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Managing Water in the West

Desalination and Water Purification Research and Development Program Report No. 122

The Role of Riverbank Filtration in Reducing the Costs of Impaired Water Desalination

Carollo Engineers, P.C.

Agreement No. 03-FC-81-0917-Task G

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Single element reverse osmosis (RO) pilot testing, managed by Carollo Engineers, P.C., was performed at three different locations throughout the United States including Louisville, Kentucky, Des Moines, Iowa, and Kansas City, Kansas. The main goal of these pilot studies was to characterize the ability of riverbank filtration to provide a cost-effective, stand alone pretreatment for RO membrane technologies. Cost estimates were developed for the use of riverbank filtration followed by RO and were compared against traditional pretreatments including microfiltration/ ultrafiltration and conventional treatment trains in terms of both membrane operational performance and economics (both capital and operation and maintenance expenses). Results indicate that use of riverbank filtration can reduce RO membrane treatment costs by 10-20 percent. In addition, overall recommendations were developed to help other utilities evaluate this technology as a potential lower cost alternative for minimizing RO membrane treatment costs.

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MISSION STATEMENTS

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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The field testing organization, Carollo Engineers, P.C. (Denver, Colorado), was responsible for overall management of this study and elements in the testing sequence including calibration and verification of instruments, data collection and analysis, data management, data interpretation, quality assurance/quality control, and the preparation of this report. Operations, pilot management, and laboratory services were provided by the Des Moines Water Works, Kansas Board of Public Utilities, and the Louisville Water Company. Selected laboratory analyses were performed by Montgomery Watson Laboratories, Pasadena, California.

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Abbreviations and Acronyms

Alk	Alkalinity
Ba	Barium
BPU	Kansas Board of Public Utilities
°C	Degrees Celsius
Ca	Calcium
CFU	Colony Forming Units
Cl	Chloride
cm	Centimeter
DMWW	Des Moines Water Works
DOC	Dissolved organic carbon
°F	Degrees Fahrenheit
F	Fluoride
Fe	Iron
ft^2	Square feet
gfd	Gallons per square foot per day
gpm	Gallons per minute
HPC	Heterotrophic Plate Count
hr	Hour
LWC	Louisville Water Company
MF	Microfiltration
Mg	Magnesium
mg/L	Milligrams per liter
Mn	Manganese
MPN	Most Probably Number
NCPP	Nearman Creek Power Plant
NDP	Net Driving Pressure
NF	Nanofiltration
NO_3	Nitrate
NWTP	Nearman Water Treatment Plant
ppm	Parts per million
psi	Pounds per square inch
PWTP	Payne Water Treatment Plant
QA/QC	Quality Assurance/Quality Control
RBF	Riverbank Filtration
RO	Reverse osmosis

Abbreviations and Acronyms (continued)

SiO_2	Silica
SO_4	Sulfate
SOC	Synthetic organic compound
Sr	Strontium
TDS	Total dissolved solids
TMP	Transmembrane pressure
T&O	Taste and odor
TOC	Total organic carbon
TSS	Total suspended solids
µg/L	Micrograms per liter
µm	Micrometers
µS/cm	Microsiemens per centimeter
UF	Ultrafiltration
UVA	Ultraviolet absorbance
VFD	Variable frequency drive
WTP	Water treatment plant
ZLD	Zero liquid discharge

Executive Summary

As water demand continues to grow throughout United States, drinking water utilities are facing a universal concern; the need for water has begun to outpace high quality drinking water supplies. This issue is of major concern for many Mid-Western and Western States that now must turn to surface water supplies containing higher salts, dissolved agricultural contaminants (i.e., nitrate and synthetic organic compounds), or overall poorer water quality. These impaired surface waters often require reverse osmosis (RO) desalting treatment technologies to produce high quality potable water. However, due in large part to the often extensive pretreatment requirements, overall RO costs can be high. Riverbank filtration is one lower cost alternative to traditional RO pretreatment. This paper presents the results of a series of pilot-scale studies investigating the long-term ability of riverbank filtration as a lower cost alternative to expensive traditional pretreatment.

Single element RO pilot testing, managed by Carollo Engineers, P.C., was performed at three different locations throughout the United States including Louisville, Kentucky, Des Moines, Iowa, and Kansas City, Kansas. The main goal of these pilot studies was to characterize the ability of riverbank filtration to provide a cost-effective, stand alone pretreatment for RO membrane technologies. Cost estimates were developed for the use of riverbank filtration followed by RO and were compared against traditional pretreatments including microfiltration/ ultrafiltration and conventional treatment trains in terms of both membrane operational performance and economics (both capital and operation and maintenance expenses). Results indicate that use of riverbank filtration can reduce RO membrane treatment costs by 10-20 percent. In addition, overall recommendations were developed to help other utilities evaluate this technology as a potential lower cost alternative for minimizing RO membrane treatment costs.

1. Introduction

1.1 Purpose and Program Operation

Authorized by the Water Desalination Act of 1996, the Bureau of Reclamation (Reclamation) Desalination and Water Purification Research and Development (DWPR) program forms partnerships with private industry, universities, local communities, and others to address a broad range of national desalting and water purification needs. The overall objective of the program is to reduce the cost of desalting and water purification technologies in order to augment water supply in the United States. A number of objectives are inherent in this goal including:

- Increasing the ability of communities of varying sizes and financial resources to economically treat saline or otherwise impaired waters to potable standards
- Increasing the ability of the United States desalting industry to compete throughout the world, by fostering partnerships with them for the development of new and innovative technologies
- Developing methods to make desalting more efficient through promotion of dual-use facilities in which waste energy could be applied to desalting water
- Developing methods to ensure desalting technologies are environmentally friendly
- Ensuring regulations are appropriate for the application by working with regulators to fully evaluate effects of concentrate streams
- Capitalizing on the recovery of concentrate streams
- Maximizing technology transfer to ensure full transfer of knowledge and commercialization of technology

One specific way the Reclamation DWPR program serves to accomplish these goals is through cost sharing in the design, fabrication, and testing of pilot-scale systems, processes, and concepts. Beginning in January 2004, the Reclamation DWPR program began working in collaboration with the Des Moines Water Works (DMWW), Kansas Board of Public Utilities (BPU), Louisville Water Company (LWC), and Carollo Engineers (Carollo), to pilot test the long-term ability of riverbank filtration (RBF) to provide a cost-effective, stand alone pretreatment for membrane desalting. This research was divided into two phases with overall objectives as described below. This report includes a review on current RBF use in the United States and details results collected during Phase I of this research.

1.1.1 Phase I

The overall goal of Phase I was to investigate RBF followed by reverse osmosis (RO) as a more cost-effective, technologically efficient, and implementable means to desalinate impaired source waters. Phase I involved 3-month single element pilot testing at each of the participating utilities (DMWW, BPU, and LWC). In addition, data from multi-stage RO pilot testing at DMWW and full-scale RO operations at BPU were compiled to compare RBF with ultrafiltration (UF) and conventional treatment (flocculation, sedimentation, and filtration), which are traditional pretreatments to RBF. Phase I research began February 2004 at the DMWW and was completed October 2004 at the LWC. Specific goals of the Phase I research were:

- Document the performance and economical benefits of RBF followed by RO at three different locations within the United States using single element pilot testing.
- Identify the ability of RBF to serve as stand alone pretreatment to RO systems.
- Compare RBF with UF and conventional treatment (flocculation, sedimentation, and filtration) as a pretreatment to RO both in terms of plant operations and economics.
- Determine bank filtration removal efficacy for several contaminants including algae, synthetic organic compounds (SOCs), etc.
- Characterize the toxicity and nature of Mid-Western surface water desalination concentrate.
- Derive RO concentrate disposal alternatives and exemplify the decisionmaking process involved in alternative selection.
- Based on pilot testing results, develop budgetary costs for full-scale implementation of RBF and subsequent RO (both capital and operation and maintenance [O&M] expenditures). In addition, develop costs for UF and conventional treatment treatment and quantify the potential cost saving involved with use of RBF as stand alone pretreatment.

1.1.2 Phase II

Phase II is scheduled to begin early 2005 and will further develop information that demonstrates the cost effectiveness of RBF followed by RO as means to desalinate impaired source waters. This portion of the research will confirm the benefits of RBF/membrane treatment as a viable desalination method and firmly determine full-scale implementation costs. A 12-month pilot-scale testing protocol using a larger scale, 2-stage, 21-element membrane array will be used. This larger scale pilot system will most accurately predict full-scale water quality, operation, and maintenance costs.

1.2 Testing Participants and Responsibilities

Carollo Engineers, P.C. was the field testing organization for this research. Operator and test site staffing and laboratory services were provided by the Des Moines Water Works, Kansas Board of Public Utilities, and the Louisville Water Company. Selected laboratory analyses were performed by Montgomery Watson Laboratories, Pasadena, California. Specific responsibilities of each participant are detailed below.

1.2.1 Reclamation Responsibilities

Reclamation is an organization dedicated to public health, safety, and the protection of the environment. Since 1902, Reclamation has worked to meet water needs and balance the multitude of competing uses of water in the West as well as the rest of the nation. The main mission of Reclamation is to assist in meeting the increasing water demands of the Nation while protecting the environment and the public's capital investments. Reclamation provisions for this research included:

- Cost sharing of this research
- Technical oversight of the work conducted as part of this research
- A field audit of the testing equipment, field analytical and data gathering, and recording procedures
- Review of the project Work Plan, quarterly reports, and this report

1.2.2 Field Testing Organization Responsibilities

Carollo Engineers, P.C., the field testing organization for this research, provided and maintained the membrane pilot plant equipment supplied and managed the testing for the pilot equipment and treatment technology. Responsibility of Carollo Engineers included:

- Provide partial funding for the project
- Coordinate with the Reclamation project manager for this study
- Establish a communications network with the testing participants and site hosts

- Schedule and coordinate the activities of all testing participants
- Provide needed logistical support
- Develop and distribute a research Work Plan and Quality Assurance/Quality Control (QA/QC) program consistent with the objectives of the research
- Develop and distribute Standard Operating Procedures (SOP) for the pilot equipment
- Provide complete, field-ready equipment for the testing including pilot and water conveyance equipment
- Provide equipment set up, calibration, operator training, maintenance, testing, and coordinating all site activities
- Ensure that the locations selected have feed water quality consistent with the objectives of the research
- Manage, evaluate, interpret, and report all data generated by the testing
- Evaluate the performance of the treatment technology
- Compile research results in this report

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1.2.3 Operator and Test Site Host Responsibilities

Equipment operators, test site staff, and laboratory services were provided by the Des Moines Water Works, Kansas Board of Public Utilities, the Louisville Water Company, and Carollo Engineers. Their responsibilities included:

- Provide partial funding for the project
- Provide equipment set-up, operation, maintenance, and sampling activities in association with the project Work Plan
- Conduct daily walkthroughs, data collection, and sampling five days each week

- Provide on-site analytical services according to the project Work Plan and QA/QC procedures
- Provide the necessary and appropriate space for the equipment used throughout the testing
- Provide necessary electrical power, feed water, and other utilities required
- Provide necessary drains for disposal of concentrate and other waste streams resulting from the research

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1.2.4 Water Quality Analyst Responsibilities

Most water quality analytical services were performed through laboratories at each of the participating utilities. Some analytical services were performed by MWH Laboratories, Pasadena, California including barium and strontium testing for all of the participating utilities. In addition, MWH laboratories also performed SOC testing for samples collected at DMWW and dissolved organic carbon/ultraviolet absorbance (DOC/UVA) testing for samples collected at BPU. Bioassay whole effluent toxicity testing and determination of LC50 (concentrate causing 50 percent mortality) were performed by Marinco Bioassay Laboratory, Inc., Sarasota, Florida.

Laboratory responsibilities were to provide all water quality analyses prescribed in the Work Plan according to the QA/QC protocols developed for this research. In addition, the laboratories were responsible for providing reports with the analytical results to the data manager along with the analytical procedures implemented.

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2. Conclusions and Recommendations

2.1 Overall Conclusions for Use of RBF as a Stand Alone Pretreatment to RO

Single element RO pilot testing, managed by Carollo Engineers, P.C., was performed at three different locations throughout the United States including the Des Moines Water Works, Kansas Board of Public Utilities, and the Louisville Water Company. The main goal of these pilot studies was to characterize the ability of riverbank filtration to provide a cost-effective, stand alone pretreatment for RO membrane technologies. Cost estimates were developed for the use of RBF followed by RO and were compared against traditional pretreatments including UF and conventional treatment trains (flocculation, sedimentation, filtration) in terms of both membrane operational performance and economics (both capital and O&M expenses).

The main findings from this research include:

- RBF had a strong positive impact on the particulate, organic, and biological water quality at all three testing locations.

- RBF significantly reduced SOCs at all three testing locations.

- Although some inorganic parameters remained essentially unchanged or slightly increased through RBF at DMWW and LWC, overall water quality improved dramatically with regard to subsequent RO.

- A majority of the tested inorganic parameters increased in concentration through the RBF process at BPU. Barium, iron, and manganese, which have potential to play a significant role in membrane fouling, increased most dramatically. The high iron concentrations in the RBF waters (membrane feed) were responsible for membrane fouling at this location.

- The RO processes performed as expected with regard to effective contaminant removal and provided an average contaminant rejection of greater than 90 percent.

- Operational data collected at DMWW and LWC suggest that RBF could viably serve as stand alone pretreatment to RO. However, cartridge filter replacement frequencies were relatively high at both of these locations indicating the need for lower cartridge filter loading rates when considering full-scale design (i.e., <3.4 gallons per minute (gpm)/10 inches).

- Operational data collected at BPU was less favorable and clearly indicated that RBF alone is inadequate for RO pretreatment with site source water and aquifer characteristics. Iron fouling proved to be the reason for rapid membrane fouling. Reducing feed water pH to as low as 5.5 using acid feed showed reduction in iron fouling. However, particulate fouling from turbidity spikes associated with routine RBF well pump rotation limited RO membrane run times to less than 13 days. Such short run times economically preclude the feasibility of this technology under these conditions.

- Multi-stage pilot testing using UF pretreatment followed by RO was conducted in parallel to single element pilot testing at DMWW. When compared to RBF alone, UF did provide for significantly longer RO run times (i.e., 60 days for UF versus 30 days for RBF alone). However, the increased costs associated with operation and maintenance of UF pretreatment led to higher life-cycle costs when compared to use of RBF pretreatment alone.

- UVA and TOC removals provided by RBF/UF were nearly the same as those found from RBF pretreatment alone according to tests at the DMWW.

- Full-scale RO operations were conducted in parallel to single element pilot testing at BPU using water treated with RBF followed by conventional treatment. Membrane hydraulic performance was very stable when using conventional treatment upstream of RO with no decline in specific flux observed over the entire 124-day testing period. This data verified the viability of conventional treatment followed by RO as a treatment alternative for BPU or other utilities with iron and particulate laden source waters.

- Cost estimates indicate that appropriate use of RBF can reduce RO membrane treatment costs by 10-20 percent when compared to traditions pretreatments such as UF or conventional treatment (i.e., coagulation, flocculation, sedimentation, filtration). The major savings stem from a reduction in capital costs as well as a reduction in O&M expenditures.

- Overall, the ability of RBF to serve as a stand alone pretreatment to RO is dependent upon site-specific water quality and aquifer conditions. Two of three testing sites showed promise for this technology. Data from the third testing site clearly preclude this technology for aerobic aquifers producing waters high in iron and/or manganese.

2.2 RBF as Pretreatment to RO at DMWW

Both single element and multi-stage pilot tests were performed using RBF as a stand alone pretreatment to RO at the DMWW. During the initial 30 days of single element operation, there was significant membrane fouling due to RBF breakthrough of manganese particulate matter. During this period, cartridge filter replacement frequency was approximately 1-3 days, which is much more frequent than the desired average frequency of 30 days. This breakthrough was likely due in large part to the aged condition of the existing infiltration gallery.

Such total suspended solids (TSS) breakthrough is common to older or poorly constructed wells. In the case of DMWW, much of the infiltration piping is greater than 80 years old, which may explain the inconsistent water quality and particulate breakthrough. Following Run 1, subsequent piloting did not experience RBF particulate breakthrough. As a result, the single element pilot ran smoothly for greater than 50 days. Likewise, the multi-stage RO pilot ran smoothly using RBF pretreatment alone and yielded a rate of flux decline of approximately 0.0027 gfd/psi/day. At this rate of fouling, full-scale cleaning frequencies of approximately 32 days can be expected.

In addition to piloting with RBF pretreatment alone, the multi-stage pilot was operated using a combined RBF/UF pretreated water. This pretreatment yielded reduced flux decline when compared to RBF pretreatment alone. Flux decline with this pretreatment scheme was approximately 0.0015 gfd/psi. At this rate of fouling, full-scale cleaning frequencies of approximately 63 days can be expected.

Financial analysis was conducted on the use of RBF versus UF pretreatment to RO using a life cycle of 20 years. Present worth costs for RBF followed by RO were $122.6 million. Despite the reduction in RO flux decline, overall present worth analysis for UF followed by RO was more expensive at $171.3 million.

Based on pilot test and financial analysis results, RBF as a stand alone pretreatment to RO is a viable treatment scheme at the DMWW. However, if RBF is to be the sole pretreatment to RO at DMWW, rehabilitation of the RBF gallery will be required or construction of a new RBF process capable of providing efficient, reliable particulate matter removal.

2.3 RBF as Pretreatment to RO at BPU

Single element pilot testing was performed at BPU using RBF as a stand alone pretreatment to RO. Rapid membrane fouling was experienced throughout the testing due to both iron precipitants and particulate matter. At ambient feed water pH (~7.0), membrane run times were less than 10 days. Based on field observations and chemical cleaning results, iron was a primary cause of fouling. Reducing feed water pH to as low as 5.5 using acid feed showed reduction in iron fouling. However, particulate fouling from turbidity spikes associated with routine RBF well pump rotation limited membrane run times to less than 13 days. Results from single element pilot testing at this location clearly indicate that RBF pretreatment alone is insufficient for RO operations at BPU.

In addition to single element pilot testing, full-scale RO operations were conducted in parallel to the single element pilot testing using water treated with RBF followed by conventional treatment (flocculation, sedimentation, filtration). Membrane hydraulic performance was very stable with no decline in specific flux observed over the entire 124-day testing period verifying the viability of conventional treatment followed by RO as a treatment alternative for BPU.

Results from single element piloting at BPU clearly indicate that RO operations with RBF pretreatment alone is not feasible at this location. However, to compliment the costs developed for RBF and UF pretreatments, financial analysis was conducted on the use of RBF and conventional treatment as pretreatment to RO. Present worth analysis was performed using a 20-year life cycle. Present worth costs for RBF followed by RO were $122.6 million. Present worth costs for conventional treatment followed by RO were more expensive at about $161 million.

2.4 RBF as Pretreatment to RO at LWC

Single element pilot testing was performed using RBF as a stand alone pretreatment to RO at the LWC. Water quality data collected throughout the pilot verified the ability of RO to remove dissolved contaminants to very low levels. Contaminant rejection averaged greater than 90 percent. In addition, RBF proved to be effective stand alone RO pretreatment allowing good membrane hydraulic performance. The membrane experienced no significant fouling after more than 75 days of operational time. It should be noted, however, during the test period cartridge filter fouling was relatively frequent with replacement required every 4-8 days. Fouling of the cartridge filters was due to high feed water manganese concentrations (0.3 milligrams per liter [mg/L]) and the resulting black manganese precipitate. Future membrane piloting should target a reduced cartridge filter loading rate (i.e., <3.4 gpm/10 inches) to achieve replacement frequencies near 30 days.

Based on this pilot testing, RBF as a stand alone pretreatment to RO is a viable treatment scheme at the LWC. Longer term multi-stage testing, such as the testing targeted for Phase II of this Reclamation research, is a logical next step in accessing this treatment technology at the LWC. Multi-stage testing is the only pilot equipment capable of developing accurate and reliable water quality and operations costs data. In addition, multi-stage testing is required to provide accurate data on chemical cleaning frequency, membrane life, feed pressures, and hydraulic design criteria.

2.5 Recommendations for Use of RBF as Pretreatment to RO

- Particulate breakthrough common to aged wells may preclude the use of RBF as a stand alone pretreatment to RO. In the case of DMWW, much of the infiltration piping is greater than 80 years old, which led to inconsistent water quality and periods of problematic particulate breakthrough. These results indicate that well rehabilitation or new RBF well construction may be required for aged utilities.

- Due to the sensitivity of RO processes to particulate fouling, feed water particulate control is paramount. Particulate spikes occurred in the RBF process due to pump rotation and were problematic at BPU. Particulate spikes due to pump rotation and other operational changes should be taken into consideration when considering RBF pretreatment. Methods of mitigation may include use of well-to-waste operations and conservative design of cartridge filter loading rates.

- The treatment associated with RBF processes has less operator control than traditional pretreatments to RO. As a result, utilities considering RBF technology as a stand alone pretreatment to RO should implement a conservative membrane design with a relatively low cartridge filter loading rates.

- The research work herein involved three single-element pilot tests operated for 3-4 months each. Long term multi-stage pilot testing (i.e., 12 months) should be conducted to verify this technology. Multi-stage piloting is the only membrane pilot type capable of predicting accurate and reliable full-scale technology performance and operations cost data. In addition, multi-stage piloting is required to accurately predict membrane cleaning frequency, membrane life, full-scale feed pressures and hydraulic design criteria.

3. Literature Review

As water demand continues to grow throughout United States, drinking water utilities are facing a universal concern; the need for water has begun to outpace high quality drinking water supplies. This issue is of major concern for Midwestern states that now must turn to supplies of higher salts, dissolved agricultural contaminants, and overall poorer water quality. To confront the challenge of growing water needs, many utilities have developed water supply plans to help secure a safe and adequate supply of water to meet future demands. Many water suppliers, particularly in the West and Midwest, are required by law to manage water resources and the amount of water taken from various sources. Often times, these utilities are faced with the challenge of acquiring water from one supply with out subsequent impacts to another. For example, the Kansas Water Appropriation Act requires “water rights” to be issued by the State that are allocated to either a groundwater or surface water supply. This practice is common of many Western and Midwestern States. Furthermore, as the demand for water approaches the capacity of available high quality supplies, acquisition of additional water rights is typically coupled with supplies of lesser quality (i.e., hard, brackish, and colored surface water such as the Des Moines River or Big Arkansas River).

RBF is defined as surface water seeping from the bank of a river or lake to the production wells of a water treatment plant. Collector wells that acquire low quality surface water through RBF may prove a viable treatment alternative for managing surface water acquisition without impacting ground water rights. This RBF water may then be subsequently treated with RO technology to produce potable, high quality drinking water with out further pretreatment. This can result in significant capital, operational, and maintenance cost savings.

3.1 Historical Use of Horizontal Collector Wells and Riverbank Filtration

The use of RBF and horizontal collector wells is an old method to acquire surface water. European water suppliers have been using this technology in conjunction with conventional treatment methods for over a century due to its relatively inexpensive and sustainable means of improving quality of surface waters (Hiscock and Grischeck, 2002). In contrast, the use of RBF in the United Stated began less than 50 years ago (Ray et al., 2002). As a result, most of the research performed using RBF has been performed in Europe, while few studies have been conducted within the United States.

RBF provides passive exposure to processes such as adsorption, oxidation-reduction reactions, and physical-chemical filtration. RBF also provides biodegradation and dilution that can significantly improve water quality (Weiss et al., 2003). Through these mechanisms, RBF changes surface water in to a water with characteristics close to that of a groundwater (Speth et al., 2002). Numerous studies presented in Tufenkji, et al. (2002) and Ray, et al. (2002), have shown that RBF can effectively remove organic pollutants such as DBP precursors, herbicides, pesticide, pharmaceuticals, and odorous compounds including geosmin. Achten et al. (2002), showed that MTBE may be eliminated by RBF comparable to other contaminants including suspended solids, parasites, bacteria, and viruses. Verstaeten et al. (2002) reported changes in concentrations of triazine and acetamide herbicides via RBF of the River Platte in Nebraska. Furthermore, RBF attenuates shock loads and water quality changes thereby providing relatively consistent water quality.

Research has shown the removal effectiveness of RBF for DBP precursors and *Giardia* and *Cryptosporidium*. Weiss et al. (2003) showed that RBF performed as well as or better than conventional treatment for removal of NOM and DBP precursors. Furthermore, studies by Gollinitz et al. (2003), which investigated RBF on the Great Miami River, showed that RBF provided biological particulate removal that was more efficient than conventional surface water treatment. However, a lack of data collected within the United States has made the Environmental Protection Agency (EPA) and State environmental agencies reluctant to grant pathogen removal credits for RBF. Because pollutant attenuation by RBF is dependent on site specific microbial and chemical activity (Hiscock and Grischek, 2002), in EPA's proposed LT2ESWTR, RBF may be awarded Cryptosporidium log removal credits only if site-specific testing proves effective. Due to cost restraints many utilities within the United States are reluctant or unable to invest in site-specific testing needed to demonstrate effective filtration and subsequent regulatory benefit.

3.2 Use of Horizontal Collector Wells and Riverbank Filtration as Pretreatment to RO

One of the biggest obstacles for efficient RO operation is minimization of membrane fouling. Optimized pretreatment to control fouling will not only influence capital costs, but will largely impact operational flexibility and running costs (Alawadhi, 1997). However, the control of fouling often requires advanced pretreatment and presents a major financial obstacle to RO systems treating surface waters, such as the Big Arkansas and Des Moines Rivers. Although the benefit of RBF pretreatment in concert with downstream conventional treatment has long been recognized, few studies have been performed to determine the potential of RBF for providing suitable pretreatment for high pressure membrane systems such as nanofiltration (NF) or RO. Proper pretreatment is considered to be key to cost effective RO plant operation (Isaias, 2001). Research presented in the literature supports the idea that RBF holds promise as a stand alone, cost-effective pretreatment for RO (Seacord and Grooters, 2003).

Research by Kuehn and Meuller (2000) showed that RBF may support or even replace treatment steps by dampening contaminant shock loads, reducing biological growth potential, and removing contaminants such as turbidity, silt, and particulates that may otherwise preclude the use of RO technology. Nederlof et al. (2000) compared RBF against more traditional RO pretreatments including slow sand filtration, conventional sand filtration (CSF), and CSF followed by ultrafiltration. Their research showed that a significant cost is associated with RO pretreatment and that, depending on local circumstances, RO systems using RBF pretreatment may lead to the lowest costs. This was especially true when the RO raw water was kept anaerobic (which affects iron and manganese chemistry). Paassen et al. (1998) studied the effects of NF pretreatment via RBF followed by aeration and rapid filtration steps for a Dutch source water high in color and hardness. Their research showed a positive effect on biofouling control, but the stand-alone effects of RBF were not quantified. Merkel et al. (1998) investigated Ohio River RBF followed by NF. The results suggested that RBF pretreatment reduces specific flux decline and increases membrane cleaning effectiveness after treating bank filtered pretreated waters compared to water pretreated with convention treatment. Speth et al. (2002) performed a short-term study of the effects of RBF using Ohio River and Little Miami River waters. The results showed that RBF holds promise as an effective pretreatment for NF membranes and allowed a reduction in specific flux decline and chemical cleaning frequency. However, like the study by Mereke et al., (1998) the explanation for the benefit of RBF was not identified. Foulant autopsies completed on the membranes identified no specific foulant on the conventionally pretreated membranes that was not found on the RBF pretreated membranes. Additional researched is needed to quantify the benefits to a degree that can be realized in practical application. This type of research will advance the use and application of desalination in inland areas like Kansas, Iowa, Missouri, etc.

In addition to the potential fouling control provided by RBF, as indicated in the proposed LT2ESWTR, if the hydrogeologic conditions are favorable, log-removal credits can be attained for *Giardia* and *Cryptosporidium*. This is important because, while RO can meet these objectives, a portion of the bank filtered water may bypass the RO process for blending purposes and will require treatment to address the SWTR.

In summary, pretreatment to RO via RBF has the potential to reduce membrane down-time, chemical cleaning frequency, operation and maintenance, membrane replacement frequency, and overall system costs. However, RBF as a pretreatment to RO has not been research significantly within the United States. Many water suppliers throughout the country (i.e., Des Moines, Iowa; Wichita, Kansas; Saint Joseph, Missouri; and the Board of Public Utilities; Kansas) hold promise in the use of RBF to provide adequate pretreatment to membranes.

Furthermore, horizontal collector well technology has enormous potential for Wichita, Kansas, and other water suppliers throughout the West and Mid-west as a solution for those utilities where a sufficient amount of groundwater is not available through water rights.

4.0 Proposed Treatment Technology

The treatment technology tested as part of this research consisted of RBF, scale inhibitor addition, cartridge filtration, and RO membrane filtration. Historically, standard RO operation has required the combined use of mineral acid (i.e., sulfuric acid) and scale inhibitors. Mineral acid pretreatment provides a means for controlling calcium carbonate deposition and fouling of RO membranes. However, the development of new scale inhibitor technology has led to products that are capable of sequestering calcium carbonate precipitation and fouling of RO membranes at Langelier Saturation Index (LSI) values as high as +3.0 and has facilitated the reduction and/or elimination of acid pretreatment for many water utilities. Therefore, only scale inhibitors were used during this pilot testing.

Cartridge filtration was provided as a final barrier prior to RO to minimize membrane fouling caused from particles or solids in the water supply due to periodic upsets that can occur during well field start-up or operational changes.

For the purposes of this study, post treatment and corrosion control were not implemented during pilot operation. However, when implementing full-scale RO treatment, corrosion control and post treatment must be considered. Traditionally, aeration, blending, and chemical post treatment have provided a means for corrosion control.

Figure 1 provides a conceptual full-scale flow diagram of the treatment processes that were piloted for this study. The issues discussed in the section, relating to pretreatment, chemical addition, RO operation, and post treatment processes are indicated.

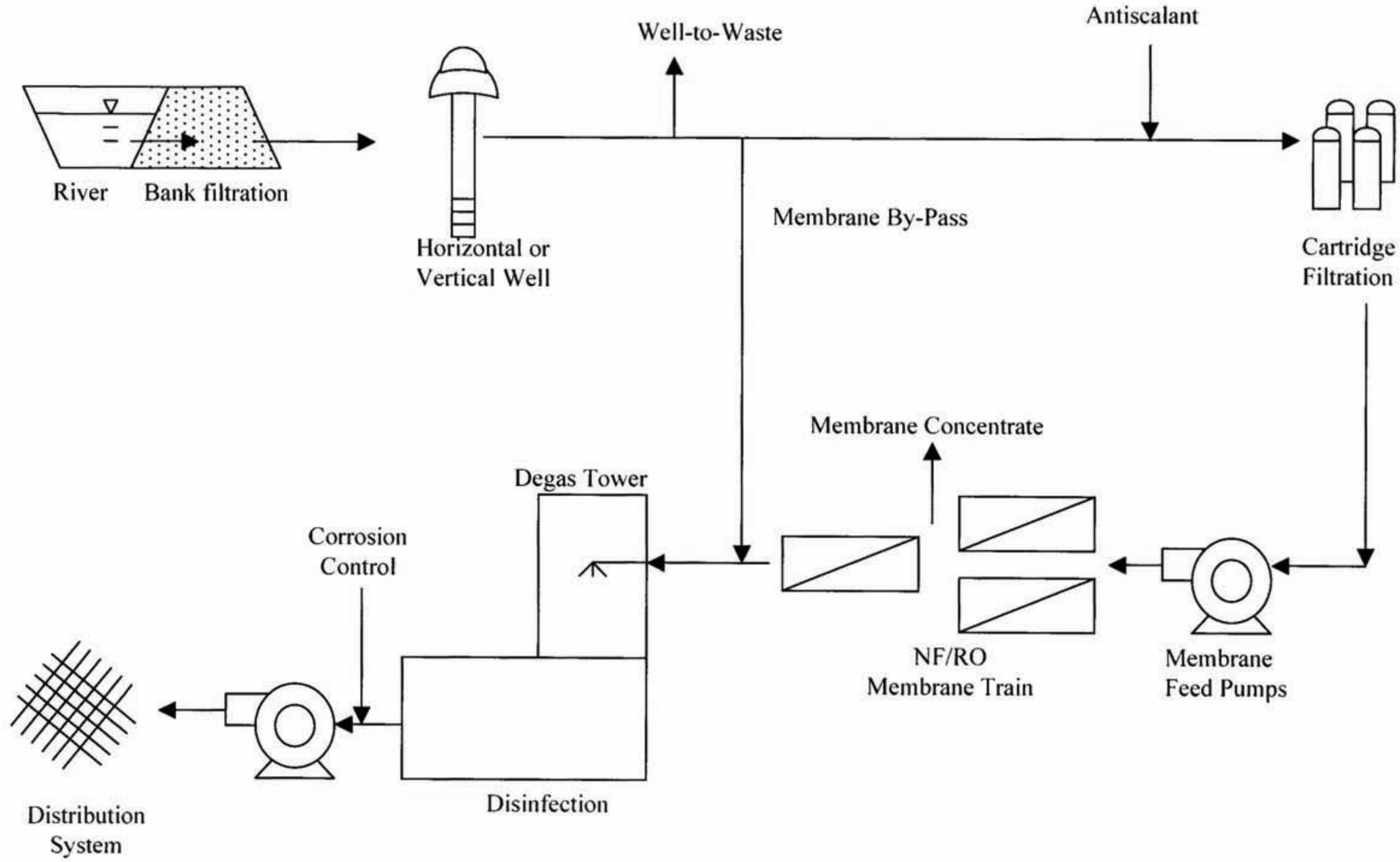


FIGURE 1
A CONCEPTUALFULL-SCALE
FLOW DIAGRAM OF RBF AS A STAND ALONE
PRETREATMENT TO NF/RO MEMBRANE PROCESSES

5. Pilot Testing Treatment and Process Goals

5.1 Treatment Process Goals

Table 1 presents the system treatment objectives. These treatment objectives were developed based on industry standards for cost-effectiveness and design guidelines typical of RO membrane treatment.

Table 1 – Treatment Process Goals
DWPR Phase I

Parameter	Units	Goal
Chemical Cleaning Interval	days	[1]90
Flux Recovery Following Chemical Cleaning	%	95

[1] Defined as the length of time to a decline in specific flux (productivity) of 20%.

5.2 Water Treatment Goals

Table 2 presents the water quality objectives for the production of water from RBF pretreatment and RO membrane filtration. These treatment objectives were developed based on current EPA regulations, secondary maximum contaminant limits (SMCLs), and overall aesthetic water quality.

Table 2 – Finished Water Quality Goals
DWPR Phase I

Parameter	Units	Goal
RBF Pretreatment		
Coliforms	CFU/mL	0
HPC	MPN/100 mL	See Footnote[1]
Algae	#/mL	See Footnote[1]
SDI	Standard Units	<3
Overall Treatment		
TDS	mg/L	<400
Sulfate	mg/L	<200
Hardness	mg/L as $CaCO_3$	200
pH	SU	7-8
CCPP	mg/L as $CaCO_3$	4 to 10
Turbidity	NTU	<0.1
Iron	mg/L	<0.24
Manganese	mg/L	<0.04
Nitrate	mg/L	8
SOCs (EPA 525.2)[2]		
Alachlor	mg/L	0.0016
Atrazine	mg/L	0.0024
Benzo(a)pyrene	mg/L	0.00016
Di(2-ethylhexyl)adipate	mg/L	0.32
Di(2-ethylhexyl)phthalate	mg/L	0.0048
Endrin	mg/L	0.0016
Heptachlor	mg/L	0.00032
Heptchlor epoxide	mg/L	0.00016
Hexachlorobenzene	mg/L	0.0008
Hexachlorocyclopentadiene	mg/L	0.04
Lindane	mg/L	0.00016
Methoxychlor	mg/L	0.032
Simazine	mg/L	0.0032

[1] Sufficient foulant removal so as to permit a minimum membrane chemical cleaning interval of 90 days.

[2] This is not a complete list of the 30 regulated SOCs that may be present in the source waters. The SOCs listed are intended to provide an indication for overall SOC removal performance.

6. Methods and Materials

The section describes the methods used to validate the proposed treatment processes including pilot testing, sample collection and analysis, pilot operational criteria, equipment operations, chemical doses, and testing durations.

6.1 Testing Locations

6.1.1 Des Moines Water Works

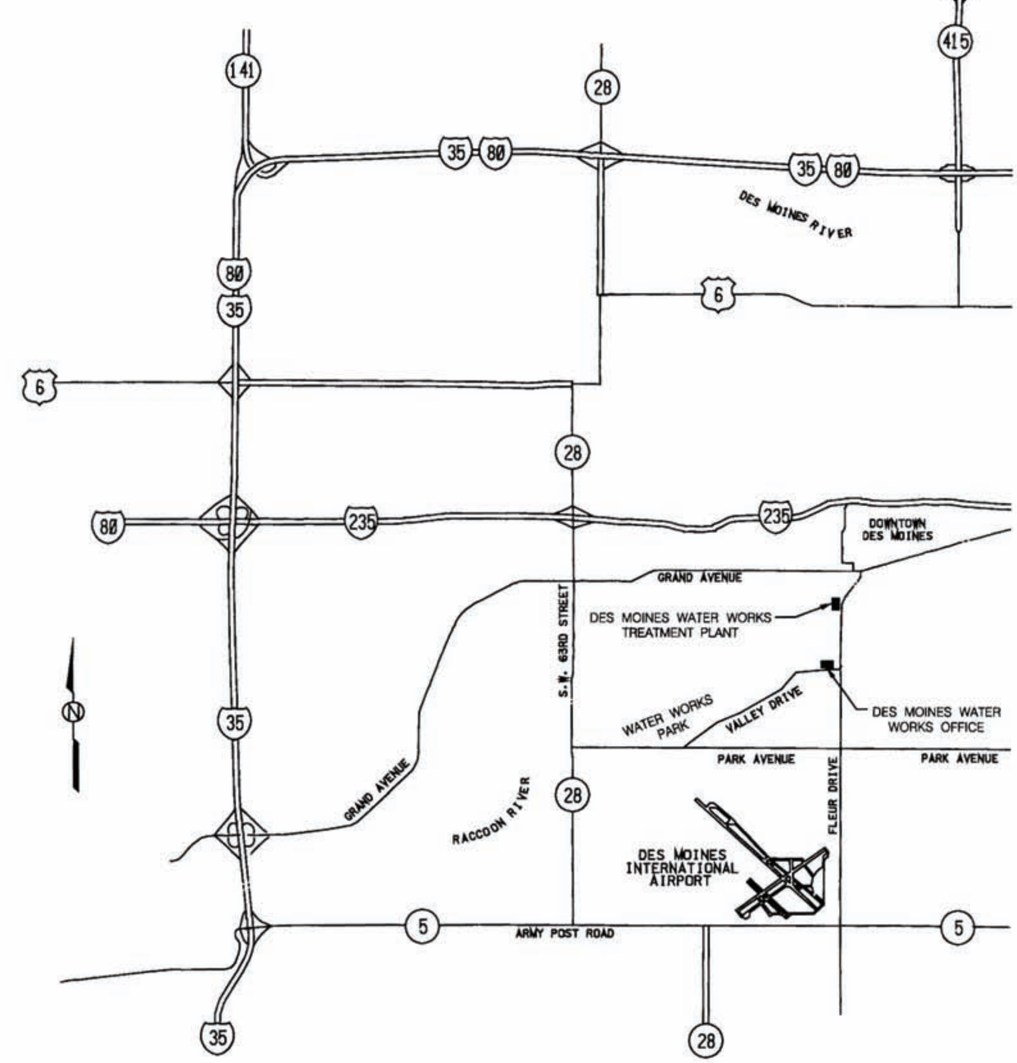
Pilot testing at DMWW was conducted at the east portion of the Pump Station on the DMWW Fleur Water Treatment Plant campus. Figures 2 and 3 illustrate the location of the piloting at DMWW. As shown in the figure, the pilot unit was fed by an existing gravity-fed bank infiltration gallery located along the south side of the Raccoon River in Water Works Park. A submersible pump was used to pump RBF water from the influent channel to a break tank near the pilot plant. A separate pilot plant transfer pump was used to deliver water to the pilot plant skid.

Specifics on the DMWW collector well construction are shown in table 3. The infiltration gallery piping is 48 inches in diameter and approximately 3 miles in length. Pipe segments are 2 feet long each, with gap spacing between adjacent segments to allow infiltration. The RBF water collected by this gallery system flows into a concrete vault where it was then pumped to the pilot unit.

Table 3 – DMWW Well Construction Summary
DWPR Phase I

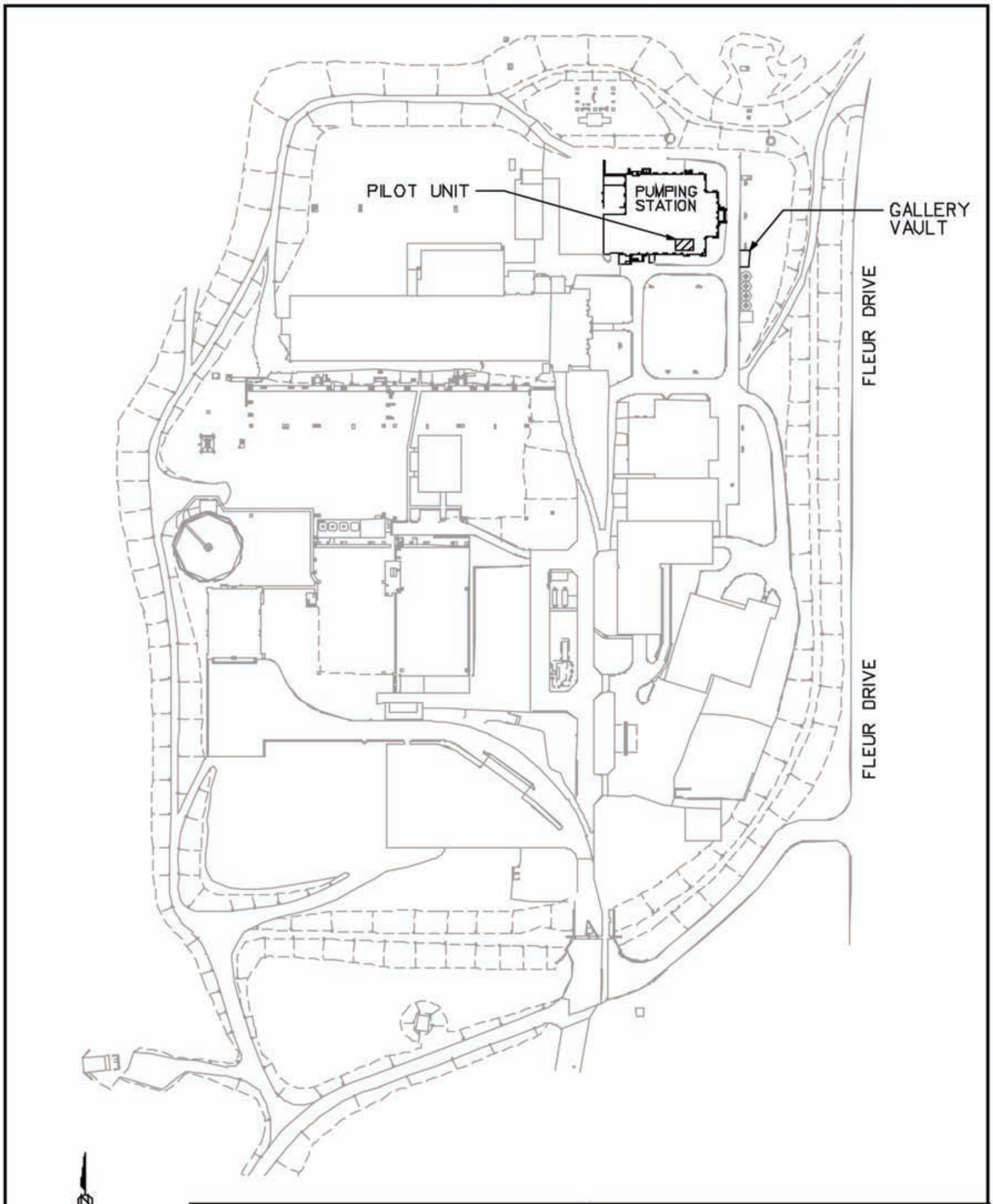
Parameter	Units	Value
Pipe Material	–	Reinforced Concrete
Pipe Diameter	in	48
Pipe Wall Thickness	in	4.5
Average Depth of Piping Below River	ft	[1]35
Minimum Depth of Piping Below River	ft	30
Completion Date	year	1884-1932
Total Length of Piping	miles	3.1

[1] Piping follows the path of the riverbank along Raccoon River with a depth at or near bedrock.



DES MOINES WATER WORKS
ENGINEERING DEPARTMENT
Des Moines, Iowa

FIGURE 2
DES MOINES WATER WORKS
FLEUR PLANT VICINITY MAP



NOT TO SCALE

DES MOINES WATER WORKS
ENGINEERING DEPARTMENT
Des Moines, Iowa

FIGURE 3
DES MOINES WATER WORKS PLANT
CAMPUS MAP AND PILOT TEST LOCATION

6.1.2 Kansas Board of Public Utilities (BPU)

Single element pilot testing at BPU was conducted at the Nearman Water Treatment Plant (NWTP). The NWTP is a conventional water treatment facility (rapid mix, flocculation, sedimentation, and filtration) with a plant design treatment capacity of 36 million gallons per day (mgd) and an ultimate hydraulic capacity of 54 mgd. A single horizontal collector well located along the Missouri River is the sole raw water source to the plant. The well is designed for a flow of 25 mgd under worst-case river levels and up to 40 mgd under favorable river levels for limited periods of time. The collector well has four 12-mgd vertical turbine diffusion vane raw water pumps that operate singularly or in combination, as operating conditions dictate. Raw water is transmitted to the plant via a 42-inch prestressed concrete main extending approximately 7,300 feet (1.4 miles) from the collector well to the NWTP (approximately 525,000 gallons of water storage capacity). At the NWTP, water flows into a splitter box, which equally divides influent flow between two parallel conventional treatment trains. A submersible pump was installed in the plant influent splitter box to provide RBF water to the pilot plant skid. The skid was located between the two treatment trains inside the flocculator dry pit at the South end of the flocculation basins. Figure 4 and 5 illustrate the location of the piloting at BPU. Specifics on the construction of the BPU collector well are shown in table 4.

Table 4 – BPU Well Construction Summary
DWPR Phase I

Parameter	Units	Value
Pipe Material	–	Prestressed Concrete
Well Caisson Inside Diameter	ft	20
Depth of Caisson	ft	126
Number of Laterals	#	[1]14
Diameter of Laterals	in	12
Length of Laterals	ft	[2]180
Average Depth of Laterals Below River Bottom	ft	73
Completion Date	year	[3]1999
Length of RBF Water Transmission Piping	ft	7,300

[1] There are two tiers of seven laterals.

[2] 10 feet of blank screening was installed immediately next to the well caisson to prevent short-circuiting.

[3] Construction was completed July 1999. Water was first pumped to the NWTP June 2000.

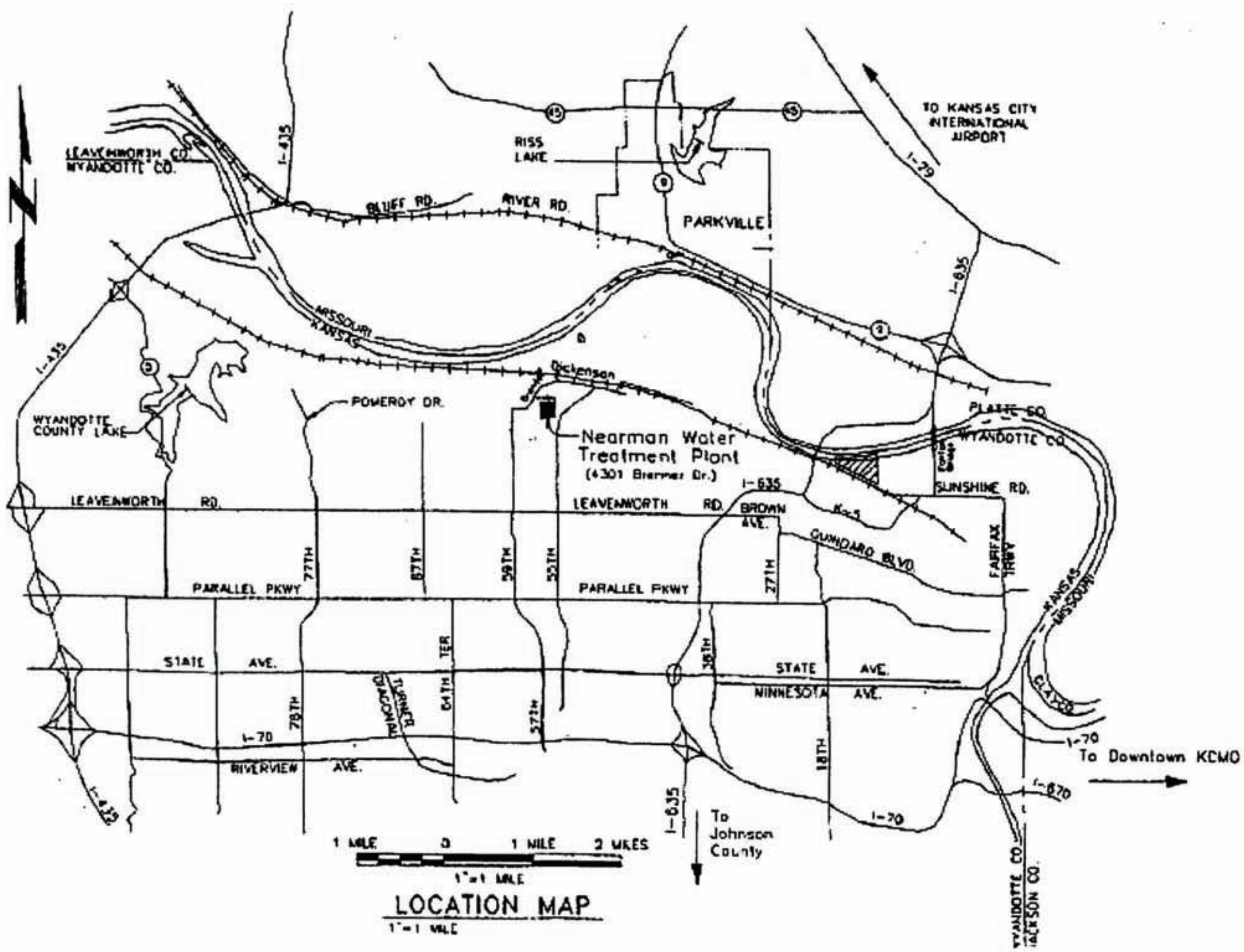


FIGURE 4
KANSAS BOARD OF PUBLIC UTILITIES
NEARMAN WATER TREATMENT PLANT VICINITY MAP

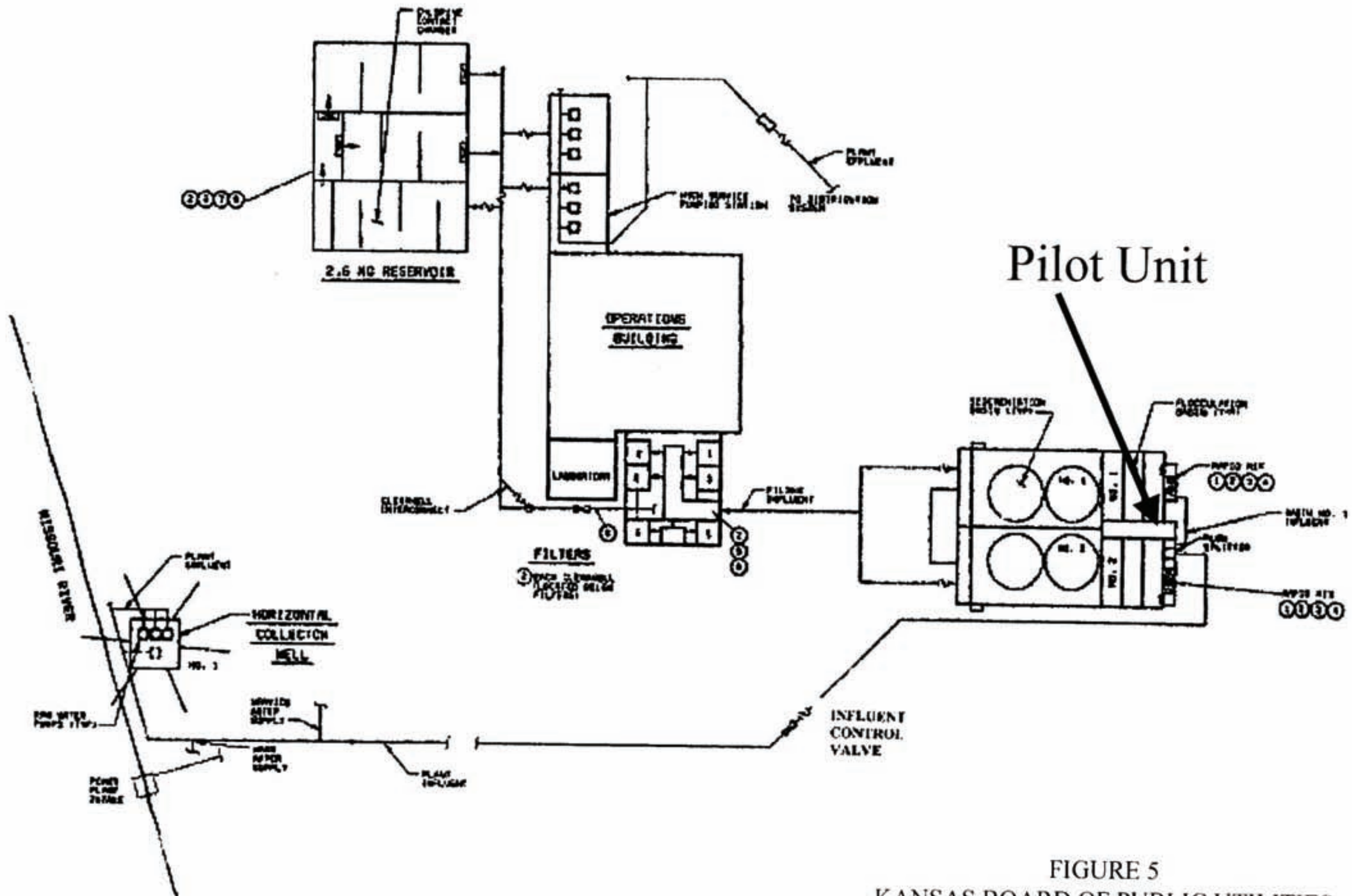


FIGURE 5
KANSAS BOARD OF PUBLIC UTILITIES
CAMPUS MAP AND PILOT TEST LOCATION

6.1.3 Louisville Water Company (LWC)

Single element pilot testing was conducted at the Louisville Water Company B.E. Payne Water Treatment Plant (PWTP) in Louisville, Kentucky. The PWTP is a conventional water treatment facility with a plant design treatment capacity of 60 mgd. A single horizontal collector well located along the Ohio River supplies an average of 15 mgd, but is capable of flow between 10-23 mgd. An Ohio River surface water intake structure supplies the remaining portion of the plant's flow.

The collector well has seven horizontal laterals feeding into a caisson about 100 feet deep as measured from ground level. Four of the laterals are oriented towards the river and have a length of 240 feet each. Two laterals run parallel to the river and one lateral runs perpendicular away from the river each with a length of 200 feet. The laterals are 12 inches in diameter with stainless steel wire wound screens running along their entire length.

The collector well operates with two vertical turbine pumps; one fixed speed and one variable frequency drive pump. Water from the collector well is piped approximately 4,000 feet via a 48-inch transmission line to a low lift station where it is blended with raw river water in a common manifold. The blended water is then pumped approximately,1,000 feet via a 60-inch transmission line to the head of the PWTP for treatment.

The pilot plant was located on the ground floor of the low lift pump station. Water supplied to the pilot plant was captured upstream of the low lift station blending manifold to ensure that only RBF water was supplied to the pilot for this testing. Figure 6 illustrates the location of the piloting at LWC. Specifics on the construction of the LWC collector well are shown in table 5.

Table 5 – LWC Well Construction Summary
DWPR Phase I

Parameter	Units	Value
Well Caisson Inside Diameter	ft	20
Depth of Caisson	ft	110
Number of Laterals	#	7
Diameter of Laterals	in	12
Length of Laterals	ft	200-240
Average Depth of Laterals Below River Bottom	ft	50
Completion Date	year	1999
Length of RBF Water Transmission Piping	feet	[1]5,000

[1] RBF water is pumped approximately 4,000 feet to a low lift station. Blended water from the lift station is then pumped an additional 1,000 feet to the head of the PWTP.

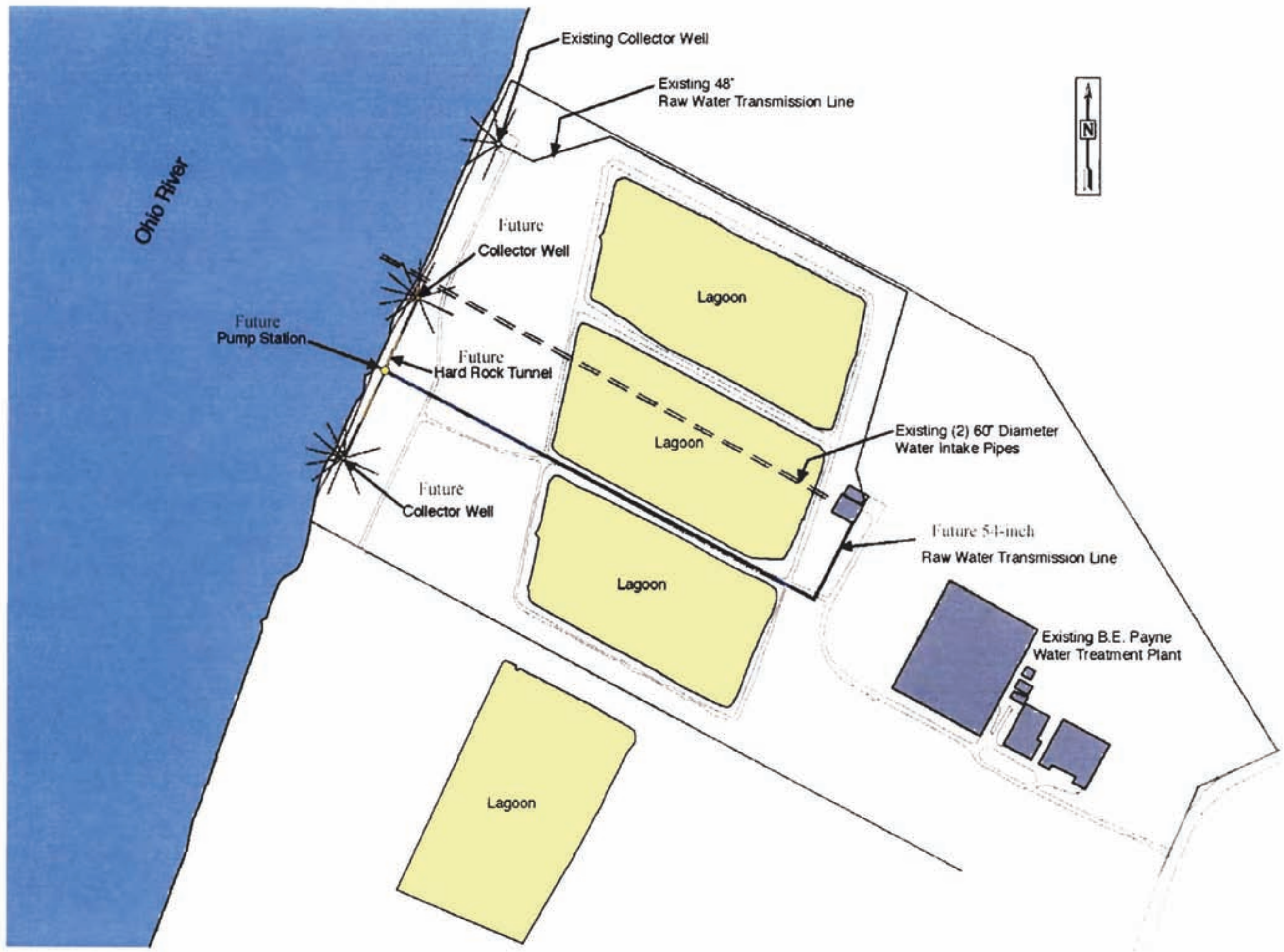


FIGURE 6
LOUISVILLE WATER COMPANY
B.E. PAYNE WATER TREATMENT PLANT
CAMPUS MAP AND PILOT TEST LOCATION

6.2 Equipment

Pilot equipment constructed by Harn R.O. Systems, Inc. was used for all single element pilot testing. The pilot equipment was designed for transport with a standard forklift or pallet jack and is used with commercially available RO membrane elements from a variety of manufacturers. The pilot skid contained pumps to feed the membrane unit and had provisions for chemical cleaning, recirculation, and recovery adjustment. The unit was equipped with a programmable logic control (PLC) unit that provided a significant degree of automation. The PLC was capable of maintaining feed pH (if dosing acid), flow rates (i.e., flux), pressures, and control valve positions. The PLC also had the ability to shut down the system under alarm conditions such as high feed pressure, low liquid levels, low chemical tank levels, etc.

The pilot process was configured for this specific application through a Windows-based interface. Flow, pressure, alarms, and dose set points were customized via the PLC panel. This greatly reduced the required operator training and operational time requirements. All functions were adjusted, initiated, and monitored manually during this pilot testing. The system was also equipped with a backup data acquisition system logged in database format. The system was operated without a fulltime operator; however, operators provided daily and routine system maintenance such as analytical sampling, chemical tank filling, maintaining water quality monitoring devices, cartridge filter replacement, and trouble shooting.

The single element pilot skid required a feed of approximately 12 gpm at 30-60 psi. As water flowed through the pilot plant, pretreatment chemicals were added and then the water was cartridge filtered using a 1.0 µm spun polypropylene progressive-density cartridge filter. Cartridge filtered water was mixed with recycled concentrate water and the pressure boosted using a high pressure RO feed pump. Flow and pressure were metered at all critical locations including the pre- and post-cartridge filtration and membrane feed, concentrate, permeate, and recycle streams. Permeate flow rate was controlled by metering permeate water flow and varying the speed of the high-pressure pump VFD. Recovery was PLC controlled by metering concentrate flow and a manual recovery control valve. A sample tap panel was provided to gather water from all critical points throughout the process. Manual flow measurement was taken at the start of the study to verify electronic meter calibration.

Specifications for the single element pilot plant used in this research are summarized in table 6. A photo of the pilot is included in figure 7. A P&ID for the pilot plant is provided in figure 8. Although the pilot has capabilities of pretreating the membrane feed water with both scale inhibitor and acid, only scale inhibitors were used during the pilot testing of this project.

Table 6 – Single Element Pilot Plant Equipment Specifications DWPR Phase I

Item	Units	Specification
Power	--	480 V, 3-Phase, 20 A
Dimensions	Inches	40.5 L x 35 W x 80 H
Weight	Pounds	600

Figure 7 – A Photograph of the Pilot Plant.

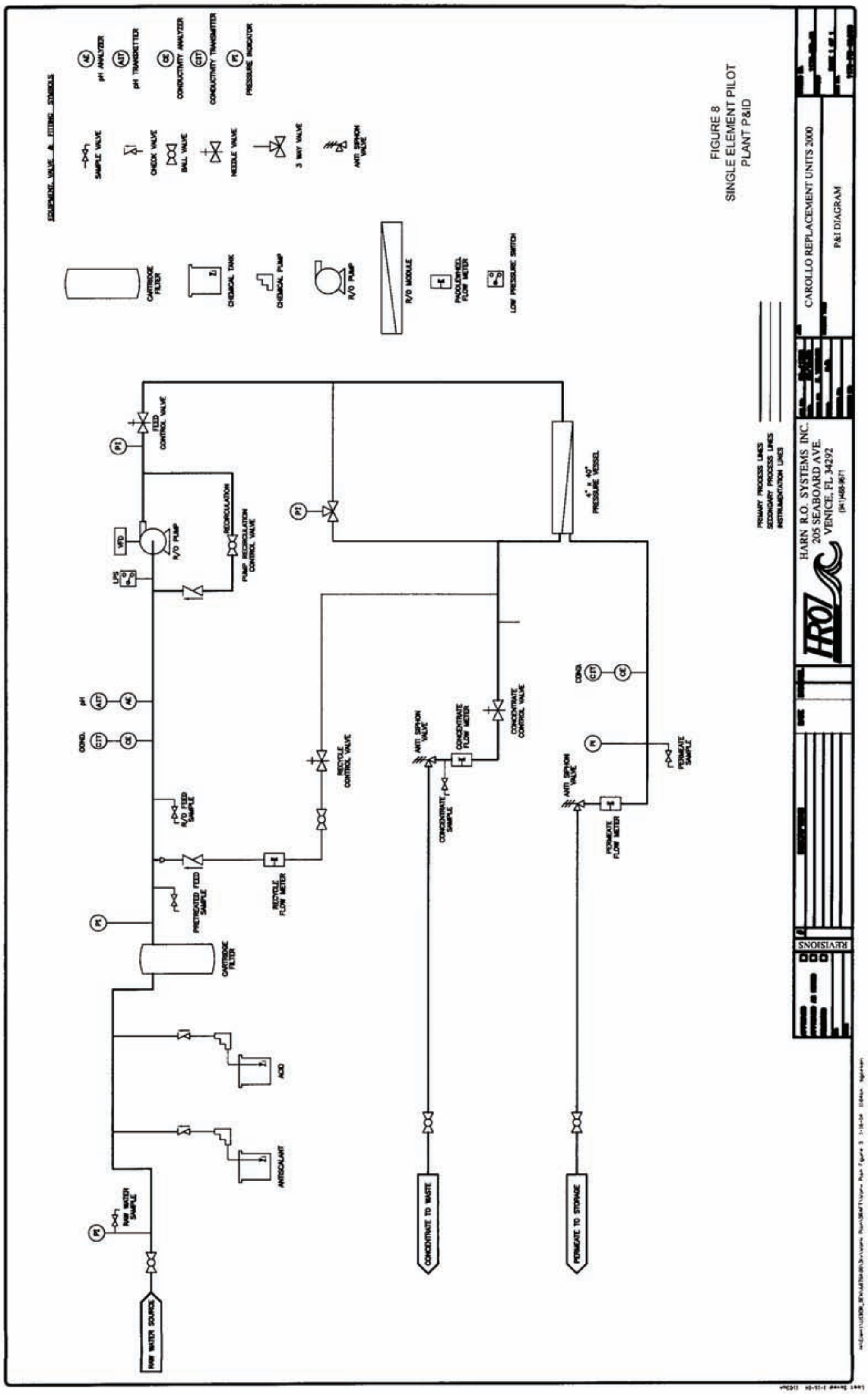


FIGURE 8
SINGLE ELEMENT PILOT
PLANT P&ID
HARN R.O. SYSTEMS INC.
205 SEABOARD AVE.
VENICE, FL 34292
CAROLLO REPLACEMENT UNITS 2000
P&I DIAGRAM
REVISIONS
RAW WATER SOURCE
CONCENTRATE TO WASTE
PERMEATE TO STORAGE
CARTRIDGE FILTER
R/O PUMP
4" x 40" PRESSURE VESSEL
ACID
ANTISCALANT

6.3 Testing Conditions

This section details the various types of tests performed as part of this research. The experimental matrix is shown in figure 9.

6.3.1 Single Element Pilot Plant Test Conditions

In full-scale membrane operations, lead elements are subjected to the greatest potential for particulate and biological fouling. Piloting conditions for this testing, including flux, beta values, flow rates, etc., were designed to model performance of these lead elements to allow comparison of RBF with traditional RO pretreatments such as MF/UF, which typically remove particles very well. Specifically, piloting conditions were designed to mimic lead element performance for a full-scale plant operated at a flux and recovery of 15 gfd and 80 percent, respectively. These full-scale operating conditions are typical of inland RO membrane plants treating surface water. A matrix showing the operating conditions for the single element piloting is presented in table 7.

6.3.2 Multi-Stage Pilot Testing at DMWW Using UF Pretreatment to RO

As a separate project, the DMWW conducted multi-stage RO pilot testing. Portions of this multi-stage RO pilot testing were performed in parallel to the single element piloting (during the same dates) and were operated first using combined RBF/Ultrafiltration (UF) and later using RBF alone as the pretreatment to the RO system. The multi-stage pilot plant was operated with a total of 18 4-inch XLE membrane elements. The elements were installed in pressure vessels containing three elements each in a 2 x 2 x 1 x 1 array. The system was operated with an average flux of 15.3 gfd and recovery of 80 percent.

6.3.3 Full-Scale Testing at BPU Using Conventional Pretreatment to RO

As part of its operations, the Nearman Creek Power Plant (NCPP) runs a full-scale RO plant which processes water that has been pretreated using RBF followed by conventional treatment (rapid mix, flocculation, sedimentation, and filtration) at the NWTP. Finished water from the NWTP is then treated with polish filtration and carbon filtration for chlorine removal prior to RO. Figure 10 shows a process flow diagram for this full-scale RO testing. RO permeate water is further treated using anion, cation, and mixed bed ion exchange technology before use as make-up water in the power plant's boiler system. As part of this research, specific data was collected at the NCPP full-scale RO plant during the same dates as the single element pilot testing. This data was used to evaluate the performance and economic benefits of RBF versus conventional treatment as pretreatment to RO.

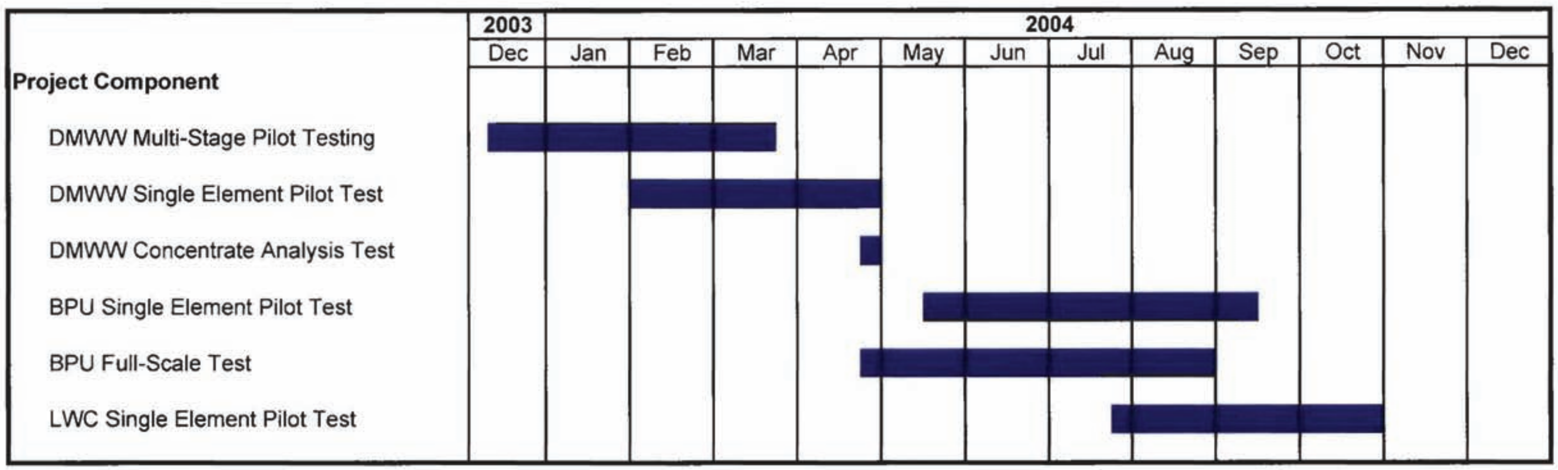


FIGURE 9
PROJECT EXPERIMENTAL MATRIX AND TIMELINE

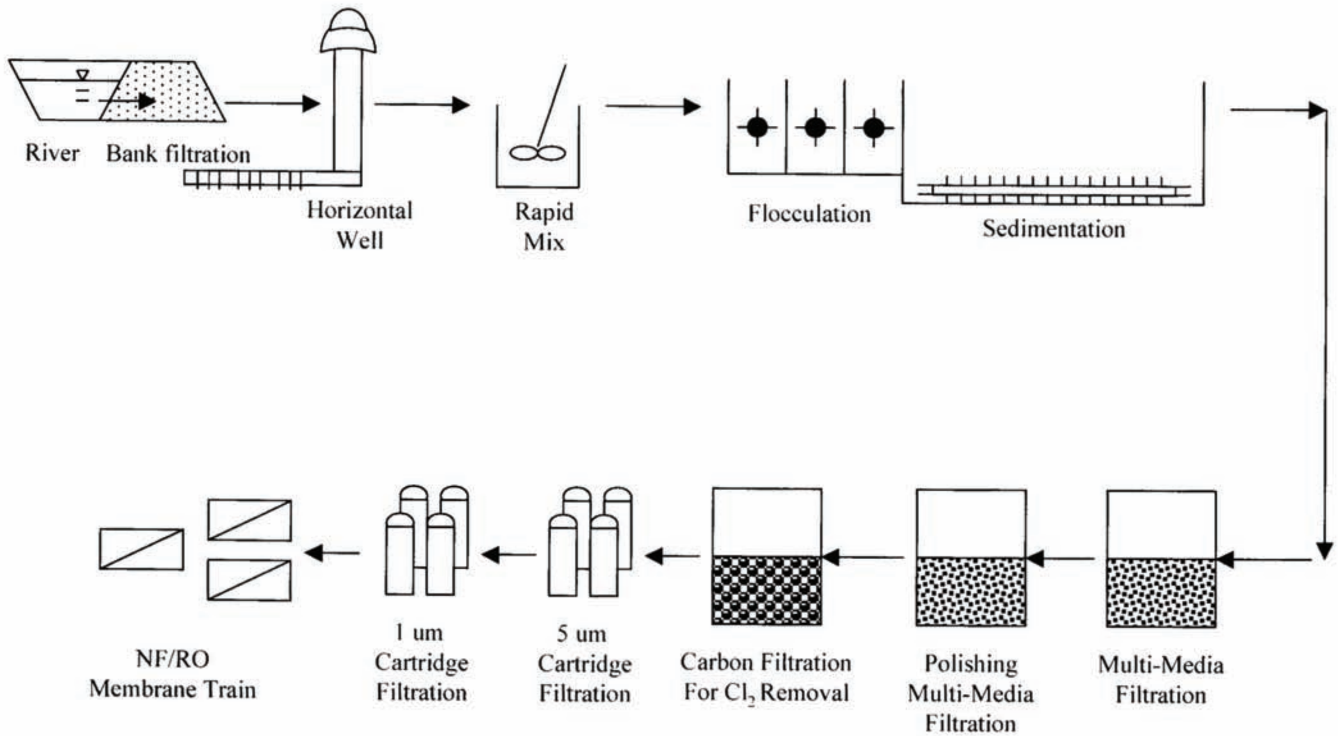


FIGURE 10
A PROCESS FLOW DIAGRAM OF FULL-SCALE RO OPERATIONS AT BPU

Table 7 – Single Element Pilot Plant Operating Conditions DWPR Phase I

Parameter	Units	Specification
Membrane	–	XLE
Flux	gfd	19.7
Recovery (Influent Flow)[1]	%	10.1
Scale Inhibitor	–	King Lee Pretreat Plus 0100
Scale Inhibitor Dose	mg/L	1.0
Influent Flow[2]	gpm	11.7
Cartridge Filter Loading Rate	gpm/10 inches	3.4
Permeate Flow[2]	gpm	1.19
Concentrate Flow[2]	gpm	5.65
Recycle Flow[2, 3]	gpm	4.90

[1] Based on Influent flow (Influent Flow = Feed Flow + Recycle Flow).

[2] Modeled using ROSA. Specified flows are specific to the XLE membrane.

[3] Recycle flow is necessary to achieve recovery while maintaining element flows within specified limits (i.e., Beta<1.2 and minimum concentrate flows).

The full-scale RO plant at the NCPP was operated with a total of 18 8-inch membrane elements. The elements were installed in pressure vessels containing six elements each in a 2x1 array. The system contained Trisep X-20 membranes approximately 6 years old and was chemically cleaned immediately prior to the time period of this research. The system was operated with an average system flux of 13.3 gfd and recovery of 59 percent.

6.4 Operation and Monitoring

Daily pilot plant operations at each location were performed by plant staff. During the 3 months of operation, the pilot plant was monitored once daily. Operating tasks performed during site visits consisted of manual hydraulic data recording, water quality sampling and analysis, refreshing chemical stock solutions, calibrating on-line instruments and metering pumps, and adjusting flows. Manually collected data was entered into spreadsheets that were provided by Carollo Engineers. Copies of acquired data were forwarded (electronically by email) to Carollo Engineers on a weekly basis.

6.5 Water Quality Sampling

Throughout the pilot testing samples were collected and tested from the raw source water (River), RBF (membrane feed water), membrane permeate water, and membrane concentrate water. Tables 8 and 9 show the sampling schedule for inorganic and biological/organic parameters, respectively. Sampling and analyses were conducted according to Standard Methods for the Examination of Water and Wastewater, 20th Edition (APHA, 1998) and by Methods for Chemical Analysis of Water and Wastes (EPA, 1979), where applicable as shown in tables 10 and 11. Table 12 lists the operational data that was collected throughout the pilot testing.

6.6 Quality Assurance/Quality Control

Throughout the testing period, strict Quality Assurance/Quality Control methods and procedures were followed to ensure accuracy of the data collected. QA for the testing procedures and experimental plan aspects of this project was the responsibility of Carollo. Analytical chemistry and issues relating to the delivery of reliable data was under the scrutiny of Carollo and utility management. Carollo reviewed all methods used for analytical measurements to provide data high in quality and to reduce errors to a statistically tolerable limit. Specific aspects of the QA/QC program for this study are detailed below. Overall, the objectives of the project's QA/QC program were to assure verification, validation, precision accuracy, completeness, representativeness, and comparability of the data to what is known and documented.

6.6.1 Peer Review

Carollo developed project-specific QA/QC aspects including: 1) quality control which included experimental setup at each testing location, sampling and testing procedures, sample chain of custody, measurements of data, calibration procedures and frequency, data reduction, validation, and reporting; 2) quality assessment, which included performance and system audits, and corrective action; and 3) reporting.

6.6.2 Daily Walkthroughs

Routine walkthroughs were conducted daily to verify that equipment and each instrument was operating properly. Walkthroughs included daily verification of process flow rates, chemical feed pump flow rates, PLC pressure transmitter accuracy compared with a manual pressure gauge, cartridge filter checks/replacements, and other operational parameters necessary for proper system operation. Operational and analytical data collected in the field was recorded on specially designed spreadsheets and then input into electronic spreadsheets. Field procedures, observations, and maintenance activities were recorded in a dedicated notebook kept in the field.

Table 8 – Single Element Pilot Testing Inorganics Sample Schedule (1-Week Schedule)
DWPR Phase I

Parameter	Units	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Flow	gpm		F, P, C, Rec	F, P, C, Rec	F, P, C, Rec	F, P, C, Rec	F, P, C, Rec	
Pressure	psi		$CF_{1\&2}$, F, P, C	$CF_{1\&2}$, F, P, C	$CF_{1\&2}$, F, P, C	$CF_{1\&2}$, F, P, C	$CF_{1\&2}$, F, P, C	
pH	Standard Units		R, F, P, C	R, F, P, C	R, F, P, C	R, F, P, C	R, F, P, C	
Conductivity	µS/cm		R, F, P, C	R, F, P, C	R, F, P, C	R, F, P, C	R, F, P, C	
Temperature	C		R, F	R, F	R, F	R, F	R, F	
Turbidity	NTU		R, F, P	R, F, P	R, F, P	R, F, P	R, F, P	
SDI	Standard Units		F	F	F	F	F	
Alkalinity	mg/L as $CaCO_3$		R,F,P					
Ca	mg/L		R,F,P					
Mg	mg/L		R,F,P					
SiO_2	mg/L		R,F,P					
Fe	mg/L		R,F,P					
Mn	mg/L		R,F,P					
TDS	mg/L		R, F, P, C					
Ba	mg/L		R, F, P					
Sr	mg/L		R, F, P					
SO_4	mg/L		R, F, P					
NO_3	mg/L as N		R, F, P					
F	mg/L		R, F, P					
Cl	mg/L		R, F, P					

R = River
F = Feed to RO
P = Permeate of RO
C = Concentrate of RO
Rec = Recycle
CF = Cartridge Filter

Table 9 – Single Element Pilot Testing Biological/Organic Parameters Sample Schedule (1- Week Schedule) DWPR Phase I

Parameter	Units	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Coliforms	CFU/ml		R, F					
HPC	MPN/100ml		R, F					
Algae	#/ml		R, F					
Taste & Odor			R, F, P					
DOC	mg/L		R, F, P					
UVA	cm^{-1}		R, F, P					
SOCs	mg/L			R, F[1]				

R = River
F = Feed to RO
P = Permeate of RO
C = Concentrate of RO
Rec = Recycle
CF = Cartridge Filter
[1] Sampled Monthly

Table 10 – Inorganic Water Quality Monitoring Parameters and Methods DWPR Phase I

Parameter	Units	Method	Frequency	By
pH	Standard Units	SM 4500	Daily	Plant Staff
Conductivity	µS/cm	SM 2510	Daily	Plant Staff
Temperature	C	SM 2550	Daily	Plant Staff
Turbidity	NTU	SM 2130	Daily	Plant Staff
Silt Density Index	Standard Units	ASTM D4189-95	Daily	Plant Staff
Alkalinity	mg/L as $CaCO_3$	SM2320, Hach 8221, or Hach 8203	Weekly	Plant Staff
Ca	mg/L	EPA 200.7	Weekly	Plant Staff
Mg	mg/L	EPA 200.8	Weekly	Plant Staff
SiO_2	mg/L	SM 4500-Si D, E, or F SM 3120B	Weekly	Plant Staff
Fe	mg/L	SM 3500-Fe D or Hach 8146 and Hach 8147, 8008, 8214, or 8112	Weekly	Plant Staff
Mn	mg/L	SM 3500-Mn, or Hach 8149	Weekly	Plant Staff
TDS	mg/L	SM 1030 F	Weekly	Plant Staff
Ba	mg/L	EPA 200.8	Weekly	MWH Laboratories, Monrovia, California
Sr	mg/L	EPA 200.7	Weekly	MWH Laboratories, Monrovia, California
SO_4	mg/L	SM 4500-SO_4^{2-}	Weekly	Plant Staff
NO_3	mg/L as N	EPA 300	Weekly	Plant Staff
F	mg/L	SM 4500CN-F	Weekly	Plant Staff
Cl	mg/L	EPA 300	Weekly	Plant Staff

Table 11 – Biological/Organic Water Quality Monitoring Parameters and Methods DWPR Phase I

Parameter	Units	Method	Frequency	By
Coliforms	CFU/mL	SM 9223	Weekly	Plant Staff
HPC	MPN/100 mL	SM 9215B	Weekly	Plant Staff
Algae	#/mL	SM 10200	Weekly	Plant Staff
Taste and Odor		SM 2150	Weekly	Plant Staff
DOC	mg/L	SM 5310B	Weekly	Plant Staff or MWH Laboratories, Monrovia, California[1]
UVA	cm^{-1}	SM 5910B	Weekly	Plant Staff or MWH Laboratories, Monrovia, California[1]
Particle Testing	–	SM 2540D	Monthly	Plant Staff
SOCs	mg/L	EPA 525.2	Monthly	Plant Staff or MWH Laboratories, Monrovia, California[2]

[1] DOC and UVA samples collected at BPU were analyzed by MWH Laboratories, Monrovia, California.

[2] SOC samples collected at DMWW were analyzed by MWH Laboratories, Monrovia, California. SOC samples collected at BPU and LWC were analyzed at the LWC laboratory facilities.

Table 12 – Operational Parameters Sampling Schedule DWPR Phase I

Operation Parameter	Sampling Frequency
Feed/Filtrate Water Flow	Daily
Feed Pressure	Daily
Feed Temperature	Daily
Permeate Pressure	Daily
Concentrate Pressure	Daily
Flux @ 20 °C (calculated)	Daily
Specific Flux @ 20 °C (calculated)	Daily
Recovery (calculated)	Daily

6.6.3 Data Correctness

QA/QC was maintained to control analytical measurement errors and included assurance of data representativeness. Throughout the testing, consistent analysis and sampling procedures, adherence to sound laboratory practice, use of verified and specified analytical methods, and consistent use of instrument standard operating procedures (e.g., calibration, standardization, reporting limits and detection limits) was maintained. Data entry was validated by comparing hard copies of created electronic spreadsheets with the original data entry sheets. Appropriate corrections were made. Data representativeness was ensured by executing consistent sample collection procedures including the following:

- Sample locations – Tables 8 and 9 present the sampling matrix and location for each sample.
- Timing of sample collection – River, feed, permeate, and concentrate sampling was done within 1 hour of each other to ensure that the treated water quality samples were representative of source water quality.
- Sample procedures – Prior to the collection of water quality samples, the sample taps were allowed to run a minimum of 30 seconds to purge the sample tap and tubing of stagnant water.
- Sample preservation, packaging, and shipping – Sampling container materials (i.e., glass, polypropylene, etc.) and hold times were compatible with the sample being collected according to sound laboratory practice. Some of the sample analytical work was performed using an on-site test kit or at the on-site laboratory. Samples that required shipping were packed immediately on blue ice for transport to the analytical laboratory.

