Texas Water Development Board
Contract #0704830718

San Antonio Water System
Brackish Groundwater Desalination Facility
Enhanced Recovery Alternatives Evaluation and Pilot Test Report

Prepared for the San Antonio Water System (SAWS)
by
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Acronyms and Definitions

AF	Acre-feet
ASME	American Society of Mechanical Engineers
ANSI	American National Standards Institute
ASR	SAWS Twin Oaks Aquifer Storage and Recovery Facility
Availability	Percentage of time a component is available for service
ºC	Degrees Celsius
CAPEX	Capital Expenses
CFR	Code of Federal Regulations
City	City of San Antonio
Concentrate	Reverse osmosis process desalination process wastewater
Conventional RO Process	Reverse osmosis process typically used for desalination in municipal facilities
dB	Decibels
dBA	Decibels Absolute (sound pressure level)
DFC	Desired Future Conditions, established by Groundwater Management Areas in Texas
Decarbonation	Process for removing carbon dioxide
CPM	Critical Period Management, approach used for managing withdrawals from Edwards Aquifer
HEEPM™	EET Corporation High Efficiency Electro-Pressure Membrane Process
Enhanced recovery	Recovery of 90 percent or greater, exceeds the recovery typically obtainable with a conventional reverse osmosis processes using brackish groundwater as feedwater
ºF	Degrees Fahrenheit
Formation plugging	Effect caused by material collecting in geological formation interstices such that it restricts the flow of fluid through the geological formation
gfd	Unit of membrane flux, gallons per square foot of membrane surface area per day
GMA	Groundwater management areas
gpm	Gallons per minute
Hardness	Sparingly soluble mineral salts species such as calcium and magnesium that precipitate in piping and the cause soap scum most noticeable on plumbing fixtures
HERO™ process	High Efficiency Reverse Osmosis Process™
Ion exchange	Process for removing dissolved salts with ion exchange media
kWh	Kilowatt-hour
flux	Permeate production per square foot of membrane surface area
mL/min	Milliliters per minute
MW	Megawatt
MWh	Megawatt-hour
MGD	Million gallons per day
mg/L	Milligrams per liter
NELAP	National Environmental Laboratory Accreditation Program

NEMA	National Electric Manufacturer's Association
NSF	National Sanitation Foundation
O&M	Operation and maintenance
OPEX	Operating expenses
OSHA	Occupational Safety and Health Administration
pCi/L	picoCurie per liter
Permeate	Desalinated product water from a reverse osmosis process
Permeability	Membrane ability to allow water or dissolved solids through the membrane
pH	Metric for the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, decreasing with increasing acidity and increasing with increasing alkalinity
Project	Proposed SAWS Brackish Groundwater Desalination Project
Protocol	Protocol for the VSEP™ pilot
psi	Pounds per square inch
psig	Pounds per square inch gauge
QA/QC	Quality Assurance/Quality Control
Recovery	Percentage of RO process feedwater recovered as permeate
Recovery (Spiral)	Recovery from a Conventional RO Process
Recovery (VSEP™)	Recovery of the VSEP™ process
Redundancy factor	Percent of excess equipment capacity installed to accommodate equipment malfunctions
Reliability	Percentage of time that a given piece of equipment or system will satisfactorily perform its intended function
RO	Reverse osmosis process
Salt rejection	Percentage of dissolved solids removed from system feedwater by the membrane equal to (feedwater salt concentration minus permeate salt concentration) divided by feedwater salt concentration
SAWS	San Antonio Water System
SEM	Scanning electron microscope
Significant Response	Response defined by New Logic Research, Inc. as significant to an anti-scalant dose that produces either: (1) a 25 percent increase in average flux rate during the test; or (2) a 50 percent increase in the flux rate 24 hours after cleaning
Softening	Process for removing hardness from water
Sparingly soluble materials	Dissolved materials with a high tendency to precipitate due to a low solubility
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality
TDS	Total dissolved solids
TPDES	Texas Pollutant Discharge Elimination System
VSEP™	New Logic Research Vibratory Shear Enhanced Process™
ZLD	Zero liquid discharge process
µS/cm	microSiemens per centimeter

1 Executive Summary

As the City of San Antonio ("City") continues to grow, the San Antonio Water System ("SAWS") must investigate new sources of water to meet its projected demand. Since SAWS conducts their analysis with the knowledge that some projects will discarded due to technical, cost, or political reasons, SAWS seeks to incorporate a diversity of sources and takes a conservative approach in assuring that its new water supply projects will provide sufficient capacity to meet the City's future needs. Therefore, SAWS' long-range water planning incorporates a diverse portfolio of potential water supply projects.

One of the sources under development is the Brackish Groundwater Desalination Project ("Project"). The Project is highly desirable because it provides SAWS with additional water resource diversification and a vast, unused resource near the City that is virtually drought-proof and that does not rely on potentially limited Edwards Aquifer resources. Further, the Project is very consistent with SAWS economic criteria because it can be developed with a phased approach to more closely match new facility development with the City's drinking water demand.

The Project will be an inland desalination facility. Consequently, it has limited options for concentrate disposal. The most viable option is deep well injection. Due to the cost of a deep well injection system for concentrate disposal and SAWS established keystone policy objectives related to being a good steward of the environment and promoting the collective public good, SAWS opted to undertake an evaluation of enhanced recovery alternatives. Since the use of a high recovery alternative for a full-scale, 10 to 20 million gallons per day ("MGD") desalination facility is a cutting edge application, SAWS entered into a contract with the Texas Water Development Board (Contract No. 0704830718) to perform an assessment of the viability of high recovery alternatives for the Project.

The evaluation included: (1) an assessment of potentially viable enhanced recovery options to select an enhanced recovery alternative for pilot testing and to provide a baseline for evaluation after pilot testing; (2) a three-month pilot testing program to confirm the operating characteristics of the enhanced recovery option selected for piloting; and (3) an assessment comparing the selected enhanced recovery technology with conventional methods for concentrate disposal for the Project.

The initial step was to identify the enhanced recovery options that were potentially viable for the Project and then to select an alternative for pilot testing. The screening process first eliminated processes that were not considered to be fully commercial at the time of the evaluation. Then the remaining processes were ranked to select the process that best met SAWS criteria for enhanced recovery for pilot testing.

As a result of the screening step, three options were retained for further evaluation[1]:

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[1] Report dated September 17, 2007 Mickley, Mike, P.E., Ph.D., Mickley & Associates, Boulder Colorado, April 21, 2009, Enhanced Recovery Alternatives Review for SAWS Brackish Groundwater Desalination Feasibility Assessment Project. Mickley & Associates served as a subconsultant to R. W. Beck, Inc.

- A thermal brine concentrator
- The Aquatech HERO™ process
- The New Logic Research Vibratory Shear Enhanced Process™ (“VSEP™”) system

Mickley[2] then ranked the three remaining options using the following criteria as metrics:

- Experience in wastewater applications
- Experience in inorganic wastewater applications
- Energy consumption
- Chemical consumption
- Residual solids quantities requiring disposal
- Process simplicity
- Mechanical reliability
- Footprint
- Cost

Based on the ranking process, Mickley recommended selecting the VSEP™ system for further evaluation and piloting. Key performance metrics for the pilot test included effluent quality, recovery efficacy, equipment reliability, and economics.

Pilot testing was conducted in six phases. Phase 1 was used to verify the equipment operated properly, Phase 2 was used to determine if two anti-scalant materials provided sufficient benefits to justify continued use, Phases 3 and 4 were used to optimize the anti-scalant dosing rate with and without acid addition to the VSEP™ feedwater, Phase 5 served to establish an optimum recovery rate for the VSEP™ equipment, and Phase 6 provided an extended run to verify process efficacy at an optimized recovery and anti-scalant dosing rate, economics, and equipment reliability.

The pilot testing showed that:

- The VSEP™ process could reduce the concentrate volume by 50 percent. The recovery of 50 percent was achieved with an anti-scalant dosage of 25 milligrams per liter (“mg/L”).
- A 50 percent reduction in concentrate volume would increase the solids content of the concentrate by approximately 50 percent.
- The permeate from the process during most of Phase 5 appeared to be of sufficient quality such that it could be co-mingled directly with the permeate from the conventional reverse osmosis (“RO”) process provided that New Logic Research could supply equipment that meets the requirements of National Sanitation Foundation/American National Standards Institute (“NSF/ANSI”) Standard 61 (Drinking Water System Components).
- Membrane salt passage increased towards the end of Phase 5 and throughout Phase 6 such that the permeate was not of sufficient quality to be reused without treatment in the Conventional RO Process.

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[2] Mickley & Associates Report dated September 17, 2007.

- Electricity consumption for the pilot unit was approximately 300 kilowatt-hour ("kWh")/1,000 gallons of permeate produced.
- The equipment achieved a 44 percent Availability during Phase 6. The equipment was out of service for mechanical repair for approximately 40 percent of the time and in a chemical cleaning mode for 16 percent of the time during Phase 6.
- Equipment mechanical reliability issues were experienced in Phases 1 and 6. The issues encountered in Phase 1 were associated with a feed pump failure and membrane filter pack gasket leakage. The issues in Phase 6 were related service runs of less than one day and equipment leaks.
- Noise levels in the vicinity of the equipment exceeded 90 decibels ("dB") while the equipment was in service.
- pH adjustment may be a very effective enhancement in terms of run time for the VSEP™ system when processing feedwater with high calcium and bicarbonate levels.

2 Introduction

SAWS periodically reviews its long-range water supply plans to provide assurance that sufficient water resources are available to the City to meet future needs. As the City continues to grow, SAWS must investigate new sources of water to meet its projected demand. Figure 2-1 illustrates SAWS' existing supplies with respect to projected demand through year 2060. Based on the Low, Normal and High water supply demand projections, it is clear that additional water supply must be developed for the future.

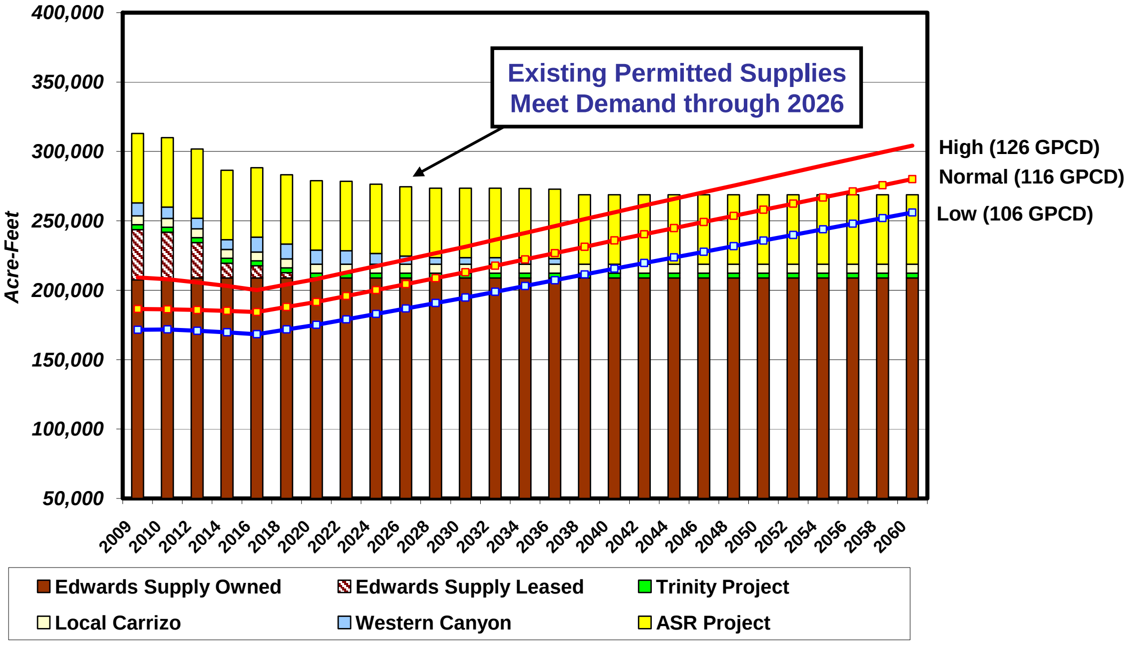

Figure 2-1. Existing Supplies in the Water Resources Portfolio. (Courtesy of SAWS)

As part of SAWS' long-range water planning process, a portfolio of potential water supply projects must be investigated. SAWS conducts the analysis with the knowledge that some projects will be discarded due to technical, cost, or political reasons. Consequently, SAWS seeks to incorporate a diversity of sources and takes a conservative approach in assuring that its new water supply projects will be sufficient to meet the City's future needs.

The primary criteria used by SAWS for investigating new sources of water, and periodically updating SAWS' water supply plan are as follows:

- **Edwards Aquifer Authority Enabling Act Changes** – Senate Bill 3 (2007 Texas Legislative Session) changed the maximum pumping limits from 400,000 acre-feet ("AF") per year to 572,000 AF. Junior/Senior and interruptible pumping limitations were removed and were replaced with a new statutory Demand Management/Critical Period Management ("CPM") regime.
- **Population** – The 2005 population projections did not incorporate the housing boom that occurred in 2005, 2006, and 2007. Consequently, SAWS has used more recent population models to refine the projections in their previous plans.
- **Technical Work** – SAWS has completed considerable feasibility and design efforts for a number of water supply projects. These activities have provided a more comprehensive definition of project implementation requirements and costs.
- **Economic** – Additional information was defined about current construction costs and economic conditions affecting the cost of proposed water supply projects. SAWS has developed a consistent method for analyzing project economics to allow effective comparison between water supply projects.
- **Regulatory/Legal** – The role of groundwater districts in state water planning continues to evolve. Groundwater district rules continue to emerge and Groundwater Management Areas ("GMA") have been established to manage water resources from a more regional perspective. In an effort to establish the desired condition for each aquifer 50 years into the future, the State of Texas has mandated that GMAs determine "Desired Future Conditions" ("DFCs") for each aquifer within their boundaries. DFCs may impact groundwater supply projects under consideration by SAWS.
- **Plan to Meet SAWS Service Area Demand** – SAWS will acknowledge and honor feedback from other communities and purveyors regarding long-range planning for the region. It is recognized that the high ongoing costs to SAWS ratepayers to meet peaking demands of regional water purveyors is not economically sustainable. However, SAWS will continue to plan with other communities, on an equitable partnership basis.
- **Drought of Record Planning** – SAWS will use the Drought of Record for water planning which is consistent with the Regional Water Plan and State Water Plan.
- **Diversification** – SAWS has made considerable progress toward diversification and reduced demand on potable water resources. Since 1998, the Recycled water, Aquifer Storage & Recovery, Western Canyon, Local Carrizo, and Trinity projects have come online. Diversification will always represent a portion of SAWS water supply.

Based on the above criteria, SAWS has elected to include a brackish groundwater desalination project (the Project) in its portfolio of new water supplies. The Project is highly desirable because it provides SAWS with additional water resource diversification and a vast, unused resource near the City that is virtually drought-proof and that does not rely on potentially limited Edwards Aquifer resources. Further, the Project is very consistent with SAWS economic criteria because it can be developed with a phased approach to more closely match new facility development with the City's drinking water demand.

SAWS has also established keystone policy objectives related to being a good steward of the environment and promoting the collective public good. Therefore, SAWS also opted to investigate the benefits of enhanced concentrate recovery as an improvement to the Project to minimize its concentrate disposal and the raw water requirements for the facility. The decision to test the VSEP^{TM} system was reached on the basis of screening studies commissioned by SAWS evaluating available, commercial processes for enhanced recovery that considered technical and economic factors. The screening studies were conducted as part of SAWS feasibility evaluation for the Project.

3 Conclusions

The Project will be an inland desalination facility with limited options for concentrate disposal. Therefore the objectives of the enhanced recovery alternatives evaluation were to identify potentially viable enhanced recovery options, to screen the options to selected an alternative for further evaluation with pilot testing, and to evaluate the feasibility and economics of the option.

Once the potentially viable options were identified, they were screened to determine if they were considered to be fully commercial and had been demonstrated in the United States. Since the options would be used for a 20 MGD municipal drinking water treatment plant, reliability was a paramount criterion. Therefore, alternatives that were not deemed to be commercial were eliminated from further consideration. Three options remained after the initial screening process was completed.

Next, the three remaining processes were ranked to select the alternative that best met SAWS criteria for enhanced recovery for pilot testing. The result of the ranking process indicated that the VSEP^{TM} system manufactured by New Logic Research best met SAWS selection criteria and a decision was made to evaluate the system further with a pilot testing program.

New Logic Research initially estimated that the VSEP^{TM} system might be able to reduce the concentrate waste volume in excess of 50 percent and possibly by as much as 75 percent. A 50 percent reduction in concentrate would save capital costs for the deep wells for concentrate disposal and lower pumping costs for concentrate disposal. Further, the system could also increase the output of the Project by approximately 1.55 MGD provided that the permeate conductivity issues in Phase 6 can be resolved with full-scale VSEP^{TM} equipment and VSEP^{TM} units compliant with the NSF/ANSI Standard 61 (Drinking Water System Components) are provided.

Although it is anticipated that the VSEP™ process will increase the total dissolved solids ("TDS") level of the concentrate from approximately 11,000 mg/L[3] to approximately 22,000 mg/L, there may not be significant changes in the Project schedule or cost per well.

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[3] Average Raw Water Quality for the ASR Test Well installed for the R.W. Beck Feasibility Evaluation. SAWS Brackish Groundwater Desalination Project Water Quality Assessment Technical Memorandum, T. Hickey and H. Steiman to K. Morrison dated October 17, 2008.

Currently, both scenarios would require Class 1 deep well pursuant to Texas Commission on Environmental Quality ("TCEQ") regulations and the salt mass loading from the concentrate would essentially the same.

However, R. W. Beck is of the opinion that other issues revealed by the pilot testing would preclude the use of the VSEP™ option for the Project. Based on the pilot test results, New Logic Research estimated that 204 of their 84-inch VSEP™ units would be required to treat a 4 MGD concentrate flow.[4] For conservatism, New Logic Research included a 30 percent redundancy factor in their design. Assuming a 30 percent redundancy and a flow of 3.09 MGD as estimated by R. W. Beck[5], 158, 84-inch VSEP™ units would be required.

In our opinion, the anticipated operation and maintenance ("O&M") burden of 158 VSEP™ units seems impractical. Further, an estimated $38,700,000 in the combination of capital cost for the units, the potential for reliability issues that could affect the overall Availability of the Project, and electricity consumption in the range of 30.4 kWh (New Logic Research estimate) to 300 kWh (pilot test data) per 1,000 gallons of permeate produced significantly outweigh the potential benefits derived from fewer concentrate disposal wells and an additional 1.55 MGD of finished water output for the 20 MGD facility configuration. It should be noted that Mickley's estimated cost of $6.50 per thousand gallons of equipment cost did not prove to be accurate due to the low fluxes and level of reliability the VSEP™ equipment achieved in Phase 6. These factors increased the required number of VSEP™ units and consequently, increased the capital costs substantially.

In addition, concerns about potential effects on the deep well injection system that will be used for residuals disposal in the Project should be investigated before a decision is made to use the VSEP™ system. Formation plugging is a potential concern since it is expected that the VSEP™ system will operate far beyond the solubility point of various sparingly soluble materials. It is anticipated that these effects on deep well performance would be addressed during subsequent Project design activities in the event that SAWS opts to include a VSEP™ system in the Project.

4 Enhanced Recovery Alternatives Review

4.1 Technology Comparison

The enhanced recovery alternatives review[6] was performed by Mickley and Associates in September 2007. The review methodology used a two-step approach. The first step was to identify the enhanced recovery options that were potentially viable for the Project and eliminate other processes. The second step was to then evaluate the potentially viable options and score them against pre-established evaluation criteria to select an alternative for the pilot testing phase.

For the purposes of the screening analysis: (1) enhanced recovery processes were judged to be viable for the Project only if they were considered to be commercial and had been demonstrated

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[4] New Logic Research, VSEP Pilot Test Report dated November 10, 2010.

[5] Memorandum Tara Hickey and Howard Steiman to Kevin Morrison dated October 17, 2008, SAWS Desalination Project Treatment Options Evaluation.

[6] Mickley, Mike, Mickley and Associates, September 17, 2007, "Enhanced Recovery Alternatives Review for SAWS Brackish Groundwater desalination Feasibility Assessment Project."

in the United States prior to the analysis in 2007; and (2) a process was considered to be commercial only if the process had an established experience record in the United States in terms of use in industrial applications. After performing the screening analysis, Mickley used the following criteria as metrics for scoring each remaining process:

- Experience in wastewater applications
- Experience in inorganic wastewater applications
- Energy consumption
- Chemical consumption
- Residual solids quantities requiring disposal
- Process simplicity
- Mechanical reliability
- Footprint
- Cost

The metrics were selected by Mickley as indicators of process economics, reliability, ease of operation, and the potential for a significant impact on Project design. Each criterion was equally weighted and individually scored on a relative 1 to 5 basis. The total score was then used to identify a process for further evaluation through a pilot study with a score of one representing the best and a score of five indicating the worst.

Factors that were not discriminators were not included by Mickley. For example, inherent fouling and plugging protection was not included as a criterion since it would not have been a discriminator. Assuming appropriate process chemistry is maintained, the thermal brine concentrator, the Proprietary Process (Aquatech HERO™) and VSEP™ system were all designed to provide inherent fouling and plugging protection. Therefore, they would have been scored equally by Mickley.

After eliminating processes that were not considered to be fully commercial, Mickley evaluated the three enhanced recovery approaches he deemed viable: (1) a generic thermal brine concentrator system; (2) the Aquatech HERO™ process, a proprietary process to reduce the level of sparingly soluble materials in the concentrate from the conventional RO system so that additional recovery with an RO process is feasible; and (3) the VSEP™ manufactured by New Logic Research, Inc. Table 4-1 outlines the primary features of these processes.

Table 4-1. Enhanced Recovery Processes Retained for Further Consideration. [a]

Process	Description	Status [b]
Thermal brine concentrator	Thermal evaporative process extensively used for wastewater volume reduction. Creates a high purity product stream requiring disposal or further treatment if zero liquid discharge ("ZLD") is desired.	Used in approximately 150 industrial ZLD processes in the United States at the time the analysis was performed by Mickley.
Aquatech HERO™ process	Pretreatment (typically lime softening or ion exchange and decarbonation used to control the scaling potential of calcium and carbonate. Conditions RO feed such that it allows a higher process recovery. The RO is operated at a high pH if silica is present.	Used in an estimated 20 or so non-municipal applications around the world at the time the analysis was performed by Mickley.
VSEP™	RO membrane based system with membrane utilized in a flat sheet configuration that operates beyond the solubility point of sparingly soluble salts. Vibration induced shear forces used to control membrane fouling. Creates a high purity product stream and a waste brine stream requiring disposal or further treatment if ZLD is desired.	Technology developed in the 1980s. Primarily used for food waste streams and oil/water mixtures at the time the analysis was performed by Mickley.

[a] From Mickley Report dated September 17, 2007.
[b] Judged to be viable for the Project only if they were considered to be commercial and had been demonstrated in the United States prior to the time Mickley conducted the analysis.

The processes eliminated from further consideration by Mickley are listed in Table 4-2.

Table 4-2. Enhanced Recovery Processes Eliminated from Further Consideration. [a]

Process	Description	Status [b]
Geo_Processsor SAL-PROC™ Process	Process consists of a series of volume reduction and salt removal steps for selective salt recovery. Relies on salt solubility characteristics to achieve the selective recovery of various salts.	No commercial demonstrations in the United States at the time the analysis was performed.
Obrien & Gere ARROW™ Process	Process uses a two-stage RO membrane process. Second stage concentrate is treated to remove sparingly soluble salts and then recycled to the inlet of the second stage RO process. Produces a sludge and a small concentrate stream requiring disposal.	No commercial demonstrations in the United States at the time the analysis was performed.
EET HEEPM™ Process	Process uses a proprietary electrodialysis stack that operates in parallel with an RO process. RO process concentrate is recycled back to the RO process feed tank. The RO process feed tank also serves as the feed tank for the HEEPM™ electrodialysis stack and the product water from the HEEPM™ process is recycled back to the RO process feed tank. Thus, the HEEPM™ process reduces the dissolved solids and sparingly soluble salt levels in the RO feedwater so that higher recoveries are feasible. The only process waste stream is from the electrodialysis stack.	No commercial demonstrations in the United States at the time the analysis was performed.
Various ongoing research projects to remove sparingly soluble salts	Process removes sparingly soluble salts from RO feedwater with chemically enhanced precipitation.	No commercial demonstrations in the United States at the time the analysis was performed.
Watervap FBHX	Process uses a fluidized bed heat exchanger in an evaporator to process RO concentrate.	No commercial demonstrations in the United States at the time the analysis was performed.

[a] Based on Mickley Report dated September 17, 2007.

[b] Judged to be viable for the Project only if they were considered to be commercial and had been demonstrated in the United States prior to the time of the analysis.

4.2 Viable Enhanced Recovery Option Evaluation

The VSEP™ was selected for pilot testing based on the evaluation described in Section 4.1. Table 4-3 summarizes the ranking of each alternative that was considered to be viable for the Project. A 1 to 5 relative scoring system was used with 1 being the best and five being the worst. Thus, the lowest score indicates highest ranked process.

Table 4-3. Ranking of Viable Enhanced Recovery Options. [a]

Process	Proprietary Process	VSEP™	Generic Thermal Brine Concentrator
High recovery wastewater experience	3	2	1
High recovery inorganic wastewater experience	3	4	1
Energy consumption	1	2	5
Chemical consumption	4	1	2
Residual solids quantity requiring disposal	4	1	2
Process simplicity	4	1	4
Mechanical reliability	2	5	2
Process footprint	4	1	4
Cost	3	2	5
Total	28	19	26

[a] Reprinted from the Mickley Report dated September 17, 2007.

4.2.1 VSEP™ Process Description and Rating

While there were concerns about the potential for mechanical reliability issues in the VSEP™ system due to the vibratory action of the membrane cleaning process, the VSEP™ system was primarily chosen for the following reasons:

- Lowest cost
- Process simplicity
- Lowest use of chemicals
- Fewer solids produced
- Smallest footprint
- Inherent fouling and plugging protection

New Logic Research originally estimated that their process may be capable of recoveries in excess of 50 percent with the potential to range up to 75 percent of the concentrate stream from the Conventional RO Process. In this scenario, the VSEP™ permeate would then likely be reused as feedwater for the Conventional RO Process. Thus, if such recoveries with the VSEP™ prove feasible, the VSEP™ would produce significant benefits for the Project including: (1) a proportionate reduction in the volume of the concentrate residuals stream and the size of the deep well injection system; and (2) the higher overall process recovery would reduce the amount of feedwater required to produce 25 MGD of finished water.

The VSEP™ process differs significantly from a Conventional RO Process. Conventional RO Processes use spiral-wound RO membrane elements for economic reasons to maximize membrane area for a given equipment footprint. Figures 4-1 and 4-2, provided courtesy of Hydranautics, show the construction of a typical spiral-wound RO membrane element.[7] With the spiral-wound construction, to maximize the membrane area for a given RO element diameter,

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[7] Bates, Wayne T., Bartels, Craig, and Franks, Rich, Hydranautics, Oceanside, CA, 2008, "Improvements in Spiral Wound RO and NF Membrane & Element Construction for High Fouling Feedwater Applications"

membrane leaves and feed spacer mesh are wound around a pipe used to transport the permeate. For example, using this construction, 40-inch long RO elements with an 8-inch diameter for brackish water applications can provide up to 440 square feet of membrane surface for filtration. However, this membrane element construction requires a relatively thin feed spacer between the layers of the membrane surface. As explained by Bates, et. al., the feed spacers used for spiral-wound RO elements have typically been 26 mils to 31 mils thick.[7] Figure 4-2 shows a magnified view of a feed/brine spacer obtained with a scanning electron microscope (“SEM”).

Figure 4-1 also illustrates that the bulk feedwater flow is parallel to the membrane surface and filtration is in a perpendicular direction. Hence, this configuration is called cross-flow filtration. In a cross-flow filtration configuration such as this, due to the thickness of the brine spacer, feedwater and concentrate suspended solids concentrations, flux levels, and the shear force created by the cross-flow action are all important considerations to prevent membrane fouling. High suspended solids levels will lead to solids deposition. Similarly, high flux levels can lead to the rapid build-up of deposits as well. However, the shear force created by the cross-flow action tends to prevent the deposition of solids on the membrane surface. Consequently, the shear force needs to be high enough to help prevent solids deposition without being too high which can affect membrane performance and cause membrane damage. Therefore, membrane manufacturers’ generally establish guidelines for feedwater contaminants, membrane flux levels and the bulk flow of fluid through their membrane elements.

These factors are often further complicated by fluid chemistry changes while the fluid transforms from feedwater to concentrate as the feedwater flows from the membrane element inlet to the outlet. As the fluid flows from the element inlet to the outlet, permeate is forced through the membrane by pressure applied to the feedwater. Thus, due to the production of permeate, the concentration of impurities in the feedwater and the pH both increase. The attendant increases in impurity concentration and pH promote the precipitation of sparing soluble salts such as calcium carbonate, barium sulfate, strontium sulfate, and calcium fluoride, and other materials such as silica. As a result, some combination of RO feedwater pretreatment processes to remove suspended solids, lower pH, and add anti-scalant materials are frequently employed when cross-flow RO processes are used.

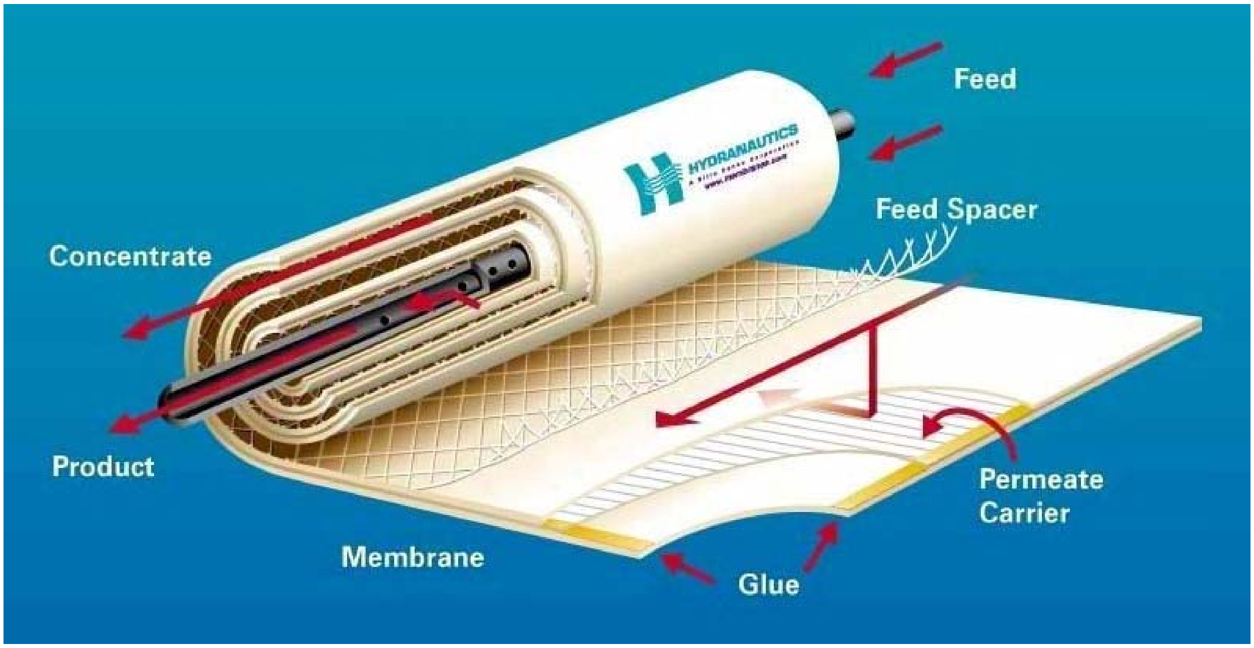

Figure 4-1. **Typical Spiral-Wound RO Element Configuration. (Courtesy of Hydranautics)** (refer to previous Footnote 7)

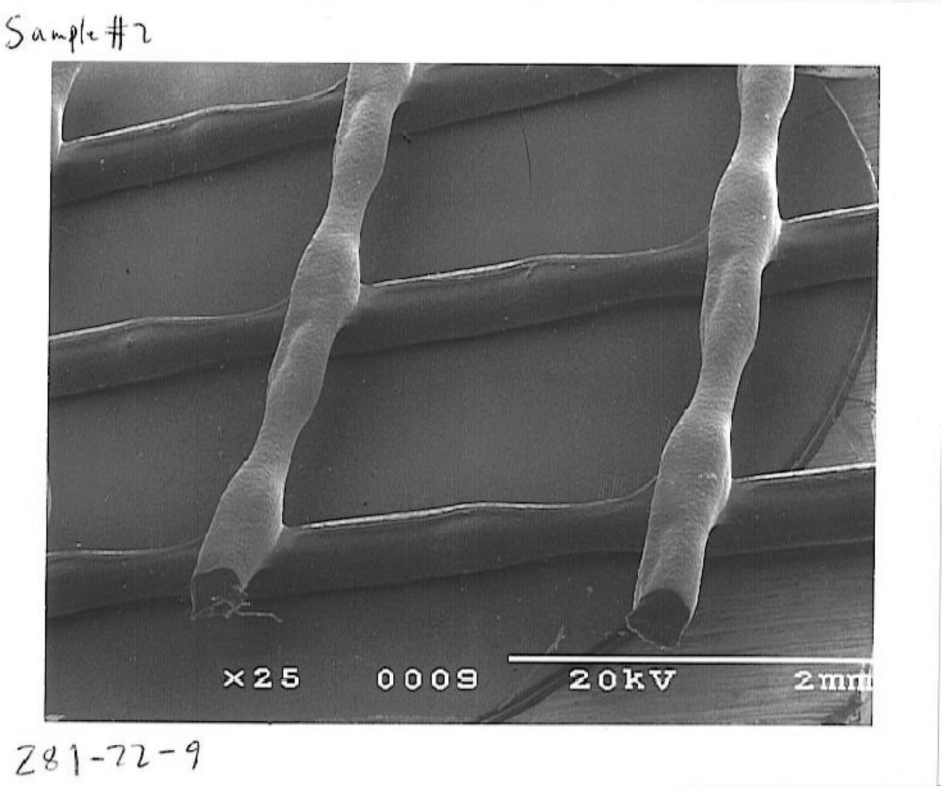

Figure 4-2. **Feed Spacer - Magnified View. (Courtesy of Hydranautics)** (refer to previous Footnote 7)

Figures 4-3 and 4-4 depict conceptual renderings of the VSEP™ equipment. As shown, the configuration of the VSEP™ process is significantly different than that used for the Conventional RO Process which uses spiral wound membrane elements. In the VSEP™ process, the RO membrane leaves are configured in a flat-sheet arrangement in a filter pack. Thus, maximizing membrane area for a given equipment footprint is not the primary goal. Instead, the filter pack arrangement provides more space between membrane surfaces to minimize membrane fouling with the New Logic Research vibration-enhanced membrane cleaning process. As a result, based on their experience, New Logic Research places less emphasis on feedwater and concentrate fouling characteristics than that normally associated with a Conventional RO Process. Therefore, while New Logic Research anticipated that anti-scalant addition would be beneficial, they did not foresee the need for acid as a feedwater conditioning agent.

In the actual VSEP™ system, feedwater to the VSEP™ system is drawn by a feed pump through two 100-mesh strainers arranged in parallel which are used to protect the RO membranes in the system (the strainers are not shown in the conceptual rendering depicted in Figure 4-3). After leaving the strainers, the feedwater is pumped into the RO membrane filter pack where the permeate is forced through the membranes by the pressure imparted by the feed pump so that the flow is separated into permeate and concentrate streams. Permeate is collected in a center plenum in the filter pack and discharged. After a pre-set time interval related to the desired recovery, concentrate is discharged from the bottom of the filter pack via Valve 1. Consequently, the VSEP™ system is not actually a cross-flow filtration system like a Conventional RO Process. Instead, the VSEP™ process more closely resembles dead-end filtration where all of the filter feed is forced through the filter media.

New Logic Research did not specify a maximum flux limitation. Therefore, as explained in Appendix II, initial permeate flux levels reach 53 gallons per square foot (“gfd”). As a benchmark, 53 gfd is 3.8 to 2.9 times the 14 gfd to 18 gfd range of average flux often used in brackish water desalination with a convention, spiral wound RO process.

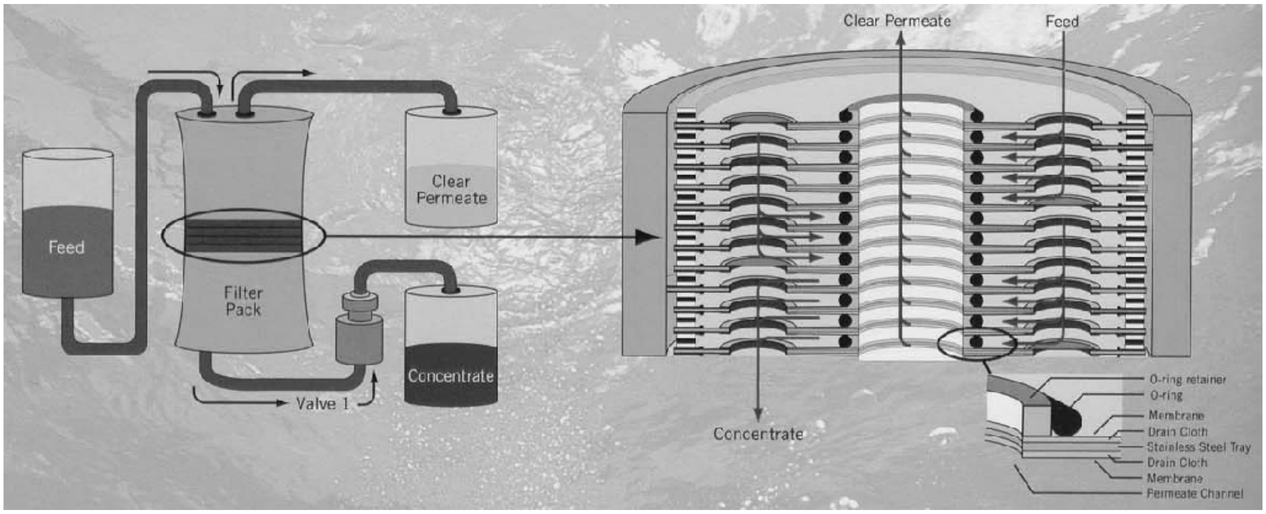

Figure 4-3. **VSEP™ Flow Diagram.**[8]
(Courtesy of New Logic Research)

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[8] Figure courtesy of New Logic Research, Inc.

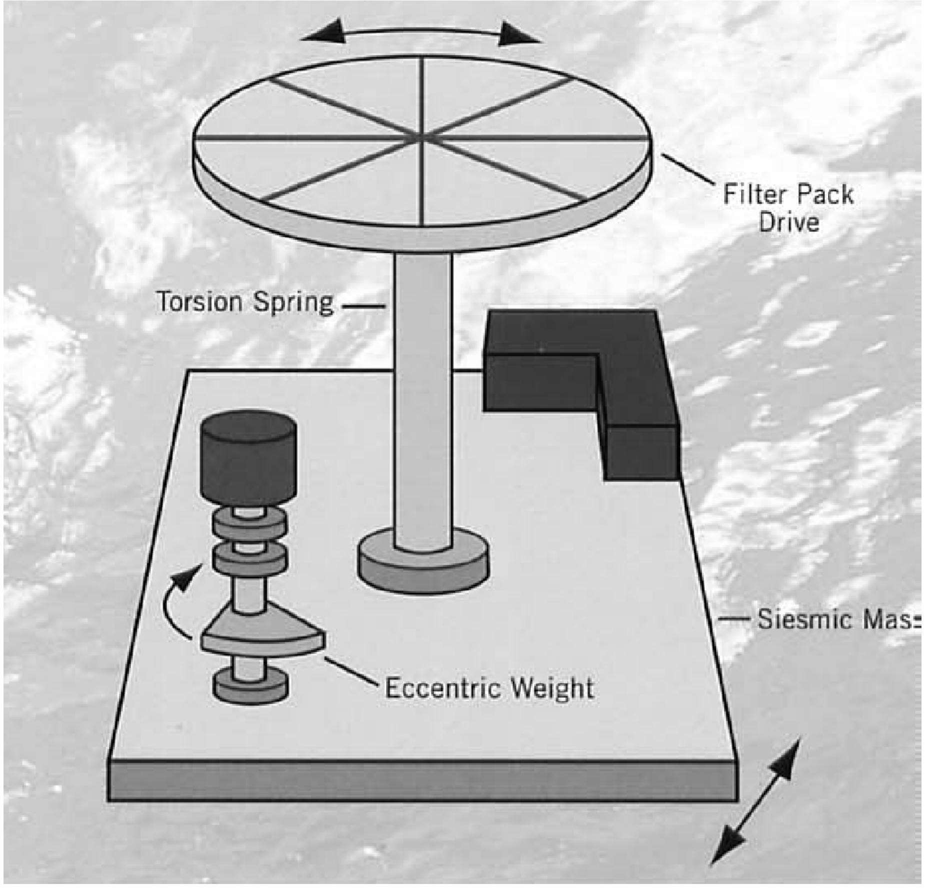

Figure 4-4. **VSEP™ Resonating Drive System.**
(Courtesy of New Logic Research)

The membranes in the filter pack are configured such that they are layered over a drain cloth on the top and the bottom of a stainless steel tray used to provide support and convey permeate into the center plenum. The seal at the plenum is provided by an O-ring and O-ring retainer. The membranes, drain cloths and steel trays are clamped to the exterior side of the filter pack to hold them in place.

The filter pack is mounted on top of a torsion spring mounted on a seismic mass. An eccentric weight on the seismic mass is then used to vibrate the filter pack. According to New Logic Research, membrane fouling is prevented by the oscillation of the filter pack with a torsion spring since the oscillation creates a shear force at the membrane surface. New Logic Research's VSEP™ product literature states[9] that this shear rate is approximately ten times the shear rate of a conventional cross-flow RO system. Therefore, New Logic Research's VSEP™ product literature[10] further states the shear serves to sweep particulate matter away from the membrane surfaces and; thereby, provides a cleaning action that allows the VSEP™ system to operate at

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[9] http://www.vsep.com/pdf/VSEP_Brochure.pdf.

[10] http://www.vsep.com/pdf/VSEP_Brochure.pdf.

very high solids levels. A cleaning solution is also periodically needed to maintain membrane performance. VSEP™ product literature[11] further states that the high shear also allows a maximum throughput that is typically between three and ten times the throughput of conventional cross-flow systems.

An automated version of a Series L/P VSEP™ system in an L mode (single membrane filter pack) was selected by New Logic Research for the test program. Table 4-4 summarizes the New Logic Research specifications for their equipment and indicated operating pressures up to 600 pounds per square inch ("psi") are permissible. Since it is related to osmotic pressure and membrane cleanliness, operating pressure varies as a function of VSEP™ system concentrate TDS levels and membrane fouling. An operating pressure of 500 psi was expected by New Logic Research for this pilot program.

The specifications also indicate that the VSEP™ system rated for continuous operation in an ambient temperature range of 32 to 104 degrees Fahrenheit ("°F") or (0 to 40 degrees Celsius ("°C"). While these conditions reflect typical specification limitations often used for equipment, maintaining the ambient temperature conditions for equipment installed in Texas likely requires that the equipment be housed in an enclosure with ventilation for temperature control.

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[11] http://www.vsep.com/pdf/VSEP_Brochure.pdf.

Table 4-4. New Logic Research Series L/P VSEP™ Specifications.

