | 20.94 | 72.32 |
| 4/10/2013 16:30 | 3607 | 3652 | 1394 | 8463 | 5454 | 4057 | 110.5 | 168.3 | 48.17 | 20.92 | 67 |
| 4/11/2013 12:05 | 3478 | 3460 | 1346 | 8025 | 4921 | 3508 | 109.6 | 153.5 | 45.53 | 20.87 | 54.55 |
| 4/11/2013 14:47 | 3608 | 3556 | 1404 | 8216 | 5106 | 3609 | 111.7 | 166.4 | 43.83 | 21.33 | 77.35 |
| 4/11/2013 16:22 | 3584 | 3583 | 1399 | 8286 | 5200 | 3780 | 109.7 | 167.3 | 43.56 | 21.11 | 55.85 |
| 4/17/2013 10:57 | 3489 | 3351 | 1422 | 7707 | 4508 | 3137 | 112.4 | 150.5 | 43.51 | 20.6 | 129 |
| 4/17/2013 14:35 | 3374 | 3361 | 1366 | 7702 | 4648 | 3232 | 111.2 | 165.3 | 45.24 | 22.13 | 77.66 |
| 4/17/2013 16:34 | 3451 | 3382 | 1375 | 7862 | 4702 | 3336 | 108.8 | 150.3 | 46.38 | 20.91 | 114.2 |
| 4/18/2013 10:31 | 3444 | 3426 | 1369 | 7879 | | 3509 | 113.4 | 144.3 | 44.71 | 21.8 | 44.82 |
| 4/18/2013 13:00 | 3457 | 3414 | 1330 | 7920 | 4950 | 3638 | 112 | 163.2 | 46.17 | 21.38 | 96.42 |
| 4/18/2013 14:11 | 3545 | 3553 | 1403 | 8175 | 5099 | 3706 | 111 | 164.4 | 45.84 | 24.2 | 128.5 |
| 4/18/2013 16:21 | 3459 | 3445 | 1364 | 8010 | 5032 | 3716 | 110.5 | 166.4 | 47.42 | 21.82 | 90.6 |
| 4/19/2013 10:52 | 3759 | 3525 | 1403 | 8065 | 5090 | 3702 | 110.8 | 153.3 | 47.39 | 22.6 | 57.27 |
| 4/19/2013 17:35 | 3635 | 3553 | 1392 | 8198 | 5084 | 3698 | 112.8 | 165.3 | 46.25 | 23.88 | 133.8 |
| 4/19/2013 21:30 | 3590 | 3591 | 1402 | 8244 | 5181 | 3839 | 108.8 | 158.9 | 44.97 | 22.87 | 67.8 |
| 4/22/2013 11:06 | 3375 | 3357 | 1362 | 7739 | 4799 | 3472 | 110.8 | 139.2 | 47.12 | 22.54 | 125.9 |
| 4/22/2013 13:40 | 3350 | 3361 | 1344 | 7787 | 4920 | 3655 | 110.5 | 161 | 47.33 | 23.19 | 112.6 |
| 4/22/2013 16:23 | 3343 | 3390 | 1354 | 7851 | 5134 | 3704 | 112.9 | 163.4 | 47.22 | 22.81 | 55.62 |
| 4/22/2013 21:20 | 3303 | 3440 | 1357 | 7871 | 5088 | 3835 | 109.6 | 163.6 | 46.86 | 23.13 | 120.2 |

|  | Source | NF Feed | NF Perm | NF Conc | EDM Feed | EDM Diluate | Mix Na | Mix Cl | NaCl | E-Rinse | RO/DI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date/Time | μS/cm | μS/cm | μS/cm | μS/cm | μS/cm | μS/cm | mS/cm | mS/cm | mS/cm | mS/cm | μS/cm |
| 4/23/2013 8:07 | 3514 | 3573 | 1389 | 8230 | 5394 | 4096 | 106.5 | 159.2 | 44.6 | 22.24 | 278.3 |
| 4/23/2013 11:10 | 3576 | 3621 | 1404 | 8318 | 5360 | 3917 | 107.8 | 162.3 | 43.92 | 21.52 | 73.4 |
| 4/23/2013 15:31 | 3571 | 3603 | 1416 | 8304 | 5476 | 3879 | 108.4 | 162.8 | 44.77 | 23.98 | 71.75 |
| 4/24/2013 8:23 | 3446 | 3614 | 1368 | 8319 | 5706 | 4294 | 107.2 | 162.2 | 45.04 | 28.87 | 131.2 |
| 4/26/2013 8:39 | 3391 | 3374 | 1408 | 7672 | 5129 | 3519 | 106 | 154 | 51.58 | 24.33 | 111.1 |
| 4/30/2013 16:16 | 3709 | 3434 | 1479 | 7984 | 5203 | 3358 | 108.2 | 151.9 | 52.4 | 23.5 | 68.2 |
| 5/1/2013 9:13 | 3407 | 3536 | 1467 | 8351 | 5497 | 4100 | 109.5 | 159.7 | 53.83 | 21.46 | 107.3 |
| 5/1/2013 13:40 | 3455 | 3448 | 1514 | 8038 | 5222 | 3794 | 109.1 | 156 | 53.73 | 21.27 | 53.53 |
| 5/1/2013 16:50 | 3285 | 3289 | 1395 | 8061 | 5053 | 3571 | 108.6 | 156.9 | 53.06 | 21.34 | 53.69 |
| 5/1/2013 21:30 | 3152 | 3178 | 1342 | 8093 | 4911 | 3609 | 108.9 | 156.8 | 52.57 | 21.14 | 158.8 |
| 5/2/2013 14:54 | 3228 | 3220 | 1369 | 7525 | 4710 | 3442 | 106.2 | 153.7 | 52.7 | 21.29 | 39.77 |
| 5/29/2013 13:59 | 2873 | 2923 | 1036 | 7879 | 4844 | 3445 | 107.9 | 153.6 | 52.27 | 22.2 | 196.7 |
| 5/31/2013 13:50 | 3136 | 3300 | 1185 | 7886 | 5198 | 4033 | 109.1 | 157.7 | 51.29 | 21.7 | 108.3 |
| 5/31/2013 15:25 | 3244 | 3533 | 1248 | 8300 | 6879 | 4850 | 109.6 | 160.6 | 51.9 | 21.49 | 74.69 |
| 6/3/2013 11:42 | 3185 | 3374 | 1242 | 8075 | 5494 | 4238 | 109.4 | 141.9 | 51.08 | 21.56 | 95.26 |
| 6/3/2013 14:53 | 3168 | 3426 | 1253 | 8121 | 5508 | 4403 | 109.5 | 159.2 | 50.69 | 23.06 | 46.82 |
| 6/4/2013 11:16 | 3035 | 3189 | 1150 | 7859 | 5577 | 3985 | 107.8 | 141 | 51.82 | 25.25 | 156.5 |
| 6/4/2013 14:55 | 3010 | 3194 | 1158 | 7849 | 5165 | 3947 | 105.7 | 102.4 | 50.58 | 27.18 | 65.81 |
| 6/4/2013 16:55 | 3000 | 3186 | 1152 | 7873 | 5092 | 4083 | 109.3 | 164.6 | 52.57 | 21.22 | 115 |
| 6/14/2013 15:45 | 3053 | 2941 | 1147 | 7930 | 4350 | 2882 | 111.4 | 138.4 | 48.74 | 20.93 | 61.02 |
| 6/17/2013 14:03 | 3077 | 3146 | 1098 | 7504 | 4838 | 3572 | 110.9 | 153.2 | 53.91 | 21.32 | 33.2 |
| 6/18/2013 11:02 | 3126 | 3162 | 1113 | 7481 | 4699 | 3435 | 108.1 | 139.2 | 49.96 | 29 | 39.04 |
| 6/18/2013 14:24 | 3058 | 3085 | 1131 | 7407 | 4631 | 3397 | 113.7 | 153.2 | 51.02 | 27.89 | 48.14 |
| 6/19/2013 10:50 | 3106 | 3386 | 1134 | 8130 | 5703 | 4581 | 113.4 | 152.9 | 49.75 | 21.25 | 72.03 |
| 6/19/2013 14:32 | 3065 | 3138 | 1088 | 7198 | 4649 | 3571 | 112.7 | 158.9 | 52.02 | 25.2 | 124.1 |

|  | Source | NF Feed | NF Perm | NF Conc | EDM Feed | EDM Diluate | Mix Na | Mix Cl | NaCl | E-Rinse | RO/DI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date/Time | μS/cm | μS/cm | μS/cm | μS/cm | μS/cm | μS/cm | mS/cm | mS/cm | mS/cm | mS/cm | μS/cm |
| 6/20/2013 10:35 | 3111 | 3301 | 1131 | 7484 | 5029 | 3985 | 104.3 | 153.6 | 51.53 | 21.35 | 112.7 |
| 6/20/2013 14:55 | 3123 | 3099 | 1110 | 7038 | 4485 | 3308 | 104.8 | 157.3 | 50.38 | 21.12 | 180.4 |
| 6/21/2013 11:10 | 3064 | 3165 | 1102 | 7282 | 4788 | 3692 | 107.9 | 151.5 | 50.16 | 21.56 | 108.2 |
| 6/21/2013 15:09 | 3051 | 3039 | 1095 | 6958 | 4271 | 3199 | 115.5 | 158.4 | 50.48 | 21.583 | 82.15 |
| 6/24/2013 13:34 | 3102 | 3117 | 1147 | 7148 | 4507 | 3422 | 107.8 | 150.8 | 49.44 | 22.69 | 142.7 |
| 6/24/2013 16:35 | 3063 | 3110 | 1096 | 6857 | 4524 | 3351 | 111.8 | 157.3 | 52.26 | 21.59 | 124.7 |
| 6/25/2013 8:20 | 3113 | 3268 | 1162 | 7397 | 5042 | 3983 | 109.7 | 159.1 | 50.94 | 21.09 | 49.81 |
| 6/26/2013 14:30 | 3101 | 3113 | 1093 | 6994 | 4457 | 3355 | 109.2 | 153.6 | 52.12 | 20.35 | 67.39 |
| 6/26/2013 16:23 | 3121 | 3131 | 1094 | 7085 | 4614 | 3441 | 112.2 | 158.2 | 52.86 | 22.2 | 57.02 |
| 6/27/2013 8:31 | 3019 | 3238 | 1080 | 7187 | 5118 | 4056 | 107.5 | 150.8 | 51.87 | 22.9 | 82.38 |
| 6/27/2013 16:59 | 3070 | 3154 | 1144 | 7247 | 4710 | 3680 | 111.1 | 161.58 | 52.4 | 22.79 | 61.9 |
| 6/28/2013 7:58 | 3074 | 3278 | 1151 | 7286 | 5809 | 4035 | 110.1 | 161.4 | 49.83 | 20.75 |  |
| 6/28/2013 15:37 | 3048 | 3119 | 1113 | 7022 | 4612 | 3477 | 112.4 | 159.3 | 50.09 | 23.03 | 61.64 |
| 7/8/2013 11:51 | 3196 | 3087 | 1195 | 6719 | 4397 | 3216 | 108.3 | 142.6 | 50.45 | 25.4 | 34 |
| 7/8/2013 15:57 | 3121 | 3132 | 1123 | 7101 | 4491 | 3425 | 110.8 | 158.2 | 50.19 | 21.84 | 73.45 |
| 7/9/2013 8:34 | 3098 | 3296 | 1140 | 7353 | 4940 | 3913 | 110.3 | 158.9 | 50.05 | 22.36 | 95.97 |
| 7/9/2013 15:34 | 3066 | 3126 | 1096 | 7071 | 4530 | 3455 | 112.6 | 158.6 | 51.08 | 22.52 | 160.8 |
| 7/10/2013 8:22 | 3009 | 3131 | 1104 | 7022 | 4342 | 3692 | 110.3 | 157.7 | 50.05 | 23.56 | 116.9 |
| 7/10/2013 15:57 | 3134 | 3194 | 1143 | 7154 | 4833 | 3407 | 111.6 | 157.7 | 50.33 | 22.45 |  |
| 7/11/2013 8:45 | 3080 | 3196 | 1115 | 7177 | 4612 | 3584 | 109.4 | 156.4 | 48.34 | 25.73 | 78.01 |
| 7/12/2013 9:30 | 3101 | 3220 | 1132 | 7186 | 4829 | 3749 | 109.7 | 164.6 | 49.68 | 22.33 | 103.1 |
| 7/12/2013 17:10 | 3154 | 3270 | 1158 | 7292 | 4929 | 3810 | 109.4 | 163 | 49.97 | 23.64 |  |
| 7/13/2013 11:30 | 3028 | 3150 | 1124 | 7088 | 4447 | 3518 | 101.3 | 147.3 | 49.22 | 24.44 | 201.8 |
| 7/13/2013 16:40 | 3070 | 3307 | 1104 | 7334 | 4748 | 3781 | 109.2 | 156.1 | 55.61 | 28.38 | 100.6 |

Table A2-1.—Grab Samples - pH

| Date/Time | Source<br>µS/cm | NF Feed<br>µS/cm | NF Perm<br>µS/cm | NF Conc<br>µS/cm | EDM Feed<br>µS/cm | EDM Diluate<br>µS/cm | Mix Na<br>mS/cm | Mix Cl<br>mS/cm | NaCl<br>mS/cm | E-Rinse<br>mS/cm | RO/DI<br>µS/cm |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4/5/2013 10:25 | 7.37 | 6.79 | 6.8 | 6.93 | 6.69 | 6.9 | 7.92 | 4.13 | 6.1 | 11.1 | 6.17 |
| 4/8/2013 16:40 | 7.46 | 6.76 | 6.71 | 6.88 | 6.62 | 6.39 | 7.88 | 3.62 | 4.31 | 11.43 | 5.74 |
| 4/9/2013 10:33 | 7.5 | 6.8 | 6.91 | 7.04 | 6.52 | 6.37 | 7.89 | 2.54 | 4.22 | 11.74 | 6.05 |
| 4/9/2013 16:37 | 7.53 | 6.92 | 6.93 | 6.96 | 6.56 | 6.27 | 7.5 | 2.71 | 3.92 | 12.2 | 6.51 |
| 4/10/2013 11:17 | 7.49 | 6.77 | 6.78 | 6.83 | 6.6 | 6.27 | 7.77 | 2.32 | 3.6 | 12.07 | 6.53 |
| 4/10/2013 13:30 | 7.39 | 6.74 | 6.83 | 6.82 | 6.49 | 6.27 | 8.03 | 2.58 | 3.82 | 12.12 | 6.01 |
| 4/10/2013 16:30 | 7.43 | 6.87 | 6.75 | 6.93 | 6.79 | 6.33 | 8 | 2.39 | 3.95 | 12.08 | 6.31 |
| 4/11/2013 12:05 | 7.5 | 6.77 | 6.75 | 6.87 | 6.57 | 6.37 | 8.11 | 2.2 | 3.5 | 11.79 | 5.68 |
| 4/11/2013 14:47 | 7.45 | 6.68 | 6.85 | 7 | 6.53 | 6.33 | 7.74 | 2.23 | 3.54 | 11.73 | 5.87 |
| 4/11/2013 16:22 | 7.43 | 6.89 | 6.91 | 6.92 | 6.54 | 6.35 | 7.83 | 2.2 | 3.46 | 11.63 | 5.71 |
| 4/17/2013 10:57 | 7.5 | 6.96 | 7.02 | 6.86 | 6.8 | 6.43 | 8.18 | 2.7 | 5.85 | 11.5 | 7.03 |
| 4/17/2013 14:35 | 7.54 | 6.64 | 6.73 | 6.98 | 6.41 | 6.39 | 7.91 | 2.76 | 4.04 | 11.55 | 6.66 |
| 4/17/2013 16:34 | 7.49 | 6.96 | 6.96 | 7.07 | 6.5 | 6.33 | 7.85 | 2.53 | 4.58 | 11.7 | 6.83 |
| 4/18/2013 10:31 | 7.49 | 7.01 | 6.95 | 6.98 | 6.37 | 6.36 | 8.13 | 2.52 | 3.83 | 11.42 | 6.84 |
| 4/18/2013 13:00 | 7.49 | 6.96 | 6.6 | 6.99 | 6.47 | 6.33 | 7.95 | 2.63 | 3.85 | 11.8 | 6.36 |
| 4/18/2013 14:11 | 7.08 | 6.27 | 6.28 | 6.35 | 6.45 | 6.21 | 7.48 | 2.34 | 3.73 | 12.15 | 5.77 |
| 4/18/2013 16:21 | 7.44 | 6.69 | 6.9 | 6.78 | 6.85 | 6.56 | 7.81 | 2.7 | 3.89 | 11.74 | 6.23 |
| 4/19/2013 10:52 | 7.48 | 6.66 | 6.66 | 6.77 | 6.31 | 6.1 | 8.08 | 2.28 | 3.44 | 12 | 5.94 |
| 4/19/2013 17:35 | 7.07 | 6.24 | 6.2 | 6.34 | 6.16 | 5.94 | 7.62 | 2.26 | 4.12 |  | 6.43 |
| 4/19/2013 21:30 | 7.07 | 6.26 | 6.24 | 6.36 | 6.16 | 5.94 | 7.59 | 2.25 | 3.8 | 12.33 | 5.64 |
| 4/22/2013 11:06 | 7.08 | 6.54 | 6.54 | 6.5 | 6.58 | 6.46 | 7.89 | 2.04 | 3.47 | 12.32 | 6.41 |
| 4/22/2013 13:40 | 7.13 | 6.38 | 6.42 | 6.27 | 6.64 | 6.31 | 7.51 | 2.15 | 3.5 | 12.33 | 6.02 |
| 4/22/2013 16:23 | 7.14 | 6.56 | 6.56 | 6.58 | 6.73 | 6.33 | 7.53 | 2.12 | 3.57 | 12.34 | 5.78 |
| 4/22/2013 21:20 | 7.09 | 6.47 | 6.62 | 6.51 | 6.42 | 6.28 | 7.6 | 2.02 | 3.49 | 12.46 | 6.56 |

|  | Source | NF Feed | NF Perm | NF Conc | EDM Feed | EDM Diluate | Mix Na | Mix Cl | NaCl | E-Rinse | RO/DI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date/Time | μS/cm | μS/cm | μS/cm | μS/cm | μS/cm | μS/cm | mS/cm | mS/cm | mS/cm | mS/cm | μS/cm |
| 4/23/2013 8:07 | 7.07 | 6.26 | 6.23 | 6.41 | 5.53 | 5.27 | 7.11 | 2.11 | 3.4 | 12.24 | 6.22 |
| 4/23/2013 11:10 | 7.26 | 6.26 | 6.27 | 6.32 | 6.07 | 5.89 | 6.85 | 1.98 | 3.52 | 12.33 | 5.64 |
| 4/23/2013 15:31 | 7.25 | 6.26 | 6.25 | 6.3 | 6.09 | 5.88 | 7.01 | 1.99 | 4.1 | 12.37 | 5.81 |
| 4/24/2013 8:23 | 7.43 | 6.38 | 6.28 | 6.42 | 6.19 | 5.97 | 7.58 | 2.08 | 3.78 | 12.54 | 6.01 |
| 4/25/2013 21:37 | 7.32 | 6.42 | 6.42 | 6.24 |  |  |  |  |  |  |  |
| 4/26/2013 8:39 | 7.38 | 6.38 | 6.31 | 6.25 | 6.15 | 5.73 | 7.94 | 2.2 | 3.73 | 10.2 | 5.99 |
| 4/30/2013 16:16 | 7.27 | 6.22 | 6.22 | 6.2 | 5.84 | 5.64 | 8.12 | 2.03 | 3.6 | 11.51 | 5.7 |
| 5/1/2013 9:13 | 7.23 | 6.5 | 6.15 | 6.16 | 5.71 | 5.5 | 8.01 | 2.05 | 3.47 | 10.43 | 6.02 |
| 5/1/2013 13:40 | 7.36 | 6.65 | 6.68 | 6.64 | 6.24 | 6.01 | 7.97 | 2.06 | 3.52 | 10.17 | 5.66 |
| 5/1/2013 16:50 | 7.36 | 6.77 | 6.56 | 6.51 | 6.12 | 5.99 | 8.03 | 2.04 | 3.49 | 10.27 | 5.74 |
| 5/1/2013 21:30 | 7.41 | 6.72 | 6.67 | 6.55 | 6.16 | 5.95 | 8 | 1.99 | 3.44 | 10.59 | 6.24 |
| 5/2/2013 14:54 | 7.42 | 6.72 | 6.71 | 6.64 | 6.24 | 5.99 | 8.1 | 2.01 | 3.57 | 10.81 | 5.73 |
| 5/29/2013 13:59 | 7.65 | 6.12 | 6.03 | 6.05 | 5.42 | 5.3 | 7.91 | 2 | 3.15 | 9.79 | 7.11 |
| 5/31/2013 13:50 | 7.06 | 6.08 | 5.97 | 5.82 | 5.64 | 5.48 | 7.41 | 2.1 | 3.5 | 9.7 | 5.81 |
| 5/31/2013 15:25 | 7.39 | 5.86 | 6.36 | 5.75 | 6.02 | 5.78 | 7.52 | 2.14 | 3.5 | 9.55 | 5.93 |
| 6/3/2013 11:42 | 7.43 | 6.05 | 6.15 | 6.04 | 5.6 | 5.53 | 8.47 | 2.16 | 3.2 | 9.84 | 6.06 |
| 6/3/2013 14:53 | 7.46 | 6.1 | 6.04 | 6 | 5.67 | 5.6 | 6.99 | 2.17 | 3.55 | 9.68 | 5.56 |
| 6/4/2013 11:16 | 7.5 | 6.1 | 6.06 | 6.1 | 5.58 | 5.36 | 7.17 | 2.05 | 3.19 | 9.74 | 6.15 |
| 6/4/2013 14:55 | 7.51 | 6.02 | 6.25 | 6.02 | 5.62 | 5.72 | 6.79 | 1.98 | 3.25 | 9.74 | 5.69 |
| 6/4/2013 16:55 | 7.54 | 6.12 | 6.07 | 5.94 | 5.62 | 5.42 | 6.62 | 1.78 | 3.15 | 9.93 | 6.15 |
| 6/14/2013 15:45 | 7.54 | 6.44 | 6.5 | 6.52 | 6.07 | 5.92 | 7.7 | 3.85 | 5.95 | 11.04 | 5.58 |
| 6/17/2013 14:03 | 7.54 | 6.31 | 6.41 | 6.48 | 5.98 | 5.86 | 7.36 | 5.3 | 6.03 | 10.79 | 5.33 |
| 6/18/2013 11:02 | 7.48 | 6.33 | 6.46 | 6.53 | 6.14 | 6.11 | 7.56 | 5.52 | 6.03 | 10.75 | 5.39 |
| 6/18/2013 14:24 | 7.5 | 6.29 | 6.34 | 6.38 | 6.06 | 5.82 | 7.38 | 5.28 | 5.94 | 10.69 | 5.6 |
| 6/19/2013 10:50 | 7.56 | 6.26 | 6.23 | 6.42 | 6.01 | 6.29 | 6.38 | 5.27 | 5.84 | 10.7 | 6.05 |

|  | Source | NF Feed | NF Perm | NF Conc | EDM Feed | EDM Diluate | Mix Na | Mix Cl | NaCl | E-Rinse | RO/DI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date/Time | μS/cm | μS/cm | μS/cm | μS/cm | μS/cm | μS/cm | mS/cm | mS/cm | mS/cm | mS/cm | μS/cm |
| 6/19/2013 14:32 | 6.99 | 6.21 | 6.35 | 6.28 | 5.97 | 5.7 | 7.26 | 5.211 | 5.84 | 10.3 | 6.1 |
| 6/20/2013 10:35 | 7.46 | 6.21 | 6.29 | 6.28 | 5.9 | 5.82 | 6.99 | 5.23 | 5.88 | 10.68 | 6.02 |
| 6/20/2013 14:55 | 7.48 | 6.31 | 6.63 | 6.3 | 6.03 | 5.85 | 7.66 | 5.24 | 5.89 | 10.68 | 6.03 |
| 6/21/2013 11:10 | 7.54 | 6.41 | 6.32 | 6.49 | 6.04 | 5.94 | 6.01 | 5.07 | 5.98 | 10.79 | 5.8 |
| 6/21/2013 15:09 | 7.55 | 6.25 | 6.258 | 6.33 | 5.91 | 5.67 | 7.87 | 5.16 | 5.99 | 10.71 | 5.89 |
| 6/24/2013 13:34 | 6.59 | 6.33 | 6.29 | 6.3 | 6.07 | 5.82 | 7.44 | 5.65 | 6.02 | 10.52 | 6.08 |
| 6/24/2013 16:35 | 7.59 | 6.258 | 6.32 | 6.36 | 6.07 | 5.81 | 7.33 | 5.04 | 5.89 | 10.6 | 6.64 |
| 6/25/2013 8:20 | 7.58 | 6.31 | 6.33 | 6.37 | 6.1 | 5.87 | 7.39 | 5.12 | 5.96 | 10.477 | 5.63 |
| 6/26/2013 14:30 | 7.37 | 6.02 | 6.13 | 6.25 | 5.9 | 5.71 | 7.02 | 3.13 | 5.1 | 10.47 | 6.08 |
| 6/26/2013 16:23 | 7.47 | 6.17 | 6.18 | 6.18 | 6.03 | 5.85 | 7.19 | 3.66 | 5.49 | 10.77 | 6.35 |
| 6/27/2013 8:31 | 7.53 | 6.17 | 6.47 | 6.35 | 6.11 | 5.85 | 7.42 | 5.42 | 5.586 | 10.75 | 6.64 |
| 6/27/2013 16:59 | 7.59 | 6.2 | 6.18 | 6.1 | 5.93 | 5.69 | 6.82 | 5.058 | 5.91 | 10.54 | 6.14 |
| 6/28/2013 7:58 | 7.63 | 6.5 | 6.41 | 6.41 | 6.28 | 6.04 | 7.53 | 5.3 | 6.05 | 10.7 |  |
| 6/28/2013 15:37 | 7.6 | 6.49 | 6.38 | 6.37 | 6.13 | 5.9 | 7.83 | 5.51 | 6.32 | 9.75 | 5.92 |
| 7/8/2013 11:51 | 7.58 | 6.2 | 6.36 | 6.31 | 5.96 | 5.87 | 6.7 | 2.59 | 3.81 | 7.98 | 6.13 |
| 7/8/2013 15:57 | 7.62 | 6.51 | 6.38 | 6.39 | 6.15 | 5.92 | 7.38 | 3.08 | 5.38 | 9.89 | 6.92 |
| 7/9/2013 8:34 | 7.65 | 6.36 | 6.44 | 6.6 | 6.22 | 5.99 | 7.36 | 5.1 | 5.87 | 10.28 | 6 |
| 7/9/2013 15:34 | 7.6 | 6.42 | 6.33 | 6.49 | 6.16 | 5.95 | 7.478 | 4.83 | 6.01 | 10.05 | 6.32 |
| 7/10/2013 8:22 | 7.65 | 6.44 | 6.37 | 6.53 | 6.18 | 6.01 | 7.64 | 4.91 | 6.08 | 9.14 | 6.33 |
| 7/10/2013 15:57 | 7.54 | 6.52 | 6.44 | 6.43 | 6.21 | 5.92 | 7.97 | 4.91 | 6.21 | 10.34 |  |
| 7/11/2013 8:45 | 7.64 | 6.44 | 6.39 | 6.44 | 6.09 | 5.74 | 7.98 | 4.17 | 6.16 | 8.87 | 6.03 |
| 7/12/2013 9:30 | 7.28 | 6.29 | 6.21 | 6.3 | 6.25 | 5.92 | 7.69 | 4.79 | 6.15 | 9.95 | 6.46 |
| 7/12/2013 17:10 | 7.57 | 6.4 | 6.37 | 6.56 | 6.25 | 6.06 | 7.74 | 5.02 | 6.25 | 8.18 |  |
| 7/13/2013 11:30 | 7.46 | 6.43 | 6.58 | 6.53 | 6.06 | 5.88 | 7.95 | 5.31 | 6.24 | 6.86 | 5.96 |
| 7/13/2013 16:40 | 7.42 | 6.37 | 6.39 | 6.53 | 6.13 | 5.91 | 8.22 | 5.48 | 6.4 | 6.82 | 6.07 |

Table A2-1. Grab Samples - Temperatures

| | Source | NF Feed | NF Perm | NF Conc | EDM Feed | EDM Diluate | Mix Na | Mix Cl | NaCl | E-Rinse | RO/DI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4/5/2013 10:25 | 19.1 | 20.8 | 20.9 | 21 | 24 | 25.8 | 25.5 | 25.7 | 26 | 25.5 | 19.8 |
| 4/8/2013 16:40 | 20.9 | 22.8 | 23.2 | 23.4 | 26.2 | 27.8 | 28.1 | 28.1 | 27.8 | 27.9 | 23.7 |
| 4/9/2013 10:33 | 18.9 | 20.8 | 20.5 | 20.5 | 23.8 | 25.2 | 25.7 | 25 | 25.4 | 24.4 | 20.3 |
| 4/9/2013 16:37 | 19.4 | 20.9 | 21.2 | 21.3 | 24.3 | 26 | 26.2 | 26.1 | 26 | 25 | 21.3 |
| 4/10/2013 11:17 | 19.2 | 20.7 | 20.9 | 21 | 24.1 | 26 | 25.6 | 26.1 | 26 | 25.4 | 21.7 |
| 4/10/2013 13:30 | 19.2 | 20.8 | 21.2 | 20.9 | 24.3 | 25.9 | 26.2 | 26 | 26.1 | 25.5 | 21.5 |
| 4/10/2013 16:30 | 19 | 20.6 | 20.9 | 20.9 | 24.2 | 26.1 | 25.5 | 25 | 26.1 | 26.1 | 20.6 |
| 4/11/2013 12:05 | 18.5 | 20.2 | 20.2 | 20.4 | 24.3 | 25.4 | 25.4 | 25.4 | 25.3 | 25 | 19.2 |
| 4/11/2013 14:47 | 18.8 | 20.6 | 20.7 | 21.3 | 24.9 | 25.9 | 26.5 | 26.4 | 26.3 | 26.9 | 21.6 |
| 4/11/2013 16:22 | 19.2 | 20.6 | 20.8 | 20.9 | 24.8 | 25.5 | 26.5 | 26.9 | 26.8 | 27.7 | 21.4 |
| 4/17/2013 10:57 | 20.2 | 21.9 | 22.6 | 22.4 | 25.4 | 25.9 | 26 | 26.2 | 26.4 | 26.2 | 23 |
| 4/17/2013 14:35 | 21.6 | 22.7 | 22.5 | 23.5 | 25.6 | 27.3 | 27.5 | 27.5 | 27.5 | 27.8 | 22.7 |
| 4/17/2013 16:34 | 21.4 | 22.4 | 22.5 | 22.7 | 26 | 27.1 | 27.3 | 27.3 | 27 | 27.3 | 23.2 |
| 4/18/2013 10:31 | 18.6 | 20 | 20.7 | 20.3 | 23.1 | 23.6 | 24.6 | 24.5 | 24.6 | 24 | 20.5 |
| 4/18/2013 13:00 | 19 | 20.4 | 20.5 | 20.9 | 24.3 | 25.2 | 25.1 | 25.6 | 25.6 | 25.3 | 20.6 |
| 4/18/2013 14:11 | 18.6 | 20.7 | 20.5 | 21.4 | 24.7 | 25.8 | 25.7 | 25.7 | 25.5 | 25.2 | 21.1 |
| 4/18/2013 16:21 | 19.1 | 20.8 | 20.8 | 21.1 | 25 | 26 | 25.1 | 26 | 26 | 26.3 | 21.6 |
| 4/19/2013 10:52 | 18.2 | 20 | 20 | 20.4 | 23.1 | 24.4 | 24.7 | 24.2 | 24.5 | 24.4 | 20.6 |
| 4/19/2013 17:35 | 19.3 | 20.7 | 20.9 | 20.7 | 24.9 | 25.9 | 26.2 | 26.3 | 26.3 | 26.4 | 20.7 |
| 4/19/2013 21:30 | 18.3 | 20.1 | 20.3 | 20.3 | 24.3 | 25.6 | 25.9 | 25.9 | 25.7 | 25.4 | 20.3 |
| 4/22/2013 11:06 | 20.9 | 21.5 | 21.6 | 21.9 | 25.3 | 26.2 | 25.9 | 25.7 | 26.2 | 27 | 23.2 |
| 4/22/2013 13:40 | 21.1 | 22 | 22 | 22.7 | 26 | 27.1 | 26.8 | 26.8 | 27 | 27.5 | 22.9 |
| 4/22/2013 16:23 | 21.3 | 22.3 | 22.1 | 22.4 | 26.4 | 27.3 | 27.6 | 27.5 | 27.4 | 28 | 22.2 |
| 4/22/2013 21:20 | 19.5 | 21.4 | 21.3 | 21.3 | 25.9 | 26.6 | 26.7 | 26.8 | 26.6 | 26.8 | 22.7 |
| 4/23/2013 8:07 | 19.4 | 21.1 | 21.4 | 21.2 | 24.7 | 26.1 | 26.2 | 26.7 | 26.6 | 26.7 | 22.5 |

|  | Source | NF Feed | NF Perm | NF Conc | EDM Feed | EDM Diluate | Mix Na | Mix Cl | NaCl | E-Rinse | RO/DI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4/23/2013 11:10 | 20.2 | 22.3 | 22.3 | 22.3 | 26 | 26.9 | 27.6 | 27.4 | 27.32 | 26.9 | 22.6 |
| 4/23/2013 15:31 | 20.6 | 22.3 | 22.5 | 23.5 | 27 | 28 | 28.2 | 28.2 | 28.1 | 28.3 | 23.6 |
| 4/24/2013 8:23 | 18.1 | 20.8 | 21.2 | 21 | 25.2 | 26.3 | 26.3 | 26.4 | 26.1 | 25.4 | 21.4 |
| 4/25/2013 9:37 | 20.1 | 21.7 | 21.8 | 21.8 |  |  |  |  |  |  |  |
| 4/26/2013 8:39 | 19.4 | 20.9 | 21 | 20.8 | 24 | 24.7 | 25.1 | 24.7 | 24.7 | 23.8 | 20.9 |
| 4/30/2013 16:16 | 23.2 | 24.4 | 24.1 | 25.1 | 28.3 | 29.2 | 29.5 | 29.4 | 29 | 29.1 | 25.3 |
| 5/1/2013 9:13 | 21.5 | 22.8 | 22.9 | 23 | 26.2 | 27.2 | 27.1 | 27.1 | 27.4 | 27 | 23.3 |
| 5/1/2013 13:40 | 23.4 | 24 | 24 | 25 | 27.9 | 29 | 29 | 28.9 | 28.8 | 29.2 | 24.7 |
| 5/1/2013 16:50 | 23.4 | 24.7 | 25.1 | 25.7 | 29.2 | 30.3 | 30.3 | 30.2 | 30.1 | 30.4 | 26.3 |
| 5/1/2013 21:30 | 22.2 | 23.5 | 23.5 | 23.7 | 27.7 | 28.7 | 28.4 | 27.9 | 27.8 | 27.4 | 24.2 |
| 5/2/2013 14:54 | 21.4 | 22.9 | 23 | 23.1 | 26.8 | 27.8 | 27.7 | 27.5 | 27.4 | 27.4 | 23.8 |
| 5/29/2013 13:59 | 27.1 | 28 | 28.2 | 28.2 | 30.8 | 32.5 | 32.6 | 32.7 | 32.6 | 31.5 | 26.2 |
| 5/31/2013 13:50 | 23.6 | 25.2 | 25.2 | 25.2 | 26.3 | 29.4 | 29.6 | 29.7 | 29.7 | 30 | 25.7 |
| 5/31/2013 15:25 | 24.9 | 25.4 | 25.5 | 26.3 | 29.1 | 29.6 | 30.1 | 30.1 | 30 | 29.9 | 24.8 |
| 6/3/2013 11:42 | 23.8 | 25.7 | 25.6 | 25.7 | 29.4 | 30.4 | 30.4 | 30.2 | 30.3 | 30.4 | 25.5 |
| 6/3/2013 14:53 | 24.6 | 26.2 | 26.1 | 26.3 | 30.6 | 31.4 | 31.1 | 31.3 | 31.5 | 32.1 | 27.1 |
| 6/4/2013 11:16 | 24.3 | 26.3 | 25.8 | 25.9 | 29.6 | 30.6 | 30.1 | 30.5 | 30 | 30.1 | 26.3 |
| 6/4/2013 14:55 | 24.5 | 26.8 | 26.3 | 27.2 | 30.7 | 31.7 | 31.7 | 31 | 31.8 | 32.3 | 27.1 |
| 6/4/2013 16:55 | 25.7 | 26.3 | 26.4 | 26.6 | 31.1 | 32 | 32 | 31.9 | 32.2 | 32.7 | 26.5 |
| 6/14/2013 15:45 | 23.8 | 26.3 | 26.5 | 26.7 | 30.7 | 31.8 | 31.1 | 29.9 | 31.6 | 30.7 | 27.4 |
| 6/17/2013 14:03 | 25.2 | 27.3 | 27 | 27.9 | 30.5 | 31.5 | 31.5 | 31.4 | 31.2 | 30.7 | 28.3 |
| 6/18/2013 11:02 | 24.7 | 26.7 | 26.7 | 27.3 | 29.7 | 30.8 | 30.1 | 30.6 | 30.5 | 30 | 27.5 |
| 6/18/2013 14:24 | 25.4 | 27.3 | 27.4 | 28 | 30.8 | 31.8 | 31.4 | 31 | 31.7 | 31.5 | 28.8 |
| 6/19/2013 10:50 | 24.8 | 26.2 | 26.9 | 26.7 | 30 | 30.9 | 30.9 | 31 | 30.9 | 30.8 | 28 |
| 6/19/2013 14:32 | 25.6 | 27.4 | 27.5 | 28.1 | 30.9 | 31.7 | 31.7 | 31.6 | 31.7 | 31.1 | 29.1 |
| 6/20/2013 10:35 | 25.1 | 27 | 26.8 | 27.4 | 30.2 | 31 | 31.1 | 31.1 | 31 | 30.3 | 28.3 |

| | Source | NF Feed | NF Perm | NF Conc | EDM Feed | EDM Diluate | Mix Na | Mix Cl | NaCl | E-Rinse | RO/DI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/20/2013 14:55 | 26 | 27.5 | 27.5 | 28.6 | 31.2 | 32 | 31.6 | 31.9 | 32.2 | 32 | 29 |
| 6/21/2013 11:10 | 25.1 | 26.7 | 26.9 | 27 | 30.1 | 30.8 | 30.9 | 30.4 | 31 | 30.8 | 28.1 |
| 6/21/2013 15:09 | 26.4 | 27.4 | 27.4 | 27.6 | 31.4 | 32.1 | 32.2 | 32.1 | 32.4 | 32 | 28.3 |
| 6/24/2013 13:34 | 26.8 | 28.2 | 28.5 | 28.6 | 32 | 32.8 | 32.5 | 32.4 | 32.6 | 31.8 | 28.9 |
| 6/24/2013 16:35 | 26.8 | 27.7 | 27.7 | 27.7 | 31.3 | 32.1 | 32.1 | 32 | 32.3 | 31.5 | 29.2 |
| 6/25/2013 8:20 | 24.6 | 26 | 26.3 | 26.4 | 29.7 | 30.6 | 30.3 | 30.1 | 30.4 | 29.1 | 26.8 |
| 6/26/2013 14:30 | 24.5 | 26 | 26.1 | 26.2 | 29.4 | 30.4 | 30.2 | 30.2 | 30.4 | 30.4 | 25.8 |
| 6/26/2013 16:23 | 24.5 | 26.3 | 26.5 | 27.3 | 30 | 30.7 | 30.9 | 30.8 | 30.9 | 30.9 | 26.2 |
| 6/27/2013 8:31 | 22.7 | 24.4 | 24.7 | 24.3 | 27.6 | 28.6 | 28.4 | 28.4 | 28.5 | 27.6 | 25.5 |
| 6/27/2013 16:59 | 28.1 | 27.6 | 27.5 | 28.3 | 31.2 | 32.1 | 32.1 | 32 | 32 | 32.2 | 29.1 |
| 6/28/2013 7:58 | 24.4 | 26.4 | 26.5 | 26.2 | 29.6 | 30.8 | 30.4 | 30.6 | 30.5 | 29.4 | |
| 6/28/2013 15:37 | 27 | 27.9 | 27.7 | 27.9 | 31.4 | 32.3 | 32.4 | 32.4 | 32.5 | 32.3 | 28.6 |
| 7/8/2013 11:51 | 26 | 27.8 | 28.2 | 28.5 | 31.4 | 32.3 | 32.3 | 32.2 | 32.2 | 31 | 27.4 |
| 7/8/2013 15:57 | 26.9 | 27.7 | 27.9 | 28.6 | 31.6 | 32.5 | 32.5 | 32.5 | 32.5 | 32 | 29.3 |
| 7/9/2013 8:34 | 24.4 | 26.5 | 26.5 | 26.6 | 29.9 | 31.1 | 30.7 | 29.3 | 30.8 | 29.5 | 27.4 |
| 7/9/2013 15:34 | 26.4 | 27.6 | 27.6 | 27.7 | 31.5 | 32.4 | 32.4 | 32.3 | 32.5 | 32.4 | 28.9 |
| 7/10/2013 8:22 | 24.9 | 26.6 | 26.8 | 26.9 | 26.3 | 30.9 | 31 | 30.9 | 31.2 | 29.8 | 27.7 |
| 7/10/2013 15:57 | 25.7 | 27.4 | 27.4 | 27.6 | 31.7 | 32.6 | 32.4 | 32.6 | 32.8 | 32.4 | |
| 7/11/2013 8:45 | 25.2 | 27.1 | 27.1 | 27.3 | 30.8 | 31.5 | 31.3 | 31.1 | 31.6 | 30.2 | 28 |
| 7/12/2013 9:30 | 24.7 | 26.6 | 26.8 | 26.7 | 30.6 | 31.6 | 31.6 | 31.1 | 31.3 | 30.3 | 27.9 |
| 7/12/2013 17:10 | 25.6 | 27.1 | 27.3 | 27.9 | 30.8 | 32.4 | 32.5 | 32.5 | 32.6 | 32.3 | |
| 7/13/2013 11:30 | 25.2 | 26.9 | 27.1 | 27.6 | 30.1 | 31.1 | 31.3 | 31.9 | 31.5 | 31.4 | 27.2 |
| 7/13/2013 16:40 | 24.9 | 27.1 | 27.3 | 27.3 | 30.7 | 32.1 | 32.5 | 32.6 | 32.6 | 32.3 | 29 |

# APPENDIX A3
# Brighton, Colorado

# Appendix A3-1 Brighton, Colorado Grab Sample Data

| **Date** | **Time** | **RO perm** pH | **NF perm** pH | **NF conc** pH | **RO conc** pH | **NF/RO conc** pH | **EDM-feed** pH |
|---|---|---|---|---|---|---|---|
| 10/1/13 | 12:51 | 5.8 | 5.11 | 4.64 | 7.32 | 5.46 | 5.35 |
| 10/2/13 | 13:30 | 5.02 | 4.91 | 4.43 | 7.2 | 5.36 | 5.11 |
| 10/3/13 | 8:45 | 6 | 4.88 | 4.18 | 7.32 | 5.29 | 4.96 |
| 10/3/13 | 19:45 |  |  |  |  | 5.59 | 5.38 |
| 10/4/13 | 13:45 | 5.76 | 5.03 | 4.47 | 7.51 | 5.42 | 5.14 |
| 10/5/13 | 12:30 | 5.66 | 5.16 | 4.65 | 7.41 | 5.56 | 5.24 |
| 10/6/13 | 13:30 | 5.87 | 5.12 | 4.66 | 7.5 | 5.49 | 5.18 |
| 10/7/13 | 14:00 | 5.66 | 4.58 | 3.94 | 7.47 | 5.17 | 4.77 |
| 10/8/13 | 14:00 | 5.61 | 5.07 | 4.4 | 7.49 | 5.53 | 5.23 |
| 10/9/13 | 14:40 | 5.86 | 4.63 | 3.86 | 7.55 | 5.33 | 4.85 |
| 10/10/13 | 20:30 | 5.6 | 4.9 | 4.26 | 7.45 | 5.46 | 5.1 |
| 10/11/13 | 14:00 | 6.07 | 4.96 | 4.19 | 7.51 | 5.5 | 5.14 |
| 10/12/13 | 14:15 | 5.71 | 5.02 | 4.36 | 7.57 | 5.56 | 5.2 |
| 10/15/13 | 16:00 | 5.58 | 5.17 | 4.89 | 7.46 | 5.53 | 5.25 |
| 10/15/13 | 20:00 |  |  | 5 | 7.49 | 5.53 | 5.36 |
| 10/16/13 | 13:30 | 5.5 | 5.04 | 4.54 | 7.54 | 5.55 | 5.31 |
| 10/17/13 | 16:00 | 5.51 | 4.95 | 4.32 | 7.39 | 5.43 | 5.1 |
| 10/18/13 | 14:00 | 5.9 | 4.94 | 4.28 | 7.52 | 5.48 | 5.1 |
| 10/22/13 | 14:15 | 5.71 | 5.26 | 4.97 | 7.48 | 5.64 | 5.46 |
| 10/23/13 | 16:30 | 5.65 | 5.01 | 4.49 | 7.54 | 5.63 | 5.36 |
| 10/24/13 | 16:20 | 5.48 | 4.94 | 4.32 | 7.53 | 5.54 | 5.17 |
| 10/25/13 | 16:15 | 5.48 | 4.86 | 4.18 | 7.52 | 5.44 | 5.09 |

| **Date** | Time | **RO perm μS/cm** | **NF perm μS/cm** | **NF conc μS/cm** | **RO conc μS/cm** | **NF/RO conc μS/cm** | **EDM-feed μS/cm** |
|---|---|---|---|---|---|---|---|
| 10/1/13 | 12:51 | 56.5 | 784.1 | 4495 | 5269 | 4916 | 3353 |
| 10/2/13 | 13:30 | 52.94 | 757.7 | 4435 | 5186 | 4830 | 3294 |
| 10/3/13 | 8:45 | 52.71 | 728.9 | 4441 | 4970 | 4690 | 3246 |
| 10/3/13 | 19:45 |  |  |  |  | 4805 | 3298 |
| 10/4/13 | 13:45 | 59.1 | 775.6 | 4644 | 5225 | 4947 | 3409 |
| 10/5/13 | 12:30 | 71.6 | 882.4 | 5281 | 5498 | 5372 | 3825 |
| 10/6/13 | 13:30 | 64.07 | 818.9 | 5246 | 5232 | 5174 | 3690 |
| 10/7/13 | 14:00 | 62 | 788.2 | 4979 | 4972 | 4902 | 3511 |
| 10/8/13 | 14:00 | 68 | 796.3 | 5240 | 4969 | 5042 | 3603 |
| 10/9/13 | 14:40 | 72 | 782.8 | 4883 | 4741 | 4770 | 3462 |
| 10/10/13 | 20:30 | 66.2 | 875.6 | 5646 | 4948 | 5359 | 3965 |
| 10/11/13 | 14:00 | 56.5 | 902 | 5780 | 5320 | 5505 | 4039 |
| 10/12/13 | 14:15 | 54.7 | 869.9 | 5793 | 5421 | 5543 | 4062 |
| 10/15/13 | 16:00 | 58.7 | 925.6 | 5050 | 5151 | 5127 | 3624 |
| 10/15/13 | 20:00 |  |  | 5100 | 5250 | 5144 | 3679 |
| 10/16/13 | 13:30 | 62 | 902.6 | 5423 | 5069 | 5262 | 3823 |
| 10/17/13 | 16:00 | 61 | 892.6 | 5646 | 4859 | 5204 | 3855 |
| 10/18/13 | 14:00 | 81 | 857.1 | 5559 | 4623 | 4985 | 3743 |
| 10/22/13 | 14:15 | 56 | 962.3 | 5105 | 5267 | 5151 | 3714 |
| 10/23/13 | 16:30 | 57 | 922 | 5502 | 5178 | 5291 | 3863 |
| 10/24/13 | 16:20 | 54 | 932.9 | 5786 | 5230 | 5419 | 4007 |
| 10/25/13 | 16:15 | 52 | 925.5 | 5873 | 5236 | 5479 | 4095 |

# Appendix A3-1 Brighton, Colorado Grab Sample Data

| **Date** | **Time** | **EDM-diluate** pH | **E-Rinse** pH | **NaCl** pH | **M. Na** pH | **M. Cl** pH | **Plant raw** pH |
|---:|---:|---:|---:|---:|---:|---:|---:|
| 10/1/13 | 12:51 | 4.99 | 10.55 | 5.85 | 7.19 | 4.61 | |
| 10/2/13 | 13:30 | 4.75 | 8.83 | 5.48 | 7.03 | 2.76 | |
| 10/3/13 | 8:45 | 4.61 | 9.19 | 5.58 | 7.05 | 2.61 | |
| 10/3/13 | 19:45 | 5.12 | | | 7.23 | | |
| 10/4/13 | 13:45 | 4.85 | 10.34 | 5.65 | 7.2 | 2.94 | |
| 10/5/13 | 12:30 | 4.99 | 10.98 | 5.62 | 7.27 | 3.09 | |
| 10/6/13 | 13:30 | 4.89 | 10.3 | 5.49 | 7.36 | 2.95 | 6.84 |
| 10/7/13 | 14:00 | 4.36 | 8.46 | 3.49 | 6.99 | 2.53 | 6.84 |
| 10/8/13 | 14:00 | 4.85 | 8.23 | 5.79 | 7.6 | 2.95 | 6.94 |
| 10/9/13 | 14:40 | 4.25 | 8.51 | 3.49 | 7.63 | 2.21 | 6.94 |
| 10/10/13 | 20:30 | 4.7 | 8.14 | 3.97 | 7.84 | 2.6 | |
| 10/11/13 | 14:00 | 4.71 | 8.18 | 4.16 | 7.95 | 2.66 | 6.93 |
| 10/12/13 | 14:15 | 4.75 | 9.11 | 4.8 | 8.3 | 2.75 | 6.91 |
| 10/15/13 | 16:00 | 5.09 | 8.68 | 5.08 | 7.2 | 3.38 | |
| 10/15/13 | 20:00 | | | | | | |
| 10/16/13 | 13:30 | 4.99 | 8.6 | 5.85 | 7.5 | 4.21 | 6.85 |
| 10/17/13 | 16:00 | 4.75 | 8.67 | 5.08 | 7.75 | 2.73 | |
| 10/18/13 | 14:00 | 4.71 | 9.3 | 3.91 | 7.75 | 2.78 | 6.98 |
| 10/22/13 | 14:15 | 5.28 | 10.42 | 5.73 | 7.23 | 4.9 | 6.9 |
| 10/23/13 | 16:30 | 5.08 | 9.59 | 5.87 | 7.84 | 3.73 | |
| 10/24/13 | 16:20 | 4.73 | 9.75 | 4.58 | 8.14 | 2.67 | |
| 10/25/13 | 16:15 | 4.61 | 9.78 | 3.77 | 8.02 | 2.71 | |

| **Date** | Time | **EDM-diluate µS/cm** | **E-Rinse mS/cm** | **NaCl mS/cm** | **M. Na mS/cm** | **M. Cl mS/cm** | **Plant raw µS/cm** |
|---:|---:|---:|---:|---:|---:|---:|---:|
| 10/1/13 | 12:51 | 2639 | 28.08 | 46.82 | 47.53 | 125.5 | |
| 10/2/13 | 13:30 | 2581 | 34.22 | 48.03 | 52.42 | 125.7 | |
| 10/3/13 | 8:45 | 2588 | 30.67 | 48.17 | 56.37 | 117.7 | |
| 10/3/13 | 19:45 | 2603 | | | 59.82 | | |
| 10/4/13 | 13:45 | 2753 | 28.27 | 45.8 | 61.4 | 118.3 | |
| 10/5/13 | 12:30 | 3147 | 28.57 | 48.9 | 58.57 | 124.4 | |
| 10/6/13 | 13:30 | 3024 | 30.01 | 48.54 | 60.61 | 118.9 | 1287 |
| 10/7/13 | 14:00 | 2885 | 32.53 | 48.38 | 62.4 | 122.7 | 1286 |
| 10/8/13 | 14:00 | 2998 | 43.51 | 48.11 | 60.11 | 115.7 | 128.5 |
| 10/9/13 | 14:40 | 2884 | 31.43 | 46.61 | 60.29 | 119 | 1292 |
| 10/10/13 | 20:30 | 3338 | 34.56 | 46.7 | 55.7 | 119.1 | |
| 10/11/13 | 14:00 | 3424 | 33.1 | 46.7 | 58 | 116.6 | 1294 |
| 10/12/13 | 14:15 | 3416 | 30.44 | 52.1 | 57.71 | 102.8 | 1293 |
| 10/15/13 | 16:00 | 2924 | 37.19 | 47.07 | 60.24 | 115.8 | |
| 10/15/13 | 20:00 | | | | | | |
| 10/16/13 | 13:30 | 3177 | 41.38 | 47.53 | 66.33 | 119.6 | 1254 |
| 10/17/13 | 16:00 | 3269 | 37.54 | 46.77 | 63.28 | 113.5 | |
| 10/18/13 | 14:00 | 3212 | 22.52 | 46.71 | 61.45 | 114.4 | 1252 |
| 10/22/13 | 14:15 | 3038 | 20.99 | 45.76 | 60.08 | 113.2 | 1277 |
| 10/23/13 | 16:30 | 3203 | 23.73 | 46.26 | 61.23 | 116.3 | |
| 10/24/13 | 16:20 | 3391 | 23.3 | 48.69 | 65.68 | 119.1 | |
| 10/25/13 | 16:15 | 3485 | 21.14 | 50.21 | 54.97 | 97.24 | |

# Appendix A3-1 Brighton, Colorado Grab Sample Data

| Date | Time | Total Alkalinity (mg/L $CaCO_3$) | | |
|---|---|---|---|---|
| | | RO conc | NF/RO conc | M. Na |
| 10/1/13 | 12:51 | 1300 | 134 | 2260 |
| 10/2/13 | 13:30 | | 145 | 2220 |
| 10/3/13 | 8:45 | 1120 | 97 | 2280 |
| 10/3/13 | 19:45 | | 185 | 184 |
| 10/4/13 | 13:45 | 1190 | 118 | 2560 |
| 10/5/13 | 12:30 | 1190 | 154 | 2700 |
| 10/6/13 | 13:30 | 1200 | 130 | 2530 |
| 10/7/13 | 14:00 | 1120 | 69 | 2000 |
| 10/8/13 | 14:00 | 1090 | 131 | |
| 10/9/13 | 14:40 | 1440 | 81 | 2860 |
| 10/10/13 | 20:30 | 1150 | 128 | 2520 |
| 10/11/13 | 14:00 | 1250 | 142 | 3360 |
| 10/12/13 | 14:15 | 1340 | 158 | 3690 |
| 10/13/13 | 16:00 | 1180 | 162 | 2920 |
| 10/15/13 | 20:00 | | 159 | |
| 10/16/13 | 13:30 | 1110 | 120 | 3280 |
| 10/17/13 | 16:00 | 1120 | 139 | 2900 |
| 10/18/13 | 14:00 | 1000 | 110 | 2800 |
| 10/22/13 | 14:15 | 1180 | 192 | 2400 |
| 10/23/13 | 16:30 | 1200 | 184 | 3380 |
| 10/24/13 | 16:20 | 1080 | 152 | 3540 |
| 10/25/13 | 16:15 | 1100 | 129 | 2760 |

# Appendix A3-1 Brighton, Colorado Grab Sample Data

| Date | | | Specific Gravity | |
|---|---|---|---|---|
| | Date | Time | M. Na | M. Cl |
| 10/1/13 | 10/1/13 | 12:51 | 1.032 | 1.074 |
| 10/2/13 | 10/2/13 | 13:30 | 1.038 | 1.076 |
| 10/3/13 | 10/3/13 | 8:45 | 1.042 | 1.068 |
| 10/3/13 | 10/3/13 | 19:45 | 1.046 | |
| 10/4/13 | 10/4/13 | 13:45 | 1.048 | 1.07 |
| 10/5/13 | 10/5/13 | 12:30 | 1.044 | 1.076 |
| 10/6/13 | 10/6/13 | 13:30 | 1.046 | 1.07 |
| 10/7/13 | 10/7/13 | 14:00 | 1.048 | 1.07 |
| 10/8/13 | 10/8/13 | 14:00 | 1.046 | 1.066 |
| 10/9/13 | 10/9/13 | 14:40 | 1.046 | 1.066 |
| 10/10/13 | 10/10/13 | 20:30 | 1.04 | 1.07 |
| 10/11/13 | 10/11/13 | 14:00 | 1.044 | 1.066 |
| 10/12/13 | 10/12/13 | 14:15 | 1.044 | 1.046 |
| 10/13/13 | 10/13/13 | 16:00 | 1.046 | 1.066 |
| 10/15/13 | 10/16/13 | 13:30 | 1.052 | 1.07 |
| 10/16/13 | 10/17/13 | 16:00 | 1.048 | 1.066 |
| 10/17/13 | 10/18/13 | 14:00 | 1.046 | 1.064 |
| 10/18/13 | 10/22/13 | 14:15 | 1.044 | 1.066 |
| 10/22/13 | 10/23/13 | 16:30 | 1.048 | 1.068 |
| 10/23/13 | 10/24/13 | 16:20 | 1.05 | 1.068 |
| 10/24/13 | 10/25/13 | 16:15 | 1.04 | 1.052 |
| 10/25/13 | | | | |

# Appendix A3-1 Brighton, Colorado Grab Sample Data

| | | Silica (mg/L) | | | | | |
|---|---|---|---|---|---|---|---|
| **Date** | **Time** | **NF perm** | **NF conc** | **RO conc** | **NF/RO conc** | **EDM-feed** | **EDM-diluate** |
| 10/1/13 | 12:51 | 93.8 | 127.6 | 102.8 | 112 | 110.8 | 117.8 |
| 10/2/13 | 13:30 | 98.2 | 115.4 | 100.2 | 106.8 | 110 | 112 |
| 10/3/13 | 8:45 | 96.8 | 117.4 | 89.4 | 102.6 | 103.4 | 97.4 |
| 10/3/13 | 19:45 | | | | 107.4 | 111.4 | 116.6 |
| 10/4/13 | 13:45 | | | | 105.6 | 101.6 | 105.6 |
| 10/5/13 | 12:30 | 106.8 | 120 | 96.4 | 109.8 | 100.4 | 114 |
| 10/6/13 | 13:30 | | 109.8 | | | 106.4 | 99.4 |
| 10/7/13 | 14:00 | | 99.2 | | 89.2 | 86.2 | 98.8 |
| 10/8/13 | 14:00 | 56.2 | 106.8 | 84.8 | 101.16 | 107.2 | 101.4 |
| 10/9/13 | 14:40 | | | | | | |
| 10/10/13 | 20:30 | | | | | | |
| 10/11/13 | 14:00 | 98.8 | 100.2 | 91.4 | 106.8 | 100.6 | 101.6 |
| 10/12/13 | 14:15 | | 109.8 | 96.4 | | 103.2 | |
| 10/13/13 | 7:25 | | 123.6 | 92.6 | | 105.6 | |
| 10/15/13 | 20:00 | | 129.8 | 96 | | 120 | |
| 10/15/13 | 22:00 | | 128 | 81.2 | | 113.6 | |
| 10/16/13 | 8:20 | 98.4 | 120.6 | 99.4 | | 110 | |
| 10/16/13 | 13:30 | 84.8 | 114.4 | | | 99.8 | 108.6 |
| 10/17/13 | 16:00 | | 122.2 | 62 | 105 | | |
| 10/18/13 | 14:00 | | 103.6 | 82.4 | 91.8 | | |
| 10/22/13 | 14:15 | | | | | 114.2 | |
| 10/23/13 | 16:30 | | | | | 105 | |
| 10/24/13 | 16:20 | | 127.8 | | | 106.2 | |
| 10/25/13 | 16:15 | | 105.2 | | | 108 | |

# Appendix A3-2 Brighton Log Sheet Data
## NF and EDM Stream Conductivity

| Date | Time | NF feed μS/cm | NF perm μS/cm | NF conc μS/cm | NF/RO conc μS/cm | EDM-feed μS/cm | EDM-diluate μS/cm |
|---|---|---|---|---|---|---|---|
| 10/1/13 | 12:51 | 2688 | 733 | 4571 | 4899 | 3424.22 | 2612 |
| 10/2/13 | 13:15 | 2632 | 707 | 4521 | 4854 | 3372 | 2555 |
| 10/2/13 | 17:50 | 2601 | 694 | 4454 | 4820 | 3336 | 2522 |
| 10/2/13 | 20:55 | 2650 | 709 | 4508 | 4841 | 3387 | 2607 |
| 10/3/13 | 8:24 | 2637 | 662 | 4525 | 4696 | 3315 | 2554 |
| 10/3/13 | 18:30 | 2646 | 693 | 4531 | 4927 | 3402 | 2562 |
| 10/4/13 | 11:50 | 2740 | 709 | 4691 | 4966 | 3504 | 2682 |
| 10/4/13 | 16:50 | 2695 | 675 | 4669 | 4772 | 3419 | 2675 |
| 10/4/13 | 19:40 | 2781 | 696 | 4772 | 4803 | 3477 | 2740 |
| 10/5/13 | 8:25 | 3134 | 782 | 5211 | 5358 | 3956 | 3156 |
| 10/5/13 | 12:15 | 3202 | 801 | 5382 | 5387 | 3939 | 3119 |
| 10/5/13 | 17:45 | 3149 | 785 | 5312 | 5391 | 3940 | 3106 |
| 10/6/13 | 13:15 | 3072 | 748 | 5298 | 5196 | 3791 | 2987 |
| 10/6/13 | 15:30 | 2947 | 724 | 5136 | 4965 | 3635 | 2845 |
| 10/6/13 | 20:05 | 2942 | 736 | 5060 | 4938 | 3627 | 2918 |
| 10/7/13 | 11:05 | 2952 | 742 | 5055 | 4919 | 3630 | 2902 |
| 10/7/13 | 13:45 | 2929 | 729 | 5042 | 4883 | 3589 | 2853 |
| 10/7/13 | 16:30 | 2956 | 752 | 5047 | 5038 | 3670 | 2918 |
| 10/7/13 | 20:15 | 3077 | 756 | 5343 | 5120 | 3787 | 3023 |
| 10/8/13 | 7:30 | 3140 | 765 | 5369 | 5205 | 3919 | 3140 |
| 10/8/13 | 10:30 | 3185 | 769 | 5562 | 5240 | 3900 | 3095 |
| 10/8/13 | 13:35 | 3082 | 738 | 5455 | 5185 | 3793 | 3019 |
| 10/8/13 | 16:30 | 3051 | 773 | 5415 | 5162 | 3774 | 2971 |
| 10/8/13 | 20:00 | 3109 | 744 | 5437 | 5199 | 3838 | 3095 |
| 10/9/13 | 8:50 | 3207 | 756 | 5553 | 5242 | 3906 | 3118 |
| 10/9/13 | 14:30 | 2970 | 738 | 5195 | 4866 | 3592 | 2874 |
| 10/9/13 | 17:20 | 2938 | 716 | 5038 |  | 3610 | 2904 |
| 10/10/13 | 8:30 | 2956 | 703 | 5046 | 4866 | 3665 | 3001 |
| 10/10/13 | 13:45 | 3270 | 774 | 5715 | 5590 | 4208 | 3393 |
| 10/10/13 | 17:50 | 3284 | 790 | 5738 | 5422 | 4032 | 3224 |
| 10/10/13 | 20:15 | 3410 | 808 | 5890 | 5491 | 4141 | 3361 |
| 10/11/13 | 8:30 | 3391 | 813 | 5859 | 5449 | 4113 | 3993 |
| 10/11/13 | 1:50 | 3473 | 826 | 5976 | 5585 | 4202 | 3413 |
| 10/11/13 | 17:40 | 3468 | 814 | 5958 | 5559 | 4187 | 3386 |
| 10/11/13 | 20:30 | 3518 | 822 | 5958 | 5583 | 4234 | 3453 |
| 10/12/13 | 10:30 | 3567 | 833 | 6043 | 5679 | 4282 | 3477 |
| 10/12/13 | 13:45 | 3513 | 798 | 5976 | 5667 | 4250 | 3437 |
| 10/12/13 | 17:00 | 3504 | 810 | 5971 | 5651 | 4216 | 3415 |
| 10/12/13 | 19:20 | 3504 | 793 | 6088 | 5710 | 4288 | 3455 |
| 10/13/13 | 7:25 | 3445 | 843 | 5993 | 5284 | 4014 | 3304 |
| 10/15/13 | 15:15 | 3045 | 877 | 5234 | 5229 | 3798 | 3012 |
| 10/15/13 | 20:00 | 3027 | 823 | 5221 | 5240 | 3804 | 3030 |
| 10/15/13 | 22:05 | 3126 | 893 | 5346 | 5304 | 3890 | 3082 |
| 10/16/13 | 6:45 | 3278 | 866 | 5534 | 5390 | 4014 | 3248 |
| 10/16/13 | 8:10 | 3323 | 789 | 5628 | 5440 | 4092 | 3313 |
| 10/16/13 | 13:10 | 3288 | 880 | 5656 | 5385 | 3982 | 3170 |
| 10/16/13 | 17:10 | 3244 | 847 | 5685 | 5429 | 4002 | 3211 |

## Appendix A3-2 Brighton Log Sheet Data
## NF and EDM Stream Conductivity

| Date | Time | Condition | M. Na mS/cm | M. Cl mS/cm | NaCl mS/cm | E-Rinse mS/cm |
|---|---|---|---|---|---|---|
| 10/1/13 | 12:51 | M.Na-45mS | 43.4 | 115.42 | 49.4 | 31.8 |
| 10/2/13 | 13:15 | M.Na-50 mS | 47.81 | 115.25 | 51.3 | 37.1 |
| 10/2/13 | 17:50 | M.Na-50 mS | 52.29 | 117.32 | 49.7 | 31.3 |
| 10/2/13 | 20:55 | M.Na-55 mS | 53.32 | 116.71 | 50.3 | 32.2 |
| 10/3/13 | 8:24 | M.Na-55mS | 52.76 | 117.05 | 51 | 34.5 |
| 10/3/13 | 18:30 | M.Na-60 mS | 58.81 | 119.33 | 48.7 | 32.2 |
| 10/4/13 | 11:50 | M.Na-60 mS | 59.25 | 119.06 | 50 | 32.4 |
| 10/4/13 | 16:50 | M.Na-60 mS | 58.88 | 114.7 | 48.1 | 33.8 |
| 10/4/13 | 19:40 | M.Na-60 mS | 50.84 | 94.64 | 51.1 | 34.1 |
| 10/5/13 | 8:25 | M.Na-60 mS | 58.75 | 105.64 | 50.2 | 31.2 |
| 10/5/13 | 12:15 | M.Na-60 mS | 57.72 | 117.21 | 50.3 | 32.3 |
| 10/5/13 | 17:45 | M.Na-60 mS | 58.09 | 114.98 | 50.9 | 35.7 |
| 10/6/13 | 13:15 | M.Na-60 mS | 58.28 | 114.7 | 50.1 | 31.9 |
| 10/6/13 | 15:30 | M.Na-60 mS | 58.46 | 116.57 | 50 | 32.3 |
| 10/6/13 | 20:05 | M.Na-60 mS | 57.61 | 115.16 | 49.8 | 33.7 |
| 10/7/13 | 11:05 | M.Na-60 mS | 60.3 | 113.58 | 50.6 | 37 |
| 10/7/13 | 13:45 | M.Na-60 mS | 59.3 | 116.75 | 50 | 32 |
| 10/7/13 | 16:30 | M.Na-60 mS | 59.32 | 115.94 | 47.5 | 32.7 |
| 10/7/13 | 20:15 | M.Na-60 mS | 59.72 | 117.86 | 50.3 | 33.9 |
| 10/8/13 | 7:30 | M.Na-60 mS | 57.51 | 115.92 | 51.3 | 36.4 |
| 10/8/13 | 10:30 | M.Na-60 mS | 57.29 | 118.03 | 49.8 | 38.4 |
| 10/8/13 | 13:35 | M.Na-60 mS | 56.67 | 119.08 | 48.5 | 39.3 |
| 10/8/13 | 16:30 | M.Na-60 mS | 58.27 | 114.42 | 49.3 | 31.6 |
| 10/8/13 | 20:00 | M.Na-60 mS | 59.19 | 114.72 | 49 | 33 |
| 10/9/13 | 8:50 | M.Na-60 mS | 57.8 | 118.52 | 49.8 | 36.6 |
| 10/9/13 | 14:30 | M.Na-60 mS | 60.72 | 112.92 | 50.8 | 30.8 |
| 10/9/13 | 17:20 | M.Na-60 mS | 57.7 | 117.59 | 48.7 | 31.3 |
| 10/10/13 | 8:30 | M.Na-60 mS | 58.96 | 117.59 | 50.3 | 37.9 |
| 10/10/13 | 13:45 | M.Na-60 mS | 58.57 | 114.64 | 51.2 | 36.2 |
| 10/10/13 | 17:50 | M.Na-60 mS | 5748 | 115.78 | 50.5 | 33.9 |
| 10/10/13 | 20:15 | M.Na-60 mS | 5724 | 115.88 | 51.8 | 34.5 |
| 10/11/13 | 8:30 | M.Na-60 mS | 58.51 | 113.42 | 50.3 | 31.6 |
| 10/11/13 | 1:50 | M.Na-60 mS | 57.89 | 119.68 | 51.5 | 33 |
| 10/11/13 | 17:40 | M.Na-60 mS | 59.73 | 114.93 | 52.2 | 33.8 |
| 10/11/13 | 20:30 | M.Na-60 mS | 60.73 | 114.17 | 51.6 | 30.8 |
| 10/12/13 | 10:30 | M.Na-60 mS, M.Cl-100 mS | 58.44 | 96.09 | 53.5 | 32.1 |
| 10/12/13 | 13:45 | M.Na-60 mS, M.Cl-100 mS | 58.99 | 96.98 | 55.6 | 31.9 |
| 10/12/13 | 17:00 | M.Na-60 mS, M.Cl-100 mS | 57.59 | 95.8 | 54.1 | 32.2 |
| 10/12/13 | 19:20 | M.Na-60 mS, M.Cl-100 mS | 57.72 | 98.31 | 55.6 | 32.9 |
| 10/13/13 | 7:25 | M.Na-60 mS, M.Cl-100 mS | 58.02 | 96.35 | 55.6 | 36.4 |
| 10/15/13 | 15:15 | M.Na-65 mS, M.Cl-120 mS | 63.29 | 116.31 | 50.9 | 36.6 |
| 10/15/13 | 20:00 | M.Na-65 mS, M.Cl-120 mS | 63.74 | 119.28 | 51.4 | 33.4 |
| 10/15/13 | 22:05 | M.Na-65 mS, M.Cl-120 mS | 63.38 | 114.24 | 51.2 | 33.8 |
| 10/16/13 | 6:45 | M.Na-65 mS, M.Cl-120 mS | 63.04 | 116.35 | 51.1 | 36.6 |
| 10/16/13 | 8:10 | M.Na-65 mS, M.Cl-120 mS | 62.13 | 116.48 | 51.5 | 36.9 |
| 10/16/13 | 13:10 | M.Na-65 mS, M.Cl-120 mS | 65.27 | 115.63 | 50 | 37 |
| 10/16/13 | 17:10 | M.Na-65 mS, M.Cl-120 mS | 66.1 | 119.63 | 49.5 | 31.5 |