7. DMWW Pilot Testing Results and Discussion

The following sections detail the results of pilot data collected at the DMWW. Single element pilot testing at this location was conducted from February 4 to April 30, 2004.

7.1 Water Quality

This section includes the water quality results and discussion for data collected during the single element and multi-stage pilot testing performed at DMWW.

7.1.1 Single Element Pilot Testing

Tables 13 and 14 show both inorganic and biological water quality for the Raccoon River and RBF (membrane feed) waters, respectively. Tables 15 and 16 show membrane permeate and concentrate water quality, respectively. The concentrate water quality shown in table 16 refers to samples collected during the operational conditions at 17-percent recovery. In later experiments, the pilot plant was operated at 80-percent recovery to simulate full-scale concentrate water quality as detailed in section 7.3. Table 17 shows a summary of SOC results for the Raccoon River, RBF, and membrane permeate. Only those SOCs that were detected in the Raccoon River are shown in the table. The remaining 47 SOCs tested as part of this research for the river, RBF, and permeate were all below the method reporting limit (MRL). For reference, table 18 includes a complete list of the SOCs tested at DMWW.

7.1.1.1 Effect of Riverbank filtration on Water Quality

Inorganic parameters including calcium, magnesium, silica, and fluoride were essentially unchanged through the RBF process with average concentrations of about 75, 35, 0.88, and 0.31 mg/L, respectively. Alkalinity, chloride, and sulfate all increased from 197, 27, and 37 to 252, 36, and 58 mg/L, respectively. As a result of the increase in these inorganic parameters, conductivity and total dissolved solids (TDS) experienced a like increase from 0.61 and 349, to 0.71 µS/cm and 422 mg/L, respectively.

Table 13 – Raccoon River Water Quality
DWPR Phase I

Parameter	Units	Count	Median[1]	Range		Average[1]	Standard[1, 2] Deviation	95% Confidence Interval[1, 2]	
				Low	High			Low	High
pH		52	8.3	7.7	8.6	8.2	0.3	8.1	8.3
Conductivity	µS/cm	53	630	330	1420	611	168	566	656
Turbidity	NTU	52	45.8	2.4	713.0	131.2	176.9	83.1	179.2
Temperature	C	52	6.4	0.0	17.8	6.5	5.7	5.0	8.1
TDS	mg/L	12	354	243	456	349	67	312	387
Alkalinity	mg/L	12	204	142	250	197	39	174	219
Calcium	mg/L	12	83.8	52.0	99.2	79.5	15.2	70.9	88.1
Magnesium	mg/L	12	22.2	8.3	83.2	34.3	26.7	19.2	49.4
SiO_2	mg/L	7	0.90	0.82	0.92	0.89	N/A	N/A	N/A
Iron	mg/L	7	0.684	0.108	1.211	0.634	N/A	N/A	N/A
Manganese	mg/L	7	0.088	0.058	0.474	0.190	N/A	N/A	N/A
Barium	mg/L	12	0.125	0.097	0.370	0.155	0.079	0.110	0.199
Strontium	mg/L	12	0.24	0.15	1.10	0.30	0.25	0.16	0.44
Sulfate	mg/L	12	37.45	19.58	61.90	37.49	13.38	29.92	45.06
Nitrate	mg/L	12	8.80	2.82	13.43	7.87	3.87	5.68	10.06
Fluoride	mg/L	12	0.35	0.10	0.47	0.34	0.10	0.28	0.39
Chloride	mg/L	12	27.65	17.03	38.39	27.05	6.70	23.26	30.84
Coliforms	CFU/ 100 mL	12	2,203	225	81,640	15,482	25,216	1,215	29,748
HPC	MPN/ 100 mL	12	5,982	268	78,000	21,878	26,837	6,694	37,062
Algae	#/mL	12	916	12	5,496	1,757	2,111	563	2,952
T&O	TON	11	1	0	2	1	1	1	2
DOC	mg/L	12	3.57	2.43	8.64	4.31	1.88	3.25	5.38
UVA	cm^{-1}	12	0.107	0.054	0.319	0.144	0.094	0.091	0.197

[1] Values reported as non-detect were assumed to be one-half of the detection limit for the purposes of statistical evaluation.

[2] If less than eight data points exist for the data, statistical analysis for standard deviation and the confidence interval was not performed.

Table 14 – RBF (Membrane Feed) Water Quality
DWPR Phase I

Parameter	Units	Count	Median[1]	Range		Average[1]	Standard[1, 2] Deviation	95% Confidence Interval[1, 2]	
				Low	High			Low	High
pH		53	7.4	6.6	7.7	7.4	0.2	7.4	7.5
Conductivity	μS/cm	55	690	620	900	707	67	690	725
Turbidity	NTU	52	0.30	0.08	3.43	0.53	0.61	0.36	0.70
Temperature	C	58	11.4	9.6	21.5	11.9	2.1	11.3	12.4
TDS	mg/L	12	404	384	485	422	35	402	442
Alkalinity	mg/L	12	242	233	286	252	20	241	264
Calcium	mg/L	12	78.0	23.8	89.6	71.1	22.2	58.5	83.6
Magnesium	mg/L	12	35.0	23.8	51.5	36.5	7.6	32.2	40.7
SiO_2	mg/L	9	0.92	0.65	0.94	0.86	0.10	0.80	0.92
Iron	mg/L	7	0.025	0.025	0.105	0.036	N/A	N/A	N/A
Manganese	mg/L	7	0.088	0.058	0.474	0.190	N/A	N/A	N/A
Barium	mg/L	12	0.074	0.064	0.094	0.076	0.010	0.070	0.082
Strontium	mg/L	12	0.21	0.19	0.23	0.21	0.01	0.20	0.22
Sulfate	mg/L	12	55.62	47.34	71.20	56.79	9.09	51.65	61.93
Nitrate	mg/L	12	3.39	1.79	6.11	3.81	1.84	2.77	4.85
Fluoride	mg/L	12	0.27	0.15	0.34	0.27	0.05	0.24	0.30
Chloride	mg/L	12	36.92	29.93	42.95	36.26	4.90	33.49	39.04
Coliforms	CFU/ 100 mL	11	1	0	82	12	25	-2	27
HPC	MPN/ 100 mL	11	18	2	116	40	41	16	65
Algae	#/mL	12	ND	ND	ND	ND	ND	ND	ND
T&O	TON	11	1	0	3	1	1	1	2
DOC	mg/L	12	2.05	1.70	2.37	2.03	0.20	1.92	2.14
UVA	cm^{-1}	12	0.045	0.033	0.051	0.043	0.006	0.040	0.046

[1] Values reported as non-detect were assumed to be one-half of the detection limit for the purposes of statistical evaluation.

[2] If less than eight data points exist for the data, statistical analysis for standard deviation and the confidence interval was not performed.

Table 15 – Permeate Water Quality
DWPR Phase I

Parameter	Units	Count	Median[1]	Range		Average[1]	Standard[1, 2] Deviation	95% Confidence Interval [1, 2]	
				Low	High			Low	High
pH		51	5.6	5.0	6.9	5.7	0.3	5.6	5.7
Conductivity	µS/cm	53	10.0	7.0	37.0	11.0	4.8	9.7	12.3
Turbidity	NTU	51	0.09	0.03	0.37	0.11	0.06	0.09	0.12
TDS	mg/L	11	5.17	2.22	9.17	5.75	2.00	4.57	6.93
Alkalinity	mg/L	7	3	2	6	3	N/A	N/A	N/A
Calcium	mg/L	4	1.0	0.8	3.2	1.5	N/A	N/A	N/A
Magnesium	mg/L	4	0.00	ND	0.97	ND	N/A	N/A	N/A
SiO_2	mg/L	7	0.00	ND	0.15	ND	N/A	N/A	N/A
Iron	mg/L	10	ND	ND	ND	ND	0	ND	ND
Manganese	mg/L	9	ND	ND	ND	ND	0	ND	ND
Barium	mg/L	12	ND	ND	ND	ND	0	ND	ND
Strontium	mg/L	12	ND	ND	ND	ND	0	ND	ND
Sulfate	mg/L	11	ND	ND	ND	ND	0	ND	ND
Nitrate	mg/L	11	0.22	0.10	0.39	0.23	0.13	0.15	0.31
Fluoride	mg/L	11	0.01	0.01	0.20	0.03	0.06	ND	0.06
Chloride	mg/L	11	0.40	0.23	3.11	0.64	0.83	0.15	1.13
Coliforms	CFU/ 100 mL	11	ND	ND	ND	ND	0	ND	ND
HPC	MPN/ 100 mL	11	66	6	1,540	386	550	61	711
T&O	TON	10	ND	ND	ND	ND	0	ND	ND
DOC	mg/L	10	0.48	0.15	0.96	0.48	0.23	0.33	0.62
UVA	cm^{-1}	11	0.000	0.000	0.005	0.001	0.002	0.000	0.002

[1] Values reported as non-detect were assumed to be one-half of the detection limit for the purposes of statistical evaluation.

[2] If less than eight data points exist for the data, statistical analysis for standard deviation and the confidence interval was not performed.

Table 16 – Membrane Concentrate Water Quality at 17-Percent Recovery DWPR Phase I

Parameter	Units	Count	Median[1]	Range	Average[1]	Standard[1] Deviation	95% Confidence Interval[1]
pH		52	7.5	7.4	7.8	7.6	0.1
Conductivity	µS/cm	52	805	730	1110	842	88
TDS	mg/L	11	490	452	607	506	50

[1] Values reported as non-detect were assumed to be one-half of the detection limit for the purposes of statistical evaluation.

Table 17 – A Summary of Raccoon River, RBF, and Membrane Permeate Positive "Hit" SOC Analyses DWPR Phase I

Parameter	MRL[1]	Units	Count	Median	Range	Average
Raccoon River						
Atrazine	0.050	ug/L	3	0.11	0.1-0.53	0.25
Metolachlor	0.050	ug/L	3	0.27	0.21-0.56	0.35
Phenanthrene	0.020	ug/L	3	0.01	0.01-0.02	0.01
Simazine	0.050	ug/L	3	0.03	0.03-0.08	0.04
RBF (Membrane Feed)						
Atrazine	0.050	ug/L	3	0.06	0.03-0.07	0.05
Metolachlor	0.050	ug/L	3	0.16	0.09-0.20	0.15
Phenanthrene	0.020	ug/L	3	ND[2]	ND	ND
Simazine	0.050	ug/L	3	ND	ND	ND
Membrane Permeate						
Atrazine	0.050	ug/L	3	ND	ND	ND
Metolachlor	0.050	ug/L	3	ND	ND	ND
Phenanthrene	0.020	ug/L	3	ND	ND	ND
Simazine	0.050	ug/L	3	ND	ND	ND

[1] MRL = Method Reporting Limit.

[2] ND = Non-Detect

Table 18 – A Complete List of SOC Analyses Performed During Pilot Testing at DMWW DWPR Phase I

Parameter	MRL[1]	Units
2, 4-Dinitrotoluene,	0.10	ug/L
Acenaphthylene,	0.10	ug/L
Alachlor	0.050	ug/L
Aldrin	0.050	ug/L
alpha-Chlordane	0.050	ug/L
Anthracene	0.020	ug/L
Atrazine	0.050	ug/L
Benz(a)Anthracene	0.050	ug/L
Benzo(a)pyrene	0.020	ug/L
Benzo(b)Fluoranthene	0.020	ug/L
Benzo(g,h,i)Perylene	0.050	ug/L
Benzo(k)Fluoranthene	0.020	ug/L
Bromacil	0.20	ug/L
Butachlor	0.050	ug/L
Butylbenzylphthalate	0.50	ug/L
Caffeine	0.050	ug/L
Chrysene	0.020	ug/L
Di(2-ethylhexyl)adipate	0.60	ug/L
Diazinon	0.10	ug/L
Dibenz(a,h)Anthracene	0.050	ug/L
Dieldrin	0.20	ug/L
Diethylphthalate	0.50	ug/L
Dimethoate	2.0	ug/L
Dimethylphthalate	0.50	ug/L
Di-n-Butylphtalate	1.0	ug/L
Di(2-ethylhexyl)phthalate	0.60	ug/L
Endrin	0.10	ug/L
Fluoranthene	0.10	ug/L
Fluorene	0.050	ug/L
gamma-Chlordane	0.050	ug/L
Heptachlor	0.040	ug/L
Heptachlor epoxide	0.020	ug/L
Heptachlor epoxide (isomer b)	0.020	ug/L
Hexachlorobenzene	0.050	ug/L
Hexachlorocyclopentadiene	0.050	ug/L
Indeno (1, 2, 3, c, d) Pyrene	0.050	ug/L
Isophorone	0.50	ug/L
Lindane	0.020	ug/L
Methoxylchlor	0.10	ug/L

Table 18 – A Complete List of SOC Analyses Performed During Pilot Testing at DMWW (Continued)
DWPR Phase I

Parameter	MRL[1]	Units
Metolachlor	0.050	ug/L
Metribuzin	0.050	ug/L
Molinate	0.20	ug/L
Pentachlorophenol	1.0	ug/L
Phenanthrene	0.020	ug/L
Prometryn	0.50	ug/L
Propachlor	0.050	ug/L
Pyrene	0.050	ug/L
Simazine	0.050	ug/L
Thiobencarb	0.20	ug/L
trans-Nonachlor	0.050	ug/L
Trifluralin	0.10	ug/L

[1] MRL = Method Reporting Limit.

Although overall TDS slightly increased through RBF (15 percent), nitrate and nuisance parameters common to membrane scaling were greatly reduced including iron, barium, and strontium. Nitrate was reduced from an average of 7.9 to 3.8 mg/L. Iron concentrations were reduced from an average of 0.63 mg/L to below detection (<0.025 mg/L). Barium and strontium averages were reduced from 0.155 and 0.300 to 0.076 and 0.210 mg/L, respectively. RBF also served to reduce the scaling potential of the river water by decreasing pH by 0.8 units from 8.2 to 7.4. In addition, the relatively cold temperatures of the Raccoon River were dampened through RBF with an average increase of 5.5 °C from 6.4 to 11.9 °C. Manganese concentrations were reduced by nearly 50 percent through the RBF process. However, the remaining concentration of manganese fed to the RO pilot remained relatively high at 0.100 mg/L and played a significant role in membrane fouling. This is discussed in greater detail in section 7.2.

In addition to improving overall inorganic water quality, RBF had a strong positive impact on particulate, organic, and biological quality of the water. Average river turbidity was reduced from 131.2 to 0.53 NTU and consistently low SDI measurements averaging 2.4 were provided. DOC and UVA measurements (surrogates for organic fouling potential) were reduced through RBF from 4.31 mg/L and 0.144 cm^{-1} to 2.03 mg/L and 0.043 cm^{-1}, respectively. Coliforms, HPC, and algae counts were also greatly reduced from 15,482, 21,878, and 1,757 to 12 CFU/mL, 40 MPN/100 mL, and 12 #/mL, respectively. Because taste and odor compounds (measured by the threshold odor number, TON) were very low in the river water with an average value of 1 TON, a decrease in TON was not noticeable through RBF at the DMWW location.

Of the 51 SOCs tested as part of this piloting only 4 were detected in the river including atrazine, metolachlor, phenanthrene, and simazine. RBF reduced atrazine concentrations by 80 percent from 0.25 to 0.05 µg/L. Metolachlor concentrations were reduced by more than 50 percent from 0.35 to 0.15 µg/L. Phenanthrene and simazine were reduced from 0.01 and 0.04 µg /L to levels below detection, respectively.

In summary, although some inorganic parameters remained essentially unchanged or slightly increased through RBF, the process had a notable positive impact on overall water quality. Although removed by nearly 50 percent in the RBF process, manganese concentrations remained relatively high in the RBF water.

7.1.1.2 Effect of Membrane Filtration on Water Quality

Table 19 summarizes removal/rejection performance of the RO membrane. As expected, the RO membrane process proved very effective at removing both inorganic and organic contaminants. Conductivity and TDS were rejected at 97 and 99 percent, respectively. Alkalinity, calcium, magnesium, silica, barium, strontium, sulfate, nitrate, fluoride and chloride were rejected an average of 97 percent. In 9 out of 10 permeate measurements, manganese was removed to below detection (<0.010) giving an average rejection of greater than 90 percent. The one detectable permeate manganese measurement had a value higher than any feed water sample at 0.294 mg/L and was discarded from the statistical analysis. Iron concentrations in both the feed and permeate samples were below detection. Therefore, an iron rejection could not be calculated.

Like the inorganic parameters, particulate, organic, and biological contaminants were effectively removed through the RO process. Although reduced by a significant degree, sample permeate turbidities were much higher than expected for RO permeate waters. This is likely due in part to typical field measurement error and the fact that filtration turbidities were so near the detection limit of the instrument. The ability of membranes to remove particulate matter to extremely low levels has been well documented elsewhere in the literature. Taste and odor was non-detectable in all of the permeate water samples. DOC and UVA rejection was 76 and 98 percent, respectively. Coliform bacteria were removed at a rejection of >99 percent with no coliform bacteria being detected in the permeate. Although HPC concentrations were higher than expected in the permeate, it is not believed that these HPC results were indicative of a breach in membrane integrity. Although sample taps were allowed to flush prior to sample collection, it is possible that HPC bacteria accumulated in sample tubing lines and sloughed off during sampling. Contamination may also have occurred because the sampling was not performed in a sterile environment.

Table 19 – A Summary of RO Rejection Performance at DMWW DWPR Phase I

Parameter	Units	Average Membrane Feed	Average Membrane Permeate	Rejection, %
pH	pH Units	7.4	5.7	N/A
Conductivity	mS/cm	0.710	0.023	97%
Turbidity	NTU	0.53	0.11	79%[1]
TDS	mg/L	422	6	99%
Alkalinity	mg/L	252	3	99%
Calcium	mg/L	71.1	1.5	98%
Magnesium	mg/L	36.5	0.24	99%
SiO_2	ug/L	0.86	0.04	95%
Iron	mg/L	non-detect	non-detect	N/A
Manganese	mg/L	0.096	<0.010	>90%
Barium	mg/L	0.076	0.001	99%
Strontium	mg/L	0.210	0.005	98%
Sulfate	mg/L	56.8	0.5	99%
Nitrate	mg/L	3.81	0.23	94%
Fluoride	mg/L	0.27	0.03	89%
Chloride	mg/L	36.3	0.6	98%
Coliforms	CFU/mL	12	0	>99%
HPC	MPN/100 mL	40	386	N/A[2]
T&O	TON	1	non-detect	>99%
DOC	mg/L	2.03	0.48	76%
UVA	cm^{-1}	0.043	0.001	98%

[1] Sample permeate turbidities were much higher than expected for RO permeate waters. This is likely due in part to typical field measurement error and the fact that filtration turbidities were so near the detection limit of the instrument..

[2] Although HPC concentrations were higher than expected in the permeate, it is not believed that these HPC results were indicative of a breach in membrane integrity. Although sample taps were allowed to flush prior to sample collection, it is possible that HPC bacteria accumulated in sample tubing lines and sloughed off during sampling. Contamination may also have occurred because the sampling was not performed in a sterile environment.

Of the 51 SOCs tested as part of this piloting, 4 were detected in the river including atrazine, metolachlor, phenanthrene, and simazine. Of these, only atrazine and metolachlor were detected in the RO feed. The RO membrane removed these SOCs in all samples to levels below detection.

In summary, the RO membrane process performed as expected with regard to contaminant removal and provided an average contaminant rejection of greater than 90 percent.

7.1.2 Multi-Stage Pilot Testing

A minor amount of water quality data was collected during the multi-stage pilot testing and is included in Appendix A. However, this portion of the piloting was conducted primarily to compare the difference in pretreatments (RBF/UF versus RBF alone) regarding their resulting RO hydraulic performance. Due to the limited amount of water quality data collected during this portion of the piloting a direct comparison of water quality provided by each of the pretreatments cannot be made. However, in general it can be stated that inorganic water quality remained about equal between the combined RBF/UF and RBF pretreated waters. The combined RBF/UF pretreatment did provide a reduction in turbidity. TOC and UVA removals provided by RBF/UF were essentially equal to the removals provided by RBF alone.

7.2 Hydraulic Performance

Operating conditions for the single element membrane pilot plant were given in chapter 6. Single element pilot testing at DMWW was conducted under constant flux (19.7 gfd), increasing pressure conditions from February 4 to April 30, 2004. Figure 11 shows the hydraulic performance throughout the DMWW piloting. For the purposes of discussion, the single element piloting at DMWW is divided into two "runs." Run 1 was performed from February 4 to March 17. Run 2 was performed from March 17 to April 30. The multi-stage pilot testing was conducted during the same time frame as the single element testing. Hydraulic performance from each pilot test run is discussed in the following.

7.2.1 Single Element Run 1 (RBF Pretreatment)

As indicated by the rise in required net driving pressure, relatively rapid fouling was experienced during the first 36 days of pilot operation at DMWW (Run 1). The rise in net driving pressure mandated a chemical clean after approximately 30 days of operation, far below the targeted cleaning interval of 90 days. During Run 1, several factors may have contributed to membrane fouling as further detailed in the following.

Relatively poor RBF feed water was supplied to the membrane during the week of February 9, 2004. During this time, the pilot plant feed water turbidity was relatively low with an average of about 0.25 NTU. However, the pilot feed waters during this time experienced two spikes in SDI, one in excess of 6.0 units. The relatively high feed water SDI measurements indicate a significant potential for membrane particulate fouling. Relatively poor quality RBF water was confirmed by the high cartridge filter replacement frequency required during the first 14 days of operation. During this period cartridge filter replacement frequency was approximately 1-3 days, which is much more frequent than the desired maximum short-term replacement frequency of 7-14 days.

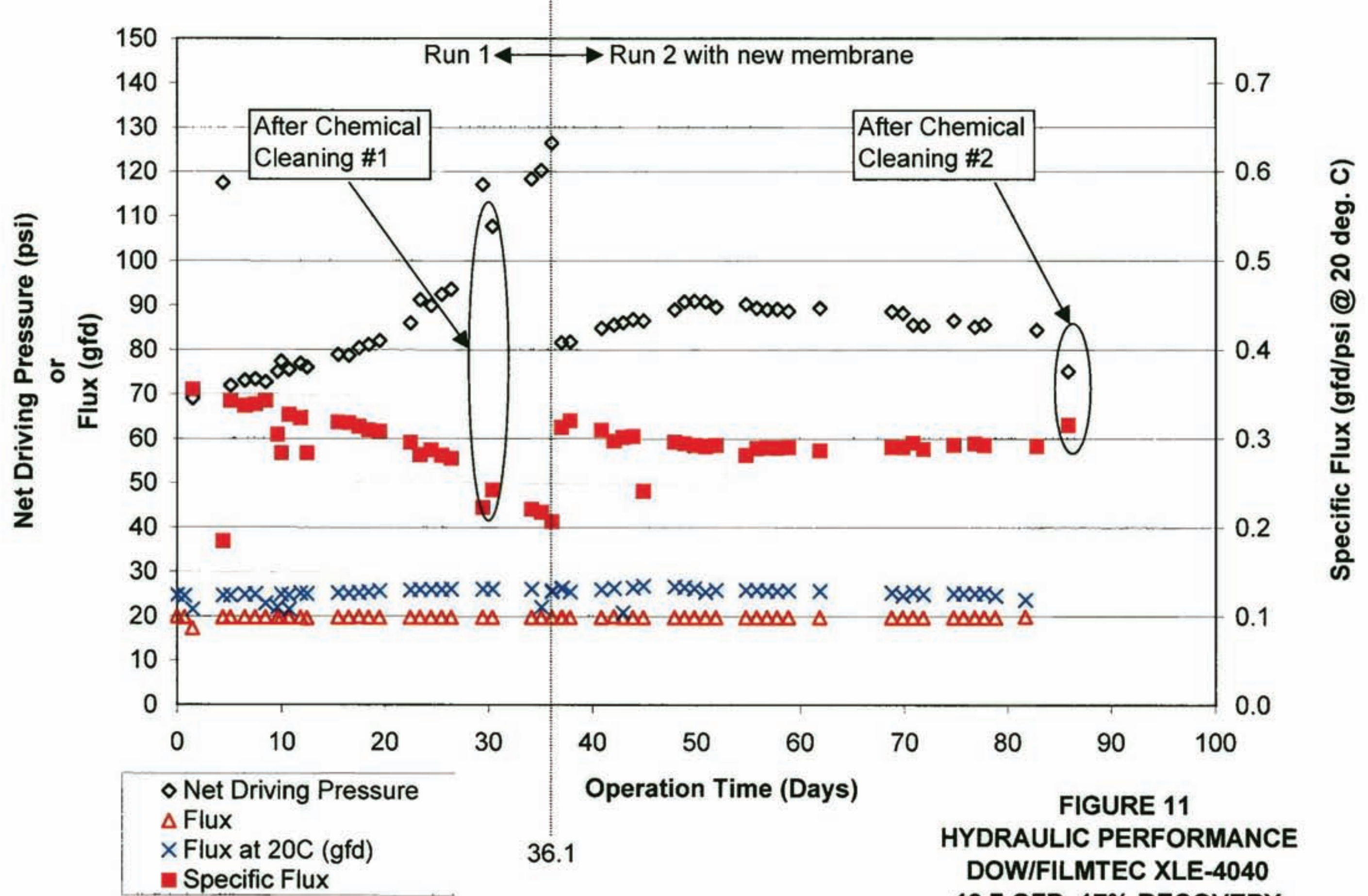


FIGURE 11
HYDRAULIC PERFORMANCE
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
SINGLE ELEMENT PILOT TESTING DMWW

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Due the expense of frequent replacement, a typical design target is to provide additional particulate removal if average cartridge filter run times are less than 30 days. If carefully constructed, most wells can provide particulate removal sufficient for cartridge filter run times of 30 days. TSS breakthrough is common to older, poorly constructed wells. In the case of DMWW, much of the infiltration piping is greater than 80 years old, which may account for the breakthrough in particulate matter.

On February 19, 2004, after approximately 11 days of run time, the first of three anti-scalant pump failures occurred. Problems with the anti-scalant pump were again noted from February 25-February 27 and March 2-March 3. In all of these instances, operators noted air binding in the pump suction line. This air binding reduced (and in one case completed halted) the amount of dosed anti-scalant fed into the pilot plant feed water. To some degree, this may have led to the formation of scale on the membrane. However, it should be noted that under the operational conditions of this piloting, barium sulfate was the only scale-forming salt in excess of its saturation limits (i.e., 175 percent). Given the slow formation kinetics of barium sulfate and the slight exceedance of its saturation limits, it is unlikely that failures in the anti-scalant pump contributed to fouling to a significant degree.

On March 8, 2004, plant operators noted severe plugging of the cartridge filter by a slug of black manganese particulate matter delivered to the pilot in the RBF feed water. This slug of particulate matter was also noted in other parallel piloting operations being conducted by the DMWW. Although cartridge filtration should have prevented these particles from reaching the membrane element, the net driving pressure jumped from approximately 123 psi to 150 psi and the delta-P increased from about 14 psi to 24 psi following this event. Due to the severity of the cartridge filter fouling, it was evident that some of this particulate matter penetrated the cartridge filter and ultimately contributed greatly to the fouling of the membrane.

As a result of this membrane fouling, the pilot plant was taken off-line for chemical cleaning. Ultimately, the specific flux of this membrane could not be recovered due to irreversible fouling and the membrane was replaced for the start of Run 2. Figures 12 and 13 are photos taken of the membrane used for Run 1 after it was removed from the pilot plant. The pictures show the severely fouled membrane by black manganese particulate matter.

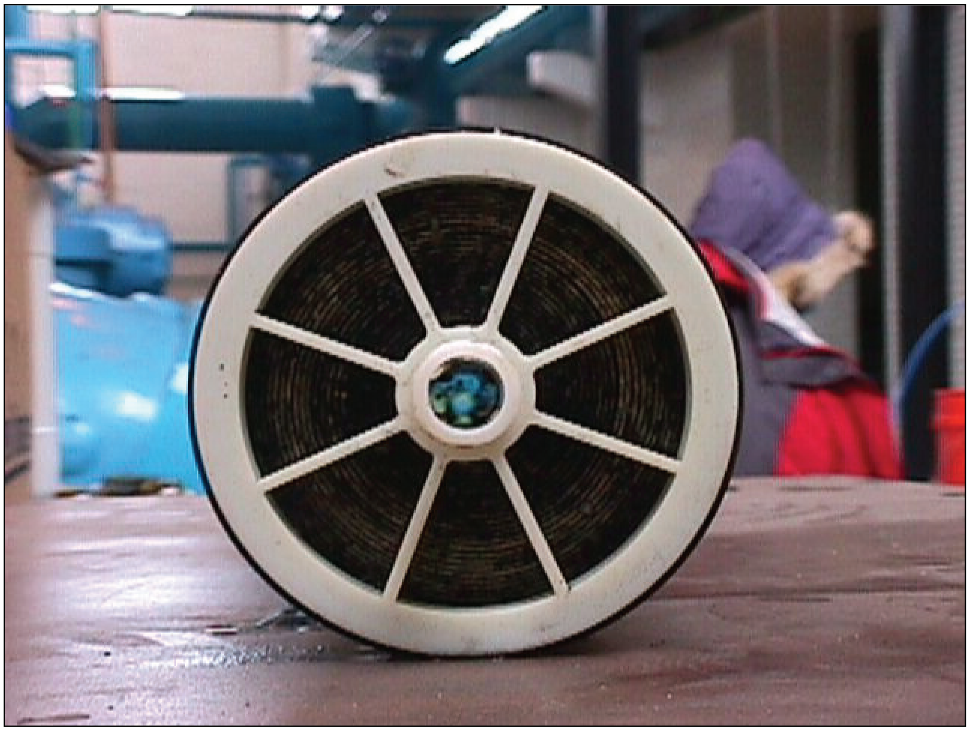

Figure 12 – Photograph Showing the Feed End of the Membrane Element Fouled by Particulate Manganese During Run 1 at the DMWW.

Figure 13 – Photograph Showing the Membrane Surface of the Membrane Element Fouled by Particulate Manganese During Run 1 at the DMWW.

7.2.2 Single Element Run 2 (RBF Pretreatment)

Following installation of a new membrane, Run 2 began on March 17, 2004, and was terminated following 50 days of successful operation. During the first 10 days of operation the required net driving pressure increased by about 10 percent. Following this initial 10-day period, the required net driving pressure stabilized for the remainder of the pilot testing with no indications of fouling. The required net driving pressure at the end of Run 2 was less than 4 percent higher than at the start of this run. Specific flux declined 6.5 percent during Run 2 from 0.31 to 0.29 gfd/psi at a rate of 0.0004 gfd/psi. This rate of decline yields an estimated chemical cleaning frequency of 138 days. However, it is important to note that the single element pilot operational conditions were set up to mimic the performance of the lead element in a full-scale plant only and were not set to model average full-scale performance. For this reason, cleaning frequency estimates from the multi-stage pilot testing (section 7.2.3) serve as a more appropriate estimate of full-scale cleaning frequency.

Although not required from a fouling standpoint, a chemical cleaning was performed at the end of Run 2 to determine the degree of irreversible fouling. The cleaning was successful in fully recovering what minor losses in specific flux had occurred with no evidence of irreversible fouling. Throughout Run 2, RBF water was both stable and high in quality. As a result, membrane operations for Run 2 were drastically improved over Run 1.

7.2.3 Multi-Stage (RBF/UF Followed by RBF Alone Pretreatment)

Figure 14 shows hydraulic performance for the XLE membrane operated in the multi-stage pilot plant. As indicated on the figure, the first 27 days were operated using membrane feed pretreated by combined RBF/UF pretreatment. The remaining 60 days of testing were operated with RBF pretreatment alone. During operation with combined RBF/UF pretreatment, membrane specific flux declined from 0.47 to 0.43 gfd/psi at a rate of 0.0015 gfd/psi/day. This rate of decline yields an estimated chemical cleaning frequency of 63 days. As shown in the figure, the rate of loss in specific flux was greater during operation with RBF pretreatment alone. The loss in specific flux during operation with RBF pretreatment alone was at a rate of 0.0027 gfd/psi/day yielding an estimated RO cleaning frequency of 32 days. (Note: cleaning frequency is defined as the operation time required to cause a 20 percent drop in specific flux.) It should be noted that there is a significant difference in the specific flux loss observed in these multi-stage pilot tests (0.0015-0.0027 gfd/psi/day) when compared to the single element test (0.0004 gfd/psi/day). As stated previously, it is important to note that the single element pilot operational conditions were set up to mimic the performance of the lead element in a full-scale plant only. Lead elements are most susceptible to particulate fouling, not scaling. The fact that the rate of specific flux loss for the multi-stage pilot was greater than the single-element pilot suggests that the multi-stage fouling is more due to scaling and less due to particulate matter.

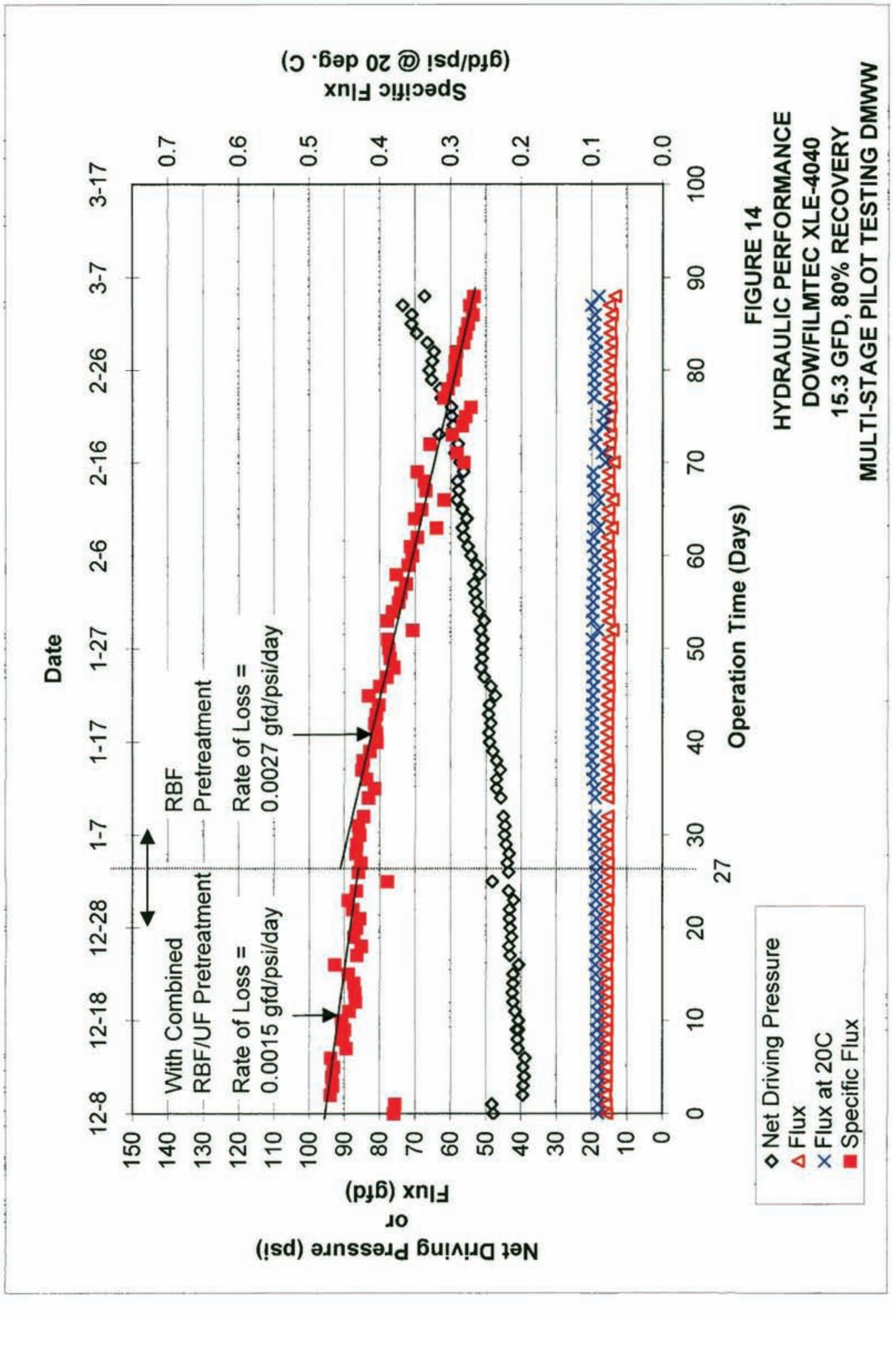

FIGURE 14
HYDRAULIC PERFORMANCE
DOW/FILMTEC XLE-4040
15.3 GFD, 80% RECOVERY
MULTI-STAGE PILOT TESTING DMWW

h:\client\usbor_den\6870a.00\dsgteam\data sheets\dmww data set -quarterly report.xls

7.3 Concentrate Water Quality and Toxicity Analysis

7.3.1 Concentrate Analysis Methods and Materials

The intent of this task was to provide data for use in determining concentrate discharge alternatives feasible to typical Mid-Western utilities and their associated budgetary costs. A detailed discussion of concentrate disposal alternatives and regulations is presented in chapter 10.

Concentrate water quality and toxicity analysis was completed at the DMWW location by operating the pilot at a recovery of 80 percent to simulate the average concentrate water quality of theoretical full-scale operations. When the pilot system reached stable steady-Stateoperation, concentrate water was collected for water quality testing and whole effluent toxicity testing. Water quality testing was performed using the standard methods listed in tables 10 and 11.

Bioassay whole effluent toxicity testing and determination of LC50 (concentrate causing 50 percent mortality) were performed on a 1-gallon concentrate sample shipped on wet ice via overnight delivery to Marinco Bioassay Laboratory, Inc., Sarasota, Florida. All bioassay tests were run according to EPA-821-R-02-012, October 2002 methods. Three 96-hour renewal multi-concentration tests (6.25, 12.5, 25, 50, and 100 percent strength of sampled concentrate) were performed. Two of these tests were performed with invertebrate species (i.e., *Ceriodaphnia dubia* and the *Daphnia magna*) and one with a vertebrate species (i.e., *Pimephales promelas*). Both invertebrate and vertebrate species were tested in order to simulate a range of biological sensitivities. Both of the renewal tests for the invertebrate species were performed using four replicates. The renewal test for the vertebrate species was performed in duplicate.

7.3.2 Concentrate Analysis Results and Discussion

7.3.2.1 Water Quality

Table 20 is a summary of the concentrate water quality from the membrane system operated at 80-percent recovery. For comparison Iowa DNR water quality standards for Class A and B (WW) receiving waters are also included in the table for the tested parameters. A complete list of all of the Chapter 61 Water Quality standards for Class A and B (WW) receiving waters is included in Appendix B. Overall, concentrate water quality was as expected with parameter concentrations roughly five (5) times that of the membrane feed water. (Note: Membrane operation at 80-percent recovery yields a concentration factor of five). Nearly all of the tested parameters met their respective Class A and B (WW) discharge standards. However, TDS is one parameter of concern with regards to the discharge of this concentrate. A discussion of how TDS and overall concentrate water quality affects available discharge alternatives is included in chapter 10.

Table 20 – A Summary of Concentrate Water Quality at 80-Percent Recovery DWPR Phase I

Parameter	Units	Concentrate Value	Iowa DNR Water Quality Standard[2]
pH	Standard Units	8.4	l.5-9.0
Conductivity	mS/cm	2.07	–
Temperature	C	12.4	<3 °C Increase
TDS	mg/L[1]	2,110	750 mg/L[3]
Alkalinity	mg/L[1]	1,260	–
Ca	mg/L[1]	355.5	–
Mg	mg/L[1]	182.5	–
SiO_2	mg/L[1]	4.30	–
Fe	mg/L	0.21	–
Mn	mg/L	0.553	–
Ba	mg/L[1]	0.380	–
Sr	mg/L[1]	1.05	–
SO_4	mg/L[1]	284.0	–
NO_3 - N	mg/L[1]	16.6	–
F	mg/L[1]	1.35	–
Cl	mg/L[1]	181.3	–
Na	mg/L[1]	80.8	–
Ni	mg/L	0.173	0.650
Pb	mg/L	<0.006	0.030
Zn	mg/L	<0.01	0.450
Total Chlorine	mg/L	0.00	0.020
Ammonia	mg/L	0.04	1.26 (at 20 °C)
DOC	mg/L[1]	10.2	–
UVA	cm^{-1} [1]	0.157	–
TTHMs			
Chloroform	mg/L	<0.0005	4.70
Bromodichloromethane	mg/L	<0.0005	–
Dibromochloromethane	mg/L	<0.0005	0.460
Bromoform	mg/L	<0.0005	3.60
VOCs			
Benzene	mg/L	<0.01	0.7128
Carbon tetrachloride	mg/L	<0.01	0.0442
Chlorobenzene	mg/L	<0.01	0.021
p-dichlorobenzene	mg/L	<0.01	0.0026

Table 20 – A Summary of Concentrate Water Quality at 80-Percent Recovery (Continued)
DWPR Phase I

Parameter	Units	Concentrate Value	Iowa DNR Water Quality Standard[2]
1,2 dichloroethane	mg/L	<0.01	0.986
1,1 dichloroethylene	mg/L	<0.01	0.032
Toluene	mg/L	<0.01	0.050
1,1,1- trichloroethane	mg/L	<0.01	0.173
Trichloroethylene	mg/L	<0.01	0.080
Vinyl chloride	mg/L	<0.01	5.250

[1] Estimated value based on measured feed water quality and rejection performance typical of the XLE membrane at 80% recovery.

[2] Iowa Chapter 61 Water Quality Standards for receiving waters of Class A and B(WW). Raccoon River and Des Moines River segments near the DMWW fall within these classifications.

[3] Per Iowa Chapter 61 Standards, TDS may not exceed 750 mg/L in any stream with a flow rate equal to or greater than three times the flow rate of upstream point source discharges. This standard applies to the TDS within the discharge mixing zone.

7.3.2.2 Whole Effluent Toxicity Testing

Table 21 is a summary of organism survival rates and the resulting LC50 observed during the concentrate whole effluent toxicity testing. The complete laboratory report for this testing is included in Appendix C. Survival rates for Daphnia Magna were 100 percent for all of the diluted concentrate concentrations. However, a 60 percent survival rate was observed at a concentrate concentration of 100 percent. As is typical for RO concentrate waters, Ceriodaphnia Dubia experienced slightly greater sensitivity. Survival rates for Ceriodaphnia Dubia were reduced to 95 and 55 percent at sample concentrations of 50 and 100 percent, respectively. Survival rates of 100 percent were observed for Pimephales Promelas at all sample concentrations. As shown in table 9, the resulting LC50 sample concentrations were greater than 100 percent for all species tested and indicate that this concentrate water exhibits low toxicity.

Table 21 – A Summary of Organism Survival Rates and LC_{50} Observed During Concentrate Whole Effluent Toxicity Testing
DWPR Phase I

Concentrate Sample Concentration (%)	Organism Survival Rate (%)	
	Daphnia Magna	***Daphnia Magna***
0 (Control) [1]	100	100
6.25	100	100
12.5	100	100
25	100	100
50	100	100
100	60	60
Resulting LC_{50}	> 100%	> 100%

[1] Control solution was prepared in accordance with EPA-821-R-02-012, October 2002 methods.

8. BPU Pilot Testing Results and Discussion

The following sections detail the results of pilot data collected at BPU. Single element pilot testing at this location was conducted from May 21 to September 14, 2004. Full-scale RO testing was conducted from April 29 to August 31, 2004.

8.1 Water Quality

This section includes the water quality results and discussion for data collected during the single element and full-scale RO operations performed at BPU.

8.1.1 Single Element Pilot Testing

Tables 22 and 23 show both inorganic and biological water quality for the Missouri River and RBF (membrane feed) waters, respectively. Tables 24 and 25 show membrane permeate and concentrate water quality, respectively. It should be noted that the concentrate water quality shown in table 25 refers to samples collected during the operational conditions at 17-percent recovery and does not reflect theoretical full-scale concentrate water quality. Table 26 shows a summary of synthetic organic compound and volatile and semi-volatile compound results for the Missouri River, RBF, and membrane permeate. Only those compounds that were detected in the samples are shown in the table. The remaining SOCs tested as part of this research for the river, RBF, and permeate were all below the method reporting limit (MRL). For reference, table 27 shows a complete list of the SOCs and volatile and semi-volatile compounds tested at BPU.

8.1.1.1 Effect of Riverbank filtration on Water Quality

The RBF process had a significant impact on nearly all of the parameters tested. Most of the inorganic parameters increased in concentration though the RBF process with increases ranging from 12 to more than 570 percent. Mean conductivity, TDS, alkalinity, calcium, and silicate concentrations increased an average of 15 percent. Conductivity increased from 0.652 to 0.743 mS/cm. TDS, alkalinity, calcium, and silicate increased from 433, 178, 142 and 11.3 to 498, 199, 166, and 13.4 mg/L, respectively. Inorganic scale forming compounds including barium, iron, and manganese had the largest increases through the RBF process at 51, 531, and 570 percent, respectively. Mean concentrations of barium, iron, and manganese increased from 0.118, 0.189, and 0.094 to 0.178, 1.266, and 0.593 mg/L, respectively.

Table 22 – Missouri River Water Quality
DWPR Phase I

Parameter	Units	Count	Median[1]	Range		Average[1]	Standard[1, 2] Deviation	95% Confidence Interval[1, 2]	
				Low	High			Low	High
pH				7.3	8.4			7.9	8.1
Conductivity	µS/cm	34	694	420	735	652	96	620	684
Turbidity	NTU	33	103	37	4,192	653	1194	245	1060
Temperature	C	38	27.5	21.2	35.9	27.9	3.5	26.8	29.0
TDS	mg/L	6	462	284	478	433	N/A	N/A	N/A
Alkalinity	mg/L	6	184	149	189	178	N/A	N/A	N/A
Calcium	mg/L	6	146	116	160	142	N/A	N/A	N/A
SiO_2	mg/L	6	11.7	8.9	12.6	11.3	N/A	N/A	N/A
Iron	mg/L	6	0.174	0.011	0.567	0.189	N/A	N/A	N/A
Manganese	mg/L	6	0.096	0.019	0.166	0.094	N/A	N/A	N/A
Barium	mg/L	5	0.130	0.093	0.730	0.241	N/A	N/A	N/A
Strontium	mg/L	6	0.51	0.48	0.51	0.50	N/A	N/A	N/A
Sulfate	mg/L	6	142	61	178	138	N/A	N/A	N/A
Nitrate	mg/L	6	6.00	0.65	15.00	7.11	N/A	N/A	N/A
Fluoride	mg/L	6	0.50	0.41	0.69	0.51	N/A	N/A	N/A
Chloride	mg/L	6	17	12	20	17	N/A	N/A	N/A
Coliforms	CFU/ 100 mL	4	1,754	275	10,600	3,596	N/A	N/A	N/A
HPC	MPN/ 100 mL	6	13,600	13,600	13,600	13,600	N/A	N/A	N/A
DOC	mg/L	6	3.25	2.90	4.50	3.47	N/A	N/A	N/A
UVA	cm^{-1}	6	0.088	0.067	0.150	0.094	N/A	N/A	N/A

[1] Values reported as non-detect were assumed to be one-half of the detection limit for the purposes of statistical evaluation.

[2] If less than eight data points exist for the data, statistical analysis for standard deviation and the confidence interval was not performed.

Table 23 – RBF (Membrane Feed) Water Quality
DWPR Phase I

Parameter	Units	Count	Median[1]	Range		Average[1]	Standard Deviation [1, 2]	95% Confidence Interval	
				Low	High			Low	High
				6.8	7.5			6.9	7.1
pH #4		9	6.3	5.8	7.1	6.3	0.4	6.0	6.5
pH #5-6		9	5.4	5.0	6.3	5.4	0.4	5.2	5.7
Conductivity	μS/cm	34	717	559	1213	743	133	698	787
Turbidity	NTU	34	0.793	0.284	10.800	1.085	1.750	0.497	1.673
SDI		27	1.11	0.20	3.80	1.34	1.03	0.96	1.73
Temperature	C	36	24.4	19.0	26.5	23.3	2.3	22.6	24.0
TDS	mg/L	6	464	423	696	498	N/A	N/A	N/A
Alkalinity	mg/L	6	201	190	204	199	N/A	N/A	N/A
Calcium	mg/L	6	169	142	181	166	N/A	N/A	N/A
SiO_2	mg/L	6	13.5	11.7	15.2	13.4	N/A	N/A	N/A
Iron	mg/L	6	1.510	0.137	1.620	1.266	N/A	N/A	N/A
Manganese	mg/L	6	0.611	0.519	0.617	0.593	N/A	N/A	N/A
Barium	mg/L	6	0.180	0.160	0.200	0.178	N/A	N/A	N/A
Strontium	mg/L	6	0.52	0.47	0.56	0.52	N/A	N/A	N/A
Sulfate	mg/L	6	132	123	153	135	N/A	N/A	N/A
Nitrate	mg/L	6	2.23	0.13	3.00	1.84	N/A	N/A	N/A
Fluoride	mg/L	6	0.48	0.33	0.49	0.46	N/A	N/A	N/A
Chloride	mg/L	6	15	13	17	15	N/A	N/A	N/A
Coliforms	CFU/ 100 mL	6	1	1	73	21	N/A	N/A	N/A
HPC	MPN/ 100 mL	6	847	93	1,600	847	N/A	N/A	N/A
DOC	mg/L	6	2.2	2.1	2.2	2.2	N/A	N/A	N/A
UVA	cm^{-1}	6	0.061	0.056	0.062	0.060	N/A	N/A	N/A

[1] Values reported as non-detect were assumed to be one-half of the detection limit for the purposes of statistical evaluation.

[2] If less than eight data points exist for the data, statistical analysis for standard deviation and the confidence interval was not performed.

Table 24 – Membrane Permeate Water Quality
DWPR Phase I

Parameter	Units	Count	Median[1]	Range		Average[1]	Standard[1, 2] Deviation	95% Confidence Interval[1, 2]	
				Low	High			Low	High
				4.8	5.9			5.4	5.7
pH #4		9	5.4	5.2	5.5	5.4	0.1	5.3	5.4
pH #5-6		9	5.4	5.0	6.3	5.4	0.4	5.2	5.7
Conductivity	µS/cm	37	20	12	425	39	67	18	61
Turbidity	NTU	33	0.154	0.064	0.651	0.175	0.106	0.139	0.212
TDS	mg/L	6	16	8	44	21	N/A	N/A	N/A
Alkalinity	mg/L	6	8.3	5.7	12.1	8.6	N/A	N/A	N/A
Calcium	mg/L	6	3.5	1.0	7.2	3.7	N/A	N/A	N/A
SiO_2	mg/L	6	0.4	0.2	1.2	0.5	N/A	N/A	N/A
Iron	mg/L	6	0.009	0.005	0.019	0.010	N/A	N/A	N/A
Manganese	mg/L	6	0.003	0.001	0.006	0.003	N/A	N/A	N/A
Barium	mg/L	6	<0.002	<0.002	<0.002	<0.002	N/A	N/A	N/A
Strontium	mg/L	5	<0.01	<0.01	<0.01	<0.01	N/A	N/A	N/A
Sulfate	mg/L	6	0.48	0.10	7.00	1.52	N/A	N/A	N/A
Nitrate	mg/L	6	0.33	0.05	0.48	0.29	N/A	N/A	N/A
Fluoride	mg/L	6	0.03	0.01	0.20	0.07	N/A	N/A	N/A
Chloride	mg/L	6	0.45	0.28	6.00	1.43	N/A	N/A	N/A
Coliforms	CFU/ 100mL	6	ND	ND	ND	ND	N/A	N/A	N/A
HPC	MPN/ 100mL	6	98	ND	>200	N/A	N/A	N/A	N/A
DOC	mg/L	6	<0.5	<0.5	<0.5	<0.5	N/A	N/A	N/A
UVA	cm^{-1}	6	0.005	0.005	0.005	0.005	N/A	N/A	N/A

[1] Values reported as non-detect were assumed to be one-half of the detection limit for the purposes of statistical evaluation.

[2] If less than eight data points exist for the data, statistical analysis for standard deviation and the confidence interval was not performed.

Table 25 – Membrane Concentrate Water Quality at 17-Percent Recovery DWPR Phase I

Parameter	Units	Count	Median[1]	Range		Average[1]	Standard[1, 2] Deviation	95% Confidence Interval[1, 2]	
				Low	High			Low	High
pH #1-3		15	7.5	7.4	7.6	7.5	0.1	7.4	7.5
pH #4		9	6.8	6.3	7.4	6.7	0.3	6.6	6.9
pH #5-6		9	5.6	3.1	5.7	5.3	0.8	4.7	5.8
Conductivity	µS/cm	35	807	638	1,216	824	94	793	855
TDS	mg/L	6	536	500	586	540	N/A	N/A	N/A

[1] Values reported as non-detect were assumed to be one-half of the detection limit for the purposes of statistical evaluation.

[2] If less than eight data points exist for the data, statistical analysis for standard deviation and the confidence interval was not performed.

Table 26 – A Summary of Missouri River, RBF, and Membrane Permeate Positive "Hit" SOC Analyses DWPR Phase I

Parameter	MRL[1]	Units	Sample 1	Sample 2	Sample 3
Missouri River					
SOCs					
Atrazine	0.1	ug/L	0.11	ND[2]	ND
Diethyl phthalate	0.1	ug/L	1.33	ND	1.29
Bis(2-ethylhexyl) phthalate	1.0	ug/L	8.75	ND	3.75
Dimethyl phthalate	0.1	ug/L	0.16	ND	0.13
Volaites and Semi-Volaties					
2,4-bis(1,1-dimethylethyl)-phenol	0.1	ug/L	ND	0.1	0.31
2,6-bis(1,1-dimethylethyl)-2,5-Cyclohexadiene-1,4-dione	0.1	ug/L	ND	0.27	0.26
2-Undecanone	0.1	ug/L	ND	0.1	ND
3,4-dihydro-3,3,6,8-tetramethyl-1(2H)-Naphthalenone	0.1	ug/L	0.27	0.24	0.31
Caffeine	0.1	ug/L	0.19	ND	ND
Citric acid	0.1	ug/L	0.24	ND	ND
Cyclododecane	0.1	ug/L	ND	0.54	ND
Diethyltoluamide (DEET)	0.1	ug/L	0.1	0.05	0.14
Fyrol FR-2	0.1	ug/L	0.1	ND	ND
Limonene	0.1	ug/L	0.28	0.05	1.44
o-Hydroxybiphenyl	0.1	ug/L	ND	0.82	0.29
Tri (2-chloroethyl) phosphate	0.1	ug/L	1.23	ND	1.15

Table 26 – A Summary of Missouri River, RBF, and Membrane Permeate Positive "Hit" SOC Analyses (continued)
DWPR Phase I

Parameter	MRL[1]	Units	Sample 1	Sample 2	Sample 3
RBF (Membrane Feed)					
SOCs					
Atrazine	0.1	ug/L	0.12	ND	ND
Volaites and Semi-Volaties					
2,4-bis(1,1-dimethylethyl)-phenol	0.1	ug/L	ND	0.33	0.15
2,6-bis(1,1-dimethylethyl)-2,5-Cyclohexadiene-1,4-dione	0.1	ug/L	ND	0.56	0.32
2-Undecanone	0.1	ug/L	ND	0.87	ND
3,4-dihydro-3,3,6,8-tetramethyl-1(2H)-Naphthalenone	0.1	ug/L	0.4	0.28	0.21
Cyclododecane	0.1	ug/L	ND	3.19	ND
Limonene	0.1	ug/L	ND	ND	0.16
Metolachlor	0.1	ug/L	0.12	ND	ND
Membrane Permeate					
Volaites and Semi-Volaties					
2,6-bis(1,1-dimethylethyl)-2,5-Cyclohexadiene-1,4-dione	0.1	ug/L	0.36	0.33	0.32
2-Undecanone	0.1	ug/L	ND	1.24	0.74
3,4-dihydro-3,3,6,8-tetramethyl-1(2H)-Naphthalenone	0.1	ug/L	ND	0.41	0.3
Butylbenzenesulfonamide	0.1	ug/L	ND	ND	0.38
Limonene	0.1	ug/L	ND	ND	0.22

[1] MRL = Method Reporting Limit.

[2] ND= Non-Detect.

Table 27 – A Complete List of SOCs and Volatile and Semi-Volatile Compounds Tested at BPU
DWPR Phase I

Parameter	MRL[1]	Units
SOCs		
Acenaphthylene	0.1	ug/L
Alachlor	0.1	ug/L
Aldrin	0.1	ug/L
Anthracene	0.1	ug/L
Atrazine	0.1	ug/L
Benzo(a)anthracene	0.1	ug/L
Benzo(b)fluoranthene	0.1	ug/L
Benzo(k)fluoranthene	0.1	ug/L
Benzo(a)pyrene	0.1	ug/L
Butyl benzyl phthalate	1.0	ug/L
Alpha-chlordane	0.1	ug/L
Gamma-chlordane	0.1	ug/L
Trans nonachlor	0.1	ug/L
Gamma BHC (Lindane)	0.1	ug/L
2-Chlorobiphenyl	0.1	ug/L
Chrysene	0.1	ug/L
Di-n-butyl phthalate	1.0	ug/L
2,3-Dichlorobiphenyl	0.1	ug/L
Diethyl phthalate	0.1	ug/L
Di(2-ethylhexyl)adipate	0.1	ug/L
Bis(2-ethylhexyl) phthalate	0.1	ug/L
Dimethyl phthalate	0.1	ug/L
Endrin	0.1	ug/L
Fluorene	0.1	ug/L
Heptachlor	0.1	ug/L
Heptachlor Epoxide	0.1	ug/L
2,2',3,3',4,4',6-Heptachlorobiphenyl	0.1	ug/L
Hexachlorobenzene	0.1	ug/L
2,2',4,4',5,6'-Hexachlorobiphenyl	0.1	ug/L
Methoxychlor	0.1	ug/L
2,2',3,3',4,5',6,6'-Octachlorobiphenyl	0.1	ug/L
2,2',3',4,6-Pentachlorobiphenyl	0.1	ug/L
Pentachlorophenol	0.1	ug/L
Phenanthrene	0.1	ug/L
Pyrene	0.1	ug/L
Simazine	0.1	ug/L
2,2',4,4'-Tetrachlorobiphenyl	0.1	ug/L
Toxaphene	4.0	ug/L
2,4,5-Trichlorobiphenyl	0.1	ug/L

Table 27 – A Complete List of SOCs and Volatile and Semi-Volatile Compounds Tested at BPU (Continued)
DWPR Phase I

Parameter	MRL[1]	Units
Dibenz[a,h]anthracene	0.5	ug/L
Indeno(1,2,3,c,d)pyrene	0.5	ug/L
Benzo(g,h,i)perylene	0.5	ug/L
Volatile and Semi-Volatile Compounds	0.1	ug/L
2,4-bis(1,1-dimethylethyl)-phenol	0.1	ug/L
2,6-bis(1,1-dimethylethyl)-2,5-Cyclohexadiene-1,4-dione	0.1	ug/L
2-Undecanone	0.1	ug/L
3,4-dihydro-3,3,6,8-tetramethyl-1(2H)-Naphthalenone	0.1	ug/L
Butylbenzenesulfonamide	0.1	ug/L
Caffeine	0.1	ug/L
Cholesterol	0.1	ug/L
Citric acid	0.1	ug/L
Cyclododecane	0.1	ug/L
Diethyltoluamide (DEET)	0.1	ug/L
Fyrol FR-2	0.1	ug/L
Limonene	0.1	ug/L
Metolachlor	0.1	ug/L
o-Hydroxybiphenyl	0.1	ug/L
Squalene	0.1	ug/L
Tri(2-chloroethyl) phosphate	0.1	ug/L

[1] MRL = Method Reporting Limit.

Although the majority of inorganic compounds increased in concentration through RBF, strontium, sulfate, and chloride concentrations remained constant at about 0.52, 136, and 16 mg/L, respectively. Mean fluoride and pH measurements decreased about 10 percent from 0.51 mg/L and pH 8.0 to 0.46 mg/L with pH 7.0. Average water temperature decreased 16 percent through RBF from 27.9 to 23.3 °C. Nitrate concentrations experienced the most significant reduction through the RBF process with an average reduction of 74 percent from 7.11 to 1.84 mg/L.

RBF had a strong positive impact on particulate, organic, and biological quality of the water. Average river turbidity was reduced more than 99 percent from 653 to 1.085 NTU and consistently low SDI measurements averaging 1.34 were obtained. It should be noted, however, that average values of turbidity measured for both the river and the RBF water were impacted by one or more turbidity spike events. Therefore, median values may be a better indication of typical turbidity measured in these waters. Median values were reduced about 99 percent through the RBF process from 103 to 0.793 NTU. Average DOC and

UVA measurements (surrogate for organic fouling potential) were reduced about 39 percent through RBF from 3.58 mg/L and 0.099 cm^{-1} to 2.20 and 0.060 cm^{-1}, respectively. Coliforms and HPC were also significantly reduced from 3596 to 21 CFU/100 mL and 3,600 to 847 MPN/100 mL, respectively.

As part of this piloting, 42 SOCs were tested. In addition, 16 volatile and semi-volatile were tested in these waters. River samples tested positive for 4 SOCs and 11 other volatile and semi-volatile compounds. Following the RBF process 1 SOC and 7 other volatile and semi-volatile compounds were detected.

In summary, a majority of the tested inorganic parameters increased in concentration through the RBF process. Barium, iron, and manganese, which have potential to play a significant role in membrane fouling, increased most dramatically. These relatively high concentrations, specifically with respect to iron, were of concern throughout the pilot testing. Organic and biological parameters were overall positively impacted through the RBF process. However, turbidity spikes in the RBF water (membrane fee) were recorded on more than one occasion, which created concerns with respect to particulate fouling of the membrane. Specific discussion on membrane performance and how it related to water quality is provided in subsequent sections.

8.1.1.2 Effect of Membrane Filtration on Water Quality

Table 28 summarizes removal/rejection performance of the RO membrane. As expected, the RO membrane process proved very effective at removing both inorganic and organic contaminants. Conductivity and TDS were both rejected at 95 percent. Alkalinity, calcium, silica, iron, manganese, barium, strontium, and sulfate were rejected an average of 98 percent. Chloride rejection was 91 percent. Nitrate and fluoride rejection was slightly less at an average of about 84 percent.

Like the inorganic parameters, particulate, organic, and biological contaminants were effectively removed through the RO process. Although reduced by a significant degree, sample permeate turbidities were much higher than expected for RO permeate waters. This is likely due in part to typical field measurement error and the fact that the permeate turbidities were so near the detection limit of the instrument. The ability of membranes to remove particulate matter to extremely low levels has been well documented elsewhere in the literature. DOC rejection was >77 percent, and UVA rejection was 92 percent. Coliform bacteria were removed at a rejection of >99 percent with no coliform bacteria being detected in the permeate. HPC concentrations were higher than expected in some of the permeate samples, but were below detection in most samples. It is not believed that high HPC results were indicative of a breach in membrane integrity. Although sample taps were allowed to flush prior to sample collection, it is possible that HPC bacteria accumulated in sample tubing lines and sloughed off during sampling. Contamination may also have occurred because the sampling was not performed in a sterile environment.

Table 28 –A Summary of RO Rejection Performance at BPU DWPR Phase I

Parameter	Units	Average Membrane Feed	Average Membrane Permeate	Rejection, %
pH #1-3	pH Units	7.0	5.6	N/A
pH #4	pH Units	6.3	5.4	N/A
pH #5-6	pH Units	5.4	5.4	N/A
Conductivity	µS/cm	743	40	95%
Turbidity	NTU	1.085	0.175 [1]	84%
TDS	mg/L	498	21	96%
Alkalinity	mg/L	199	9	96%
Calcium	ug/L	166	4	98%
SiO_2	mg/L	13.43	0.48	96%
Iron	mg/L	1.266	0.010	99%
Manganese	mg/L	0.593	0.003	>99%
Barium	mg/L	0.178	<0.002	>99%
Strontium	mg/L	0.52	<0.01	>99%
Sulfate	mg/L	135	1.522	99%
Nitrate	mg/L	1.84	0.290	84%
Fluoride	mg/L	0.46	0.074	84%
Chloride	mg/L	15	1.428	91%
Coliforms	CFU/mL	21	ND	>99%
HPC	MPN/100 mL	847	N/A [2]	N/A [2]
DOC	mg/L	2.17	<0.5	>77%
UVA	cm^{-1}	0.06	0.005	92%

[1] Sample permeate turbidities were much higher than expected for RO permeate waters. This is likely due in part to typical field measurement error and the fact that filtration turbidities were so near the detection limit of the instrument.

[2] HPC concentrations were higher than expected in some of the permeate samples and were below detection in most of the collected samples. It is not believed that these HPC results were indicative of a breach in membrane integrity. Although sample taps were allowed to flush prior to sample collection, it is possible that HPC bacteria accumulated in sample tubing lines and sloughed off during sampling. Contamination may also have occurred because the sampling was not performed in a sterile environment.

Of the 42 SOCs and 16 volatile and semi-volatile compounds tested as part of this piloting, river samples tested positive for 4 SOCs and 11 other volatile and semi-volatile compounds. Following the RBF process 1 SOC and 7 other volatile and semi-volatile compounds were detected. Although no SOCs were detected in permeate samples, 4 volatile and semi-volatile compounds were detected. It should be noted that one of these detected permeate volatile and semi-volatile compounds, butylbenzenesulfonamide, was not detected in any of the river or membrane feed waters and was detected in only one of three permeate sample events.

In summary, the RO membrane process performed as expected with regard to effective contaminant removal and provided an average contaminant rejection of greater than 90 percent.

8.1.2 Full-Scale RO Testing

Data available from full-scale RO operations was primarily related to hydraulic performance data. However, a small amount of water quality data was collected during the parallel full-scale RO operations and is shown in table 29. Due to the limited amount of water quality data collected during this portion of the piloting, a direct comparison of water quality provided by RBF and RBF combined with conventional treatment cannot be made.

Table 29 – A Summary of Full-Scale RO Water Quality Data Collected at BPU DWPR Phase I

Parameter	Units	Count	Median [1]	Range		Average [1]	Standard [1,2] Deviation	95% Confidence Interval [1,2]	
				Low	High			Low	High
Feed Water [3]									
Conductivity	μS/cm	119	712	638	760	709	34	704	716
Concentrate									
Conductivity	μS/cm	119	1,838	1,696	1,989	1,831	83	1816	1846
Permeate									
Conductivity	μS/cm	119	33	20	42	32	4	31	33
SiO_2	mg/L	11	0.954	0.738	1.216	0.960	0.182	0.852	1.067

[1] Values reported as non-detect were assumed to be one-half of the detection limit for the purposes of statistical evaluation.

[2] If less than eight data points exist for the data, statistical analysis for standard deviation and the confidence interval was not performed.

[3] RBF water that has been conventionally treated (rapid mix, flocculation, sedimentation, filtration, polish filtration, carbon filtration.

8.2 Hydraulic Performance

Single element pilot testing at BPU was conducted under constant flux (19.7 gfd), increasing pressure conditions from May 21 to September 14, 2004, using the operating conditions detailed in chapter 6. Single element pilot testing at BPU involved six (6) single element pilot "runs" to test for satisfactory operational performance. Runs 1-3 were operated with an scale inhibitor dose of 1 mg/L.

Water quality data collected during Runs 1-3 indicated a need to increase the scale inhibitor target dose (i.e., from 1 to 10 mg/L) for subsequent runs and showed extreme potential for iron fouling.

Field data collected at the end of Runs 1-3 verified iron as a major cause of fouling. As a result, acid addition targeting a decreased membrane feed pH for iron fouling control was included for all subsequent runs. A membrane feed pH of 6.5 was targeted as part of the Run 4 operations. Runs 5-6 targeted a feed pH of 5.5 to further control iron fouling potential. Figure 15 shows the hydraulic performance throughout the piloting at BPU. Hydraulic performance from each pilot test run is discussed in the following.

8.2.1 Single Element Runs 1-3 (RBF Followed by RO)

Single element pilot Runs 1-3 were conducted from May 21 to July 22, 2004. As indicated in figure 15, Runs 1-3 each experienced an extremely rapid rise in the required net driving pressure due to membrane fouling. Run times were far below the targeted cleaning interval of 90 days. The rise in net driving pressure mandated chemical cleanings after approximately 11, 5, and, 6 days of run time for Runs 1, 2, and 3, respectively. Several factors contributed to this rapid membrane fouling. Pilot operators experienced occasions of air blockage in the scale inhibitor pump suction line. As a result, scale inhibitor was not dosed at the targeted flow rates during times of air blockage and, in some cases, dosing of scale inhibitor was halted completely. In addition, the water quality for this source was anticipated to be very low in dissolved oxygen (i.e., <0.5 mg/L) with very low oxidation reduction potential. Under low oxidation reduction potential conditions, iron and manganese remain in their reduced states and do not exhibit significant fouling potential for RO operations. However, the actual water quality and field data collected during Runs 1-3 confirmed the presence of significant amounts of dissolved oxygen (i.e., 3.4 mg/L) and the resulting oxidized colloidal and particulate iron. As shown in figure 16, spent cartridge filters and pilot piping were observed to be covered with significant amounts of an orange/red iron foulant. In addition, spent RO chemical cleaning solutions were of a dark red color confirming iron to be a major cause of fouling.

Figure 16 – Photograph Showing a New Cartridge Filter (Left) Next to Filters Fouled by Particulate Iron During Piloting at BPU.

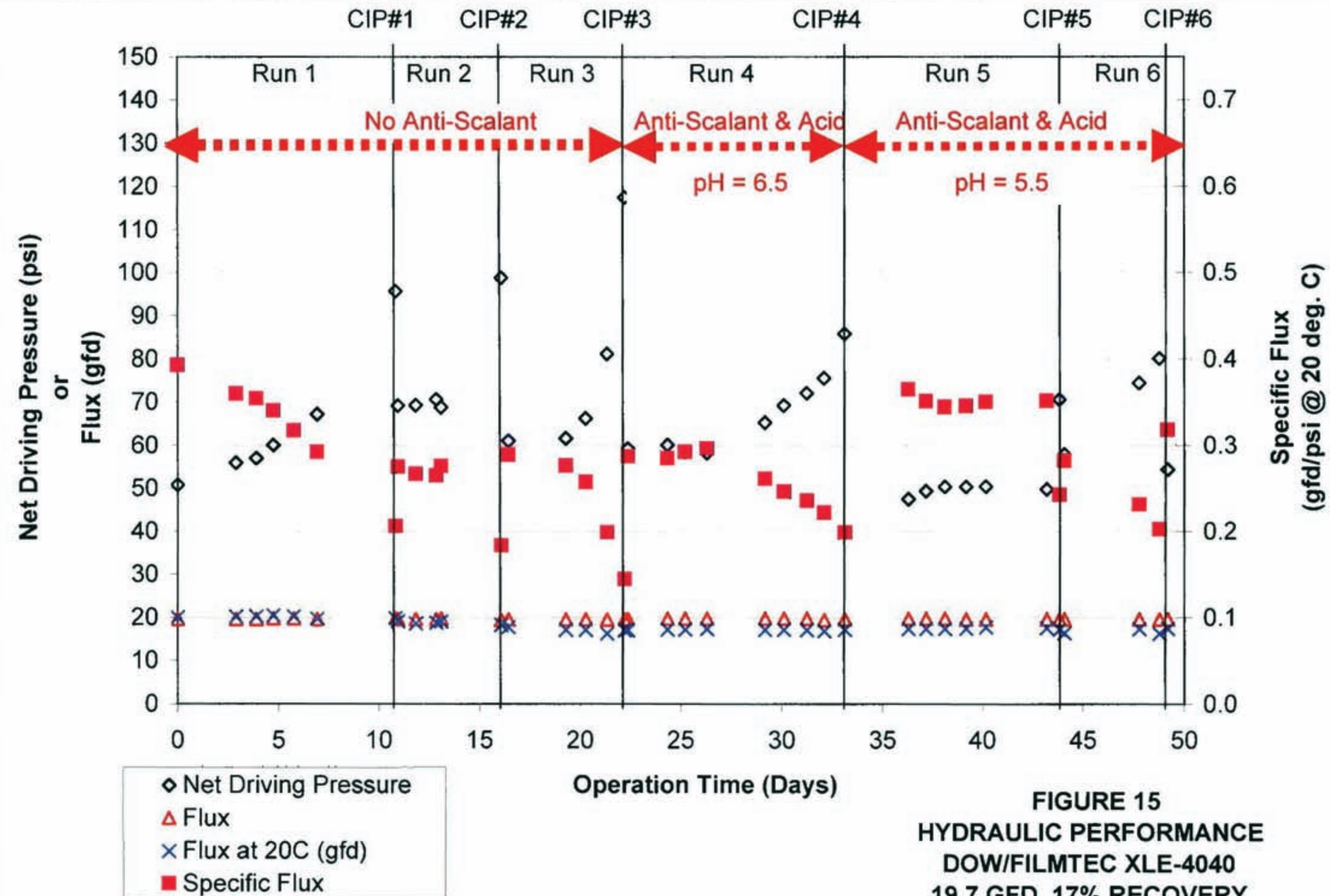

FIGURE 15
HYDRAULIC PERFORMANCE
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
SINGLE ELEMENT PILOT TESTING BPU

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8.2.2 Single Element Run 4 (RBF Followed by RO)

A review of data collected during Runs 1-3 indicated the need for iron fouling control beyond scale inhibitor addition. Iron chemistry is very complex, but is strongly related to both pH and oxidation-reduction potential, pε. The oxidation-reduction potential was found to be at concentrations much higher than initially anticipated. As a result, the iron chemistry of the water was driven toward the formation of iron precipitates. For reference, figure 17 shows the relationship between oxidation-reduction potential, pH, and iron chemistry.

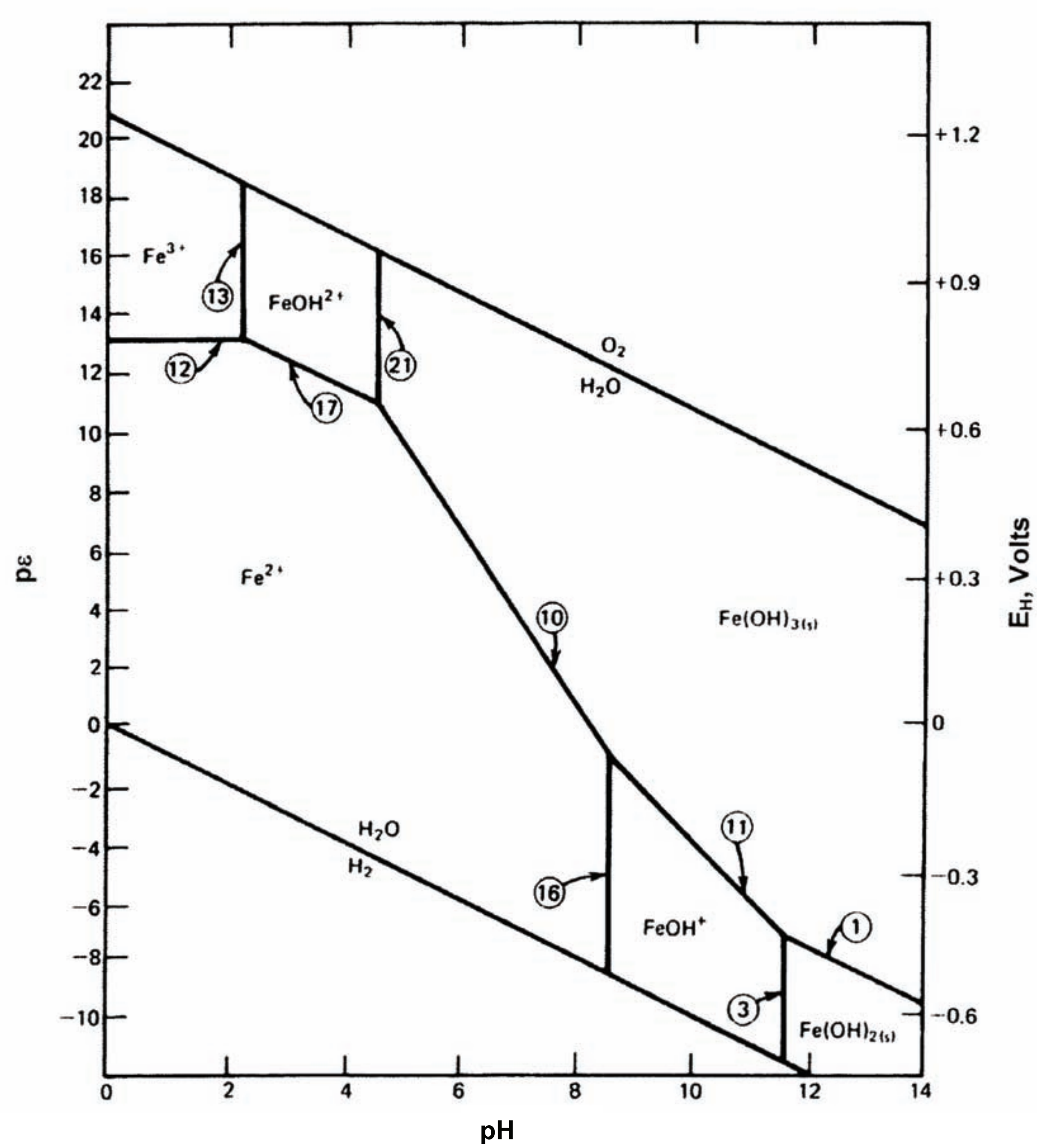

Figure 17 – Diagram Showing the Relationship Between Iron Chemistry, pH, and pε. Taken from *Water Chemistry*, Snoeyink and Jenkins, 1980.

Single element pilot Run 4 was conducted from July 26 to August 4, 2004. The conditions of Run 4 involved an increase in scale inhibitor dose from 1 to 10 mg/L and the addition of sulfuric acid to decrease feed pH to 6.5. The decrease in pH was designed to drive the iron chemistry to Fe^{+2}, which remains in solution and does not exhibit significant fouling potential. As shown in figure 15, the rate of fouling observed during Run 4 was slightly reduced when compared to Runs 1-3. However the overall run time for Run 4 was a mere 11 days, well below the targeted run duration of 90 days. Spent cartridge filters were again covered with an orange/red foulant. Like Runs 1-3, spent RO chemical cleaning solutions were of a dark red color confirming iron to be a major cause of fouling.

8.2.3 Single Element Runs 5-6 (RBF Followed by RO)

Single element pilot Run 5 was conducted from August 5 to August 24, 2004. Run 6 was conducted from September 10 to September 14, 2004. The conditions of Runs 5-6 involved the addition of sulfuric acid to decrease feed pH to 5.5. As shown in figure 15, the net driving pressure and specific flux observed during Run 5 were very stable for more than 10 days suggesting that iron fouling was stabilized under these pH conditions. Following 10 days of stable operation the membrane became rapidly fouled as indicated by a sharp drop in specific flux (>30 percent drop) from 0.35 to 0.24 gfd/psi in a duration of less than 20 hours. This rapid fouling was likely due to a turbidity spike in the RBF water of greater than 10 NTU. The spike in RBF turbidity followed a rotation of the RBF service pumps. Operators noted that pump start-up events have often led to turbidity spikes similar in nature to that experienced during Run 5.

Unlike the stable operation observed for these pH conditions during Run 5, the specific flux experienced during Run 6 had steady rapid decline. Despite consistently low RBF turbidity and the low feed pH, Run 6 resulted in a run time of only 4.75 days.

Unlike Runs 1-4 spent RO chemical cleaning solutions following Runs 5 and 6 were not a dark red color. Instead, the high pH chemical solution was slightly brown in color and the low pH solution was a faint yellow color (figure 18). The faint coloring (i.e., not dark or red) suggested that iron was not a major foulant under these pH conditions. In addition, the specific flux recovery resulting from the high pH solution was a relatively large portion of the total specific flux recovered during the entire cleaning procedure. This suggests that particulate matter (colloids, turbidity, etc.) was the major cause of membrane fouling during these runs.

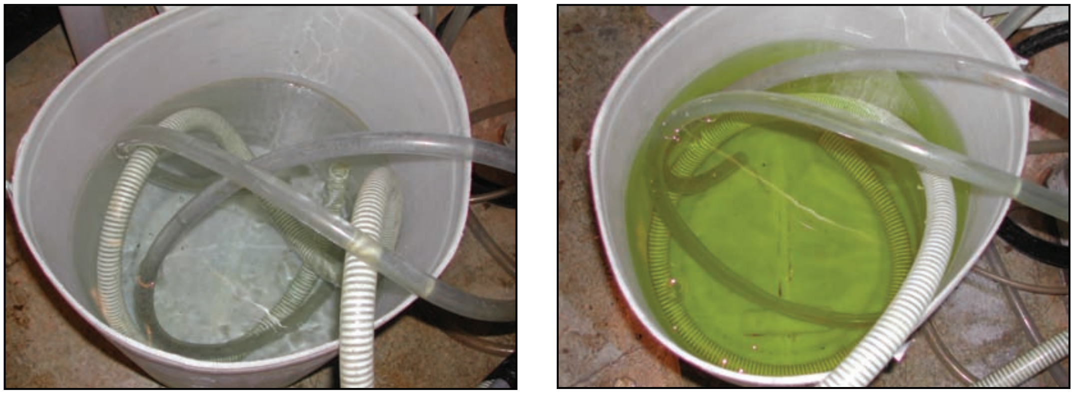

Figure 18 – High pH (Left) and Low pH (Right) Spent Chemical Cleaning Solutions of the Membrane Element Fouled by Particulate Matter During Runs 5 and 6 at BPU.

8.2.4 Full-Scale RO Test (RBF + Conventional Treatment Followed by RO)

Full-scale RO operations were conducted in parallel to the single element pilot plant testing. Figure 19 shows hydraulic performance for the full-scale RO membranes operated in the Nearman Creek Power Plant using feed water pretreated by RBF combined with conventional treatment. As shown in the figure, membrane hydraulic performance was very stable with no decline in specific flux observed over the entire 124-day testing period. It should be noted that although no significant fouling was observed following the 124 days of operation, RO plant operations were ended for plant maintenance. Long run times are common with this pretreatment. For example, more than 20 months of operation was achieved in the run preceding this testing.

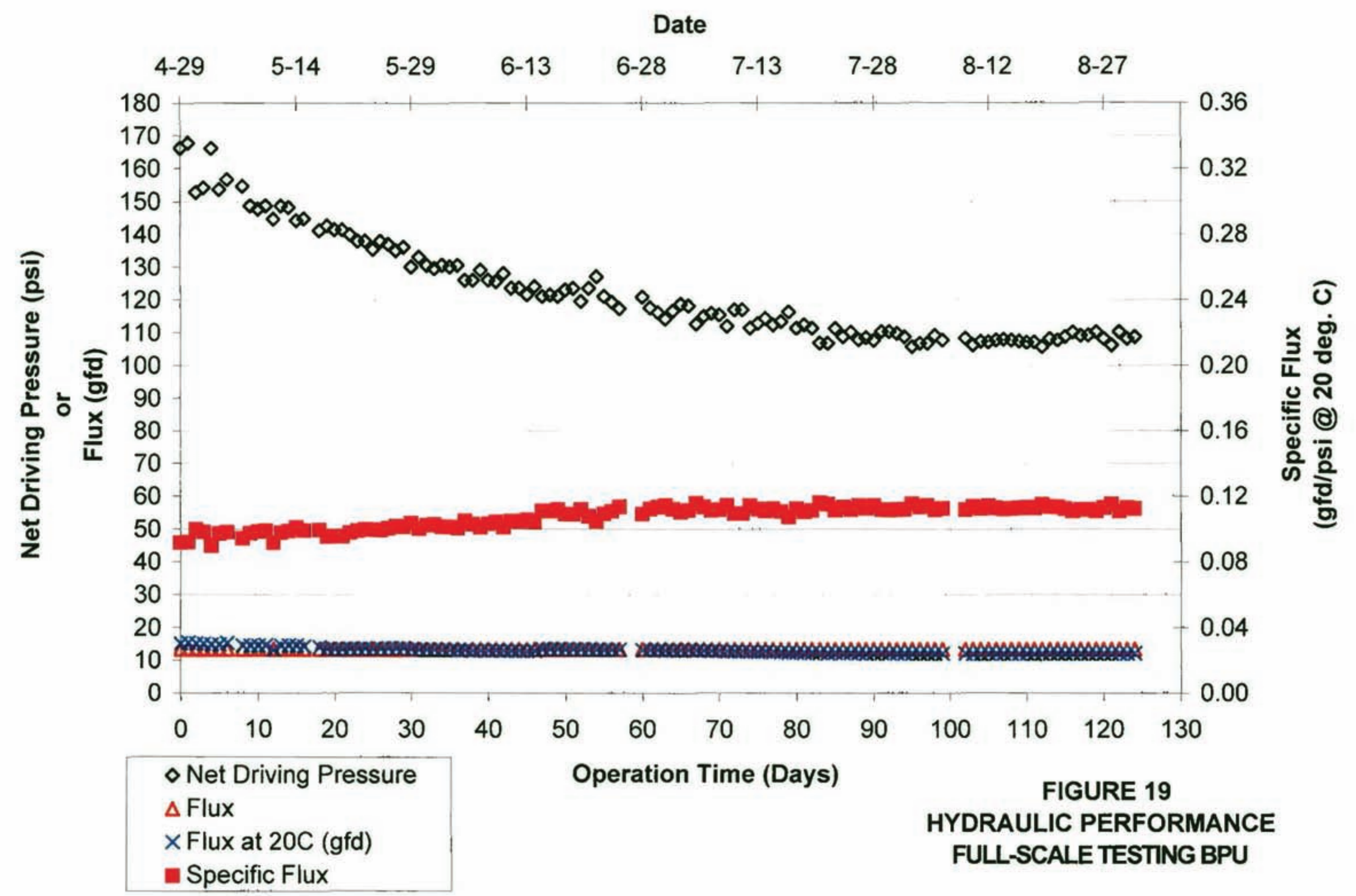

FIGURE 19
HYDRAULIC PERFORMANCE
FULL-SCALE TESTING BPU

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9. LWC Pilot Testing Results and Discussion

The following sections detail the results of pilot data collected at LWC. Single element pilot testing at this location was conducted from August 2 to October 22, 2004. Details on the tested treatment technology, methods and materials, and QA/QC procedures used for the single element pilot testing are detailed in chapter 6.