Filter Pack

Membrane Area - L Mode: 0.48 square feet (0.16 square meters)

Filtrate Removal Capacity: 2.25 gallons per minute (gpm") (8,500 milliliters per minute ("ml/min")

Maximum Operating Pressure: 600 psi (41 bar)

Wetted Materials: 316 Stainless Steel, Polypropylene, EPDM

Vibration Drive System

Motor: Baldor, 2 horsepower, 1,725 RPM

Speed Controller: ABB ACS401600422

Drive Bearings: Morse Sealmaster RFB2102

Electrical Specifications

Power Supply Voltage: 208-24- VAC 3 Phase

Normal Full Load Operating Current: 9-12 Amps

Required Receptacle: National Electric Manufacturers Association ("NEMA") L15-30, 30 Amp Circuit

Feed System

Pump: Hydra-Cell

Motor: Baldor, 2 horsepower

Pump Bypass Valve: Wanner

Pump Motor Controller: ABB ACS401600522

Voltage: Wanner

Control Valve at Process Outlet: Parker

Actuator: Parker Model 71

Instrumentation

Pressure Gauges: Ashcroft Model 1009 (0-600 psi [0-41 bar])

Temperature Probe: Ashcroft Type 2410E Digital

Conductivity Monitor/Controller: Myron Model 758 Series II

Conductivity Sensor: Myron Model CS51

pH/ORP Controller: Oakton Model WD-35100-10

pH/ORP Electrode: Cole-Parmer Model EW-27011-11

Flow Meter: King Instruments Model 7511

Operating Site Conditions

Equipment Rating: NEMA 4, Indoor-Outdoor (Protect from Sun and Rain)

Ambient Temperature: 32 to -104°F or 0 to 40°C

Storage Temperature: -4 to 140°F

Relative Humidity: 90 percent or less (Non-Condensing)

Elevation: 3,300 feet (1,006 meters) without De-rating

4.2.2 Brine Concentrator Rating

There is an extensive amount of experience with brine concentrators used to recover wastewater and inorganic wastewater. According to Mickley, there were more than 120 such applications as of 2007. When properly designed and operated, brine concentrators are reliable processes that are effective in achieving volume reduction.

Brine concentrators use thermal energy to distill water. The salts in the feedwater are retained in the brine. Therefore, they produce a high purity product stream and a brine waste stream. A brine waste stream is required to achieve internal chemistry control. The quantity of brine is generally a function of the brine concentrator materials of construction, the concentration of impurities in the feedwater, and the solubility of the various salts and scaling materials in the feedwater. The chemistry of the liquor in the concentrator must be controlled to prevent equipment damage from corrosion and minimize heat transfer efficiency losses due to heat transfer fouling and scaling.

Brine concentrators have two primary drawbacks. They have high capital and operating costs. Since they must be capable of withstanding highly concentrated salt solutions at elevated temperatures, they often are constructed with expensive, highly corrosion resistant components using materials such as titanium. Further, they have a relatively large footprint. Thus, they are capital intensive. Brine concentrators are also very energy intensive. According to Mickley, they consume 65 to 95 kWh per thousand gallons of product water. As a benchmark, this is more than 20 times the energy consumption of a brackish water desalination facility using an RO process.

Consequently, Mickley ranked the brine concentrator process higher for experience, chemical consumption and mechanical reliability factors and lower for cost, energy consumption, footprint, and process simplicity factors.

4.2.3 Aquatech HERO^{TM} Process Rating

Mickley's September 2007 report describes the Aquatech HERO^{TM} Process that would use a lime softening step followed by an additional RO stage. Thus, he did not envision that it would be necessary to use ion exchange and decarbonation steps in the Aquatech HERO^{TM} Process for the Project. Since the process would use several unit operations including pH control, lime slaking, lime addition, and produce a sludge that would need to be dewatered prior to disposal, Mickley ranked the process lower for process simplicity, chemical consumption, residual solids production, and footprint. However, he rated it higher for mechanical reliability and energy consumption because the process involves conventional, commonly used water treatment processes. Mickley also rated the process midway between a high and a low rating for high recovery wastewater experience and cost. According to his evaluation, cost is moderate since several unit operations are needed, but standard, commercial components are used. Similarly, while standard, commercial components are used, the Aquatech HERO^{TM} Process did not have extensive experience in wastewater applications at the time the evaluation was performed.

4.2.4 Baseline Economics

Mickley estimated order-of-magnitude capital costs and O&M expenses for the Aquatech HERO^{TM} , VSEP^{TM}, and brine concentrator processes. As shown in Figure 4-5 below, depicting costs provided by Mickley, the estimated capital expenses ("CAPEX") in the range of $24 to $25 per thousand gallons for a brine concentrator (thermal evaporative process), $16 to $17 per thousand gallons for the Aquatech HERO^{TM} process (enhanced pretreatment), and $9 to $10 per thousand gallons for the VSEP^{TM} process.

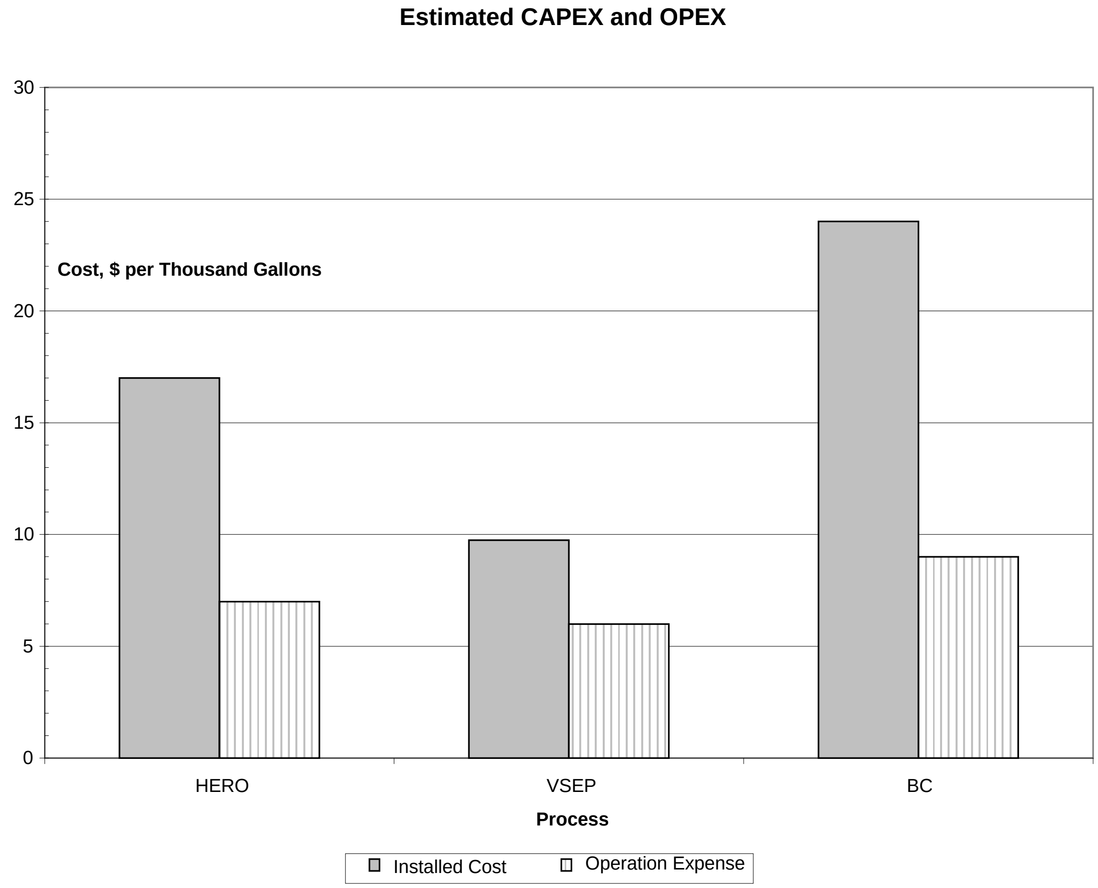

Figure 4-5. Typical Equipment and Total Package CAPEX for the Desalination Processes.

The methodology used by Mickley for estimating installed cost considered the complexity, the degree to which the process is modular and footprint of the process. Based on these characteristics, Mickley used a factor from 1.5 to 2.0 to multiply equipment costs to account for installation costs. Values of 1.2 to 2.0 are often used for this purpose. Due to the complexity of the processes, the range of 1.5 to 2.0 appears reasonable. Table 4-5 shows the factors for each process.

Table 4-5. Process Installed Cost.

Process	Equipment Cost $ per Thousand Gallons	Installation Factor	Installed Cost $ per Thousand Gallons
VSEP™	6.5	1.5	9.75
HERO™	8.5	2	17
Brine Concentrator	12	2	24

Mickley selected a factor of 2.0 for the HERO™ and brine concentrator alternatives due to their complexity. He opted to use a factor of 1.5 for the VSEP™ option because it is modular.

5 Initial Water Quality and Testing Conditions

5.1 Test Conditions

The pilot test configuration was developed to simulate the actual field conditions the VSEP™ equipment would encounter if used for a full-scale application in the Project. If used, concentrate from the Conventional RO Process would be routed to the VSEP™ equipment for volume reduction and enhanced process recovery for the full-scale application. Therefore, as shown in Figure 6-1 herein, the VSEP™ pilot equipment was installed such that its feedwater was supplied from the actual concentrate stream from the pilot that SAWS used to test the RO membranes for the full-scale Conventional RO Process for the Project. Both the VSEP™ and the RO pilot units were installed at the SAWS Twin Oaks Aquifer Storage and Recovery ("ASR") Facility. The pilot for the Conventional RO Process was designed, provided, and operated by others.

The raw water for the pilot for the Conventional RO Process was withdrawn from the test well installed by SAWS for the feasibility study for the Project. The raw water was treated with acid and anti-scalant and processed through the pilot for the Conventional RO Process. The pilot for the Conventional RO Process was operated with recoveries that varied from 85 percent for the first month of the VSEP™ pilot program to 90 percent for the balance of the pilot test. The VSEP™ equipment was challenged at various recoveries exceeding 45 percent.

5.2 Conventional RO System Water Quality

The VSEP™ pilot system used the concentrate from the pilot testing of the Conventional RO Process as feedwater. Table 5-1 depicts the average raw water, concentrate and permeate qualities from the Conventional RO Process that were anticipated in the protocol for the VSEP™ pilot (the "Protocol"). The Conventional RO Process uses the test well at SAWS ASR site as a raw water source. The raw water quality constituents in Table 5-1 were obtained from laboratory test data obtained during the SAWS feasibility assessment for the Project (LBG Guyton, May 2008, SAWS Brackish Wilcox Groundwater Investigation Southern Bexar and Northern Atascosa Counties, Texas). The concentrate and permeate concentration values shown were estimated by modeling RO system performance using Dow-FilmTec ROSA v6.1.5 ConfigDB U238786_55 freeware. Since it is likely that the pilot for the Conventional RO Process test will demonstrate that a recovery in the range of 80 to 90 percent is feasible, permeate and concentrate cases for 80, 85, and 90 percent were modeled. The modeling for the Conventional RO Process system was conducted assuming a two-stage design per the R. W. Beck feasibility report dated October 2008. The R. W. Beck feasibility report used 85 percent recovery as a design point for the Conventional RO Process studied.

Table 5-1. R. W. Beck Feasibility Report Modeled Conventional RO Pilot Quality Constituents.

Constituent		ASR Test Well Water Quality[12]	Conventional RO Pilot Concentrate Quality					
			80 Percent Recovery		85 Percent Recovery		90 Percent Recovery	
			Concentrate	Permeate	Concentrate	Permeate	Concentrate	Permeate
NH_4^{+1}	mg/L	0.92	4.10	0.13	5.35	0.14	7.82	0.15
K^{+1}	mg/L	8.50	41.70	0.20	55.20	0.22	82.72	0.26
Na^{+1}	mg/L	395.70	1,947.88	7.48	2,579.93	8.32	3,870.22	10.14
Mg^{+2}	mg/L	22.80	113.26	0.17	150.26	0.20	226.10	0.24
Ca^{+2}	mg/L	43.70	217.12	0.33	288.04	0.37	433.45	0.45
Sr^{+2}	mg/L	0.01	0.05	0.00	0.06	0.00	0.10	0.00
Ba^{+2}	mg/L	0.01	0.05	0.00	0.07	0.00	0.10	0.00
CO_3^{-2}	mg/L	0.70	29.70	0.00	44.33	0.00	78.72	0.00
HCO_3^{-1}	mg/L	247.90	1,159.33	5.75	1,524.29	6.40	2,258.83	7.81
NO_3^{-1}	mg/L	1.00	3.42	0.37	4.26	0.40	5.76	0.45
Cl^{-1}	mg/L	245.71	1186.19	5.15	1,570.63	5.71	2354.78	6.94
F^{-1}	mg/L	1.31	6.31	0.03	8.34	0.04	12.49	0.05
SO_4^{-2}	mg/L	516.26	2,512.08	5.85	3,330.70	6.54	5,006.58	8.00
SiO_2	mg/L	19.40	95.79	0.29	127.03	0.31	190.99	0.36
B^{+3}	mg/L	0.01	0.02	0.01	0.02	0.01	0.03	0.01
CO_2	mg/L	10.30	10.47	4.57	14.08	4.90	22.60	5.44
TDS	mg/L	1,488.12	7,317.09	25.80	9,688.62	28.68	14,528.81	34.91
pH	SU	7.91	7.95	6.27	7.90	6.29	7.82	6.33

SAWS opted to use a three-stage design for a 90 percent recovery for its pilot testing program for the Conventional RO Process. Table 5-2 contains permeate and concentrate water quality information predicted by modeling performed by others for a 90 percent recovery in the three-stage pilot design used for SAWS pilot program for the Conventional RO Process.[13] As shown, the conventional RO system water quality predicted for the three-stage design is similar to that for the 90 percent recovery case in Table 5-2. However, it differs in specific instances where different raw water characteristics were used. Specific examples include: sodium, bicarbonate and TDS. The basis for the raw water data used in Table 5-2 for the modeling the three-stage design was not defined in the protocol for the pilot testing program for the Conventional RO Process.

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[12] Average Raw Water Quality for the ASR Test Well installed for the R.W. Beck Feasibility Evaluation. SAWS Brackish Groundwater Desalination Project Water Quality Assessment Technical Memorandum, T. Hickey and H. Steiman to K. Morrison dated October 17, 2008.

[13] Carollo Engineers, San Antonio Water Systems (SAWS) Membrane Pilot Test Protocol, Brackish Groundwater Desalination Project, Final, dated June 2008.

Table 5-2. Modeled Conventional RO Pilot Quality Constituents.

			Conventional RO Pilot Concentrate Quality. Modeling provided by SAWS[14]					
			85 Percent Recovery		90 Percent Recovery		85 Percent Recovery	
			Two-stage RO System Toray		Three-stage RO System Dow		Three-stage RO System Hydranautics	
Constituent		Feedwater Quality	Concentrate	Permeate	Concentrate	Permeate	Concentrate	Permeate
NH_4^{+1}	mg/L	0.0	0.0	0.0	0.00	0.00	0.0	0.000
K^{+1}	mg/L	7.8	51.0	0.15	74.85	0.33	50.4	0.282
Na^{+1}	mg/L	444.9[15]	2,921	7.61	4,043.45	14.19	2,892.8	12.925
Mg^{+2}	mg/L	21.9	145	0.1	216.32	0.31	145.2	0.134
Ca^{+2}	mg/L	42.7	284	0.2	421.89	0.59	283.2	0.262
Sr^{+2}	mg/L	0.000	0.0	0.0	0.00	0.00	0.000	0.000
Ba^{+2}	mg/L	0.028	0.19	0.001	0.27	0.00	0.186	0.000
CO_3^{-2}	mg/L	4.0[16]	22.4	0.0002	50.14	0.00	2.2	0.000
HCO_3^{-1}	mg/L	381.0[17]	2,155	9.2	2,557.58	11.47	2,092.8	18.172
NO_3^{-1}	mg/L	0.0	0.0	0.0	0.00	0.00	0.0	0.000
Cl^{-1}	mg/L	230.0	1,511	3.96	2,220.91	8.89	1,492.9	7.128
F^{-1}	mg/L	1.3	8.98	0.0159	13.04	0.06	8.2	0.079
SO_4^{-2}	mg/L	506.0	3,636	3.86	5,266.44	11.54	3,659.1	4.325
SiO_2	mg/L	21.8	141	0.73	213.77	0.48	142.6	0.48
B^{+3}	mg/L	0.00	0.0	0.0	0.00	0.00	0.00	0.00
CO_2	mg/L	3.22[18]	40.8	41.1	48.78	30.17		
TDS	mg/L	1,661.4[19]	1,0872	25.8	15,078.66	47.86	10,769.6	43.8
pH	SU	8.0	7.75	5.5	7.52	5.73	7.7	5.8

VSEP™ performance was not modeled as the manufacturer does not have a publicly distributed performance model available for their process.

6 VSEP™ Pilot Testing Protocol

The Protocol discusses the purpose of the program, the goals and objectives of the pilot testing program, the pilot testing equipment, initial raw water quality of the ASR test well, VSEP™ equipment feedwater quality, test conditions, test procedure, and the test management, monitoring and quality assurance/quality control ("QA/QC") activities. It also provides a process flow diagram and identifies the Project team and delineates their role and responsibilities. The protocol for the VSEP™ pilot program is included as Appendix I hereto.

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[14] Carollo Engineers, San Antonio Water Systems (SAWS) Membrane Pilot Test Protocol, Brackish Groundwater Desalination Project, Final, dated June 2008.

[15] A sodium ("Na") value of 381.00 mg/L for the raw water was used to model the Dow membranes.

[16] A carbonate ("CO_3") value of 3.78 mg/L for the raw water was used to model the Toray membranes.

[17] A bicarbonate ("HCO_3") value of listed as 307.00 mg/L for the raw water was used to model the Dow membranes.

[18] A carbon dioxide ("CO_2") was listed as 3.78 mg/L for the raw water was used to model the Toray membranes.

[19] A TDS value of 1,523.61 mg/L for the raw water was used to model the Dow membranes.

6.1 Pilot Test Goals and Objectives

The goals of the VSEP™ system pilot testing program were to investigate process effluent and residuals quality and quantity and system reliability to facilitate a decision about incorporating VSEP™ into the design. These goals were selected to confirm scale-up factors for the full-scale process in terms of process economics, reliability, ease of operation, and the potential for a significant impact on Project design. Further, the process effluent goals were selected to determine if the permeate from the VSEP™ equipment could be directly blended with the permeate from the Conventional RO Process prior to post treatment or if the VSEP™ permeate should be treated with the Conventional RO Process instead. The quality and quantity of the VSEP™ concentrate would be important factors in determining if suitable disposal options exist. For example, test data shows the concentrate TDS ranged to approximately 26,000 mg/L. Thus, if deep well injection is considered for use, the concentrate will need to be injected into a Class 1 well.

The purpose of the piloting is to assess the performance of the VSEP™ equipment if used as an enhanced recovery stage for the Project. Therefore, the goals of the VSEP™ equipment piloting program are to:

- Evaluate the efficacy of the VSEP™ system to accomplish a reduction in concentrate volume under the conditions in the Project
- Identify the need for any process chemical addition such as acid or anti-scalant and, if so, to estimate dosing requirements
- Evaluate the operational reliability of the VSEP™ system
- Determine the required frequency for chemical cleaning operations and chemical consumption
- Identify process interface requirements and scale-up factors for full-scale application
- Develop the data necessary to conduct a technical and economic benefit assessment of VSEP™ after pilot testing is complete

6.2 Sampling and Testing Plan

Data collected for the assessment included, but was not limited to:

- Recovery
- Permeate and concentrate flow rate
- Feedwater (inlet), concentrate (exit), and permeate pressures
- Feedwater temperature
- Water quality of feed, concentrate, and permeate
- Membrane flux
- Membrane salt rejection
- Feedwater, concentrate, and permeate chemical constituents
- Energy use
- Membrane cleaning frequency
- Time required for cleaning/downtime from production

- Chemical use (from cleaning)
- Amount of operational labor required
- Operational and/or reliability issues
- Changes in protocol
- Need for peripheral equipment on full-scale process – tanks, additional control systems, instrumentation, etc.

The Protocol included in Appendix I herein contains complete descriptions of the test procedures and data collection requirements.

6.3 Schedule for Pilot Testing Activities

As described in the Protocol, testing was originally scheduled to be conducted in six phases. These are described in Table 6-1.

Table 6-1. Pilot Test Phases as Originally Conceived.

Phase	Description	Purpose
1	Initial Run-in and Tune-up Period	Verify equipment operability.
2	Anti-scalant Response Testing - On/Off	Determine if the two anti-scalant materials selected for testing provide sufficient benefits to justify their continued use.
3	SpectraGuard SC^{TM} Dosing Optimization Testing	Optimize the dosing rate for SpectraGuard SC^{TM} without acid.[19]
4	PT-100/400 Dosing Optimization Testing	Optimize the dosing rate for PT-100/400 without acid.[19]
5	Recovery Optimization Testing	Establish an optimum VSEP™ equipment recovery rate for the equipment reliability test.
6	Equipment Reliability Testing	Provide an extended run to verify process efficacy at an optimized recovery and anti-scalant dosing rate, economics, and equipment reliability.

However, based on the data we observed during testing Phases 2 and 4, we altered the test sequence. Table 6-2 describes the purpose and actual duration of each phase after adjustments optimizing the Protocol based on actual test data were incorporated. Test durations and the basic equipment performance testing procedures for each phase of piloting were established by New Logic Research on the basis of their experience in operating their VSEP™ equipment.[20] Phase 3 was not performed as dosing with Anti-scalant 1, SpectraGuard SC^{TM}, since SpectraGuard SC^{TM} did not produce a significant response. The acid conditioning test in Phase 4B was added because the testing in Phase 4 indicated that calcium carbonate precipitation was potentially a

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[19] Based on their experience with the effectiveness of the vibratory shear process for membrane surface cleaning, New Logic Research did not anticipate that feedwater conditioning with acid would be necessary.

[20] E-mails Roger Torres, New Logic Research to Howard Steiman dated September 26, 2007, 3:26 PM and April 7, 2009, 4:08 PM.

limiting factor for the VSEP™ equipment run time between chemical cleanings.[21] Phase 5 was shortened from 20 days to 15 days since, based on the previous test data, three recovery levels were tested rather than 4 recovery levels (5 days per recovery level). Similarly, Phase 6 was reduced from 40 days to 30 days based on previous results.

Table 6-2. Pilot Test Phases.

Phase	Description	Duration (Days)
Phase 1	Initial Run-in and Tune-up Period	5
Phase 2	Anti-scalant Response Testing - On/Off	5
Phase 3	SpectraGuard SC™ Dosing Optimization Testing	0
Phase 4	PT-100/400 Dosing Optimization Testing	6
Phase 4B	pH Response Testing	1
Phase 5	Recovery Optimization Testing	15
Phase 6	Equipment Reliability Testing	30

6.3.1 Testing Parameters and Pilot Unit Set-up

The key test parameters were:

- Feed pressure: 500 pounds per square inch gauge (“psig”) – constant in all phases of testing
- Vibration amplitude: 3/4 inch – constant in all phases of testing
- Anti-scalant: Anti-scalant material and dosing varied in Phases 2 – 6
- Recovery (VSEP™): 65 percent and 75 percent in Phase 2; 55 percent in Phase 4; 45 percent, 50 percent and 55 percent in Phase 5; and based on the results from Phase 5, 50 percent in Phase 6
- Recovery (Spiral): 80 – 90 percent - established by the pilot testing program of the Conventional RO Process
- pH (VSEP™): Not adjusted – established by the pilot testing program for the Conventional RO Process
- Cleaning procedure: NLR 404/NLR 505 – constant in all phases of testing
- Cleaning frequency: To be determined via testing – consistent approach in all phases of testing

6.4 Process Flow Diagram

Process Flow Diagram PFD 001, depicted in Figure 6-1, provides a process flow diagram for the pilot configuration, sampling and chemical feed facilities. As shown, concentrate from the pilot for the Conventional RO Process for SAWS full-scale 20 MGD facility is dosed with anti-scalant and routed to a 100-gallon feed tank. The feed pump draws the feedwater through a duplex

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[21] Acid conditioning was used as a means to lower the VSEP™ equipment feedwater pH since a pH reduction also would reduce the tendency of calcium carbonate, which is a sparingly soluble salt, to precipitate. As shown in Tables 5-1 and 5-2, process modeling predicted the feedwater would contain relatively high levels of calcium and bicarbonate ions as feedstock for the formation of calcium carbonate.

100-mesh strainer system and pumps the feedwater through the VSEP™ equipment. The VSEP™ permeate and concentrate streams are then both routed back to a mixing tank at the conventional pilot unit where the streams are commingled prior to disposal.

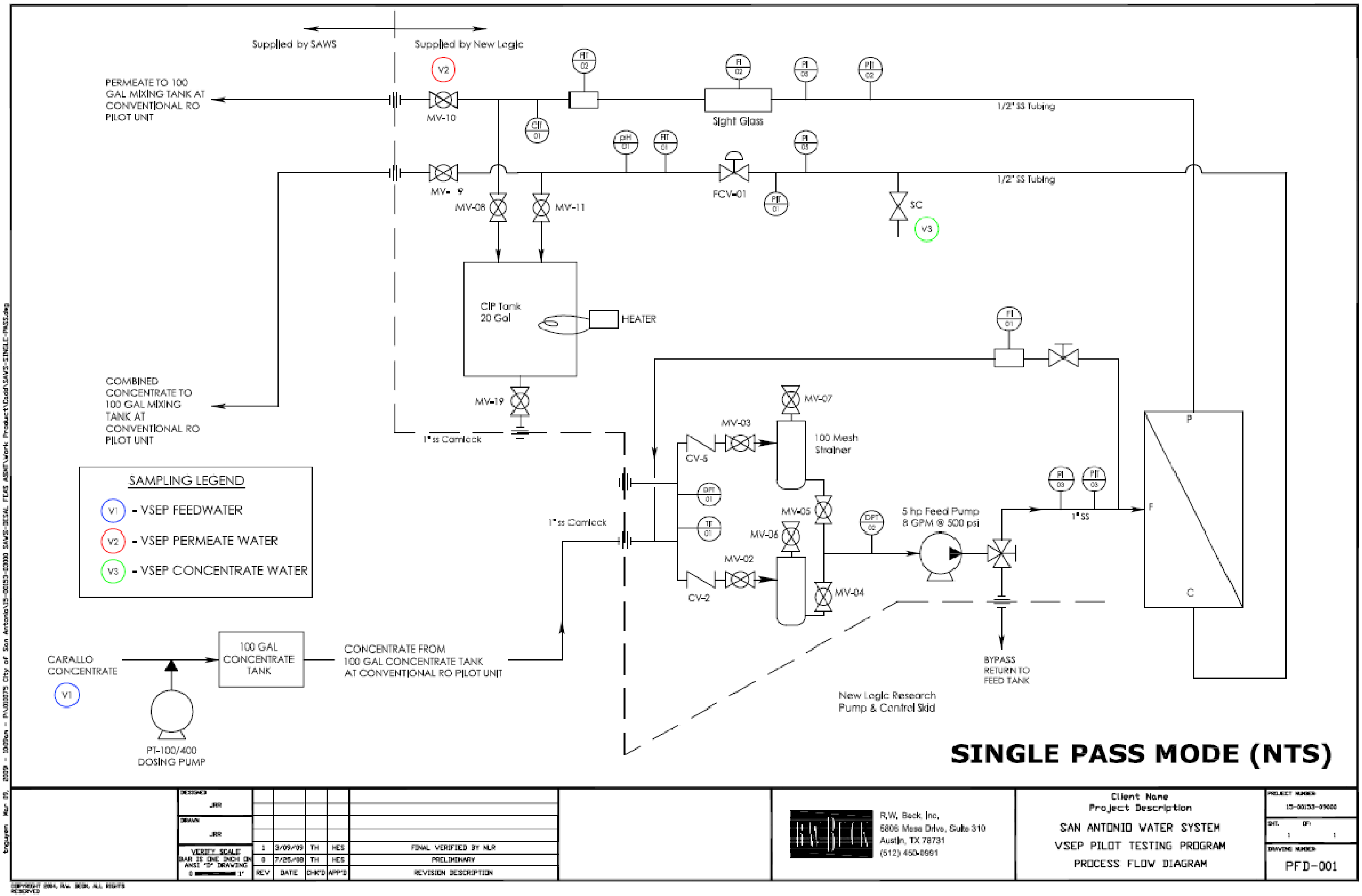

Figure 6-1. Process Flow Diagram for the Pilot Configuration.

6.5 Cleaning Requirements and Schedule

There are many factors potentially affecting cleaning effectiveness and consequently flux restoration after cleaning. These include:

1. The nature and thickness of the material deposited on the membrane;
2. The cleaning chemicals used and their sequence of application;
3. The concentration of the cleaning chemicals, the temperature of the cleaning solutions, and the amount of contact time between the membrane and the cleaning solutions; and
4. Adequate shear force to remove surface deposits.

As explained in Appendix II, VSEP^{TM} can prevent colloidal fouling of the membrane surfaces. However, as also stated therein, VSEP^{TM} is ineffective in preventing fouling caused by mineral scaling and chemical bonding. Therefore, New Logic Research anticipated the need for supplemental chemical cleaning procedures. Even with such chemical cleaning measures, irreversible membrane fouling still occurs. Consequently, all membranes experience performance loss over time. This performance loss is exacerbated in heavily fouled membranes as more fouling becomes irreversible. Further, in full-scale applications, optimum chemical cleaning solutions and cleaning procedures are usually chosen on the basis of information from membrane autopsies and testing membrane samples with various cleaning solutions. Since the pilot test was designed to be a long-term challenge test for the VSEP^{TM} equipment without membrane replacement, this type of information was not available during the pilot test. As a result, there were no opportunities for membrane autopsies or for testing membrane samples with various cleaning solutions during the pilot test. Therefore, based on their experience, New Logic Research selected a broad-based cleaning process designed to remove mineral scales, organics and silica. Adequate shear force was not deemed to be an issue due to the shear force induced by the vibratory action of the VSEP^{TM} equipment.

Chemical cleaning were performed in accordance with New Logic Research instructions. As a result, the cleanings were performed in two primary steps, an acid cleaning step for mineral scale removal and a caustic step for organics. The procedure was based on New Logic Research's experience with similar applications and initially used proprietary New Logic Research cleaning agents: NLR 404, an acidic material and NLR 505, a caustic material. The cleaners were applied in a 3 percent by volume solution and circulated at approximately 2.5 gpm by the VSEPTM process feed pump. To improve cleaning effectiveness, starting at cleaning 39, NLR 550 was added in a 1 percent concentration to the NLR 505 cleaning step. New Logic Research's description of the cleaning agents is presented below.

- **NLR 404** - An acidic liquid cleaner designed to remove mineral scale in RO, nanofiltration ("NF") and ultrafiltration ("UF") membranes. It removes metallic salts such as iron, aluminum, barium and strontium sulfate, calcium sulfate, calcium carbonate, as well as dyes and polymers.
- **NLR 505** - A caustic liquid membrane cleaner designed to remove biological and organic materials, silt, particulates, colloids, silica and emulsified oil from a wide range of RO, NF, UF and microfiltration ("MF") membranes. The material contains a combination of

ingredients, which provide cleaning actions that include lifting, dispersing, emulsifying, sequestering, dissolving and suspending foulant materials.

- **NLR 550** - A powder membrane cleaner designed to remove biological foulants, organics, oil, grease, lignin, and dyes. This cleaner is also effective on man-made polymers often found in wastewater treatment systems. NLR 550 has been tested for membrane compatibility by New Logic Research and considered safe for use by New Logic Research with RO membranes.

Cleaning was performed throughout the pilot test on an as-needed basis. Informal communication with New Logic Research during meetings related to the pilot program indicated that they consider an average flux of approximately 10 gfd as a low-end cut-off point to indicate when cleaning should be performed. Consequently, service runs for testing Phases 2 through 5 were generally terminated when the flux dropped approximately to the 10 gfd low-end cut-off average flux criterion. Testing for Phase 6 continued below 10 gfd because 10 gfd was reached very quickly.

6.6 Pilot Program Management and Monitoring

Section 10 of the Protocol describes the Management and Monitoring Plan for the pilot program. As explained therein, all work was coordinated by R. W. Beck who served as the project manager and operated the pilot unit during Phase 6; New Logic Research conducted the pilot testing activities on behalf of the R. W. Beck team for Phases 1 through 5; Baer Engineering provided field oversight for New Logic Research activities and reviewed laboratory reports for QA/QC issues.

As the equipment supplier and operator for Phases 1 through 5, New Logic Research performed the pilot unit set-up, and pilot testing O&M. R. W. Beck served as the operator for Phase 6 and performed the tear-down/removal of the VSEP™ process and all associated equipment with the assistance of Baer Engineering. To fulfill their obligations, New Logic Research and/or R. W. Beck operating personnel were present on site on a one shift per day, five-day per week basis during the periods of time in which they operated the equipment and were responsible for all sampling, data logging, and operational records related to equipment performance and reliability.

Representatives of Baer Engineering visited the site each week that testing was conducted to review equipment operation, sampling and laboratory analysis data, field data, and the operator's log. In addition, the R. W. Beck team reviewed pilot results on a weekly basis throughout the field testing segment of the pilot program to confirm the activities that would be performed during the next week.

Water quality was monitored for the raw water, permeate (from SAWS' pilot for the Conventional RO Process), concentrate (from SAWS' pilot for the Conventional RO Process) and permeate and concentrate from the VSEP™ process. Since the pilot testing of the VSEP™ process was conducted in conjunction with the pilot test for the Conventional RO Process testing of the raw groundwater, New Logic Research's activities were coordinated with those of the SAWS' RO pilot testing consultant. Consequently, the SAWS' RO pilot testing consultant operating the pilot test for the Conventional RO Process collected all sampling and analysis information needed from the conventional RO pilot equipment. The data collected by the SAWS' RO pilot testing consultant consisted of the water quality laboratory data for the ASR test well raw water and the permeate and the concentrate streams from the conventional RO pilot equipment. The SAWS' RO pilot testing consultant also maintained records of pertinent process data for the conventional RO pilot equipment such as temperatures, pressures and flows.

New Logic Research and R. W. Beck's pilot program operation staff also collected appropriate process information including, but not be limited to, throughput, percent recovery, membrane performance recovery after cleaning, permeate quality and quantity, and residuals quantities and qualities and physical data, such as flow rates, cleaning requirements, chemical addition, pressure, and other observations. Where feasible, field data was crosschecked by the R. W. Beck team against the laboratory data. The pilot program operation staff augmented the data they collected with a detailed log of all changes in operating conditions containing notes describing the reasons for changes in operating parameters and identifying operating conditions associated with changes.

Section 11 of the Protocol describes the Quality Assurance/Quality Control ("QA/QC") Plan. The QA/QC Plan steps implemented during the program and activities conducted by the various team members are summarized in Table 6-3.

Table 6-3. QA/QC Plan Summary.

Phase	Step	Activity	Responsibility
All	General	Field and laboratory data cross checked as feasible on a routine basis to confirm consistency.	R. W. Beck, New Logic Research & Baer Engineering and Environmental Consulting
1	VSEP™ set up	Erect and start-up equipment.	New Logic Research
		Witness equipment operation.	R. W. Beck
2	Pretreatment testing	Anti-scalant response test.	New Logic Research
		Site visit during test to witness operation and review operators log and data during test.	Baer Engineering and Environmental Consulting
3	SpectraGuard SC™ threshold concentration testing	Concentration response test.	New Logic Research
		Site visit during test to witness operation and review operators log and data during test.	Baer Engineering and Environmental Consulting
4	Pretreat Plus™ 0100 / Pretreat Plus™ 0400 threshold concentration testing	Concentration response test.	New Logic Research
		Site visit during test to witness operation and review operators log and data during test.	Baer Engineering and Environmental Consulting
5	Recovery testing	Recovery testing.	New Logic Research
		Site visit during test to witness operation, observe sampling and review operators log and data during test.	Baer Engineering and Environmental Consulting
		Review laboratory report for QA/QC issues.	New Logic Research & Baer Engineering and Environmental Consulting
		Review laboratory and field data for consistency.	New Logic Research, Baer Engineering and Environmental Consulting & R. W. Beck
6	Confirmatory testing	Reliability testing.	R. W. Beck
		Site visit during test to witness operation, observe sampling and review operators log and data during test.	Baer Engineering and Environmental Consulting
		Review laboratory report for QA/QC issues.	New Logic Research & Baer Engineering and Environmental Consulting
		Review laboratory and field data for consistency. Data will be compiled as soon as practical after the receipt of each data set from the laboratory for anomalies.	New Logic Research, Baer Engineering and Environmental Consulting and R. W. Beck
7	VSEP™ dismantling and clean-up	Tear-down, pack-up, and remove equipment.	R. W. Beck
		Site inspection.	R. W. Beck

7 Data Collection and Analysis

New Logic Research served as the on-site equipment operator for Phases 1 through 5 of the test. However, at the request of New Logic Research, the responsibility for pilot equipment operation was transitioned from New Logic Research to R. W. Beck for the reliability challenge in Phase 6 of the pilot study. This realignment of operational responsibility added the advantage of assuring an objective assessment of equipment performance and reliability based on hands-on experience. New Logic Research supported the transition by providing two days of on-site training and two days of on-site observation of R. W. Beck's operational activities.

7.1 Physical Data

The New Logic Research Report included as Appendix II presents the physical data collected during the pilot test. Sections describing the results for Phases 2, 4, 5, and 6 present summaries of flux, recovery, and VSEP™ feedwater temperature data. A summary of the raw data is contained in Appendix A of the New Logic Research Report.

7.2 Performance and Water Quality Data

The results from Phases 1 through 6 are summarized below.

7.2.1 Phase 1 – Equipment Operability

A feed pump failure and membrane stack gasket leaks were encountered. The VSEP™ equipment operated properly once feed pump failure and membrane stack gasket leaks issues were resolved.

7.2.2 Phase 2 – Anti-scalant Response Testing

To establish a metric for the test, New Logic Research defined a Significant Response to an anti-scalant as either: (1) a 25 percent increase in average flux rate during the test; or (2) a 50 percent increase in the flux rate 24 hours after cleaning. With the conventional pilot plant operating at a recovery of approximately 85 percent, the initial recovery target for the VSEP™ system of 75 percent proved to be impractical since neither anti-scalant produced a Significant Response. Once the VSEP™ system recovery was reduced to 65 percent, dosing Anti-scalant 2 (PT-100/400) to 20 mg/L provided a Significant Response. SpectraGuard SC™ did not provide a Significant Response. Figures 7-1 and 7-2 reproduced from data presented in Appendix II, depict the results.

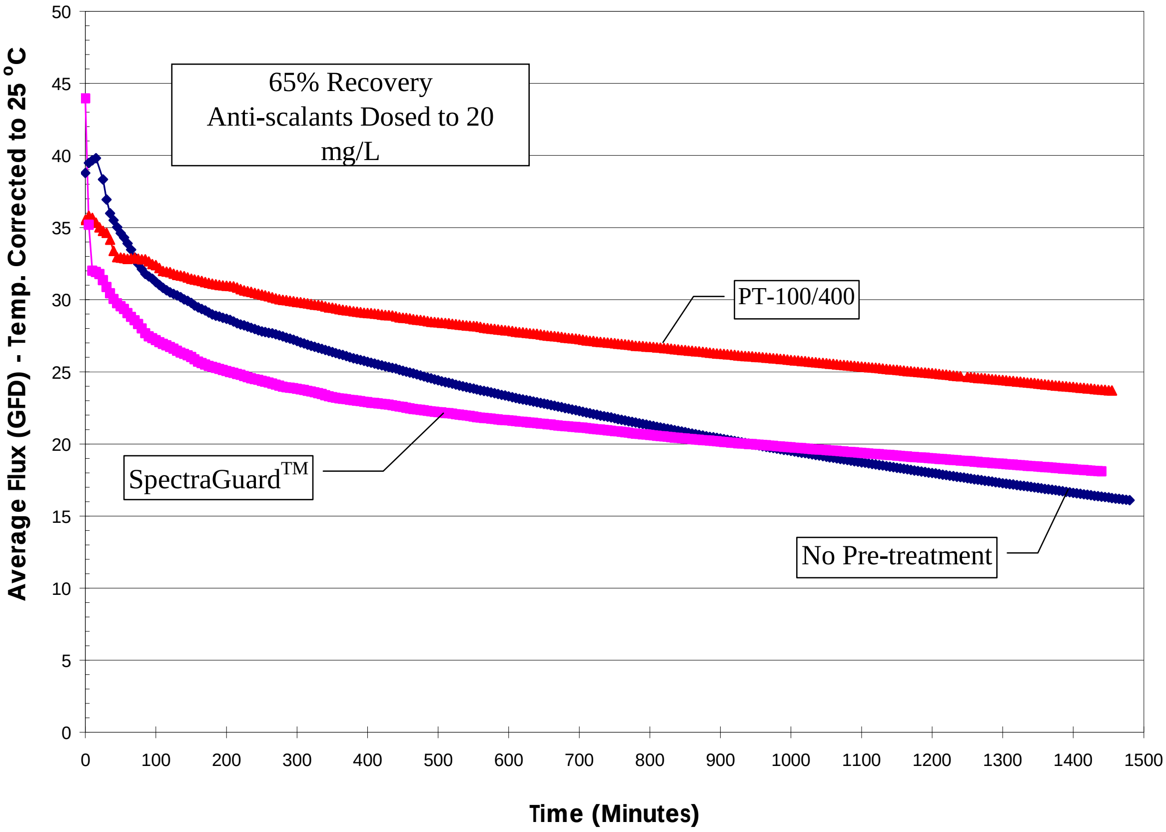

Figure 7-1. **Phase 2 – Anti-scalant Selection.**

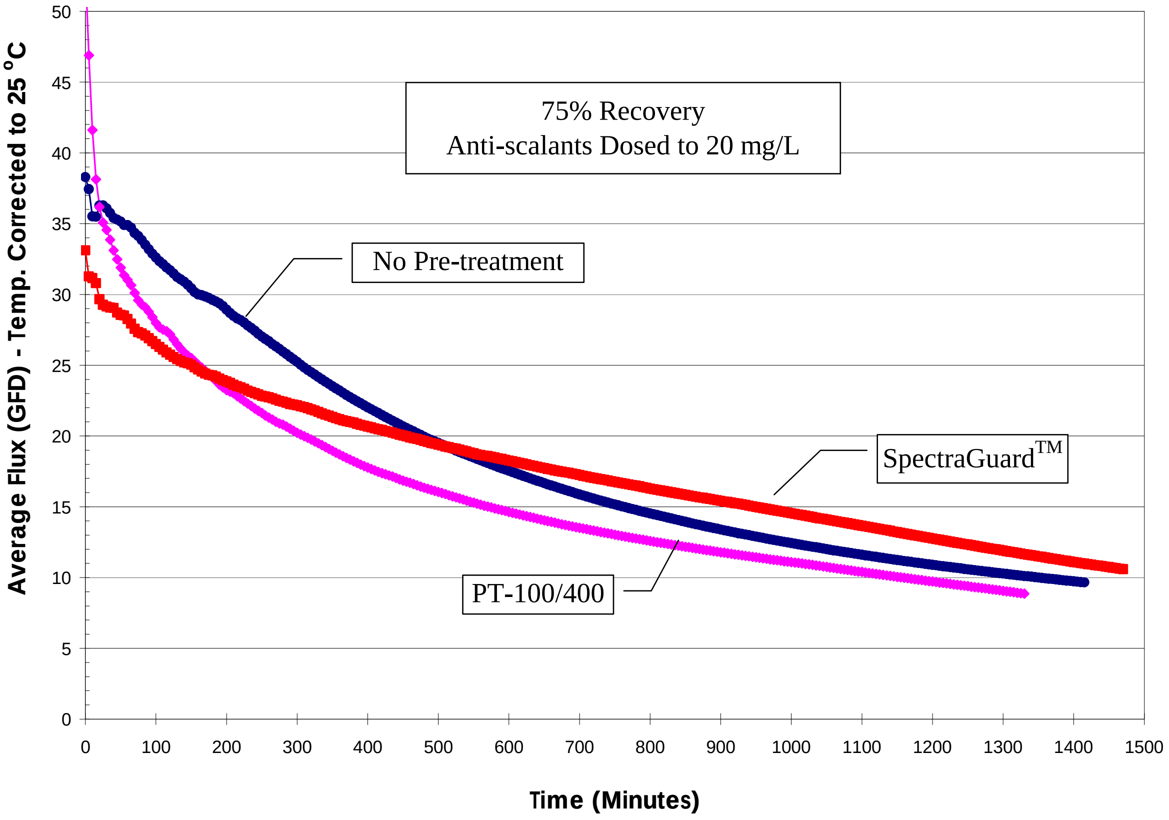

Figure 7-2. **Phase 2 – No Significant Response.**

7.2.3 Phase 3 – Anti-scalant 1, SpectraGuard SC^{TM} Dose Optimization

Phase 3 was not performed since SpectraGuard SC^{TM} failed to provide a Significant Response in Phase 2 testing.