## Appendix A3-2 Brighton Log Sheet Data
## NF and EDM Stream Conductivity

| **Date** | **Time** | **NF feed**<br>**µS/cm** | **NF perm**<br>**µS/cm** | **NF conc**<br>**µS/cm** | **NF/RO conc**<br>**µS/cm** | **EDM-feed**<br>**µS/cm** | **EDM-diluate**<br>**µS/cm** |
|---|---|---|---|---|---|---|---|
| 10/17/13 | 8:00 | 3642 | 911 | 6172 | 5722 | 4364 | 3597 |
| 10/17/13 | 12:20 | 3687 | 919 | 6365 | 5733 | 4439 | 3628 |
| 10/17/13 | 14:30 | 3373 | 838 | 5957 | 5265 | 4056 | 3293 |
| 10/17/13 | 16:00 | 3351 | 826 | 5857 | 5258 | 4035 | 3294 |
| 10/17/13 | 17:30 | 3364 | 841 | 5868 | 5270 | 4050 | 3331 |
| 10/17/13 | 19:55 | 3351 | 841 | 5850 | 5260 | 4035 | 3291 |
| 10/18/13 | 7:15 | 3490 | 842 | 6015 | 5325 | 4162 | 3430 |
| 10/18/13 | 13:30 | 3404 | 865 | 5939 | 5162 | 4059 | 3331 |
| 10/18/13 | 15:25 | 3396 | 864 | 5929 | 5145 | 4050 | 3342 |
| 10/18/13 | 17:25 | 3400 | 853 | 5926 | 5168 | 4079 | 3364 |
| 10/18/13 | 20:20 | 3521 | 872 | 6078 | 5238 | 4185 | 3488 |
| 10/19/13 | 7:55 | 3615 | 932 | 6181 | 5265 | 4258 | 3550 |
| 10/22/13 | 13:05 | 3194 | 903 | 5383 | 5413 | 3993 | 3191 |
| 10/22/13 | 14:00 | 3189 | 916 | 5383 | 5411 | 3954 | 3140 |
| 10/22/13 | 16:00 | 3203 | 917 | 5401 | 5417 | 3994 | 3202 |
| 10/22/13 | 16:20 | 3225 | 915 | 5410 | 5409 | 3979 | 3169 |
| 10/22/13 | 20:25 | 3333 | 925 | 5562 | 5476 | 4063 | 3253 |
| 10/23/13 | 5:00 | 3508 | 972 | 6010 | 5682 | 4320 | 3529 |
| 10/23/13 | 9:05 | 3602 | 978 | 6155 | 5739 | 4345 | 3544 |
| 10/23/13 | 10:50 | 3579 | 983 | 6128 | 5716 | 4331 | 3543 |
| 10/23/13 | 13:40 | 3557 | 971 | 6106 | 5686 | 4297 | 3463 |
| 10/23/13 | 16:15 | 3374 | 921 | 5899 | 5622 | 4162 | 3336 |
| 10/23/13 | 18:10 | 3427 | 897 | 5940 | 5630 | 4188 | 3375 |
| 10/23/13 | 20:30 | 3427 | 871 | 5849 | 5591 | 4165 | 3381 |
| 10/24/13 | 8:20 | 3615 | 955 | 6244 | 5798 | 4407 | 3592 |
| 10/24/13 | 9:50 | 3633 | 912 | 6203 | 5772 | 4367 | 3583 |
| 10/24/13 | 15:30 | 3589 | 881 | 6191 | 5762 | 4330 | 3528 |
| 10/24/13 | 17:30 | 3670 | 950 | 6281 | 5797 | 4429 | 3655 |
| 10/25/13 | 10:00 | 3876 | 980 | 6529 | 5916 | 4574 | 3763 |
| 10/25/13 | 10:22 | 3242 | 851 | 5938 | 5597 | 4266 | 3508 |
| 10/25/13 | 14:10 | 3670 | 910 | 6263 | 5779 | 4397 | 3594 |
| 10/25/13 | 16:00 | 3657 | 852 | 6245 | 5799 | 4400 | 6310 |
| 10/25/13 | 17:50 | 3679 | 924 | 6280 | 5799 | 4410 | 3626 |
| 10/25/13 | 20:30 | 3746 | 908 | 6343 | 5826 | 4472 | 3719 |
| 10/26/13 | 10:40 | 3858 | 910 | 6477 | 5874 | 4560 | 3758 |

Appendix A3-2 Brighton Log Sheet Data
NF and EDM Stream Conductivity

| **Date** | **Time** | **Condition** | **M. Na mS/cm** | **M. Cl mS/cm** | **NaCl mS/cm** | **E-Rinse mS/cm** |
|---|---|---|---|---|---|---|
| 10/17/13 | 8:00 | M.Na-65 mS, M.Cl-120 mS | 62.26 | 117.13 | 49 | 35.9 |
| 10/17/13 | 12:20 | M.Na-65 mS, M.Cl-120 mS | 63.37 | 114.24 | 51 | 32.9 |
| 10/17/13 | 14:30 | M.Na-65 mS, M.Cl-120 mS | 64.7 | 118.21 | 51.2 | 33.4 |
| 10/17/13 | 16:00 | M.Na-65 mS, M.Cl-120 mS | 65.98 | 119.45 | 50.6 | 33.9 |
| 10/17/13 | 17:30 | M.Na-65 mS, M.Cl-120 mS | 65.87 | 114.39 | 52.4 | 31.8 |
| 10/17/13 | 19:55 | M.Na-65 mS, M.Cl-120 mS | 65.07 | 119.51 | 51.6 | 32.2 |
| 10/18/13 | 7:15 | M.Na-65 mS, M.Cl-120 mS | 64.15 | 120.4 | 48.8 | 31.1 |
| 10/18/13 | 13:30 | M.Na-65 mS, M.Cl-120 mS | 64.27 | 119.34 | 49.4 | 22 |
| 10/18/13 | 15:25 | M.Na-65 mS, M.Cl-120 mS | 62.21 | 115.53 | 50.6 | 23.1 |
| 10/18/13 | 17:25 | M.Na-65 mS, M.Cl-120 mS | 62.77 | 118.98 | 50.1 | 24 |
| 10/18/13 | 20:20 | M.Na-65 mS, M.Cl-120 mS | 62.37 | 113.52 | 50.3 | 25 |
| 10/19/13 | 7:55 | M.Na-65 mS, M.Cl-120 mS | 63.47 | 114.58 | 51.7 | 28 |
| 10/22/13 | 13:05 | M.Na-65 mS, M.Cl-120 mS | 62.96 | 113.94 | 49.2 | 23.9 |
| 10/22/13 | 14:00 | M.Na-65 mS, M.Cl-120 mS | 64.66 | 120.02 | 50.2 | 24 |
| 10/22/13 | 16:00 | M.Na-65 mS, M.Cl-120 mS | 61.12 | 118.77 | 50 | 24.3 |
| 10/22/13 | 16:20 | M.Na-65 mS, M.Cl-120 mS | 65.02 | 113.94 | 51.3 | 24.4 |
| 10/22/13 | 20:25 | M.Na-65 mS, M.Cl-120 mS | 62.61 | 119.54 | 50.5 | 24.4 |
| 10/23/13 | 5:00 | M.Na-65 mS, M.Cl-120 mS | 63.77 | 112.68 | 50.8 | 24.7 |
| 10/23/13 | 9:05 | M.Na-65 mS, M.Cl-120 mS | 64.75 | 119.82 | 50.5 | 22.9 |
| 10/23/13 | 10:50 | M.Na-65 mS, M.Cl-120 mS | 62 | 118.2 | 50 | 23.4 |
| 10/23/13 | 13:40 | M.Na-65 mS, M.Cl-120 mS | 62.5 | 116.43 | 49.7 | 24.5 |
| 10/23/13 | 16:15 | M.Na-65 mS, M.Cl-120 mS | 62.21 | 113.48 | 51.6 | 24.5 |
| 10/23/13 | 18:10 | M.Na-65 mS, M.Cl-120 mS | 64.41 | 114.41 | 51 | 23.9 |
| 10/23/13 | 20:30 | M.Na-65 mS, M.Cl-120 mS | 62.47 | 115.28 | 50.8 | 24.6 |
| 10/24/13 | 8:20 | M.Na-65 mS, M.Cl-120 mS | 63.31 | 114.27 | 51.3 | 22.7 |
| 10/24/13 | 9:50 | M.Na-65 mS, M.Cl-120 mS | 63.39 | 117.98 | 49 | 23.1 |
| 10/24/13 | 15:30 | M.Na-65 mS, M.Cl-120 mS | 63.01 | 114.84 | 50 | 23.9 |
| 10/24/13 | 17:30 | M.Na-65 mS, M.Cl-120 mS | 61.79 | 119.01 | 51.3 | 21.1 |
| 10/25/13 | 10:00 | M.Na-55 mS, M.Cl-110 mS | 53.13 | 106.57 | 51.1 | 25.4 |
| 10/25/13 | 10:22 | M.Na-55 mS, M.Cl-110 mS | 53.02 | 104.77 | 50.9 | 21.8 |
| 10/25/13 | 14:10 | M.Na-55 mS, M.Cl-100 mS | 52.38 | 94.19 | 50.5 | 23.6 |
| 10/25/13 | 16:00 | M.Na-55 mS, M.Cl-100 mS | 56.64 | 96.66 | 48.4 | 22.6 |
| 10/25/13 | 17:50 | M.Na-55 mS, M.Cl-100 mS | 53.41 | 99.62 | 49.8 | 23.4 |
| 10/25/13 | 20:30 | M.Na-55 mS, M.Cl-100 mS | 52.35 | 94.21 | 52 | 24.3 |
| 10/26/13 | 10:40 | M.Na-55 mS, M.Cl-100 mS | 55.01 | 96.46 | 49.7 | 25.3 |

Appendix A3-2 Brighton Log Sheet Data

NF and EDM Flows

| Date | Time | NF perm | 1st stage NF perm gpm | NF conc (rotameter) gpm | RO conc (rotameter) gpm | NF/RO conc gpm |
|---|---|---|---|---|---|---|
| 10/1/13 | 12:51 | 5 | 3.8 | 4 | 5.2 | 9.1 |
| 10/2/13 | 13:15 | 5 | 3.8 | 4 | 5.2 | 9.2 |
| 10/2/13 | 17:50 |  |  | 4 | 5.2 | 9.2 |
| 10/2/13 | 20:55 | 5 | 3.8 | 4 | 5.2 | 9.2 |
| 10/3/13 | 8:24 | 5 | 3.8 | 4 | 5.1 | 9 |
| 10/3/13 | 18:30 | 5 | 3.8 | 4.1 | 5.1 | 9.2 |
| 10/4/13 | 11:50 | 5 | 3.8 | 4 | 5.2 | 9.2 |
| 10/4/13 | 16:50 | 5 | 3.8 | 4 | 5.2 | 9.2 |
| 10/4/13 | 19:40 | 5 | 3.8 | 4 | 5.2 | 9.1 |
| 10/5/13 | 8:25 | 5 | 3.75 | 4 | 5.1 | 9.2 |
| 10/5/13 | 12:15 | 5 | 3.75 | 4 | 5.2 | 9.3 |
| 10/5/13 | 17:45 | 5 | 3.8 | 4 | 5.2 | 9.2 |
| 10/6/13 | 13:15 | 5 | 3.8 | 4 | 5.2 | 9.2 |
| 10/6/13 | 15:30 | 5 | 3.8 | 4.1 | 5.2 | 9.2 |
| 10/6/13 | 20:05 | 5 | 3.8 | 4 | 5.1 | 9.2 |
| 10/7/13 | 11:05 | 5 | 3.8 | 4 | 5.2 | 9.2 |
| 10/7/13 | 13:45 | 5 | 3.8 | 4 | 5.2 | 9.2 |
| 10/7/13 | 16:30 | 5 | 3.8 | 4 | 5.2 | 9.2 |
| 10/7/13 | 20:15 | 5 | 3.8 | 3.9 | 5.1 | 9.15 |
| 10/8/13 | 7:30 | 5 | 3.8 | 4.1 | 5 | 9.35 |
| 10/8/13 | 10:30 | 5 | 3.8 | 4 | 5 | 9.25 |
| 10/8/13 | 13:35 | 5 | 3.85 | 4 | 5.1 | 9.25 |
| 10/8/13 | 16:30 | 5 | 3.9 | 4 | 5 | 9.15 |
| 10/8/13 | 20:00 | 5 | 3.8 | 4 | 5.1 | 9.15 |
| 10/9/13 | 8:50 | 5 | 3.8 | 4 | 5 | 9.1 |
| 10/9/13 | 14:30 | 5 | 3.8 | 4 | 5 | 9.25 |
| 10/9/13 | 17:20 | 5 | 3.8 | 4.1 | 5 | 9.15 |
| 10/10/13 | 8:30 | 5 | 3.75 | 4.15 | 5 | 9.15 |
| 10/10/13 | 13:45 | 5 | 3.8 | 4 | 5.2 | 9.15 |
| 10/10/13 | 17:50 | 5 | 3.8 | 4 | 5 | 9.05 |
| 10/10/13 | 20:15 | 5 | 3.8 | 4 | 5 | 9.15 |
| 10/11/13 | 8:30 | 5 | 3.8 | 4 | 5 | 9.1 |
| 10/11/13 | 1:50 | 5 | 3.8 | 4 | 5 | 9.15 |
| 10/11/13 | 17:40 | 5 | 3.8 | 4 | 5 | 9.15 |
| 10/11/13 | 20:30 | 5 | 3.75 | 4 | 5 | 9.15 |
| 10/12/13 | 10:30 | 5 | 3.75 | 4 | 5 | 9.15 |
| 10/12/13 | 13:45 | 5 | 3.8 | 4.1 | 5 | 9.2 |
| 10/12/13 | 17:00 | 5 | 3.8 | 4.1 | 5 | 9.15 |
| 10/12/13 | 19:20 | 5 | 3.8 | 4 | 5 | 9.15 |
| 10/13/13 | 7:25 | 5 | 3.9 | 4.1 | 4.9 | 9.05 |
| 10/15/13 | 15:15 | 5 | 3.8 | 3.9 | 5.2 | 9.15 |
| 10/15/13 | 20:00 | 5 | 3.8 | 3.9 | 5.2 | 9.2 |

# Appendix A3-2 Brighton Log Sheet Data
## NF and EDM Flows

| Date | Time | EDM-feed<br>gpm | M. Na<br>gpm | M. Cl<br>gpm | NaCl<br>gpm | E-Rinse<br>gpm |
|---|---|---|---|---|---|---|
| 10/1/13 | 12:51 | 31.8 | 26.8 | 26.5 | 27.8 | 5.2 |
| 10/2/13 | 13:15 | 32.1 | 26.7 | 26.6 | 27 | 4.9 |
| 10/2/13 | 17:50 | 32.1 | 26.7 | 26 | 27.5 | 5 |
| 10/2/13 | 20:55 | 32.2 | 26.7 | 26.2 | 27.2 | 5 |
| 10/3/13 | 8:24 | 31.5 | 26.6 | 26.4 | 27.3 | 5 |
| 10/3/13 | 18:30 | 32.1 | 27.1 | 26.3 | 27.4 | 5.1 |
| 10/4/13 | 11:50 | 31.7 | 26.7 | 26.2 | 27.3 | 5.1 |
| 10/4/13 | 16:50 | 32 | 26.8 | 26.2 | 27.3 | 5.1 |
| 10/4/13 | 19:40 | 31.8 | 26.7 | 26.4 | 27.4 | 5 |
| 10/5/13 | 8:25 | 31.4 | 26.8 | 26.4 | 27.4 | 5 |
| 10/5/13 | 12:15 | 31.5 | 27 | 26.2 | 27.5 | 5.1 |
| 10/5/13 | 17:45 | 31.6 | 27.3 | 26.4 | 27.2 | 5 |
| 10/6/13 | 13:15 | 31.6 | 26.7 | 26.4 | 27.7 | 5 |
| 10/6/13 | 15:30 | 31.8 | 26.6 | 26 | 27.2 | 4.9 |
| 10/6/13 | 20:05 | 31.8 | 27 | 26.2 | 27.1 | 4.9 |
| 10/7/13 | 11:05 | 31.7 | 27.2 | 26.4 | 27.3 | 4.9 |
| 10/7/13 | 13:45 | 31.6 | 27.1 | 26.5 | 27.3 | 5 |
| 10/7/13 | 16:30 | 31.8 | 26.6 | 26.4 | 27.1 | 4.9 |
| 10/7/13 | 20:15 | 31.3 | 26.8 | 26.4 | 27.1 | 4.9 |
| 10/8/13 | 7:30 | 31.6 | 27.1 | 26.4 | 27.2 | 4.8 |
| 10/8/13 | 10:30 | 31.9 | 27.1 | 26.3 | 27.7 | 4.9 |
| 10/8/13 | 13:35 | 31.8 | 26.8 | 26.2 | 27 | 4.9 |
| 10/8/13 | 16:30 | 31.7 | 27.6 | 26.3 | 26.8 | 5 |
| 10/8/13 | 20:00 | 31.6 | 27.6 | 26.3 | 27 | 4.9 |
| 10/9/13 | 8:50 | 31.5 | 26.7 | 26.5 | 27.3 | 4.9 |
| 10/9/13 | 14:30 | 32.1 | 27.2 | 26.6 | 27 | 4.9 |
| 10/9/13 | 17:20 | 31.9 | 26.8 | 26.6 | 26.8 | 4.9 |
| 10/10/13 | 8:30 | 31.7 | 26.7 | 26.4 | 27.1 | 4.9 |
| 10/10/13 | 13:45 | 31.7 | 27.1 | 26.1 | 27.1 | 4.9 |
| 10/10/13 | 17:50 | 31.5 | 26.6 | 26.2 | 27.4 | 4.9 |
| 10/10/13 | 20:15 | 31.9 | 27.1 | 26.5 | 27.4 | 4.9 |
| 10/11/13 | 8:30 | 31.7 | 26.9 | 26.3 | 27.1 | 4.9 |
| 10/11/13 | 1:50 | 31.7 | 27.1 | 26.5 | 27.4 | 4.9 |
| 10/11/13 | 17:40 | 31.7 | 27.1 | 26.5 | 27.4 | 4.9 |
| 10/11/13 | 20:30 | 31.7 | 27.3 | 26.6 | 26.6 | 4.8 |
| 10/12/13 | 10:30 | 31.6 | 27.4 | 26.4 | 26.9 | 4.9 |
| 10/12/13 | 13:45 | 31.6 | 27 | 26.3 | 27.2 | 4.9 |
| 10/12/13 | 17:00 | 31.7 | 27 | 26.3 | 27.6 | 4.7 |
| 10/12/13 | 19:20 | 31.6 | 26.9 | 26.1 | 27.5 | 4.7 |
| 10/13/13 | 7:25 | 31.9 | 26.4 | 26.1 | 27.1 | 4.6 |
| 10/15/13 | 15:15 | 31.5 | 26.5 | 26 | 26.7 | 4.9 |
| 10/15/13 | 20:00 | 31.4 | 26.8 | 26 | 27.2 | 4.9 |

# Appendix A3-2 Brighton Log Sheet Data
## NF and EDM Flows

| Date | Time | silica purge | silica purge | | NF F |
|---|---|---|---|---|---|
| | | gph | gpm | Δ height (in) | time (min) |
| 10/1/13 | 12:51 | 4 | 0.067 | | |
| 10/2/13 | 13:15 | 4 | 0.067 | | |
| 10/2/13 | 17:50 | 4 | 0.067 | | |
| 10/2/13 | 20:55 | 4 | 0.067 | | |
| 10/3/13 | 8:24 | 3 | 0.050 | | |
| 10/3/13 | 18:30 | 3 | 0.050 | | |
| 10/4/13 | 11:50 | 3 | 0.050 | | |
| 10/4/13 | 16:50 | 3 | 0.050 | | |
| 10/4/13 | 19:40 | 3 | 0.050 | 3.500 | 130 |
| 10/5/13 | 8:25 | 3 | 0.050 | 1.5 | 120 |
| 10/5/13 | 12:15 | 3 | 0.050 | | |
| 10/5/13 | 17:45 | 3 | 0.050 | 1.250 | 75 |
| 10/6/13 | 13:15 | 3 | 0.050 | 1.000 | 60 |
| 10/6/13 | 15:30 | 3 | 0.050 | | |
| 10/6/13 | 20:05 | 3 | 0.050 | | |
| 10/7/13 | 11:05 | 2.5 | 0.042 | | |
| 10/7/13 | 13:45 | 2.5 | 0.042 | | |
| 10/7/13 | 16:30 | 2.5 | 0.042 | | |
| 10/7/13 | 20:15 | 2.5 | 0.042 | 3.125 | 140 |
| 10/8/13 | 7:30 | 2.5 | 0.042 | | |
| 10/8/13 | 10:30 | 2.5 | 0.042 | 1.5 | 120 |
| 10/8/13 | 13:35 | 2.5 | 0.042 | | |
| 10/8/13 | 16:30 | 2.5 | 0.042 | | |
| 10/8/13 | 20:00 | 2.5 | 0.042 | | |
| 10/9/13 | 8:50 | 1.25 | 0.021 | | |
| 10/9/13 | 14:30 | 1.25 | 0.021 | | |
| 10/9/13 | 17:20 | 2 | 0.033 | | |
| 10/10/13 | 8:30 | 2 | 0.033 | | |
| 10/10/13 | 13:45 | 3 | 0.050 | | |
| 10/10/13 | 17:50 | 3.25 | 0.054 | | |
| 10/10/13 | 20:15 | 3.25 | 0.054 | 2.5 | 166 |
| 10/11/13 | 8:30 | 3.25 | 0.054 | | |
| 10/11/13 | 1:50 | 3.25 | 0.054 | | |
| 10/11/13 | 17:40 | 3.25 | 0.054 | | |
| 10/11/13 | 20:30 | 3.25 | 0.054 | 2.125 | 390 |
| 10/12/13 | 10:30 | 3.25 | 0.054 | | |
| 10/12/13 | 13:45 | 3.25 | 0.054 | | |
| 10/12/13 | 17:00 | 3.25 | 0.054 | | |
| 10/12/13 | 19:20 | 3.25 | 0.054 | | |
| 10/13/13 | 7:25 | 3.25 | 0.054 | | |
| 10/15/13 | 15:15 | 3.25 | 0.054 | | |
| 10/15/13 | 20:00 | 4 | 0.067 | | |

# Appendix A3-2 Brighton Log Sheet Data
## NF and EDM Flows

| **Date** | **Time** | **eed Tank oveflowing?** |
|---|---|---|
| 10/1/13 | 12:51 | |
| 10/2/13 | 13:15 | |
| 10/2/13 | 17:50 | |
| 10/2/13 | 20:55 | |
| 10/3/13 | 8:24 | |
| 10/3/13 | 18:30 | |
| 10/4/13 | 11:50 | |
| 10/4/13 | 16:50 | |
| 10/4/13 | 19:40 | |
| 10/5/13 | 8:25 | |
| 10/5/13 | 12:15 | |
| 10/5/13 | 17:45 | |
| 10/6/13 | 13:15 | |
| 10/6/13 | 15:30 | |
| 10/6/13 | 20:05 | |
| 10/7/13 | 11:05 | |
| 10/7/13 | 13:45 | |
| 10/7/13 | 16:30 | |
| 10/7/13 | 20:15 | |
| 10/8/13 | 7:30 | yes |
| 10/8/13 | 10:30 | no |
| 10/8/13 | 13:35 | no |
| 10/8/13 | 16:30 | no |
| 10/8/13 | 20:00 | no |
| 10/9/13 | 8:50 | yes |
| 10/9/13 | 14:30 | no |
| 10/9/13 | 17:20 | no |
| 10/10/13 | 8:30 | no |
| 10/10/13 | 13:45 | no |
| 10/10/13 | 17:50 | no |
| 10/10/13 | 20:15 | no |
| 10/11/13 | 8:30 | no |
| 10/11/13 | 1:50 | no |
| 10/11/13 | 17:40 | no |
| 10/11/13 | 20:30 | no |
| 10/12/13 | 10:30 | yes |
| 10/12/13 | 13:45 | no |
| 10/12/13 | 17:00 | no |
| 10/12/13 | 19:20 | no |
| 10/13/13 | 7:25 | no |
| 10/15/13 | 15:15 | no |
| 10/15/13 | 20:00 | no |

# Appendix A3-2 Brighton Log Sheet Data
## NF and EDM Flows

| Date | Time | NF perm | 1st stage NF perm gpm | NF conc (rotameter) gpm | RO conc (rotameter) gpm | NF/RO conc gpm |
|---|---|---|---|---|---|---|
| 10/15/13 | 22:05 | 5 | 3.8 | 3.95 | 5.2 | 9.15 |
| 10/16/13 | 6:45 | 5 | 3.75 | 4 | 5 | 9.15 |
| 10/16/13 | 8:10 | 5 | 3.8 | 4.1 | 5 | 9.15 |
| 10/16/13 | 13:10 | 5 | 3.8 | 4 | 5 | 9.15 |
| 10/16/13 | 17:10 | 5 | 3.9 | 3.9 | 5.1 | 9.15 |
| 10/17/13 | 8:00 | 5 | 3.75 | 4 | 4.9 | 9.05 |
| 10/17/13 | 12:20 | 5 | 3.9 | 4.1 | 5 | 9.25 |
| 10/17/13 | 14:30 | 5 | 3.8 | 3.9 | 5.2 | 9.25 |
| 10/17/13 | 16:00 | 5 | 3.8 | 3.9 | 5.1 | 9.15 |
| 10/17/13 | 17:30 | 5 | 3.8 | 3.9 | 5.1 | 9.2 |
| 10/17/13 | 19:55 | 5 | 3.8 | 3.9 | 5.1 | 9.15 |
| 10/18/13 | 7:15 | 5 | 3.8 | 4 | 5.1 | 9.15 |
| 10/18/13 | 13:30 | 5 | 3.8 | 4 | 5.1 | 9.15 |
| 10/18/13 | 15:25 | 5 | 3.8 | 3.9 | 5.1 | 9.15 |
| 10/18/13 | 17:25 | 5 | 3.8 | 4 | 5 | 9.15 |
| 10/18/13 | 20:20 | 5 | 3.8 | 4 | 5 | 9.15 |
| 10/19/13 | 7:55 | 5 | 3.8 | 4 | 5.1 | 9.15 |
| 10/22/13 | 13:05 | 5 | 3.8 | 4 | 5.1 | 9.15 |
| 10/22/13 | 14:00 | 5 | 3.8 | 4 | 5 | 9.15 |
| 10/22/13 | 16:00 | 5 | 3.8 | 4 | 5 | 9.25 |
| 10/22/13 | 16:20 | 5 | 3.75 | 4 | 5 | 9.15 |
| 10/22/13 | 20:25 | 5 | 3.75 | 4.1 | 4.9 | 9.2 |
| 10/23/13 | 5:00 | 5 | 3.8 | 4 | 5 | 9.15 |
| 10/23/13 | 9:05 | 5 | 3.75 | 4 | 5 | 9.15 |
| 10/23/13 | 10:50 | 5 | 3.8 | 4 | 5 | 9.15 |
| 10/23/13 | 13:40 | 5 | 3.8 | 4 | 5.1 | 9.15 |
| 10/23/13 | 16:15 | 5 | 3.8 | 4 | 5 | 9.15 |
| 10/23/13 | 18:10 | 5 | 3.8 | 3.9 | 5.1 | 9.15 |
| 10/23/13 | 20:30 | 5 | 3.8 | 4 | 5 | 9.15 |
| 10/24/13 | 8:20 | 5 | 3.8 | 4 | 5 | 9.15 |
| 10/24/13 | 9:50 | 5 | 3.8 | 4.1 | 4.9 | 9.25 |
| 10/24/13 | 15:30 | 5 | 3.8 | 4.1 | 5 | 9.2 |
| 10/24/13 | 17:30 | 5 | 3.8 | 4.1 | 4.9 | 9.15 |
| 10/25/13 | 10:00 | 5 | 3.75 | 4.15 | 4.8 | 9.2 |
| 10/25/13 | 10:22 | 5 | 3.8 | 4 | 4.9 | 9.05 |
| 10/25/13 | 14:10 | 5 | 3.8 | 4 | 4.9 | 9.15 |
| 10/25/13 | 16:00 | 5 | 3.8 | 4 | 4.9 | 9.2 |
| 10/25/13 | 17:50 | 5 | 3.8 | 4.1 | 5 | 9.2 |
| 10/25/13 | 20:30 | 5 | 3.8 | 4.1 | 4.9 | 9.2 |
| 10/26/13 | 10:40 | 5 | 3.8 | 4.15 | 4.9 | 9.2 |

# Appendix A3-2 Brighton Log Sheet Data
## NF and EDM Flows

| Date | Time | EDM-feed<br>gpm | M. Na<br>gpm | M. Cl<br>gpm | NaCl<br>gpm | E-Rinse<br>gpm |
|---|---|---|---|---|---|---|
| 10/15/13 | 22:05 | 31.4 | 26.8 | 26 | 27.7 | 4.9 |
| 10/16/13 | 6:45 | 31.3 | 26.6 | 25.9 | 26.9 | 4.9 |
| 10/16/13 | 8:10 | 31.1 | 26.9 | 25.8 | 26.5 | 4.9 |
| 10/16/13 | 13:10 | 31.2 | 26.4 | 25.9 | 27 | 4.9 |
| 10/16/13 | 17:10 | 31.4 | 26.5 | 26.1 | 27.2 | 4.9 |
| 10/17/13 | 8:00 | 31 | 26.4 | 25.7 | 27.2 | 4.8 |
| 10/17/13 | 12:20 | 31.1 | 26.5 | 25.9 | 26.9 | 4.9 |
| 10/17/13 | 14:30 | 31.4 | 26.8 | 25.7 | 26.8 | 4.9 |
| 10/17/13 | 16:00 | 31.3 | 26.5 | 26 | 27.1 | 4.9 |
| 10/17/13 | 17:30 | 31.3 | 26.3 | 25.9 | 26.9 | 4.9 |
| 10/17/13 | 19:55 | 31.1 | 26.9 | 25.8 | 27.5 | 4.9 |
| 10/18/13 | 7:15 | 31.3 | 26.5 | 25.9 | 27.4 | 4.9 |
| 10/18/13 | 13:30 | 31.4 | 26.8 | 26 | 27 | 4.9 |
| 10/18/13 | 15:25 | 31 | 26.3 | 25.6 | 27.1 | 4.9 |
| 10/18/13 | 17:25 | 31 | 26 | 25.9 | 26.5 | 4.9 |
| 10/18/13 | 20:20 | 31.1 | 25.7 | 25.8 | 27.1 | 4.9 |
| 10/19/13 | 7:55 | 31.4 | 26.2 | 25.7 | 27.1 | 4.8 |
| 10/22/13 | 13:05 | 31.4 | 26.3 | 26.1 | 24.8 | 5 |
| 10/22/13 | 14:00 | 30.7 | 26.8 | 26 | 24.5 | 5 |
| 10/22/13 | 16:00 | 31.2 | 26.1 | 25.7 | 26.7 | 5 |
| 10/22/13 | 16:20 | 31.2 | 26.7 | 25.7 | 27.3 | 4.9 |
| 10/22/13 | 20:25 | 31.3 | 26.9 | 25.5 | 27 | 5 |
| 10/23/13 | 5:00 | 31.3 | 26.1 | 25.7 | 27 | 5 |
| 10/23/13 | 9:05 | 31.2 | 26.5 | 25.7 | 26.7 | 4.9 |
| 10/23/13 | 10:50 | 30.8 | 27.1 | 25.9 | 26.7 | 5 |
| 10/23/13 | 13:40 | 31.1 | 26.1 | 25.7 | 27 | 5 |
| 10/23/13 | 16:15 | 31 | 26.8 | 26 | 27 | 4.9 |
| 10/23/13 | 18:10 | 31.2 | 26.5 | 25.8 | 27 | 4.9 |
| 10/23/13 | 20:30 | 31.7 | 26.4 | 25.8 | 26.7 | 4.9 |
| 10/24/13 | 8:20 | 31.2 | 26.3 | 25.7 | 26.5 | 4.9 |
| 10/24/13 | 9:50 | 30.8 | 26.4 | 25.6 | 26.5 | 4.9 |
| 10/24/13 | 15:30 | 30.7 | 26.4 | 25.9 | 26.9 | 4.9 |
| 10/24/13 | 17:30 | 31.2 | 26.5 | 25.8 | 27.1 | 4.9 |
| 10/25/13 | 10:00 | 31.1 | 26.4 | 25.7 | 27.1 | 4.9 |
| 10/25/13 | 10:22 | 31.5 | 26.4 | 25.5 | 26.7 | 4.9 |
| 10/25/13 | 14:10 | 30.7 | 26.3 | 25.7 | 27.8 | 4.9 |
| 10/25/13 | 16:00 | 31 | 26.3 | 25.8 | 27.1 | 4.9 |
| 10/25/13 | 17:50 | 30.7 | 26.5 | 25.6 | 27.2 | 4.9 |
| 10/25/13 | 20:30 | 31.2 | 26.4 | 25.5 | 27.2 | 4.9 |
| 10/26/13 | 10:40 | 31 | 26.5 | 25.4 | 27.1 | 4.8 |

# Appendix A3-2 Brighton Log Sheet Data
## NF and EDM Flows

| **Date** | **Time** | **silica purge** | **silica purge** | | **NF F** |
|---|---|---|---|---|---|
| | | **gph** | **gpm** | **Δ height (in)** | **time (min)** |
| 10/15/13 | 22:05 | 4 | 0.067 | | |
| 10/16/13 | 6:45 | 4 | 0.067 | 2 | 80 |
| 10/16/13 | 8:10 | 4 | 0.067 | | |
| 10/16/13 | 13:10 | 4 | 0.067 | | |
| 10/16/13 | 17:10 | 4 | 0.067 | | |
| 10/17/13 | 8:00 | 4 | 0.067 | 5.25 | 180 |
| 10/17/13 | 12:20 | 4 | 0.067 | | |
| 10/17/13 | 14:30 | 4 | 0.067 | | |
| 10/17/13 | 16:00 | 4 | 0.067 | | |
| 10/17/13 | 17:30 | 4 | 0.067 | 1.25 | 73 |
| 10/17/13 | 19:55 | 4 | 0.067 | 1.4 | 135 |
| 10/18/13 | 7:15 | 4 | 0.067 | | |
| 10/18/13 | 13:30 | 4 | 0.067 | | |
| 10/18/13 | 15:25 | 4 | 0.067 | 1.6 | 120 |
| 10/18/13 | 17:25 | 4 | 0.067 | | |
| 10/18/13 | 20:20 | 4 | 0.067 | | |
| 10/19/13 | 7:55 | 4 | 0.067 | | |
| 10/22/13 | 13:05 | 4 | 0.067 | | |
| 10/22/13 | 14:00 | 4 | 0.067 | | |
| 10/22/13 | 16:00 | 4 | 0.067 | | |
| 10/22/13 | 16:20 | 4 | 0.067 | | |
| 10/22/13 | 20:25 | 4 | 0.067 | | |
| 10/23/13 | 5:00 | 4 | 0.067 | | |
| 10/23/13 | 9:05 | 4 | 0.067 | 1 | 60 |
| 10/23/13 | 10:50 | 4 | 0.067 | | |
| 10/23/13 | 13:40 | 4 | 0.067 | | |
| 10/23/13 | 16:15 | 4 | 0.067 | | |
| 10/23/13 | 18:10 | 4 | 0.067 | | |
| 10/23/13 | 20:30 | 4 | 0.067 | 1.375 | 150 |
| 10/24/13 | 8:20 | 4 | 0.067 | | |
| 10/24/13 | 9:50 | 4 | 0.067 | | |
| 10/24/13 | 15:30 | 4 | 0.067 | | |
| 10/24/13 | 17:30 | 4 | 0.067 | | |
| 10/25/13 | 10:00 | 4 | 0.067 | | |
| 10/25/13 | 10:22 | 4 | 0.067 | | |
| 10/25/13 | 14:10 | 4 | 0.067 | | |
| 10/25/13 | 16:00 | 4 | 0.067 | 1 | 120 |
| 10/25/13 | 17:50 | 4 | 0.067 | | |
| 10/25/13 | 20:30 | 4 | 0.067 | 2 | 180 |
| 10/26/13 | 10:40 | 4 | 0.067 | 0.75 | 30 |

# Appendix A3-2 Brighton Log Sheet Data
## NF and EDM Flows

| Date | Time | eed Tank oveflowing? |
|---|---|---|
| 10/15/13 | 22:05 | no |
| 10/16/13 | 6:45 | yes |
| 10/16/13 | 8:10 | no |
| 10/16/13 | 13:10 | no |
| 10/16/13 | 17:10 | no |
| 10/17/13 | 8:00 | yes |
| 10/17/13 | 12:20 | no |
| 10/17/13 | 14:30 | no |
| 10/17/13 | 16:00 | no |
| 10/17/13 | 17:30 | no |
| 10/17/13 | 19:55 | no |
| 10/18/13 | 7:15 | yes |
| 10/18/13 | 13:30 | yes (overflowed from 11-1:30) |
| 10/18/13 | 15:25 | no |
| 10/18/13 | 17:25 | no |
| 10/18/13 | 20:20 | no |
| 10/19/13 | 7:55 | no |
| 10/22/13 | 13:05 | no |
| 10/22/13 | 14:00 | no |
| 10/22/13 | 16:00 | no |
| 10/22/13 | 16:20 | no |
| 10/22/13 | 20:25 | no |
| 10/23/13 | 5:00 | yes |
| 10/23/13 | 9:05 | yes |
| 10/23/13 | 10:50 | no |
| 10/23/13 | 13:40 | yes (from ~12-1:40) |
| 10/23/13 | 16:15 | no |
| 10/23/13 | 18:10 | no |
| 10/23/13 | 20:30 | no |
| 10/24/13 | 8:20 | yes |
| 10/24/13 | 9:50 | no |
| 10/24/13 | 15:30 | no |
| 10/24/13 | 17:30 | no |
| 10/25/13 | 10:00 | no |
| 10/25/13 | 10:22 | no |
| 10/25/13 | 14:10 | no |
| 10/25/13 | 16:00 | no |
| 10/25/13 | 17:50 | no |
| 10/25/13 | 20:30 | no |
| 10/26/13 | 10:40 | yes |

# Appendix A3-2 Brighton Log Sheet Data
## EDM NaCl Usage

| | **Condition** | **NaCl level** | **NaCl after addn** | **NaCl added (#bags)** | **NaCl (lb/in)** |
|---|---|---|---|---|---|
| 9/30/13 | M.Na-45 mS | 25 | | | |
| 10/1/13 | M.Na-45 mS | 30.25 | | | |
| 10/1/13 | M.Na-50 mS | 31.25 | | | |
| 10/2/13 | M.Na-50 mS | 34.5 | | | |
| 10/2/13 | M.Na-50 mS | 36 | 17.5 | 16 | 34.59 |
| 10/2/13 | M.Na-55mS | 17.75 | | | |
| 10/2/13 | M.Na-55mS | 18.25 | | | |
| 10/3/13 | M.Na-55mS | 21.5 | | | |
| 10/4/13 | M.Na-60 mS | 26.5 | | | |
| 10/4/13 | M.Na-60 mS | 27.5 | | | |
| 10/5/13 | M.Na-60 mS | 31.5 | | | |
| 10/5/13 | M.Na-60 mS | 33.5 | 13.75 | 16 | 32.41 |
| 10/6/13 | M.Na-60 mS | 19.75 | | | |
| 10/6/13 | M.Na-60 mS | 20.5 | | | |
| 10/7/13 | M.Na-60 mS | 25 | | | |
| 10/7/13 | M.Na-60 mS | 26 | 19.75 | 6 | 38.40 |
| 10/8/13 | M.Na-60 mS | 23.75 | | | |
| 10/8/13 | M.Na-60 mS | 25 | 16 | 8 | 35.56 |
| 10/10/13 | M.Na-60 mS | 26 | | | |
| 10/11/13 | M.Na-60 mS | 36 | 21 | 13 | 34.67 |
| 10/11/13 | M.Na-60 mS | 22 | | | |
| 10/11/13 | M.Na-60 mS | 23 | | | |
| 10/12/13 | M.Na-60 mS, M.Cl-100 mS | 29.75 | | | |
| 10/12/13 | M.Na-60 mS, M.Cl-100 mS | 31.5 | | | |
| 10/13/13 | M.Na-60 mS, M.Cl-100 mS | 35.25 | | | |
| 10/15/13 | M.Na-65 mS, M.Cl-120 mS | 37.125 | 19.25 | 14 | 31.33 |
| 10/15/13 | M.Na-65 mS, M.Cl-120 mS | 20.5 | | | |
| 10/16/13 | M.Na-65 mS, M.Cl-120 mS | 23.5 | | | |
| 10/16/13 | M.Na-65 mS, M.Cl-120 mS | 25 | 20 | 4 | 32.00 |
| 10/17/13 | M.Na-65 mS, M.Cl-120 mS | 24.75 | | | |
| 10/17/13 | M.Na-65 mS, M.Cl-120 mS | 26.75 | 17.25 | 8 | 33.68 |
| 10/18/13 | M.Na-65 mS, M.Cl-120 mS | 22.25 | | | |
| 10/22/13 | M.Na-65 mS, M.Cl-120 mS | 27.75 | 22.75 | 4 | 32.00 |
| 10/22/13 | M.Na-65 mS, M.Cl-120 mS | 23.5 | | | |
| 10/23/13 | M.Na-65 mS, M.Cl-120 mS | 27.75 | | | |
| 10/23/13 | M.Na-65 mS, M.Cl-120 mS | 28.25 | 16.5 | 10 | 34.04 |
| 10/23/13 | M.Na-65 mS, M.Cl-120 mS | 17.25 | | | |
| 10/24/13 | M.Na-65 mS, M.Cl-120 mS | 21.75 | | | |
| 10/24/13 | M.Na-65 mS, M.Cl-120 mS | 23.75 | | | |
| 10/25/13 | M.Na-55 mS, M.Cl-100 mS | 29.75 | | | |
| 10/26/13 | M.Na-55 mS, M.Cl-100 mS | 34.125 | | | |

# Appendix A3-2 Brighton Log Sheet Data
## EDM Concentrate Overflow (Waste) Flows

| | | | | M. Na | | | M. Cl | |
|---|---|---|---|---|---|---|---|---|
| **Date** | **Time** | **Condition** | **gal** | **time** | **gpm** | **gal** | **time** | **gpm** |
| 10/1/13 | 12:51 | M.Na-45 mS | 27 | 60 | 0.45 | 21 | 150 | 0.14 |
| 10/1/13 | 5-6 pm | M.Na-50mS | 25 | 60 | 0.42 | 9 | 60 | 0.15 |
| 10/2/13 | am | M.Na-50mS | 24.5 | 60 | 0.41 | 9 | 60 | 0.15 |
| 10/3/13 | 4-5 pm | M.Na-55 mS | 22.5 | 60 | 0.38 | 17 | 120 | 0.14 |
| 10/3/13 | | M.Na-60 mS | 20 | 60 | 0.33 | 16 | 120 | 0.13 |
| 10/4/13 | 2-4 pm | M.Na-60 mS | 19 | 60 | 0.32 | 17 | 120 | 0.14 |
| 10/5/13 | 12-2 pm | M.Na-60 mS | 20 | 60 | 0.33 | 19 | 120 | 0.16 |
| 10/6/13 | 1-3 pm | M.Na-60 mS | 20 | 60 | 0.33 | 17.5 | 120 | 0.15 |
| 10/7/13 | 2-4 pm | M.Na-60 mS | 19 | 60 | 0.32 | 17 | 120 | 0.14 |
| 10/8/13 | 10am-1pm | M.Na-60 mS | 19 | 60 | 0.32 | 17.5 | 120 | 0.15 |
| 10/8/13 | 4-5 pm | M.Na-60 mS | 17.5 | 60 | 0.29 | 9 | 60 | 0.15 |
| 10/9/13 | 8-10am | M.Na-60 mS | 19.2 | 60 | 0.32 | 17.3 | 120 | 0.14 |
| 10/9/13 | 10-11am | M.Na-60 mS | 19.2 | 60 | 0.32 | 17.3 | 120 | 0.14 |
| 10/9/13 | 2:30-5pm | M.Na-60 mS | 20.0 | 64 | 0.31 | 12.0 | 95 | 0.13 |
| 10/10/13 | 12-2pm | M.Na-60 mS | 19 | 60 | 0.32 | 17 | 120 | 0.14 |
| 10/10/13 | 5:50 PM | M.Na-60 mS | 19 | 60 | 0.32 | 17 | 120 | 0.14 |
| 10/11/13 | 4-6pm | M.Na-60 mS | 21 | 61 | 0.34 | 18.5 | 120 | 0.15 |
| 10/12/13 | 10:30-12 | M.Na-60 mS, M.Cl-100 mS | 19.5 | 60 | 0.33 | 24 | 120 | 0.20 |
| 10/15/13 | 4-6pm | M.Na-65 mS, M.Cl-120 mS | 19 | 60 | 0.32 | 17.5 | 122 | 0.14 |
| 10/16/13 | 1-3pm | M.Na-65 mS, M.Cl-120 mS | 21 | 70 | 0.30 | 17 | 121 | 0.14 |
| 10/17/13 | 3-5pm | M.Na-65 mS, M.Cl-120 mS | 21 | 72 | 0.29 | 15.5 | 120 | 0.13 |
| 10/18/13 | 2-4pm | M.Na-65 mS, M.Cl-120 mS | 15 | 60 | 0.25 | 16 | 120 | 0.13 |
| 10/22/13 | 2-4pm | M.Na-65 mS, M.Cl-120 mS | 18.5 | 60 | 0.31 | 19.5 | 121 | 0.16 |
| 10/23/13 | 4-6pm | M.Na-65 mS, M.Cl-120 mS | 27.5 | 90 | 0.31 | 12.5 | 90 | 0.14 |
| 10/24/13 | 1-3pm | M.Na-65 mS, M.Cl-120 mS | 25 | 88 | 0.28 | 15 | 88 | 0.17 |
| 10/25/13 | 4-6pm | M.Na-55 mS, M.Cl-100 mS | 29 | 86 | 0.34 | 16.5 | 86 | 0.19 |

## Appendix A3-2 Brighton Log Sheet Data
## NF and EDM Pressures

| Date | Time | 2nd stage CF-inlet psi | 2nd stage CF-outlet psi | NF perm psi | NF conc (final stage) psi | EDM-feed psi |
|---|---|---|---|---|---|---|
| 10/1/13 | 12:51 | 36 | 32.8 | 2.2 | 28.4 | 17.1 |
| 10/2/13 | 13:15 | 36.7 | 35.9 | 2.1 | 21.2 | 17 |
| 10/2/13 | 17:50 | 37.1 | 35.5 | 2.1 | 21 | 17 |
| 10/2/13 | 20:55 | 37.5 | 35.9 | 2.1 | 21.2 | 17 |
| 10/3/13 | 8:24 | 37.5 | 35.9 | 2.1 | 21.3 | 17 |
| 10/3/13 | 18:30 | 39.1 | 36.3 | 2.1 | 21.7 | 17 |
| 10/4/13 | 11:50 | 40.3 | 37.7 | 2.1 | 22.6 | 17.5 |
| 10/4/13 | 16:50 | 40.1 | 37.3 | 2 | 22.4 | 17.1 |
| 10/4/13 | 19:40 | 40.3 | 37.7 | 2 | 22.6 | 17.1 |
| 10/5/13 | 8:25 | 40.4 | 39.6 | 2.1 | 24.4 | 17.1 |
| 10/5/13 | 12:15 | 39.5 | 38.9 | 2.1 | 24.2 | 17.1 |
| 10/5/13 | 17:45 | 39 | 38.5 | 2 | 24 | 17 |
| 10/6/13 | 13:15 | 41.5 | 39.1 | 2 | 24.3 | 17.1 |
| 10/6/13 | 15:30 | 40.8 | 38.4 | 2 | 23.5 | 17.1 |
| 10/6/13 | 20:05 | 42 | 37.6 | 2.1 | 23 | 17.1 |
| 10/7/13 | 11:05 | 41.8 | 37.5 | 2.2 | 22.9 | 17.1 |
| 10/7/13 | 13:45 | 41.9 | 37.4 | 2.1 | 22.8 | 17 |
| 10/7/13 | 16:30 | 42 | 37.5 | 2.1 | 23 | 17 |
| 10/7/13 | 20:15 | 43 | 38.7 | 2.1 | 24.4 | 17.1 |
| 10/8/13 | 7:30 | 41.7 | 39.7 | 2 | 24.7 | 17.1 |
| 10/8/13 | 10:30 | 41.9 | 40 | 2 | 25.5 | 17.1 |
| 10/8/13 | 13:35 | 41.4 | 39.4 | 2 | 25.1 | 17 |
| 10/8/13 | 16:30 | 41.5 | 38.9 | 2 | 24.8 | 17 |
| 10/8/13 | 20:00 | 42 | 39.3 | 2.1 | 25.1 | 17 |
| 10/9/13 | 8:50 | 42.5 | 39.9 | 2 | 25.4 | 17.1 |
| 10/9/13 | 14:30 | 40.2 | 37.5 | 2 | 23 | 17 |
| 10/9/13 | 17:20 | 40.5 | 37.9 | 2.1 | 23 | 17 |
| 10/10/13 | 8:30 | 40.8 | 38.1 | 2 | 23.4 | 17.1 |
| 10/10/13 | 13:45 | 40.9 | 40.6 | 2 | 26.3 | 17 |
| 10/10/13 | 17:50 | 40.7 | 40.5 | 2 | 26.2 | 17 |
| 10/10/13 | 20:15 | 41.3 | 41.1 | 2.1 | 26.7 | 17.1 |
| 10/11/13 | 8:30 | 41.1 | 40.9 | 2.1 | 26.4 | 17.1 |
| 10/11/13 | 1:50 | 41.3 | 41.1 | 2.2 | 26.8 | 17 |
| 10/11/13 | 17:40 | 41.4 | 41.1 | 2.2 | 26.9 | 17.1 |
| 10/11/13 | 20:30 | 41.3 | 41.1 | 2.1 | 26.8 | 17.1 |
| 10/12/13 | 10:30 | 41.5 | 41.3 | 2 | 26.9 | 17 |
| 10/12/13 | 13:45 | 41.3 | 41 | 2.2 | 26.7 | 17 |
| 10/12/13 | 17:00 | 41.2 | 40.9 | 2 | 26.7 | 17.2 |
| 10/12/13 | 19:20 | 45.4 | 42.4 | 2.1 | 28 | 17.2 |
| 10/13/13 | 7:25 | 44.9 | 41.8 | 1.9 | 26.7 | 17.4 |
| 10/15/13 | 15:15 | 39.6 | 39.3 | 2.1 | 24.7 | 17.6 |
| 10/15/13 | 20:00 | 39.9 | 39.2 | 2.1 | 24.6 | 17.7 |

# Appendix A3-2 Brighton Log Sheet Data
## NF and EDM Pressures

| Date | Time | M. Na<br>psi | M. Cl<br>psi | NaCl<br>psi | E-Rinse<br>psi |
|---|---|---|---|---|---|
| 10/1/13 | 12:51 | 16.5 | 16.7 | 16.5 | 17.4 |
| 10/2/13 | 13:15 | 16.2 | 16.8 | 16.6 | 16.7 |
| 10/2/13 | 17:50 | 16.3 | 16.8 | 16.6 | 16.9 |
| 10/2/13 | 20:55 | 16.3 | 18.8 | 16.6 | 17 |
| 10/3/13 | 8:24 | 16.3 | 16.9 | 16.7 | 16.9 |
| 10/3/13 | 18:30 | 16.4 | 16.8 | 16.6 | 17 |
| 10/4/13 | 11:50 | 16.5 | 16.7 | 16.9 | 17.3 |
| 10/4/13 | 16:50 | 16.4 | 16.8 | 16.7 | 17.1 |
| 10/4/13 | 19:40 | 16.4 | 16.6 | 16.7 | 17.2 |
| 10/5/13 | 8:25 | 16.5 | 16.8 | 16.7 | 17.1 |
| 10/5/13 | 12:15 | 16.4 | 16.8 | 16.6 | 17.1 |
| 10/5/13 | 17:45 | 16.4 | 16.7 | 16.6 | 17.1 |
| 10/6/13 | 13:15 | 16.5 | 16.8 | 16.7 | 17 |
| 10/6/13 | 15:30 | 16.5 | 16.8 | 16.8 | 16.9 |
| 10/6/13 | 20:05 | 16.5 | 16.8 | 16.7 | 16.8 |
| 10/7/13 | 11:05 | 16.6 | 16.8 | 16.7 | 16.9 |
| 10/7/13 | 13:45 | 16.4 | 16.7 | 16.7 | 17.1 |
| 10/7/13 | 16:30 | 16.5 | 16.7 | 16.7 | 17 |
| 10/7/13 | 20:15 | 16.5 | 16.8 | 16.9 | 17.1 |
| 10/8/13 | 7:30 | 16.5 | 16.8 | 16.8 | 16.9 |
| 10/8/13 | 10:30 | 16.5 | 16.7 | 16.7 | 17.1 |
| 10/8/13 | 13:35 | 16.4 | 16.7 | 16.6 | 17 |
| 10/8/13 | 16:30 | 16.5 | 16.6 | 16.6 | 17.1 |
| 10/8/13 | 20:00 | 16.5 | 16.7 | 16.7 | 17.1 |
| 10/9/13 | 8:50 | 16.6 | 16.8 | 16.7 | 17.1 |
| 10/9/13 | 14:30 | 16.5 | 16.6 | 16.7 | 17 |
| 10/9/13 | 17:20 | 16.5 | 16.7 | 16.7 | 16.9 |
| 10/10/13 | 8:30 | 16.7 | 16.8 | 16.8 | 17.2 |
| 10/10/13 | 13:45 | 16.6 | 16.6 | 16.7 | 17.2 |
| 10/10/13 | 17:50 | 16.5 | 16.7 | 16.7 | 17.3 |
| 10/10/13 | 20:15 | 16.6 | 16.7 | 16.8 | 17.3 |
| 10/11/13 | 8:30 | 16.6 | 16.7 | 16.8 | 17.3 |
| 10/11/13 | 1:50 | 16.6 | 16.7 | 16.7 | 17.3 |
| 10/11/13 | 17:40 | 16.7 | 16.6 | 16.7 | 17.2 |
| 10/11/13 | 20:30 | 16.7 | 16.7 | 16.7 | 17.3 |
| 10/12/13 | 10:30 | 16.6 | 16.5 | 16.8 | 17.4 |
| 10/12/13 | 13:45 | 16.7 | 16.4 | 16.7 | 17.5 |
| 10/12/13 | 17:00 | 16.9 | 16.6 | 17 | 17.1 |
| 10/12/13 | 19:20 | 16.9 | 16.7 | 17 | 17.2 |
| 10/13/13 | 7:25 | 17 | 16.7 | 17.1 | 17.2 |
| 10/15/13 | 15:15 | 17.3 | 17.2 | 17.4 | 17.5 |
| 10/15/13 | 20:00 | 17.4 | 17.3 | 17.4 | 17.5 |

# Appendix A3-2 Brighton Log Sheet Data
## NF and EDM Pressures

| **Date** | **Time** | **2nd stage CF-inlet psi** | **2nd stage CF-outlet psi** | **NF perm psi** | **NF conc (final stage) psi** | **EDM-feed psi** |
|---|---|---|---|---|---|---|
| 10/15/13 | 22:05 | 40.2 | 39.5 | 2 | 24.8 | 17.7 |
| 10/16/13 | 6:45 | 40.5 | 40.3 | 2.2 | 25.6 | 17.8 |
| 10/16/13 | 8:10 | 41.8 | 41.6 | 2.1 | 26.4 | 17.8 |
| 10/16/13 | 13:10 | 40.8 | 40.6 | 2.2 | 26 | 17.7 |
| 10/16/13 | 17:10 | 40.6 | 40.3 | 2 | 26.1 | 17.7 |
| 10/17/13 | 8:00 | 42 | 41.7 | 2.1 | 27.3 | 17.7 |
| 10/17/13 | 12:20 | 44 | 43.7 | 2 | 28.8 | 17.7 |
| 10/17/13 | 14:30 | 43 | 40.9 | 1.9 | 26.7 | 17.7 |
| 10/17/13 | 16:00 | 43 | 40.9 | 2.1 | 26.6 | 17.7 |
| 10/17/13 | 17:30 | 43.1 | 41.1 | 2 | 26.8 | 17.7 |
| 10/17/13 | 19:55 | 43.2 | 41.1 | 2.1 | 26.7 | 17.7 |
| 10/18/13 | 7:15 | 43.9 | 41.8 | 1.9 | 27.2 | 17.9 |
| 10/18/13 | 13:30 | 43.2 | 41.2 | 1.9 | 26.7 | 17.8 |
| 10/18/13 | 15:25 | 43.2 | 41.2 | 2.1 | 26.8 | 17.8 |
| 10/18/13 | 17:25 | 43.2 | 41.2 | 2 | 26.8 | 17.8 |
| 10/18/13 | 20:20 | 43.2 | 42.2 | 2.1 | 27.7 | 17.9 |
| 10/19/13 | 7:55 | 43.3 | 42.3 | 2.1 | 27.7 | 17.9 |
| 10/22/13 | 13:05 | 39.7 | 39.5 | 2.1 | 24.8 | 17.7 |
| 10/22/13 | 14:00 | 39.7 | 39.5 | 2.1 | 24.7 | 17.8 |
| 10/22/13 | 16:00 | 39.7 | 39.4 | 2 | 24.9 | 17.8 |
| 10/22/13 | 16:20 | 39.7 | 39 | 2 | 24.6 | 17.9 |
| 10/22/13 | 20:25 | 40 | 39.9 | 2.2 | 25.2 | 17.9 |
| 10/23/13 | 5:00 | 42.2 | 42 | 2.1 | 27.3 | 17.8 |
| 10/23/13 | 9:05 | 42.5 | 42.2 | 2.2 | 27.7 | 17.9 |
| 10/23/13 | 10:50 | 42.2 | 41.9 | 2.1 | 27.6 | 17.8 |
| 10/23/13 | 13:40 | 42.1 | 41.8 | 2.2 | 27.6 | 17.8 |
| 10/23/13 | 16:15 | 41.5 | 41.2 | 2.1 | 27 | 17.7 |
| 10/23/13 | 18:10 | 43.6 | 41.1 | 2.2 | 26.9 | 17.8 |
| 10/23/13 | 20:30 | 43.4 | 40.9 | 2.1 | 26.5 | 17.8 |
| 10/24/13 | 8:20 | 43.2 | 42.9 | 2.1 | 28.3 | 17.9 |
| 10/24/13 | 9:50 | 43.1 | 42.8 | 2.1 | 28 | 17.9 |
| 10/24/13 | 15:30 | 42.5 | 42.3 | 2 | 27.8 | 17.8 |
| 10/24/13 | 17:30 | 42.6 | 42.4 | 2.1 | 28 | 17.8 |
| 10/25/13 | 10:00 | 43.9 | 43.5 | 2.1 | 28.9 | 18 |
| 10/25/13 | 10:22 | 42.4 | 42.1 | 1.8 | 27.1 | 17.9 |
| 10/25/13 | 14:10 | 42.4 | 42.1 | 2.1 | 27.7 | 17.9 |
| 10/25/13 | 16:00 | 42.4 | 42.1 | 2.1 | 27.7 | 17.8 |
| 10/25/13 | 17:50 | 42.6 | 42.4 | 2.1 | 27.9 | 17.9 |
| 10/25/13 | 20:30 | 42.8 | 42.6 | 2.1 | 28 | 17.9 |
| 10/26/13 | 10:40 | 43.2 | 43 | 2 | 28.4 | 18 |

# Appendix A3-2 Brighton Log Sheet Data
## NF and EDM Pressures

| Date | Time | M. Na<br>psi | M. Cl<br>psi | NaCl<br>psi | E-Rinse<br>psi |
|---|---|---|---|---|---|
| 10/15/13 | 22:05 | 17.4 | 17.3 | 17.5 | 17.6 |
| 10/16/13 | 6:45 | 17.4 | 17.5 | 17.4 | 17.5 |
| 10/16/13 | 8:10 | 17.4 | 17.4 | 17.5 | 17.7 |
| 10/16/13 | 13:10 | 17.4 | 17.3 | 17.3 | 17.5 |
| 10/16/13 | 17:10 | 17.4 | 17.3 | 17.3 | 17.5 |
| 10/17/13 | 8:00 | 17.4 | 17.3 | 17.4 | 17.2 |
| 10/17/13 | 12:20 | 17.4 | 17.2 | 17.4 | 17.5 |
| 10/17/13 | 14:30 | 17.4 | 17.3 | 17.4 | 17.5 |
| 10/17/13 | 16:00 | 17.4 | 17.3 | 17.4 | 17.4 |
| 10/17/13 | 17:30 | 17.4 | 17.3 | 17.4 | 17.5 |
| 10/17/13 | 19:55 | 17.4 | 17.3 | 17.4 | 17.5 |
| 10/18/13 | 7:15 | 17.5 | 17.4 | 17.5 | 17.6 |
| 10/18/13 | 13:30 | 17.5 | 17.4 | 17.5 | 17.4 |
| 10/18/13 | 15:25 | 17.5 | 17.3 | 17.5 | 17.4 |
| 10/18/13 | 17:25 | 17.5 | 17.4 | 17.6 | 17.5 |
| 10/18/13 | 20:20 | 17.6 | 17.4 | 17.6 | 17.5 |
| 10/19/13 | 7:55 | 17.5 | 17.4 | 17.6 | 17.1 |
| 10/22/13 | 13:05 | 17.4 | 17.3 | 16.5 | 17.4 |
| 10/22/13 | 14:00 | 17.6 | 17.4 | 16.6 | 17.4 |
| 10/22/13 | 16:00 | 17.5 | 17.4 | 17.5 | 17.3 |
| 10/22/13 | 16:20 | 17.6 | 17.3 | 17.6 | 17.3 |
| 10/22/13 | 20:25 | 17.6 | 17.5 | 17.5 | 17.4 |
| 10/23/13 | 5:00 | 17.5 | 17.4 | 17.6 | 17.4 |
| 10/23/13 | 9:05 | 17.6 | 17.3 | 17.6 | 17.4 |
| 10/23/13 | 10:50 | 17.5 | 17.4 | 17.5 | 17.5 |
| 10/23/13 | 13:40 | 17.5 | 17.3 | 17.5 | 17.4 |
| 10/23/13 | 16:15 | 17.4 | 17.2 | 17.4 | 17.3 |
| 10/23/13 | 18:10 | 17.5 | 17.3 | 17.5 | 17.5 |
| 10/23/13 | 20:30 | 17.5 | 17.3 | 17.5 | 17.5 |
| 10/24/13 | 8:20 | 17.5 | 17.4 | 17.6 | 17.5 |
| 10/24/13 | 9:50 | 17.6 | 17.4 | 17.5 | 17.6 |
| 10/24/13 | 15:30 | 17.5 | 17.3 | 17.5 | 17.5 |
| 10/24/13 | 17:30 | 17.5 | 17.4 | 17.5 | 17.7 |
| 10/25/13 | 10:00 | 17.6 | 17.4 | 17.7 | 17.7 |
| 10/25/13 | 10:22 | 17.6 | 17.4 | 17.7 | 17.7 |
| 10/25/13 | 14:10 | 17.5 | 17.1 | 17.5 | 17.7 |
| 10/25/13 | 16:00 | 17.6 | 17.1 | 17.5 | 17.8 |
| 10/25/13 | 17:50 | 17.6 | 17.2 | 17.6 | 17.8 |
| 10/25/13 | 20:30 | 17.6 | 17.2 | 17.6 | 17.9 |
| 10/26/13 | 10:40 | 17.7 | 17.4 | 17.7 | |

# Appendix A3-2 Brighton Log Sheet Data
## NF and EDM Temperatures

| Date | Time | NF/RO conc | EDM-feed | EDM-diluate | M. Na | M. Cl | E-Rinse |
|---|---|---|---|---|---|---|---|
| | | °C | °C | °C | °C | °C | °C |
| 10/1/13 | 12:51 | 20.5 | 21.2 | | 22 | 22.2 | 23.3 |
| 10/2/13 | 13:15 | 21.1 | 21.7 | 22.3 | 22.4 | 22.7 | 24 |
| 10/2/13 | 17:50 | 21 | 21.8 | 22.3 | 22.5 | 22.58 | 23.9 |
| 10/2/13 | 20:55 | 20.4 | 21 | 21.6 | 21.9 | 21.9 | 22.4 |
| 10/3/13 | 8:24 | 20.2 | 20.6 | 21.1 | 21.3 | 21.4 | 21.2 |
| 10/3/13 | 18:30 | 20.3 | 20.9 | 21.4 | 21.7 | 22 | 22.7 |
| 10/4/13 | 11:50 | 19.1 | 19.5 | 19.9 | 19.9 | 20 | 19.2 |
| 10/4/13 | 16:50 | 19.3 | 19.8 | 20.2 | 20.4 | 20.4 | 19.9 |
| 10/4/13 | 19:40 | 19 | 19.2 | 19.6 | 19.7 | 19.7 | 17.8 |
| 10/5/13 | 8:25 | 18.7 | 19 | 19.4 | 19.5 | 19.5 | 17.9 |
| 10/5/13 | 12:15 | 19.9 | 20.4 | 20.9 | 21 | 21.2 | 21.5 |
| 10/5/13 | 17:45 | 20 | 20.7 | 21.2 | 21.2 | 21.4 | 21.2 |
| 10/6/13 | 13:15 | 20.3 | 20.9 | 21.4 | 21.4 | 21.6 | 21.7 |
| 10/6/13 | 15:30 | 20.6 | 21.3 | 21.8 | 22 | 22.1 | 22.8 |
| 10/6/13 | 20:05 | 20.1 | 20.6 | 21 | 21.3 | 21.3 | 21 |
| 10/7/13 | 11:05 | 20.1 | 20.5 | 21 | 21.1 | 21.3 | 21.1 |
| 10/7/13 | 13:45 | 20.9 | 21.4 | 21.9 | 22 | 22.3 | 23.2 |
| 10/7/13 | 16:30 | 21.1 | 21.8 | 22.3 | 22.6 | 22.8 | 24.2 |
| 10/7/13 | 20:15 | 20.2 | 20.8 | 21.3 | 21.5 | 21.5 | 21.9 |
| 10/8/13 | 7:30 | 19.9 | 20.4 | 20.9 | 21.1 | 21.1 | 21.4 |
| 10/8/13 | 10:30 | 20.3 | 21 | 21.5 | 21.8 | 21.8 | 22.8 |
| 10/8/13 | 13:35 | 21.3 | 22 | 22.5 | 22.7 | 22.9 | 24.2 |
| 10/8/13 | 16:30 | 21.4 | 22.3 | 22.9 | 23 | 23.4 | 24.7 |
| 10/8/13 | 20:00 | 20.4 | 21.1 | 21.7 | 21.7 | 22 | 22.1 |
| 10/9/13 | 8:50 | 19.9 | 20.5 | 21 | 21 | 21.2 | 21.8 |
| 10/9/13 | 14:30 | 21.3 | 22.1 | 22.7 | 22.8 | 23 | 23.7 |
| 10/9/13 | 17:20 | 20.9 | 21.7 | 22.2 | 22.3 | 22.6 | 23.4 |
| 10/10/13 | 8:30 | 18.8 | 20.3 | 20.8 | 20.7 | 20.9 | 21.5 |
| 10/10/13 | 13:45 | 20.3 | 21.1 | 21.7 | 21.9 | 22 | 22.8 |
| 10/10/13 | 17:50 | 20.1 | 21 | 21.6 | 21.7 | 22 | 22.5 |
| 10/10/13 | 20:15 | 19.5 | 20.2 | 20.7 | 20.7 | 20.9 | 20.8 |
| 10/11/13 | 8:30 | 19.9 | 20.6 | 21.1 | 21.2 | 21.3 | 21.4 |
| 10/11/13 | 1:50 | 20.5 | 21.3 | 21.8 | 21.9 | 22.1 | 22.6 |
| 10/11/13 | 17:40 | 20.4 | 21.2 | 21.8 | 22 | 22.3 | 23 |
| 10/11/13 | 20:30 | 20.2 | 20.7 | 21.3 | 21.3 | 21.5 | 21.3 |
| 10/12/13 | 10:30 | 20 | 20.7 | 21.3 | 21.4 | 21.6 | 21.7 |
| 10/12/13 | 13:45 | 20.7 | 21.6 | 22.1 | 22.3 | 22.4 | 22.3 |
| 10/12/13 | 17:00 | 20.5 | 21.4 | 22 | 22.1 | 22.2 | 22.5 |
| 10/12/13 | 19:20 | 20.1 | 21 | 21.6 | 21.6 | 21.8 | 22.1 |
| 10/13/13 | 7:25 | 19.7 | 20.4 | 20.9 | 20.8 | 21 | 20.5 |
| 10/15/13 | 15:15 | 20.1 | 20.4 | 20.9 | 21 | 21.2 | 21.3 |
| 10/15/13 | 20:00 | 19.8 | 20.2 | 20.7 | 20.7 | 21 | 20.7 |

## Appendix A3-2 Brighton Log Sheet Data
## NF and EDM Temperatures

| Date | Time | NF/RO conc | EDM-feed | EDM-diluate | M. Na | M. Cl | E-Rinse |
|---|---|---|---|---|---|---|---|
| | | °C | °C | °C | °C | °C | °C |
| 10/15/13 | 22:05 | 19.6 | 20 | 20.4 | 20.4 | 20.7 | 20.3 |
| 10/15/13 | 6:45 | 19.2 | 19.5 | 19.9 | 19.8 | 20 | 18.7 |
| 10/15/13 | 8:10 | 19.2 | 19.4 | 19.8 | 19.7 | 19.9 | 18.8 |
| 10/15/13 | 13:10 | 20.4 | 20.9 | 21.4 | 21.5 | 21.6 | |
| 10/15/13 | 17:10 | 20.6 | 21.2 | 21.7 | 21.8 | 22 | 22.1 |
| 10/17/13 | 8:00 | 19.5 | 20.1 | 20.6 | 20.6 | 20.9 | 20.9 |
| 10/17/13 | 12:20 | 20.3 | 20.9 | 21.4 | 21.7 | 22 | 23.1 |
| 10/17/13 | 14:30 | 20.5 | 21.1 | 21.6 | 21.8 | 22 | 22.6 |
| 10/17/13 | 16:00 | 20.5 | 21.1 | 21.6 | 21.8 | 22 | 22.5 |
| 10/17/13 | 17:30 | 20.2 | 20.7 | 21.3 | 21.4 | 21.6 | 21.7 |
| 10/17/13 | 19:55 | 20 | 20.6 | 21.2 | 21.3 | 21.5 | 21.7 |
| 10/18/13 | 7:15 | 19.2 | 19.7 | 19.2 | 20.1 | 20.3 | 19.9 |
| 10/18/13 | 13:30 | 19.9 | 20.4 | 21 | 21.1 | 21.3 | 21.4 |
| 10/18/13 | 15:25 | 20.1 | 20.6 | 21.1 | 21.3 | 21.5 | 22.1 |
| 10/18/13 | 17:25 | 20 | 20.5 | 21.1 | 21.2 | 21.4 | 22 |
| 10/18/13 | 20:20 | 19.2 | 19.7 | 20.1 | 20.1 | 20.4 | 20.1 |
| 10/19/13 | 7:55 | 19.1 | 19.6 | 20 | 20 | 20.3 | 19.9 |
| 10/22/13 | 13:05 | 20.6 | 21 | 21.5 | 21.6 | 21.8 | 22.5 |
| 10/22/13 | 14:00 | 20.7 | 21.2 | 21.6 | 21.8 | 21.9 | 22.8 |
| 10/22/13 | 16:00 | 20.5 | 21.1 | 21.6 | 21.7 | 21.9 | 22.7 |
| 10/22/13 | 16:20 | 20.5 | 21 | 21.5 | 21.8 | 21.9 | 22.6 |
| 10/22/13 | 20:25 | 19.7 | 20.2 | 20.7 | 20.7 | 20.9 | 20.8 |
| 10/23/13 | 5:00 | 19.3 | 19.8 | 20.3 | 20.3 | 20.5 | 20.2 |
| 10/23/13 | 9:05 | 19.4 | 20 | 20.5 | 20.6 | 20.8 | 21.1 |
| 10/23/13 | 10:50 | 19.7 | 20.2 | 20.8 | 20.9 | 21.1 | 21.7 |
| 10/23/13 | 13:40 | 20.4 | 21 | 21.6 | 21.8 | 22 | 23.1 |
| 10/23/13 | 16:15 | 20.5 | 21.4 | 22 | 22.2 | 22.3 | 23.4 |
| 10/23/13 | 18:10 | 20.1 | 20.9 | 21.5 | 21.7 | 21.8 | 22.3 |
| 10/23/13 | 20:30 | 19.9 | 20.6 | 21.2 | 21.3 | 21.5 | 21.7 |
| 10/24/13 | 8:20 | 19.3 | 20 | 20.5 | 20.6 | 20.8 | |
| 10/24/13 | 9:50 | 19.4 | 20 | 20.6 | 20.6 | 20.9 | 21 |
| 10/24/13 | 15:30 | 20.5 | 21.3 | 21.9 | 22.1 | 22.3 | 23.5 |
| 10/24/13 | 17:30 | 20.3 | 21.1 | 21.6 | 21.8 | 22 | 22.3 |
| 10/25/13 | 10:00 | 19.4 | 19.9 | 20.4 | 20.4 | 20.6 | 20.8 |
| 10/25/13 | 10:22 | 19.2 | 20 | 20.6 | 20.7 | 20.9 | 20.9 |
| 10/25/13 | 14:10 | 20.6 | 21.2 | 21.7 | 21.8 | 22 | 22.8 |
| 10/25/13 | 16:00 | 20.6 | 21.3 | 21.8 | 22 | 22.1 | 22.8 |
| 10/25/13 | 17:50 | 20.1 | 20.8 | 21.3 | 21.4 | 21.6 | 21.8 |
| 10/25/13 | 20:30 | 19.7 | 20.3 | 20.6 | 20.9 | 21.1 | 21.4 |
| 10/26/13 | 10:40 | 19.4 | 20.5 | 20.5 | 20.5 | 20.6 | 20.7 |

# APPENDIX B
# ONLINE DATA

**Appendix B1 – Alamogordo, Year 1**
**Appendix B2 – Alamogordo, Year 2**
**Appendix B3 – Brighton, Colorado**

# APPENDIX B1
# ALAMOGORDO,
# YEAR 1 ONLINE DATA

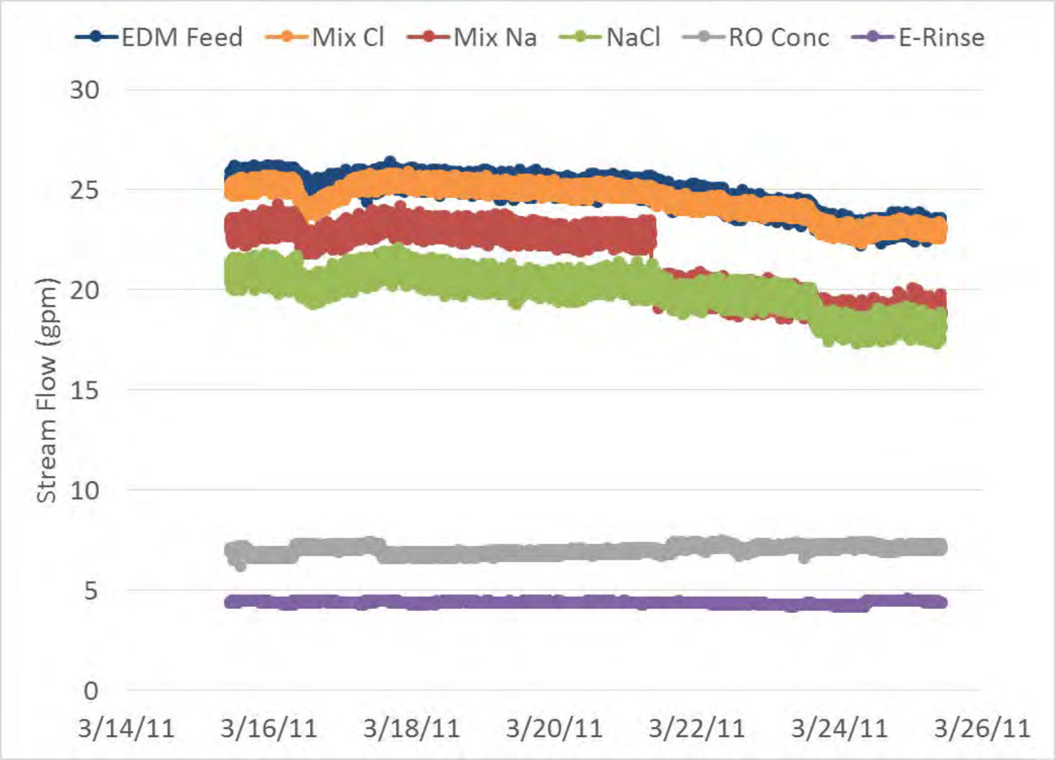

Figure B1-1.—NF concentrate and EDM stream flows (14 gpm NF permeate).