9.1 Water Quality

Tables 30 and 31 show both inorganic and biological water quality for the Ohio River and RBF (membrane feed) waters, respectively. Tables 32 and 33 show membrane permeate and concentrate water quality, respectively. It should be noted that the concentrate water quality shown in table 33 refers to samples collected during operational conditions at 17-percent recovery and does not reflect theoretical full-scale concentrate water quality. Table 34 shows a summary of positive "hit" SOC results for the Ohio River, RBF, and membrane permeate. As shown, atrazine was the only SOC detected. The remaining SOCs tested as part of this research for the river, RBF, and permeate were all below the method reporting limit (MRL). For reference, a complete list of the SOCs tested for this portion of the research is show in table 35.

9.1.1 Effect of Riverbank Filtration on Water Quality

The average temperature of the RBF water was 21 °C, or about 20 percent less than the mean Ohio River readings of 26 °C. Inorganic parameters including silica, strontium, and sulfate were essentially unchanged through the RBF process with average concentrations of about 0.16, 0.20, and 59 mg/L, respectively. Mean magnesium, manganese, fluoride, and chloride concentrations increased an average of 37 percent through the RBF process from about 10, 0.21, 0.18, and 15 to 13, 0.30, 0.24, and 22 mg/L, respectively. Changes in calcium and alkalinity concentrations were more dramatic with increases of 66 and 93 percent, respectively. Calcium increased from about 36 to 61 mg/L. Alkalinity increased from about 78 to 152 mg/L. Because of the increased concentration of these inorganic parameters, conductivity and TDS experienced an increase of approximately 25 percent. Conductivity increased from 346 to 438 µS/cm. TDS increased from 235 to 288 mg/L.

Although the overall TDS of the water increased through RBF, nitrate and nuisance parameters common to membrane scaling were reduced. Mean nitrate concentrations dropped 10 percent from about 0.47 to 0.43 mg/L.

Table 30 – Ohio River Water Quality
DWPR Phase I

Parameter	Units	Count	Median[1]	Range		Average[1]	Standard[1, 2] Deviation	95% Confidence Interval[1, 2]	
				Low	High			Low	High
				7.5	8.0			7.7	7.8
Conductivity	µS/cm	40	379	224	448	346	72	324	368
Turbidity	NTU	46	11.9	4.7	622	63.3	118.6	29.0	97.6
Temperature	C	44	28.1	20.9	29.1	26.3	3.0	25.4	27.2
TDS	mg/L	11	212	136	356	235	82	187	284
Alkalinity	mg/L	12	79.6	62.7	99.0	78.4	12.0	71.6	85.2
Calcium	mg/L	12	37.7	27.1	44.2	36.4	5.7	33.2	39.7
Magnesium	mg/L	12	10.4	6.5	16.4	10.0	2.7	8.5	11.5
SiO_2	mg/L	12	0.10	0.06	0.54	0.16	0.15	0.08	0.24
Iron	mg/L	12	0.170	0.060	>3.00	0.650	0.909	0.136	1.164
Manganese	mg/L	12	0.080	0.061	>0.700	0.214	0.228	0.085	0.342
Barium	mg/L	9	0.047	0.035	0.120	0.055	0.026	0.038	0.072
Strontium	mg/L	9	0.21	0.14	0.27	0.20	0.05	0.17	0.23
Sulfate	mg/L	12	60	38	78	59	15	51	67
Nitrate	mg/L	12	0.5	ND	1.1	0.5	0.3	0.3	0.7
Fluoride	mg/L	12	0.19	0.14	0.23	0.18	0.04	0.16	0.20
Chloride	mg/L	9	13.6	0.4	24.2	15.3	9.2	9.3	21.3
Total Coliforms	CFU/ 100 mL	12	43	10	271	84	83	37	131
HPC	MPN/ 100 mL	12	955	410	2,420	1,144	693	752	1,536
Algae	#/mL	8	670	344	1341	703	312	487	920
T&O	TON	12	1	1	2	1	0.3	1	1
DOC	mg/L	11	3.12	2.64	4.80	3.33	0.72	2.91	3.75
UVA	cm^{-1}	12	0.089	0.072	0.137	0.095	0.019	0.085	0.106

[1] Values reported as non-detect were assumed to be one-half of the detection limit for the purposes of statistical evaluation.

[2] f less than eight data points exist for the data, statistical analysis for standard deviation and the confidence interval was not performed.

Table 31 – RBF (Membrane Feed) Water Quality
DWPR Phase I

Parameter	Units	Count	Median[1]	Range		Average[1]	Standard[1,2] Deviation	95% Confidence Interval[1,2]	
				Low	High			Low	High
				7.0	7.8			7.5	7.5
Conductivity	µS/cm	55	445	363	510	438	45	426	450
Turbidity	NTU	54	0.117	0.074	0.540	0.131	0.066	0.113	0.148
SDI		43	2.12	0.64	3.12	2.09	0.54	1.93	2.25
Temperature	C	56	21.2	13.7	25.3	20.6	2.5	20.0	21.3
TDS	mg/L	11	290	254	342	288	30	270	306
Alkalinity	mg/L	12	149.5	139.1	171.0	151.5	10.4	145.6	157.4
Calcium	mg/L	12	59.1	53.1	75.8	60.6	7.7	56.3	65.0
Magnesium	mg/L	12	13.9	7.6	16.1	13.4	2.2	12.1	14.7
SiO_2	mg/L	12	0.08	0.06	1.00	0.16	0.27	0.01	0.31
Iron	mg/L	12	0.010	ND	0.050	0.013	0.013	0.005	0.020
Manganese	mg/L	12	0.303	0.279	0.320	0.300	0.012	0.293	0.307
Barium	mg/L	9	0.027	0.023	0.029	0.026	0.003	0.024	0.028
Strontium	mg/L	9	0.20	0.17	0.21	0.19	0.02	0.18	0.20
Sulfate	mg/L	12	60	38	78	59	15	51	67
Nitrate	mg/L	12	0.4	0.3	0.7	0.4	0.1	0.4	0.5
Fluoride	mg/L	12	0.23	0.22	0.25	0.24	0.01	0.23	0.24
Chloride	mg/L	12	22.1	16.1	27.1	21.6	3.5	19.6	23.6
Total Coliforms	CFU/ 100 mL	12	ND	ND	0	ND	N/A	ND	ND
HPC	MPN/ 100 mL	8	12,850	336	20,800	12,780	7,201	7,789	17,770
Algae	#/mL	12	ND	ND	18	ND	N/A	ND	ND
T&O	TON	12	ND	ND	ND	ND	0.0	ND	ND
DOC	mg/L	11	1.38	1.22	1.57	1.40	0.12	1.33	1.47
UVA	cm^{-1}	12	0.030	0.022	0.033	0.029	0.003	0.027	0.031

[1] Values reported as non-detect were assumed to be one-half of the detection limit for the purposes of statistical evaluation.

[2] If less than eight data points exist for the data, statistical analysis for standard deviation and the confidence interval was not performed.

Table 32 – Permeate Water Quality
DWPR Phase I

Parameter	Units	Count	Median[1]	Range		Average[1]	Standard[1, 2] Deviation	95% Confidence Interval[1, 2]	
				Low	High			Low	High
				5.3	6.6			5.7	5.8
Conductivity	μS/cm	56	3.75	2.00	37.90	4.58	4.77	3.33	5.83
Turbidity	NTU	54	0.079	0.044	0.139	0.079	0.022	0.073	0.085
TDS	mg/L	11	22.0	0.0	42.0	18.0	16.4	8.4	27.7
Alkalinity	mg/L	11	4.3	3.5	60.0	9.4	16.8	ND	19.3
Calcium	mg/L	12	ND	ND	ND	ND	0.0	ND	ND
Magnesium	mg/L	12	0.3	ND	8.8	1.1	2.5	ND	2.5
SiO_2	mg/L	12	0.03	ND	0.07	0.03	0.02	0.02	0.04
Iron	mg/L	11	0.010	ND	0.050	0.015	0.014	0.007	0.024
Manganese	mg/L	11	0.004	ND	0.007	0.004	0.001	0.003	0.004
Barium	mg/L	9	ND	ND	ND	ND	0	ND	ND
Strontium	mg/L	9	ND	ND	ND	ND	0	ND	ND
Sulfate	mg/L	12	ND	ND	1	ND	0.3	ND	ND
Nitrate	mg/L	12	0.2	0.1	0.2	0.2	0.1	0.1	0.2
Fluoride	mg/L	12	0.030	0.022	0.036	0.030	0.004	0.027	0.032
Chloride	mg/L	12	0.1	ND	0.6	0.1	0.2	0.0	0.2
T&O	TON	12	ND	ND	ND	ND	0	ND	ND
DOC	mg/L	11	0.20	0.10	0.26	0.20	0.06	0.16	0.23
UVA	cm^{-1}	11	0.003	0.001	0.004	0.003	0.001	0.002	0.003

[1] Values reported as non-detect were assumed to be one-half of the detection limit for the purposes of statistical evaluation.

[2] If less than eight data points exist for the data, statistical analysis for standard deviation and the confidence interval was not performed.

Table 33 – Membrane Concentrate Water Quality at 17-Percent Recovery
DWPR Phase I

Parameter	Units	Count	Median[1]	Range		Average[1]	Standard[1, 2] Deviation	95% Confidence Interval[1, 2]	
				Low	High			Low	High
				6.8	7.8			7.4	7.5
Conductivity	µS/cm	55	537	434	605	526	52	512	540
TDS	mg/L	11	352	216	530	351	82	400	303

[1] Values reported as non-detect were assumed to be one-half of the detection limit for the purposes of statistical evaluation.

[2] If less than eight data points exist for the data, statistical analysis for standard deviation and the confidence interval was not performed.

Table 34 – A Summary of Ohio River, RBF, and Membrane Permeate Positive "Hit" SOC Analyses
DWPR Phase I

Parameter	MRL[1]	Units	Sample 1 8-09-04	Sample 2 8-26-04	Sample 3 9-14-04	Sample 4 9-28-04	Sample 5 10-08-04
Ohio River							
Atrazine	0.050	ug/L	0.15	0.11	ND[2]	ND	ND
RBF (Membrane Feed)							
Atrazine	0.050	ug/L	ND	ND	ND	ND	ND
Membrane Permeate							
Atrazine	0.050	ug/L	ND	ND	ND	ND	ND

[1] MRL = Method Reporting Limit.

[2] ND = Non-Detect.

Table 35 A Complete List of SOC Analyses Performed During Pilot Testing at LWC
DWPR Phase I

Parameter	MRL[1]	Units
Alachlor	0.10	ug/L
Atrazine	0.10	ug/L
Benzo(a)pyrene	0.10	ug/L
Di(2-ethylhexyl)adipate	0.10	ug/L
Di(2-ethylhexyl)phthalate	0.60	ug/L
Endrin	0.10	ug/L
Heptachlor	0.040	ug/L
Heptachlor epoxide	0.020	ug/L
Hexachlorobenzene	0.050	ug/L
Lindane	0.020	ug/L
Methoxylchlor	0.10	ug/L
Simazine	0.050	ug/L

[1] MRL = Method Reporting Limit

Barium concentrations were reduced 53 percent from 0.055 to 0.026 mg/L. Iron concentrations experienced the most dramatic reduction with mean concentrations dropping 98 percent from 0.650 to 0.013 mg/L. RBF also served to reduce the scaling potential of the river water by decreasing pH by 0.3 units from 7.8 to 7.5.

RBF had a strong positive impact on the particulate, organic, and overall biological quality of the water. Average river turbidity was reduced from 63 to 0.13 NTU and consistently low SDI measurements averaging 2.09 were provided. DOC and UVA measurements (surrogates for organic fouling potential) were reduced about 65 percent through RBF from 3.33 mg/L and 0.095 cm^{-1} to 1.40 mg/L and 0.029 cm^{-1}, respectively. Average river measurements for coliforms and algae measurements were 84 CFU/mL and 703 #/mL, respectively and were both reduced to levels below detection. Taste and odor compounds (measured by the threshold odor number, TON) were very low in the river water (average value of 1 TON), but were below detection in all RBF samples. Mean HPC counts increased through RBF from 1,144 to 12,780 MPN/100 mL. This increase may have been due to sample tap contamination. Extensive research by Wang, Hubbs, and Song (2002) showed a consistent decrease in HPC counts through RBF from about 1000 to about 10 CFU/mL at this location.

9.1.2 Effect of Membrane Filtration on Water Quality

Table 36 summarizes removal/rejection performance of the RO membrane. As expected, the RO membrane process proved very effective at removing both inorganic and organic contaminants. Conductivity and TDS were rejected at 99 and 94 percent, respectively. Alkalinity, calcium, magnesium, manganese, barium, strontium, sulfate, and chloride were rejected an average of 96 percent. Silica and fluoride rejection was less at an average of 84 percent. Measured concentrations of RBF nitrate and iron were near detection limits prior to membrane treatment resulting in low calculated values for nitrate and iron rejection at 63 and 0 percent, respectively.

Table 36 – A Summary of RO Rejection Performance at LWC DWPR Phase I

Parameter	Units	Average Membrane Feed	Average Membrane Permeate	Rejection, %
pH	pH Units	7.5	5.8	N/A
Conductivity	µS/cm	438	4.58	99
Turbidity	NTU	0.131	0.079[1]	N/A
TDS	mg/L	288	18	94
Alkalinity	mg/L	151.5	9.4	94
Calcium	mg/L	60.6	ND	>99
Magnesium	mg/L	13.4	1.1	92
SiO_2	ug/L	0.16	0.03	81
Iron	mg/L	0.013[2]	0.015[2]	0[(2)]
Manganese	mg/L	0.300	0.004	99
Barium	mg/L	0.026	0.002	>92
Strontium	mg/L	0.19	0.01	>95
Sulfate	mg/L	59	1	98
Nitrate	mg/L	0.4	0.2	63
Fluoride	mg/L	0.24	0.030	87
Chloride	mg/L	21.6	99	99
T&O	TON	ND	ND	N/A
DOC	mg/L	1.40	0.20	86
UVA	cm^{-1}	0.029	0.003	91

[1] Sample permeate turbidities were much higher than expected for RO permeate waters. This is likely due in part to typical field measurement error and the fact that filtration turbidities were so near the detection limit of the instrument.

[2] Iron levels in the RBF (membrane feed) and permeate samples were near limits of detection.

Like inorganic parameters, particulate, organic, and biological contaminants were effectively removed through the RO process. Although reduced by a significant degree, sample permeate turbidities were much higher than expected for RO permeate waters. This is likely due in part to typical field measurement error and the fact that the permeate turbidities were so near the detection limit of the instrument. The ability of membranes to remove particulate matter to extremely low levels is documented elsewhere in the literature. DOC and UVA rejection was 86 and 91 percent, respectively. No taste, odor, and SOCs were detected in RBF and permeate samples. Therefore, no rejection data is available.

In summary, the RO membrane process performed as expected with regard to effective contaminant removal and provided an average contaminant rejection of greater than 90 percent.

9.2 Hydraulic Performance

Operating conditions for the single element membrane pilot plant were given in chapter 6. Single element pilot testing at LWC was conducted under constant flux (19.7 gfd), increasing pressure conditions from August 2 to October 22, 2004. Figure 20 shows the hydraulic performance throughout the piloting.

As indicated in figure 20, net driving pressure (NDP) data exhibited a U-shape pattern. This is directly related to the effects of feed water seasonal temperature change. Colder water temperatures require greater NDP to produce the same membrane flux. Prior to pilot testing, the RBF well was off-line several months for maintenance. Upon start-up of the RBF well, the water temperature rose relatively rapidly until reaching a relative equilibrium with the river. As a result, a relatively rapid change in NDP is notable at the beginning of the run.

Specific flux is a calculated parameter adjusted for temperature to indicate the relative permeability of the membrane. As the membrane fouls, specific flux values will decline. Membranes are typically taken off-line for chemical cleaning when specific flux drops 20 percent when compared to values recorded at start-up. As shown in figure 20, no significant drop in specific flux was noted during the 75 days of operation indicating that no significant fouling occurred. This was verified through visual inspection of the membrane module at the end of the pilot test. Figure 21 is a picture of the membrane following 75 days of operation showing no visual signs of significant fouling.

In general, cartridge filters were replaced as necessary when the pressure drop through the filter exceeded 10 psi (the manufacturer's limit). However, in several cases, the cartridge filter was replaced before achieving the maximum pressure drop to allow unattended operation through the weekend.

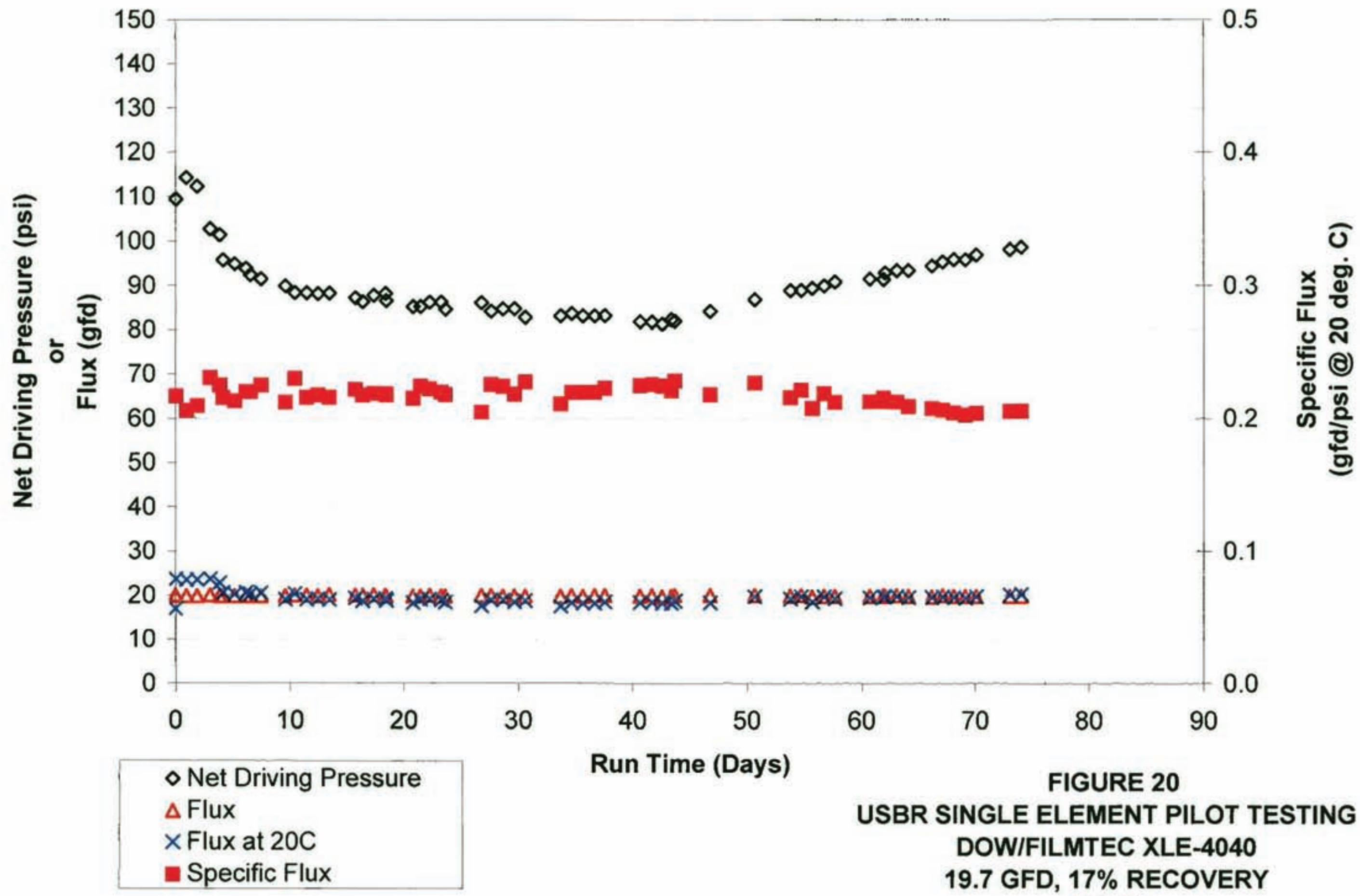

FIGURE 20
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC

Figure 21 – Photograph Showing No Significant Fouling of the Membrane Following 75 Days of Operation at the LWC.

Replacement frequency ranged from as low as 45 to 190 hours of continuous operation, with an average of about 88 hours. In every case, the filters were fouled with black/charcoal particulate matter. The nature and color of the foulant suggests it was due to particulate manganese. The relatively high concentration of manganese in the membrane feed water (RBF water Mn = 0.3 mg/L) supports the idea that manganese played a major role in cartridge filter fouling. An example of a fouled cartridge filter is shown in figure 22. The filter shown was operated for 190 hours prior to this photo. The relatively frequent replacement of the cartridge filters suggests that the loading rate (3.4 gpm/10 inches) was too great for this source water. Ideally, cartridge filter replacement frequency should not be more frequent than 30 days.

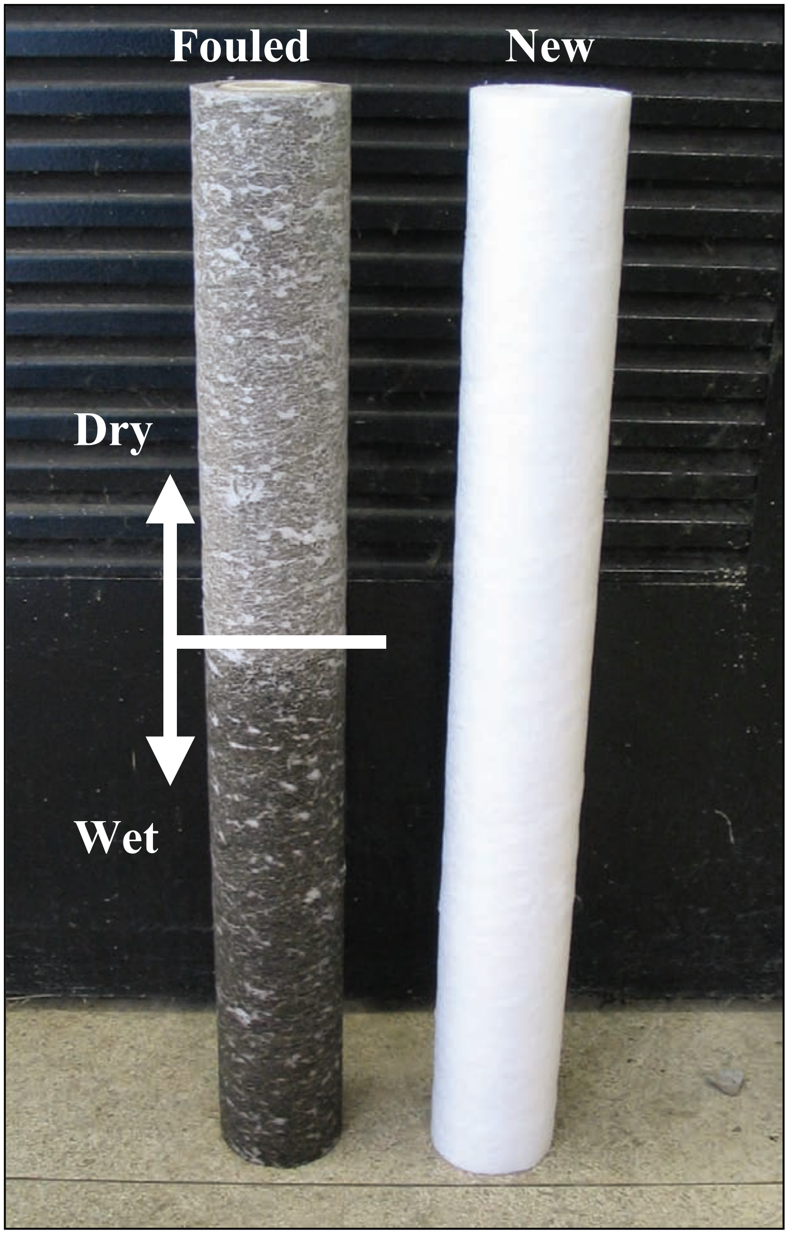

Figure 22 – Photograph Showing a Cartridge Filter Fouled with Black Manganese Particulate Matter Following 190 Hours of Operation at the LWC.

10. Concentrate Disposal

Disposal of concentrate from membrane processes is a challenging issue that contributes greatly to costs and, in some locations, has precluded the application of RO technology. There are currently many levels associated with the regulation of membrane concentrate. Federal, State, and local agencies all have specific requirements for its disposal. The process of complying with these regulations is complex and requires a detailed review in the pre-design phase. This section includes an overview of the regulations, which currently govern concentrate disposal in the United States, and a review of the most common types of concentrate disposal methods in the US. Specific discussion on the feasibility of each alternative in relation to the DMWW facility is also included to exemplify the engineering and regulatory decisionmaking effort involved when determining appropriate concentrate disposal methods for a given utility.

10.1 Concentrate Disposal Regulations

This section includes an overview of many of the regulations, which currently govern disposal of membrane concentrate. Specific State and local regulations must also be considered when planning for concentrate disposal.

10.1.1 Clean Water Act (CWA)

The discharge of waste, domestic wastewater plant effluent, and membrane concentrate to any surface water is regulated by the CWA. The CWA requires all point source discharges to have a National Pollutant Discharge Elimination [NPDES] permit. While the EPA administers the NPDES program, the State of Iowa is responsible for issuing permits and establishing water quality based discharge limits for receiving waters.

Water bodies within the State of Iowa have been assigned a class rating that reflects water quality and potential uses. NPDES permits are issued to discharges and specify discharge limits for maintaining the water quality standards particular to that class of receiving water. This process is know as Iowa's antidegradation policy for maintaining surface water quality. In addition to discharge limits that serve to protect water quality, NPDES permits may also specify requirements for monitoring, operation and maintenance of the waste treatment facilities, reporting, and record keeping. Additionally, new (or expanded) discharges must meet the test of public interest and public acceptance. Disposal of concentrate generally meets the needs of public interest. However, a balance between the public's needs and environmental protection must be considered along with a review of any disposal alternative. Generally speaking, alternatives meeting public needs must be formally reviewed. Reuse (such as irrigation), multiple discharge locations, and dilution with domestic wastewater plant effluent should all be considered.

Discharge of membrane concentrate to a domestic or municipal wastewater treatment plant is also regulated by the CWA. While indirect discharges of concentrate are not required to hold a specific NPDES permit (amount typically limited to 20 percent of the wastewater average daily flow), the membrane plant may be required to comply with the EPA Pretreatment Control Program standards. Pretreatment standards are focused on preserving the performance of the wastewater treatment facilities. Corrosive and/or toxic contaminants that would inhibit the biological processes at the wastewater plant must be removed from the concentrate water before discharge to the sewer.

The CWA also regulates disposal of sewage sludge from wastewater treatment facilities. It is unlikely that the concentrate will contribute significantly to the concentration of solids from a wastewater treatment facility. However, this should be considered and limits may eventually need to be imposed upon the volume of discharge accepted by a wastewater plant.

10.1.2 Safe Drinking Water Act (SDWA)

The SDWA specified the underground injection control (UIC) program regulations that were developed by the EPA. The SDWA UIC program regulates the disposal of concentrate via deep well injection. Deep injection wells are ranked in Classes 1-5. Concentrate is currently classified as an industrial waste and requires deep well injection wells be Class 1 construction. UIC regulations are very stringent and encompass requirements from geological surveys, well construction, well operation, and extensive monitoring. Currently, Iowa does not have primacy with regard to UIC regulations. These regulations are administered in the State of Iowa by the EPA.

The Wellhead Protection Program (WPP) is also administered as part of the SDWA. These regulations are intended to protect Underground Sources of Drinking Water (USDW), which are defined as an aquifer with less than 10,000 mg/L TDS. The WPP is intended to protect USDW from contamination due to underground injection of wastewater, or land application of wastewater from a reuse system.

10.1.3. Resource Conservation and Recovery Act (RCRA)

Concentrate is typically not considered RCRA classified waste. However, in RCRA subtitle C specific language is included regarding water and wastewater treatment plant residuals management. Therefore, it is the responsibility of a water utility to determine if the concentrate meets the definition of a hazardous waste under RCRA. For a waste to be considered hazardous under RCRA, it must be:

- A solid waste (membrane concentrate could, in specific circumstances, meet the very broad definition of a solid waste under RCRA)
- Specifically listed in 40 Code of Federal Regulations 261, or
- Have the characteristics of ignitability, reactivity, corrosivity, or toxicity.

Although concentrate waters are non-ignitable and non-reactive, some concentrate may be corrosive or exhibit toxicity. If it is determined that the concentrate meets these definitions, a EPA generator number must be obtained and specific treatment and operational design requirements will be imposed.

10.1.4 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

Water and wastewater treatment residuals are only applicable to CERCLA if the water plant has stored, treated, or disposed of a hazardous waste as defined by RCRA. Particularly for Mid-Western states, it is not anticipated that RO plants would have reportable quantities of any hazardous substances as defined by CERCLA.

10.1.5 Solid Waste Disposal Act (SWDA)

Non-hazardous solid waste disposal activities are regulated by the SWDA. This a State-administered program authorized by the EPA and would apply to membrane plants that use evaporation/land filling as a method of concentrate disposal.

10.1.6 Hazardous Materials Transportation Act (HMTA)

Execution of the HMTA is delegated to the U.S. Department of Transportation. Residuals from water or wastewater treatment processes that are transported off-site are regulated by the HMTA. Concentrate disposal of zero liquid discharge salts or evaporation pond residuals may fall within the jurisdiction of this act if they are found to contain hazardous levels of contaminants. Some membrane facility designs include removal of chemical cleaning waste by truck, which would also require compliance with the HMTA.

10.1.7 Toxic Substances Control Act (TSCA)

TSCA controls the sale of toxic substances. If a concentrate is determined to be toxic and is sold for reuse (i.e., blended with treated wastewater for land application), compliance with the TSCA would be required.

10.2 Concentrate Disposal Alternatives

In many cases, concentrate disposal is the main driver regarding planning and design considerations for construction of new membrane treatment facilities. It is therefore critical to develop a plan(s) for membrane concentrate disposal which addresses all of the key issues including regulatory compliance, reliability, and overall cost. As shown in figure 23, there are six main alternatives for disposal and reuse of membrane concentrate including: 1) Surface water discharge, 2) WWTP discharge, 3) Irrigation/Reuse, 4) Evaporation Ponds, 5) Deep well injection, and 6) Zero liquid discharge. Figure 24 is a comparison of the relative number of membrane plants within the continental United States that use each of these disposal methods. As shown in the figure, by far, the most common disposal methods are surface discharge and discharge to a WWTP, which account for nearly 75 percent of all membrane plants. Irrigation/reuse, deep well injection, and evaporation ponds combined make up the remaining 25 percent. The number of plants currently using zero liquid discharge are less than 1 percent. Data gathered for concentrate water quality and toxicity at the DMWW facility were reviewed to determine the feasibility and viability of each of these six main disposal alternatives. A description of each of these alternatives and how they specifically relate to the DMWW is given in the following sections.

10.2.1 Surface Water Discharge

Surface water disposal involves conveyance and discharge to a point of outfall such as a lake, stream, bay, tidal lake, brackish canal, or ocean. Discharge can be direct or following a degree of treatment such as aeration, scale-control, or passage over soil prior to water body discharge. The location and potential required concentrate treatment necessary prior to discharge are determined by regulatory agency water quality standards and bioassay toxicity testing. For this type of disposal an NPDES permit is required and maintained by the membrane plant owner. Although design and construction considerations are minimized with surface water disposal, regulatory requirements at the local, State, and Federal levels can be tedious.

Concentrate water quality analysis collected at the DMWW facility were compared to the Iowa DNR water quality standards for two likely receiving waters: Raccoon River segment from its mouth to Polk-Dallas County line and the Des Moines River segment from Lee County to the confluence with the Raccoon River. The State classifies these receiving waters as listed below:

- Raccoon River Segment: A1 and B (WW).
- Des Moines River Segment: A1 and B (WW).

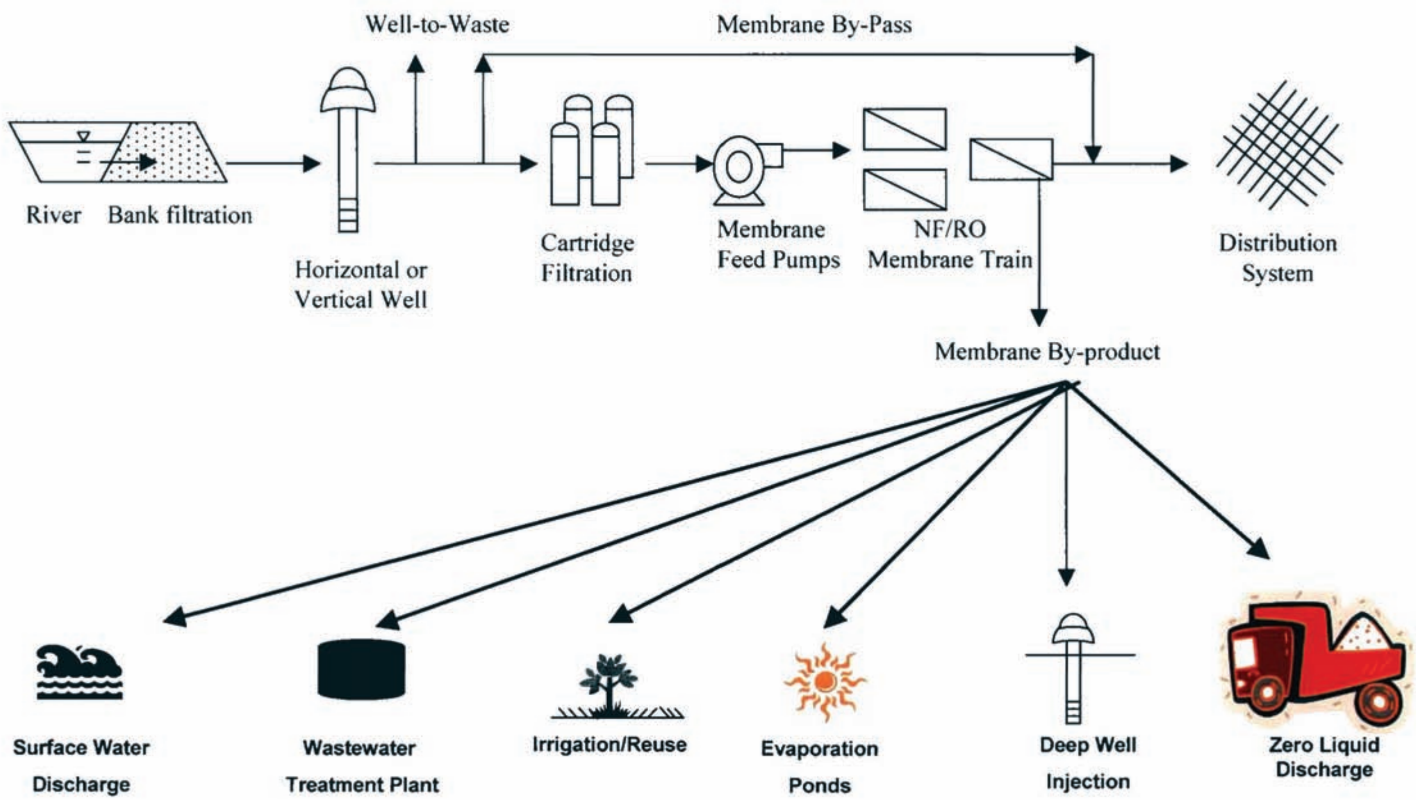

FIGURE 23
A CONCEPTUALFULL-SCALE
FLOW DIAGRAM OF THE SIX MOST COMMON
METHODS OF CONCENTRATE DISPOAL

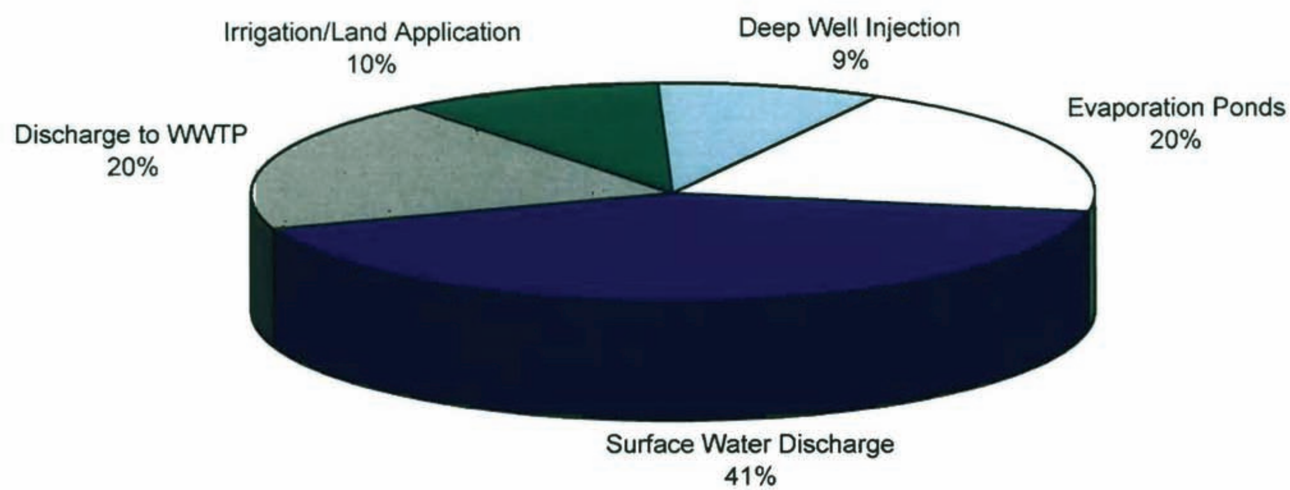

FIGURE 24
A COMPARISON OF THE RELATIVE NUMBER OF MEMBRANE PLANTS IN THE US USING EACH OF THE MAIN CONCENTRATE DISPOSAL METHODS (2004)

As stated in section 7.3.2 nearly all of the tested parameters directly met their respective Class A and B (WW) discharge standards. One parameter of concern with regards to the discharge of this DMWW concentrate is TDS. Section 61.3 of the Iowa Chapter 61 standards states that “Total dissolved solids shall not exceed 750 mg/L in any lake or impoundment or in any stream with a flow rate equal to or greater than three times the flow rate of upstream point source discharges.” Low flows for the Raccoon River and Des Moines River are on the order of 21 mgd and therefore, even under these low flow conditions, provide a large dilution potential for the 2 mgd of concentrate. (It should be noted, however, that the State restricts the amount of flow that can be used in the dilution calculation to 25 percent of the actual river flow). Many of the water quality restrictions are considered passing if the parameter meets the listed criteria at the downstream end of the discharge mixing zone. The State TDS limit of 750 mg/L, however, must be met within the mixing zone of the discharge. Options to meet this restriction include the use of an outfall diffuser system or dilution through mixing with wastewater treatment plant effluent prior to river discharge. Should dissolved oxygen levels fall below the State requirement of 5 mg/L, aeration would be required prior to discharge. Based on historical data for dissolved oxygen (averaging <5 mg/L) in the DMWW gallery water, aeration will be required.

In addition to specific water quality standards, surface water discharge generally mandates requirements regarding bioassay toxicity. The results of bioassay toxicity testing as presented in 7.3.2 demonstrate the low toxicity of this water. Overall, surface water discharge is a viable alternative for concentrate disposal at the DMWW.

10.2.2 Wastewater Treatment Plant (WWTP) Discharge

Sewer discharge is dependent on the ability of the WWTP plant to:

- Accept relatively higher salinity discharge and other potential contaminants,
- Maintain adequate water quality at the outfall location. For example, the WWTP may be affected by total dissolved solids restrictions or other limiting water quality concerns,
- Provide adequate conveyance capacity from the point of discharge to the WWTP, and
- Provide adequate treatment capacity for the additional flow.

Average daily flow at the Des Moines WWTP is on the order of 50 mgd. Based on this flow and the concentrate water quality data presented in section 7.3.2, dilution potential is available to help maintain adequate TDS levels for the protection of biological processes through the plant. The dilution of TDS and other concentrate contaminants is also a benefit with regard to ultimate river discharge water quality restrictions. Although technically feasible, further studies should be conducted to review collection system and plant capacity and verify the viability of this alternative for DMWW.

10.2.3 Irrigation/Reuse

Irrigation is sometimes used for concentrate of relatively low salinity. For this reason irrigation is more common with NF concentrate than RO concentrate waters. Vegetation compatible with the water quality is essential. In addition, if the chance for surface water runoff exists, additional permitting including an NPDES permit is required. Site selection is very important, depending on the concentrate water quality, to avoid public health concerns and contact with crops for human consumption. Examples of site alternatives that minimize public health concerns are landscape vegetation, highway medians, airport strips, golf courses, parks, and recreational or wildlife areas.

In clay-bearing or fine-textured soils, a high sodium ion concentration can have a negative effect on soil permeability and may be toxic to plants. The U.S. Department of Agriculture developed a measure of sodium sensitivity known as the sodium adsorption ratio (SAR). Some membrane concentrate waters exhibit high SAR values (i.e., greater than 9) and may decrease soil capacity and/or kill plants. Trace elements should also be monitored since a drop in pH can cause a release of metals that jeopardizes surrounding water quality. In addition, backup storage capacity must be considered and should be sized conservatively to account for variation in the groundwater table, precipitation, and demand.

Other considerations that impact the feasibility of irrigation disposal include:

- Annual rainfall and seasonal variation in water demand
- Proximity of membrane plant to site of irrigation
- Depth to groundwater or proximity to other potential receiving waters
- Soil composition and permeability
- Availability of salt tolerant landscape vegetation
- Containment of irrigated runoff water
- Availability and cost of land

Perhaps the largest considerations with respect to the DMWW are the annual rainfall and seasonal variation in demand (and the resulting storage requirements). Annual rainfall in the Des Moines area is on the order of +32 inches per year (in/yr). In addition, nearly 5 months out of the year in are colder months not requiring irrigation. Concentrate generated during these months would need to be stored or disposed of using some other method. Although irrigation may be feasible for portions of the year, the overall reliability of this method for use in the Des Moines area is low.

10.2.4 Evaporation Ponds

Evaporation ponds use solar energy to reduce or eliminate concentrate flows. This process is land-intensive and requires relatively warm, dry climates with level terrain. Dry salt is the waste product and it must be characterized and disposed of accordingly as solid waste. The main benefits of evaporation ponds for concentrate disposal include reduced operation and maintenance cost, easy construction, and low mechanical equipment requirements. In some cases, these advantages are offset by land requirements and risk associated with potential contamination of underground drinking water supplies. A comparison of typical precipitation and evaporation rates is an indicator of whether this option is practical for the location of interest, but it is generally only viable in the southwestern portion of the United States. Special consideration must be given to monthly variation in evaporation, yearly changes in rainfall, and the potential for several wet years in succession.

A comparison of typical precipitation and evaporation rates were conducted with regard to the viability of evaporation ponds at the DMWW. Annual average evaporation losses in the Des Moines area are approximately 33 in/yr. However, evaporation pond designs must take into account a reduction in evaporation rates caused by the increase in salinity. Typical engineering design includes a 0.70 evaporation multiplier to account for evaporation rate decrease. Applying this factor to the annual average evaporation rate leaves a design evaporation potential of approximately 23 in/yr, which is less than the average rainfall of about 32 in/yr for the Des Moines area. Because more water accumulates than evaporates, this disposal method is not a viable alternative for DMWW.

10.2.5 Deep Well Injection

Deep well injection (or injection wells) are currently used in many areas of the United States for membrane concentrate disposal. This process involves injection of membrane concentrate into a subsurface aquifer. Well depths vary depending on geographic area, but typically range from 1,000 to 8,000 feet. The injection aquifer must be isolated from other aquifers by means of one or more geologic confining layers. Because injected concentrate displaces existing groundwater (similar to aquifer storage and recovery schemes), it is important to model potential impacts on the entire radius of influence, not just the point of injection. The radius of influence is dependant on site-specific conditions, but is typically on the order of 2 miles. This radius must be void of vertical conduits (i.e., geologic faults, poorly abandoned wells, etc.) that could potentially channel waste concentrate back up into underground sources of drinking water.

As stated previously, injection wells are regulated by the Federal Underground Injection Control program. Currently, membrane concentrate is regulated as an industrial waste, which mandates that injection wells be Class 1 construction. Class 1 wells are required to have extensive safety built into them to ensure that waste does not contaminate aquifers used for, or potentially used for water supply. Permitting a deep well requires extensive monitoring before, during, and after installation, which contributes greatly to the cost of this disposal alternative. In addition, pretreatment (such as cartridge filtration to prevent plugging of the well or chemical addition for corrosion and/or precipitation control) may be required prior to injection.

Favorable geology and site-specific conditions are typically found in the mid-continental, Gulf Coast, and Great Lakes regions. Southern Florida currently leads the nation in operating Class I disposal wells and has more membrane drinking water plants than any other state. Due largely to State geology, Iowa does not currently have any concentrate injection wells. The depth to bedrock in the Des Moines region is very shallow, on the order of 60 feet. For this reason, deep well injection of concentrate is not a feasible alternative in the Des Moines area.

10.2.6 Zero Liquid Discharge

Zero liquid discharge (ZLD) processing of RO concentrate waters consists of a mechanically enhanced thermal evaporation process and a final crystallization process. The final waste product from ZLD is a solid waste (i.e., 40 dry metric tons of salt per day, 5 to 15 percent moisture content from ZLD processing of 2 mgd of DMWW concentrate) that can be disposed of in a landfill. Typically, the final crystallization process takes place within an evaporation pond that may vary in size from 3 to 5 acres. Evaporation ponds are most frequently used because they are the most cost effective crystallization alternative. However, there are potential environmental impacts including liner failure and water fowl exposure to concentrated toxic inorganic compounds. In areas were evaporation cannot be used (i.e., due to climate or environmental protection) final crystallization can be performed using mechanically enhanced thermal process.

Figure 25 depicts a process flow diagram for a typical ZLD process. Although the basic processes of ZLD consist of a brine concentrator followed by a crystallization process, each equipment supplier has their own variation on this basic concept using a combination of heat and pressure (i.e., positive or negative pressure) to enhance the evaporation and crystallization process. The example presented in figure 25 uses vapor compression (e.g., heat pump) to enhance the thermodynamics of the evaporation/distillation process.

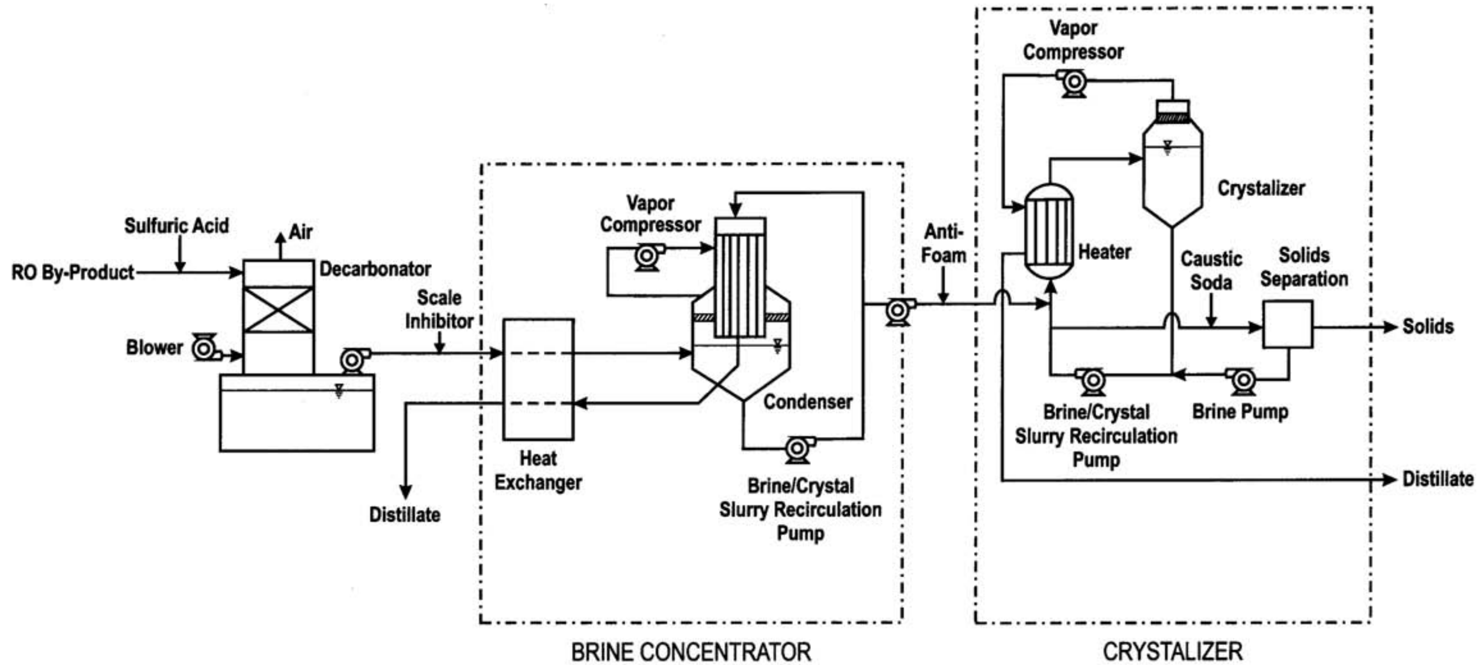

FIGURE 25
EXAMPLE ZLD PROCESS FLOW DIAGRAM

A combination of chemical conditioning and a brine slurry recirculation is also commonly used to prevent mineral scale build-up within the equipment and on the heat exchanging surfaces.

The end product from ZLD will consist primarily of calcium sulfate. However, trace concentrations of toxic inorganic contaminants (i.e., selenium) may also be present. The ultimate disposal of the end product will depend on its characteristics. For ultimate disposal in a landfill, the end product must undergo:

- The EPA Paint Filter Test to classify the waste as a solid or liquid waste.

- Toxic Contaminant Leachate Potential (TCLP) Test to determine if toxic contaminants can leach from the solid waste.

Before implementation of any ZLD process, sample wastes should be produced and analyzed to verify compliance with federal, state, and local disposal regulations. Other specific considerations for ZLD processes are the availability of potentially significant amounts of cooling water and aesthetic concerns with the relatively tall equipment required for this process. With respect to the DMWW, ZLD is one potential alternative available for disposal of concentrate.

10.2.7 A Comparison of Alternatives for Use at the DMWW

The overall viability of all of the six conventional concentrate disposal options discussed above were evaluated on a relative scale as they relate to the DMWW facility. Each alternative was evaluated based upon feasibility, required treatment, relative permitting, required engineering, and relative costs as described below.

10.2.7.1 Feasibility

Due to the length of winter and relatively high annual rainfall compared to evaporation in Des Moines, irrigation and evaporation pond disposal alternatives were determined not to be feasible. In addition, deep well injection was eliminated as an option due to the unsuitable local geology and relatively shallow depth to bedrock in the Des Moines area.

10.2.7.2 Treatment Required

Treatment of concentrate water is often required before disposal. Membrane concentrate water may be corrosive and/or toxic compounds such as hydrogen sulfide may need to be removed. In addition, aeration may be required to elevate the dissolved oxygen concentration to an acceptable level. Treatment requirements were included as a criterion for assessing viability of disposal options to provide a basis for understanding what is involved in engineering or permitting of concentrate discharge. Options requiring sophisticated treatment prior to discharge or treatment were given a high rating.

10.2.7.3 Engineering

Some disposal options require extensive engineering. Where infrastructure does not currently exist or cannot be easily integrated into the DMWW facility, a high rating was provided. Disposal of concentrate water to a surface water was given a low rating because it could easily be integrated into the DMWW facility. It was assumed that no construction of additional capacity would be required for discharge to the WWTP. Therefore, this option was given a low rating for engineering. Due to chemical pretreatment, cooling water, additional power infrastructure, etc., ZLD was given a high rating for engineering.

10.7.2.4 Permitting

Discharge of membrane concentrate to a surface water (i.e., direct discharge or blending with WWTP effluent) requires federal, state, and local permits and was therefore given medium ratings for permitting. Discharge to a WWTP does not require significant permitting and was therefore rated low for this category. This assumes that the concentrate flow does not exceed 20 percent of the WWTP capacity. In the case of the DMWW, the concentrate discharge is only approximately 3-4 percent of the total WWTP flow.

10.2.7.5 Relative Cost

Costs were provided on a preliminary basis for each feasible alternative. For this comparison it was assumed that no additional WWTP capacity would be required for that option resulting in a low overall cost rating. Economics for concentrate disposal have historically shown that ZLD is the most expensive option due to the high energy requirements for this process (i.e., on the order of 400-1,000 kilowatts (kW)/1,000 gallons, depending on the specific process used and end product desired). In addition, although the footprint for ZLD is relatively small, capital costs are very high. Preliminary cost estimates for the capital required for ZLD treatment of 2 mgd of concentrate water from DMWW are $16 million. Furthermore, given the chemistry of the concentrate water, a solid end product may not be possible. Landfill disposal of such a liquid waste often is more restrictive than solid end products. One potential ZLD alternative would be to lime soften the RO concentrate stream and process this water through high-rejection seawater membranes. This would serve to further reduce the volume of the concentrate water requiring ZLD (i.e., from 2 to 0.4 mgd) and, with the removal of much of the calcium and magnesium, could provide concentrate water chemistry suitable for a solid end product. The ZLD equipment costs for treating 0.4 mgd of concentrate would be on the order of $7 million, but does not include the additional capital required for lime softening or high-rejection membranes.

Table 37 presents a summary of the overall viability of each concentrate disposal alternative for the DMWW. Due to the extremely high costs associated with ZLD, this alternative was given a low rating for overall viability at the DMWW facility. As shown in the table, the most viable alternatives are discharge to a surface water or WWTP. Costs were developed for these two alternatives in chapter 11.

Table 37 – Preliminary Evaluation of Concentrate Disposal Options for the DMWW DWPR Phase 1

	Discharge to a Surface Water	Discharge to a Domestic Wastewater Treatment Plant	Irrigation	Evaporation Ponds	Injection Wells	Zero Liquid Discharge
Feasibility	Yes[1]	Yes	No[2]	No	No	Yes
Treatment Required	Yes	Yes	–	–	–	No
Relative Engineering Requirements	Low	Low	–	–	–	Medium
Relative Permit Requirements	Medium	Low (N/A)	–	–	–	Low
Relative Cost	Low	Low	–	–	–	Very High
Relative Viability for Des Moines Iowa	High	High	–	–	–	Low

[1] Could be either direct discharge or blended discharge with WWTP effluent.

[2] Irrigation may be possible for portions of the flow during portions of the year, but year round disposal of 100 percent of the concentrate flow by this method is not feasible.

11. Costs Estimates

11.1 Capital Costs

Budgetary-level cost opinions (present worth) were developed for RBF pretreatment, UF pretreatment, conventional treatment (flocculation, sedimentation, and filtration) and RO membrane system costs. In addition, costs were developed for the two most viable concentrate disposal alternatives as presented in chapter 10. Cost opinions were based on preliminary data and conceptual design. Ultimate project costs will depend on actual labor and material costs, actual site conditions, competitive market conditions, final project scope, final project schedule, and other variable factors. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

The level of accuracy for construction cost estimates varies depending on the level of detail to which the project has been defined. Feasibility studies and master plans represent the lowest level of accuracy, while pre-bid estimates (based on detailed plans and specifications) represent a higher level. The American Association of Cost Engineers has developed the following guidelines:

Type of Estimate	Anticipated Accuracy
Order-of-Magnitude (Facilities Plans)	+50% to -30%
Budget Estimate (Predesign Report)	+30% to -15%
Definitive Estimate (Pre-Bid)	+15% to -5%

The opinions of cost presented in this report should be considered order-of-magnitude estimates, with an anticipated level of accuracy of +50 to -30 percent. This cost opinion for the listed alternatives represents January 2005 dollars. Order-of-magnitude costs include a contingency of 25 percent. This contingency represents undeveloped or unforeseen design details at the planning stage. Design for additional or required process equipment and structures that are known, but not yet defined, were also included. Costs for the maintenance of operations during construction were not included. Legal and administrative costs reflect assistance with permitting and financing. For planning purposes, the percentages of engineering costs, and for legal and administrative costs were 10 percent each. Costs for contractor's fees, overhead, and profit were also included in the estimate at 8 percent. Capital costs were calculated as the sum of the construction, engineering, legal and administrative, and contractor's costs.

Specific assumptions related to the costing of RBF, UF, conventional treatment, and RO are listed below:

- The intent of these cost estimates is to show relative cost savings associated with the tested treatment technology. Costs were developed based on specifics associated with the DMWW location. Assumptions used for the development of these costs may or may not be applicable to other utilities.

- Costs associated with RBF pretreatment include collector well installation, hydrogeologic testing, and pump/piping related costs. For the purposes of this evaluation it was assumed that an RBF capacity of 16.5 mgd would be required for delivery to downstream processes based on the amount of blending available to meet water quality goals. The total RBF flow includes 6.5 mgd for raw water bypass and 10 mgd for feed to the RO treatment system.

- The total RBF capacity would be delivered through seven collector wells of approximately 2.5 mgd each. Each collector well was assumed to be constructed to a subsurface depth of 60 feet with an aboveground height of 20 feet to remain above surface water flood stage.

- It was assumed that water produced from each of the collector wells would be combined in a common header approximately 0.5 miles long for conveyance to the treatment facility.

- UF pretreatment costs were based on the use of UF to treat river water at a capacity of 16.5 mgd, sufficient for both 6.5 mgd of raw water bypass and 10 mgd of RO feed. For this alternative it was assumed that no RBF treatment would be used and that UF would treat river water directly.

- Conventional pretreatment costs were based on treating river water at a capacity of 16.5 mgd, sufficient for both 6.5 mgd of raw water bypass and 10 mgd of RO feed. For this alternative, it was assumed that no RBF treatment would be used and that water would be treated directly from the river.

- Collection of raw water for conventional treatment via an intake structure at the river and pumped approximately 0.5 miles to the treatment facility.

- Sewer disposal of solids produced from filter backwash and sedimentation. Costs for this solids handling include low-lift pumps and a basin to equalize flow to the sewer.

- Chlorine contact time is achieved through the finished water storage tank.

- Design criteria typical of conventional surface water treatment plants were used to size and cost conventional treatment processes. Similarly design criteria typical of UF treatment plants was used to size and cost UF treatment processes.

- Capital costs associated with a new RO membrane plant are largely dependent upon feed water quality and finished water quality goals. These factors not only affect the type of membrane, pressure energy requirements, rejection, and the degree of blending, but also the amount of RO recovery that can be achieved. For example, in order to produce 10 mgd of finished water capacity, the increase in an RO system recovery from 75 to 85 percent will decrease the required pretreatment and pumping capacity (and subsequent capital and O&M costs) from 13.3 to 11.8 mgd. For this costs analysis, a system recovery of 80 percent was used to reflect a typical plant operation.

- Although nitrate is also of concern for portions of the year at the DMWW and other inland utilities, the water quality collected from this research indicates that hardness is the most restricting contaminant with regards to raw water bypass blending. Based on the rejection data collected during piloting a permeate ratio (percent of permeate flow compared to total blended water flow) of 55 percent is capable of meeting a hardness goal of 150 mg/L as $CaCO_3$ at all three of the testing locations. (Note: at this blend ratio nitrate concentrations of the blend will be <8 mg/L-N even with membrane feed concentrations of up to 15 mg/L-N). This blending ratio was assumed for all three pretreatment options (RBF, UF, and conventional treatment).

- Concentrate disposal costs were developed based on specifics associated with the DMWW location. It is important to note that concentrate disposal alternatives used for these estimates may or may not be feasible at other utilities.

- For the purposes of evaluating concentrate disposal to a WWTP, it was assumed that sufficient conveyance and treatment capacity already existed to handle the additional 2 mgd of RO membrane concentrate.

A summary of the design parameters used for development of conventional treatment, UF, and RO capital costs are presented in tables 38-40, respectively. Table 41 shows a summary of the capital costs associated with the addition of RO facilities using RBF, UF, and conventional pretreatment. The capital costs presented herein include construction of a raw water conveyance, process buildings, yard piping, RO side stream treatment, 1 MG of finished water clear well capacity, and other components typically associated with RO plant design. These costs do not include finished water pumping or finished water conveyance costs. Detailed worksheets developed for these costs are included in Appendix D. As shown in table 41, capital costs associated with RBF are approximately 10-20 percent less expensive compared to UF and conventional treatment processes.

Table 38– Design Parameters Used to Cost Conventional Treatment DWPR Phase I

Design Parameter	Units	Value
Operating Conditions		
Design Flow	mgd	16.5
Raw Water Intake		
Number of Intake Structures	#	1
Number of Pumps	#	7
Diameter of Transmission Piping	inches	24
Length of Transmission Piping	miles	0.5
Unit Process Design		
Chemical Feed System	–	Coagulant
Rapid Mix Detention Time	minutes	0.5
Rapid Mix G-Value	s^{-1}	600
Flocculation Detection Time	minutes	30
Flocculation G-Values	s^{-1}	60:50:40 [1]
Sedimentation Basin Loading Rate	gpm/ft^2	0.55
Filter Media	Type	Multi-Media
Number of Filters	#	10
Filter Media Total Depth	inches	36
Filter Loading Rate	gpm/ft^2	3

[1] Assumes three-stage tapered flocculation.

Table 39 – Design Parameters Used to Cost UF DWPR Phase I

Design Parameter	Units	Value
Operating Conditions		
Design Flow	mgd	16.5
Raw Water Intake		
Number of Intake Structures	#	1
Number of Pumps	#	7
Diameter of Transmission Piping	inches	24
Length of Transmission Piping	miles	0.5
UF Process Design		
Chemical Feed System	–	Coagulant
UF Flux	gfd	50
Membrane Element Surface Area	ft^2	530
Number of Membrane Elements	#	623
Clean-in-Place System	Type	Caustic and Citric Acid

Table 40 – Design Parameters Used to Cost an RO System DWPR Phase I

Design Parameter	Units	Quantity
Operating Conditions		
RO Feed Flow	mgd	10
RO Permeate Flow	mgd	8
RO Concentrate Flow	mgd	2
RO Recovery	%	80
Flux	gfd	15
Scale inhibitor Dose	mg/L	3.5
Blend to Meet	Hardness mg/L as $CaCO_3$	150
Blend Ratio (Permeate/Total) *100	%	55
Raw Water Bypass Flow	mgd	6.5
Total Flow to Distribution (RO Permeate + Bypass)	mgd	14.5
Skid Design		
Number of Skids	#	4
Skid Feed Capacity (each)	mgd	2.5
Number of Stages	#	2
Array Configuration	–	32:16
Elements per Vessel	#	7
Element Characteristics		
Dimensions	in	8x40
Brine Spacer Thickness	in	0.0028
Element Surface Area	ft^2	400

Table 41 – A Summary of Capital Costs Associated with RO Using RBF and Conventional Treatment DWPR Phase I

Component	RBF Pretreatment	UF Pretreatment	Conventional Treatment
RBF	$15.6	–	–
UF	–	$18.7	–
Conventional Treatment	–	–	$24.6
RO	$25.1	$25.1	$25.1
Concentrate Option 1 - Surface Water	$1.10	$1.10	$1.10
Concentrate Option 2 - WWTP	$0.37	$0.37	$0.37
Total w/Concentrate to Surface Water	$41.8	$44.9	$50.8
Total w/Concentrate to WWTP	$41.1	$44.2	$50.1

Note: Costs are in Millions as January 2005 Dollars. ENRCCI = 7112.

11.2 Operation and Maintenance Costs

Operations and maintenance can be the most significant portion of lifecycle costs for membrane desalting facilities. RO is an energy-intensive process and compared to conventional treatment requires more chemicals and manpower for daily operations. Many of these costs represent a relatively small portion of the overall capital, but over the lifecycle of the facility can play a dominant role in overall costs. Table 42 lists the assumptions used to develop operations and maintenance costs including chemicals, labor, electricity, membrane replacement, and cleaning frequency. Table 43 is a summary of overall operation and maintenance costs for treating water through RBF followed by RO, UF followed by RO and conventional treatment followed by RO. Membrane replacement costs were included as part of the operation and maintenance costs shown herein. These costs do not include finished water pumping or conveyance.

The benefit of UF or conventional pretreatment over RBF alone is an increased RO run time (from 32 to 63 days). However, as indicated in table 43, the overall operation and maintenance costs of providing UF or conventional pretreatment are higher than with RBF alone.

Table 42 – Design Parameters Used to Calculate O&M Cost
DWPR Phase I

Design Parameter	Units	Quantity
Labor- 3 FTE for RBF, 5 FTE for UF and Conventional Treatment	$/hr	35
Electricity	$/kWh	0.07
Chemical Costs		
Scale inhibitor	$/lb	1.90
Hypochlorite	$/lb	0.90
Caustic	$/lb	0.30
Sodium Bisulfite	$/lb	0.25
Citric Acid	$/lb	1.00
Chemical Doses		
Scale inhibitor Dose	mg/L	3.5
Hypochlorite Dose	mg/L	3
UF Chemical Cleaning		
Interval	days	30
Caustic per Cleaning	lbs	1,100
Hypochlorite per Cleaning	lbs	25
Sodium Bisulfite per Cleaning	gal	9
Citric Acid per Cleaning	lbs	1,100
RO Chemical Cleaning		
RBF Pretreatment Interval	days	32
UF Pretreatment Interval	days	63
Conventional Treatment Interval	days	63
Caustic per Cleaning	lbs	1,600
Citric Acid per Cleaning	lbs	1,600
Cartridge Filter Loading Rate	gpm/10 inches	2.5
Cartridge Filter Replacement Frequency for UF and Conv. Treatment	days	60
Cartridge Filter Replacement Frequency for RBF	days	30
Membrane Life		
UF Membranes	yr	7
NR/RO Membranes	yr	5
Membrane Cost		
UF Membranes	$/module	1,650
RO Membranes	$/module	500

Table 43 A Summary of O&M Costs Associated with RO Using RBF and UF Pretreatments DWPR Phase I

Alternative	
RBF Followed by RO	$0.66/kgal
UF Followed by RO	$1.02/kgal
Conventional Treatment Followed by RO	$0.90/kgal
Concentrate to Surface Water [!]	$0.11/kgal
Concentrate to WWTP [2]	$3.15/kgal

[1] Includes $0.01/kgal for aeration power and miscellaneous costs and annual permit/monitoring costs of $75,000.

[2] Based on conversations with the Des Moines WWTP. This cost may potentially be negotiated given the extremely low TSS and BOD of this waste.

11.3 Present Worth Analysis

A present worth analysis was performed for the debt service of capital and O&M expenditures over a 20-year life cycle. A cost of monies of 6 percent and annual inflation of 3 percent was used for this analysis. In addition, it was assumed that design and construction services would be begin in 2005 and 2006, respectively with operation beginning in 2007. For this analysis a surface water discharge for concentrate disposal was assumed. The results of the present worth analysis are presented in Table 44. As shown, the life-cycle costs of using RBF pretreatment to RO are less than those associated with UF or conventional pretreatment to RO.

Table 44 – A Summary of Present Worth Costs Associated with RO Using RBF and UF Pretreatments DWPR Phase I

Alternative	
RBF Followed by RO	$122.6 Million ($1.16/kgal)
UF Followed by RO	$171.3 Million ($1.62/kgal)
Conventional Treatment Followed by RO	$161.0 Million ($1.52/kgal)

12. References

Achten, C., Kolb, A., and W. Puttmann, 2002. "Occurrence of Mthly *tert*-Butyle Ether (MTBE) in Riverbank Filtered Water and Drinking Water Produced by Riverbank filtration," *Environmental Science and Technology*, Vol. 36, p. 3662-3670.

Alawadhi, A., 1997. "Pretrement Plant Design – Key to a Successful Reverse Osmosis Desalination Plant," *Desalination*, Vol. 100, p. 1-10.

Allgeier, S., and R. Summers, 1995. "Evaluating NF for DBP Control with the RBSMT," *Journal AWWA*, Vol. 87, No. 3, p. 87.

Clesceri, L.S. and A.E. Greenberg, editors, 1998. *Standard Methods for the Examination of Water and Wastewater*, 20th Edition, APHA, AWWA, and WEF.

Gollnitz, W., J. Clancy, B. Whittebarry, and J. Vogt, 2003. "RBF as a Microbial Treatment Process." *Journal AWWA*. Vol. 95, No. 12, p. 56-66.

Grooters, S., G. Amy, and R. Summers, 2002. "Nanofiltration Scale-up Issues: Using Bench-Scale Testing as a Cost-Effective Approach for Membrane Selection." *Proceedings American Water Works Association*, 2002 Annual Conference and Exposition, New Orleans, Louisiana, June 16-20.

Hiscock, K. and T. Grischek, 2002. "Attenuation of Groundwater Pollution by Riverbank Filtration," *Journal of Hydrology*, Vol. 266, p. 139-144.

Isaias, N., 2001. "Experience in Reverse Osmosis Pretreatment," *Desalination*, Vol. 139, p. 57-64.

Kuehn, W. and U. Mueller, 2000. "Riverbank Filtration: An Overview," *Journal AWWA*, Vol. 92, No. 12, p. 60-69.

Lutz , Donna S., Sara J. Eggers, and Randall L. Esser, 2001. "Water Quality Studies—Red Rock and Saylorville Reservoirs, Des Moines River, Iowa, Annual Report," Department of the Army Rock Island District Corps of Engineers, Rock Island, Illinois, and Iowa State University, Ames, Iowa, Engineering Research Institute, *Annual Report ISU-ERI-Ames-01336*, March 2001.

Merkel, T., T. Speth, J. Wang, R.S. Summers, 1998. "The Performance of Nanofiltration in the Treatment of Bank-Filtered and Conventionally Treated Surface Waters," *Proceedings 1998 AWWA WQTC*, San Diego, California.

Nederlof, M., J. Kruithof, J. Taylor, D. van der Kooij, J. Schippers, 2000. "Comparison of NF/RO Membrane Performance in Integrated Membrane Systems," *Desalination*, Vol. 131, p. 257-269.

Ray, C., T. Grischeck, J. Schubert, J. Wang, T. Speth, 2002. "A Perspective of Riverbank filtration." *Journal AWWA*, Vol. 94, No. 4, p. 149-160.

Seacord, T. and S. Grooters, 2003. "Controlling Quality and Cost of Municipal Surface Water Desalination and Membrane Softening," paper presented at the American Water Works Association 2003 Bi-Annual Membrane Technology Conference, Atlanta, Georgia, March 2-5.

Speth, TF, T. Merkel, and A.M. Gusses, 2002. "Riverbank Filtration as a Pretreatment for Nanofiltration Membranes," *Riverbank Filtration: Improving Source-Water Quality*, C. Ray, G. Melin, and R.B. Linsky, editors, Dordrecht, The Netherlands: Kluwer Academic Publishers, pp. 261-266.

Tufenkji, N., J. Ryan, and M. Elimelech, 2002. "The Promise of Riverbank filtration," *Environmental Science and Technology*, November 1, p. 423A-428A.

U.S. Environmental Protection Agency, 1979. M*ethods for Chemical Analysis of Water and Wastes*, EPA 600/479-020, March 1979.

______________, 1983. *Methods for Chemical Analysis of Water and Wastes*, EPA 600/479-020, Revision March 1983.

Verstraeten, I., E, Thurman, M. Lindsey, E, Lee, R. Smith, 2002. "Changes in Concentration of Triazine and Acetamide Herbicides by Riverbank Filtration, Ozonation, and Chlorination in a Public Water Supply," *Journal of Hydrology*.

Wang, J.Z., S.A. Hubbs, and R. Song, R., 2002. "Evaluation of Riverbank filtration as a Drinking Water Treatment Process," *AWWA Research Foundation*, Report ISBN 1-58321-269-8.

Weiss, W., E. Bouwer, W, Ball, C. O'Melia, M. Lechevallier, H. Arora, and T. Speth, 2003. "Riverbank Filtration – Fate of DBP Precursors and Selected Microoganisms." *Journal AWWA*, Vol. 95, No. 10, p. 68-81.

APPENDIX A

DMWW Multi-Stage Pilot Testing Water Quality

Feedwater Summary (RBF) DOW XLE			100						
Parameter	**Units**	**Count**	**Median**	**Low**	**High**	**Average**	**St. Dev**	**95% CI Low**	**95% CI High**
Bacti CFU		6	33	0	81	41	N/A	N/A	N/A
Chloride		8	39.76	38.72	47.30	41.39	3.48	41.32	41.47
Conductivity	mS/cm	15	7.58	7.22	8.27	7.66	0.31	7.65	7.66
Iron	mg/L	6	0.028	0.016	0.034	0.027	N/A	N/A	N/A
Manganese	mg/L	6	0.222	0.184	0.270	0.226	N/A	N/A	N/A
Nitrate-N		8	1.35	0.88	2.36	1.46	0.55	1.45	1.47
pH		7	7.59	7.55	7.64	7.59	N/A	N/A	N/A
SDI		0	--	--	--	--	--	--	--
Sulfate		4	69.23	64.80	74.40	69.42	N/A	N/A	N/A
Temperature	F	5	54	53	57	55	N/A	N/A	N/A
TOC	mg/L	5	1.78	1.62	1.99	1.78	N/A	N/A	N/A
Total Alkalinity	mg/L as $CaCO_3$	7	268	262	278	269	N/A	N/A	N/A
Total Dissolved Solids	mg/L as $CaCO_4$	4	447	433	457	446	N/A	N/A	N/A
Total Hardness	mg/L as $CaCO_5$	14	357	345	384	359	11	358	359
TSS	mg/L	0	--	--	--	--	--	--	--
TTHMS		0	--	--	--	--	--	--	--
Turbidity	NTU	7	0.186	0.101	0.786	0.253	N/A	N/A	N/A
UV-254 Absorbance	cm^{-1}	6	0.036	0.034	0.041	0.037	N/A	N/A	N/A
Fluoride		4	0.32	0.27	0.43	0.34	N/A	N/A	N/A
Nitrite-N		4	0.00	0.00	0.18	0.05	N/A	N/A	N/A
Bromide		4	0.00	0.00	0.00	0.00	N/A	N/A	N/A
Phosphate-P		4	0.00	0.00	0.00	0.00	N/A	N/A	N/A

Feedwater Summary (UF) DOW XLE									
Parameter	**Units**	**Count**	**Median**	**Low**	**High**	**Average**	**St. Dev**	**95% CI Low**	**95% CI High**
Bacti CFU		4	6	0	8	5	N/A	N/A	N/A
Chloride		0	--	--	--	--	--	--	--
Conductivity		4	698	679	728	701	N/A	N/A	N/A
Iron	mg/L	4	0.031	0.019	0.044	0.031	N/A	N/A	N/A
Manganese	mg/L	4	0.292	0.277	0.312	0.293	N/A	N/A	N/A
Nitrate-N		0	--	--	--	--	--	--	--
pH		3	7.55	7.52	7.60	7.56	N/A	N/A	N/A
SDI		3	0.667	0.000	2.220	0.962	N/A	N/A	N/A
Sulfate		0	--	--	--	--	--	--	--
Temperature	F	3	59	58	60	59	N/A	N/A	N/A
TOC	mg/L	3	1.90	1.55	1.96	1.80	N/A	N/A	N/A
Total Alkalinity	mg/L as $CaCO_3$	4	262	258	262	261	N/A	N/A	N/A
Total Dissolved Solids	mg/L as $CaCO_4$	4	410	8	437	316	N/A	N/A	N/A
Total Hardness	mg/L as $CaCO_5$	5	330	330	345	336	N/A	N/A	N/A
TSS	mg/L	0	--	--	--	--	--	--	--
TTHMS		0	--	--	--	--	--	--	--
Turbidity	NTU	4	0.160	0.131	0.239	0.173	N/A	N/A	N/A
UV-254 Absorbance	cm^{-1}	2	0.037	0.036	0.037	0.037	N/A	N/A	N/A
Fluoride		0	--	--	--	--	--	--	--
Nitrite-N		0	--	--	--	--	--	--	--
Bromide		0	--	--	--	--	--	--	--
Phosphate-P		0	--	--	--	--	--	--	--

Permeate Summary (RBF) **DOW XLE**									
Parameter	**Units**	**Count**	**Median**	**Low**	**High**	**Average**	**St. Dev**	**95% CI Low**	**95% CI High**
Bacti CFU		6	82	8	742	250	N/A	N/A	N/A
Chloride		8	0.96	0.78	2.58	1.15	0.58	1.13	1.16
Conductivity		15	14	13	30	15	4	15	15
Iron	mg/L	6	0.013	0.000	0.019	0.012	N/A	N/A	N/A
Manganese	mg/L	6	0.003	0.000	0.004	0.002	N/A	N/A	N/A
Nitrate-N		8	0.28	0.19	0.40	0.28	0.08	0.27	0.28
pH		7	6.23	5.72	6.60	6.22	N/A	N/A	N/A
SDI		0	--	--	--	--	--	--	--
Sulfate		4	0.04	0.00	0.11	0.05	N/A	N/A	N/A
Temperature	F	0	--	--	--	--	--	--	--
TOC	mg/L	5	0.20	0.13	0.32	0.21	N/A	N/A	N/A
Total Alkalinity	mg/L as $CaCO_3$	7	4	4	6	4	N/A	N/A	N/A
Total Dissolved Solids	mg/L as $CaCO_4$	7	8	8	9	8	N/A	N/A	N/A
Total Hardness	mg/L as $CaCO_5$	14	2	1	8	3	2	3	3
TSS	mg/L	0	--	--	--	--	--	--	--
TTHMS		0	--	--	--	--	--	--	--
Turbidity	NTU	7	0.081	0.062	0.248	0.119	N/A	N/A	N/A
UV-254 Absorbance	cm^{-1}	6	0.001	0.000	0.005	0.002	N/A	N/A	N/A
Fluoride		4	0.00	0.00	0.00	0.00	N/A	N/A	N/A
Nitrite-N		4	0.00	0.00	0.00	0.00	N/A	N/A	N/A
Bromide		4	0.00	0.00	0.00	0.00	N/A	N/A	N/A
Phosphate-P		4	0.00	0.00	0.00	0.00	N/A	N/A	N/A

Permeate Summary (UF) **DOW XLE**									
Parameter	**Units**	**Count**	**Median**	**Low**	**High**	**Average**	**St. Dev**	**95% CI Low**	**95% CI High**
Bacti CFU		4	26	16	999	267	N/A	N/A	N/A
Chloride		0	--	--	--	--	--	--	--
Conductivity		4	13	13	14	14	N/A	N/A	N/A
Iron	mg/L	4	0.022	0.000	0.024	0.017	N/A	N/A	N/A
Manganese	mg/L	4	0.003	0.000	0.004	0.003	N/A	N/A	N/A
Nitrate-N		0	--	--	--	--	--	--	--
pH		3	6.21	5.89	6.27	6.12	N/A	N/A	N/A
SDI		0	--	--	--	--	--	--	--
Sulfate		0	--	--	--	--	--	--	--
Temperature	F	0	--	--	--	--	--	--	--
TOC	mg/L	3	0.06	0.00	0.45	0.17	N/A	N/A	N/A
Total Alkalinity	mg/L as $CaCO_3$	4	6	4	6	6	N/A	N/A	N/A
Total Dissolved Solids	mg/L as $CaCO_4$	4	8	8	9	8	N/A	N/A	N/A
Total Hardness	mg/L as $CaCO_5$	6	2	2	4	2	N/A	N/A	N/A
TSS	mg/L	0	--	--	--	--	--	--	--
TTHMS		0	--	--	--	--	--	--	--
Turbidity	NTU	3	0.140	0.060	0.256	0.152	N/A	N/A	N/A
UV-254 Absorbance	cm^{-1}	2	0.000	0.000	0.000	0.000	N/A	N/A	N/A
Fluoride		0	--	--	--	--	--	--	--
Nitrite-N		0	--	--	--	--	--	--	--
Bromide		0	--	--	--	--	--	--	--
Phosphate-P		0	--	--	--	--	--	--	--

Concentrate Summary (RBF)
DOW XLE

Parameter	Units	Count	Median	Low	High	Average	St. Dev	95% CI Low	95% CI High
Bacti CFU		0	--	--	--	--	--	--	--
Chloride		0	--	--	--	--	--	--	--
Conductivity		15	2830	2580	3030	2843	133	2841	2845
Iron	mg/L	6	0.059	0.040	0.077	0.058	N/A	N/A	N/A
Manganese	mg/L	6	1.523	0.680	1.980	1.447	N/A	N/A	N/A
Nitrate-N		0	--	--	--	--	--	--	--
pH		7	7.90	7.83	7.94	7.89	N/A	N/A	N/A
SDI		0	--	--	--	--	--	--	--
Sulfate		0	--	--	--	--	--	--	--
Temperature	F	0	--	--	--	--	--	--	--
TOC	mg/L	0	--	--	--	--	--	--	--
Total Alkalinity	mg/L as $CaCO_3$	7	999	999	999	999	N/A	N/A	N/A
Total Dissolved Solids	mg/L as $CaCO_4$	7	1674	1548	1806	1675	N/A	N/A	N/A
Total Hardness	mg/L as $CaCO_5$	8	999	999	999	999	0	#NUM!	#NUM!
TSS	mg/L	0	--	--	--	--	--	--	--
TTHMS		0	--	--	--	--	--	--	--
Turbidity	NTU	7	0.287	0.184	0.548	0.329	N/A	N/A	N/A
UV-254 Absorbance	cm^{-1}	6	0.157	0.151	0.167	0.157	N/A	N/A	N/A
Fluoride		0	--	--	--	--	--	--	--
Nitrite-N		0	--	--	--	--	--	--	--
Bromide		0	--	--	--	--	--	--	--
Phosphate-P		0	--	--	--	--	--	--	--

Concentrate Summary (UF)
DOW XLE

Parameter	Units	Count	Median	Low	High	Average	St. Dev	95% CI Low	95% CI High
Bacti CFU		0	--	--	--	--	--	--	--
Chloride		0	--	--	--	--	--	--	--
Conductivity		4	2602	2310	3240	2689	N/A	N/A	N/A
Iron	mg/L	4	0.071	0.046	0.086	0.068	N/A	N/A	N/A
Manganese	mg/L	4	0.890	0.767	1.220	0.942	N/A	N/A	N/A
Nitrate-N		0	--	--	--	--	--	--	--
pH		2	7.92	7.91	7.93	7.92	N/A	N/A	N/A
SDI		0	--	--	--	--	--	--	--
Sulfate		0	--	--	--	--	--	--	--
Temperature	F	0	--	--	--	--	--	--	--
TOC	mg/L	0	--	--	--	--	--	--	--
Total Alkalinity	mg/L as $CaCO_3$	4	999	999	999	999	N/A	N/A	N/A
Total Dissolved Solids	mg/L as $CaCO_4$	4	1561	1386	1944	1613	N/A	N/A	N/A
Total Hardness	mg/L as $CaCO_5$	5	999	999	1366	1072	N/A	N/A	N/A
TSS	mg/L	0	--	--	--	--	--	--	--
TTHMS		0	--	--	--	--	--	--	--
Turbidity	NTU	3	0.204	0.180	0.250	0.211	N/A	N/A	N/A
UV-254 Absorbance	cm^{-1}	2	0.155	0.144	0.166	0.155	N/A	N/A	N/A
Fluoride		0	--	--	--	--	--	--	--
Nitrite-N		0	--	--	--	--	--	--	--
Bromide		0	--	--	--	--	--	--	--
Phosphate-P		0	--	--	--	--	--	--	--

APPENDIX B

Iowa Chapter 61 Standards for Water Quality

Table B1 – A Summary of Iowa Chapter 61 Water Quality Standards for Class A and B (WW) Receiving Waters		
DWPR Parameter [(1)]	**Units**	**DWPR Requirement for Reference**
E. Coli		
3/15-11/15	#/100 ml	126 (235)[(2)]
pH	Standard Units	6.5-9.0
Aluminum	mg/L	388 (1106) [(3)]
Ammonia	mg/L	- [4]
Arsenic (III)	mg/L	200 (360) [(3)]
Arsenic (III) Human Health – Fish	mg/L	50
Benzene Human Health –Fish	mg/L	712.8
Bromoform Human Health – Fish	mg/L	3600
Cadmium	mg/L	15 (75) [3]
Cadmium Human Health – Fish	mg/L	168
Carbon Tetrachloride Human Health – Fish	mg/L	44.2
Chlorobenzene	mg/L	21
Chlorodibromomethane Human Health – Fish	mg/L	340
Chloroform Human Health – Fish	mg/L	4700
Copper	mg/L	35 (60) [3]
Copper Human Health – Fish	mg/L	1000
para-Dichlorobenzene Human Health – Fish	mg/L	2.6
3,3 Dichlorobenzidine Human Health – Fish	mg/L	0.2
Dichlorobromomethane Human Health – Fish	mg/L	460
1,2 Dichloroethane Human Health Fish	mg/L	986
1,1 Dichloroethylene Human Health – Fish	mg/L	32
Lead	mg/L	30 (200) [3]
Selenium (VI)	mg/L	125 (175) [3]
Silver	mg/L	(100) [3]
Temperature		<3C increase and never contribute to water above 32C
Toluene	mg/L	50 (2500) [3]
Toluene Human Health – Fish	mg/L	300
Total Residual Chlorine	mg/L	20 (35) [3]
1,1,1 Trichlorethane Human Health – Fish	mg/L	173
TCE	mg/L	80 (4000) [3]

Table B1 – A Summary of Iowa Chapter 61 Water Quality Standards for Class A and B (WW) Receiving Waters

DWPR Parameter [(1)]	Units	DWPR Requirement for Reference
TCE Human Health – Fish	mg/L	807
Vinyl Chloride Human Health – Fish	mg/L	5250
Zinc	mg/L	450 (500)
Zinc Human Health – Fish	mg/L	5000

[1] Acute, chronic, and human health criteria are defined in Chapter 61 Water Quality Standards.
[2] Number indicated geometric mean, number in parenthesis indicates sample maximum.
[3] Number indicates chronic limit, number in parenthesis indicates acute limit.
[4.] Varies with pH and/or temperature. Consult Chapter 61 Water Quality Standards.