7.2.4 Phase 4 – Anti-scalant 2, PT-100/400 Dose Optimization

Figure 7-3 depicts the results of Phase 4 testing. As shown, dosing PT-100/400 to maintain a 25 mg/L feedwater concentration was effective in maintaining average flux levels acceptable to New Logic Research for their equipment. Dosing to lower levels produced a rapid decline in average flux. Consequently, testing was not conducted at a 55 percent VSEP™ system recovery at dosing levels below 20 mg/L. Informal communication with New Logic Research during meetings related to the pilot program indicated that they consider an average flux of approximately 10 gfd as a low-end cut-off point. New Logic Research did not specify that an upper limit for flux for their equipment.

The test also showed that pH adjustment may be a very effective enhancement for the VSEP™ system for feedwater with high bicarbonate levels. As shown, the decline in average flux was minimal during a 12-hour test when acid was added. Based on their experience with the effectiveness of the vibratory shear process for membrane surface cleaning, New Logic Research did not anticipate that automatic pH adjustment would be necessary. Therefore, they did not include automatic pH adjustment with their equipment. The 12-hour test evaluating the effect of pH adjustment was run as a batch test after anti-scalant and sulfuric acid were added to the feed tank.

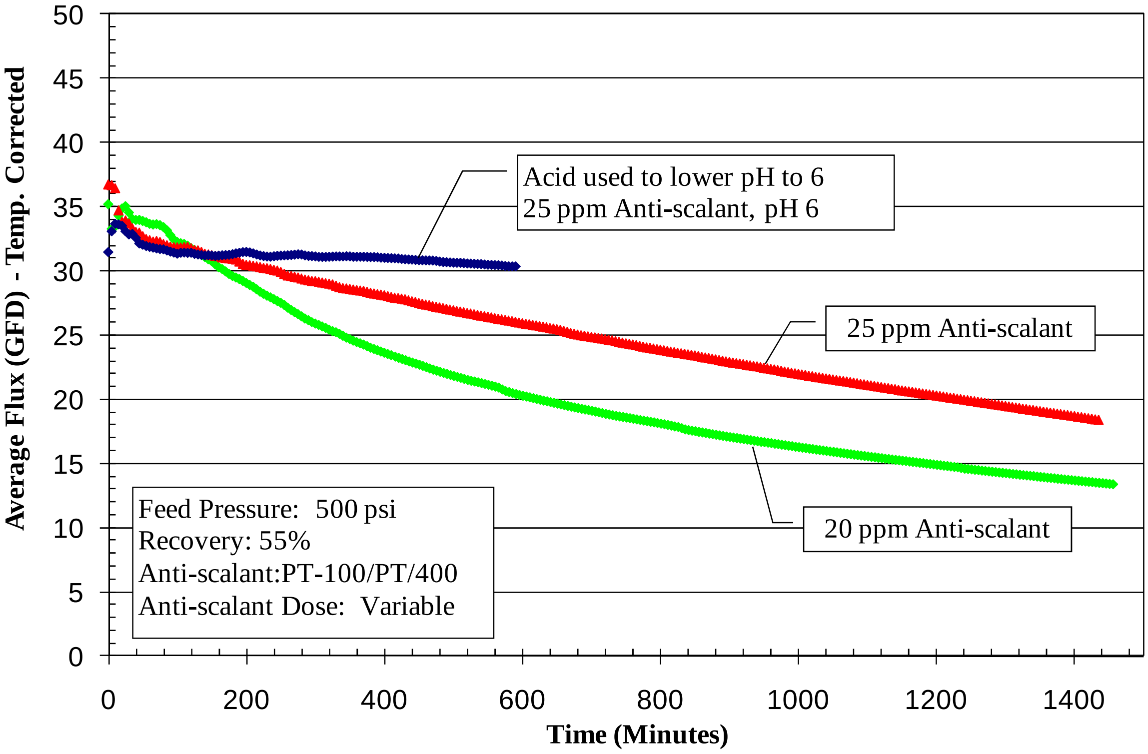

Figure 7-3. **Phase 4 – Anti-scalant Dose Optimization.**

The testing also provided the opportunity for lessons learned. Field observations of the original anti-scalant dosing equipment configuration revealed the potential for mixing efficacy issues. Initially, the VSEP^{TM} equipment feed tank was dosed with anti-scalant at the start of each test run and the metering pump injected anti-scalant at the top of the VSEP^{TM} equipment feed tank to pace the flow of additional feed from the Conventional RO Process into the tank. The feed flow from the Conventional RO Process always exceeded the VSEP^{TM} equipment consumption rate so there was a continuous overflow from the feed tank. As a result, there was a concern that the tank overflow could contain a portion of the anti-scalant dose before mixing with the bulk fluid in the VSEP^{TM} equipment feed tank was completed. In order to preclude such a situation, an injection port was installed for in-line dosing in the pipe conveying feed material to the VSEP feed tank. The in-line dosing configuration is shown in Figure 6-1. In-line dosing was subsequently used for the remainder of testing.

Section 4.3a of the New Logic Research Report included in Appendix II discusses the testing and the test results before and after the change in anti-scalant dosing equipment configuration in detail. New Logic Research Figure 7 and Tables 8 and 9 present the results. While a comparison of test results before and after the change in anti-scalant dosing equipment configuration was inconclusive, R. W. Beck recommends utilizing in-line dosing when conducting similar testing as a precaution to preclude the possibility of biasing test results if mixing is ineffective.

7.2.5 Phase 5 - Recovery Optimization

Figure 7-4 presents the normalized results of the recovery optimization test. As shown, the results indicate that a recovery of approximately 50 percent is viable with a two-day chemical cleaning cycle and reducing the recovery to approximately 45 percent could reduce cleaning frequency. Informal communication with New Logic Research during meetings related to the pilot program indicated that they consider an average flux of approximately 10 gfd as a low-end cut-off point.

Figure 7-5 shows the recovery optimization test results prior to normalization. The figure demonstrates that chemical cleaning effectiveness could vary significantly, by as much as 10 gfd, in terms of the initial flux level after a cleaning. Consequently, it was necessary to normalize the average flux data in Phase 5 to obtain meaningful results. All fluxes were adjusted to account for the differences in the initial flux after a chemical cleaning.

The normalization process consisted of adjusting the fluxes in the 55 percent and 45 percent recovery runs such that the fluxes at the start of these runs and after chemical cleaning were equal to the fluxes at the start and after chemical cleaning in the 50 percent recovery run. Thus, normalization eliminated the effects of chemical cleaning efficacy so that more meaningful relative comparisons could be conducted. Once this normalization process was completed, the flux declines in Figure 7-4 demonstrated that, as expected, recovery percentage and flux decline are inversely proportional.

Figure 7-4 also shows that the 45 percent recovery run after chemical cleaning was terminated prior to either reaching the 10 gfd as a low-end cut-off point or completing a 2-day run. The graph is truncated because of an equipment malfunction that resulted in a data loss for the 45 percent initial recovery run. As shown, the equipment malfunction and data loss occurred very shortly after the chemical cleaning for this portion of the test was completed. Consequently, Figure 7-4 does not contain the data for the majority of this portion of the test.

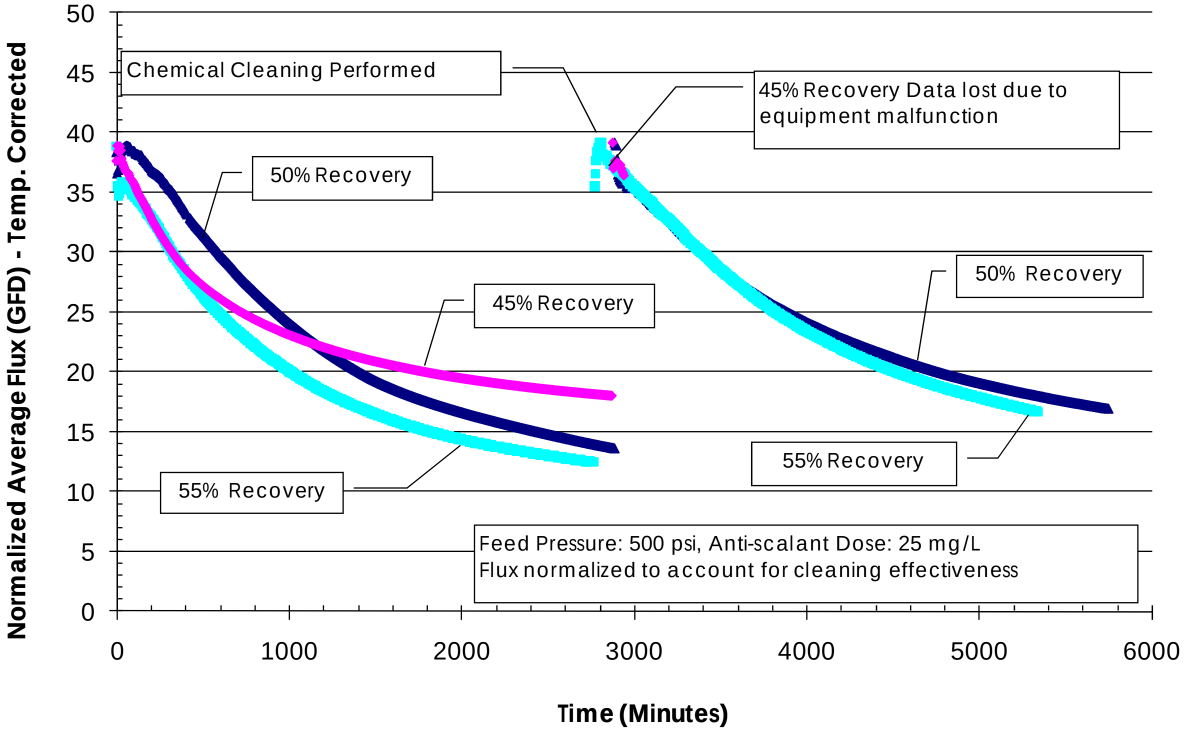

Figure 7-4. **Phase 5 – Recovery Optimization – Normalized Data.**

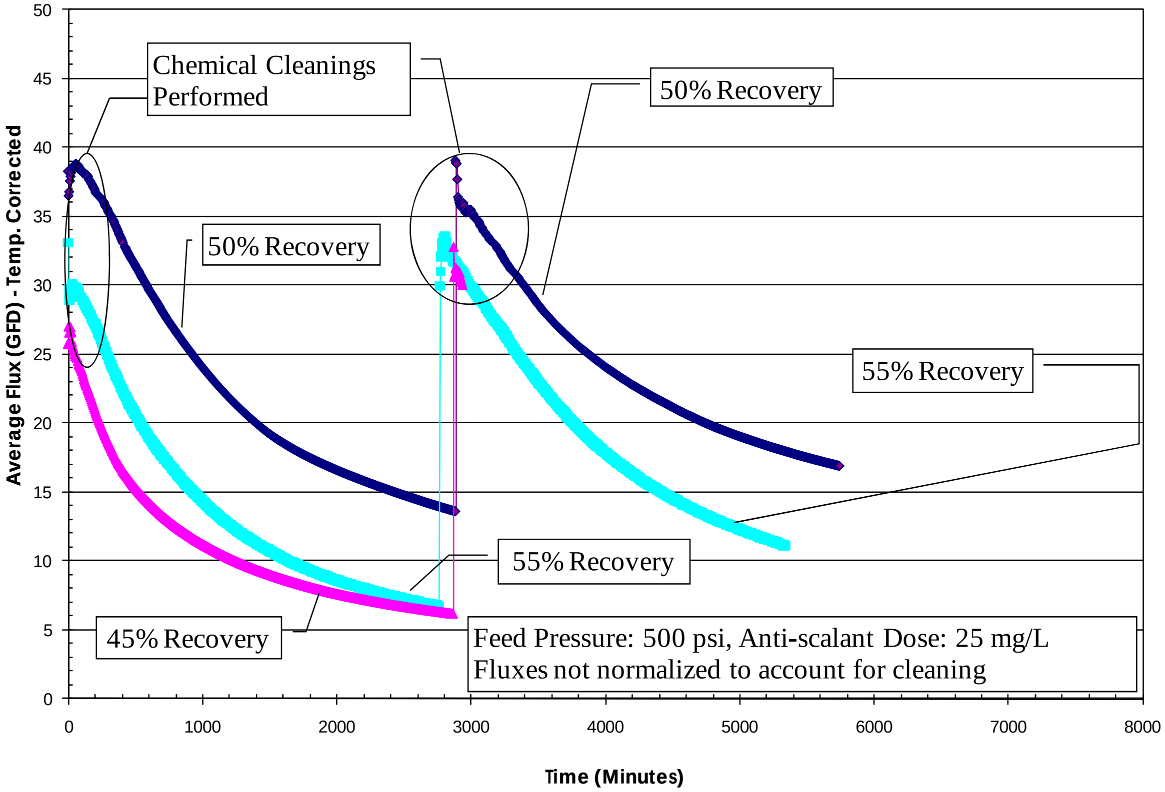

Figure 7-5. Phase 5 – Recovery Optimization – Data Not Normalized.

Feedwater, permeate and concentrate water quality information were also obtained during Phase 5. Tables 7-1, 7-2, and 7-3 present the data. The data indicate that: (1) the permeate from Phase 5 was of sufficient quality such that it could potentially be co-mingled with the permeate from a Conventional RO Process in the facility product water; (2) the feedwater had a high bicarbonate content and sparing soluble constituents such as silica, iron and calcium carbonate may be precipitating; and (3) the concentrate from the VSEP™ process had a high tendency to form precipitates which could prove to be problematic during long-term operation for a deep well injection system or a pipeline from the plant to a disposal location. While membrane autopsy information is unavailable, based on the water quality data, it is conceivable that sulfate-based scaling materials and silica played a significant role in membrane fouling. Further, as explained in Section 6.5, heavy fouling may have been a significant factor limiting chemical cleaning efficacy by causing irreversible fouling.

The data in Tables 7-1, 7-2, and 7-3 also show several anomalies. These include significant deviations between laboratory and field data for specific conductivity and between the TDS levels measured for the feedwater for the VSEP™ pilot. Based on a comparison of the ratios of TDS and specific conductivity in these tables, the field results for these parameters appear to be inaccurate. A range of 0.5 to 0.6 for these ratios which is typical is obtained using the laboratory results. The range of ratios for field results varies from 0.3 to 1.06.

Table 7-1. VSEP™ System Feedwater, Concentrate, and Permeate Water Quality – 55 Percent Recovery.

Constituent	Units	Feedwater	Concentrate	Permeate	Percent Rejection[b]
Calcium	mg/L	404	902	0.32	99.92%
Barium	mg/L	0.21	0.45	ND [a]	-
Magnesium	mg/L	221	492	ND [a]	-
Strontium	mg/L	29.1	85.6	0.04	99.86%
Sodium	mg/L	3,570	8,460	120	96.64%
Iron	mg/L	1.68	3.27	ND [a]	-
Chloride	mg/L	2,900	6,140	91.6	96.84%
Bicarbonate	mg/L	1,100	2,300	160	85.45%
Sulfate	mg/L	7,900	17,400	21.5	99.73%
Silica	mg/L	73.2	75.8	3.85	94.74%
TDS	mg/L	13,800	34,100	380	97.25%
pH					
Field	SU	7.03	7.3	6.61	NA [c]
Laboratory	SU	7.52	7.77	6.99	NA [c]
Specific Conductivity					
Field	µS/cm	19,100	37,000	640	NA [c]
Laboratory	µS/cm	24,400	98,500	629	NA [c]

[a] Not detected (ND).
[b] Salt Rejection equals (feedwater salt concentration minus permeate salt concentration) divided by feedwater salt concentration.
[c] Not applicable (NA).

Table 7-2. VSEP™ System Feedwater, Concentrate, and Permeate Water Quality – 50 Percent Recovery.

Constituent	Units	Feedwater	Concentrate	Permeate	Percent Rejection[b]
Calcium	mg/L	390	650	1.32	99.66%
Barium	mg/L	0.2	0.33	ND [a]	-
Magnesium	mg/L	217	362	0.43	99.80%
Strontium	mg/L	28.1	65.9	0.06	99.79%
Sodium	mg/L	3,330	6,100	60.2	98.19%
Iron	mg/L	2.27	2.75	ND [a]	-
Chloride	mg/L	2,560	4,860	72.2	97.18%
Bicarbonate	mg/L	990	1,800	38	96.16%
Sulfate	mg/L	6,980	13,200	28.9	99.59%
Silica	mg/L	75.9	84.2	2.05	97.30%
TDS	mg/L	13,000	23,600	197	98.48%
pH					
Field	SU	7.02	7.25	5.69	NA [c]
Laboratory	SU	6.82	6.91	6.17	NA [c]
Specific Conductivity					
Field	µS/cm	18,100	30,900	354	NA [c]
Laboratory	µS/cm	22,200	42,500	343	NA [c]

[a] Not detected (ND).
[b] Salt Rejection equals (feedwater salt concentration minus permeate salt concentration) divided by feedwater salt concentration.
[c] Not applicable (NA).

Table 7-3. VSEP™ System Feedwater, Concentrate, and Permeate Water Quality – 45 Percent Recovery.

Constituent	Units	Feedwater	Concentrate	Permeate	Percent Rejection[b]
Calcium	mg/L	433	762	1.3	99.70%
Barium	mg/L	0.196	0.325	ND[a]	-
Magnesium	mg/L	238	420	1.04	99.56%
Strontium	mg/L	30.3	51.1	0.168	99.45%
Sodium	mg/L	4,140	6,340	149	96.40%
Iron	mg/L	1.58	2.6	ND[a]	-
Chloride	mg/L	2,490	4,850	152	93.90%
Bicarbonate	mg/L	1,170	1,980	104	91.11%
Sulfate	mg/L	6800	13300	79.8	98.83%
Silica	mg/L	80.2	54.8	4.81	94.00%
TDS	mg/L	16,700	31,500	483	97.11%
pH					
Field	SU	7.07	7.21	6.22	NA[c]
Laboratory	SU	7.32	7.53	6.37	NA[c]
Specific Conductivity					
Field	µS/cm	17,310	29,800	1,590	NA[c]
Laboratory	µS/cm	31,300	49,000	804	NA[c]

[a] Not detected (ND).

[b] Salt Rejection equals (feedwater salt concentration minus permeate salt concentration) divided by feedwater salt concentration.

[c] Not applicable (NA).

7.2.6 VSEP™ Phase 6: Field Operations Summary

As shown in Process Flow Diagram PFD-001, all phases used the concentrate from SAWS conventional RO pilot test as feedwater for the VSEP™ process. The feedwater to the conventional RO pilot during Phases 1 through 5 was not aerated. However, the feedwater to the conventional RO pilot for Phase 6 was aerated and filtered prior to treatment in the conventional RO pilot. While the test conditions during Phase 6 were somewhat different than those for Phases 1 to 5, all concentrate from the conventional RO pilot used as feedwater for the VSEP™ equipment was aerated to some degree since it was stored in an open, atmospheric tank prior to treatment with the VSEP™ equipment.

Several equipment reliability issues were experienced during the reliability run. These included shortened runs between cleanings, unplanned shutdowns due to equipment leaks and malfunctions, and high permeate conductivity levels. The following is a summary of these issues.

7.2.6.1 Unplanned Shutdowns

The targeted run time between cleanings for Phase 6 was a minimum of 48 hours. However, during Phase 6, the pilot equipment achieved an overall average run time of 18.5 hours between cleanings. The shortened filtration run times are attributable to three general causes:

1. Excessive system pressures
2. Bypass valve gages/piping replacement
3. Low permeate flow

The first series of shutdowns resulted from excessive pressure build-up caused by improper bypass valve positioning. Since the operating pressure for the system was near the feed pump shut-off head, the feed pump bypass valve needed to be slightly open to prevent feed pump deadheading. However, instructions provided during the on-site training for R. W. Beck operators inaccurately indicated the bypass valve should remain closed during normal operation. Consequently, the pump deadheaded and the system automatically shut down when the high pressure set point for the equipment was reached. R. W. Beck operators corrected the valve setting after diagnosing the problem collaboratively with New Logic Research.

Two equipment leak events occurred concurrently with the feed pump bypass valve set point issues. The events included leaking pipe joints, blown gauges and possibly a damaged bypass valve. The leaks are attributed to the pressure and temperature rating conditions for the pipe fittings provided with the VSEP™ equipment for the pilot study. The fittings and valves supplied with the pilot equipment were American Society of Mechanical Engineers/American National Standards Institute ("ASME/ANSI") Class 150, which are rated for a maximum operating pressure of less than 300 psig at the approximate operating temperature of 100 F. However, the VSEP™ unit was set to operate at 500 psig and experienced pressure spikes to 550 psig during the pilot test. The R. W. Beck operators upgraded the piping and appurtenant components from 150 psi to 600 psi piping elbows and couplings to resolve the equipment leak problems.

Once the equipment failures described above were resolved, another series of shutdowns were experienced due to low permeate flow rates. With the VSEP™ process, permeate flow rates decrease during a run as membranes become fouled until a cleaning is performed. The criterion that identifies when a chemical cleaning is required is based on permeate flow. The need for a chemical cleaning is triggered by a predetermined threshold permeate flow of 100 milliliters per minute ("mL/min"). However, the VSEP™ unit reached the 100 mL/min threshold much more rapidly than anticipated because of the rate of membrane fouling. Consequently, the VSEP™ equipment required shutdowns for chemical cleanings more frequently than anticipated.

7.2.6.2 Anti-Scalant

Anti-scalant was dosed at 25 mg/L throughout Phase 6. However, maintaining a prime on the chemical dosing pump during the initial two weeks of Phase 6 operations proved troublesome. Anti-scalant dosing was interrupted several times when the pump shut down during unmanned overnight periods. In collaboration with New Logic Research, several mechanical measures were adopted to improve the anti-scalant feed reliability. These measures included leaving the doors open to the tank room overnight to cool the pump, ensuring the anti-scalant reservoir remained full and shortening the dosing line connecting the pump to the feed tank. Once the chemical dosing pump mechanical issue was resolved, run times for the VSEP™ system became shorter. New Logic Research deduced that the PT-100 anti-scalant solution was interacting with high sulfate levels in the feedwater which produced precipitate on the membrane surface that was not effectively removed by the vibratory cleaning mechanism used by the VSEP™ process. New Logic Research then recommended changing the anti-scalant mixture to a 90 percent PT-100 anti-scalant solution and a 10 percent PT-400 solution. This change in anti-scalant composition in conjunction with the intensified chemical cleanings described below increased run times by approximately three hours. A 48-hour run time was not attainable under the prescribed conditions for Phase 6.

7.2.6.3 Chemical Cleaning

Table 7-4 summarizes the initial chemical cleaning instructions for the membranes in the VSEP™ filter pack for Phases 1-5.

Table 7-4. New Logic Research Phases 1-5 Chemical Cleaning Procedure.

Step	Description	Chemical	Temperature	Duration (Minutes)
1	Acid cleaning	3 percent solution of 404 cleaner (citric acid), pH~ 2	>40°C	60
2	Water flush	RO permeate	Ambient	20
3	Caustic cleaning	3 percent solution of 505 cleaner (detergent), pH ~ 11	>40°C	60
4	Water flush	RO permeate	Ambient	20

As shown by Table 7-5, due to the short run times, the chemical cleanings became more intensive in terms of contact time, temperature and chemicals used. The modifications to the chemical cleaning procedures were adopted per instructions from New Logic Research during Phase 6 operations.

Table 7-5. New Logic Research Phase 6 Chemical Cleaning Procedure.

Step	Description	Chemical	Temperature	Duration (Minutes)
1	Acid Cleaning	3 percent solution of 404 cleaner (citric acid), pH~ 2	>40°C Increased to 50°C	60 Increased to 75
2	Water Flush	RO permeate	Ambient	20
3	Caustic Cleaning	4 percent solution of 505 cleaner (detergent), pH ~ 11 Added 1 percent 550 powder cleaner (sodium percarbonate) near end of Phase 6	>40°C Increased to 50 °C	60 Increased to 75
4	Water Flush	RO permeate	Ambient	20 minutes
5	Caustic Cleaning	4 percent solution of 505 cleaner (detergent), pH ~ 11 Added 1 percent 550 powder cleaner (sodium percarbonate) near end of Phase 6	>40°C – Increased to 50°C	60 Increased to 75
6	Water Flush	RO permeate	Ambient	20

Accounting for preparation, pipe changeovers, cleaning run durations and flushing durations, the typical cleaning time averaged 6.5 hours and was performed nearly daily in order to achieve desired permeate flow rates. Cleaning effectiveness ranged between 48 percent and 70 percent, as compared to an unused membrane used as the standard by New Logic Research, and varied with the intensity of the cleaning in terms of duration, temperature, number of caustic cleaning steps, and cleaning chemicals. None of the cleaning enhancements permitted a 48-hour service run under the prescribed conditions for Phase 6. The flow rate for each cleaning operation was not specifically monitored. However, since the feed pump for the VSEP™ system was used to circulate cleaning and flush fluids, the flow rate for all chemical cleaning and flush steps was approximately 2.5 gpm.

7.2.6.4 Permeate Conductivity

VSEP™ permeate conductivity in Phase 6 was notably higher than the previous phases, despite a constant and similar feedwater conductivity of approximately 18,000 microSiemens per centimeter ("µS/cm"). High permeate conductivity is an issue of concern because it could preclude commingling permeate from the VSEP™ process with permeate from the conventional RO facility for the full-scale Project.

Phase 6 permeate conductivity began to rise after the first cleaning in Phase 6 was performed and continued to climb more steeply after the bypass valve assembly and pipe replacements. Based on the results of the previous phases, we had expected the permeate conductivity to remain at approximately 500 to 750 µS/cm for the duration of Phase 6. However, the permeate conductivity initially increased with each subsequent recovery/cleaning cycle and appeared to stabilize near the end of Phase 6 at approximately 4,000 µS/cm.

At the request of New Logic Research, a salt rejection test was also performed by the R. W. Beck operators to assess membrane performance near the end of Phase 6. According to the New Logic Research Report contained in Appendix II, Hydranautics Type ESPA 1 (Hydranautics designator for energy saving polyamide) membranes were used in the filter pack. As manufactured, these membranes have a salt rejection capability exceeding 99 percent; New Logic Research factory testing of the filter pack they provided in the pilot unit confirmed this level of performance. The subsequent salt rejection test revealed a significantly lower level of salt rejection performance by the membrane during the pilot study than observed when the membrane was new and originally tested. This second salt rejection test conducted at 300 psi (approximately 60 percent of the actual operating pressure) indicated the membrane salt rejection was approximately 79.4 percent.

Based on the permeate conductivity and the results of the salt rejection test, the order-of-magnitude increase from the permeate quality in the other phases was initially attributed to either a leak in the membrane filter pack assembly or a membrane failure. However, an examination by New Logic Research of the filter pack after the equipment was returned did not reveal either condition. Consequently, no specific root cause has been identified.

7.2.7 Phase 6 Operational Summary

During the first three weeks of Phase 6, the operators achieved run times ranging from 3 to 40 hours due to the issues described above. After resolving the mechanical and chemical cleaning issues more consistent run times of 17 hours were achieved with 20-hour durations achieved during the last 2 days of Phase 6. While typical recovery run times became more consistent and longer in duration over the course of the pilot study, the target 48-hour recovery run time was never achieved.

The reliability statistics for the VSEP™ equipment over the course of the 30-day duration of Phase 6 are depicted in Figure 7-6. As shown, the equipment operated in the service mode for 44 percent of the time (316 hours), in the cleaning mode for 16 percent of the time (112 hours) and was out of service for maintenance 40 percent of the time (292 hours).

The equipment produced a total of 2,850 gallons of permeate during Phase 6. Assuming the maintenance issues related to the pilot equipment could be eliminated with full-scale equipment specifically provided for the operating conditions of the Project, the average production for the equipment was approximately 6.7 gallons per hour or 160 gallons per day based on 428 total hours (316 hours of in-service operation plus 112 hours of time for chemically cleaning the equipment).

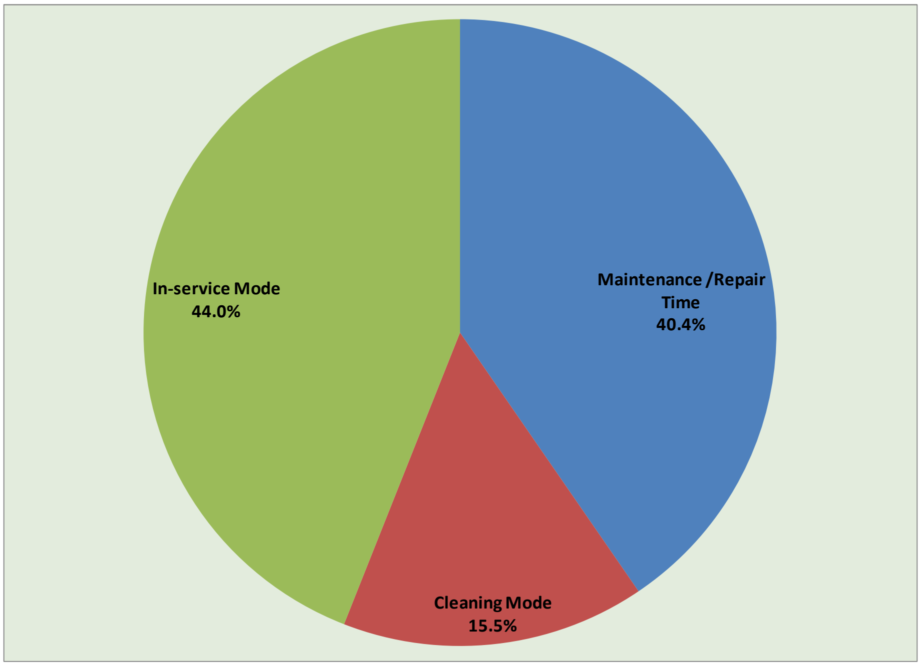

Figure 7-6. Phase 6 VSEP™ Reliability.

Due to the equipment reliability and permeate conductivity issues, only one sampling event was performed rather than the two planned events. The analytical data is presented in Table 7-6. As shown, the TDS permeate quality is almost equivalent to the raw water from the test well at the ASR site. The VSEP™ permeate did not meet SAWS' TDS Standard of 400 mg/L for finished water for the Project. Therefore, if the VSEP™ equipment is incorporated into the Project the VSEP™ permeate would need to be routed to the facility headworks so it could be reprocessed unless the permeate quality issues can be resolved.

Table 7-6. Phase 6 Water Quality Readouts.

Parameter	Units	Raw Feed	Feed	Permeate	Concentrate
Aluminum	mg/L	<0.051	<0.051	<0.051	<0.051
Antimony	mg/L	<0.021	<0.021	<0.021	<0.021
Arsenic	mg/L	<0.021	<0.021	<0.021	<0.021
Barium	mg/L	0.024	0.202	<0.011	0.363
Beryllium	mg/L	<0.002[a]	<0.002[a]	<0.002[a]	<0.002[a]
Boron	mg/L	0.64	1.55	0.96	2.051
Cadmium	mg/L	<0.003[a]	<0.003[a]	<0.003[a]	<0.003[a]
Calcium	mg/L	44.6	449	16.2	820
Chromium	mg/L	<0.011	<0.011	<0.011	<0.011
Copper	mg/L	<0.021	<0.021	<0.021	<0.021
Iron	mg/L	0.15	<0.031	<0.031	<0.031
Lead	mg/L	<0.015[a]	<0.0151	<0.015[a]	<0.0151
Magnesium	mg/L	24.3	248	9.91	453
Manganese	mg/L	0.037	0.394	0.02	0.656
Nickel	mg/L	<0.015[a]	<0.0151	<0.015[a]	<0.0151
Potassium	mg/L	12.6	103	10.8	188
Selenium	mg/L	<0.021	<0.021	<0.021	<0.021
Sodium	mg/L	460	4760	380	9800
Strontium	mg/L	2.75	26.8	1.02	49
Thallium	mg/L	<0.051	<0.051	<0.051	<0.051
Zinc	mg/L	<0.021	0.02	<0.021	0.11
Mercury	mg/L	NA[b]	<0.0021	<0.0002[a]	<0.00021
Chloride	mg/L	NA[b]	2580	409	4340
Fluoride	mg/L	NA[b]	<21	0.828	22.4
Nitrate-N	mg/L	NA[b]	8.95	2.79	17.2
Nitrite -N	mg/L	NA[b]	<21	<0.21	<21
Sulfate	mg/L	NA[b]	6130	334	11600
Alkalinity	mg/L	NA[b]	1290	152	2300
Cyanide	mg/L	NA[b]	<0.021	<0.021	<0.021
Carbon Dioxide	mg/L	98.6	220	70.4	264
Carbonate	mg/L	<11	<11	<11	<11
Color	CU	NA[b]	<11	<11	<11
Dissolved Oxygen	mg/L	8.64	9.46	8.71	9.82
Hardness	mg/L	NA[b]	2160	96	4020
Bicarbonate	mg/L	270	1290	152	2300
Ammonia	mg/L	<11	<11	<11	<11
Threshold Odor	TON	<11	<11	<11	<11
pH		NA[b]	7.19	6.82	7.27
Dissolved Sulfide	mg/L	NA[b]	<21	<21	<21
Silica	mg/L	NA[b]	51.6	9.55	35.6
TDS	mg/L	NA[b]	13600	1120	25700
Turbidity	mg/L	NA[b]	<0.051	<0.051	<0.051
Conductivity	uS	NA[b]	21100	2180	44500
Bromodichloromethane	mg/L	<51	<51	<51	<51
Bromoform	mg/L	<51	<51	<51	<51
Chloroform	mg/L	<51	<51	<51	<51
Dibromochloromethane	mg/L	<51	<51	<51	<51
Radionuclides					
Gross Alpha	pCi/L[c]		44.455[a]	11.726	32.217[a]
Gross Beta	pCi/L		120.249[a]	8.705	106.479[a]
U-234	pCi/L		0.534	.0200[a]	0.944
U-235	pCi/L		-0.056[a]	0.039[a]	0.028[a]
U-238	pCi/L		0.145[a]	0.100[a]	0.169[a]
TH-228	pCi/L		-0.391	0.127	-3.99[a]
TH-230	pCi/L		1.893	0.803	2.211[a]
TH-323	pCi/L		-0.756[a]	-0.555	1.103[a]

[a] Below Minimum Detectable Concentration for analyte that the laboratory can detect for the specific analysis.
[b] Not Analyzed.
[c] PicoCurie per liter.

7.2.7.1 Power Consumption

Power consumption data was collected throughout Phase 6 via two watt-hour meters (Meters USA Model CD3234-3). The data from the meters was coupled with total permeate production data during Phase 6 to compute an average kWh/1,000 gallons of permeate produced power consumption. As shown in Table 7-7, the VSEP™ equipment had a unit consumption of approximately 300 kWh/1,000 gallons of permeate produced. On this basis, assuming that SAWS full-scale conventional RO facility produces 3.09 MGD of concentrate at a finished water production rate of 20 MGD[22], the full-scale VSEP™ equipment would produce approximately 1.55 MGD of permeate[23] and require approximately 469 megawatt-hours ("MWh") per day or a 19.5 megawatt ("MW") load.

Table 7-7. Phase 6 Electricity Consumption. (kWh/1,000 gallons of permeate production).

Phase 6 water produced (gal)			2,857.8
Electricity consumed (kWh)	**Meter 1**	**Meter 2**	**Total**
	88.5	776	864.5
Unit electricity consumption (kWh/1,000 gallons of permeate production)			302.5

Discussion with New Logic Research indicated that New Logic Research does not believe the pilot data for unit electrical consumption can be directly scaled up due to the differences in the manner that motor sizing is conducted for their pilot and full-scale equipment. Consequently, as stated in Section 7.0 of the New Logic Research Report (Appendix II), they predict a unit consumption of approximately 30.4 kWh/1,000 gallons of permeate produced. With a permeate production of approximately 1.55 MGD, this unit consumption would correspond to 47.1 MWh per day or a 1.96 MW load.

Assuming the fouling and low flux issues observed during the pilot test can be resolved, the full-scale power consumption will likely be between the value measured during the test and the manufacturer's estimate. Consequently, in the interim, the measured value and the manufacturer's estimated value represent boundary conditions for an O&M cost estimate. To be conservative, R. W. Beck would propose using the test results as the basis for an economic evaluation for the Project until new test information is available. It should be noted that the power consumption for a different feedwater with different fouling characteristics could require a substantially a different power consumption if chemical cleaning and flux levels are appreciably different.

7.2.7.2 Noise Survey Results

Baer Engineering conducted a noise survey on September 2, 2009 while the equipment was in service with an Extech Model 407355 Datalogging Noise Dosimeter operating in the instantaneous mode, 70 decibels absolute ("dBA") threshold, fast response. The instrument was calibrated with an Extech 407766 Sound Level Calibrator at 94 and 114 dBA prior to use. The Occupational Safety and Health Association ("OSHA") standard for occupational exposure to noise (29 Code of Federal Regulations ("CFR") 1910.95) specifies a maximum permissible exposure limit of 90 dBA-slow response for a duration of eight hours per day.[24]

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[22] Assumed to operate at an 85 percent recovery per the R. W. Beck Brackish Groundwater Desalination Feasibility Assessment Report dated October 28, 2008.

[23] Assumed to operate at a 50 percent recovery based on pilot test results.

[24] http://www.osha.gov/SLTC/autobody/docs/cdc003.html#Noise/HearingLoss.

Table 7-8 depicts the approximate noise ranges measured near the VSEP™ equipment. Based on the data, hearing protective devices such as ear plugs and/or ear muffs should be considered when working in the vicinity of the VSEP™ equipment. Further, depending on the proximity to neighbors or other sensitive receptors, noise barriers may be required.

Table 7-8. VSEP™ Equipment Noise Levels[25]

Location	Measured Noise Level
VSEP™ trailer entrance	91.6 to 92.2 dBA
VSEP™ control panel	92.7 to 93.1 dBA
VSEP™ unit ™ left side	95.5 to 95.9 dBA
Behind VSEP™ unit	96.0 to 96.5 dBA

7.3 Quality Assurance/Quality Control

Alamo Analytical Laboratories, Ltd located at 10526 Gulfdale, San Antonio, Texas 78216 was selected to perform the laboratory analytical services for SAWS pilot program for the Conventional RO Process. For consistency, Alamo Analytical Laboratories, LTD, was also used to analyze the samples for both the VSEP™ pilot and the pilot programs for the Conventional RO Process.

According to the TCEQ, Alamo Analytical Laboratories, LTD (Certificate T104704367-09-TX Expiration Date: 6/30/2010) is accredited under the National Environmental Laboratory Accreditation Program ("NELAP") for a variety of non-potable water, solid and chemicals matrices, and air laboratory analyses. While not certified for drinking water, the use of Alamo Analytical Laboratories, LTD was allowed by TCEQ for the pilot program for the Conventional RO Process and by the Texas Water Development Board for the VSEP™ pilot.

Test data were reviewed regularly to assure satisfactory quality control conditions were maintained throughout each phase of testing. Consistency of water quality data and closure of material balances were used as indicators of the quality of flow and mass data.

8 Technical and Economic Benefit Assessment

8.1 Purpose

The purpose of this section is to discuss the primary advantages and disadvantages of enhanced recovery options, when compared to conventional concentrate disposal methods. The Project is used as a case study.

8.2 Comparison of the VSEP™ Process with Deep Well Injection

The most commonly used conventional methods of concentrate disposal are surface water disposal and deep well injection. The primary benefit of an enhanced recovery process is that the processes provide a higher product water yield per gallon of raw water (higher recovery) and a lower quantity of concentrate requiring disposal.

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[25] e-mail Donald Schaezler (Baer Engineering) to Rosemary Wyman; Robert Long; Tara Hickey, Leo Cannyn, Robert Bergeron, and Howard Steiman dated 9/2/2009 7:22 PM.

Other benefits are case-specific. Depending on the costs of the enhanced recovery process, the equipment costs related to the disposal of residuals from the enhanced recovery process, and the savings related to smaller disposal pipelines, pumps, and discharge structures or fewer deep wells, it is conceivable that enhanced recovery processes could result in lower overall Project capital costs. Similarly, a reduction in O&M costs could be realized due to the off-set between lowered pumping costs with the enhanced recovery option (smaller volumes to pump in both the desalination and concentrate disposal processes) and the increased O&M costs associated with the enhanced recovery system. However, there is no general rule of thumb. Each situation should be evaluated individually to determine whether an enhanced recovery process lowers or increases costs.

The Project provides an illustrative example. As shown in modeling conducted for the Project feasibility study[26], the RO process would produce a concentrate flow of approximately 3.09 MGD when operating at a recovery of 85 percent for the facility's 20 MGD finished water output. The VSEP™ pilot testing program indicates adding the process would reduce the concentrate by 50 to 55 percent or by approximately 1.55 MGD to 1.70 MGD. Thus, the number of deep wells for concentrate disposal could decrease by about half and raw water and concentrate pumping flows could be lowered by approximately 1.55 MGD to 1.70 MGD. This would result in additional savings for pumps, piping and wells.

The VSEP™ process will also increase the TDS level of the concentrate by approximately 50 to 55 percent. This would cause a corresponding increase in concentrate TDS levels from the range of 10,930 mg/L to 11,201 mg/L estimated in the Project feasibility report[27] to a range of 21,860 mg/L to 24,891 mg/L with the VSEP™ process. As both scenarios would require Class 1 deep wells, pursuant to TCEQ regulations and the salt mass loading from the concentrate would essentially be the same, there may not be significant changes in the Project schedule or the cost per well. However, other issues revealed by the pilot testing could preclude the use of the VSEP™ option for the Project.

8.3 Advantages and Disadvantages for the Project

8.3.1 Major Advantages

The major advantages of the of the VSEP™ process are associated with the reduction in concentrate volume by approximately 50 percent. This has the potential to save capital costs for the deep wells for concentrate disposal and lower pumping costs for concentrate disposal. Further, assuming the permeate conductivity issues in Phase 6 can be resolved with full-scale VSEP™ equipment and VSEP™ units compliant with NSF/ANSI Standard 61 (Drinking Water System Components) are provided, the system could also increase the output of the Project by approximately 1.55 MGD. Thus, there are potentially several major advantages that the VSEP™ process could provide.