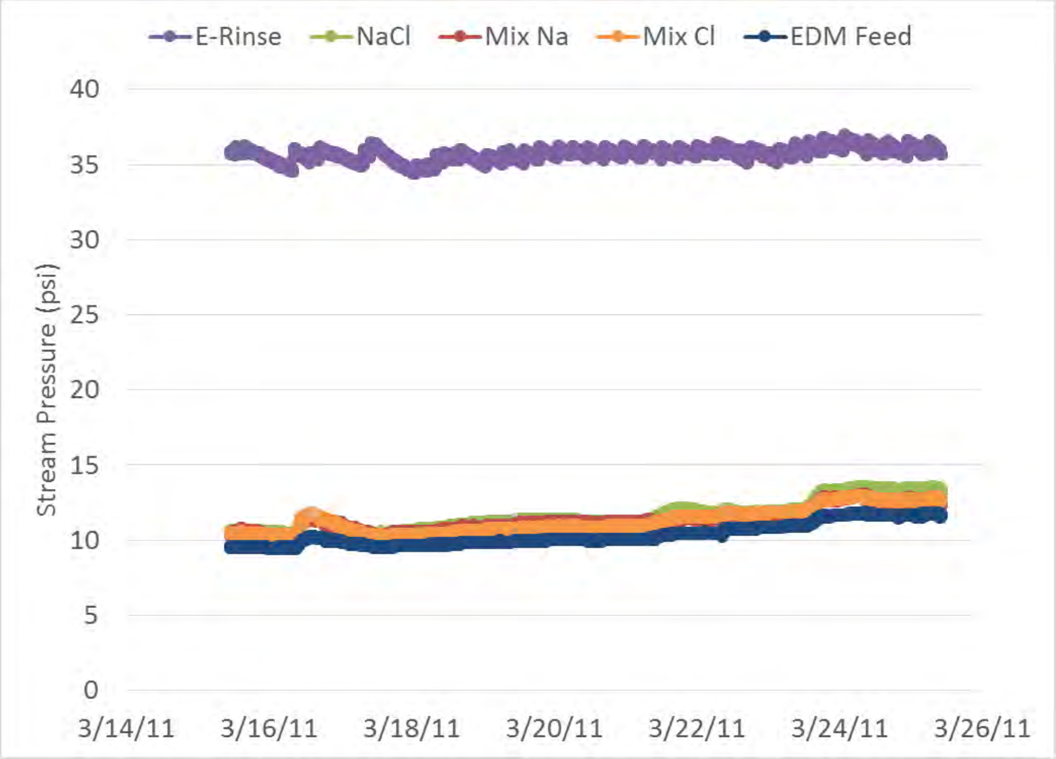

Figure B1-2.—EDM stream pressures (14 gpm NF permeate).

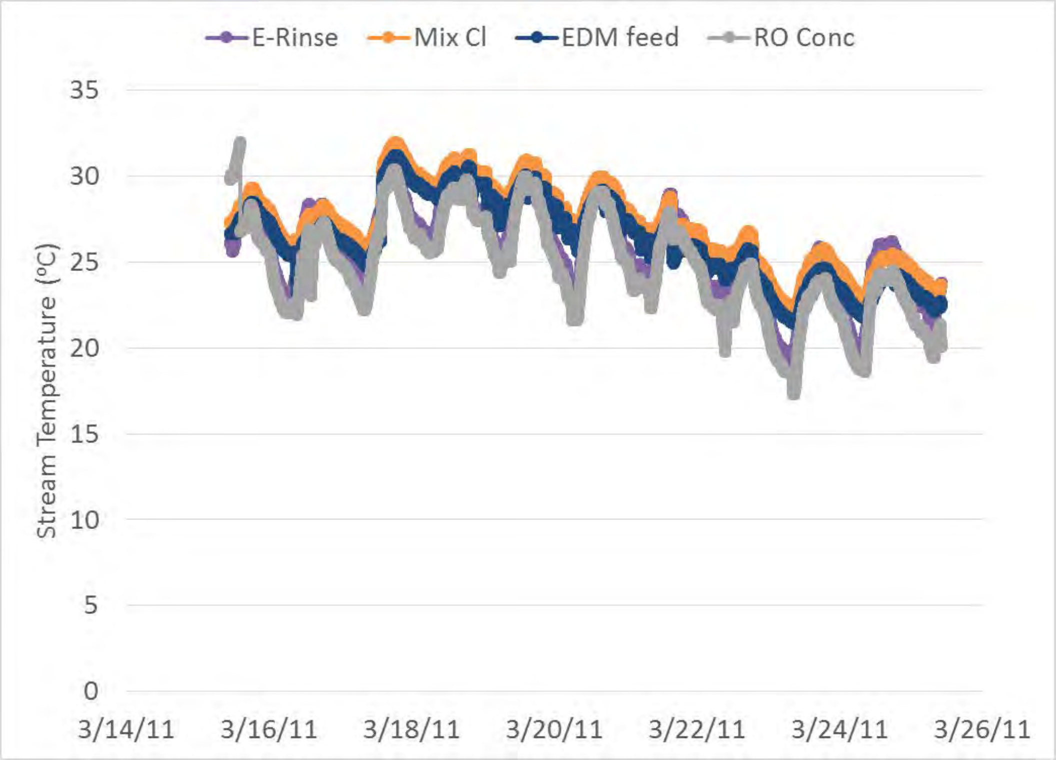

Figure B1-3.—EDM stream temperatures (14 gpm NF permeate).

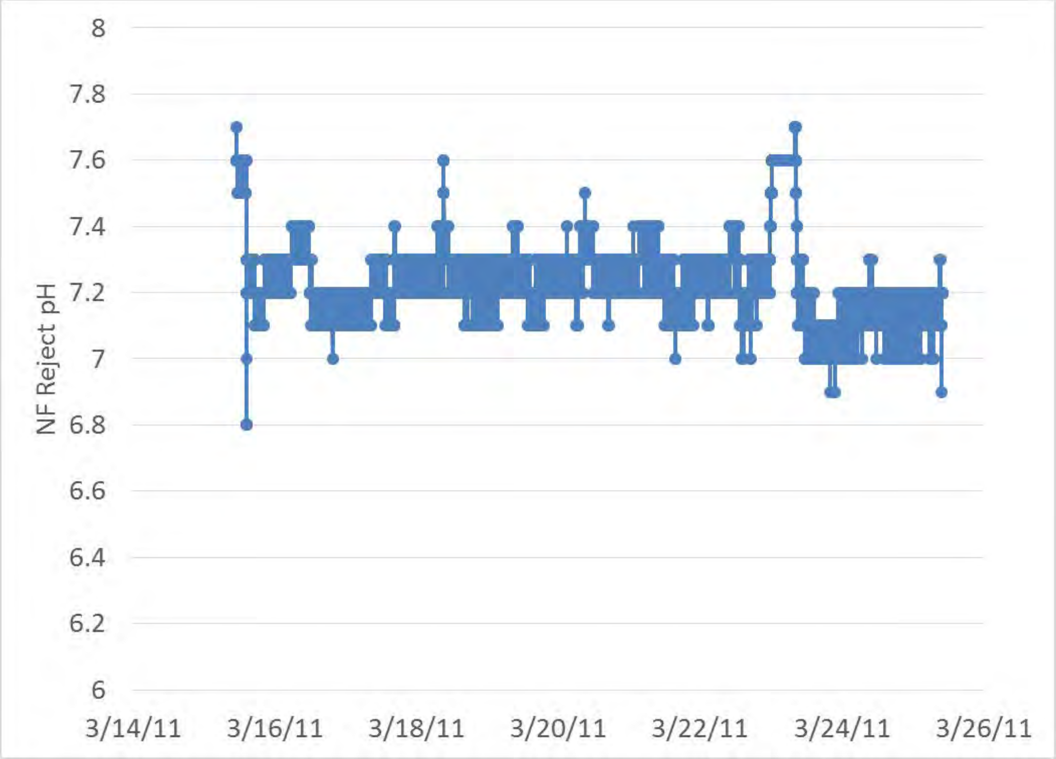

Figure B1-4.—NF reject pH (14 gpm NF permeate).

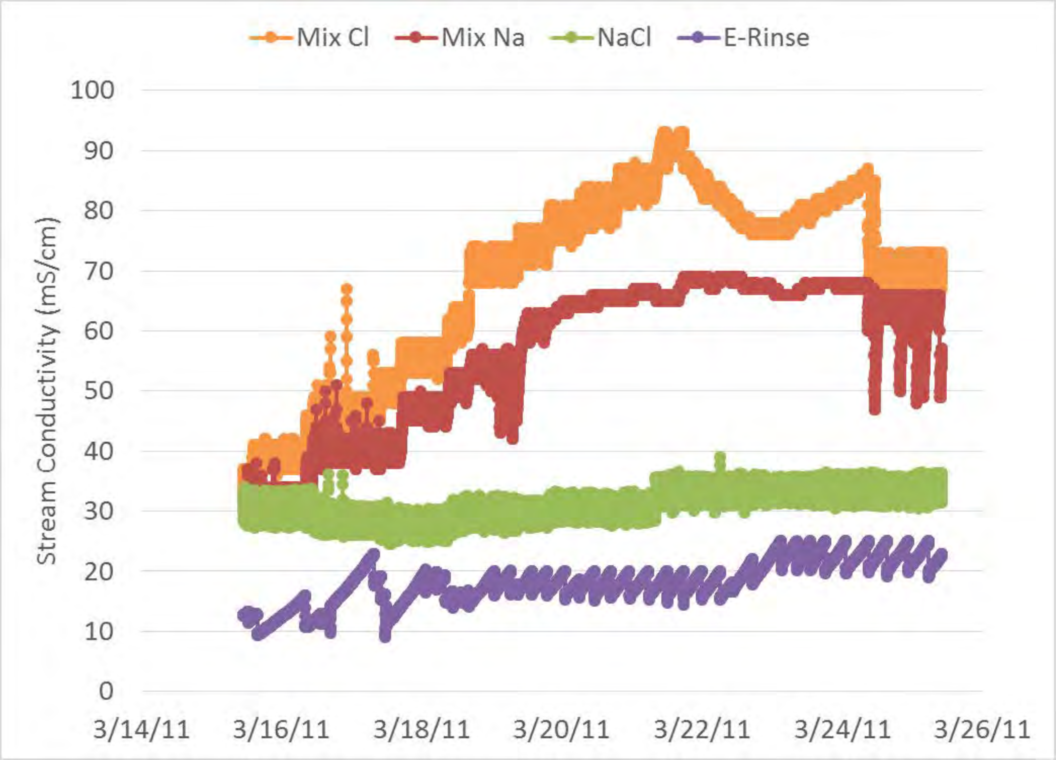

**Figure B1-5.—High concentration EDM stream conductivity (14 gpm NF permeate).**
*(note: Mixed Cl & Mixed Na are not calibrated or scaled)*

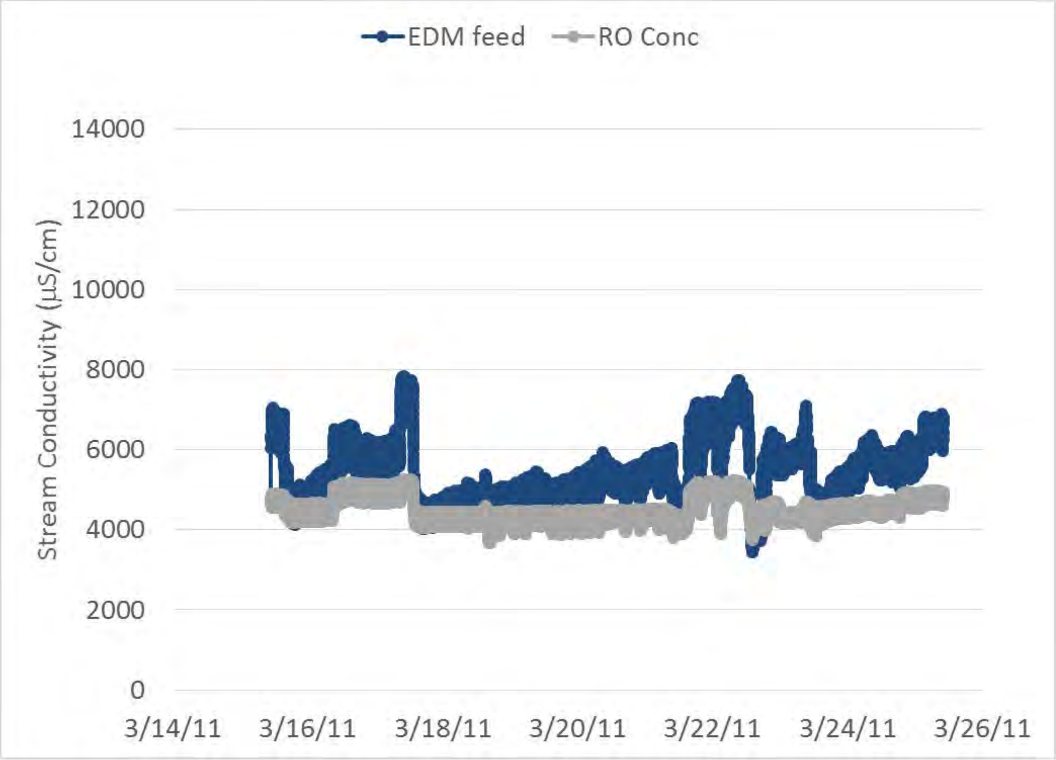

**Figure B1-6.—Low concentration EDM stream conductivity (14 gpm NF permeate)**

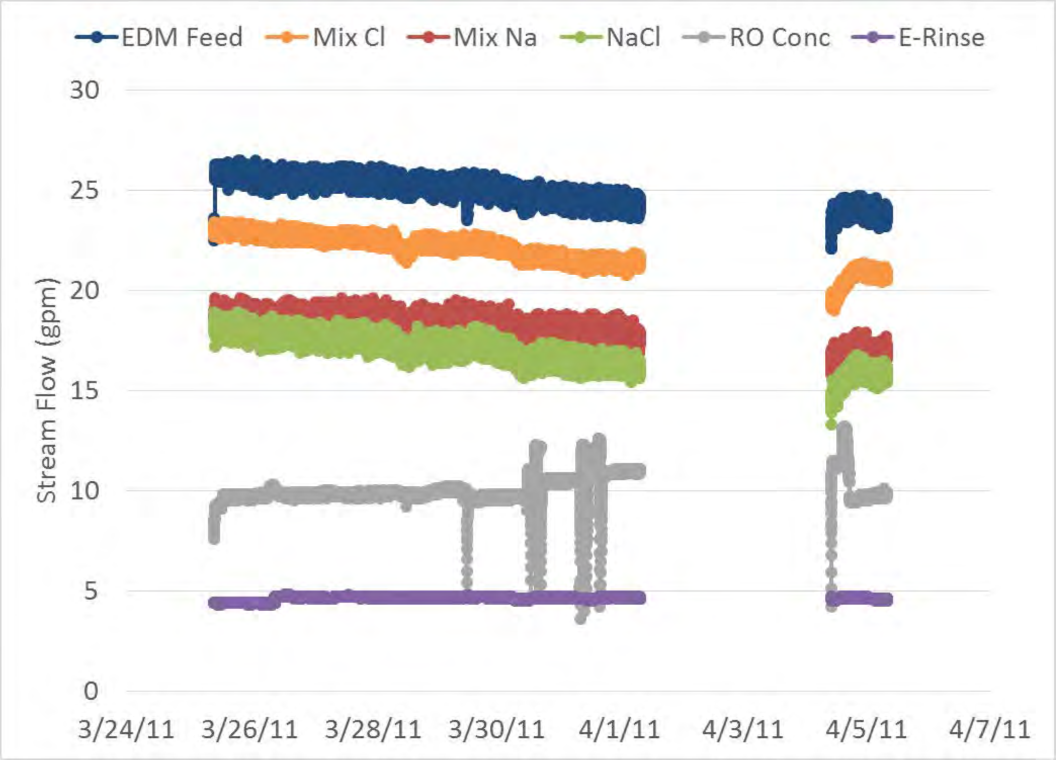

Figure B1-7.—EDM stream flows (20 gpm NF permeate).

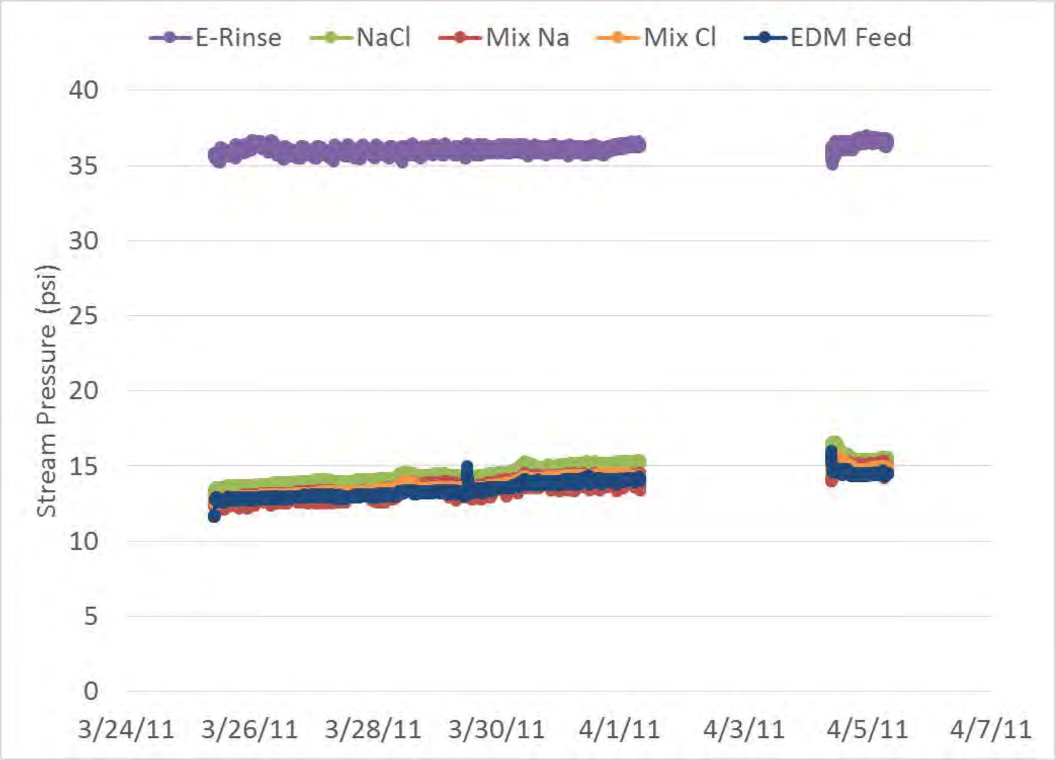

Figure B1-8.—EDM stream pressures (20 gpm NF permeate).

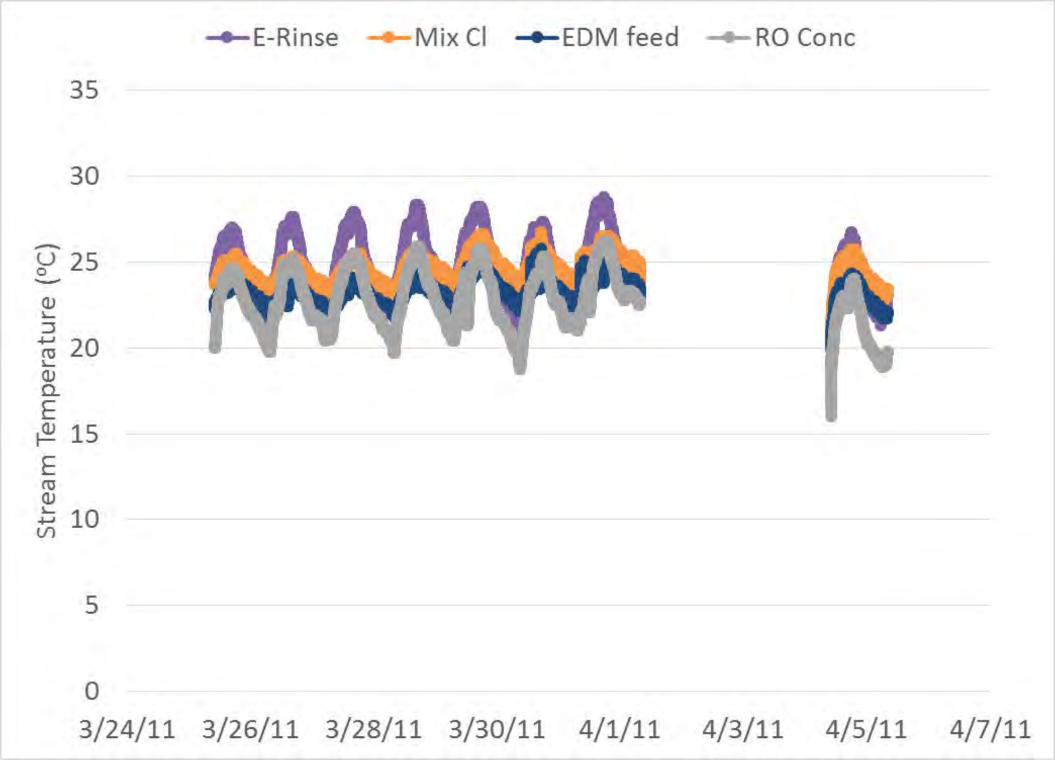

Figure B1-9.—EDM stream temperatures (20 gpm NF permeate).

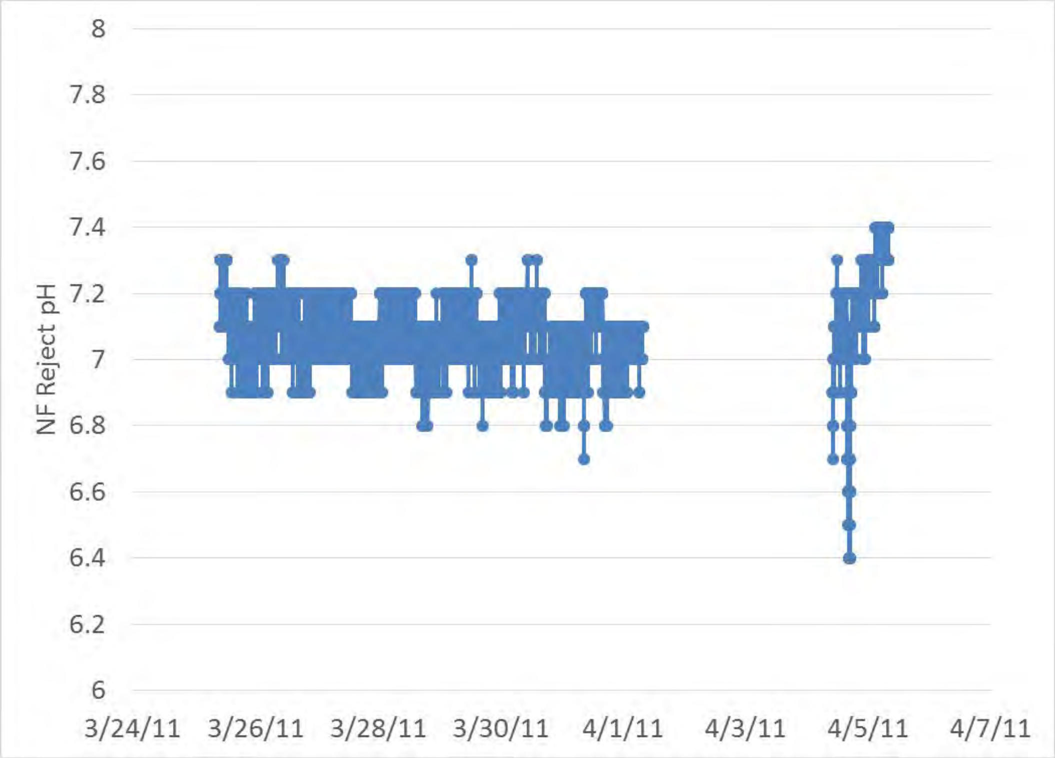

Figure B1-10.—NF concentrate pH (20 gpm NF permeate).

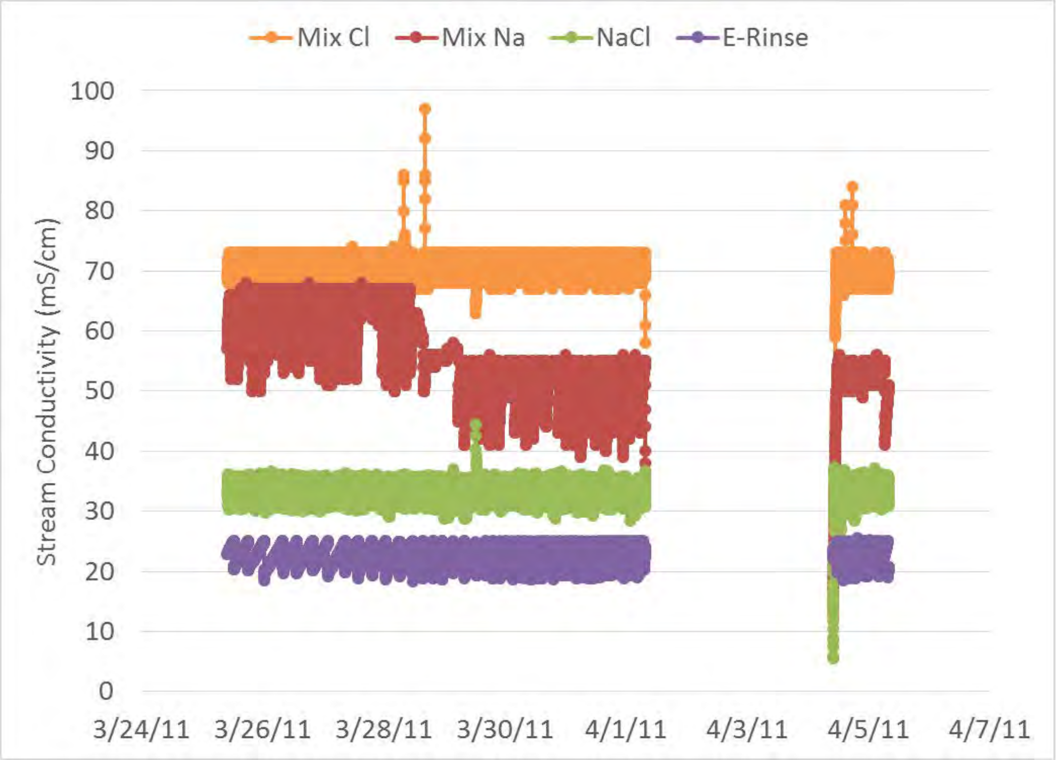

**Figure B1-11.—High concentration EDM stream conductivity (20 gpm NF permeate).**
*(note: Mixed Cl & Mixed Na are not calibrated or scaled)*

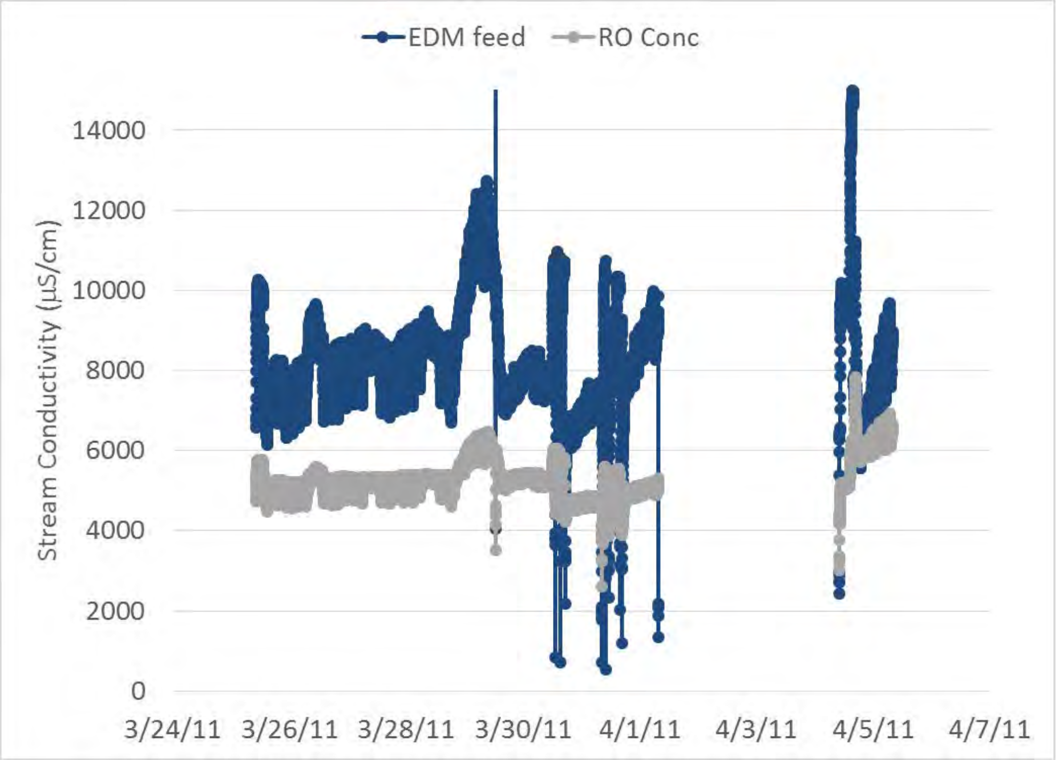

**Figure B1-12.—Low concentration EDM stream conductivity (20 gpm NF permeate).**

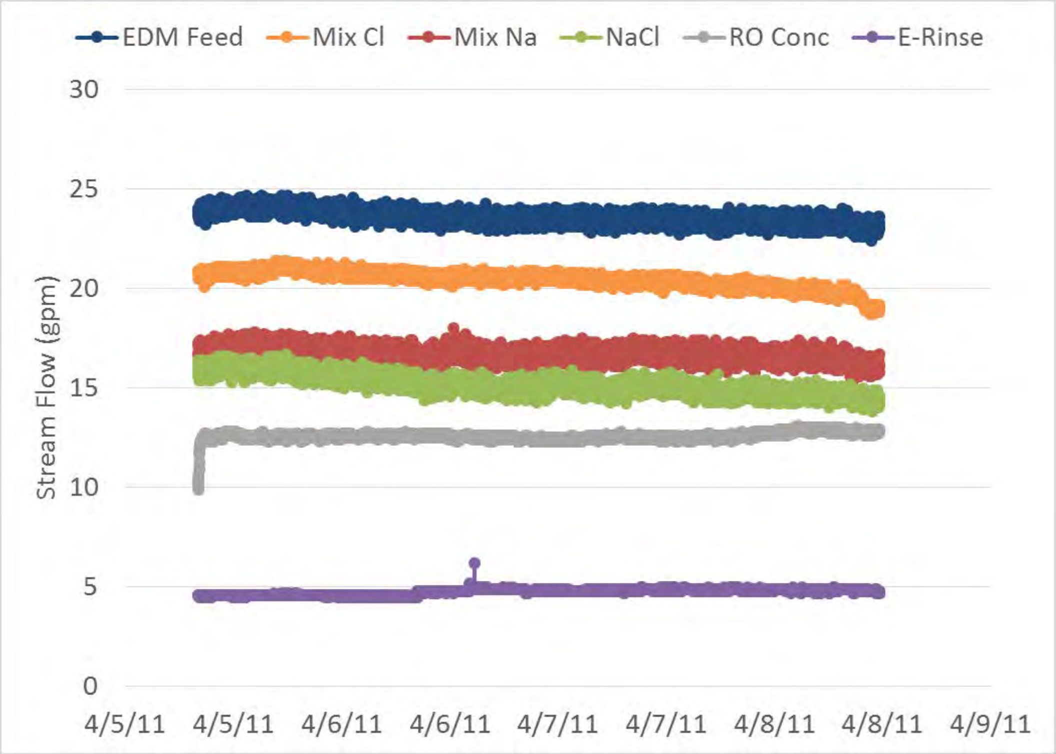

Figure B1-13.—EDM stream flows (25 gpm NF permeate).

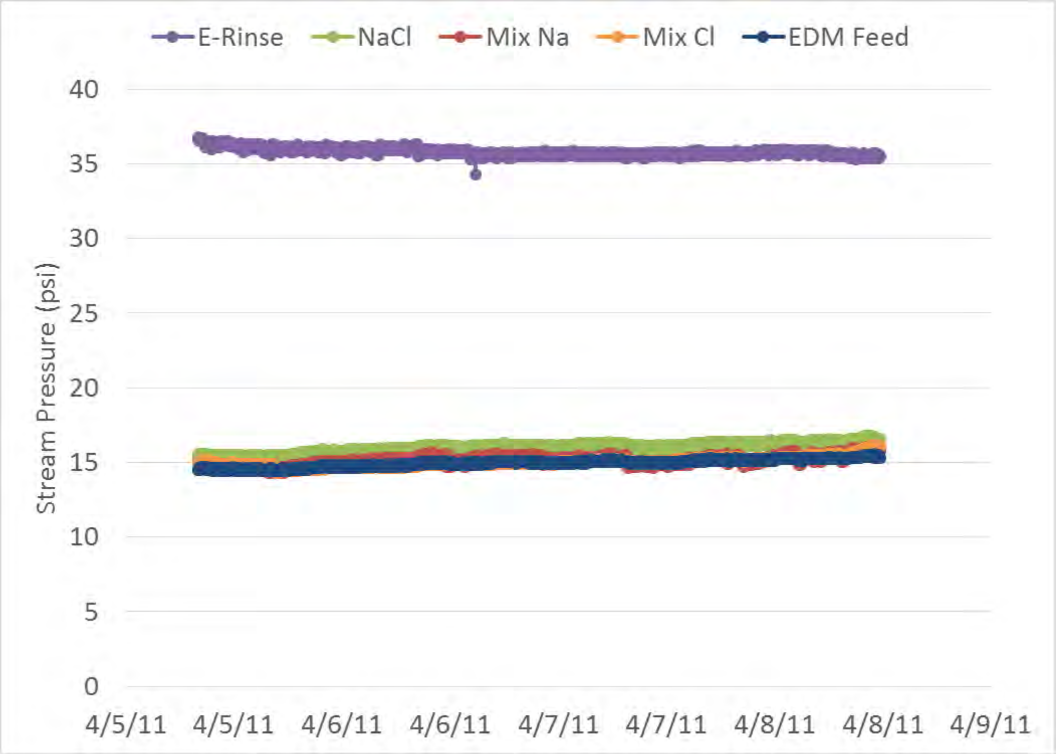

Figure B1-14.—EDM stream pressures (25 gpm NF permeate).

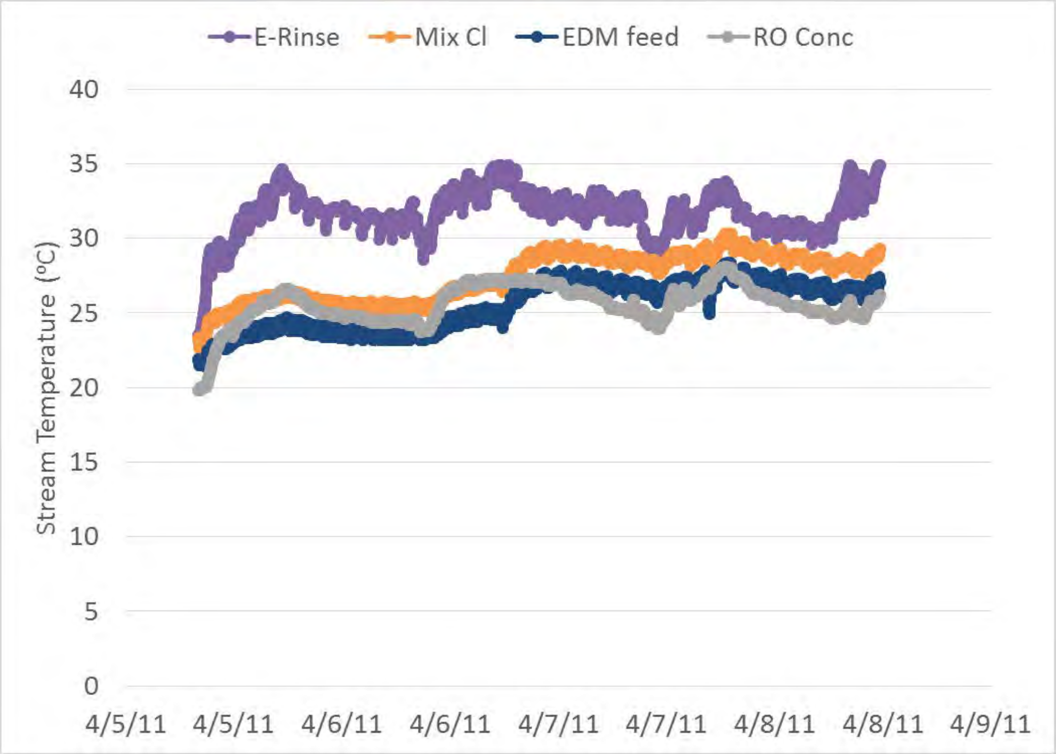

Figure B1-15.—EDM stream temperatures (25 gpm NF permeate).

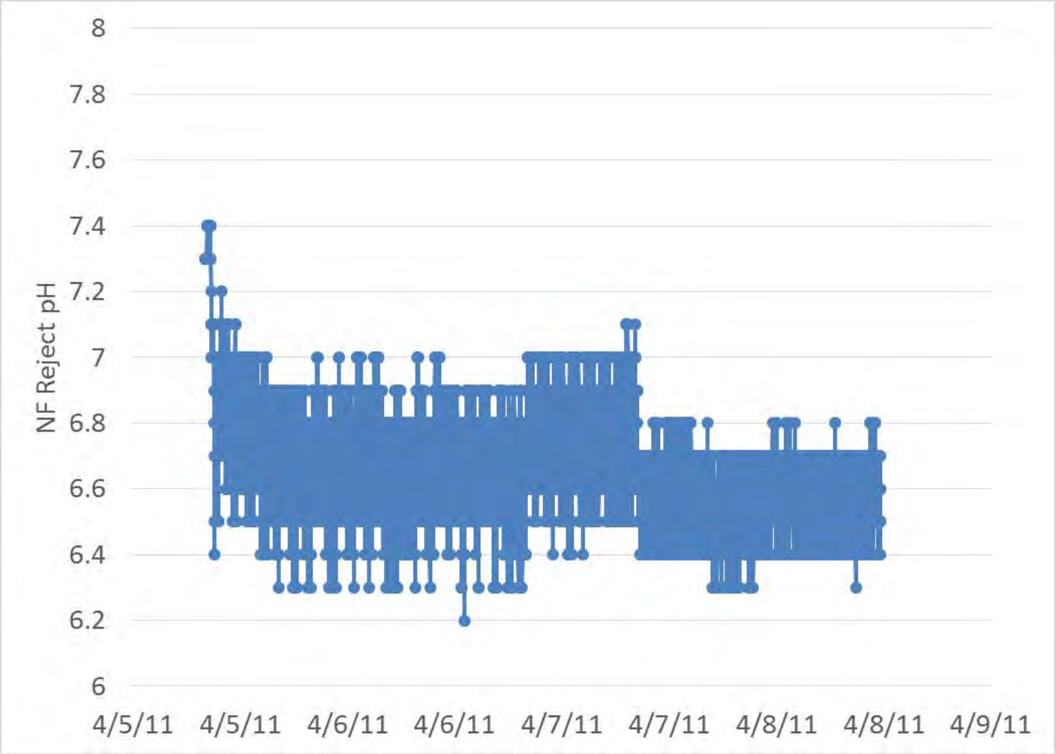

Figure B1-16.—NF reject pH (25 gpm NF permeate).

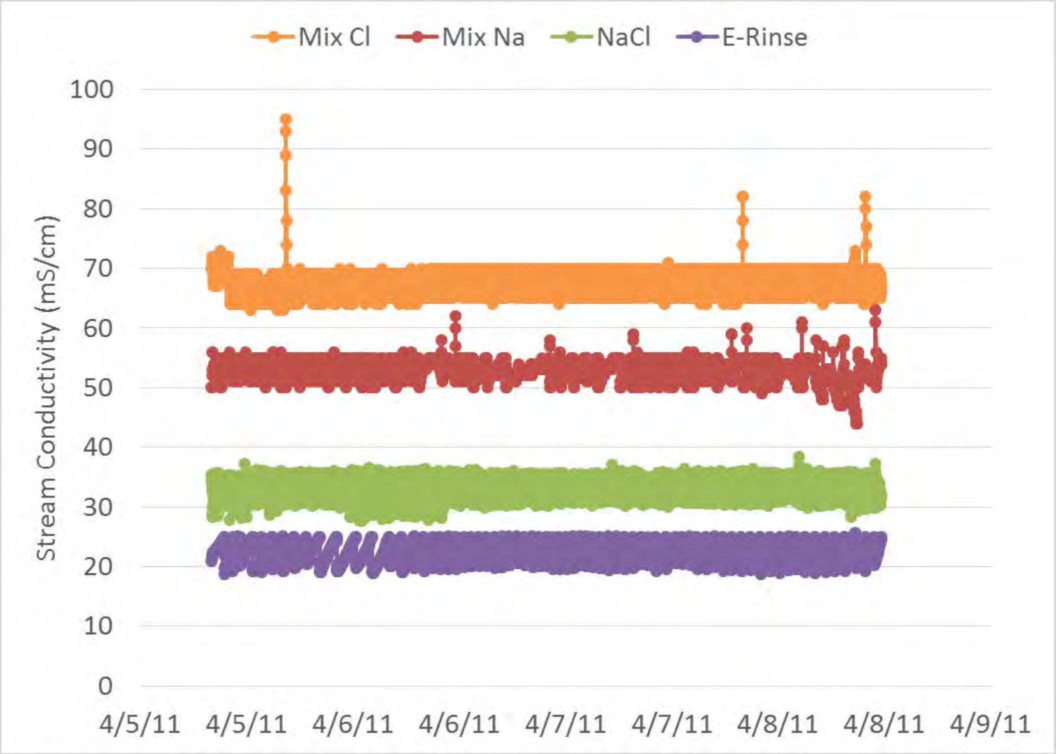

**Figure B1-17.—High concentration EDM stream conductivity (25 gpm NF permeate).**
*(note: Mixed Cl & Mixed Na are not calibrated or scaled)*

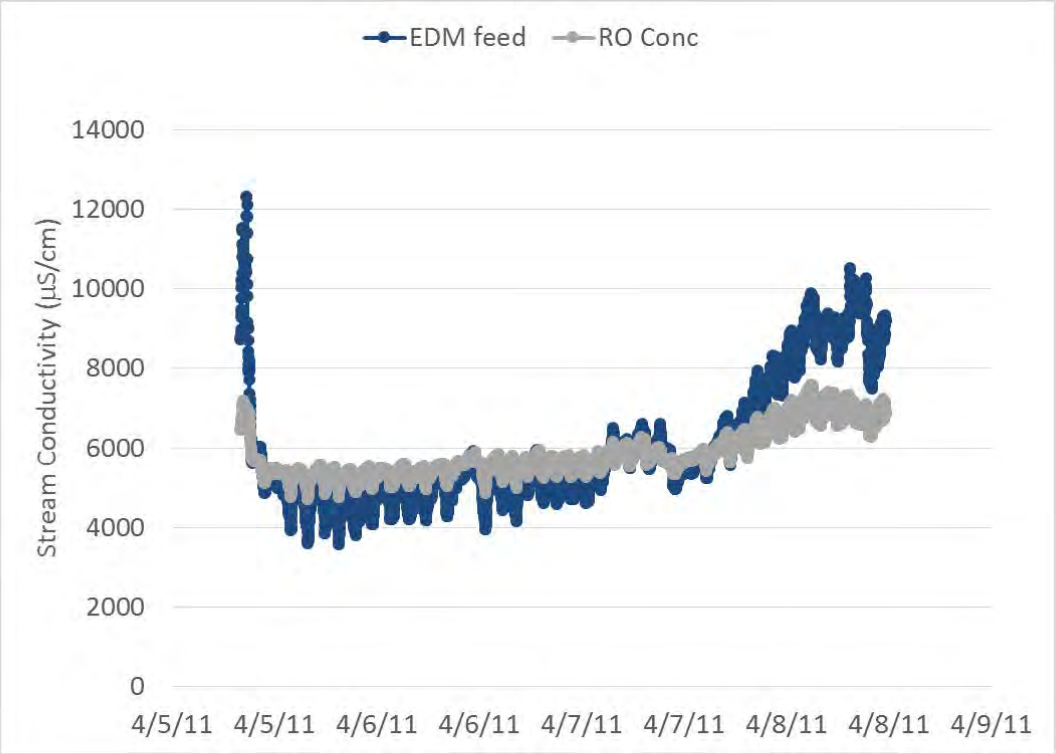

**Figure B1-18.—Low concentration EDM stream conductivity (25 gpm NF permeate).**

# APPENDIX B2
# ALAMOGORDO,
# YEAR 2 ONLINE DATA

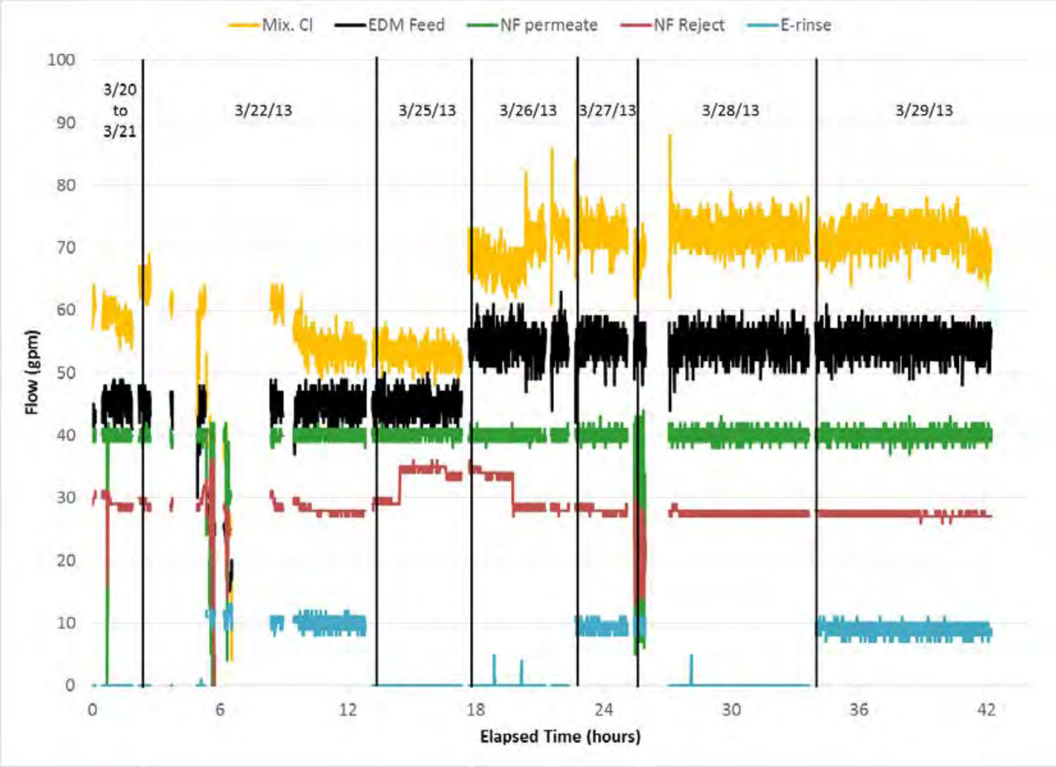

Figure B2-19.—EDM stream flows (preliminary experiments-1).

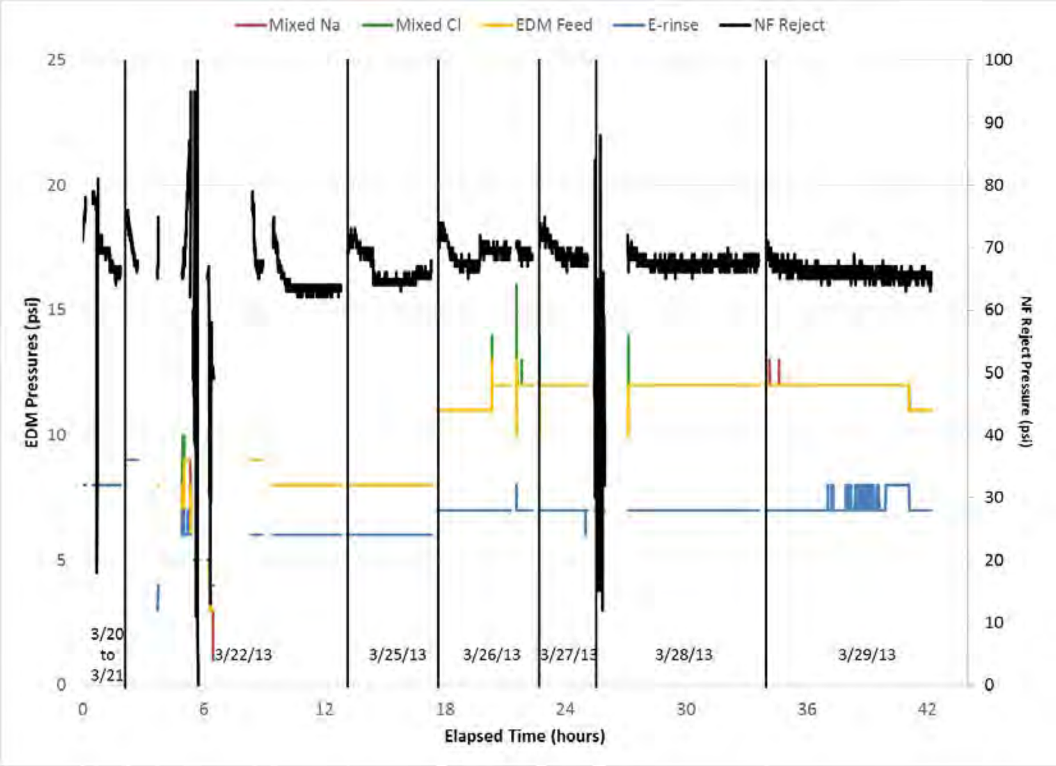

Figure B2-20.—EDM and NF reject stream pressures (preliminary experiments-1).

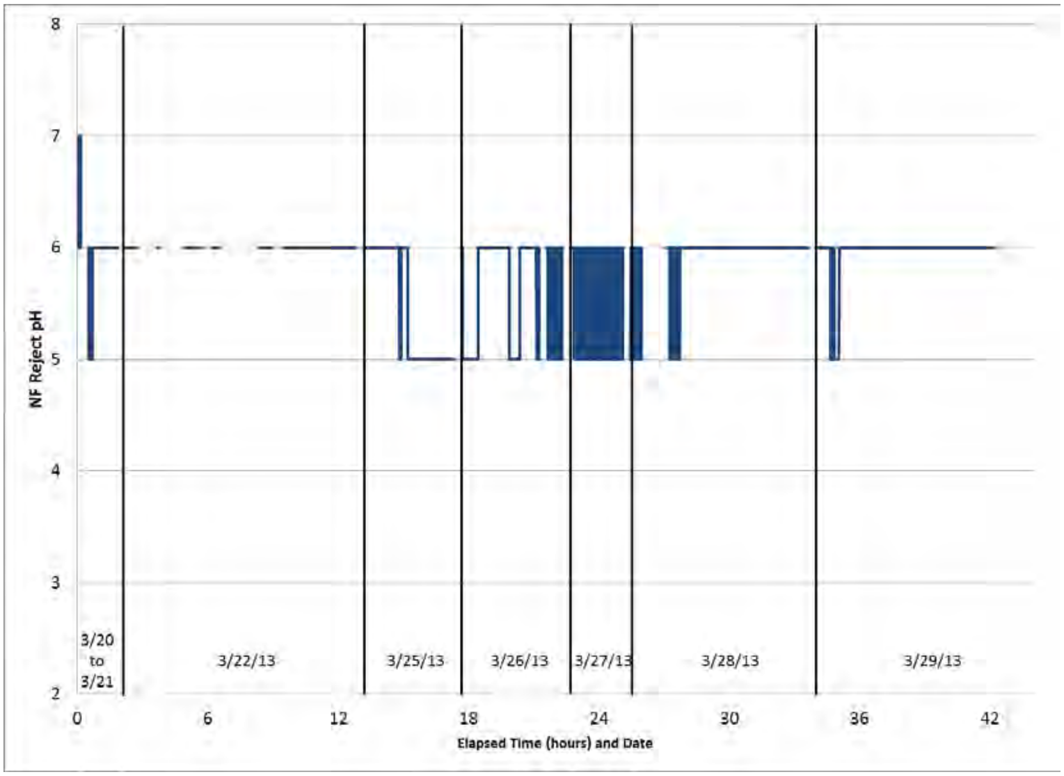

Figure B2-21.—NF reject pH (preliminary experiments-1).

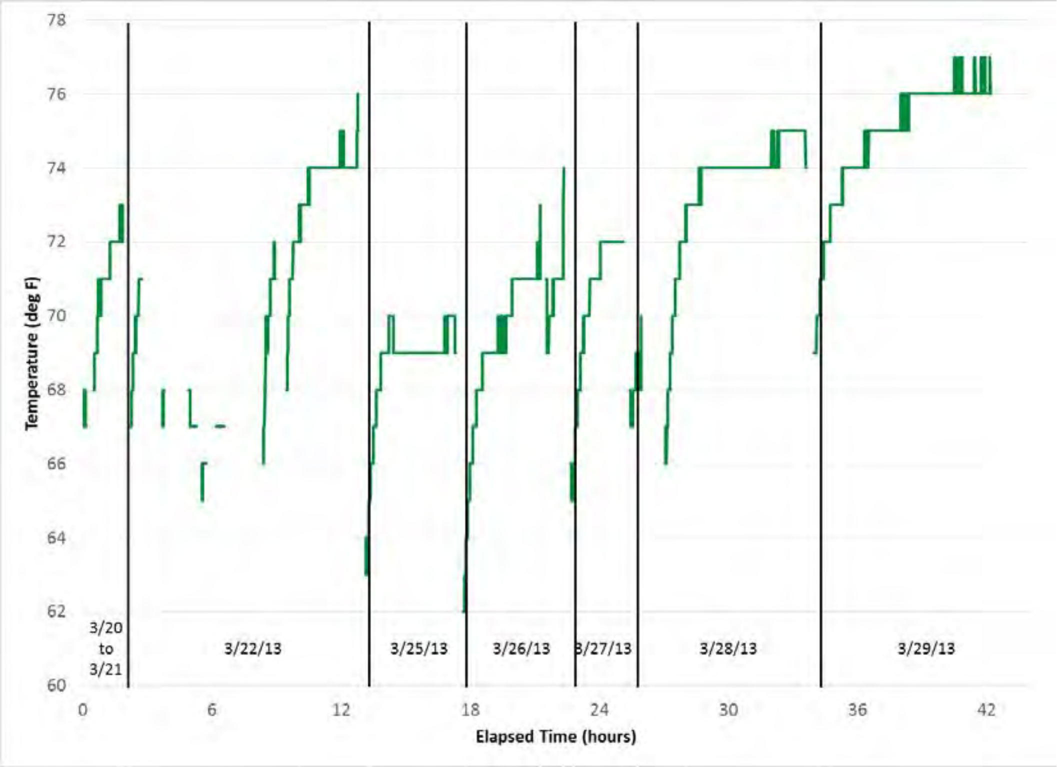

Figure B2-22.—EDM electrode rinse temperature (preliminary experiments-1).

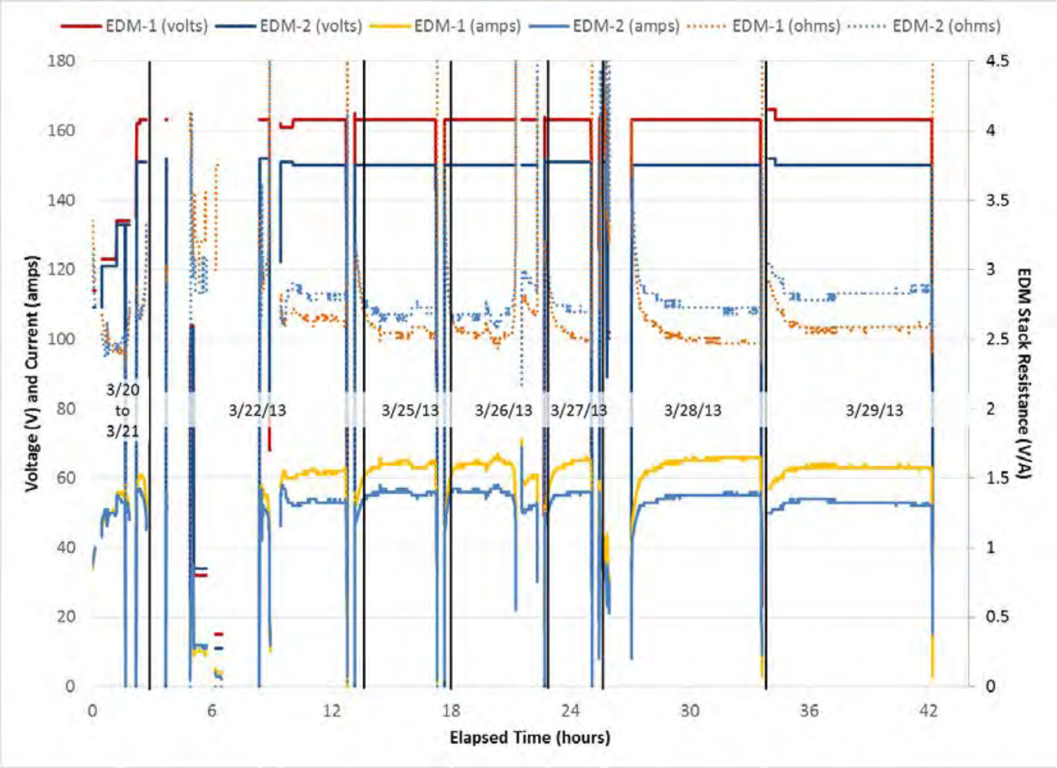

Figure B2-23.—EDM voltage, current, stack resistance (preliminary experiments-1).

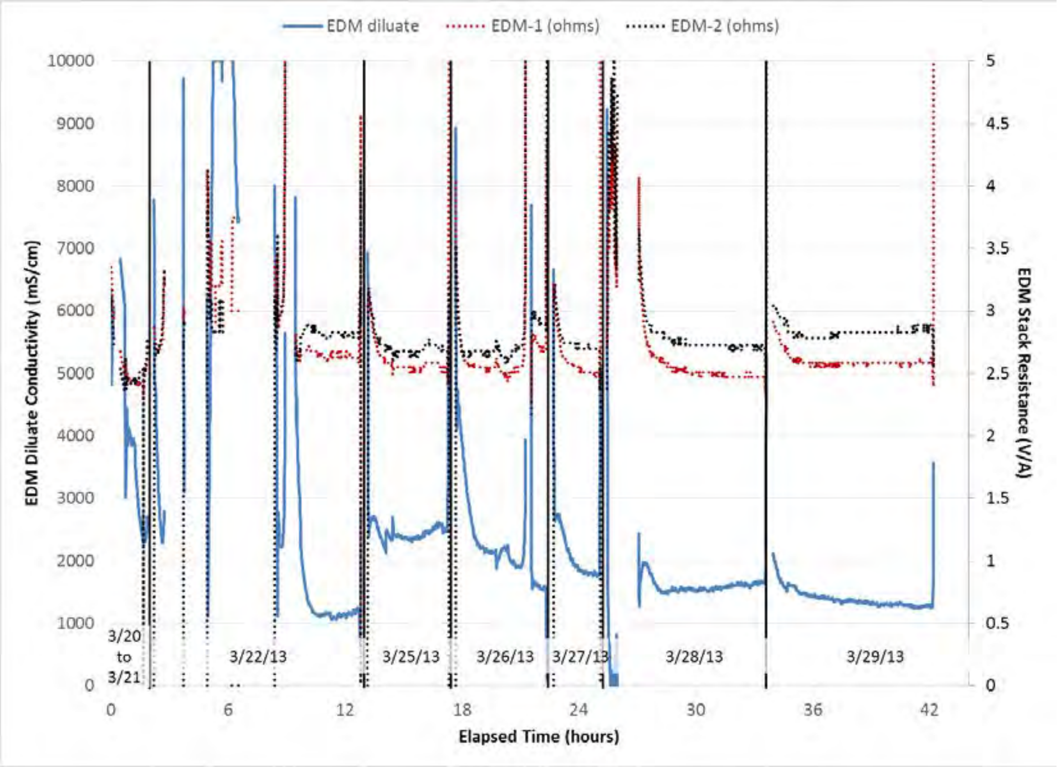

Figure B2-24.—EDM diluate conductivity and stack resistance (preliminary experiments-1).

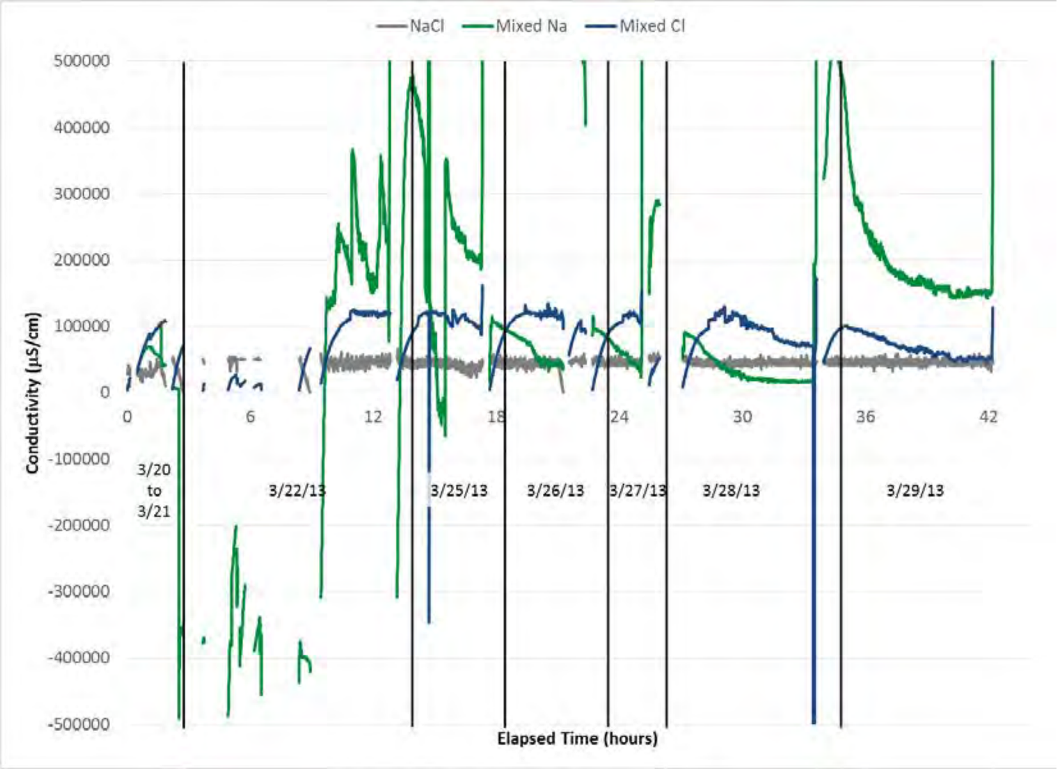

**Figure B2-25.—High concentration EDM stream conductivity (preliminary experiments-1).** *(note: Mixed Cl & Mixed Na are not calibrated or scaled)*

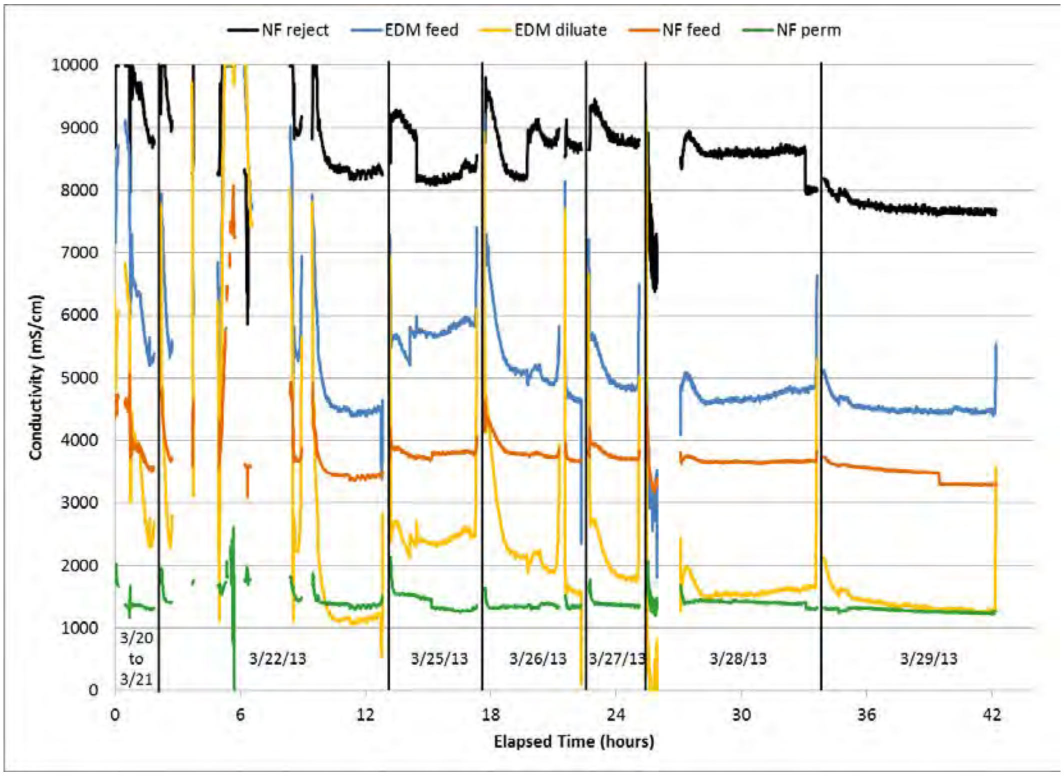

**Figure B2-26.—Low concentration EDM stream conductivity (preliminary experiments-1).**

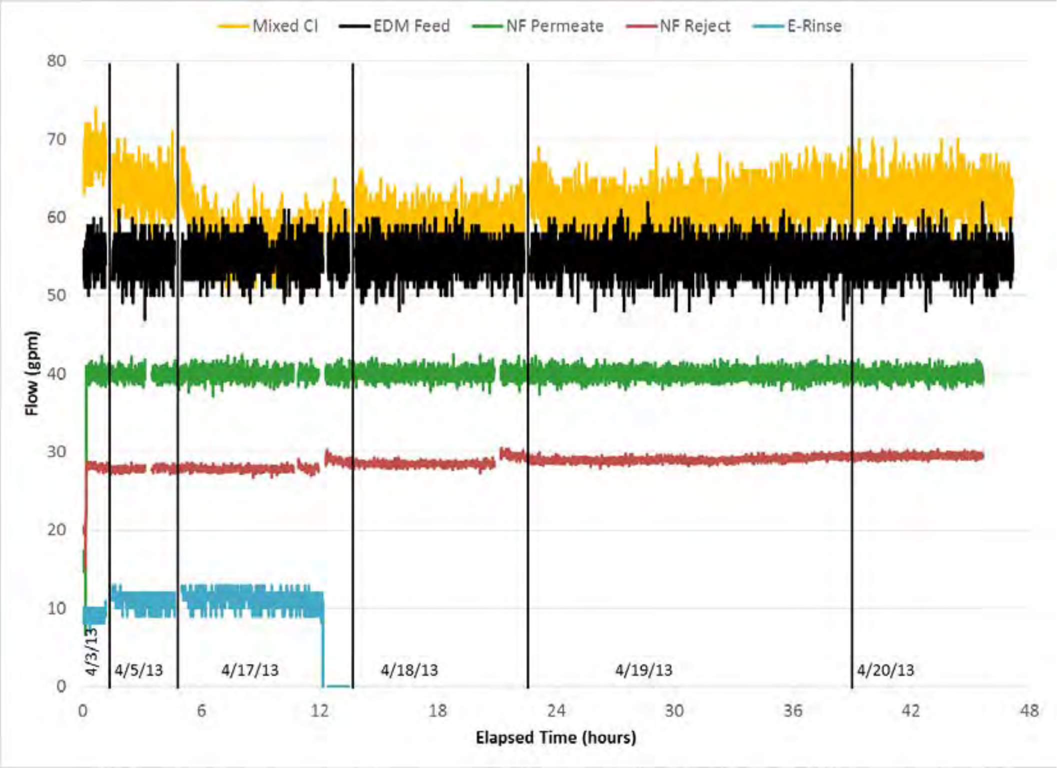

Figure B2-27.—EDM stream flows (preliminary experiments-2).

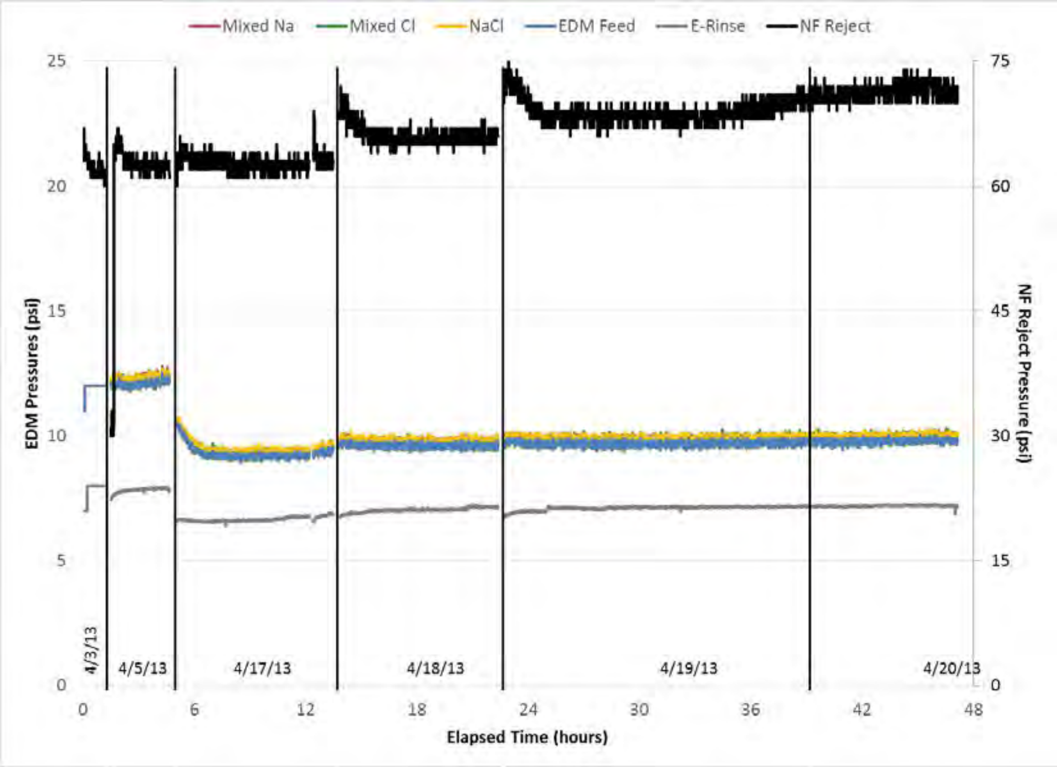

Figure B2-28.—EDM and NF reject stream pressures (preliminary experiments-2).