APPENDIX C

DMWW Whole Effluent Toxicity Test Report

MARINCO BIOASSAY LABORATORY
The Aquatic Toxicology Specialists

Whole Effluent Toxicity Testing Summary Page

Client name: Des Moines Water Works c/o Carollo Engineers

MBL Project/Report # 040508

MBL Sample #	Species	Permit Requirements	Test Results	Passing or Failure
040508-1	*Daphnia magna*	N/A	LC50 >100%	N/A
040508-1	*Ceriodaphnia dubia*	N/A	LC50 >100%	N/A
040508-1	*Pimephales promelas*	N/A	LC50 >100%	N/A
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Invertebrate (Daphnia magna, Ceriodaphnia dubia); Vertebrate (Pimephales promelas)

Additional Testing Required: **No**

Comments:
These are non-compliance tests. No permit requirements were provided.

QA/QC Officer/Reviewer: Signature [signature]

Date: 5/18/04

State of Florida Wastewater Whole Effluent Toxicity Testing Report Form

All blanks on this form are to be filled in. Blanks that are not should be filled in with "N/A" or a line drawn through the blank. Please print.

ATTACHMENTS: Please attach the following items to this report form and indicate with an "X" in box.

1. All Chain-of-Custody Forms	X
2. Standard Reference Toxicant (SRT) Reports attached. 3SRT Reports attached.	X
3. All Raw Data (Bench Sheets) Pertaining to the Tests (i.e., all physical, chemical and biological measurements)	X
4. All Result Calculations	X

Facility/ Industry/ Client Name and address: Des Moines Water Works, c/o Carollo Engineers, 380 Interlocken Crescent, Ste. 780, Broomfield, CO 80021

NPDES Number: N/A — County: N/A

Non-NPDES (1) N/A Yes — Project N/A

Dates Test(s) Conducted:

Start Date: 05/07/2004 — Start 1540

End Date: 05/11/2004

Name, Address, & Phone Number of Consultant Company: Marinco Bioassay Laboratory, Inc. (MBL), 4569 Samuel Street Sarasota, Florida 34233, (941) 925-3594, Certification #E84191, Contact: Jason Weeks Laboratory Director or Lisa Rouwenhorst QA/QC Officer

Name(s) of Person(s) Conducting Test(s):(Printed): Lisa Rouwenhorst, Smiljana Kerkez, Katie Gray, and Marlena Beck

QA/QC Officer/Reviewer: Signature: [signature] — Date: 5/18/04

Laboratory Report #/ Project #: 040508 — Sampler's Name: (Print) N/A

Routine Test: X — Additional: N/A — For failed routine test dated: N/A

Samples

#	Date and Time Collected	Lab Sample #	Sample Type: Grab or Composite	Arrival Temp oC	Initial Residual Chlorine (mg/L)	Lab Dechlorination	Chemical Used
1	05/06/2004 0830	040508-1	Grab	1	0.03	------	-------
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Type of Refrigerant Used for Sample Transportation: X Wet Ice; N/A Blue Ice; N/A Other

Samples Aerated: Yes, to increase DO level. Yes (Describe) — N/A No

Samples Delivered By: N/A Bus; N/A Hand; X Common Carrier

Samples Filtered: N/A Yes (Describe) — X No

Provide Description: **Pilot Plant - Concentrate Brine Sample**

(1) If toxicity testing data are reported for any project other than permit compliance testing, mark "yes" and identify the reason that toxicity data are being submitted, e.g., Consent Order, ambient monitoring, mixing zone evaluation.

This Page Last Edited By: Diane Thornton on: 05/12/2004

Summary of Test Conditions

Type of Test (1)	Test Conc. (% Effluent) (2)	Age of Test Organism	Test Species Used (3)	Amount & Type Food	How Often Fed	Test Chamber Volume	Volume of Effluent Used	Type of Chamber	# of Organism/ Chamber	# of Replicates	Temp Range (Degrees Celsius)
D	0, 6.25, 12.5, 25, 50, 100	<24 hours	DM	0.25 mL Selenastrum & 0.25 mL YCT per replicate	Once at renewal	30 mL	25 mL	Medicine cup	5	4	21
D	0, 6.25, 12.5, 25, 50, 100	<24 hours	CD	0.2 mL Selenastrum & 0.2 mL YCT per replicate	Once at renewal	30 mL	25 mL	Medicine cup	5	4	25
D	0, 6.25, 12.5, 25, 50, 100	11 days	FM	0.04 mL of 1200 Artemia nauplii/0.1 mL per replicate	Once at renewal	1000 mL	250 mL	Beaker	10	2	24-25
-	----------	------	--	----------------	---------------	------	------	----------	------	--	-----
-	----------	------	--	----------------	---------------	------	------	----------	------	--	-----

G. Other: N/A

Temperature Readings Were: N/A Single N/A Multiple X Continuous

Description of Control Water: Synthetic Moderately Hard (Reconstituted)

Photoperiod During Test: 16 Hrs. Light : 8 Hrs. Dark

Reference Toxicant Data (4)

Name of Toxicant	Dates of Test Begin and End	Species (3)	In-House or Commercially Obtained	LC50/IC25
NaCl	04/28/2004-05/03/2004	DM	In-House	5.10 g/L NaCl
NaCl	04/12/2004-04/16/2004	CD	In-House	1.37 g/L NaCl
NaCl	04/12/2004-04/16/2004	FM Fathead Minnow	In-House	6.73 g/L NaCl
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(1) Please fill the "Type of Test" Box with the Appropriate Letter:
- **A.** 48-Hr/Non-Renewal/Single Concentration (Screen)
- **B.** 48-Hr/Non-Renewal/Multi-Concentration (Definitive)
- **C.** 96-Hr/Renewed Every 48-Hrs/Single Concentration (Screen)
- **D.** 96-Hr/Renewed Every 48-Hrs/Multi-Concentration (Definitive)
- **E.** 7-Day Chronic/Single Concentration (Screen)/Renewed Daily
- **F.** 7-Day Chronic/Multi-Concentration (Definitive)/Renewed Daily
- **G.** Other - Describe in the "G" Box

(3) Write Appropriate Letters for the following species in this column:
- CD Ceriodaphnia dubia
- FM Pimephales promelas (fathead minnow)
- SS Menidia beryllina (inland silverside)
- MS Mysidopsis bahia (mysid shrimp)
- DP Daphnia pulex
- DM Daphnia magna
- CL Cyprinella leedsi (bannerfin shiner)
- Other - Please Describe ____________

(2) List all concentrations of effluent used (i.e., 0%, 6.25%, 12.5%, 25%, 50%, 100%)

(4) Attach all reference toxicant raw data and control charts for each organism/reference toxicant used for the test.

QA/QC Officer/Reviewer: Signature [signature]

Date: 5/18/04

ACUTE Test Results. Test conducted in accordance with EPA-821-R-02-012.						
Test Species	**Test Concentration (2) (% Effluent)**	**Sample # (3)**	**% Mortality 24 Hrs (4)**	**% Mortality 48 Hrs (4)**	**% Mortality 96 Hrs (4)**	**LC50 (5)**
DM Control	0	---------------	-----	-----	0	------
DM	6.25, 12.5, 25, 50, 100	040508-1	-----	-----	-------	> 100% *
---------------	-----------------------------------	---------------	-----	-----	-------	------
CD Control	0	---------------	-----	-----	0	------
CD	6.25, 12.5, 25, 50, 100	040508-1	-----	-----	-------	> 100%
---------------	-----------------------------------	---------------	-----	-----	-------	------
FM Control	0	---------------	-----	-----	0	------
FM	6.25, 12.5, 25, 50, 100	040508-1	-----	-----	-------	> 100% *
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(1) List % control mortality in appropriate column (48 or 96 hr.) for organisms (use abbreviations shown on footnote 3, Page 2) that you list under the word "Control."
(2) List all concentrations of effluent used (i.e., 0%, 6.25%, 12.5%, 25%, 50%, 100%).
(3) Record number that corresponds with the number of the sample in the "Date and Time Collected" column in sample section on Page 1.
(4) List % Mortality for each organism and control if you are conducting a single concentration (Screen) test.

Species	LC50 (6)
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(5) If multi-concentration (Definitive) tests are conducted on grab or composite samples, record the calculated LC50 in this column for each sample. Enter "N/A" in all % Mortality columns and LC50 box at bottom of this table.
(6) If a single concentration (Screen) test is conducted and >50% mortality occurs in any one of the four grab or composites, record <100% in this box. If <=50% mortality occurs in all four grabs or composites, record >100% in this box. Draw a line through the LC50 column in above table.
F = Flagged data, see page 4.
* No statistical test was used in endpoint determination as the data either did not appropriately fit

QA/QC Officer/Reviewer: Signature [signature]

Date: 5/18/04

Specify if samples DO NOT meet NELAC standards:	
Standard violation	**Yes/No**
Improper container	No
36-hour holding time exceeded	No
Temperature above 6 degrees Celsius	No

Specify any deviations from, additions to, or exclusions from the test method or any non-standard conditions that may have affected the quality of the results, and include any data qualifiers.

All calculated statistical endpoints were calculated using ToxCalc version 5.0.21 - Tidepool Scientific Software.
The results contained in this report relate only to the items tested or to the samples as received by the laboratory. MBL certifies the results contained in this report meet NELAC standards.
This report shall not be reproduced except in full, without the written approval of MBL.

QA/QC Officer/Reviewer: Signature [signature] Date: 5/18/04

SURVIVAL BENCH SHEET

Project #: 040508
Test Organism: *Daphnia magna*
Organism Age: <24 hours

Test Start: 5/7/04 1840
Test End: 5/11/04 1531
Brood #: DM040506-1700

Time Fed (48 hours): 0730 Initials & Date KG 5/9/04
Time Renewed (48 hours): 1458 Initials & Date KG 5/9/04

Effluent Concentration %	Sample Number	Survival Replicate A					Survival Replicate B					A & B Total
		0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	
100	040508-1	5	5	5	5	4	5	5	4	4	1	5
50		5	5	5	5	5	5	5	5	5	5	10
25		5	5	5	5	5	5	5	5	5	5	10
12.5		5	5	5	5	5	5	5	5	5	5	10
6.25		5	5	5	5	5	5	5	5	5	5	10
Control		5	5	5	5	5	5	5	5	5	5	10
0 Hours started/checked by:; 24, 72, 96 Hours counted by:; 48 Hours renewed by:		KG / LR	LR	KG	KG	LR	KG / LR	LR	KG	KG	LR	LR

Effluent Concentration %	Sample Number	Survival Replicate C					Survival Replicate D					C & D Total
		0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	
100	040508-1	5	5	5	4	2	5	5	5	5	5	7
50		5	5	5	5	5	5	5	5	5	5	10
25		5	5	5	5	5	5	5	5	5	5	10
12.5		5	5	5	5	5	5	5	5	5	5	10
6.25		5	5	5	5	5	5	5	5	5	5	10
Control		5	5	5	5	5	5	5	5	5	5	10
0 Hours started/checked by:; 24, 72, 96 Hours counted by:; 48 Hours renewed by:		KG / LR	LR	KG	KG	LR	KG / LR	LR	KG	KG	LR	LR

Total Survival/Start Count = % Survival at end of test					
100	50	25	12.5	6.25	Control
12/20 = ~~100~~ 60 % (initialed and dated)	20/20 = 100 %	20/20 = 100 %	20/20 = 100 %	20/20 = 100 %	20/20 = 100 %

Comments: 24 Hours: The 100% effluent replicates have a film on the top of the replicates. LR 5/8/04.

Reviewed by: DT

Date: 05/12/04

MBL #0016. Ver. 4

ACUTE TOXICITY TEST PHYSICAL AND CHEMICAL MEASUREMENTS

EPA Method # 21 ~~2002.0~~ KG 5/7

Project #: 040508 **Test Start:** 5/7/04 1540

Test Organism: *Daphnia magna* **Test End:** 5/11/04 1531

Effluent Concentration %	Sample Number	Dissolved Oxygen (mg/L) 0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	pH 0 Hours	24 Hours	48 Hours	72 Hours	96 Hours
100	040508-1	8.4	8.1	8.7 / 8.7	7.7	8.0	8.0	8.3	8.3 / 8.0	8.3	8.3
50.0		8.6	8.2	8.6 / 8.7	7.8	7.9	8.2	8.6	8.7 / 8.1	8.7	8.7
25.0		8.6	8.2	8.5 / 8.7	7.8	7.9	8.2	8.4	8.6 / 8.2	8.5	8.5
12.5		8.6	8.2	8.4 / 8.6	7.8	7.8	8.2	8.3	8.4 / 8.2	8.4	8.3
6.25		8.4	7.9	8.4 / 8.5	7.8	7.8	8.1	8.1	8.3 / 8.1	8.2	8.1
Control		8.2	7.7	8.3 / 8.5	7.8	7.7	7.7	7.8	7.9 / 7.8	7.8	7.7
Measured by:		KG	LR	KG / KG	KG	LR	KG	LR	KG / KG	KG	LR

Effluent Concentration %	Sample Number	Temperature (Degrees Celsius) 0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	Conductivity (mS/cm) 0 Hours	24 Hours	48 Hours	72 Hours	96 Hours
100	040508-1	21	21	21 / 21	21	21	2.53	—	— / 2.55	—	2.02
50.0		21	21	21 / 21	21	21	1.480	—	— / 1.484	—	1.400
25.0		21	21	21 / 21	21	21	0.918	—	— / 0.920	—	0.885
12.5		21	21	21 / 21	21	21	0.617	—	— / 0.617	—	0.612
6.25		21	21	21 / 21	21	21	0.462	—	— / 0.462	—	0.452
Control		21	21	21 / 21	21	21	0.299	—	— / 0.301	—	0.293
Measured by:		KG	LR	KG / KG	KG	LR	KG	—	— / KG	—	LR

Comments or corrections:

Reviewed by: JT

Date: 05/12/04

MBL #0006. Ver. 5

Acute Fish Test-96 Hr Survival

Start Date:	5/7/2004	Test ID:	040508CD	Sample ID:	040508-1
End Date:	5/11/2004	Lab ID:	MBL-Marinco Bioassay Lab.	Sample Type:	
Sample Date:		Protocol:	EPA Method #2002.0	Test Species:	CD-*Ceriodaphnia dubia*

Comments: This analysis was performed by Lisa Rouwenhorst at MBL.

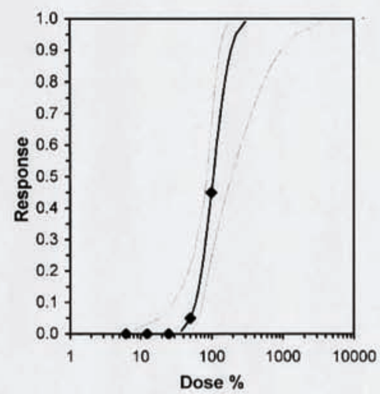
Conc-%	1	2	3	4
Control	1.0000	1.0000	1.0000	1.0000
6.25	1.0000	1.0000	1.0000	1.0000
12.5	1.0000	1.0000	1.0000	1.0000
25	1.0000	1.0000	1.0000	1.0000
50	0.8000	1.0000	1.0000	1.0000
100	0.6000	0.6000	0.4000	0.6000

			Transform: Untransformed					Number	Total
Conc-%	Mean	N-Mean	Mean	Min	Max	CV%	N	Resp	Number
Control	**1.0000**	1.0000	1.0000	1.0000	1.0000	0.000	4	0	20
6.25	**1.0000**	1.0000	1.0000	1.0000	1.0000	0.000	4	0	20
12.5	**1.0000**	1.0000	1.0000	1.0000	1.0000	0.000	4	0	20
25	**1.0000**	1.0000	1.0000	1.0000	1.0000	0.000	4	0	20
50	**0.9500**	0.9500	0.9500	0.8000	1.0000	10.526	4	1	20
100	**0.5500**	0.5500	0.5500	0.4000	0.6000	18.182	4	9	20

Maximum Likelihood-Probit

Parameter	Value	SE	95% Fiducial Limits		Control	Chi-Sq	Critical	P-value	Mu	Sigma	Iter
Slope	5.12843	1.72031	1.75662	8.50025	0	0.01547	7.81472	1	2.02379	0.19499	3
Intercept	-5.3789	3.30843	-11.863	1.10567							
TSCR											

Point	Probits	%	95% Fiducial Limits	
EC01	2.674	37.168	7.66064	53.252
EC05	3.355	50.4725	18.2789	65.5817
EC10	3.718	59.415	28.6528	74.3233
EC15	3.964	66.3272	38.2587	82.0236
EC20	4.158	72.39	47.3638	90.1659
EC25	4.326	78.0311	55.8065	99.6804
EC40	4.747	94.2729	75.6142	143.213
EC50	5.000	**105.63**	**85.3445**	**189.426**
EC60	5.253	118.355	94.1732	256.281
EC75	5.674	142.99	108.435	433.277
EC80	5.842	154.133	114.221	535.793
EC85	6.036	168.222	121.157	687.403
EC90	6.282	187.793	130.259	942.169
EC95	6.645	221.065	144.681	1506.91
EC99	7.326	300.196	175.413	3652.31



ToxCalc v5.0
Reviewed by: [signature]

SURVIVAL BENCH SHEET

Project #: 040508
Test Organism: *Ceriodaphnia dubia*
Organism Age: <24 hours

Test Start: 5/7/04 1342
Test End: 5/11/04 1337
Brood #: CD040507

Time Fed (48 hours): 0732 Initials & Date KG 5/9/04
Time Renewed (48 hours): 1517 Initials & Date KG 5/9/04

Effluent Concentration %	Sample Number	Survival Replicate A					Survival Replicate B					A & B Total
		0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	—
100	040508-1	5	5	5	5	3	5	5	4	4	3	6
50		5	5	4	4	4	5	5	5	5	5	9
25		5	5	5	5	5	5	5	5	5	5	10
12.5		5	5	5	5	5	5	5	5	5	5	10
6.25		5	5	5	5	5	5	5	5	5	5	10
Control		5	5	5	5	5	5	5	5	5	5	10
0 Hours started/checked by:; 24, 72, 96 Hours counted by:; 48 Hours renewed by:		KG / MB	LR	KG	SK	MB	KG / MB	LR	KG	SK	MB	MB

Effluent Concentration %	Sample Number	Survival Replicate C					Survival Replicate D					C & D Total
		0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	—
100	040508-1	5	4	4	4	2	5	5	4	4	3	5
50		5	5	5	5	5	5	5	5	5	5	10
25		5	5	5	5	5	5	5	5	5	5	10
12.5		5	5	5	5	5	5	5	5	5	5	10
6.25		5	5	5	5	5	5	5	5	5	5	10
Control		5	5	5	5	5	5	5	5	5	5	10
0 Hours started/checked by:; 24, 72, 96 Hours counted by:; 48 Hours renewed by:		KG / MB	LR	KG	SK	MB	MB	LR	KG	SK	MB	MB

Total Survival/Start Count = % Survival at end of test					
100	50	25	12.5	6.25	Control
11/20 = 55%	19/20 = 95%	20/20 = 100%	20/20 = 100%	20/20 = 100%	20/20 = 100%

Comments: 24 Hours: The 100% effluent replicates have a film on the top of the replicates. LR 5/8/04.

Reviewed by: DI

Date: 05/12/04

MBL #0016, Ver. 4

ACUTE TOXICITY TEST PHYSICAL AND CHEMICAL MEASUREMENTS

EPA Method # 2002.0

Project #: 040508 **Test Start:** 5/7/04 1342

Test Organism: Ceriodaphnia ~~magna~~ dubia (KG 5/7) **Test End:** 5/11/04 1337

Effluent Concentration %	Sample Number	Dissolved Oxygen (mg/L) 0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	pH 0 Hours	24 Hours	48 Hours	72 Hours	96 Hours
100	040508-1	8.3	7.8	7.5 / 8.2	7.7	5.6	8.2	8.3	8.2 / 8.0	8.3	8.3
50.0		8.3	7.9	7.5 / 8.3	7.7	6.3	8.3	8.5	8.7 / 8.1	8.6	8.6
25.0		8.3	7.8	7.5 / 8.3	7.8	6.8	8.3	8.4	8.5 / 8.2	8.6	8.4
12.5		8.3	7.8	7.6 / 8.3	7.8	7.4	8.3	8.3	8.2 / 8.2	8.4	8.3
6.25		8.3	7.7	7.7 / 8.3	7.8	7.7	8.1	8.1	8.1 / 8.1	8.2	~~7.1~~ (8.1) SK 5/11/04
Control		8.3	7.6	7.7 / 8.2	7.8	7.7	7.7	7.8	7.7 / 7.8	7.9	7.8
Measured by:		KG	LR	SK / KG	SK	SK	KG	LR	SK / KG	SK	SK

Effluent Concentration %	Sample Number	Temperature (Degrees Celsius) 0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	Conductivity (mS/cm) 0 Hours	24 Hours	48 Hours	72 Hours	96 Hours
100	040508-1	25	25	25 / 25	25	25	2.51	—	— / 2.54	—	2.05
50.0		25	25	25 / 25	25	25	1.469	—	— / 1.487	—	1.410
25.0		25	25	25 / 25	25	25	0.908	—	— / 0.917	—	0.896
12.5		25	25	25 / 25	25	25	0.611	—	— / 0.611	—	0.609
6.25		25	25	25 / 25	25	25	0.458	—	— / 0.458	—	0.455
Control		25	25	25 / 25	25	25	0.301	—	— / 0.304	—	0.300
Measured by:		KG	LR	SK / KG	SK	SK	KG	—	— / KG	—	SK

Comments or corrections: ____________________

Reviewed by: DT

Date: 05/12/04

MBL #0006, Ver. 5

SURVIVAL BENCH SHEET

Project #: 040508

Test Start: 5/7/04 1402

Test Organism: Pimephales promelas

Test End: 5/11/04 1342

Organism Age: 11 days

Brood #: PM040426-1610

Concentration %	Sample Number	Survival: Replicate A					Survival: Replicate B					A & B %
		0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	
100	040508-1	10	10	10	10	10	10	10	10	10	10	100
50		10	10	10	10	10	10	10	10	10	10	100
25		10	10	10	10	10	10	10	10	10	10	100
12.5		10	10	10	10	10	10	10	10	10	10	100
6.25		10	10	10	10	10	10	10	10	10	10	100
Control		10	10	10	10	10	10	10	10	10	10	100
Organisms Fed AM / PM		—/—	—/—	DA 0830/—	—/—	—/—	—/—	—/—	DA 0830/—	—/—	—/—	—
0 Hours started/checked by: 24, 72, 96 Hours counted by: 48 Hours renewed/cleaned by:		KG/MB	VR	KG	SK	MB	KG/MB	VR	KG	SK	MB	MB

Comments or Corrections: 24 Hours: The 100% effluents have a film on the top of the replicates. VR 5/8/04.

Reviewed by: DT

Date: 05/12/04

MBL #0022. Ver. #3

ACUTE TOXICITY TEST PHYSICAL AND CHEMICAL MEASUREMENTS

EPA Method # 2000.0

Project #: 040508 **Test Start:** 5/7/04 1402

Test Organism: Pimephales promelas. **Test End:** 5/11/04 1342

Effluent Concentration %	Sample Number	Dissolved Oxygen (mg/L)					pH				
		0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	0 Hours	24 Hours	48 Hours	72 Hours	96 Hours
100	040508-1	8.3	7.6	7.3 / 8.2	6.5	4.1 (1)	8.2	8.5	8.1 / 8.0	8.1	8.1
50.0		8.3	7.6	7.5 / 8.3	6.8	4.5	8.3	8.5	8.7 / 8.1	8.6	8.4
25.0		8.3	7.6	7.4 / 8.3	5.9	3.8	8.3	8.4	8.5 / 8.2	8.5	8.2
12.5		8.3	7.7	7.2 / 8.3	4.5	3.5	8.3	8.2	8.3 / 8.2	8.0	7.9
6.25		8.3	7.6	7.3 / 8.3	5.3	3.5	8.1	8.0	8.1 / 8.1	7.8	7.7
Control		8.3	7.6	7.5 / 8.2	7.3	6.3	7.7	7.7	7.8 / 7.8	7.8	7.7
Measured by:		KG	LR	SK / KG	SK	SK	KG	LR	SK / KG	SK	SK

Effluent Concentration %	Sample Number	Temperature (Degrees Celsius)					Conductivity (mS/cm)				
		0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	0 Hours	24 Hours	48 Hours	72 Hours	96 Hours
100	040508-1	25	24	25 / 25	24	25	2.51	—	— / 2.54	—	1.902
50.0		25	24	25 / 25	24	25	1.469	—	— / 1.487	—	1.445
25.0		25	24	25 / 25	24	25	0.908	—	— / 0.917	—	0.980
12.5		25	24	25 / 25	24	25	0.611	—	— / 0.611	—	0.653
6.25		25	24	25 / 25	24	25	0.458	—	— / 0.458	—	0.491
Control		25	24	25 / 25	24	25	0.301	—	— / 0.304	—	0.334
Measured by:		KG	LR	SK / KG	SK	SK	KG	—	— / KG	—	SK

Comments or corrections: (1) aeration started on all Pimephales promelas replicates at a rate of ~100 bubbles/min. MB 5/11/04 0920.
D.O. after aeration: CTR = 7.7 mg/L 25 = 7.2 mg/L
MB 5/11/04 1338 6.25 = 7.3 mg/L 50 = 7.1 mg/L
12.5 = 6.0 mg/L 100 = 7.1 mg/L

Reviewed by: DT

Date: 05/12/04

MBL #0006 Ver. 5

SAMPLE/CONTROL WATER INFORMATION

Project #: 040508

Control Water and Sample Analysis

Section		Laboratory Number	Alkalinity (mg/L)	Date	Measured by:	Hardness (mg/L)	Date	Measured by:	Chlorine (mg/L)	Date	Measured by:	Cond. (mS/cm)*	Date	Measured by:
Initial Sample Analysis		040508-1	1020	5/4/04	JK	1332	5/4/04	JK	0.03	5/7/04	KG	2.51	5/7/04	KG
Control Water	Initial	SMH040504	55	5/6/04	JK	80	5/6/04	JK	—			0.301	5/7/04	KG
Control Water	Renewal	SMH040504 (DM)	55	5/6/04	JK	80	5/6/04	JK	—			0.301	5/9/04	KG
Control Water	Renewal	SMH040507 (CO, FM)	56	5/4/04	JK	80	5/4/04	JK	—			0.304	5/4/04	KG

*Conductivity values indicated at a reference temperature of 25 degrees celsius. Values in this column for salt-control-water, SWyymmdd, are for salinity determined at the time of initial use in the test.

Sample Aeration

Sample #	Initial D.O. (mg/L)	Aeration Duration (min.)	Aeration Rate (ml/min.)	Final D.O. (mg/L)	Aerated by: Initials/Date/Time/Volume	Initial Sample pH	Measured by:
040508-1 (CO,FM)	5.6	6.0	~500	8.3	KG 5/7/04 1252 (1.4L)	7.8	KG
040508-1 (DM)	5.3	3.0	~500	8.4	KG 5/7/04 1316 (0.4L)	7.8	KG
040508-1 (DM)	8.7	N/A	N/A	N/A	KG 5/9/04 1405	7.9	KG
040508-1 (CO,FM)	8.2	N/A	N/A	N/A	KG 5/9/04 1413	7.9	KG

Comments or corrections:

Reviewed by: DT

Date: 05/12/04

SAMPLE.FRP Ver. #8

ACUTE TEST CONDITIONS

Project #: 040508 **Client:** Des Moines Water Works.

Test type: CD, DM, FM 96 hr @ def **Test run in Environmental Chamber #:** 1(CD, FM) + 3 (DM)

Species Code (1)	Receipt Date and Supplier of Organism (If commercially obtained)	Init.	Amount & Type of Food (2)	Init.	How Often Fed (3)	Init.	Test Chamber Vol. (mL)	Init.	Vol. of Effluent Used (mL)	Init.	Type of Chamber (4)	Init.
CD	N/A	KG	A	KG	R	KG	30	KG	25	KG	M	KG
DM	N/A	KG	O	KG	R	KG	30	KG	25	KG	M	KG
FM	N/A	KG	E	DM	R	DM	1000	KG	250	KG	B	KG

(1) CD Ceriodaphnia dubia
FM Pimephales promelas (fathead minnow)
SS Menidia beryllina (inland silverside)
MS Mysidopsis bahia (mysid shrimp)
DP Daphnia pulex
DM Daphnia magna
CL Cyprinella leedsi (bannerfin shiner)
Other - Please Describe ________

(2) Please fill the "Amount & Type of Food" Box with the appropriate letter:
'A' 0.2 mL Selenastrum, 0.2 mL YCT
'B' 1.4 mL Selenastrum/200 mL of sample, 1.4 mL YCT/200 mL of sample
'C' 0.1 mL conc. Artemia nauplii
'D' 0.03 mL of 1200 Artemia nauplii/0.1 mL per replicate
'E' 0.04 mL of 1200 Artemia nauplii/0.1 mL per replicate
'F' 0.06 mL of 1200 Artemia nauplii/0.1 mL per replicate
'G' 0.07 mL of 1200 Artemia nauplii/0.1 mL per replicate
'H' 0.08 mL of 1200 Artemia nauplii/0.1 mL per replicate
'O' Other 0.25 mL selenastrum, ~~0.2 mL~~ 0.25 mL YCT KG 5/4

(3) Please fill the "How Often Fed" box with the appropriate letter:
'R' Once, at least two hours before renewal
'D' Once daily
'T' Twice daily
'O' Other ________

(4) Please fill the "Type of Chamber" box with the appropriate letter:
'B' Plastic Beaker
'M' Plastic Medicine Cup
'P' Plastic Cup
'G' Glass Beaker
'C' Plastic Container
'O' Other ________

Photoperiod: [KG] 16 hours Light/8 hours dark
[—] Other —

Test(s) conducted in accordance with EPA-821-R-02-012

Randomization version: CD: G, DM: G, FM: 5

Method number 2002.0, 2021.0, 2000.0

Physical and Chemical Measurement Equipment

Equipment type	Test start	24 hours	48 hours	72 hours	96 hours
Thermometer (A)	A	A	A / A	A	A
DO Meter (B)	3	3	3 / 3	3	3
pH Meter (C)	7	7	7 / 7	7	7
Conductivity meter (D)	10	N/A	N/A / 10	N/A	10
Freshwater cond. checked by	KG	—	— / KG	—	—
Used by (Initials)	KG	LR	SK KG / KG	SK KG	SK LR-DM's

(A)Thermometer number is the serial number or designated number on thermometer.
(B)DO Meters: "3" Orion 830
"4" Hach Sension 6
"5" Orion 830A
"6" Orion 820
(C)pH Meters "7" Hach Sension 2
"8" Orion 290A
"9" Orion 720
(D)Conductivity "10" Orion 160
"11" Orion 126
"O" Other ________

Comments or Corrections: FM portion of test moved to EC#3 mB. 5/11/04

Reviewed by: DT

Date: 05/12/04

MBL #0026a, Ver. 12

Des Moines Water Works
Pilot Plant
Concentrate Brine Sample
5-6-04
8:30 AM

Steve Grooters
380 Interlocken Crescent
Suite 780
Broomfield, CO 80021
303 635-1220

Received by: Lisa ~~Ro~~ Rouwenhorst at ~~1027~~ 1019 LR 5/7/04 LR 5/7/04 LR 5/7/04
Shipped on wet ice via Fed Ex #845912106018
MBL # 040508-1 Arrival Temp 1°C

INTERNAL CHAIN OF CUSTODY
MARINCO BIOASSAY LABORATORY, INC.
Acute Toxicity Test

Project # 040508

Sample expiration date/time 5/7/04 2030

Sample #(s)	040508-1	040508-1
Procedure	Test Start	Test Renewal
Sample(s) checked in by Initials/Date/Time	LR 5/7/04 1019	N/A
Sample(s) warmed by Initials/Date/Time	KG 5/7/04 1237	KG 5/9/04 KG 5/9 1404
Total Residual Chlorine measured by Initials/Date/Time	KG 5/7/04 1351	N/A
Sample(s) salted to test salinity using HW Marinemix by: Initials/Date/Time	N/A	N/A
Dilutions prepared by: Initials/Date/Time	KG 5/7/04 1300 (CD+FM) KG 5/7/04 1323 (DM)	KG 5/9/04 1418(DM) KG 5/9/04 1424 (CD, FM)
Test Start-test started by: Test renewal-test renewed by: Initials/Date/Time	KG 5/7/04 1402(CD+FM) KG 5/7/04 1540(DM)	KG 5/9/04 1458(DM) KG 5/9/04 1524 (CD, FM)
Remaining sample(s) returned to refrigerator by: Initials/Date/Time	KG 5/7/04 1251	N/A
Samples disposed of by & disposal method Initials/Date/Time	N/A	sample consumed in test KG 5/9/04 1424

All samples are stored in the laboratory refrigerator from just above freezing to 6 degrees Celsius unless noted on this Internal chain of custody.

Comments: ______________________

Reviewed by DT 05/12/04

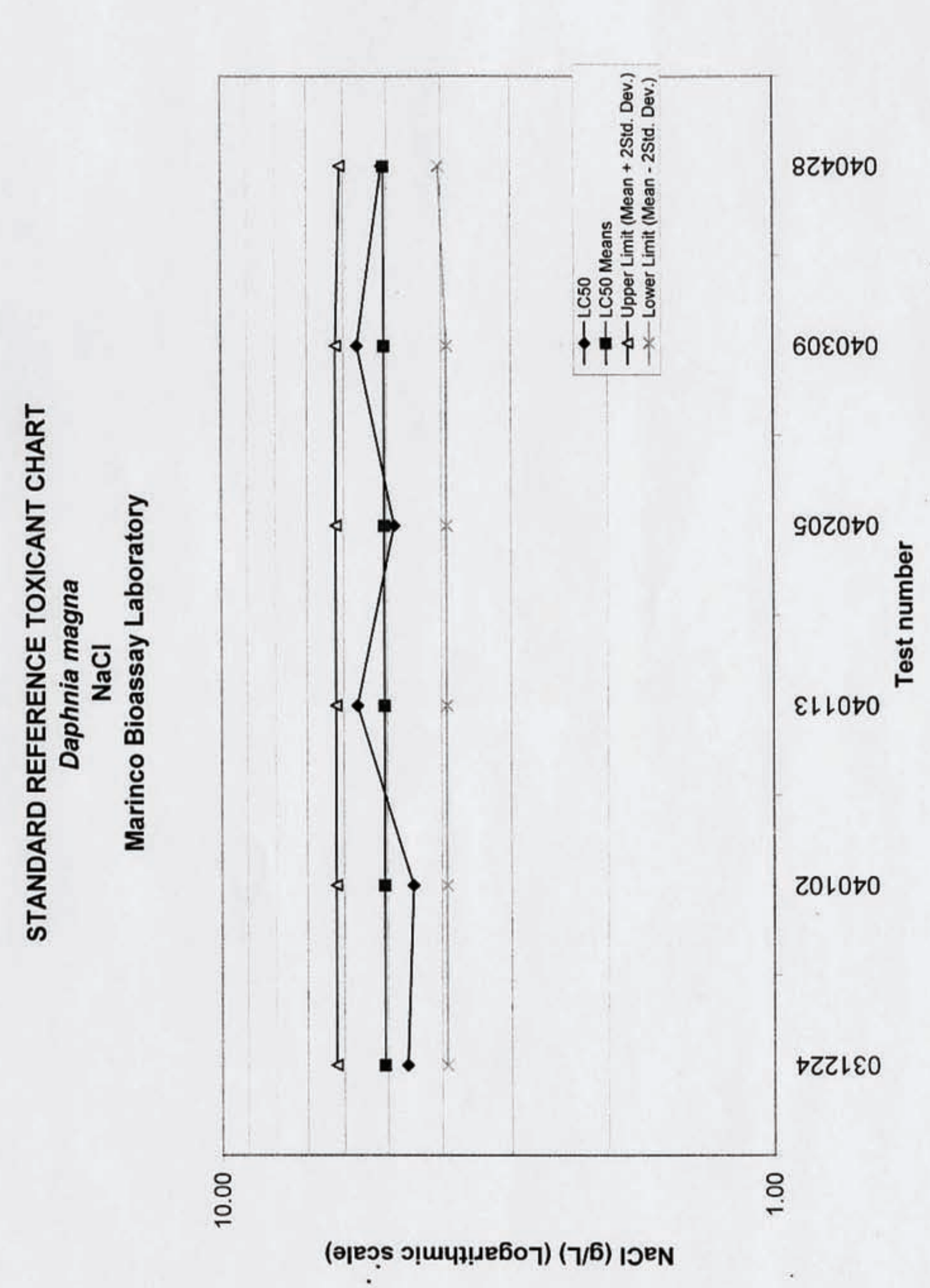
MBL#ac-int Ver#4

***Daphnia magna* Acute Standard Reference Toxicant (SRT) Report.**

This quality control test was conducted by Marinco Bioassay Laboratory, Inc. personnel using Whole Effluent Toxicity (WET) Test method number 2021.0

SRT Test No. 040428DMACSRT

Reviewed by: Diane Thornton Date: 05/06/04


STANDARD REFERENCE TOXICANT CHART
Daphnia magna
NaCl
Marinco Bioassay Laboratory
LC50
LC50 Means
Upper Limit (Mean + 2Std. Dev.)
Lower Limit (Mean - 2Std. Dev.)
NaCl (g/L) (Logarithmic scale)
10.00
1.00
031224
040102
040113
040205
040309
040428
Test number

Acute Fish Test-96 Hr Survival

Start Date:	4/28/2004	Test ID:	040428DMACSRT	Sample ID:	8.0 g/L NaCl
End Date:	5/2/2004	Lab ID:	MBL-Marinco Bioassay Lab.	Sample Type:	NACL-Sodium chloride
Sample Date:		Protocol:	EPA Method #2021.0	Test Species:	DM-*Daphnia magna*

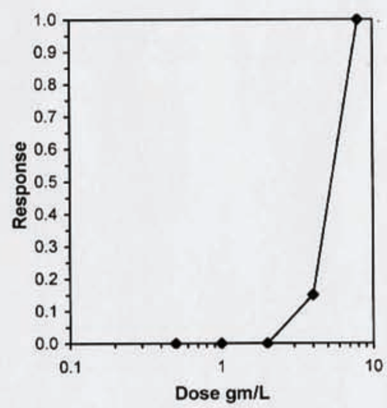
Comments: This analysis was performed by Lisa Rouwenhorst at MBL.

Conc-gm/L	1	2	3	4
Control	1.0000	1.0000	1.0000	1.0000
0.5	1.0000	1.0000	1.0000	1.0000
1	1.0000	1.0000	1.0000	1.0000
2	1.0000	1.0000	1.0000	1.0000
4	0.8000	0.8000	1.0000	0.8000
8	0.0000	0.0000	0.0000	0.0000

			Transform: Untransformed					Number	Total
Conc-gm/L	Mean	N-Mean	Mean	Min	Max	CV%	N	Resp	Number
Control	**1.0000**	1.0000	1.0000	1.0000	1.0000	0.000	4	0	20
0.5	**1.0000**	1.0000	1.0000	1.0000	1.0000	0.000	4	0	20
1	**1.0000**	1.0000	1.0000	1.0000	1.0000	0.000	4	0	20
2	**1.0000**	1.0000	1.0000	1.0000	1.0000	0.000	4	0	20
4	**0.8500**	0.8500	0.8500	0.8000	1.0000	11.765	4	3	20
8	**0.0000**	0.0000	0.0000	0.0000	0.0000	0.000	4	20	20

Trimmed Spearman-Karber

Trim Level	EC50	95% CL	
0.0%	5.0982	4.5640	5.6950
5.0%	5.2099	4.5766	5.9309
10.0%	5.2897	4.4710	6.2583
20.0%	5.3212	4.9289	5.7449
Auto-0.0%	**5.0982**	**4.5640**	**5.6950**



ToxCalc v5.0

Reviewed by: [signature]

SURVIVAL BENCH SHEET

Project #: 040428DMACSRT
Test Organism: *Daphnia magna*
Organism Age: <24 hours

Test Start: 4/28/04 1540
Test End: 5/2/04 1405
Brood #: DM040428

Time Fed (48 hours): 0742 Initials & Date LR 4/30/04 LR 4/30/04
Time Renewed (48 hours): 1120 Initials & Date LR 4/30/04

Effluent Concentration %	Sample Number	Survival Replicate A 0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	Survival Replicate B 0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	A & B Total
100	8.0 g/L NaCl	5	0	—	—	—	5	0	—	—	—	0
50		5	5	5	5	4	5	5	5	4	4	8
25		5	5	5	5	5	5	5	5	5	5	10
12.5		5	5	5	5	5	5	5	5	5	5	10
6.25		5	5	5	5	5	5	5	5	5	5	10
Control		5	5	5	5	5	5	5	5	5	5	10
0 Hours started/checked by:; 24, 72, 96 Hours counted by:; 48 Hours renewed by:		LR/MB	LR	LR	LR	KG	LR/MB	LR	LR	LR	KG	KG

Effluent Concentration %	Sample Number	Survival Replicate C 0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	Survival Replicate D 0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	C & D Total
100	8.0 g/L NaCl	5	0	—	—	—	5	0	—	—	—	0
50		5	5	5	5	5	5	5	5	5	4	9
25		5	5	5	5	5	5	5	5	5	5	10
12.5		5	5	5	5	5	5	5	5	5	5	10
6.25		5	5	5	5	5	5	5	5	5	5	10
Control		5	5	5	5	5	5	5	5	5	5	10
0 Hours started/checked by:; 24, 72, 96 Hours counted by:; 48 Hours renewed by:		LR/MB	LR	LR	LR	KG	LR/MB	LR	LR	LR	KG	KG

Total Survival/Start Count = % Survival at end of test

100	50	25	12.5	6.25	Control
0/20 = 0 %	17/20 = 85 %	20/20 = 100 %	20/20 = 100 %	20/20 = 100 %	20/20 = 100 %

Comments: ______

Reviewed by: DI

Date: 05/06/04

MBL #0016, Ver. 4

ACUTE TOXICITY TEST PHYSICAL AND CHEMICAL MEASUREMENTS

EPA Method # 2021.0

Project #: 040428DMACSRT **Test Start:** 4/28/04 1540

Test Organism: Daphnia magna **Test End:** 5/2/04 1405

Effluent Concentration %	Sample Number	Dissolved Oxygen (mg/L) 0 Hours	24 Hours	48 Hours	72 Hours	96 Hours
100	8.0g/L NaCl	8.4	7.8	—	—	—
50.0		8.6	8.0	8.8 / 8.1	8.0	7.6
25.0		8.6	8.1	8.1 / 8.7	8.6	7.7
12.5		8.6	8.0	8.3 / 8.8	8.0	7.8
6.25		8.5	8.0	7.9 / 8.7	8.0	7.8
Control		8.4	7.8	7.8 / 8.6	7.9	7.6
Measured by:		LR	LR	LR / LR	LR	KG

Effluent Concentration %	pH 0 Hours	24 Hours	48 Hours	72 Hours	96 Hours
100	7.5	7.6	—	—	—
50.0	7.6	7.7	7.7 / 7.7	7.7	7.8
25.0	7.6	7.7	7.7 / 7.7	7.8	7.8
12.5	7.7	7.8	7.9 / 7.7	7.8	7.8
6.25	7.7	7.8	7.8 / 7.7	7.8	7.9
Control	7.7	7.8	7.8 / 7.8	7.8	7.9
Measured by:	LR	LR	LR / LR	LR	KG

Effluent Concentration %	Sample Number	Temperature (Degrees Celsius) 0 Hours	24 Hours	48 Hours	72 Hours	96 Hours
100	8.0g/L NaCl	20	21	21 LR 4/30/04	—	—
50.0		20	21	21 / 21	21	21
25.0		20	21	21 / 21	21	21
12.5		20	21	21 / 21	21	21
6.25		20	21	21 / 21	21	21
Control		20	21	21 / 21	21	21
Measured by:		LR	LR	LR / LR	LR	KG

Effluent Concentration %	conductivity (mS/cm) 0 Hours	24 Hours	48 Hours	72 Hours	96 Hours
100	14.51	13.35	—	—	—
50.0	7.64	—	— / 7.61	—	7.53
25.0	4.08	—	— / 4.08	—	3.98
12.5	2.30	—	— / 2.22	—	2.20
6.25	1.316	—	— / 1.320	—	1.282
Control	0.304	—	— / 0.303	—	0.304
Measured by:	LR	LR	— / LR	—	KG

Comments or corrections:

Reviewed by: DI

Date: 05/06/04

MBL #0006. Ver. 5

SRT Tracking Sheet

Test ID: 040428DMACSRT

Test LC50: 5.10g/L NaCl

Test Species: Daphnia magna

Test NOEC: N/A

Test Dates : 4/28/04 to 5/2/04

Test IC25: N/A

SRT Solution Data

Test Concentration and Toxicant: 8.0 g/L NaCl Lot # ST0585

Mass of Toxicant from Balance Log (g)	Measured by Init./Date	Volume Mixed (L)	Mixed by Init./Date	Cond. (mS/cm)	Measured by Init./Date	Balance Used to measure toxicant Init./date
3.20006	LR 4/28/04	0.4	LR 4/28/04	14.51	LR 4/28/04	Mettler LR 4/28/04
1.99992	LR 4/30/04	0.25	LR 4/30/04	14.50	LR 4/30/04	Mettler LR 4/30/04

Control and Dilution Waters

Laboratory Number	Alkalinity (mg/L)	Measured by Init./Date	Hardness (mg/L)	Measured by Init./Date	Cond. (mS/cm)	Measured by Init./Date
SMH040423	56	SK 4/28/04	80	SK 4/28/04	0.304	LR 4/28/04

Comments or Corrections:

Reviewed by: DT

Date: 05/04/04

MBL #0031 Ver. #9

ACUTE TEST CONDITIONS

Project #: 040428DMACSRT **Client:** —

Test type: 96 hr (R) DM def. **Test run in Environmental Chamber #:** 3

Species Code (1)	Receipt Date and Supplier of Organism (If commercially obtained)	Init.	Amount & Type of Food (2)	Init.	How Often Fed (3)	Init.	Test Chamber Vol. (mL)	Init.	Vol. of Effluent Used (mL)	Init.	Type of Chamber (4)	Init.
DM	N/A	LR	O	LR	R	LR	30	LR	25	LR	M	LR

(1) CD Ceriodaphnia dubia
FM Pimephales promelas (fathead minnow)
SS Menidia beryllina (inland silverside)
MS Mysidopsis bahia (mysid shrimp)
DP Daphnia pulex
DM Daphnia magna
CL Cyprinella leedsi (bannerfin shiner)
Other - Please Describe ____

(2) Please fill the "Amount & Type of Food" Box with the appropriate letter:
'A' 0.2 mL Selenastrum, 0.2 mL YCT
'B' 1.4 mL Selenastrum/200 mL of sample, 1.4 mL YCT/200 mL of sample
'C' 0.1 mL conc. Artemia nauplii
'D' 0.03 mL of 1200 Artemia nauplii/0.1 mL per replicate
'E' 0.04 mL of 1200 Artemia nauplii/0.1 mL per replicate
'F' 0.06 mL of 1200 Artemia nauplii/0.1 mL per replicate
'G' 0.07 mL of 1200 Artemia nauplii/0.1 mL per replicate
'H' 0.08 mL of 1200 Artemia nauplii/0.1 mL per replicate
'O' Other 0.25 mL Selenastrum + 0.25 mL YCT per replicate

(3) Please fill the "How Often Fed" box with the appropriate letter:
'R' Once, at least two hours before renewal
'D' Once daily
'T' Twice daily
'O' Other ____

(4) Please fill the "Type of Chamber" box with the appropriate letter:
'B' Plastic Beaker
'M' Plastic Medicine Cup
'P' Plastic Cup
'G' Glass Beaker
'C' Plastic Container
'O' Other ____

Photoperiod: [LR] 16 hours Light/8 hours dark
[—] Other —

Test(s) conducted in accordance with EPA-821-R-02-012

Randomization version: ~~E~~ G LR 4/28/04

Method number 2021.0

Physical and Chemical Measurement Equipment

Equipment type	Test start	24 hours	48 hours	72 hours	96 hours
Thermometer (A)	A	A	A / A	A	A
DO Meter (B)	3	3	3 / 3	3	3
pH Meter (C)	7	7	7 / 7	7	7
Conductivity meter (D)	10	10	N/A / 10	N/A	10
Freshwater cond. checked by	LR	—	— / LR	—	—
Used by (Initials)	LR	LR	LR / LR	LR	KG

(A) Thermometer number is the serial number or designated number on thermometer.
(B) DO Meters: "3" Orion 830
"4" Hach Sension 6
"5" Orion 830A
"6" Orion 820
(C) pH Meters "7" Hach Sension 2
"8" Orion 290A
"9" Orion 720
(D) Conductivity "10" Orion 160
"11" Orion 126
"O" Other ____

Comments or Corrections: ____

Reviewed by: DT

Date: 05/06/04

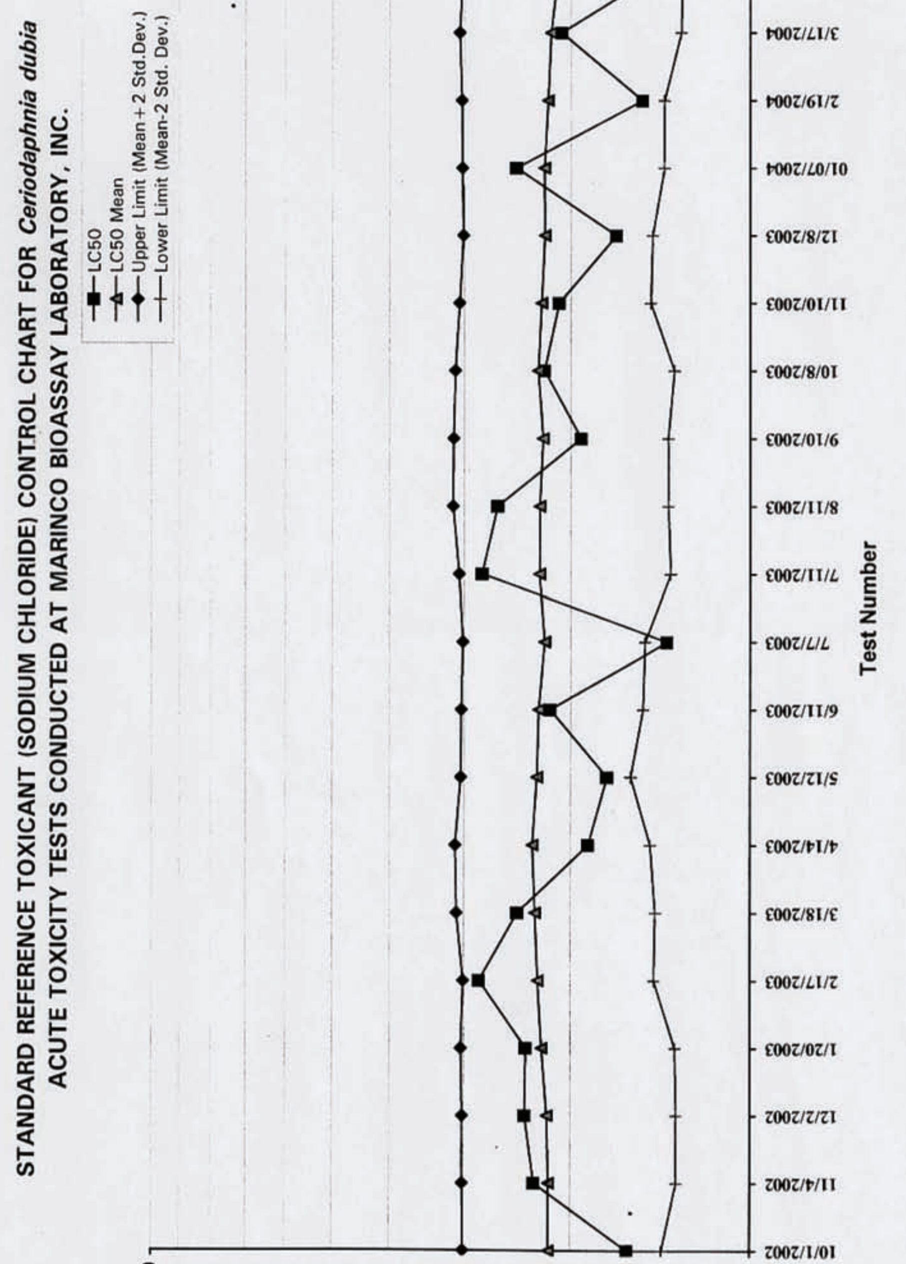
MBL #0026a. Ver. 12

Ceriodaphnia dubia **Acute Standard Reference Toxicant (SRT) Report.**

This quality control test was conducted by Marinco Bioassay Laboratory, Inc. personnel using Whole Effluent Toxicity (WET) Test method number 2002.0

SRT Test No. 040412CDACSRT

Reviewed by: Diane Thornton Date: 04/20/04


STANDARD REFERENCE TOXICANT (SODIUM CHLORIDE) CONTROL CHART FOR Ceriodaphnia dubia
ACUTE TOXICITY TESTS CONDUCTED AT MARINCO BIOASSAY LABORATORY, INC.
LC50
LC50 Mean
Upper Limit (Mean+2 Std.Dev.)
Lower Limit (Mean-2 Std. Dev.)
10
1
NaCl (g/L) (Logarithmic scale)
10/1/2002
11/4/2002
12/2/2002
1/20/2003
2/17/2003
3/18/2003
4/14/2003
5/12/2003
6/11/2003
7/7/2003
7/11/2003
8/11/2003
9/10/2003
10/8/2003
11/10/2003
12/8/2003
01/07/2004
2/19/2004
3/17/2004
4/12/2004
Test Number

Acute Fish Test-96 Hr Survival

Start Date:	4/12/2004	Test ID:	040412CDACSRT	Sample ID:	4.0 g/L NaCl
End Date:	4/16/2004	Lab ID:	MBL-Marinco Bioassay Lab.	Sample Type:	NACL-Sodium chloride
Sample Date:		Protocol:	EPA Method #2002.0	Test Species:	CD-*Ceriodaphnia dubia*

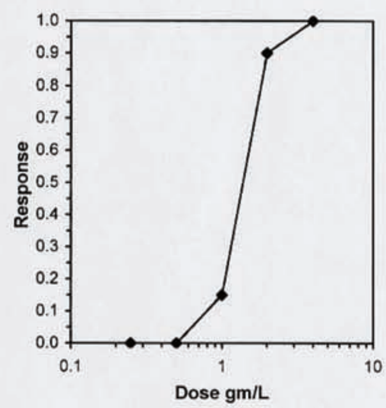
Comments: This analysis was performed by Lisa Rouwenhorst at MBL.

Conc-gm/L	1	2	3	4
Control	1.0000	1.0000	1.0000	1.0000
0.25	1.0000	1.0000	1.0000	1.0000
0.5	1.0000	1.0000	1.0000	1.0000
1	0.6000	1.0000	0.8000	1.0000
2	0.0000	0.0000	0.4000	0.0000
4	0.0000	0.0000	0.0000	0.0000

			Transform: Untransformed						
Conc-gm/L	Mean	N-Mean	Mean	Min	Max	CV%	N	Number Resp	Total Number
Control	**1.0000**	1.0000	1.0000	1.0000	1.0000	0.000	4	0	20
0.25	**1.0000**	1.0000	1.0000	1.0000	1.0000	0.000	4	0	20
0.5	**1.0000**	1.0000	1.0000	1.0000	1.0000	0.000	4	0	20
1	**0.8500**	0.8500	0.8500	0.6000	1.0000	22.528	4	3	20
2	**0.1000**	0.1000	0.1000	0.0000	0.4000	200.000	4	18	20
4	**0.0000**	0.0000	0.0000	0.0000	0.0000	0.000	4	20	20

Trimmed Spearman-Karber

Trim Level	EC50	95% CL	
0.0%	1.3660	1.1822	1.5785
5.0%	1.3652	1.1783	1.5816
10.0%	1.3740	1.1490	1.6430
20.0%	1.3819	1.2533	1.5237
Auto-0.0%	**1.3660**	**1.1822**	**1.5785**



 ToxCalc v5.0 Reviewed by: DT

SURVIVAL BENCH SHEET

Project #: 040412CDACSRT
Test Organism: *Ceriodaphnia dubia*
Organism Age: <24 hours

Test Start: 4/12/04 1304
Test End: 4/16/04 1501
Brood #: CD040412a

Time Fed (48 hours): 0800 Initials & Date MB 4/14/04
Time Renewed (48 hours): 1324 Initials & Date MB 4/14/04

Effluent Concentration %	Sample Number	Survival Replicate A					Survival Replicate B					A & B Total
		0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	—
100	4 g/L NaCl	5	1	0	—	—	5	1	0	—	—	0
50		5	5	2	2	0	5	5	2	1	0	0
25		5	5	5	5	3	5	5	5	5	5	[illegible] 8
12.5		5	5	5	5	5	5	5	5	5	5	10
6.25		5	5	5	5	5	5	5	5	5	5	10
Control		5	5	5	5	5	5	5	5	5	5	10
0 Hours started/checked by:; 24, 72, 96 Hours counted by:; 48 Hours renewed by:		KG/DM	SK	MB	LB	KG	KG/DM	SK	MB	LB	KG	KG

Effluent Concentration %	Sample Number	Survival Replicate C					Survival Replicate D					C & D Total
		0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	—
100	4 g/L NaCl	5	0	—	—	—	5	2	0	—	—	0
50		5	5	4	2	2	5	5	1	1	0	2
25		5	5	5	5	4	5	5	5	5	5	9
12.5		5	5	5	5	5	5	5	5	5	5	10
6.25		5	5	5	5	5	5	5	5	5	5	10
Control		5	5	5	5	5	5	5	5	5	5	10
0 Hours started/checked by:; 24, 72, 96 Hours counted by:; 48 Hours renewed by:		KG/DM	SK	MB	LB	KG	KG/DM	SK	MB	LB	KG	KG

Total Survival/Start Count = % Survival at end of test

100	50	25	12.5	6.25	Control
0/20 = 0 %	2/20 = 10 %	17/20 = 85 %	20/20 = 100 %	20/20 = 100 %	20/20 = 100 %

Comments: ______

Reviewed by: DT

Date: 04/20/04

MBL #0016. Ver. 4

ACUTE TOXICITY TEST PHYSICAL AND CHEMICAL MEASUREMENTS

EPA Method # 2002.0

Project #: 040412CDACSRT **Test Start:** 4/12/04 1504

Test Organism: Ceriodaphnia dubia **Test End:** 4/16/04 1501

Effluent Concentration %	Sample Number	Dissolved Oxygen (mg/L) 0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	pH 0 Hours	24 Hours	48 Hours	72 Hours	96 Hours
100	4 g/L NaCl	8.0	7.7	7.7/	—	—	7.5	7.9	7.8/	—	—
50.0		8.1	7.7	7.7/8.8	7.9	7.9	7.6	7.9	7.8/7.8	8.0	7.9
25.0		8.2	7.7	7.7/8.8	8.0	7.9	7.7	7.9	7.9/7.9	7.9	7.8
12.5		8.2	7.8	7.7/8.3	7.9	7.9	7.7	7.9	7.9/7.9	7.9	7.9
6.25		8.2	7.7	7.8/8.3	7.9	7.8	7.8	7.9	7.8/7.9	7.9	7.9
Control		8.2	7.7	7.8/8.8	7.9	7.8	7.8	7.9	7.8/7.9	7.9	7.8
Measured by:		KG	SK	SK/MB	DM	SK	KG	SK	SK/MB	DM	SK

Effluent Concentration %	Sample Number	Temperature (Degrees Celsius) 0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	conductivity (mS/cm) 0 Hours	24 Hours	48 Hours	72 Hours	96 Hours
100	4 g/L NaCl	25	26	26/	—	—	7.66	—	7.21/	—	—
50.0		25	26	26/25	26	26	4.08	—	—/4.05	—	3.99
25.0		25	26	26/25	26	26	2.24	—	—/2.24	—	2.21
12.5		25	26	26/26	26	26	1.302	—	—/1.299	—	1.289
6.25		25	26	26/25	26	26	0.782	—	—/0.808	—	0.798
Control		25	26	26/25	26	26	0.301	—	—/0.307	—	0.304
Measured by:		KG	SK	SK/MB	DM	SK	KG	—	SK/MB	—	SK

Comments or corrections: ______

Reviewed by: [initials]

Date: 04/20/04

MBL #0006, Ver. 5

SRT Tracking Sheet

Test ID: 040412CDACSRT

Test Species: Ceriodaphnia dubia

Test Dates : 4/12/04 to 4/16/04

Test LC50: 1.37 g/L NaCl

Test NOEC: N/A

Test IC25: N/A

SRT Solution Data

Test Concentration and Toxicant: 4 g/L NaCl (Lot # ST0885)

Mass of Toxicant from Balance Log (g)	Measured by Init./Date	Volume Mixed (L)	Mixed by Init./Date	Cond. (mS/cm)	Measured by Init./Date	Balance Used to measure toxicant Init./date
1.59998	KG 4/12/04	0.4	KG 4/12/04	7.68	KG 4/12/04	Mettler KG 4/12/04
1.00015	MB 4/14/04	0.25	MB 4/14/04	7.65	MB 4/14/04	Mettler MB 4/14/04

Control and Dilution Waters

Laboratory Number	Alkalinity (mg/L)	Measured by Init./Date	Hardness (mg/L)	Measured by Init./Date	Cond. (mS/cm)	Measured by Init./Date
SMH040406	56	SK 4/8/04	80	SK 4/8/04	0.301	KG 4/12/04
SMH040408	55	SK 4/15/04	80	SK 4/15/04	0.307	MB 4/14/04

Comments or Corrections:

Reviewed by: NT

Date: 04/20/04

MBL #0031 Ver. #9

ACUTE TEST CONDITIONS

Project #: 040412CDACGRT **Client:** —

Test type: CD 96 hr @ def **Test run in Environmental Chamber #:** #2 KG 4/12

Species Code (1)	Receipt Date and Supplier of Organism (if commercially obtained)	Init.	Amount & Type of Food (2)	Init.	How Often Fed (3)	Init.	Test Chamber Vol. (mL)	Init.	Vol. of Effluent Used (mL)	Init.	Type of Chamber (4)	Init.
CD	N/A	KG	A	MB	R	MB	30	KG	25	KG	M	KG

(1) CD Ceriodaphnia dubia
FM Pimephales promelas (fathead minnow)
SS Menidia beryllina (inland silverside)
MS Mysidopsis bahia (mysid shrimp)
DP Daphnia pulex
DM Daphnia magna
CL Cyprinella leedsi (bannerfin shiner)
Other - Please Describe ______

(2) Please fill the "Amount & Type of Food" Box with the appropriate letter:
'A' 0.2 mL Selenastrum, 0.2 mL YCT
'B' 1.4 mL Selenastrum/200 mL of sample, 1.4 mL YCT/200 mL of sample
'C' 0.1 mL conc. Artemia nauplii
'D' 0.03 mL of 1200 Artemia nauplii/0.1 mL per replicate
'E' 0.04 mL of 1200 Artemia nauplii/0.1 mL per replicate
'F' 0.06 mL of 1200 Artemia nauplii/0.1 mL per replicate
'G' 0.07 mL of 1200 Artemia nauplii/0.1 mL per replicate
'H' 0.08 mL of 1200 Artemia nauplii/0.1 mL per replicate
'O' Other ______

(3) Please fill the "How Often Fed" box with the appropriate letter:
'R' Once, at least two hours before renewal
'D' Once daily
'T' Twice daily
'O' Other ______

(4) Please fill the "Type of Chamber" box with the appropriate letter:
'B' Plastic Beaker
'M' Plastic Medicine Cup
'P' Plastic Cup
'G' Glass Beaker
'C' Plastic Container
'O' Other ______

Photoperiod: [KG] 16 hours Light/8 hours dark
[—] Other ——

Test(s) conducted in accordance with EPA-821-R-02-012

Randomization version: G

Method number 2002.0

Physical and Chemical Measurement Equipment

Equipment type	Test start	24 hours	48 hours	72 hours	96 hours
Thermometer (A)	A	A	A / A	A	A
DO Meter (B)	3	3	3 / 3	3	3
pH Meter (C)	7	7	7 / 7	7	7
Conductivity meter (D)	10	N/A	10 / 10	N/A	10
Freshwater cond. checked by	KG	—	— / MB	—	—
Used by (Initials)	KG	SK	SK / MB	DM	SK

(A)Thermometer number is the serial number or designated number on thermometer.
(B)DO Meters: "3" Orion 830
"4" Hach Sension 6
"5" Orion 830A
"6" Orion 820
(C)pH Meters "7" Hach Sension 2
"8" Orion 290A
"9" Orion 720
(D)Conductivity "10" Orion 160
"11" Orion 126
"O" Other ______

Comments or Corrections: Test moved to EC#1 by 4/15/04

Reviewed by: DT

Date: 04/20/04

MBL #0026a. Ver. 12

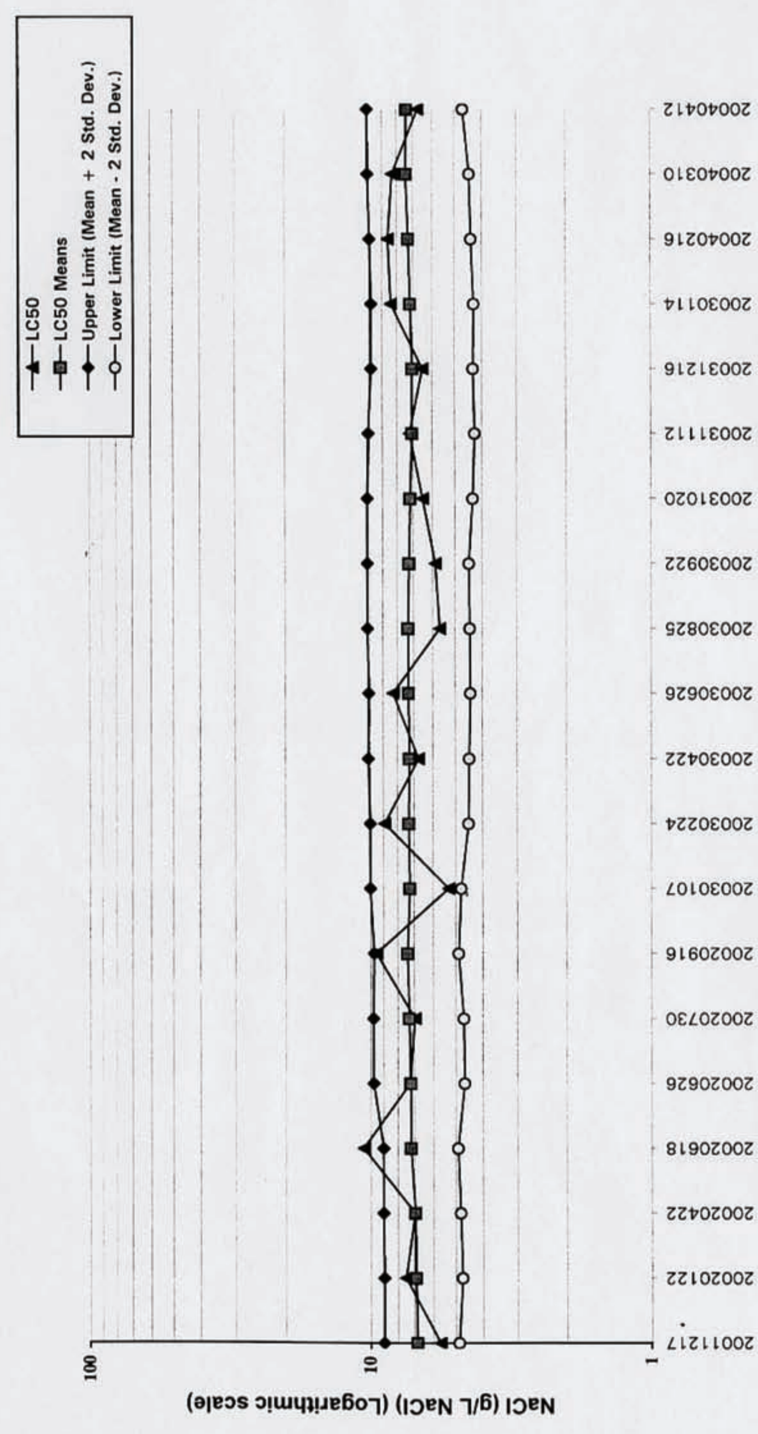
***Pimephales promelas* Acute Standard Reference Toxicant (SRT) Report.**

This quality control test was conducted by Marinco Bioassay Laboratory, Inc. personnel using Whole Effluent Toxicity (WET) Test method number 2000.0

SRT Test No. 040412FMACSRT

Reviewed by: Diane Thornton Date: 04/20/04

STANDARD REFERENCE TOXICANT (SODIUM CHLORIDE) CONTROL CHART FOR *Pimephales promelas* 96-HOUR ACUTE TOXICITY TESTS CONDUCTED AT MARINCO BIOASSAY LABORATORY, INC.



Acute Fish Test-96 Hr Survival

Start Date:	4/12/2004	Test ID:	040412FMACSRT	Sample ID:	16.0 g/L NaCl
End Date:	4/16/2004	Lab ID:	MBL-Marinco Bioassay Lab.	Sample Type:	NACL-Sodium chloride
Sample Date:		Protocol:	EPA Method #2000.0	Test Species:	PP-*Pimephales promelas*

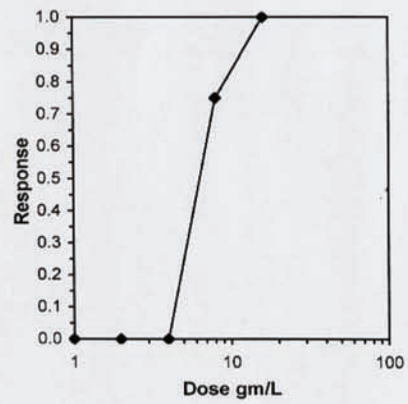
Comments: This analysis was performed by Lisa Rouwenhorst at MBL.