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[26] Average Raw Water Quality for the ASR Test Well installed for the R.W. Beck Feasibility Evaluation. SAWS Brackish Groundwater Desalination Project Water Quality Assessment Technical Memorandum, T. Hickey and H. Steiman to K. Morrison dated October 17, 2008.

[27] Average Raw Water Quality for the ASR Test Well installed for the R.W. Beck Feasibility Evaluation. SAWS Brackish Groundwater Desalination Project Water Quality Assessment Technical Memorandum, T. Hickey and H. Steiman to K. Morrison dated October 17, 2008.

8.3.2 Major Disadvantages

Based on the performance observed during the pilot test, the major disadvantages of the VSEP™ process are related to the capital cost of the VSEP™ equipment, its operating cost, and the potential for reliability issues that could affect the overall Availability of the Project. Therefore, R. W. Beck is of the opinion that the potential advantages are outweighed by the potential disadvantages so that a detailed cost evaluation was not required by SAWS as a basis for their decision.

The New Logic Research VSEP™ pilot test report[28] contained in Appendix II indicates that, based on the flux achieved during the pilot test, New Logic Research would recommend 204, 84-inch 1,500 square foot VSEP™ units for a 4 MGD concentrate flow. The report also states that one 2-hour chemical cleaning per day per VSEP™ unit is projected to be necessary. To account for chemical cleaning requirements and provide redundancy for their equipment, New Logic Research included a 30 percent redundancy factor in their design basis recommendation. Based on the 3.09 MGD flow predicted for the full-sized 20 MGD SAWS facility, the design basis offered by New Logic Research corresponds to 158, 84-inch 1,500 square foot VSEP™ units. According to New Logic Research, the capital cost of 204 units would be approximately $50,000,000.[29] Therefore, uninstalled capital costs for 158, 84-inch 1,500 square foot VSEP™ units are approximately $38,700,000. Using a factor of 1.5 times the equipment cost to account for installed cost in a manner consistent with the Baseline Economics discussed in Section 4.2.2 herein, the $38,700,000 uninstalled equipment cost results in an estimated installed cost of approximately $58,100,000. Consequently, assuming the 50 to 55 percent recovery demonstrated during pilot testing is feasible for the full-scale facility and a 3.09 MGD concentrate flow, the range of unit cost for the Project varies from approximately $34,200 to $37,600 per 1,000 gallons of permeate produced by the VSEP™ equipment. Since the unit capital cost is more than twice the estimated unit cost for the entire Project (including an extensive pipeline network), this would not be a cost-effective option.

It should be noted that each chemical cleaning required four to six hours during the pilot test. Assuming four hours per cleaning for each full-sized VSEP™ unit, a redundancy of 35 to 40 percent would appear to be reasonable. Further, as shown in Figure 7-6, the equipment operated in the service mode for 41 percent of the time (316 hours), in the cleaning mode for 16 percent of the time (112 hours) and was out of service for maintenance 41 percent of the time (292 hours). Assuming the mechanical issues that were encountered during piloting could be resolved with full-scale VSEP™ units, equipment Availability would still be about 75 percent due to chemical cleaning requirements. Therefore, in R. W. Beck's opinion, reliable VSEP™ units with higher capacities and higher flux rates are needed before incorporating the VSEP™ concept into the Project. Further, in R. W. Beck's opinion, the anticipated O&M burden of 158 VSEP™ units at 30 percent redundancy or 170 VSEP™ units with 40 percent redundancy seems impractical.

The New Logic Research Report estimates the unit consumption of electricity with the full-scale VSEP™ units would be 30.4 kWh per 1,000 gallons of permeate produced and pilot test data indicated a value of approximately 300 kWh per 1,000 gallons of permeate produced.

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[28] New Logic Research, VSEP Pilot Test Report dated November 10, 2010.

[29] Email M. Galimberti (New Logic Research to Howard Steiman dated 11/20/2009 11:31 AM.

Consequently, it appears likely that the pumping cost benefits derived from a 50 percent smaller volume of concentrate requiring disposal via the deep wells would be substantially diminished or could be eliminated by the energy consumption of the VSEP™ equipment.

8.4 Concentrate Management Alternative Selection Decision Model

Figures 8-1 through 8-9 present a Concentrate Management Alternative Selection Decision Model (the “Model”) that may be employed when concentrate management alternatives are evaluated. The Model provides a systematic approach to evaluation process via a set of decision tree analyses that may be used once basic enhanced recovery process features and projected operating conditions have been defined.

The Model is divided into five main modules. The first is an overview that defines the overall decision process. The second provides a framework for key decisions related to the technical viability of the enhanced recovery option that is being considered. The third describes a cost estimating process that could be used for evaluating the alternative economically. The fourth provides guidance for evaluating permitting process risks. The fifth provides a framework for assessing public acceptance risks.

The Modules use a series of yes-no questions as a screening tool to eliminate options that are not viable from further consideration. Then, the methodology uses weighted scoring criteria to compare the concentrate management options to identify which of the viable options best satisfies the owner’s metrics for process selection. The example in Section 8.5, herein, illustrates the use of the Model. Figure 8-1 defines the symbols used in the Model.

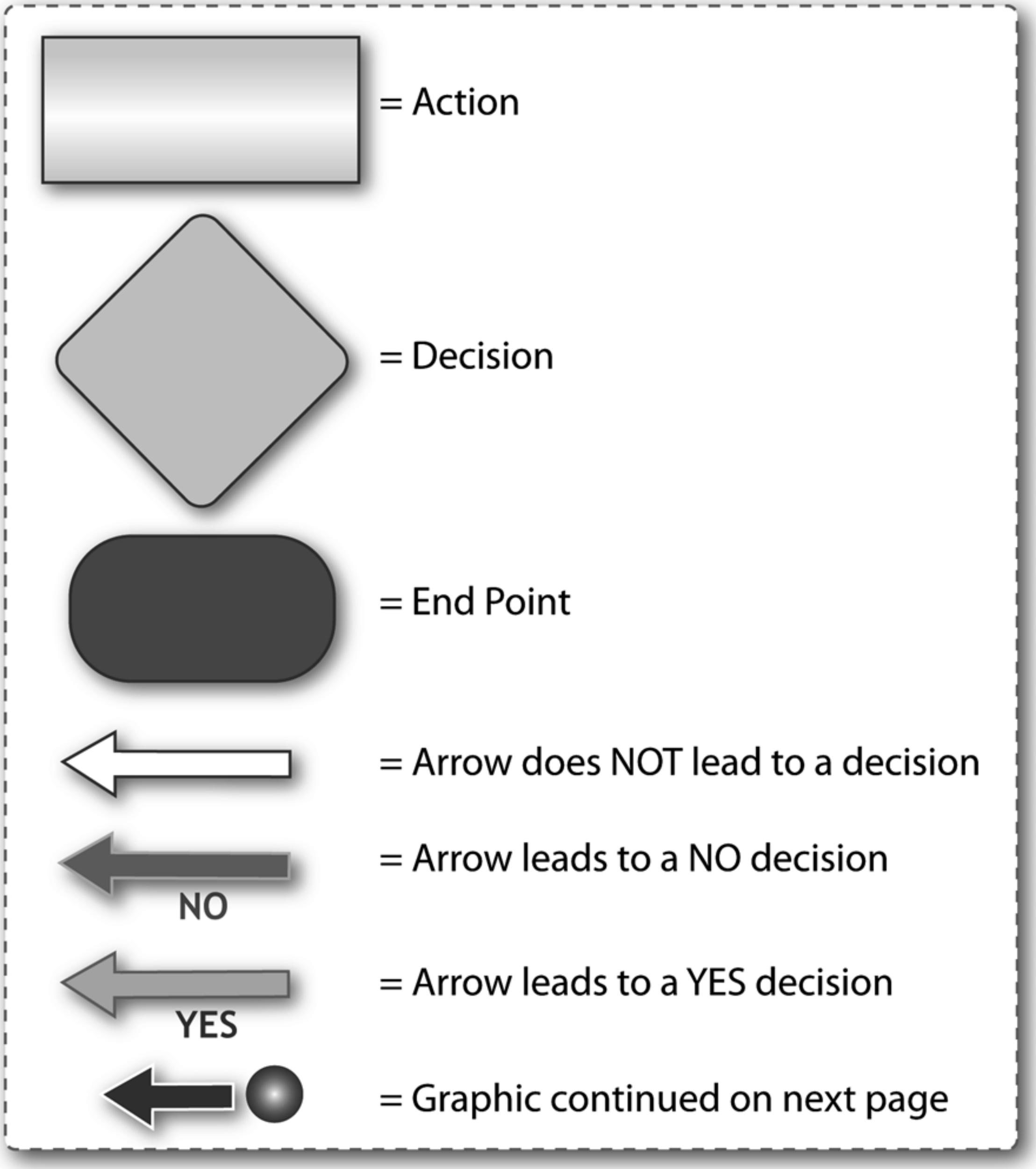

Figure 8-1. **Concentrate Management Alternative Selection Decision Analysis Model Symbols.**

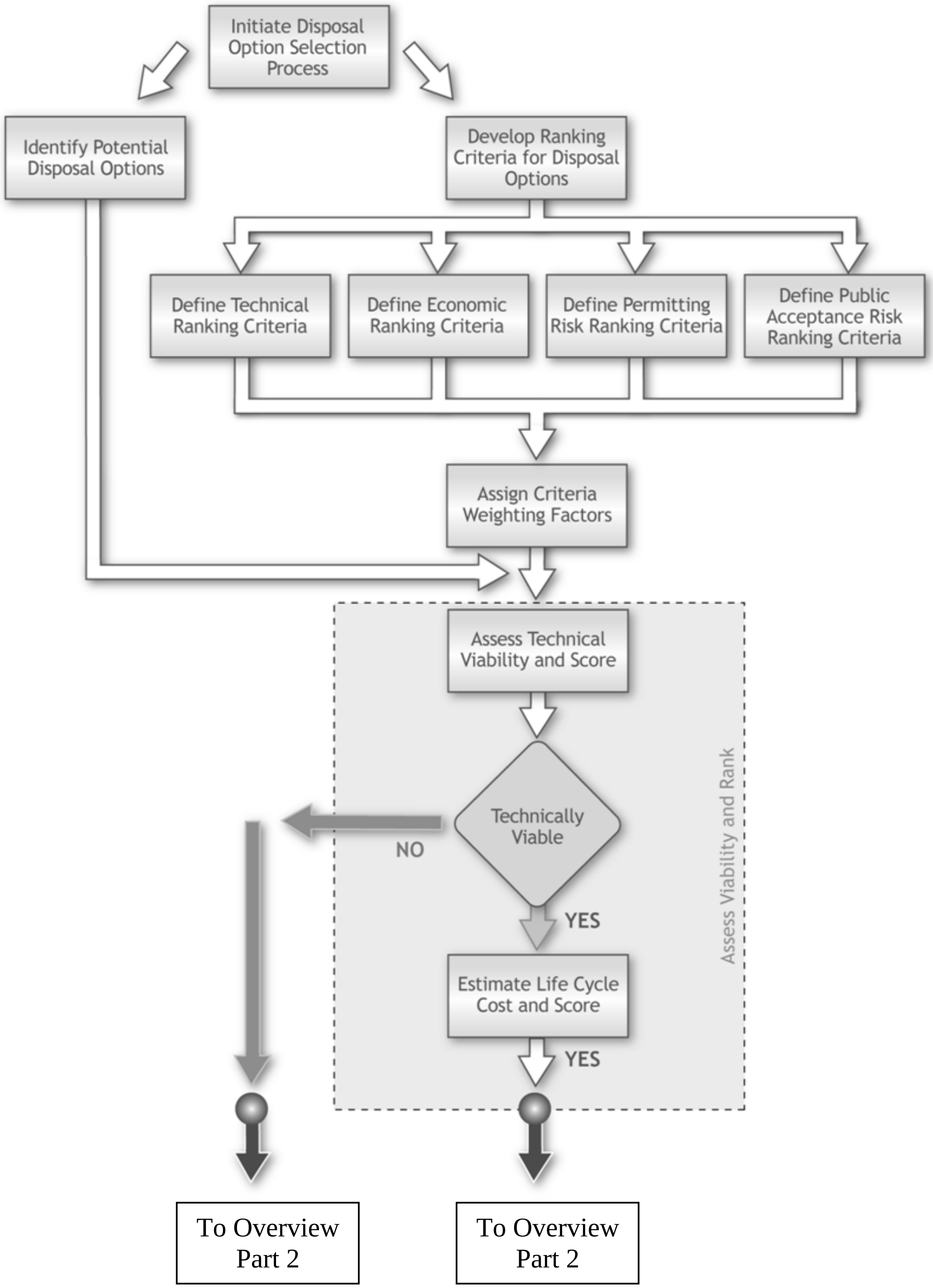

Figure 8-2. **Concentrate Management Alternative Selection Decision Analysis Model Overview – Part 1.**

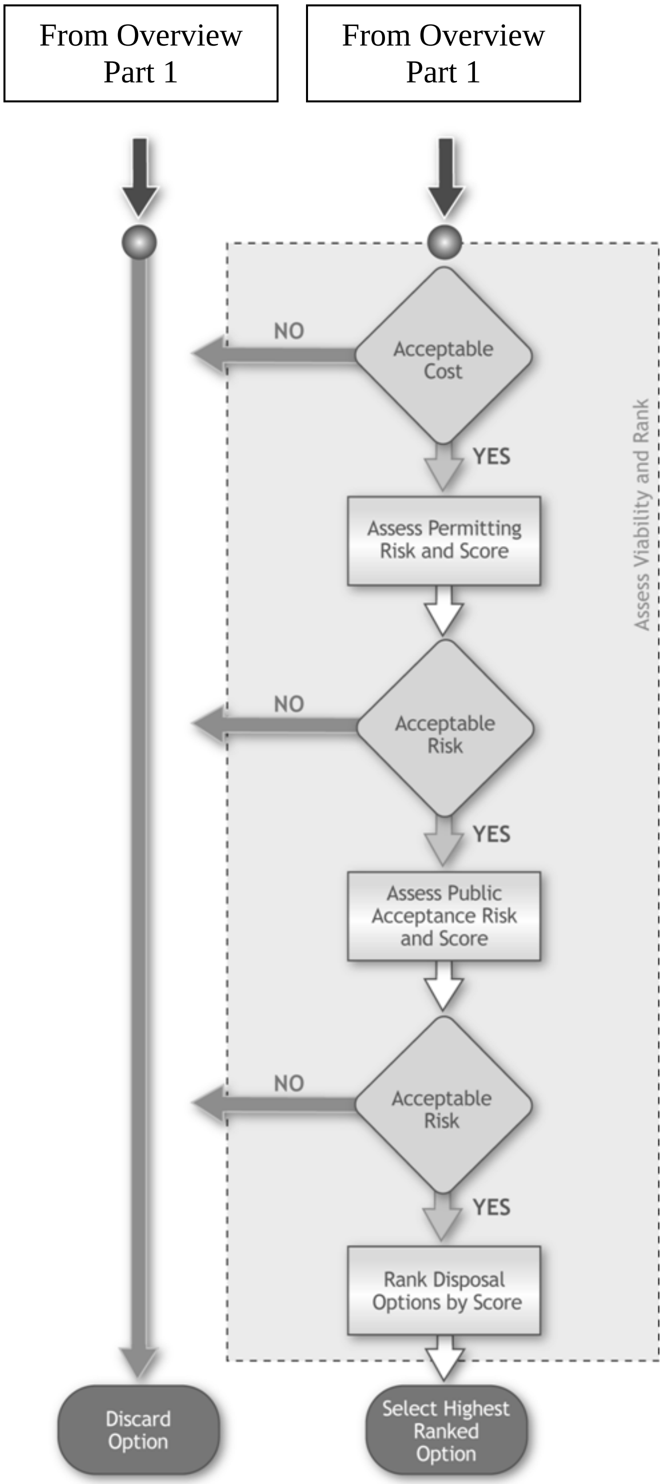

Figure 8-3. **Concentrate Management Alternative Selection Decision Analysis Model Overview – Part 2.**

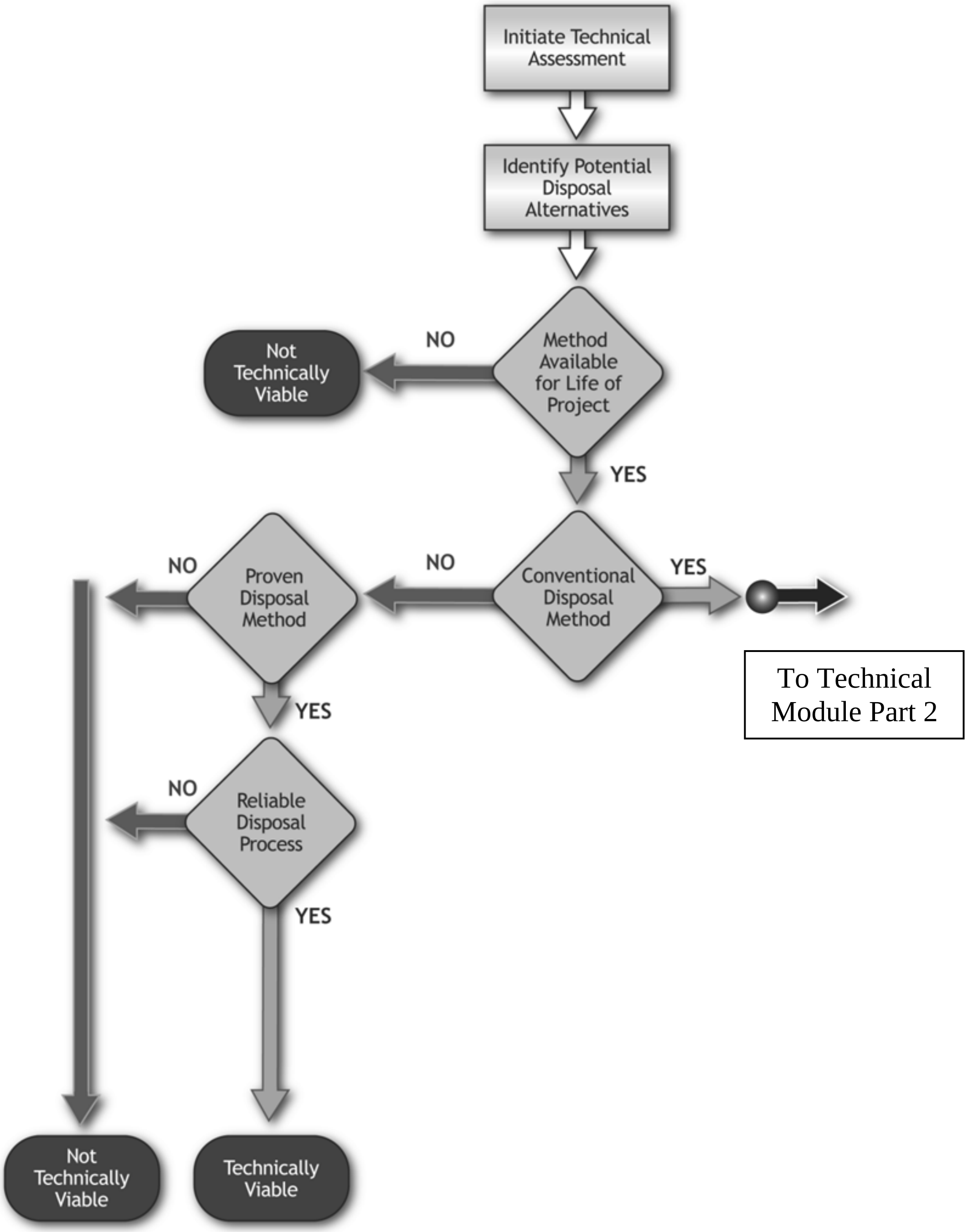

Figure 8-4. **Concentrate Management Alternative Selection Decision Analysis Technical Module – Part 1.**

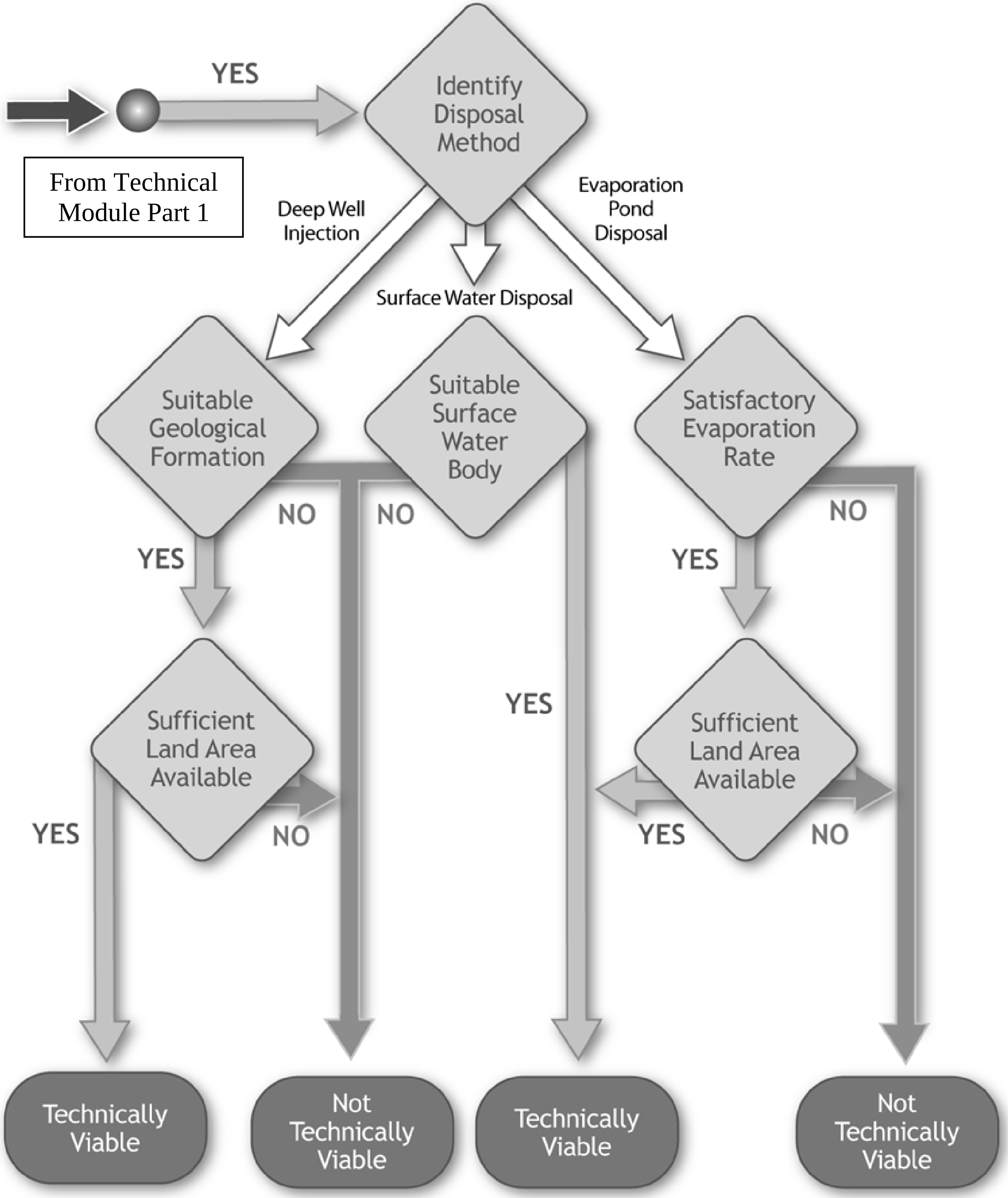

Figure 8-5. **Concentrate Management Alternative Selection Decision Analysis Technical Module – Part 2.**

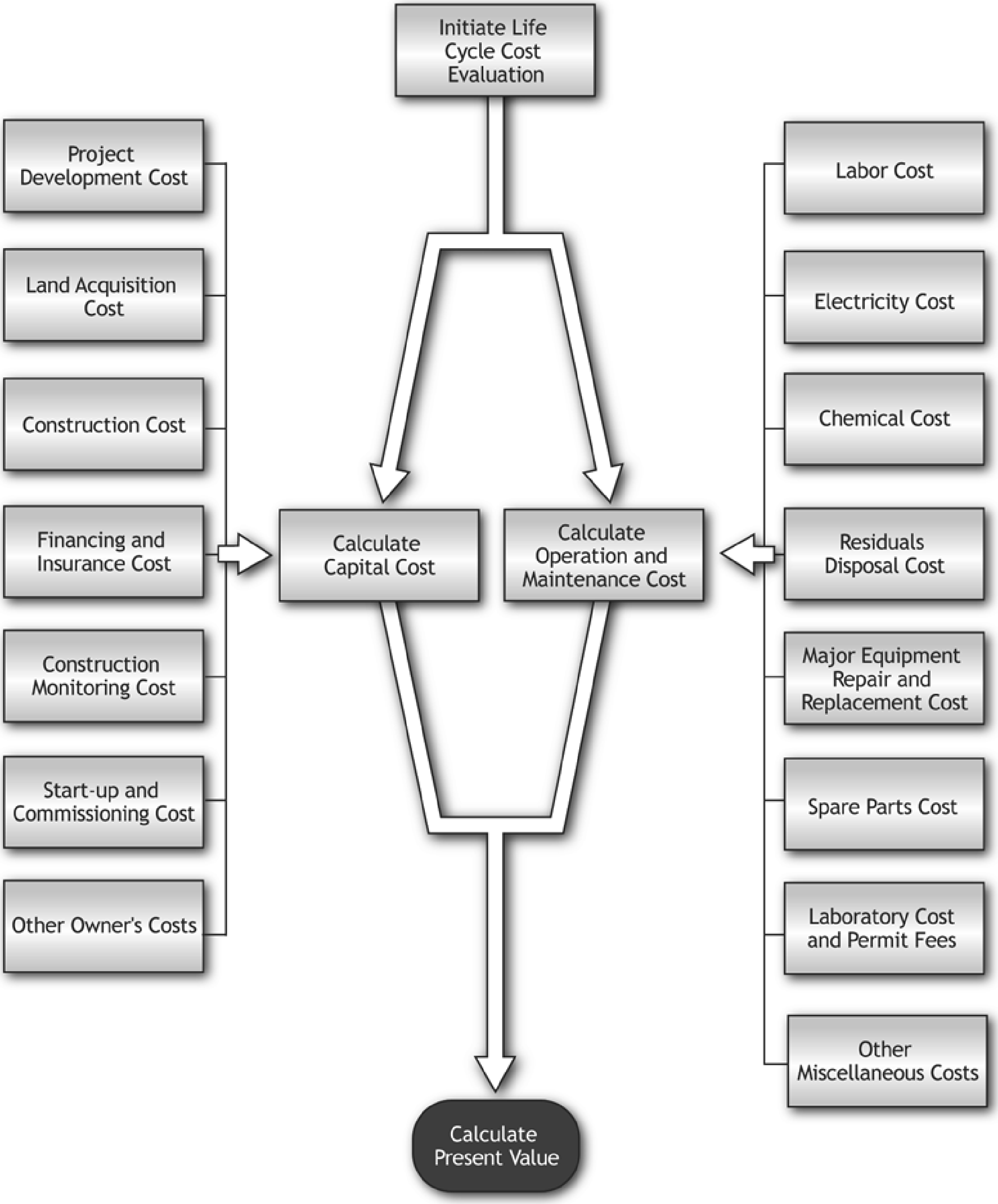

Figure 8-6. **Concentrate Management Alternative Selection Decision Analysis Life Cycle Cost Module.**

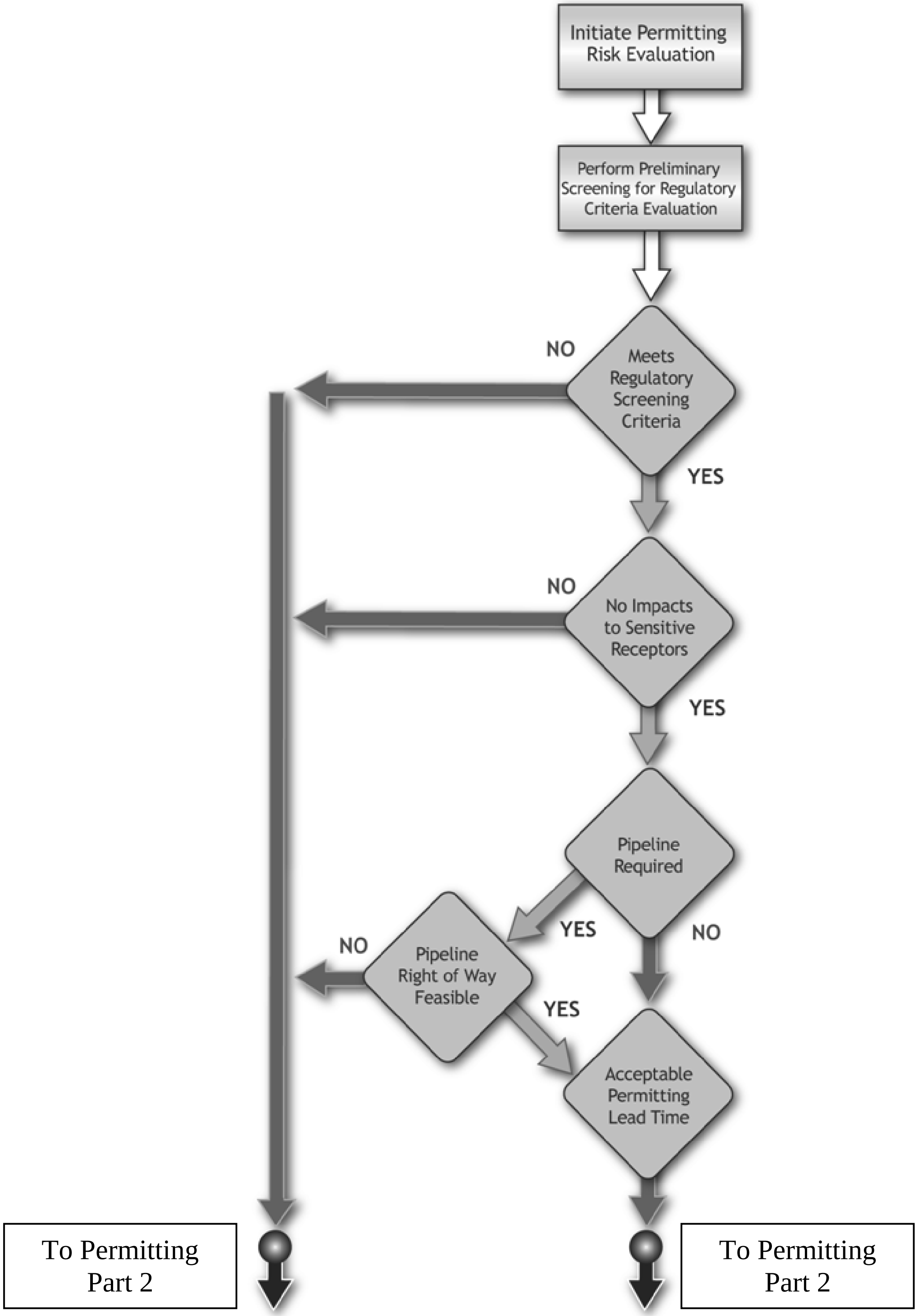

Figure 8-7. **Concentrate Management Alternative Selection Decision Analysis Permitting Module – Part 1.**

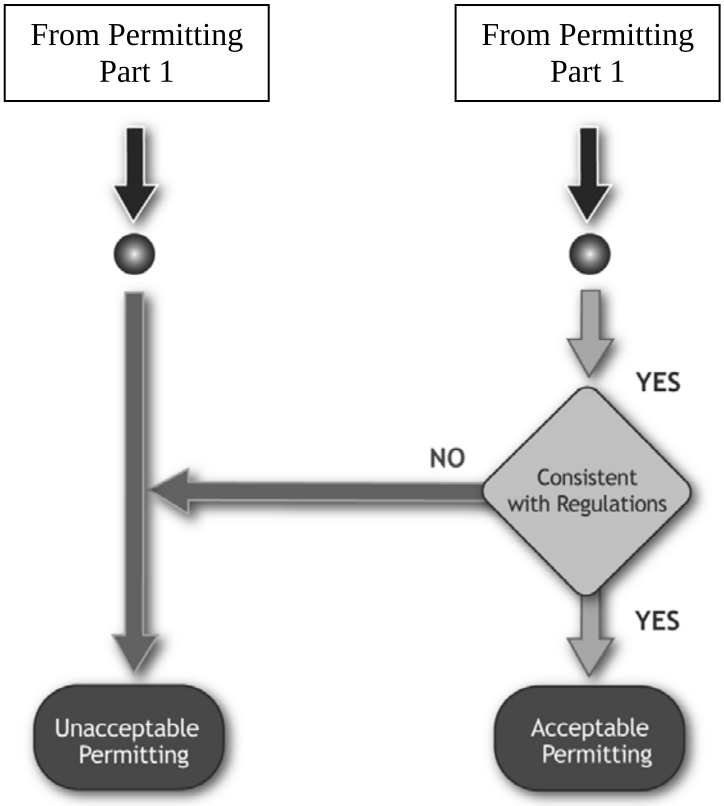

Figure 8-8. **Concentrate Management Alternative Selection Decision Analysis Permitting Module – Part 2.**

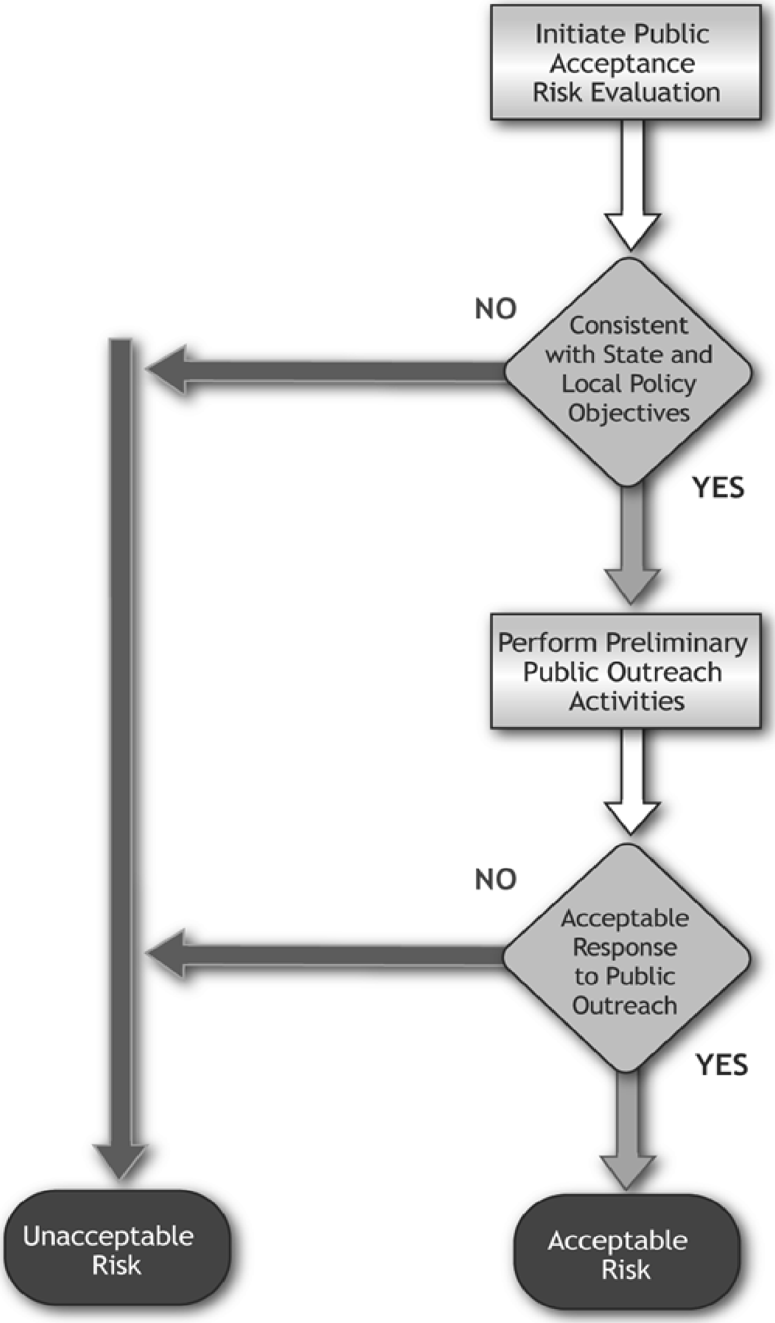

Figure 8-9. **Concentrate Management Alternative Selection Decision Analysis Public Acceptance Module.**

The Model uses Acceptable Cost and Acceptable Risk related to permitting and public acceptance as decision points in the go/no go evaluation process. Acceptable is a user-defined term as cost-benefit analyses are project-specific and acceptable risk levels are generally organizational policy decisions. Further, the order in which the evaluations of cost, permitting risk and public acceptance factors are performed may be varied at user discretion, according to the importance each organization assigns to them. However, the significant aspect of the decision process is that each evaluation should be viewed as an individual go/no go decision process so that a disposal alternative should either be technically viable, have an acceptable cost, and have acceptable risk levels for permitting and public acceptance or it should be discarded.

The Technical Assessment Module employs “Proven Disposal Method” as a go/no go decision criterion. This criterion is also user-defined since comfort levels based on industry experience are also usually organizational policy decisions.

The Permitting Module contains decision criteria related to compliance with all applicable regulations and meeting regulatory screening criteria. These have both been included because regulatory screening criteria can provide a relatively inexpensive mechanism to confirm whether an alternative merits continued study; whereas, a determination if an option meets all regulatory criteria is often a much more expensive evaluation. For example, pursuant to 30 TAC 307.10, the TCEQ has published surface water quality criteria that can be used for screening surface water discharge locations for feasibility before a complete evaluation of all applicable Texas Pollutant Discharge Elimination System (“TPDES”) regulatory criteria is completed. Therefore, if consistent with the project schedule, due to the relatively high expense, a complete evaluation of all regulatory criteria is often completed once the other go/no go steps are completed.

The Public Acceptance Risk Module contains steps related to performing public outreach and assessing the response. Similar to the Permitting Module, if consistent with the project schedule, due to the relatively high expense, a complete a full public outreach program is often completed once the other go/no go steps are completed. However, a limited public outreach process is often valuable for an evaluation of whether various options are consistent with public policy.

The Economic Module utilizes a present worth assessment approach that incorporates a capital cost and O&M cost components. This is frequently based on the preliminary engineering included in the project development phase of project activities. The components of these costs should be modified as necessary depending on the project delivery method. The Life Cycle Cost Module depicted in Figure 8-6 is consistent with the Design-Build Project Delivery method originally selected by SAWS for the Project. An engineering cost component would have been added to the capital cost configuration if a Design-Bid-Build method had been selected instead.

8.5 Brackish Groundwater Desalination Facility Example

For the purposes of providing an example for using the decision model, the selection process is based on the following assumptions about major Project features and operating conditions from the Project:

- The desalination facility is an inland facility that uses groundwater as its raw water and produces a net finished water of 20 MGD
- The potential conventional concentrate management processes include deep well injection and surface water disposal

- Enhanced concentrate recovery processes being considered include the EET HEEPM™ Process and New Logic Research VSEP™ equipment followed by deep well injection
- The disposal of concentrate with the surface water discharge option would meet TCEQ screening criteria, however, the discharge would be upstream of other users withdrawing raw water for drinking water production
- Satisfactory geological conditions and land is available for a deep injection wellfield option

As explained in the Overview Module, the first steps are to identify potential disposal options, develop the ranking criteria for disposal options, and assign weighting factors for the ranking criteria. Pursuant to the assumptions listed above, the disposal options include deep well injection, surface water disposal, or the use of the EET HEEPM™ Process and New Logic Research VSEP™ equipment. Table 8-1 shows the ranking criteria, scoring weighting factors, and scoring for this example. However, the ranking criteria and scoring weighting factors should be tailored by the owner such that they best satisfy the owner's objectives.

The EET HEEPM™ and surface water discharge options were eliminated from further consideration during the screening processes. The EET HEEPM™ option was eliminated from further consideration in the Technical Viability Module since, at the time the evaluation was performed, it was unproven in terms of commercial experience. The surface water disposal option was similarly discarded during the screening process related to the Public Acceptance Risk Module because public outreach efforts indicated public concern about the potential for sensitive receptor impacts (downstream raw water withdrawal for drinking water facility source water). The deep well injection and VSEP™ followed by deep well injection methods were deemed viable (refer to discussion in Section 4 herein for the discussion related to the EET HEEPM™ and VSEP™ processes).

There is considerable deep well injection experience for brackish groundwater desalination plants. While this is a reliable option, it is not inexpensive. Further, there is a significant amount of regulatory experience successfully permitting deep injection wells. However public outreach activities indicated that there could be potential public acceptance issues.

The VSEP™ process has commercial experience. However, the experience is primarily with wastewater laden with organic material rather than RO concentrate with substantial amounts of sparingly soluble materials like calcium carbonate and silica. Consequently, it has a high potential for membrane fouling because it operates well beyond the saturation concentration for these sparingly soluble materials. Further the VSEP™ has the potential for mechanical issues as it relies on a vibratory action to function properly, and as discussed in Section 7, a number of reliability issues were observed during the pilot test. The process can lower costs as it provides additional volume reduction and product water recovery. However, this was not achieved for the SAWS example due to the large number of VSEP™ units needed for the full-scale plant. While it is anticipated that the reduction in the concentrate volume would enhance public perception due to improved efficiency, a deep well injection system, albeit smaller, is still needed. It is also important to note that while the VSEP™ reduces the volume of the concentrate disposal stream, it does not remove salt from the waste stream. As a result, even though the volume is reduced, the salt concentration in the waste stream increases and the total pounds of salt per day disposed via deep injection wells remains about the same. Therefore, the VSEP™ followed by deep well injection option could produce public acceptance risks similar to those of a deep well injection option without VSEP™.

Scoring was then conducted for the two remaining options based on the information above. As shown in Table 8-1, scoring indicated that the deep well injection option satisfied SAWS' criteria more completely than the VSEP™ followed by deep well injection method.

Table 8-1. Concentrate Management Option Evaluation and Weighing Factors.

			Deep Well Injection		**VSEP™ Followed by Deep Well Injection**	
Criteria Number	**Description**	**Weighting Factor**	**Criterion Score**	**Weighted Score**	**Criterion Score**	**Weighted Score**
1	Technical viability based on feasibility and industry experience with the method	10	10	100	1	10
2	Least cost	5	10	50	2	20
3	Permitting risk based on consistency with regulatory criteria and impacts to sensitive receptors	10	5	50	5	50
4	Public acceptance based on impacts to sensitive receptors, consistency with public policy objectives and response to public outreach	5	5	25	7	35
Total				**225**		**115**

Based on the above evaluation, SAWS has not opted to include the VSEP™ alternative in their Project design.

9 Resolution of the Texas Water Development Board Review Comments

Appendix III depicts the resolution of the Texas Water Development Board review comments.

10 References

1. Report dated September 17, 2007 Mickley, Mike P.E., Ph.D., Mickley & Associates, Boulder Colorado, April 21, 2009, Enhanced Recovery Alternatives Review for SAWS Brackish Groundwater Desalination Feasibility Assessment Project, Mickley & Associates served as a subconsultant to R. W. Beck, Inc.
2. Average Raw Water Quality for the ASR Test Well installed for the R. W. Beck Feasibility Evaluation. SAWS Brackish Groundwater Desalination Water Quality Assessment Technical memorandum, T. Hickey and H. Steiman to K. Morrison dated October 17, 2010.
3. New Logic Research, VSEP Pilot Test Report dated November 10, 2010.
4. Memorandum Tara Hickey and Howard Steiman to Kevin Morrison dated October 17, 2008, SAWS Desalination Project Treatment Options Evaluation.
5. Bates, Wayne T., Bartels, Craig, and Franks, Rich, Hydranautics, CA, 2008, "Improvements to Spiral Wound RO and NF Membrane & Element Construction for High Fouling Feedwater Applications"
6. http://www.vsep.com/pdf/VSEP Brochure.pdf (New Logic Research, Inc. web posting).