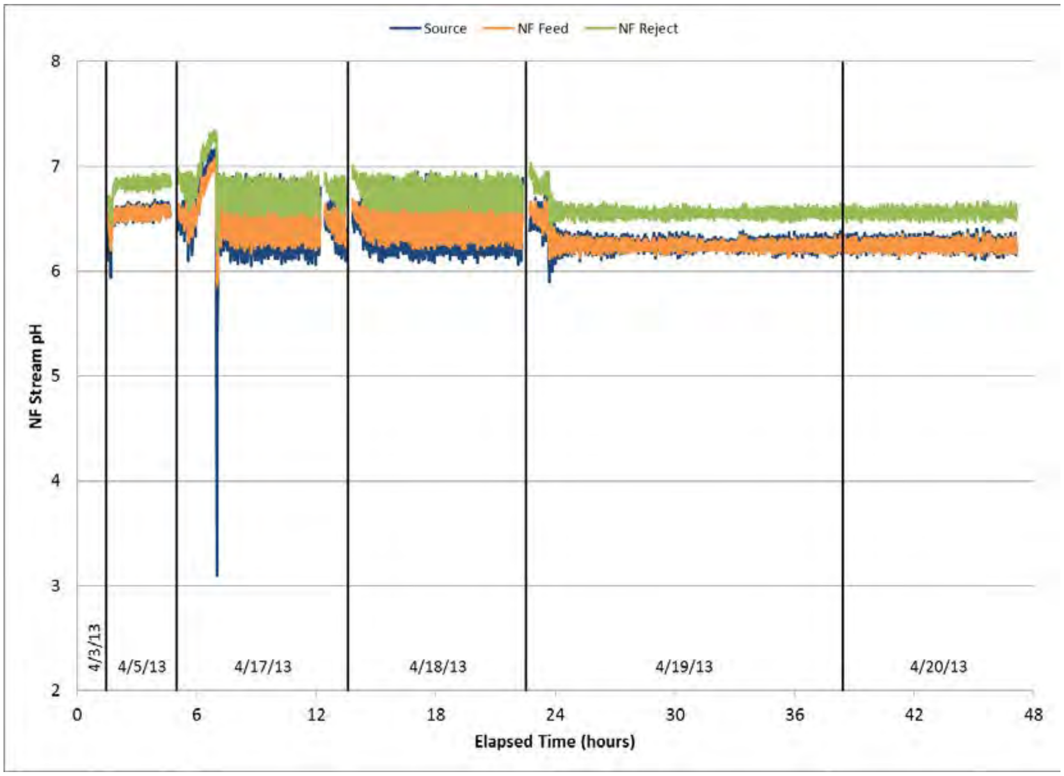

Figure B2-29.—NF stream pH (preliminary experiments-2).

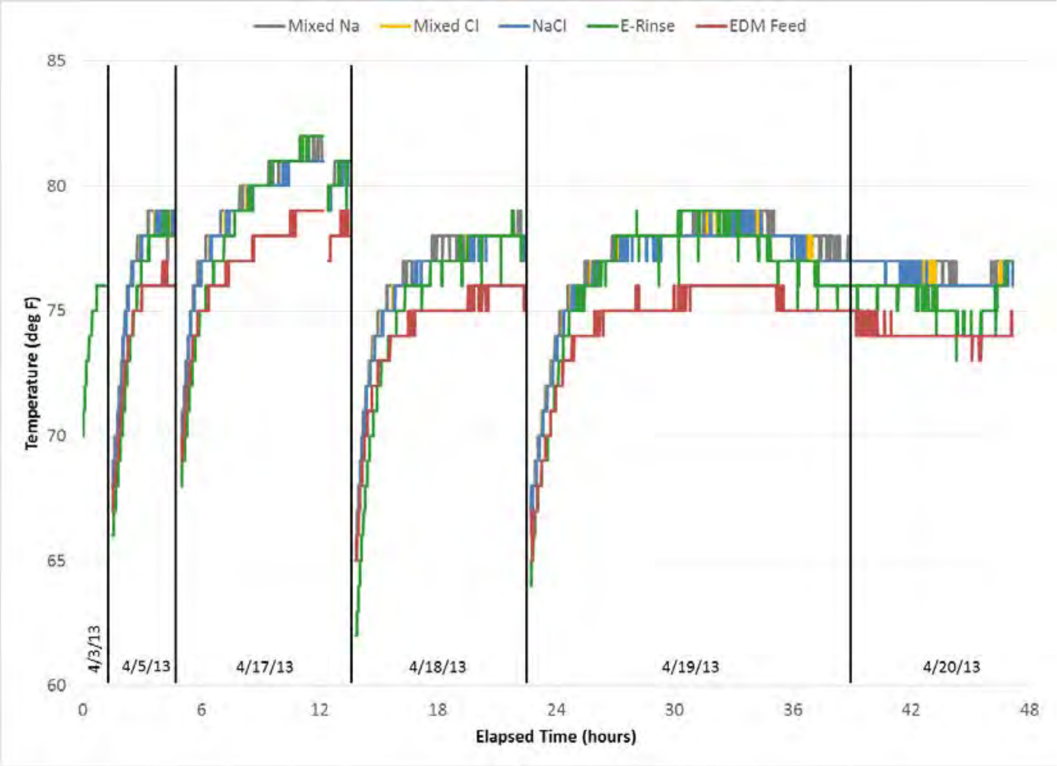

Figure B2-30.—EDM stream temperature (preliminary experiments-2).

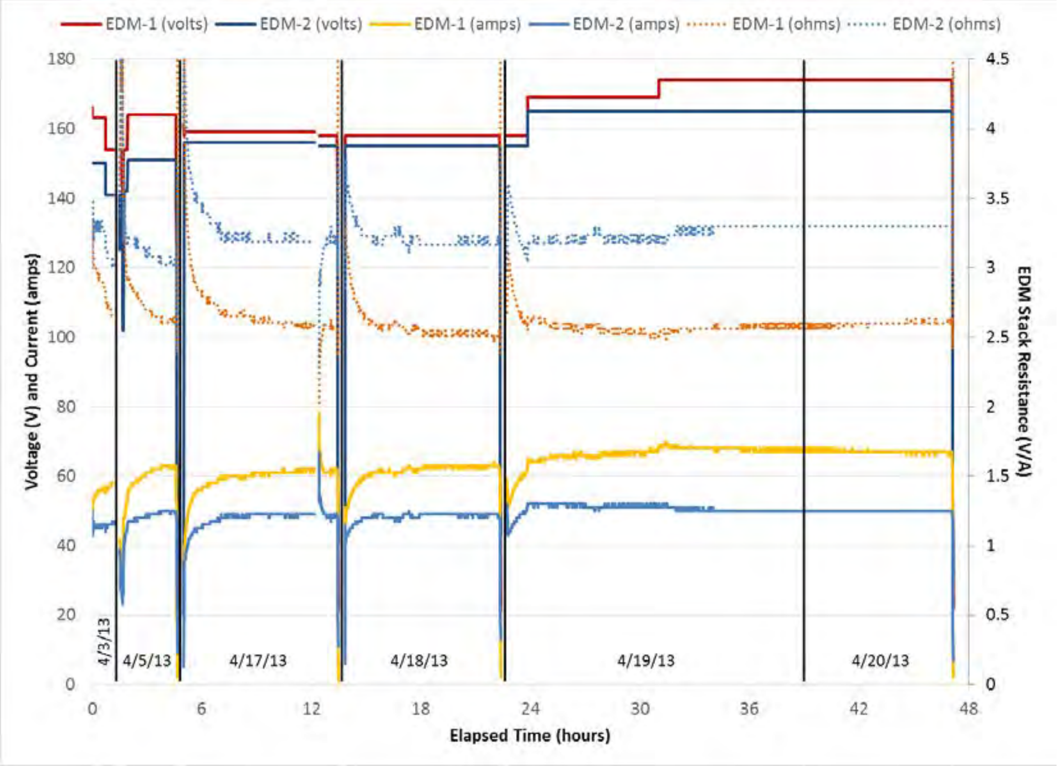

Figure B2-31.—EDM voltage, current, stack resistance (preliminary experiments-2).

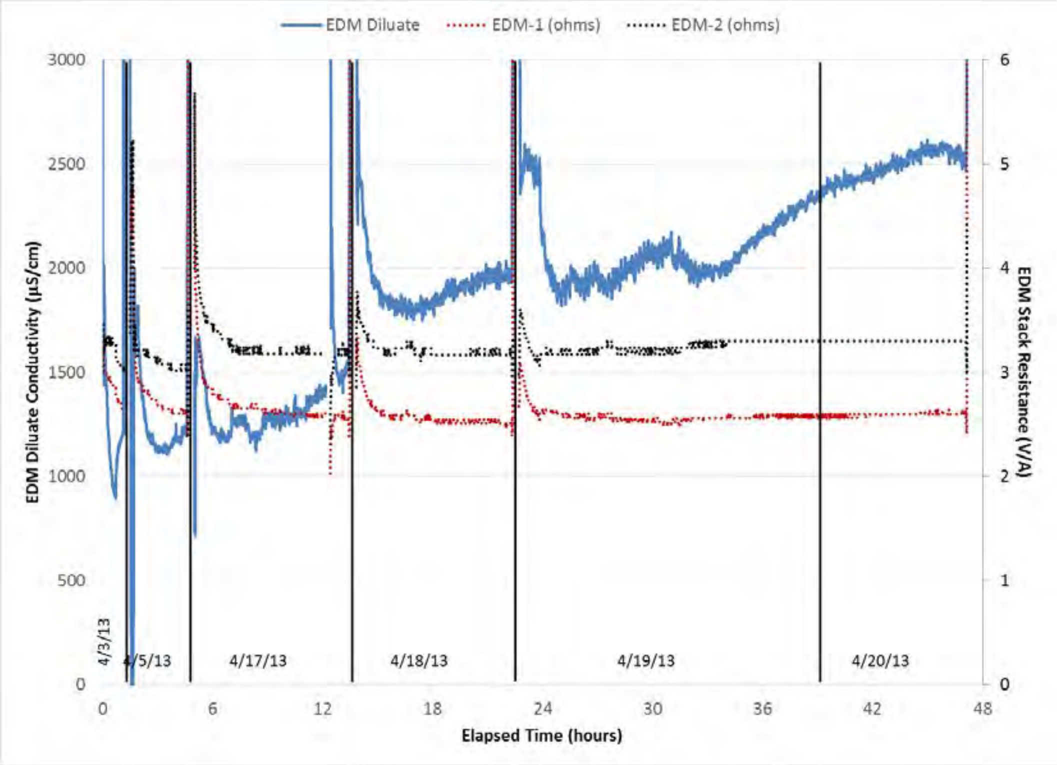

Figure B2-32.—EDM diluate conductivity and stack resistance (preliminary experiments-2).

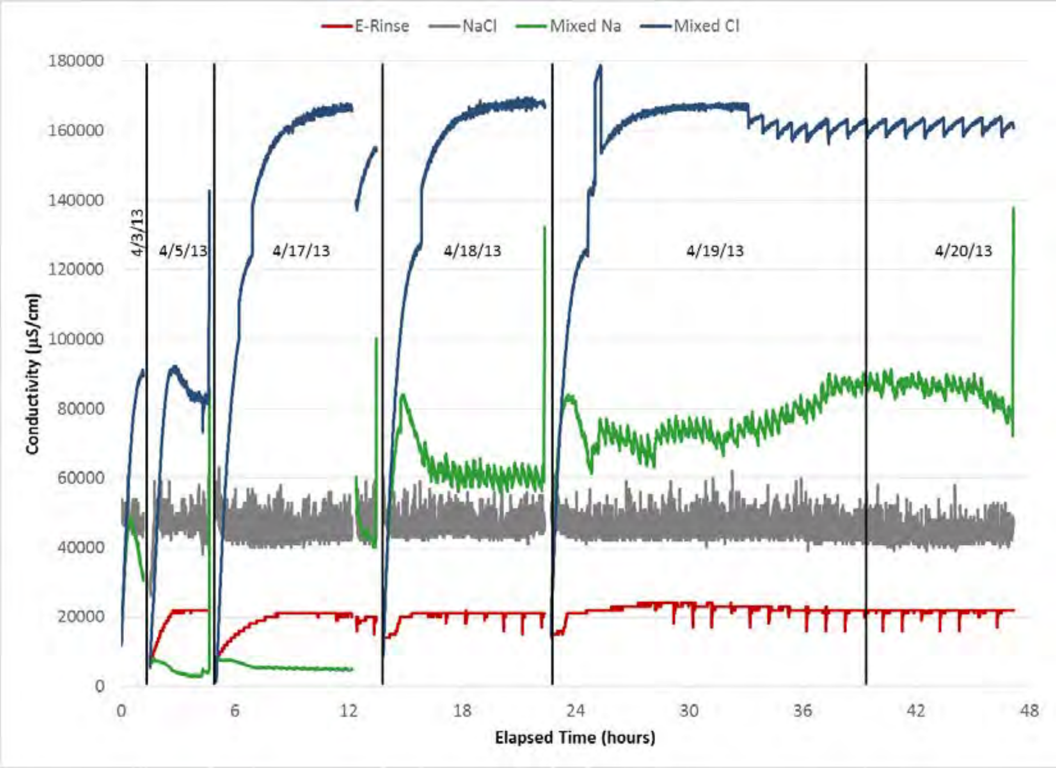

**Figure B2-33.—High concentration EDM stream conductivity (preliminary experiments-2).**

*(note: Mixed Cl & Mixed Na are not calibrated or scaled)*

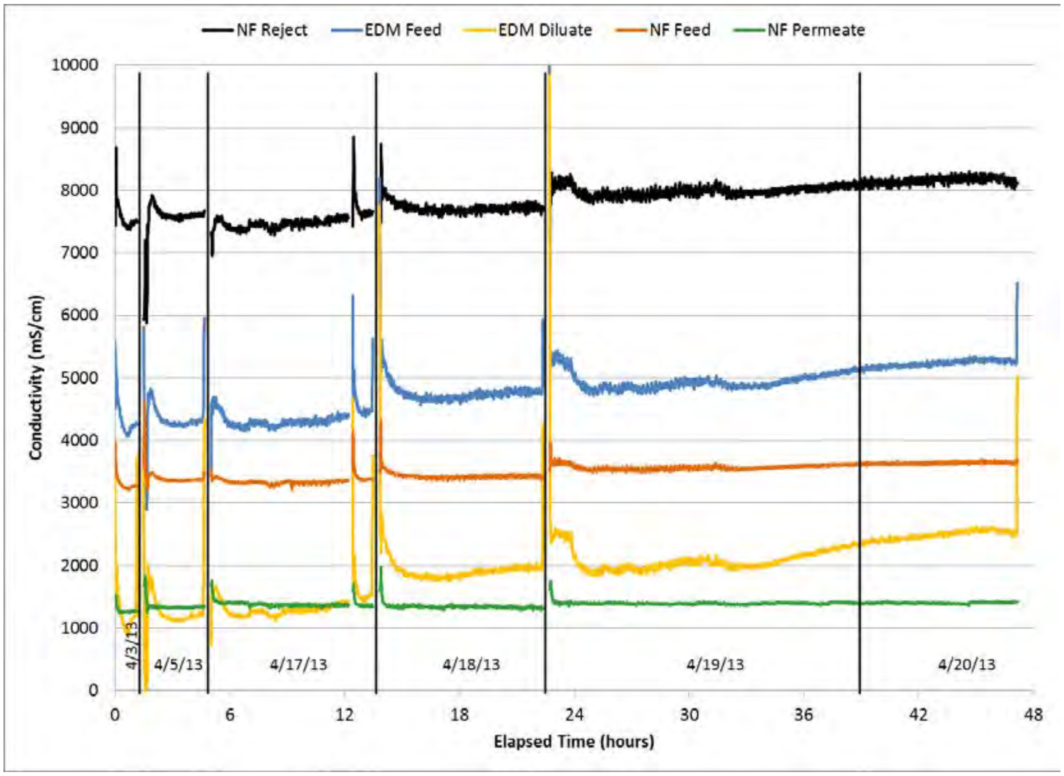

**Figure B2-34.—Low concentration EDM stream conductivity (preliminary experiments-2).**

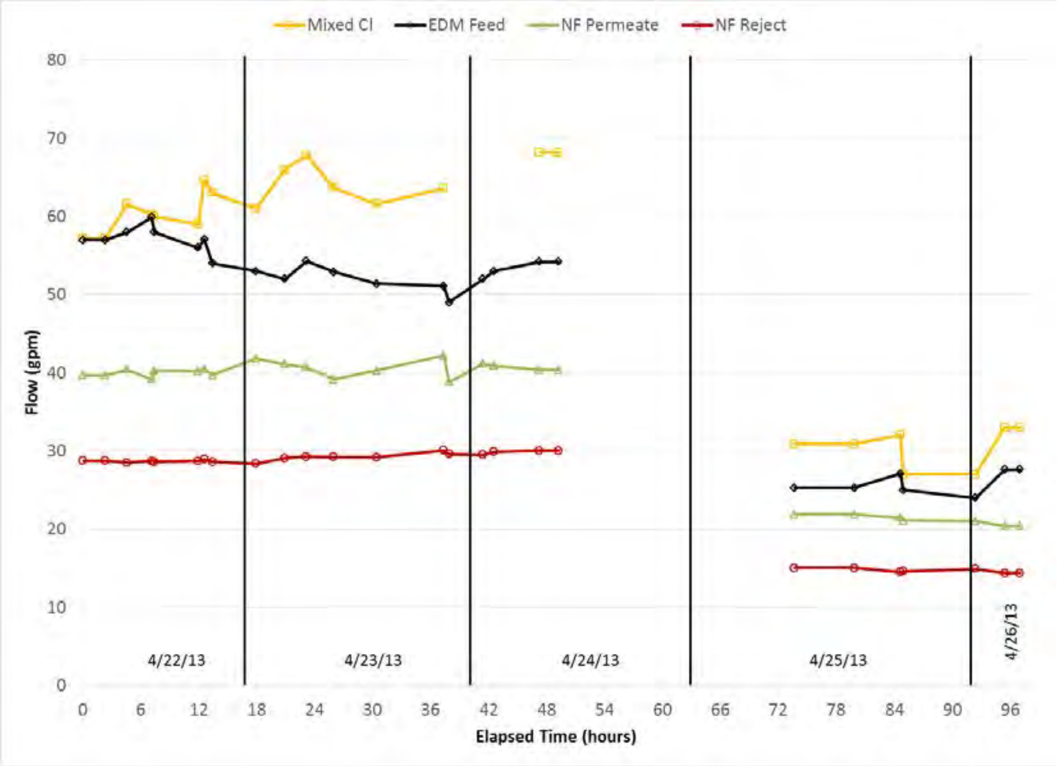

**Figure B2-35.—EDM stream flows (experiments 1a + 1b).**
*(Datalogger failed during this period. Data was recorded on logsheets from online meters, probes, and gauges.)*

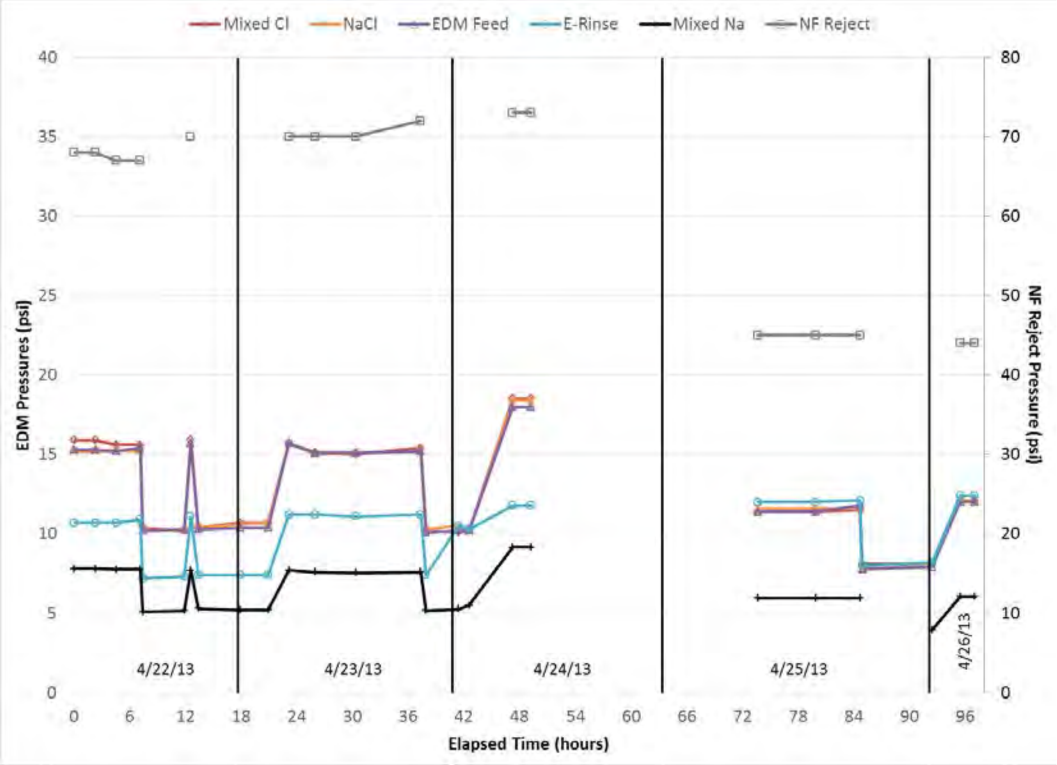

**Figure B2-36.—EDM and NF Reject Stream Pressures (Experiments 1a + 1b)**
*(Datalogger failed during this period. Data was recorded on logsheets from online meters, probes, and gauges.)*

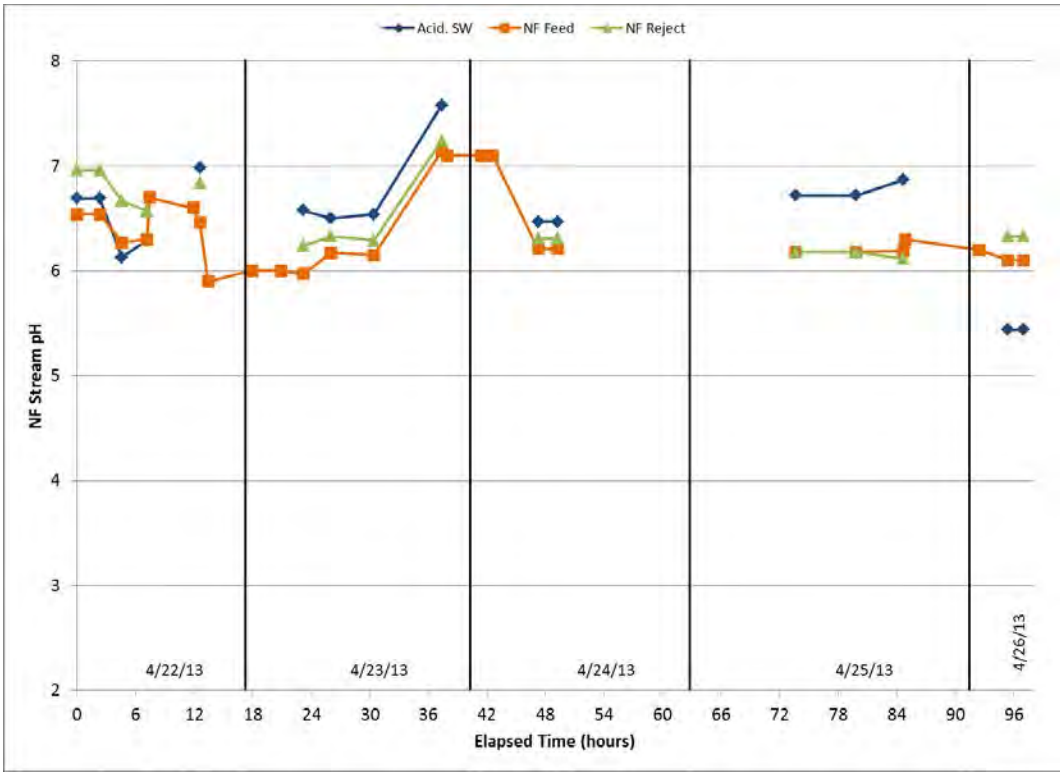

**Figure B2-37.—NF stream pH (experiments 1a + 1b).**
*Datalogger failed during this period. Data was recorded on logsheets from online meters, probes, and gauges.*

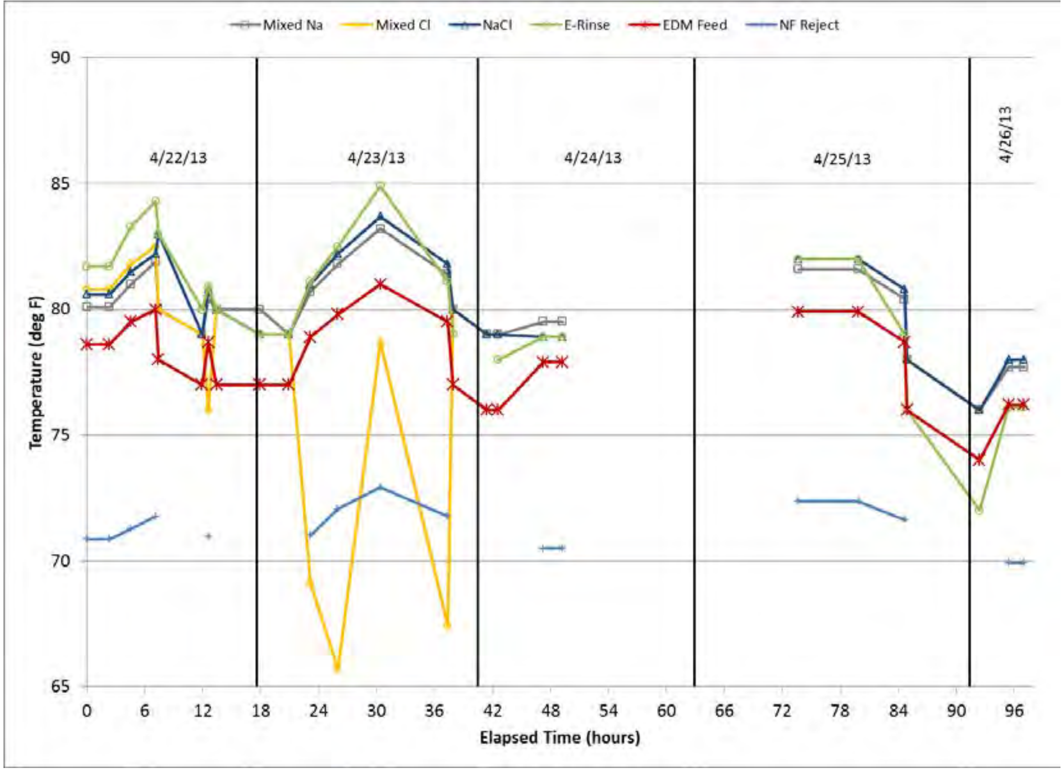

**Figure B2-38.—EDM stream temperature (experiments 1a + 1b).**
*Datalogger failed during this period. Data was recorded on logsheets from online meters, probes, and gauges.*

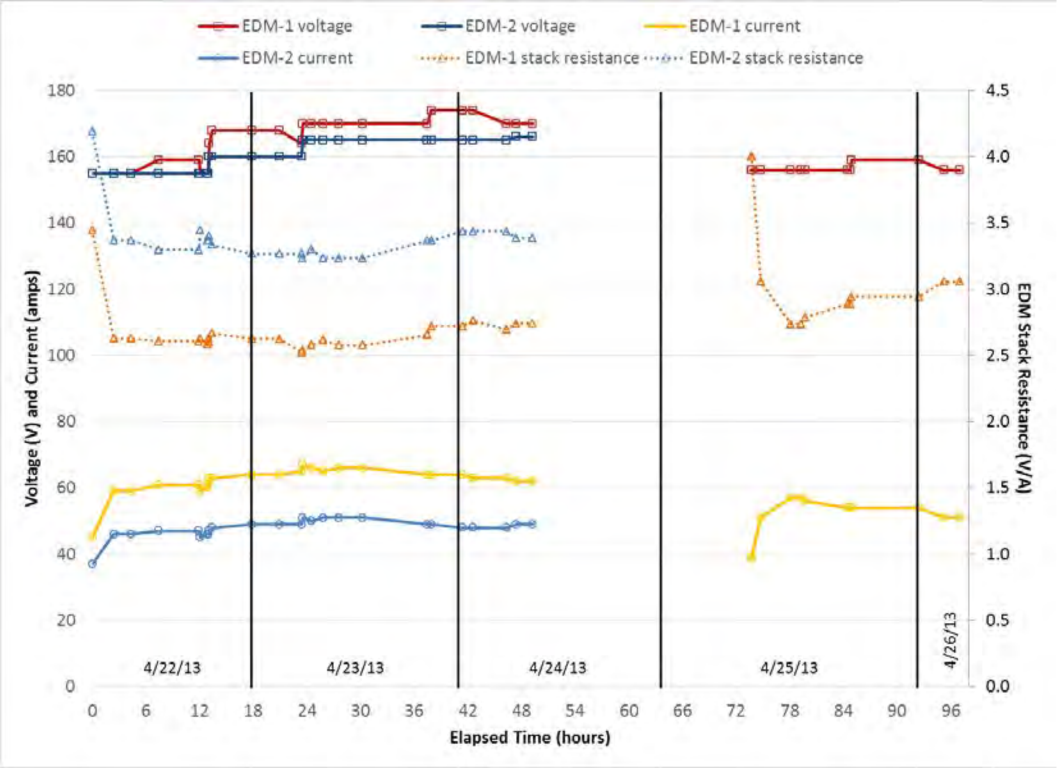

**Figure B2-39.—EDM voltage, current, stack resistance (experiments 1a + 1b).**
*Datalogger failed during this period. Data was recorded on logsheets from online meters, probes, and gauges.*

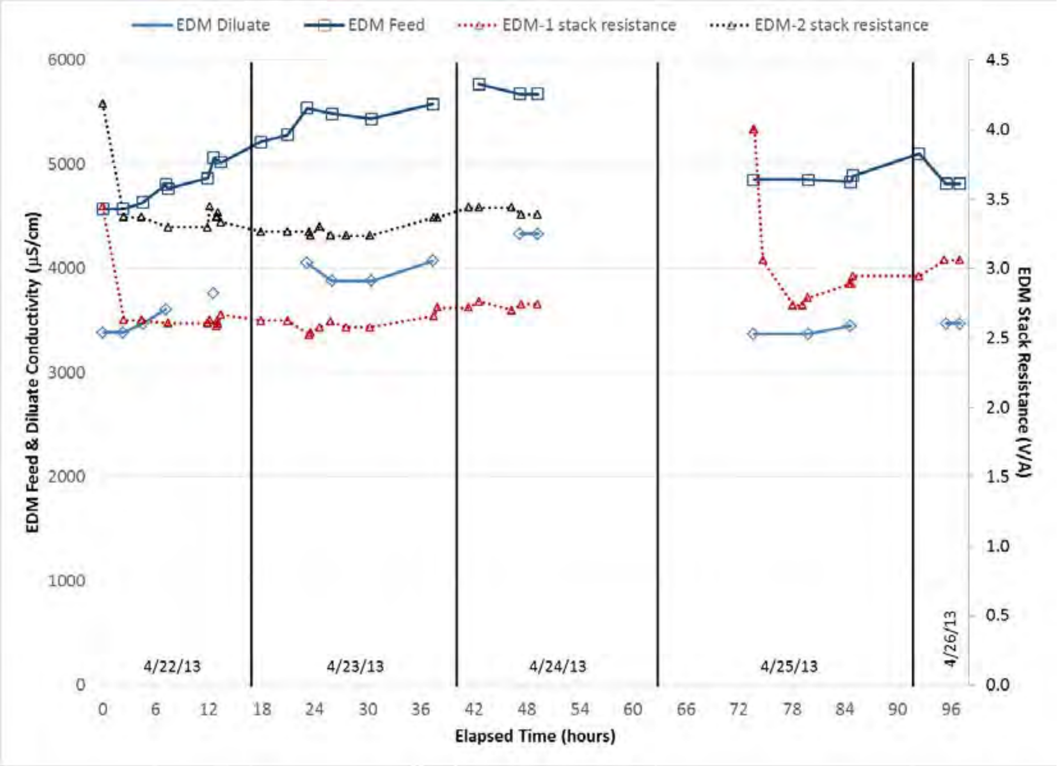

**Figure B2-40.—EDM diluate conductivity and stack resistance (experiments 1a + 1b).**
*Datalogger failed during this period. Data was recorded on logsheets from online meters, probes, and gauges.*

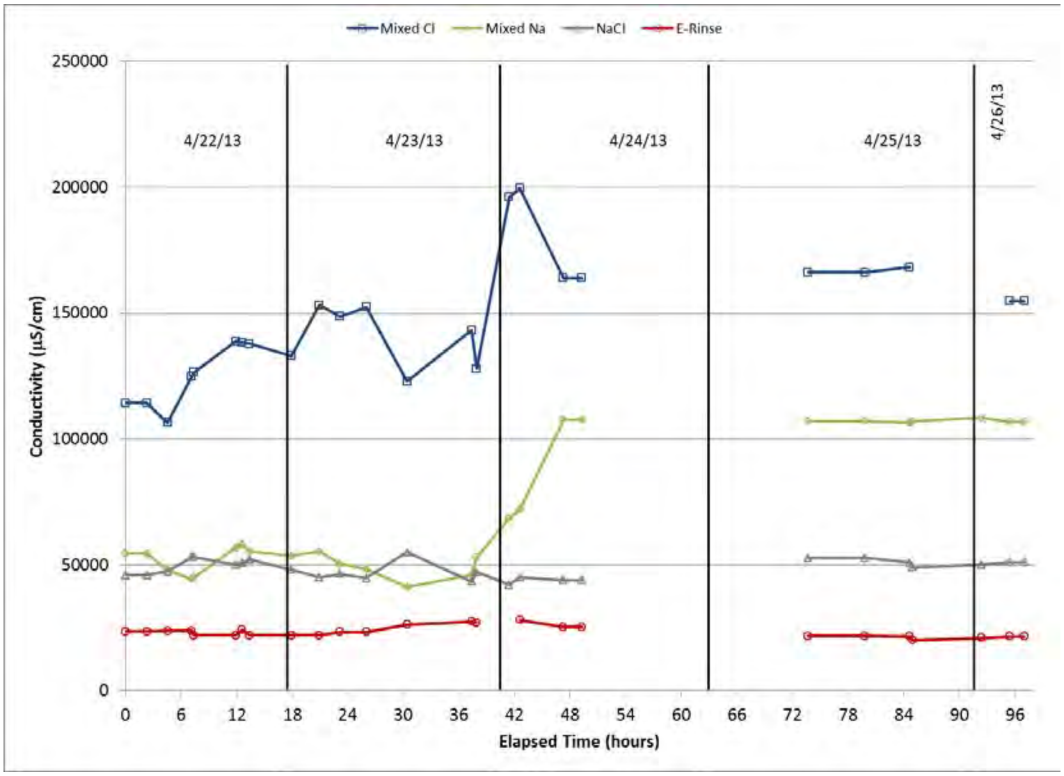

**Figure B2-41.—High concentration EDM stream conductivity (experiments 1a + 1b).**
*(note: Mixed Cl & Mixed Na are not calibrated or scaled)*
*Datalogger failed during this period. Data was recorded on logsheets from online meters, probes, and gauges.*

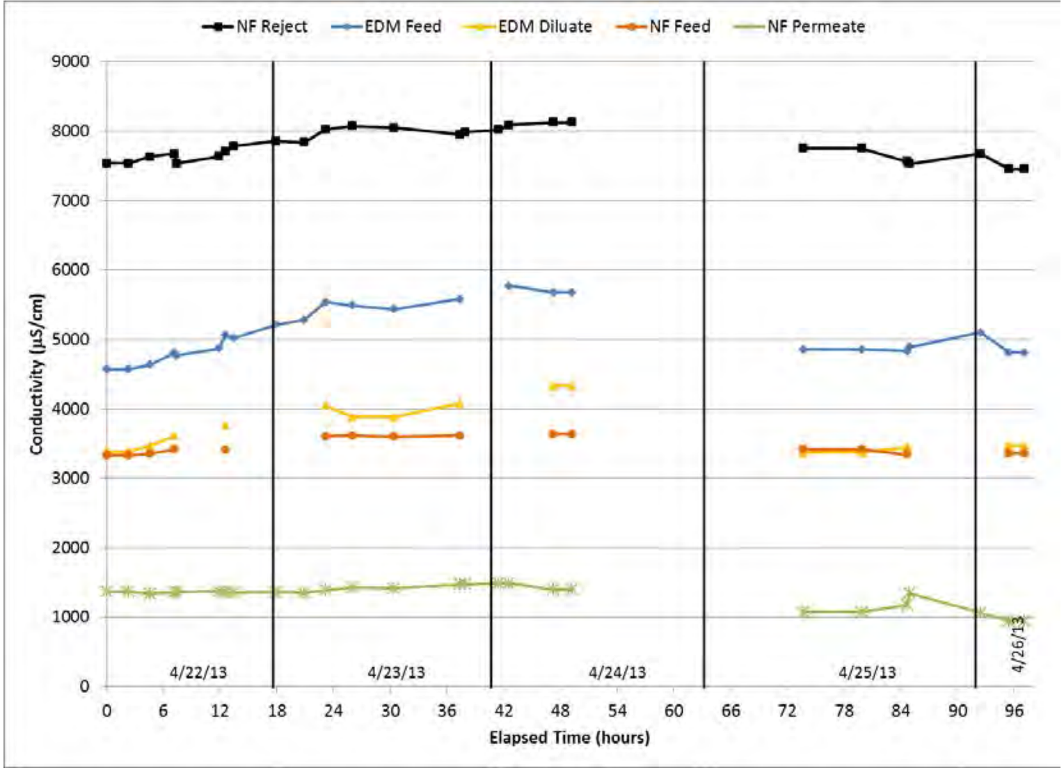

**Figure B2-42.—Low concentration EDM stream conductivity (experiments 1a + 1b).**
*Datalogger failed during this period. Data was recorded on logsheets from online meters, probes, and gauges.*

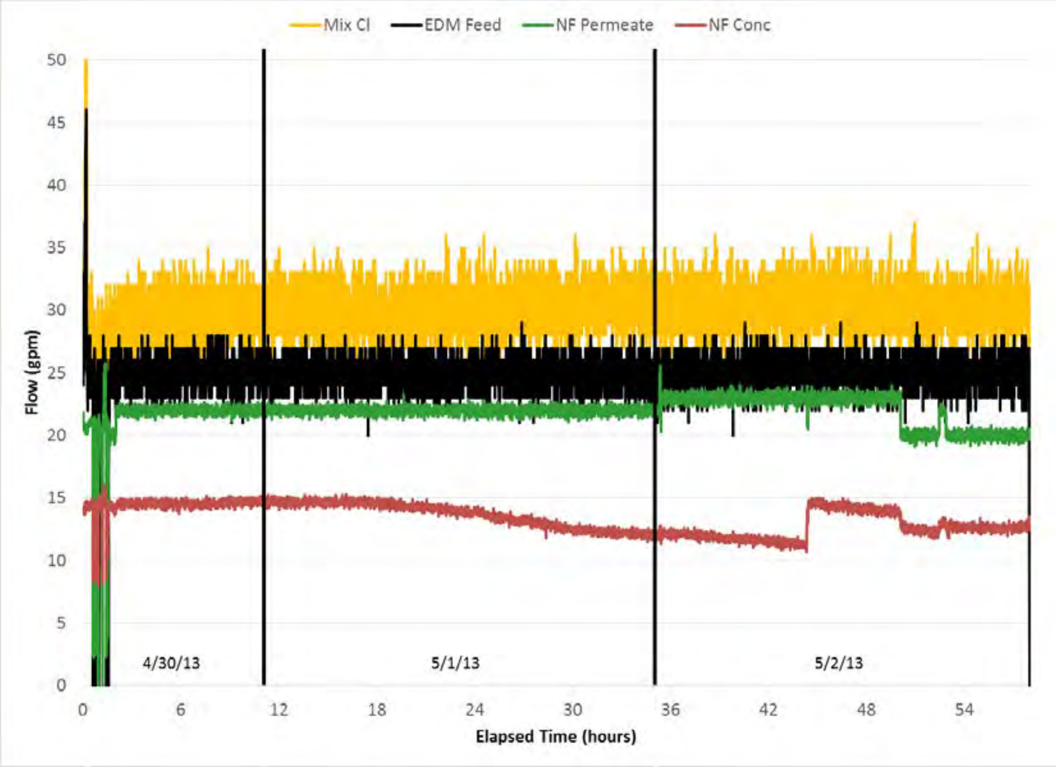

Figure B2-43.—EDM stream flows (experiment 2).

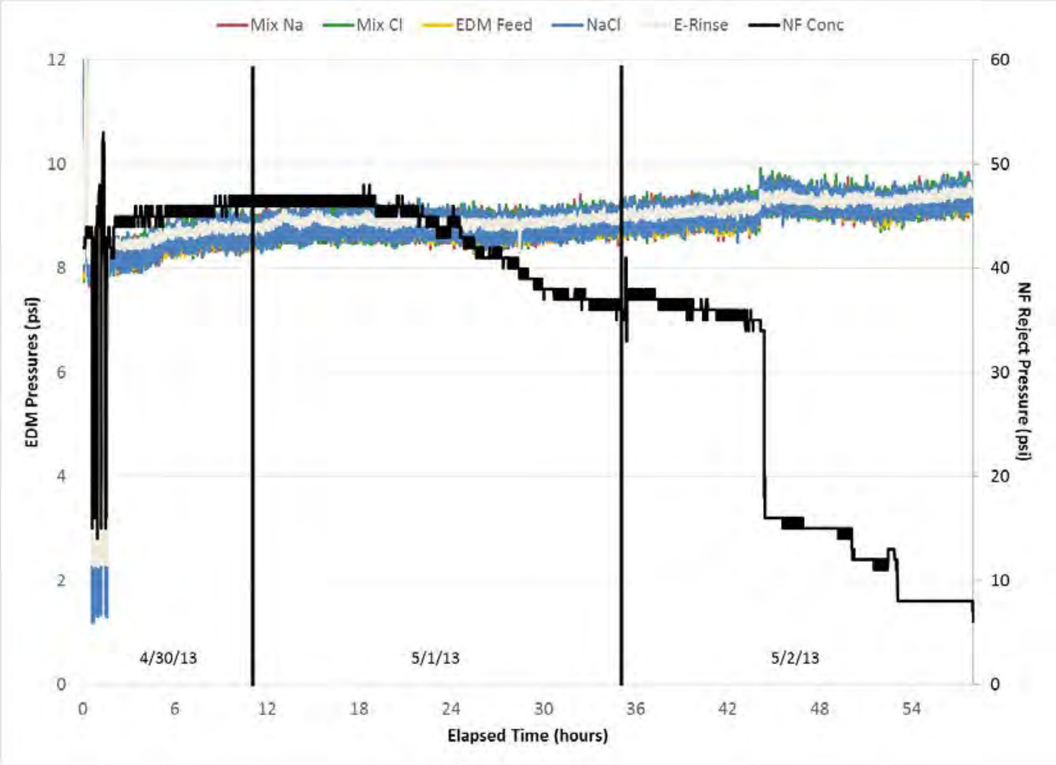

Figure B2-44.—EDM and NF reject stream pressures (experiment 2).

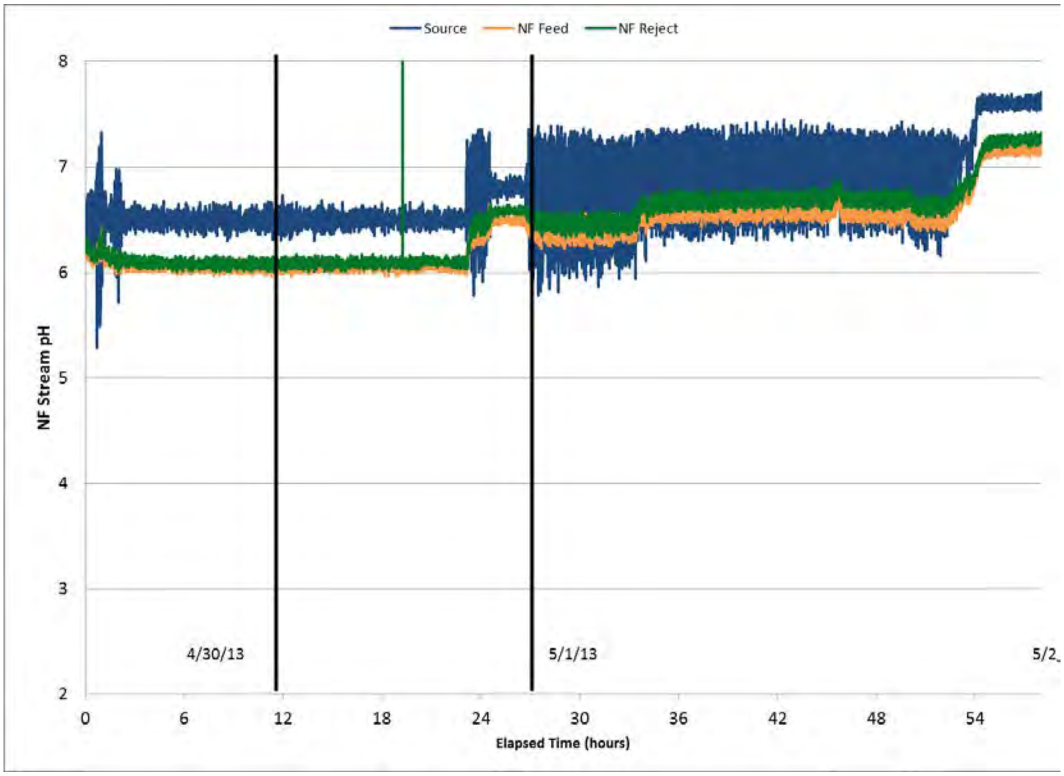

Figure B2-45.—NF stream pH (experiment 2).

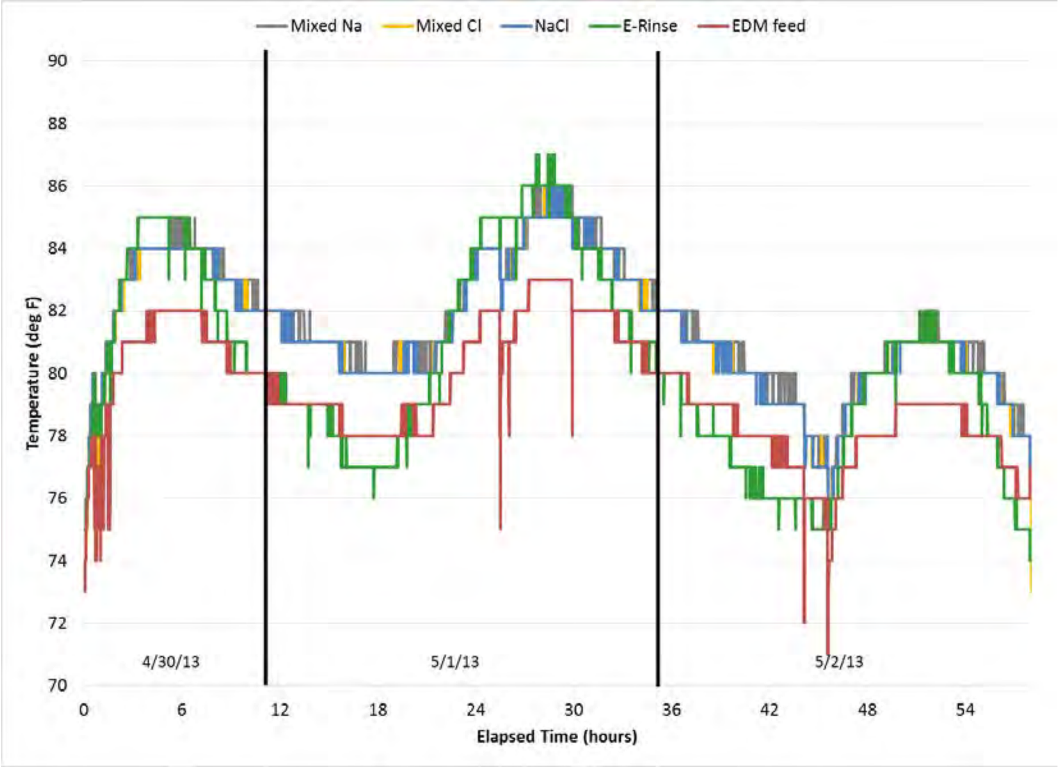

Figure B2-46.—EDM stream temperature (experiment 2)

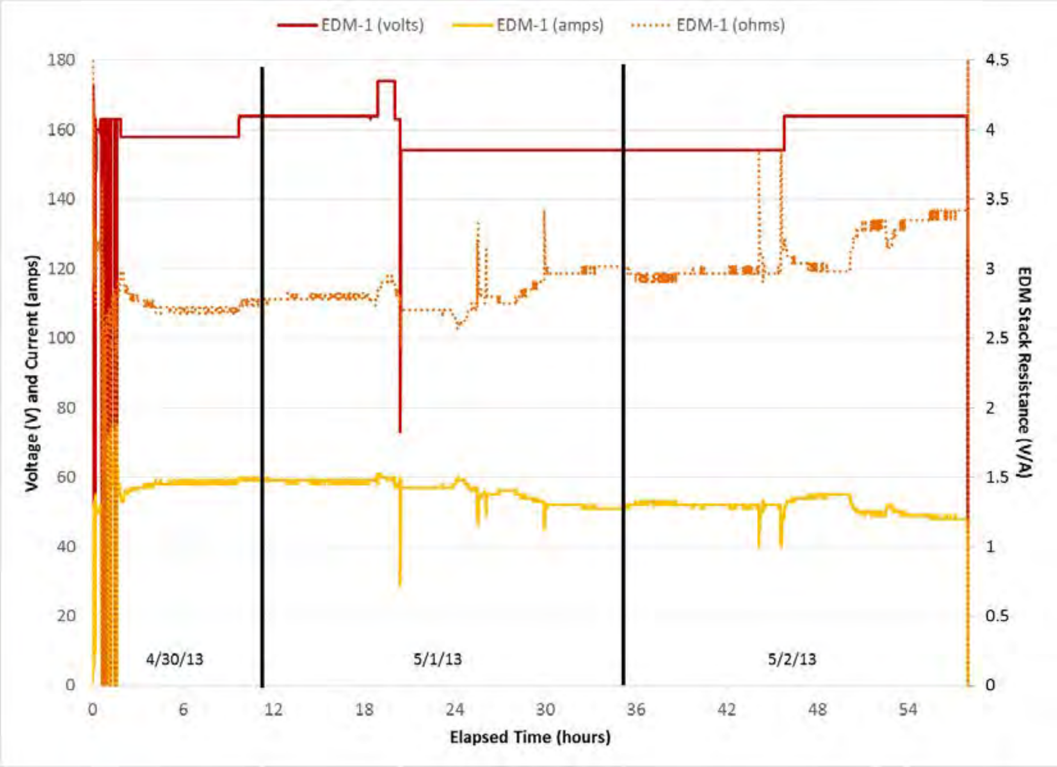

Figure B2-47.—EDM voltage, current, stack resistance (experiment 2).

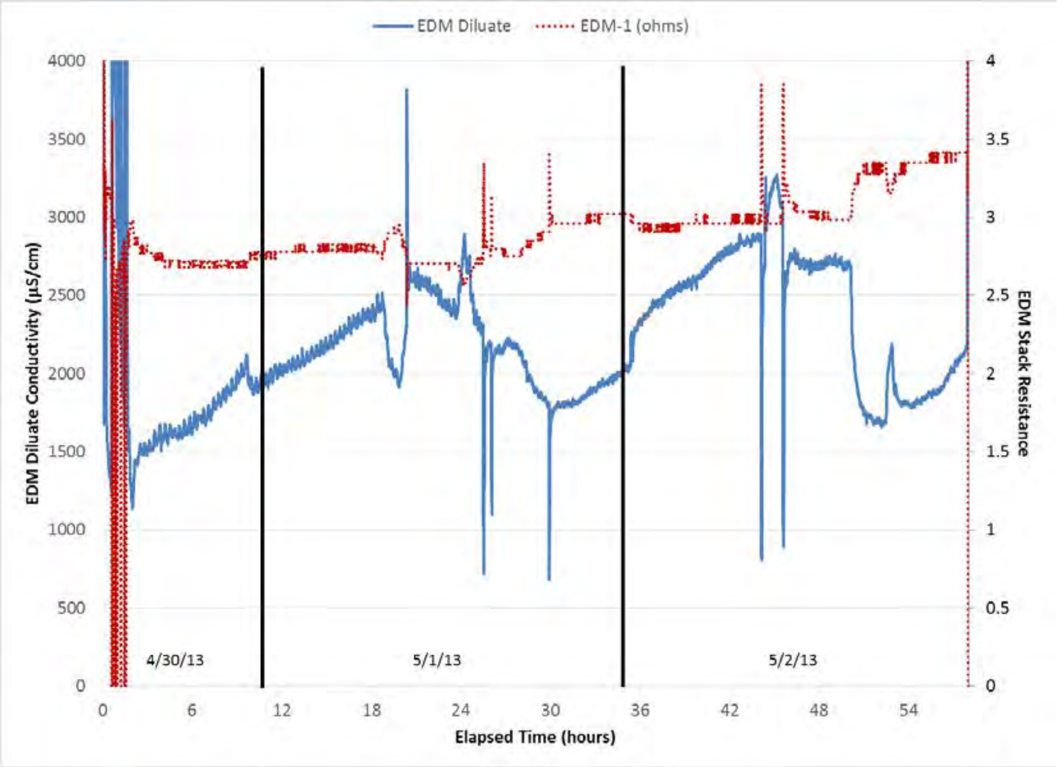

Figure B2-48.—EDM diluate conductivity and stack resistance (experiment 2).

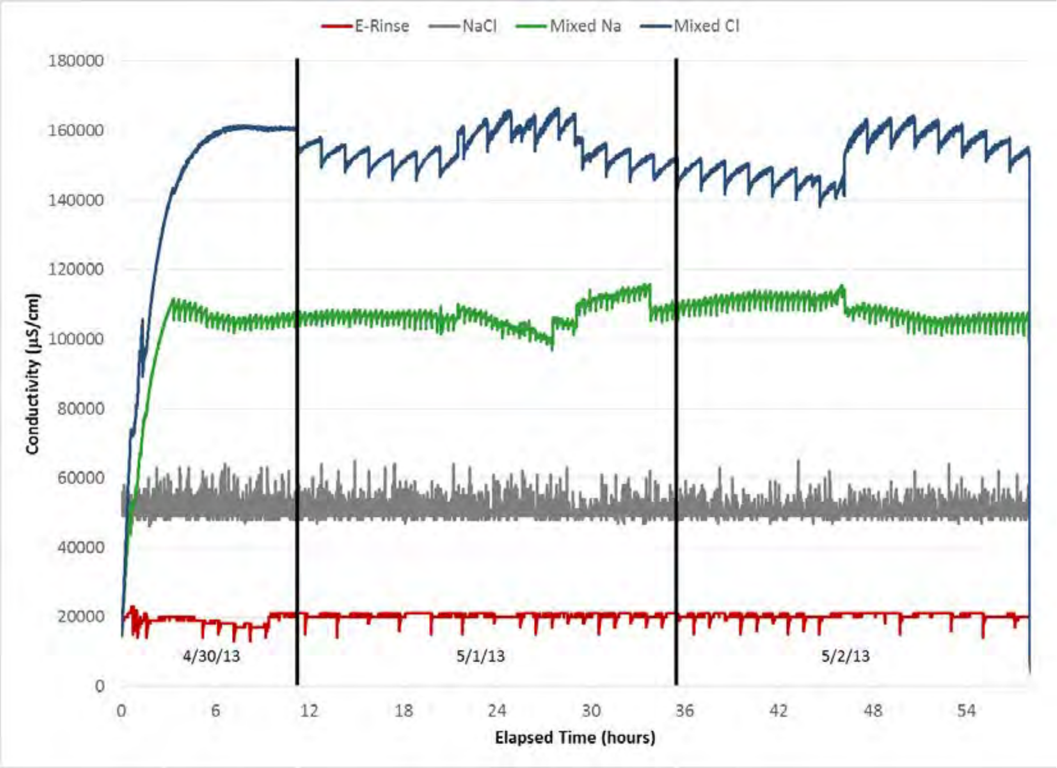

Figure B2-49.—High concentration EDM stream conductivity (experiment 2).

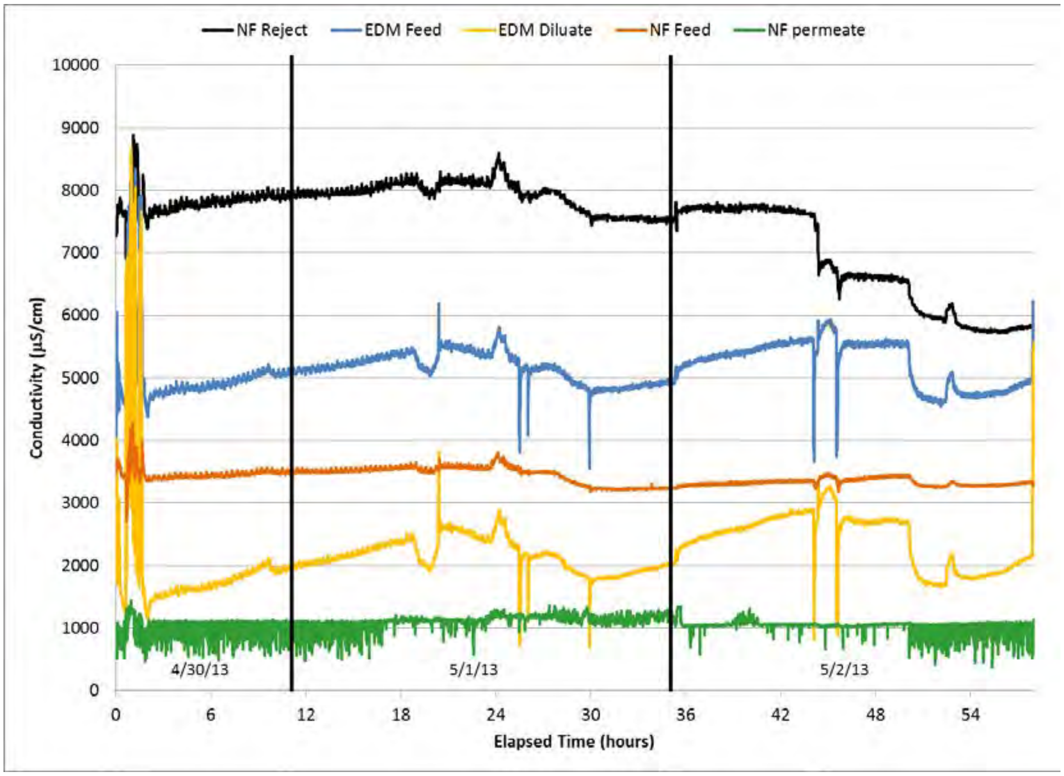

Figure B2-50.—Low concentration EDM stream conductivity (experiment 2).

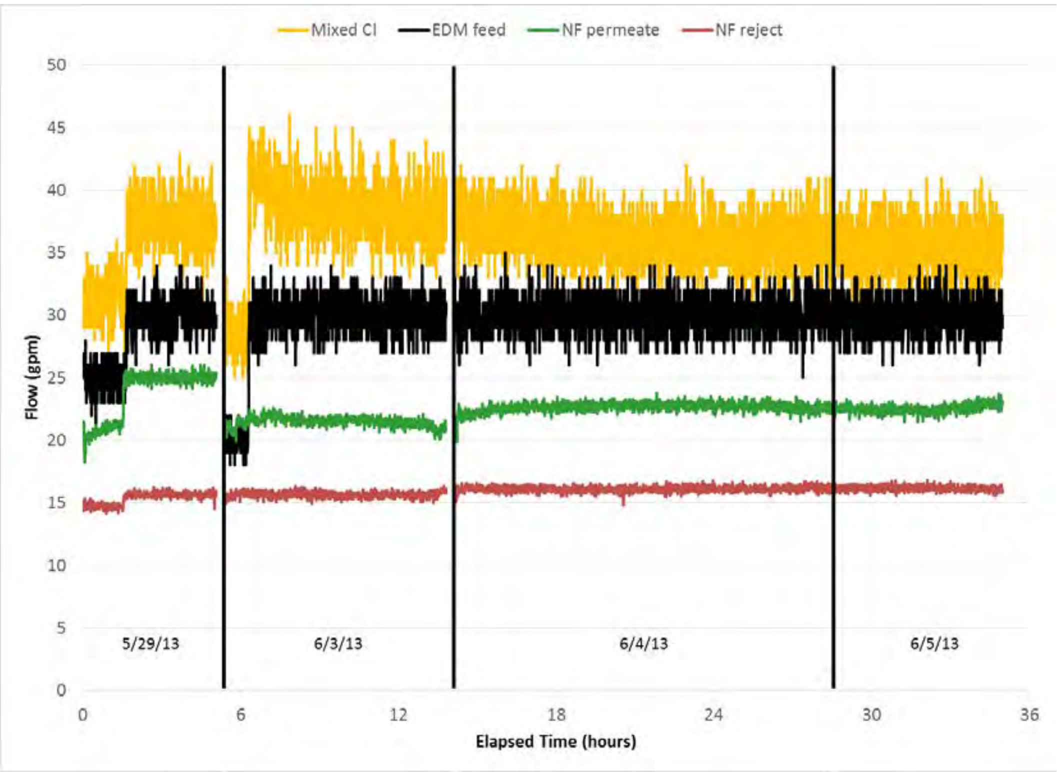

Figure B2-51.—EDM stream flows (experiment 3).

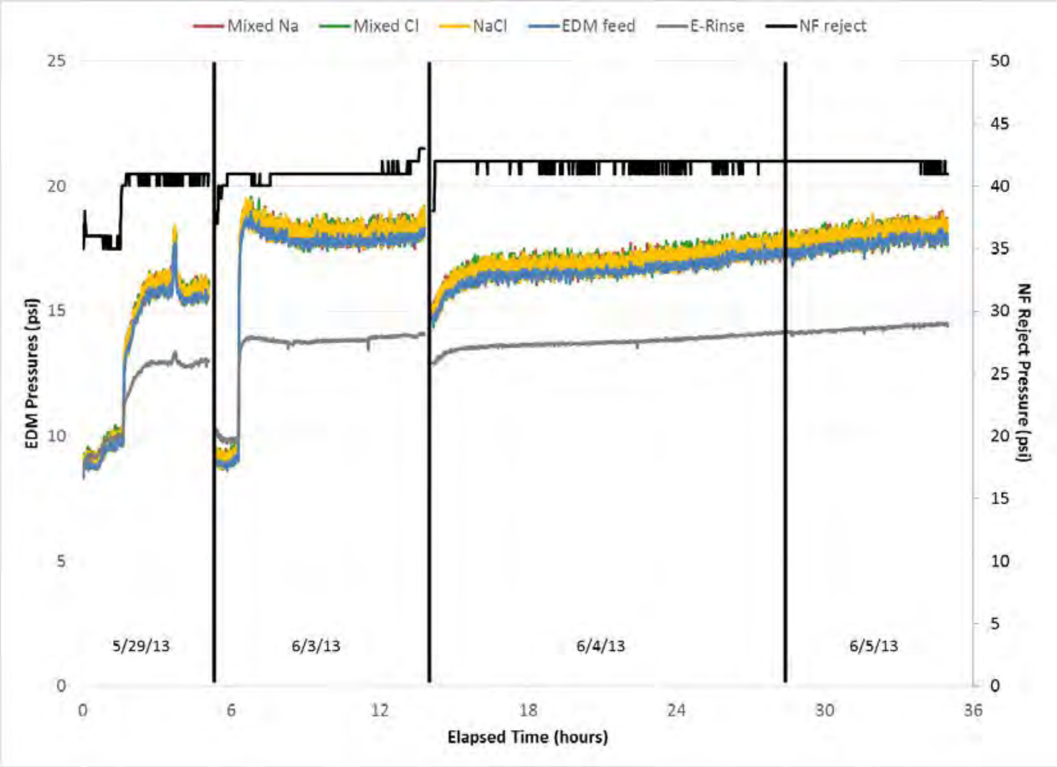

Figure B2-52.—EDM and NF reject stream pressures (experiment 3).

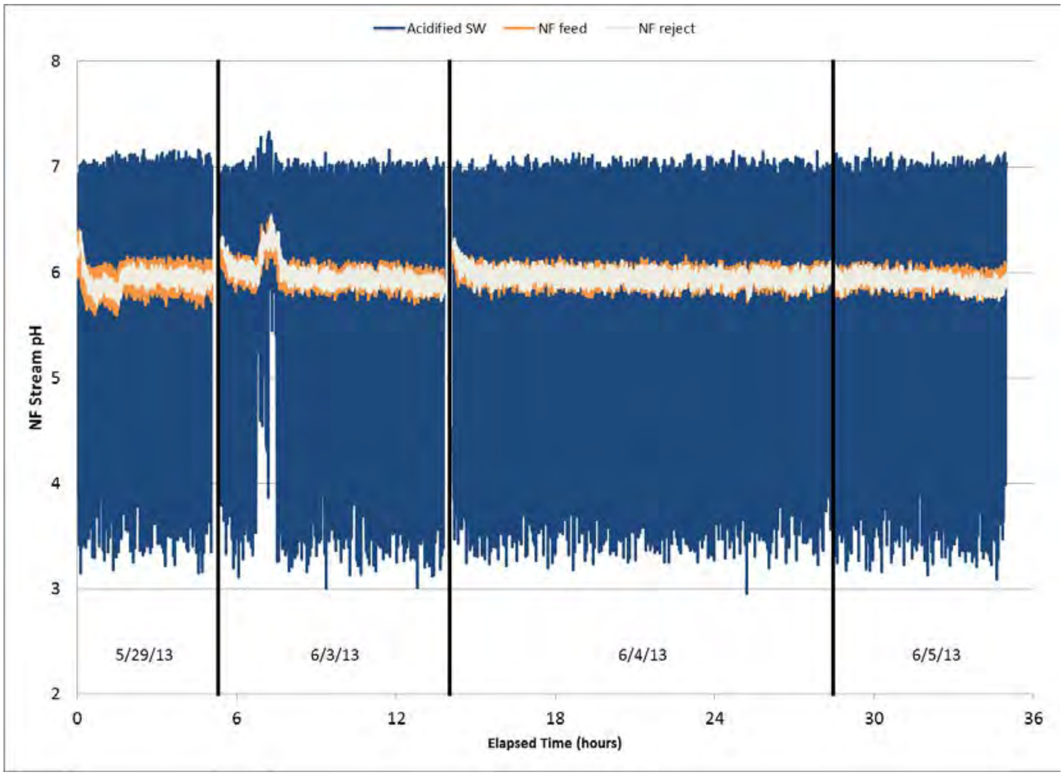

**Figure B2-53.—NF stream pH experiment 3).**
*(note: 93% $H_2SO_4$ added at this point. pH control not modifiable in the field, which increased variation in pH.)*

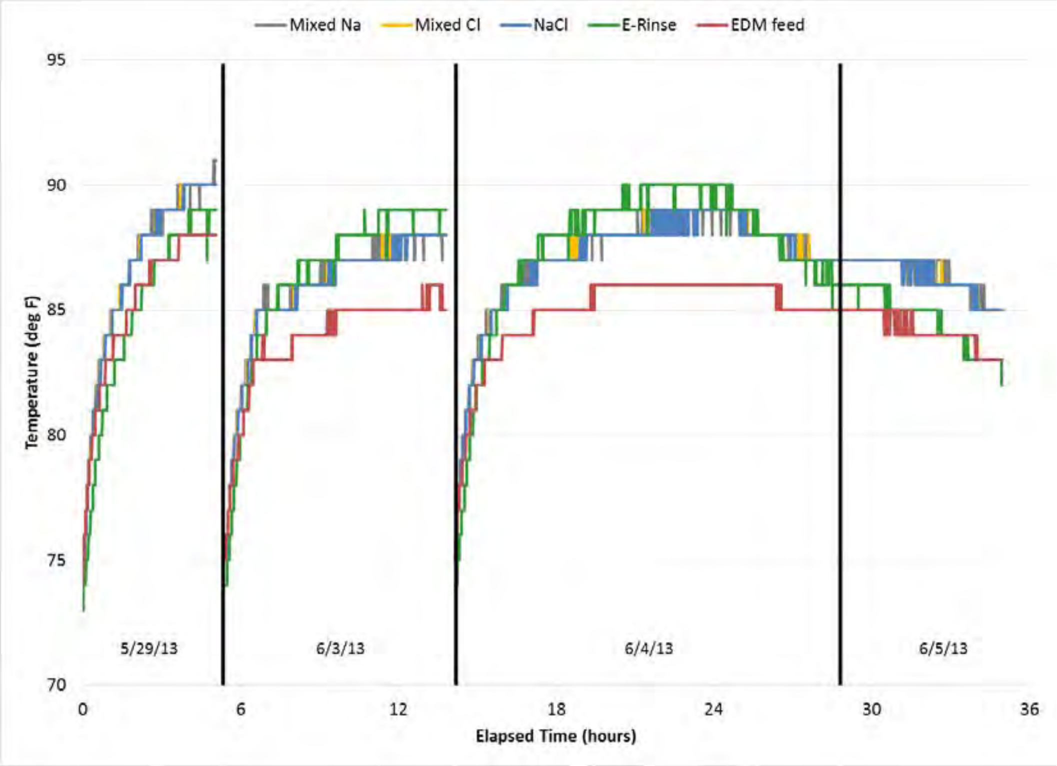

**Figure B2-54.—EDM stream temperature (experiment 3).**

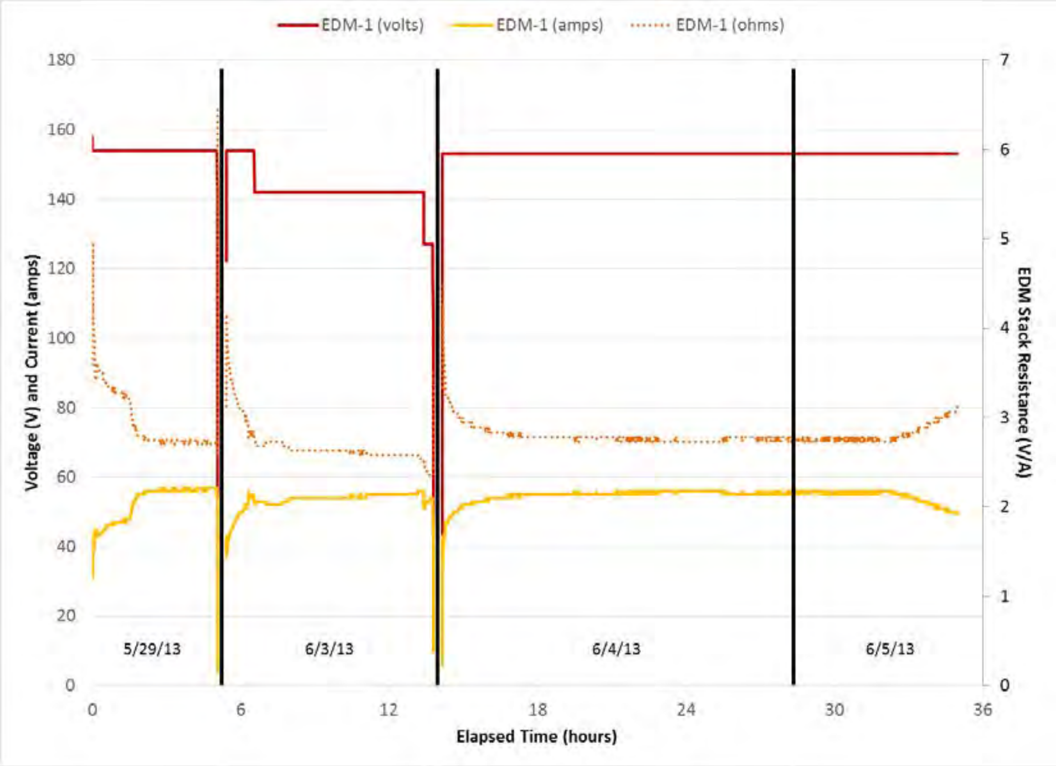

Figure B2-55.—EDM voltage, current, stack resistance (experiment 3).

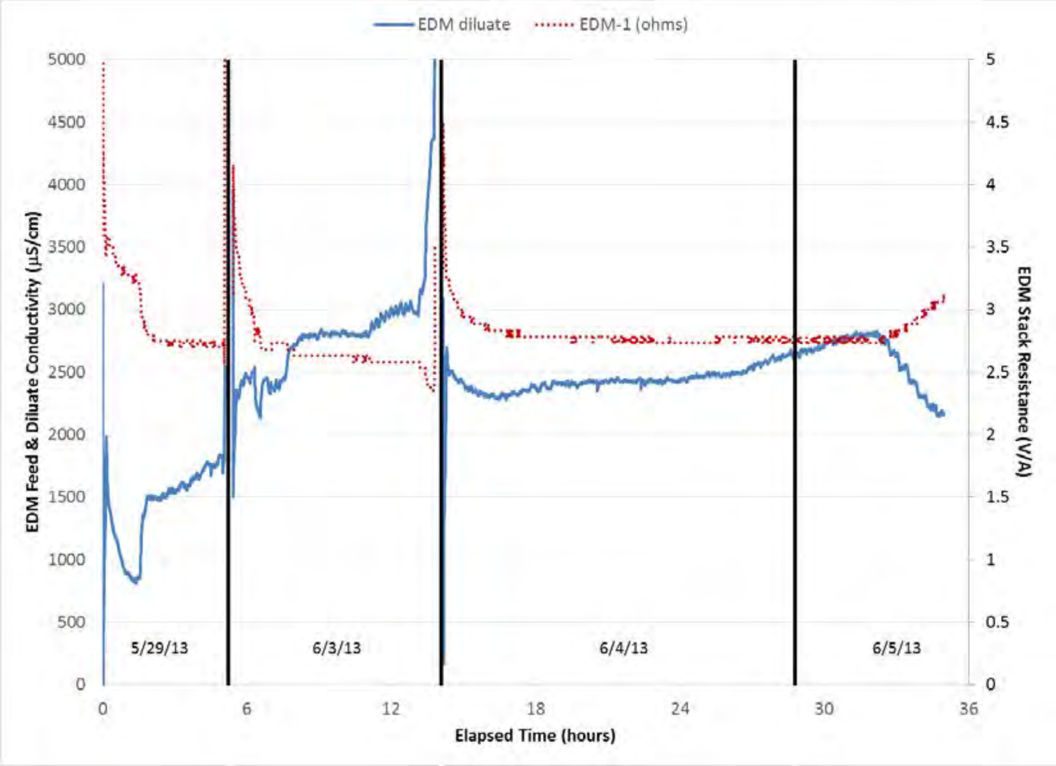

Figure B2-56.—EDM diluate conductivity and stack resistance (experiment 3).