Conc-gm/L	1	2
Control	1.0000	1.0000
1	1.0000	1.0000
2	1.0000	1.0000
4	1.0000	1.0000
8	0.2000	0.3000
16	0.0000	0.0000

			Transform: Untransformed					Number	Total
Conc-gm/L	Mean	N-Mean	Mean	Min	Max	CV%	N	Resp	Number
Control	**1.0000**	1.0000	1.0000	1.0000	1.0000	0.000	2	0	20
1	**1.0000**	1.0000	1.0000	1.0000	1.0000	0.000	2	0	20
2	**1.0000**	1.0000	1.0000	1.0000	1.0000	0.000	2	0	20
4	**1.0000**	1.0000	1.0000	1.0000	1.0000	0.000	2	0	20
8	**0.2500**	0.2500	0.2500	0.2000	0.3000	28.284	2	15	20
16	**0.0000**	0.0000	0.0000	0.0000	0.0000	0.000	2	20	20

Trimmed Spearman-Karber

Trim Level	EC50	95% CL	
0.0%	6.7272	5.8822	7.6935
5.0%	6.6158	5.7143	7.6596
10.0%	6.5168	5.5763	7.6159
20.0%	6.3741	5.4312	7.4807
Auto-0.0%	**6.7272**	**5.8822**	**7.6935**



Reviewed by: DT

SURVIVAL BENCH SHEET

Project #: 040412 FMACSET **Test Start:** 4/12/04 1440

Test Organism: Pimephales promelas **Test End:** 4/16/04 1430

Organism Age: 8 days **Brood #:** FM040404-1500

Concentration %	Sample Number	Survival: Replicate A					Survival: Replicate B					A & B %
		0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	
100	16.0g/L NaCl	10	0	—	—	—	10	0	—	—	—	0
50		10	7	7	7	2	10	6	6	6	3	25
25		10	10	10	10	10	10	10	10	10	10	100
12.5		10	10	10	10	10	10	10	10	10	10	100
6.25		10	10	10	10	10	10	10	10	10	10	100
Control		10	10	10	10	10	10	10	10	10	10	100
Organisms Fed AM / PM		— / —	— / —	DM 0830 / -	— / —	— / —	— / —	— / —	DM 0830 / —	— / —	— / —	—
0 Hours started/checked by: 24, 72, 96 Hours counted by: 48 Hours renewed/cleaned by:		MB / DM	SK	UR 1124	CB	KG	MB / DM	SK	UR 1124	SB	KG	KG

Comments or Corrections:

Reviewed by: DT

Date: 04/20/04

MBL #0022. Ver. #3

ACUTE TOXICITY TEST PHYSICAL AND CHEMICAL MEASUREMENTS

EPA Method # 2000.0

Project #: 040412 FMAN SET **Test Start:** 4/12/04 1440

Test Organism: Pimephales promelas **Test End:** 4/16/04 1420

Effluent Concentration %	Sample Number	Dissolved Oxygen (mg/L)					pH				
		0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	0 Hours	24 Hours	48 Hours	72 Hours	96 Hours
100	16.0g/L NaCl	7.7	6.4	—	—	—	7.6	7.6	—	—	—
50.0		7.9	7.1	7.2 / 7.8	7.2	7.2	7.6	7.7	7.9 / 7.6	7.8	7.7
25.0		8.1	7.4	7.4 / 8.0	7.2	6.9	7.7	7.7	7.9 / 7.7	7.7	7.6
12.5		8.2	7.4	7.4 / 8.1	7.0	6.7	7.7	7.8	7.9 / 7.7	7.7	7.6
6.25		8.2	7.4	7.4 / 8.1	7.4	7.4	7.8	7.8	7.9 / 7.8	7.8	7.7
Control		8.2	7.5	8.1 / 8.1	7.2	7.0	7.8	7.9	8.0 / 7.9	7.8	7.7
Measured by:		MB	SK	SK / LR	DM	SK	MB	SK	SK / LR	DM	SK

Effluent Concentration %	Sample Number	Temperature (Degrees Celsius)					Conductivity (mS/cm)				
		0 Hours	24 Hours	48 Hours	72 Hours	96 Hours	0 Hours	24 Hours	48 Hours	72 Hours	96 Hours
100	16.0g/L NaCl	25	26	—	—	—	27.4	27.4	—	—	—
50.0		25	26	25 / 25	25	25	14.40	—	— / 14.31	—	15.69
25.0		25	26	25 / 25	25	25	7.59	—	— / 7.62	—	8.27
12.5		25	26	25 / 26	25	25	4.05	—	— / 4.06	—	4.46
6.25		25	26	25 / 25	25	25	2.26	—	— / 2.20	—	2.43
Control		25	26	25 / 25	25	25	0.301	—	— / 0.310	—	0342
Measured by:		MB	SK	SK / LR	DM	SK	MB	SK	— / LR	—	SK

Comments or corrections: ______________________

Reviewed by: DT

Date: 04/20/04

MBL #0006 Ver. 5

SRT Tracking Sheet

Test ID: 040412FMACSRT

Test Species: Pimephales promelas

Test Dates : 4/12/04 to 4/16/04

Test LC50: 6.73 g/L NaCl

Test NOEC: N/A

Test IC25: N/A

SRT Solution Data

Test Concentration and Toxicant: 16.0 g/L NaCl (Lot# ST0585)

Mass of Toxicant from Balance Log (g)	Measured by Init./Date	Volume Mixed (L)	Mixed by Init./Date	Cond. (mS/cm)	Measured by Init./Date	Balance Used to measure toxicant Init./date
16.00015	MB 4/12/04	1.0	MB 4/12/04	27.4	MB 4/12/04	Mettler MB 4/12/04
8.00003	LR 4/14/04	0.5	LR 4/14/04	27.3	LR 4/14/04	Mettler LR 4/14/04

Control and Dilution Waters

Laboratory Number	Alkalinity (mg/L)	Measured by Init./Date	Hardness (mg/L)	Measured by Init./Date	Cond. (mS/cm)	Measured by Init./Date
SMH040406	56	SK 4/8/04	80	SK 4/8/04	0.301	MB 4/12/04
SMH040408	55	SK 4/15/04	80	SK 4/15/04	0.310	LR 4/14/04

Comments or Corrections:

Reviewed by: DT

Date: 04/20/04

MBL #0031 Ver. #9

ACUTE TEST CONDITIONS

Project #: 040412FmA0SDT **Client:** —

Test type: Fm 96hr. Ddef. **Test run in Environmental Chamber #:** 2

Species Code (1)	Receipt Date and Supplier of Organism (if commercially obtained)	Init.	Amount & Type of Food (2)	Init.	How Often Fed (3)	Init.	Test Chamber Vol. (mL)	Init.	Vol. of Effluent Used (mL)	Init.	Type of Chamber (4)	Init.
Fm	—	MB	E	DM	R	DM	1000	MB	250	MB	B	MB

(1) CD Ceriodaphnia dubia
FM Pimephales promelas (fathead minnow)
SS Menidia beryllina (inland silverside)
MS Mysidopsis bahia (mysid shrimp)
DP Daphnia pulex
DM Daphnia magna
CL Cyprinella leedsi (bannerfin shiner)
Other - Please Describe ______

(2) Please fill the "Amount & Type of Food" Box with the appropriate letter:
'A' 0.2 mL Selenastrum, 0.2 mL YCT
'B' 1.4 mL Selenastrum/200 mL of sample, 1.4 mL YCT/200 mL of sample
'C' 0.1 mL conc. Artemia nauplii
'D' 0.03 mL of 1200 Artemia nauplii/0.1 mL per replicate
'E' 0.04 mL of 1200 Artemia nauplii/0.1 mL per replicate
'F' 0.06 mL of 1200 Artemia nauplii/0.1 mL per replicate
'G' 0.07 mL of 1200 Artemia nauplii/0.1 mL per replicate
'H' 0.08 mL of 1200 Artemia nauplii/0.1 mL per replicate
'O' Other ______

(3) Please fill the "How Often Fed" box with the appropriate letter:
'R' Once, at least two hours before renewal
'D' Once daily
'T' Twice daily
'O' Other ______

(4) Please fill the "Type of Chamber" box with the appropriate letter:
'B' Plastic Beaker
'M' Plastic Medicine Cup
'P' Plastic Cup
'G' Glass Beaker
'C' Plastic Container
'O' Other ______

Photoperiod: [MB] 16 hours Light/8 hours dark
[—] Other ——

Test(s) conducted in accordance with EPA-821-R-02-012

Randomization version: 5

Method number 2000.0

Physical and Chemical Measurement Equipment

Equipment type	Test start	24 hours	48 hours	72 hours	96 hours
Thermometer (A)	A	A	A / A	A	A
DO Meter (B)	3	3	3 / 3	3	3
pH Meter (C)	7	7	7 / 7	7	7
Conductivity meter (D)	10	10	N/A / 10	N/A	10
Freshwater cond. checked by	—	—	— / —	—	—
Used by (Initials)	MB	SK	SK / LR	DM	SK

(A)Thermometer number is the serial number or designated number on thermometer.
(B)DO Meters: "3" Orion 830
"4" Hach Sension 6
"5" Orion 830A
"6" Orion 820
(C)pH Meters "7" Hach Sension 2
"8" Orion 290A
"9" Orion 720
(D)Conductivity "10" Orion 160
"11" Orion 126
"O" Other ______

Comments or Corrections: Test moved to EC#1 DM 4/14/04

Reviewed by: DT

Date: 04/20/04

MBL #0026a. Ver. 12

APPENDIX D

Cost Sheets

Project: USBR DWPR Phase I
Job #: 6870A.00
Location: DMWW

Date: 1-20-05
Estimator: SJG

Estimate ENR: 7112
Construction Mid Point ENR: 7112

Item No.	Description	Unit Quantity	Std. Unit	Unit Price	Item Total	Install Factor	Total Cost
RBF Wells and Pumping							
	Horizontal Collectors	7	ea.	$ 800,000	$ 5,600,000	1.0	$ 5,600,000
	Well Testing	ls	--	$ 350,000	$ 350,000	1.0	$ 350,000
	Wellhead Pumps	14	ea.	$ 50,000	$ 700,000	1.5	$ 1,050,000
	Wellhead Building	7	ea.	$ 110,000	$ 770,000	1.0	$ 770,000
	Well Head Piping	158,400	in-dia. ft	$ 6.00	$ 950,400	1.0	$ 950,000
	Header Piping	31,680	in-dia. ft	$ 6.00	$ 190,080	1.0	$ 190,000
	CIVIL @ 10%						$ 296,000
	ELECTRICAL I & C @ 18%						$ 533,000
						Subtotal	$ 9,739,000
	CONTINGENCY @ 25%						$ 2,435,000
						Total Construction Cost	**$ 12,174,000**
	CONTRACTOR OVERHEAD AND PROFIT @ 8%						$ 973,920
	ENGINEERING FEES @ 10%						$ 1,217,000
	ADMINISTRATION AND LEGAL @ 10%						$ 1,217,000
						Total Project Cost	**$ 15,582,000**

Carollo Engineers

Project: USBR DWPR Phase I
Job #: 6870A.00
Location: DMWW

Date: 1-20-05
Estimator: SJG

Estimate ENR: 7112
Construction Mid Point ENR: 7112

Item No.	Description	Unit Quantity	Std. Unit	Unit Price	Item Total	Install Factor	Total Cost
UF Membrane Facility (16.5 mgd)							
	Raw Water Intake	ls	--	$ 200,000	$ 200,000	1.0	$ 200,000
	Raw Water Pumps	7	ea.	$ 40,000	$ 280,000	1.0	$ 280,000
	Raw Water Piping	63,360	in-dia. ft	$ 6.00	$ 380,000	1.0	$ 380,000
	Structural/Concrete	1,500	cu yd	$ 500	$ 750,000	1.0	$ 750,000
	Membrane Building	15,000	sq ft	$ 200	$ 3,000,000	1.0	$ 3,000,000
	UF Membrane Equip	10	mgd	$ 300,000	$ 3,000,000	1.0	$ 3,000,000
	Chemical Feed System	ls	--	--	$ 250,000	1.0	$ 250,000
	Clean-in-Place System	ls	--	--	$ 300,000	1.0	$ 300,000
	Chemical Storage Tanks	4	ea.	$ 20,000	$ 80,000	1.2	$ 96,000
	Misc. Equipment	ls	--	--	$ 200,000	1.0	$ 200,000
	Misc. Metals	ls	--	--	$ 230,000	1.0	$ 230,000
	Process Piping	ls	--	--	$ 250,000	1.0	$ 250,000
	Yard Piping	ls	--	--	$ 170,000	1.0	$ 170,000
	CIVIL @ 10%						$ 911,000
	ELECTRICAL I & C @ 18%						$ 1,639,000
						Subtotal	$ 11,656,000
	CONTINGENCY @ 25%						$ 2,914,000
						Total Construction Cost	**$ 14,570,000**
	CONTRACTOR OVERHEAD AND PROFIT @ 8%						$ 1,165,600
	ENGINEERING FEES @ 10%						$ 1,457,000
	ADMINISTRATION AND LEGAL @ 10%						$ 1,457,000
						Total Project Cost	**$ 18,650,000**

carollo engineers

Project: USBR DWPR Phase I
Job #: 6870A.00
Location: BPU/DMWW

Date: 1-20-05
Estimator: JCG/SJG

Estimate ENR: 7112
Construction Mid Point ENR: 7112

Item No.	Description	Unit Quantity	Std. Unit	Unit Price	Item Total	Install Factor	Total Cost
Conventional Treatment Facility (16.5 mgd)							
	Raw Water Intake	ls	--	$ 200,000	$ 200,000	1.0	$ 200,000
	Raw Water Pumps	7	ea.	$ 40,000	$ 280,000	1.0	$ 280,000
	Raw Water Piping	63,360	in-dia. ft	$ 6.00	$ 380,000	1.0	$ 380,000
	Excavaton/Fill/Compact	18,000	cu yd	$ 50	$ 900,000	1.0	$ 900,000
	Structural/Concrete	3,300	cu yd	$ 500	$ 1,650,000	1.0	$ 1,650,000
	Rapid Mix Equipment	ls	--	$ 100,000	$ 100,000	1.0	$ 100,000
	Coagulant Storage/Feed System	ls	--	$ 200,000	$ 200,000	1.0	$ 200,000
	Flocculation Equipment	ls	--	$ 1,000,000	$ 1,000,000	1.0	$ 1,000,000
	Sedimentation Equipment	ls	--	$ 500,000	$ 500,000	1.0	$ 500,000
	Filter and Control Building	15,000	sq ft	$ 200	$ 3,000,000	1.0	$ 3,000,000
	Filter Media	ls	--	--	$ 400,000	1.0	$ 400,000
	Filter Structures/Concrete	ls	--	--	$ 2,000,000	1.0	$ 2,000,000
	Solids Handling to Sewer	ls	--	--	$ 500,000	1.0	$ 500,000
	Misc. Equipment	ls	--	--	$ 200,000	1.0	$ 200,000
	Misc. Metals	ls	--	--	$ 200,000	1.0	$ 200,000
	Process Piping	ls	--	--	$ 500,000	1.0	$ 500,000
	CIVIL @ 10%						$ 1,201,000
	ELECTRICAL I & C @ 18%						$ 2,162,000
						Subtotal	$ 15,373,000
	CONTINGENCY @ 25%						$ 3,843,000
						Total Construction Cost	**$ 19,216,000**
	CONTRACTOR OVERHEAD AND PROFIT @ 8%						$ 1,537,280
	ENGINEERING FEES @ 10%						$ 1,922,000
	ADMINISTRATION AND LEGAL @ 10%						$ 1,922,000
						Total Project Cost	**$ 24,597,000**

carollo engineers

Project: USBR DWPR Phase I
Job #: 6870A.00
Location: DMWW

Date: 1-20-05
Estimator: SJG

Estimate ENR: 7112
Construction Mid Point ENR: 7112

Item No.	Description	Unit Quantity	Std. Unit	Unit Price	Item Total	Install Factor	Total Cost
RO Membrane Facility (8 mgd Permeate)							
	Structural/Concrete	900	cu yd	$ 500	$ 450,000	1.0	$ 450,000
	Membrane Building	10,000	sq ft	$ 175	$ 1,750,000	1.0	$ 1,750,000
	Reverse Osmosis	8	mgd	$ 800,000	$ 6,400,000	1.0	$ 6,400,000
	Chemical Feed System	ls	--	--	$ 150,000	1.0	$ 150,000
	Chemical Storage Tanks	2	ea.	$ 20,000	$ 40,000	1.2	$ 48,000
	1 MG Clear Well	3.3E+06	gal	$ 0.8	$ 2,640,000	1.0	$ 2,640,000
	Misc. Equipment	ls	--	--	$ 100,000	1.0	$ 100,000
	Misc. Metals	ls	--	--	$ 110,000	1.0	$ 110,000
	Process Piping	ls	--	--	$ 293,000	1.0	$ 293,000
	Yard Piping	ls	--	--	$ 293,000	1.0	$ 293,000
	CIVIL @ 10%						$ 1,223,000
	ELECTRICAL I & C @ 18%						$ 2,202,000
						Subtotal	$ 15,659,000
	CONTINGENCY @ 25%						$ 3,915,000
						Total Construction Cost	**$ 19,574,000**
	CONTRACTOR OVERHEAD AND PROFIT @ 8%						$ 1,565,920
	ENGINEERING FEES @ 10%						$ 1,957,000
	ADMINISTRATION AND LEGAL @ 10%						$ 1,957,000
						Total Project Cost	**$ 25,054,000**

carollo engineers

Project: USBR DWPR Phase I
Job #: 6870A.00
Location: DMWW

Date: 1-20-05
Estimator: SJG

Estimate ENR: 7112
Construction Mid Point ENR: 7112

Item No.	Description	Unit Quantity	Std. Unit	Unit Price	Item Total	Install Factor	Total Cost
By-Product Disposal to Surface Water							
	By-Product Piping	26,400	in-dia. ft	$ 6.00	$ 160,000	1.0	$ 160,000
	Aeration Equipment	1	ea.	$ 50,000	$ 50,000	1.0	$ 50,000
	Diffusor	ls	--	--	$ 150,000	1.0	$ 150,000
	Permits & Initial Monitoring		--	--	$ 300,000	1.0	$ 300,000
						Subtotal	$ 660,000
	CONTINGENCY @ 25%						$ 165,000
						Total Construction Cost	**$ 825,000**
	CONTRACTOR OVERHEAD AND PROFIT @ 8%						$ 66,000
	ENGINEERING FEES @ 10%						$ 83,000
	ADMINISTRATION AND LEGAL @ 10%						$ 83,000
						Total Project Cost	**$ 1,057,000**

carollo engineers

Project: USBR DWPR Phase I
Job #: 6870A.00
Location: DMWW

Date: 1-20-05
Estimator: SJG

Estimate ENR: 7112
Construction Mid Point ENR: 7112

Item No.	Description	Unit Quantity	Std. Unit	Unit Price	Item Total	Install Factor	Total Cost
By-Product Disposal to WWTP							
	By-Product Piping	13,200	in-dia. ft	$ 6.00	$ 80,000	1.0	$ 80,000
	Permits & Initial Monitoring		--	--	$ 150,000	1.0	$ 150,000
						Subtotal	$ 230,000
	CONTINGENCY @ 25%						$ 58,000
						Total Construction Cost	**$ 288,000**
	CONTRACTOR OVERHEAD AND PROFIT @ 8%						$ 23,040
	ENGINEERING FEES @ 10%						$ 29,000
	ADMINISTRATION AND LEGAL @ 10%						$ 29,000
						Total Project Cost	**$ 369,000**

O&M Estimates
USBR

Classification	Annual Costs ($2004)		
	USBR DWPR Phase I	**With RBF Pretreatment**	**With Conv. Pretreatment**
RO Feed Pumping (Raw Water + Pressurization)	450,612	568,192	450,612
Other Pumping (UF Treatment or Rapid Mix, Floc w/ no Finished Water Pumping)	67,887	0	8,899
Electrical Pumping Costs	518,499	568,192	459,511
General Building Electric Load	40,880	20,440	20,440
Electrical Operating Costs (w/o pumping)	40,880	20,440	20,440
Scale Inhibitor	303,176	303,176	303,176
Sodium Hypochlorite	178,486	178,486	178,486
RO Membrane Cleaning Chemicals	16,222	31,938	16,222
UF Membrane Cleaning Chemicals	34,690	0	0
Chemical Operating Costs	532,574	513,599	497,884
Cartridge Filters	58,637	117,273	58,637
RO Membrane Replacement	133,333	133,333	133,333
UF Membrane Replacement	146,765	0	0
Equipment Replacement Parts and Consumables	1,311,120	1,219,080	1,489,530
Labor	1,533,000	919,800	1,533,000
Indirect Operating Costs	3,182,855	2,389,486	3,214,500
Sludge and/or Backwash Dipsoal to Sewer	1,138,253	0	569,126
Annual Cost	5,413,061	3,491,718	4,761,461
Cost per Kgal	1.02	0.66	0.90

By-Product Disposal

Surface Water Discharge		
Power and Misc Costs	0.01	$/kgal
Permits and Monitoring	75000	$/year
Total Annual	82300	$/yr
Total	0.11	$/kgal
WWTP Discharge		
Diposal Costs	3.15	$/kgal
Permits and Monitoring	0	$/year
Total Annual	2299500	$/yr
Total	3.15	$/kgal
Sludge/Backwash Disposal to Sewer		
Diposal Costs	3.15	$/kgal

Present Worth Analysis
USBR

RBF Pretreatment NF/RO

ISBR DWPR		Capital Cost	O&M	Present Worth
2004		$0	$0	$0
2005		$0	$0	$0
2006		$8,338,600	$0	$7,421,324
2007		$16,677,200	$0	$14,842,649
2008	0	$16,677,200	$0	$14,842,649
2009	1	$0	$3,574,018	$3,180,864
2010	2	$0	$3,681,239	$3,276,289
2011	3	$0	$3,791,676	$3,374,578
2012	4	$0	$3,905,426	$3,475,815
2013	5	$0	$4,022,589	$3,580,090
2014	6	$0	$4,143,267	$3,687,493
2015	7	$0	$4,267,565	$3,798,117
2016	8	$0	$4,395,592	$3,912,061
2017	9	$0	$4,527,459	$4,029,423
2018	10	$0	$4,663,283	$4,150,305
2019	11	$0	$4,803,182	$4,274,815
2020	12	$0	$4,947,277	$4,403,059
2021	13	$0	$5,095,695	$4,535,151
2022	14	$0	$5,248,566	$4,671,205
2023	15	$0	$5,406,023	$4,811,341
2024	16	$0	$5,568,204	$4,955,682
2025	17	$0	$5,735,250	$5,104,352
2026	18	$0	$5,907,308	$5,257,483
2027	19	$0	$6,084,527	$5,415,207
2028	20	$0	$6,267,063	$5,577,663
			TOTAL	$122,577,615

UF Pretreatment to NF/RO

	Year	Capital Cost	O&M	Present Worth
2004		$0	$0	$0
2005		$0	$0	$0
2006		$8,952,200	$0	$7,967,426
2007		$17,904,400	$0	$15,934,852
2008	0	$17,904,400	$0	$15,934,852
2009	1	$0	$5,495,361	$4,890,852
2010	2	$0	$5,660,222	$5,037,577
2011	3	$0	$5,830,029	$5,188,705
2012	4	$0	$6,004,930	$5,344,366
2013	5	$0	$6,185,077	$5,504,697
2014	6	$0	$6,370,630	$5,669,838
2015	7	$0	$6,561,749	$5,839,933
2016	8	$0	$6,758,601	$6,015,131
2017	9	$0	$6,961,359	$6,195,585
2018	10	$0	$7,170,200	$6,381,452
2019	11	$0	$7,385,306	$6,572,896
2020	12	$0	$7,606,865	$6,770,083
2021	13	$0	$7,835,071	$6,973,185
2022	14	$0	$8,070,123	$7,182,381
2023	15	$0	$8,312,227	$7,397,852
2024	16	$0	$8,561,594	$7,619,788
2025	17	$0	$8,818,441	$7,848,381
2026	18	$0	$9,082,995	$8,083,833
2027	19	$0	$9,355,485	$8,326,348
2028	20	$0	$9,636,149	$8,576,138
			TOTAL	$171,256,152

Conventional Treatment as Pretreatment to NF/RO

	Year	Capital Cost	O&M	Present Worth
2004		$0	$0	$0
2005		$0	$0	$0
2006		$10,141,600	$0	$9,025,988
2007		$20,283,200	$0	$18,051,976
2008	0	$20,283,200	$0	$18,051,976
2009	1	$0	$4,843,761	$4,310,930
2010	2	$0	$4,989,074	$4,440,258
2011	3	$0	$5,138,747	$4,573,466
2012	4	$0	$5,292,909	$4,710,670
2013	5	$0	$5,451,696	$4,851,990
2014	6	$0	$5,615,247	$4,997,550
2015	7	$0	$5,783,704	$5,147,476
2016	8	$0	$5,957,216	$5,301,901
2017	9	$0	$6,135,932	$5,460,958
2018	10	$0	$6,320,010	$5,624,786
2019	11	$0	$6,509,610	$5,793,530
2020	12	$0	$6,704,899	$5,967,336
2021	13	$0	$6,906,046	$6,146,356
2022	14	$0	$7,113,227	$6,330,747
2023	15	$0	$7,326,624	$6,520,669
2024	16	$0	$7,546,422	$6,716,289
2025	17	$0	$7,772,815	$6,917,778
2026	18	$0	$8,006,000	$7,125,311
2027	19	$0	$8,246,180	$7,339,070
2028	20	$0	$8,493,565	$7,559,243
			TOTAL	$160,966,255

APPENDIX E

Des Moines Water Works Data Set

Operator (initials)	Comments	Date MM/DD/YY	Time hh:mm	Operation time hh.hh	Operation time Days	T_R (C)	T_F (C)	P_{CF1} (psi)	P_{CF2} (psi)	P_F (psi)	P_P (psi)	P_B (psi)	Q_P (gpm)	Q_B (gpm)	Q_{REC} (gpm)	pH: pH_R	pH: pH_F	pH: pH_P	pH: pH_B	Conductivity (mS/cm): C_R	Conductivity (mS/cm): C_F	Conductivity (mS/cm): C_P	Conductivity (mS/cm): C_B	Turbidity (NTU): NTU_R	Turbidity (NTU): NTU_F	Turbidity (NTU): NTU_P	SDI: SDI_R	SDI: SDI_F
SJG	Start-Up	02-04-04	3:00 PM	9617.7	0.00											---	---	---	---	---	---	---	---	---	---	---	---	---
SJG		02-05-04	8:00 AM	9634.7	0.71	---	12.5	31.5	33.0	93.0	14.5	85	1.20	5.77	4.87	---	6.6	---	--	---	710	20	---	---	---	---	---	---
BD		02-06-04	8:30 AM	9653.4	1.49	0.0	12.5	32.5	37.0	94.0	14.5	86	1.19	5.63	4.98	7.8	6.6	5.6	7.6	770	720	19	930	5.35	0.16	0.37	---	---
BD		02-09-04	8:45 AM	9723.3	4.40	0.0	12.3	27.5	26.0	133.0	4.5	124	1.04	6.33	6.93	7.7	7.5	5.6	7.5	760	750	9	930	2.38	0.52	0.11	17.92	4.10
BD		02-10-04	10:30 AM	9740.0	5.10	0.0	12.4	31.5	31.0	101.0	19.5	95	1.19	5.64	4.89	7.8	7.4	5.7	7.5	780	740	10	940	5.49	0.09	0.08	32.17	6.14
BD		02-11-04	10:20 AM	9772.8	6.46	0.0	12.4	33.0	32.0	98.0	15.0	91	1.19	5.61	4.89	7.7	7.4	5.9	7.5	760	780	8	920	5.65	0.22	0.06	24.33	1.91
BD		02-12-04	10:00 AM	9796.5	7.45	0.0	12.1	31.5	31.0	99.0	15.5	91	1.19	5.65	4.93	7.8	7.5	5.6	7.6	750	760	10	880	6.28	0.23	0.06	<5.1	1.48
BD		02-13-04	9:45 AM	9820.2	8.44	0.0	12.0	33.0	31.0	98.0	15.5	91	1.19	5.64	4.98	7.7	7.4	5.7	7.6	740	760	10	900	5.21	0.23	0.08	13.4	1.91
BD	Pilot Off Low Suction Pressure	02-16-04	8:10 AM	9847.6	9.58	0.0	14.9	31.0	33.0	100.0	15.0	93	1.19	5.64	4.96	7.8	7.5	6.0	7.5	720	750	8	910	4.10	0.18	0.08	---	1.91
BD	Pilot Off Feed Pump	02-17-04	10:55 AM	9874.4	10.69															-	-	-	-					
BD		02-17-04	1:50 PM	9856.5	9.95	0.0	16.3	31.0	32.0	103.0	15.5	95	1.19	5.65	4.99	8.1	7.5	5.7	7.6	720	850	10	870	6.21	0.11	0.08	---	1.91
BD		02-18-04	8:20 AM	9874.9	10.72	0.0	12.3	30.0	31.0	100.0	14.9	94	1.19	5.67	4.98	7.8	7.5	5.8	7.6	700	760	8	930	4.18	0.09	0.08		1.91
BD	Antiscalant Off	02-19-04	11:10 AM	9901.7	11.83	0.0	12.1	30.0	31.0	102.0	14.9	94	1.19	5.62	4.92	8.0	7.3	5.7	7.7	920	860	12	890	6.60	0.10	0.14	---	1.67
BD	Pilot Off	02-20-04	10:00 AM	9916.7	12.46	0.0	16.9	29.5	30.5	101.0	15.0	94	1.19	5.66	4.92	7.9	7.7	5.9	7.6	1420	770	8	920	72.8	1.81	0.16	---	1.33
BD		02-23-04	10:00 AM	9988.8	15.46	0.0	11.7	30.5	31.5	105.0	15.5	98	1.19	5.72	5.07	8.2	7.5	5.6	7.5	430	810	9	1010	124	0.41	0.10	---	1.67
BD		02-24-04	10:45 AM	10013.5	16.49	0.0	11.6	30.5	31.5	106.0	15.5	98	1.18	5.69	4.95	8.1	7.4	5.6	7.5	370	900	9	1110	713	0.46	0.16	---	2.22
BD		02-25-04	10:50AM	10037.5	17.49	0.0	11.6	30.5	31.5	106.0	14.5	97	1.19	5.62	4.87	8.1	7.4	5.9	7.5	410	750	10	940	250	0.53	0.12	---	2.22
BD		02-26-04	8:30 AM	10059.6	18.41	0.0	11.7	30.5	31.0	107.0	15.0	98	1.19	5.60	4.94	8.2	7.5	5.5	7.5	410	790	10	900	155	0.12	0.03	---	2.22
BD		02-27-04	10:15 AM	10085.0	19.47	-	11.8	30.5	31.0	108.0	15.0	99	1.20	5.66	4.99	8.2	7.6	5.5	7.7	470	770	10	920	74	0.27	0.08	---	2.96
BD		03-01-04	9:55 AM	10156.6	22.45	2.2	11.3	30.0	30.5	112.0	14.8	102	1.19	5.70	5.15	8.1	7.5	5.5	7.6	400	770	8	880	592	0.15	0.08	---	3.03
BD		03-02-04	8:15 AM	10179.0	23.39	1.1	11.0	30.5	30.5	115.0	15.0	104	1.19	5.74	5.01	8.0	7.4	5.4	7.5	370	760	9	910	469	0.64	0.10	---	2.42
BD		03-03-04	9:55 AM	10204.4	24.45	-	10.8	30.5	30.5	117.0	14.0	105	1.19	5.62	4.89	8.0	7.5	5.7	7.5	330	750	9	1000	407	0.23	0.24	---	3.33
BD		03-04-04	10:45 AM	10229.0	25.47	1.7	10.6	30.5	30.5	120.0	15.0	108	1.19	5.68	4.93	8.1	7.5	6.2	7.6	360	750	9	930	279	0.2	0.12	---	3.33
BD		03-05-04	8:20 AM	10250.7	26.38	2.2	10.6	30.5	31.0	123.0	15.0	108	1.19	5.73	4.98	8.2	7.5	5.5	7.6	440	780	7	980	255	0.18	0.09	---	3.33
BD		03-08-04	9:50 AM	10324.1	29.43	2.8	10.6	34.0	35.0	150.0	15.0	126	1.19	6.05	5.54	8.2	7.5	5.8	7.5	460	750	37	870	389	0.32	0.12	---	3.56
BD		03-09-04	8:50 AM	10346.9	30.38	3.9	10.5	31.5	34.5	139.0	15.5	120	1.19	5.66	4.86	8.2	7.5	6.0	7.6	480	760	23	900	282	0.38	0.08	---	3.81
BD	Pilot Off-Line	03-10-04	-	-	#VALUE!	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	---	-
BD	After NaOH Clean	03-11-04			-400.74		17.5			134.0	15.0	119	1.19	5.66	4.89		8.0			-	650	21	0				---	
BD	After Citric Clean	03-11-04	3:30 PM	10349.7	30.50		16.7	32.5	33.5	130.0	15.0	118	1.19	5.64	4.88		5.7			-	680	18	0				---	
BD	Prior to Clean	03-12-04	9:45 AM	10367.9	31.26		11.3	31.5	31.5	134.0	15.0	118	1.19	5.66	4.96		6.6			-	670	18	0				---	
BD	After Warm Water Flush	03-12-04			-400.74					147.0		130								-	0	0	0				---	
BD	After Warm Water NaOH	03-12-04	3:05 PM	10368.8	31.30		21.6			144.0	15.0	131	1.19	5.61	4.90		7.7			-	68	17	0				---	

Operator (initials)	Comments	Date MM/DD/YY	Time hh:mm	Operation time hh.hh	Operation time Days	T_R (C)	T_F (C)	P_{CF1} (psi)	P_{CF2} (psi)	P_F (psi)	P_P (psi)	P_B (psi)	Q_P (gpm)	Q_B (gpm)	Q_{REC} (gpm)	pH pH_R	pH_F	pH_P	pH_B	Conductivity (mS/cm) C_R	C_F	C_P	C_B	Turbidity (NTU) NTU_R	NTU_F	NTU_P	SDI SDI_R	SDI_F
BD		03-15-04	10:50 AM	10436.6	34.12	5.6	10.5	32.5	32.0	149.0	15.5	130	1.19	5.60	4.86	8.3	7.4	6.1	7.4	570	680	14	810	63.5	0.34	0.09	—	3.59
BD		03-16-04	9:30 AM	10459.3	35.07	1.7	10.5	32.0	32.5	151.0	15.2	131	1.19	5.71	4.92	8.4	7.5	6	7.5	590	690	10	790	45.5	1.03	0.19	—	3.59
BD		03-17-04	9:40 AM	10483.4	36.07	3.3	10.5	32	32.5	157.0	15.2	137	1.19	5.75	5.05	8.3	7.4	6.9	7.8	600	670	10	770	38.2	0.98	0.12	—	3.59
BD	new membrane	03-17-04	1:30 PM	10483.9	36.09		16.2	31.5	31.5	107.0	15.0	100	1.19	5.67	4.89					-	-	-	-				—	
BD		03-18-04	10:40 AM	10505.0	36.97	5.6	11.2	31.5	32.0	106.0	15.0	99	1.19	5.66	4.85	8.3	7.4	6	7.5	640	700	10	840	42.8	0.14	0.09	—	2.79
BD		03-18-04	1:30 PM	10507.9	37.09		10.9	31.5	32.5	106.0	15.0	99	1.19	5.66	4.85					-	-	-	-				—	
BD		03-19-04	8:10 AM	10525.5	37.83	6.7	10.3	32.5	33.0	107.0	15.5	99	1.19	5.64	4.96	8.3	7.5	5.6	7.5	640	700	10	810	49.3	0.76	0.08	—	2.22
BD		03-22-04	8:14 AM	10597.6	40.83	6.1	10.2	32.5	33.0	111.0	15.5	101	1.19	5.66	5.03	8.4	7.5	5.6	7.5	600	670	10	800	76.8	0.14	0.21	—	2.22
BD		03-23-04	1:03 PM	10626.4	42.03	6.7	11.3	32	32.0	111.0	14.5	100	1.19	5.63	4.84	8.4	7.4	5.5	7.5	640	690	10	770	50.5	0.1	0.08	—	2.78
BD		03-24-04	9:56 AM	10647.3	42.90	7.8	10.6	32	32.0	112.0	15.5	102	1.19	5.65	4.94	8.3	7.4	5.7	7.5	640	660	10	760	44.3	0.11	0.09	—	3.03
BD		03-25-04	8:30 AM	10670.1	43.85	12.2	10.5	32	32.0	113.0	15.2	102	1.20	5.67	4.93	8.3	7.4	5	7.5	650	650	10	780	39.8	0.08	0.21	—	3.03
BD		03-26-04	10:06 AM	10694.5	44.87	13.3	18.1	30	31.0	111.0	15.0	103	1.19	5.66	4.91	8.4	7.5	5.6	7.6	640	670	10	780	41.8	0.13	0.09	—	3.03
BD		03-29-04	10:18 AM	10766.7	47.88	11.1	10.1	30.5	31.0	114.0	15.0	105	1.19	5.67	4.96	8.1	7.5	5.5	7.6	490	640	8	780	671	3.43	0.14	—	3.03
BD		03-30-04	9:39 AM	10790.1	48.85	10.0	9.6	30.5	31.5	117.0	15.3	106	1.19	5.68	4.92	8.2	7.4	5.5	7.6	560	630	8	760	246	0.22	0.09	—	2.42
BD		03-31-04	8:16 AM	10812.7	49.79	8.3	9.8	30.5	31.5	117.0	15.2	106	1.19	5.66	4.90	8.2	7.5	5.5	7.5	580	630	10	760	302	1.79	0.14	—	2.42
BD		04-01-04	10:03 AM	10838.4	50.86	9.4	10	30.5	31.5	116.0	15.0	106	1.19	5.67	4.88	8.3	7.5	5.5	7.5	600	640	9	740	218	0.22	0.09	—	0.95
BD		04-02-04	10:23 AM	10862.8	51.88	-	10.3	30.5	31.5	115.0	15.0	105	1.19	5.67	4.90	8.3	7.4	5.5	7.6	650	660	10	770	132	0.13	0.07	—	2.67
BD		04-05-04	8:21 AM	10931.8	54.75	10	11.4	30.5	31.0	115.0	14.5	105	1.19	5.63	4.89	8.4	7.5	5.5	7.5	650	660	10	750	60.4	1.98	0.08	—	2
BD		04-06-04	9:44 AM	10957.0	55.80	11.7	10.8	30.5	31.0	114.0	14.5	104	1.19	5.64	4.87	8.5	7.5	5.5	7.6	650	620	10	730	49.7	0.19	0.1	—	2.42
BD		04-07-04	9:43 AM	10981.0	56.80	12.8	10.8	30.5	31.0	115.0	15.5	105	1.19	5.63	4.95	8.4	7.4	5.5	7.5	650	640	10	770	46.1	0.9	0.07	—	2.67
BD		04-08-04	8:36 AM	11003.9	57.76	12.2	10.8	30.5	31.0	115.0	15.5	105	1.19	5.65	4.91	8.4	7.4	5.5	7.5	660	650	10	760	41.9	0.8	0.15	—	1.48
BD		04-09-04	11:08 AM	11030.4	58.86	12.8	10.9	30.5	31.5	114.0	14.9	104	1.19	5.64	4.89	8.5	7.4	5.5	7.7	650	640	10	770	35.4	0.66	0.09	—	1.11
BD		04-12-04	10:54 AM	11102.2	61.85	11.7	11.1	30.5	31.5	114.0	14.4	104	1.19	5.63	4.91	8.6	7.5	5.5	7.5	640	640	15	750	21.1	0.63	0.11	—	2.22
BD		04-13-04	8:25 AM	11123.7	68.73	9.4	10.9	31.0	31.5	114.0	15.0	104	1.19	5.63	4.90	8.6	7.4	5.5	7.5	620	650	20	770	20.5	0.49	0.08	—	1.67
BD		04-14-04	10:10 AM	11148.9	69.80	10.6	21.5	30.5	31.0	114.0	15.0	103	1.19	5.63	4.90	8.6	7.4	5.6	7.7	640	650	8	750	18.8	1.41	0.12	—	1.48
BD		04-15-04	9:47 AM	11172.5	70.78	11.7	11.5	30.5	31.0	112.0	16.0	102	1.19	5.63	4.93	8.6	7.4	5.5	7.5	630	640	10	770	18.8	0.51	0.08	—	1.67
BD		04-16-04	10:08 AM	11196.9	71.80	13.3	12.4	30.5	30.5	111.0	14.5	100	1.19	5.62	4.81	8.6	7.4	5.6	7.5	640	650	10	790	15.8	0.58	0.07	—	1.48
BD		04-19-04	9:08 AM	11267.9	74.76	17.8	11.4	31.0	31.5	112.0	15.0	102	1.19	5.64	4.90	8.4	7.4	5.5	7.5	580	660	10	770	21.5	0.67	0.07	—	0.83
BD		04-20-04	8:20 AM	11291.1	75.72	16.1	12.0	30.5	31.0	112.0	15.0	101	1.19	5.64	4.90	8.3	7.4	5.5	7.5	-	660	-	-	27.2	0.72	0.08	—	1.11
BD		04-21-04	10:26 AM	11317.2	76.81	14.4	11.8	30	30.5	111.0	14.9	100	1.19	5.65	4.88	8.5	7.4	-	7.7	550	650	10	780	42.2	0.61	-	—	1.91
BD		04-22-04	8:07 AM	11338.8	77.71	14.4	11.8	30.5	31	112.0	15	100	1.19	5.65	4.89	8.3	7.4	5.5	7.6	530	640	10	760	226	0.12	0.06	—	1.11
BD		04-23-04	10:05 AM	11364.8	78.80	13.9	11.8	31	31.5	112.0	15	101	1.19	5.65	4.88					-	-	-	-				—	1.91
BD		04-26-04	8:11 AM	11434.9	81.72	12.8	11.7	31	31.5	111.0	15	100	1.19	5.64	4.89					610	660	-	-				—	2.67
BD		04-27-04	10:06 AM	11460.7	82.80	12.8	12.4	31	31	110.0	14.6	99	1.19	5.60	4.89					613.4	656.3	10.4	772.9				—	
BD	Begin Concentrate Test	04-27-04	10:26 AM	11461.0	82.81		13.4			82.0	9.1	75	0.91	0.21	4.08	8.6	7.6	6.1	8.4	650.0	660.0	35.9	2070.0	59.7	1.26	0.08	—	3.33
BD	After High pH Cleaning	04-28-04	1:10 PM	11466.8	83.92	14.4	22.3			110.0	14.9	99	1.20	5.65	4.83					0.0	0.0	0.0	0.0					
BD	After Low pH Cleaning	04-28-04	1:48 PM	11466.9	83.95		16.5			111.0	15	103	1.19	5.65	4.90					0.0	0.0	0.0	0.0					
BD	After 2 Hour Run	04-30-04	10:30 AM	11468.9	85.81		14			109.0	15	100	1.20	5.67	4.89					613.4	611.8	10.5	762.5					
					Count	52	58									52	53	51	52	53	55	53	52	52	52	51	4	53
					Median	6.4	11.4									8.3	7.4	5.6	7.5	630.00	690.00	10.000	805.000	45.8	0.30	0.09	21.13	2.22
					Low	0.0	9.6									7.7	6.6	5.0	7.4	330.00	620.00	7.000	730.000	2.4	0.08	0.03	13.40	0.83
					High	17.8	21.5									8.6	7.7	6.9	7.8	1420.00	900.00	37.000	1110.000	713.0	3.43	0.37	32.17	6.14
					Average	6.5	11.9									8.2	7.4	5.7	7.6	610.82	707.21	11.030	841.978	131.2	0.53	0.11	21.96	2.41
					Standard Deviation	5.7	2.1									0.3	0.2	0.3	0.1	168.24	66.56	4.835	87.605	176.9	0.61	0.06	8.15	0.96
					95% CI Low	5.0	11.3									8.1	7.4	5.6	7.5	565.53	689.61	9.728	818.167	83.1	0.36	0.09	13.96	2.15
					95% CI High	8.1	12.4									8.3	7.5	5.7	7.6	656.11	724.80	12.331	865.789	179.2	0.70	0.12	29.95	2.66

Operator (initials)	Comments	2-4-04 Run Time Days	Date MM/DD/YY	TDS, mg/L TDS_R	TDS_F	TDS_P	TDS_B	Alkalinity, mg/L Alk_R	mg/L Alk_F	Alk_P	Calcium, mg/L Ca_R	mg/L Ca_F	Ca_P	Magnesium, mg/L Mg_R	mg/L Mg_F	Mg_P
BD		5	02-09-04	456	450	5.40	558	250	276	--	99.2	23.8	--	83.2	38.3	--
BD		12	02-16-04	432	450	4.80	546	250	278	--	91.2	26.2	--	83.2	39.3	--
BD		19	02-23-04	272	485	5.2	607	142	286	--	52.0	84.8	--	16.5	39.4	--
BD		26	03-01-04	243	463	4.94	528	147	274	--	59.2	84.8	--	8.26	37.4	--
BD		33	03-08-04	276	450	2.22	522	142	248	6	59.0	82.0	--	14.0	32.0	--
BD		40	03-15-04	342	408	8.76	490	193	241	3	87.6	77.6	--	16.7	31.5	--
BD		47	03-22-04	359	400	4.86	480	207	238	2	84.0	76.8	--	21.1	32.6	--
BD		54	03-29-04	294	384	5.13	468	166	234	3	74.0	72	0.8	13.8	31.5	0.97
BD		61	04-05-04	391	396	5.17	454	222	233	2	83.6	72	1.2	28.9	32.5	0
BD		68	04-12-04	385	386	9.17	452	223	236	2	94.8	89.6	0.8	23.3	23.8	0
BD		75	04-19-04	348	397	7.58	465	200	242	3	83.2	78.4	3.2	50.5	47.6	0
		82	04-26-04													
BD	Concentrate Analysis	83	04-27-04	395	397			219	242		86.4	84.8		52.5	51.5	
			Count	12	12	11	11	12	12	7	12	12	4	12	12	4
			Median	354	404	5.17	490	204	242	3	83.8	78.0	1.0	22.2	35.0	0.00
			Low	243	384	2.22	452	142	233	2	52.0	23.8	0.8	8.3	23.8	ND
			High	456	485	9.17	607	250	286	6	99.2	89.6	3.2	83.2	51.5	0.97
			Average	349	422	5.75	506	197	252	3	79.5	71.1	1.5	34.3	36.5	ND
			Standard Deviation	67	35	2.00	50	39	20	N/A	15.2	22.2	N/A	26.7	7.6	N/A
			95% CI Low	312	402	4.57	477	174	241	N/A	70.9	58.5	N/A	19.2	32.2	N/A
			95% CI High	387	442	6.93	536	219	264	N/A	88.1	83.6	N/A	49.4	40.7	N/A

Operator (initials)	Comments	2-4-04 Run Time Days	Date MM/DD/YY	SiO$_2$, mg/L Si_R	mg/L Si_F	Si_P	Iron, mg/L Fe_R	mg/L Fe_F	Fe_P	Manganese, mg/L Mn_R	mg/L Mn_F	Mn_P	Barium, mg/L Ba_R	mg/L Ba_F	Ba_P
BD		5	02-09-04	--	--	--	--	--	--	--	--	--	0.120	0.094	0.001
BD		12	02-16-04	0.9	0.65	--	0.108	0.025	0.025	0.088	0.136	0.01	0.130	0.089	0.001
BD		19	02-23-04	0.9	0.87	--	0.87	0.105	0.025	0.271	0.228	0.01	0.130	0.089	0.001
BD		26	03-01-04	0.82	0.78	--	-	-	0.025	-	-	0.01	0.370	0.081	0.001
BD		33	03-08-04	0.9	0.92	0.15	1.14	0.025	0.025	0.474	0.108	0.01	0.230	0.073	0.001
BD		40	03-15-04	>1.0	>1.0	0.05	-	-	0.025	-	-	\0.294	0.120	0.077	0.001
BD		47	03-22-04	0.9	0.82	0	0.257	0.025	0.025	0.071	0.067	0.01	0.120	0.069	0.001
BD		54	03-29-04	>1.0	0.92	0	1.211	0.025	0.025	0.307	0.025	0.01	0.200	0.067	0.001
BD		61	04-05-04	>1.0	>1.0	0	0.684	0.025	0.025	0.058	0.047	0.01	0.130	0.064	0.001
BD		68	04-12-04	0.92	0.92	0.1	-	-	0.025	-	-	0.01	0.097	0.069	0.001
BD		75	04-19-04	0.92	0.92	0	0.171	0.025	0.025	0.063	0.058	0.01	0.100	0.067	0.001
		82	04-26-04										0.110	0.074	0.001
BD	Concentrate Analysis	83	04-27-04	>1.0	0.94		-	-		-	-				
			Count	7	9	7	7	7	10	7	7	9	12	12	12
			Median	0.90	0.92	0.00	0.684	0.025	ND	0.088	0.067	ND	0.125	0.074	ND
			Low	0.82	0.65	ND	0.108	0.025	ND	0.058	0.025	ND	0.097	0.064	ND
			High	0.92	0.94	0.15	1.211	0.105	ND	0.474	0.228	ND	0.370	0.094	ND
			Average	0.89	0.86	ND	0.634	0.036	ND	0.190	0.096	ND	0.155	0.076	ND
			Standard Deviation	N/A	0.10	N/A	N/A	N/A	0	N/A	N/A	0.000	0.079	0.010	0.000
			95% CI Low	N/A	0.80	N/A	N/A	N/A	ND	N/A	N/A	ND	0.110	0.070	ND
			95% CI High	N/A	0.92	N/A	N/A	N/A	ND	N/A	N/A	ND	0.199	0.082	ND

Operator (initials)	Comments	2-4-04 Run Time Days	Date MM/DD/YY	Strontium, mg/L Sr_R	mg/L Sr_F	Sr_P	Sulfate, mg/L $S04_R$	mg/L $S04_F$	$S04_P$	Nitrate, mg/L $N03_R$	mg/L $N03_F$	$N03_P$
BD		5	02-09-04	0.28	0.23	0.005	61.03	69.41	0.5	3.50	1.79	0.1
BD		12	02-16-04	0.28	0.23	0.005	61.90	71.20	0.5	3.62	1.88	0.1
BD		19	02-23-04	0.15	0.23	0.005	27.79	69.54	0.5	2.82	1.91	0.1
BD		26	03-01-04	0.21	0.22	0.005	19.58	59.71	0.5	2.93	1.94	0.1
BD		33	03-08-04	0.19	0.21	0.005	21.82	58.16	0.5	7.41	2.61	0.39
BD		40	03-15-04	0.21	0.20	0.005	38.52	58.13	0.5	8.98	3.16	0.1
BD		47	03-22-04	0.21	0.20	0.005	36.38	53.1	0.5	9.46	3.62	0.22
BD		54	03-29-04	1.1	0.19	0.005	27.12	49.01	0.5	8.61	4.85	0.28
BD		61	04-05-04	0.25	0.20	0.005	40.60	47.87	0.5	13.43	5.86	0.36
BD		68	04-12-04	0.24	0.20	0.005	41.33	47.34	0.5	10.83	6	0.39
BD		75	04-19-04	0.24	0.21	0.005	40.41	50.16	0.5	9.45	6.11	0.38
		82	04-26-04	0.24	0.21	0.005						
BD	Concentrate Analysis	83	04-27-04				33.43	47.86		13.43	6.04	
			Count	12	12	12	12	12	11	12	12	11
			Median	0.24	0.21	ND	37.45	55.62	ND	8.80	3.39	0.22
			Low	0.15	0.19	ND	19.58	47.34	ND	2.82	1.79	0.10
			High	1.10	0.23	ND	61.90	71.20	ND	13.43	6.11	0.39
			Average	0.30	0.21	ND	37.49	56.79	ND	7.87	3.81	0.23
			Standard Deviation	0.25	0.01	0.000	13.38	9.09	0.000	3.87	1.84	0.13
			95% CI Low	0.16	0.20	ND	29.92	51.65	ND	5.68	2.77	0.15
			95% CI High	0.44	0.22	ND	45.06	61.93	ND	10.06	4.85	0.31

Operator		2-4-04	Date	Fluoride, mg/L			Chloride, mg/L			Coliforms, CFU/ml			HPC, MPN/100ml		
		Run Time			mg/L			mg/L							
(initials)	Comments	Days	MM/DD/YY	F_R	F_F	F_P	Cl_R	Cl_F	Cl_P	$Coli_R$	$Coli_F$	$Coli_p$	HPC_R	HPC_F	HPC_p
BD		5	02-09-04	0.30	0.31	0.01	36.59	38.94	0.65	496	1	0	380	48	1060
BD		12	02-16-04	0.35	0.31	0.01	38.39	40.15	0.43	225	0	0	268	45	1007
BD		19	02-23-04	0.1	0.24	0.01	32.66	42.95	0.40	81640	6	0	53000	116	376
BD		26	03-01-04	0.27	0.27	0.01	17.03	42.66	0.37	36540	82	0	78000	96	1540
BD		33	03-08-04	0.35	0.28	0.01	18.10	40.61	3.11	11588	31	0	48000	84	6
BD		40	03-15-04	0.44	0.34	0.2	24.41	38.53	0.45	1203	9	0	380	9	31
BD		47	03-22-04	0.41	0.32	0.01	26.38	35.31	0.36	2419	7	0	8300	17	66
BD		54	03-29-04	0.38	0.26	0.01	19.79	32.4	0.47	41060	0	0	36000	2	70
BD		61	04-05-04	0.47	0.15	0.01	27.77	31.75	0.23	1961	0	0	33000	4	20
BD		68	04-12-04	0.3	0.25	0.01	28.00	30.55	0.29	866	0	0	740	18	41
BD		75	04-19-04	0.26	0.25	0.01	27.93	31.39	0.28	1986	1	0	800	3	30
		82	04-26-04												
BD	Concentrate Analysis	83	04-27-04	0.4	0.26		27.53	29.93		5794			3664		
			Count	12	12	11	12	12	11	12	11	11	12	11	11
			Median	0.35	0.27	0.01	27.65	36.92	0.40	2203	1	ND	5982	18	66
			Low	0.10	0.15	0.01	17.03	29.93	0.23	225	0	ND	268	2	6
			High	0.47	0.34	0.20	38.39	42.95	3.11	81640	82	ND	78000	116	1540
			Average	0.34	0.27	0.03	27.05	36.26	0.64	15482	12	ND	21878	40	386
			Standard Deviation	0.10	0.05	0.06	6.70	4.90	0.83	25216	25	0	26837	41	550
			95% CI Low	0.28	0.24	-0.01	23.26	33.49	0.15	1215	-2	ND	6694	16	61
			95% CI High	0.39	0.30	0.06	30.84	39.04	1.13	29748	27	ND	37062	65	711

Operator (initials)	Comments	2-4-04 Run Time Days	Date MM/DD/YY	Algae/ml $Algae_R$	$Algae_F$	T&O (TON) $T\&O_R$	$T\&O_F$	$T\&O_P$	DOC, mg/L DOC_R	DOC_F	DOC_P	UVA, cm^{-1} UVA_R	UVA_F	UVA_P
BD		5	02-09-04	230	12	1	1	0	2.43	1.83	0.46	0.054	0.033	0.003
BD		12	02-16-04	153	12	1	1	0	2.45	1.74	--	0.058	0.036	0.005
BD		19	02-23-04	12	12	-	-	-	8.64	2.02	0.50	0.319	0.037	0.000
BD		26	03-01-04	12	12	2	1	0	6.36	1.7	0.24	0.173	0.040	0.001
BD		33	03-08-04	12	12	2	2	0	5.87	2.14	0.32	0.306	0.047	0.001
BD		40	03-15-04	3206	12	1	3	0	5.23	2.11	0.56	0.132	0.045	0.001
BD		47	03-22-04	916	12	2	2	0	3.58	2.08	0.61	0.121	0.045	0.000
BD		54	03-29-04	4122	12	1	0	0	4.42	2.22	0.15	0.229	0.047	0.000
BD		61	04-05-04	916	12	1	0	0	2.94	2.37	0.96	0.093	0.047	0.000
BD		68	04-12-04	916	12	0	1	0	3.28	2.17	0.62	0.077	0.048	0.000
BD		75	04-19-04	5496	12	1	1	0	2.99	1.97	0.35	0.073	0.044	0.000
		82	04-26-04											
BD	Concentrate Analysis	83	04-27-04	5100	12	1	1		3.56	1.98		0.088	0.051	
			Count	12	12	11	11	10	12	12	10	12	12	11
			Median	916	ND	1	1	ND	3.57	2.05	0.48	0.107	0.045	0.000
			Low	11.5	ND	0	0	ND	2.43	1.70	0.15	0.054	0.033	0.000
			High	5496	ND	2	3	ND	8.64	2.37	0.96	0.319	0.051	0.005
			Average	1757	ND	1	1	ND	4.31	2.03	0.48	0.144	0.043	0.001
			Standard Deviation	2111	ND	1	1	0	1.88	0.20	0.23	0.094	0.006	0.002
			95% CI Low	563	ND	1	1	ND	3.25	1.92	0.33	0.091	0.040	0.000
			95% CI High	2952	ND	2	2	ND	5.38	2.14	0.62	0.197	0.046	0.002

Operator		Date	TDS, mg/L				Alkalinity, mg/L			Calcium, mg/L			Magnesium, mg/L		
(initials)	Comments	MM/DD/YY	TDS_R	TDS_F	TDS_P	TDS_B	Alk_R	Alk_F	Alk_P	Ca_R	Ca_F	Ca_P	Mg_R	Mg_F	Mg_P
BD/SJG	Concentrate Analysis	04-27-04	395	397	21.5	1242	219	242	6	86.4	84.8	2.4	52.5	51.5	0

Operator		Date	SiO$_2$, ug/L			Iron, mg/L			Manganese, mg/L			Barium, mg/L			Strontium, mg/L			Sulfate, mg/L		
(initials)	Comments	MM/DD/YY	Si_R	Si_F	Si_P	Fe_R	Fe_F	Fe_P	Mn_R	Mn_F	Mn_P	Ba_R	Ba_F	Ba_P	Sr_R	Sr_F	Sr_P	$S04_R$	$S04_F$	$S04_P$
BD/SJG	Concentrate Analysis	04-27-04	>1.0	0.94	0.12	-	-	<0.05	-	-	<0.02							33.43	47.86	<1.0

Operator (initials)	Comments	Date MM/DD/YY	Nitrate, mg/L			Fluoride, mg/L			Chloride, mg/L			Coliforms, CFU/ml		
			$N03_R$	$N03_F$	$N03_P$	F_R	F_F	F_P	Cl_R	Cl_F	Cl_P	$Coli_R$	$Coli_F$	$Coli_p$
BD/SJG	Concentrate Analysis	04-27-04	13.43	6.04	1.6	0.4	0.26	<0.02	27.53	29.93	1.52	5794		0

Operator		Date	HPC, MPN/100ml			Algae/ml		T&O			DOC, mg/L			UVA, cm^{-1}		
(initials)	Comments	MM/DD/YY	HPC_R	HPC_F	HPC_p	$Algae_R$	$Algae_F$	$T\&O_R$	$T\&O_F$	$T\&O_P$	DOC_R	DOC_F	DOC_P	UVA_R	UVA_F	UVA_P
BD/SJG	Concentrate Analysis	04-27-04	3664			5100	<23	1ME	1 Pet	0	3.56	1.98	0.74	0.088	0.051	0.005

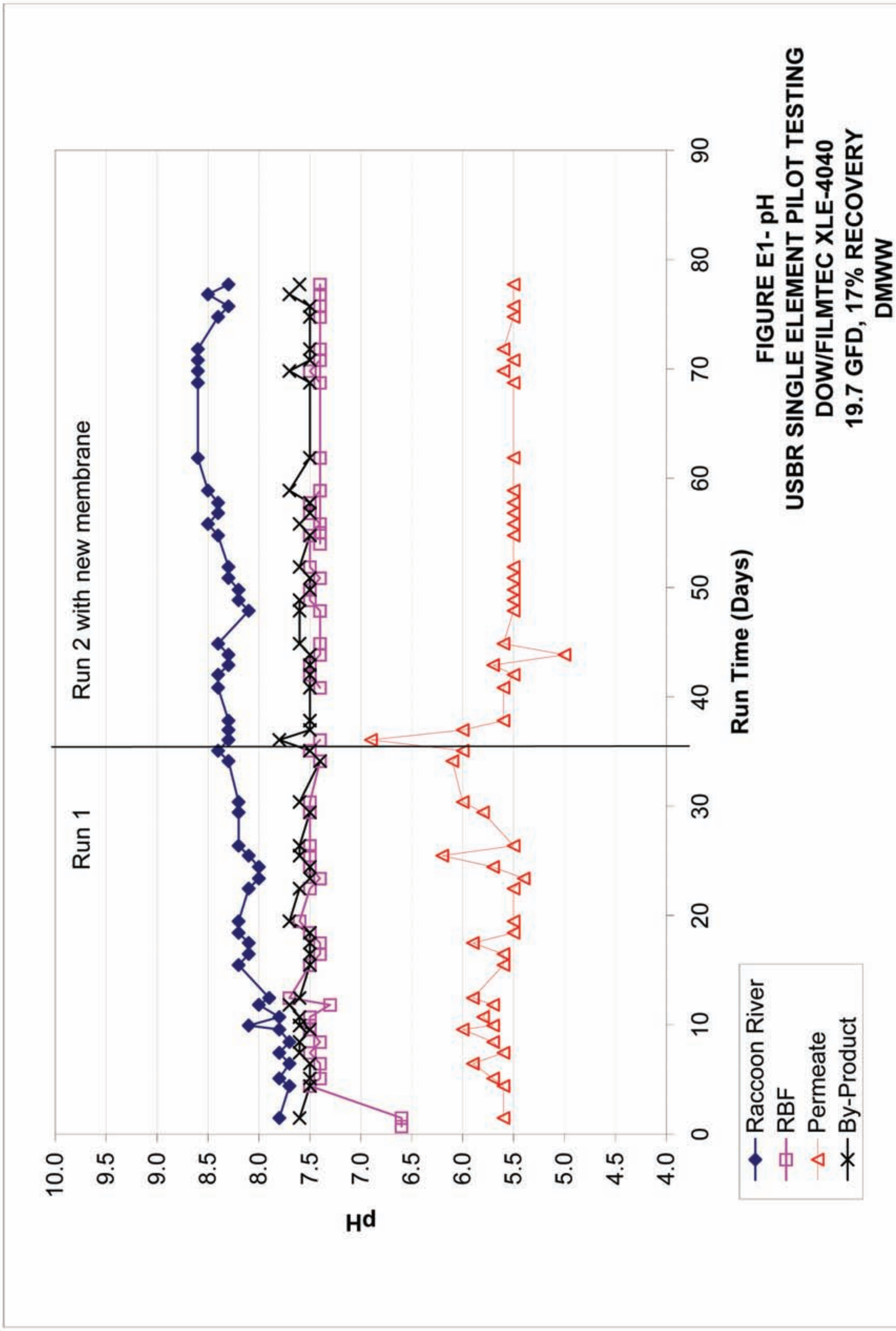


FIGURE E1- pH
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
DMWW

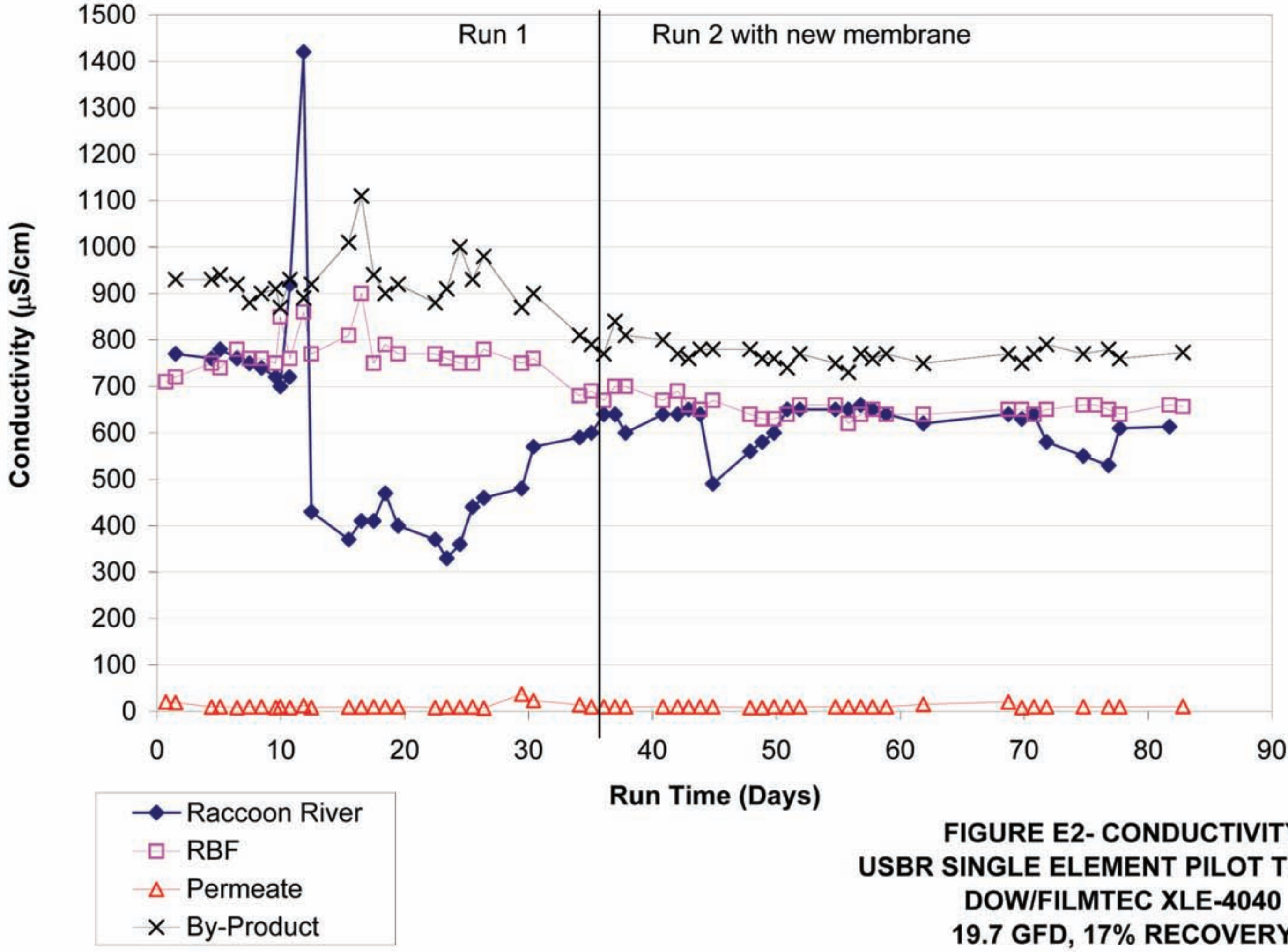


FIGURE E2- CONDUCTIVITY
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
DMWW

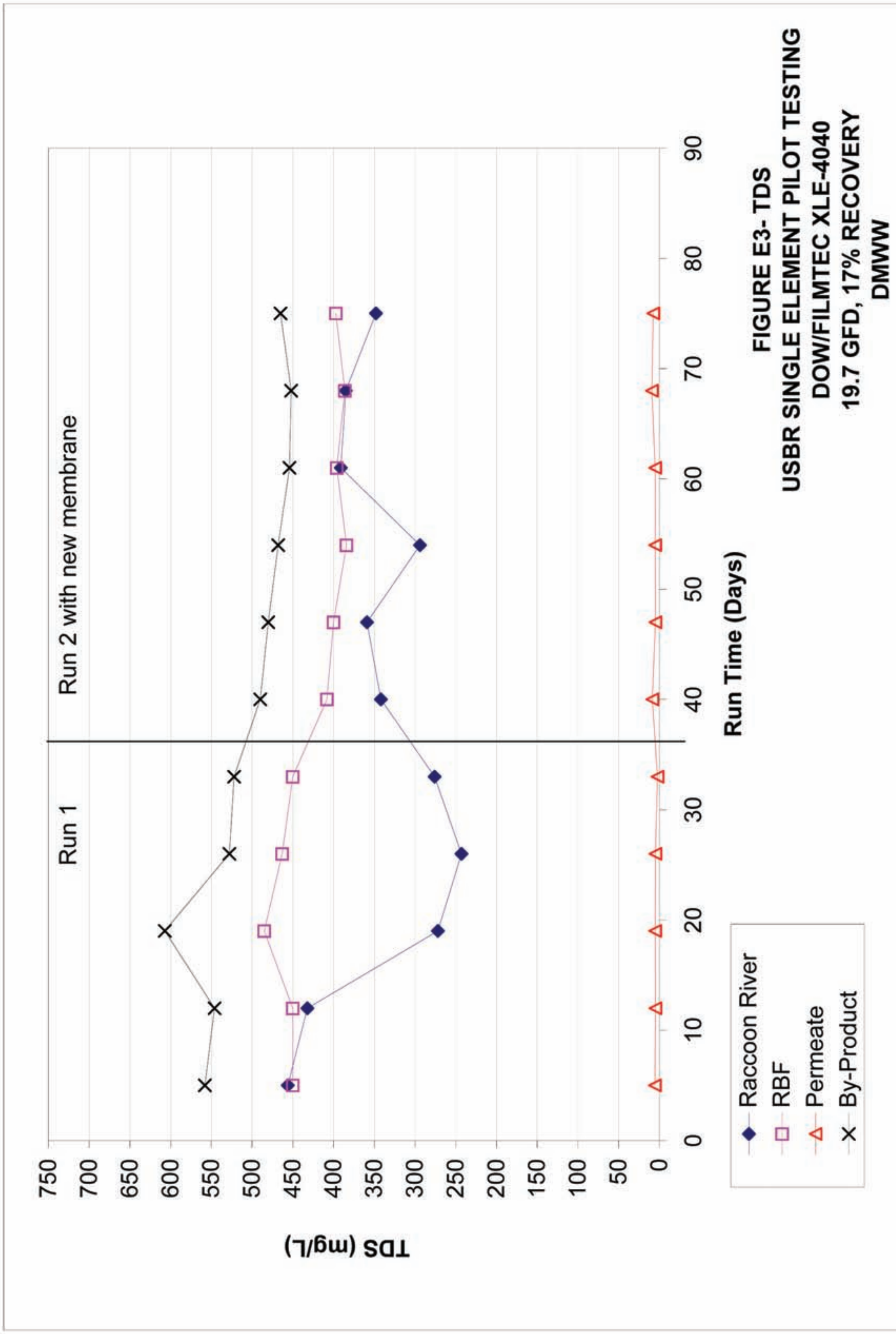


FIGURE E3- TDS
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
DMWW

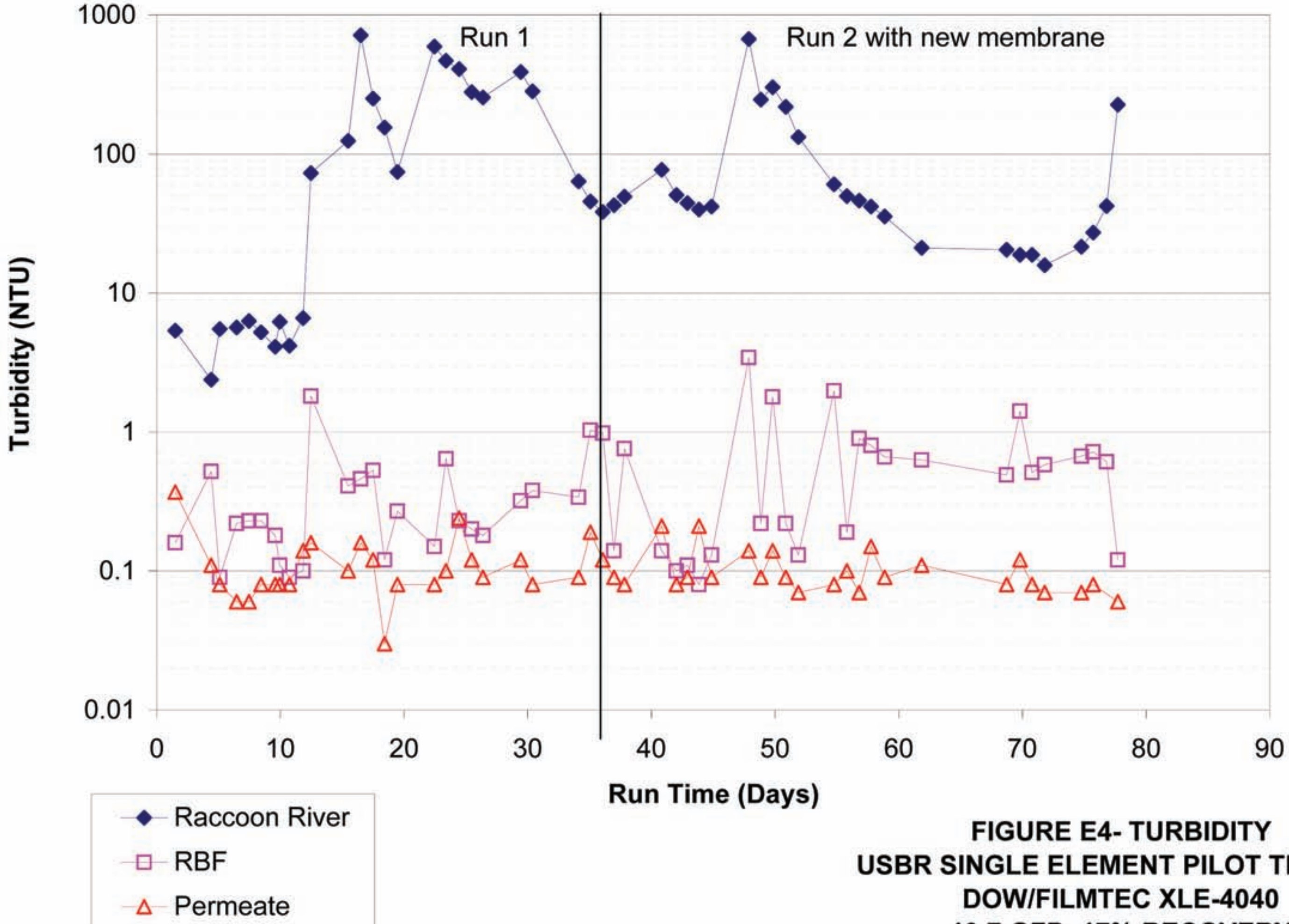


FIGURE E4- TURBIDITY
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
DMWW

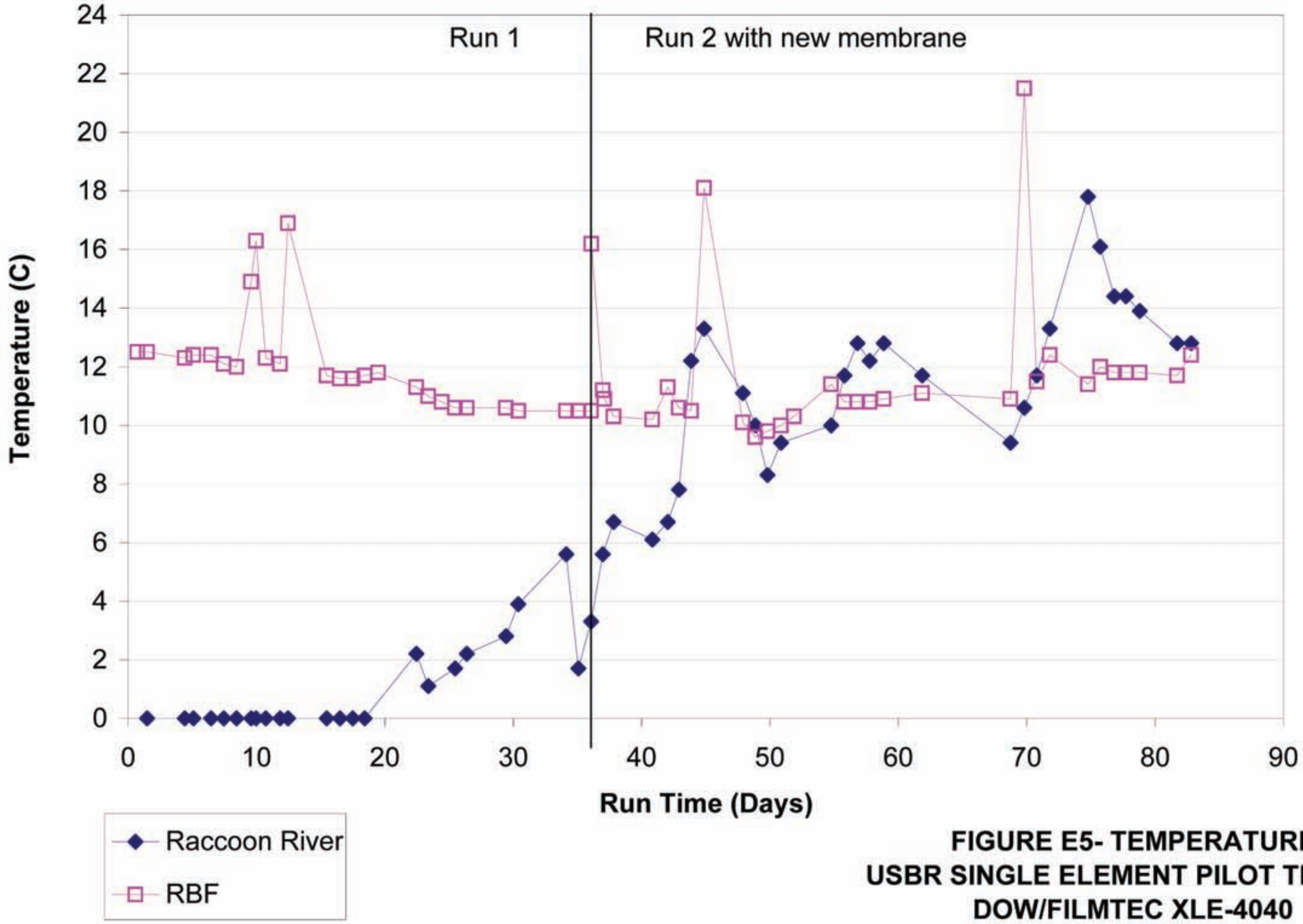


FIGURE E5- TEMPERATURE
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
DMWW