7. LBG Guyton, May 2008, SAWS Brackish Wilcox Groundwater Investigation Southern Bexar and Northern Atascosa Counties, Texas.
8. Carollo Engineers, San Antonio Water Systems (SAWS) Membrane Pilot Test Protocol, Brackish Groundwater Desalination Project, Final, dated June 2008.
9. E-mails Roger Torres, New Logic Research to Howard Steiman dated September 26, 2007, 3:26 PM and April 7, 2009, 4:08 PM.
10. http://www.osha.gov/SLTC/autobody/docs/cdc003.html#Noise/HearingLoss.
11. E-mail Donald Schaezler (Baer Engineering) to Rosemary Wyman; Robert Long; Tara Hickey, Leo Cannyn, Robert Bergeron, and Howard Steiman dated 9/2/2009 7:22 PM.
12. E-mail M. Galimberti (New Logic Research to Howard Steiman dated 11/20/2009 11:30 AM.)

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Appendix I. Protocol for the VSEP™ Pilot Program

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San Antonio Water System

Protocol for VSEP™ Feasibility Pilot Testing Program

Prepared by: R. W. Beck, Inc.

August 5, 2008

Revised: February 2, 2009

Revised: April 8, 2009

Revised: July 28, 2009

Revised: June 4, 2010

Revised: November 10, 2010

R·W·BECK

An SAIC Company

1.0 Purpose

The R. W. Beck, Inc. (“R. W. Beck”) Team has been commissioned by the San Antonio Water System (“SAWS”) to perform a feasibility and pilot evaluation of an enhanced recovery treatment technology of concentrate for SAWS’ proposed 20 million gallon per day (“MGD”) reverse osmosis (“RO”) facility. The tasks in the study include:

- Reviewing enhanced recovery alternatives and identifying the most promising enhanced recovery option for the SAWS Brackish Groundwater Desalination Facility Project (the “Project”).
- Defining the initial water quality and testing conditions for enhanced recovery pilot testing.
- Developing a pilot test protocol and conducting a three- to four-month pilot testing program for the enhanced recovery alternative selected as the most promising option for the Project.
- Providing a pilot study report.
- Providing a technical and economic benefit assessment and an evaluation program report for the selected enhanced recovery option.

A review of available enhanced recovery alternatives for the Project indicated that the New Logic Research Inc. Vibratory Shear Enhanced Process™ (“VSEP™”) system merited further evaluation. The purpose of this document is to provide the protocol for pilot testing the VSEP™ system (“Protocol”).

2.0 Protocol Overview

The Protocol addresses the following items:

- Goals and objectives of pilot testing activities.
- The schedule for pilot testing activities.
- Testing parameters and pilot unit set-up for each phase of testing.
- Schematics of testing, sampling and chemical feed facilities.
- Sampling and testing plan, including all parameters to be monitored throughout the process.
- Cleaning requirements and schedule.
- Management and monitoring plan.
- Data collection and analysis.
- Quality Assurance/Quality Control (“QA/QC”) Plan.

Following conclusion of the pilot testing, the R. W. Beck Team will prepare a pilot study report. The pilot study report will include a chronology of the pilot testing activities; all operating data and water quality analyses; findings; and recommendations for full-scale operation.

3.0 Project Team

The Project team for piloting activities consists of SAWS, R. W. Beck, New Logic Research Inc., Mickley and Associates, and Baer Engineering and Environmental Consulting representatives. SAWS will administer and oversee the activities. The R. W. Beck Team will be responsible for recommending a preferred enhanced recovery alternative for the Project, conducting the pilot test, providing the pilot test and evaluation program reports, and preparing an economic benefit assessment. The responsibilities for each entity on the R. W. Beck Team are as follows:

- R. W. Beck – manage and direct all program activities.
- New Logic Research, Inc. – provide and operate the pilot test equipment, perform all process sampling and data logging functions, and assist with the preparation of all reports related to pilot activities. New Logic Research will utilize Alamo Analytical Laboratories for analyzing the non-field reported samples.
- Mickley and Associates – Review enhanced recovery alternatives to identify the most promising enhanced recovery option for the Project, provide a technical and economic benefit assessment for the selected enhanced recovery option, review pilot test data, and assist with the preparation of reports.
- Baer Engineering and Environmental Consulting – perform QA/QC services for pilot field testing activities and laboratory data review and assist with the preparation of reports related to pilot activities.

Attachment A provides a contact list of Project participants. Tara Hickey and Howard Steiman will serve as the principal points of contact for communications with SAWS. SAWS should be notified directly and immediately in the event of chemical spills, personnel accidents or other such emergency situations. Robert Macias, ASR Plant Manager, (Mobile Phone: 210.325.6748) will serve as the principal point of contact with SAWS for notification of these types of contingencies. Kevin Morrison or Duane Bryant should be contacted directly in the event that Mr. Macias is unavailable. Tara Hickey and/or Howard Steiman should be contacted as soon as incident conditions permit.

4.0 Goals and Objectives

The purpose of the piloting is to assess the performance of the VSEP™ equipment if used as an enhanced recovery stage for the Project. Therefore, the goals of the VSEP™ equipment piloting program are to:

- Evaluate the efficacy of the VSEP™ system to accomplish a reduction in concentrate volume under the conditions anticipated for the Project.

- Identify the need for any process chemical addition such as acid or anti-scalant and, if so, to estimate dosing requirements.
- Evaluate the operational reliability of the VSEP™ system.
- Determine the required frequency for chemical cleaning operations and chemical consumption.
- Identify process interface requirements and scale-up factors for full-scale application.
- Develop the data necessary to conduct a technical and economic benefit assessment of VSEP™ after pilot testing field activities are complete.

The purpose of the assessment is to compare VSEP™ with conventional methods for concentrate management and disposal.

5.0 Pilot Equipment Description

New Logic Research will provide pilot testing services for the VSEP™ system at a test well site on the SAWS' Aquifer Storage Recovery Facility ("ASR") property using a Series LP VSEP™ pilot unit. Figures 1, 2, and 3 below depict the VSEP™ equipment.

As shown in Figure 1, feed water enters the filter pack and is separated into permeate and concentrate streams by the membrane leaves configured in a flat-sheet arrangement in the filter pack.

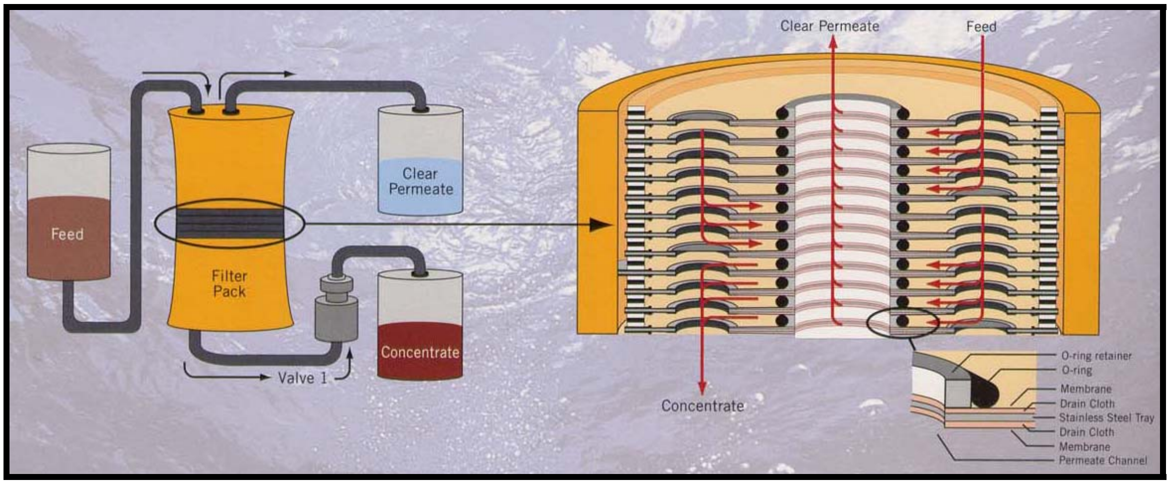

Figure 1 - VSEP™ Process Diagram
(Courtesy of New Logic Research, Inc.)

For the purposes of the pilot testing program, the Series LP VSEP™ pilot unit will be configured in an L mode (single membrane filter pack). According to New Logic Research, this equipment can be directly scaled up to a full-sized production unit. Table 1 summarizes key equipment specifications and Figure 2 shows the equipment.

Table 1 – New Logic Research Series P VSEP™ Specifications

Filter Pack

Membrane Area - P Mode: 16.44 sq. feet.

Filtrate Removal Capacity: 2.25 gpm

Maximum Operating Pressure: 600 psi

Wetted Materials: 316 Stainless Steel, Polypropylene, EPDM/Viton/Buna

Vibration Drive System

Motor: Baldor, 2HP, 3450 RPM

Speed Controller: AB Power Flex 40 22B-B-017-F-1-0-4

Drive Bearings: Morse Sealmaster RFB2102

Electrical Specifications

Power Supply Voltage: 208-24- VAC 3 Phase

Normal Full Load Operating Current: 24-30 Amps

Power Cord: 8 Feet with NEMA L15-30 Plug

Required Receptacle: NEMA L15-30, 30 Amp Circuit

Feed System

Pump: Hydra-Cell

Motor: Baldor, 5 horsepower

Pump Motor Controller: AB Power Flex 40 22B-B-017-F-1-0-4

Voltage: 7.5, 10 horsepower

Flow Control Valve: Sharpe Model V8466TTTE

Actuator: Sea Mark II Model SEA-11-SA-PP

Instrumentation

Pressure Gauges: Ashcroft Model 1009 (0-600 psi)

Temperature Probe: Ashcroft Type 2410E Digital

Conductivity Meter: Signet Model 3-2850-52-41 (0 – 10,000 microS)

Temperature Transmitters: Effector Model TN2530 (-40 – 125ºC)

Pressure Transmitters: Effector Model TN2530 (0-1450psi)

pH Meter: Signet 0-14 Model 3-2774-1 and 3-2750-2

Flow Meter: Foxboro Model IMT25-SETB10M-AB, 801QA-WCR-PJGFNA-A

Flow Indicator: GFI Model A109GMA100NA1 (3-50 gpm)

Operating Site Conditions

Equipment Rating: NEMA 4, Indoor-Outdoor (Protect from Sun and Rain)

Ambient Temperature: 32 to -104°F (0 to40°C)

Storage Temperature: -2 to 140°F (-55 to 60°C)

Relative Humidity: 90% or Less (Non-Condensing)

Elevation: 3,300 Feet Without De-rating

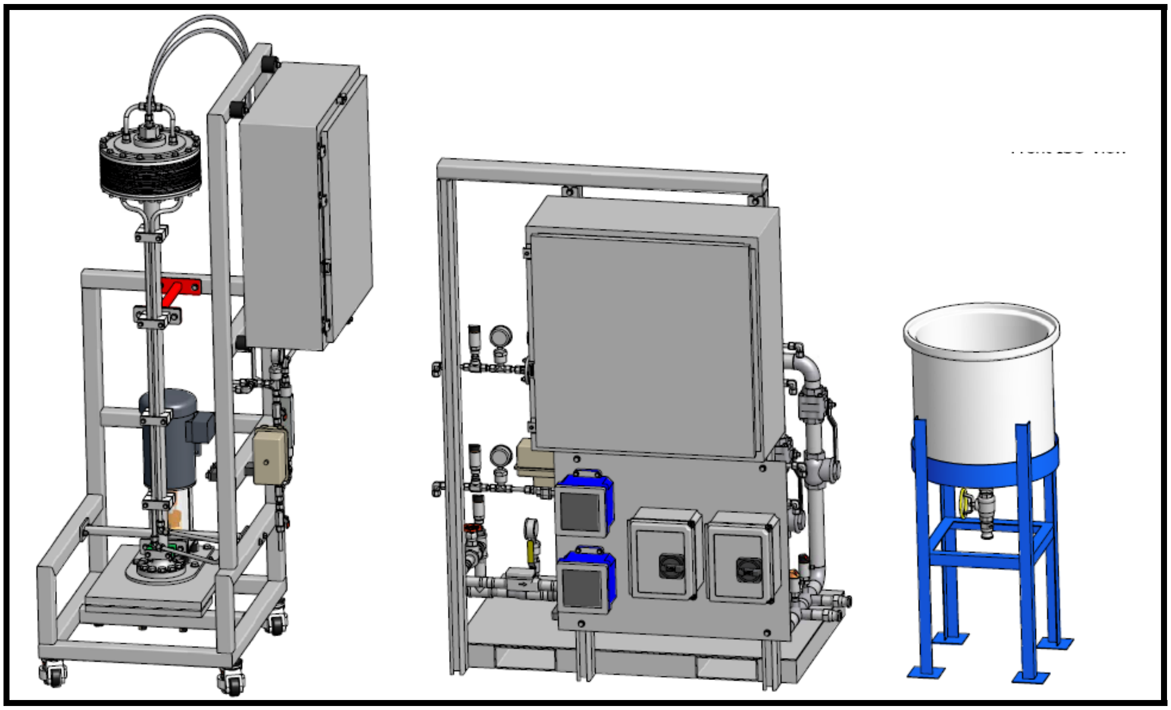

Figure 2 - New Logic Research Automated LP VSEP™ System
(Courtesy of New Logic Research, Inc.)

Figure 3 illustrates the New Logic Research concept for allowing the VSEP™ equipment to concentrate its feedwater well beyond the solubility point for sparingly soluble materials such as silica, calcium fluoride, barium sulfate, calcium carbonate, and calcium sulfate. According to New Logic Research, membrane fouling is prevented by the oscillation of the filter pack with a torsion spring. New Logic Research also asserts that this oscillation creates a shear force at the membrane surface which is approximately ten times the shear rate of a conventional cross-flow RO system. The shear serves to sweep particulate matter away from the membrane surfaces and; thereby, provides a cleaning action that allows the VSEP™ system to operate well beyond the saturation levels for sparing soluble materials that can be achieved with a conventional cross-flow RO system. A cleaning solution is also occasionally needed to maintain membrane performance. New Logic Research literature[1] further states that the high shear also allows a maximum permeate flux that is typically between three and ten times the permeate flux in conventional cross-flow systems.

As explained in Section 5.0 of their report[2], New Logic Research anticipates a two-year membrane life based on their experience in other similar applications. Membrane life for this application is likely limited by irreversible fouling caused by the deposition of sparingly soluble materials and the high, cumulative number of chemical cleanings the membranes in the VSEP™ system experience due to the deposition of the sparingly soluble materials. Consequently, the high shear rate is not expected to be a limiting factor for membrane life.

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[1] http://www.vsep.com

[2] Logic Research, Ins. VSEP Pilot Test Report dated July 30, 2010.

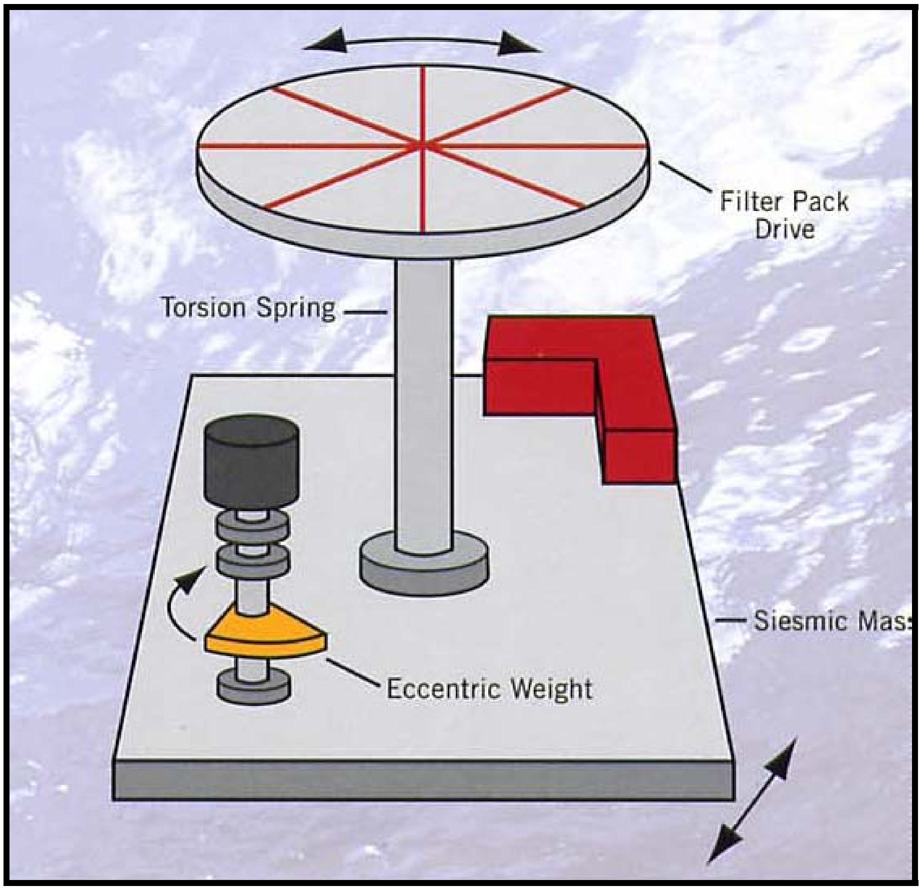

Figure 3 - VSEP™ Resonating Drive System
(Courtesy of New Logic Research, Inc.)

According to New Logic Research, the process may be capable of recovering more than 50 percent of the concentrate stream which would likely be reused as feedwater for the Conventional RO Process. Thus, if feasible, VSEP™ would reduce the volume of the concentrate residuals stream by more than 50 percent; thereby, decreasing the size of the deep well injection system for the SAWS Facility proportionately. The VSEP™ equipment will be fed from the conventional RO concentrate stream that SAWS is using to the pilot the RO membranes for their 20 MGD desalination facility. Thus, actual operating conditions for the SAWS desalination facility will be simulated.

6.0 Process Flow Diagram

The pilot testing of the VSEP™ process will be conducted in conjunction with the pilot testing of the Conventional RO Process for the desalination facility. Figure 4 provides the process flow diagram for the VSEP™ pilot test equipment. As shown, the VSEP™ pilot unit uses concentrate from the pilot unit for the Conventional RO Process as feedwater and returns the VSEP™ permeate and concentrate to a common 100-gallon mixing tank where they are combined with the residuals from the Conventional RO Process pilot unit prior to disposal. Continuous temperature, flow, pressure, pH, and conductivity instrumentation and sampling points for the VSEP™ feedwater, concentrate, and permeate have been incorporated into the system configuration. The automated L/P VSEP^{TM} system includes a data logger that will record these continuous sampling parameters will be recorded throughout the operation of the unit

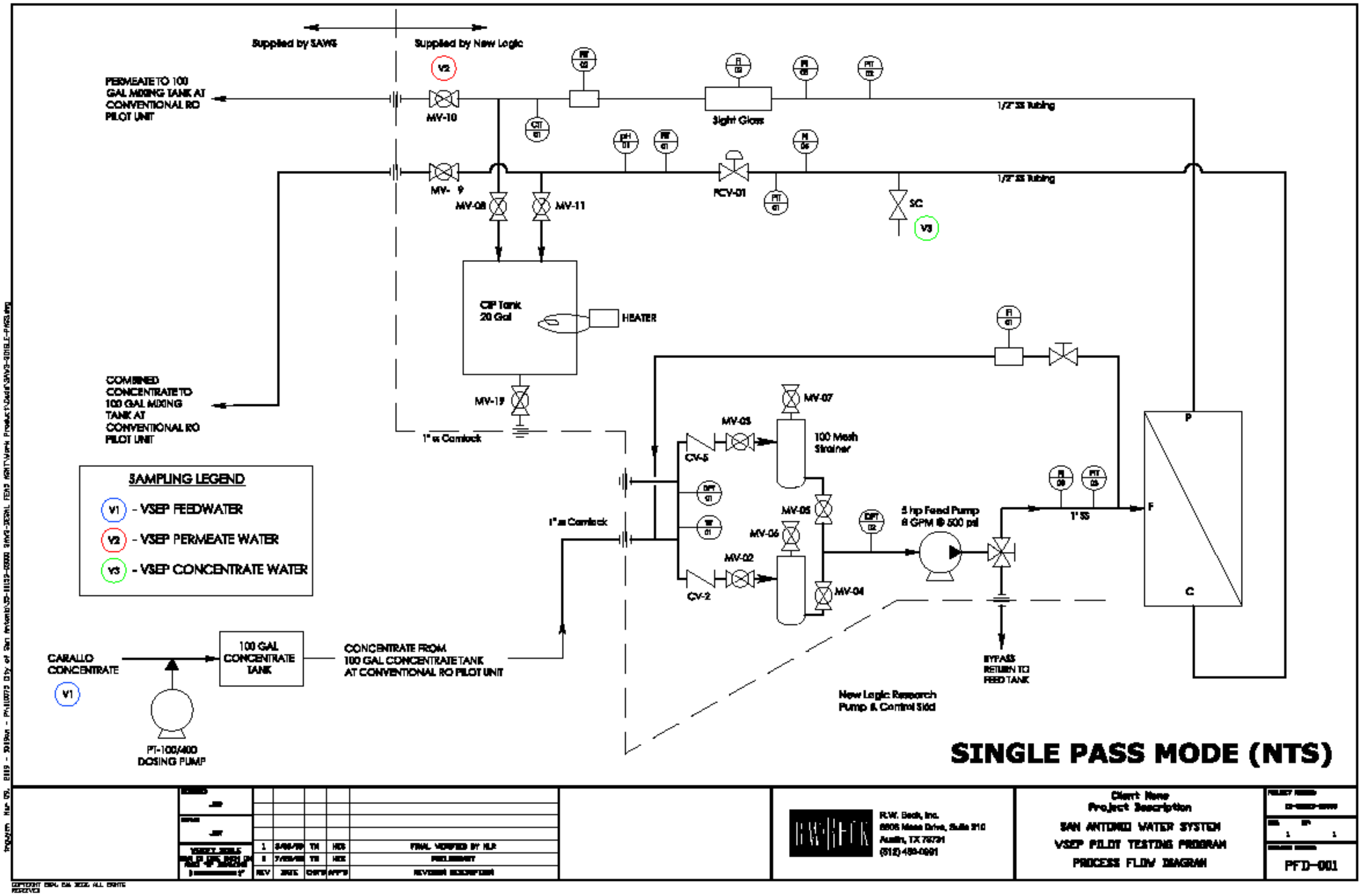

Figure 4 – Process Flow Diagram

7.0 Initial Water Quality Conditions and Testing Conditions

Table 2 depicts the average raw water, concentrate and permeate qualities anticipated from the Conventional RO Process. The Conventional RO Process will use the test well at the SAWS Aquifer Storage and Recovery Facility ("ASR") site as a raw water source.

The raw water quality constituents in Table 2 were obtained from laboratory test data collected during the SAWS feasibility assessment for the Project (LBG Guyton, May 2008, *SAWS Brackish Wilcox Groundwater Investigation Southern Bexar and Northern Atascosa Counties, Texas*). The concentrate and permeate concentration values shown were estimated by modeling RO system performance using Dow-FilmTec ROSA v6.1.5 ConfigDB U238786_55 freeware. Since it is likely that the Conventional RO Process pilot test will demonstrate that a recovery in the range of 80 to 90 percent is feasible, permeate and concentrate cases for 80, 85, and 90 percent were modeled.

The VSEP™ Piloting will use the concentrate from the pilot testing of the Conventional RO Process as feedwater. Thus, the actual feedwater quality for the VSEP™ process will vary with the recovery in the Conventional RO Process and with actual raw water quality. Consequently, the feedwater quality for the VSEP™ process will need to be verified during the conventional RO pilot testing program. The modeling was conducted assuming a two-stage design per the R. W. Beck Feasibility Report dated October 2008. The need for a three-stage design at an 85 or 90 percent recovery will also be established during the conventional RO pilot testing program.

Table 2 - Modeled Conventional RO Pilot Quality Constituents

			Conventional RO Pilot Concentrate Quality					
		ASR Test Well Water Quality	80 Percent Recovery		85 Percent Recovery		90 Percent Recovery	
Constituent			Concentrate	Permeate	Concentrate	Permeate	Concentrate	Permeate
NH_4	mg/L	0.92	4.10	0.13	5.35	0.14	7.82	0.15
K	mg/L	8.50	41.70	0.20	55.20	0.22	82.72	0.26
Na	mg/L	395.70	1,947.88	7.48	2,579.93	8.32	3,870.22	10.14
Mg	mg/L	22.80	113.26	0.17	150.26	0.20	226.10	0.24
Ca	mg/L	43.70	217.12	0.33	288.04	0.37	433.45	0.45
Sr	mg/L	0.01	0.05	0.00	0.06	0.00	0.10	0.00
Ba	mg/L	0.01	0.05	0.00	0.07	0.00	0.10	0.00
CO_3	mg/L	0.70	29.70	0.00	44.33	0.00	78.72	0.00
HCO_3	mg/L	247.90	1,159.33	5.75	1,524.29	6.40	2,258.83	7.81
NO_3	mg/L	1.00	3.42	0.37	4.26	0.40	5.76	0.45
Cl	mg/L	245.71	1186.19	5.15	1,570.63	5.71	2354.78	6.94
F	mg/L	1.31	6.31	0.03	8.34	0.04	12.49	0.05
SO_4	mg/L	516.26	2,512.08	5.85	3,330.70	6.54	5,006.58	8.00
SiO_2	mg/L	19.40	95.79	0.29	127.03	0.31	190.99	0.36
Boron	mg/L	0.01	0.02	0.01	0.02	0.01	0.03	0.01
CO_2	mg/L	10.30	10.47	4.57	14.08	4.90	22.60	5.44
TDS	mg/L	1,488.12	7,317.09	25.80	9,688.62	28.68	14,528.81	34.91
pH	SU	7.91	7.95	6.27	7.90	6.29	7.82	6.33

8.0 Pilot Testing Procedure

The VSEP™ pilot unit will be operated by New Logic Research Incorporated. Testing activities will be monitored by SAWS and R. W. Beck Team personnel.

The pilot testing will be conducted in six phases. The key test parameters are:

■ Feed Pressure:	500 psig – constant in all phases of testing
■ Vibration Amplitude:	3/4 inch – constant in all phases of testing
■ Anti-scalants:	Anti-scalant material and dosing varies in Phases 2 through 6

Recovery (VSEP™): (Target goals prior to testing)	65 percent in Phase 2, 60 percent in Phase 4, 60 percent, 65 percent and 70 percent in Phase 5, and variable depending on the results from Phase 5 in Phase 6
Recovery (Conventional: RO Process)	80 to 90 percent - constant value established by the conventional RO pilot testing program
Feedwater flow rate	To be determined via testing – consistent approach in all phases of testing
pH (VSEP™):	Not adjusted – established by the Conventional RO Process pilot testing program
Cleaning Procedure:	NLR 404 / NLR 505 – constant in all phases of testing
Cleaning Frequency:	To be determined via testing – consistent approach in all phases of testing

The purpose, duration and procedure for each phase are described below. Test durations and the basic equipment performance testing procedures for each phase of piloting were established by New Logic Research on the basis of their experience in operating their VSEP™ equipment (e-mail Roger Torres, New Logic Research to Howard Steiman dated 9/26/2007 3:26 PM).

1. **Phase 1 - Initial Run-in and Tune-up Period (~ 5 days)**

   The purpose of Phase 1 is to start up the equipment, allow the flux rate to stabilize and to verify that verify the equipment is operating properly. Recovery rates are maintained at 75 percent, no anti-scalants are used, and cleaning is performed as needed based on flux trends. No sampling for laboratory analysis is conducted in this phase. Physical process parameters such as flows, pressures, temperatures and vibration amplitude are recorded to verify proper equipment operation.

2. **Phase 2 – Anti-scalant Testing - On/Off (~ 5 days)**

   The purpose of Phase 2 is to determine if the use of an anti-scalant will produce a significant increase in VSEP™ average flux rate and/or reduce the frequency of chemical cleanings. For the purposes of the pilot test, a Significant Response to an anti-scalant is defined as either: (1) a 25 percent increase in average flux rate during the test; or (2) a 50 percent increase in the flux rate 24 hours after cleaning. If the anti-scalants produce a Significant Response, then the testing will proceed to Phase 3 and/or Phase 4 for additional pre-treatment testing. If anti-scalants do not produce a Significant Response, then the testing will proceed directly to Phase 5 using no anti-scalants. No sampling for laboratory analysis is conducted in this phase. Physical process parameters such as flows, pressures, temperatures and vibration amplitude are recorded to verify proper equipment operation and to substantiate the magnitude of the Significant Responses (if any) for each anti-scalant).

   Two anti-scalants will be tested, SpectraGuard SC™ and a 90 percent /10 percent mixture of Pretreat Plus^{TM} 0100/Pretreat Plus^{TM}0400. SpectraGuard SC™ was selected for testing in the VSEP™ testing program because it will be used as an anti-scalant in the conventional RO pilot testing program. Consequently, if SpectraGuard SC™ proves to be effective, its use would serve to simplify full-scale facility operation by reducing the number of chemicals needed for full-scale facility operation. Pretreat Plus™ 0100/Pretreat Plus™0400 was selected by New Logic Research as an anti-scalant based on their experience. Table 3 summarizes the Phase 2 testing protocol.

Table 3 - Phase 2 Testing Overview

				Sample Collection for Laboratory Analysis			
Phase 2 Test	Duration (hrs)	Cleaning Frequency	Variable	Feed (1)	Feed (VSEP™)	Perm (VSEP™)	Reject (VSEP™)
1	24 hours	Before Test	Anti-scalant Feed: OFF	None	None	None	None
2	24 hours	Before Test	SpectraGuard SC™: ON	None	None	None	None
3	24 hours	Before Test	Pretreat Plus™ 0100/Pretreat Plus™0400: ON	None	None	None	None
Test Parameters Varied During Phase 2 Testing:							
SpectraGuard SC™:			Dosing to be determined in Phase 2				
Pretreat Plus™ 0100/Pretreat Plus™0400:			Dosing to be determined in Phase 2, 90 percent / 10 percent mixture				
Recovery (VSEP™):			65 percent				

1. Conventional RO Process.

3. Phase 3 – SpectraGuard SC™ Threshold Concentration Testing (~ 5 days)

The purpose of Phase 3 is to determine the minimum concentration of SpectraGuard SC™ required to produce a Significant Response. This threshold concentration test will only be carried out if the results in Phase 2 indicate that the use of SpectraGuard SC™ produces a Significant Response. Four concentration conditions will be studied. The SpectraGuard SC™ concentrations used for each of the four threshold concentration tests will be determined based on the results from Phase 2.

Data substantiating the magnitude of the Significant Response will be recorded. Physical process parameters such as flows, pressures, temperatures and vibration amplitude will be used. No sampling for laboratory analysis is conducted in this phase. Table 4 summarizes Phase 3 testing protocol.

Table 4 - Phase 3 Testing Overview

				Sample Collection for Laboratory Analysis			
Phase 3 Test	Duration (hrs)	Cleaning Frequency	Variable	Feed [(1)]	Feed (VSEP™)	Perm (VSEP™)	Reject (VSEP™)
1	24 hours	Before Test	SpectraGuard SC™ (Conc. 1)	None	None	None	None
2	24 hours	Before Test	SpectraGuard SC™ (Conc. 2)	None	None	None	None
3	24 hours	Before Test	SpectraGuard SC™ (Conc. 3)	None	None	None	None
4	24 hours	Before Test	SpectraGuard SC™ (Conc. 4)	None	None	None	None
Test Parameters Varied During Phase 3 Testing:							
SpectraGuard SC™:			Variable as indicated above				
Pretreat Plus™ 0100/Pretreat Plus™0400:			OFF				
Recovery (VSEP™):			60 percent [(2)]				

1. Conventional RO Process.
2. Pretesting target goal.

4. Phase 4 – Pretreat Plus^{TM} 0100/Pretreat Plus^{TM}0400 Threshold Concentration Testing (~ 5 days)

The purpose of Phase 4 is to determine the minimum concentration of Pretreat Plus^{TM} 0100 required to produce a Significant Response. This threshold concentration test will only be carried out if the results in Phase 2 indicate that the use of Pretreat Plus^{TM} 0100/Pretreat Plus^{TM}0400 produces a Significant Response. Three concentration conditions will be studied. Pretreat Plus^{TM} 0100/Pretreat Plus^{TM}0400 concentrations used for each of the four threshold concentration tests will be determined based on the results from Phase 2.

Data substantiating the magnitude of the Significant Response will be recorded. Physical process parameters such as flows, pressures, temperatures and vibration amplitude will be used. No sampling for laboratory analysis is conducted in this phase. Table 5 summarizes the Phase 4 testing protocol.

Table 5 - Phase 4 Testing Overview

				Sample Collection for Laboratory Analysis			
Phase 4 Test	Duration (hrs)	Cleaning Frequency	Variable	Feed (1)	Feed (VSEP™)	Perm (VSEP™)	Reject (VSEP™)
1	24 hours	Before Test	Pretreat Plus™ 0100/Pretreat Plus™0400 (25 mg/L)	None	None	None	None
2	24 hours	Before Test	Pretreat Plus™ 0100/Pretreat Plus™0400 (20 mg/L)	None	None	None	None
3	24 hours	Before Test	Pretreat Plus™ 0100/Pretreat Plus™0400 (15 mg/L)	None	None	None	None

Test Parameters To Be Varied During the Phase 4 Testing:

SpectraGuard SC™:	OFF
Pretreat Plus™ 0100/Pretreat Plus™0400:	Variable as indicated above, 90 percent / 10 percent mixture The concentration for Test 4 will be determined based on field data for the other three tests. The apparent optimum dose rate will be repeated in Test 4 to confirm results.
Recovery (VSEP™):	55 percent (2)

1. Conventional RO Process.
2. Goal adjusted due to Phase 2 results.

Phase 4B - Testing for pH Response (~10 hours)

Description: Recent VSEP™ testing performed by New Logic Research on RO Reject for a California-based customer has shown that reducing the pH from 7.5 to 6.5 or less produced significant improvement in flux stability in a VSEP™ system. While the composition of the RO concentrate tested in California may be different than the RO concentrate being tested for SAWS, the testing protocol has been amended based on a recommendation from New Logic Research to include a 10-hour pH test to investigate whether there is a pH response with the RO concentrate being tested for SAWS. This 10-hour test is designated as Phase 4B.

Phase 4B Test Procedure:

The procedure for Phase 4B will consist of the following steps:

- Prior to testing a titration curve will be generated for the concentrate from the conventional RO pilot to estimate the amount of acid that may be needed for the Phase 4B test.
- Testing will begin with a fully cleaned VSEP™ System.
- The pH of the 125-gallon feed tank (RO Reject) will be adjusted to a target value of 6.0.
- The VSEP™ System will be operated for ten hours under the same conditions as the Phase 4 tests with the exception of the anti-scalant dose. Anti-scalant will be dosed at the same level as that judged as the optimum concentration during Phase 4.
- The operator will monitor the pH of the feed tank and keep the pH adjusted manually within the range of 5.5 to 6.5 at all times during the 10-hour test.
- Flux data collected during the 10-hour Phase 4B study will be compared to the first 10 hours of the Phase 4 test runs to determine if there is a response to lowering pH.

5. Phase 5 - Recovery Testing (~ 15 days)

The purpose of Phase 5 is to identify the variation in average flux rate over time at different recovery rates while the feedwater for the VSEP™ equipment is dosed with the optimum level of the anti-scalant that showed the largest Significant Response when the Significant Response results in Phases 3 and 4 are evaluated. Anti-scalant addition will be performed as determined in Phases 2 through 4, above. Data substantiating equipment performance will be recorded. Physical process parameters such as flows, pressures, temperatures and vibration amplitude will be used.

In addition samples will be collected and submitted for laboratory analysis to evaluate salt rejection, concentrate quality, and permeate quality at each recovery rate. The sampling and analyses will be augmented by daily conductivity analyses. Table 6 summarizes the Phase 5 testing protocol.

Table 6 - Phase 5 Overview

Phase 5 Test	Duration (hrs)	Cleaning Frequency	Variable	Sample Collection for Laboratory Analysis Feed [(1)]	Feed (VSEP™)	Perm (VSEP™)	Reject (VSEP™)
1	~5 days	As Needed	Recovery 45%	Carollo Engineers	Carollo Engineers	Per Table 8	Per Table 8
2	~5 days	As Needed	Recovery 50%	Carollo Engineers	Carollo Engineers	Per Table 8	Per Table 8
3	~5 days	As Needed	Recovery 55%	Carollo Engineers	Carollo Engineers	Per Table 8	Per Table 8

Test Parameters To Be Varied During the Phase 5 Testing:

SpectraGuard SC™:	As determined by Phases 2 through 4
Pretreat Plus™ 0100/Pretreat Plus™0400:	As determined by Phases 2 through 4, 90 percent / 10 percent mixture
Recovery (VSEP™):	Trials at 45 percent, 50 percent and 55 percent

1. Conventional RO Process.

6. Phase 6 - Confirmatory Testing (~ 30 days)

The purpose of Phase 6 is to operate the system for an extended period to evaluate equipment reliability and assess longer term operating performance at optimized recovery and anti-scalant dosage conditions (recovery as determined in Phase 5 and anti-scalant dosage as determined in Phases 2 through 4).

Samples will be collected so that salt rejection, concentrate quality, and permeate quality can be evaluated. These will be augmented by daily conductivity analyses. Data substantiating equipment performance will also be recorded. Physical process parameters such as flows, pressures, temperatures and vibration amplitude will be used. Table 7 summarizes the Phase 6 testing protocol.

Table 7 - Phase 6 Overview

				Sample Collection for Laboratory Analysis			
Phase 6 Test	Duration (hrs)	Cleaning Frequency	Variable	Feed (1)	Feed (VSEP™)	Perm (VSEP™)	Reject (VSEP™)
1	~30 days	As Needed	None	Carollo Engineers	Carollo Engineers	Per Table 8	Per Table 8

Test Parameters To Be Varied During the Phase 6 Testing:

SpectraGuard SC™:	As determined in Phases 2 through 4
Pretreat Plus™ 0100/ Pretreat Plus™0400:	As determined in Phases 2 through 4, 90 percent / 10 percent mixture
Recovery (VSEP™):	As determined in Phase 5

1. Conventional RO Process.

7. Chemical Cleaning (Phases 2 through 6)

7.1 Chemical Cleaning Theory

There are many factors potentially affecting cleaning effectiveness and consequently flux restoration after cleaning. These include:

1. The nature and thickness of the material deposited on the membrane;

2. The cleaning chemicals used and their sequence of application;

3. The concentration of the cleaning chemicals, the temperature of the cleaning solutions, and the amount of contact time between the membrane and the cleaning solutions; and

4. Adequate shear force to remove surface deposits.

As explained in New Logic Research's report, the VSEP™ can prevent colloidal fouling of the membrane surfaces. However, as also stated, VSEP™ is ineffective in preventing fouling caused by mineral scaling and chemical bonding. Therefore, supplemental chemical cleaning procedures are needed. Even with these, irreversible membrane fouling still occurs. Consequently, all membranes experience performance loss over time. This performance loss is exacerbated in heavily fouled membranes as more fouling becomes irreversible. Further, in full-scale applications, optimum chemical cleaning solutions and cleaning procedures are usually chosen on the basis of information from membrane autopsies and testing membrane samples with various cleaning solutions. Such information was not available during the pilot test as the pilot test was also designed to be a long-term challenge test for the VSEP™ equipment without membrane replacement. As a result, there were no opportunities for membrane autopsies or for testing membrane samples with various cleaning solutions during the pilot test. Consequently, based on their experience, New Logic Research selected a broad-based cleaning process designed to remove mineral scales, organics and silica. Adequate shear force was not deemed to be an issue due to the vibratory action of the VSEP^{TM} equipment.

7.2 Chemical Cleaning Procedure

Chemical cleaning will be performed in accordance with New Logic Research instructions. As a result, the cleanings will be performed in two primary steps, an acid cleaning step with for mineral scale removal and a caustic step for organics. The procedure selected by New Logic Research is based on their experience with similar applications and used proprietary New Logic Research cleaning agents: NLR 404, an acidic material and NLR 505, a caustic material. The cleaners will be applied in a 3 percent by volume solution and circulated at approximately 2 gpm to 2.5 gpm by the VSEP^{TM} process feed pump. Note: Based on pilot test results New Logic Research changed the procedure to improve cleaning effectiveness, starting at cleaning 39, NLR 550 to add as a 1 percent to the NLR 505 cleaning step. New Logic Research's description of the cleaning agents is presented below.

- **NLR 404** - An acidic liquid cleaner designed to remove mineral scale in RO, NF and UF membranes. It removes metallic salts such as iron, aluminum, barium and strontium sulfate, calcium sulfate, calcium carbonate, as well as dyes and polymers.
- **NLR 505 -** A caustic liquid membrane cleaner designed to remove biological and organic materials, silt, particulates, colloids, silica and emulsified oil from a wide range of RO, NF, UF and MF membranes. The material contains a combination of ingredients, which provide cleaning actions that include lifting, dispersing, emulsifying, sequestering, dissolving and suspending foulant materials.
- **NLR 550 -** A powder membrane cleaner designed to remove biological foulants, organics, oil, grease, lignin, and dyes. This cleaner is also effective on man-made polymers often found in wastewater treatment systems. NLR 550 has been tested for membrane compatibility by NLR and considered safe for use with RO membranes.

9.0 Data Collection and Analysis

Data will be collected, analyzed, and reviewed for consistency through each of the testing phases. Physical data, such as flow rates (permeate and concentrate), cleaning requirements, chemical addition, pressure (feedwater, concentrate, and permeate), and other observed information will be collected, logged and analyzed for consistency throughout the pilot testing process. A detailed log of all changes in operating conditions will be maintained with notes describing the reasons for changes and operating conditions associated with changes.

Water quality will be monitored for the raw water, permeate (from traditional RO treatment), concentrate (from traditional RO treatment) and permeate and concentrate from the VSEP™ process as delineated in Table 8. All water quality samples will be analyzed by Alamo Analytical Laboratories Ltd. (certain analyses such as radiological evaluations shall be subcontracted by Alamo Analytical Laboratories Ltd.) and will also be analyzed for consistency throughout the pilot testing process. In addition, the laboratory data will be used to calculate Langlier Saturation and Ryzner Indices for the VSEP™ permeate and concentrate streams.

The QA/QC plan will be followed for all data collection and analysis.