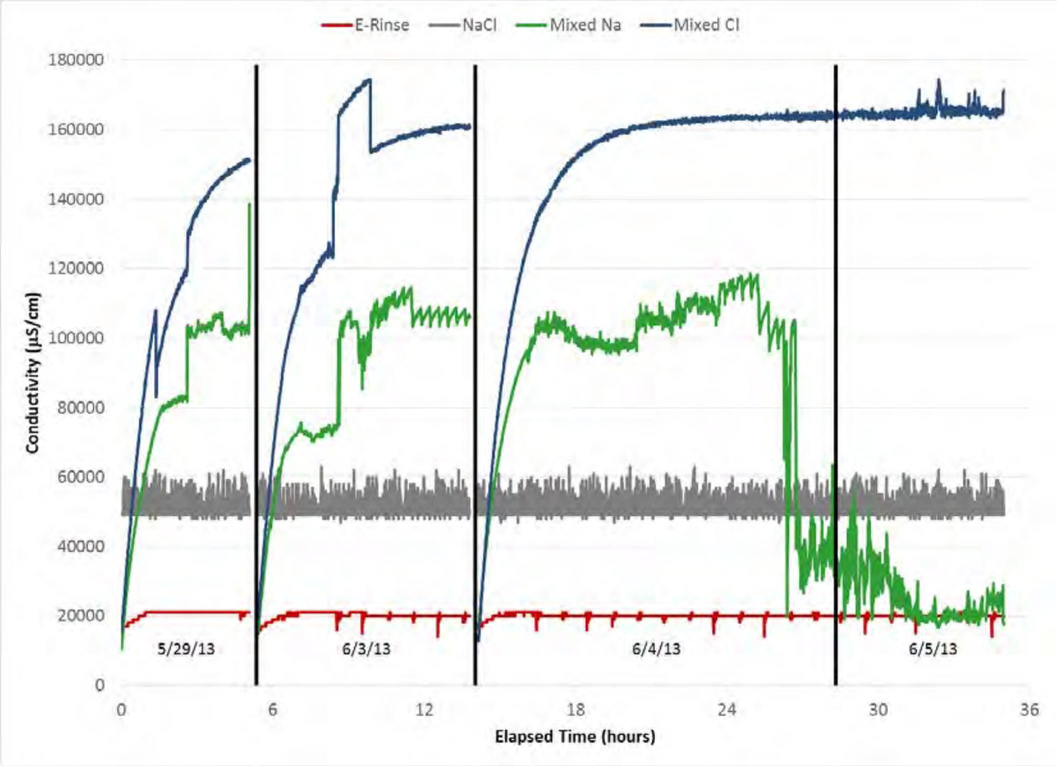

**Figure B2-57.—High concentration EDM stream conductivity (experiment 3).**
*(note: Mixed Na not calibrated or scaled after 6/4/13).*

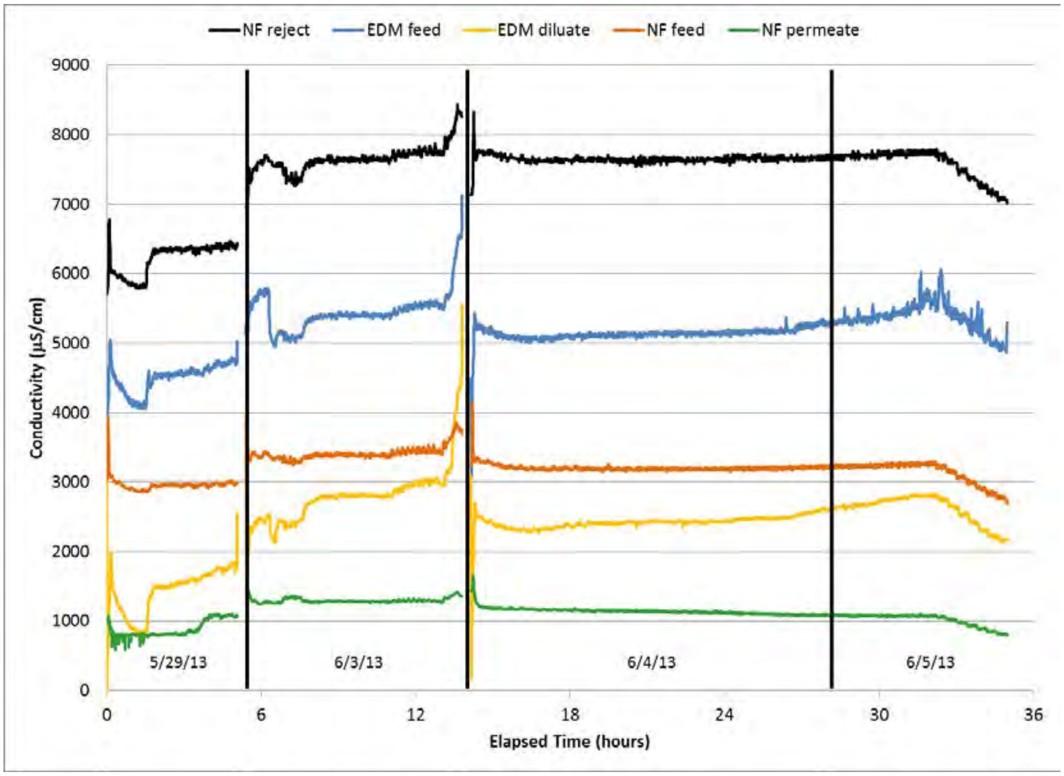

**Figure B2-58.—Low concentration EDM stream conductivity (experiment 3).**

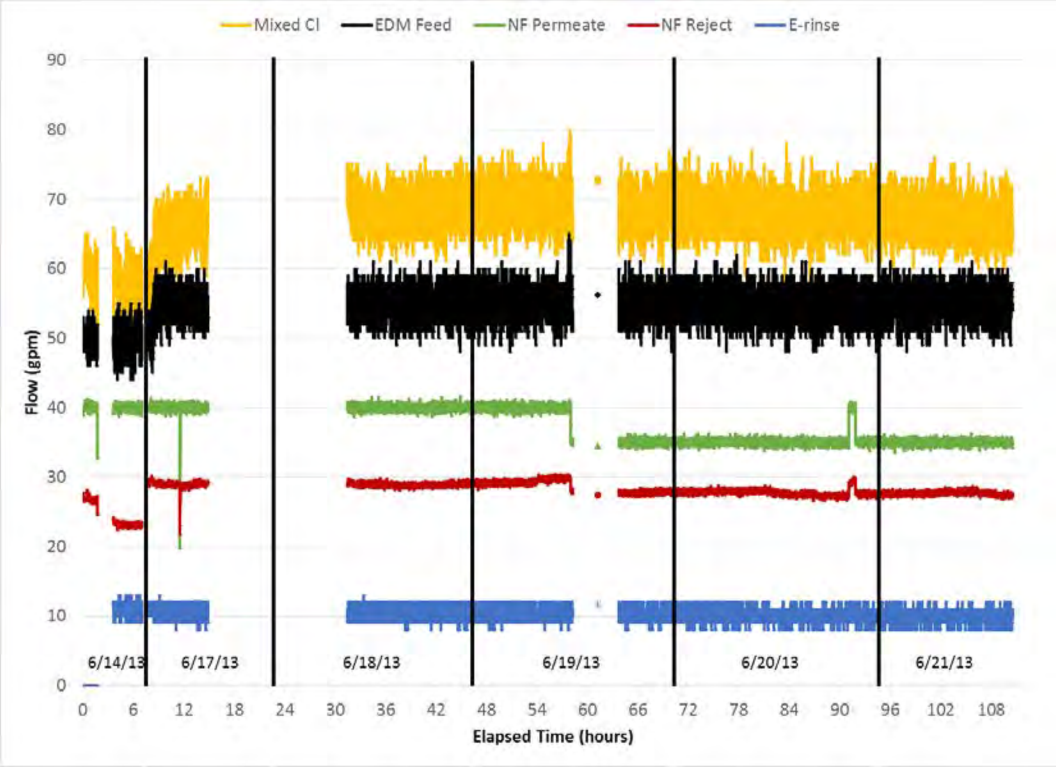

**Figure B2-59.—EDM stream flows (experiment 4).**
*Datalogger failed on 6/19/13. Data was recorded on logsheets from online meters, probes, and gauges.*

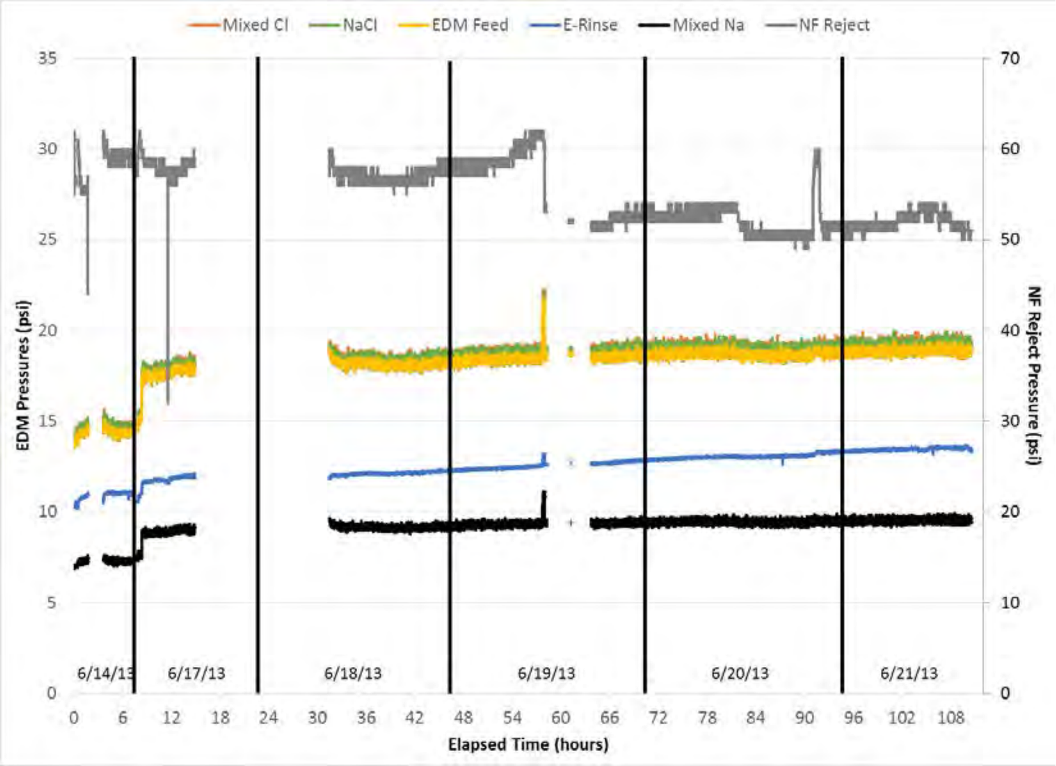

**Figure B2-60.—EDM and NF reject stream pressures (experiment 4).**
*Datalogger failed on 6/19/13. Data was recorded on logsheets from online meters, probes, and gauges.*

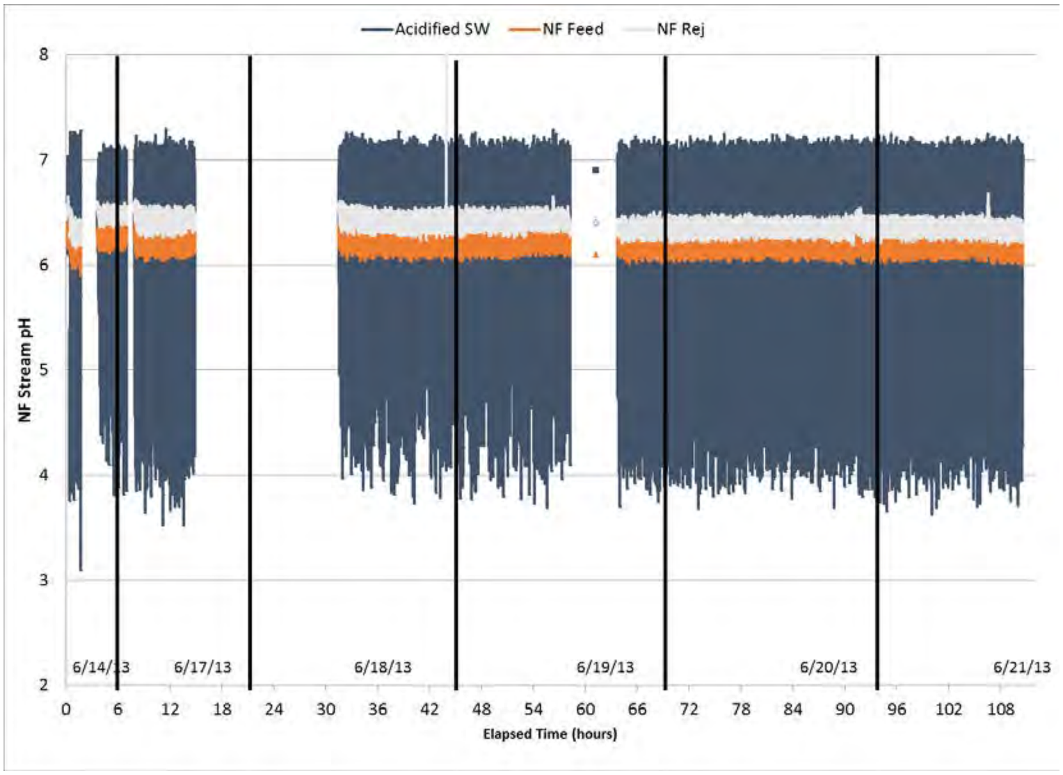

**Figure B2-61.—NF stream pH (experiment 4).**

*Datalogger failed on 6/19/13. Data was recorded on logsheets from online meters, probes, and gauges.*
*Note: 93% $H_2SO_4$ added at this point. pH control not modifiable in the field, which increased variation in pH*

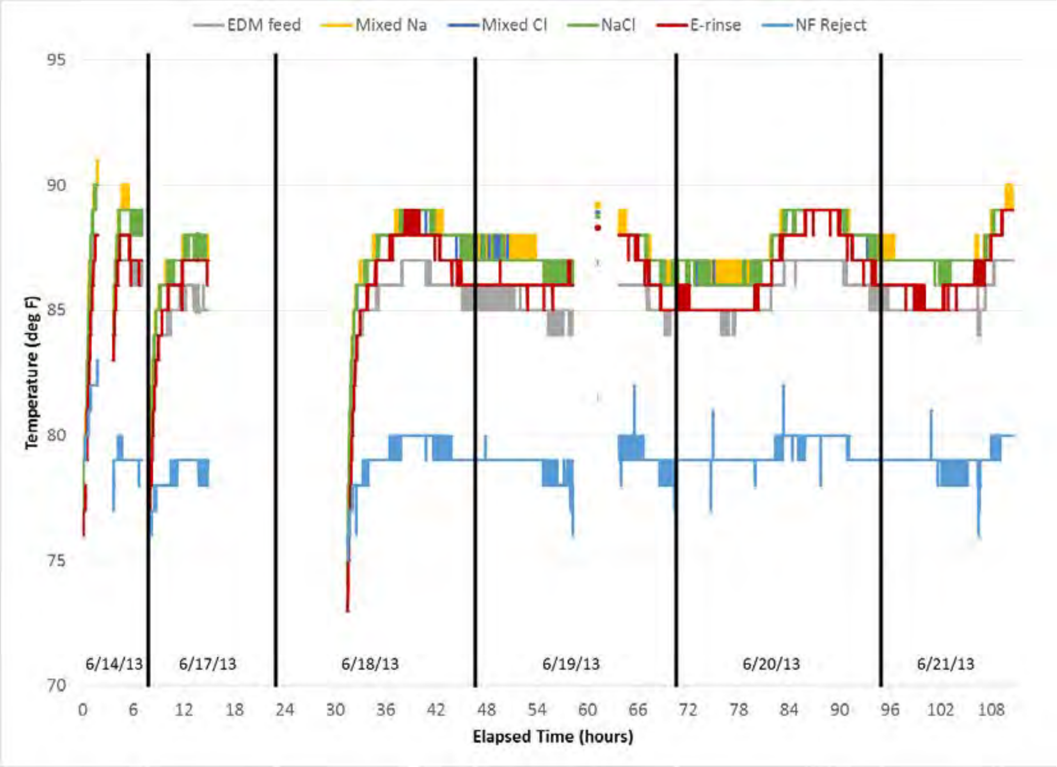

**Figure B2-62.—EDM stream temperature (experiment 4).**
*Datalogger failed on 6/19/13. Data was recorded on logsheets from online meters, probes, and gauges.*

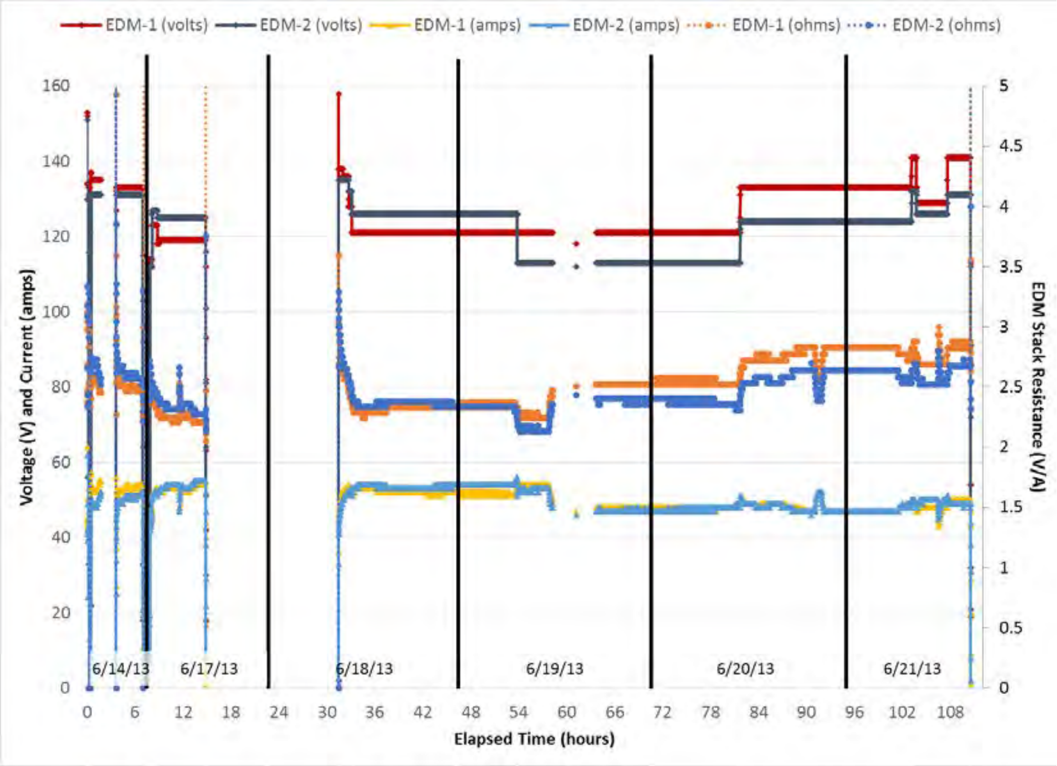

**Figure B2-63.—EDM voltage, current, stack resistance (experiment 4).**
*Datalogger failed on 6/19/13. Data was recorded on logsheets from online meters, probes, and gauges.*

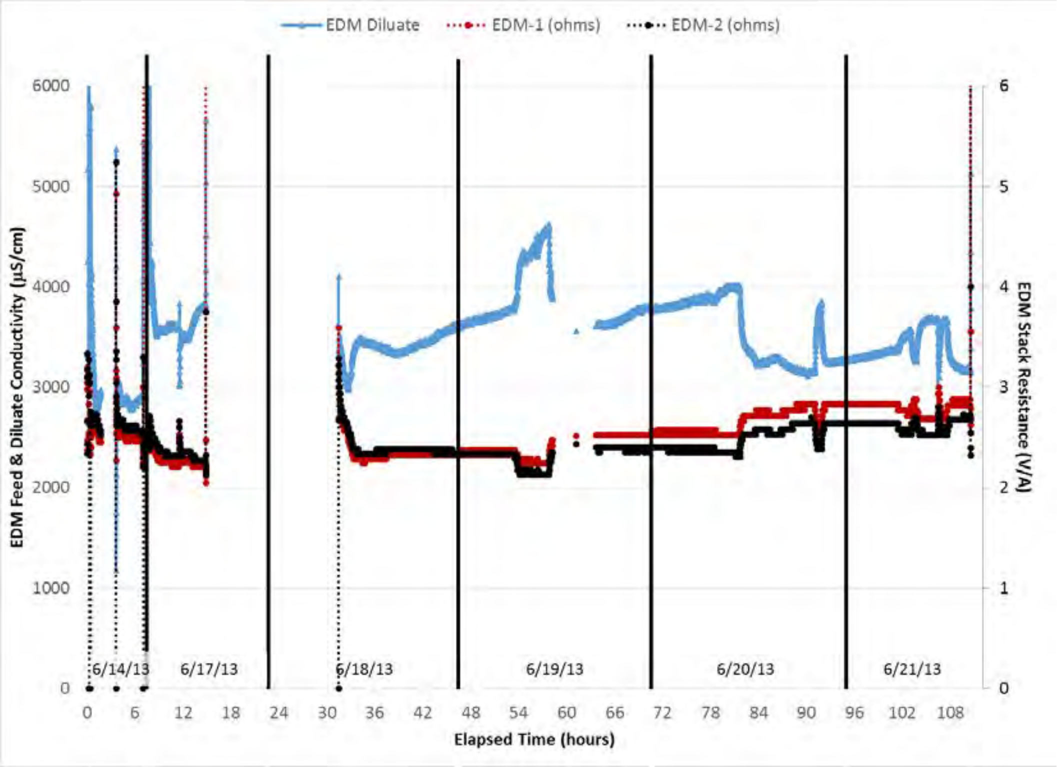

**Figure B2-64.—EDM diluate conductivity and stack resistance (experiment 4).**

*Datalogger failed on 6/19/13. Data was recorded on logsheets from online meters, probes, and gauges.*

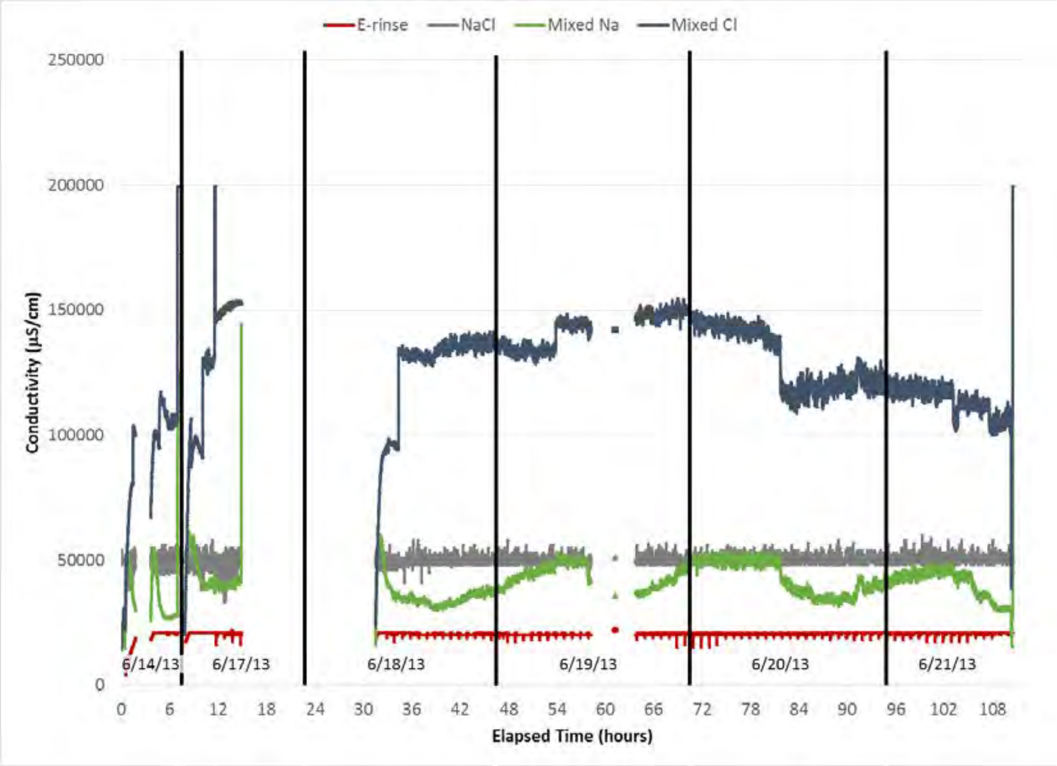

**Figure B2-65.—High concentration EDM stream conductivity (experiment 4).**

*(note: Mixed Cl & Mixed Na are not calibrated or scaled)*

*Datalogger failed on 6/19/13. Data was recorded on logsheets from online meters, probes, and gauges.*

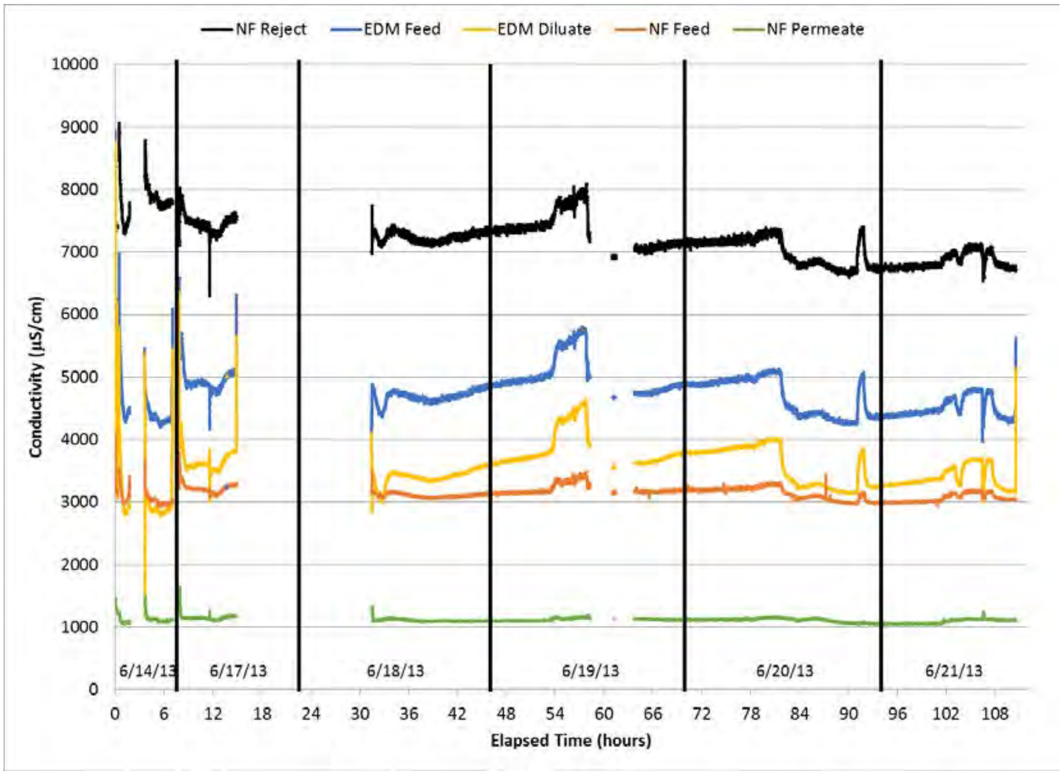

**Figure B2-66.—Low concentration EDM stream conductivity (experiment 4).**
*Datalogger failed on 6/19/13. Data was recorded on logsheets from online meters, probes, and gauges.*

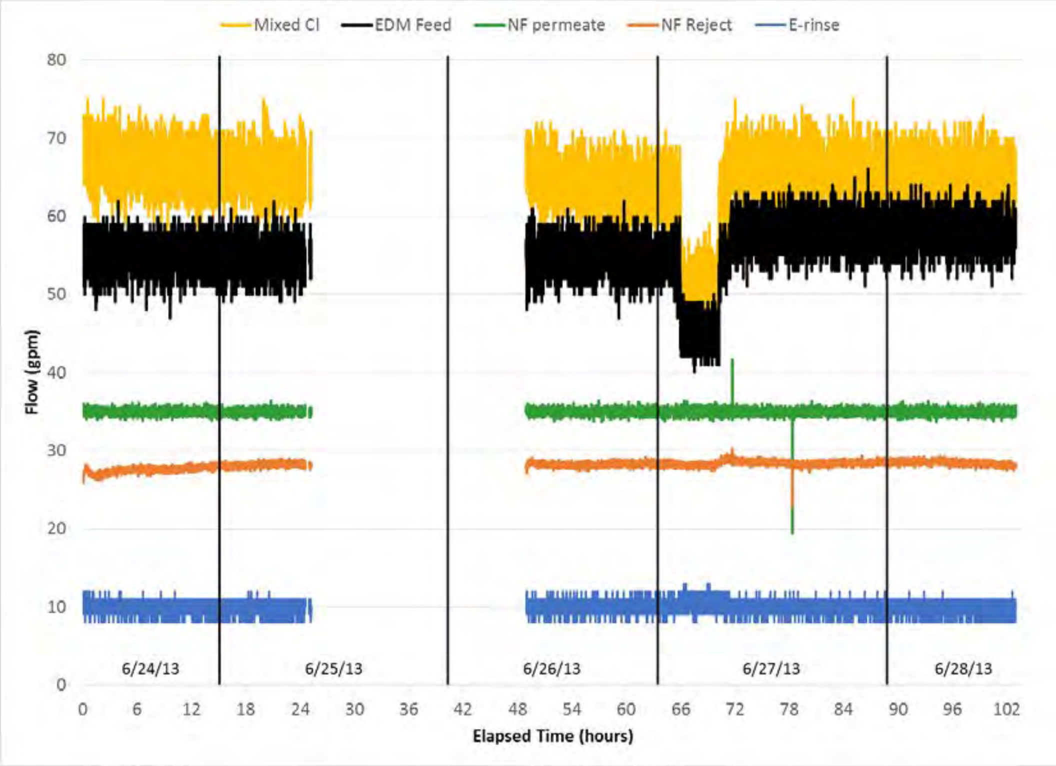

**Figure B2-67.—EDM stream flows (experiment 5).**

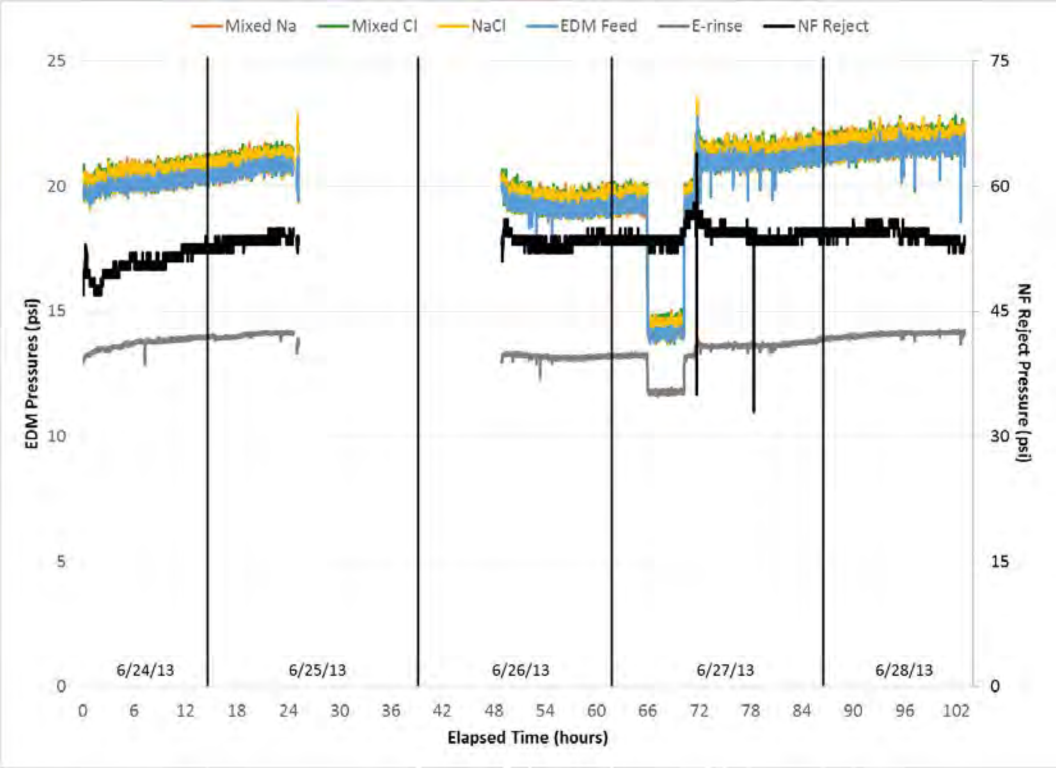

Figure B2-68.—EDM and NF reject stream pressures (experiment 5).

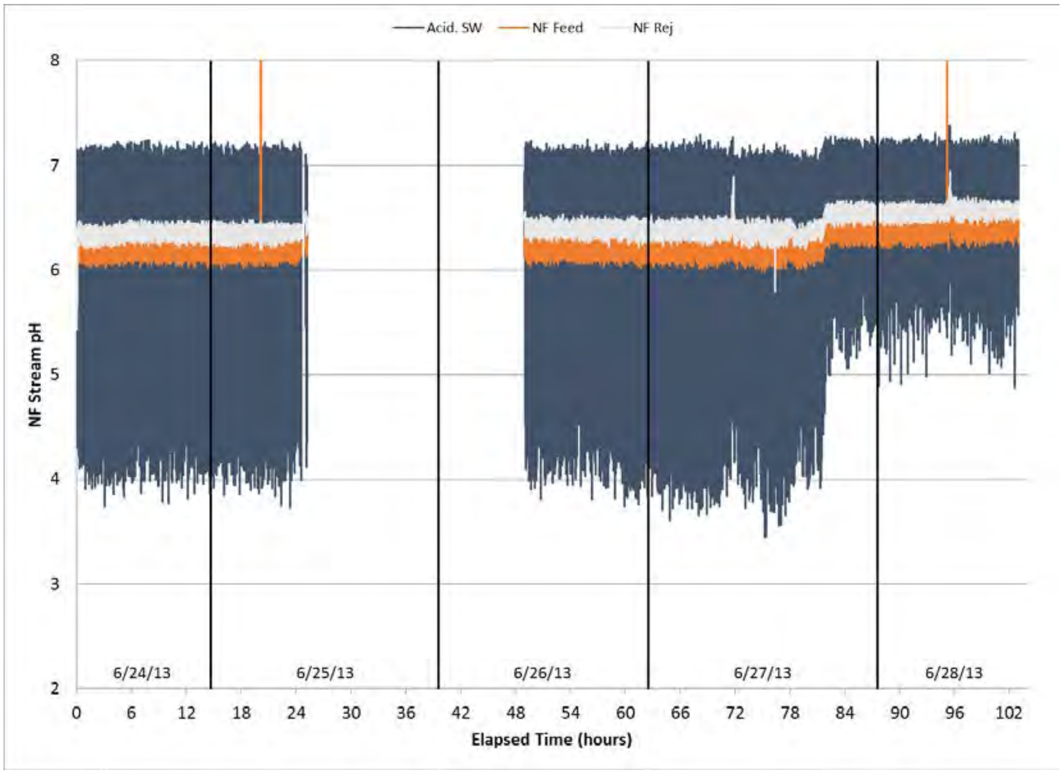

Figure B2-69.—NF stream pH (experiment 5).
*(vote: 93% $H_2SO_4$ added at this point. pH control not modifiable in the field, which increased variation in pH)*

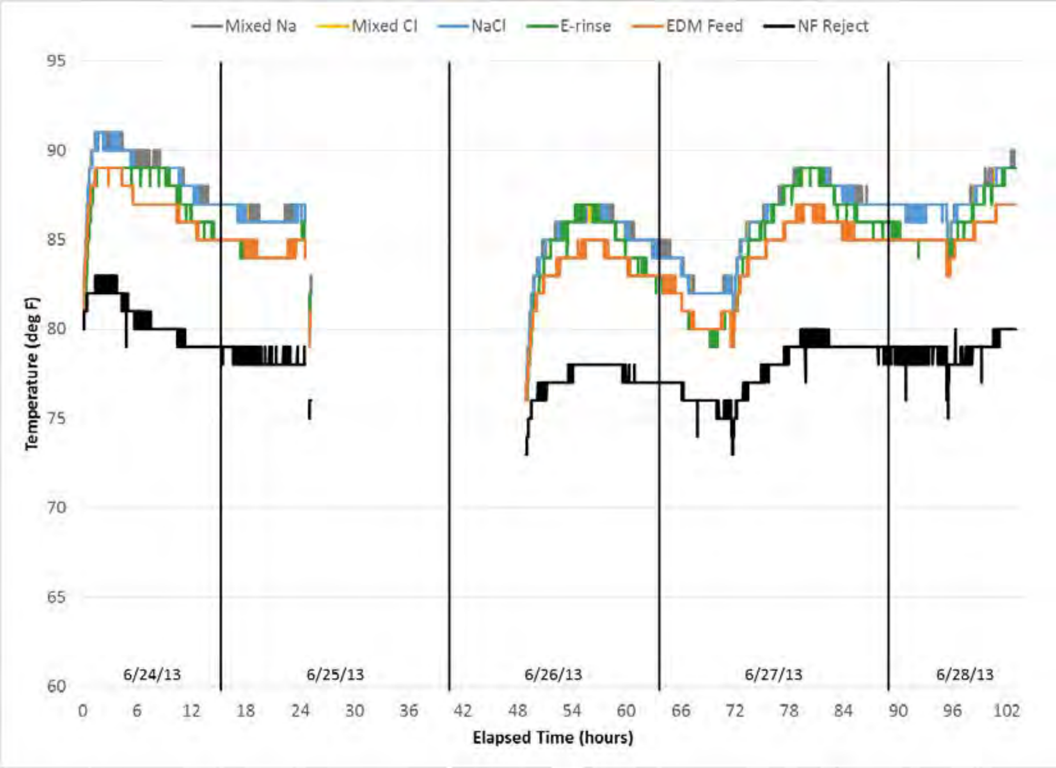

Figure B2-70.—EDM stream temperature (experiment 5).

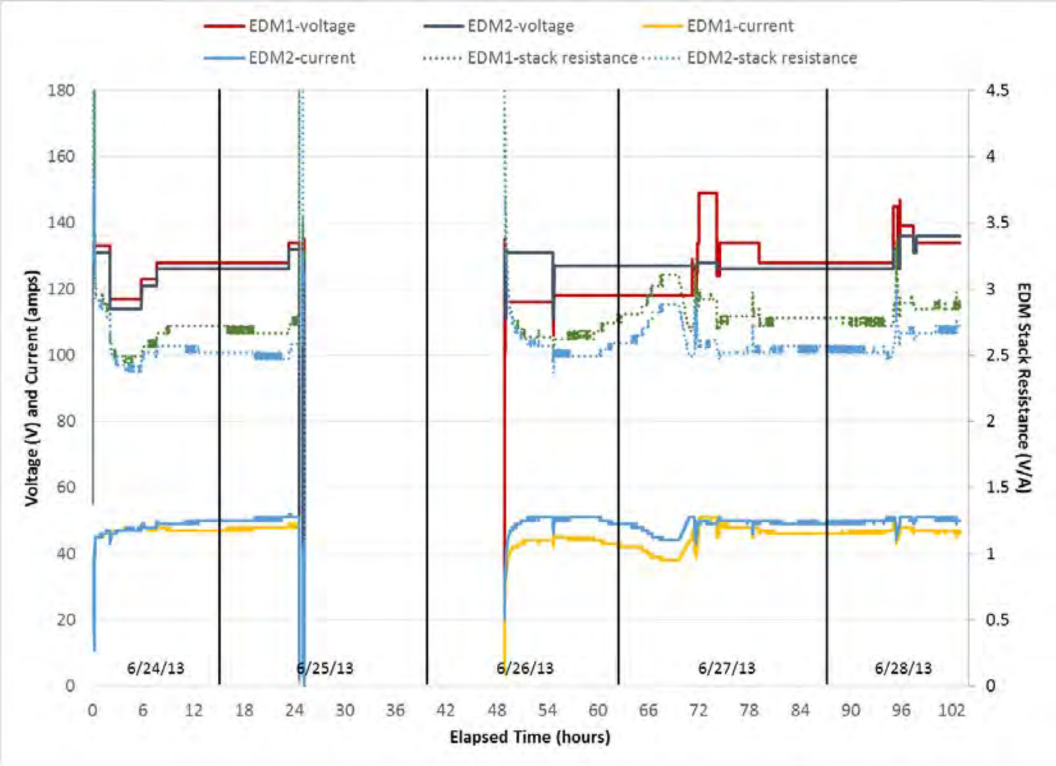

Figure B2-71.—EDM voltage, current, stack resistance (experiment 5).

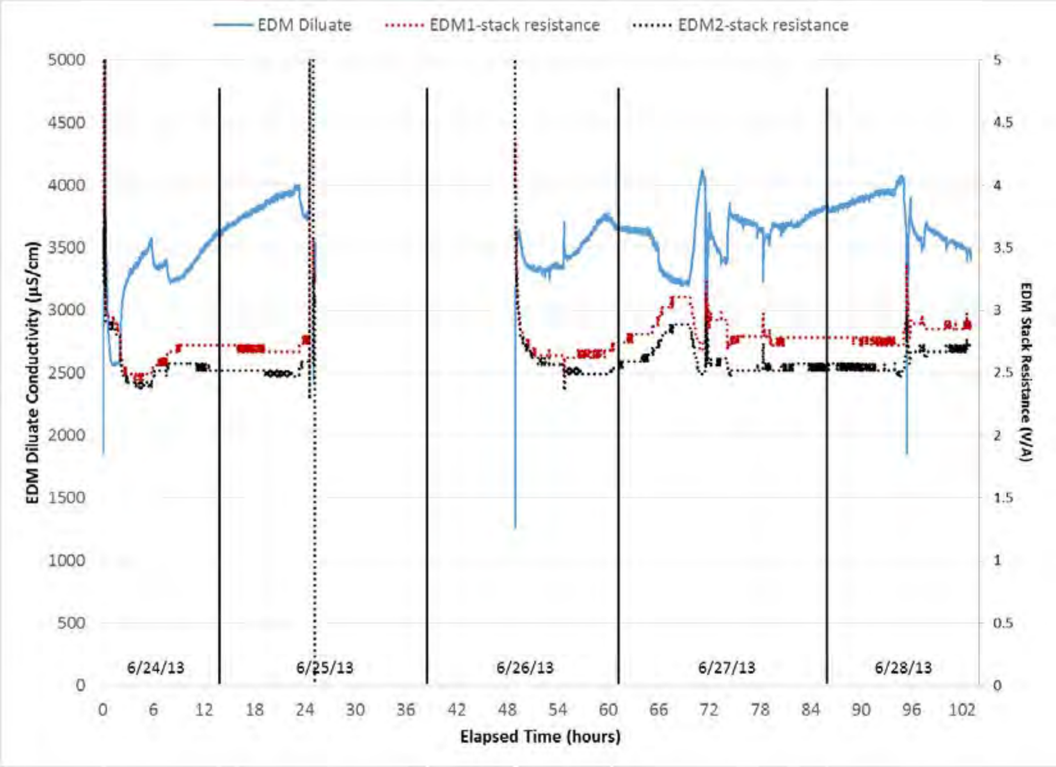

**Figure B2-72.—EDM diluate conductivity and stack resistance (experiment 5).**

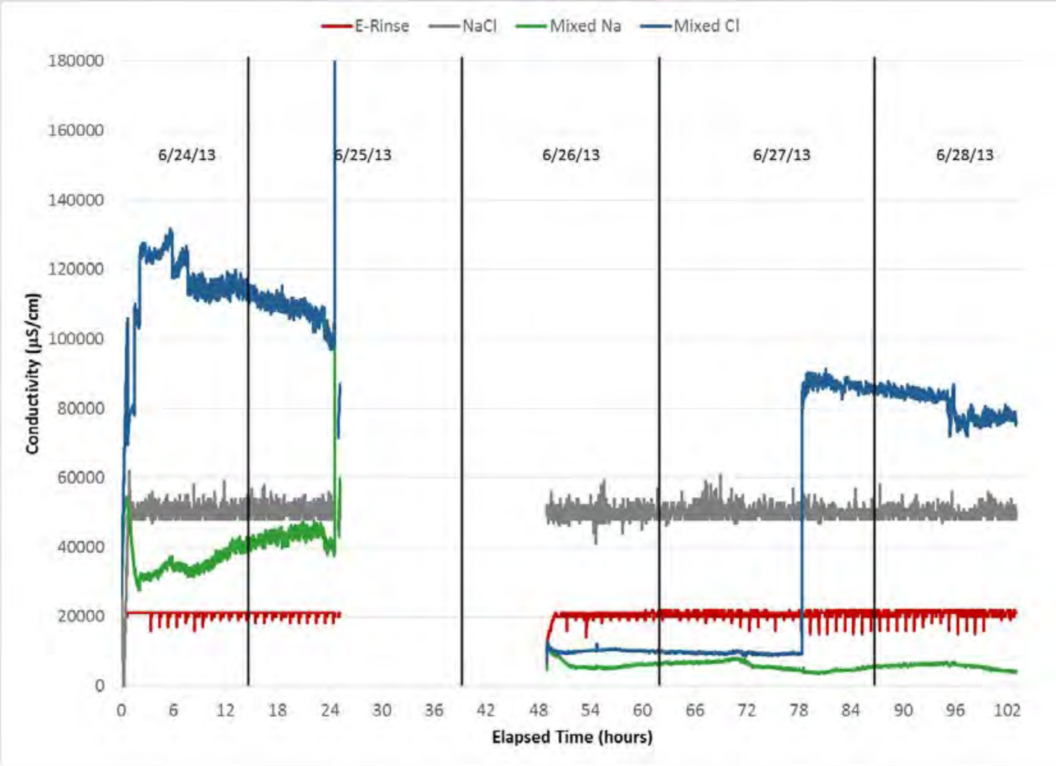

**Figure B2-73.—High concentration EDM stream conductivity (experiment 5).**
*(note: Mixed Cl & Mixed Na are not calibrated or scaled)*

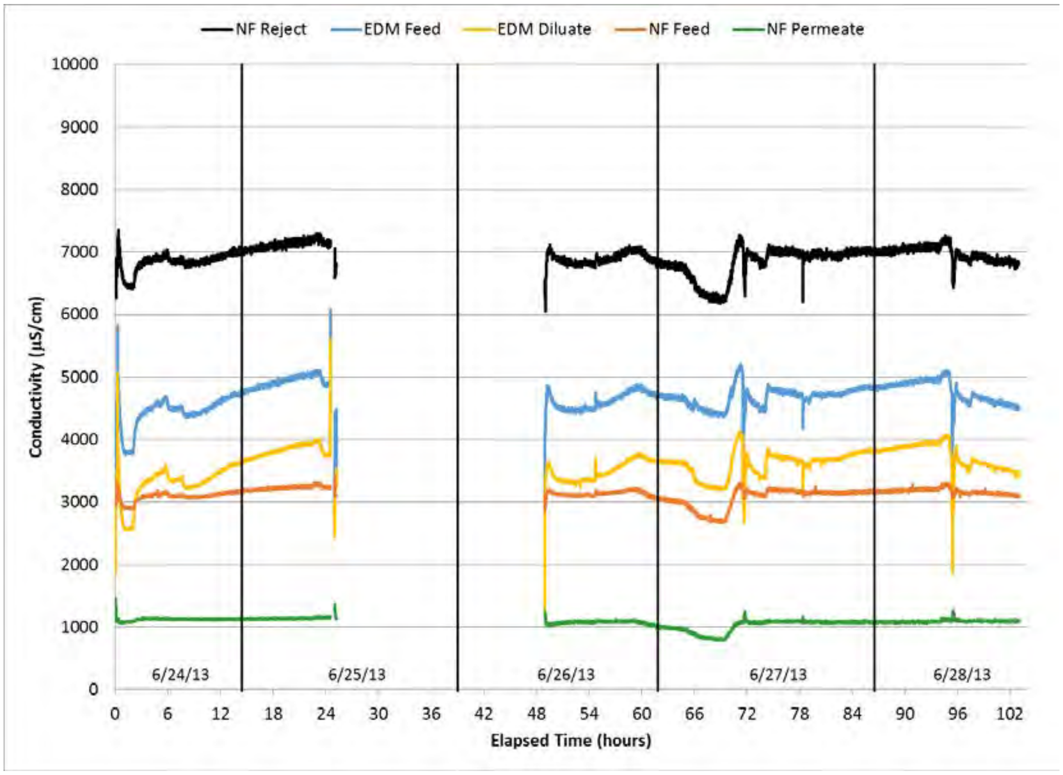

**Figure B2-74.—Low concentration EDM stream conductivity (experiment 5).**

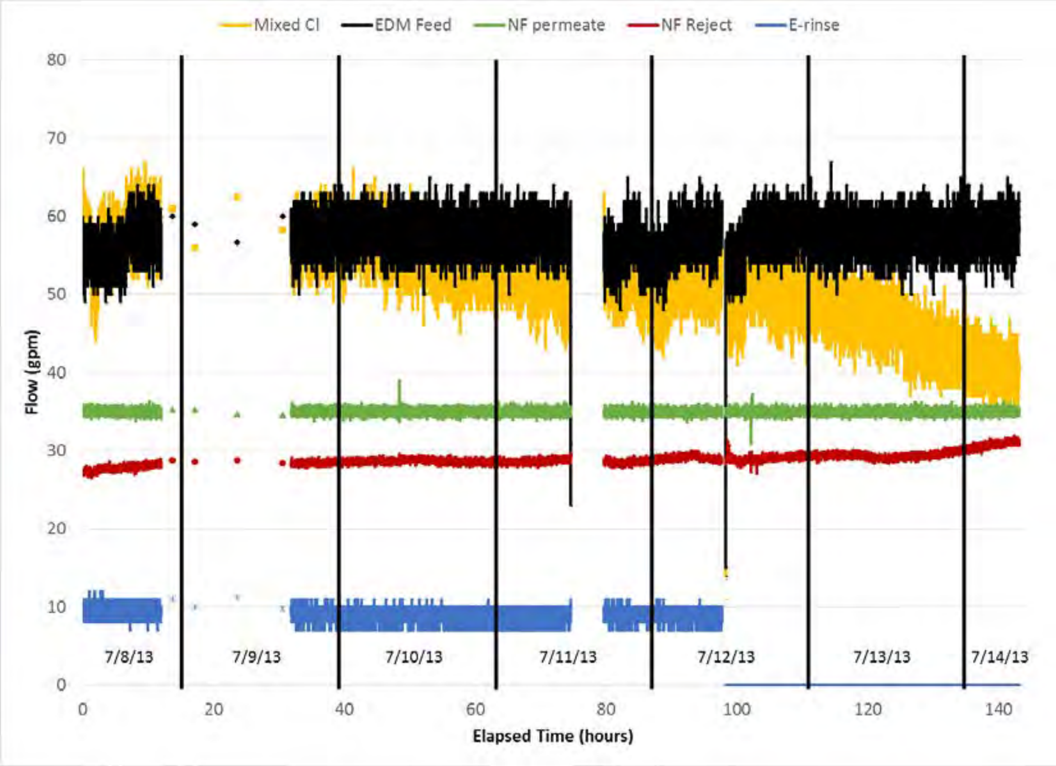

**Figure B2-75.—EDM stream flows (experiment 6).**
*Datalogger failed on 7/8-9/13. Data was recorded on logsheets from online meters, probes, and gauges.*

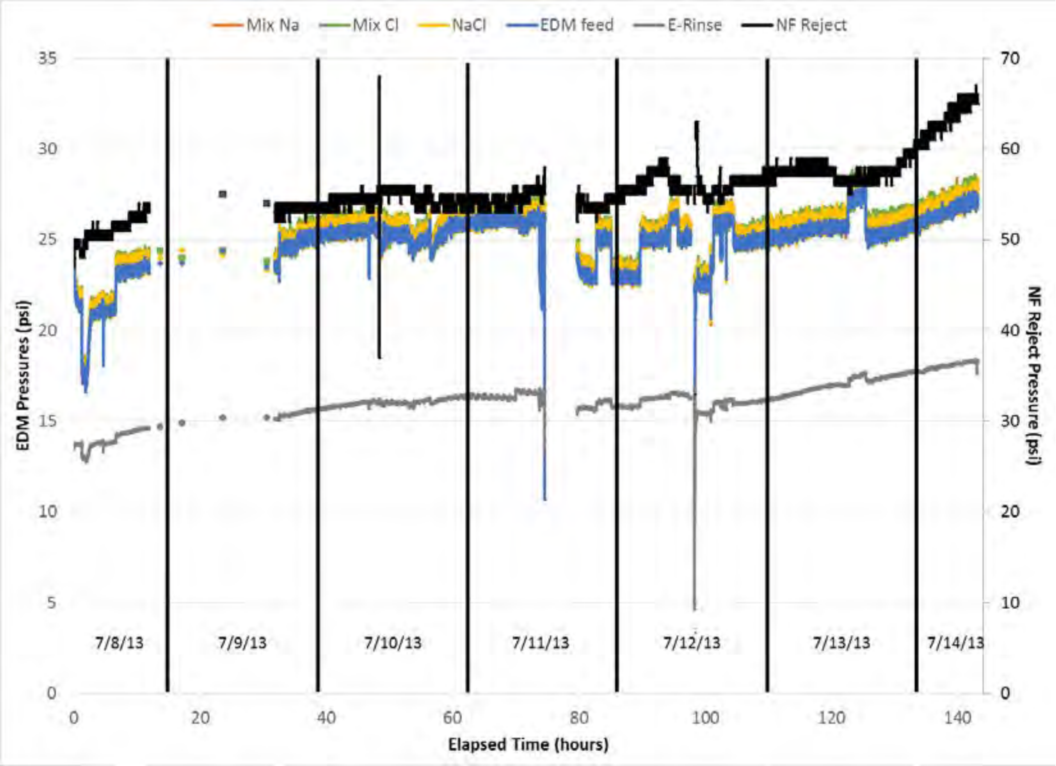

**Figure B2-76.—EDM and NF reject stream pressures (experiment 6).**
*Datalogger failed on 7/8-9/13. Data was recorded on logsheets from online meters, probes, and gauges.*

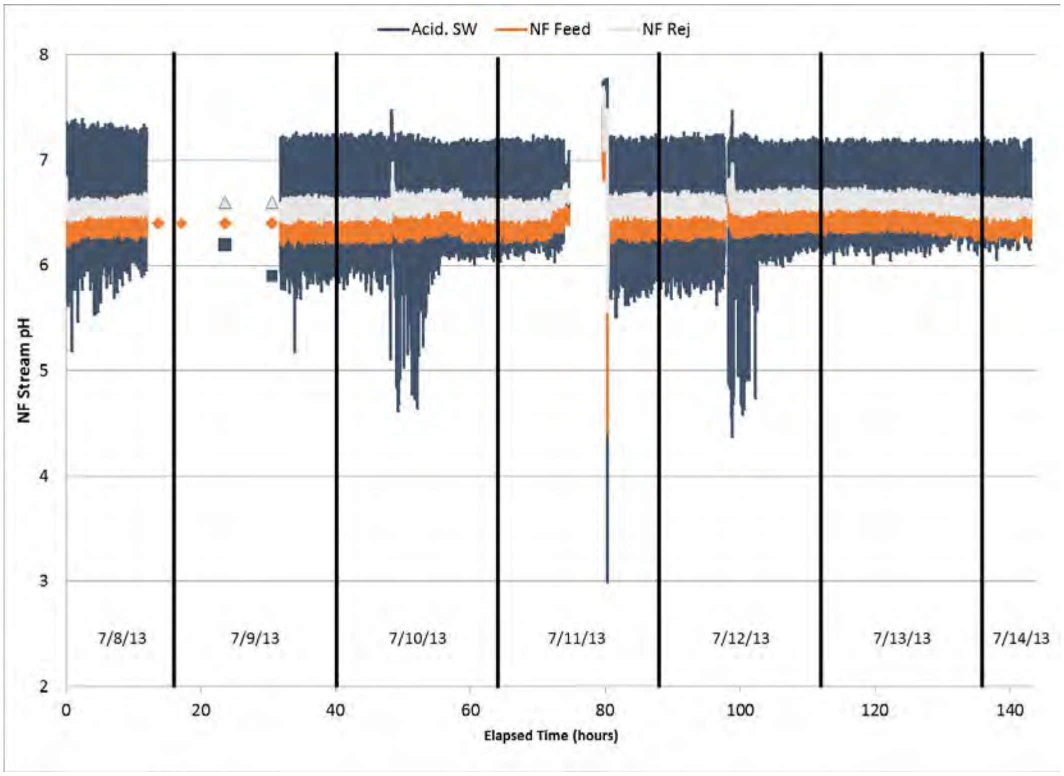

**Figure B2-77.—NF stream pH (experiment 6).**
*Datalogger failed on 7/8-9/13. Data was recorded on logsheets from online meters, probes, and gauges.*
*(note: 93% $H_2SO_4$ added at this point. pH control not modifiable in the field, which increased variation in pH)*

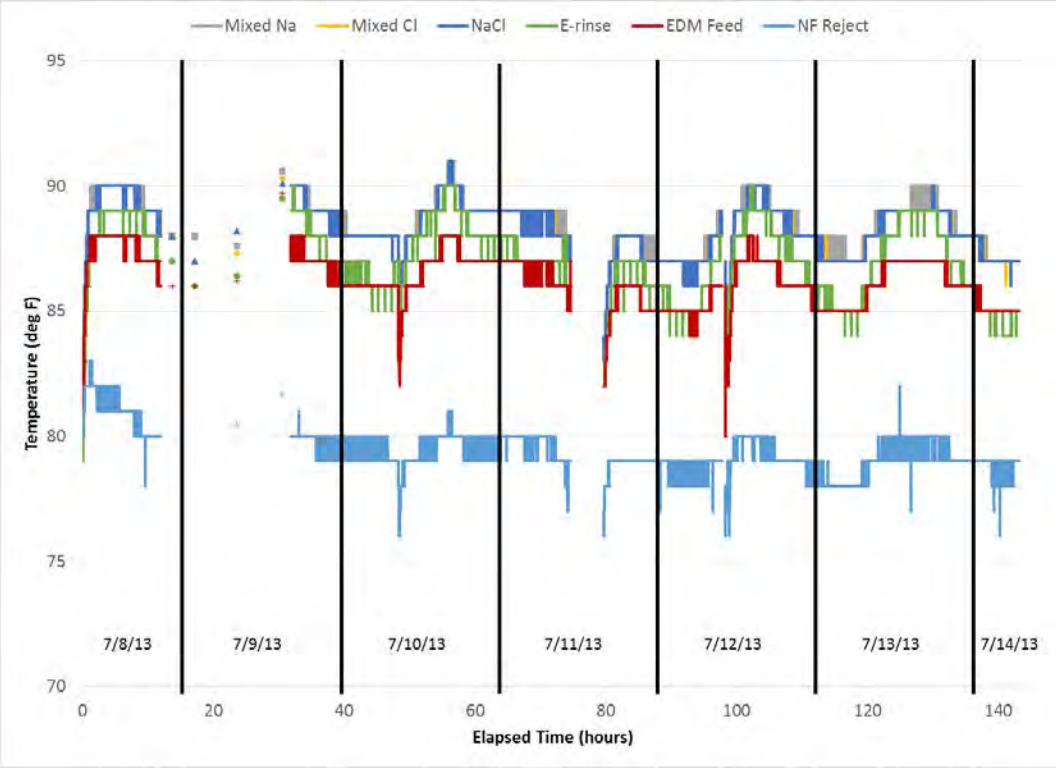

**Figure B2-78.—EDM stream temperature (experiment 6).**
*(note: 93% $H_2SO_4$ added at this point. pH control not modifiable in the field, which increased variation in pH)*

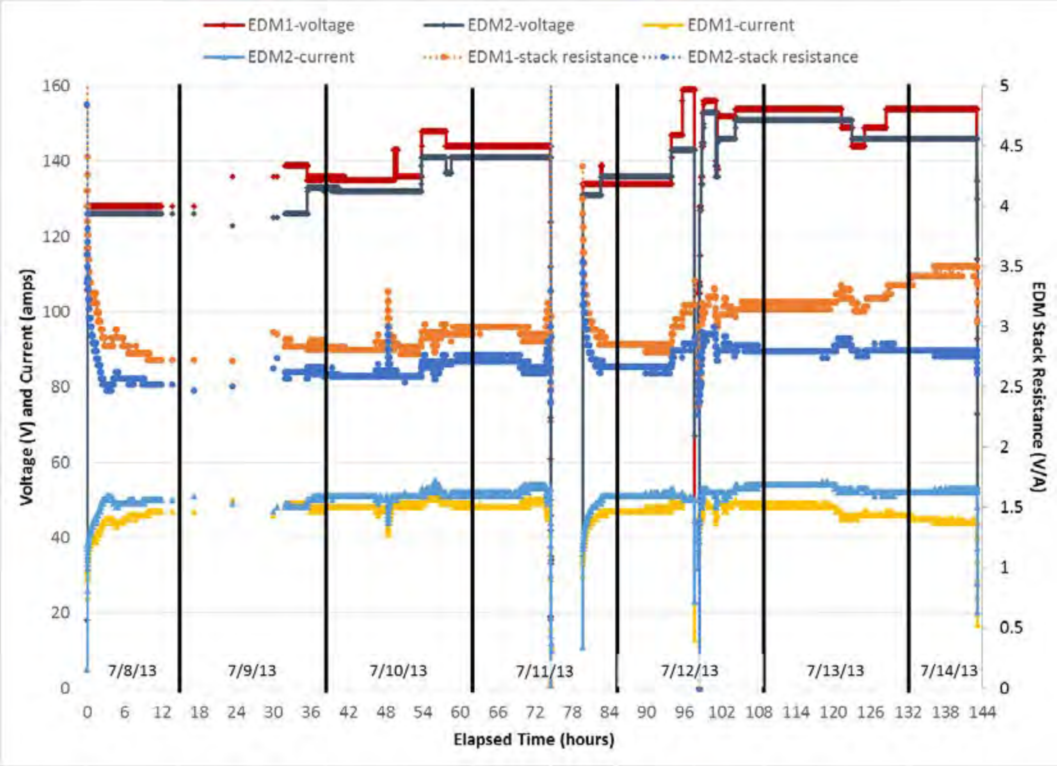

**Figure B2-79.—EDM voltage, current, stack resistance (experiment 6).**
*(Datalogger failed on 7/8-9/13. Data was recorded on logsheets from online meters, probes, and gauges.)*

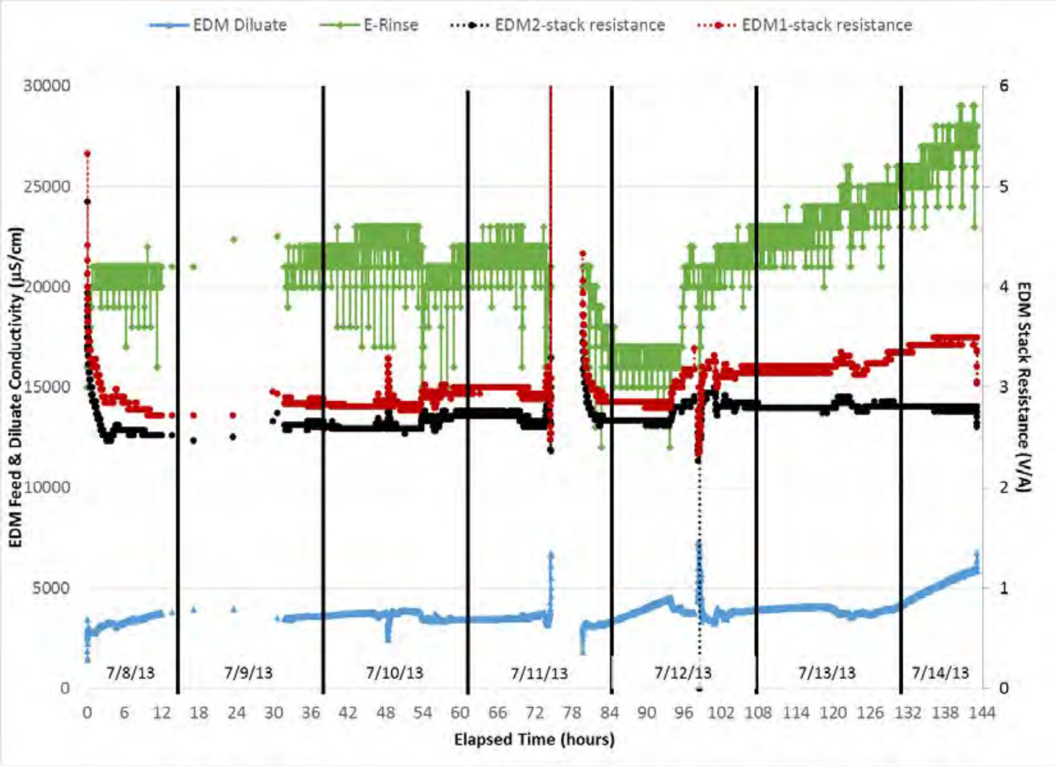

**Figure B2-80.—EDM diluate conductivity and stack resistance (experiment 6).**
*(Datalogger failed on 7/8-9/13. Data was recorded on logsheets from online meters, probes, and gauges.)*

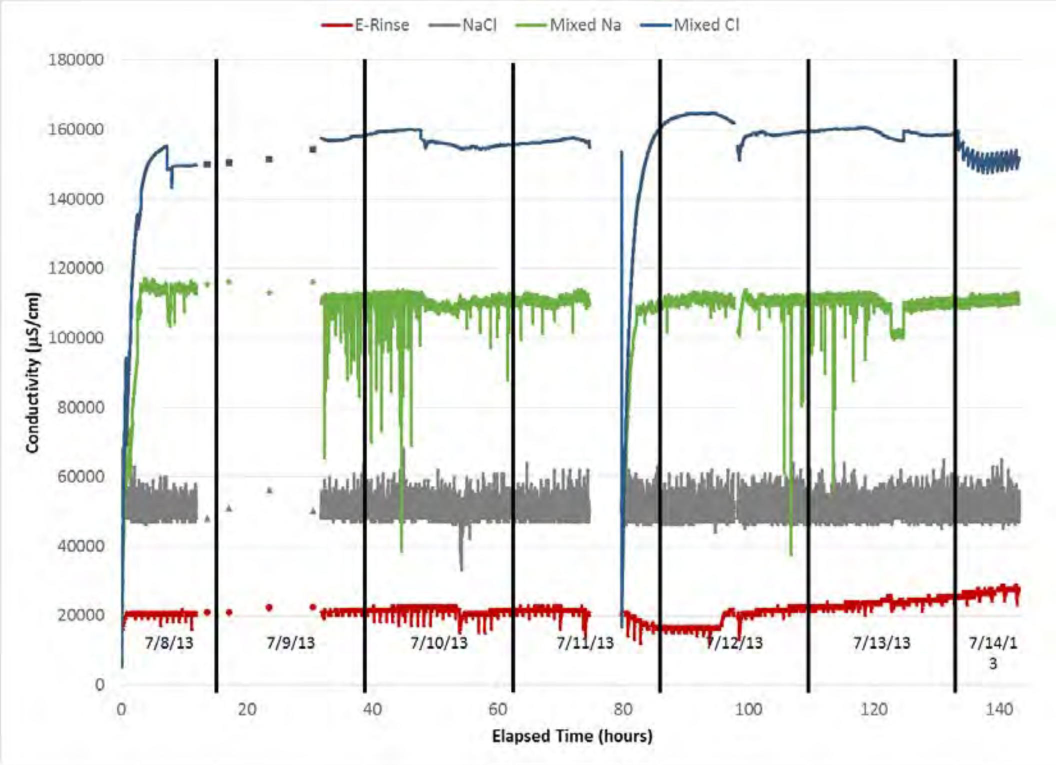

**Figure B2-81.—High concentration EDM stream conductivity (experiment 6).**
*(Datalogger failed on 7/8-9/13. Data was recorded on logsheets from online meters, probes, and gauges.)*

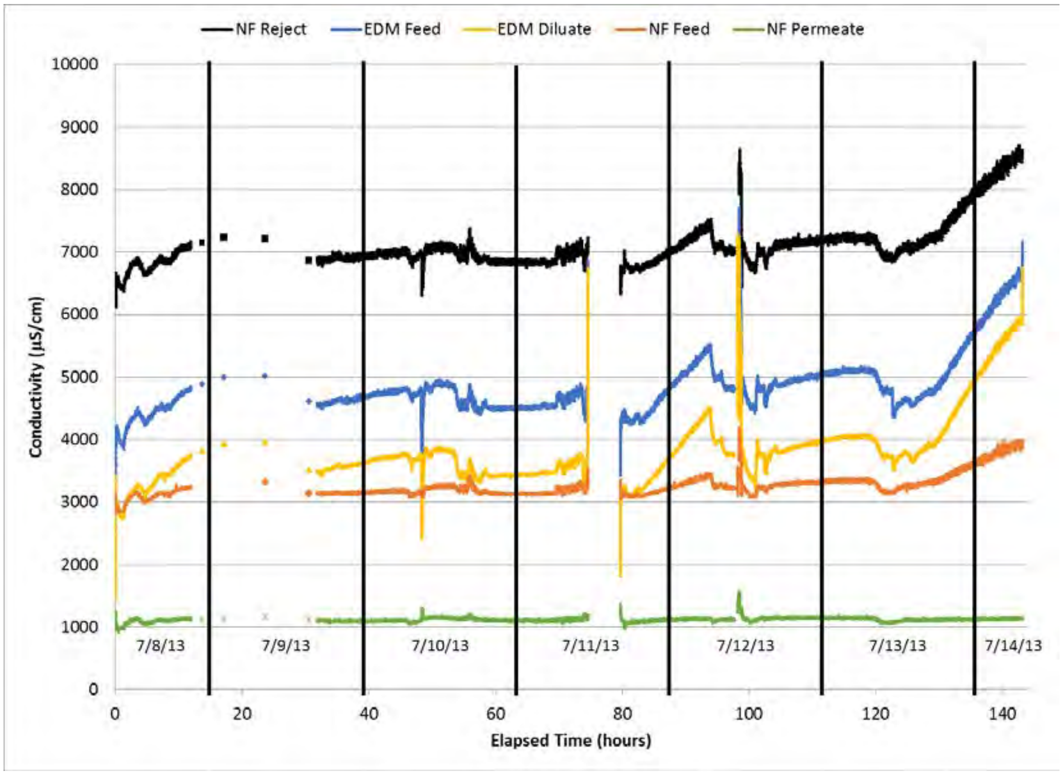

**Figure B2-82.—Low concentration EDM stream conductivity (experiment 6).**
*(Datalogger failed on 7/8-9/13. Data was recorded on logsheets from online meters, probes, and gauges.)*

# APPENDIX B3
# BRIGHTON ONLINE DATA

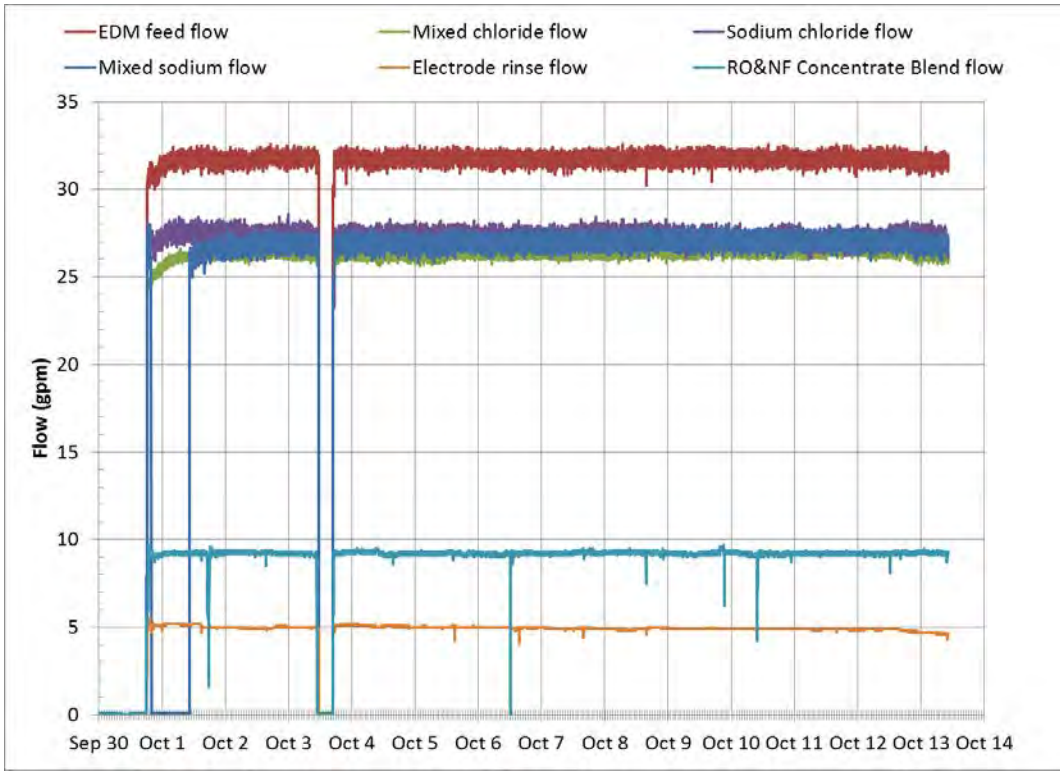

Figure B3-83.—EDM and NF stream flows (experiment 1).