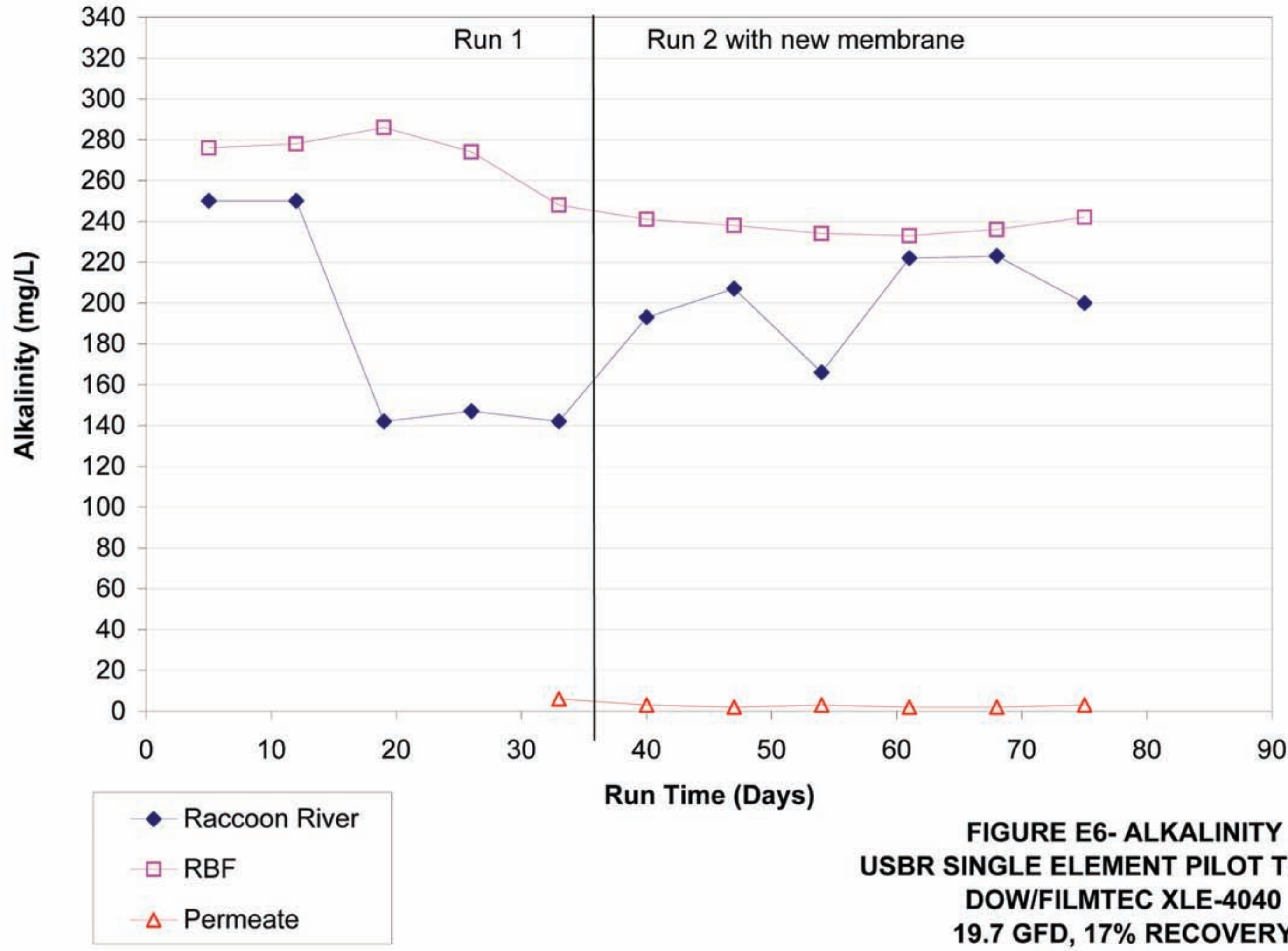


FIGURE E6- ALKALINITY
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
DMWW

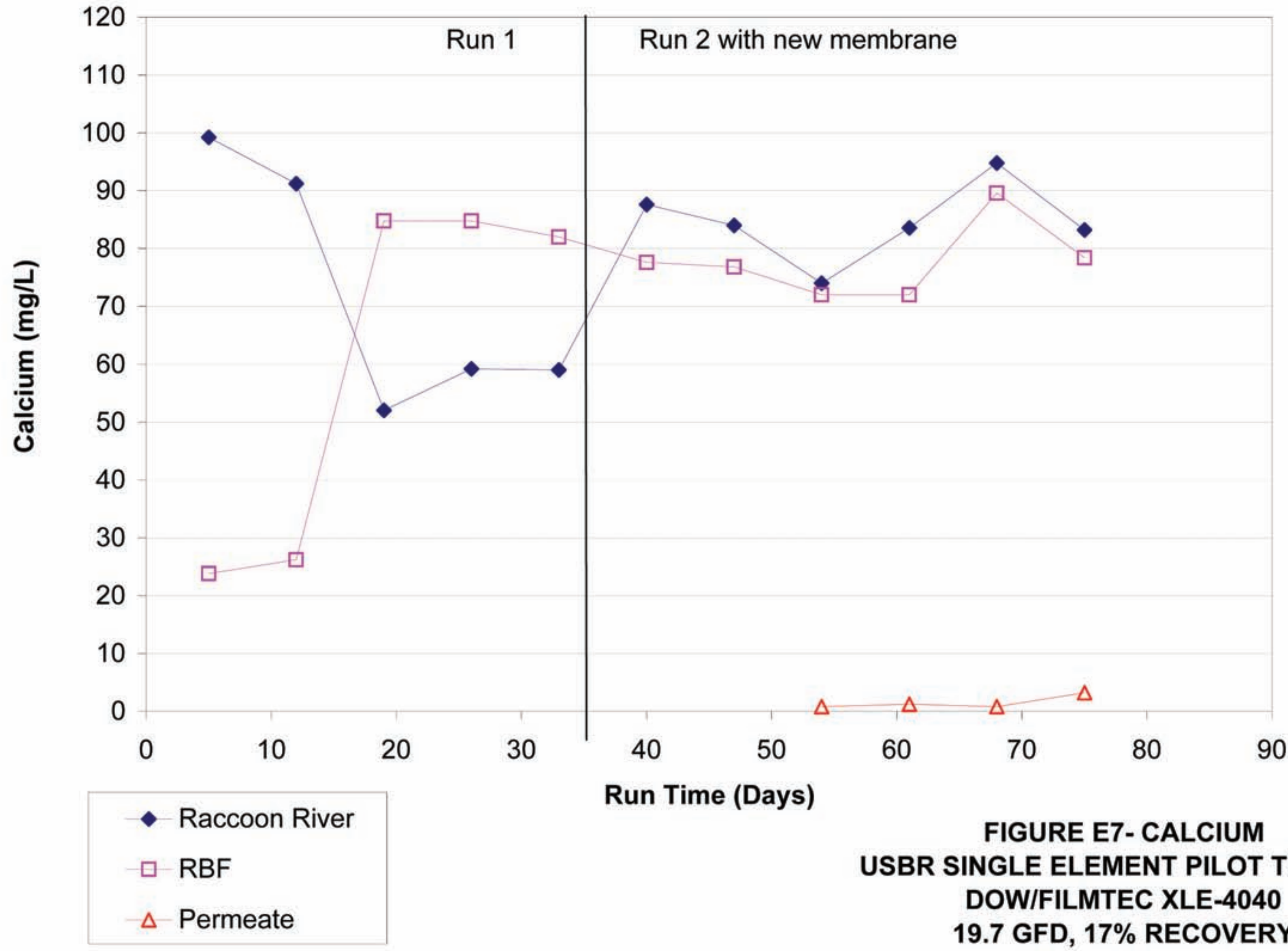


FIGURE E7- CALCIUM
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
DMWW

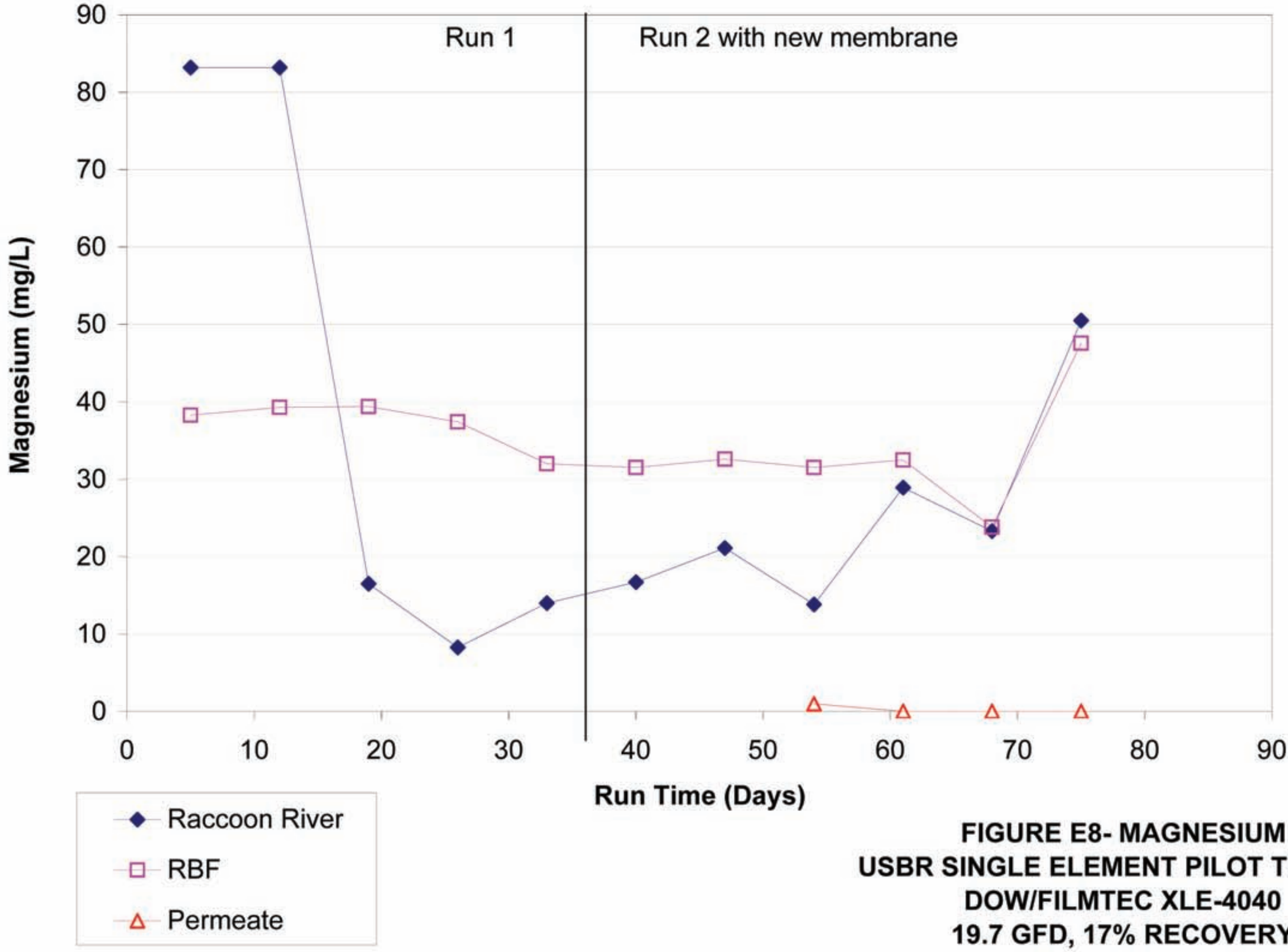


FIGURE E8- MAGNESIUM
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
DMWW

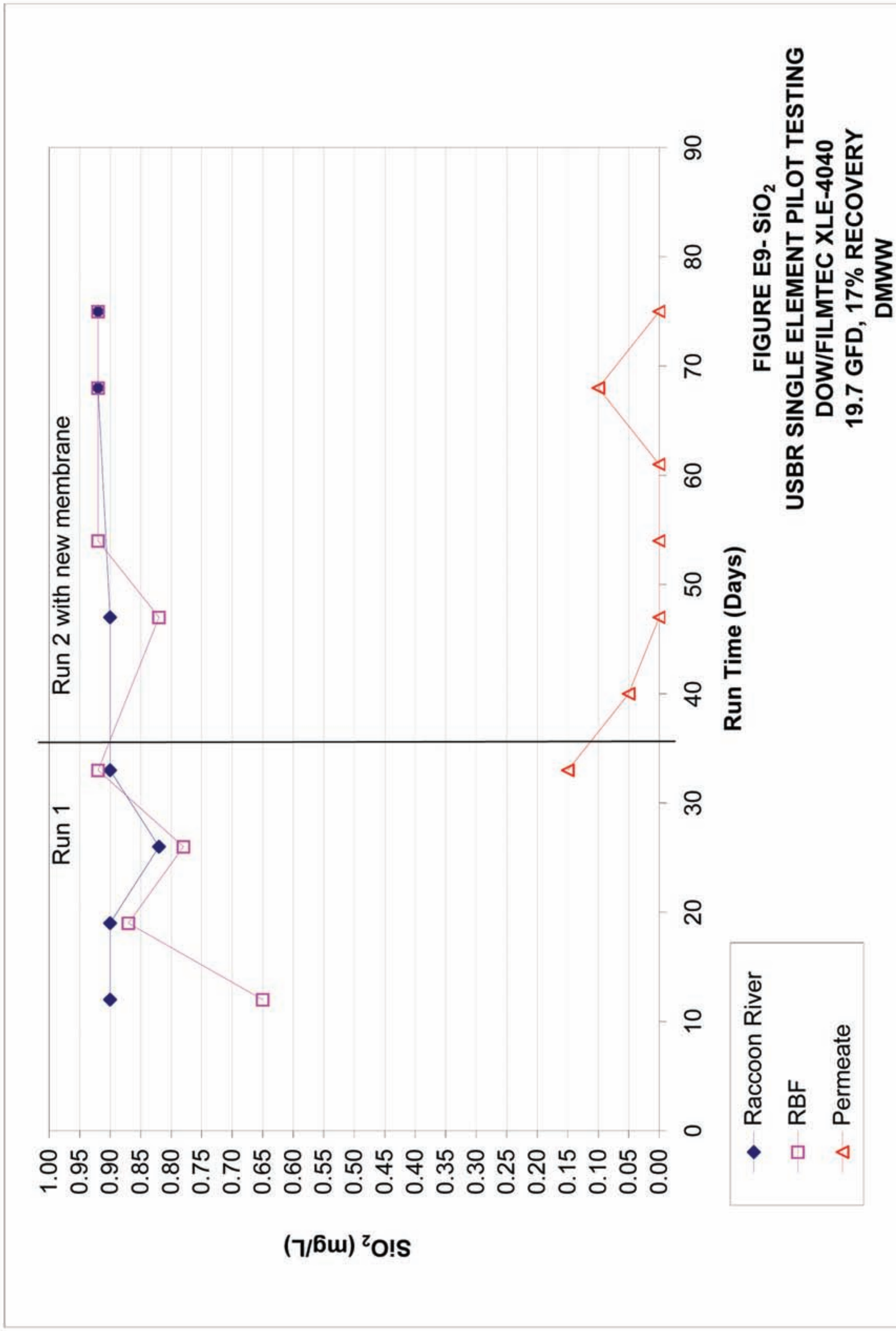


FIGURE E9- SiO$_2$
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
DMWW

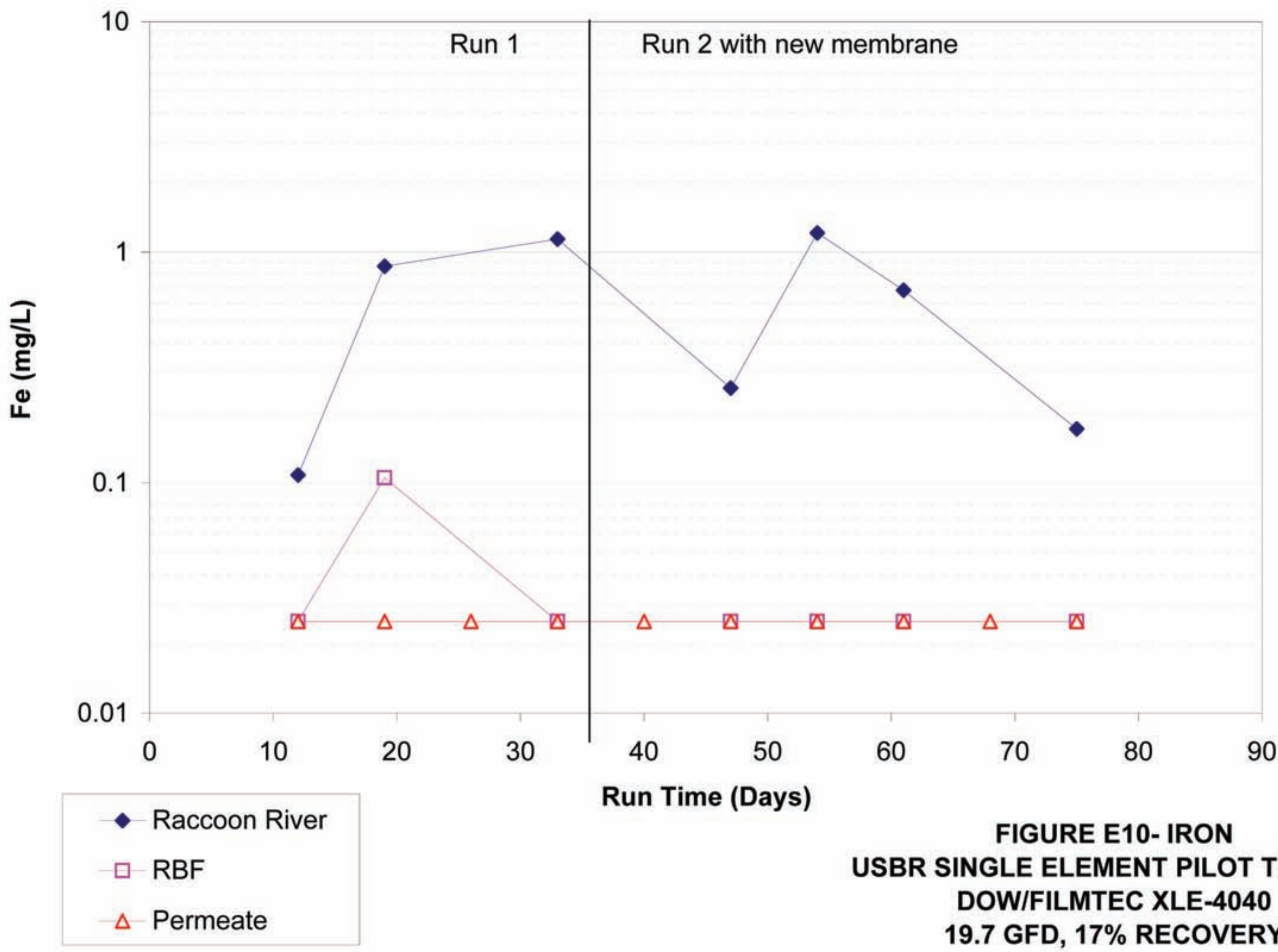


FIGURE E10- IRON
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
DMWW

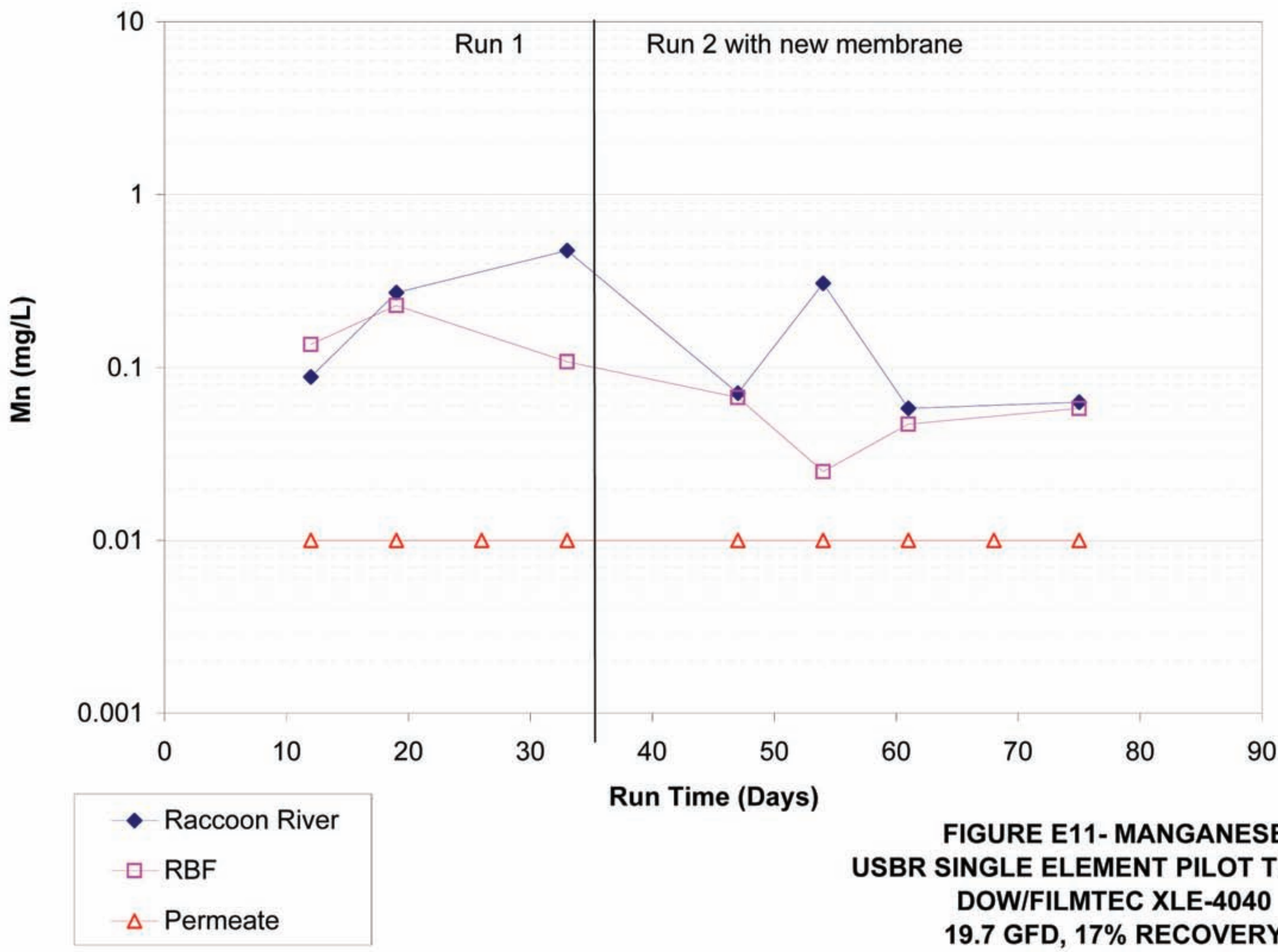


FIGURE E11- MANGANESE
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
DMWW

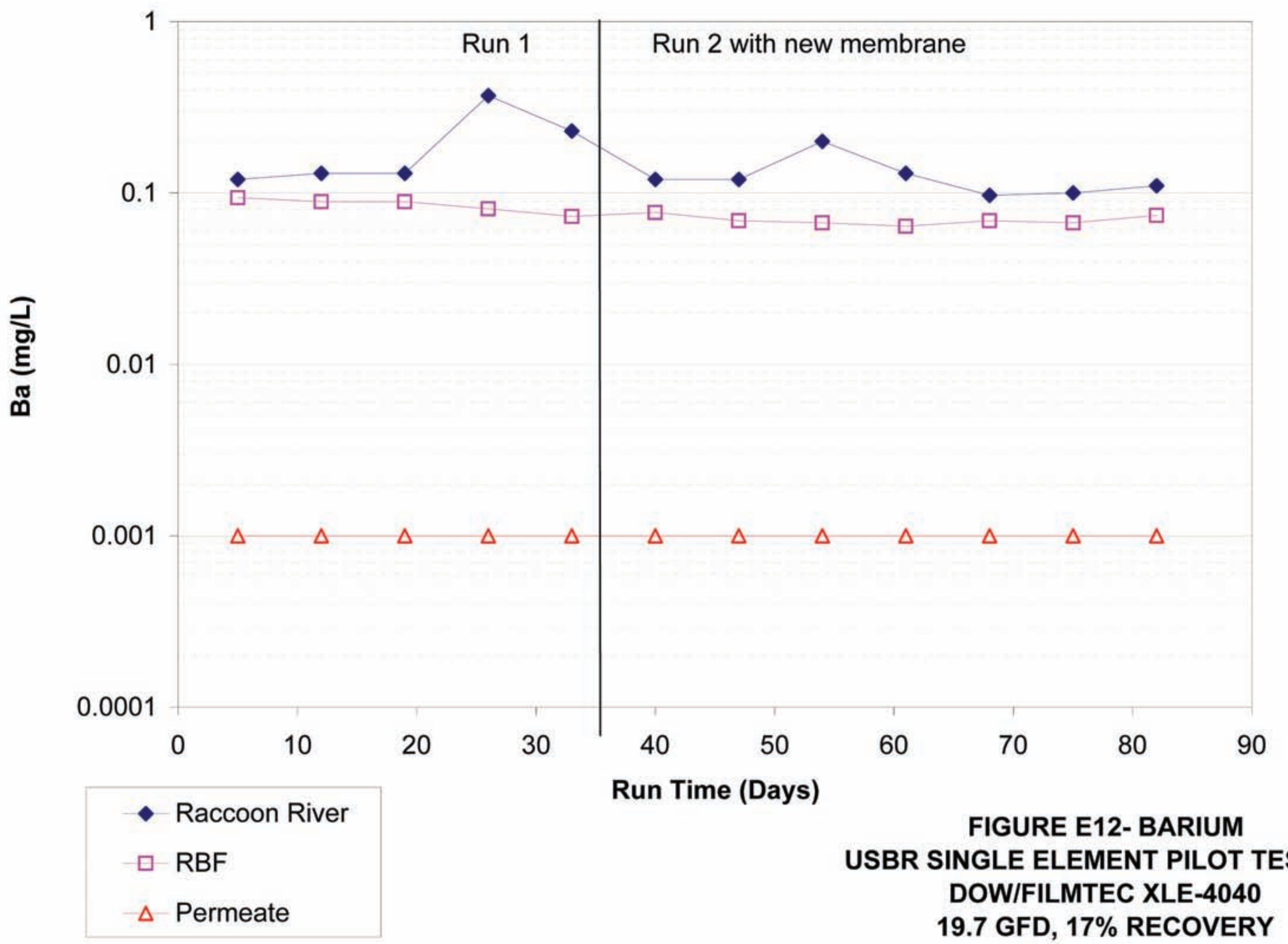


FIGURE E12- BARIUM
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
DMWW

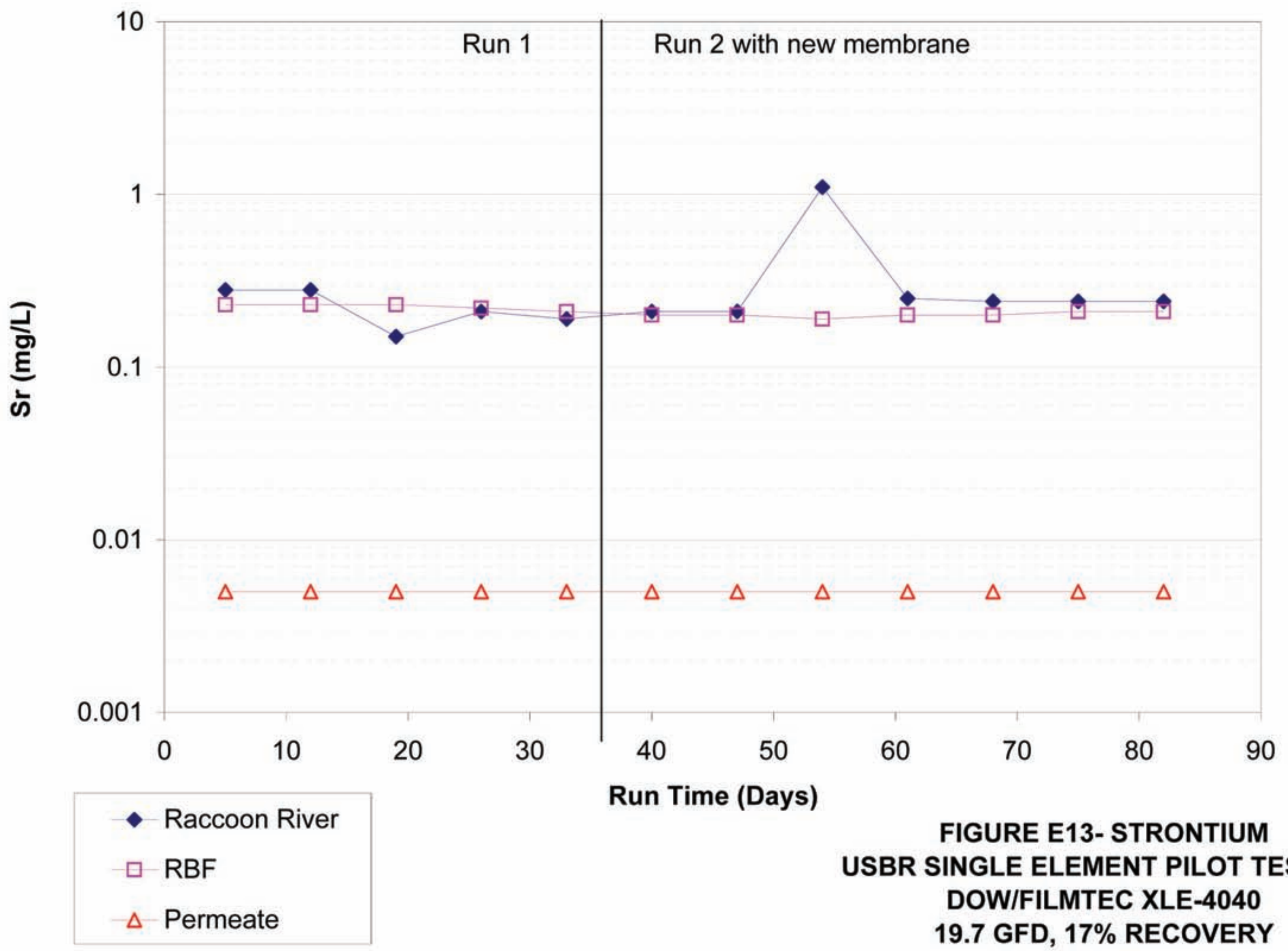


FIGURE E13- STRONTIUM
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
DMWW

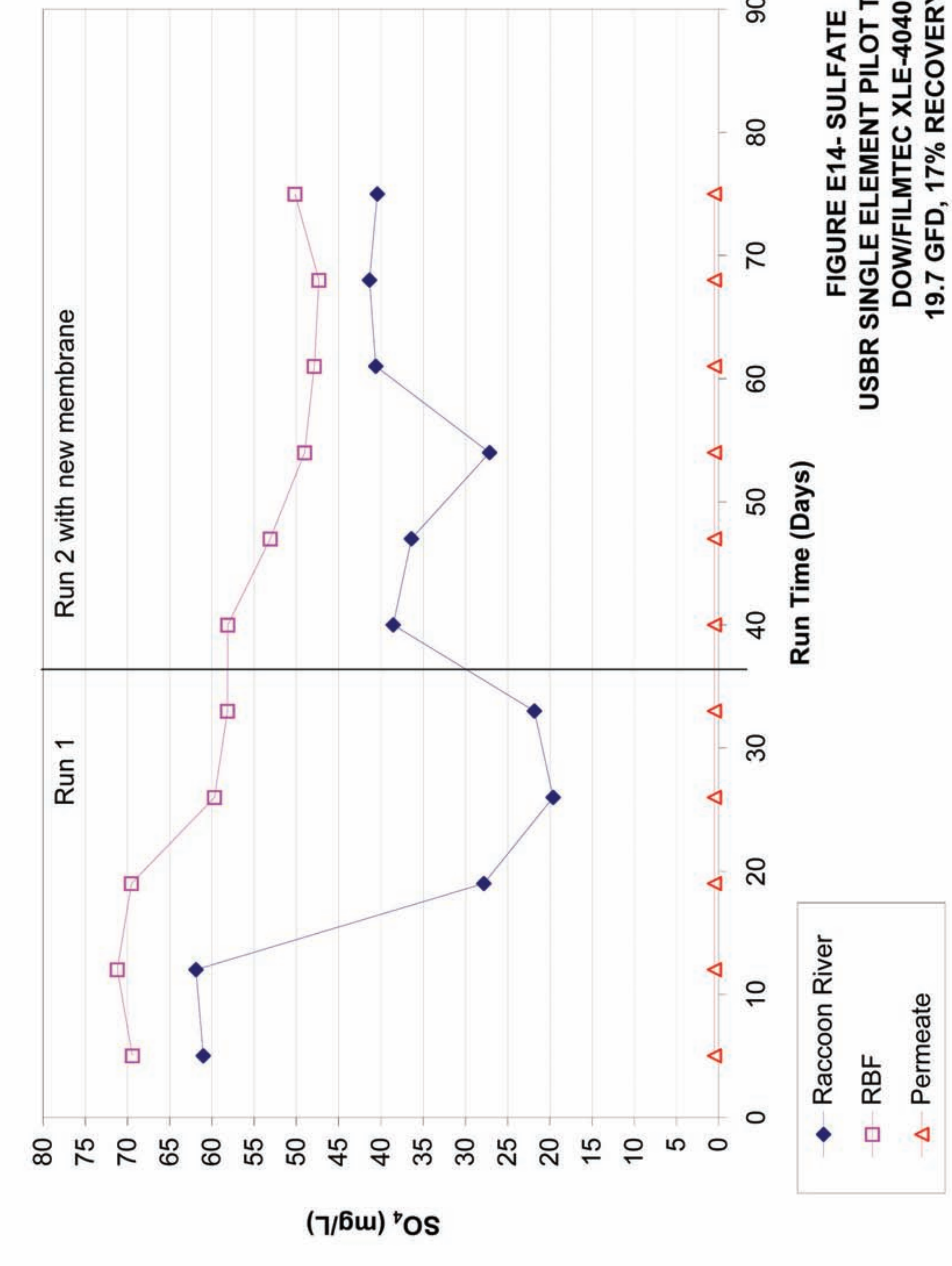


FIGURE E14- SULFATE
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
DMWW

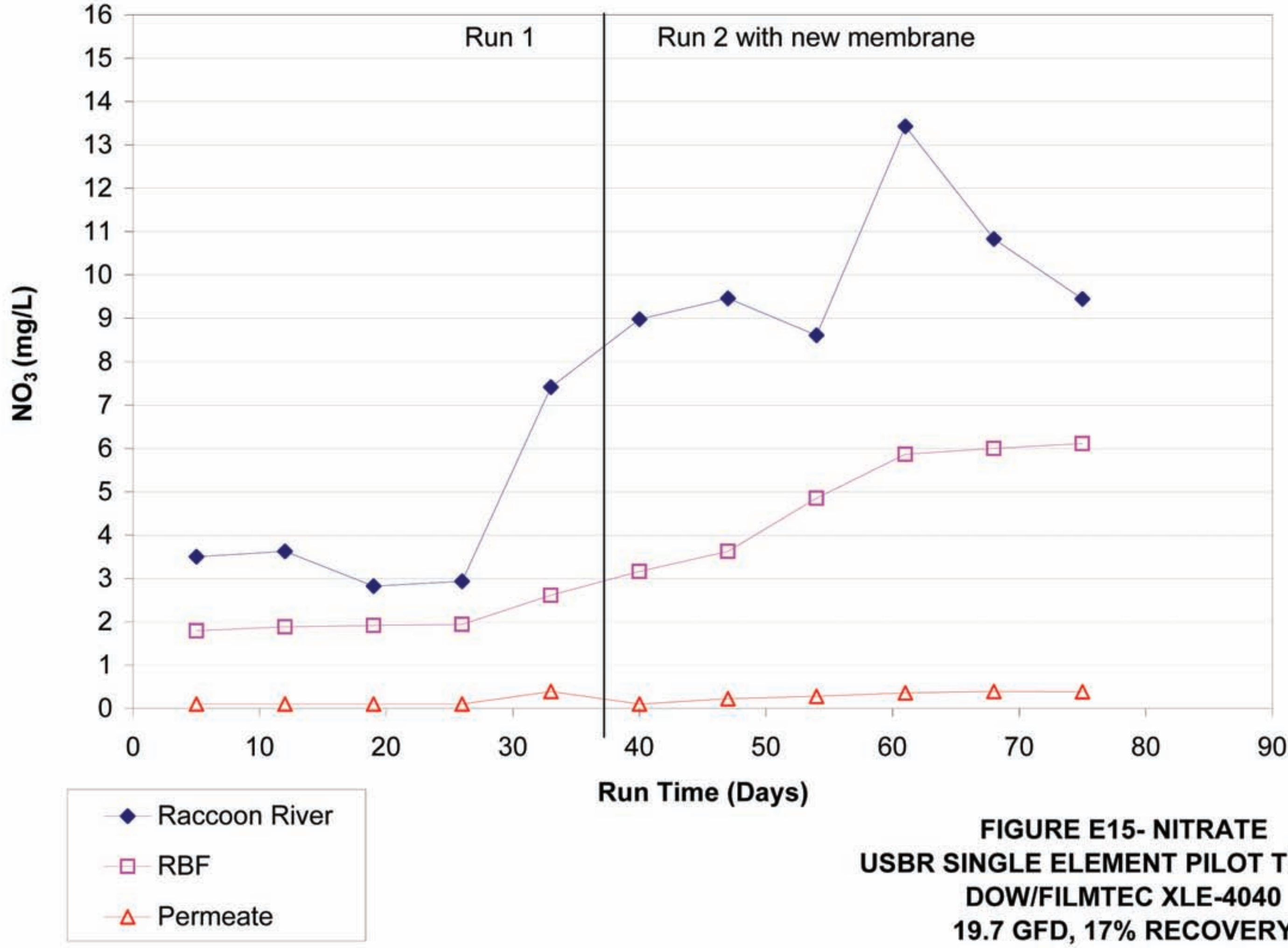


FIGURE E15- NITRATE
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
DMWW

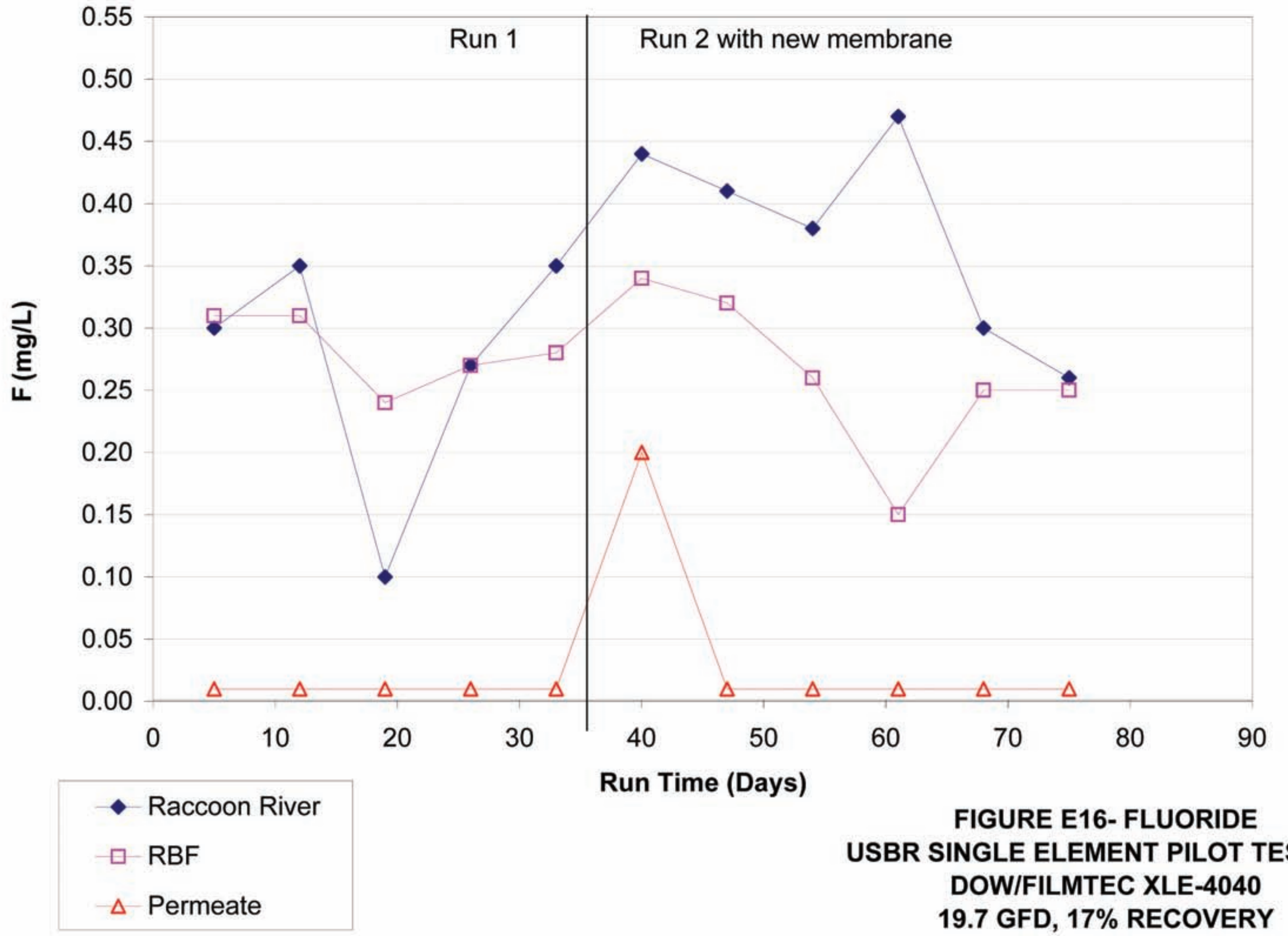


FIGURE E16- FLUORIDE
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
DMWW

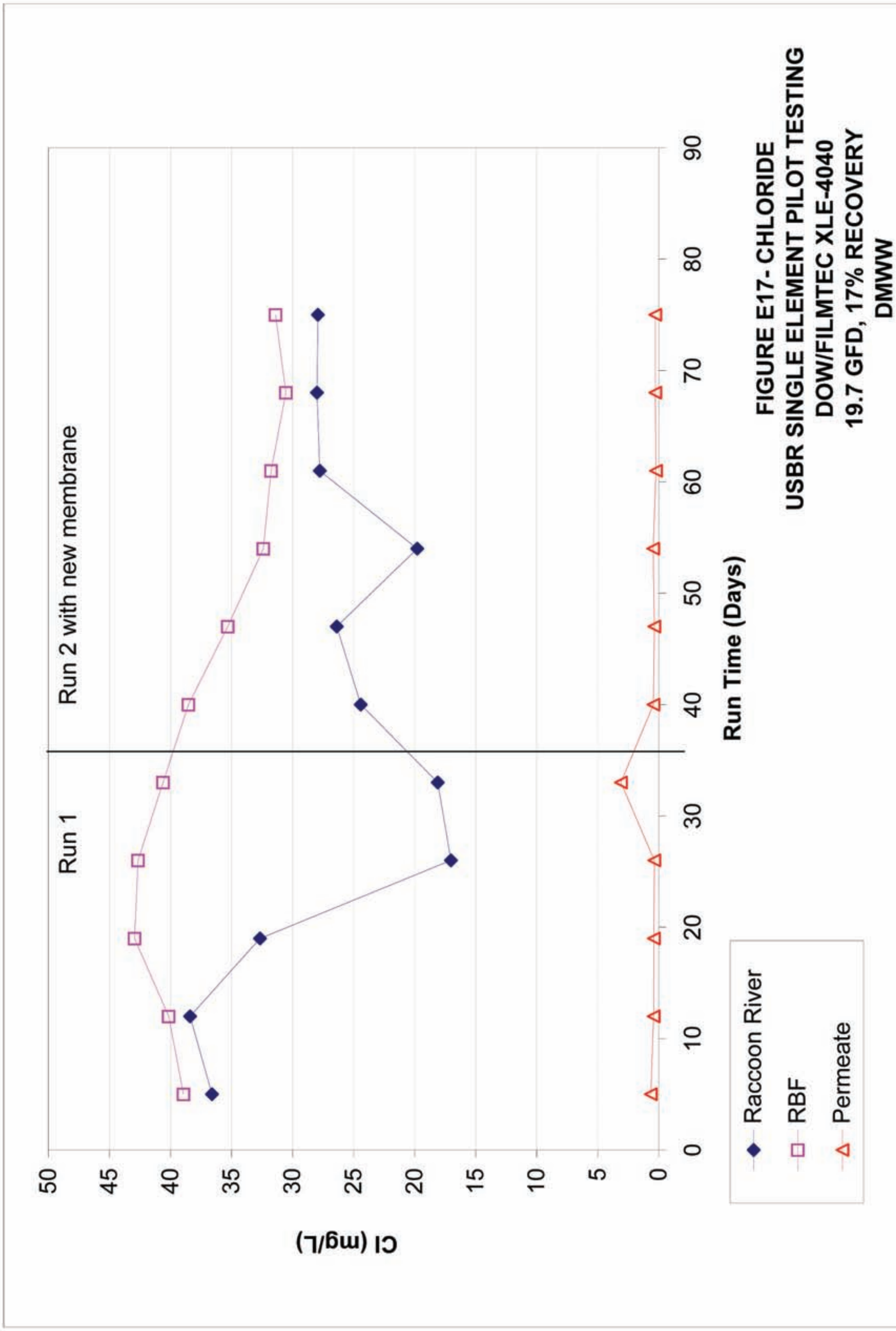


FIGURE E17- CHLORIDE
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
DMWW

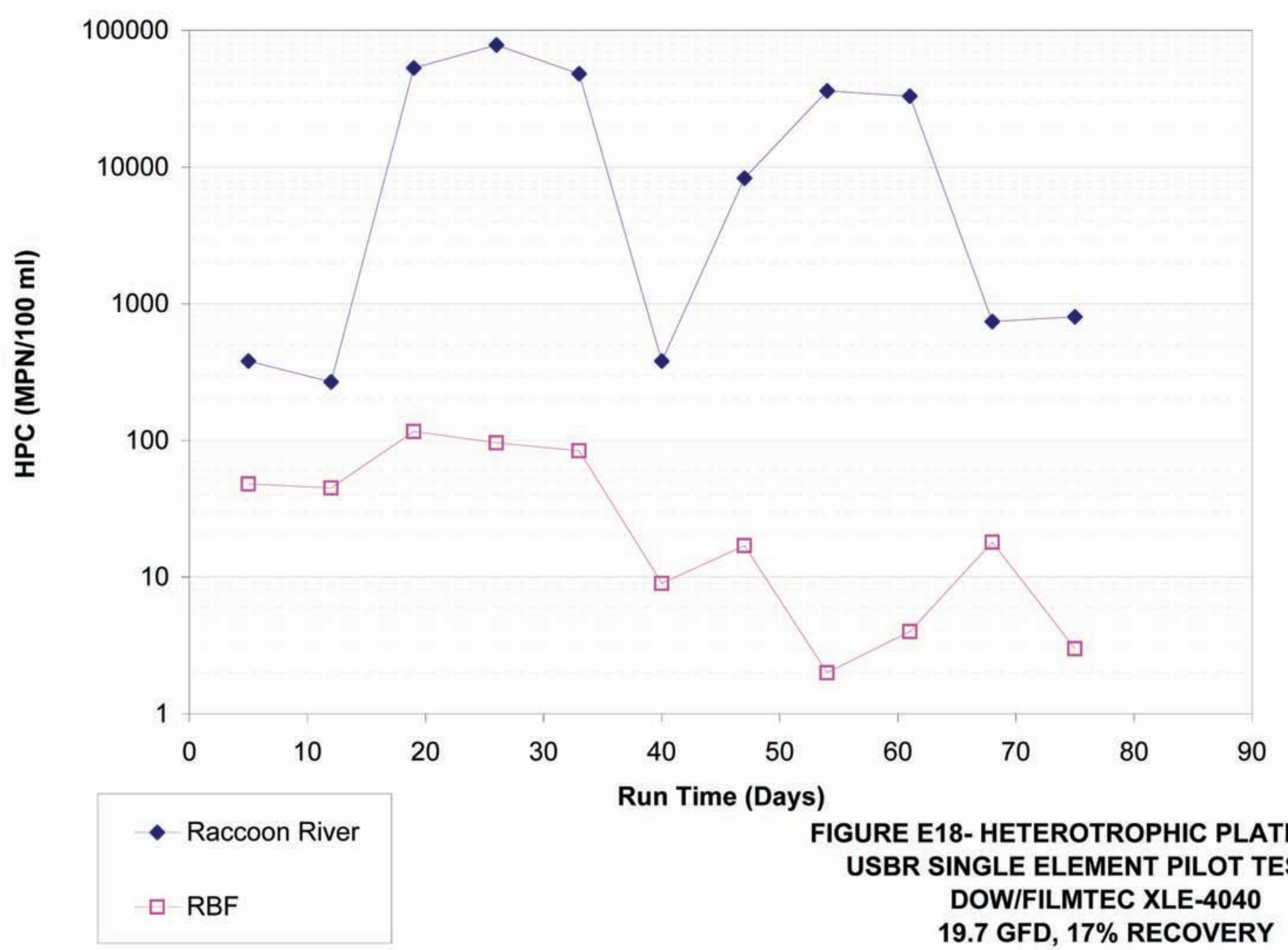


FIGURE E18- HETEROTROPHIC PLATE COUNT
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
DMWW

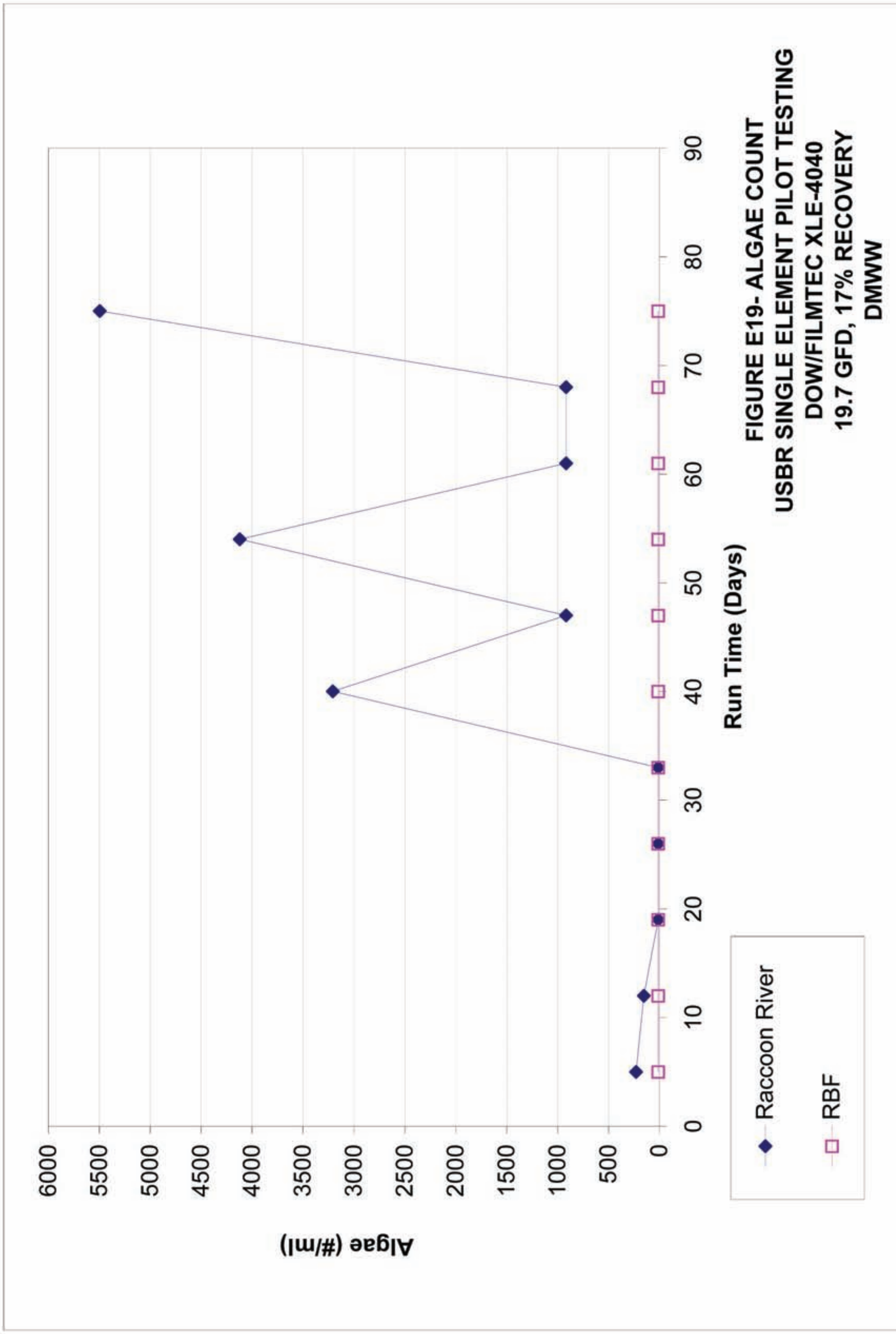


FIGURE E19- ALGAE COUNT
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
DMWW
Algae (#/ml)
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Run Time (Days)
0
10
20
30
40
50
60
70
80
90
Raccoon River
RBF

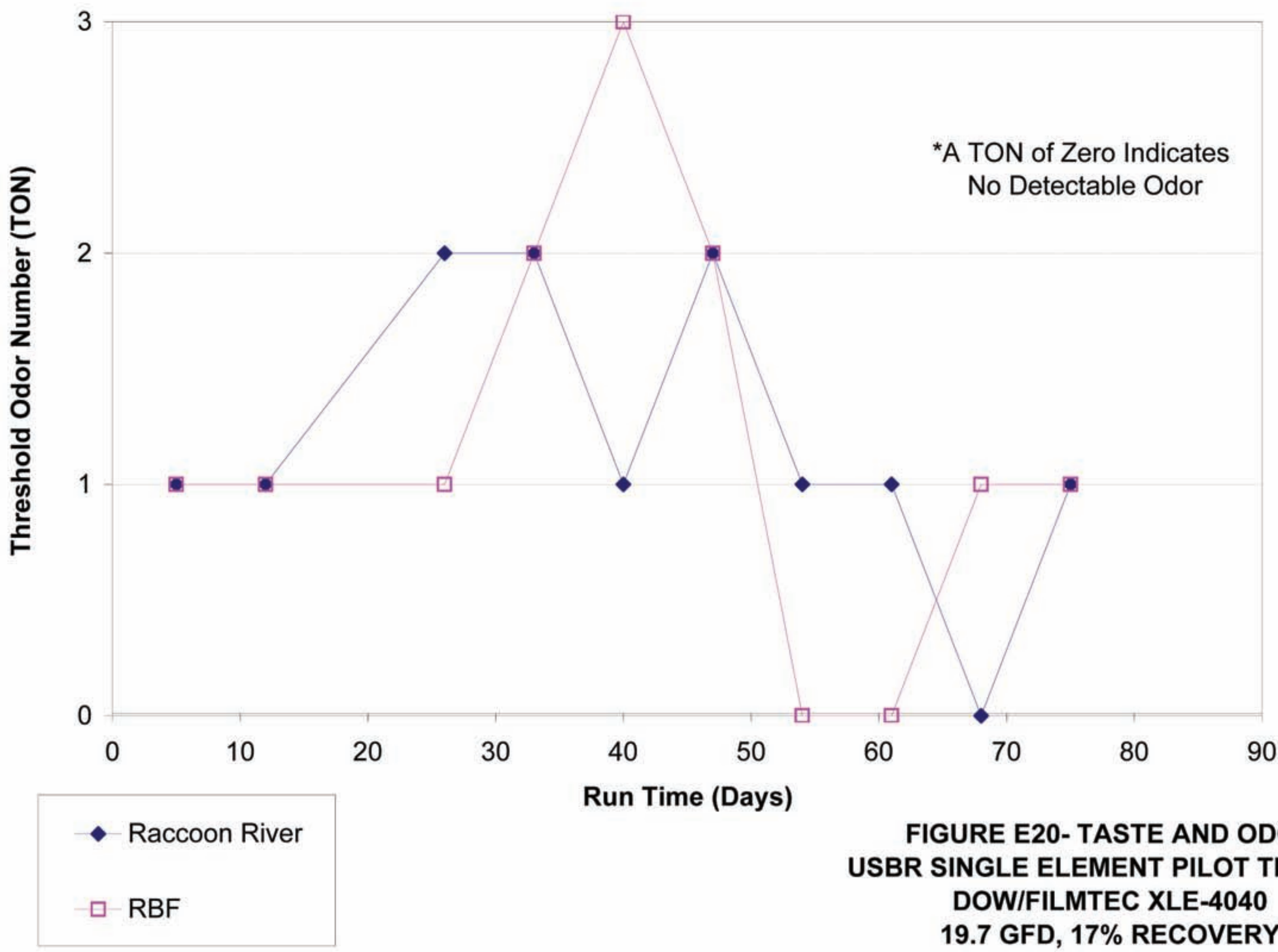


FIGURE E20- TASTE AND ODOR
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
DMWW

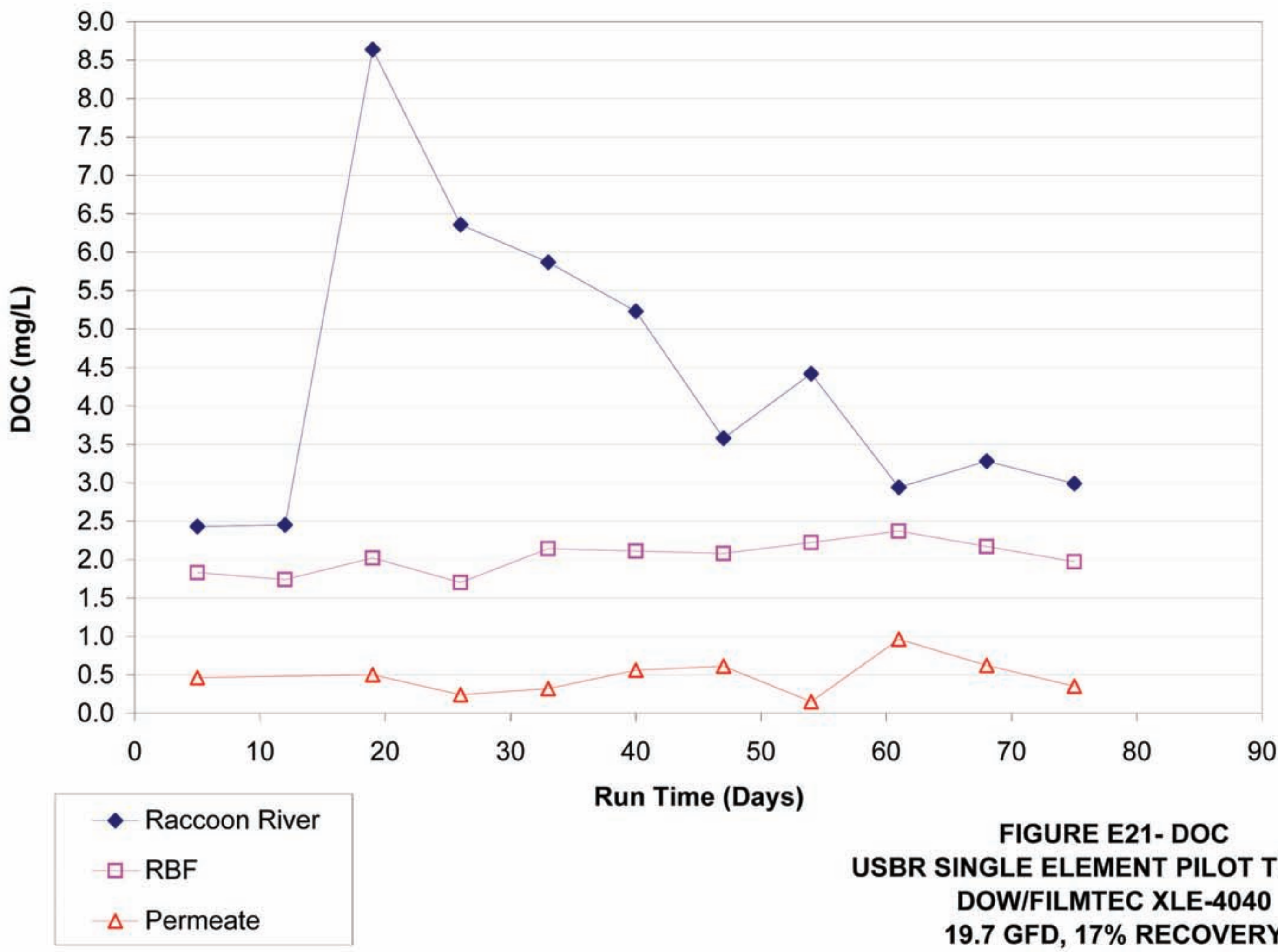


FIGURE E21- DOC
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
DMWW

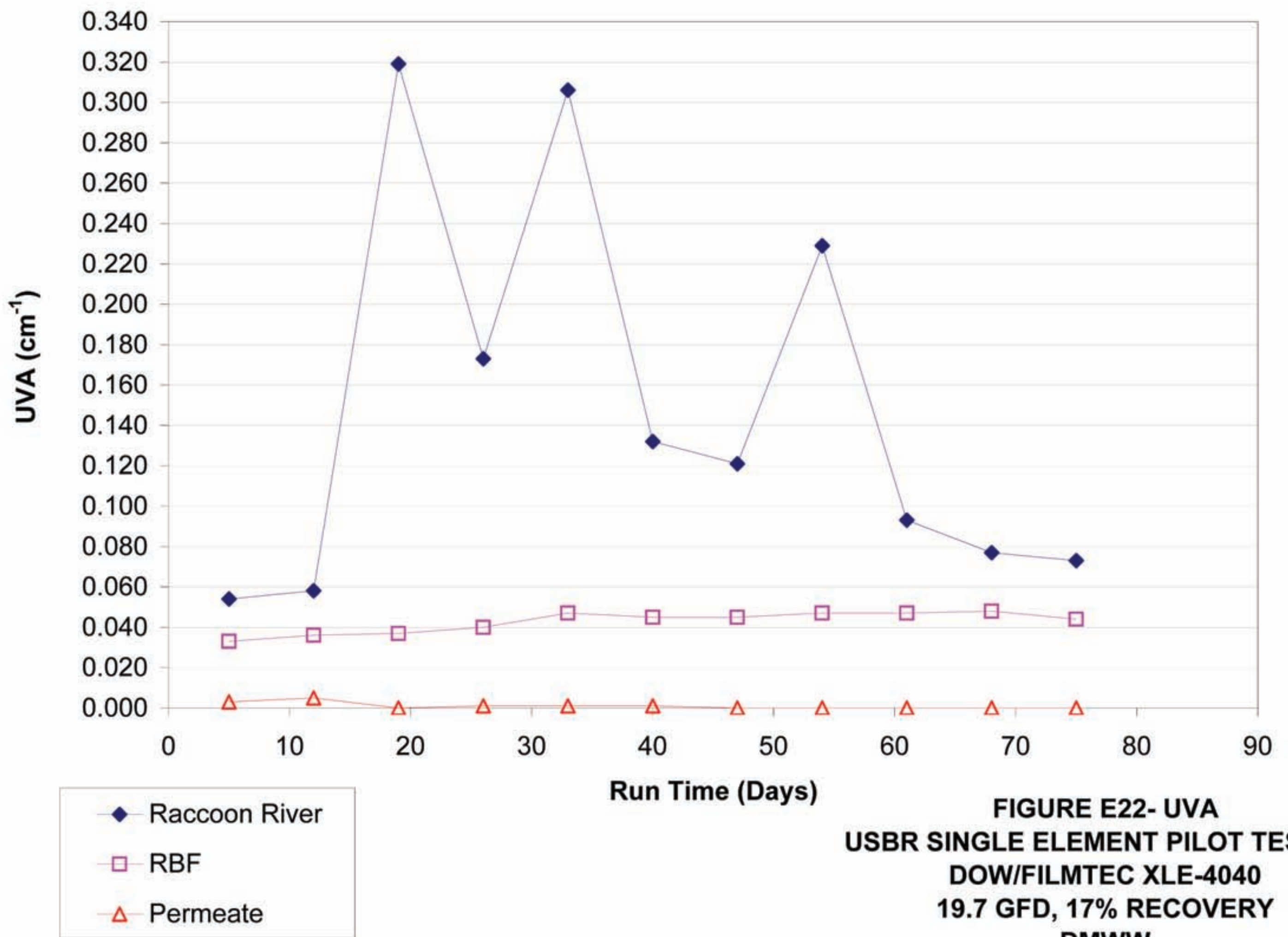


FIGURE E22- UVA
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
DMWW

APPENDIX F

Kansas Board of Public Utilities Data Set

Operator (initials)	Comments	Date MM/DD/YY	Time hh:mm	Operation time hh.hh	Operation time Days	T_F (C)	P_{CF1} (psi)	P_{CF2} (psi)	P_F (psi)	P_P (psi)	P_B (psi)	Q_P (gpm)	Q_B (gpm)	Q_{REC} (gpm)
SJG	New CF	05-21-04	3:00 PM	11529.3	0.00	19.5	44	44	104	45	98	1.19	5.68	4.84
CSS	Prep. 5 gal AS solution	05-24-04	1:30 PM	11599.0	2.90	19.2	45	42	109	45	103	1.19	5.68	4.88
CSS		05-25-04	1:00 PM	11623.0	3.90	19.1	44	39	110	45	105	1.19	5.67	4.90
CSS	Changed filter	05-26-04	9:13 AM	11643.0	4.74	19.0	44	33	115	47	110	1.20	5.64	4.91
DJW	Prep. 5 gal AS solution	05-27-04	9:16 AM	11667.7	5.77	19.4	42	41	122	50	116	1.20	5.64	4.90
FTL		05-28-04	1:01 PM	11695.4	6.92	20.0	44	44	120	45	115	1.19	5.60	4.85
DJW	Prep. 5 gal AS solution	06-01-04	10:41 AM	11789.2	10.83	20.1	30	23	145	42	139	1.20	5.66	4.91
RDV	CHEMICAL CLEANED	06-15-04	1:42 PM	11792.2	10.95	21.1	46	44	121	44	115	1.19	5.64	4.93
RDV		06-16-04	10:40 AM	11813.5	11.84	22.0	46	42	122	44	115	1.19	5.64	4.99
CSS		06-17-04	11:00 AM	11837.7	12.85	21.6	45	43	123	44	117	1.19	5.68	4.92
CSS		06-18-04	1:30 PM	11843.7	13.10	21.4	31	28	123	45	115	1.20	5.70	4.88
RDV		06-21-04	12:50PM	11915.2	16.08	22.3	26	23	155	43	139	1.18	6.24	5.82
CSS	CHEMICAL CLEANED	07-16-04	1:00 PM	11923.7	16.43	23.5	45	42	103	34	98	1.19	5.63	4.86
SAP		07-19-04	9:30 AM	11992.2	19.29	24.7	45	42	104	34	98	1.19	5.65	4.85
SAP		07-20-04	9:15 AM	12015.7	20.27	24.7	47	42	104	28	95	1.19	5.63	4.56
SAP		07-21-04	12:45 PM	12041.1	21.33	26.5	45	45	119	28	110	1.19	5.65	5.03
RDV	Changed Filter	07-22-04	9:13 AM	12062.2	22.20	24.8	46	43	147	21.5	141	1.19	5.65	4.97
Extrapolate	CHEMICAL CLEANED	07-26-04		12066.0	22.36		46	44	103	98	100			
RDV		07-27-04	11:16 AM	12086.2	23.20	24.4	46	44	103	98	100	1.19	5.68	4.96
RDV	Prep. 5 gal cleaning solution	07-28-04	2:30 PM	12113.4	24.34	na	46	43	105	37	100	1.20	5.67	5.11
CSS		07-29-04	11:15 AM	12134.3	25.21	24.9	45	41	104	37	98	1.20	5.67	4.97
RDV		07-30-04	12:00 PM	12160.4	26.30	24.6	46	43	104	37	98	1.20	5.73	4.87
DJW		08-02-04	10:41 AM	12229.6	29.18	25.0	45	43	108	35	104	1.20	5.81	4.94
DJW		08-03-04	9:07 AM	12252.1	30.12	25.0	45	41	113	35	107	1.20	5.65	4.93
SAP		08-04-04	12:30 PM	12279.5	31.26	25.1	46	41	115	35	111	1.20	5.72	5.05

Operator (initials)	Comments	Date MM/DD/YY	Time hh:mm	Operation time hh.hh	Operation time Days	T_F (C)	P_{CF1} (psi)	P_{CF2} (psi)	P_F (psi)	P_P (psi)	P_B (psi)	Q_P (gpm)	Q_B (gpm)	Q_{REC} (gpm)
SAP		08-05-04	9:00 AM	12300.1	32.12	25.0	46	43	120	35	113	1.18	5.67	4.94
SAP		08-06-04	9:30 AM	12324.5	33.13	24.7	45	42	130	35	123	1.19	5.82	5.48
RDV		08-16-04	12:00 AM	12400.0	36.28	24.5	46	42	99	44	96	1.20	5.63	4.95
DJW		08-17-04	10:30 AM	12421.4	37.17	24.5	46	42	102	45	99	1.20	5.65	4.89
DJW		08-18-04	9:10 AM	12444.1	38.12	24.5	45	41.5	103	45	100	1.20	5.65	4.91
RDV		08-19-04	12:00 AM	12469.7	39.18	24.1	45	42	103	45	100	1.19	5.72	4.93
RDV		08-20-04	12:00 AM	12493.3	40.17	23.6	44	43	104	46	101	1.19	5.62	4.86
RDV		08-23-04	11:07 AM	12566.0	43.20	23.9	43	40	103	45	99	1.19	5.62	4.92
DJW		08-24-04	2:30 PM	12581.1	43.83	24.6	44	39	129	43	111	1.19	5.64	4.95
TD		09-10-04	2:30 PM	12587.1	44.08	26.2	44	42	113	48	110	1.19	5.52	4.90
DJW		09-13-04	11:00 AM	12675.8	47.77	24.4	46	41	132	48	125	1.19	5.63	4.97
DJW		09-14-04	10:45 AM	12699.7	48.77	26.4	44	39	138	48	130	1.19	5.70	4.91
TD		9-27-04	10:00AM	12709.7	49.18	24.3			103	40	98	1.19	5.64	4.88
					Count	36.0								
					Median	24.4								
					Low	19.0								
					High	26.5								
					Average	23.3								
					Standard Deviation	2.3								
					95% CI Low	22.6								
					95% CI High	24.0								

Operator	Comments	Date	Time	Operation time	Operation time	T_R	pH				Conductivity (uS/cm)				Turbidity (NTU)			
(initials)		MM/DD/YY	hh:mm	hh.hh	Days	(C)	pH_R	pH_F	pH_P	pH_B	C_R	C_F	C_P	C_B	NTU_R	NTU_F	NTU_P	SDI_F
SJG		05-21-04	3:00 PM	11529.4	0.00	31.7		6.90			X	719	19	X	X	0.948	X	2.44
CSS		05-24-04	1:30 PM	11599.0	2.90	29.2	8.06	6.90	5.45	7.45	648	709	16	723	165	0.488	0.140	1.67
CSS		05-25-04	1:00 PM	11623.0	3.90	25.2	7.73	6.90	5.53	7.49	579	693	16	788	1685	0.601	0.102	1.37
CSS		05-26-04	9:13 AM	11643.0	4.73	24.2	7.49	6.90	5.54	7.54	437	684	15	783	3977	0.468	0.165	1.40
DJW		05-27-04	9:16 AM	11667.7	5.76	24.8	7.57	6.90	5.58	7.57	420	675	15	775	4192	0.422	0.115	0.71
FTL		05-28-04	1:01 PM	11695.4	6.92	27.2	7.59	6.90	5.79	7.53	427	653	16	765	3481	1.120	0.081	3.26
DJW		06-01-04	10:41 AM	11789.2	10.83	26.7	7.30	6.80	5.59	7.48	433	568	18	638	2940	0.530	0.064	1.82
RDV		06-15-04	1:42 PM	11792.2	10.95	29.6	NA	7.00	NA	NA	NA	NA	17	NA	NA	0.622	NA	NA
RDV		06-16-04	10:40 AM	11813.5	11.84	30.3	7.80	7.00	5.84	7.44	561	650	16	750	725	0.284	0.211	1.11
CSS		06-17-04	11:00 AM	11837.7	12.85	27.9	7.78	6.90	5.50	7.35	606	642	16	771	497	0.324	0.201	0.867
CSS		06-18-04	1:30 PM	11843.7	13.10	25.9	7.63	6.90	5.86	7.44	601	622	15	750	882	0.294	0.110	--
RDV		06-21-04	12:50PM	11915.2	16.08	28.3	7.84	6.90	5.76	7.35	609	559	12	758	933	--	0.154	3.39
CSS		07-16-04	1:00 PM	11923.7	16.43	31.2	7.91	7.20	4.75	7.49	640	NA	20	774	295	0.839	0.651	-0.53
SAP		07-19-04	9:30 AM	11992.2	19.28	32.8	7.85	7.10	5.30	7.40	639	674	15	762	207	0.552	0.179	1.11
SAP		07-20-04	9:15 AM	12015.7	20.26	34.7	7.98	7.00	5.62	7.52	627	667	18	756	187	1.190	0.217	0.2
SAP		07-21-04	12:45 PM	12041.1	21.32	35.9	7.97	7.50	5.87	7.50	673	650	18	769	139	1.190	0.195	0.4
RDV		07-22-04	9:13 AM	12062.2	22.20	32.6	8.01	6.90	5.81	7.45	700	649	19	736	124	1.290	0.266	NA
MICAL CLEANED		07-26-04		12066.0	22.36	27.3												
RDV		07-27-04	11:16 AM	12086.2	23.20	28.8	7.94	5.90	5.44	6.49	718	711	38	807	103	0.598	0.223	0.62
RDV		07-28-04	2:30 PM	12113.4	24.33	28.4	8.13	7.10	5.35	7.38	698	na	16	776	73.4	0.750	0.212	0.21
CSS		07-29-04	11:15 AM	12134.3	25.20	26.6	8.14	5.80	5.16	6.34	689	920	43	807	67	0.552	0.172	0.833
RDV		07-30-04	12:00 AM	12160.4	26.29	25.8	8.29	6.00	5.35	6.65	712	717	36	838	66.7	1.080	0.285	1.03
DJW		08-02-04	10:41 AM	12229.6	29.18	32.5	8.03	6.30	5.40	6.84	730	723	29	830	54.7	0.810	0.135	-0.36
DJW		08-03-04	9:07 AM	12252.1	30.11	34.4	8.05	6.40	5.33	6.77	734	725	29	840	73.2	1.600	0.137	3.8
SAP		08-04-04	12:30 PM	12279.5	31.25	29.9	8.01	6.30	5.42	6.77	728	741	31	864	50.4	0.954	0.156	0.33
SAP		08-05-04	9:00 AM	12300.0	32.11	27.8	8.15	6.20	5.28	6.67	734	744	31	864	61.6	0.881	0.217	0.25
SAP		08-06-04	9:30 AM	12324.5	33.13	26.6	8.28	6.30	5.50	6.79	734	736	30	837	48.6	0.892	0.343	3.1

Operator (initials)	Comments	Date MM/DD/YY	Time hh:mm	Operation time hh.hh	Operation time Days	T_R (C)	pH				Conductivity (uS/cm)				Turbidity (NTU)			SDI_F
							pH_R	pH_F	pH_P	pH_B	C_R	C_F	C_P	C_B	NTU_R	NTU_F	NTU_P	
RDV		08-16-04	12:00 AM	12400.0	36.28	25.8	7.99	5.30	4.78	5.55	703	771	47	876	73.2	0.810	0.100	1.92
DJW		08-17-04	10:30 AM	12421.4	37.17	27.8	7.95	5.10	4.58	5.24	732	786	45	893	42.7	1.030	0.102	1.07
DJW		08-18-04	9:10 AM	12444.1	38.11	29.4	8.30	5.60	4.90	5.73	735	777	46	901	53.5	1.600	0.159	ND
RDV		08-19-04	12:00 AM	12469.7	39.18	22.7	8.26	5.40	4.73	5.41	731	790	44	898	41.1	0.736	0.104	0.4
RDV		08-20-04	12:00 AM	12493.3	40.16	21.2	8.21	5.40	4.94	5.69	723	785	44	887	49.6	0.776	0.152	0.587
RDV		08-23-04	11:07 AM	12566.0	43.19	26.6	8.36	5.30	4.82	5.42	708	803	44	907	37	0.975	0.110	1.19
DJW		08-24-04	2:30 PM	12581.1	43.82	26.4	8.31	6.30	3.32	3.08	682	991	425	1216	131	10.800	0.104	NA
DJW		09-10-04	2:30 PM	12587.1	44.07	24.5	--	--	--	--	648	718	38	817	--	--	--	--
DJW		09-13-04	11:00 AM	12675.8	47.77	24.2	8.35	5.00	5.11	5.72	709	1213	70	915	39.3	0.503	0.146	ND
DJW		09-14-04	10:45 AM	12699.7	48.76	24.4	8.35	5.50	5.06	5.61	721	1070	68	893	46.8	0.391	0.076	1.22
TD		9-27-04	10:00AM	12709.7	49.18	22.1	--	--	--	--	--	716	15	875	--	--	--	--
					Count	38	33	35	33	33	34	34	37	35	33	34	33	27
					Median	27.5	8.01	6.80	5.40	6.84	694	717	20	807	103.0	0.793	0.154	1.11
					Low	21.2	7.30	5.00	3.32	3.08	420	559	12	638	37.0	0.284	0.064	0.20
					High	35.9	8.36	7.50	5.87	7.57	735	1213	425	1216	4192.0	10.800	0.651	3.80
					Average	27.9	7.99	6.39	5.28	6.67	652	743	39	824	652.8	1.085	0.175	1.34
					Standard Deviation	3.5	0.27	0.71	0.50	1.02	96	133	67	94	1194.4	1.750	0.106	1.03
					95% CI Low	26.8	7.90	6.16	5.11	6.32	620	698	18	793	245.3	0.497	0.139	0.96
					95% CI High	29.0	8.08	6.63	5.45	7.02	684	787	61	855	1060.3	1.673	0.212	1.73

Operator (initials)	Comments	Date MM/DD/YY	Time hh:mm	Operation time hh.hh	TDS, mg/L TDS_R	TDS_F	TDS_P	TDS_B	Alkalinity, mg/L Alk_R	Alk_F	Alk_P	Calcium, mg/L Ca_R	Ca_F	Ca_P
FTL	4.7	05-26-04	10:00 AM	11643.0	284	445	10.0	509	149	190	5.7	127	170	2.4
FTL	21.4	07-21-04	1:05PM	12042.00	437	423	11.7	500	187	197	7.0	116	167	4.6
FTL	24.3	07-28-04	2:30 PM	12113.4	454	437	7.8	505	189	201	6.0	142	142	5.4
FTL	31.3	8-4-04	2:30PM	12281.0	473	482	20.2	562	184	203	9.5	160	171	1.6
FTL	38.1	8-18-04	9:10 AM	12444.1	478	505	29.9	586	183	201	11.0	149	167	1.0
FTL	48.9	09-14-04	1:10 PM	12701.90	469	696	44.2	580	174	204	12.1	155	181	7.2

Count	6	6	6	6	6	6	6	6	6	6
Median	462	464	16.0	536	184	201	8.3	146	169	3.5
Low	284	423	7.8	500	149	190	5.7	116	142	1.0
High	478	696	44.2	586	189	204	12.1	160	181	7.2
Average	433	498	20.6	540	178	199	8.6	142	166	3.7
Standard Deviation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
95% CI Low	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
95% CI High	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Operator (initials)	Comments	Date MM/DD/YY	Time hh:mm	Operation time hh.hh	SiO_2, mg/L Si_R	Si_F	Si_P	Iron, mg/L Fe_R	Fe_F	Fe_P
FTL	4.7	05-26-04	10:00 AM	11643.0	12.5	12.8	0.5	0.163	1.25	0.005
FTL	21.4	07-21-04	1:05PM	12042.00	12.6	11.7	0.3	0.011	0.137	0.010
FTL	24.3	07-28-04	2:30 PM	12113.4	11.6	13.1	0.3	0.013	1.56	0.008
FTL	31.3	8-4-04	2:30PM	12281.0	11.8	13.9	0.4	0.567	1.46	0.019
FTL	38.1	8-18-04	9:10 AM	12444.1	10.3	13.9	0.2	0.194	1.57	0.006
FTL	48.9	09-14-04	1:10 PM	12701.90	8.9	15.2	1.2	0.185	1.62	0.011

	Si_R	Si_F	Si_P	Fe_R	Fe_F	Fe_P
Count	6	6	6	6	6	6
Median	11.7	13.5	0.4	0.174	1.510	0.009
Low	8.9	11.7	0.2	0.011	0.137	0.005
High	12.6	15.2	1.2	0.567	1.620	0.019
Average	11.3	13.4	0.5	0.189	1.266	0.010
Standard Deviation	N/A	N/A	N/A	N/A	N/A	N/A
95% CI Low	N/A	N/A	N/A	N/A	N/A	N/A
95% CI High	N/A	N/A	N/A	N/A	N/A	N/A

Operator (initials)	Comments	Date MM/DD/YY	Time hh:mm	Operation time hh.hh	Manganese, mg/L			Barium, mg/L			Strontium, mg/L		
					Mn_R	Mn_F	Mn_P	Ba_R	Ba_F	Ba_P	Sr_R	Sr_F	Sr_P
FTL	4.7	05-26-04	10:00 AM	11643.0	0.026	0.519	0.001	1.7	0.160	0.001	0.51	0.47	0.81
FTL	21.4	07-21-04	1:05PM	12042.00	0.019	0.585	0.001	0.150	0.160	0.001	0.48	0.49	0.005
FTL	24.3	07-28-04	2:30 PM	12113.4	0.031	0.61	0.003	0.130	0.180	0.001	0.49	0.54	0.005
FTL	31.3	8-4-04	2:30PM	12281.0	0.166	0.617	0.002	0.093	0.200	0.001	0.51	0.56	0.005
FTL	38.1	8-18-04	9:10 AM	12444.1	0.161	0.616	0.006	0.100	0.190	0.001	0.51	0.53	0.005
FTL	48.9	09-14-04	1:10 PM	12701.90	0.163	0.611	0.004	0.730	0.180	0.001	0.51	0.50	0.005

	Mn_R	Mn_F	Mn_P	Ba_R	Ba_F	Ba_P	Sr_R	Sr_F	Sr_P
Count	6	6	6	5	6	6	6	6	5
Median	0.096	0.611	0.003	0.130	0.180	<0.002	0.51	0.52	<0.01
Low	0.019	0.519	0.001	0.093	0.160	<0.002	0.48	0.47	<0.01
High	0.166	0.617	0.006	0.730	0.200	<0.002	0.51	0.56	<0.01
Average	0.094	0.593	0.003	0.241	0.178	<0.002	0.50	0.52	<0.01
Standard Deviation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
95% CI Low	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
95% CI High	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Operator (initials)	Comments	Date MM/DD/YY	Time hh:mm	Operation time hh.hh	Sulfate, mg/L $S04_R$	$S04_F$	$S04_P$	Nitrate, mg/L $N03_R$	$N03_F$	$N03_P$	Fluoride, mg/L F_R	F_F	F_P	Chloride, mg/L Cl_R	Cl_F	Cl_P
FTL	4.7	05-26-04	10:00 AM	11643.0	61	136	0.55	15.00	2.95	0.48	0.41	0.49	0.01	12	14	0.47
FTL	21.4	07-21-04	1:05PM	12042.00	139	126	0.23	12.00	2.59	0.42	0.69	0.48	0.02	20	17	0.42
FTL	24.3	07-28-04	2:30 PM	12113.4	140	127	0.10	8.00	1.86	0.25	0.49	0.47	0.01	16	17	0.28
FTL	31.3	8-4-04	2:30PM	12281.0	143	123	0.40	4.00	3.00	0.40	0.5	0.49	0.03	17	13	0.40
FTL	38.1	8-18-04	9:10 AM	12444.1	166	145	0.85	3.00	0.53	0.14	0.55	0.47	0.18	17	14	1.00
FTL	48.9	09-14-04	1:10 PM	12701.90	178	153	7.00	0.65	0.13	0.05	0.41	0.33	0.20	17	16	6.00
		Count			6	6	6	6	6	6	6	6	6	6	6	6
		Median			141.50	131.50	0.48	6.00	2.23	0.33	0.50	0.48	0.03	17	15	0.45
		Low			61.00	123.00	0.10	0.65	0.13	0.05	0.41	0.33	0.01	12	13	0.28
		High			178.00	153.00	7.00	15.00	3.00	0.48	0.69	0.49	0.20	20	17	6.00
		Average			137.83	135.00	1.52	7.11	1.84	0.29	0.51	0.46	0.07	17	15	1.43
		Standard Deviation			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		95% CI Low			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		95% CI High			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Operator (initials)	Comments	Date MM/DD/YY	Time hh:mm	Operation time hh.hh	Coliforms, CFU/ml $Coli_R$	$Coli_F$	$Coli_p$	HPC, MPN/100ml HPC_R	HPC_F	HPC_p	DOC, mg/L DOC_R	DOC_F	DOC_P	UVA, cm^{-1} UVA_R	UVA_F	UVA_P
FTL	4.7	05-26-04	10:00 AM	11643.0	NA	1	<1	NA	>200	>200	4.5	2.1	0.3	0.150	0.056	0.005
FTL	21.4	07-21-04	1:05PM	12042.00	NA	0.5	<1	>200	93	>200	3.3	2.2	0.3	0.093	0.062	0.005
FTL	24.3	07-28-04	2:30 PM	12113.4	517	73	<1	>200	>200	>200	3.8	2.2	0.3	0.095	0.062	0.005
FTL	31.3	8-4-04	2:30PM	12281.0	10600	0.5	<1	--	--	--	3.2	2.2	0.3	0.082	0.061	0.005
FTL	38.1	8-18-04	9:10 AM	12444.1	275	0.5	<1	13600	1600	<1	3.1	2.2	0.3	0.074	0.06	0.005
FTL	48.9	09-14-04	1:10 PM	12701.90	2990	48.7	<1	>200	>200	98	2.9	2.1	0.3	0.067	0.058	0.005
		Count			4	6	6	6	6	6	6	6	6	6	6	6
		Median			1754	1	ND	13600	847	98	3.3	2.2	<0.5	0.088	0.061	0.005
		Low			275	0.5	ND	13600	93	ND	2.9	2.1	<0.5	0.067	0.056	0.005
		High			10600	73	ND	13600	1600	>200	4.5	2.2	<0.5	0.150	0.062	0.005
		Average			3596	21	ND	13600	847	N/A	3.5	2.2	<0.5	0.094	0.060	0.005
		Standard Deviation			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		95% CI Low			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		95% CI High			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

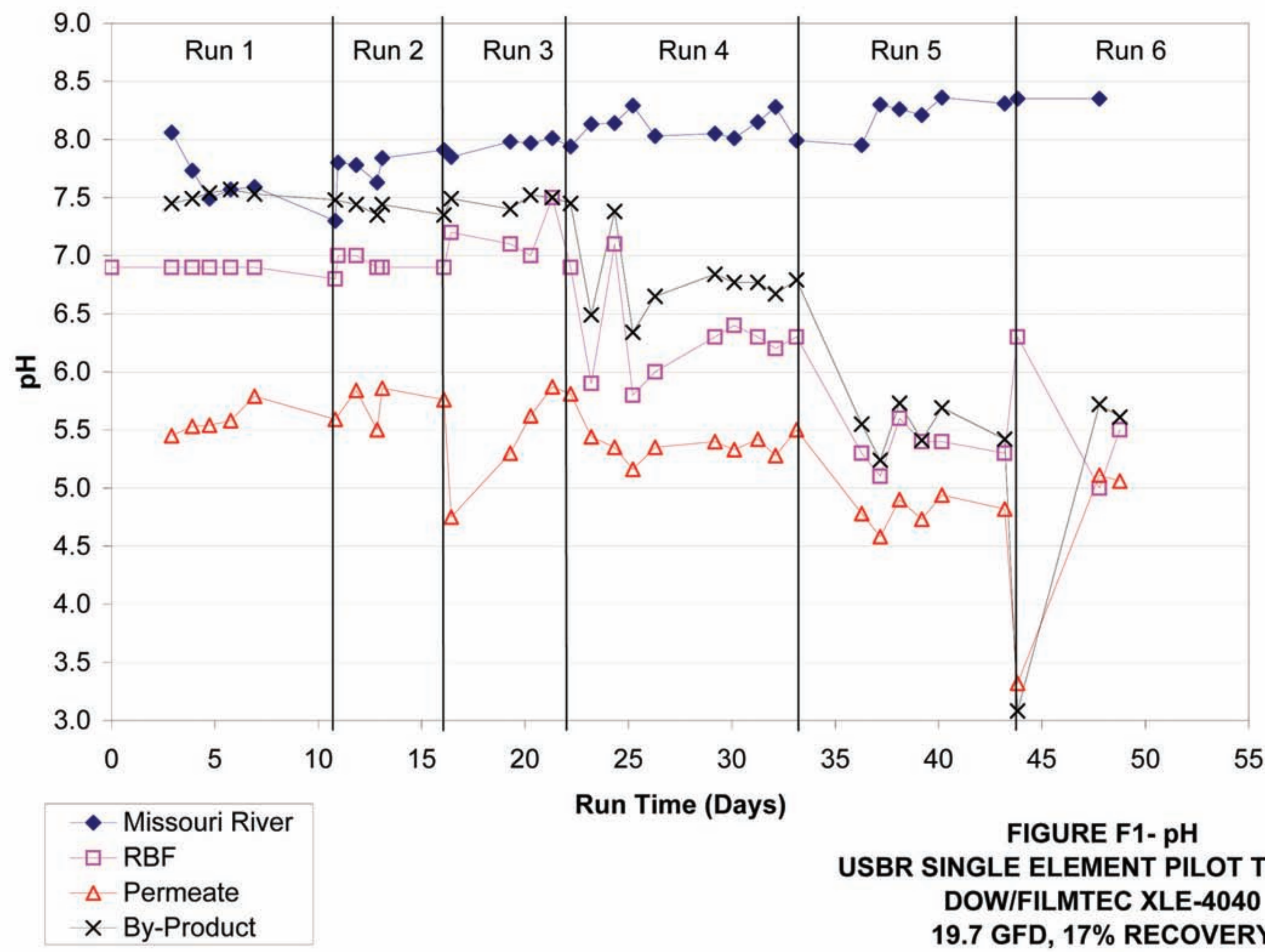


FIGURE F1- pH
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
BPU

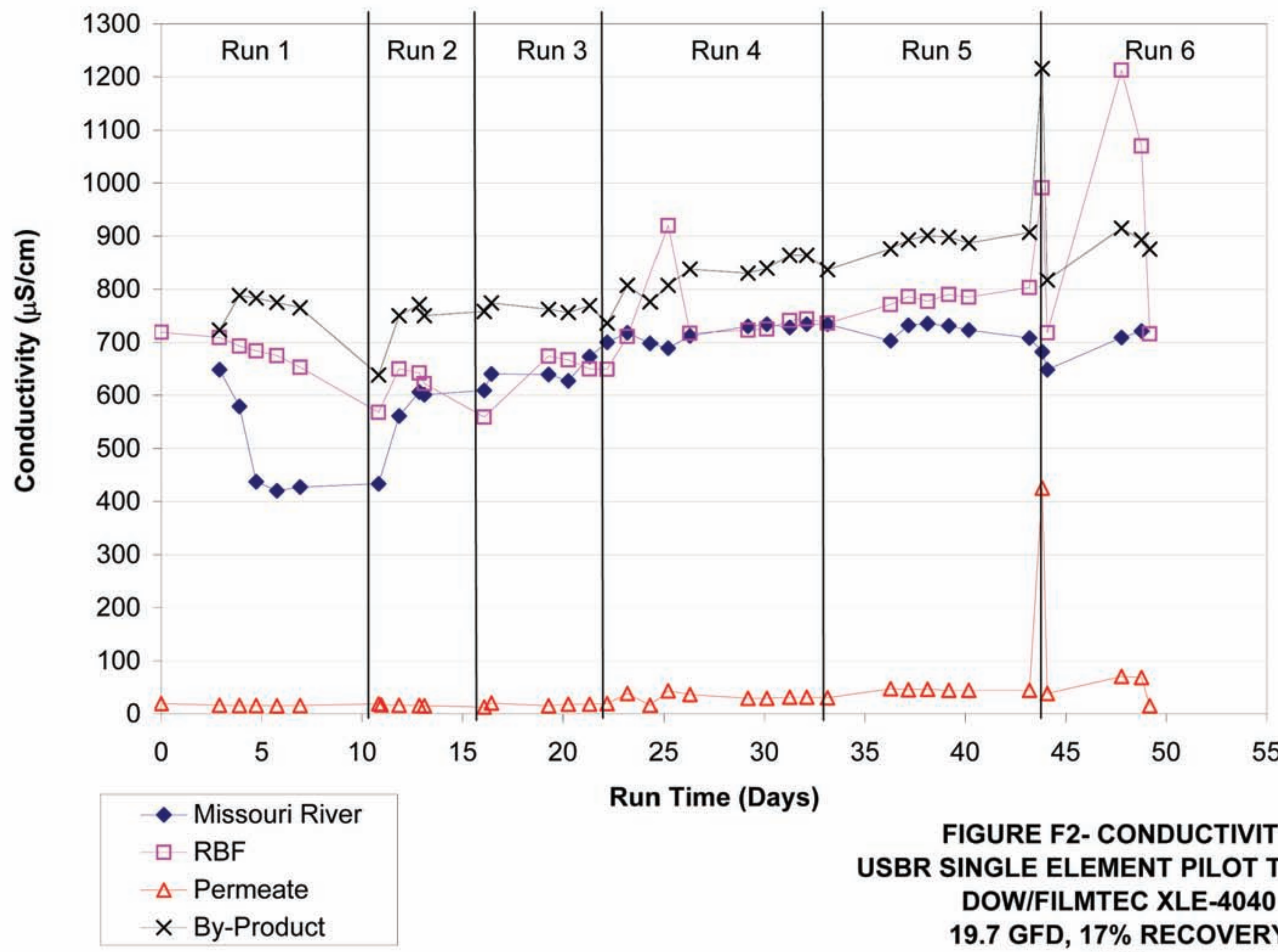


FIGURE F2- CONDUCTIVITY
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
BPU

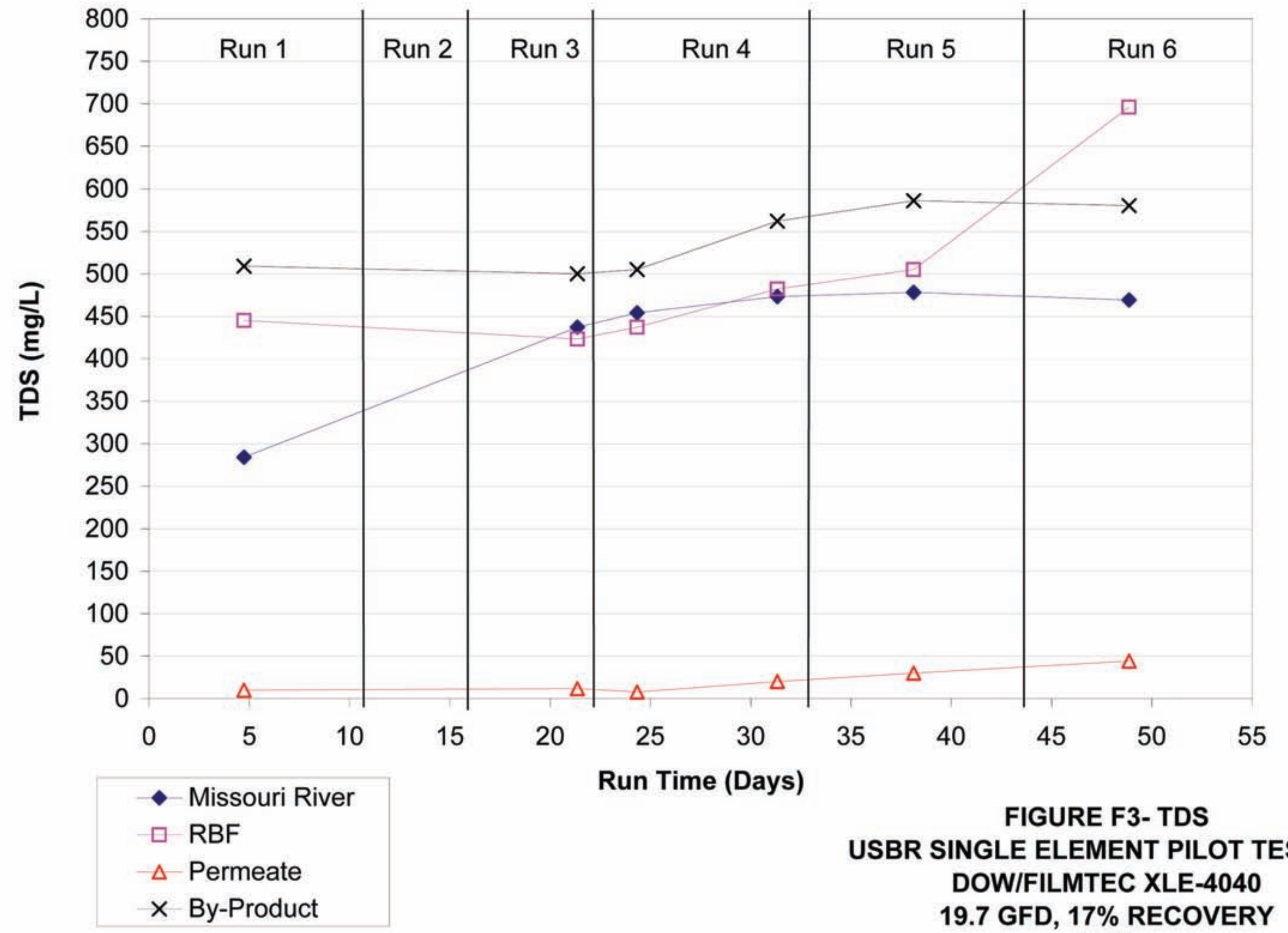


FIGURE F3- TDS
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
BPU

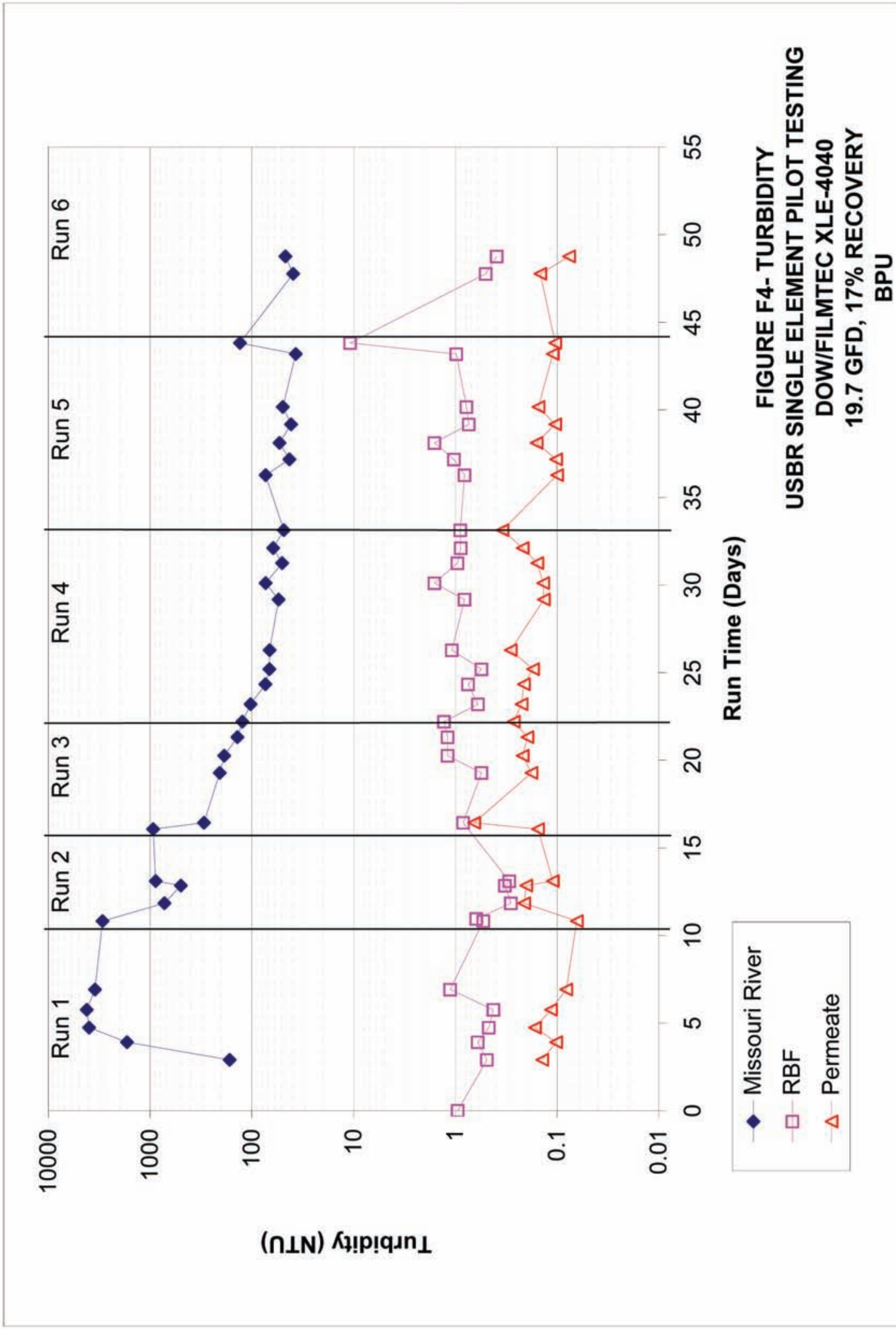


FIGURE F4- TURBIDITY
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
BPU

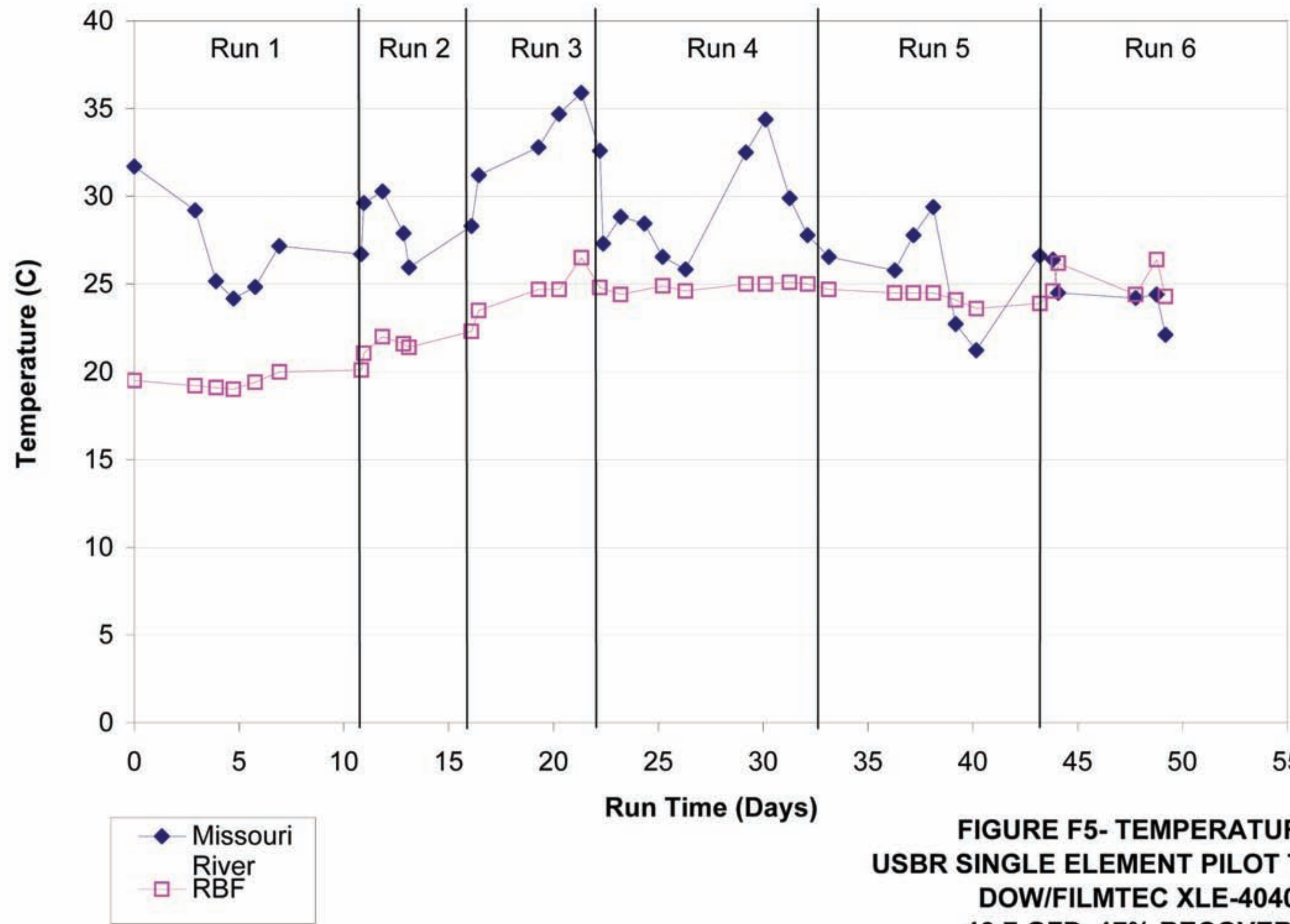


FIGURE F5- TEMPERATURE
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
BPU

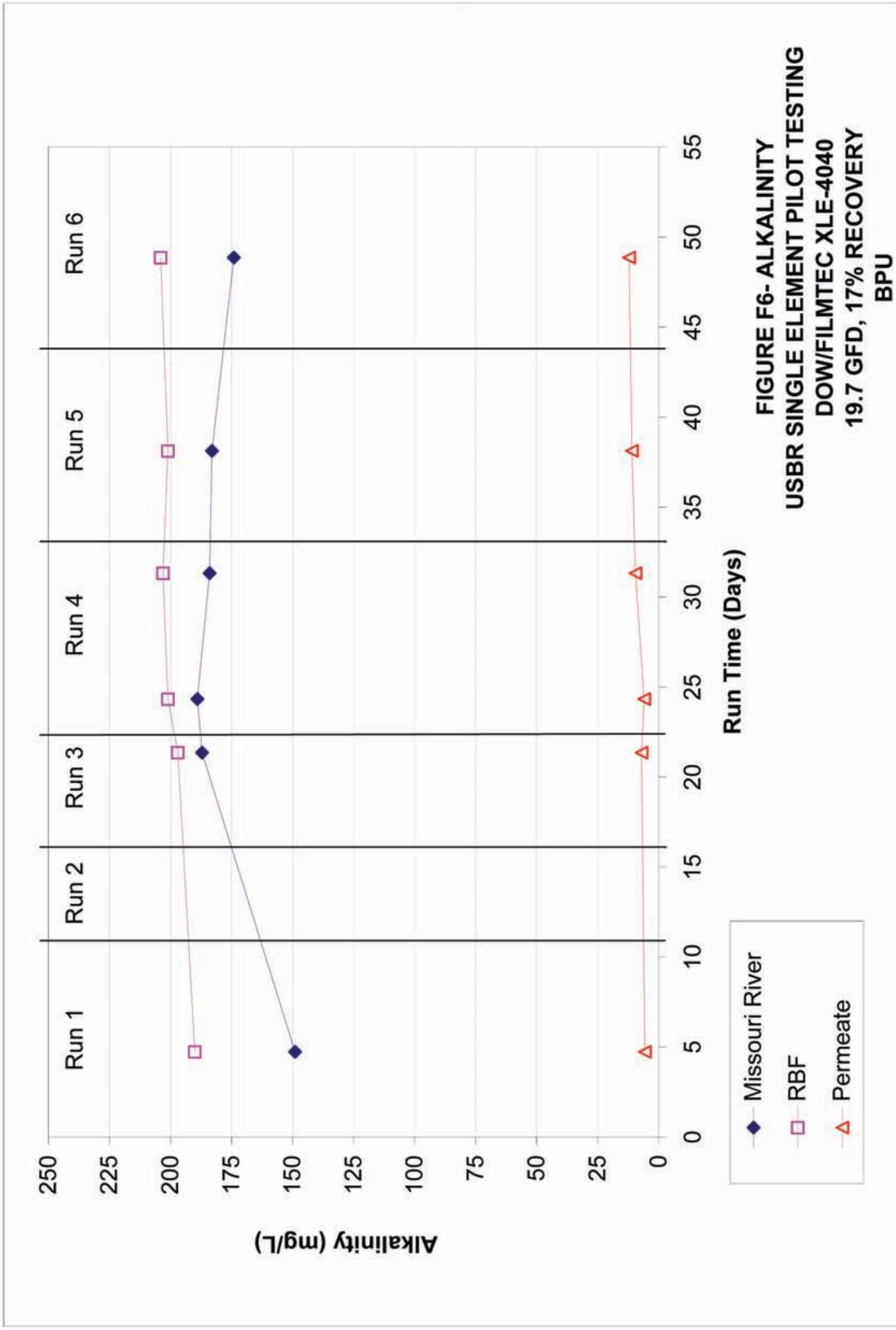


FIGURE F6- ALKALINITY
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
BPU
Alkalinity (mg/L)
Run Time (Days)
Run 1
Run 2
Run 3
Run 4
Run 5
Run 6
Missouri River
RBF
Permeate
0
25
50
75
100
125
150
175
200
225
250
0
5
10
15
20
25
30
35
40
45
50
55