Table 8 - Sampling and Laboratory Analysis Summary[1]

					Phase 5 - Number of Samples					Phase 6 - Number of Samples				
Parameter	Laboratory Method	Sample Bottle	Preservative[3]	Holding Time	Raw Water[4]	VSEP™ Feedwater[4]	VSEP™ Permeate	VSEP™ Concentrate	Total Number	Raw Water	VSEP™ Feedwater	VSEP™ Permeate	VSEP™ Concentrate	Total Number
Arsenic	E200.8	250-mL HDPE	HNO_3	6 months		0	0	0	0	Carollo Engineers	2	2	2	6
Color, True	SM2120B	1-L amber glass	None	2 days		0	0	0	0	Carollo Engineers	2	2	2	6
Hydrogen Sulfide[2]	SM4500-S2	1-L amber glass	None	7 days		0	0	0	0	Carollo Engineers	2	2	2	6
Manganese	E200.8	250-mL HDPE	HNO_3	6 months		0	0	0	0	Carollo Engineers	2	2	2	6
Calcium	E200.7	250-mL HDPE	HNO_3	6 months	3	3	3	3	12	Carollo Engineers	Carollo Engineers	2	2	6
pH	Electrode	Field Parameter	None	7 days	3	3	3	3	12	Carollo Engineers	2	2	2	6
Conductivity	E120.1	250-mL HDPE	None	28 days	3	3	3	3	12	Carollo Engineers	2	2	2	6
Temperature	Field Parameter		N/A	N/A	Carollo Engineers	2/Day	2/Day	2/Day		Carollo Engineers	2/Day	2/Day	2/Day	
Turbidity	SM2130B	250-mL HDPE	None	2 days		0	0	0	0	Carollo Engineers	2	2	2	6
Odor	SM2150B	16-oz clear glass	None	7 days		0	0	0	0	2s	2	2	2	6
Alkalinity	SM2320B	500-mL HDPE	None	14 days		0	0	0	0	Carollo Engineers	2	2	2	8
Dissolved Oxygen	SM4500-O-G	1-L HDPE	None	2 days		0	0	0	0	2	2	2	2	8

Table 8 - Sampling and Laboratory Analysis Summary[1]

					Phase 5 - Number of Samples					Phase 6 - Number of Samples				
Parameter	Laboratory Method	Sample Bottle	Preservative[3]	Holding Time	Raw Water[4]	VSEP™ Feedwater[4]	VSEP™ Permeate	VSEP™ Concentrate	Total Number	Raw Water	VSEP™ Feedwater	VSEP™ Permeate	VSEP™ Concentrate	Total Number
Hardness, Total	E200.7	250-mL HDPE	HNO_3	6 months		0	0	0	0	Carollo Engineers	2	2	2	6
TDS	SM2540C	500-mL HDPE	None	7 days	Carollo Engineers	3	3	3	12	Carollo Engineers	2	2	2	6
Bromate	E300.1	100-mL HDPE	EDA	14 days		0	0	0	0	2	2	2	2	8
Total Trihalomethanes (TTHM)	E524.2	40-mL clear glass	$NaHSO_3$	14 days		0	0	0	0	2s	2	2	2	8
Haloacetic Acids (HAA5)	E552.2	60-mL amber glass	NH_4Cl	14 days		0	0	0	0	2s	2	2	2	8
Al	E200.8	250-mL HDPE	HNO_3	6 months		0	0	0	0	Carollo Engineers	2	2	2	6
Mn	E200.8	250-mL HDPE	HNO_3	6 months		0	0	0	0	Carollo Engineers	2	2	2	6
NH_4	E350.1	250-mL HDPE	H_2SO_4	28 days		0	0	0	0	2s	2	2	2	8
K	E200.7	250-mL HDPE	HNO_3	6 months		0	0	0	0	2s	2	2	2	8
Na	E200.7	250-mL HDPE	HNO_3	6 months	Carollo Engineers	3	3	3	12	Carollo Engineers	2	2	2	6
Mg	E200.7	250-mL HDPE	HNO_3	6 months	Carollo Engineers	3	3	3	12	Carollo Engineers	2	2	2	6
Sr	E200.8	250-mL HDPE	HNO_3	6 months	Carollo Engineers	3	3	3	12	2s	2	2	2	8

Table 8 - Sampling and Laboratory Analysis Summary[1]

					Phase 5 - Number of Samples					Phase 6 - Number of Samples				
Parameter	Laboratory Method	Sample Bottle	Preservative[3]	Holding Time	Raw Water[4]	VSEP™ Feedwater[4]	VSEP™ Permeate	VSEP™ Concentrate	Total Number	Raw Water	VSEP™ Feedwater	VSEP™ Permeate	VSEP™ Concentrate	Total Number
Ba	E200.8	250-mL HDPE	HNO_3	6 months	Carollo Engineers	3	3	3	12	Carollo Engineers	2	2	2	6
CO_3	SM2320B	500-mL HDPE	None	14 days	Carollo Engineers	3	3	3	12	2s	2	2	2	8
HCO_3	SM2320B	500-mL HDPE	None	14 days	Carollo Engineers	3	3	3	12	2s	2	2	2	8
NO_2	E300	250-mL HDPE	None	48 hours		3	3	3	0	Carollo Engineers	2	2	2	6
NO_3	E300	250-mL HDPE	None	48 hours		3	3	3	0	Carollo Engineers	2	2	2	6
Cl	E300	250-mL HDPE	None	28 days	Carollo Engineers	3	3	3	12	Carollo Engineers	2	2	2	6
F	E300	250-mL HDPE	None	28 days		0	0	0	0	Carollo Engineers	2	2	2	6
SO_4	E300	250-mL HDPE	None	28 days	Carollo Engineers	3	3	3	12	Carollo Engineers	2	2	2	6
SiO_2	SM4500-SiO2-C	500-mL HDPE	None	28 days	Carollo Engineers	3	3	3	12	Carollo Engineers	2	2	2	6
B	E200.7	250-mL HDPE	HNO_3	6 months		0	0	0	0	2s	2	2	2	8
CO_2	SM4500-CO2	1-L HDPE	None	14 days		0	0	0	0	2s	2	2	2	8
Fe Dissolved[2]	E200.7	250-mL HDPE	HNO_3	6 months		0	0	0	0	2s	2	2	2	8
Fe Total[2]	E200.7	250-mL HDPE	HNO_3	6 months	Carollo Engineers	3	3	3	12	2s	2	2	2	8

Table 8 - Sampling and Laboratory Analysis Summary^1

					Phase 5 - Number of Samples					Phase 6 - Number of Samples				
Parameter	Laboratory Method	Sample Bottle	Preservative^3	Holding Time	Raw Water^4	VSEP™ Feedwater^4	VSEP™ Permeate	VSEP™ Concentrate	Total Number	Raw Water	VSEP™ Feedwater	VSEP™ Permeate	VSEP™ Concentrate	Total Number
ORP	Electrode	Field Parameter	None	N/A	Carollo Engineers	2/Day	2/Day	2/Day		Carollo Engineers	2/Day	2/Day	2/Day	
Antimony (w/ prep)	E200.8	250-mL HDPE	HNO_3	6 months		0	0	0	0	Carollo Engineers	2	2	2	6
Asbestos (fibers > 10 microns)	Asbestos	1-L HDPE	None	7 days		0	0	0	0	Carollo Engineers	2	2	2	6
Beryllium	E200.8	250-mL HDPE	HNO_3	6 months		0	0	0	0	Carollo Engineers	2	2	2	6
Cadmium	E200.8	250-mL HDPE	HNO_3	6 months		0	0	0	0	Carollo Engineers	2	2	2	6
Chromium	E200.8	250-mL HDPE	HNO_3	6 months		0	0	0	0	Carollo Engineers	2	2	2	6
Copper	E200.8	250-mL HDPE	HNO_3	6 months		0	0	0	0	Carollo Engineers	2	2	2	6
Cyanide	E335.4	1-L HDPE	NaOH	14 days		0	0	0	0	Carollo Engineers	2	2	2	6
Fluoride	E300	250-mL HDPE	None	28 days		0	0	0	0	Carollo Engineers	2	2	2	6
Lead	E200.8	250-mL HDPE	HNO_3	6 months		0	0	0	0	Carollo Engineers	2	2	2	6
Mercury	E200.8	250-mL HDPE	HNO_3	6 months		0	0	0	0	Carollo Engineers	2	2	2	6
Nitrate	E300	250-mL HDPE	None	48 hours		0	0	0	0	Carollo Engineers	2	2	2	6
Nitrite	E300	250-mL HDPE	None	48 hours		0	0	0	0	Carollo Engineers	2	2	2	6

Table 8 - Sampling and Laboratory Analysis Summary[1]

					Phase 5 - Number of Samples					Phase 6 - Number of Samples				
Parameter	Laboratory Method	Sample Bottle	Preservative[3]	Holding Time	Raw Water[4]	VSEP™ Feedwater[4]	VSEP™ Permeate	VSEP™ Concentrate	Total Number	Raw Water	VSEP™ Feedwater	VSEP™ Permeate	VSEP™ Concentrate	Total Number
Selenium	E200.8	250-mL HDPE	HNO_3	6 months		0	0	0	0	Carollo Engineers	2	2	2	6
Thallium	E200.8	250-mL HDPE	HNO_3	6 months		0	0	0	0	Carollo Engineers	2	2	2	6
Alpha Particles	SM7110	4-L cubitainer	HNO_3	6 months		0	0	0	0	Carollo Engineers	2	2	2	6
Beta Particles and photon emitters	SM7110	4-L cubitainer	HNO_3	6 months		0	0	0	0	Carollo Engineers	2	2	2	6
Radium 226 & 228 total	SM7500 Ra B&D	1-L HDPE	None	6 months		0	0	0	0	Carollo Engineers	2	2	2	6
Radon		1-L HDPE	None	6 months		0	0	0	0	Carollo Engineers	2	2	2	6
Uranium	E200.8	250-mL HDPE	HNO_3	6 months		0	0	0	0	Carollo Engineers	2	2	2	6

1. Sampling by others assumes samples and analysis by Carollo as part of conventional RO pilot testing program or field testing performed for the VSEP™ pilot program by Carollo.
2. One field test per day during Phases 5 and 6 by Carollo.
3. All samples will be preserved at a hold temperature below 10ºCelsius.
4. Raw Water and VSEP Feedwater samples will be collected by Carollo Engineers.

10.0 Management and Monitoring

All work shall be coordinated by the R. W. Beck Project Manager. New Logic Research will conduct all pilot testing activities on behalf of the R. W. Beck Team. Their activities will include the pilot unit set-up, pilot testing, and tear-down/removal of the VSEP™ process and all associated equipment. In addition, new Logic will also start-up, debug, operate and maintain and maintain the pilot equipment. New Logic Research's services will be overseen by SAWS and the other entities on the R. W. Beck Team.

New Logic Research personnel will be present on site on a one shift per day, five-day per week basis throughout the testing period and be responsible for all sampling, data logging, and operational records related to equipment performance and reliability. Laboratory analyses will be conducted by TCEQ certified laboratories. Representatives of the R. W. Beck Team will visit the site each week during that testing is conducted to review equipment operation, sampling and laboratory analysis data, field data, and the New Logic Research operator's log. Water quality will be monitored for the raw water, permeate (from traditional RO treatment), concentrate (from traditional RO treatment) and permeate and concentrate from the VSEP™ process.

It is anticipated that the pilot testing of the VSEP™ process will be conducted in conjunction with conventional RO pilot testing of the raw groundwater. Consequently, New Logic Research's activities will be coordinated with SAWS' RO pilot testing consultant. SAWS' RO pilot testing consultant will be responsible for all sampling and analysis information needed from the conventional RO pilot equipment. Thus, SAWS' RO pilot testing consultant will provide the water quality laboratory data for the ASR test well raw water and the permeate and the concentrate streams from the conventional RO pilot equipment. The SAWS' RO pilot testing consultant will also maintain records of pertinent process data for the conventional RO pilot equipment such as temperatures, pressures and flows. A list of water quality parameters to be monitored, in each flow stream, is contained in Section 9, Data Collection and Analysis herein.

New Logic Research will also collect appropriate process data including, but not be limited to, throughput, percent recovery, membrane performance recovery after cleaning, permeate quality and quantity, and residuals quantities and qualities. Where feasible, field data will be crosschecked by the R. W. Beck Team against the laboratory data. New Logic Research will also collect physical data, such as flow rates, cleaning requirements, chemical addition, pressure, and other observed information. The physical data will be collected, logged and analyzed throughout the pilot testing process. A detailed log of all changes in operating conditions will be maintained with notes describing the reasons for changes in operating parameters and identifying operating conditions associated with changes.

Following conclusion of the pilot testing, the R. W. Beck Team will prepare a pilot study report. The pilot study report will include a chronology of the pilot testing activities; all operating data and water quality analyses; findings; and recommendations for full-scale operation.

11.0 QA/QC Plan

QA/AC Plan steps and responsibilities are summarized in Table 9 below. As explained in Section 3.0 herein, New Logic Research is responsible for operating the VSEP™ equipment, obtaining and recording field data, performing all water quality sampling, and arranging for the laboratory analysis of water quality samples. Baer Engineering will provide field oversight for New Logic Research activities and review laboratory reports for QA/QC issues. Mickley and Associates will review field and laboratory data for consistency and for anomalies. R. W. Beck is responsible for directing all program activities and overall program quality.

Table 9 - QA/AC Plan Summary[1, 2]

Phase	Step	Activity	Responsibility
All	General	Field and laboratory data will be cross checked as feasible on a routine basis to confirm consistency	R. W. Beck, New Logic Research & Baer Engineering and Environmental Consulting
1	VSEP™ set up.	Erect and start-up equipment	New Logic Research
		Witness equipment operation	R. W. Beck
2	Pretreatment Testing	Anti-scalant response test	New Logic Research
		Site visit during test to witness operation and review operators log and data during test	Baer Engineering and Environmental Consulting
3	SpectraGuard SC™ Threshold Concentration Testing	Concentration response test	New Logic Research
		Site visit during test to witness operation and review operators log and data during test	Baer Engineering and Environmental Consulting
4	Pretreat Plus™ 0100 / Pretreat Plus™0400 Threshold Concentration Testing	Concentration response test	New Logic Research
		Site visit during test to witness operation and review operators log and data during test	Baer Engineering and Environmental consulting
5	Recovery Testing	Recovery Testing	New Logic Research
		Site visit during test to witness operation, observe sampling and review operators log and data during test	Baer Engineering and Environmental Consulting

Table 9 - QA/AC Plan Summary[1, 2]

Phase	Step	Activity	Responsibility
		Review laboratory report for QA/QC issues	New Logic Research & Baer Engineering and Environmental Consulting
		Review laboratory and field data for consistency	New Logic Research, Mickley and Associates, Baer Engineering and Environmental Consulting & R. W. Beck
6	Confirmatory Testing	Recovery Testing	New Logic Research
		Site visit during test to witness operation, observe sampling and review operators log and data during test	Baer Engineering and Environmental Consulting
		Review laboratory report for QA/QC issues	New Logic Research & Baer Engineering and Environmental Consulting
		Review laboratory and field data for consistency. Data will be compiled as soon as practical after the receipt of each data set from the laboratory for anomalies	New Logic Research, Mickley and Associates, Baer Engineering and Environmental Consulting & R. W. Beck
7	VSEP™ Dismantling & Clean-up	Tear-down, pack-up, and remove equipment.	New Logic Research
		Site inspection	R. W. Beck

1. Baer Engineering and Environmental Consulting shall perform a site visit once per week throughout Phases 5 and 6.
2. R. W. Beck shall perform a site visit once per two weeks throughout Phases 5 and 6.

12.0 Health and Safety Plan

A separate Health and Safety Plan is not required for the VSEP Pilot Testing Protocol, as all operations and chemical usage on the pilot plant site will be conducted in accordance with the safety policies of SAWS. A safety shower and eyewash is provided at the Project site by SAWS. Potable water and soap for washing hands will be provided at a sink on the site. Key items related to health and safety issues are summarized as follows:

1. Carollo personnel operating the convention RO pilot unit (under separate contract with SAWS) will be considered as "Authorized" personnel for SAWS for this Project.
2. Material Safety Data Sheets ("MSDS") will be provided and posted visibly for the chemicals brought on site.
3. New Logic Research personnel collecting samples are experienced in collecting samples to avoid contamination of the sample.

4. SAWS lock-out/tag-out procedures will be used. SAWS Section III.B.12 Lockout/Tagout/Blankout Program, August 2000, is provided in Appendix B.
5. SAWS has provided adequate lighting in the proposed site area for off-hours response.
6. In accordance with ANSI requirements, the safety shower has been plumbed independently (of others, such as sink) for potable water connection.
7. Project personnel will use appropriate personal protective gear and safety glasses when handling chemicals; however, hard hats will not be necessary.
8. Hearing protection shall be worn by all personnel working in the vicinity of the VSEP Pilot trailer while the VSEP equipment is operating. Protection for visitors shall be made available and a warning sign that hearing protection is required is posted.
9. The storage of the acid containers and the caustic containers shall be in separate trailers. All product and waste stream spills from the pilot units will be directed to the discharge trench. The pilot units have been designed to minimize the potential for major spills. However, in case of significant equipment or piping failure causing a large spill of solids or chemicals, New Logic Research shall be responsible for the clean-up and arranging for piping/equipment repairs.
10. SAWS and R. W. Beck shall be notified of any injuries to personnel, and spills with reportable quantities of chemicals in accordance with the instructions in Section 3 herein.

Attachment A - San Antonio Water System - VSEP Pilot Project Contact List

San Antonio Water System
VSEP Pilot Project Contact List

Name	Role	Address	Phone	Email Address
San Antonio Water System				
Duane Bryant	Project Manager Piloting	2800 U.S. Hwy 281 North P.O. Box 2449 San Antonio, TX 78298-2449	Office: 210.233.3701	dbryant@saws.org
Kevin Morrison	Manager RO Project		Office: 210.233.3667	kmorrison@saws.org
Robert Macias	ASR Plant Manager	Twin Oaks ASR 4859 Hardy Road Elmendorf, TX 78112	Office: 210.233.3987 Mobile: 210.325.6748	rmacias@saws.org
R. W. Beck				
Howie Steiman	Task Manager	Meditech Corporate Center, West Wing 550 Cochituate Road Framingham, MA 01701-4654	Office: 508.935.1657 Mobile: 617.610.5129	hsteiman@rwbeck.com
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Tara Hickey	Project Coordinator		Office: 512.651.6403 Mobile: 512.422.4712	thickey@rwbeck.com
Baer Engineering and Environmental Consulting				
Rosemary Wyman	Project Manager	7756 Northcross Drive, Suite 211 Austin, TX 78757	Office: 512.453.3733 Mobile: 512.585.0176	rwyman@baereng.com
Donald Schaezler	Field Personnel		Office: 512.453.3733 Mobile: 210.862.0314	donald@schaezler.net
Robert Long	Field Personnel		Office: 512.453.3733 Mobile: 210.663.9848	rlong@baereng.com
New Logic Research				
Mark Galimberti	Regional Sales Manager	24 Wilts Lane State College, PA 16803	Office: 814.861.1506 Mobile: 814.244.6581	mgalimberti@vsep.com

San Antonio Water System
VSEP Pilot Project Contact List

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Landon Graham	Field Personnel		Office: 510.655.7305 x 221 Mobile:949.338.2629	lgraham@vsep.com
John Fordham	Field Personnel		Office: 510.655.7305 Mobile:510.325.7310	jfordham@vsep.com
Kira Farnham	Field Personnel		Office: 510.655.7305 x 237 Mobile: 530.902.3554	kfarnham@vsep.com
Roger Torres			Office: 510.655.7305 x 218 Mobile: 612.875.0102	rtorres@vsep.com
Carollo Engineers				
Brian Adams	Project Manager	8918 Tesoro Drive, Suite 400 San Antonio, TX 78217	Office: 210.829.5612	Badams@carollo.com
Justin Sutherland	Asst. Project Manager	8911 Capital of Texas Highway North, Suite 2200 Austin, Texas 78759	Office: 512.453.5383	Jsutherland@carollo.com
Alamo Analytical Laboratories Ltd.				
Don Williams	Laboratory Liaison	10526 Gulfdale San Antonio TX 78216	Office: 210-340-8121 Mobile: 210-872-1152	dwilliams@alamoanalytical.com

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Appendix II. The New Logic Research Report and Pilot Test Data

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NEW LOGIC RESEARCH
1295 67th Street Emeryville California 94608-1120 Phone: (510) 655-7305 Fax: (510)655-7307

VSEP Pilot Test Report

For: R. W. Beck/SAWS

Testing Dates: February 13th – September 10th 2009
Report Issue: November 10, 2010 (R. W. Beck)
Report Date: July 30th 2010 (NLR release)
Sales Engineer: Mark Galimberti
Field Technician: Frazier Glenn (NLR), Nick Auger (NLR), Landon Graham (NLR)
Robert Bergeron (R. W. Beck), Leo Cannyn (R. W. Beck)
Field Pilot Manager: Angie DeSchutter

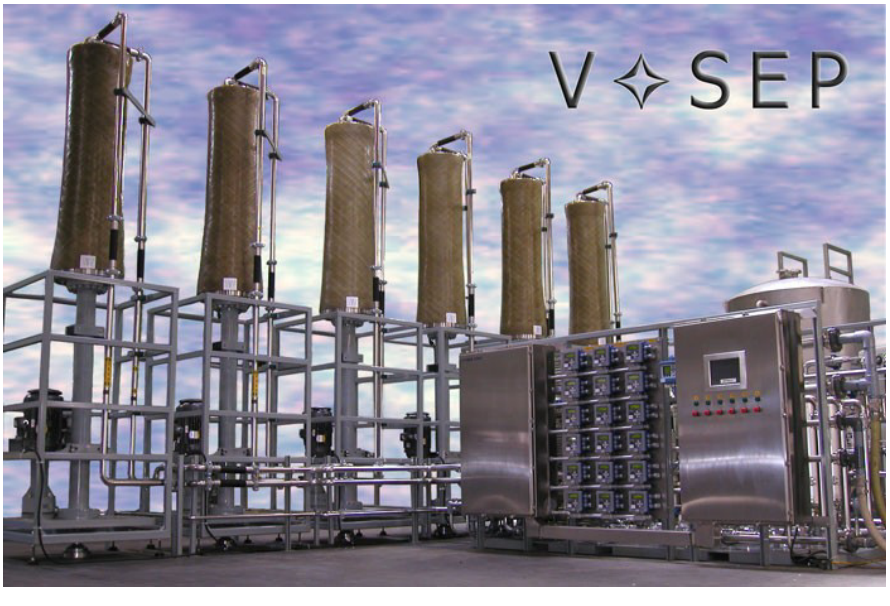

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Table of Contents

1.0 Background Information

The San Antonio Water System (SAWS) Brackish Groundwater Desalination Facility Project is has a primary treatment system of Reverse Osmosis (RO) Spiral membranes. They are considering options to treat the leftover RO spiral concentrate in order to increase the overall recovery rates to support the increasing demand for drinking quality water. The water was initially processed with a two- or three-stage single pass RO system operating ~90 percent recovery. The concentrate was processed by VSEP during this study.

New Logic Research (NLR) and R. W. Beck have conducted a P-Mode VSEP test (pilot mode) at the ASR Twin Oaks Facility in San Antonio, Texas as part of a testing plan designed to demonstrate the separation ability of VSEP. VSEP is a unique membrane filtration technology that uses vibration to minimize fouling of the filtration media.

2.0 Study Objectives

Concentrate from the spiral system that cannot be further processed will most likely be disposed of by deep well injection. VSEP was tested to treat the concentrate in order to reduce the volume of material sent to the deep well and to increase the overall recovery of permeate for use. The permeate must meet the Texas Commission on Environmental Quality and SAWS standards.

3.0 Equipment and Set-Up

NLR provided an AutoLP VSEP membrane filtration unit and periphery equipment. Figure 1 below illustrates the basic set up for a VSEP Series AutoLP. The VSEP pilot unit was tested in P-mode which has 16.7 square feet of membrane area. The P-unit was installed with Hydranautic's RO membrane type ESPA-1. This membrane was chosen based on previous experience with similar applications. This membrane tends to provide higher permeate quality while maintaining higher flux rates compared to other RO membranes available.

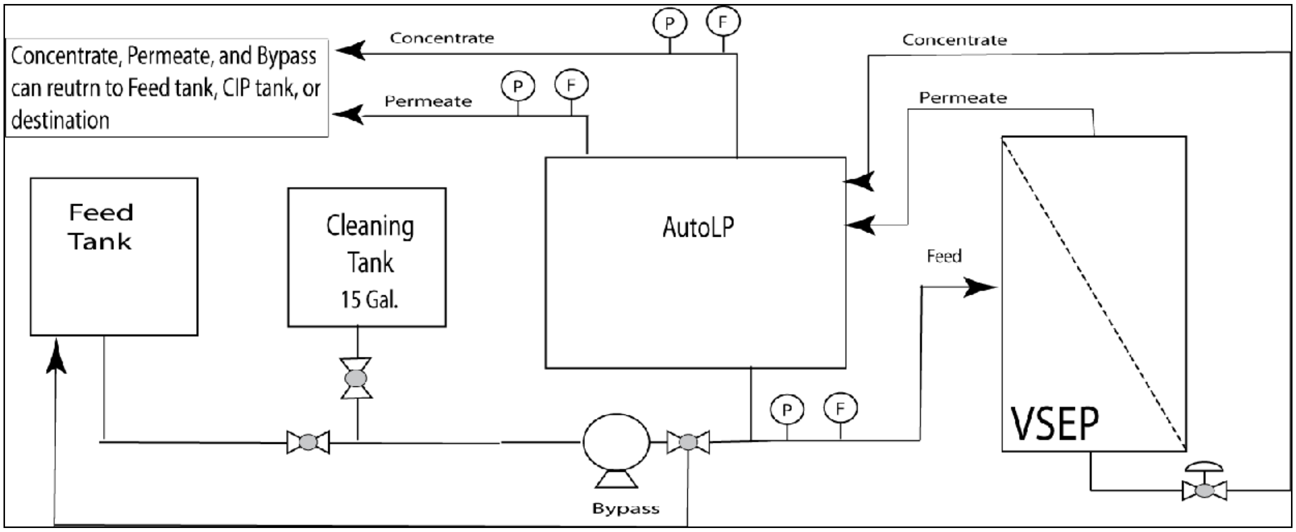


Figure 1: Slipstream Mode VSEP Schematic

The VSEP system was operated in slipstream mode. During slipstream operation, new feed material is continuously added to the feed tank while the two discharge streams of the filtration unit (Permeate and Concentrate lines) are allowed to leave the system either to the drain, or to the next stage of the overall system. As feed material is continuously pumped to the VSEP, the concentrate valve is opened and closed based on a timed interval, while the permeate is continuously exiting the filter pack. One cycle is described as the total of one open and one closed period of the concentrate valve. When the valve is closed, the feed material is allowed to concentrate inside the filter pack. The concentrated feed material is then purged from the system during the open period of the concentrate valve and then the cycle repeats. The time interval of the open/closed period is varied in order to obtain the desired recovery rate. The recovery rate is calculated for each cycle time using the total volume of permeate and concentrate removed during the open/closed time interval. The system automatically adjusts the time interval in order to maintain the recovery rate set point as permeate flow rates decrease during operation due to fouling.

The setup is shown in Figure 1. The equipment is shown in Figure 2. The VSEP LP unit consists of the membrane filter pack and vibration motor. The AutoLP skid consists of flow and pressure sensors for the feed, permeate, and concentrate lines, concentrate actuator valve, concentrate pH sensor, permeate conductivity sensor, temperature probe, a diaphragm pump, electrical control unit, and PLC. A 15-gallon CIP tank and hoses were also provided. The equipment was chosen for its ability to continuously record data without the need for constant monitoring by an operator. The system was equipped with sensors to monitor all the necessary data to be used for full-scale system sizing.

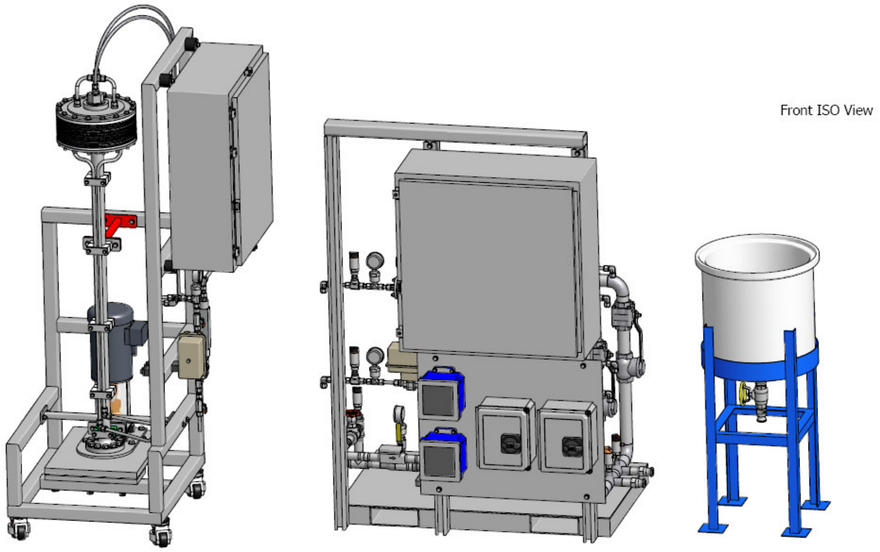


Figure 2: VSEP LP Unit, AutoLP Skid, CIP Tank

Samples were collected periodically throughout testing for analysis. Analytical results were provided by Alamo Analytical Laboratories, Ltd.

4.0 Results

4.1 Phase 1 Testing

The purpose of Phase 1 was to start up the equipment, allow the flux rate to stabilize and to verify that the equipment was operating properly. When a new membrane is exposed to feed material, it may take time for the flux to stabilize and a ‘short line out’ was performed by setting the system at set points that were lower than the expected maximum for about 2 hours and at 300 pounds per square inch (psi) and a minimal recovery rate in order to condition the brand new membrane before continuing testing. The results of the short line out on feed are shown in Figure 3. Once the system was stable, the system was set to 75 percent recovery and 500 psi using raw Spiral concentrate as feed material. The data collected was used as a baseline for comparison during further testing with various pre-treatments. A slipped o-ring at the top of the system had caused a leak about 200 minutes into the first run. The o-ring was replaced and the system was cleaned before starting a new run. The results are shown in Figure 4 and Tables 1 and 2. The results of parameters tested in the field are shown in Table 2. Further analysis of the VSEP feed water is shown in Appendices A and B, which was sampled during Phases 5 and 6 of testing. These results may be similar, but are not representative of the VSEP feed water during Phase 1 testing due to changes made to the primary RO system during Phase 4 of testing. The feed concentration to the VSEP during Phases 1 and 2 was lower than the results shown in Appendices A and B because the primary RO system recovery rate was increased from 80 to 85 percent (Phases 1 and 2) to 90 percent (Phases 4-6).

The flux rates are calculated based on the permeate flow rate and membrane area of the LP unit. The calculated average flux for the VSEP is based on a weighted average of the flux over time. A viscosity correction factor is used to temperature correct all the flux rates to the same temperature for comparison. Typically an average flux of 10 gallons per square foot of membrane surface per day (GFD) is used as an end point before a cleaning is initiated.

The reported instantaneous recovery rate for the VSEP is the recovery rate for each cycle as described in Section 3. The overall recovery rate is based on the recovery rate of permeate from the conventional RO system plus permeate from the VSEP™ equipment divided by the amount of feed water for the conventional RO pilot equipment.

Note: The o-ring damage could have been due to the long-term storage of the equipment which may have dried out the elastomer. At the end of Phase 1 testing, the pump was not working properly and was replaced with the spare pump on site.

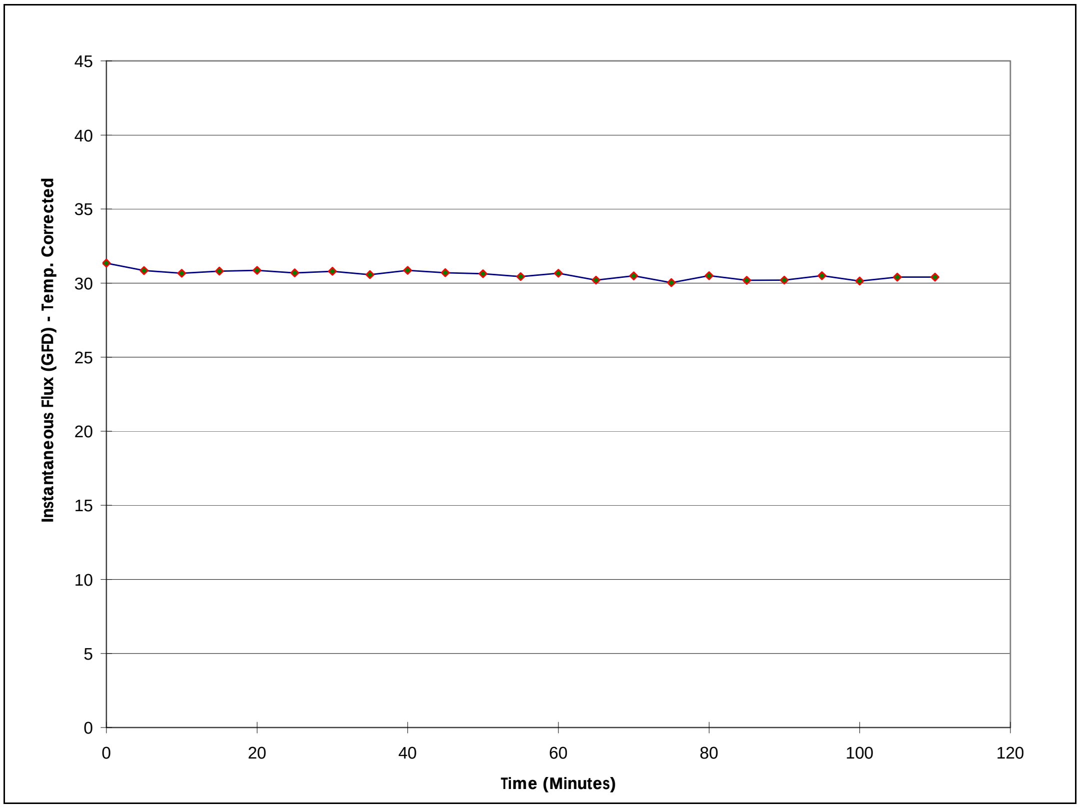


Figure 3: Phase 1 Short Line Out, 300 psi

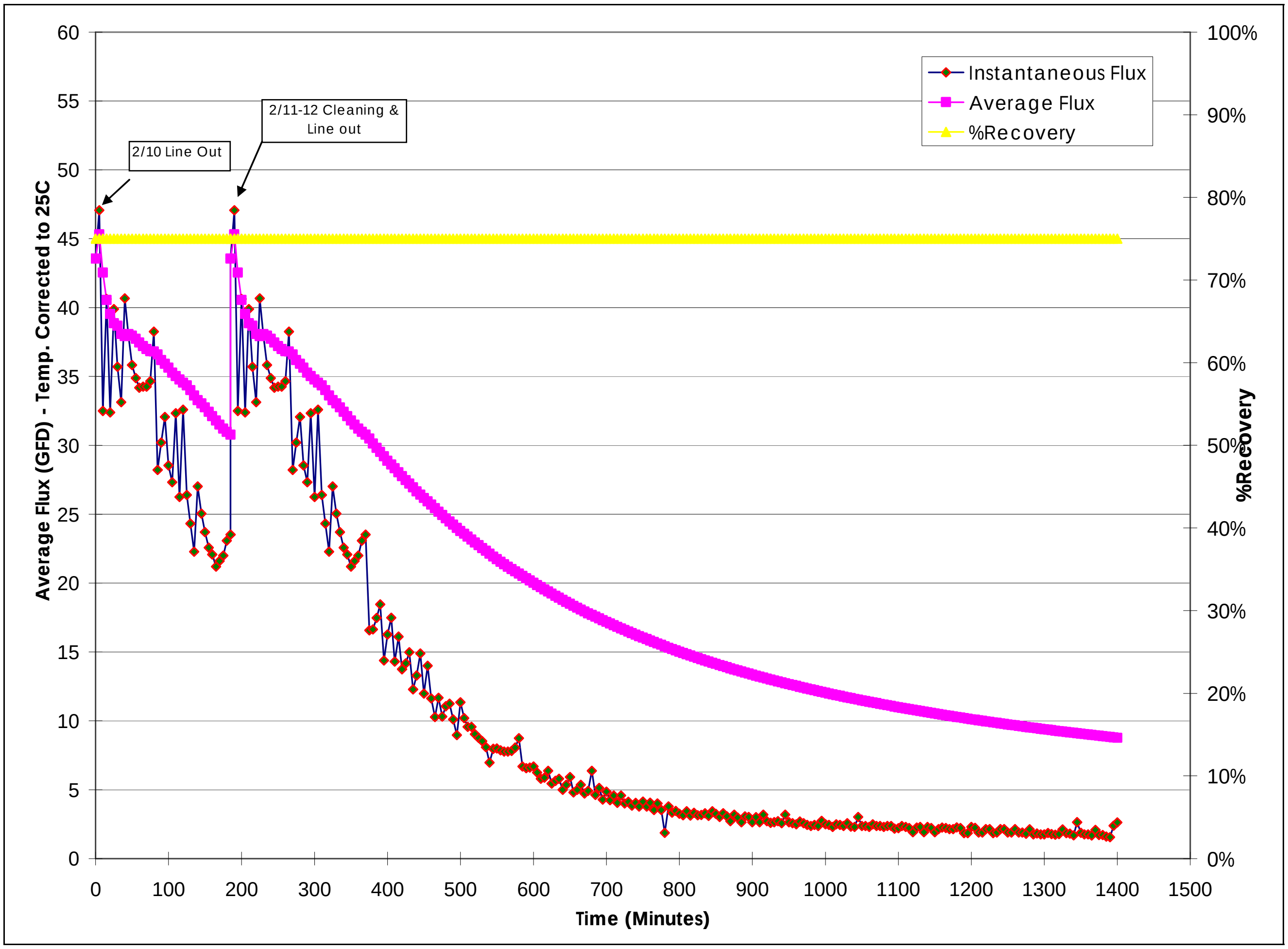


Figure 4: Phase 1 75 Percent Recovery, 500 psi

Table 1: Phase 1 Flux* Summary

Run	VSEP Percent Recovery	Spiral Percent Recovery*	Initial Flux	Final Flux	Average Flux
2/10	75%	91.7%	46.4 GFD	36.7 GFD	37.2 GFD
2/11-12	75%	90.7%	43.6 GFD	2.6 GFD	8.8 GFD

*Flux temperature corrected to 25 degrees Celsius “ºC.

*Reported Recovery by Carollo.

Table 2: Phase 1 Field Average Analytical Summary

Sample	Parameter	Feed	Permeate	Concentrate
2/11-12 VSEP Feed Water	pH	7.12	6.05	8.10
	Conductivity	12.0 mS*	200 µS**	52.2 mS
	Temperature	31.47ºC	-	-

*Milli Siemens per centimeters (mS).

**Micro Siemens per centimeter (µS).

4.2 Phase 2 – Anti-scalant Testing On/Off

The purpose of Phase 2 was to determine if the use of an anti-scalant would produce a significant increase in the average flux rate and/or reduce the frequency of chemical cleanings. For the purposes of the pilot test, a Significant Response to an anti-scalant was defined as either: (1) a 25 percent increase in average flux rate during the test; or (2) a 50 percent increase in the flux rate 24 hours after cleaning. If the anti-scalants produce a Significant Response, then the testing would proceed to Phase 3 and/or Phase 4 for additional pre-treatment testing. If anti-scalants did not produce a Significant Response, then the testing would proceed directly to Phase 5 using no anti-scalants. Two anti-scalants were tested, SpectraGuard SC™ and a 90 percent/10 percent mixture of Pretreat Plus^{TM} 0100/Pretreat Plus^{TM}0400. SpectraGuard SC™ was selected for testing because it was being used as an anti-scalant in the conventional RO pilot testing program prior to VSEP. Consequently, if SpectraGuard SC™ proved to be effective, its use would serve to simplify full-scale facility operation by reducing the number of chemicals needed for full-scale facility operation. Pretreat Plus^{TM} 0100/Pretreat Plus^{TM}0400 was selected by NLR as an anti-scalant based on previous experience with this product on similar applications.

The system was set to 75 percent recovery rate and 500 psi, the same conditions as the raw feed baseline study completed in Phase 1 testing. Both anti-scalants were dosed at 20 parts per million (ppm). A metering pump was used to dose the treatment into the top of the feed tank. At 75 percent recovery, the anti-scalants did not show a significant response. The tests were re-run at a lower recovery rate to determine if concentrating to 75 percent was too high and overshadowing any effect the anti-scalant treatment may have had. The recovery was set to 65 percent and all streams showed an improvement in flux. Both anti-scalants showed a response. The PT-100/400 showed a significant response of 47.2 percent improved average flux over a 24-hour period, while SpectraGuard SC™ had 12.4 percent improvement in average flux. PT-100/400 was chosen for further testing. The results are shown in Figure 5 and Tables 3, 4, and 5.

Note: The reported Primary Spiral RO System recovery was around 90 percent. It was later found the system was not calibrated correctly and was operating at 80 to 85 percent recovery. This was adjusted during the inline dosing comparison test in Section 4.3. The change in operating conditions of the conventional Spiral RO unit did not occur until the middle of Phase 4 testing. Phase 2 testing was completed before the incorrect recovery for the Spiral RO unit was observed.

The initial flux of each run showed variation. The cause for this variation may be due to the variation in feed quality to the VSEP system, which can be seen in the feed conductivity. The typical relationship between flux and feed quality is that a more concentrated feed material produces a lower flux. The feed quality should also be taken into account when comparing average flux rates. For example, the average flux rate when running feed material without anti-scalant was higher when compared to the feed material with 20 ppm of PT-100/400 at a 75 percent recovery. We attribute this effect to the difference in conductivity of these two feed streams. The conductivity of the feed material without anti-scalant was 12.4 mS compared to 15.6 mS for the feed material with anti-scalant. Further, other factors for the VSEP equipment include the cleaning efficacy. Chemical concentration and temperature, contact time, and the precise nature and extent of the scale and fouling materials all affect cleaning efficacy. It is conceivable that these factors varied during piloting and contributed to the observed variations in initial flux levels.