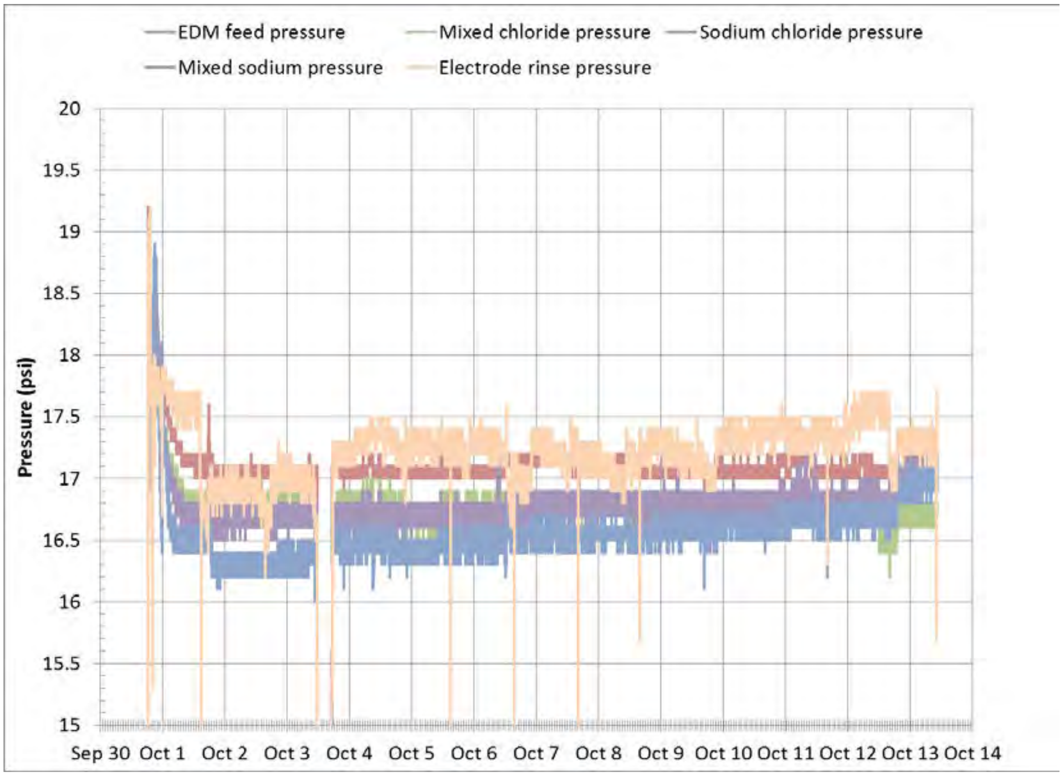

Figure B3-84.—EDM stream pressures (experiment 1).

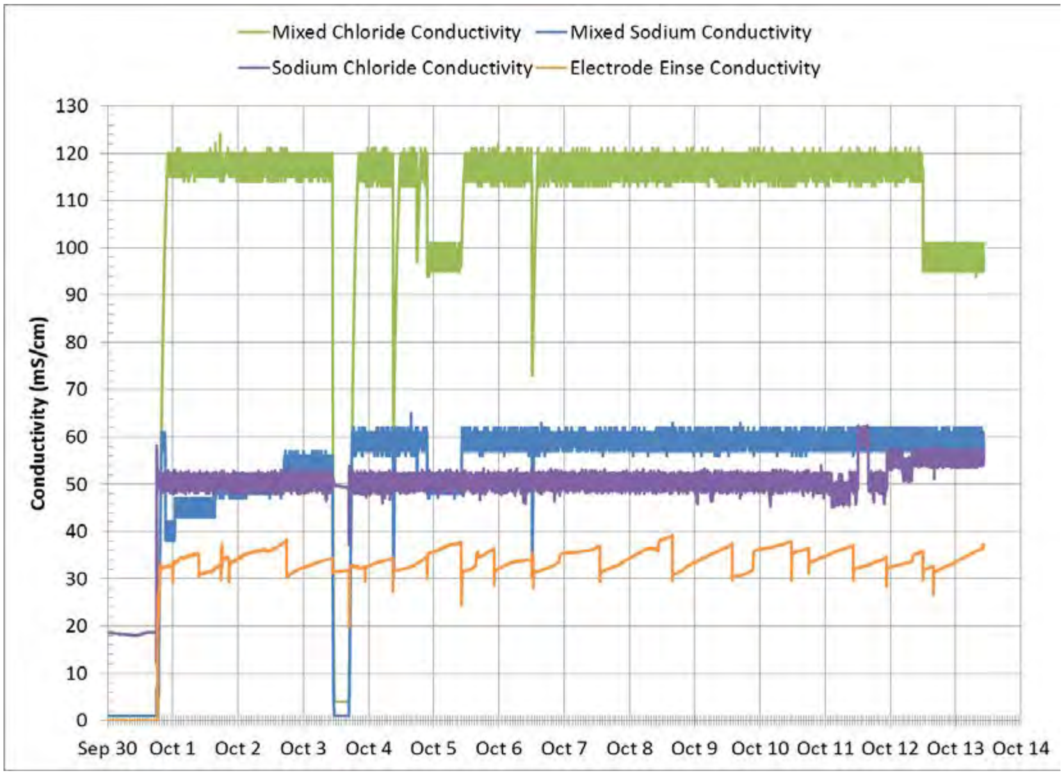

**Figure B3-85.—High concentration EDM stream conductivity (experiment 1).**

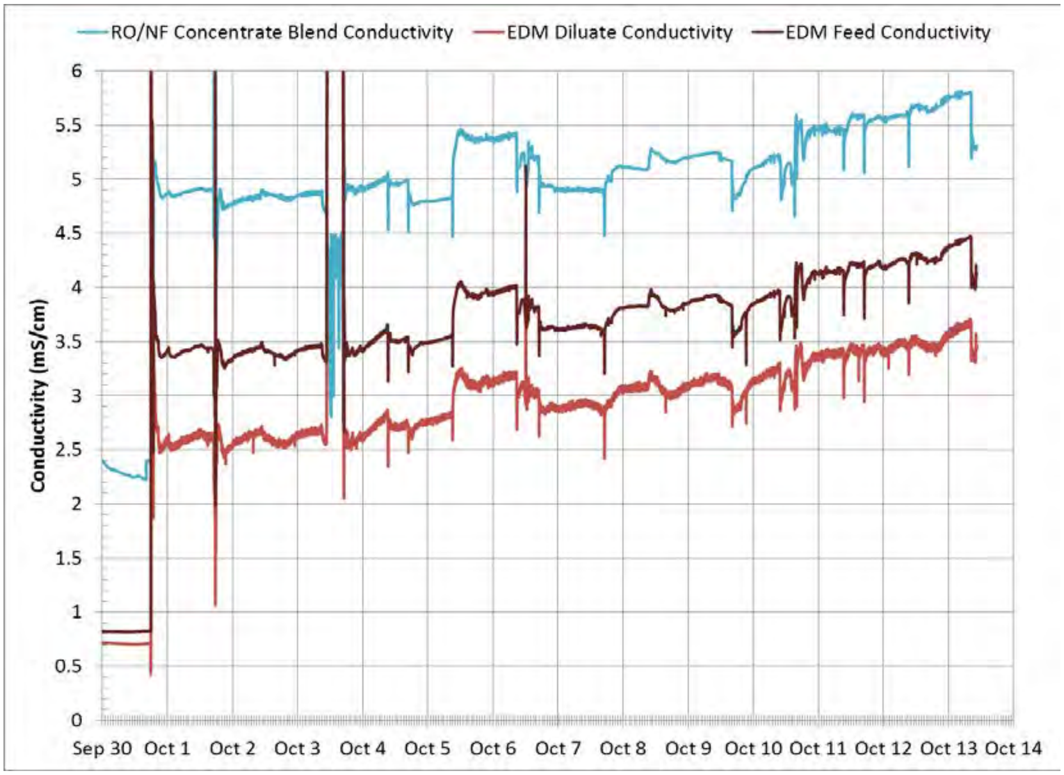

**Figure B3-86.—Low concentration EDM stream conductivity (experiment 1).**

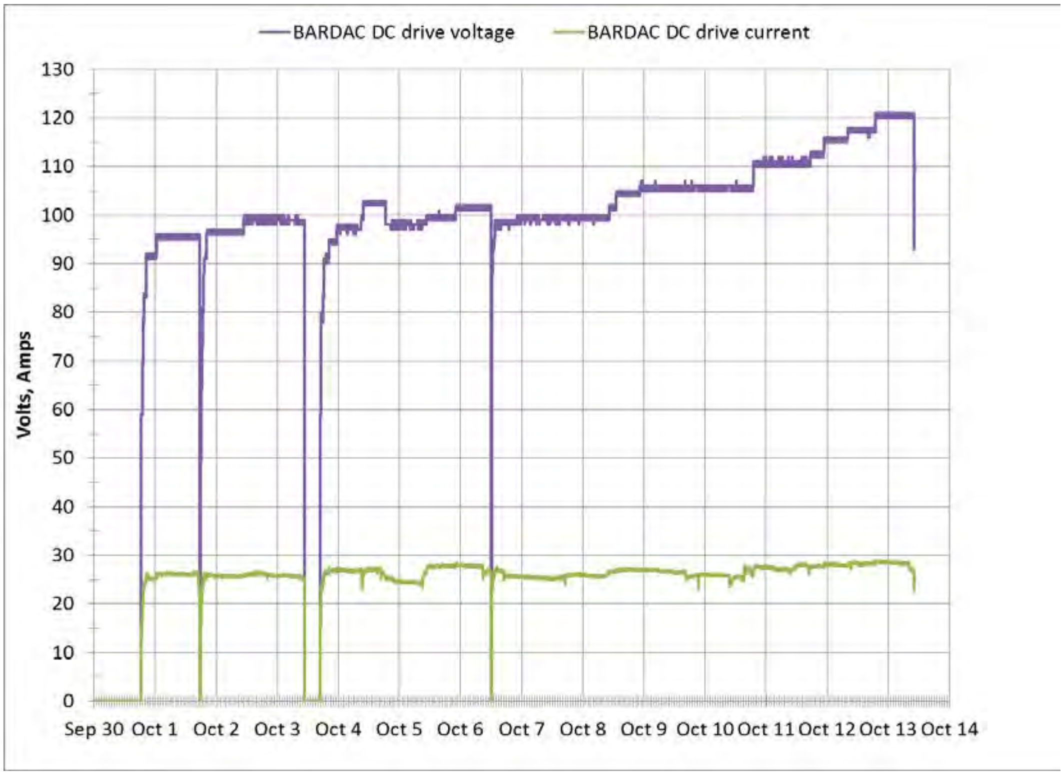

Figure B3-87.—EDM voltage, current (experiment 1).

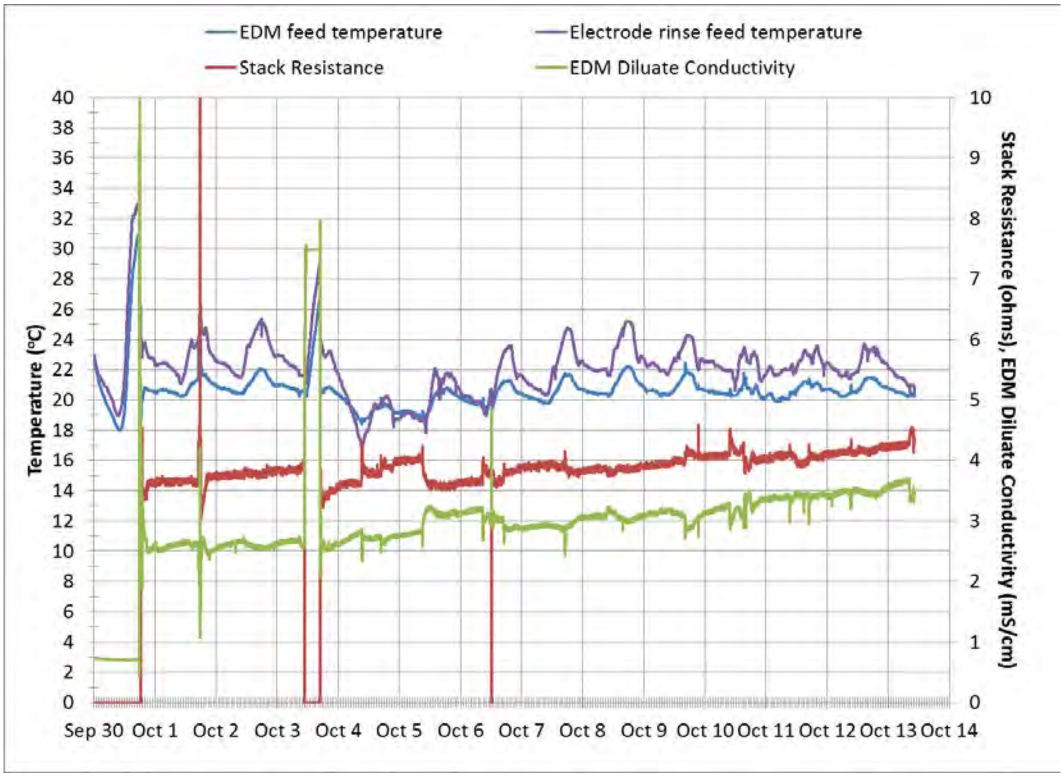

Figure B3-88.—EDM temperatures and stack resistance (experiment 1).

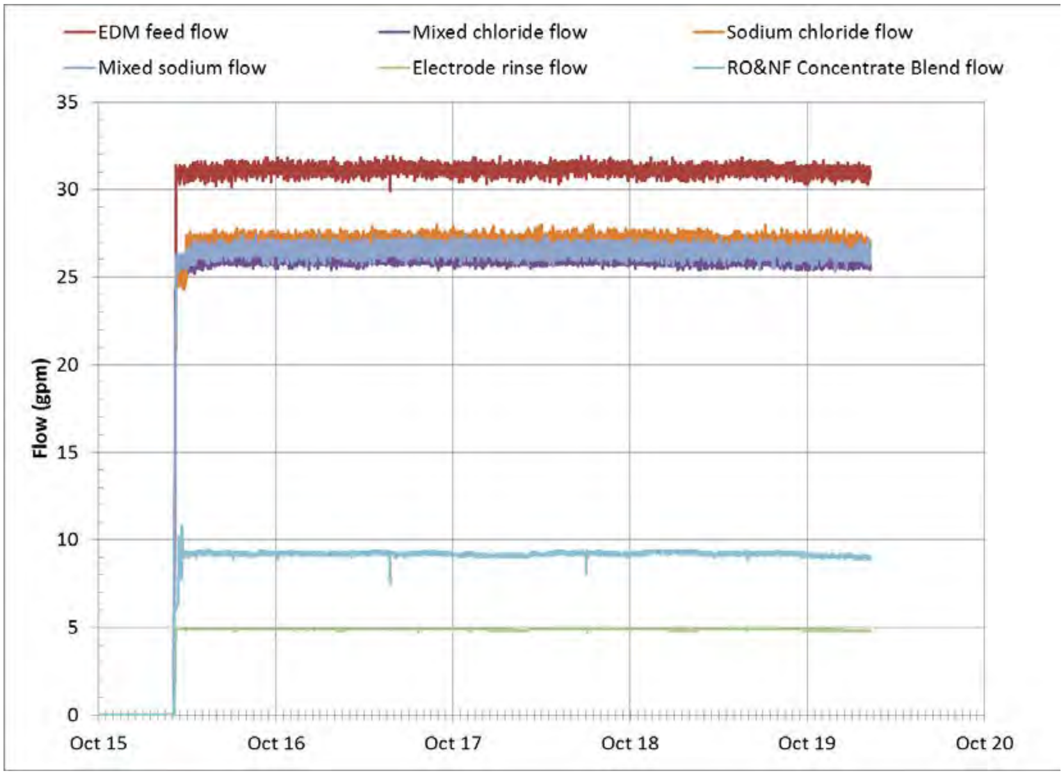

Figure B3-89.—EDM and NF stream flows (experiment 2).

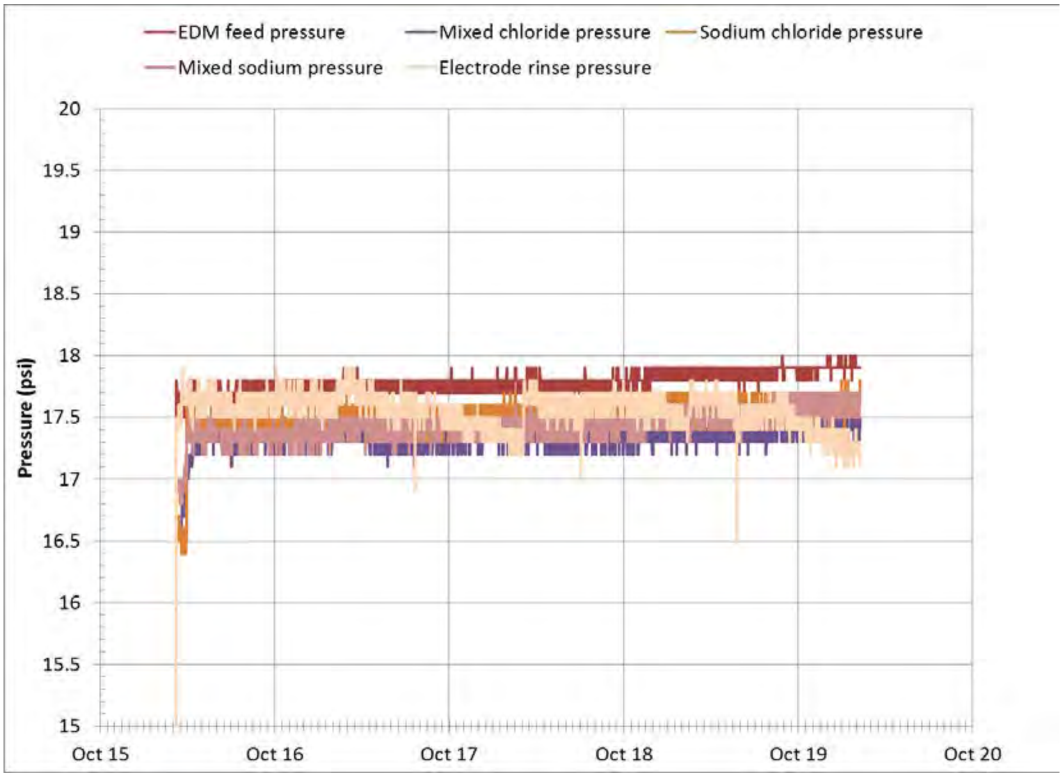

Figure B3-90.—EDM stream pressures (experiment 2).

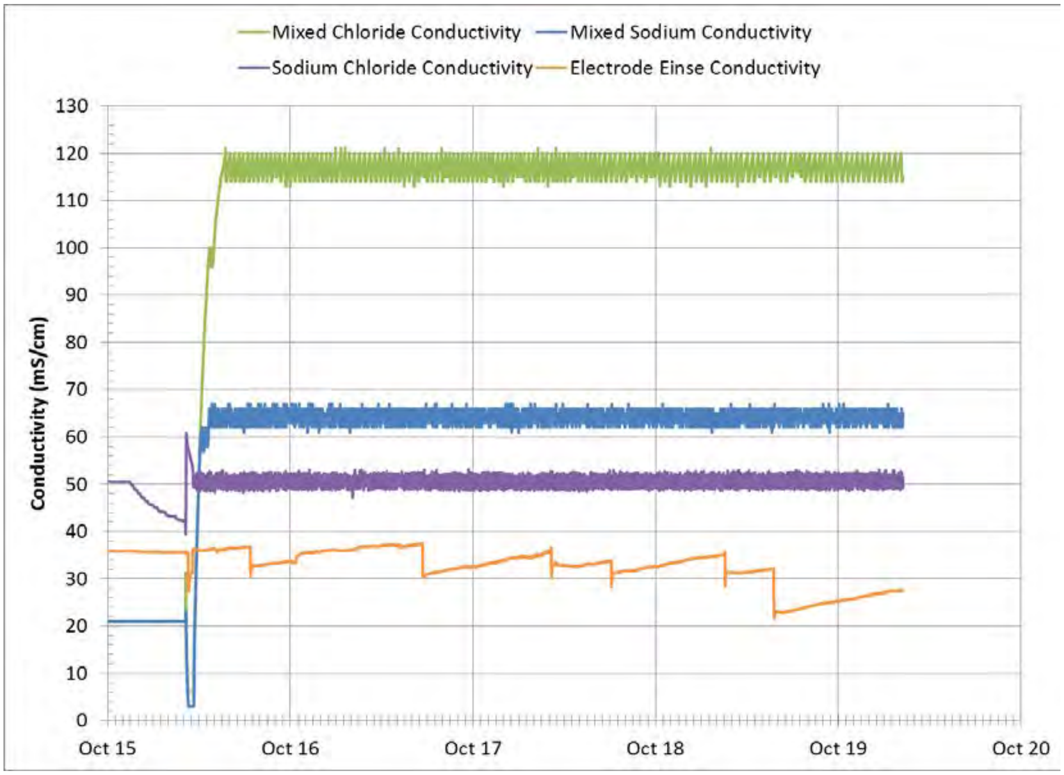

Figure B3-91.—High concentration EDM stream conductivity (experiment 2).

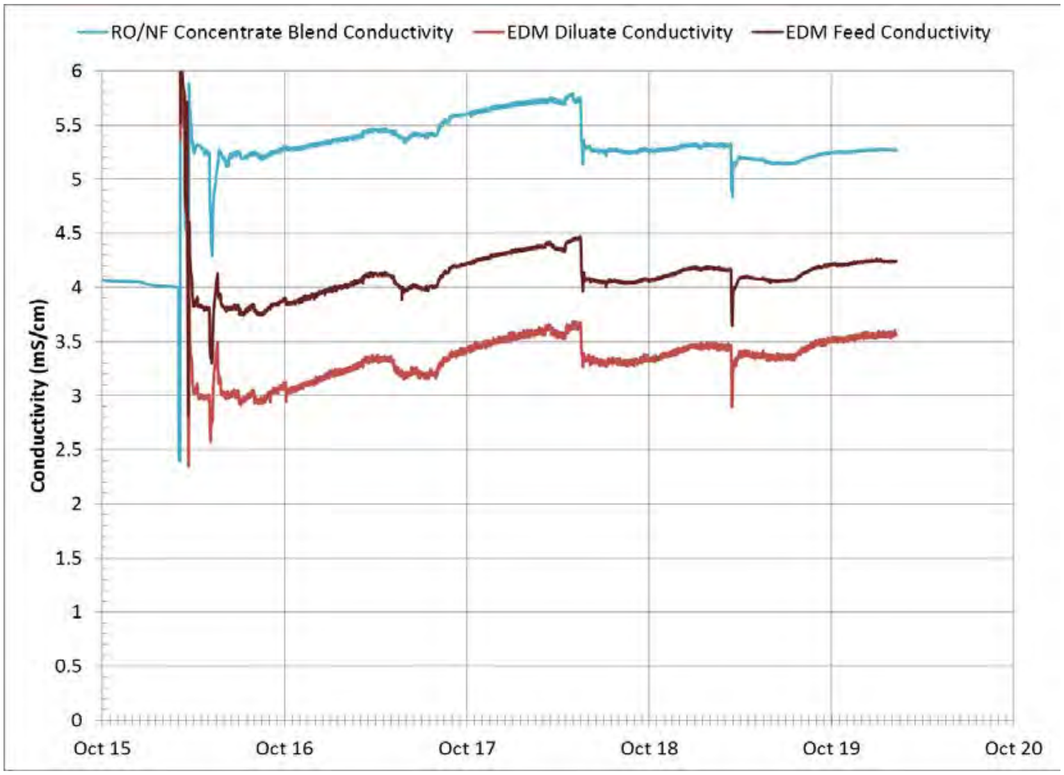

Figure B3-92.—Low concentration EDM stream conductivity (experiment 2).

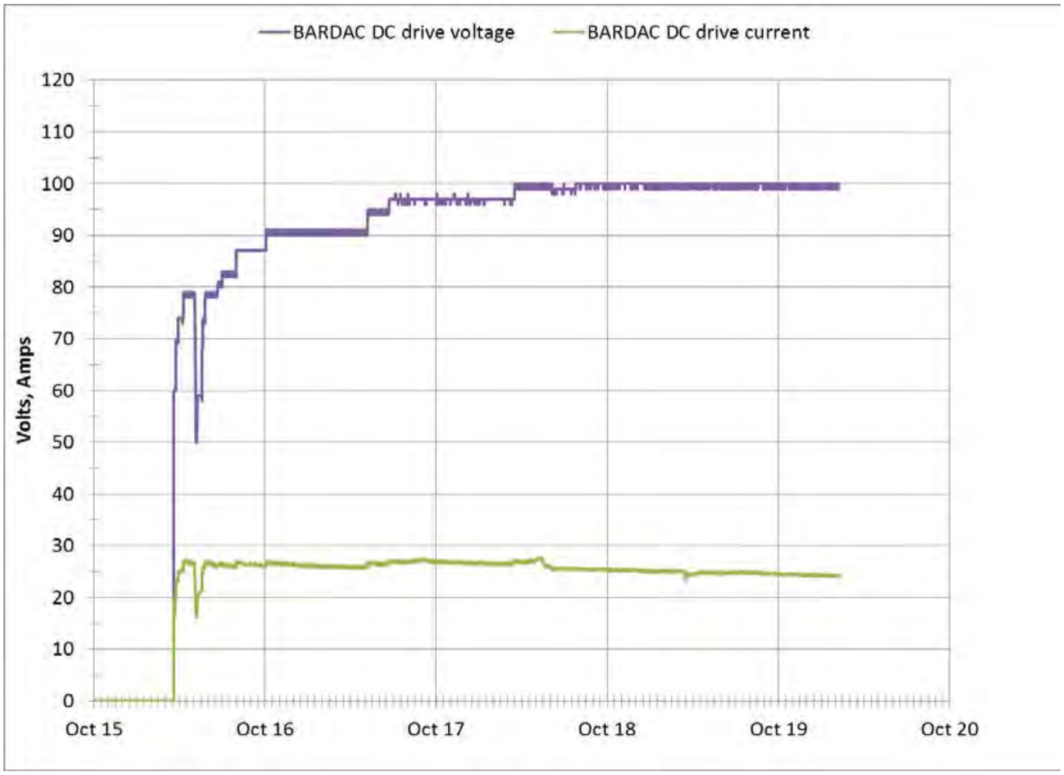

Figure B3-93.—EDM voltage, current (experiment 2).

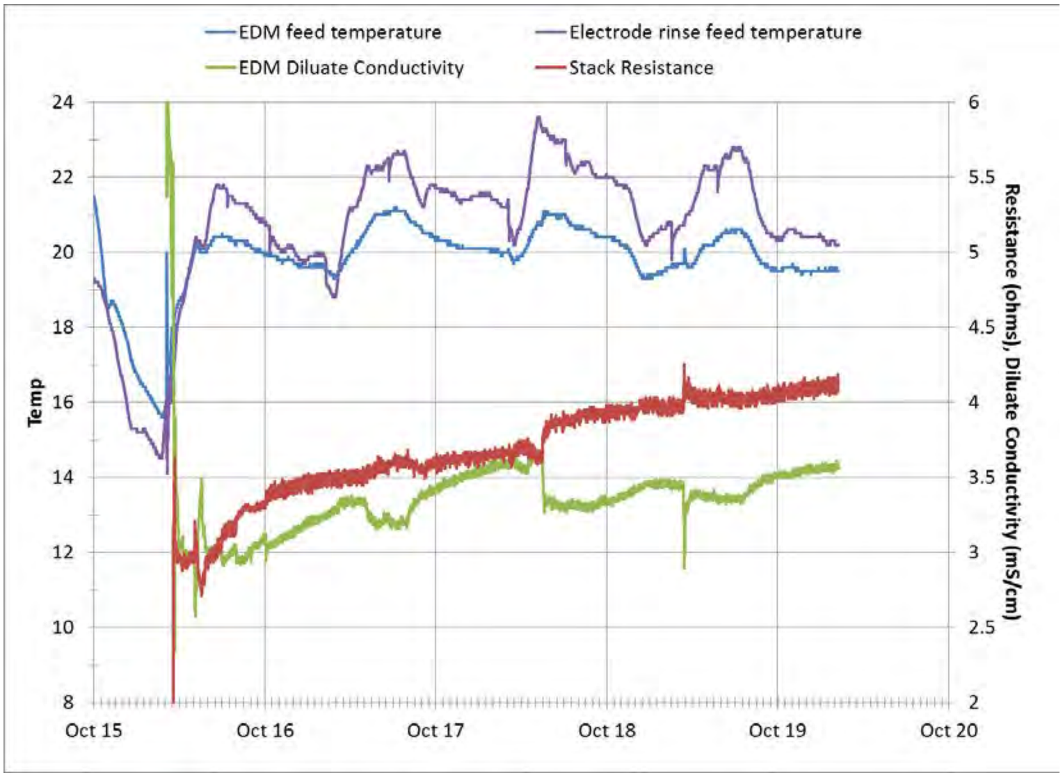

Figure B3-94.—EDM temperatures and stack resistance (experiment 2).

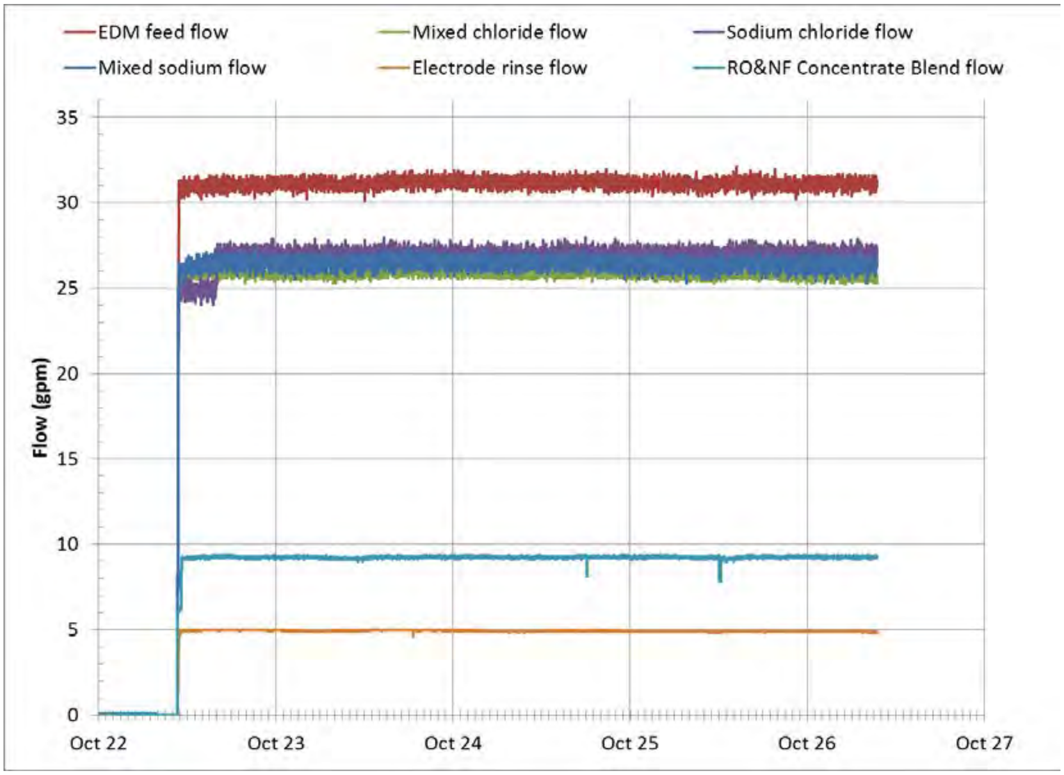

Figure B3-95.—EDM and NF stream flows (experiment 2).

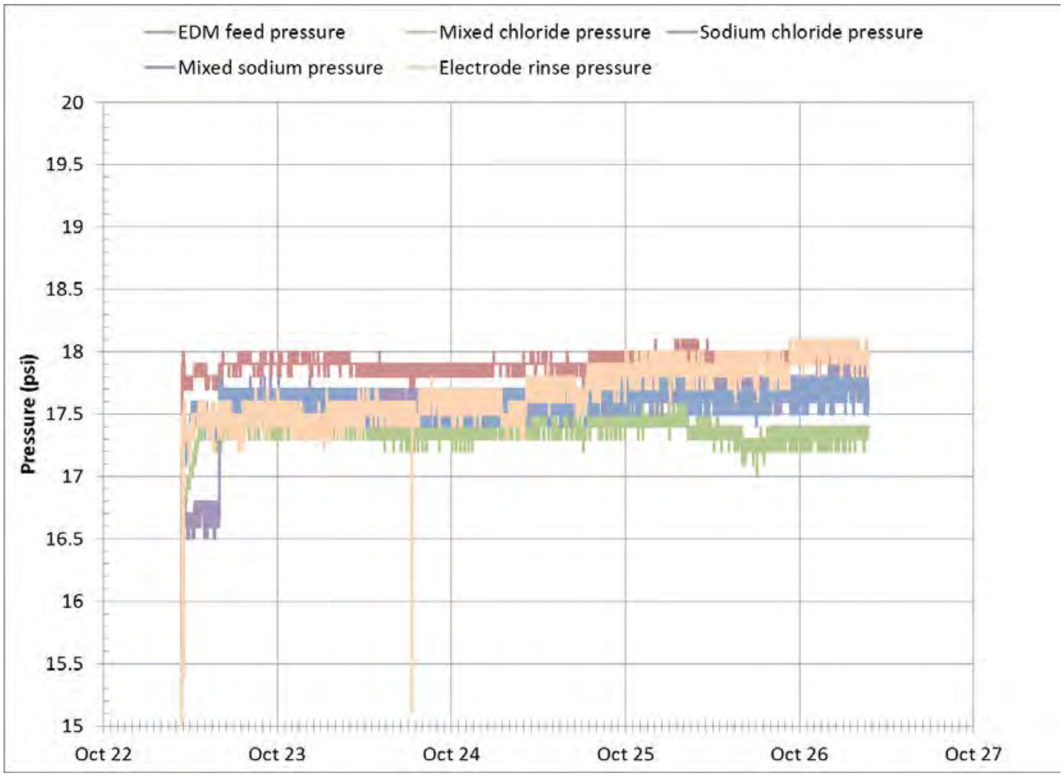

Figure B3-96.—EDM stream pressures (experiment 2).

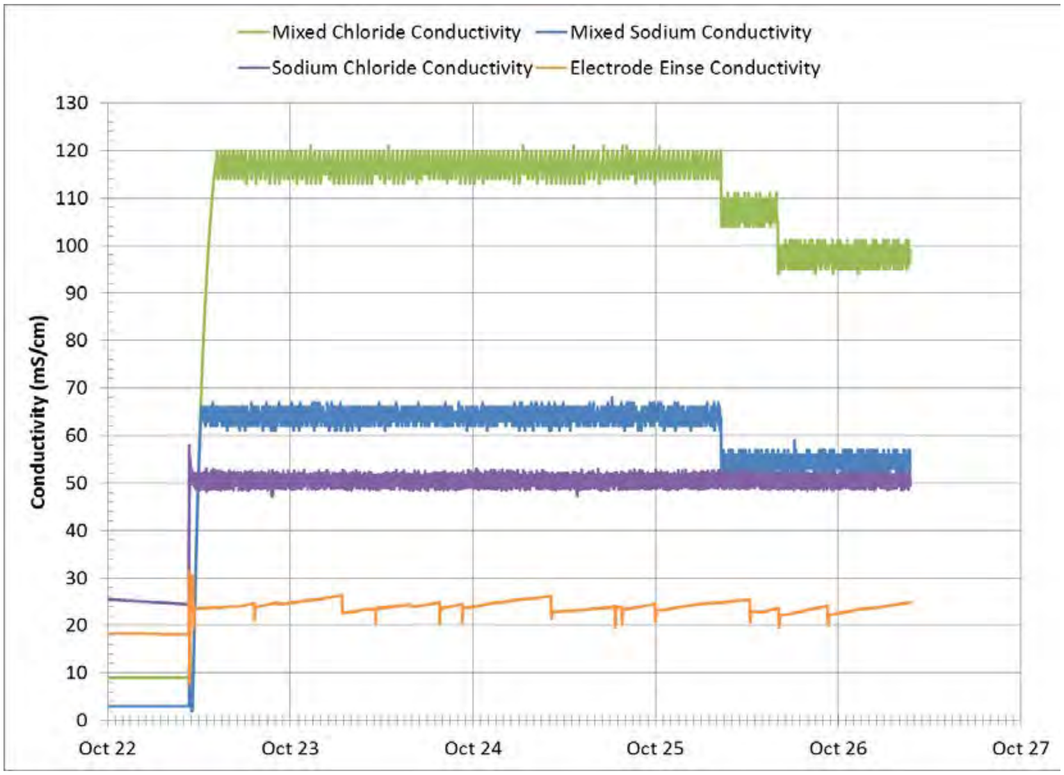

Figure B3-97.—High concentration EDM stream conductivity (experiment 2).

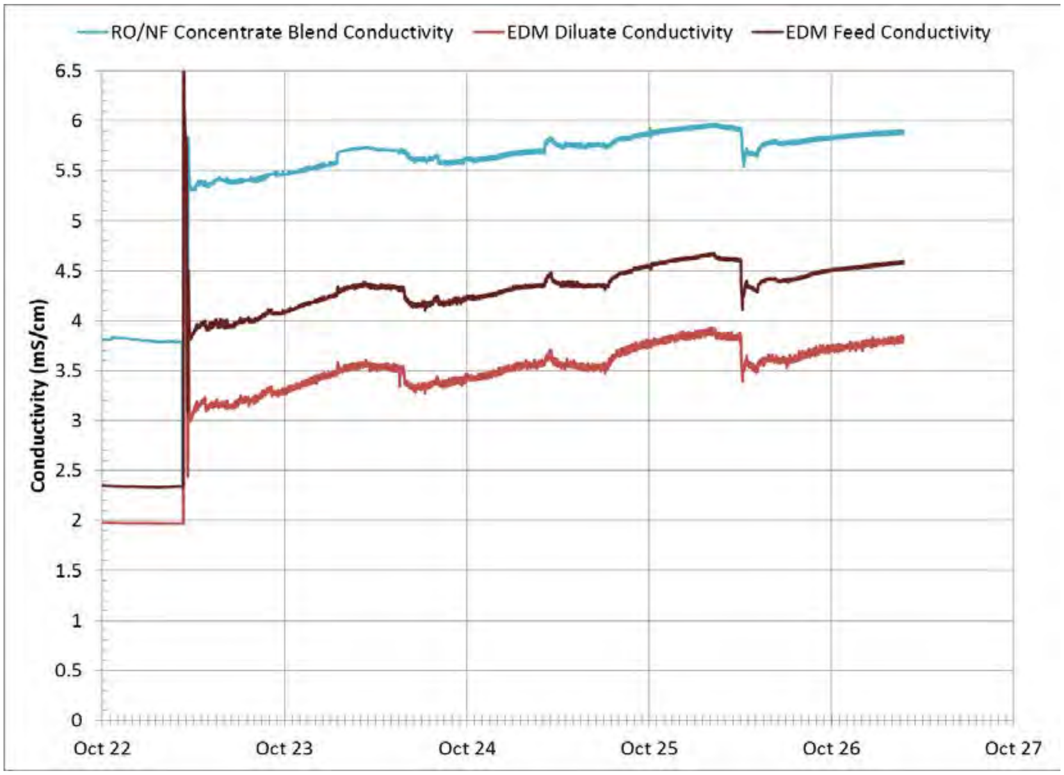

Figure B3-98.—Low concentration EDM stream conductivity (experiment 2).

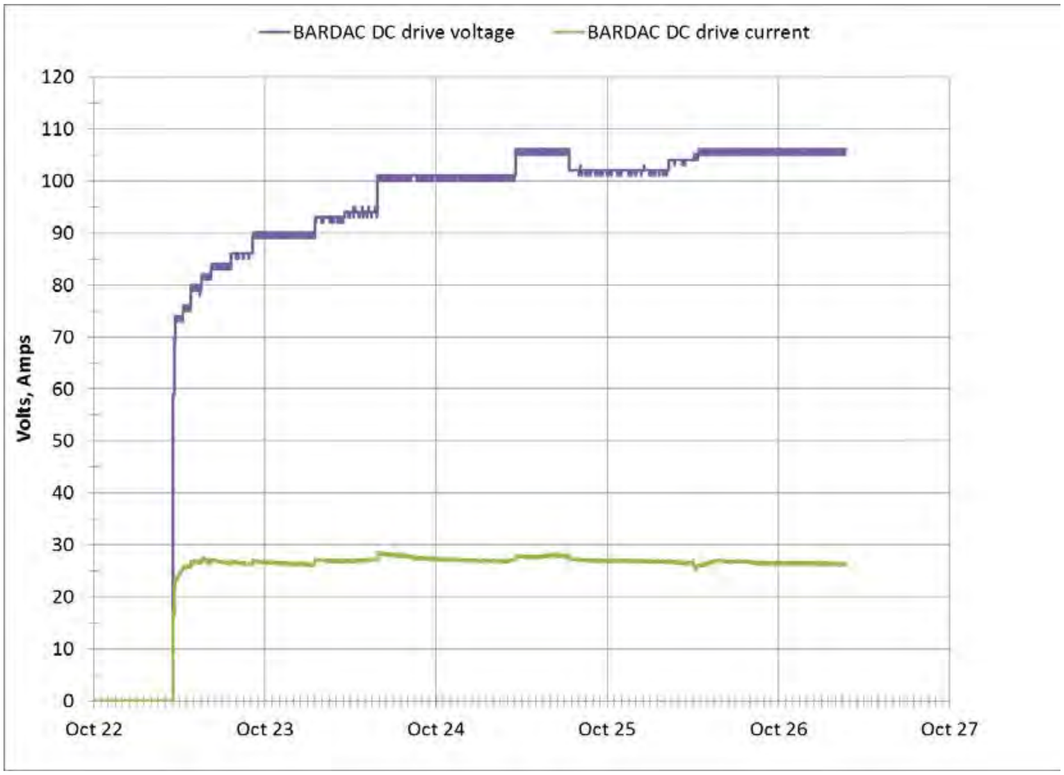

Figure B3-99.—EDM voltage, current (experiment 2).

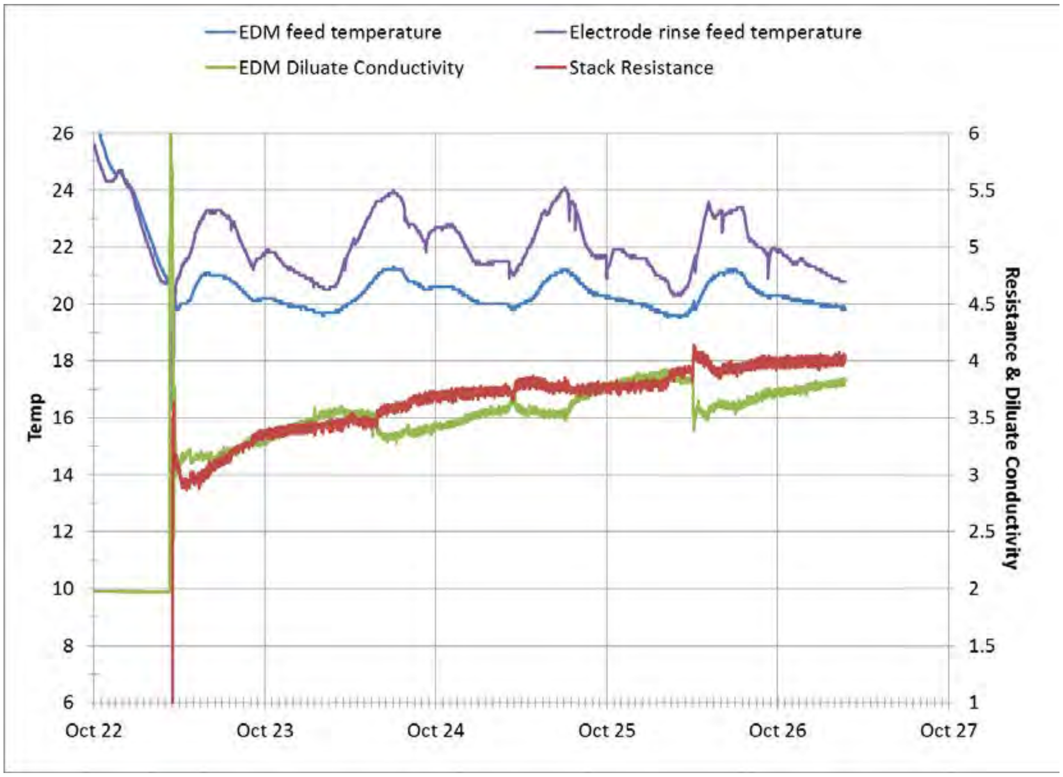

Figure B3-100.—EDM temperatures and stack resistance (experiment 2).

# APPENDIX C
# WATER QUALITY ANALYSES

**Appendix C1 – Alamogordo, Year 1**
**Appendix C2 – Alamogordo, Year 2**
**Appendix C3 – Brighton, Colorado**

# APPENDIX C1

# ALAMOGORDO, YEAR 1

Table C-1.—Water Quality Analyses by Stream

| | | pH | Conductivity | TDS* | $HCO_3$ | Ca | Mg | Na | Cl | $SO_4$ | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | - | (µS/cm) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) |
| 3/22/2013 | Edm dil | 6.2 | 3390 | 2590 | 51.9 | ND | ND | ND | ND | ND | 26.2 |
| 3/25/2013 | Edm dil | 6.4 | 4370 | 3555 | 62.2 | 249.4 | 433.4 | ND | 104.2 | 2179.0 | 18.0 |
| 3/26/2013 | Edm dil | 7.0 | 4130 | 4090 | 112.2 | 265.0 | 199.6 | 467.1 | 110.9 | ND | 28.0 |
| 3/27/2013 | Edm dil | 6.0 | 3780 | 2790 | 62.2 | 278.4 | 160.7 | 455.8 | 102.3 | 1880.4 | ND |
| 3/28/2013 | Edm dil | 6.6 | 3630 | 3420 | 87.2 | 274.3 | 92.4 | 459.2 | 100.7 | ND | 27.0 |
| 3/29/2013 | Edm dil | 6.8 | 3300 | 3060 | 89.1 | 235.5 | 195.2 | 387.7 | 92.4 | 1552.1 | 26.0 |
| 4/5/2013 | Edm dil | 6.5 | 3270 | 2710 | 122.0 | 214.2 | 118.2 | 344.2 | 82.9 | 1531.3 | 22.2 |
| 4/8/2013 | Edm dil | 6.2 | 3710 | 3075 | 183.0 | 244.5 | 133.0 | 410.2 | 95.8 | 1759.2 | 25.0 |
| 4/9/2013 | Edm dil | 6.6 | 4140 | 3315 | 185.4 | ND | ND | ND | ND | ND | 23.0 |
| 4/10/2013 | Edm dil | 6.6 | 3950 | 3320 | 80.5 | ND | ND | ND | ND | ND | 23.2 |
| 4/11/2013 | Edm dil | 6.3 | 3740 | 3295 | 78.1 | 317.7 | 147.9 | 447.6 | 110.7 | 1977.1 | 23.8 |
| 4/17/2013 | Edm dil | 6.8 | 3530 | 2700 | 53.7 | 245.3 | 121.9 | 382.0 | 86.6 | 1664.8 | 21.0 |
| 4/18/2013 | Edm dil | 6.7 | 3930 | 3480 | 67.7 | 271.3 | 134.4 | 429.1 | 99.9 | 1858.9 | 24.0 |
| 4/20/2013 | Edm dil | 6.6 | 4410 | 3840 | 50.0 | 343.8 | 163.2 | 485.6 | 120.0 | 2257.6 | 25.5 |
| 4/22/2013 | Edm dil | 6.3 | 3940 | 3175 | 81.7 | 297.5 | 136.9 | 673.4 | 124.1 | 2252.8 | 25.0 |
| 4/25/2013 | Edm dil | 6.3 | 3690 | 3050 | 38.8 | 283.2 | 132.5 | 390.7 | 112.8 | 1839.6 | 25.0 |
| 4/26/2013 | Edm dil | 7.2 | 3780 | 3055 | 39.0 | 304.7 | 142.8 | 438.2 | 95.5 | 1945.5 | 23.5 |
| 4/30/2013 | Edm dil | 5.7 | 3620 | 3280 | ND | 290.2 | 144.7 | 395.4 | 90.4 | 1844.7 | 23.0 |
| 5/29/2013 | Edm dil | 5.5 | 3570 | 2975 | 34.2 | 223.6 | 102.7 | 496.8 | 85.2 | 1952.9 | 23.4 |
| 5/31/2013 | Edm dil | 5.7 | 5050 | 4590 | 48.8 | 353.5 | 181.7 | 714.5 | 133.2 | 2864.7 | 26.0 |
| 6/3/2013 | Edm dil | 5.9 | 4450 | 3955 | 61.0 | 328.5 | 172.6 | 639.9 | 125.0 | 2485.1 | 25.0 |
| 6/4/2013 | Edm dil | 5.9 | 3890 | 3420 | 42.7 | 267.3 | 129.6 | 541.8 | 100.4 | 2035.2 | 27.0 |
| 6/14/2013 | Edm dil | 6.7 | 3140 | 2395 | 48.8 | 174.6 | 87.6 | 370.7 | 94.3 | 1385.8 | 29.0 |
| 6/18/2013 | Edm dil | 6.8 | 3500 | 2770 | 54.9 | 199.7 | 99.4 | 452.2 | 90.3 | 1622.8 | 29.0 |
| 6/19/2013 | Edm dil | 6.5 | 3790 | 3070 | 54.9 | 211.4 | 105.3 | 512.3 | 92.8 | 1771.5 | 27.0 |
| 6/20/2013 | Edm dil | 6.3 | 3380 | 2665 | 54.9 | 190.5 | 92.8 | 437.2 | 90.1 | 1540.0 | 27.0 |
| 6/21/2013 | Edm dil | 6.6 | 3330 | 2650 | 122.0 | 192.4 | 102.2 | 434.2 | 97.5 | 1537.3 | 29.0 |

|  |  | pH | Conductivity | TDS* | $HCO_3$ | Ca | Mg | Na | Cl | $SO_4$ | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | - | (µS/cm) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) |
| 6/24/2013 | Edm dil | 6.4 | 3520 | 2815 | 61.0 | 202.0 | 99.8 | 454.7 | 92.4 | 1625.3 | 27.0 |
| 6/26/2013 | Edm dil | 6.5 | 3600 | 2855 | 73.2 | 204.0 | 100.0 | 473.0 | 90.6 | 1679.4 | 28.0 |
| 6/27/2013 | Edm dil | 6.2 | 3840 | 3080 | 91.5 | 202.0 | 100.6 | 538.7 | 95.5 | 1805.7 | 27.0 |
| 7/8/2013 | EDM Dil | 6.4 | 3580 | 2810 | 79.3 | 177.5 | 95.9 | 506.5 | 82.5 | 1648.9 | 26.0 |
| 7/9/2013 | EDM Dil | 6.3 | 3620 | 2860 | 91.5 | 180.2 | 98.0 | 507.7 | 86.8 | 1660.0 | 27.0 |
| 7/10/2013 | EDM Dil | 6.5 | 3720 | 2965 | 97.6 | 196.3 | 113.0 | 511.4 | 89.9 | 1754.1 | 33.0 |
| 7/11/2013 | Edm dil | 6.4 | 3900 | 3105 | 183.0 | 191.8 | 109.1 | 535.5 | 89.1 | 1824.2 | 28.0 |
| 7/12/2013 | EDM Dil 3:45pm | 6.5 | 4070 | 3095 | 36.6 | 188.5 | 104.9 | 536.2 | 93.9 | 1818.9 | 28.0 |
| 7/12/2013 | EDM Dil 5:20pm | 6.5 | 4150 | 3140 | 42.7 | 189.2 | 106.8 | 546.2 | 93.4 | 1850.8 | 29.0 |
| 7/13/2013 | EDM Dil 5:15pm | 6.4 | 4530 | 3445 | 97.6 | 207.8 | 114.4 | 618.9 | 89.0 | 2042.5 | 32.0 |
| 7/14/2013 | Edm dil | 7.3 | 6280 | 5735 | 54.9 | 363.5 | 206.5 | 992.5 | 103.2 | 3349.3 | 27.0 |
| 7/20/2013 | Edm dil | 6.0 | 3780 | 3090 | 6.1 | 168.5 | 91.6 | 586.8 | 75.9 | 1803.9 | 25.0 |
| 3/22/2013 | Edm feed | 6.5 | 5360 | 26195 | 108.0 | ND | ND | ND | ND | ND | 35.0 |
| 3/25/2013 | Edm feed | 6.3 | 6380 | 5735 | 111.0 | 458.1 | 624.8 | ND | 149.8 | 3428.6 | 27.1 |
| 3/26/2013 | Edm feed | 7.1 | 5740 | 5555 | 189.1 | 533.9 | 305.4 | 584.8 | 156.8 | 3183.6 | 27.0 |
| 3/27/2013 | Edm feed | 6.3 | 5340 | 4840 | 111.0 | ND | ND | ND | ND | ND | 27.2 |
| 3/28/2013 | Edm feed | 6.9 | 5250 | 5335 | 163.5 | 480.0 | 347.2 | 533.1 | 138.0 | ND | 25.0 |
| 3/29/2013 | Edm feed | 6.9 | 4840 | 4895 | 200.1 | 434.4 | 268.4 | 502.2 | 124.2 | 2526.8 | 25.0 |
| 4/5/2013 | Edm feed | 6.4 | 4820 | 4315 | 126.9 | 419.1 | 213.0 | 475.9 | 117.4 | 2507.6 | 22.3 |
| 4/8/2013 | Edm feed | 6.4 | 5220 | 4825 | 126.9 | 441.9 | 224.5 | 526.4 | 126.1 | 2688.5 | 25.0 |
| 4/9/2013 | Edm feed | 6.5 | 5580 | 4965 | 142.7 | ND | ND | ND | ND | ND | 23.6 |
| 4/10/2013 | Edm feed | 6.7 | 5340 | 5090 | 141.5 | ND | ND | ND | ND | ND | 24.1 |
| 4/11/2013 | Edm feed | 6.7 | 5180 | 4975 | 263.5 | 547.8 | 238.0 | 578.7 | 147.3 | 3029.6 | 25.2 |
| 4/17/2013 | Edm feed | 7.1 | 4980 | 4475 | 103.1 | 437.3 | 203.9 | 498.3 | 119.0 | 2569.8 | 29.6 |
| 4/18/2013 | Edm feed | 6.8 | 5360 | 5030 | 117.1 | 476.0 | 221.8 | 565.5 | 133.1 | 2862.5 | 25.1 |
| 4/20/2013 | Edm feed | 6.7 | 5870 | 5490 | 97.6 | 548.1 | 244.5 | 603.4 | 152.4 | 3222.3 | 22.1 |

| | | **pH** | **Conductivity** | **TDS*** | **$HCO_3$** | **Ca** | **Mg** | **Na** | **Cl** | **$SO_4$** | **$SiO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **-** | **(µS/cm)** | **(mg/L)** | **(mg/L)** | **(mg/L)** | **(mg/L)** | **(mg/L)** | **(mg/L)** | **(mg/L)** | **(mg/L)** |
| 4/22/2013 | Edm feed | 6.5 | 5300 | 4700 | 25.6 | 494.4 | 208.9 | 596.2 | 138.9 | 2901.9 | 26.0 |
| 4/25/2013 | Edm feed | 6.8 | 5240 | 4765 | 67.7 | 474.5 | 209.2 | 508.4 | 113.1 | 2808.6 | 23.4 |
| 4/26/2013 | Edm feed | 6.5 | 5250 | 4645 | 67.1 | 518.8 | 223.5 | 567.4 | 120.9 | 3005.1 | 22.5 |
| 4/30/2013 | Edm feed | 5.9 | 5290 | 4905 | ND | 527.6 | 241.1 | 549.0 | 114.1 | 3015.2 | 23.0 |
| 5/29/2013 | Edm feed | 5.8 | 4890 | 4440 | 67.1 | 395.9 | 169.8 | 646.8 | 90.8 | 2935.3 | 22.7 |
| 5/31/2013 | Edm feed | 5.9 | 6160 | 5920 | 67.1 | 523.4 | 252.8 | 830.2 | 128.6 | 3751.3 | 26.0 |
| 6/3/2013 | Edm feed | 6.2 | 5540 | 5350 | 24.4 | 482.3 | 236.9 | 720.4 | 120.0 | ND | 25.0 |
| 6/4/2013 | Edm feed | 6.1 | 5060 | 4830 | 61.0 | 433.3 | 199.0 | 668.6 | 102.2 | ND | 26.0 |
| 6/14/2013 | Edm feed | 6.8 | 4690 | 3945 | 91.5 | 350.5 | 165.3 | 509.6 | 113.7 | 2281.0 | 28.0 |
| 6/18/2013 | Edm feed | 6.8 | 4800 | 4195 | 79.3 | 361.8 | 169.9 | 576.0 | 108.0 | 2435.0 | 29.0 |
| 6/19/2013 | Edm feed | 6.5 | 4950 | 4360 | 79.3 | 363.0 | 171.1 | 620.7 | 107.1 | 2494.7 | 27.0 |
| 6/20/2013 | Edm feed | 6.6 | 4560 | 3970 | 91.5 | 337.1 | 155.8 | 552.2 | 103.3 | 2282.7 | 27.0 |
| 6/21/2013 | Edm feed | 6.8 | 4500 | 3935 | 67.1 | 338.3 | 169.7 | 541.7 | 109.7 | 2258.2 | 29.0 |
| 6/24/2013 | Edm feed | 6.7 | 4670 | 4070 | 91.5 | 347.4 | 162.8 | 561.4 | 108.4 | 2340.0 | 27.0 |
| 6/26/2013 | Edm feed | 6.5 | 4780 | 4190 | 91.5 | 351.0 | 163.9 | 582.3 | 108.1 | 2407.6 | 28.0 |
| 6/27/2013 | Edm feed | 6.4 | 4920 | 4250 | 79.3 | 342.8 | 161.4 | 639.1 | 108.6 | 2494.0 | 27.0 |
| 6/28/2013 | Edm feed 4pm | 6.6 | 4720 | 3775 | 91.5 | 329.2 | 154.2 | 604.4 | 107.7 | 2366.9 | 29.0 |
| 7/8/2013 | EDM Feed | 6.5 | 4680 | 4030 | 122.0 | 317.6 | 156.4 | 608.0 | 95.7 | 2333.4 | 25.0 |
| 7/9/2013 | EDM Feed | 6.5 | 4740 | 4075 | 146.4 | 329.7 | 162.4 | 614.4 | 103.0 | 2372.9 | 27.0 |
| 7/10/2013 | EDM Feed | 6.6 | 4930 | 4320 | 146.4 | 357.6 | 186.0 | 622.3 | 110.6 | 2510.9 | 27.0 |
| 7/11/2013 | Edm feed | 6.5 | 4970 | 4290 | 91.5 | 334.6 | 170.2 | 633.2 | 105.3 | 2502.7 | 27.0 |
| 7/12/2013 | EDM Feed 3:45pm | 6.6 | 5230 | 4295 | 91.5 | 330.6 | 165.7 | 635.0 | 109.6 | 2524.9 | 29.0 |
| 7/12/2013 | EDM Feed Post Side filter 5:20pm | 6.8 | 5330 | 4445 | 85.4 | 344.5 | 171.0 | 650.9 | 111.0 | 2593.9 | 26.0 |
| 7/12/2013 | EDM Feed Pre Side filter 5:20pm | 6.7 | 5300 | 4405 | 67.1 | 339.1 | 169.5 | 648.7 | 111.5 | 2574.7 | 28.0 |

| | | pH | Conductivity | TDS* | $HCO_3$ | Ca | Mg | Na | Cl | $SO_4$ | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | - | (µS/cm) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) |
| 7/13/2013 | EDM Feed 5:15pm | 6.6 | 5680 | 4715 | 115.9 | 361.7 | 177.1 | 723.7 | 103.8 | 2771.4 | 31.0 |
| 7/14/2013 | Edm feed | 6.8 | 7200 | 6930 | 97.6 | 513.9 | 271.0 | 1075.3 | 110.2 | 4004.4 | 25.0 |
| 7/20/2013 | Edm feed | 6.5 | 4740 | 4155 | 115.9 | 295.7 | 145.7 | 682.9 | 87.9 | 2429.7 | 27.0 |
| 3/22/2013 | E-rinse | 10.6 | 19700 | 15850 | 106.1 | ND | ND | ND | ND | ND | 2.8 |
| 3/26/2013 | E-rinse | 11.0 | 22860 | 19025 | 139.1 | 11.0 | ND | 6788.9 | 130.7 | 13898.9 | 2.0 |
| 3/27/2013 | E-rinse | 11.0 | 22100 | 17875 | 183.0 | 12.8 | 14.5 | 6682.7 | 124.7 | 13111.8 | 20.5 |
| 3/28/2013 | E-rinse | 10.9 | 24510 | 20640 | 179.3 | 20.0 | ND | ND | 144.1 | ND | 3.0 |
| 3/29/2013 | E-rinse | 10.9 | 24290 | 20880 | 262.3 | 28.1 | 12.5 | ND | 149.9 | 13023.8 | 3.0 |
| 4/5/2013 | E-rinse | 11.5 | 24590 | 20760 | 315.4 | 18.2 | 1.7 | 6547.7 | 93.8 | 12974.1 | 0.0 |
| 4/8/2013 | E-rinse | 11.6 | 22920 | 18765 | 449.0 | 37.0 | 1.2 | 5913.7 | 120.9 | 11518.2 | 2.0 |
| 4/9/2013 | E-rinse | 11.9 | 22630 | 18405 | 788.1 | ND | ND | ND | ND | ND | 0.0 |
| 4/10/2013 | E-rinse | 12.2 | 20800 | 18905 | 899.1 | ND | ND | ND | ND | ND | 0.5 |
| 4/11/2013 | E-rinse | 11.7 | 20840 | 18930 | 561.2 | 55.0 | 1.0 | 6330.6 | 171.4 | 11578.1 | 0.3 |
| 4/17/2013 | E-rinse | 11.8 | 22170 | 18505 | 507.5 | 39.3 | 1.9 | 5849.9 | 149.8 | 11047.1 | 0.8 |
| 4/18/2013 | E-rinse | 12.0 | 22730 | 18685 | 677.1 | 55.3 | ND | 5722.2 | 157.1 | 10692.7 | 1.4 |
| 4/20/2013 | E-rinse | 12.3 | 24540 | 17320 | 2293.6 | 34.5 | 1.6 | 5287.3 | 404.3 | 8366.2 | 3.7 |
| 4/22/2013 | E-rinse | 12.5 | 25070 | 17495 | 39.0 | 39.5 | ND | 5844.7 | 392.4 | 9439.5 | 2.0 |
| 4/25/2013 | E-rinse | 12.1 | 26920 | 23425 | 1006.5 | 21.4 | 0.5 | 7299.3 | 146.4 | 14303.6 | 2.1 |
| 4/26/2013 | E-rinse | 10.2 | 26820 | 24060 | 433.1 | 40.9 | 8.4 | 8193.3 | 120.8 | 16085.1 | 1.8 |
| 4/30/2013 | E-rinse | 11.8 | 25710 | 22020 | ND | 17.4 | 1.5 | 7515.0 | 175.1 | 13724.0 | 2.0 |
| 5/1/2013 | E-rinse | 10.6 | 23010 | 19755 | 597.8 | 5.4 | 4.0 | 6396.7 | 96.1 | 8177.8 | 3.0 |
| 5/2/2013 | E-rinse | 11.2 | 23210 | 19755 | 658.8 | 4.2 | 0.6 | 6560.5 | 55.9 | 8178.6 | 4.0 |
| 5/29/2013 | E-rinse | 9.8 | 22330 | 20130 | 390.4 | 24.3 | 11.1 | 6461.0 | 232.3 | 13288.1 | 1.1 |
| 5/31/2013 | E-rinse | 9.8 | 21460 | 19660 | 384.3 | 24.4 | 11.4 | 6012.4 | 164.5 | 11985.1 | 4.0 |
| 6/3/2013 | E-rinse | 10.0 | 20890 | 19335 | 134.2 | 28.7 | 12.2 | 6022.6 | 152.3 | 11408.5 | 4.0 |
| 6/14/2013 | E-rinse | 11.3 | 22370 | 19230 | 305.0 | 23.1 | 1.9 | 6019.3 | 153.3 | 11682.6 | 10.0 |
| 6/18/2013 | E-rinse | 11.1 | 22400 | 19495 | ND | 26.6 | 2.6 | 6047.6 | 165.5 | 11479.8 | 4.0 |
| 6/19/2013 | E-rinse | 11.0 | 22550 | 19840 | 170.8 | 21.6 | 3.6 | 6144.6 | 175.9 | 11270.8 | 1.0 |

| | | pH | Conductivity | TDS* | $HCO_3$ | Ca | Mg | Na | Cl | $SO_4$ | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | - | (µS/cm) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) |
| 6/20/2013 | E-rinse | 11.1 | 22500 | 19750 | 195.2 | 19.3 | 3.5 | 6099.5 | 237.5 | 11029.7 | 2.0 |
| 6/21/2013 | E-rinse | 11.0 | 22800 | 20100 | 164.7 | 15.7 | 2.8 | 6182.2 | 193.7 | 11089.2 | 3.0 |
| 6/24/2013 | E-rinse | 10.9 | 22660 | 19785 | 250.1 | 24.1 | 3.6 | 6090.9 | 268.7 | 11081.9 | 3.0 |
| 6/26/2013 | E-rinse | 11.0 | 23200 | 20285 | 201.3 | 26.3 | 3.1 | 6344.2 | 124.8 | 12361.3 | 3.0 |
| 6/27/2013 | E-rinse | 10.8 | 24090 | 21450 | 280.6 | 21.3 | 3.7 | 6840.0 | 188.3 | 12777.6 | 2.0 |
| 6/28/2013 | E-rinse 4pm | 10.8 | 23840 | 21275 | 305.0 | 22.3 | 3.9 | 6885.6 | 221.1 | 12481.9 | 6.0 |
| 7/11/2013 | E-rinse | 7.7 | 24770 | 22480 | 256.2 | 38.2 | 7.5 | 6737.9 | 348.3 | 11895.5 | 3.0 |
| 7/12/2013 | E-Rinse 3:45pm | 7.9 | 26070 | 21710 | 146.4 | 47.9 | ND | 6903.8 | 335.1 | 12896.5 | 3.0 |
| 7/14/2013 | E-rinse | 3.7 | 32200 | 31535 | ND | 82.5 | 14.0 | 9408.1 | 456.7 | 16055.6 | 4.0 |
| 7/20/2013 | E-rinse | 10.1 | 23840 | 21470 | 170.8 | 28.6 | 4.3 | 6651.3 | 263.7 | 12765.5 | 3.0 |
| 3/22/2013 | Mix Na | 7.9 | 110800 | 144730 | 3523.4 | ND | ND | ND | ND | ND | 10.9 |
| 3/26/2013 | Mix Na | 7.8 | 123700 | 179780 | 5827.9 | 429.8 | 321.4 | 66561.2 | 11834.5 | 113899.9 | 2.7 |
| 3/27/2013 | Mix Na | 7.9 | 125600 | 186020 | 4912.9 | 516.0 | 340.6 | 69412.6 | 12294.5 | 114761.8 | 7.7 |
| 3/28/2013 | Mix Na | 7.7 | 134900 | 224640 | 6425.0 | 611.7 | 373.8 | 74624.2 | 15236.4 | 131499.1 | 2.0 |
| 3/29/2013 | Mix Na | 7.6 | 126900 | 193655 | 5620.0 | 490.4 | 447.8 | 65855.9 | 13326.6 | 111874.7 | 6.0 |
| 4/5/2013 | Mix Na | 8.1 | 104700 | 129590 | 4392.0 | 193.6 | 120.0 | 41239.3 | 8378.6 | 71578.8 | 3.9 |
| 4/8/2013 | Mix Na | 7.9 | 118700 | 164365 | 4538.4 | 382.9 | 303.2 | 52196.4 | 11415.9 | 91183.5 | 9.0 |
| 4/9/2013 | Mix Na | 7.7 | 114900 | 152920 | 4514.0 | ND | ND | ND | ND | ND | |
| 4/10/2013 | Mix Na | 7.9 | 111100 | 163935 | 5172.8 | ND | ND | ND | ND | ND | 7.3 |
| 4/11/2013 | Mix Na | 7.8 | 107800 | 154080 | 4544.5 | 664.0 | 297.9 | 55603.9 | 13500.7 | 91153.4 | 6.8 |
| 4/17/2013 | Mix Na | 7.6 | 114700 | 143850 | 3672.2 | 668.0 | 249.5 | 51058.0 | 11331.0 | 87719.8 | 5.0 |
| 4/18/2013 | Mix Na | 7.6 | 118400 | 164285 | 4428.6 | 746.0 | 298.4 | 53441.1 | 11571.6 | 93002.5 | 8.1 |
| 4/20/2013 | Mix Na | 7.7 | 116900 | 160290 | 3775.9 | 694.2 | 209.1 | 59274.3 | 12756.9 | 97633.9 | 6.2 |
| 4/22/2013 | Mix Na | 7.8 | 120700 | 173135 | ND | 748.8 | 274.9 | 59865.3 | 14669.0 | 100324.8 | 7.0 |
| 4/25/2013 | Mix Na | 8.2 | 114900 | 161990 | 2807.2 | 650.2 | 229.7 | 53244.5 | 10238.6 | 98126.8 | 6.9 |
| 4/26/2013 | Mix Na | 8.3 | 11700 | 151825 | 3379.4 | 814.5 | 228.7 | 53477.4 | 9532.0 | 90613.1 | 9.7 |
| 4/30/2013 | Mix Na | 8.2 | 116100 | 163070 | ND | 907.5 | 248.6 | 52591.4 | 9476.5 | 96569.0 | 9.0 |
| 5/1/2013 | Mix Na | 8.3 | 116000 | 160500 | ND | 519.0 | 193.9 | 50293.8 | 10213.7 | 87932.3 | 8.0 |

|  |  | pH | Conductivity | TDS* | $HCO_3$ | Ca | Mg | Na | Cl | $SO_4$ | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | - | (µS/cm) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) |
| 5/2/2013 | Mix Na | 8.1 | 112100 | 150346 | ND | 216.1 | 85.2 | 52606.0 | 9764.8 | 88642.4 | 9.0 |
| 5/29/2013 | Mix Na | 8.2 | 111500 | 167535 | 1421.3 | 884.2 | 316.2 | 56083.2 | 10383.5 | 112802.3 | 7.7 |
| 5/31/2013 | Mix Na | 7.5 | 108300 | 164280 | 1128.5 | 910.9 | 295.2 | 54198.0 | 9437.8 | 103814.8 | 8.0 |
| 6/3/2013 | Mix Na | 7.5 | 106700 | 161935 | 597.8 | 1056.3 | 406.9 | 50966.7 | 9285.3 | 91857.9 | 9.0 |
| 6/4/2013 | Mix Na | 7.4 | 105400 | 155070 | 854.0 | 1169.2 | 507.4 | 59856.7 | 9621.5 | 107103.6 | 10.0 |
| 6/14/2013 | Mix Na | 8.0 | 119300 | 177680 | 3233.0 | 702.5 | 172.9 | 57315.6 | 10066.4 | 100496.3 | 12.0 |
| 6/18/2013 | Mix Na | 7.9 | 119000 | 174560 | 3135.4 | 716.2 | 210.4 | 56184.2 | 11420.0 | 97511.5 | 20.0 |
| 6/19/2013 | Mix Na | 7.7 | 114900 | 162465 | 2696.2 | 533.5 | 168.8 | 52567.5 | 11023.0 | 89800.1 | 7.0 |
| 6/20/2013 | Mix Na | 7.9 | 115800 | 162755 | 2842.6 | 418.0 | 136.4 | 53606.3 | 11610.5 | 90813.6 | 8.0 |
| 6/21/2013 | Mix Na | 8.0 | 120700 | 177400 | 2281.4 | 294.0 | 141.5 | 58853.9 | 12393.8 | 99671.8 | 8.0 |
| 6/26/2013 | Mix Na | 7.8 | 115600 | 163260 | 3184.2 | 575.7 | 152.3 | 52207.8 | 10828.6 | 90115.8 | 27.0 |
| 6/27/2013 | Mix Na | 7.8 | 114600 | 159795 | 2806.0 | 417.8 | 143.1 | 53582.5 | 11766.5 | 91412.5 | 8.0 |
| 6/28/2013 | Mix Na 4pm | 8.0 | 116000 | 163795 | 3294.0 | 416.0 | 132.1 | 55882.5 | 12409.3 | 94414.7 | 11.0 |
| 7/8/2013 | Mix Na | 7.8 | 115200 | 163525 | 3294.0 | 625.0 | 141.8 | 53842.5 | 11327.3 | 91689.6 | 11.0 |
| 7/11/2013 | Mix Na | 8.2 | 114800 | 163035 | 3538.0 | 672.4 | 325.0 | 49713.1 | 11022.8 | 86620.7 | 5.0 |
| 7/13/2013 | Mix Na 5:15pm | 7.8 | 120900 | 164505 | 3538.0 | 816.6 | 497.2 | 49942.5 | 10952.0 | 88928.1 | 8.0 |
| 7/14/2013 | Mix Na | 8.3 | 109300 | 159990 | 2745.0 | 1051.7 | 531.6 | 65882.8 | 84716.6 | ND | 9.0 |
| 7/20/2013 | Mix Na | 8.3 | 111800 | 167340 | 3660.0 | 1361.2 | 260.0 | 54019.8 | 11258.3 | 94552.9 | 17.0 |
| 3/22/2013 | Mix Cl | 2.5 | 138600 | 122800 | 0.0 | ND | ND | ND | ND | ND | 3.0 |
| 3/25/2013 | Mix Cl | 4.5 | 145100 | 134565 | 41.5 | 10042.4 | 11288.7 | ND | 70676.2 | 1731.9 | 6.0 |
| 3/26/2013 | Mix Cl | 5.4 | 131700 | 117925 | 42.7 | 15481.4 | 9767.5 | 10479.1 | 54718.6 | 881.5 | 2.5 |
| 3/27/2013 | Mix Cl | 5.2 | 151900 | 133305 | 41.5 | 18574.8 | 9490.1 | 13432.3 | 82716.3 | 975.7 | 4.2 |
| 3/28/2013 | Mix Cl | 5.5 | 151000 | 195610 | 97.6 | 18100.9 | 6605.9 | 13108.2 | ND | 1073.2 | 4.0 |
| 3/29/2013 | Mix Cl | 5.5 | 150600 | 202925 | 67.1 | 17210.7 | ND | 14223.2 | 162830.5 | ND | 4.0 |
| 4/5/2013 | Mix Cl | 2.2 | 166300 | 163125 | 0.0 | 20130.6 | 9205.8 | 14762.7 | 85554.8 | 801.4 | 2.0 |
| 4/8/2013 | Mix Cl | 2.2 | 176300 | 184045 | 0.0 | 22372.1 | 10560.5 | 16032.1 | 95674.0 | 553.6 | 5.0 |
| 4/9/2013 | Mix Cl | 2.1 | 177600 | 185610 | 0.0 | ND | ND | ND | ND | ND | 3.1 |
| 4/10/2013 | Mix Cl | 2.1 | 166400 | 182330 | 0.0 | ND | ND | ND | ND | ND | 2.8 |