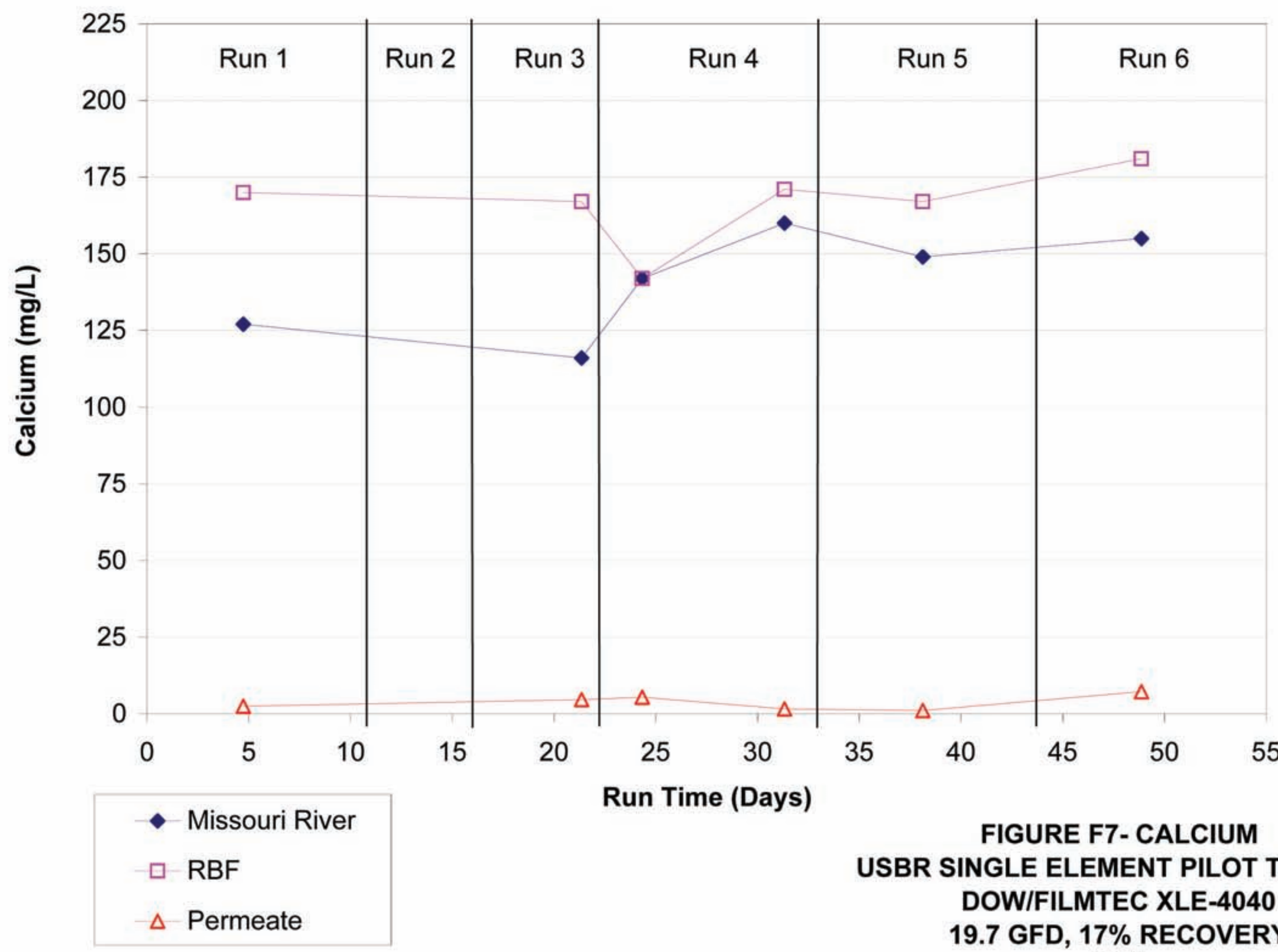


FIGURE F7- CALCIUM
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
BPU

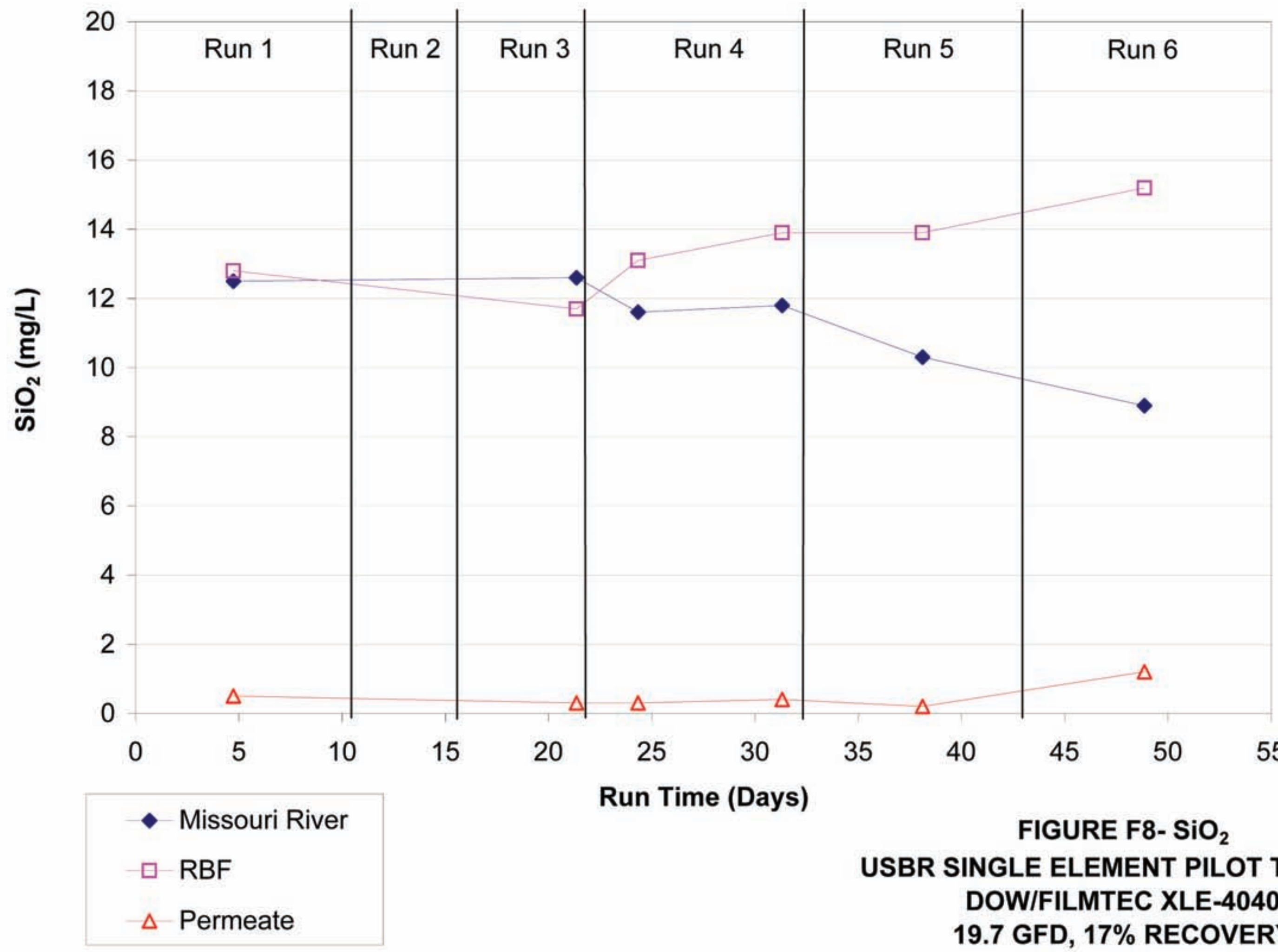


FIGURE F8- SiO_2
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
BPU

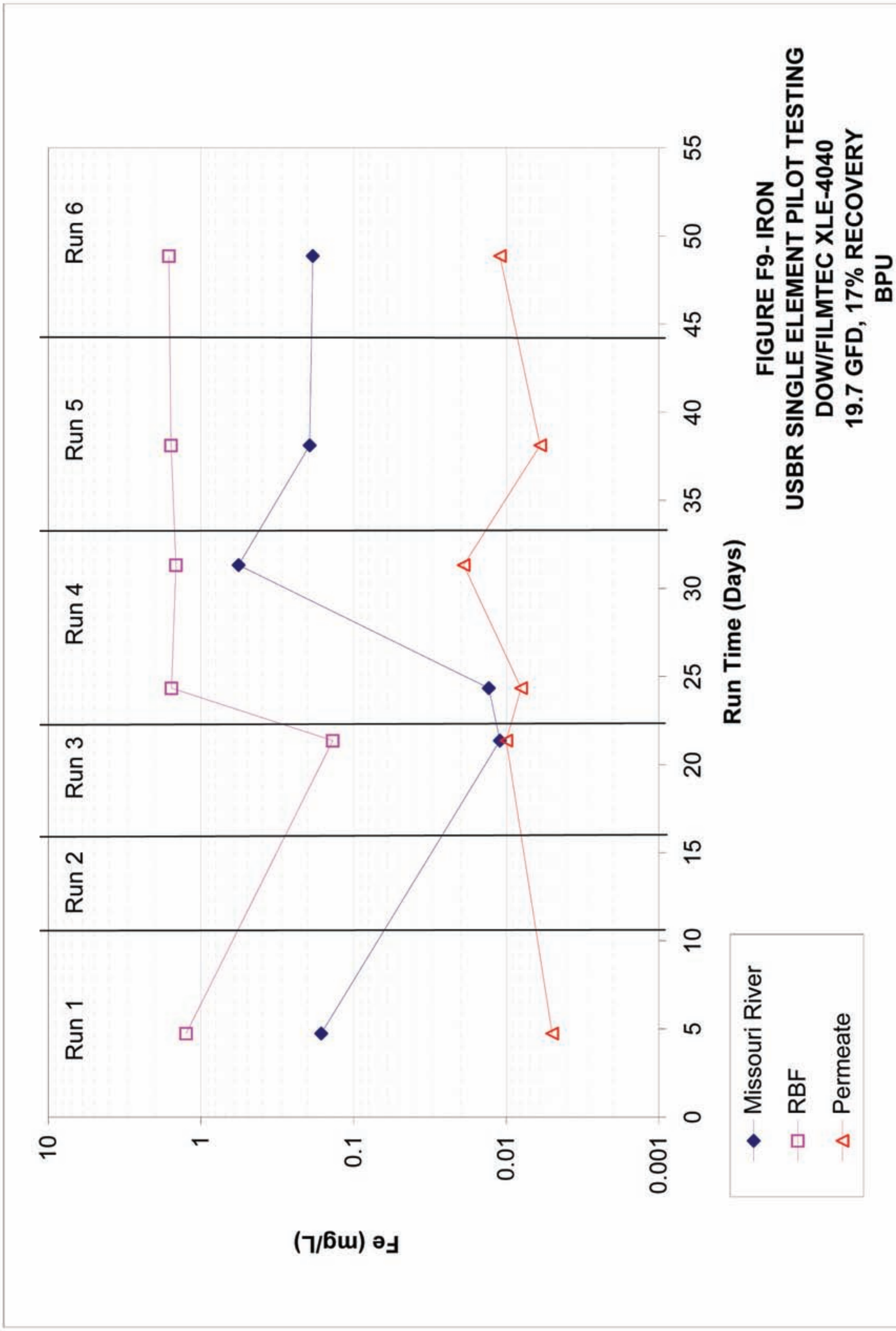


FIGURE F9- IRON
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
BPU

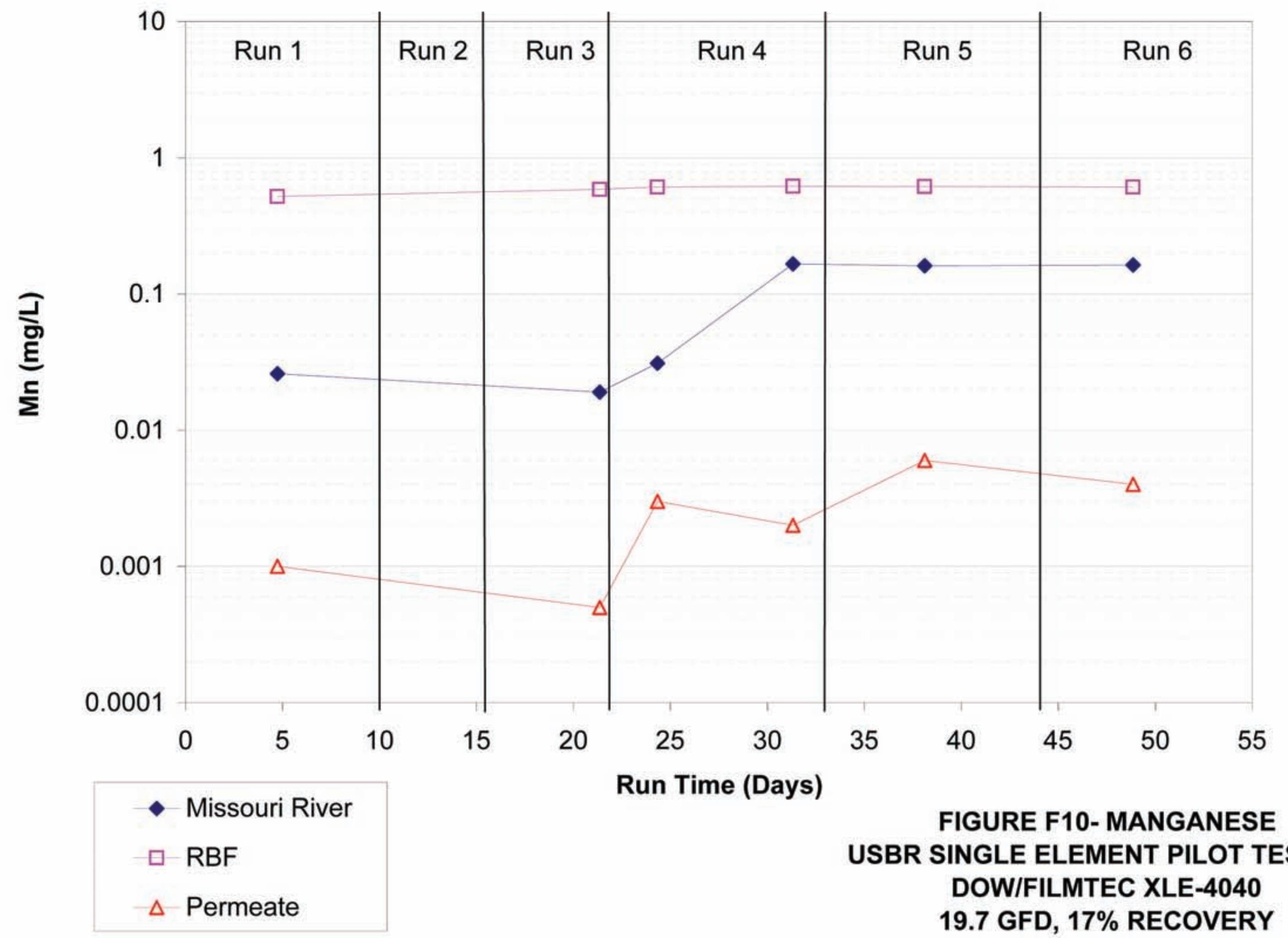


FIGURE F10- MANGANESE
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
BPU

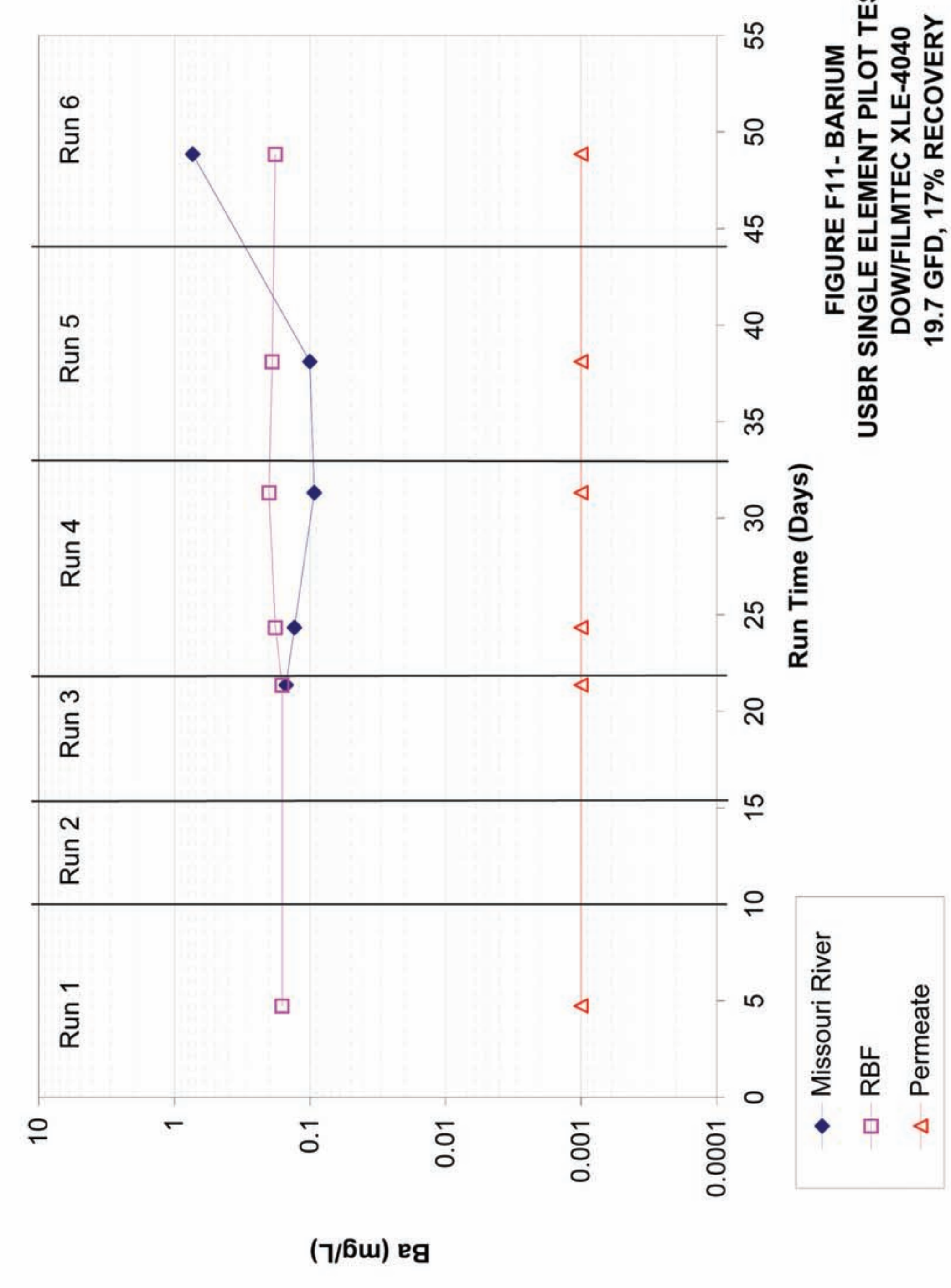


FIGURE F11- BARIUM
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
BPU

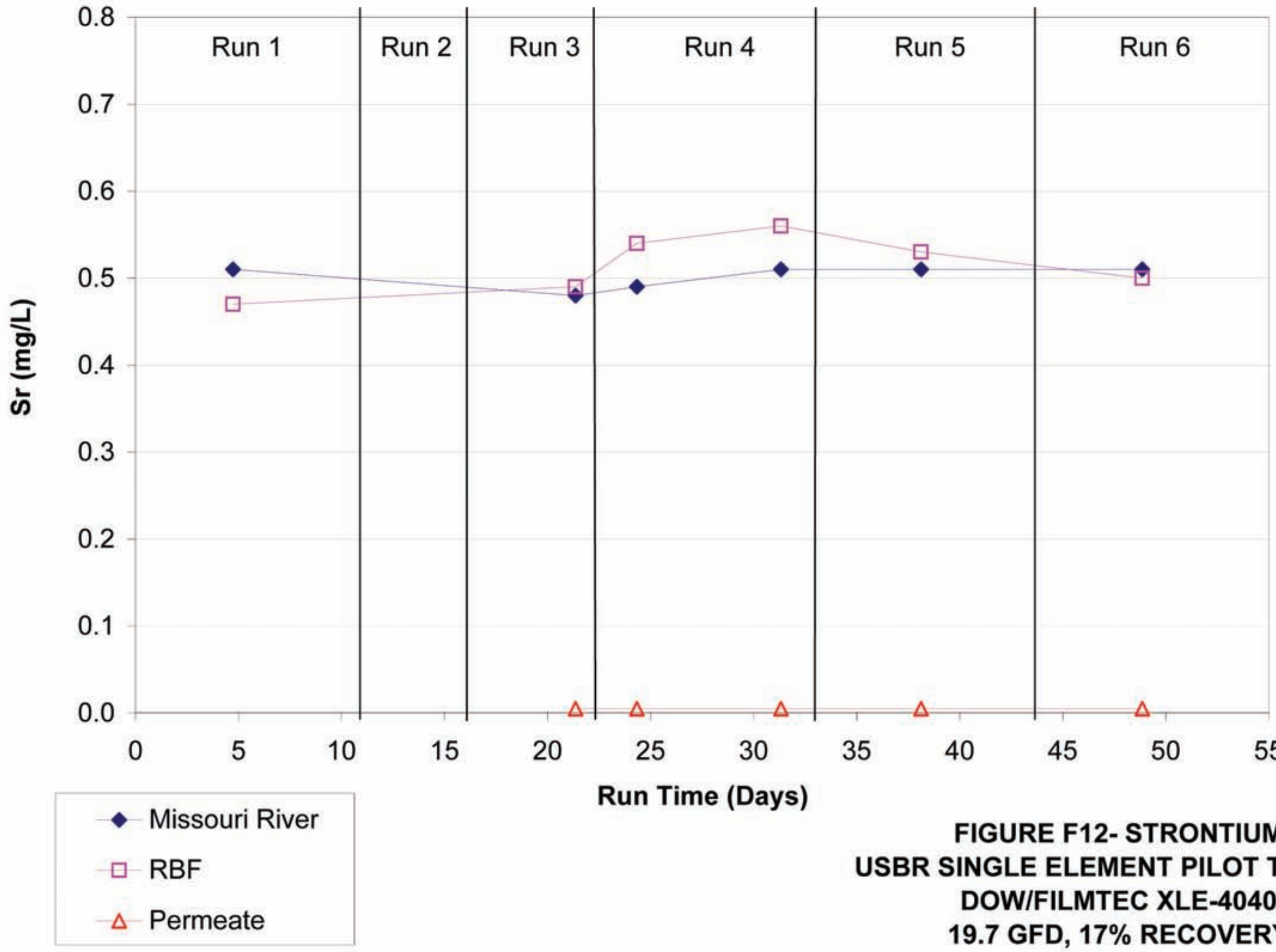


FIGURE F12- STRONTIUM
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
BPU

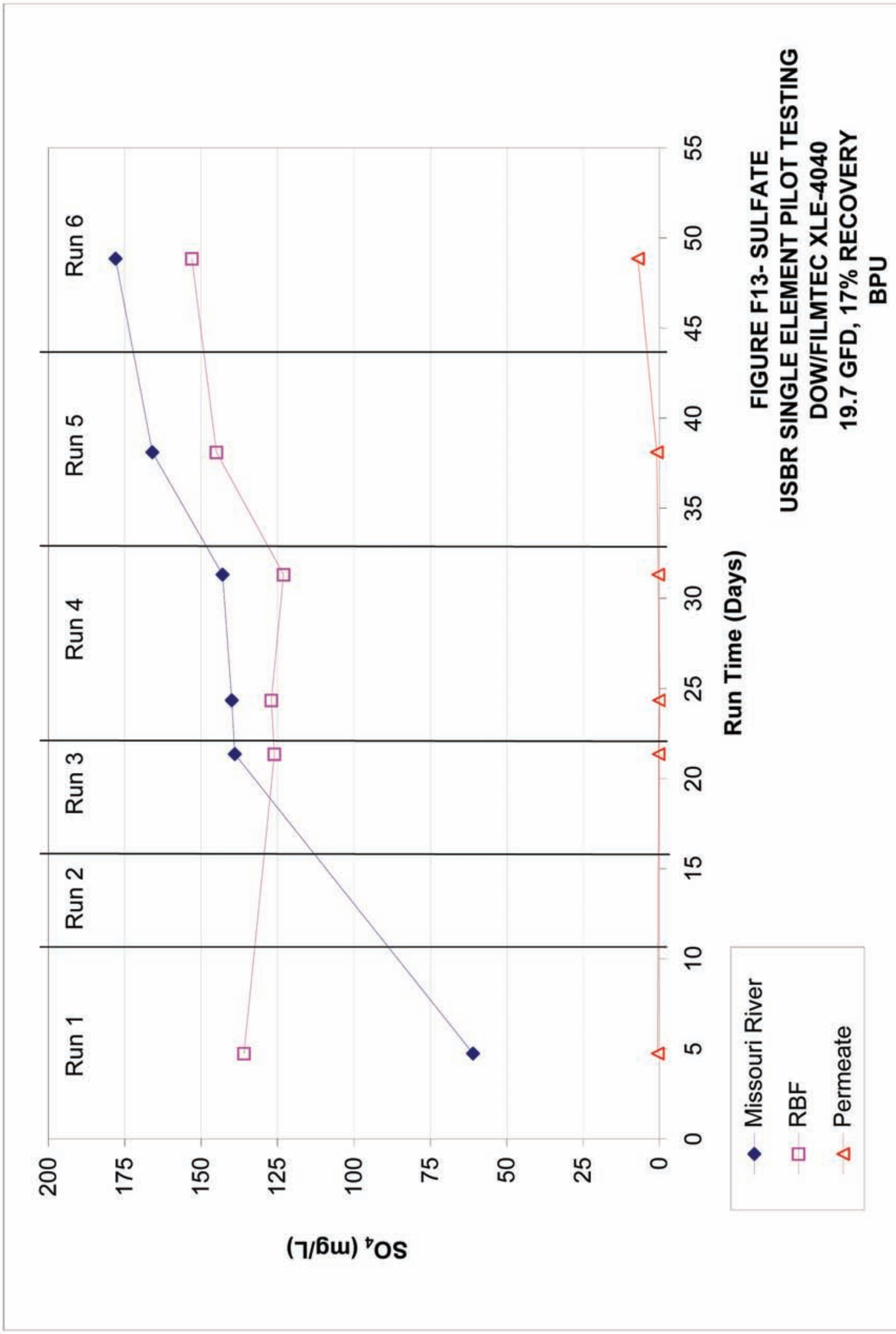


FIGURE F13- SULFATE
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
BPU

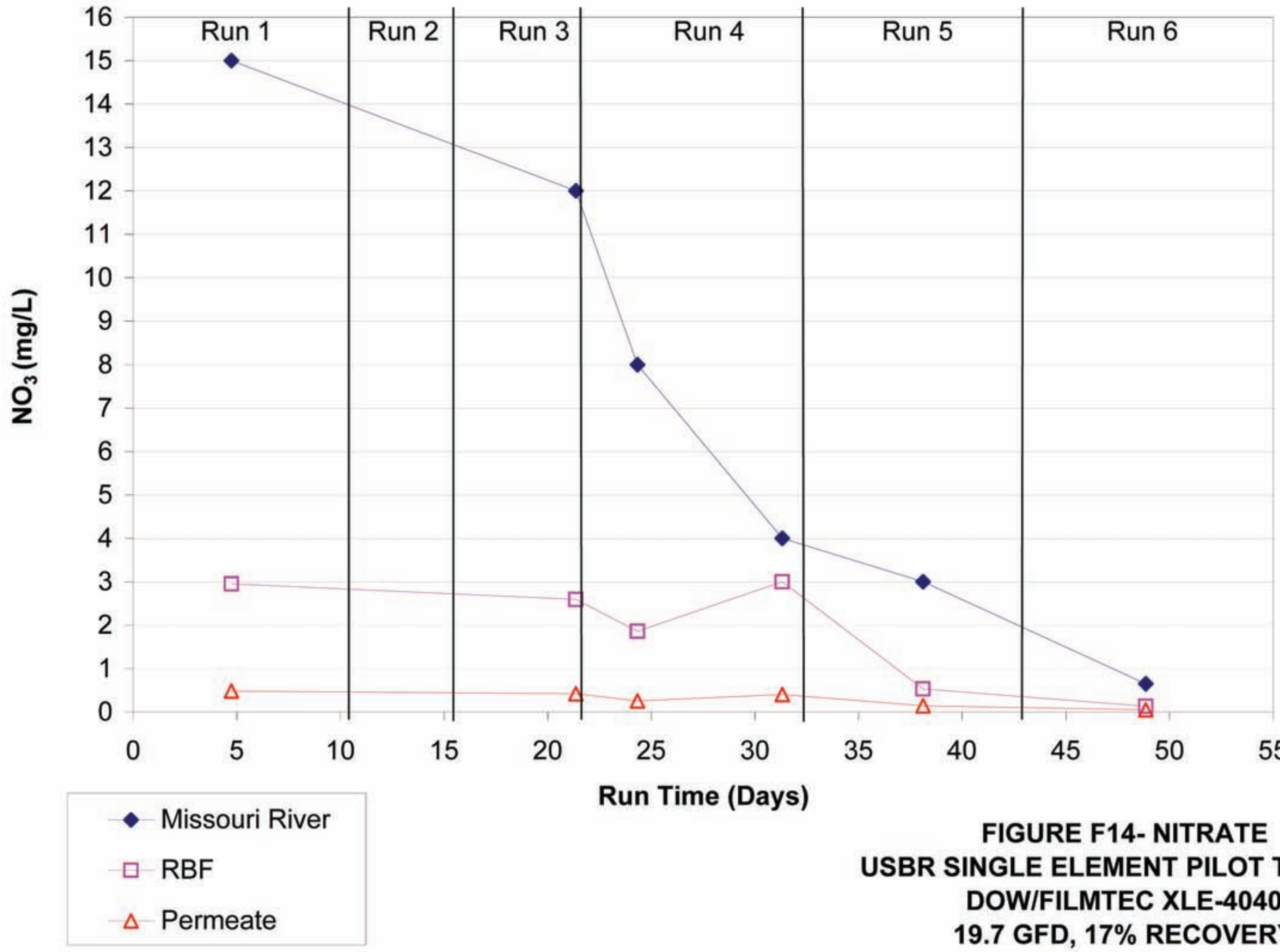


FIGURE F14- NITRATE
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
BPU

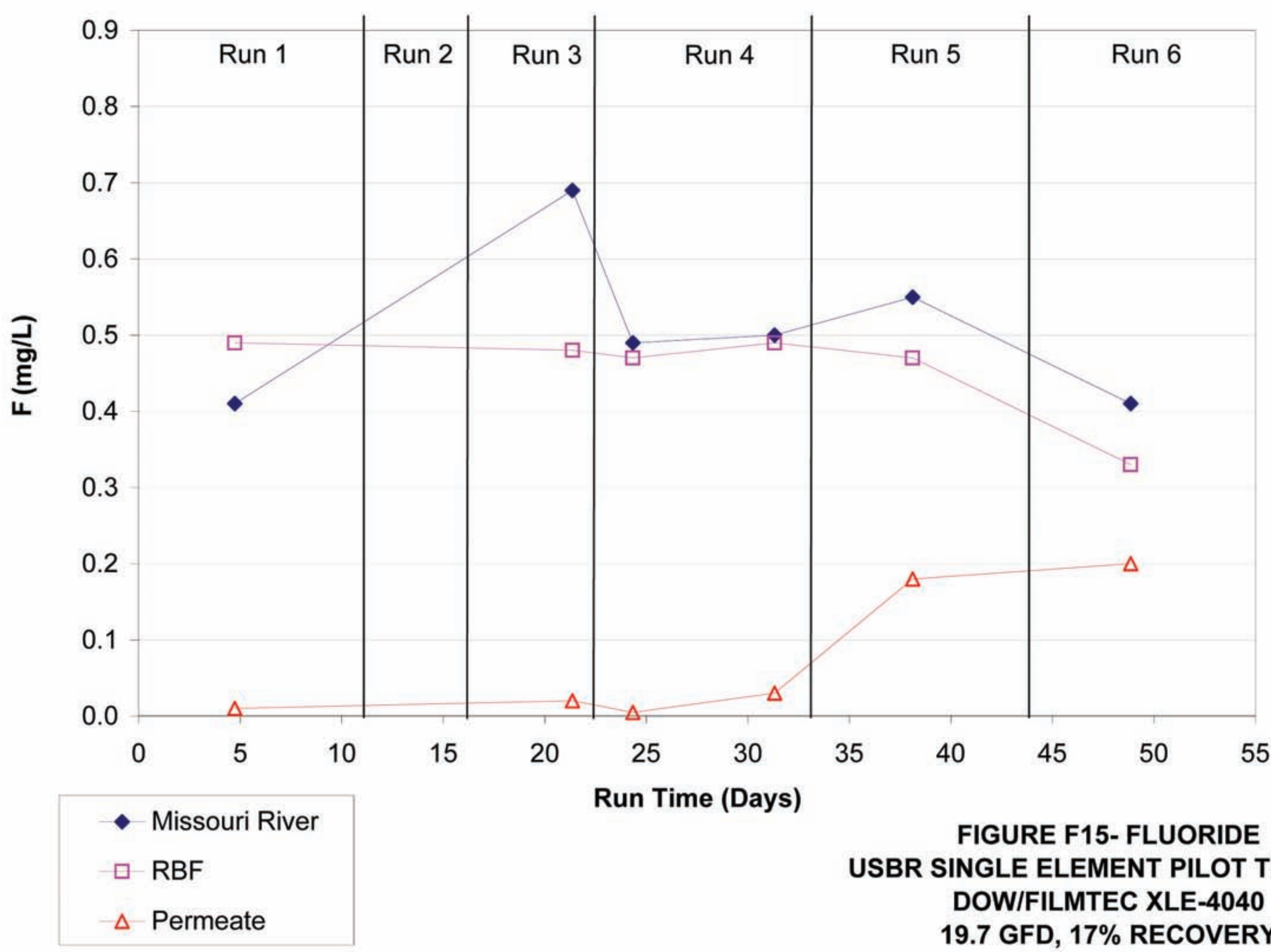


FIGURE F15- FLUORIDE
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
BPU

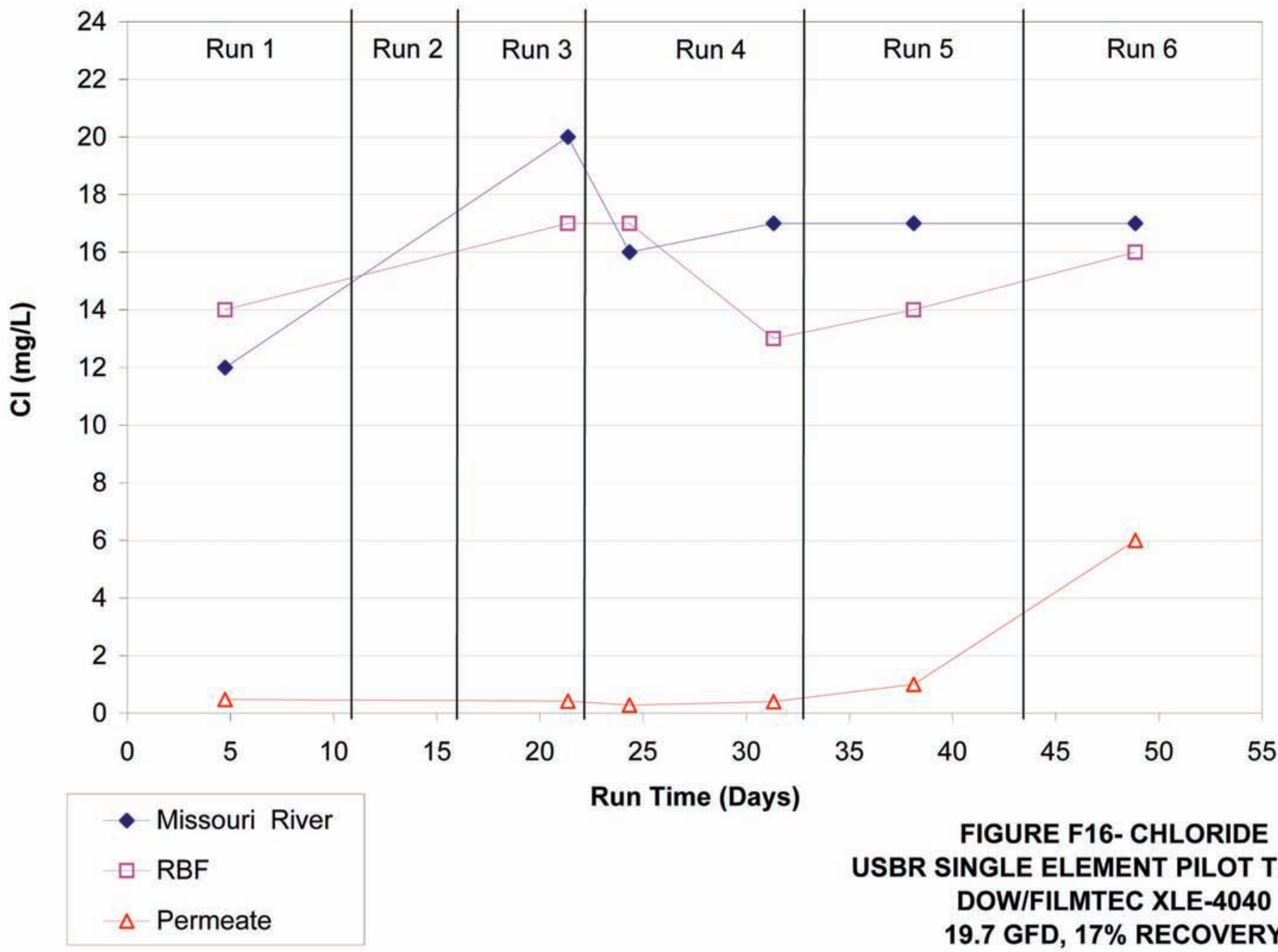


FIGURE F16- CHLORIDE
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
BPU

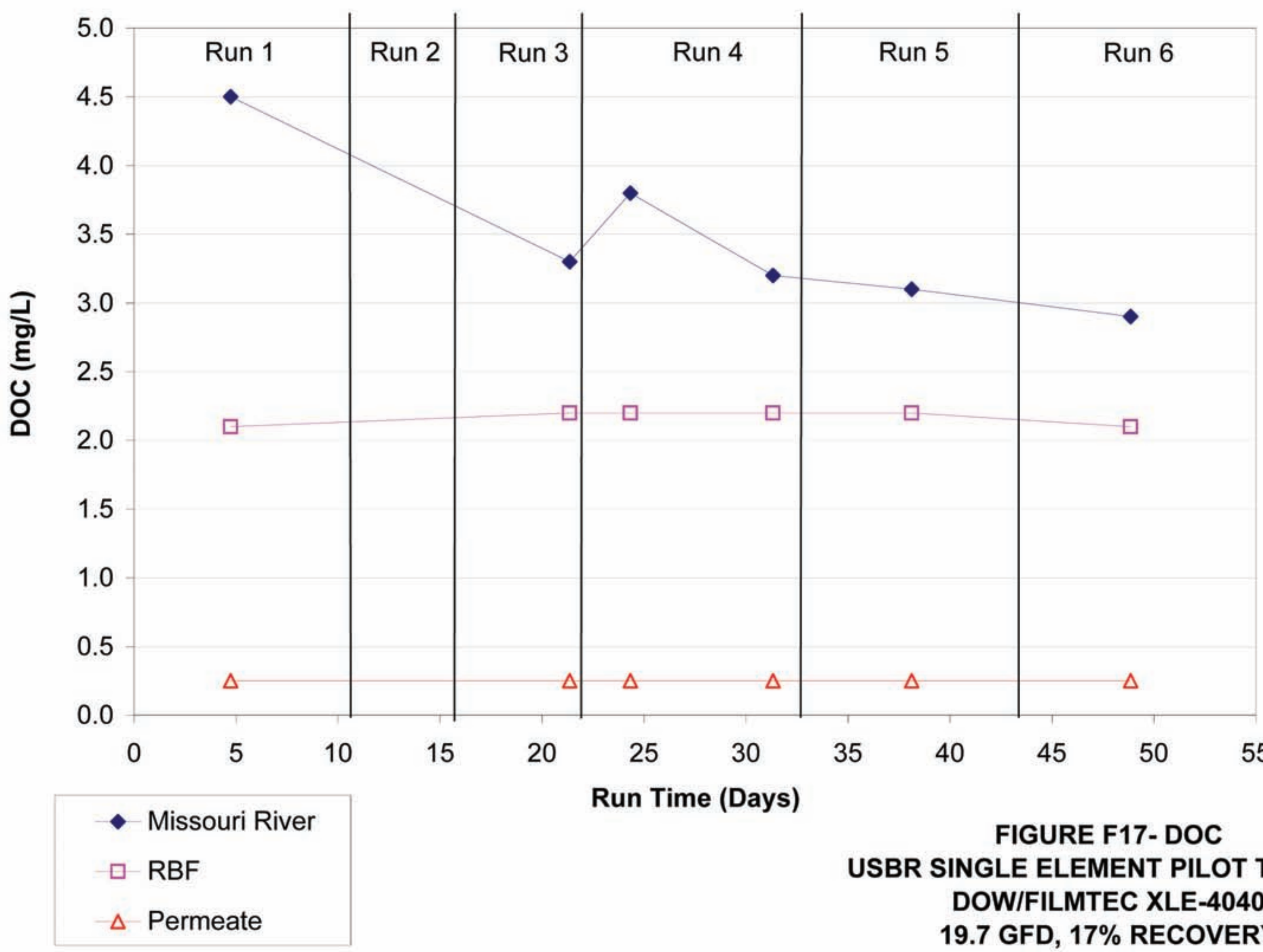


FIGURE F17- DOC
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
BPU

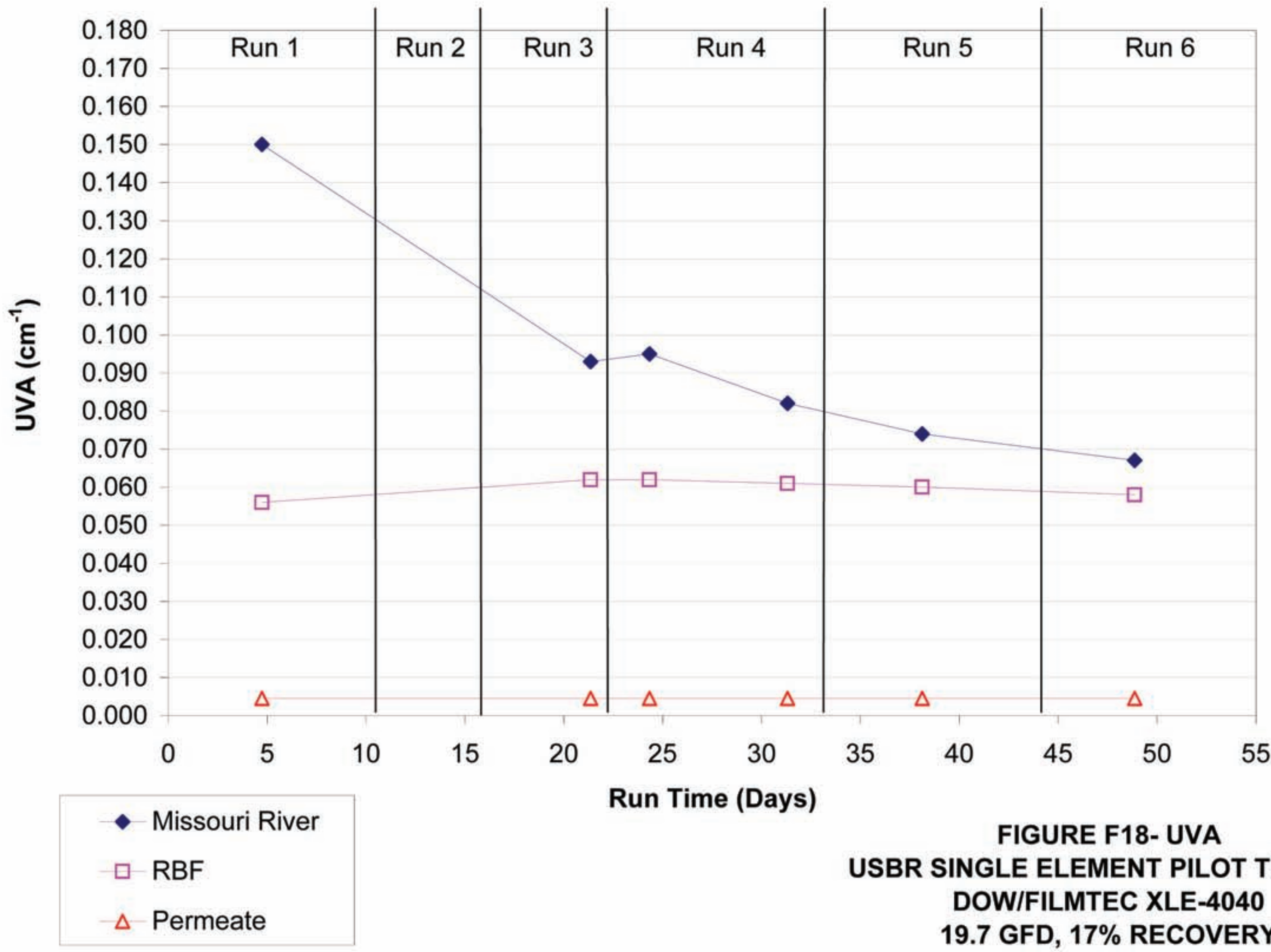


FIGURE F18- UVA
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
BPU

APPENDIX G

Louisville Water Company Data Set

Operator (initials)	Comments	Date MM/DD/YY	Time hh:mm	Operation time hh.hh	Operation time Days	T_R (C)	T_F (C)	P_{CF1} (psi)	P_{CF2} (psi)	P_F (psi)	P_P (psi)	P_B (psi)	Q_P (gpm)	Q_B (gpm)	Q_{REC} (gpm)	pH				Conductivity (uS/cm)				Turbidity (NTU)			
																pH_R	pH_F	pH_P	pH_B	C_R	C_F	C_P	C_B	NTU_R	NTU_F	NTU_P	SDI_F
sma	training	38106.00	9:42 AM	5315.6	0.00		25.3	39	28.5	65	15	63	1.20	4.90	3.50						52	2.000					
sma	official start day 1	38201.00	12:00 PM	5316.8	0.05	28.8	13.7	36	22.0	130.0	15	127	1.19	5.65	4.90	7.91	7.75	6.39	7.49	432	510	14.000	593	32.2	0.54	0.045	
sma	day2	08-03-04	11:10 AM	5338.5	0.95	29.1	14.0	41	29.0	140.0	15	127	1.19	5.61	4.93	7.79	7.54	5.56	7.60	414	499	3.700	605	45	0.2	0.066	
sma	day3	08-04-04	9:50 AM	5361.0	1.89	29.0	14.0	41	26.0	140.0	15	123	1.19	5.62	4.90	7.76	7.70	5.93	7.68	381	502	4.100	599	71	0.166	0.055	
sma	day4	08-05-04	1:20 PM	5387.7	3.00	28.8	14.0	41	29.0	124.0	15	120	1.20	5.63	4.90	7.75	7.62	5.80	7.63		496	4.300	597	26	0.13	0.085	
sma	day5	08-06-04	1:30 PM	5407.7	3.84	28.7	15.0	41	30.0	122.0	15	119	1.19	5.62	4.90	7.77	7.72	5.39	7.76		499	3.900	581	17	0.203	0.088	
sma	day6	08-09-04	10:50 AM	5414.5	4.12	28.6	18.4	41	29.5	117.0	15	113	1.19	5.65	4.90	7.80	7.62	5.25	7.62	444	498	3.900	605	13.1	0.224	0.116	
sma	day7	08-10-04	11:05 AM	5438.8	5.13	28.6	19.1	41	28.5	116.0	15	112	1.19	5.65	4.90	7.90	7.58	5.52	7.36		496	4.000	583	10	0.136	0.06	
sma	day8	08-11-04	9:30 AM	5462.2	6.11	28.6	18.4	41	29.5	115.0	15	111	1.19	5.65	4.90	7.84	7.29	5.28	7.18		506	5.100	597	11	0.078	0.044	
sma	day9	08-12-04	11:50 AM	5471.4	6.49	28.3	18.9	41	28.5	113.0	15	110	1.19	5.65	4.90	7.95	7.33	5.62	7.21	409	503	4.200	584	8.8	0.164	0.095	
sma	day10	08-13-04	10:00 AM	5493.6	7.42	27.8	18.5	41	28.5	112.0	15	109	1.19	5.65	4.90	7.97	7.63	5.29	7.44	423	505	37.900	596	8.5	0.105	0.066	
sma	day11	08-16-04	1:40 PM	5545.5	9.58	27.2	21.1	41	29.0	110.0	15	107	1.19	5.68	4.91	7.87	7.46	5.93	7.30	370	432	3.380	523	8.9	0.098	0.054	
sma	day12	08-17-04	9:19 AM	5565.1	10.40	27.7	19.2	41	29.5	109.0	15	105	1.20	5.58	4.89	7.93	7.40	5.64	7.46	384	425	3.250	519	7.3	0.145	0.059	
sma	day13	08-18-04	10:40 AM	5590.3	11.45	27.7	21.4	41	28.5	109.0	15	106	1.20	5.60	4.90	7.95	7.70	5.49	7.55	390	506.00	5.400	603	8.8	0.074	0.055	1.27
sma	day14	08-19-04	10:10 AM	5613.8	12.43		20.9	41	27.5	109.0	15	105	1.19	5.62	4.95	7.96	7.53	5.52	7.42	378	440.00	5.350	553	10.4	0.117	0.065	1.96
sma	day15	08-20-04	10:38 AM	5638.1	13.44		21.7	41	28.5	109.0	15	105	1.21	5.63	4.88		7.27	5.44	7.27		449.00	3.950	538		0.106	0.068	1.61
sma	day16	08-23-04	12:16 PM	5693.0	15.73		20.9	41	25.0	108.0	15.0	104	1.20	5.62	4.95	7.66	7.61	5.66	7.53	448	447.00	3.890	539		0.151	0.074	1.50
sma	day17	08-24-04	10:20 AM	5708.6	16.38	28.4	21.9	41	29.0	107.0	15	103	1.20	5.60	4.93	7.87	7.26	5.45	7.18	420	431.00	3.540	524	20	0.175	0.11	1.55
sma	day18	08-25-04	9:43 AM	5732.0	17.35	28.8	21.4	41	29.0	108.0	15	105	1.21	5.65	4.90	7.84	7.44	5.55	7.41	426	444.00	3.590	533	28	0.132	0.096	1.57
sma	day19	08-26-04	10:38 AM	5756.4	18.37	28.5	21.0	41	27.5	109.0	15	105	1.20	5.62	4.90	7.79	7.64	5.46	7.35	404	455.00	4.830	544	9.6	0.113	0.064	0.64
sma	day20	08-27-04	11:00 AM	5758.2	18.44	28.4	21.5	41	23.0	107.0	15	104	1.19	5.63	4.89	7.78	7.55	5.60	7.55	404	469.00	4.110	563	6.87	0.112	0.08	3.12
sma	day21	08-30-04	11:40 AM	5815.0	20.81	28.4	22.4	41	27.5	106.0	15	102	1.19	5.59	4.84	7.72	7.54	5.65	7.48	397	451.00	3.840	541	7.97	0.09	0.05	2.13
sma	day22	08-31-04	9:00 AM	5830.6	21.46	28.6	21.0	41	27.5	106.0	15	102	1.19	5.63	4.90	7.83	7.63	5.55	7.52	385	445.00	3.690	534	6.7	0.081	0.09	0.93
sma	day23	09-01-04	10:22 AM	5849.7	22.25	28.6	21.2	41	25.5	106.0	15	104	1.20	5.65	4.96	7.81	7.63	5.78	7.54	374	452.00	3.900	542	5.3	0.118	0.09	1.26
sma	day24	09-02-04	10:24 AM	5873.7	23.25		21.3	41	23.0	107.0	15	103	1.19	5.63	4.93	7.81	7.62	5.74	7.54	380	452.00	3.910	543	5.4	0.108	0.088	1.89
sma	day25	09-03-04	9:34 AM	5882.9	23.64	28.4	22.2	41	28.0	105.0	15	102	1.19	5.60	4.87	7.82	7.65	5.51	7.50		454.00	3.840	545				1.63
sma	day26	09-06-04	1:24 PM	5958.7	26.80	28.4	24.0	41	26.0	107.0	15	103	1.20	5.66	4.82	7.74	7.54	5.90	7.52	410	466.00	3.820	555	7.3	0.13	0.099	1.16
sma	day27	09-07-04	9:43 AM	5979.0	27.64	29.0	21.5	41	27.5	105.0	15	101	1.20	5.61	4.85	7.90	7.61	5.91	7.45	405	454.00	3.510	545	5.39	0.126	0.084	2.20
sma	day28	09-08-04	10:04 AM	6003.3	28.65	29.1	21.2	41	26.0	106.0	15	101	1.19	5.60	4.92	7.88	7.57	5.83	7.38	393	444.00	3.590	537	4.9	0.117	0.09	2.02
sma	day29	09-09-04	10:28 AM	6027.7	29.67	28.4	22.1	41	22.0	106.0	15	101	1.19	5.60	4.95	7.90	7.57	5.72	7.50	394	452.00	3.640	534	4.7	0.08	0.055	2.17
sma	day 30	09-10-04	8:50 AM	6050.0	30.60	28.1	21.5	41	29.0	103.0	15	100	1.19	5.55	4.94	7.80	7.16	5.63	7.06		440.00	3.740	530		0.107	0.111	2.05
sma	day31	09-13-04	11:01 AM	6124.1	33.69	28.1	23.9	41	27.0	104.0	15	100	1.19	5.66	4.92	7.52	7.55	5.79	7.38	336	454.00	3.760	546	262	0.133	0.058	2.12
sma	day32	09-14-04	10:00 AM	6147.2	34.65	27.0	22.6	41	27.0	105.0	15	100	1.20	5.58	4.89	7.56	7.47	5.54	7.51	297	458.00	3.650	542	269	0.091	0.138	1.92
sma	day33	09-15-04	9:45 AM	6170.7	35.63	25.9	22.5	41	26.0	104.0	15	100	1.19	5.61	4.90	7.65	7.60	5.83	7.51		457.00	4.110	548	222	0.125	0.053	2.49
sma	day34	09-16-04	10:13 AM	6195.3	36.65	25.4	22.8	41	23.0	105.0	15	99	1.20	5.63	4.98	7.66	7.57	5.90	7.47	334	461.00	3.680	552	77	0.105	0.095	2.23
sma	day35	09-17-04	7:30 AM	6216.6	37.54	25.6	22.3	41	28.0	104.0	15.0	100	1.20	5.64	4.74	7.63	7.49	6.15	7.51		449.00	4.060	543	47	0.109	0.108	1.97
sma	day36	09-20-04	12:11 PM	6291.2	40.65	24.3	22.3	41	22.0	103.0	15.0	98	1.19	5.55	4.88	7.75	7.30	5.74	7.36	255	435.00	4.490	526	146	0.085	0.054	2.49
sma	day37	09-21-04	1:30pm	6316.4	41.70	23.6	22.5	41	27.0	103.0	15.0	98	1.20	5.61	4.83	7.63	7.64	5.87	7.50	224	437.00	3.690	535	313	0.1	0.055	2.60
sma	day38	09-22-04	10:41 AM	6337.7	42.59	23.1	22.3	42	29.0	103.0	15.0	97	1.18	5.58	4.85	7.64	7.47	6.60	7.55		434.00	4.540	535	302	0.105	0.074	1.84
sma	day39	09-23-04	1:53pm	6357.1	43.40	22.7	22.7	42	24.0	104.0	15.0	98	1.19	5.69	4.80	7.76	7.52	5.89	7.51		432.00	3.920	527	622	0.113	0.082	2.41

Operator (initials)	Comments	Date MM/DD/YY	Time hh:mm	Operation time hh.hh	Operation time Days	T_R (C)	T_F (C)	P_{CF1} (psi)	P_{CF2} (psi)	P_F (psi)	P_P (psi)	P_B (psi)	Q_P (gpm)	Q_B (gpm)	Q_{REC} (gpm)	pH				Conductivity (uS/cm)				Turbidity (NTU)			
																pH_R	pH_F	pH_P	pH_B	C_R	C_F	C_P	C_B	NTU_R	NTU_F	NTU_P	SDI_F
sma	day40	09-24-04	9:30 AM	6364.4	43.70		22.0	42	29.0	103.0	15.0	98	1.20	5.66	4.87		7.61	5.77	7.48		417.00	3.630	506		0.157	0.061	2.93
sma	day41	09-27-04	11:39 AM	6438.4	46.78	22.1	22.7	44	30.0	105.0	15.0	100	1.20	5.71	4.84	7.46	7.54	5.66	7.52	224	400.00	3.480	480	69	0.142	0.079	2.89
sma	day42	09-28-04	11:07 AM	6461.9	47.76		21.9	42	27.0	107.0	15.0	100	1.20	5.76	5.00	7.53	7.61	5.72	7.52	251	396.00	3.530	479	48	0.15	0.139	2.83
sma	day43	09-29-04	11:37 AM	6486.4	48.78	22.2	21.0	42	27.0	107.0	15.0	101	1.19	5.71	4.92	7.65	7.51	5.65	7.47	252	383.00	3.290	465	40	0.126	0.07	2.11
sma	day44	09-30-04	11:35 AM	6510.4	49.78		21.0	42	24.0	107.0	15.0	101	1.19	5.70	4.93	7.67	7.11	6.50	7.43	255	382.00	3.400	460	30	0.135	0.106	2.43
sma	day45	10-01-04	9:30 AM	6532.3	50.70		20.3	42	30.0	108.0	15.0	102	1.20	5.69	4.92		7.53	6.11	7.45		377.00	3.920	456		0.097	0.109	2.49
sma	day46	10-04-04	12:24 PM	6607.1	53.81		20.9	43	24.0	111.0	15.0	103	1.19	5.71	5.22	7.55	7.02	6.08	6.86	241	378.00	3.300	454		0.114	0.079	2.16
sma	day47	10-05-04	10:30 AM	6629.2	54.73	21.4	20.3	42	22.0	110.0	15.0	103	1.20	5.66	5.00	7.77	7.54	5.77	7.35	271	371.00	3.180	447	16.6	0.161	0.072	2.00
sma	day48	10-06-04	9:30 AM	6652.3	55.70	21.3	21.7	43	30.0	110.0	15.0	104	1.18	5.73	4.97	7.76	7.56	5.63	7.50	280	368.00	2.990	443	12.3	0.098	0.092	2.35
sma	day49	10-07-04	10:15 AM	6676.8	56.72	21.4	20.0	43	31.0	110.0	15.0	103	1.19	5.67	4.94	7.77	7.51	6.17	7.45	297	365.00	4.000	438	11.4	0.095	0.085	2.56
sma	day50	10-08-04	9:00 AM	6699.6	57.67		20.7	42	28.0	111.0	15.0	103	1.19	5.65	5.00		7.44	5.95	7.35		375.00	3.440	452		0.097	0.087	2.56
sma	day51	10-11-04	10:17 AM	6772.9	60.72		20.4	43	31.0	111.0	15.0	103	1.19	5.66	4.93	7.75	7.41	6.20	7.36	238	363.00	2.840	434		0.117	0.074	2.04
sma	day52	10-12-04	3:17pm	6801.7	61.92	21.2	20.3	43	30.0	110.0	15.0	103	1.20	5.67	5.00	7.83	7.31	5.78	7.23		366.00	3.090	444	9.71	0.127	0.05	2.60
sma	day53	10-13-04	9:37 AM	6804.7	62.05	21.0	19.9	43	29.0	112.0	15.0	104	1.19	5.66	4.99	7.86	7.47	5.76	7.43	274	371.00	3.560	446	7.91	0.173	0.061	2.70
sma	day54	10-14-04	10:00 AM	6829.1	63.06	20.9	20.0	43	28.0	112.0	15.0	105	1.20	5.69	4.90	7.86	7.09	5.55	6.82	269	368.00	3.180	441	7.95	0.095	0.085	2.42
sma	day55	10-15-04	10:51 AM	6853.9	64.10	20.9	20.3	43	25.0	111.0	15.0	103	1.19	5.67	4.93	7.89	7.55	5.90	7.48	273	369.00	3.690	445	8.74	0.086	0.102	2.06
sma	day56	10-18-04	10:22 AM	6903.4	66.16	18.9	19.9	43	31.0	112.0	15.0	105	1.18	5.68	4.87	7.1	7.02	5.94	6.89	232	367.00	3.370	442	10.2	0.095	0.055	2.35
sma	day57	10-19-04	9:40 AM	6926.6	67.13	18.9	20.3	43	29.0	113.0	15.0	106	1.20	5.71	4.91	7.81	7.48	5.92	7.39	282	375.00	3.210	449	26.1	0.061	0.082	2.39
sma	day58	10-20-04	9:30 AM	6950.4	68.12	19.0	20.2	42	29.0	113.0	15.0	106	1.19	5.68	5.00	7.82	7.29	5.9	7.24	294	370.00	3.420	445	65.3	0.071	0.094	2.35
sma	day59	10-21-04	10:30 AM	6974.6	69.13	18.6	20.5	43	29.0	113.0	15.0	106	1.19	5.71	4.96	7.8	7.66	5.83	lost	300	359.00	2.810	522	147	0.061	0.037	2.06
sma	day60	10-22-04	10:14 AM	6997.9	70.10	18.2	19.9	43	28.0	113.0	15.0	106	1.19	5.75	4.99	7.94	7.02	5.62	6.93	313	368.00	3.060	440	143	0.235	0.06	1.94
sma		10-25-04	10:14 AM	7069.0	73.06		19.2	43	31.0	116.0	15.0	109	1.19	5.74	4.85	--	--	--	--	--	466.00	7.000	552	--	--	--	1.83
		38286.00	10:14 AM	7093.1	74.06		19.0	43	29.0	116.0	15.0	108	1.19	5.68	4.98	--	--	--	--	--	473.00	7.000	555	--	--	--	--
					Count	44	56	56	56	56	56	56	56	56	56	51	55	55	55	40	55	56	55	46	54	54	43
					Median	28.1	21.2	41.0	28.0	108.0	15.0	103.0	1.2	5.6	4.9	7.79	7.54	5.74	7.47	379	445	3.8	537.0	11.9	0.1	0.1	2.1
					Low	20.9	13.7	36.0	22.0	65.0	15.0	63.0	1.2	4.9	3.5	7.46	7.02	5.25	6.82	224	363	2.0	434.0	4.7	0.1	0.0	0.6
					High	29.1	25.3	44.0	31.0	140.0	15.0	127.0	1.2	5.8	5.2	7.97	7.75	6.60	7.76	448	510	37.9	605.0	622.0	0.5	0.1	3.1
					Average	26.3	20.6	41.4	27.2	109.2	15.0	104.1	1.2	5.6	4.9	7.77	7.50	5.75	7.43	346	438	4.6	526.0	63.3	0.1	0.1	2.1
					Standard Deviation	3.0	2.5	1.1	2.5	9.9	0.0	8.8	0.0	0.1	0.2	0.12	0.16	0.28	0.17	72	45	4.8	51.8	118.6	0.1	0.0	0.5
					95% CI Low	25.4	20.0	41.1	26.6	106.6	#NUM!	101.8	1.2	5.6	4.8	7.74	7.46	5.68	7.38	324	426	3.3	512.3	29.0	0.1	0.1	1.9
					95% CI High	27.2	21.3	41.7	27.9	111.8	#NUM!	106.4	1.2	5.7	4.9	7.81	7.54	5.83	7.47	368	450	5.8	539.7	97.6	0.1	0.1	2.3

Operator (initials)	Comments	Run Time Days	Date MM/DD/YY	Time hh:mm	Operation time hh.hh	TDS, mg/L TDS_R	TDS_F	TDS_P	TDS_B	Alkalinity, mg/L Alk_R	Alk_F	Alk_P	Calcium, mg/L Ca_R	Ca_F	Ca_P
sma	official start day 1	0.0	08-02-04	12:00 PM	5316.8					95.0	171.0	--	44.2	75.8	0.0
sma	day6	7.0	08-09-04	10:50 AM	5414.5	356	342	34.0	410	99.0	149.2	60.0	37.9	58.0	0.0
sma	day11	14.0	08-16-04	1:40 PM	5545.5	212	290	0.5	360	82.4	152.0	3.5	41.2	56.3	0.0
sma	day16	21.0	08-23-04	12:16 PM	5693.0	272	326	22.0	396	87.8	164.6	5.4	40.4	61.2	0.0
sma	day	28.0	08-30-04	11:40 AM	5815.0	350	298	40.0	530	82.6	165.4	5.2	37.5	61.6	0.0
sma	day26	35.0	09-06-04	1:24 AM	5958.7	248	296	42.0	392	82.2	149.7	4.3	38.0	61.1	0.0
sma	day31	42.0	09-13-04	11:01 AM	6124.1	338	260	14.0	216	76.9	152.6	4.2	35.2	60.1	0.0
sma	day36	49.0	09-20-04	12:11 PM	6291.20	178	290	22.0	352	74	147.7	3.7	44.2	75.8	0.0
sma	day41	56.0	09-27-04	11:39 AM	6438.40	136	254	0.0	310	63.5	142	4.4	27.1	55.2	0.0
sma	day46	63.0	10-04-04	12:24 PM	6607.10	178	306	0.0	294	62.7	142.2	5	30.1	53.1	0.0
sma	day51	70.0	10-11-04	10:17 AM	6772.90	166	254	24.0	306	63.6	139.1	3.7	30.1	53.6	0.0
sma	day56	77.0	10-18-04	10:22 AM	6903.40	156	254	0.0	296	71.5	142.2	4.1	31.3	55.6	0.0
			Count			11	11	11	11	12	12	11	12	12	12
			Median			212	290	22.0	352	80	149	4	37.7	59.1	ND
			Low			136	254	0.0	216	63	139	3.5	27.1	53.1	ND
			High			356	342	42.0	530	99	171	60	44.2	75.8	ND
			Average			235.4545455	288	18.0	351	78	151	9.4090909	36.4	60.6	ND
			Standard Deviation			82	30	16.4	82	12	10	17	5.7	7.7	0.0
			95% CI Low			187	270	8	303	72	146	-1	33.2	56.3	ND
			95% CI High			284	306	28	400	85	157	19	39.7	65.0	ND

Operator (initials)	Comments	Run Time Days	Date MM/DD/YY	Time hh:mm	Operation time hh.hh	Magnesium, mg/L Mg_R	Mg_F	Mg_P	SiO_2, ug/L Si_R	Si_F	Si_P	Iron, mg/L Fe_R	Fe_F	Fe_P	Manganese, mg/L Mn_R	Mn_F	Mn_P
sma	official start day 1	0.0	08-02-04	12:00 PM	5316.8	10.6	7.6	0.1	0.54	1.00	0.005	0.500	0.050	0.020	0.186	0.305	0.003
sma	day6	7.0	08-09-04	10:50 AM	5414.5	16.4	16.1	8.8	0.15	0.07	0.03	0.090	0.010	0.020	0.071	0.279	0.003
sma	day11	14.0	08-16-04	1:40 PM	5545.5	9.3	12.9	0.1	0.34	0.09	0.02	0.060	0.005	0.005	0.075	0.295	0.007
sma	day16	21.0	08-23-04	12:16 PM	5693.0	12.1	15.3	1.0	0.21	0.09	0.01	0.180	0.020	0.020	0.070	0.309	0.003
sma	day	28.0	08-30-04	11:40 AM	5815.0	11.0	15.3	0.7	0.15	0.07	0.07	0.120	0.010	0.010	0.080	0.312	0.002
sma	day26	35.0	09-06-04	1:24 AM	5958.7	11.1	12.6	0.1	0.06	0.11	0.03	0.110	0.010	0.050	0.080	0.308	0.004
sma	day31	42.0	09-13-04	11:01 AM	6124.1	10.2	13.9	0.1	0.1	0.08	0.03	3.000	0.010	0.020	0.700	0.320	0.004
sma	day36	49.0	09-20-04	12:11 PM	6291.20	10.5	12.4	0.2	0.07	0.12	0.04	1.730	0.010	0.005	0.608	0.305	0.004
sma	day41	56.0	09-27-04	11:39 AM	6438.40	7.3	12.1	0.4	0.1	0.06	0.05	1.270	0.005	0.12	0.401	0.287	0.004
sma	day46	63.0	10-04-04	12:24 PM	6607.10	7.0	14.1	0.3	0.06	0.06	0.04	0.440	0.010	0.010	0.16	0.291	0.004
sma	day51	70.0	10-11-04	10:17 AM	6772.90	8.0	13.8	0.1	0.06	0.08	0.02	0.140	0.010	0.010	0.061	0.284	0.004
sma	day56	77.0	10-18-04	10:22 AM	6903.40	6.5	14.8	1.4	0.06	0.06	0.01	0.160	0.010	0.010	0.07	0.301	0.004

			Mg_R	Mg_F	Mg_P	Si_R	Si_F	Si_P	Fe_R	Fe_F	Fe_P	Mn_R	Mn_F	Mn_P
Count			12	12	12	12	12	12	12	12	11	12	12	12
Median			10.4	13.9	0.25	0.100	0.080	0.030	0.170	0.010	0.010	0.080	0.303	0.004
Low			6.5	7.6	ND	0.060	0.060	ND	0.060	ND	ND	0.061	0.279	ND
High			16.4	16.1	8.80	0.540	1.000	0.070	>3.00	0.050	0.050	>0.700	0.320	0.007
Average			10.0	13.4	1.11	0.158	0.158	0.030	0.650	0.013	0.016	0.214	0.300	0.004
Standard Deviation			2.7	2.2	2.46	0.146	0.266	0.019	0.909	0.012	0.013	0.228	0.012	0.001
95% CI Low			8.5	12.1	-0.28	0.076	0.007	0.019	0.136	0.006	0.009	0.085	0.293	0.003
95% CI High			11.5	14.7	2.50	0.241	0.308	0.040	1.164	0.020	0.024	0.342	0.307	0.004

Operator (initials)	Comments	Run Time Days	Date MM/DD/YY	Time hh:mm	Operation time hh.hh	Barium, mg/L Ba_R	Ba_F	Ba_P	Strontium, mg/L Sr_R	Sr_F	Sr_P	Sulfate, mg/L $SO4_R$	$SO4_F$	$SO4_P$
sma	official start day 1	0.0	08-02-04	12:00 PM	5316.8	--	--	--	--	--	--	78	60	0.0
sma	day6	7.0	08-09-04	10:50 AM	5414.5	0.047	0.027	0.001	0.27	0.20	0.005	77	62	0.0
sma	day11	14.0	08-16-04	1:40 PM	5545.5	0.042	0.027	0.001	0.24	0.21	0.005	68	61	0.0
sma	day16	21.0	08-23-04	12:16 PM	5693.0	0.047	0.028	0.001	0.25	0.21	0.005	72	61	0.0
sma	day	28.0	08-30-04	11:40 AM	5815.0	0.046	0.029	0.001	0.24	0.20	0.005	72	59	0.0
sma	day26	35.0	09-06-04	1:24 AM	5958.7	--	--	--	--	--	--	68	67	0.0
sma	day31	42.0	09-13-04	11:01 AM	6124.1	0.120	0.029	0.001	0.21	0.20	0.005	52	66	0.0
sma	day36	49.0	09-20-04	12:11 PM	6291.20	--	--	--	--	--	--	46	64	1.0
sma	day41	56.0	09-27-04	11:39 AM	6438.40	0.069	0.025	0.001	0.14	0.17	0.005	38	52	0.0
sma	day46	63.0	10-04-04	12:24 PM	6607.10	0.036	0.023	0.001	0.15	0.17	0.005	48	50	0.0
sma	day51	70.0	10-11-04	10:17 AM	6772.90	0.035	0.023	0.001	0.15	0.17	0.005	49	51	0.0
sma	day56	77.0	10-18-04	10:22 AM	6903.40	0.054	0.023	0.001	0.16	0.17	0.005	43	56	0.0

			Ba_R	Ba_F	Ba_P	Sr_R	Sr_F	Sr_P	$SO4_R$	$SO4_F$	$SO4_P$
Count			9	9	9	9	9	9	12	12	12
Median			0.047	0	ND	0	0	ND	60	61	ND
Low			0.035	0.023	ND	0.14	0.17	ND	38	50	ND
High			0.120	0.029	ND	0.27	0.21	ND	78	67	1
Average			0.055	0.026	ND	0.20	0.19	ND	59	59	ND
Standard Deviation			0.026	0	0	0.05	0.02	0	15	6	0.3
95% CI Low			0.038	0	ND	0.17	0.18	ND	51	56	ND
95% CI High			0.072	0	ND	0.23	0.20	ND	67	62	ND

Operator (initials)	Comments	Run Time Days	Date MM/DD/YY	Time hh:mm	Operation time hh.hh	Nitrate, mg/L $NO3_R$	$NO3_F$	$NO3_P$	Fluoride, mg/L F_R	F_F	F_P	Chloride, mg/L Cl_R	Cl_F	Cl_P	Coliforms, CFU/ml $Coli_R$	$Coli_F$
sma	official start day 1	0.0	08-02-04	12:00 PM	5316.8	0.5	0.3	0.2	0.23	0.23	0.022	24.2	21.2	0.0	144.5	0.18
sma	day6	7.0	08-09-04	10:50 AM	5414.5	0.6	0.5	0.1	0.23	0.23	0.035	23.9	27.1	0.1	27.1	0.005
sma	day11	14.0	08-16-04	1:40 PM	5545.5	1.1	0.3	0.2	0.19	0.22	0.031	23.4	23.7	0.1	16.4	0.005
sma	day16	21.0	08-23-04	12:16 PM	5693.0	0.8	0.7	0.1	0.21	0.23	0.028	>25	25.9	0.1	144.5	0.005
sma	day	28.0	08-30-04	11:40 AM	5815.0	0.7	0.3	0.1	0.19	0.23	0.028	23.5	23.9	0.0	20.7	0.005
sma	day26	35.0	09-06-04	1:24 AM	5958.7	0.5	0.3	0.2	0.21	0.23	0.032	>25	23	0.1	59.1	0.005
sma	day31	42.0	09-13-04	11:01 AM	6124.1	0.05	0.4	0.2	0.18	0.24	0.031	>25	23.1	0.1	165.2	0.005
sma	day36	49.0	09-20-04	12:11 PM	6291.20	0.05	0.5	0.2	0.15	0.24	0.031	0.4	20.6	0.6	271	0.005
sma	day41	56.0	09-27-04	11:39 AM	6438.40	0.05	0.4	0.2	0.14	0.24	0.029	2.9	20.2	0.1	111	0.005
sma	day46	63.0	10-04-04	12:24 PM	6607.10	0.2	0.4	0.1	0.14	0.25	0.023	13.6	17.3	0.1	20.05	0.005
sma	day51	70.0	10-11-04	10:17 AM	6772.90	0.5	0.5	0.1	0.14	0.25	0.036	13.6	17.3	0.1	20.05	0.005
sma	day56	77.0	10-18-04	10:22 AM	6903.40	0.6	0.5	0.2	0.14	0.23	0.029	12	16.1	0.2	9.9	0.005
			Count			12	12	12	12	12	12	9	12	12	12	12
			Median			0.50	0.40	0.20	0.19	0.23	0.03	13.60	22.10	0.1	43	ND
			Low			ND	0.30	0.10	0.14	0.22	0.02	0.40	16.10	ND	9.9	ND
			High			1.10	0.70	0.20	0.23	0.25	0.04	24.20	27.10	0.6	271	0.18
			Average			0.47	0.43	0.16	0.18	0.24	0.03	15.28	21.62	0.1	84.125	ND
			Standard Deviation			0.33	0.12	0.05	0.04	0.01	0.00	9.21	3.48	0.2	83	N/A
			95% CI Low			0	0	0	0	0	0	9	20	0	37	ND
			95% CI High			1	0	0	0	0	0	21	24	0	131	ND

Operator (initials)	Comments	Run Time Days	Date MM/DD/YY	Time hh:mm	Operation time hh.hh	HPC, MPN/100ml HPC_R	HPC_F	Algae/ml $Algae_R$	$Algae_F$	T&O $T\&O_R$	$T\&O_F$	$T\&O_P$	DOC, mg/L DOC_R	DOC_F	DOC_P	UVA, cm^{-1} UVA_R	UVA_F	UVA_P
sma	official start day 1	0.0	08-02-04	12:00 PM	5316.8	2100	336	699	18	1	<1	<1	--	--	--	0.082	0.022	0.002
sma	day6	7.0	08-09-04	10:50 AM	5414.5	520		640	ND	1	<1	<1	2.64	1.22	0.168	0.088	0.032	0.039
sma	day11	14.0	08-16-04	1:40 PM	5545.5	460	19500	344	ND	1	<1	<1	3.12	1.37	0.142	0.088	0.029	0.004
sma	day16	21.0	08-23-04	12:16 PM	5693.0	1610	19600	580	ND	1	<1	<1	3.15	1.38	0.129	0.084	0.028	0.002
sma	day	28.0	08-30-04	11:40 AM	5815.0	680	20800	408	ND	1	<1	<1	2.64	1.31	0.264	0.078	0.032	0.003
sma	day26	35.0	09-06-04	1:24 AM	5958.7	410	15000	707	ND	1	<1	<1	2.82	1.38	0.160	0.072	0.024	0.001
sma	day31	42.0	09-13-04	11:01 AM	6124.1	930	TNTC	*	ND	1	<1	<1	4.19	1.28	0.101	0.111	0.027	0.003
sma	day36	49.0	09-20-04	12:11 PM	6291.20	2420		*	ND	1	<1	<1	4.8	1.30	0.25	0.12	0.032	0.003
sma	day41	56.0	09-27-04	11:39 AM	6438.40	1430	8000	*	ND	1	<1	<1	4.13	1.57	0.197	0.137	0.033	0.004
sma	day46	63.0	10-04-04	12:24 PM	6607.10	980	10700	*	ND	1	<1	<1	3.2	1.53	0.25	0.102	0.032	0.003
sma	day51	70.0	10-11-04	10:17 AM	6772.90	480		1341	ND	2	<1	<1	3.03	1.47	0.23	0.09	0.029	0.001
sma	day56	77.0	10-18-04	10:22 AM	6903.40	1710	8300	906	ND	1	<1	<1	2.9	1.55	0.263	0.091	0.03	0.002
			Count			12	8	8	12	12	12	12	11	11	11	12	12	11
			Median			955	12850	670	ND	1	ND	ND	3.12	1.38	0.20	0.089	0.030	0.003
			Low			410	336	344	ND	1	ND	ND	2.64	1.22	0.10	0.072	0.022	0.001
			High			2420	20800	1341	18	2	ND	ND	4.80	1.57	0.26	0.137	0.033	0.004
			Average			1144	12780	703	ND	1	ND	ND	3.33	1.40	0.20	0.095	0.029	0.003
			Standard Deviation			693	7201	312	N/A	0	0	0	0.72	0.12	0.06	0.019	0.003	0.001
			95% CI Low			752	7789	487	ND	1	ND	ND	2.906	1.327	0.161	0.085	0.027	0.002
			95% CI High			1536	17770	920	ND	1	ND	ND	3.752	1.466	0.231	0.106	0.031	0.003