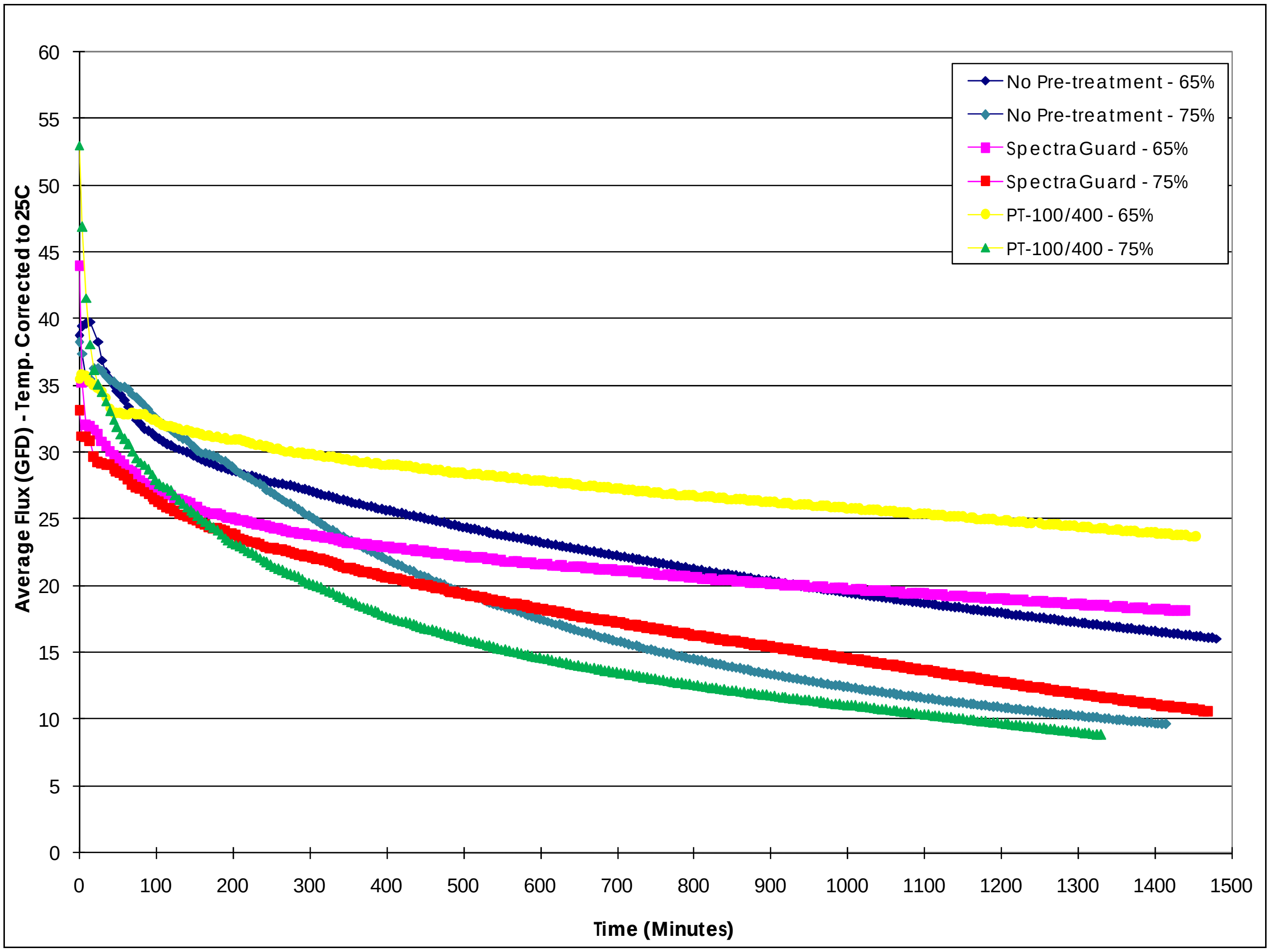


Figure 5: Phase 2 Anti-scalant Study

Table 3: Phase 2 Flux* Summary

Pre-treatment	**VSEP Percent Recovery**	**Initial Flux**	**Final Flux**	**Average Flux**	**Spiral Percent Recovery***	**Overall Percent Recovery****
Raw Feed	65%	38.8 GFD	6.9 GFD	16.1 GFD	90.0%	96.5%
Raw Feed	75%	38.3 GFD	2.9 GFD	9.7 GFD	91.7%	97.9%
SpectraGuard 20 ppm	65%	44.0 GFD	12.6 GFD	18.1 GFD	89.9%	96.5%
SpectraGuard 20 ppm	75%	33.1 GFD	0.2 GFD	10.6 GFD	91.0%	97.8%
PT-100/400 20 ppm	65%	35.5 GFD	16.6 GFD	23.7 GFD	90.0%	96.5%
PT-100/400 20 ppm	75%	53.0 GFD	0.1 GFD	8.9 GFD	91.6%	97.9%

*Flux temperature corrected to 25ºC.

*Reported Recovery by Carollo.

**Recovery is based on the approximate recovery reported by Carollo, later to be determined 80 to 85 percent.

Table 4: Phase 2 Flux Comparison

Pre-treatment	Percent Recovery	Average Flux	Raw Feed Average Flux	Percent of Flux Increase Compared to Raw Feed*
SpectraGuard 20 ppm	65%	18.1 GFD	16.1 GFD	12.4%
SpectraGuard 20 ppm	75%	10.6 GFD	9.7 GFD	9.3%
PT-100/400 20 ppm	65%	23.7 GFD	16.1 GFD	47.2%
PT-100/400 20 ppm	75%	8.9 GFD	9.7 GFD	-8.25%

*Flux is not normalized for feed quality variation.

Table 5: Phase 2 Field Average Analytical Summary

Sample	Parameter	Feed	Permeate	Concentrate
Raw Feed – 65%	pH	7.29	6.17	7.53
	Conductivity	11.9 mS	577.6 µS	33.53 mS
	Temperature	35.65ºC	-	-
Raw Feed – 75%	pH	6.90	5.66	7.70
	Conductivity	12.4 mS	200 µS	50.4 mS
	Temperature	33.40ºC	-	-
SpectraGuard – 65%	pH	7.25	5.81	7.47
	Conductivity	11.91 mS	634 µS	32.9 mS
	Temperature	33.49ºC	-	-
SpectraGuard – 75%	pH	6.83	5.57	7.50
	Conductivity	18.1 mS	290 µS	37.6 mS
	Temperature	34.93ºC	-	-
PT-100/400 – 65%	pH	7.32	5.89	7.49
	Conductivity	12.1 mS	510 µS	34.1 mS
	Temperature	33.76ºC		
PT-100/400 – 75%	pH	7.19	6.23	7.59
	Conductivity	15.6 mS	510 µS	34.5 mS
	Temperature	36.51ºC	-	-

Phase 3 testing was not performed based on Phase 2 results of the SpectraGuard not having a ‘Significant Response.’

4.3 Phase 4 - PT-100/400 Threshold Concentration Testing

The testing was completed with the reported recoveries for the Spiral RO unit by Carollo. It was observed during this phase of testing the Spiral RO pilot was not calibrated correctly and adjusted. Further details of the adjustment are described in Section 4.3a.

The purpose of Phase 4 was to determine the minimum concentration of PT-100/400 required to produce a Significant Response. The system was operated at 65 percent Recovery and 500 psi at various concentrations of PT-100/400, between <10 ppm and 25 ppm. The higher concentration of anti-scalant used resulted in a higher ending average flux rate. The results are shown in Figure 6 and Tables 6 and 7.

The effectiveness of the dosing method was in question by Baer Engineering and another run at 25 ppm of anti-scalant was tested to confirm consistency.

The initial flow rate at the beginning of each run showed variation. Some factors that can affect the starting flow rate are the effectiveness of the cleaning just prior to a given test run and the extent of fouling from the previous run. When the feed material is started on a clean membrane the flow rate can be initially high and normalize once re-conditioned such as the 15 ppm run depicted in Figure 6. This effect is also illustrated by the data in Tables 3 and 4 where the average flux of 8.9 GFD for the 20 ppm run with PT-100/400 at 75 percent recovery was less than the initial average flux of 9.7 GFD without anti-scalant.

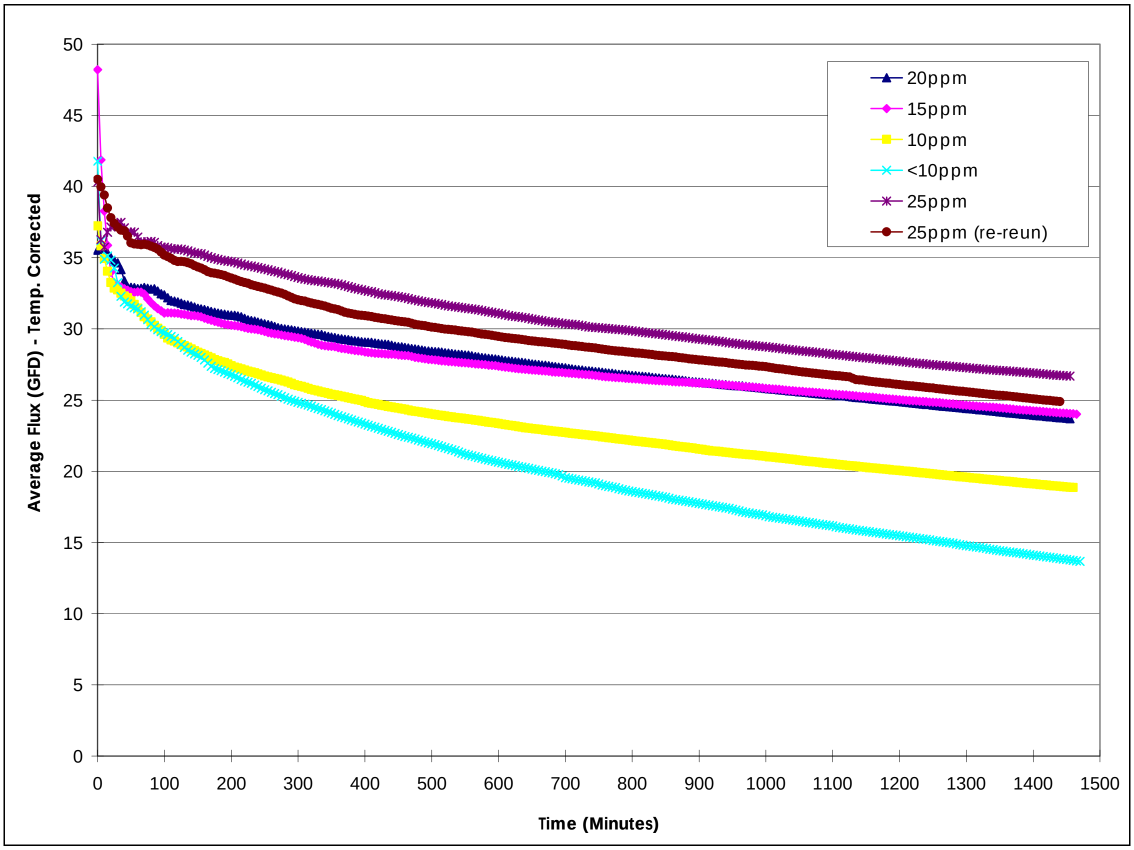


Figure 6: Phase 4 Threshold Concentration Test

Table 6: Phase 4 Flux* Summary

PT-100/400	VSEP Percent Recovery	Initial Flux	Final Flux	Average Flux	Spiral Percent Recovery*
<10 ppm	65%	41.8 GFD	4.5 GFD	13.7 GFD	90.6%
10 ppm	65%	37.2 GFD	13.6 GFD	18.8 GFD	90.0%
15 ppm	65%	48.2 GFD	18.9 GFD	24.0 GFD	90.0%
20 ppm	65%	35.5 GFD	16.6 GFD	23.7 GFD	90.0%
25 ppm	65%	40.3 GFD	20.1 GFD	26.7 GFD	90.0%
25 ppm rerun	65%	40.5 GFD	17.2 GFD	24.9 GFD	90.0%

*Flux temperature corrected to 25ºC.
*Reported by Carollo.

Table 7: Phase 4 Field Average Analytical Summary

Sample	Parameter	Feed	Permeate	Concentrate
<10 ppm	pH	7.22	6.13	7.57
	Conductivity	12.3 mS	457 µS	36.2 mS
	Temperature	35.99ºC	-	-
10 ppm	pH	7.28	5.96	7.49
	Conductivity	12.1 mS	547 µS	34.6 mS
	Temperature	35.47ºC	-	-
15 ppm	pH	7.27	5.96	7.48
	Conductivity	12.2 mS	593 µS	33.7 mS
	Temperature	34.87ºC	-	-
20 ppm	pH	7.32	5.89	7.49
	Conductivity	12.1 mS	510 µS	34.1 mS
	Temperature	33.76ºC	-	-
25 ppm	pH	7.25	5.78	7.68
	Conductivity	12.35 mS	520 µS	34.7 mS
	Temperature	32.56ºC	-	-
25 ppm	pH	7.09	5.84	7.79
	Conductivity	12.6 mS	373 µS	34.3 mS
	Temperature	32.16ºC	-	-

4.3a Operational Variables

The following test was conducted per Baer Engineering and R. W. Beck recommendations. NLR does not share the same opinions of the dosing method in question but was re-tested.

According to Baer Engineering, the effectiveness of the dosing method in use was considered inconsistent, unreliable, and unverifiable. The feed material was being pumped from another location into the VSEP feed tank. The feed flow to the tank was higher than the VSEP pilot unit could process, so there was an overflow at the top of the tank. The initial tank volume was dosed at the required concentration and the metering pump dosed the treatment at the top of the tank. There were concerns that the anti-scalant was not mixing properly and may have gone out the overflow rather than mix properly with the bulk liquid. In order to remedy this situation, an injection port was installed for inline dosing in the pipe carrying feed material to the VSEP feed tank. Two tests were completed at 10 ppm and 15 ppm of anti-scalant at 65 percent recovery. It is inconclusive on which method was more effective based on these two runs. The results are shown in Figure 7 and Tables 8 and 9. Inline dosing was used for the remainder of testing.

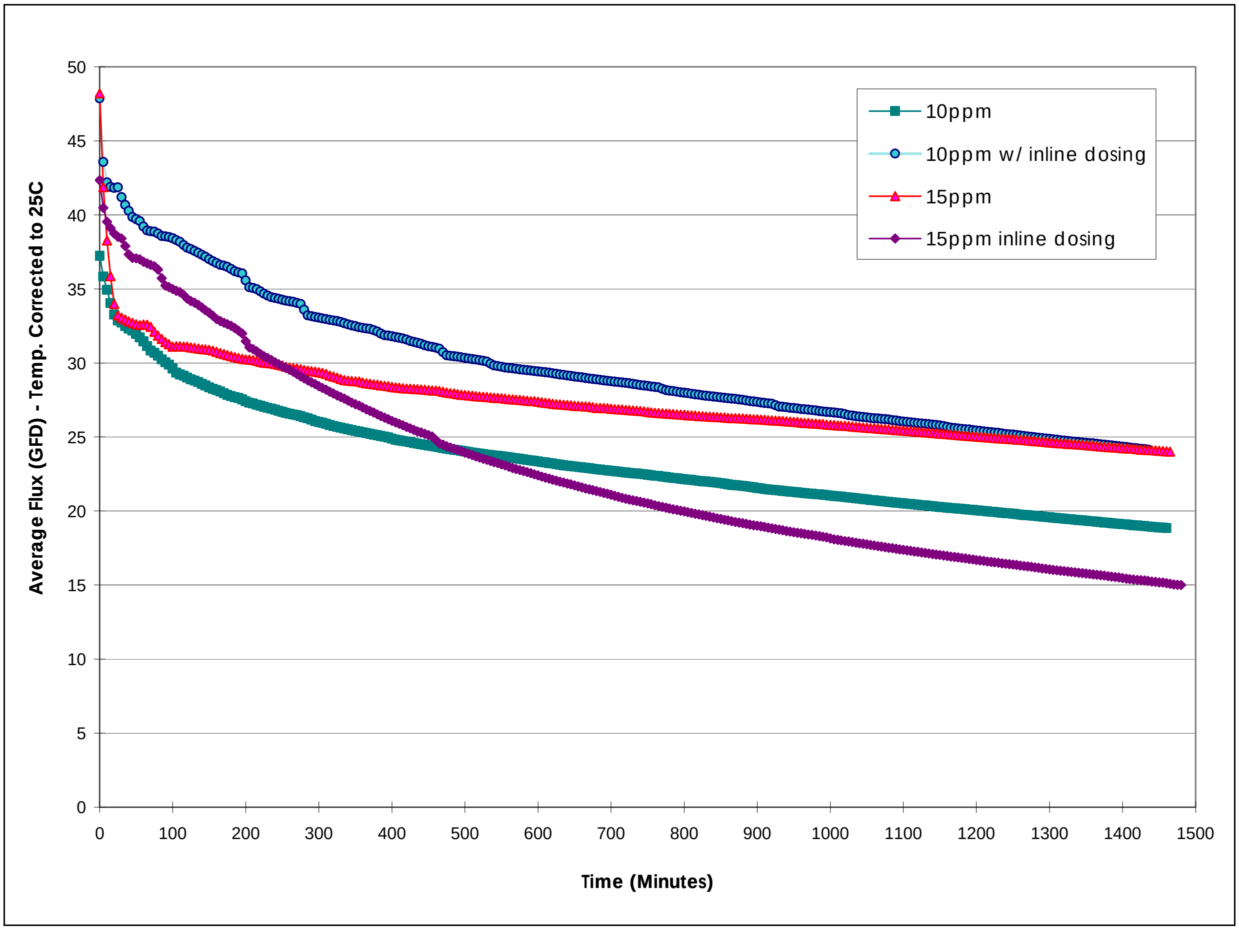


Figure 7: Phase 4 Inline Dosing Threshold Concentration Testing Comparison

Table 8: Phase 4 Flux* Summary

PT-100/400	VSEP Percent Recovery	Initial Flux	Final Flux	Average Flux	Spiral Percent Recovery*
10 ppm	65%	37.2	13.6	18.8	90.0%
10 ppm (Inline)	65%	47.9	17.0	24.2	90.0%
15 ppm	65%	48.2	18.9	24.0	90.0%
15 ppm (Inline)	65%	42.3	7.7	15.0	90.0%

*Flux temperature corrected to 25ºC.

*Reported Recovery by Carollo.

Table 9: Phase 4 Field Average Analytical Summary

Sample	Parameter	Feed	Permeate	Concentrate
10 ppm	pH	7.28	5.96	7.49
	Conductivity	12.1 mS	547 µS	34.6 mS
	Temperature	35.47ºC	-	-
10 ppm (Inline)	pH	7.21	5.75	7.78
	Conductivity	12.3 mS	306 µS	30.9 mS
	Temperature	34.47ºC	-	-
15 ppm	pH	7.27	5.96	7.48
	Conductivity	12.2 mS	593 µS	33.7 mS
	Temperature	34.87ºC	-	-
15 ppm (Inline)	pH	7.06	6.11	7.31
	Conductivity	14.0 mS	513 µS	34.3 mS
	Temperature	34.88ºC	-	-

During this phase of testing, it was found that the primary Spiral RO system was not calibrated correctly and was operating at a lower recovery rate than expected of approximately 80 to 85 percent. The system was corrected and adjusted to 90 percent recovery. This upstream change affected the feed material going to the VSEP system. The conductivity went from ~12.0 mS up to 18 to 19 mS. The increase in feed concentration had a negative effect on flux rates. Various concentrations of anti-scalant were retested at lower VSEP recovery rates due to the increased initial feed concentration in order to have an equal comparison in terms of overall system recovery (combined spiral RO and VSEP^{TM} equipment recoveries). Based on the new feed quality, the ending average flux rates were higher with a higher dosing of anti-scalant with consideration to feed quality. As shown in Figure 9, 25 ppm was chosen because it showed a significantly higher response compared to 20 ppm at 55 percent recovery with a feed from the primary RO system operating with at 90 percent recovery. Therefore, 25 ppm was chosen as the dose rate for the remainder of testing. The results are shown in Figure 8, Tables 10 and 11.

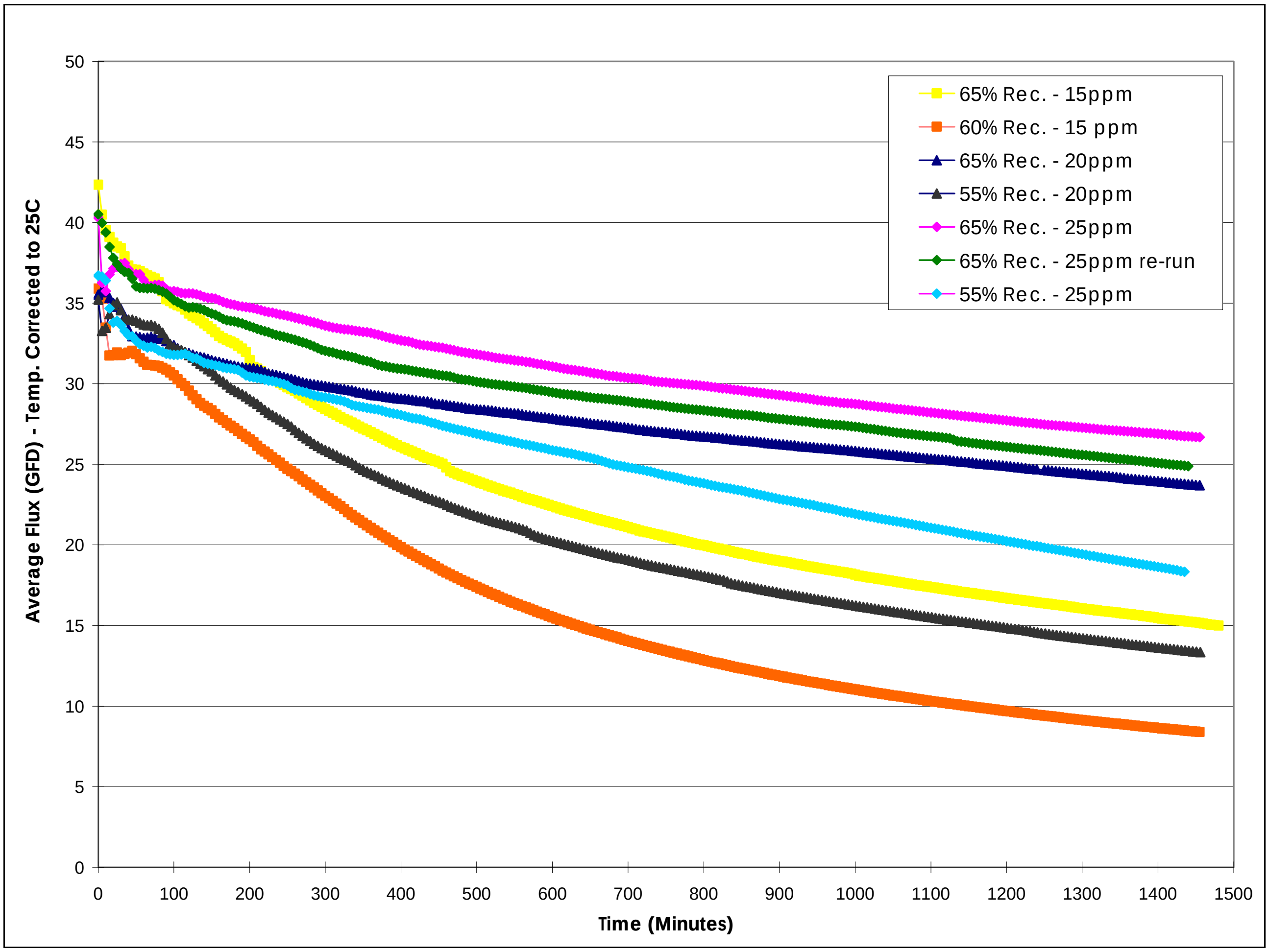


Figure 8: Phase 4 Threshold Concentration Testing at Primary Spiral RO System at 90 Percent Recovery

Table 10: Phase 4 Flux* Summary

PT-100/400	VSEP Percent Recovery	Initial Flux	Final Flux	Average Flux	Spiral Percent Recovery*
0 ppm*	65%	38.8 GFD	6.9 GFD	16.1 GFD	90.0%
15 ppm	60%	35.9 GFD	2.1 GFD	8.4 GFD	90.0%
15 ppm	65%	48.2 GFD	18.9 GFD	24.0 GFD	90.0%
20 ppm	55%	35.2 GFD	5.4 GFD	13.3 GFD	90.0%
20 ppm	65%	35.5 GFD	16.6 GFD	23.7 GFD	90.0%
25 ppm	65%	40.3 GFD	20.1 GFD	26.7 GFD	90.0%
25 ppm re-run	65%	40.5 GFD	17.2 GFD	24.9 GFD	90.0%
25 ppm	55%	36.7 GFD	6.1 GFD	18.3 GFD	90.0%

*Flux temperature corrected to 25ºC.

*Reported Recovery by Carollo.

*0 ppm: Raw VSEP feed water results from Phase 2, not shown in Figure 8.

Table 11: Phase 4 Field Average Analytical Summary

Sample	Parameter	Feed	Permeate	Concentrate
15 ppm – 60%*	pH	7.20	6.23	7.41
	Conductivity	18.5 mS	487 µS	40.6 mS
	Temperature	36.06ºC	-	-
15 ppm – 65%	pH	7.06	6.11	7.31
	Conductivity	14.0 mS	513 µS	34.3 mS
	Temperature	34.87ºC	-	-
20 ppm – 55%*	pH	7.10	5.89	7.33
	Conductivity	18.1 mS	390 µS	36.2 mS
	Temperature	36.09ºC	-	-
20 ppm – 65%	pH	7.32	5.89	7.49
	Conductivity	12.1 mS	510 µS	34.1 mS
	Temperature	33.76ºC	-	-
25 ppm – 65%	pH	7.25	5.78	7.68
	Conductivity	12.35 mS	520 µS	34.7 mS
	Temperature	32.56ºC	-	-
25 ppm re-run – 65%	pH	7.09	5.84	7.79
	Conductivity	12.6 mS	373 µS	34.3 mS
	Temperature	32.16ºC	-	-
25 ppm – 55%*	pH	7.06	5.84	7.30
	Conductivity	18.6 mS	374 µS	38.9 mS
	Temperature	35.15ºC	-	-

*The Spiral RO pilot recovery was adjusted from 80 to 85 percent to 90 percent in these test runs.

In addition to anti-scalant testing, pH adjustment was tested to obtain more stable long-term flow rate and periods between cleanings. The pH of the feed water can have a significant effect on flux performance. By lowering the pH, the solubility of foulants can be manipulated. By increasing the solubility of foulants, they will remain in the feed material rather than precipitating on the membrane surface, which can cause a flow restriction. The solubility of mineral foulants will typically increase at lower pH values and as a result the flow rates become more stable. The system was set to 55 percent Recovery and 500 psi and the feed was pH adjusted down to ~6.0 with sulfuric acid*. The addition of 25 ppm of PT-100/400 was dosed and the pH was manually adjusted for a run time of 10 hours. The flux of the pH-adjusted run had a 3.5 percent decrease in average flux after 590 minutes of operation compared to 42 percent for 20 ppm of anti-scalant only and 29 percent for 25 ppm anti-scalant only. Running with the pH-adjusted feed, the higher average flow would result in less frequent cleanings and would require less membrane area to process the same amount of feed as compared to non-adjusted pH feed water. Due to budgetary and equipment restrictions, pH adjusting was not used during the remaining test work despite these positive results. This would be an option for full-scale design with further pilot testing. A titration curve was created to determine the amount of sulfuric acid required to pH adjust the feed water pH, which can be used to calculate the costs associated at full-scale implementation. The results are shown in Figures 9 and 10 and Tables 12 to 15.

*A 93 percent sulfuric acid solution was diluted to 4.35 percent and dosed manually to maintain the desired feed water pH.

Note: Other factors influencing the initial membrane flux include the cleaning efficacy, chemical concentration and temperature, contact time, and the precise nature and extent of the scale and fouling materials. It is conceivable that these factors varied during piloting and contributed to the observed variations in initial flux.

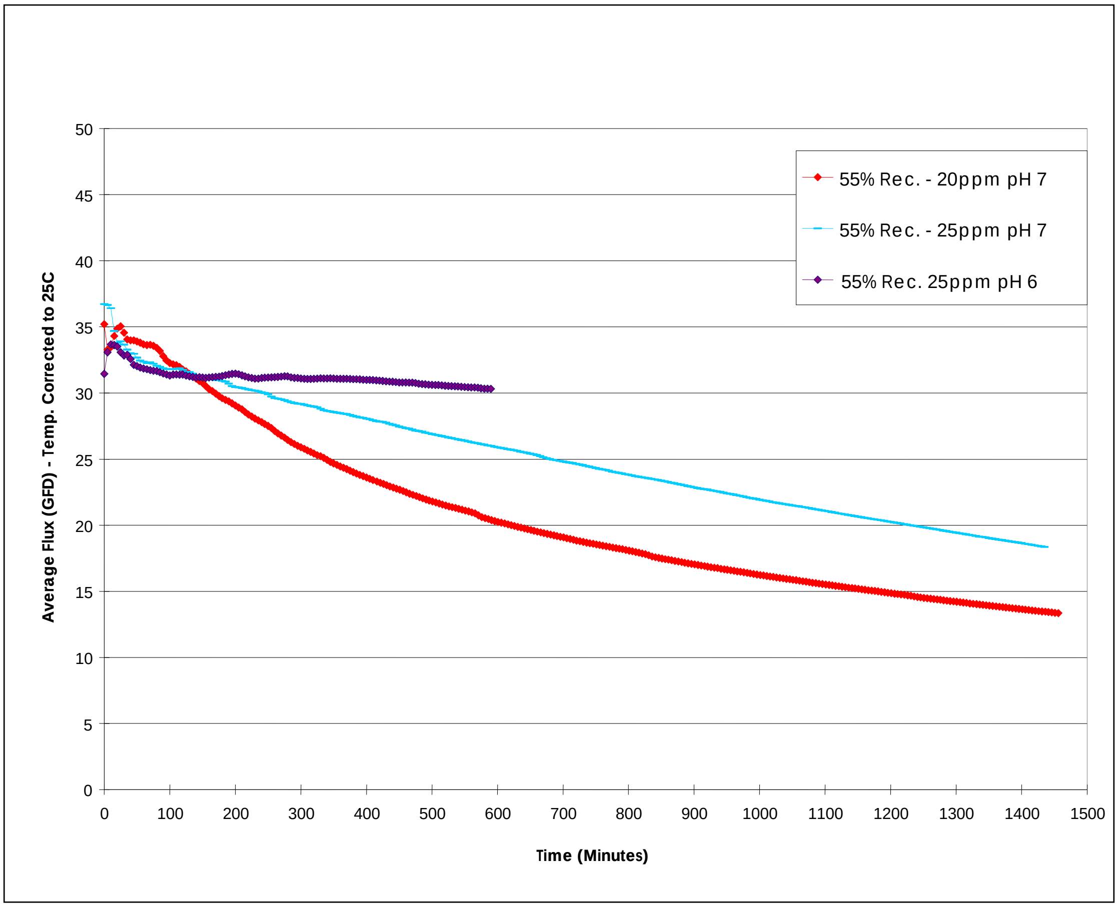


Figure 9: Phase 4B pH Comparison Study

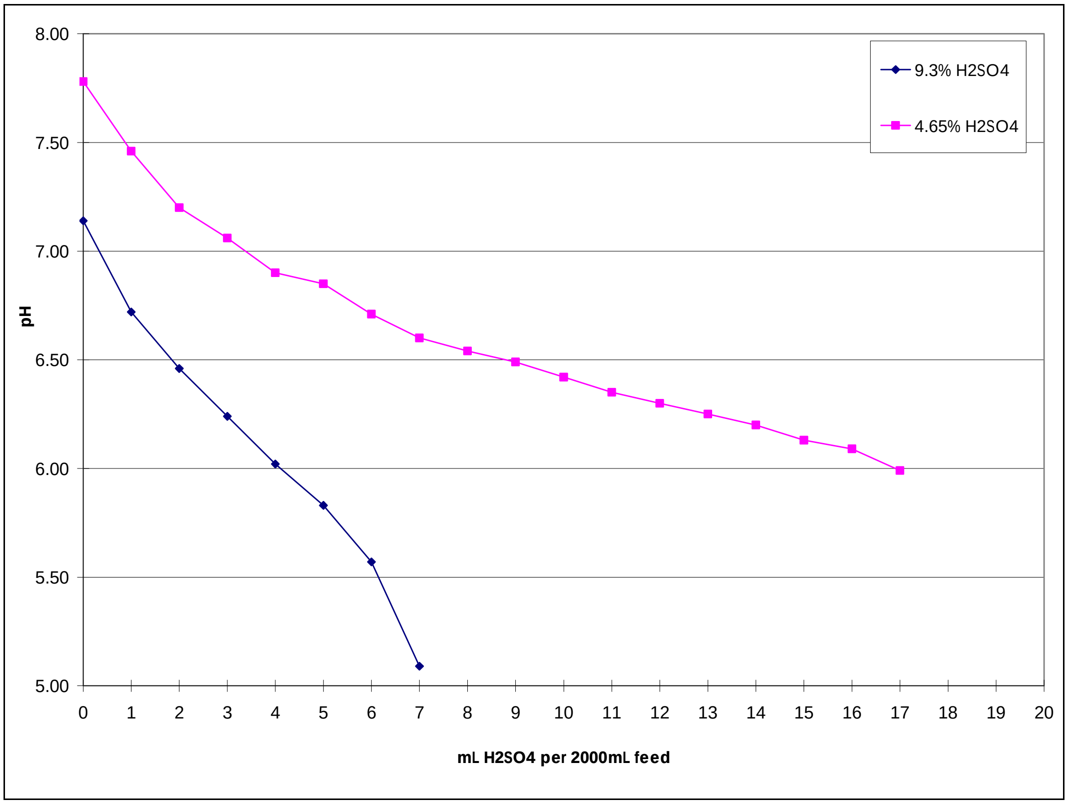


Figure 10: Phase 4B Sulfuric Acid Titration Curve

Table 12: Phase 4B Titration Data

9.3% H2SO4 (mg/L)*	pH
0	7.14
539	6.72
1077	6.46
1616	6.24
2155	6.02
2694	5.83
3233	5.57
3772	5.09

*Milligrams of acid indicated concentration per liter of feed water (mg/L).

Table 13: Phase 4B Titration Data

4.35% H2SO4 (mg/L)*	pH
0	7.78
518	7.46
1036	7.20
1554	7.06
2072	6.90
2590	6.85
3108	6.71
3626	6.60
4144	6.54
4663	6.49
5181	6.42
5699	6.35
6217	6.30
6735	6.25
7253	6.20
7771	6.13
8289	6.09
8807	5.99

Table 14: Phase 4 Flux* Summary

PT-100/400	Percent Recovery	Run Time	Initial Flux	Final Flux	Average Flux
20 ppm	55%	590 mins	35.2 GFD	12.2 GFD	20.4 GFD
25 ppm	55%	590 mins	36.7 GFD	19.5 GFD	26.0 GFD
25 ppm – pH 6	55%	590 mins	31.4 GFD	29.8 GFD	30.3 GFD

*Flux temperature corrected to 25ºC.

Table 15: Phase 4 Average Field Analytical Summary

Sample	Parameter	Feed	Permeate	Concentrate
20 ppm	pH	7.10	5.89	7.33
	Conductivity	18.1 mS	390 µS	36.2 mS
	Temperature	36.09ºC	-	-
25 ppm	pH	7.06	5.84	7.30
	Conductivity	18.6 mS	374 µS	38.9 mS
	Temperature	35.15ºC	-	-
25 ppm – pH 6	pH	6.30	5.03	6.62
	Conductivity	18.2 mS	307 µS	33.1 mS
	Temperature	37.06ºC	-	-

4.4 Phase 5 - Recovery Study

With the concentration of pre-treatment chosen as 25 ppm, various recovery rates were tested in order to define an optimum rate. The system was set at the desired recovery for 48 hours with a chemical cleaning every 48 hours for each set point: 55 percent, 50 percent, and 45 percent recovery. With the previous testing completed with the Primary Spiral RO Unit at an increased recovery of 90 percent from 80 to 85 percent, a lower recovery testing range was chosen for the VSEP than previously expected due to the change in feed conditions. The overall recovery was 93 to 94.8 percent with the VSEP at 65 percent recovery before calibration of the primary system. After the adjustments the overall recovery was 95 percent with the VSEP at 50 percent recovery.

Typically, higher recovery results in lower flow. In this case 50 percent recovery showed the higher average fluxes for each 24-hour run. 50 percent recovery was chosen for the next phase of testing. The permeate conductivity for the 45 percent recovery run was higher than expected. This could have been a result of increased total dissolved solids (TDS) and silica in the feed compared to the other runs. The results are shown in Figure 11 and Tables 15 and 16. Analytical results are shown in Appendix A. Refer to Tables 7-1 to 7-3 in the main report for concentrate characteristics.

Note: Due to technical issues associated with the equipment, the data for the second 45 percent run was not recoverable from the data logging system.

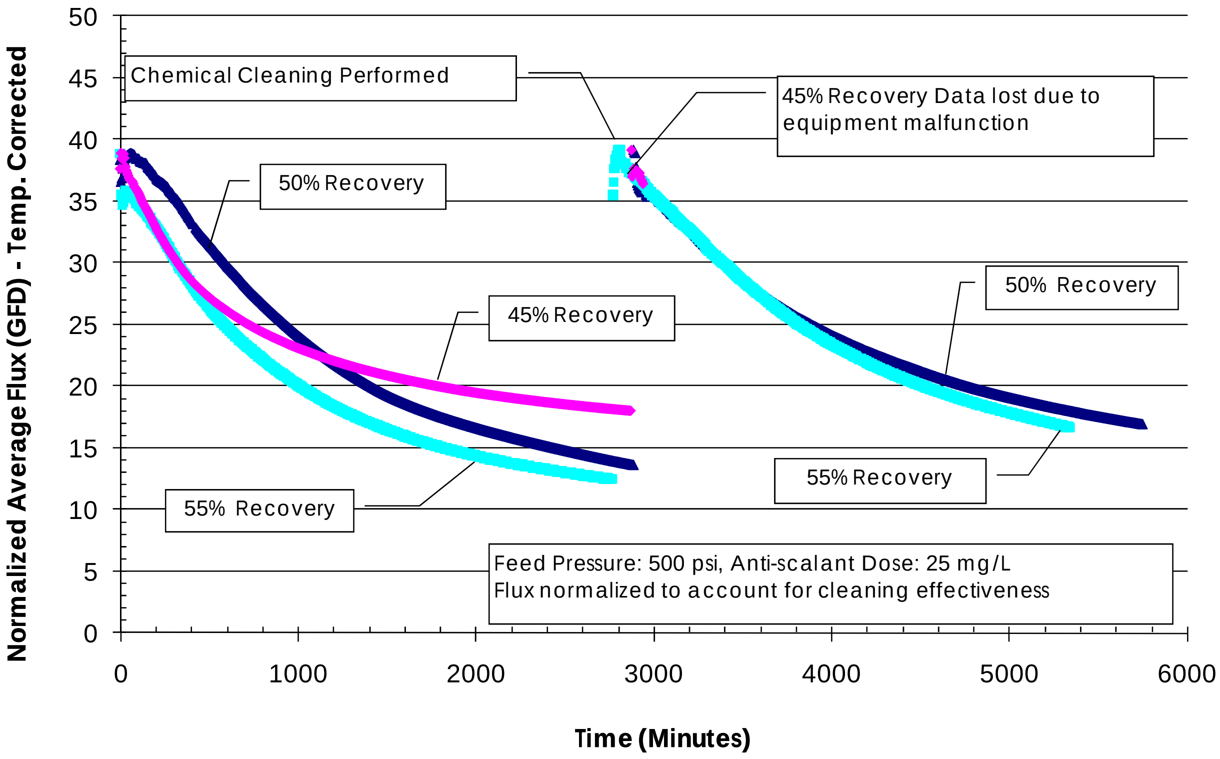


Figure 11: Phase 5
(Courtesy of R. W. Beck, Inc.)

Table 15: Phase 5 Flux* Summary

PT-100/400	VSEP Percent Recovery	Run time	Initial Flux	Final Flux	Average Flux	Spiral Percent Recovery*	Overall Percent Recovery
25 ppm	55%	46.0 hours	33.1 GFD	1.6 GFD	6.7 GFD	90%	95.5%
25 ppm	55%	42.9 hours	29.9 GFD	2.7 GFD	11.1 GFD	90%	95.5%
25 ppm	50%	48.0 hours	38.3 GFD	5.4 GFD	13.6 GFD	90%	95.0%
25 ppm	50%	47.7 hours	39.1 GFD	9.5 GFD	16.9 GFD	90%	95.0%
25 ppm	45%	47.8 hours	25.8 GFD	2.6 GFD	6.2 GFD	90%	94.5%

*Flux temperature corrected to 25ºC.

*Reported Recovery by Carollo.

Table 16: Phase 5 Average Field Analytical Summary

Sample	Parameter	Feed	Permeate	Concentrate
55% - Run 1	pH	7.09	6.33	7.31
	Conductivity	19.04 mS	546 µS	36.2 mS
	Temperature	36.38ºC	-	-
55% - Run 2	pH	7.03	5.97	7.28
	Conductivity	19.03 mS	552 µS	35.3 mS
	Temperature	36.85ºC	-	-
50% - Run 1	pH	7.37	5.95	7.45
	Conductivity	17.7 mS	294 µS	30.3 mS
	Temperature	35.32ºC	-	-
50% - Run 2	pH	7.07	5.75	7.28
	Conductivity	18.02 mS	389 µS	32.5 mS
	Temperature	36.54ºC	-	-
45% - Run 1	pH	7.07	6.16	7.23
	Conductivity	17.04 mS	1240 µS	29.5 mS
	Temperature	37.54ºC	-	-

4.5 Phase 6 Confirmatory Testing

With the chosen operating conditions determined in previous phases, a long-term 30-day operation was scheduled as a repeatability study. The system was operated for a total of 294.5 hours with an average cleaning frequency of every 18.4 hours. The run time was limited due to the unexpected shutdown of the unit during overnight runs. The cause was found to be that the concentrate pressure set point was set too low, which would trip a low concentrate flow alarm. The issue was resolved by increasing the alarm set point. In addition, a faulty bypass valve prevented the feed pressure from running over 300 psi during some of this testing. A replacement valve was provided in order to resolve the issue.

The average performance of the slipstream system was: 9.3 GFD and 50 percent recovery at 25ºC and 500 psi. The average flux and average recovery are based on the total run time and these values will be used for system sizing calculations. The results can be seen in Figure 12 and Tables 17 and 18. Additional analytical results are shown in Appendix B.

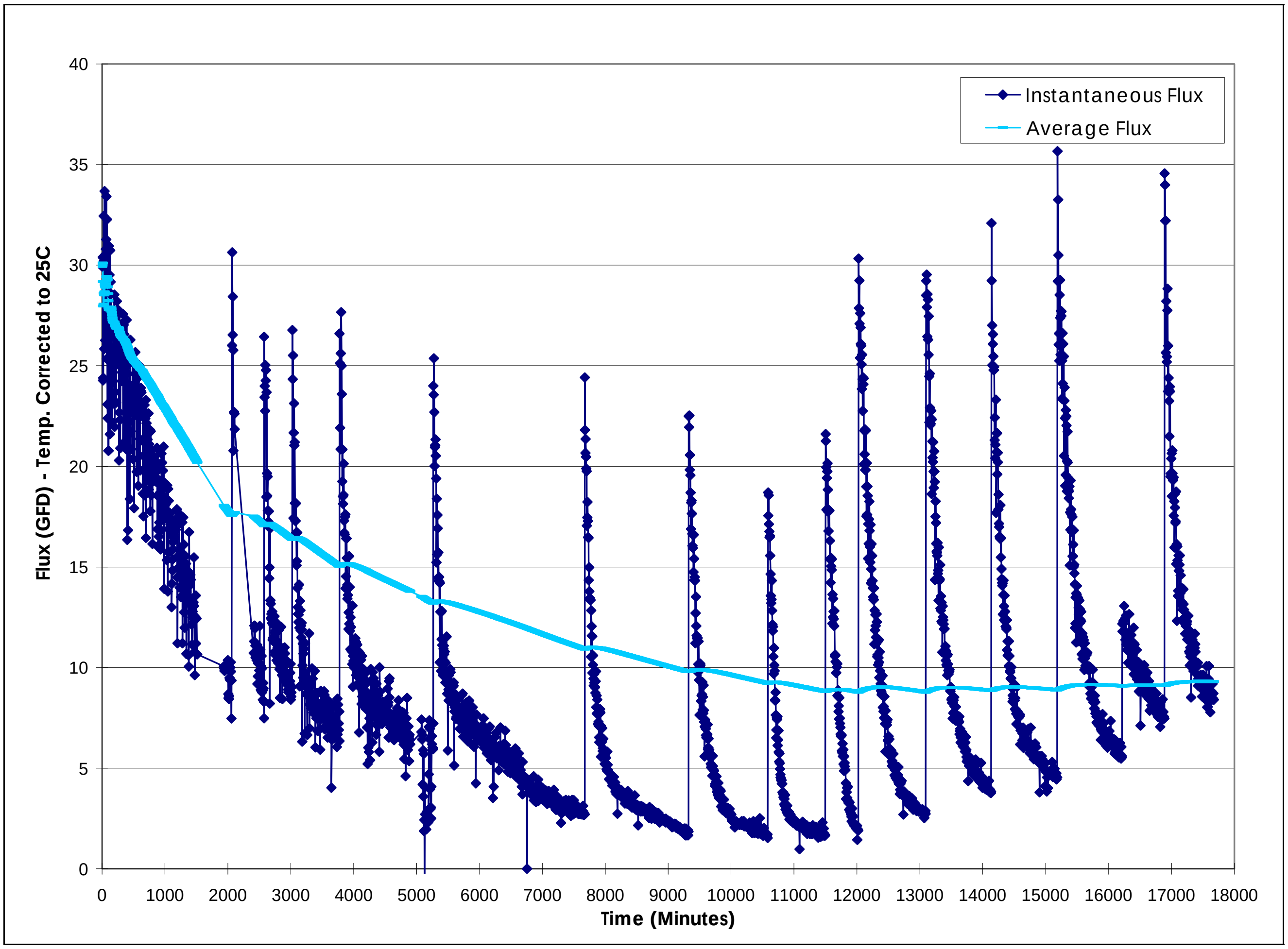


Figure 12: Phase 6 Confirmatory Testing

Table 17: Phase 6 Flux* Summary

Run	Run time (Hours)	Initial Flux	Final Flux	Spiral Percent Recovery*	Overall System Recovery
1	34.4	29.9 GFD	9.4 GFD	91.4%	95.7%
2	8.5	26.0 GFD	7.5 GFD	90.1%	95.1%
3	7.4	26.4 GFD	9.0 GFD	92.4%	96.3%
4	12.5	36.1 GFD	6.4 GFD	92.5%	96.3%
5	24.8	26.6 GFD	7.2 GFD	90.2%	95.1%
6	40.1	24.0 GFD	2.7 GFD	90.5%	95.3%
7	27.6	24.4 GFD	1.9 GFD	89.7%	94.9%
8	20.9	22.5 GFD	1.5 GFD	89.4%	94.7%
9	15.1	18.7 GFD	1.7 GFD	89.9%	95.0%
10	8.7	21.6 GFD	1.9 GFD	90.7%	95.4%
11	17.8	30.3 GFD	2.7 GFD	90.8%	95.4%
12	17.3	28.5 GFD	3.8 GFD	90.4%	95.2%
13	17.4	32.1 GFD	4.5 GFD	90.1%	95.1%
14	17.2	35.7 GFD	5.5 GFD	90.1%	95.1%
15	11.2	12.2 GFD	7.5 GFD	90.1%	95.1%
16	13.0	34.6 GFD	8.4 GFD	90.1%	95.1%

*Flux temperature corrected to 25ºC.