| | | pH | Conductivity | TDS* | $HCO_3$ | Ca | Mg | Na | Cl | $SO_4$ | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | - | (µS/cm) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) |
| 4/11/2013 | Mix Cl | 1.8 | 167100 | 185970 | 0.0 | 25902.1 | 10906.1 | 17675.0 | 102639.4 | 687.2 | 5.3 |
| 4/17/2013 | Mix Cl | 2.4 | 160100 | 157990 | 0.0 | 20176.2 | 8661.7 | 14609.3 | 84681.1 | 738.0 | ND |
| 4/18/2013 | Mix Cl | 2.1 | 177000 | 214110 | 0.0 | 23617.7 | 10257.7 | 17220.4 | 100542.9 | 599.4 | 3.9 |
| 4/22/2013 | Mix Cl | 1.9 | 175400 | 165435 | 0.0 | 23662.9 | 9757.0 | 17339.0 | 98621.2 | 888.5 | 6.0 |
| 4/25/2013 | Mix Cl | 2.0 | 171500 | 181750 | 0.0 | 21937.3 | 9058.1 | 17036.8 | 100648.2 | 1273.3 | 5.2 |
| 4/26/2013 | Mix Cl | 2.0 | 172900 | 179395 | 0.0 | 24838.9 | 10644.0 | 18448.3 | 102558.7 | 1040.0 | 7.1 |
| 4/30/2013 | Mix Cl | 1.9 | 160200 | 167725 | 0.0 | 22035.8 | 9422.0 | 16780.0 | 93362.9 | 1756.9 | 8.0 |
| 5/2/2013 | Mix Cl | 1.9 | 170300 | 178655 | 0.0 | 21810.8 | 9103.3 | 17393.0 | 93827.2 | 748.2 | 5.0 |
| 5/29/2013 | Mix Cl | 1.6 | 161500 | 162945 | 0.0 | 21821.0 | 8972.7 | 20064.4 | 108610.0 | 1463.0 | 6.4 |
| 5/31/2013 | Mix Cl | 1.9 | 164600 | 185585 | 0.0 | 24422.4 | 10169.2 | 20368.6 | 111472.7 | 922.3 | 8.0 |
| 6/3/2013 | Mix Cl | 1.6 | 161400 | 170560 | 0.0 | 19838.5 | 8649.8 | 16272.8 | 86346.2 | 612.1 | 6.0 |
| 6/4/2013 | Mix Cl | 1.6 | 164500 | 182460 | 0.0 | 19707.6 | 8365.4 | 17744.1 | 86663.3 | 895.7 | 5.0 |
| 6/14/2013 | Mix Cl | 3.3 | 162100 | 163900 | 0.0 | 19565.1 | 8621.6 | 17593.3 | 87485.8 | 981.7 | 6.0 |
| 6/18/2013 | Mix Cl | 6.2 | 172000 | 182675 | 97.6 | 21066.8 | 9216.3 | 19178.0 | 94827.5 | 888.8 | 5.0 |
| 6/19/2013 | Mix Cl | 6.0 | 172400 | 187285 | 115.9 | 21862.6 | 9548.2 | 19890.5 | 97863.3 | 573.2 | 5.0 |
| 6/20/2013 | Mix Cl | 5.8 | 173700 | 187080 | 48.8 | 21677.8 | 9486.9 | 19286.9 | 96753.5 | 419.1 | 5.0 |
| 6/21/2013 | Mix Cl | 5.8 | 175100 | 229990 | 42.7 | 16333.0 | 7682.0 | 14986.5 | 74263.0 | 365.9 | 5.0 |
| 6/24/2013 | Mix Cl | 6.0 | 170600 | 186200 | 115.9 | 20614.2 | 8994.1 | 19071.6 | 93193.9 | 806.9 | 5.0 |
| 6/26/2013 | Mix Cl | 3.9 | 168300 | 183335 | 0.0 | 21030.2 | 8944.3 | 18699.0 | 93553.4 | 1350.6 | 5.0 |
| 6/27/2013 | Mix Cl | 5.8 | 172300 | 190615 | 128.1 | 25921.1 | 11310.8 | 23294.2 | 116668.5 | 766.1 | 5.0 |
| 6/28/2013 | Mix Cl 4pm | 6.0 | 171700 | 185835 | 134.2 | 22192.2 | 9642.9 | 19634.4 | 99239.8 | 669.7 | 10.0 |
| 7/8/2013 | Mix Cl | 3.6 | 167800 | 185150 | 0.0 | 21553.0 | 9489.9 | 18665.0 | 94122.8 | 814.9 | 5.0 |
| 7/11/2013 | Mix Cl | 5.1 | 169600 | 179140 | 36.6 | 20784.5 | 9499.7 | 17368.7 | 91691.4 | 780.8 | 5.0 |
| 7/13/2013 | Mix Cl 5:15pm | 5.9 | 180900 | 180500 | 85.4 | 21523.0 | 9600.5 | 17199.8 | 93050.7 | 1380.8 | 5.0 |
| 7/14/2013 | Mix Cl | 5.8 | 154500 | 166840 | 36.6 | 20577.5 | 9146.1 | 14606.2 | 84550.0 | 1646.8 | 5.0 |
| 7/20/2013 | Mix Cl | 4.2 | 140900 | 141025 | 6.1 | 17407.4 | 7143.4 | 15695.0 | 78528.5 | 1896.8 | 6.0 |
| 3/22/2013 | NaCl | 5.5 | 46700 | 26120 | 67.1 | ND | ND | ND | ND | ND | 11.0 |
| 3/26/2013 | NaCl | 6.0 | 50300 | 29115 | 101.3 | 39.0 | 22.2 | 11921.7 | 18353.3 | 270.3 | 8.5 |

|  |  | pH | Conductivity | TDS* | $HCO_3$ | Ca | Mg | Na | Cl | $SO_4$ | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | - | (µS/cm) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) |
| 3/27/2013 | NaCl | 6.0 | 48300 | 29685 | 36.6 | 1.2 | 0.0 | 10760.6 | 16399.9 | 229.6 | 7.0 |
| 3/28/2013 | NaCl | 6.2 | 48700 | 34055 | 110.4 | 47.4 | 44.4 | 8823.7 | 13321.4 | 233.2 | 5.0 |
| 3/29/2013 | NaCl | 6.3 | 51800 | 33080 | 107.4 | 50.8 | 42.5 | 10305.4 | 15972.2 | 262.2 | 8.0 |
| 4/8/2013 | NaCl | 4.0 | 52100 | 30500 | 0.0 | 61.6 | 27.2 | 11642.2 | 17662.2 | 611.3 |  |
| 4/8/2013 | NaCl | 3.7 | 51600 | 30180 | 0.0 | 65.2 | 39.0 | 11360.9 | 17354.3 | 645.7 | 6.0 |
| 4/9/2013 | NaCl | 3.3 | 52300 | 30395 | 0.0 | ND | ND | ND | ND | ND | 4.2 |
| 4/10/2013 | NaCl | 3.5 | 45700 | 26150 | 0.0 | ND | ND | ND | ND | ND | 5.2 |
| 4/11/2013 | NaCl | 3.4 | 42500 | 26205 | 0.0 | 58.1 | 20.1 | 10358.5 | 12174.9 | 265.0 | 4.7 |
| 4/17/2013 | NaCl | 3.7 | 48600 | 27570 | 0.0 | 60.3 | 20.7 | 10878.6 | 16693.2 | 463.6 | 2.1 |
| 4/18/2013 | NaCl | 3.6 | 50700 | 29925 | 0.0 | 93.4 | 40.7 | 11445.2 | 17547.2 | 702.7 | 5.5 |
| 4/20/2013 | NaCl | 3.6 | 47500 | 27480 | 0.0 | ND | ND | ND | 17912.2 | 666.0 | 2.6 |
| 4/25/2013 | NaCl | 3.7 | 56000 | 33425 | 0.0 | 58.7 | 55.8 | 14951.7 | 23316.6 | 1962.5 | 12.5 |
| 4/26/2013 | NaCl | 3.7 | 55300 | 33010 | 0.0 | 163.6 | 53.8 | 14166.2 | 20482.5 | 797.4 | 10.0 |
| 4/30/2013 | NaCl | 3.2 | 55800 | 32825 | 0.0 | 135.4 | 50.2 | 14533.7 | 21277.9 | 310.4 | 9.0 |
| 5/1/2013 | NaCl | 3.4 | 57300 | 34060 | 0.0 | 53.7 | 18.5 | 13771.2 | 21298.3 | 909.4 | 7.0 |
| 5/2/2013 | NaCl | 3.3 | 56500 | 33440 | 0.0 | 61.6 | 22.3 | 7847.8 | 11409.3 | 151.8 | 7.0 |
| 5/29/2013 | NaCl | 2.9 | 52800 | 34010 | 0.0 | 52.6 | 38.0 | 13078.1 | 21649.4 | 2212.7 | 10.3 |
| 5/31/2013 | NaCl | 3.2 | 52200 | 33455 | 0.0 | 61.9 | 36.6 | 12764.9 | 20533.3 | 1073.9 | 9.0 |
| 6/3/2013 | NaCl | 2.9 | 50200 | 32550 | 0.0 | 78.7 | 56.0 | 12111.3 | 18207.4 | 1080.3 | 8.0 |
| 6/14/2013 | NaCl | 6.2 | 54400 | 32745 | 109.8 | 51.6 | 24.0 | 12417.8 | 18938.8 | 752.7 | 8.0 |
| 6/18/2013 | NaCl | 6.4 | 54700 | 33340 | 97.6 | 52.4 | 26.0 | 12475.0 | 18978.1 | 830.0 | 5.0 |
| 6/19/2013 | NaCl | 6.3 | 54400 | 33285 | 91.5 | 46.3 | 23.6 | 12429.2 | 18544.7 | 938.7 | 5.0 |
| 6/20/2013 | NaCl | 6.3 | 54800 | 33765 | 103.7 | 38.2 | 21.1 | 12586.3 | 18804.9 | 1033.0 | 4.0 |
| 6/21/2013 | NaCl | 6.5 | 54400 | 36190 | 213.5 | 31.9 | 22.1 | 12753.9 | 18675.9 | 1523.3 | 6.0 |
| 6/24/2013 | NaCl | 6.4 | 55500 | 33825 | 164.7 | 39.3 | 23.8 | 12671.0 | 19116.2 | 985.7 | 5.0 |
| 6/26/2013 | NaCl | 6.1 | 55400 | 33365 | 134.2 | 48.8 | 23.9 | 13201.3 | 19942.9 | 1007.3 | 5.0 |
| 6/27/2013 | NaCl | 6.3 | 56000 | 34335 | 128.1 | 39.8 | 22.8 | 13631.6 | 20380.8 | 1227.0 | 5.0 |
| 6/28/2013 | NaCl 4pm | 6.4 | 54000 | 32880 | 140.3 | 33.8 | 17.6 | 12647.5 | 18886.7 | 1179.1 | 4.0 |

| | | pH | Conductivity | TDS* | $HCO_3$ | Ca | Mg | Na | Cl | $SO_4$ | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | - | (µS/cm) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) |
| 7/11/2013 | NaCl | 6.4 | 53400 | 33345 | 195.2 | 73.2 | 51.3 | 12450.4 | 18481.4 | 1570.3 | 5.0 |
| 7/12/2013 | NaCl 3:45pm | 6.5 | 56100 | 33320 | 140.3 | 98.7 | 83.1 | 12772.1 | 18400.1 | 2301.1 | 5.0 |
| 7/14/2013 | NaCl | 7.0 | 53000 | 35530 | 219.6 | 171.2 | 81.3 | 13723.7 | 17518.0 | 3580.3 | 6.0 |
| 7/20/2013 | NaCl stand pipe | 6.7 | 56300 | 35065 | 103.7 | 49.7 | 24.0 | 12990.6 | 19597.4 | 1229.5 | 8.0 |
| 3/22/2013 | NF conc | 6.6 | 7880 | 7880 | 226.9 | ND | ND | ND | ND | ND | 27.2 |
| 3/25/2013 | NF conc | 6.5 | 8400 | 8350 | 244.0 | 699.8 | 801.0 | ND | 217.5 | 4309.8 | 25.0 |
| 3/26/2013 | NF conc | 7.4 | 4130 | 9045 | 380.6 | 472.5 | 208.8 | 924.0 | 257.1 | 4693.3 | 23.3 |
| 3/27/2013 | NF conc | 6.5 | 8520 | 8070 | 244.0 | 416.4 | 624.9 | 933.5 | 242.4 | 4494.4 | 20.1 |
| 3/28/2013 | NF conc | 7.4 | 8040 | 8960 | 327.0 | 427.6 | 864.5 | 871.4 | 254.6 | 4803.6 | 26.0 |
| 4/5/2013 | NF conc | 6.9 | 8020 | 8070 | 289.1 | 466.6 | 485.9 | 844.9 | 215.5 | 4213.2 | 25.2 |
| 4/8/2013 | NF conc | 6.9 | 9110 | 9550 | 248.9 | 475.8 | 508.9 | 895.8 | 206.9 | 4455.2 | 26.0 |
| 4/9/2013 | NF conc | 6.9 | 19380 | 9820 | 307.4 | ND | ND | ND | ND | ND | 22.0 |
| 4/10/2013 | NF conc | 6.8 | 8520 | 8120 | 301.3 | ND | ND | ND | ND | ND | 23.4 |
| 4/11/2013 | NF conc | 6.9 | 7840 | 8070 | 280.6 | 547.6 | 515.0 | 933.0 | 242.2 | 3929.9 | 25.7 |
| 4/17/2013 | NF conc | 7.5 | 7850 | 7445 | 291.6 | 539.9 | 456.5 | 864.3 | 217.5 | 4291.6 | 29.3 |
| 4/18/2013 | NF conc | 6.9 | 7880 | 8015 | 236.7 | 465.3 | 424.3 | 836.1 | 187.4 | 4017.1 | 27.3 |
| 4/20/2013 | NF conc | 6.9 | 8170 | 8300 | 263.5 | 512.0 | 478.0 | 917.2 | 234.1 | 4556.8 | 25.8 |
| 4/22/2013 | NF conc | 6.9 | 8400 | 7830 | 201.3 | 679.1 | 439.0 | 941.1 | 198.9 | 4681.5 | 25.0 |
| 4/25/2013 | NF conc | 7.0 | 77900 | 7745 | 152.5 | 488.6 | 431.0 | 862.0 | 167.2 | 4429.1 | 20.5 |
| 4/26/2013 | NF conc | 6.9 | 7640 | 7060 | 126.9 | 534.7 | 471.9 | 960.0 | 184.1 | 4168.6 | 23.4 |
| 4/30/2013 | NF conc | 6.2 | 7890 | 7960 | | 505.7 | 488.9 | 917.6 | 174.1 | 4357.5 | 23.0 |
| 5/29/2013 | NF conc | 6.1 | 8500 | 8900 | 95.2 | 916.7 | 363.3 | 1108.2 | 84.2 | 6049.3 | 22.2 |
| 5/31/2013 | NF conc | 6.0 | 8130 | 8385 | 329.4 | 452.7 | 441.0 | 1111.8 | 113.0 | 5068.1 | 25.0 |
| 6/3/2013 | NF conc | 6.4 | 9000 | 10300 | 54.9 | 1043.9 | 487.1 | 1095.8 | 122.8 | 6130.1 | 24.0 |
| 6/14/2013 | NF conc | 7.1 | 9060 | 9465 | 189.1 | 977.5 | 432.0 | 991.8 | 163.0 | 5573.4 | 28.0 |
| 6/18/2013 | NF conc | 7.1 | 8350 | 8535 | 146.4 | 841.0 | 369.7 | 946.0 | 147.0 | 5002.8 | 29.0 |
| 6/19/2013 | NF conc | 6.7 | 8210 | 8350 | 146.4 | 820.6 | 357.0 | 953.8 | 154.8 | 4882.6 | 27.0 |

|  |  | pH | Conductivity | TDS* | $HCO_3$ | Ca | Mg | Na | Cl | $SO_4$ | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | - | (µS/cm) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) |
| 6/20/2013 | NF conc | 6.8 | 7860 | 7940 | 146.4 | 794.5 | 343.2 | 903.3 | 156.0 | 4673.5 | 26.0 |
| 6/21/2013 | NF conc | 6.9 | 7830 | 7920 | 134.2 | 769.5 | 364.1 | 857.1 | 152.9 | 4445.2 | 27.0 |
| 6/24/2013 | NF conc | 6.8 | 7990 | 8080 | 134.2 | 797.0 | 345.7 | 912.8 | 148.2 | 4808.8 | 26.0 |
| 6/26/2013 | NF conc | 6.8 | 7990 | 8155 | 195.2 | 781.3 | 335.7 | 898.4 | 157.6 | 4718.3 | 27.0 |
| 6/27/2013 | NF conc | 6.6 | 8140 | 8235 | 146.4 | 794.8 | 346.1 | 986.1 | 148.4 | 4946.6 | 27.0 |
| 6/28/2013 | NF Conc. 4pm | 6.8 | 7920 | 8025 | 176.9 | 780.9 | 340.0 | 936.7 | 161.9 | 4693.6 | 26.0 |
| 7/11/2013 | NF Perm | 6.8 | 8190 | 8335 | 176.9 | 831.3 | ND | 943.5 | 3181.5 | ND | 26.0 |
| 7/12/2013 | NF Conc 3:45pm | 7.0 | 8570 | 8180 | 176.9 | 784.4 | 359.1 | 936.3 | 151.0 | 4826.6 | 25.0 |
| 7/14/2013 | NF conc | 7.3 | 8230 | 8440 | 225.7 | 862.9 | 397.5 | 961.7 | 197.2 | 4913.1 | 26.0 |
| 7/20/2013 | NF conc | 7.0 | 7780 | 7830 | 176.9 | 725.3 | 329.2 | 1017.9 | 124.1 | 4647.1 | 26.0 |
|  |  |  |  |  |  |  |  |  |  |  |  |
| 3/22/2013 | NF Feed | 6.7 | 3920 | 4800 | 144.6 | ND | ND | ND | ND | ND | 22.0 |
| 3/25/2013 | NF Feed | 6.4 | 4150 | 4435 | 152.5 | 211.9 | 365.5 | ND | 300.2 | 1657.0 | 22.3 |
| 3/26/2013 | NF Feed | 7.4 | 8880 | 3355 | 211.1 | 340.1 | 197.7 | 421.5 | 341.9 | 1609.1 | 25.7 |
| 3/27/2013 | NF Feed | 6.5 | 4040 | 2870 | 152.5 | 328.8 | 202.9 | 407.0 | 332.8 | 1582.0 | 26.7 |
| 3/28/2013 | NF Feed | 7.3 | 3980 | 3530 | 200.1 | 331.2 | 95.9 | 437.7 | 330.7 | ND |  |
| 4/5/2013 | NF Feed | 6.8 | 3870 | 3020 | 179.3 | 290.5 | 133.7 | 367.5 | 301.9 | 1428.6 | 18.4 |
| 4/8/2013 | NF Feed | 6.7 | 4000 | 3180 | 173.2 | 304.5 | 140.5 | 387.8 | 311.1 | 1504.8 | 21.0 |
| 4/9/2013 | NF Feed | 6.7 | 4030 | 3060 | 172.0 | ND | ND | ND | ND | ND | 17.0 |
| 4/10/2013 | NF Feed | 7.0 | 3890 | 3150 | 187.9 | ND | ND | ND | ND | ND | 26.3 |
| 4/11/2013 | NF Feed | 7.1 | 3870 | 3215 | 219.0 | 358.4 | 133.9 | 415.6 | 324.7 | 1628.9 | 19.3 |
| 4/17/2013 | NF Feed | 7.4 | 3860 | 2960 | 176.3 | 303.3 | 130.3 | 381.7 | 301.4 | 1446.9 | 19.7 |
| 4/18/2013 | NF Feed | 7.0 | 3910 | 3210 | 169.6 | 311.4 | 131.9 | 400.6 | 298.0 | 1522.2 | 21.5 |
| 4/20/2013 | NF Feed | 6.8 | 4160 | 3415 | 127.5 | 343.6 | 135.4 | 406.8 | 337.2 | 1617.7 | 18.6 |
| 4/22/2013 | NF Feed | 7.6 | 3880 | 2960 | 158.6 | 315.9 | 117.1 | 408.9 | 319.5 | 1570.4 | 21.0 |
| 4/25/2013 | NF Feed | 6.7 | 3900 | 3005 | ND | 312.2 | 140.3 | 379.3 | 317.3 | 1529.4 | 26.1 |
| 4/26/2013 | NF Feed | 6.7 | 3900 | 2990 | 123.2 | 330.1 | 124.7 | 406.0 | 315.3 | 742.2 | 42.3 |

|  |  | pH | Conductivity | TDS* | $HCO_3$ | Ca | Mg | Na | Cl | $SO_4$ | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | - | (µS/cm) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) |
| 4/30/2013 | NF Feed | 6.2 | 3920 | 3185 | ND | 334.2 | 128.0 | 403.2 | 307.0 | 1570.0 | 21.0 |
| 5/1/2013 | NF Feed | 6.7 | 3880 | 6740 | 158.6 | 300.4 | 124.2 | 399.7 | 309.8 | 1520.1 | 22.0 |
| 5/2/2013 | NF Feed | 6.9 | 3770 | 2920 | 148.2 | 149.7 | 117.6 | 398.6 | 145.3 | 1394.8 | 22.0 |
| 5/29/2013 | NF Feed | 6.0 | 3250 | 2570 | 67.1 | 233.4 | 91.9 | 395.7 | 228.7 | 1441.5 | 19.7 |
| 5/31/2013 | NF Feed | 5.8 | 3920 | 3230 | 79.3 | 303.0 | 130.8 | 471.2 | 278.1 | 1821.3 | 22.0 |
| 6/3/2013 | NF Feed | 6.5 | 3860 | 3290 | 97.6 | 303.2 | 138.6 | 450.5 | 280.6 | 1683.1 | 23.0 |
| 6/14/2013 | NF Feed | 7.1 | 3410 | 2545 | 122.0 | 232.9 | 100.3 | 360.0 | 253.3 | 1266.8 | 27.0 |
| 6/18/2013 | NF Feed | 7.0 | 3450 | 2635 | 109.8 | 239.7 | 102.8 | 377.9 | 244.0 | 1328.3 | 24.0 |
| 6/19/2013 | NF Feed | 6.7 | 3560 | 2750 | 97.6 | 247.6 | 105.9 | 401.3 | 246.5 | 1399.3 | 22.0 |
| 6/20/2013 | NF Feed | 6.6 | 3440 | 2640 | 97.6 | 236.8 | 100.2 | 376.6 | 240.4 | 1323.2 | 22.0 |
| 6/21/2013 | NF Feed | 6.9 | 3410 | 2635 | 97.6 | 239.2 | 110.8 | 378.5 | 152.6 | 4592.4 | 23.0 |
| 6/24/2013 | NF Feed | 6.7 | 3480 | 2650 | 115.9 | 242.6 | 104.1 | 385.6 | 243.7 | 1343.0 | 23.0 |
| 6/26/2013 | NF Feed | 6.7 | 3530 | 2700 | 122.0 | 245.5 | 103.9 | 390.6 | 247.6 | 1376.3 | 23.0 |
| 6/27/2013 | NF Feed | 6.7 | 3550 | 2720 | 146.4 | 240.2 | 102.3 | 406.5 | 243.8 | 1389.1 | 23.0 |
| 6/28/2013 | NF Feed 4pm | 6.7 | 3490 | 2655 | 164.7 | 235.7 | 101.9 | 396.9 | 241.1 | 1341.1 | 22.0 |
| 7/11/2013 | NF Feed | 6.7 | 3700 | 2855 | 256.2 | 244.9 | 114.7 | 414.4 | 251.6 | 1468.3 | 23.0 |
| 7/12/2013 | NF Feed 3:45pm | 6.8 | 3810 | 2800 | 122.0 | 239.4 | 109.2 | 407.6 | 251.0 | 1420.7 | 21.0 |
| 7/14/2013 | NF Feed | 7.1 | 3620 | 2940 | 140.3 | 262.0 | 118.3 | 412.8 | 275.8 | 1407.5 | 22.0 |
| 7/20/2013 | NF Feed | 6.9 | 3360 | 2655 | 146.4 | 216.2 | 97.6 | 418.1 | 213.2 | 1346.6 | 23.0 |
| 3/22/2013 | NF Perm | 6.9 | 1438 | 200 | 122.6 | ND | ND | ND | ND | ND | 18.7 |
| 3/26/2013 | NF Perm | 7.2 | 1539 | 790 | 156.2 | 43.8 | 17.9 | 221.8 | 359.5 | 29.3 | 19.5 |
| 3/27/2013 | NF Perm | 6.5 | 1496 | 960 | 119.3 | 45.2 | 15.8 | 217.6 | 352.5 | 29.6 | 27.5 |
| 3/28/2013 | NF Perm | 7.2 | 1539 | 1070 | 147.6 | 50.2 | 19.6 | ND | ND | 34.0 | 20.0 |
| 3/29/2013 | NF Perm | 7.3 | 1463 | 860 | 170.8 | 0.5 | ND | 208.9 | 327.1 | 28.5 | 20.0 |
| 4/5/2013 | NF Perm | 6.9 | 1496 | 820 | 142.7 | 46.2 | 16.1 | 209.6 | 339.4 | 48.8 | 17.1 |
| 4/8/2013 | NF Perm | 6.7 | 1593 | 965 | 276.9 | 46.5 | 16.1 | 217.7 | 354.1 | 43.3 | 19.0 |
| 4/9/2013 | NF Perm | 7.0 | 1565 | 875 | 137.9 | ND | ND | ND | ND | ND | 16.9 |

| | | pH | Conductivity | TDS* | $HCO_3$ | Ca | Mg | Na | Cl | $SO_4$ | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | - | (µS/cm) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) |
| 4/10/2013 | NF Perm | 6.6 | 1501 | 1980 | 280.6 | ND | ND | ND | ND | ND | 17.1 |
| 4/11/2013 | NF Perm | 6.8 | 1517 | 785 | 144.0 | 53.2 | 15.3 | 230.8 | 370.1 | 43.0 | 16.8 |
| 4/17/2013 | NF Perm | 8.2 | 1571 | 780 | 140.3 | 50.1 | 16.7 | 211.7 | 333.1 | 70.3 | 17.9 |
| 4/18/2013 | NF Perm | 7.0 | 1544 | 945 | 126.9 | 47.5 | 15.7 | 214.6 | 336.7 | 70.7 | 18.6 |
| 4/20/2013 | NF Perm | 6.9 | 1602 | 910 | 142.7 | 52.9 | 15.4 | 220.6 | 353.9 | 77.6 | 17.6 |
| 4/22/2013 | NF Perm | 8.1 | 1516 | 780 | 134.2 | 49.3 | 15.6 | 223.3 | 337.7 | 80.5 | 20.0 |
| 4/25/2013 | NF Perm | 6.6 | 1658 | 3140 | 100.7 | 55.9 | 20.0 | 217.8 | 354.6 | 104.4 | 19.8 |
| 4/26/2013 | NF Perm | 6.6 | 1609 | 900 | 103.1 | 56.9 | 19.6 | 223.1 | 360.6 | 93.4 | 17.5 |
| 4/30/2013 | NF Perm | 6.2 | 1682 | 915 | | 61.1 | 21.8 | 226.9 | 370.4 | 109.1 | 20.0 |
| 5/1/2013 | NF Perm | 6.8 | 1642 | 2540 | 134.2 | 52.6 | 20.0 | 224.0 | 339.2 | 100.6 | 21.0 |
| 5/2/2013 | NF Perm | 7.0 | 1601 | 865 | 138.2 | 54.3 | 19.4 | 221.5 | 325.7 | 101.3 | 21.0 |
| 5/29/2013 | NF Perm | 6.5 | 1145 | 605 | 63.4 | 23.2 | 8.5 | 184.0 | 289.7 | 62.5 | 18.8 |
| 5/31/2013 | NF Perm | 5.6 | 1373 | 715 | 109.8 | 30.8 | 11.7 | 220.9 | 343.1 | 82.0 | 22.0 |
| 6/3/2013 | NF Perm | 6.4 | 1398 | 770 | 97.6 | 34.0 | 13.0 | 223.5 | 338.3 | 72.2 | 21.0 |
| 6/14/2013 | NF Perm | 7.1 | 1338 | 615 | 109.8 | 26.1 | 8.3 | 182.4 | 289.5 | 38.1 | 21.0 |
| 6/18/2013 | NF Perm | 7.1 | 1237 | 600 | 97.6 | 24.3 | 8.0 | 183.7 | 281.2 | 39.8 | 21.0 |
| 6/19/2013 | NF Perm | 6.7 | 1226 | 645 | 79.3 | 24.8 | 8.1 | 187.8 | 282.6 | 35.8 | 21.0 |
| 6/20/2013 | NF Perm | 6.7 | 1203 | 605 | 91.5 | 25.4 | 8.1 | 182.7 | 278.6 | 33.2 | 21.0 |
| 6/21/2013 | NF Perm | 6.8 | 1224 | 625 | 79.3 | 25.6 | 8.9 | 181.9 | 284.5 | 34.2 | 21.0 |
| 6/24/2013 | NF Perm | 6.8 | 1217 | 660 | 103.7 | 25.8 | 8.4 | 185.1 | 280.0 | 34.0 | 21.0 |
| 6/26/2013 | NF Perm | 6.6 | 1226 | 650 | 85.4 | 25.7 | 8.1 | 187.1 | 285.0 | 36.5 | 21.0 |
| 6/27/2013 | NF Perm | 6.7 | 1219 | 625 | 85.4 | 23.6 | 7.8 | 188.7 | 280.0 | 36.3 | 21.0 |
| 6/28/2013 | NF Perm 4pm | 6.6 | 1213 | 580 | 109.8 | 23.9 | 7.9 | 186.2 | 275.2 | 34.1 | 20.0 |
| 7/8/2013 | NF Perm | 6.7 | 1230 | 635 | 109.8 | 24.7 | 9.0 | 191.9 | 286.7 | 32.7 | 22.0 |
| 7/9/2013 | NF Perm | 6.7 | 1221 | 625 | 109.8 | 24.4 | 9.1 | 191.3 | 283.1 | 33.0 | 22.0 |
| 7/10/2013 | NF Perm | 6.8 | 1329 | 680 | 146.4 | 27.8 | 10.5 | 204.7 | 308.0 | 34.4 | 22.0 |
| 7/11/2013 | NF conc | 6.7 | 1285 | 650 | 103.7 | 26.9 | 8.6 | 187.7 | 281.4 | 170.8 | 22.0 |
| 7/12/2013 | NF Perm | 6.9 | 1340 | 640 | 91.5 | 24.5 | 9.0 | 196.6 | 295.4 | 31.4 | 20.0 |

|  |  | pH | Conductivity | TDS* | HCO$_3$ | Ca | Mg | Na | Cl | SO$_4$ | SiO$_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | - | (µS/cm) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) |
|  | 3:45pm |  |  |  |  |  |  |  |  |  |  |
| 7/14/2013 | NF Perm | 7.2 | 1312 | 695 | 109.8 | 29.9 | 9.4 | 209.3 | 318.4 | 25.2 | 21.0 |
| 7/20/2013 | NF Perm | 7.2 | 1097 | 590 | 103.7 | 17.7 | 7.0 | 181.9 | 260.4 | 30.3 | 21.0 |
| 3/22/2013 | raw | 7.7 | 3970 | 2710 | 280.6 | ND | ND | ND | ND | ND | 17.0 |
| 3/25/2013 | Raw | 7.4 | 4060 | 5550 | 263.5 | 202.3 | 379.1 | ND | 1103.8 | ND | 16.0 |
| 3/26/2013 | RAW | 7.4 | 4120 | 3375 | 305.6 | 342.8 | 123.5 | 439.5 | 421.2 | 1472.0 | 19.2 |
| 3/27/2013 | raw | 7.4 | 4120 | 3255 | 263.5 | 330.7 | 169.4 | 384.2 | 395.9 | 1380.5 | 20.3 |
| 3/28/2013 | raw | 7.5 | 4130 | 3465 | 245.2 |  |  |  |  |  | 18.0 |
| 3/29/2013 | raw | 7.5 | 3910 | 3205 | 229.4 | 297.5 | ND | 379.7 | 396.2 | 1412.9 | 20.0 |
| 4/5/2013 | raw | 7.4 | 4050 | 3150 | 354.4 | 304.5 | 138.4 | 376.6 | 378.7 | 1372.8 | 17.2 |
| 4/8/2013 | raw | 7.3 | 4120 | 3155 | 406.3 | 308.8 | 141.3 | 376.8 | 384.5 | 1383.6 | 20.0 |
| 4/9/2013 | raw | 7.4 | 4020 | 2940 | 252.5 | ND | ND | ND | ND | ND | 17.7 |
| 4/10/2013 | raw | 7.3 | 3840 | 3070 | 337.9 | ND | ND | ND | ND | ND | 16.1 |
| 4/11/2013 | raw | 7.7 | 4000 | 2875 | 136.0 | 370.4 | 144.9 | 411.6 | 423.9 | 1455.3 | 17.6 |
| 4/17/2013 | raw | 7.8 | 3990 | 2980 | 247.1 | 324.0 | 131.7 | 379.7 | 376.1 | 1345.3 | 19.2 |
| 4/18/2013 | raw | 7.5 | 3960 | 3210 | 250.1 | 318.6 | 128.3 | 373.8 | 368.2 | 1336.7 | 19.5 |
| 4/20/2013 | raw | 7.6 | 4070 | 3245 | 213.5 | 337.2 | 132.6 | 397.1 | 410.8 | 1405.6 | 19.4 |
| 4/22/2013 | raw | 7.4 | 3850 | 2850 | ND | 324.0 | 125.6 | 391.4 | 373.5 | 1333.5 | 20.0 |
| 4/25/2013 | raw | 7.8 | 3920 | 2870 | 205.0 | 316.1 | 123.0 | 380.2 | 381.0 | 1325.8 | 17.6 |
| 4/26/2013 | raw | 7.6 | 3950 | 2960 | 238.5 | 343.6 | 134.4 | 400.7 | 398.2 | 1356.1 | 19.9 |
| 4/30/2013 | raw | 7.4 | 4030 | 3065 | ND | 356.5 | 143.0 | 412.6 | 404.0 | 1429.6 | 19.0 |
| 5/1/2013 | raw | 7.6 | 3750 | 16280 | 242.2 | 290.9 | 116.0 | 374.3 | 343.2 | 1278.4 | 20.0 |
| 5/2/2013 | raw | 7.6 | 3780 | 2910 | 241.6 | 320.7 | 127.0 | 398.4 | 355.7 | 1307.3 | 20.0 |
| 5/29/2013 | raw | 7.7 | 3200 | 2435 | 203.7 | 248.5 | 94.6 | 372.0 | 296.4 | 1265.3 | 18.7 |
| 5/31/2013 | raw | 7.6 | 3400 | 2670 | 201.3 | 276.2 | 107.4 | 383.1 | 316.3 | 1312.4 | 23.0 |
| 6/3/2013 | raw | 7.7 | 3750 | 3045 | 305.0 | 326.3 | 146.1 | 428.0 | 356.1 | 1485.4 | 21.0 |
| 6/18/2013 | raw | 7.9 | 3630 | 2515 | 244.0 | 250.4 | 103.9 | 380.0 | 327.6 | 1187.0 | 21.0 |
| 6/19/2013 | raw | 7.7 | 3470 | 2610 | 244.0 | 258.1 | 105.2 | 360.0 | 298.2 | 1161.6 | 20.0 |

| | | pH | Conductivity | TDS* | $HCO_3$ | Ca | Mg | Na | Cl | $SO_4$ | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | - | (µS/cm) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) |
| 6/20/2013 | raw | 7.8 | 3450 | 2555 | 207.4 | 255.4 | 103.1 | 357.3 | 296.2 | 1150.6 | 20.0 |
| 6/21/2013 | raw | 7.9 | 3430 | 2580 | 183.0 | 255.7 | 114.1 | 359.5 | 298.2 | 1161.7 | 22.0 |
| 6/24/2013 | raw | 7.9 | 3460 | 2585 | 237.9 | 258.4 | 105.7 | 359.3 | 300.5 | 1169.2 | 21.0 |
| 6/26/2013 | raw | 7.9 | 3480 | 2575 | 262.3 | 262.0 | 105.9 | 363.7 | 309.0 | 1193.4 | 21.0 |
| 6/27/2013 | raw | 7.8 | 3430 | 2535 | 256.2 | 254.4 | 102.8 | 359.4 | 299.1 | 1166.8 | 22.0 |
| 6/28/2013 | raw 4pm | 7.8 | 3420 | 2535 | 244.0 | 255.6 | 104.9 | 359.8 | 301.4 | 1159.0 | 21.0 |
| 7/8/2013 | RAW | 7.7 | 3470 | 2610 | 237.9 | 259.9 | 110.8 | 366.1 | 299.6 | 1193.1 | 20.0 |
| 7/9/2013 | RAW | 7.7 | 3440 | 2565 | 231.8 | 256.2 | 110.3 | 361.0 | 295.8 | 1165.5 | 20.0 |
| 7/10/2013 | RAW | 7.6 | 3840 | 2925 | 231.8 | 291.2 | 136.6 | 395.5 | 330.7 | 1344.9 | 21.0 |
| 7/11/2013 | raw | 7.7 | 3570 | 2675 | 231.8 | 262.2 | 116.4 | 365.5 | 309.1 | 1212.2 | 22.0 |
| 7/12/2013 | RAW 3:45pm | 7.7 | 3700 | 2670 | 225.7 | 253.9 | 111.6 | 360.7 | 316.9 | 1208.2 | 20.0 |
| 7/13/2013 | RAW 5:45pm | 7.7 | 3650 | 2635 | 219.6 | 262.5 | 108.3 | 360.3 | 304.4 | 1166.2 | 21.0 |
| 7/14/2013 | raw | 8.0 | 3230 | 2575 | 231.8 | 255.1 | 110.0 | 357.1 | 293.2 | 1153.7 | 21.0 |
| 7/20/2013 | RAW | 7.7 | 3170 | 2430 | 256.2 | 237.8 | 100.9 | 351.5 | 271.4 | 1097.5 | 21.0 |
| 3/22/2013 | RO (DI) | 6.6 | 86 | 360 | 55.5 | ND | ND | ND | ND | ND | 1.0 |
| 3/25/2013 | RO (DI) | 6.0 | 123 | 30 | 51.9 | ND | 18.2 | ND | 19.8 | 1.1 | 1.0 |
| 3/26/2013 | RO (DI) | 7.5 | 71 | 170 | 43.9 | 0.0 | 0.0 | 11.3 | 13.9 | 0.7 | 0.9 |
| 3/27/2013 | RO (DI) | 5.6 | 65 | 810 | 51.9 | 0.0 | 0.0 | 11.2 | 12.3 | 4.1 | 0.4 |
| 3/28/2013 | RO (DI) | 6.7 | 149 | 465 | 48.8 | 0.0 | 0.0 | 25.2 | 29.0 | 2.2 | 2.0 |
| 3/29/2013 | RO (DI) | 6.4 | 59 | 240 | 48.8 | 1.1 | 0.4 | 10.3 | 12.7 | 1.3 | 2.0 |
| 4/5/2013 | RO (DI) | 5.6 | 40 | 265 | 36.6 | 0.9 | 0.3 | 5.3 | 6.3 | 0.9 | 0.0 |
| 4/8/2013 | RO (DI) | 6.2 | 116 | 535 | 43.9 | 1.7 | 0.6 | 19.4 | 19.1 | 1.8 | 2.0 |
| 4/9/2013 | RO (DI) | 6.3 | 88 | 190 | 22.0 | ND | ND | ND | ND | ND | 0.0 |
| 4/10/2013 | RO (DI) | 5.9 | 93 | 340 | 22.0 | ND | ND | ND | ND | ND | 0.0 |
| 4/11/2013 | RO (DI) | 6.0 | 76 | 305 | 90.3 | 0.1 | ND | 0.1 | 0.1 | 0.1 | 0.1 |
| 4/17/2013 | RO (DI) | 7.2 | 104 | 340 | ND | 1.9 | 0.6 | 17.3 | 16.5 | 2.3 | 0.0 |
| 4/18/2013 | RO (DI) | 6.6 | 82500 | 425 | 18.9 | 1.8 | 0.5 | 13.6 | 13.6 | 2.0 | 0.0 |

| | | pH | Conductivity | TDS* | $HCO_3$ | Ca | Mg | Na | Cl | $SO_4$ | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | - | (µS/cm) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) |
| 4/20/2013 | RO (DI) | 6.6 | 107 | 355 | 25.0 | 1.8 | 0.5 | 18.5 | 16.5 | 1.9 | 0.0 |
| 4/22/2013 | RO (DI) | 5.8 | 57800 | 385 | 242.2 | 1.5 | 0.4 | 9.2 | 9.4 | 1.7 | 2.0 |
| 4/25/2013 | RO (DI) | 7.0 | 173 | 110 | 51.0 | 3.3 | 1.1 | 29.8 | 29.6 | 3.7 | 3.0 |
| 4/26/2013 | RO (DI) | 6.5 | 105 | 215 | 34.8 | 1.9 | 0.6 | 17.9 | 15.3 | 2.7 | 0.4 |
| 4/30/2013 | RO (DI) | 5.7 | 88 | 490 | ND | 2.3 | 0.7 | 13.5 | 14.1 | 3.5 | 2.0 |
| 5/1/2013 | RO (DI) | 6.1 | 81 | 150 | 25.6 | 3.3 | 0.8 | 17.1 | 13.6 | 7.7 | 2.0 |
| 5/2/2013 | RO (DI) | 6.4 | 83 | 460 | 24.4 | 1.4 | 0.4 | 14.6 | 11.9 | 1.9 | 4.0 |
| 5/29/2013 | RO (DI) | 5.8 | 64 | 510 | 46.4 | 1.3 | 0.4 | 10.7 | 11.0 | 3.1 | 2.0 |
| 5/31/2013 | RO (DI) | 6.2 | 174 | 225 | 48.8 | 1.5 | 0.5 | 34.8 | 27.1 | 3.1 | 3.0 |
| 6/3/2013 | RO (DI) | 6.3 | 59 | 360 | ND | 0.7 | 0.2 | 11.9 | 8.6 | 1.3 | 2.0 |
| 6/18/2013 | RO (DI) | 6.3 | 463 | 515 | 48.8 | 3.9 | 1.7 | 39.5 | 74.2 | 41.2 | 3.0 |
| 6/19/2013 | RO (DI) | 6.2 | 54 | 635 | 36.6 | 0.6 | 0.1 | 10.1 | 7.4 | 1.0 | 1.0 |
| 6/20/2013 | RO (DI) | 6.7 | 117 | 570 | 54.9 | 0.9 | 0.2 | 23.0 | 14.4 | 1.2 | 2.0 |
| 6/21/2013 | RO (DI) | 6.9 | 786 | 385 | 91.5 | 12.1 | 3.7 | 126.7 | 182.6 | 5.5 | 16.0 |
| 6/24/2013 | RO (DI) | 6.4 | 104 | 455 | 36.6 | 0.7 | 0.2 | 18.9 | 18.8 | 4.3 | 1.0 |
| 6/26/2013 | RO (DI) | 6.7 | 124 | 560 | 61.0 | 1.0 | 0.3 | 24.1 | 15.7 | 1.1 | 2.0 |
| 6/27/2013 | RO (DI) | 6.3 | 63 | 645 | 54.9 | 0.6 | 0.2 | 12.1 | 7.6 | 0.8 | 2.0 |
| 6/28/2013 | RO (DI) 4pm | 6.7 | 138 | 115 | 79.3 | 1.1 | 0.3 | 26.2 | 18.6 | 1.3 | 3.0 |
| 7/20/2013 | RO | 6.5 | 41000 | 20 | 61.0 | 0.4 | 0.1 | 7.1 | 5.3 | 0.7 | 1.0 |

# APPENDIX C2

# ALAMOGORDO, YEAR 2

# WATER QUALITY ANALYSES

Table C-2.—Water Quality Analyses Excluded from Statistical Analyses

| | | pH | Conductivity | TDS* | $HCO_3$ | Ca | Mg | Na | Cl | $SO_4$ | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Stream | - | (µS/cm) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) |
| 4/19/2013 | Edm dil | 6.6 | 4010 | 3385 | 78.7 | 616.1 | 347.7 | 850.9 | 227.5 | 3876.3 | 27.1 |
| 4/23/2013 | Edm dil | 6.3 | 4200 | 3565 | ND | 648.4 | 372.5 | 864.7 | 241.8 | 4096.1 | |
| 5/1/2013 | Edm dil | 6.0 | 3890 | 3210 | 39.0 | 133.3 | 72.1 | 221.4 | 47.8 | 1870.2 | 23.0 |
| 5/2/2013 | Edm dil | 6.3 | 3610 | 3035 | 40.3 | 132.8 | 143.2 | 214.2 | 99.7 | 1101.1 | 26.0 |
| 6/28/2013 | Edm dil 4pm | 6.4 | 3640 | 2895 | 128.1 | 15.4 | 6.9 | 27.8 | 91.9 | 1697.7 | 29.0 |
| 4/19/2013 | Edm feed | 6.8 | 5510 | 4940 | 86.6 | 1014.9 | 547.8 | 1083.7 | 309.7 | 5666.1 | 25.1 |
| 4/23/2013 | Edm feed | 6.6 | 5820 | 5375 | ND | 1092.7 | 612.7 | 1117.8 | 310.4 | 6130.8 | ND |
| 5/1/2013 | Edm feed | 6.4 | 5380 | 4775 | 81.7 | 231.7 | 117.8 | 287.3 | 58.1 | 2814.5 | 23.0 |
| 5/2/2013 | Edm feed | 6.6 | 4980 | 4685 | 83.0 | 221.9 | 102.0 | 272.3 | 54.5 | 1659.8 | 25.0 |
| 6/28/2013 | EDM Feed 8:45am | 6.4 | 4910 | 4330 | 146.4 | ND | ND | ND | ND | ND | 25.0 |
| 3/25/2013 | E-rinse | 10.9 | 19220 | 14600 | 183.0 | ND | 5092.8 | ND | 107.8 | 9757.0 | 3.0 |
| 4/19/2013 | E-rinse | 12.4 | 25970 | 20195 | 1372.5 | 208.1 | 1.6 | 12477.5 | 610.9 | 22851.5 | 1.2 |
| 4/23/2013 | E-rinse | 12.7 | 25640 | 16110 | ND | 51.2 | 30.8 | 9172.5 | 814.2 | 12017.6 | |
| 4/19/2013 | Mix Cl | 2.1 | 177400 | 193360 | 0.0 | 54113.4 | 25462.8 | 35662.7 | 215550.6 | 1629.7 | 7.4 |
| 4/20/2013 | Mix Cl | 2.0 | 172200 | 198520 | 0.0 | 18.9 | ND | ND | 12.9 | ND | 3.4 |
| 4/23/2013 | Mix Cl | 1.6 | 176000 | 169045 | ND | 47868.2 | 23668.2 | 32671.9 | 199267.4 | 1639.2 | ND |
| 5/1/2013 | Mix Cl | 1.9 | 166700 | 169960 | 0.0 | 12013.1 | 3465.7 | 8933.4 | 48738.0 | 459.6 | 6.0 |
| 3/25/2013 | Mix Na | 7.8 | 132800 | 202690 | 4912.9 | 216.9 | 91829.3 | ND | 12600.6 | 118851.0 | 9.0 |
| 4/19/2013 | Mix Na | 8.0 | 117100 | 161145 | 4026.0 | 1322.3 | 568.8 | 103507.8 | 23748.4 | 176571.9 | 8.1 |
| 4/23/2013 | Mix Na | 7.7 | 117200 | 163180 | ND | 1330.7 | 614.3 | 102915.9 | 23556.4 | 185453.7 | |
| 6/24/2013 | Mix Na | 7.8 | 113700 | 159935 | 2989.0 | 835.8 | 269.3 | 75460.4 | 12981.8 | 131245.2 | 8.0 |
| 3/25/2013 | NaCl | 6.0 | 36400 | 19825 | 36.6 | ND | 8384.0 | 0.0 | 11848.9 | 287.1 | 10.4 |
| 4/19/2013 | NaCl | 3.6 | 48200 | 28315 | 0.0 | 204.8 | 68.6 | 22292.4 | 18617.4 | 1209.0 | 6.0 |
| 4/22/2013 | NaCl | 3.4 | 50200 | 29230 | 0.0 | 3660.9 | 1671.0 | 534108.2 | 751208.3 | 34125.4 | 7.0 |
| 4/23/2013 | NaCl | 3.4 | 47400 | 27830 | 0.0 | 266.7 | 44.5 | 19641.0 | 26373.8 | 1792.0 | ND |
| 3/29/2013 | NF conc | 7.2 | 8120 | 8735 | 345.3 | 647.4 | 8451.6 | 8697.9 | 228.5 | 47961.4 | 26.0 |

|  |  | pH | Conductivity | TDS* | $HCO_3$ | Ca | Mg | Na | Cl | $SO_4$ | $SiO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Stream | - | (µS/cm) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) |
| 4/19/2013 | NF conc | 7.0 | 8110 | 8355 | 200.7 | 1061.1 | 1124.6 | 1787.9 | 471.1 | 8356.3 | 26.2 |
| 4/23/2013 | NF conc | 7.1 | 8010 | 7645 | 186.1 | 999.4 | 1094.0 | 1725.9 | 479.8 | 8182.6 |  |
| 5/1/2013 | NF conc | 6.6 | 8410 | 8095 | 201.3 | 272.1 | 94.0 | 1054.5 | 2247.6 | 597.1 | 24.0 |
| 5/2/2013 | NF conc | 7.1 | 7750 | 7975 | 213.5 | 276.6 | 209.5 | 907.5 | 157.6 | 4026.8 | 25.0 |
| 7/8/2013 | NF Conc | 6.8 | 7940 | 7990 | 183.0 | 21.9 | 10.1 | 149.5 | 221.4 | 14.7 | 26.0 |
| 3/29/2013 | NF Feed | 7.2 | 3760 | 3275 | 201.3 | 0.5 | 0.0 | 0.0 | 311.9 | 0.0 | 23.0 |
| 4/19/2013 | NF Feed | 6.8 | 4090 | 3210 | 115.9 | 666.6 | 321.5 | 800.8 | 642.4 | 3240.9 | 20.8 |
| 4/23/2013 | NF Feed | 7.5 | 4120 | 3105 | 122.6 | 679.6 | 328.1 | 766.1 | 651.9 | 3098.0 |  |
| 3/25/2013 | NF Perm | 6.3 | 1442 | 135 | 119.3 | 13.5 | 216.3 | ND | 340.9 | 27.5 | 18.7 |
| 4/19/2013 | NF Perm | 7.0 | 1588 | 835 | 90.9 | 102.4 | 36.7 | 430.4 | 704.7 | 137.1 | 17.4 |
| 4/23/2013 | NF Perm | 7.4 | 1715 | 830 | 96.4 | 120.1 | 47.3 | 431.9 | 780.7 | 141.8 |  |
| 4/19/2013 | raw | 7.7 | 4100 | 2986 | 213.5 | 702.4 | 331.9 | 780.0 | 814.1 | 2790.2 | 18.5 |
| 4/23/2013 | raw | 7.9 | 4090 | 3000 | 251.3 | 685.1 | 330.8 | 754.2 | 812.4 | 2730.3 | ND |
| 4/19/2013 | RO (DI) | 6.2 | 55 | 300 | 12.8 | 2.7 | 0.9 | 17.3 | 18.0 | 2.8 | 0.0 |
| 4/23/2013 | RO (DI) | 6.3 | 49 | 315 | ND | 2.2 | 0.7 | 14.7 | 14.5 | 2.6 |  |

# APPENDIX C3
# BRIGHTON, COLORADO

| Date | Location | Ca<br>mg/L | K<br>mg/L | Mg<br>mg/L | Na<br>mg/L | Cl<br>mg/L | F<br>mg/L | $NO_3$<br>mg/L |
|---|---|---|---|---|---|---|---|---|
| 10/1/2013 | EDM Dil | 133 | 5.9 | 34.1 | 430 | 110 | 3.6 | 19 |
| 10/2/2013 | EDM Dil | 120 | 5.7 | 31.3 | 415 | 103 | 3.4 | 19 |
| 10/3/2013 | EDM Dil | 120 | 5.7 | 30.3 | 422 | 99 | 2.0 | 18 |
| 10/4/2013 | EDM Dil | 138 | 5.7 | 34.9 | 447 | 110 | 3.6 | 20 |
| 10/6/2013 | EDM Dil | 145 | 6.7 | 38.6 | 507 | 110 | 3.3 | 19 |
| 10/7/2013 | EDM Dil | 128 | 6.3 | 33.7 | 469 | 104 | 3.4 | 19 |
| 10/8/2013 | EDM Dil | 140 | 6.7 | 37.0 | 515 | 110 | 3.4 | 20 |
| 10/9/2013 | EDM Dil | 130 | 6.1 | 34.5 | 495 | 102 | 3.3 | 19 |
| 10/10/2013 | EDM Dil | 168 | 7.4 | 45.9 | 569 | 120 | 3.1 | 21 |
| 10/11/2013 | EDM Dil | 161 | 8.2 | 50.1 | 581 | 113 | 3.3 | 21 |
| 10/12/2013 | EDM Dil | 158 | 8.0 | 48.5 | 583 | 114 | 3.1 | 21 |
| 10/13/2013 | EDM Dil | 142 | 7.1 | 43.8 | 545 | 104 | 2.7 | 21 |
| 10/15/2013 | EDM Dil | 136 | 7.5 | 41.3 | 484 | 131 | 3.5 | 23 |
| 10/16/2013 | EDM Dil | 140 | 8.2 | 41.0 | 545 | 129 | 3.0 | 21 |
| 10/17/2013 | EDM Dil | 148 | 8.0 | 44.6 | 564 | 126 | 3.0 | 23 |
| 10/18/2013 | EDM Dil | 153 | 7.9 | 46.2 | 569 | 125 | 2.7 | 23 |
| 10/19/2013 | EDM Dil | 175 | 8.9 | 54.4 | 621 | 133 | 2.7 | 25 |
| 10/22/2013 | EDM Dil | 167 | 6.0 | 37.5 | 498 | 126 | 4.3 | 26 |
| 10/23/2013 | EDM Dil | 186 | 6.6 | 41.2 | 564 | 129 | 4.4 | 25 |
| 10/24/2013 | EDM Dil | 191 | 7.0 | 44.5 | 594 | 130 | 4.4 | 25 |
| 10/25/2013 | EDM Dil | 175 | 9.6 | 32.8 | 614 | 122 | 0.9 | 25 |
| 10/26/2013 | EDM Dil | 195 | 10.4 | 41.8 | 651 | 130 | 1.0 | 27 |
| | | | | | | | | |
| 10/1/2013 | EDM Feed | 234 | 7.7 | 53.8 | 504 | 194 | 3.7 | 51 |
| 10/2/2013 | EDM Feed | 217 | 7.6 | 50.6 | 484 | 183 | 3.7 | 49 |
| 10/3/2013 | EDM Feed | 211 | 7.4 | 48.5 | 488 | 175 | 2.2 | 46 |
| 10/4/2013 | EDM Feed | 233 | 7.7 | 54.5 | 509 | 188 | 3.7 | 50 |
| 10/6/2013 | EDM Feed | 245 | 8.3 | 59.7 | 572 | 188 | 3.7 | 48 |
| 10/7/2013 | EDM Feed | 222 | 8.1 | 52.7 | 538 | 181 | 3.7 | 49 |
| 10/8/2013 | EDM Feed | 234 | 8.3 | 55.7 | 573 | 186 | 3.7 | 50 |
| 10/9/2013 | EDM Feed | 217 | 7.9 | 52.6 | 549 | 172 | 3.3 | 46 |
| 10/10/2013 | EDM Feed | 267 | 9.2 | 66.2 | 631 | 198 | 3.6 | 50 |
| 10/11/2013 | EDM Feed | 259 | 9.8 | 71.1 | 647 | 197 | 3.6 | 50 |
| 10/12/2013 | EDM Feed | 256 | 9.8 | 67.7 | 647 | 196 | 3.6 | 50 |
| 10/13/2013 | EDM Feed | 234 | 9.0 | 65.1 | 608 | 177 | 3.4 | 49 |
| 10/15/2013 | EDM Feed | 234 | 9.7 | 62.9 | 555 | 218 | 3.9 | 52 |
| 10/16/2013 | EDM Feed | 233 | 10.2 | 60.9 | 610 | 209 | 3.3 | 48 |
| 10/17/2013 | EDM Feed | 237 | 10.1 | 63.7 | 619 | 198 | 3.2 | 51 |
| 10/18/2013 | EDM Feed | 239 | 9.8 | 64.5 | 620 | 191 | 2.9 | 49 |
| 10/19/2013 | EDM Feed | 266 | 10.3 | 73.7 | 676 | 204 | 2.8 | 53 |
| 10/22/2013 | EDM Feed | 293 | 7.7 | 57.2 | 581 | 217 | 4.5 | 61 |
| 10/23/2013 | EDM Feed | 292 | 7.9 | 58.0 | 603 | 197 | 4.1 | 54 |

| Date | Location | $SO_4$<br>mg/L | $HCO_3$<br>mg/L | $SiO_2$<br>mg/L | TDS<br>mg/L | pH | Conductivity<br>μS/cm |
|---|---|---|---|---|---|---|---|
| 10/1/2013 | EDM Dil | 1097 | 98 | 112 | 2205 | 5.17 | 2889 |
| 10/2/2013 | EDM Dil | 1055 | 55 | 108 | 2160 | 5.11 | 2828 |
| 10/3/2013 | EDM Dil | 1061 | 61 | 104 | 2190 | 4.96 | 2836 |
| 10/4/2013 | EDM Dil | 1157 | 73 | 112 | 2335 | 5.1 | 3010 |
| 10/6/2013 | EDM Dil | 1304 | 183 | 112 | 2570 | 5.22 | 3360 |
| 10/7/2013 | EDM Dil | 1213 | 49 | 104 | 2430 | 4.71 | 3200 |
| 10/8/2013 | EDM Dil | 1305 | 110 | 116 | 2625 | 5.27 | 3390 |
| 10/9/2013 | EDM Dil | 1273 | ND | 100 | 2515 | 4.41 | 3270 |
| 10/10/2013 | EDM Dil | 1499 | 92 | 108 | 2965 | 5.01 | 3780 |
| 10/11/2013 | EDM Dil | 1519 | 110 | 116 | 3015 | 4.99 | 3850 |
| 10/12/2013 | EDM Dil | 1524 | ND | 112 | 3005 | 5.05 | 3930 |
| 10/13/2013 | EDM Dil | 1448 | 0 | 108 | 2870 | 3.71 | 3810 |
| 10/15/2013 | EDM Dil | 1202 | 104 | 116 | 2455 | 5.55 | 3360 |
| 10/16/2013 | EDM Dil | 1360 | 79 | 116 | 2625 | 5.36 | 3620 |
| 10/17/2013 | EDM Dil | 1424 | 85 | 104 | 2745 | 5.07 | 3680 |
| 10/18/2013 | EDM Dil | 1462 | 55 | 100 | 2880 | 5.12 | 3410 |
| 10/19/2013 | EDM Dil | 1616 | 61 | 100 | 3220 | 4.93 | 3690 |
| 10/22/2013 | EDM Dil | 1135 | 98 | 116 | 2710 | 5.77 | 3210 |
| 10/23/2013 | EDM Dil | 1353 | 79 | 116 | 2910 | 5.57 | 3410 |
| 10/24/2013 | EDM Dil | 1487 | 73 | 112 | 3095 | 5.2 | 3600 |
| 10/25/2013 | EDM Dil | 1550 | 67 | 120 | 3150 | 5.02 | 3690 |
| 10/26/2013 | EDM Dil | 1676 | 61 | 116 | 3285 | 4.76 | 3890 |
| | | | | | | | |
| 10/1/2013 | EDM Feed | 1333 | 128 | 112 | 2885 | 5.47 | 3670 |
| 10/2/2013 | EDM Feed | 1315 | 85 | 108 | 2815 | 5.49 | 3620 |
| 10/3/2013 | EDM Feed | 1303 | 73 | 104 | 2810 | 5.3 | 3580 |
| 10/4/2013 | EDM Feed | 1398 | 85 | 108 | 2960 | 5.42 | 3760 |
| 10/6/2013 | EDM Feed | 1565 | 140 | 108 | 3200 | 5.53 | 4100 |
| 10/7/2013 | EDM Feed | 1489 | 92 | 104 | 2995 | 5.18 | 3900 |
| 10/8/2013 | EDM Feed | 1547 | 122 | 108 | 3195 | 5.65 | 4110 |
| 10/9/2013 | EDM Feed | 1499 | 98 | 100 | 3060 | 5.13 | 3930 |
| 10/10/2013 | EDM Feed | 1747 | 140 | 108 | 3535 | 5.47 | 4510 |
| 10/11/2013 | EDM Feed | 1779 | 85 | 116 | 3625 | 5.48 | 4550 |
| 10/12/2013 | EDM Feed | 1772 | 85 | 120 | 3645 | 5.51 | 4570 |
| 10/13/2013 | EDM Feed | 1707 | ND | 108 | 3470 | 4.38 | 4460 |
| 10/15/2013 | EDM Feed | 1469 | 140 | 116 | 3105 | 5.72 | 4160 |
| 10/16/2013 | EDM Feed | 1614 | 116 | 116 | 3300 | 5.7 | 4380 |
| 10/17/2013 | EDM Feed | 1654 | 128 | 100 | 3320 | 5.42 | 4360 |
| 10/18/2013 | EDM Feed | 1687 | 61 | 100 | 3440 | 5.6 | 3990 |
| 10/19/2013 | EDM Feed | 1860 | 73 | 100 | 3740 | 5.41 | 4280 |
| 10/22/2013 | EDM Feed | 1492 | 140 | 116 | 3360 | 6 | 3920 |
| 10/23/2013 | EDM Feed | 1513 | 146 | 116 | 3565 | 5.83 | 4120 |

| **Date** | **Location** | **Ca** | **K** | **Mg** | **Na** | **Cl** | **F** | **$NO_3$** |
|---|---|---|---|---|---|---|---|---|
| | | **mg/L** | **mg/L** | **mg/L** | **mg/L** | **mg/L** | **mg/L** | **mg/L** |
| 10/24/2013 | EDM Feed | 308 | 8.6 | 63.2 | 663 | 203 | 4.7 | 55 |
| 10/25/2013 | EDM Feed | 264 | 12.9 | 55.7 | 681 | 202 | 1.3 | 56 |
| 10/26/2013 | EDM Feed | 286 | 13.1 | 67.2 | 711 | 211 | 1.3 | 58 |
| 10/1/2013 | E-Rinse | 26 | 11.2 | 0.0 | 9098 | 252 | 0.0 | 58 |
| 10/6/2013 | E-Rinse | 38 | 11.3 | 0.0 | 9659 | 248 | 26.7 | 110 |
| 10/13/2013 | E-Rinse | 28 | 5.2 | 4.2 | 4977 | 166 | 28.5 | 139 |
| 10/16/2013 | E-Rinse | 127 | 23.2 | 11.6 | 13913 | 505 | 48.3 | 328 |
| 10/25/2013 | E-Rinse | 43 | 6.9 | 3.4 | 5752 | 244 | 1.7 | 1060 |
| 10/26/2013 | E-Rinse | 456 | 12.7 | ND | 5487 | 216 | 1.6 | 979 |
| 10/1/2013 | Mix Cl | 18207 | 300 | 3674 | 13910 | 64642 | 133.5 | 126 |
| 10/2/2013 | Mix Cl | 17071 | 277 | 3596 | 13060 | 62060 | 131.1 | 201 |
| 10/3/2013 | Mix Cl | 15900 | 277 | 3227 | 12698 | 56325 | 121.1 | 178 |
| 10/4/2013 | Mix Cl | 15854 | 283 | 3259 | 12951 | 57535 | 140.7 | 226 |
| 10/6/2013 | Mix Cl | 16431 | 288 | 3370 | 12681 | 58847 | 129.6 | 220 |
| 10/7/2013 | Mix Cl | 17661 | 307 | 3706 | 13690 | 62424 | 94.0 | 260 |
| 10/8/2013 | Mix Cl | 16046 | 277 | 3410 | 12693 | 57331 | 101.9 | 235 |
| 10/9/2013 | Mix Cl | 16481 | 283 | 3486 | 13271 | 59341 | 96.0 | 234 |
| 10/10/2013 | Mix Cl | 16872 | 281 | 3631 | 12608 | 58708 | 79.5 | 244 |
| 10/11/2013 | Mix Cl | 12783 | 259 | 2966 | 10595 | 48354 | 104.8 | 179 |
| 10/12/2013 | Mix Cl | 11193 | 231 | 2541 | 9535 | 43358 | 102.5 | 160 |
| 10/13/2013 | Mix Cl | 11443 | 216 | 2579 | 9648 | 43307 | 74.5 | 160 |
| 10/15/2013 | Mix Cl | 14438 | 279 | 3271 | 11166 | 51881 | 38.7 | 221 |
| 10/16/2013 | Mix Cl | 15370 | 341 | 3427 | 13186 | 59144 | 113.9 | 223 |
| 10/17/2013 | Mix Cl | 14925 | 287 | 3403 | 12151 | 55471 | 94.6 | 229 |
| 10/18/2013 | Mix Cl | 15506 | 274 | 3565 | 11919 | 56255 | 84.4 | 257 |
| 10/19/2013 | Mix Cl | 15401 | 255 | 3552 | 11666 | 54978 | 56.3 | 242 |
| 10/22/2013 | Mix Cl | 19708 | 213 | 3091 | 11771 | 54244 | 64.8 | 280 |
| 10/23/2013 | Mix Cl | 19667 | 223 | 3246 | 12606 | 55914 | 64.3 | 238 |
| 10/24/2013 | Mix Cl | 19388 | 219 | 3156 | 12663 | 54972 | 66.5 | 231 |
| 10/25/2013 | Mix Cl | 11780 | 321 | 2202 | 9640 | 45320 | 2.4 | 162 |
| 10/26/2013 | Mix Cl | 11859 | 318 | 2382 | 9325 | 45079 | 2.3 | 159 |
| 10/1/2013 | Mix Na | 134 | 36.3 | 15.3 | 14833 | 7953 | 176.6 | 1836 |
| 10/2/2013 | Mix Na | 86 | 53.3 | 8.1 | 15636 | 8651 | 176.5 | 1917 |
| 10/3/2013 | Mix Na | 170 | 34.8 | 24.9 | 18573 | 9505 | 98.5 | 2245 |
| 10/4/2013 | Mix Na | 287 | 48.9 | 39.8 | 20160 | 10328 | 160.0 | 2538 |
| 10/6/2013 | Mix Na | 235 | 43.7 | 47.9 | 19711 | 10163 | 187.7 | 2428 |
| 10/7/2013 | Mix Na | 384 | 46.0 | 65.7 | 22491 | 11351 | 158.6 | 2804 |
| 10/8/2013 | Mix Na | 291 | 46.5 | 45.5 | 19894 | 10215 | 85.8 | 2487 |
| 10/9/2013 | Mix Na | 358 | 47.2 | 63.7 | 20033 | 10027 | 80.8 | 2451 |

| Date | Location | $SO_4$<br>mg/L | $HCO_3$<br>mg/L | $SiO_2$<br>mg/L | TDS<br>mg/L | pH | Conductivity<br>μS/cm |
|---|---|---|---|---|---|---|---|
| 10/24/2013 | EDM Feed | 1715 | 134 | 116 | 3765 | 5.69 | 4270 |
| 10/25/2013 | EDM Feed | 1796 | 140 | 116 | 3770 | 5.6 | 4350 |
| 10/26/2013 | EDM Feed | 1924 | 85 | 112 | 3890 | 5.37 | 4540 |
| | | | | | | | |
| 10/1/2013 | E-Rinse | 17501 | 195 | 1 | 27735 | 10.52 | 31100 |
| 10/6/2013 | E-Rinse | 18150 | 262 | 1 | 30530 | 10.01 | 33700 |
| 10/13/2013 | E-Rinse | 8728 | 256 | 3 | 38290 | 8.26 | excl |
| 10/16/2013 | E-Rinse | 24717 | 268 | 3 | 46595 | 8.16 | 47400 |
| 10/25/2013 | E-Rinse | 10200 | 262 | 3 | 20640 | 9.58 | 22000 |
| 10/26/2013 | E-Rinse | 9081 | 220 | 3 | 18055 | 9.34 | 19850 |
| | | | | | | | |
| 10/1/2013 | Mix Cl | 756 | 49 | 12 | 123670 | 4.87 | 145600 |
| 10/2/2013 | Mix Cl | 743 | 0 | 12 | 122640 | 2.87 | 142600 |
| 10/3/2013 | Mix Cl | 642 | 0 | 12 | 114095 | 2.69 | 133800 |
| 10/4/2013 | Mix Cl | 649 | 0 | 10 | 113295 | 2.86 | 134000 |
| 10/6/2013 | Mix Cl | 714 | 0 | 10 | 108465 | 2.81 | 136500 |
| 10/7/2013 | Mix Cl | 761 | 0 | 10 | 113335 | 2.39 | 141100 |
| 10/8/2013 | Mix Cl | 705 | 0 | 9 | 103255 | 2.87 | 132000 |
| 10/9/2013 | Mix Cl | 724 | 0 | 10 | 108220 | 2.11 | 136600 |
| 10/10/2013 | Mix Cl | 716 | 0 | 11 | 110080 | 2.6 | 137900 |
| 10/11/2013 | Mix Cl | 691 | 0 | 11 | 106765 | 2.63 | 133800 |
| 10/12/2013 | Mix Cl | 612 | 0 | 9 | 90185 | 2.66 | 116700 |
| 10/13/2013 | Mix Cl | 661 | 0 | 8 | 87905 | 2.13 | 115800 |
| 10/15/2013 | Mix Cl | 767 | 0 | 10 | 107680 | 3.44 | 134900 |
| 10/16/2013 | Mix Cl | 733 | 43 | 11 | 116100 | 5.98 | 139400 |
| 10/17/2013 | Mix Cl | 697 | 0 | 10 | 106355 | 2.75 | 131400 |
| 10/18/2013 | Mix Cl | 732 | 0 | 10 | 108595 | 2.65 | 120100 |
| 10/19/2013 | Mix Cl | 689 | 0 | 9 | 101815 | 2.59 | 117600 |
| 10/22/2013 | Mix Cl | 1033 | 79 | 11 | 105230 | 5.33 | 119100 |
| 10/23/2013 | Mix Cl | 660 | 0 | 11 | 109745 | 3.87 | 122000 |
| 10/24/2013 | Mix Cl | 635 | 0 | 10 | 107780 | 2.71 | 125600 |
| 10/25/2013 | Mix Cl | 311 | 0 | 8 | 82650 | 2.63 | 102200 |
| 10/26/2013 | Mix Cl | 301 | 0 | 9 | 85945 | 2.64 | 104700 |
| | | | | | | | |
| 10/1/2013 | Mix Na | 16277 | 2464 | 12 | 44755 | 7.36 | 53900 |
| 10/2/2013 | Mix Na | 16899 | 2525 | 11 | 50385 | 7.36 | 58400 |
| 10/3/2013 | Mix Na | 20847 | 2330 | 10 | 55380 | 7.34 | 63400 |
| 10/4/2013 | Mix Na | 22911 | 2684 | 11 | 62375 | 7.35 | 69000 |
| 10/6/2013 | Mix Na | 22395 | 2928 | 9 | 61120 | 7.58 | 68500 |
| 10/7/2013 | Mix Na | 26346 | 2257 | 11 | 63705 | 7.34 | 70700 |
| 10/8/2013 | Mix Na | 22699 | 3294 | 15 | 60225 | 7.72 | 67900 |
| 10/9/2013 | Mix Na | 23384 | 2806 | 11 | 61035 | 7.78 | 68400 |