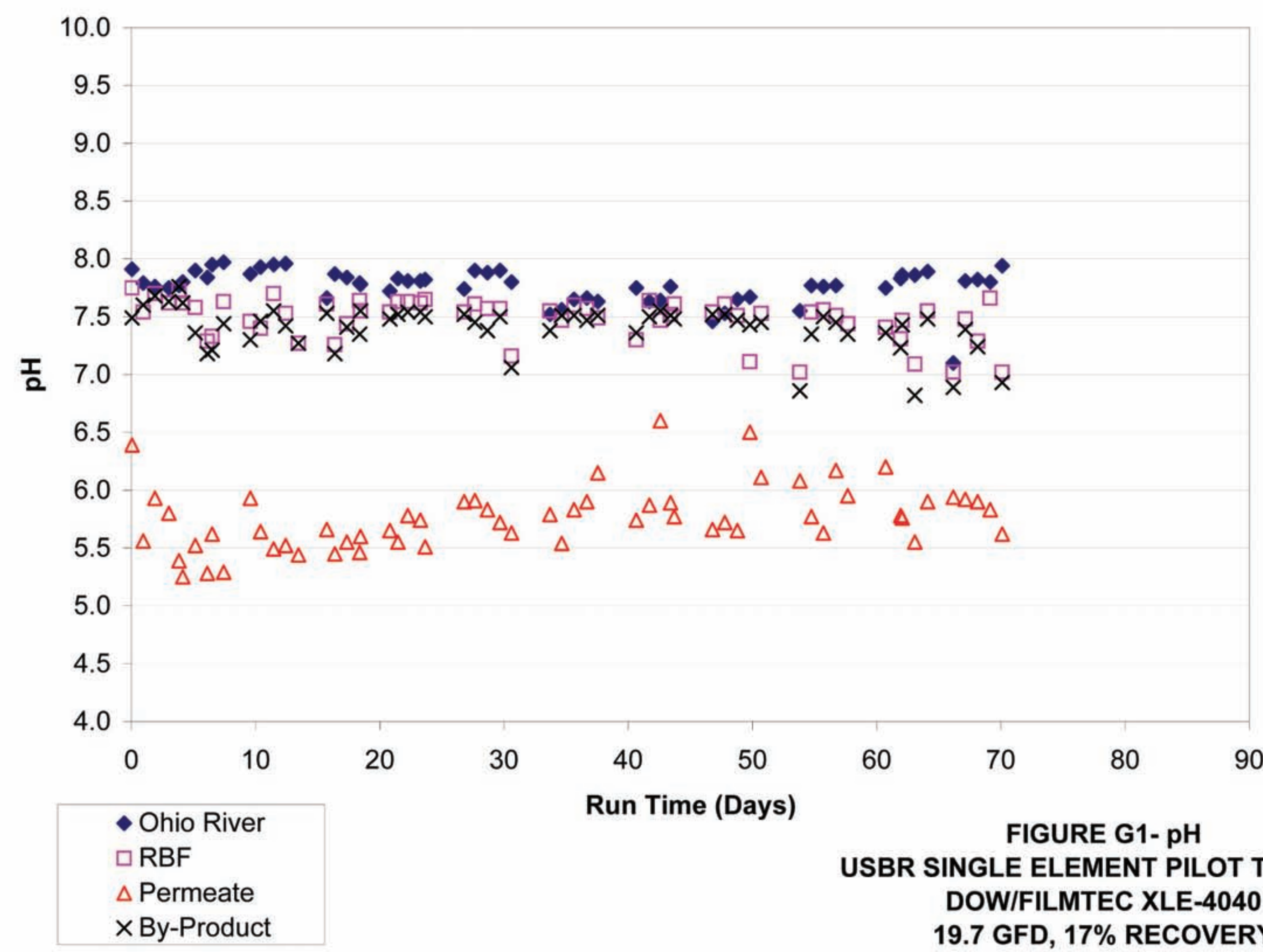


FIGURE G1- pH
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC

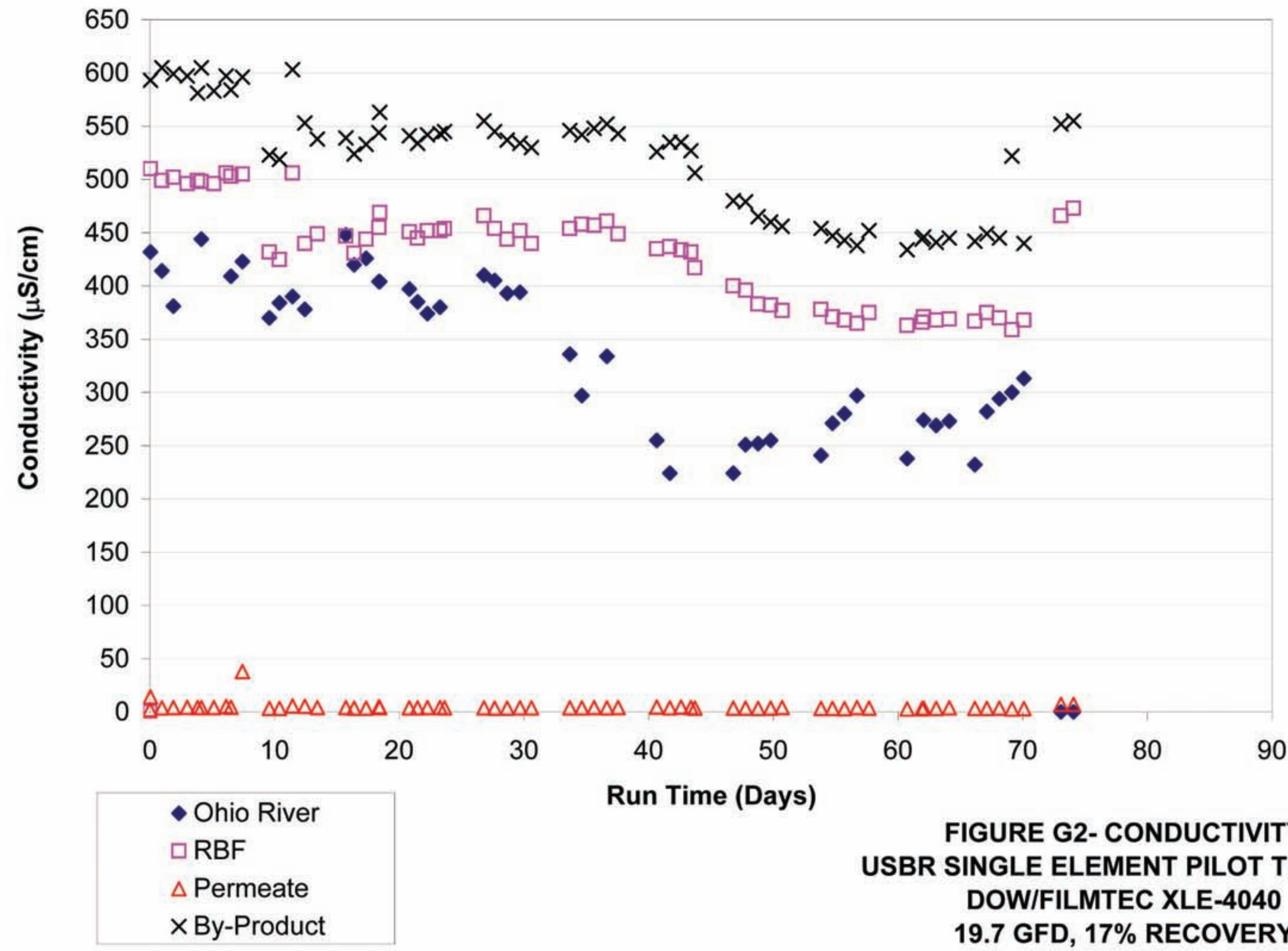


FIGURE G2- CONDUCTIVITY
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC

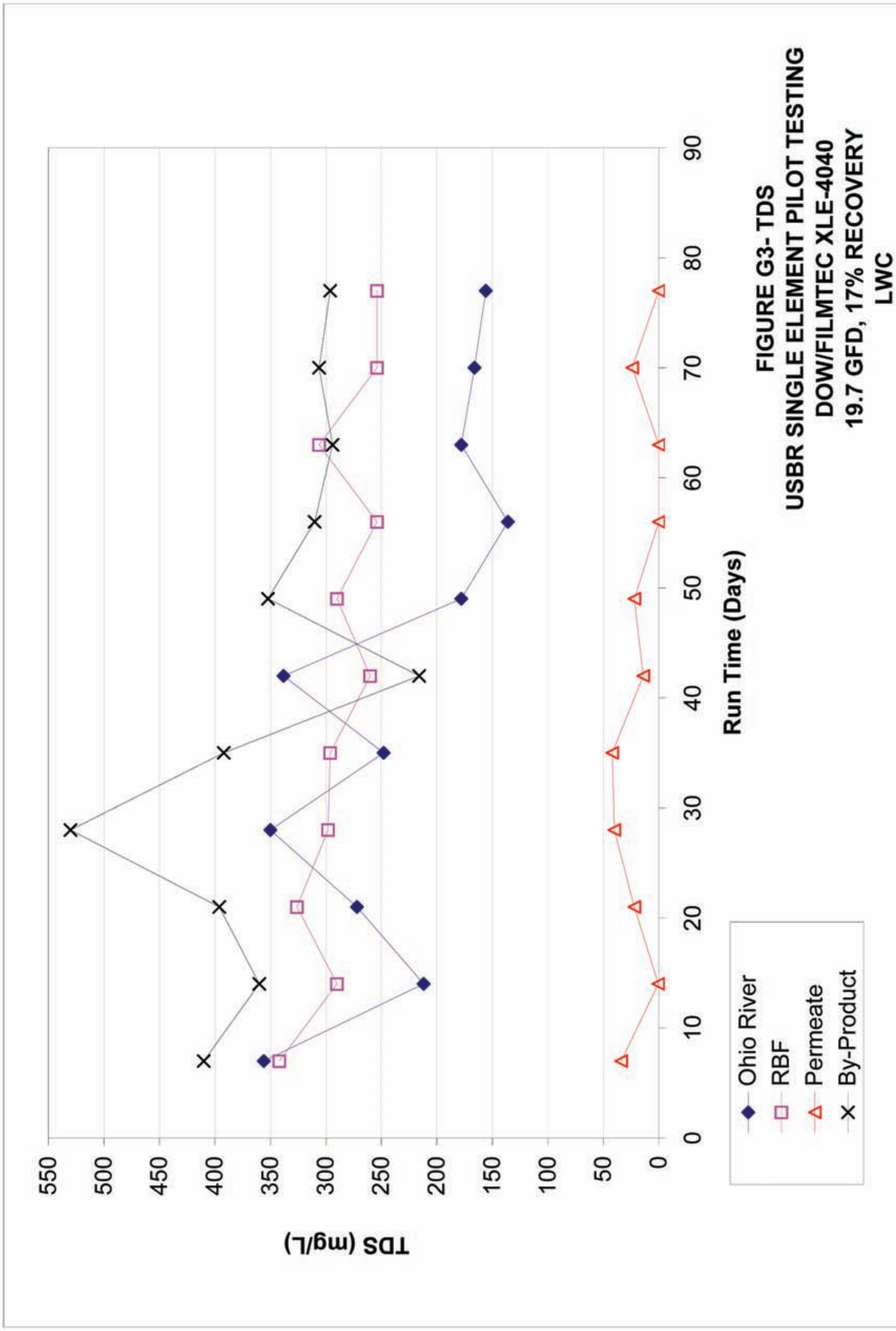


FIGURE G3- TDS
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC

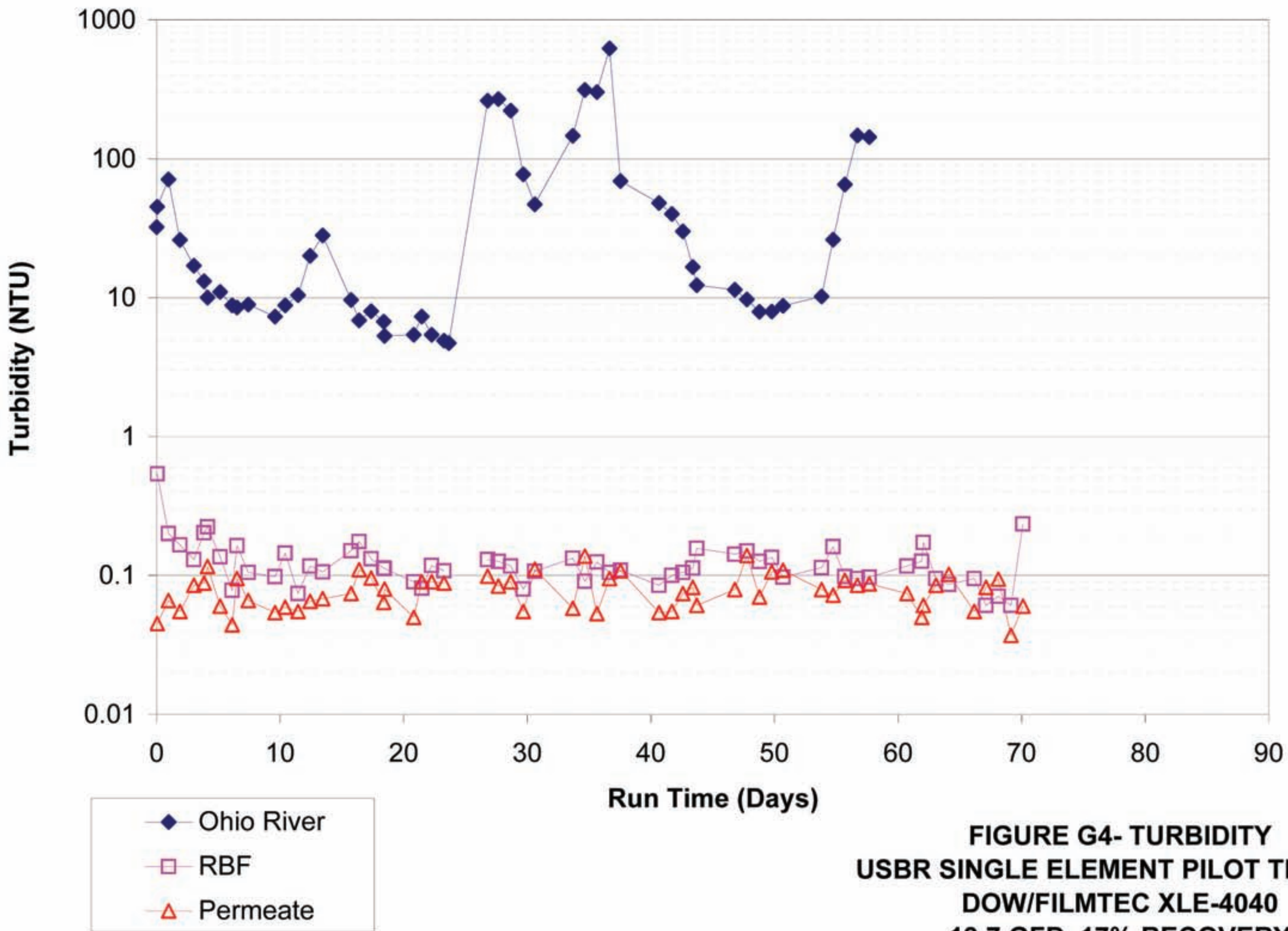


FIGURE G4- TURBIDITY
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC

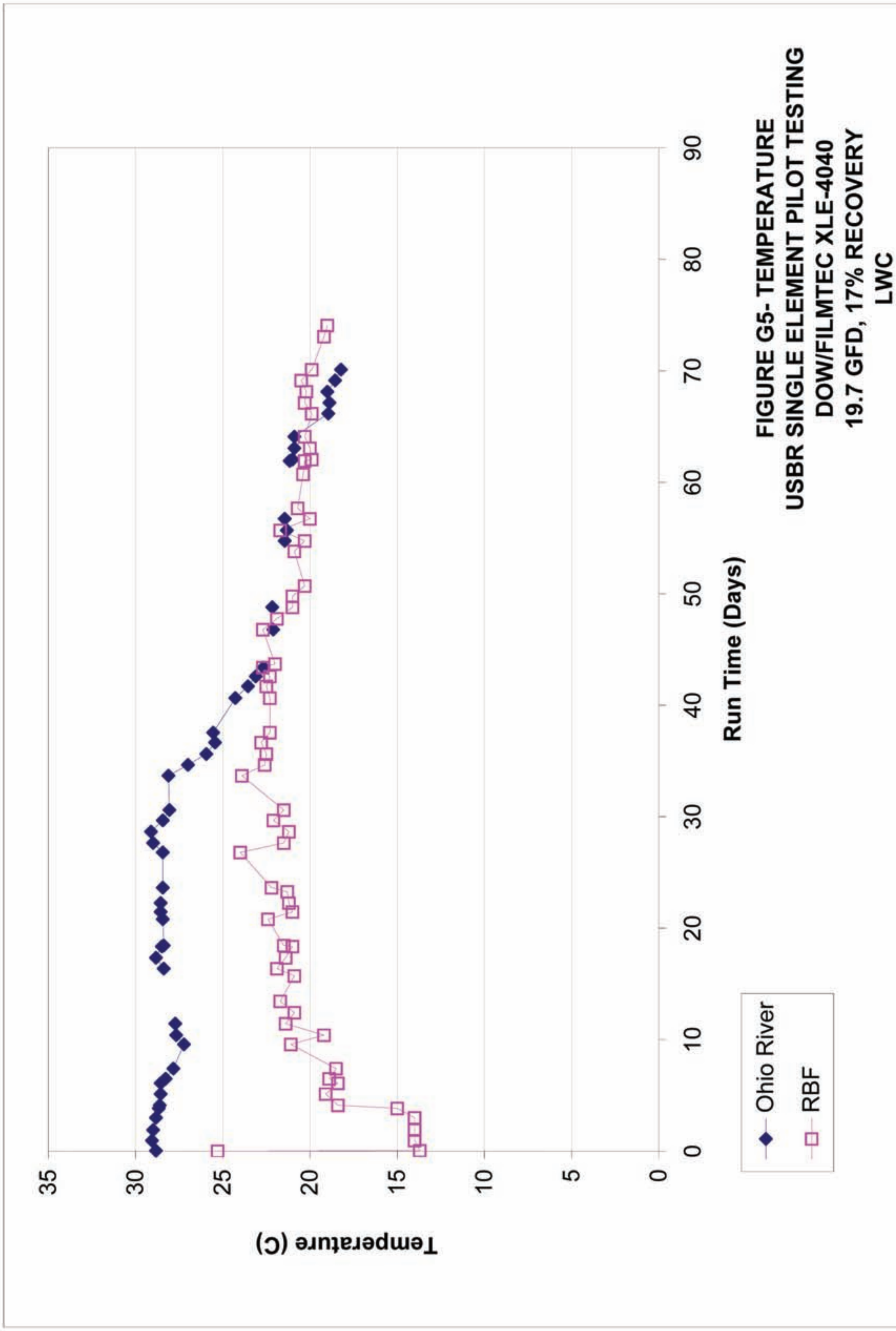


FIGURE G5- TEMPERATURE
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC

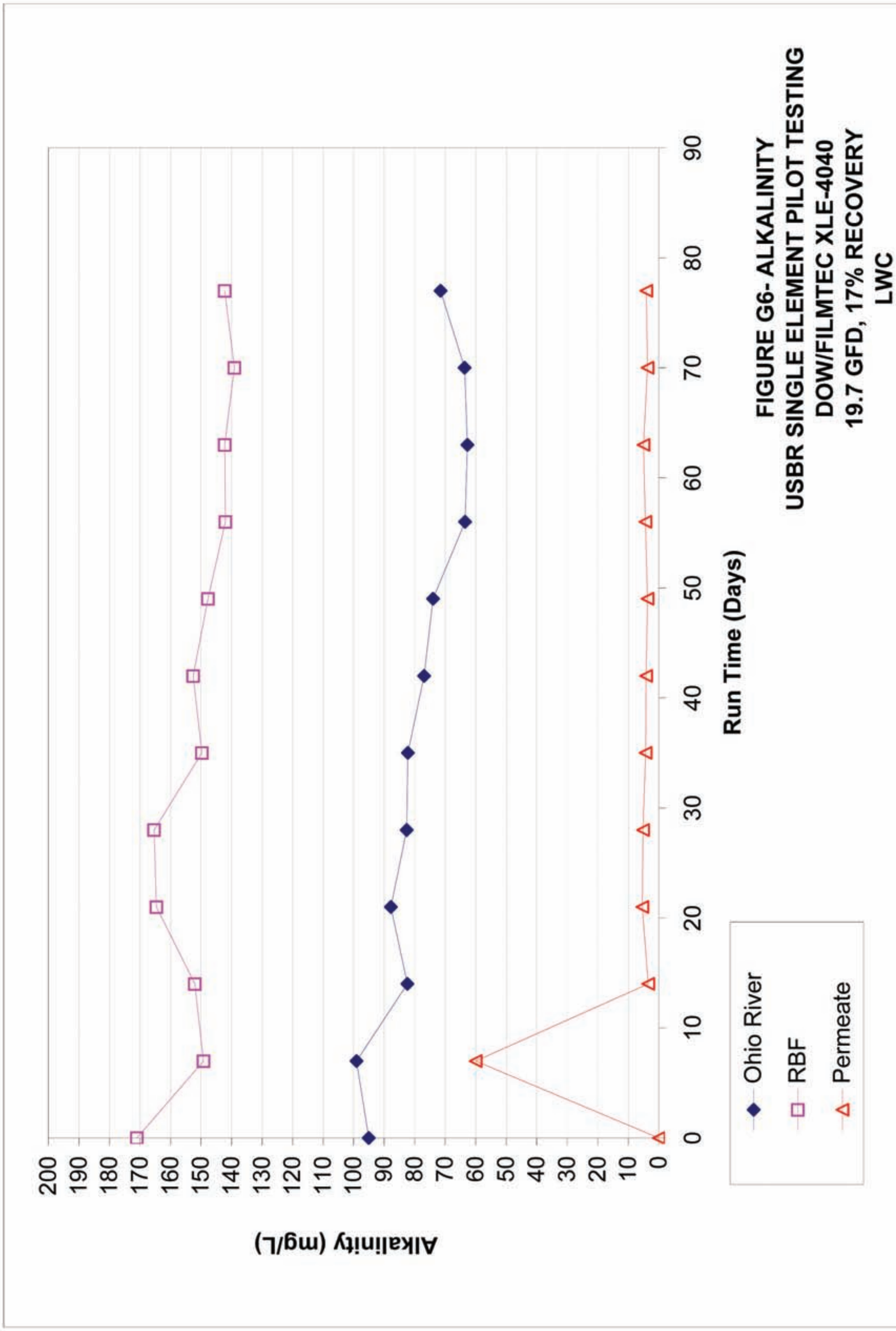


FIGURE G6- ALKALINITY
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC
Alkalinity (mg/L)
Run Time (Days)
Ohio River
RBF
Permeate
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200

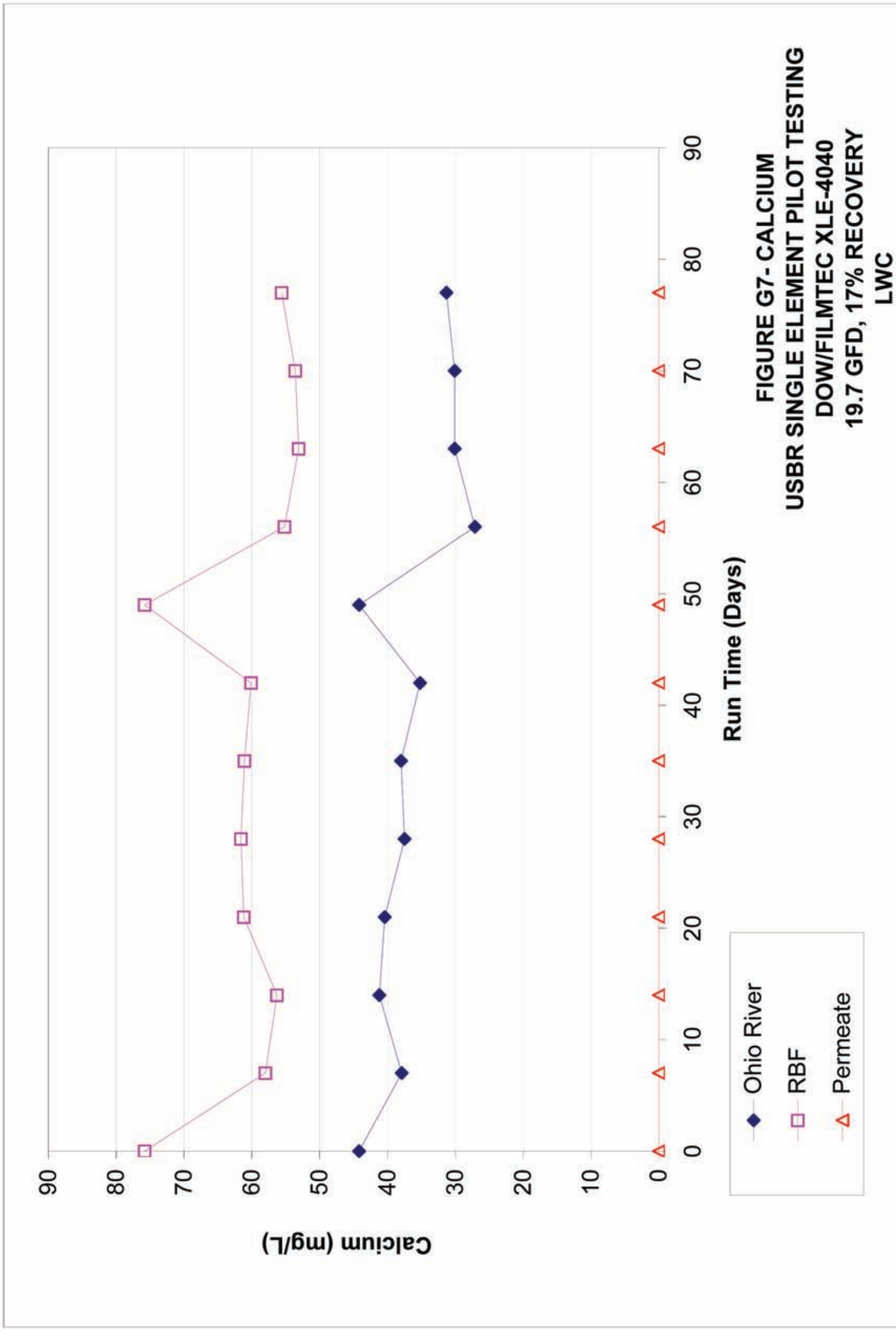


FIGURE G7- CALCIUM
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC

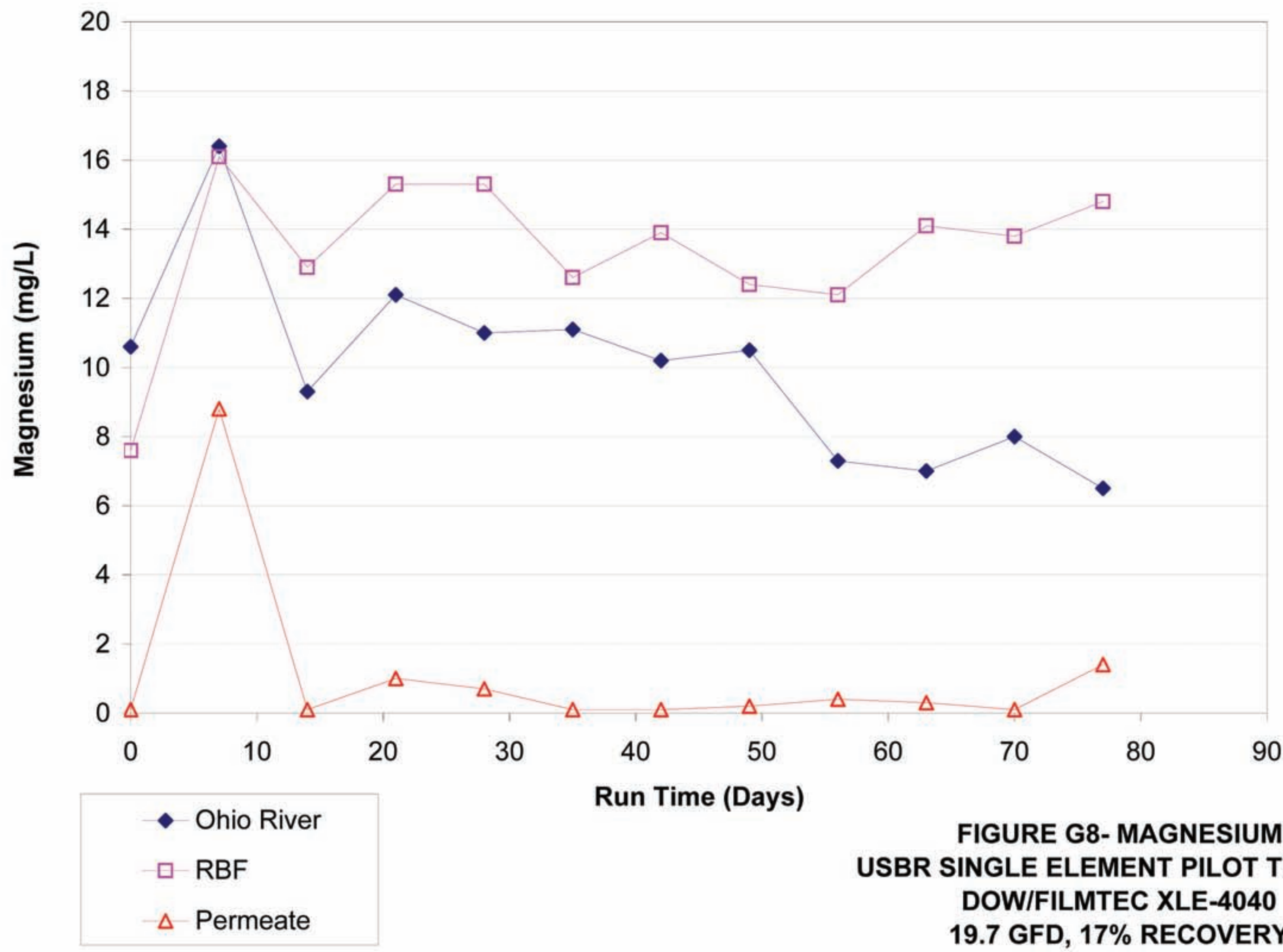


FIGURE G8- MAGNESIUM
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC

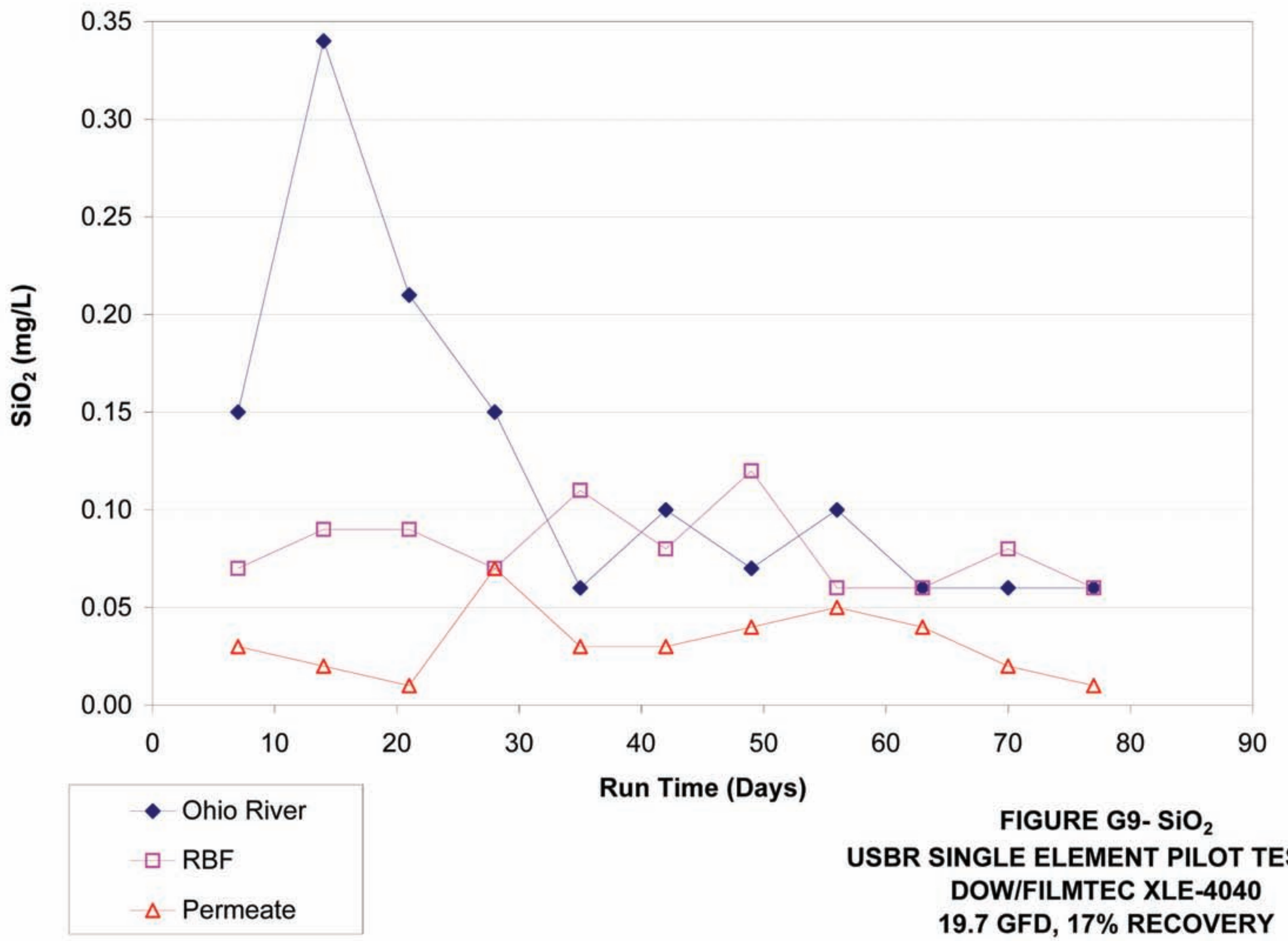


FIGURE G9- SiO_2
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC

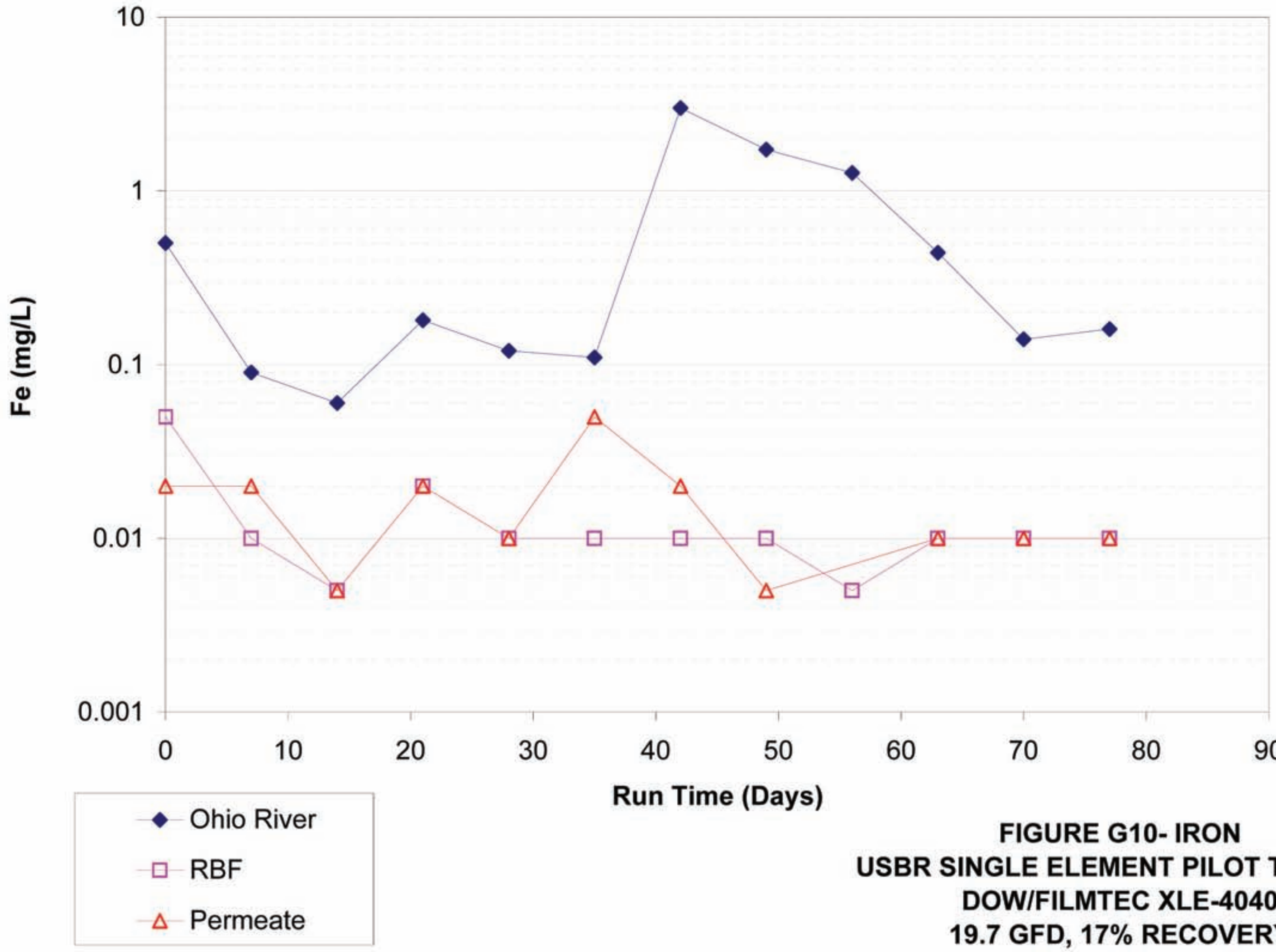


FIGURE G10- IRON
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC

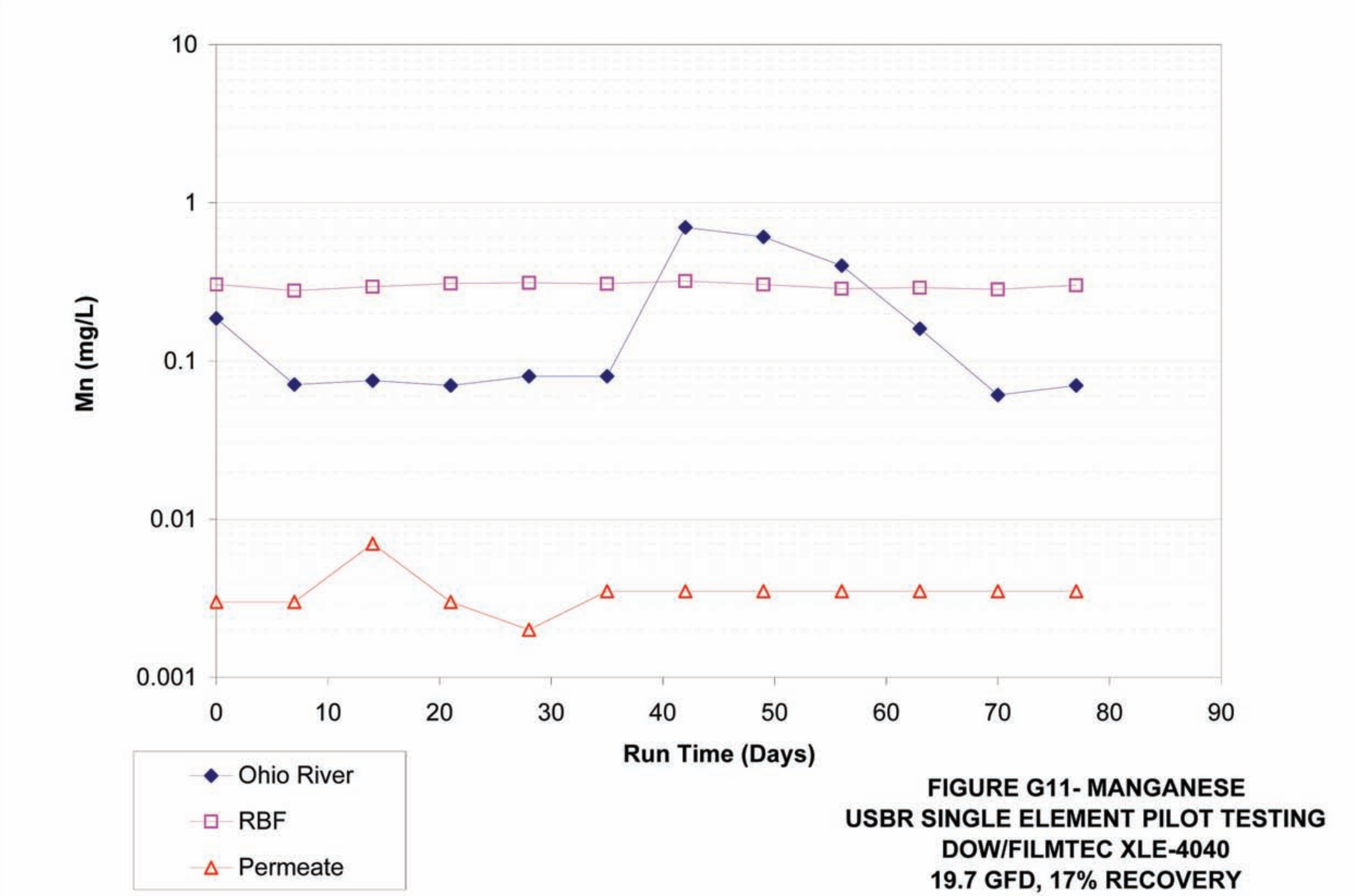


FIGURE G11- MANGANESE
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC

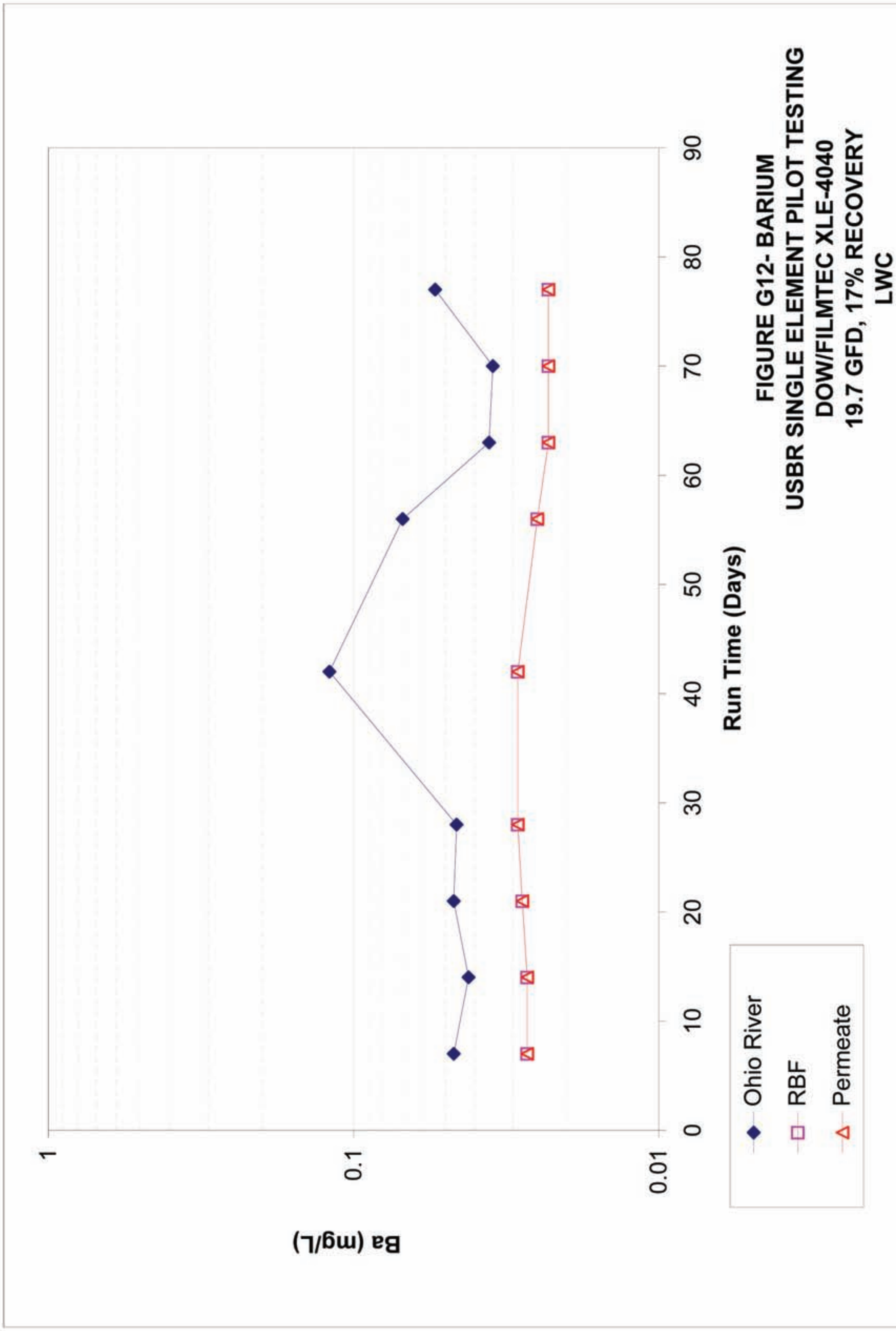


FIGURE G12- BARIUM
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC

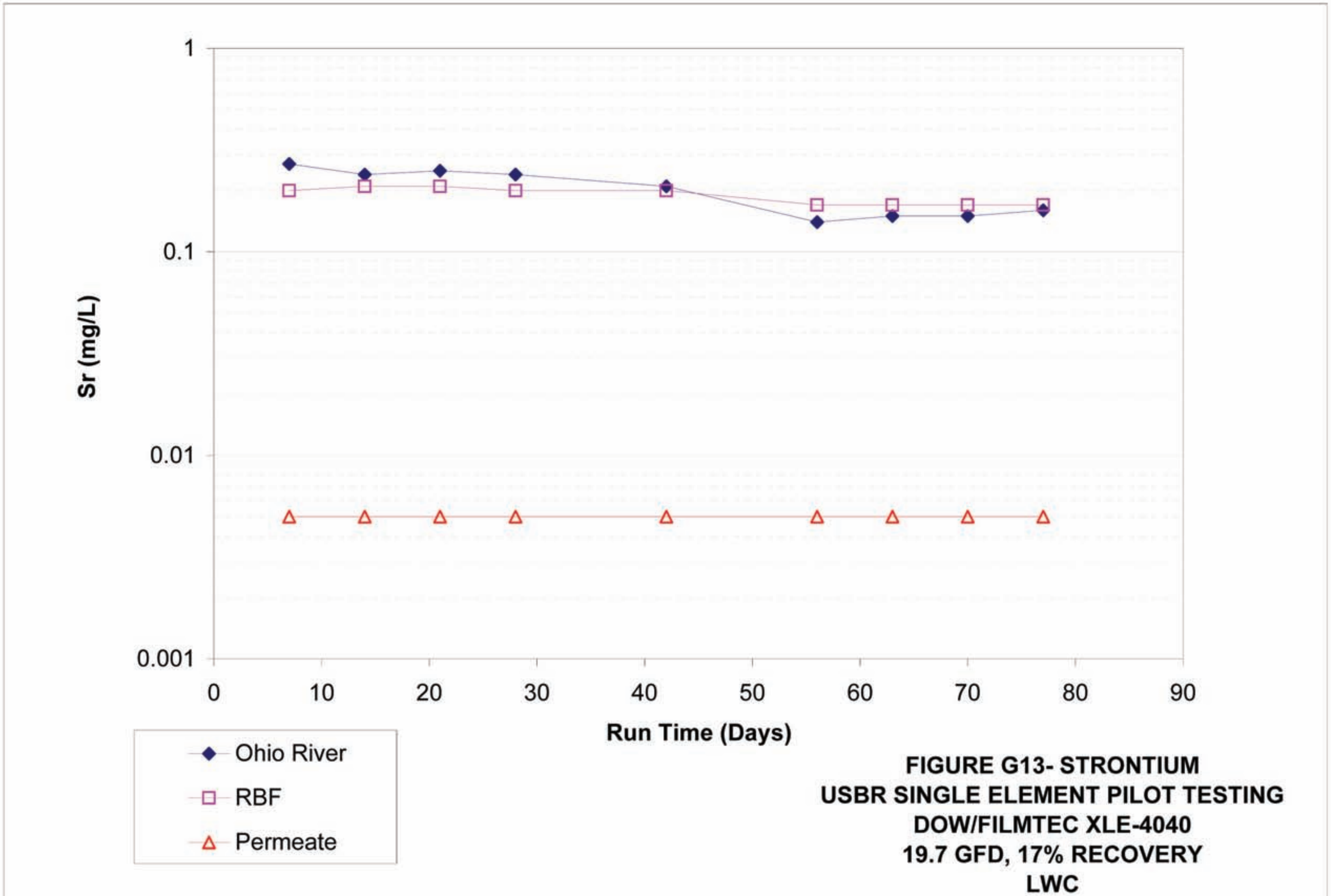


FIGURE G13- STRONTIUM
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC

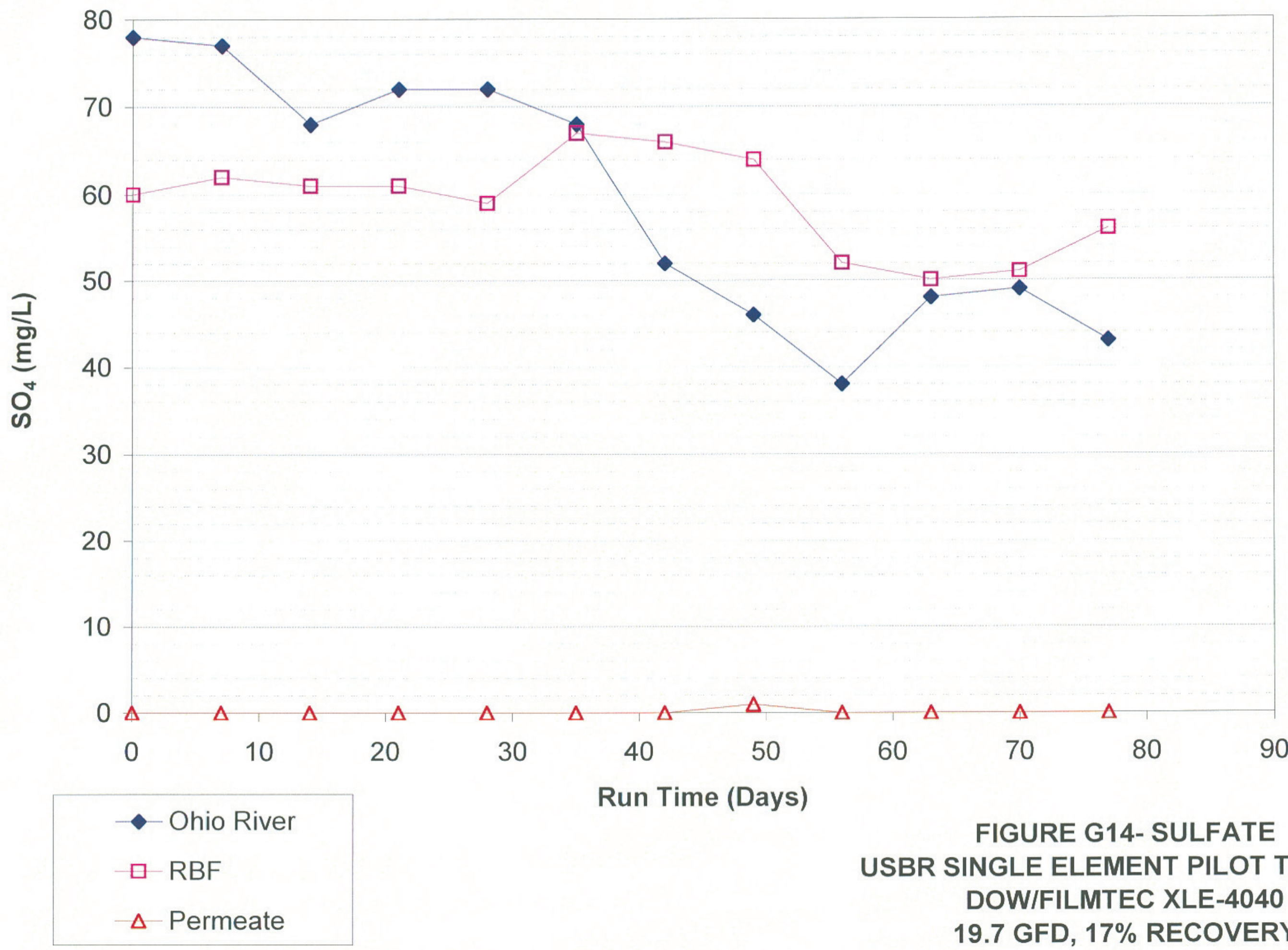


FIGURE G14- SULFATE
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC

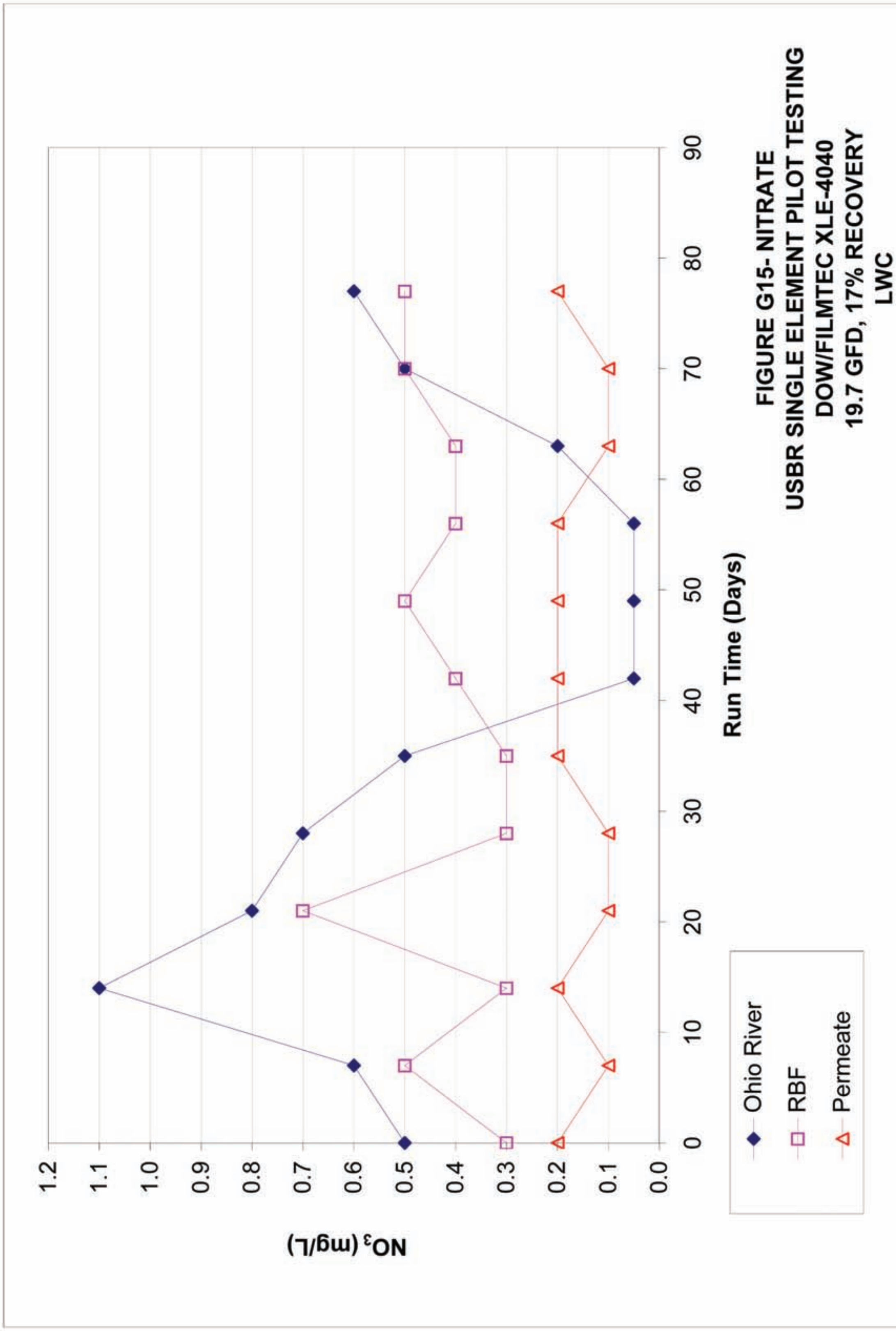


FIGURE G15- NITRATE
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC

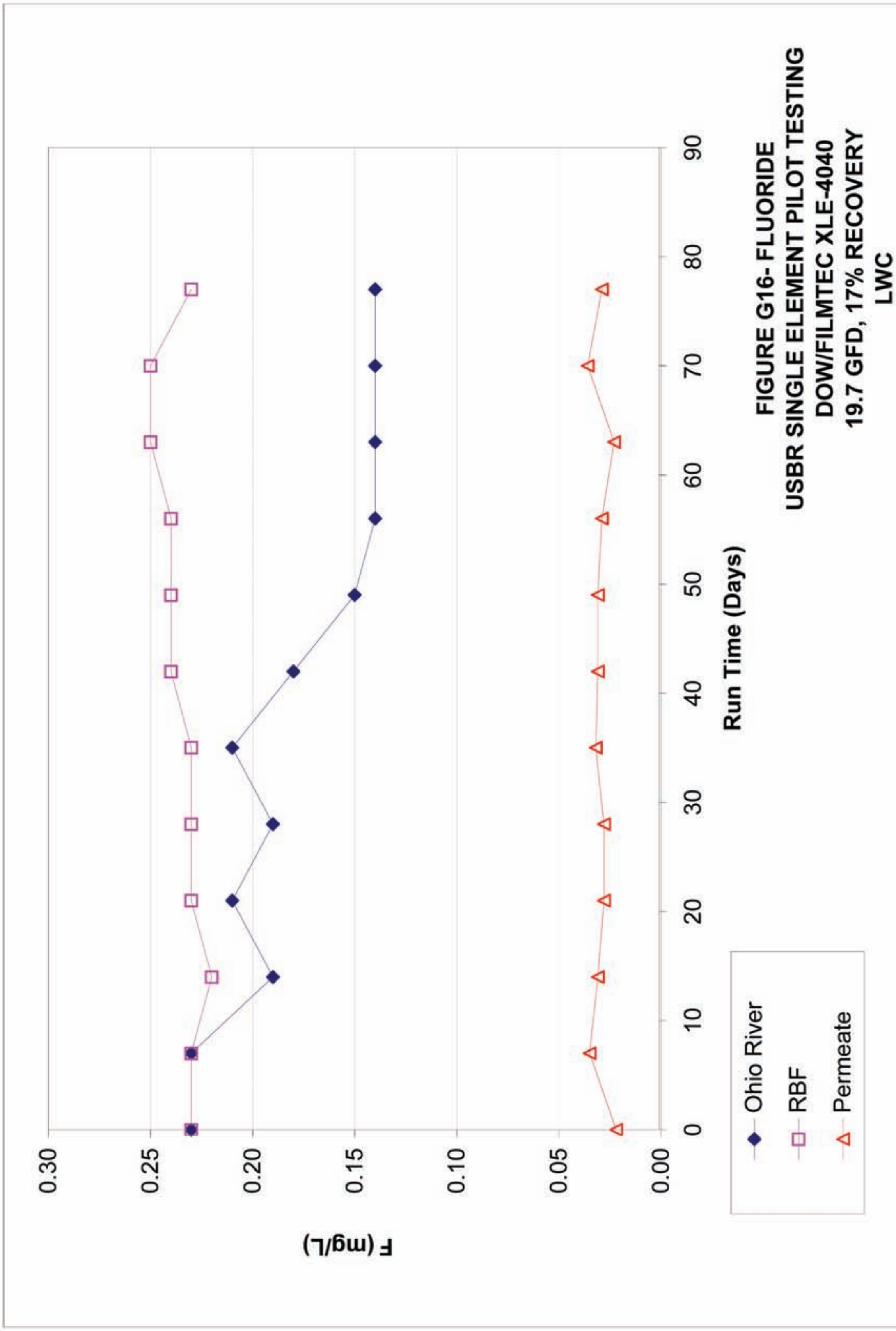


FIGURE G16- FLUORIDE
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC
F (mg/L)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Run Time (Days)
0
10
20
30
40
50
60
70
80
90
Ohio River
RBF
Permeate

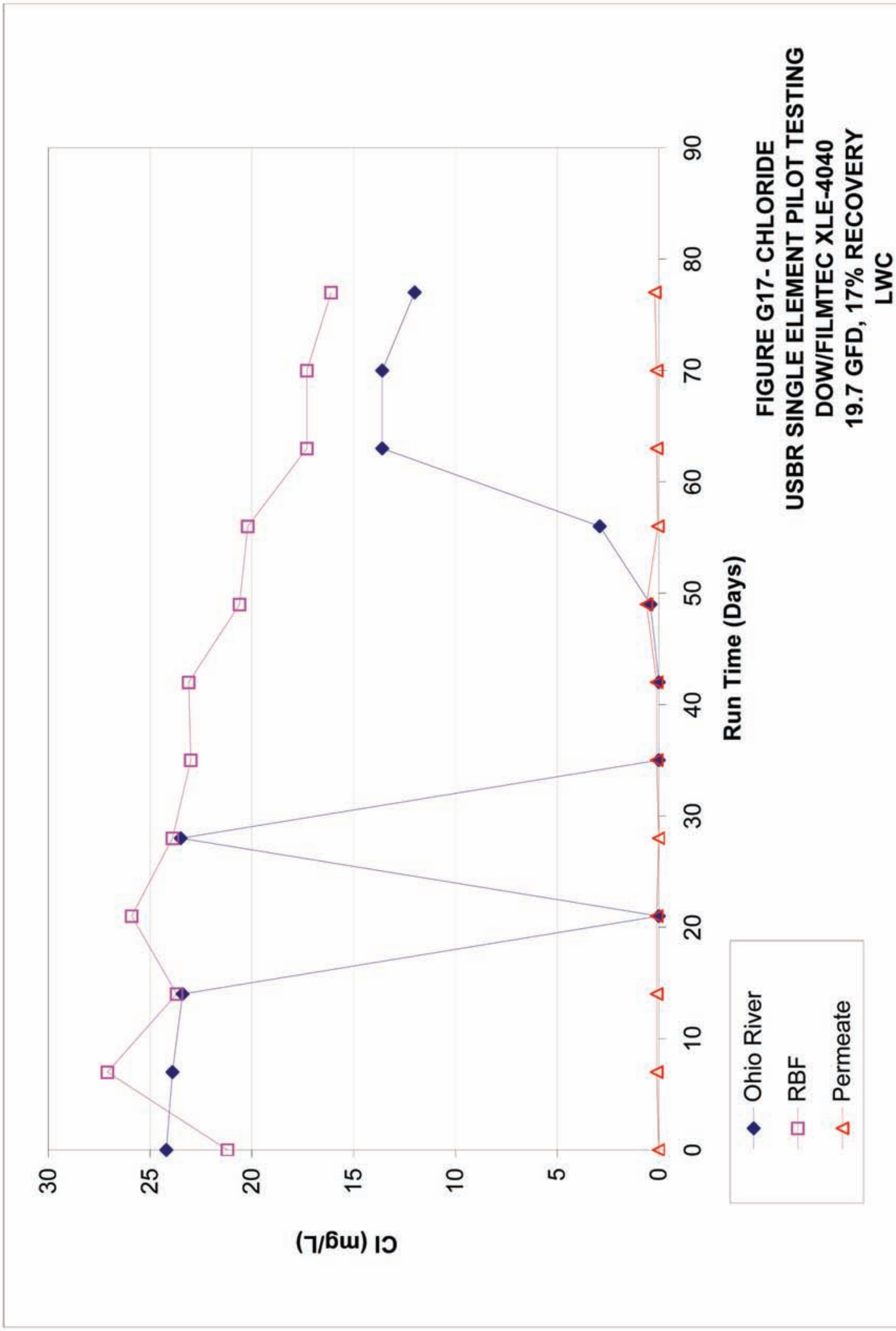


FIGURE G17- CHLORIDE
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC

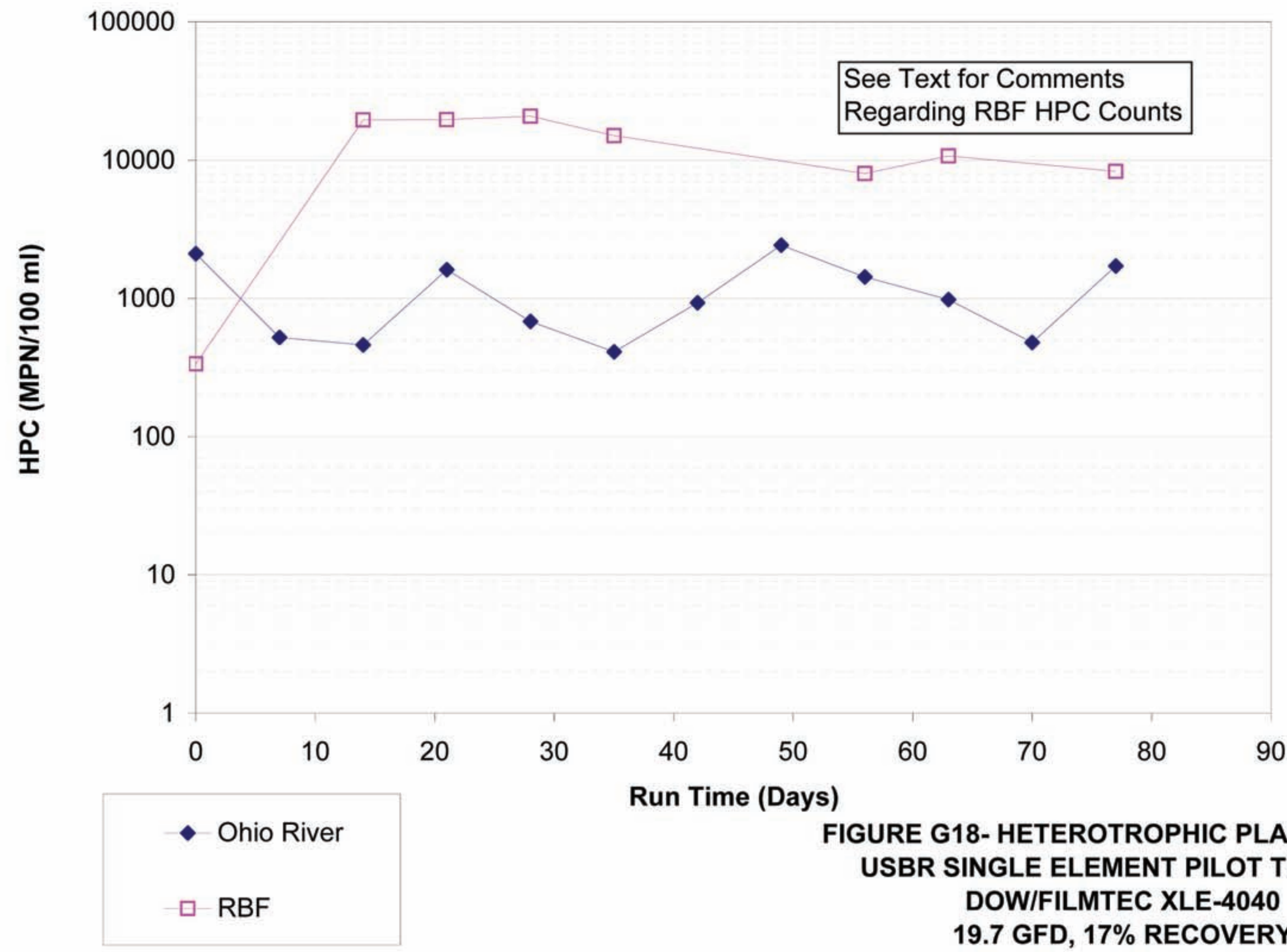


FIGURE G18- HETEROTROPHIC PLATE COUNT
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC

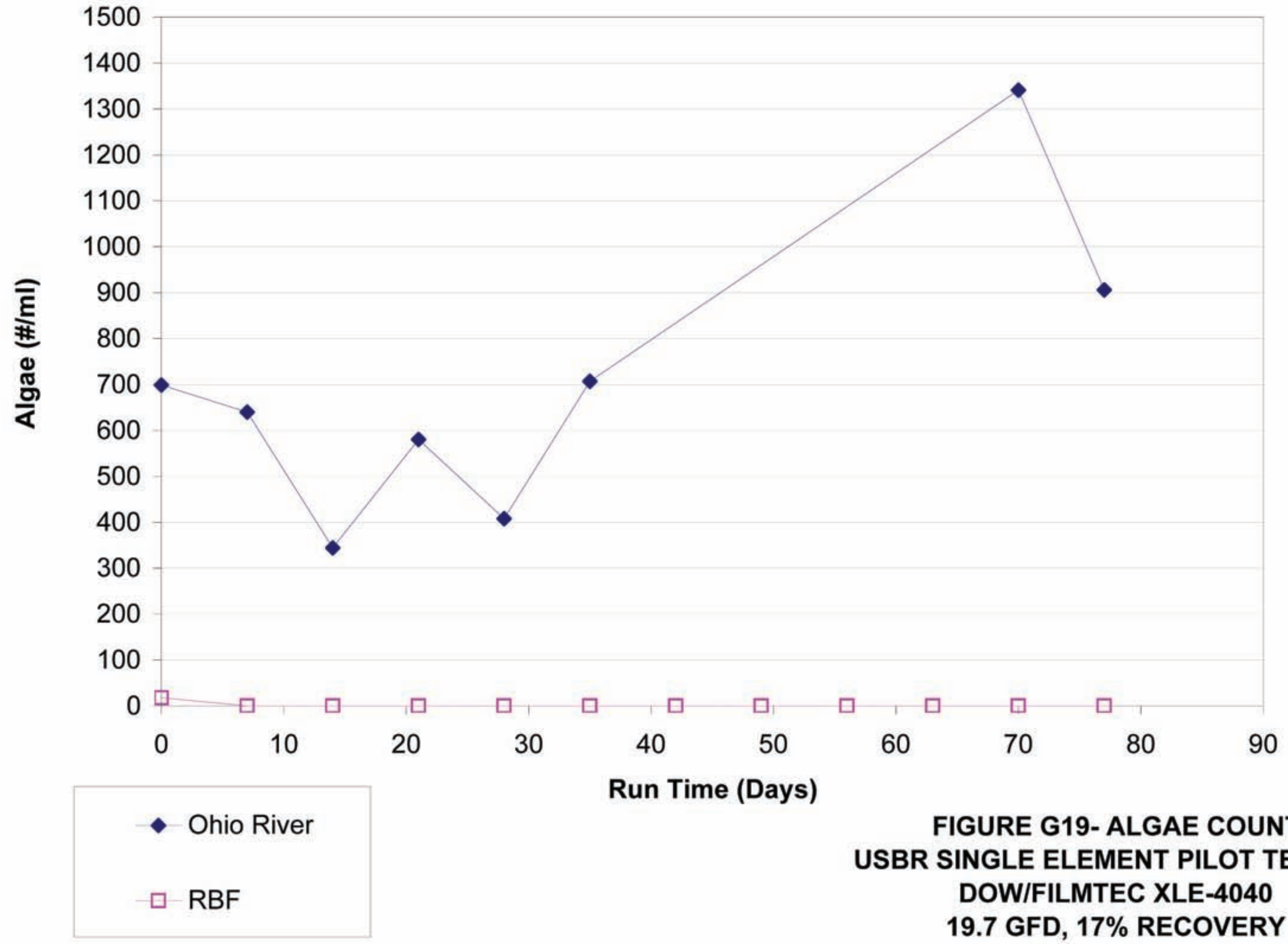


FIGURE G19- ALGAE COUNT
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC

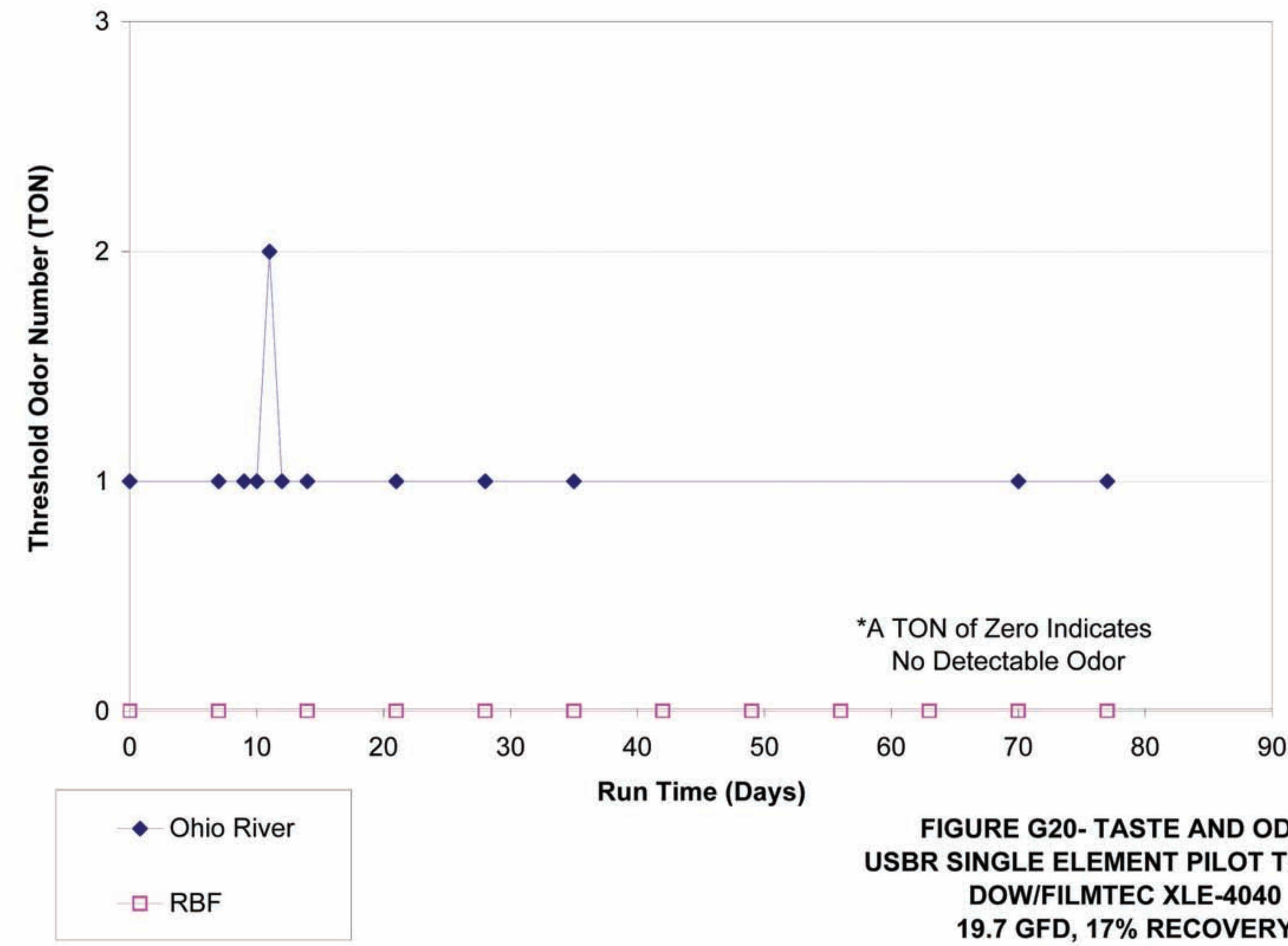


FIGURE G20- TASTE AND ODOR
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC

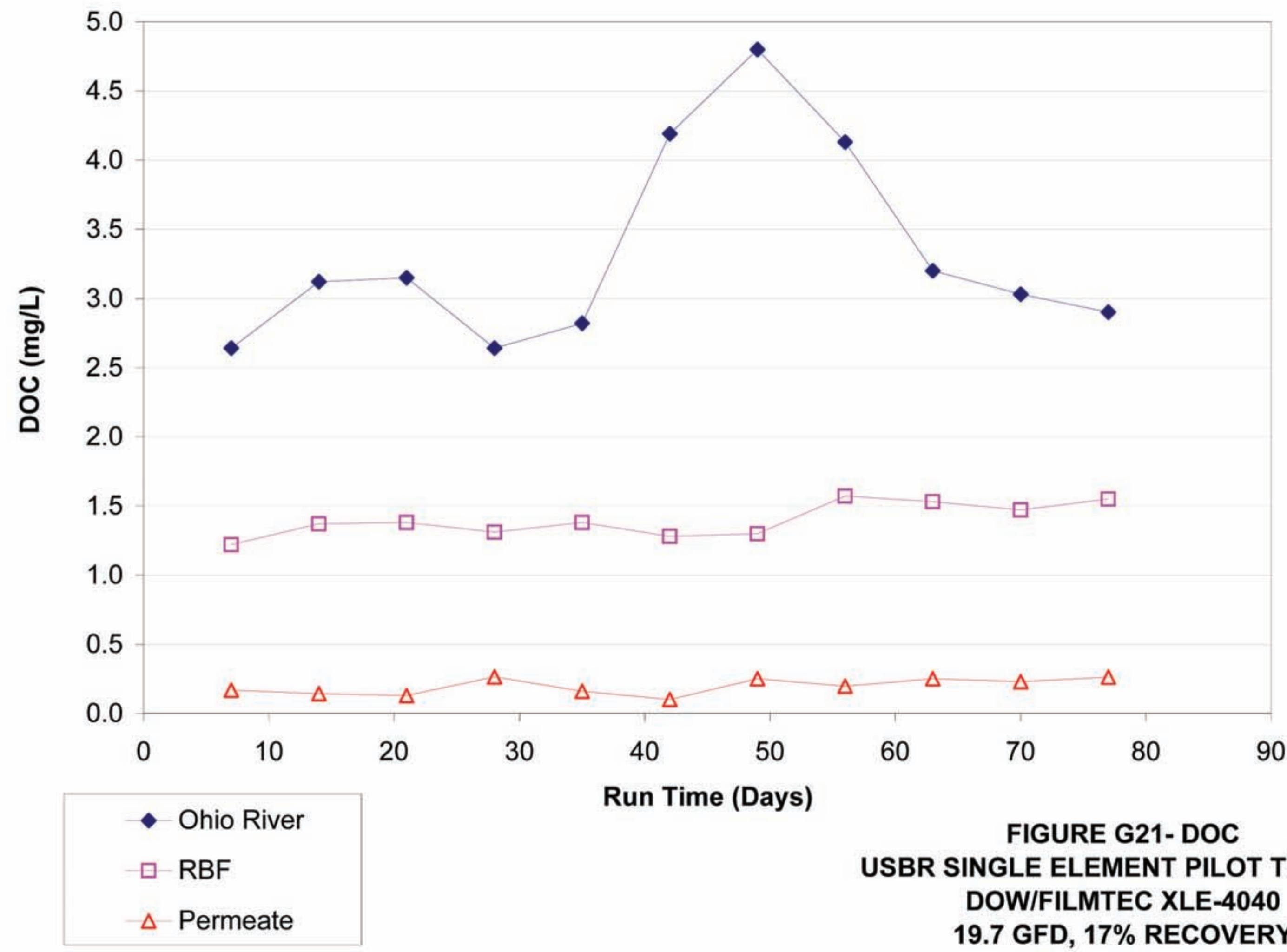


FIGURE G21- DOC
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC

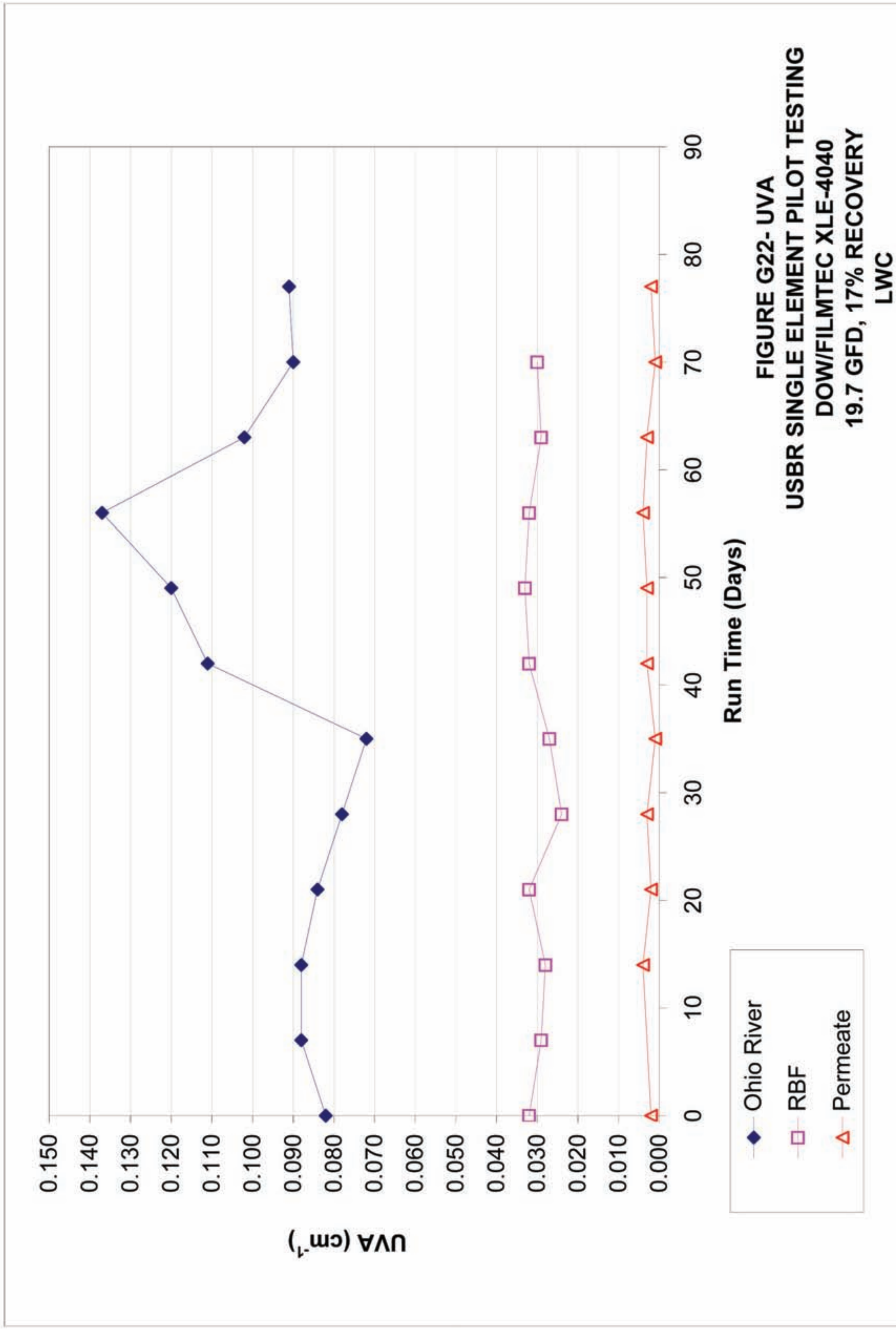


FIGURE G22- UVA
USBR SINGLE ELEMENT PILOT TESTING
DOW/FILMTEC XLE-4040
19.7 GFD, 17% RECOVERY
LWC