| **Date** | **Location** | **Ca** | **K** | **Mg** | **Na** | **Cl** | **F** | **$NO_3$** |
|---|---|---|---|---|---|---|---|---|
| | | **mg/L** | **mg/L** | **mg/L** | **mg/L** | **mg/L** | **mg/L** | **mg/L** |
| 10/10/2013 | Mix Na | 299 | 45.9 | 53.7 | 17825 | 9138 | 77.9 | 2167 |
| 10/11/2013 | Mix Na | 299 | 42.8 | 54.0 | 19028 | 9369 | 82.1 | 2258 |
| 10/12/2013 | Mix Na | 239 | 41.1 | 49.5 | 19231 | 9351 | 82.7 | 2262 |
| 10/13/2013 | Mix Na | 258 | 38.7 | 57.5 | 17659 | 8345 | 76.6 | 2055 |
| 10/15/2013 | Mix Na | 437 | 54.4 | 80.1 | 19671 | 10326 | 80.5 | 2381 |
| 10/16/2013 | Mix Na | 362 | 67.1 | 71.9 | 22172 | 11382 | 73.4 | 2491 |
| 10/17/2013 | Mix Na | 413 | 60.7 | 65.3 | 21043 | 10603 | 63.8 | 2591 |
| 10/18/2013 | Mix Na | 467 | 57.1 | 85.6 | 20306 | 10170 | 64.8 | 2490 |
| 10/19/2013 | Mix Na | 482 | 57.5 | 87.8 | 20800 | 10387 | 64.8 | 2529 |
| 10/22/2013 | Mix Na | 492 | 39.9 | 0.0 | 19690 | 9644 | 91.0 | 2588 |
| 10/23/2013 | Mix Na | 427 | 44.3 | 62.1 | 19950 | 9712 | 94.2 | 2522 |
| 10/24/2013 | Mix Na | 508 | 52.4 | 66.8 | 22138 | 10606 | 95.3 | 2755 |
| 10/25/2013 | Mix Na | 1059 | 45.4 | ND | 17595 | 8592 | 28.3 | 2253 |
| 10/26/2013 | Mix Na | 1058 | 43.6 | ND | 17170 | 8313 | 27.2 | 2238 |
| | | | | | | | | |
| 10/1/2013 | NaCl | 29 | 15.8 | 9.3 | 11848 | 17706 | 11.9 | 26 |
| 10/6/2013 | NaCl | 60 | 17.5 | 15.2 | 12084 | 18307 | 13.4 | 49 |
| 10/13/2013 | NaCl | 45 | 15.3 | 15.8 | 12542 | 19035 | 54.5 | 51 |
| 10/16/2013 | NaCl | 0 | 18.8 | 15.8 | 11678 | 17647 | 44.9 | 47 |
| 10/25/2013 | NaCl | ND | 26.1 | ND | 12501 | 19088 | 2.0 | 55 |
| 10/26/2013 | NaCl | 914 | 26.6 | ND | 11646 | 17761 | 2.4 | 54 |
| | | | | | | | | |
| 10/1/2013 | NF Conc | 307 | 9.6 | 78.8 | 772 | 52 | 2.7 | 5 |
| 10/6/2013 | NF Conc | 314 | 12.0 | 83.7 | 920 | 51 | 5.8 | 5 |
| 10/13/2013 | NF Conc | 306 | 12.8 | 95.4 | 992 | 39 | 5.1 | 6 |
| 10/16/2013 | NF Conc | 296 | 14.7 | 88.5 | 975 | 61 | 4.6 | 6 |
| 10/25/2013 | NF Conc | 367 | 18.5 | 71.9 | 1112 | 31 | 0.4 | 5 |
| 10/26/2013 | NF Conc | 391 | 19.0 | 84.9 | 1136 | 38 | 0.4 | 6 |
| | | | | | | | | |
| 10/1/2013 | NF Perm | 6 | 2.5 | 1.3 | 150 | 159 | 1.7 | 34 |
| 10/2/2013 | NF Perm | 4 | 2.3 | 1.0 | 140 | 153 | 1.5 | 33 |
| 10/3/2013 | NF Perm | 4 | 2.2 | 0.7 | 136 | excl | 0.4 | 4 |
| 10/4/2013 | NF Perm | 5 | 2.2 | 1.0 | 145 | 161 | 1.7 | 34 |
| 10/6/2013 | NF Perm | 5 | 2.5 | 0.9 | 155 | 169 | 1.8 | 34 |
| 10/7/2013 | NF Perm | 3 | 2.4 | 0.6 | 146 | 166 | 1.6 | 34 |
| 10/8/2013 | NF Perm | 4 | 2.4 | 0.8 | 151 | 165 | 1.7 | 35 |
| 10/9/2013 | NF Perm | 3 | 2.2 | 0.5 | 145 | 161 | 1.5 | 32 |
| 10/10/2013 | NF Perm | 4 | 2.6 | 0.8 | 163 | 185 | 1.8 | 37 |
| 10/11/2013 | NF Perm | 4 | 2.9 | 1.0 | 163 | 180 | 1.9 | 37 |
| 10/12/2013 | NF Perm | 4 | 2.9 | 0.9 | 163 | 179 | 1.8 | 37 |
| 10/13/2013 | NF Perm | 2 | 3.0 | 0.5 | 176 | 161 | 1.5 | 33 |
| 41562 | NF Perm | 7 | 3.3 | 1.7 | 174 | 187 | 2.1 | 37 |

| Date | Location | $SO_4$<br>mg/L | $HCO_3$<br>mg/L | $SiO_2$<br>mg/L | TDS<br>mg/L | pH | Conductivity<br>µS/cm |
|---|---|---|---|---|---|---|---|
| 10/10/2013 | Mix Na | 20275 | 2928 | 9 | 55765 | 7.88 | 63500 |
| 10/11/2013 | Mix Na | 21189 | 3294 | 9 | 59165 | 7.93 | 65700 |
| 10/12/2013 | Mix Na | 21255 | 3611 | 8 | 59260 | 8.18 | 65000 |
| 10/13/2013 | Mix Na | 20722 | 2916 | 9 | 53945 | 8.32 | 63200 |
| 10/15/2013 | Mix Na | 22547 | 2855 | 9 | 60620 | 7.52 | 69900 |
| 10/16/2013 | Mix Na | 25830 | 3209 | 13 | 68665 | 7.72 | 76100 |
| 10/17/2013 | Mix Na | 24330 | 2879 | 10 | 64875 | 7.9 | 72500 |
| 10/18/2013 | Mix Na | 23757 | 2684 | 10 | 62800 | 7.88 | 64100 |
| 10/19/2013 | Mix Na | 24811 | 2635 | 13 | 63660 | 7.78 | 64900 |
| 10/22/2013 | Mix Na | 22241 | 2586 | 15 | 61195 | 7.6 | 62800 |
| 10/23/2013 | Mix Na | 21438 | 3416 | 15 | 61790 | 7.9 | 63800 |
| 10/24/2013 | Mix Na | 24263 | 3477 | 12 | 68835 | 8.04 | 68700 |
| 10/25/2013 | Mix Na | 19574 | 2806 | 13 | 54955 | 8 | 57400 |
| 10/26/2013 | Mix Na | 19450 | 2684 | 12 | 52640 | 8.01 | 55800 |
| | | | | | | | |
| 10/1/2013 | NaCl | 518 | 122 | 6 | 30015 | 5.86 | 52700 |
| 10/6/2013 | NaCl | 445 | 159 | 7 | 31885 | 5.64 | 54700 |
| 10/13/2013 | NaCl | 531 | 0 | 5 | 33225 | 3.03 | 58800 |
| 10/16/2013 | NaCl | 478 | 146 | 6 | 30850 | 6.08 | 54200 |
| 10/25/2013 | NaCl | 103 | 0 | 3 | 32990 | 3.7 | 52500 |
| 10/26/2013 | NaCl | 97 | 0 | 4 | 31465 | 3.55 | 50100 |
| | | | | | | | |
| 10/1/2013 | NF Conc | 2384 | 92 | 124 | 4235 | 4.85 | 4890 |
| 10/6/2013 | NF Conc | 2805 | 67 | 120 | 4980 | 4.79 | 5760 |
| 10/13/2013 | NF Conc | 3035 | 0 | 120 | 5590 | 3.5 | 6630 |
| 10/16/2013 | NF Conc | 2892 | 55 | 128 | 5075 | 4.83 | 6210 |
| 10/25/2013 | NF Conc | 3258 | 6 | 144 | 5965 | 4.4 | 6310 |
| 10/26/2013 | NF Conc | 3382 | 6 | 128 | 6125 | 4.2 | 6520 |
| | | | | | | | |
| 10/1/2013 | NF Perm | 26 | 104 | 104 | 540 | 5.34 | 838 |
| 10/2/2013 | NF Perm | 24 | 73 | 100 | 535 | 5.43 | 804 |
| 10/3/2013 | NF Perm | excl | 61 | 96 | 510 | 5.28 | 777 |
| 10/4/2013 | NF Perm | 24 | 98 | 100 | 530 | 5.37 | 828 |
| 10/6/2013 | NF Perm | 29 | 116 | 100 | 540 | 5.46 | 882 |
| 10/7/2013 | NF Perm | 39 | 73 | 96 | 525 | 5.07 | 852 |
| 10/8/2013 | NF Perm | 31 | 104 | 96 | 550 | 5.56 | 875 |
| 10/9/2013 | NF Perm | 50 | 61 | 96 | 510 | 4.95 | 850 |
| 10/10/2013 | NF Perm | 36 | 116 | 96 | 585 | 5.35 | 954 |
| 10/11/2013 | NF Perm | 36 | 55 | 104 | 575 | 5.32 | 982 |
| 10/12/2013 | NF Perm | 36 | ND | 108 | 605 | 5.4 | 974 |
| 10/13/2013 | NF Perm | excl | 0 | 96 | 645 | 4.38 | 1048 |
| 41562 | NF Perm | 22 | 140 | 108 | 615 | 5.78 | 1022 |

| Date | Location | Ca<br>mg/L | K<br>mg/L | Mg<br>mg/L | Na<br>mg/L | Cl<br>mg/L | F<br>mg/L | $NO_3$<br>mg/L |
|---|---|---|---|---|---|---|---|---|
| 41563 | NF Perm | 4 | 3.2 | 1.1 | 170 | 192 | 1.8 | 35 |
| 41564 | NF Perm | 5 | 3.0 | 1.0 | 168 | 190 | 1.7 | 39 |
| 41565 | NF Perm | 4 | 2.8 | 0.9 | 165 | 192 | 1.7 | 38 |
| 41566 | NF Perm | 4 | 3.1 | 0.9 | 176 | 203 | 1.7 | 41 |
| 41569 | NF Perm | 9 | 2.5 | 1.4 | 170 | 181 | 1.5 | 41 |
| 41570 | NF Perm | 7 | 2.6 | 1.2 | 181 | 193 | 1.5 | 42 |
| 41571 | NF Perm | 6 | 2.6 | 1.0 | 180 | 200 | 1.5 | 42 |
| 41572 | NF Perm | 5 | 2.8 | 0.7 | 185 | 5 | 0.1 | 3 |
| 41573 | NF Perm | 20 | 3.1 | ND | 188 | 216 | 1.6 | 49 |
| | | | | | | | | |
| 10/1/2013 | NF/RO Conc | 463 | 13.7 | 102.1 | 674 | 401 | 7.8 | 127 |
| 10/2/2013 | NF/RO Conc | 432 | 12.4 | 96.2 | 647 | 374 | 7.5 | 122 |
| 10/3/2013 | NF/RO Conc | 406 | 12.1 | 89.1 | 632 | 348 | 7.6 | 113 |
| 10/4/2013 | NF/RO Conc | 447 | 12.4 | 99.1 | 669 | 376 | 7.4 | 122 |
| 10/6/2013 | NF/RO Conc | 458 | 13.1 | 103.4 | 721 | 370 | 7.7 | 114 |
| 10/13/2013 | NF/RO Conc | 427 | 13.9 | 111.7 | 751 | 346 | 7.2 | 113 |
| 10/16/2013 | NF/RO Conc | 431 | 16.0 | 107.2 | 757 | 390 | 6.8 | 108 |
| 10/25/2013 | NF/RO Conc | 480 | 18.7 | 89.6 | 821 | 380 | 2.1 | 125 |
| 10/26/2013 | NF/RO Conc | 501 | 19.3 | 99.3 | 844 | 387 | 2.2 | 127 |
| | | | | | | | | |
| 10/6/2013 | Raw | 108 | 3.6 | 22.3 | 123 | 137 | 3.8 | 48 |
| 10/13/2013 | Raw | 114 | 3.1 | 25.5 | 121 | 134 | 1.2 | 45 |
| 10/17/2013 | Raw | 106 | 3.6 | 23.9 | 118 | 134 | 1.7 | 40 |
| 10/26/2013 | Raw | 106 | 4.0 | 17.4 | 113 | 129 | 0.7 | 45 |
| | | | | | | | | |
| 10/1/2013 | RO Conc | 593 | 15.0 | 119.8 | 589 | 666 | 9.6 | 221 |
| 10/2/2013 | RO Conc | 554 | 14.4 | 114.9 | 559 | 635 | 9.6 | 213 |
| 10/3/2013 | RO Conc | 533 | 14.0 | 106.7 | 536 | 601 | 9.2 | 202 |
| 10/4/2013 | RO Conc | 516 | 14.7 | 116.1 | 570 | 648 | 9.3 | 217 |
| 10/6/2013 | RO Conc | 579 | 14.7 | 120.1 | 567 | 650 | 9.2 | 208 |
| 10/7/2013 | RO Conc | 529 | 14.1 | 108.4 | 539 | 614 | 9.6 | 207 |
| 10/8/2013 | RO Conc | 562 | 14.3 | 115.7 | 555 | 639 | 9.6 | 214 |
| 10/9/2013 | RO Conc | 528 | 13.3 | 110.5 | 513 | 596 | 9.0 | 199 |
| 10/10/2013 | RO Conc | 527 | 14.2 | 114.5 | 537 | 626 | 8.9 | 197 |
| 10/11/2013 | RO Conc | 559 | 15.3 | 127.1 | 565 | 657 | 9.3 | 205 |
| 10/12/2013 | RO Conc | 582 | 16.2 | 131.4 | 589 | 683 | 9.2 | 213 |
| 10/13/2013 | RO Conc | 513 | 14.3 | 116.7 | 524 | 601 | 8.8 | 201 |
| 10/15/2013 | RO Conc | 539 | 17.3 | 127.1 | 570 | 674 | 9.5 | 202 |
| 10/16/2013 | RO Conc | 523 | 16.4 | 116.5 | 556 | 650 | 7.8 | 189 |
| 10/17/2013 | RO Conc | 507 | 14.6 | 112.6 | 522 | 601 | 7.6 | 199 |
| 10/18/2013 | RO Conc | 502 | 14.1 | 116.1 | 508 | 595 | 7.4 | 194 |
| 10/19/2013 | RO Conc | 523 | 13.2 | 121.2 | 511 | 591 | 4.9 | 191 |

| **Date** | **Location** | **$SO_4$**<br>**mg/L** | **$HCO_3$**<br>**mg/L** | **$SiO_2$**<br>**mg/L** | **TDS**<br>**mg/L** | **pH** | **Conductivity**<br>**µS/cm** |
|---|---|---|---|---|---|---|---|
| 41563 | NF Perm | 28 | 85 | 104 | 515 | 5.52 | 995 |
| 41564 | NF Perm | 32 | 122 | 92 | 520 | 5.37 | 972 |
| 41565 | NF Perm | 35 | 61 | 92 | 580 | 5.5 | 885 |
| 41566 | NF Perm | 40 | 61 | 88 | 625 | 5.23 | 936 |
| 41569 | NF Perm | 21 | 122 | 100 | 660 | 5.82 | 988 |
| 41570 | NF Perm | 27 | 98 | 100 | 640 | 5.64 | 948 |
| 41571 | NF Perm | 34 | 122 | 100 | 630 | 5.53 | 958 |
| 41572 | NF Perm | 169 | 110 | 104 | 0 | 7.34 | 951 |
| 41573 | NF Perm | 42 | 61 | 112 | 600 | 5.1 | 1002 |
| | | | | | | | |
| 10/1/2013 | NF/RO Conc | 2031 | 171 | 112 | 4380 | 5.62 | 5380 |
| 10/2/2013 | NF/RO Conc | 1935 | 195 | 104 | 4310 | 5.69 | 5280 |
| 10/3/2013 | NF/RO Conc | 1883 | 110 | 100 | 4135 | 5.6 | 5120 |
| 10/4/2013 | NF/RO Conc | 2020 | 134 | 104 | 4445 | 5.62 | 5400 |
| 10/6/2013 | NF/RO Conc | 2177 | 201 | 108 | 4655 | 5.73 | 5760 |
| 10/13/2013 | NF/RO Conc | 2305 | 146 | 108 | 4860 | 5.45 | 6010 |
| 10/16/2013 | NF/RO Conc | 2216 | 183 | 116 | 4725 | 5.84 | 6020 |
| 10/25/2013 | NF/RO Conc | 2393 | 195 | 116 | 5325 | 5.85 | 5840 |
| 10/26/2013 | NF/RO Conc | 2515 | 171 | 120 | 5340 | 5.67 | 5980 |
| | | | | | | | |
| 10/6/2013 | Raw | 186 | 317 | 20 | 855 | 7.28 | 1434 |
| 10/13/2013 | Raw | 181 | 299 | 21 | 865 | 7.33 | 1478 |
| 10/17/2013 | Raw | 175 | 281 | 21 | 745 | 7.34 | 1405 |
| 10/26/2013 | Raw | 166 | 281 | 21 | 805 | 7.54 | 1321 |
| | | | | | | | |
| 10/1/2013 | RO Conc | 925 | 1098 | 100 | 4140 | 7.48 | 5810 |
| 10/2/2013 | RO Conc | 872 | 1147 | 100 | 4075 | 7.57 | 5720 |
| 10/3/2013 | RO Conc | 830 | 1049 | 96 | 3890 | 7.53 | 5480 |
| 10/4/2013 | RO Conc | 891 | 1086 | 100 | 4130 | 7.63 | 5800 |
| 10/6/2013 | RO Conc | 905 | 1183 | 96 | 4100 | 7.55 | 5890 |
| 10/7/2013 | RO Conc | 840 | 1110 | 100 | 3870 | 7.6 | 5590 |
| 10/8/2013 | RO Conc | 882 | 1171 | 100 | 4055 | 7.68 | 5780 |
| 10/9/2013 | RO Conc | 833 | 1098 | 92 | 3750 | 7.63 | 5450 |
| 10/10/2013 | RO Conc | 860 | 1147 | 96 | 3955 | 7.66 | 5690 |
| 10/11/2013 | RO Conc | 912 | 1220 | 104 | 4240 | 7.65 | 6060 |
| 10/12/2013 | RO Conc | 951 | ND | 104 | 4370 | 7.64 | 6350 |
| 10/13/2013 | RO Conc | 839 | 1110 | 96 | 3870 | 7.59 | 5720 |
| 10/15/2013 | RO Conc | 879 | 1196 | 96 | 4050 | 7.63 | 5940 |
| 10/16/2013 | RO Conc | 862 | 1098 | 104 | 3915 | 7.63 | 5820 |
| 10/17/2013 | RO Conc | 823 | 976 | 92 | 3740 | 7.61 | 5520 |
| 10/18/2013 | RO Conc | 820 | 1086 | 92 | 3790 | 7.64 | 4960 |
| 10/19/2013 | RO Conc | 820 | 1098 | 88 | 3875 | 7.63 | 4960 |

| **Date** | **Location** | **Ca** | **K** | **Mg** | **Na** | **Cl** | **F** | **$NO_3$** |
|---|---|---|---|---|---|---|---|---|
| | | **mg/L** | **mg/L** | **mg/L** | **mg/L** | **mg/L** | **mg/L** | **mg/L** |
| 10/22/2013 | RO Conc | 732 | 12.1 | 115.8 | 582 | 641 | 6.1 | 228 |
| 10/23/2013 | RO Conc | 685 | 12.0 | 110.7 | 549 | 654 | 6.3 | 225 |
| 10/24/2013 | RO Conc | 748 | 13.1 | 123.5 | 595 | 664 | 6.5 | 228 |
| 10/25/2013 | RO Conc | 433 | 19.8 | 101.6 | 586 | 677 | 2.9 | 230 |
| 10/26/2013 | RO Conc | 390 | 19.9 | 106.6 | 586 | 682 | 2.6 | 231 |
| | | | | | | | | |
| 10/1/2013 | RO Perm | 0.7 | 0.3 | 0.2 | 9.0 | 5.7 | 0.7 | 5.8 |
| 10/6/2013 | RO Perm | 0.7 | 0.3 | 0.2 | 10.3 | 6.4 | 0.6 | 8.5 |
| 10/13/2013 | RO Perm | 1.0 | 0.4 | 0.2 | 12.4 | 8.2 | 0.7 | 8.3 |
| 10/17/2013 | RO Perm | 0.8 | 0.3 | 0.2 | 7.8 | 5.7 | 0.5 | 4.6 |
| 10/26/2013 | RO Perm | 39.5 | 1.8 | 8.8 | 113.2 | 3.6 | 0.0 | 0.6 |

| **Date** | **Location** | **$SO_4$**<br>**mg/L** | **$HCO_3$**<br>**mg/L** | **$SiO_2$**<br>**mg/L** | **TDS**<br>**mg/L** | **pH** | **Conductivity**<br>**μS/cm** |
|---|---|---|---|---|---|---|---|
| 10/22/2013 | RO Conc | 857 | 1196 | 104 | 4345 | 7.63 | 5630 |
| 10/23/2013 | RO Conc | 876 | 1226 | 104 | 4370 | 7.64 | 5630 |
| 10/24/2013 | RO Conc | 891 | 1208 | 104 | 4360 | 7.64 | 5650 |
| 10/25/2013 | RO Conc | 886 | 1190 | 108 | 4330 | 7.6 | 5610 |
| 10/26/2013 | RO Conc | 892 | 1196 | 104 | 4200 | 7.54 | 5590 |
| | | | | | | | |
| 10/1/2013 | RO Perm | 3.4 | 79.3 | 1.0 | 355.0 | 5.8 | 57.7 |
| 10/6/2013 | RO Perm | 2.8 | 91.5 | 1.0 | 40.0 | 5.9 | 65.8 |
| 10/13/2013 | RO Perm | 4.2 | 103.7 | 2.0 | 75.0 | 6.2 | 84.4 |
| 10/17/2013 | RO Perm | 2.8 | 85.4 | 2.0 | 495.0 | 6.0 | 53.6 |
| 10/26/2013 | RO Perm | 331.5 | 54.9 | 1.0 | 360.0 | 5.9 | 53.1 |

# APPENDIX D
# MEGA EVALUATIONS

**Appendix D1 – Mega Evaluations of Membranes from La Junta Trials**

**Appendix D2 – Mega Evaluations of Stack 3 Membranes**
**(swollen membranes, resistance testing)**

# APPENDIX D1

# MEGA EVALUATIONS OF MEMBRANES FROM LA JUNTA TRIALS

Membránové
Inovační
Centrum

MemBrain

MemBrain s.r.o., Pod Vinicí 87, 471 27 Stráž pod Ralskem, Česká republika
www.membrain.cz

# Evaluation of membranes from La Junta trials

## Goal

Make analyses of membranes from La Junta trials. A lot of precipitants were observed on membrane surface. There was a broken membrane too.

## Precipitants

There were observed a lot of precipitant on membrane surface. A diluted hydrochloric acid (HCl) was used for cleaning. Bubbles of gaseous carbon dioxide ($CO_2$) were seen (Fig. 1). A piece of membrane (like in Fig. 2) was cut and put in diluted HCl. Bubbles of gas were seen too. That means precipitants were inside the membranes and they were carbonates.
We met the similar situation after piloting where the saturation of calcium fluoride ($CaF_2$) was overstepped (Fig. 4).

## Broken membrane

A broken membrane was found (Fig. 3). Fitting fabric (textile) did not damage, it means that the destruction was not caused by pH. Ion exchange mixture was very fragile, it was seen under microscope. It could be caused either oxidant reagents or precipitants inside membrane.

## Conclusion

We recommend you to dose hydrochloric acid (HCl) into both concentrate streams during operation (working) and keep pH 5 to 6. It could protect concentrates against precipitation of carbonates.

Elaborated by: Lubomir Machuca; lubomir.machuca@membrain.cz; August 15th, 2012

**Fig. 1: Precipitants on membrane surface, bubbles in red circuit mean gaseous $CO_2$**

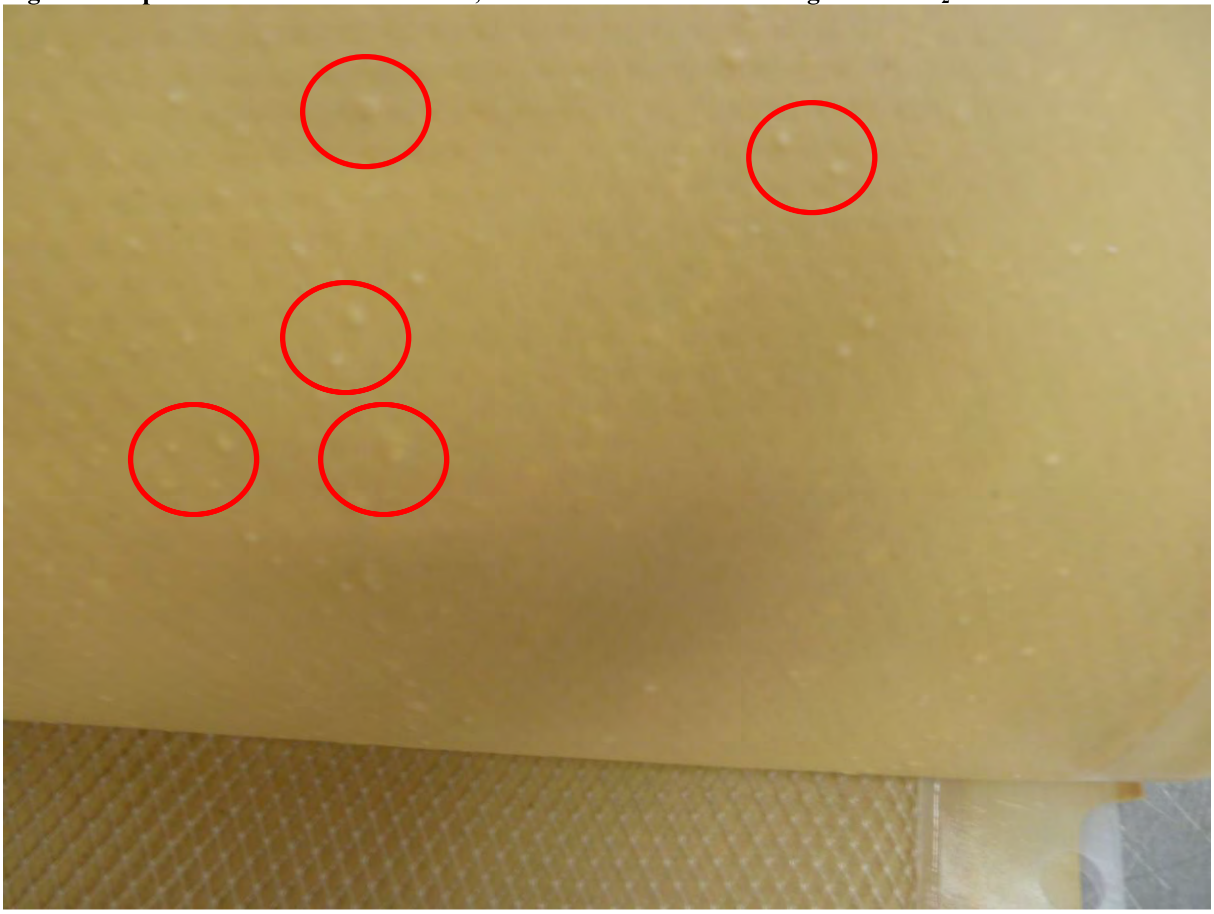

**Fig. 2: Precipitants inside membrane**

Fig. 3: Damaged membrane

Fig. 4: Precipitants of $CaF_2$ inside membrane

# APPENDIX D2 – MEGA EVALUATIONS OF STACK 3 MEMBRANES

## (SWOLLEN MEMBRANES, RESISTANCE TESTING)

Membránové
Inovační
Centrum

MemBrain

MemBrain s.r.o., Pod Vinicí 87, 471 27 Stráž pod Ralskem, Česká republika

www.membrain.cz

# EVALUATION OF STACK 3 MEMBRANES

*Authors:* **Lubomir Machuca**

Straz pod Ralskem, January 7th, 2014

MemBrain s.r.o. is part of a group mega

## Goal

Two quads from Stack 3 were sent to analysis because there were “fluffy” anion exchange membranes between NaCl and Mixed Cl. Analysis consists of:

- Measurement of electrochemical properties
- Determination of ionic content in fluffy AM
- Determination of precipitants on both sides of AM between EDM feed and Mixed Na

The Stack 3 operated at several different sites: Alamogordo New Mexico, La Junta Colorado and Brighton Colorado.

## Membranes description

Two quads were checked and described. Description is shown in Table 1 and a scheme is in Figure 1.

**Table 1: Membranes description**

| Membrane | Production batch | Production number | Position | Note |
|---|---|---|---|---|
| C1 | 13-32 | 62918 | Mixed Na – NaCl | |
| A1 | 11-82 | 98755 | NaCl – Mixed Cl | fluffy, weight of 695 g |
| C2 | 11-18 | 95213 | Mixed Cl – EDM feed | |
| A2 | 11-82 | 98805 | EDM feed – Mixed Na | red colour to EDM feed, precipitants on both side |
| C1‘ | 11-18 | 95279 | Mixed Na – NaCl | |
| A1‘ | 11-82 | 98757 | NaCl – Mixed Cl | fluffy, weight of 695 g |
| C2‘ | 11-18 | 95216 | Mixed Cl – EDM feed | |
| A2‘ | 11-82 | 98813 | EDM feed – Mixed Na | red colour to EDM feed, precipitants on both side |

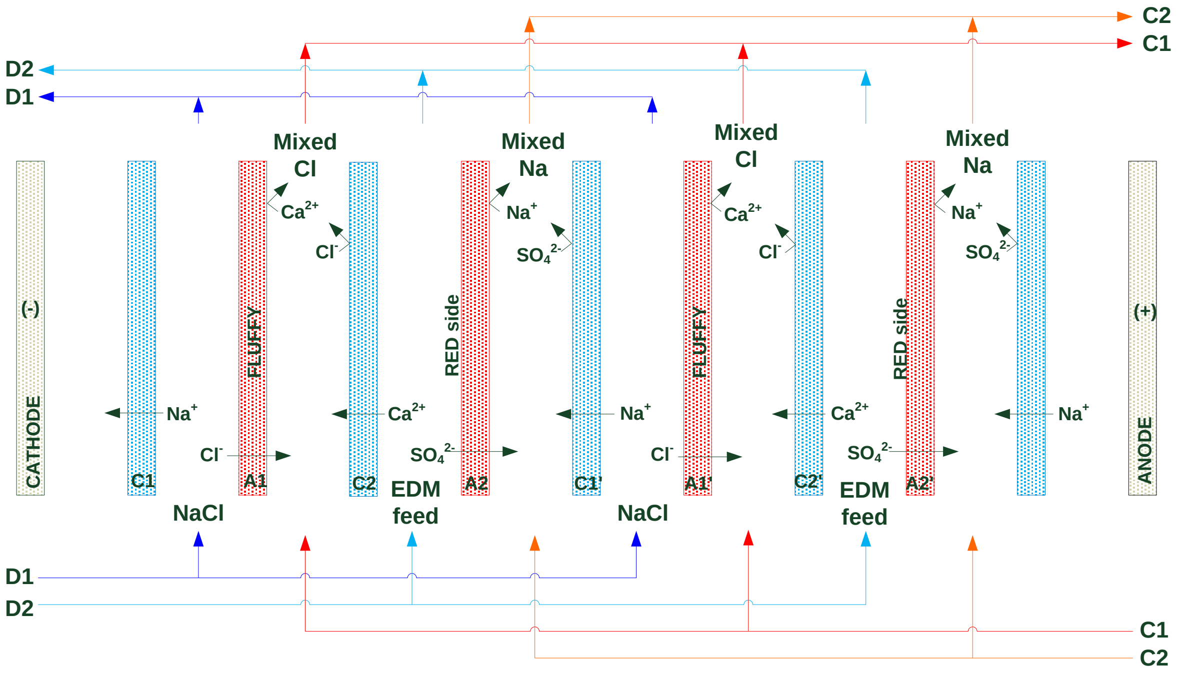

**Figure 1: EDM scheme**

Electrochemical properties

Surface resistance and specific resistance[1] both in 0.5M NaCl, and transport number and permselectivity both in 0.1/0.5M KCl were measured as electrochemical properties for each membrane. Ion exchange capacity (IEC) was determined too.

Electrochemical properties were measured by two ways, without cleaning and with cleaning. The cleaning means the washing in 1M HCl and 1M NaOH.

C1, C1' results

The cleaning was helpful and the resistances got better (go down). Lower resistance of C1 than C1' was due to C1 was produced in 2013 and it worked shorter time than C1'. Ion exchange capacity had common value, there was not any blockage or damage of ion exchange centres in the membrane.

A1, A1' results

Electrochemical properties and thickness got down after cleaning. Low resistance and low permselectivity after cleaning indicated huge channels (pores) inside the membrane. The cleaning flushed out some ions from membrane and it caused loosening the pores. In this case cations could pass through anion exchange membranes during the permselectivity measurement. We recommend you to replace all A1 membranes. Ion exchange capacity had common value, there was not any blockage or damage of ion exchange centres in the membrane.

The used membranes were thicker and heavier than new ones. New ones have thickness ~ 0.6 mm and weight ~ 500 g. Reasons of thickness and weight are discussed further.

**Table 2: Electrochemical properties of membranes**

| membrane | | **C1** | **A1** | **C2** | **A2** | **C1'** | **A1'** | **C2'** | **A2'** |
|---|---|---|---|---|---|---|---|---|---|
| batch | | 13-32 | 11-82 | 11-18 | 11-82 | 11-18 | 11-82 | 11-18 | 11-82 |
| membrane number | | 62918 | 98755 | 95213 | 98805 | 95279 | 98757 | 95216 | 98813 |
| solution | | Mixed Na - NaCl | NaCl – Mixed Cl | Mixed Cl – EDM Feed | EDM Feed – Mixed Na | Mixed Na - NaCl | NaCl – Mixed Cl | Mixed Cl – EDM Feed | EDM Feed – Mixed Na |
| **without cleaning** | | | | | | | | | |
| thickness | [mm] | 0.64 | 0.93 | 0.62 | 0.59 | 0.62 | 0.95 | 0.62 | 0.59 |
| surface resistance | [$\Omega.cm^2$] | 7.69 | 9.25 | 10.24 | 8.73 | 9.48 | 9.27 | 9.58 | 7.66 |
| specific resistance | [$\Omega$.cm] | 119.5 | 99.6 | 165.5 | 147.1 | 152.8 | 97.6 | 153.8 | 130.5 |
| transport number | | 0.9575 | 0.9255 | 0.9616 | 0.9528 | 0.9611 | 0.9251 | 0.9659 | 0.9506 |
| permselectivity | [%] | 91.50 | 85.10 | 92.31 | 90.57 | 92.22 | 85.01 | 93.18 | 90.12 |
| **with cleaning** | | | | | | | | | |
| thickness | [mm] | 0.66 | 0.73 | 0.63 | 0.60 | 0.64 | 0.75 | 0.64 | 0.59 |
| surface resistance | [$\Omega.cm^2$] | 5.82 | 4.43 | 7.01 | 7.10 | 7.21 | 4.71 | 7.01 | 7.17 |
| specific resistance | [$\Omega$.cm] | 88.6 | 60.6 | 110.9 | 119.0 | 112.9 | 62.5 | 109.0 | 121.4 |
| transport number | | 0.9419 | 0.9200 | 0.9592 | 0.9405 | 0.9607 | 0.9339 | 0.9618 | 0.9446 |
| permselectivity | [%] | 88.38 | 84.00 | 91.85 | 88.10 | 92.13 | 86.79 | 92.36 | 88.92 |
| ion exchange capacity | [meq/$g_{dry}$] | 2.44 | 1.91 | 2.38 | 1.80 | 2.42 | 1.94 | 2.40 | 1.80 |

---

[1] Resistance of membrane is measured in a special cell which is divided by membrane in two chambers. Solution of 0.5M NaCl is in each chamber. Two electrodes measure voltage under 10 mA of DC and resistance is calculated from voltage and current by Ohm's law.

C2, C2’ results

The cleaning was helpful and resistance got better. Ion exchange capacity had common value. That seems only dirt was on the membrane surface. The membranes were alright.

A2, A2’ results

The cleaning was helpful and resistance got better. Permselectivity after cleaning was rather low, it could cause that cations went through anion exchange membrane. Ion exchange capacity was 10 % lower in comparison with new membrane.

Analysis of A1, A1’ membrane

The A1 membranes were tested by two methods. The first one represented burning of membrane and analysis of ash. Inorganic ions were determined by this method. The second one was infrared (IR) spectroscopy of surface and incision of membrane. Organic pollutants were determined by this method.

Very high content of calcium (Table 3) was found in A1 in spite of this membrane was anion exchange. We suppose that $CaSO_4.2H_2O$ (and $Ca_3(PO_4)_2$) precipitated inside the membrane and it probably caused “fluffy” membrane. We recommend you to replace all A1 membranes.

IR spectra of A1 and new anion exchange membrane were the same thus there were not any organic pollutants on/in A1 membrane.

**Table 3: Content of inorganic ions in A1 membrane**

| **Ion** | **Unit** | **Value** |
|---|---|---|
| Al | mg/kg of dry membrane | 29.8 |
| Ba | mg/kg of dry membrane | 1 |
| Ca | mg/kg of dry membrane | 113 000 |
| Cu | mg/kg of dry membrane | 5.72 |
| Fe | mg/kg of dry membrane | 26.3 |
| Mg | mg/kg of dry membrane | 22.6 |
| Mn | mg/kg of dry membrane | 2.92 |
| Ni | mg/kg of dry membrane | 1.68 |
| Sr | mg/kg of dry membrane | 563 |
| $CO_3^{2-}$ | mg/kg of dry membrane | < 500 |
| $SO_4^{2-}$ | mg/kg of dry membrane | 283 000 |
| $PO_4^{3-}$ | mg/kg of dry membrane | 1 972 |
| $F^-$ | mg/kg of dry membrane | < 150 |
| $SiO_2$ | mg/kg of dry membrane | 2 900 |

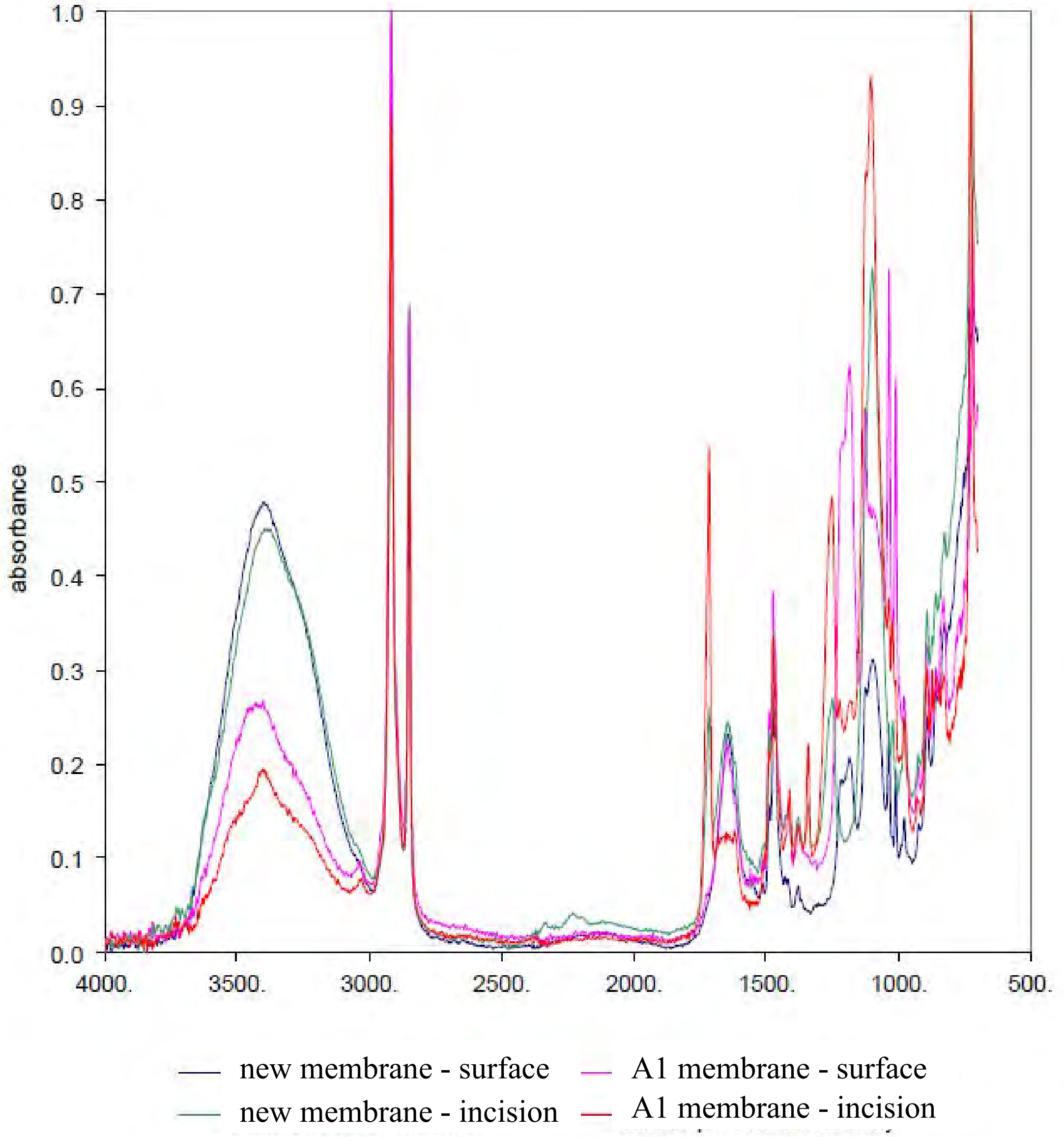

**Figure 2: IR spectra of A1 and new anion exchange membrane**

<u>Precipitants on A2, A2' surface</u>

Precipitants on A2 membrane surface which was directed at C2 membrane are shown in Figure 3. EDM feed flowed along this side. The membrane side and precipitants were brown coloured. Precipitants contained $CaSO_4.2H_2O$ based on microscopic and X-ray analysis.

Precipitants on A2 membrane surface which was directed at C1' membrane are shown in Figure 4. Mixed Na solution flowed along this side. Precipitants contained $CaCO_3$ and $CaSO_4.2H_2O$ based on microscopic and X-ray analysis.

**Figure 3: Precipitants on A2 membrane surface directed at C2**

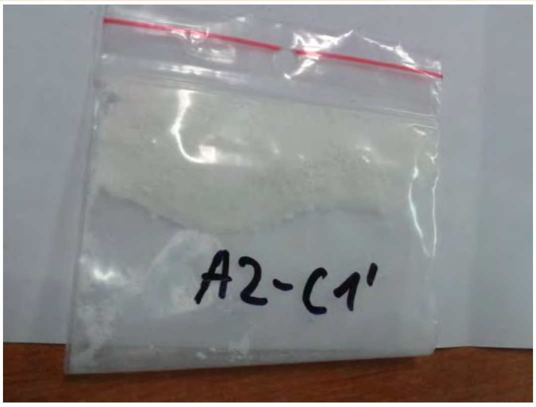

**Figure 4: Precipitants on A2 membrane surface directed at C1'**

<u>Conclusion</u>

Two quads from Stack 3 were analysed.

- The Stack 3 was produced in 2011 and FAT (Factory Acceptance Test) was carried out. The Stack 3 passed this test successfully without any mistake by assembling.
- The membranes were probably replaced several times on-site because membranes A1 – C2' were produced in 2011 and C1 membrane in 2013.
- "Fluffy" anion exchange membranes were caused probably by $CaSO_4.2H_2O$ (and $Ca_3(PO_4)_2$) precipitation. Any organic matter was not found inside "fluffy" membranes. We recommend you to replace all A1 membranes.
- The second kind of anion exchange membranes had precipitants on surface. Precipitants of $CaSO_4.2H_2O$ were on EDM feed side, mixture of $CaCO_3$ and $CaSO_4.2H_2O$ were on Mixed Na side. We are not able to determine the reason of precipitation because we do not know all operation conditions.
- We recommend you to make cleaning by acid and alkaline periodically because it is helpful for getting better electrochemical properties. It necessary to find the optimum cleaning frequency and cleaning solution for the stacks used in ZDD process, based on pilot experience.
- Permselectivity of each ion exchange membrane depends on concentration ratio of solution on both sides. The higher concentration ratio, the lower permselectivity. In RALEX membrane case we usually measure permselectivity in 0.1/0.5 M KCl and value for new anion exchange membrane is min. 90 %. If we measured anion exchange membrane in 0.05/1.5 M KCl, permselectivity was only 86 %. That is necessary to consider when using RALEX membranes for ZDD application.

# APPENDIX E
# COST CALCULATIONS

# Additional Cost Calculations

Equations and sample calculations used for capital and operational cost estimations are described here and supplemented with a 4-MGD design for Alamogordo. Summary information for Alamogordo and La Junta are provided as well.

## Adjustment to common year for cost estimates:

All cost estimates are made with 2013 as the cost year. The Producer Price Index for commodities was used to adjust prices. If sources provided the year for their cost basis, it was used. Otherwise, the year of publication was utilized.

## Calculating installed cost of equipment

The equipment capital cost was estimated as described in the report, and subsequently multiplied by 1.4 to estimate total installed cost.

The capital cost for concentrate management, both evaporation pond and deep well injection, was each estimated using four different cost models / methods. System flows, including those to the concentrate disposal systems, were calculated using Veolia's design software (called Pearl), and edited in Excel to match actual pilot operation in the field.

## Evaporation Pond Estimations

Evaporation pond size was calculated using the evaporation rate for the region (14.8 cm/month for Alamogordo and 6.9 cm/month for La Junta, CO).

> *Evaporative Area = (flow to Evap Pond) / (Evap Rate)*
>
> *The 4-MGD Alamogordo ZDD system:*
>
> *Evap Area = (57gpm) *(1440min/day) * (365 days/yr) * (1*$m^3$*/264.17gal) * (1/14.8 cm/mos) * (1yr/12mos) * (100cm/m) * (1acre/4046.856*$m^2$*) = 15.7 acres*

DWPR Report #123 includes an estimation method for estimating the total size of the evaporation pond (including dikes and 20% contingency). This method was used to estimate the pond size and used for all cost estimations.

> ***Total area** (plus 20% contingency) = 1.2 x evaporative area x (1+0.155 * dike height / sqrt evap area)*
>
> *The 4-MGD Alamogordo ZDD with a 4-ft dike height:*
>
> *Total area=1.2 x 15.7 acres x (1+0.155 x 4ft / sqrt(15.7acres))= <u>21.8 acres</u>*

Evaporation pond capital costs were estimated using four methods, adjusted to 2013 values (PPI=203.0), then averaged:

*(1)* Desalination Engineering, Planning & Design textbook (Voutchkov 2013, page 571).
*Capex = evap pond install (Figure 16.47 in Voutchkov 2013) + $0 land purchase + $8500/acre for Leak Detection.*

(2) BGNDRF, Alamogordo, NM Evaporation pond installation cost of $130,000/acre, adjusted from 2007 (PPI = 175.1)
(3) El Paso KBH Plant cost estimate of $52.3 M for 3-MGD of passive evaporation, and scaled to the Alamogordo or La Junta flowrate to Evaporation, adjusted from 2012 (PPI = 202.1)
(4) Bureau of Reclamation Report by Mickley (2006), described below, and adjusted from 2001 (PPI = 135.7), plus $8500/acre for Leak Detection.

Evaporation pond capital cost method (4) is from DWPR Report #123 (Mickley, 2006), and suggests an Evaporation Pond Regression Model to estimates the total unit area capital cost ($/acres) as follows:

***Total unit area capital cost*** *($/acre) = 5406 + 465 x liner thickness + 1.07 x land cost + 0.931 x land clearing cost + 217.5 x dike height*

*The 4-MGD Alamogordo ZDD system (assuming no land cost):*

***Total unit area capital cost*** *($/acre) = 5406 + 465 * 50mil + 1.07 * ($0) + 0.931 * $1000/acre + 217.5 * 4ft = <u>$30,457/acre</u>*

***Total Pond Cost*** *= Total area * Total unit area capital cost = $30,457 / acre * 21.8 acres = <u>$663,271</u>*

The DWPR Report 123 (Mickley, 2006) suggests a more detailed analysis can be obtained by specifying a range of evaporation pond-specific variables (Table 10.1 *"Worksheet for Evaporation Pond Disposal Capital Costs, Preliminary Level Costs Only").* Table D-1 includes this methodology for a full scale/full flow Alamogordo (4-MGD) and La Junta (6.6 MGD) plants and also includes the reported values for La Junta (1.6 MGD flow) from the WERF 5T10 report. It is important to note the following differences between this Report's analysis and the WERF analysis:

- the WERF study sized the Evaporation Pond for average plant production of 1.6-MGD, while we sized the Evaporation Pond for design plant production of 6.6-MGD,
- the WERF report assumed six ponds of 3 acres each, while this analysis assumed one large pond,

**Table E-1.—Example Evaporation Pond Estimation Calculations**

| Item | Variables | Range | Alamogordo (4MGD ZDD) | La Junta (6.6MGD ZDD) | WERF 510T (1.6MGD) |
|---|---|---|---|---|---|
| A | Evaporation Surface (Acres) | 0 to 100 | 16 | 56 | 3 |
| B | Dike height (feet) | 4, 8, 12 | 4 | 4 | 4 |
| C | Total liner thickness (mm) | 20 to 120 | 50 | 60 | 60 |
| D | Land Unit Cost ($/acre) | 0-10,000 | $0 | $10,000 | $10,000 |
| E | Land Type | 1, 2, 3, 4 | 1 (Brush) | 1 (Brush) | 1 (Brush) |
| **Item** | **Calculation of Total Acreage** | **Remarks** | | | |
| F | Ratio: Total Acreage to Evaporative Acreage | Reference | 1.17 | 1.08 | 1.3 |
| G | Total Acreage | A*F | 18.72 | 60.2 | 6.5 |
| **Item** | **Unit Area Costs Using Total Acreage** | **Remarks** | | | |
| H | Land, $/acre | Same as D | 0 | $ 10,000 | $10,000 |
| I | Land clearing, $/acre | Reference | 1000 | 1000 | $1,500 |
| J | Dike, $/acre | Reference | 3000 | 1600 | $7,400 |
| K | Nominal liner, $/acre | Reference | 26600 | 28600 | $35,300 |
| L | Liner, $/acre | K*C/60 | 22167 | 28600 | $35,300 |
| M | Fence, $/acre | Reference | 3750 | 2050 | $8,300 |
| N | Road, $/acre | Reference | 700 | 360 | $1,400 |
| | Total Unit Cost (per acre) | | $30,617 | $43,610 | $67,000 |
| | Subtotal | | *$573,144* | *$2,623,789* | $416,000 |
| | Engineering and Admin (20%) | | *$114,629* | *$524,758* | $83,200 |
| | Contingency (15%) | | *$85,972* | *$393,568* | $62,400 |
| | TOTAL (1 pond) | | *$773,744* | *$3,542,115* | $570,000 (1 pond) |
| | TOTAL (all ponds) | | *$773,744* | *$3,542,115* | $3,500,000 (6 ponds) |

- the WERF report added 20% for Engineering and Administration costs, and 15% for Contingency; while the Regression Model seems to include these Fees already.

For La Junta 6.6 MGD ZDD, the Regression Model estimated \$3.3M, while the Detailed Analysis in the Table below estimated \$3.5M installed, so the two models are quite similar. The Regression Model is an equation and requires no job-specific interpolation on plots published in the USBR 2006 publication, and therefore the Regression Model is preferred by the authors of this paper.

# Deep Well Injection Costs

For Alamogordo, Deep Well Injection was also considered as a disposal method. Five methods were calculated in this Report's cost model, and averaged. As with Evaporation Costs, these are adjusted to 2013 dollar values using PPI. The five models are described briefly below.

(1) Cost from Alamogordo EIS for conventional BWRO, which assumes 1 well for BWRO disposal for a BWRO producing 1.8MGD, is \$2.6M, in 2010 dollars (PPI = 187)

(2) Cost for each KBH (El Paso, TX) injection well is \$3.6M (2007, PPI = 175)

(3) AWWA M46 equation

DWI Capital Cost = (-0.0001*(flow to well, gpm)^2 + 1.0178*(flow to well, gpm) + 1734.2)*1000, in 2004 dollars (PPI = 147.6)

(4) Cost from Desalination Engineering, Planning & Design by (Voutchkov, 2013). Pretreatment cost \$20-\$50/m$^3$/day of plant capacity. Monitoring well \$600-\$800/well depth, m.

DWI Capital Cost = 165*(Flow, m$^3$/day) + 310*(Well depth, m) +100000+ (\$50 Pretreatment cost)*(DW plant capacity, m3/day) + (Well depth, metres)*800.

(5) Equation from DWPR Report 123 (Mickley, 2006), based upon wells in California, Florida, and Texas, and includes the cost for monitoring well, which was not required for KBH in El Paso, Texas. Last section of chapter defines Deep Well Injection. Cost basis is 2001 (PPI = 135.7).

DWI Capital Cost = -288,000 +145,900 * Tube diameter + 754 * depth.

Equations provided somewhat similar values, as shown in table D-2.

**Table E-2.—Deep Well Injection Cost Estimates According to Five Different Cost Models, Adjusted to 2013 Dollars Using PPI**

| | Deep Well Injection CapEx estimates (adjusted to 2013 dollars) | | | |
|---|---|---|---|---|
| **Model and Variables** | **Alamogordo 4-mgd BWRO** | **Alamogordo 4-mgd ZDD** | **Alamogordo 1-mgd BWRO** | **Alamogordo 1-mgd ZDD** |
| ***Flow to Well*** | *697* | *57* | *176* | *14* |
| ***Tubing Diameter (in)*** | *6* | *4* | *4* | *4* |
| ***Depth (ft)*** | *3,000* | *3,000* | *3,000* | *3,000* |
| (1) Alamogordo EIS | $2,849,599 | $2,849,599 | $2,849,599 | $2,849,599 |
| (2) El Paso KBH Plant | $4,173,615 | $4,173,615 | $4,173,615 | $4,173,615 |
| (3) AWWA M46 | $3,294,271 | $2,464,018 | $2,627,893 | $2,404,922 |
| (4) Voutchkov | $2,499,241 | $1,165,967 | $1,462,878 | $1,127,730 |
| (5) DWPR #123 | $4,222,160 | $3,785,643 | $3,785,643 | $3,785,643 |
| **AVERAGE** | **$3,407,777** | **$2,887,768** | **$2,979,926** | **$2,868,302** |

# Operating Costs

Operating costs include power, chemicals, membrane replacement, expendables, and concentrate management. Annual operating costs calculated assuming an interest rate of 6% for 20 years.

Power Consumption was calculated based on 365day/yr, 24hr/day operation, using the following equation

*Pump BHP=(GPM *PSI*Sp.Gr)/(1713*Pump.eff).*

The NF feed pump operates at 3,800 gpm and 90 psig (Since the booster pumps are outputting 30 psi pressure, the NF feed pump needs to provide only an additional 60 psi to produce permeate).

*Pump BHP=(GPM *PSI*Sp.Gr)/(1713*Pump.eff) = (3800gpm * 60 psi* 1SG)/(1714*70% assumed pump efficiency) = 190*

Unit Motor Horse Power (MHP) is a Lookup function in Excel, comparing BHP to MHP by calculating BHP*(1+BHP:MHP Ratio), where BHP:MHP Ratio = 15%. The look-up table defines 400MHP for a 350 BHP. Subsequently, Unit motor BKW is calculated.

*Unit motor BKW = BHP * 746 / (Motor effiency *1000) = 350BHP * 746 / (85% * 1000) = 307*

Motor efficiency is assumed to be 80% for motors <50HP, and 85% for motors >85HP. The Unit Motor BKW is then multiplied by a Power Factor of 0.90 to calculate the Unit Operationg BKW, and multiplied by the number of operating units to calculate the Total Operating BKW.

*Unit Operating BKW = Unit Motor BKW * Power Factor = 102.5 * 0.90 = 114*

*Total Operating BKW = Unit Operating BKW * Number of Units = 114 * 1 = 114*

The power consumed per day is calculated by multiplying the Total Operating BKW by the number of hours operating per day; and usage per year is similarly calculated.

*Electrical usage (kWhr/day) = BKW * Hrs/day = 114 * 24hrs/day = 8,198 kWhr/day.*

*Electrical usage (kWhr/yr) = 8198 *365 days/yr = 2,992,120 kWhr/yr*

*Electrical usage ($/yr) = kWhr/yr * $0.08/kWhr = $239,370/yr*

The EDM stack power is calculated from the voltage and current needed (based on the piloting results and full scale design).

*EDM Stack Power (kW) = (Voltage * Current)/(Motor Efficiency * AC-to-DC-Efficiency*1000) = (110V * 37Amps) / (85% * 97% * 1000) = 4.9 kW*

For Alamogordo, each of the 93 EDM stacks has its own DC drive which operates at 140 Volts and 46 amps. We assume an AC to DC efficiency of 97% and motor efficiency of 85%, which equates to an EDM Stack Power of 7.8 kW.

For La Junta, each of the 90 EDM stack has its own DC drive which operates at 110 volts and 37 amps. We assume an AC to DC efficiency of 97% and motor efficiency of 85%, which equates to an EDM Stack Power of 4.9 kW.

Similar to the pump power equations described previously, the Unit Operating BKW and Total Operating BKW are calculated, and subsequently the electrical usage in kWhr/day can be calculated (for La Junta):

*Unit operating BKW = EDM Stack Power (kW) / Power Factor = 4.9 / 1 = 4.9*

*Total Operating BKW = Unit Operating BKW * Number of Units = 4.9 * 90 units*

*Power consumption per day (kWhr/day) = Total Operating BKW * Operating hrs/day = 444 BKW * 24 hrs/day = 10,662 kWhr/day*

*Power consumption per year (kWhr/yr) = Daily electrical usage * days per year = 10,662 * 365 days = 3,891,799 kWhr/yr*

*Yearly power cost = 3,891,799 kWhr/yr * $0.08/kWhr = $311,344/yr from the 90 EDM stacks.*

The total annual power costs for Alamogordo and La Junta ZDD designs are summarized in Table D-3. This total power includes all pumps (feed, booster, chemical, transfer), clean in place systems, and other ancillary equipment.

**Table E-3.—Annual Power Cost by System and Location**

| | NF | EDM | Other | Deep Well Injection |
|---|---|---|---|---|
| **Alamogordo 1MGD** | $63,100 | $195,885 | $2,092 | $515 |
| **Alamogordo 4MGD** | $225,986 | $772,490 | $7079 | $2,059 |
| **La Junta 6.6MGD** | $397,682 | $644,874 | $10,894 | -- |

Chemical consumption was estimated based both on dosage and flowrate (sulfuric acid and antiscalant) and by total pounds per day calculated in Veolia's design software called Pearl (NaCl). An example equation for calculating sulfuric acid for pH adjust in the ZDD feed is as follows.

ZDD Chemical, NF Sulfuric Acid Daily Consumption

- Design flow = 2,263gpm
- Dosage = 4mg/L
- Chemical dosage frequency = 24hrs/day, 365 days/yr
- Chemical quantity (lbs/day) = (flowrate gpm) * (60min/hr) * (Dosage, mg/L) * (Hrs/day) * (8.34/1000000) = 109 lbs/day
- Chemical quantity (lbs/yr) = lbs/day * 365days/year = 39,676 lbs/yr
- Chemical cost per year = Quantity per year * Cost per lb ($0.20) = $7,935

NF CIP chemical quantities are calculated by first knowing the vessel volume. An example calculation is below.

Vessel Volume Calculation

- Bank quantity = 2 units
- Vessels per bank = 16
- Elements per vessel = 8
- Volume per vessel, gallons = ((8)/(2*12))^2)*((40/12)*Elements/vessel)*7.480519
- CIP volume for vessels, gallons =(Vessels/bank * Volume/vessel * Bank quantity) = (16*69.7*4)=4,458 gallons

Pipe Volume Calculation

- Vessels / stage, units = 16
- CIP pump capacity, gpm = # vessels/stage * 40gpm = 640-gpm
- Diameter of pipe, inches = 8”

- Length of pipe, ft = 150ft
- Volume of pipe, gal =(((Diameter, inches)/(2*12))^2)*LengthOfPipe, ft*7.48)*BankQuantity = 499gallons

*Total CIP volume required =(CIP volume required per flush, gallons) * (Number of cycles per CIP)*(1+SafetyFactor) = (4957gal per flush) * (3 cycles per CIP) * (1 + 0.20 safety factor ) = 17,845gallons*

Caustic requirement

- Concentration = 0.1%
- Quantity of NaOH required per CIP =(17,845 gal per CIP * 0.1% *100*10000*8.34)/1000000 = 149 lbs at 100%
- Quantity of NaOH required per year = (NaOH per CIP) * ( # CIP / year) = (149lbs/CIP) * (2CIP/yr) = 298 lbs at 100%

The CIP chemicals required are <$0.01/1000gal.

The biggest contributor to ZDD chemical operating costs is the NaCl required for the EDM. The NaCl required is calculated by the Veolia design software, Pearl, based upon the fact that 1 meq of NaCl is required for every meq removed from the EDM feed water. NaCl consumption for the ZDD designs evaluated in this report are listed below. NaCl is assumed $0.075 /lbs delivered.

**Table E-4.—Annual NaCl Consumption and Cost for Each Site**

| | NaCl per day (lbs) | NaCl per year (lbs) | $/yr |
|---|---|---|---|
| **Alamogordo 1MGD** | 12,204 | 4.45M | $334,104 |
| **Alamogordo 4MGD** | 48,350 | 17.6M | $1.32M |
| **La Junta 6.6MGD** | 42,327 | 15.5M | $1.16M |

The Expendables budget for ZDD and BWRO consists of Membranes, Cartridge filters, and EDM Anodes and Cathodes. Replacement costs are annualized by multiplying the average lifespan (5yrs for NF, 10yrs for EDM) by the ratio of Total units divided by the Design/Duty units. The estimated Annualized replacement costs for these items are listed below.

**Table E-5.—Annual Expendables Budget for Each Site**

| | NF Membranes | EDM Membranes & Spacers | Cartridge filters | EDM Anodes & Cathodes |
|---|---|---|---|---|
| **Alamogordo 1MGD** | $61,440 | $101,837 | $38,720 | $19,392 |
| **Alamogordo 4MGD** | $63,160 | $394,618 | $153,908 | $75,144 |
| **La Junta 6.6MGD** | $100,000 | $381,888 | $248,626 | $72,720 |

# Salt Recovery Estimation

Conceptual costs for NaCl recovery techniques described in Chapter 11 were made using estimates for typical equipment used for lime softening, solids dewatering, and electrodialysis systems common in Japan for recovering NaCl from seawater.

The first step is to determine how much NaCl is required by the EDM. This is done by calculating the difference in anion and cations, measured in equivalents per day, between the NF reject and EDM diluate. The amount of Na required is equal to the change in cations and the amount of Cl required is equal to the change in anions. Each of these values (in eq/day) is converted to mg/day and summed. Finally, the amount of NaCl is converted to lb/day.

**Table E-6.—Calculation of Daily NaCl needed for EDM (Alamogordo)**

| | | NF Concentrate EDM Feed | EDM Diluate Recycle |
|---|---|---|---|
| Flow rate | gpm | 1,521.0 | 1,513.4 |
| TDS | ppm | 6207.2 | 3144.0 |
| Conductivity | □S/cm | 4323.7 | 2598.9 |
| | | | |
| in meq/L | | | |
| Calcium | | 55.86 | 27.93 |
| Magnesium | | 20.05 | 10.02 |
| Sodium | | 15.68 | 7.84 |
| Potassium | | 0.26 | 0.13 |
| Bicarbonate | | 0.00 | 0.00 |
| Chloride | | 3.34 | 1.67 |
| Sulfate | | 86.25 | 43.13 |
| | | | |
| Σ cations | | 91.85 | 45.93 |
| Σ anions | | 89.60 | 44.80 |
| **NaCl required by EDM** | | | |
| | | **mg/day** | **meq/day** |
| Na | | 8584968863 | 373259516 |
| Cl | | 13392374033 | 382639258 |
| | | | |
| NaCl | | 48350 | lb/day |

To maximize NaCl recovery and minimize waste, lime is added to the Mixed Cl stream to remove $Mg(OH)_2$. This allows the calcium and sulfate to be nearly balanced. There will be excess Mixed Na because there is still more sulfate than calcium. The streams are blended at a ratio of the treated Mixed Cl calcium/Mixed Na sulfate to ensure a stoichiometric mix of calcium and sulfate.

The remainder of the Mixed Na stream is sent to a separate evaporation pond. The amount of NaCl recoverable is found by summing the concentration of Na and Cl in eq/day in each of the streams then converting to lb/day.

$$Available\ Na\ \left(\frac{eq}{day}\right) = Q_{M.Cl}C_{M.Cl}(Na) + Q_{M.Na}C_{M.Na}(Na)$$

$$Available\ Cl\ \left(\frac{eq}{day}\right) = Q_{M.Cl}C_{M.Cl}(Cl) + Q_{M.Na}C_{M.Na}(Cl)$$

**Table E-7.—Calculation of Daily NaCl recoverable (Alamogordo)**

| | | | | for NaCl Production | | to 2nd Evap Pond |
|---|---|---|---|---|---|---|
| | | NF Conc | Mixed Cl | Treated Mixed Cl | Mixed Na | Mixed Na |
| Flow rate | gpm | 1521.01 | 35.49 | 35.49 | 35.49 | 6.11 |
| TDS | ppm | 6207 | 107364 | 107364 | 140007 | 140007 |
| Conductivity | □S/cm | 4324 | 262428 | 262428 | 255122 | 255122 |
| | | | | | | |
| Calcium | meq/L | 56 | 1203 | 1635 | 0 | 0 |
| Magnesium | meq/L | 20 | 432 | 0 | 0 | 0 |
| Sodium | meq/L | 16 | 338 | 338 | 1975 | 1975 |
| Potassium | meq/L | 0 | 5 | 5 | 0 | 0 |
| Bicarbonate | meq/L | 0 | 0 | 0 | 0 | 0 |
| Carbonate | meq/L | 0 | 0 | 0 | 2 | 2 |
| Chloride | meq/L | 3 | 2002 | 2002 | 72 | 72 |
| Sulfate | meq/L | 86 | 0 | 0 | 1858 | 1858 |
| Nitrate | meq/L | | | | | |
| Silica | meq/L | 92 | 1978 | 1978 | 1975 | 1975 |
| CO2 | meq/L | 90 | 2002 | 2002 | 1931 | 1931 |
| | | NaCl Recoverable | | | | |
| | | | eq/day | | | |
| | | Available Na | 381,576 | | | |
| | | Available Cl | 398,665 | | | |
| | | | 39,480 | lb/day | | |
| | | | 82% | of required NaCl | | |

The next steps are shown in tabular form.

| | |
|---:|---|
| 3.26 | mgd NF feed |
| 1433.00 | mg/L $SO_4$ in feed |
| 48 | g/eq sulfate |
| 20 | g/eq calcium |
| 18 | g/eq water in dihydrate |
| 86 | g/eq of dihydrate |
| 2.57 | g of dihydrate in liter of feed (assuming all $SO_4$ is converted to dihydrate) |
| 12,331,530 | L/day of feed |
| 31.66 | mT/day of dihydrate in feed |
| 1000.00 | kg/m$^3$ bulk density of dihydrite at bottom of pond |
| 31.66 | m$^3$/day of dihydrate generated |
| 4047.00 | m$^2$/acre |
| 0.01 | fraction of feed evaporated to raise salt content of supernatant from 1.5M to 3M |
| 151.68 | m$^3$/day evaporation rate |
| 0.148 | meters/month evaporation rate in Alamogordo |
| 30.42 | days/month |
| 7.70 | acres evaporation pond needed to raise salt content of supernatant from 1.5M to 3M |
| 3.0 | days/yr |
| 0.25 | fraction of solids in pond |
| 11.4 | gpm, excess Mixed Na flow to 2nd evaporation pond (assume 2 x calculated 5.7 gpm) |
| 3 | Acres, evaporation pond |
| 12308.019 | O&M on evap pond (no disposal); assume 1% of capital cost |
| 115000 | $/Ac evap pond cost |
| 20 | years of pond life |
| 35.35 | meq/L anions in BW feed |
| 0.70 | NF rejection |
| 1230802 | capital cost of ponds (10.7 acres total) |
| 377949 | eq/day NaCl required |
| 309918 | eq/day NaCl recoverable (90%) |
| 14563609 | lb/year NaCl recoverable |
| 77228 | Annual cost of evap pond (20 years, 6% interest) |
| **Lime for $Mg(OH)_2$ Recovery** | |
| 88 | mg/L Mg in sourcewater |
| 1085 | kg/day Mg in feed |
| 2604 | kg/day $Mg(OH)_2$ in feed |
| 800 | $/mT sales price of high purity $Mg(OH)_2$ |
| 400 | $/mT sale price of $Mg(OH)_2$ |
| 31242 | $/month potential market for $Mg(OH)_2$ |

| | |
|---|---|
| 74 | molecular weight of $Ca(OH)_2$ |
| 24 | atomic weight of Mg |
| 3305 | kg/day $Ca(OH)_2$ consumption |
| 106145 | cost of $Ca(OH)_2$ $/year |
| (clarifier costs: http://www.ecodwellinternational.org/images/EC/ECvsLime%20Softening.pdf) | |
| **Clarifier for Lime:** | |
| 14427 | $/gpm treated, includes 1.4 installation factor |
| 15 | kWh/1000 gal |
| 28 | flow rate of Mixed Cl stream, gpm |
| 403944 | Cost of clarifier |
| 35218 | annual cost of clarifier (6% at 20 years) |
| 0.0024 | $/lb NaCl for lime clarifier Capex |
| 17660 | annual electricity |
| (clarifier costs: http://www.ecodwellinternational.org/images/EC/ECvsLime%20Softening.pdf) | |
| **If a Clarifier Is Used for $CaSO_4$ Recovery** | |
| 14426.56 | $/gpm treated, includes 1.4 installation factor |
| 15.00 | kWh/1000 gal |
| 56.00 | flow rate of Mixed Cl stream, gpm |
| 807887.60 | Cost of clarifier |
| 70435.32 | annual cost of clarifier (6% at 20 years) |
| 0.0048 | $/lb NaCl for CaSO4 clarifier |
| 35320.32 | annual electricity |
| (belt press costs: http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_belt_filter.pdf) | |
| **Belt Press for $CaSO_4$** | |
| 384.71 | dry lb/hr |
| 480.88 | 1.25 x calculated amount for safety, lb/hr |
| 47500.00 | Cost of 0.5 meter belt (2000) |
| 71531.90 | Cost of 0.5 meter belt (2013) |
| 6236.48 | annual cost of $CaSO_4$ belt press |
| **if ED Is Used for Salt Recovery** | |
| 3.23 | eq/sec NaCl produced |
| 51.00 | current density, UTEP experiments, mA/cm$^2$ |
| 0.90 | current efficiency |
| 678.61 | m$^2$ required |
| 1221507 | From Daniel Bar, for very large plants: ~$1,800/m$^2$ for ED with ACS/CMX |
| 1832260 | 1.5xDaniel's estimate |
| 159745 | Annual CapEx cost of ED |
| 2.38 | ₵/lb NaCl Produced, Power cost for ED, Average of two high current density UTEP experiments |
| 280,757 | $/yr, ED Power |

Capital costs for each salt recovery method are calculated by summing the reddish highlighted annual capital expenses for the equipment used:

- Method A (CapEx): Evaporation ponds + Lime Clarifier + $CaSO_4$ clarifier + $CaSO_4$ Belt Press
- Method B (CapEx): Evaporation ponds + Lime Clarifier
- Method C (CapEx): Method B (CapEx) + ED with monovalent-selective membranes
- Method D (CapEx): Method A (CapEx) + ED with monovalent-selective membranes

Operating costs are found by summing the blue highlighted annual operating costs for the process:

- Method A: Lime + $CaSO_4$ clarifier power + Lime clarifier power + Evap Pond OpEx
- Method B: Lime + Lime clarifier power + Evap Pond OpEx
- Method C: Method B (OpEx) + ED power
- Method D: Method A (OpEx) + ED power

Sources of information for capital and operating cost:

- Lime softener: http://www.ecodwellinternational.org/images/EC/ECvsLime%20Softening.pdf
- Belt press: http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_belt_filter.pdf
- ED capital cost (typical): Daniel Bar, of Ameridia
- ED electricity was calculated using experimental data (see chapter 9)