*Reported Recovery by Carollo.

Table 18: Phase 6 Flux Summary

Run	Parameter	Feed	Permeate	Concentrate
1	pH	7.15	5.64	7.31
	Conductivity	17.63 mS	439 µS	30.58 mS
	Temperature	43.27ºC	-	-
2	pH	7.29	5.97	7.38
	Conductivity	17.85 mS	778 µS	27.6 mS
	Temperature	42.09ºC	-	-
3	pH	7.02	5.82	7.18
	Conductivity	17.57 mS	786 µS	29.28 mS
	Temperature	43.39ºC	-	-
4	pH	6.98	5.61	7.08
	Conductivity	18.03 mS	763 µS	24.78 mS
	Temperature	47.65ºC	-	-
5	pH	7.02	5.76	7.02
	Conductivity	17.72 mS	908 µS	25.4 mS
	Temperature	47.00ºC	-	-
6	pH	7.16	5.88	7.31
	Conductivity	19.27 mS	1066 µS	30.88 mS
	Temperature	39.55ºC	-	-
7	pH	7.10	6.18	7.28
	Conductivity	18.46 mS	1486 µS	29.07 mS
	Temperature	35.22ºC	-	-
8	pH	7.13	6.22	7.28
	Conductivity	18.35 mS	1562 µS	28.48 mS
	Temperature	35.35ºC	-	-
9	pH	7.07	6.09	7.17
	Conductivity	17.76 mS	1619 µS	25.9 mS
	Temperature	34.47ºC	-	-
10	pH	7.14	6.08	7.29
	Conductivity	17.96 mS	1647 µS	30.09 mS
	Temperature	35.90ºC	-	-
11	pH	7.11	6.41	7.34
	Conductivity	17.84 mS	2847 µS	29.9 mS
	Temperature	35.69ºC	-	-
12	pH	7.11	6.45	7.29
	Conductivity	17.78 mS	3070 µS	29.7 mS
	Temperature	34.85ºC	-	-
13	pH	7.25	6.57	7.39
	Conductivity	17.51 mS	3540 µS	29.7 mS
	Temperature	33.07ºC	-	-
14	pH	7.15	6.45	7.28
	Conductivity	17.20 mS	3433 µS	29.9 mS
	Temperature	33.52ºC	-	-
15	pH	7.18	6.55	7.33
	Conductivity	17.67 mS	3538 µS	30.3 mS
	Temperature	33.47ºC	-	-
16	pH	7.18	6.60	7.30
	Conductivity	18.01 mS	3900 µS	29.46 mS
	Temperature	33.25ºC	-	-
Average	pH	7.13	6.14	7.26
	Conductivity	17.9 mS	1718 µS	28.8 mS
	Temperature	37.98ºC	-	-

During Phase 6 of testing, the conductivity of the permeate increased over each run while all factors such as feed conductivity and recovery remained constant. Running the system on a solution of sodium chloride and water can be used as a measure of the filter pack's status. The sodium chloride rejection was 99.1 percent when the brand new membrane was tested in house and the manufacturer reports a 99.0 percent minimum rejection. After Run 15 in Phase 6, the sodium chloride rejection was 79.4 percent. The 19.7 percent decrease in rejection was the cause of the increasing permeate conductivity.

To determine the cause for the decrease in rejection, the unit was disassembled and inspected for damage when returned to NLR. There was no visible damage to the membrane surface and no evidence of a breached membrane from a slipped o-ring, which could have caused the change in rejection. A brand new ESPA-1 membrane and the top membrane of the filter pack is shown in Figures 13 and 14. Figures 15 and 16 show a thin film left on the membrane surface shown as the dark areas. This film became more noticeable on the lower four membrane trays where the feed becomes more concentrated. The film was able to be wiped off with a cotton ball shown in Figure 15. Upon visual inspection, the cause for the decrease in sodium chloride rejection is inconclusive.

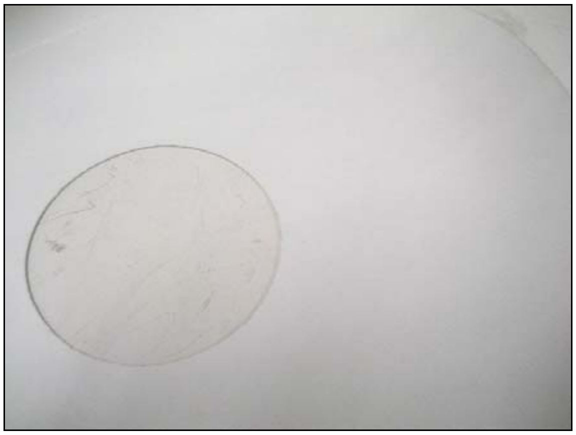


Figure 13: New ESPA Membrane

Figure 14: Top Membrane Tray at End of Testing

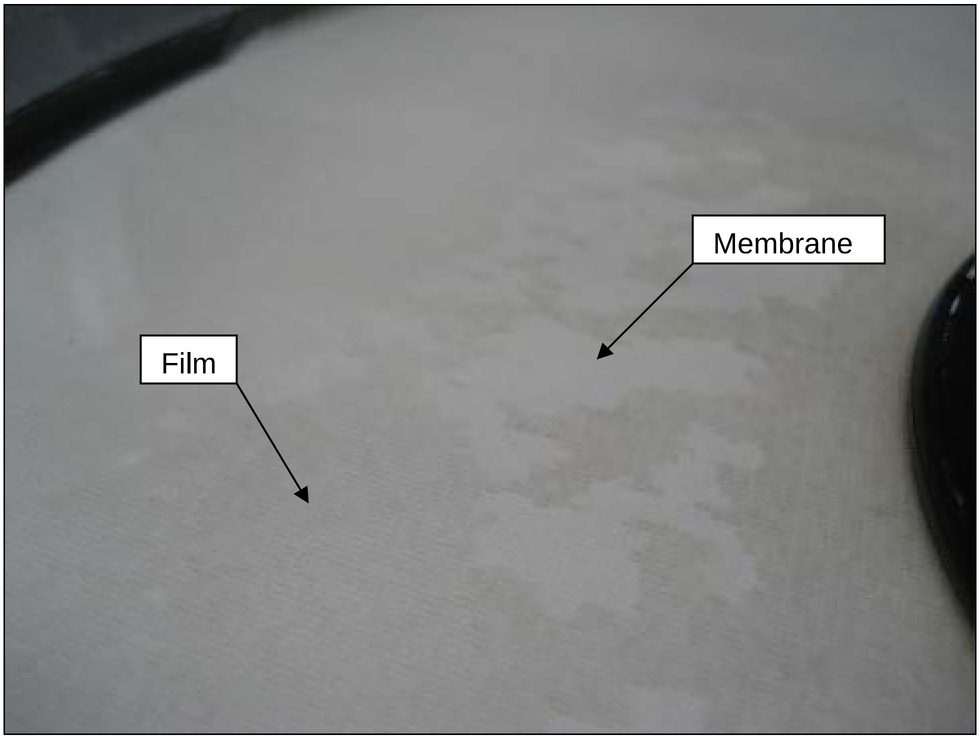


Figure 15: Bottom Membrane Tray

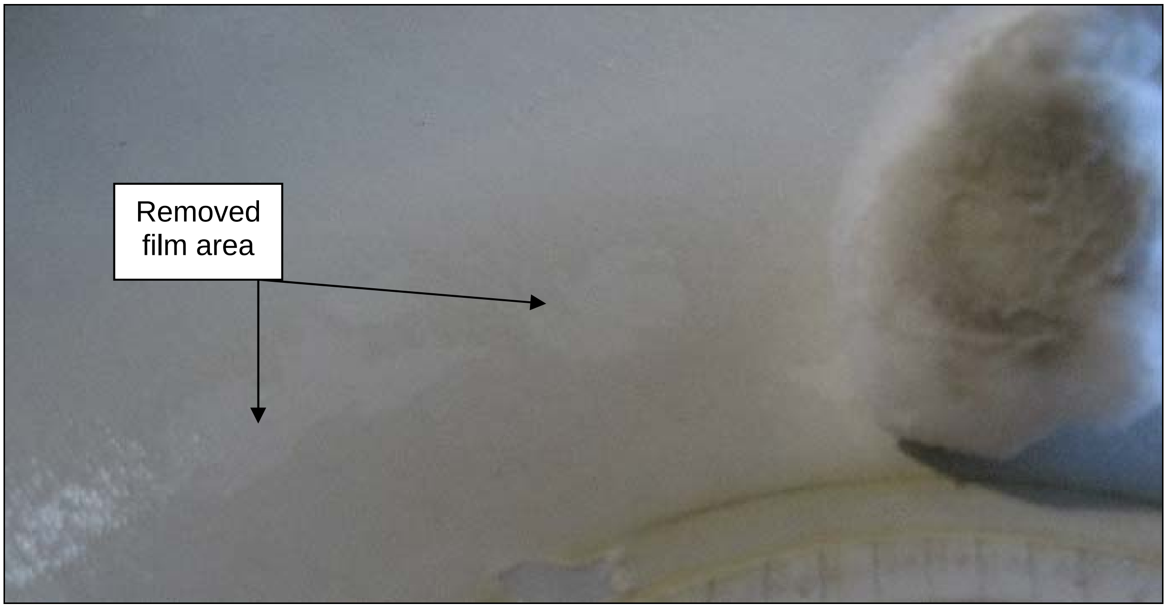


Figure 16: Film Wiped with Cotton Ball

Three sample pieces of 1.5 inch diameter circle of membrane were taken from the top, middle, and bottom membrane trays and tested in a batch cell. In a batch cell test, there is no vibration and a mixture of RO permeate and sodium chloride was used for the feed to test the rejection. The sodium chloride rejection was on the sample membrane pieces showed variation and does not conclusively pinpoint a section of damage, but rather an overall decrease in performance of the filter pack. The results are shown in Table 19.

Table 19: NaCl Rejection Test

Section	Sample	Tested Percent NaCl Rejection	Hydranautics Percent NaCl Rejection
Top	#1	63.7%	99.0%
	#2	65.5%	99.0%
	#3	76.8%	99.0%
Middle	#1	49.4%	99.0%
	#2	50.5%	99.0%
	#3	55.2%	99.0%
Bottom	#1	73.7%	99.0%
	#2	59.3%	99.0%
	#3	40.4%	99.0%

5.0 Cleaning

Chemical cleaning of the membrane is used to restore the flux rate. While VSEP can prevent colloidal fouling of the membrane and can reduce the polarization of rejected materials at the membrane surface, like other membranes, it cannot avoid all types of fouling that will occur, such as mineral scaling and chemical bonding. For this reason, chemical cleaners are used to solubilize the foulants and restore the membrane. During chemical cleaning, cleaners are re-circulated through the membrane system and then flushed out. Multiple cleaning cycles are used.

The cleaning procedure used was a two-part process. The steps in sequence were: NLR 404 acid cleaning followed by NLR 505 caustic cleaning for organics. The procedure was based on previous experience with similar applications. The cleaners were used in a 3 percent by volume solution. When cleaning was not as effective, NLR 550 was added as a 1 percent solution to the NLR 505 cleaning solution beginning with cleaning number 39. The NLR 550 was added to improve the cleanings. As shown in Figure 17, NLR 550 increased the flux. It can be said the fouling was not irreversible and the permeate flux was recovered in the 41st cleaning. When a new membrane is exposed to feed material, the membrane will take time to be conditioned. Once the membrane is conditioned, a new base line can be used for measuring a successful cleaning. Cleaning frequency is estimated every 18.4 hours based on Phase 6 data. Refer to Table 7-5 of the main report for cleaning operating parameters.

The flux rate is used as a measure of cleaning success. The rejection of the membrane before and after a cleaning was not determined due to insufficient sampling data collected, but is possible in later studies if desired. The analytical data collected on feed and permeate can be used to measure a major change in rejection of the membrane.

Based on the data, the membrane replacement frequency cannot be determined due to the membrane failure (loss of rejection) and inability to find the exact cause. The membrane replacement frequency can be estimated based on other similar applications at approximately two years.

NLR 404 is an acidic liquid cleaner designed to provide superior and rapid mineral scale cleaning of wide range of RO, nanofiltraton (NF) and ultrafiltration (UF) membranes. It removes metallic salts such as iron, aluminum, barium and strontium sulfate, calcium sulfate, calcium carbonate, as well as dyes and polymers.

NLR 505 is a caustic liquid membrane cleaner designed to provide superior and rapid soil removal properties. It contains a combination of ingredients, which provide cleaning actions that include lifting, dispersing, emulsifying, sequestering, dissolving and suspending. It removes biological and organic materials, silt, particulates, colloids, silica and emulsified oil from a wide range of RO, NF, UF and microfiltration (MF) membranes.

NLR 550 is a powder membrane cleaner is designed to target biological foulants, organics, oil, grease, lignin, and dyes. This cleaner is also effective on man-made polymers often found in wastewater treatment systems. NLR 550 has been tested for membrane compatibility by NLR and considered safe for use with RO membranes.

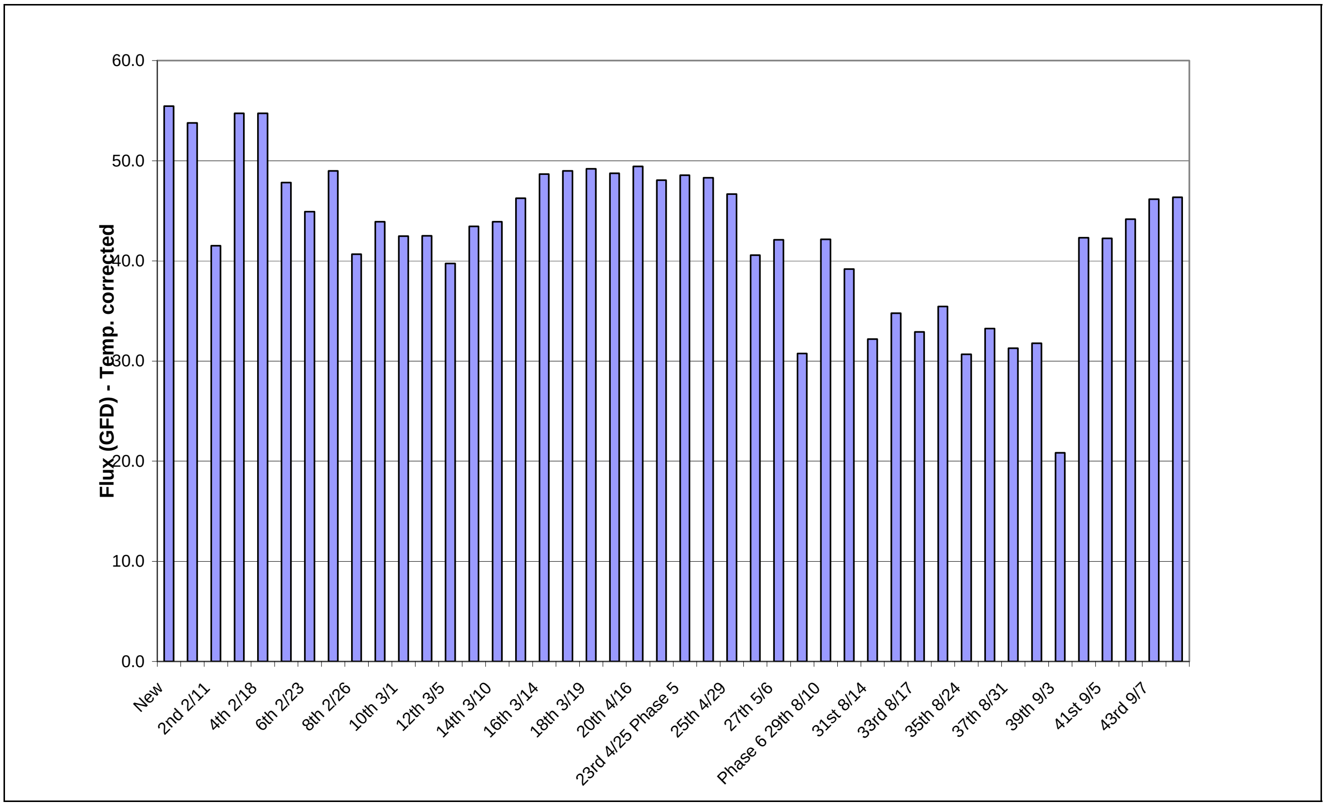


Figure 17: Cleaning Data

6.0 Summary

The following is a list of process recommendations/results:

Test Results

Membrane: ESPA
Mode of Operation: Slipstream (Described in Section 3.0)
Average Flux Rate: 9.3 GFD
Pre-treatment: 25 ppm PT-100/400
Percent Recovery: 50 percent
Pressure: 500 psi
Temperature: 25ºC
Cleaner Needed: NLR 404/505+550
Cleaning Frequency: Every 24 hrs

System Sizing Estimates for a process of 4 MGD* (2,778 GPM)**

EXAMPLE CALCULATION (50 percent recovery, 25°C):

2,778 gallons of feed* 1,440 minutes/day* 50 percent recovery rate = 2,000,000 gallons of permeate generated per day

2,000,000 gallons of permeate per day / 9.3 GFD * 24/22 hours (2 hours for cleaning) = 234,604 sf***

234,604 * 1.3 (30 percent over design) = 304,985 sf needed.

Module size = 304,985/1,500 sf = 203.3, therefore, 204 units are needed at 25°C and 50 percent recovery.

*Million gallons per day (MGD).
**Gallons per minute (GPM).
***Square feet (sf).

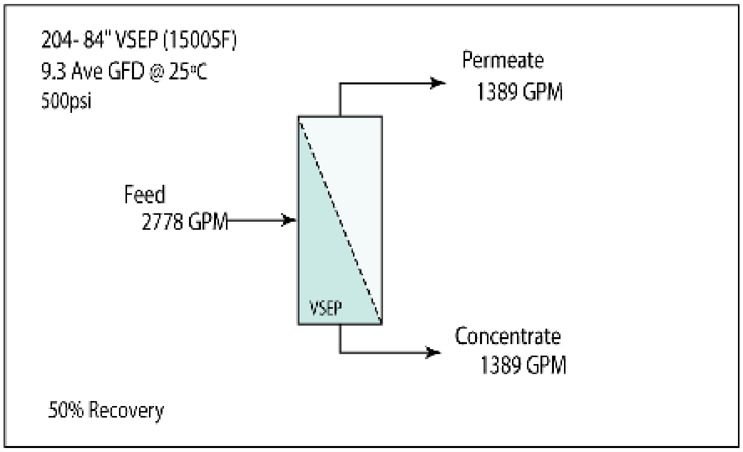
7.0 System Design Requirements

VSEP Modules:	204 - 84” 1,500 VSEP	**Elastomers:**	EPDM
Mode of Operation:	Slipstream	**Drain Cloth:**	Polyester
Membrane Type:	ESPA	**Resin:**	Epoxy
Operating Temperature:	25°C	**End Plates:**	Polypropylene
Design Pressure:	500 psi	**Membrane Trays:**	304
Feed Flow Rate:	2,778 GPM	**Operation:**	Automated
Recovery Rate:	50%	**Pre-treatment:**	PT-100/400
Design Flux Rate:	9.3 GFD AVE	**Dosage:**	25 ppm
Maximum Flux After Clean:	55 GFD @ 500 psi	**Cleaning Chemicals:**	NLR 404/505+550
Feed Pump Max Flow:	52 GPM @ 300 psi	**Cleaning Frequency:**	Every 24 hours
Energy Consumption:		**Chemical Consumption:**	404: 1,224 gallon day
Vibration:	**2,448 hp* @ ¾ inch**		505: 1,224 gallon day
Pump:	**953 hp**		550: 204 gallon day
Total kW Usage:**	**2,536.4 kW** **(30.4 kWh***/ 1,000 gallon permeate)**		PT-100/400: 91.7 gallon day

Permeate Destination:	Reuse
Concentrate Destination:	Deep Well Injection

*horse power (hp).
**kilowatt (kW).
***kilowatt-hour (kWh).

RO Reject Processing



Process Objectives:
50% Recovery of Filtrate
TCEQ/SAWS Water Standards

VSEP Advantages:
Concentrate Volume Reduction

Membrane: ESPA

Elastomers: EPDM

Cleaning: NLR 404 & 505+550

Process Conditions:

Permeate Rate shown is the average rate
Pre-treatment: 25ppm PT-100/400
Expected Temperature: Ambient
Operating Pressure: 500 psi

NEW LOGIC Research
1295 67th Street, Emeryville, CA 94608 (510) 655-7305

RW Beck/SAWS		9/18/09
RO Reject		

Appendix A: Phase 5 Analytical Results

Feed				Date:	4/29/2009	50%	5/5/2009	55%		5/6/2009	45%	
PARAMETER (2)	Lab Method	Units	TCEQ Standard	max	min	ave	max	min	ave	max	min	ave
Calcium	E200.7	mg/l				404			404			433
pH(7)	Field Parameter/ Electrode		>7.0 (4)	7.04	7.02	7.03/ 6.82	7.09	7.02	7.03/ 7.52	7.08	7.04	7.07/ 7.32
Conductivity (7)	Field Parameter/ Electrode	umho/cm		19.1	19.1	19.1/ 24.4	16.9	16.7	16.6/ 24.4	18.2	17.17	17.5/ 31.3
Temperature (8)	Field Parameter	°C		37.4	35.7	36.4	39.4	36.5	37.8	39.1	36.7	37.1
TDS	SM2540C	mg/l	1000 (5)			13000			13800			16700
Na	E200.7	mg/l				3330			3570			4140
Mg	E200.7	mg/l				217			221			238
Sr	E200.8	mg/l				28.1			29.1			30.3
Ba	E200.8	mg/l	2 (4)			0.2			0.21			0.196
CO_3	SM2320B	mg/l				<1			<1			<1
HCO_3	SM2320B	mg/l				990			1100			1170
Cl	E300	mg/l	300 (5)			2560			2900			2490
SO_4	E300	mg/l	300 (5)			6980			7900			6800
SiO_2	SM4500-SiO2-C	mg/l				75.9			73.2			80.2
Fe Total (3)	E200.7	mg/l				2.27			1.68			1.58
ORP (9)	Field Parameter/ Electrode	mV		NA	NA	NA	-177	-158	-167.5	-170	-136	-153

Permeate				Date:	4/29/2009	50%	5/5/2009	55%		5/6/2009	45%	
PARAMETER (2)	Lab Method	Units	TCEQ Standard	max	min	ave	max	min	ave	max	min	ave
Calcium	E200.7	mg/l				650			0.32		1.3	
pH (7)	Field Parameter/ Electrode		>7.0 (4)	6.62	6.59	6.6/ 6.17	6.29	6.13	6.19/ 6.99	6.48	5.73/ 6.37	6.17
Conductivity (7)	Field Parameter/ Electrode	umho/cm		671	609	642/ 343	1680	1170	1290/ 629	1590	540/ 804	1168
Temperature (8)	Field Parameter	°C		37.4	35.7	36.4	39.4	36.5	37.8	39.1	36.7	37.1
TDS	SM2540C	mg/l	1000 (5)			197			380			483
Na	E200.7	mg/l				60.2			120			149
Mg	E200.7	mg/l				0.43			<0.1			1.04
Sr	E200.8	mg/l				0.06			0.04			0.168
Ba	E200.8	mg/l	2 (4)			<0.01			<0.01			<0.01
CO_3	SM2320B	mg/l				<1			<1			<1
HCO_3	SM2320B	mg/l				38			160			104
Cl	E300	mg/l	300 (5)			72.2			91.6			152
SO_4	E300	mg/l	300 (5)			28.9			21.5			79.8
SiO_2	SM4500-SiO2-C					2.05			3.85			4.81
Fe Total (3)	E200.7	mg/l				<0.03			<0.03			<0.03
ORP (9)	Field Parameter/ Electrode	mV		NA	NA	NA	45	10	27.5	90	39	64.5

Concentrate				Date:	4/29/2009	50%	5/5/2009	55%		5/6/2009	45%	
PARAMETER [2]	Lab Method	Units	TCEQ Standard	max	min	ave	max	min	ave	max	min	ave
Calcium	E200.7	mg/l				650			902			762
pH [7]	Field Parameter/ Electrode		>7.0 [4]	7.3	7.2	7.25/ 6.91	7.25	7.18	7.22/ 7.77	7.26	7.21	7.24/ 7.53
Conductivity [7]	Field Parameter/ Electrode	umho/cm		37	36.8	36.9/ 42.5	29.7	29	29.1/ 98.5	30.2	29.7	29.9/ 49.0
Temperature [8]	Field Parameter	°C		37.4	35.7	36.4	39.4	36.5	37.8	39.1	36.7	37.1
TDS	SM2540C	mg/l	1000 [5]			23600			34100			31500
Na	E200.7	mg/l				6100			8460			6340
Mg	E200.7	mg/l				362			492			6340
Sr	E200.8	mg/l				65.9			85.6			51.1
Ba	E200.8	mg/l	2 [4]			0.33			0.45			0.325
CO_3	SM2320B	mg/l				<1			<1			<1
HCO_3	SM2320B	mg/l				1800			2300			1980
Cl	E300	mg/l	300 [5]			4860			6140			4850
SO_4	E300	mg/l	300 [5]			13200			17400			13300
SiO_2	SM4500-SiO2-C					84.2			75.8			54.8
Fe Total [3]	E200.7	mg/l				2.75			3.27			2.6
ORP [9]	Field Parameter/ Electrode	mV		NA	NA	NA	-134	-134	-134	-126	-121	-123.5

Footnotes displayed on next page.

1. According to “Protocol for VSEP Feasibility Pilot Testing Program” dated August 5, 2008(“Protocol”).
2. All samples will be preserved at a hold temperature below 10ºC.
3. One field parameter per day during Phases 5 and 6 testing by Carollo Engineers.
4. TCEQ Drinking Water Standards as established by Title 30 Part 1 Chapter 290 Subchapter F, Drinking Water Standards Governing Drinking Water Quality and Reporting Requirements for Public Drinking Water Systems Effective January 9, 2008.
5. Requirement is a Secondary Standard.
6. Notes included such items as confirmation of Carollo raw water sampling occurring on the same day as the sampling for the VSEP permeate and concentrate is collected.
7. To be performed by NLR in field; Will need two duplicate, but confirmatory samples measured by Alamo through the entire Phase 5.
8. To be performed by NLR 2 times a day in the field.
9. To be performed by NLR 2 times a day in the field; will need four duplicate, but confirmatory samples measured by Alamo through the entire Phase 5.

Appendix B: Phase 6 Analysis

9/2/2009					
Parameter	**Units**	**Raw Feed**	**Feed**	**Permeate**	**Concentrate**
Aluminum	mg/L	<0.05	<0.05	<0.05	<0.05
Antimony	mg/L	<0.02	<0.02	<0.02	<0.02
Arsenic	mg/L	<0.02	<0.02	<0.02	<0.02
Barium	mg/L	0.024	0.202	<0.01	0.363
Beryllium	mg/L	<0.002	<0.002	<0.002	<0.002
Boron	mg/L	0.64	1.55	0.96	2.05
Cadmium	mg/L	<0.003	<0.003	<0.003	<0.003
Calcium	mg/L	44.6	449	16.2	820
Chromium	mg/L	<0.01	<0.01	<0.01	<0.01
Copper	mg/L	<0.02	<0.02	<0.02	<0.02
Iron	mg/L	0.15	<0.03	<0.03	<0.03
Lead	mg/L	<0.015	<0.015	<0.015	<0.015
Magnesium	mg/L	24.3	248	9.91	453
Manganese	mg/L	0.037	0.394	0.02	0.656
Nickel	mg/L	<0.015	<0.015	<0.015	<0.015
Potassium	mg/L	12.6	103	10.8	188
Selenium	mg/L	<0.02	<0.02	<0.02	<0.02
Sodium	mg/L	460	4760	380	9800
Stronitium	mg/L	2.75	26.8	1.02	49
Thallium	mg/L	<0.05	<0.05	<0.05	<0.05
Zinc	mg/L	<0.02	0.02	<0.02	0.11
Mercury	mg/L	<0.002	<0.002	<0.0002	<0.0002
Chloride	mg/L		2580	409	43440
Fluoride	mg/L		<2	0.828	22.4
Nitrate-N	mg/L		8.95	2.79	17.2
Nitrite -N	mg/L		<2	<0.2	<2
Sulfate	mg/L		6130	334	11600
Alkalinity	mg/L		1290	152	2300
Cyanide	mg/L		<0.02	<0.02	<0.02
Carbon Dioxide	mg/L	98.6	220	70.4	264
Carbonate	mg/L	<1	<1	<1	<1
Color	CU		<1	<1	<1
Dissolved Oxygen	mg/L	8.64	9.46	8.71	9.82
Hardness	mg/L		5160	96	4020
Bicarbonate	mg/L	270	1290	152	230
Ammonia	mg/L	<1	<1	<1	<1
Threshold Odor	TON	<1	<1	<1	<1
pH			7.19	6.82	7.27
Dissolved Sulfide	mg/L		<2	<2	<2
Silica	mg/L		51.6	9.55	35.6
TDS	mg/L		13600	1120	25700
Turbidity	mg/L		<0.05	<0.05	<0.05
Conductivity	uS		21100	2180	44500
Bromodichloromethane	mg/L	<5	<5	<5	<5
Bromoform	mg/L	<5	<5	<5	<5
Chloroform	mg/L	<5	<5	<5	<5
Dibromochloromethane	mg/L	<5	<5	<5	<5

Appendix III. Resolution of the Texas Water Development Board Staff Comments

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Appendix III

SAWS Brackish Groundwater Desalination Facility
Enhanced Recovery Alternatives Evaluation and Pilot Test Report
TWDB Staff Comments

RWB Tracking No.	TWDB Comment	Proposed Resolution
	GENERAL COMMENTS	
1.	1. Please include an "Acronym and Definition" page in front of the report.	New Acronym and Definition section added to front of report.
2.	2. The report is missing the "Introduction" section.	New Introduction section added as Section 2.
3.	3. Appendix A (Now Appendix I) contains two different versions of the Mickley report (Enhanced Recovery Alternatives Review). The latest version of the report was published in 2009, and the previous version of the same report was published in 2007. Significant portions of these reports are redundant. Please consider combining these two reports into one.	Pursuant to discussion with the Water Development Board, the R. W. Beck Report was revised to summarize the findings of the Mickley Reports in the main body of the R. W. Beck Report, attribute the work, and delete the subject Appendix.
4.	4. To draw a distinction between the main report and appendices, please consider using a different numbering system for appendices (e.g., A-1, B-1, C-1).	Appendices to RWB Report re-titled as Appendices I and II to address.
	SPECIFIC COMMENTS	
	Executive Summary	
5.	Please discuss San Antonio's brackish groundwater desalination strategy. The discussion may include information on current water availability, water need by 2060 and other relevant information for building a desalination facility in San Antonio.	Discussion related to SAWS desalination strategy added to Executive Summary.

RWB Tracking No.	**TWDB Comment**	**Proposed Resolution**
	3.2.1 VSEP Process Description (Pages 8 and 9)	
6.	a. The criteria “Inherent fouling and plugging protection” has not been included in Table 3-3.	Explanation added to Section 4.1
7.	b. Second paragraph, lines 1 and 2: The statement, “the process may be capable of recovering up to **75 percent** of the concentrate” and the statement of the first paragraph of Page 6 in Appendix B, where it is mentioned that the process may be capable of recovering more than **50 percent** of the concentrate should be revised for clarity and consistency.	Addressed in Section 4.2.1, second paragraph, line 2 and line 3.
8.	c. Figure 3-1, please note that the flow diagram does not show the 100-micron strainer noted in the narrative description.	Addressed in Section 4.2.1 – added description for VSEP drawing.
	Table 3-4 (Page 11)	
9.	a. Please include the average operating pressure for a VSEP system in the table.	Addressed in Section 4.2.1 text discussing Table 4-4.
10.	b. Please comment on the potential effect of Texas high summer temperatures with respect to the Ambient Temperature Specification noted on Table 3-4.	Addressed in Section 4.2.1 text discussing Table 4-4.
	4.1 Test Conditions (Page 13)	
11.	A schematic diagram for the system will help the readers to understand the process clearly. Please refer to the process flow diagram of Page 20 for the schematics.	Addressed in the text of Section 5.1.

RWB Tracking No.	TWDB Comment	Proposed Resolution
12.	**<u>5.3 Schedule for Pilot Testing Activities (Page 18)</u>**	
13.	a. The activities mentioned in this section do not match with the activities mentioned in Section 6.2 (Pages 24 to 30). Specifically, according to Section 6.2, anti-scalant response testing was performed in the second phase only (not in the second and third phase as mentioned in Section 5.3), optimization of anti-scalant dose was performed in the third and fourth phases (not only in the third phase as mentioned in Section 5.3), recovery optimization was performed in the fifth phase (not in the fourth phase as mentioned in Section 5.3).	An explanation of changes to test sequence and a description of original and modified test phases was added to Section 6.3.
14.	b. Please provide a brief explanation of the relevance of dosing acid to improve the VSEP^{TM} performance.	The text of Section 6.3 was modified to address.
	<u>5.3.1 Testing Parameters and Pilot Unit Set-up (Page 19)</u>	
15.	a. Recovery (VSEP^{TM}): According to the result shown in Figure 5 of the Pilot Study (Appendix C), Phase 2 test was carried out at two different recoveries (65 percent and 75 percent). For completeness and consistency, replace the words “65 percent in Phase 2” with the words “65 percent and 75 percent in Phase 2”.	The text of Section 6.3.1 was modified to address.
16.	b. – **No comment b from TWDB**	
17.	c. Cleaning Procedure: The result of the pilot study (Page 25 of Appendix C) shows that the anti-scalant NLR 505 was also used along with NLR 404/NLR 5052 during the cleaning. Please include the name of NLR 505 as a cleaning agent in the text.	Should reference NLR404/NLR505. The text of Section 6.3.1 was modified to address.

RWB Tracking No.	**TWDB Comment**	**Proposed Resolution**
	5.4 Process Flow Diagram (Page 19)	
18.	Please spell-out PFD at the beginning of the paragraph.	The text of Section 6.4.1 was modified to address.
	5.6 Pilot Program Management Monitoring (Page 21)	
19.	a. The fourth paragraph contains references to both traditional and conventional reverse osmosis. These probably refer to the same type of process. Please reconcile the terms and provide a brief explanation of the concept.	The text of Section 6.6 was modified to address.
20.	b. This section, and the report, would benefit from a brief discussion of key chemical processes involved in the pretreatment and treatment phases of reverse osmosis and VSEP^{TM}.	Section 5.6 (now Section 6.6) discusses QA/QC. Therefore, the text of Section 4.2.1 was revised to address.
	6.2.2 Phase 2 – Anti-scalant Response Testing (Page 24)	
21.	a. Graphical representation of the result will be helpful for readers. A figure similar to Figure 5 of Appendix C could be used to plot the results.	Figures 7-1 and 7-2 were added to address.
22.	b. Please replace the words “anti-scalant 1” and “anti-scalant 2” with the actual name of the anti-scalants. Also, please mention that SpectraGuard SC^{TM} is referred as anti-scalant 1 and PT-100/400 is referred as anti-scalant 2 henceforward.	The text was modified to refer to SpectraGuard SC^{TM} and PT-100/400 rather than Anti-scalant 1 and Anti-scalant 2.
23.	**6.2.4 Phase 4 – Anti-scalant 2 Dose Optimization**	
24.	Please mention the upper and lower limit (in GFD) of average flux levels that is acceptable to New Logic Research for their equipment.	The text in Sections 4.2.1describing VSEP^{TM} and 7.2.4 was modified to explain NLR did not specify a maximum flux.

RWB Tracking No.	TWDB Comment	Proposed Resolution
	6.2.5 Recovery Optimization (Pages 26 and 27)	
25.	a. Figures 6-1 and 6-2 show that the experiments were started at an initial recovery and as the experiments progressed, the system recoveries changed due to the decline of the permeate flux. Therefore, please replace the word "recovery" with the words "initial recovery" in the second and third lines in Page 26, and in the legends of Figure 6-1 and Figure 6-2.	The text in Section 4.2.1 describing VSEP^{TM} was modified to explain how the VSEP^{TM} equipment maintains a constant recovery.
26.	b. Please describe the process of normalizing the average flux.	The text in Section 7.2.5 was modified to address.
27.	c. Please plot the original flux data (the data that was obtained prior to normalization) before and after chemical cleaning to explain the fact that chemical cleaning effectiveness could vary as much as 10 GFD in terms of initial flux level after a cleaning.	Figure 7-5 was added to address.
28.	d. Please discuss the factors that might impede restoring initial flux after chemical cleaning.	An overview of cleaning factors was added to Section 6.5. The text in Section 7.5 was modified to discuss cleaning results.
29.	e. Page 26, last paragraph, line 5: The words "Figure 6-1" should be replaced with the words "Figure 6-2".	The text was corrected to refer to Figure 7-4.
	Figure 6-2 (Page 27)	
30.	a. Results of the same test were plotted in Figure 6-2 of the report (Page 27) and in Figure 10 of Appendix C (Page 17). However, these figures do not match with each other. Please explain the reason for the difference in the figures.	A discussion of normalized data versus data that were not normalized and new Figure 7-5 was added to address.

RWB Tracking No.	TWDB Comment	Proposed Resolution
31.	b. Before cleaning is performed, the difference between the final flux of 45 percent and 55 percent recovery is ~5 GFD; however, after cleaning the membrane, the difference of the final flux for these two recoveries is negligible. Please explain the reason.	The missing data were explained in text. One curve is truncated so it does not overlie the 50 percent and 55 percent recovery curves.
	<u>Tables 6-1, 6-2, and 6-3 (Pages 28 and 29)</u>	
32.	In each of the tables, please include a column showing the rejection (%).	Tables 7-1, 7-2 and 7-3 were modified to include rejection percent.
33.	**<u>Tables 6-4 and 6-5 (Pages 31 and 32)</u>**	
34.	In each of these tables, please include a column showing the flow rate of cleaning solution during the cleaning.	Text of Section 7.2.6.3 modified to indicate a 2.5 GPM flow rate for all cleaning and flush steps.
	<u>6.2.7.1 Power Consumption (Page 36 and other instances)</u>	
35.	The report describes two different power estimates for VSEP, one from the manufacturer and the other as developed in the testing; it is important to clearly indicate which was used as the basis for full-scale projections and why.	The text of Section 7.2.7.1 was modified to state pilot test values should be used as the basis for scale-up until new test data is available.
	<u>Table 6-8, (Page 37)</u>	
36.	Please provide a brief narrative assessing the results noted in this table.	The text of Section 7.2.7.2 was modified to discuss the significance of noise levels.
	<u>7.3.2 Major Disadvantages (Page 39)</u>	
37.	Please provide cost estimates for capital and O&M in $/1000 gallons basis (Paragraphs 3 and 4).	Pursuant to discussion with the Water Development Board, R. W. Beck added a unit capital cost on a $/1,000 gallons of permeate produced to the section.
	APPENDIX B – NOW APPENDIX I	
	<u>5.0 Pilot Equipment Description</u>	
38.	a. Please explain if high shear rate could affect membrane life.	The text of Section 5 was modified to discuss effect of membrane shear rate on membrane life.

RWB Tracking No.	TWDB Comment	Proposed Resolution
39.	b. Please define the term “throughput”.	The text of Section 5 modified to present the discussion in terms of membrane flux rather than throughput.
	<u>8.0 Pilot Testing Procedure</u>	
40.	a. Please include the feed flow rate in the key parameters.	The text of Section 8 was modified to include feed flow rate as a key parameter.
41.	c. Cleaning Procedure: Same as comment “b” for Sections 5.3.1. – 5.6 b?	The text of Section 8 modified to include a brief discussion of key chemical processes involved in the pretreatment and treatment phases of reverse osmosis and VSEP^{TM}.
	APPENDIX C – NOW APPENDIX II	
	<u>4.0 Results</u>	
42.	a. Average flux and overall recovery for different experimental setup have been estimated and plotted in Tables 1, 3, 5, 7, 9, 13, 15, and 16. Please discuss the process of estimating these two parameters in the study.	The text of Section 4.1 was modified to explain average flux and overall recovery.
43.	b. Please replace the word “recovery” with the words “initial recovery” in the following instances:	The text of Sections 3.0 and 4.1 were modified to describe how VSEP achieves a constant recovery.
	• Page 4, first paragraph, line 6.	
	• Page 6, second paragraph, line 1.	
	• Page 9, line 5.	
	• Tables 1, 3, 5, 7, 9, 13, and 15.	
	• Figures 4, 5, 8, 9, and 10 (Page 17).	
	<u>4.1 Phase 1 Testing (Page 4)</u>	
44.	a. Please provide the feed water characteristics for the VSEP^{TM} system.	The text of Section 4.1 was modified to refer to the feedwater analyses in Appendices A and B of the NLR Report.

RWB Tracking No.	TWDB Comment	Proposed Resolution
45.	**Figure 4 (Page 5)**	
46.	The term "% recovery", cited in the legend of the figure, is not accurate as the yellow line indicates the initial recovery of the system.	The text of Sections 3.0 and 4.1 were modified to describe how VSEP achieves a constant recovery.
	Figure 5	
47.	Same colors were used for identifying the data points of 65 percent and 75 percent recoveries, which make it difficult to recognize these recoveries separately in the figure. We suggest considering using six different colors for six different sets of data points in this figure.	Figure 5 was revised to provide unique colors for all curves in the graph.
	Table 3	
48.	a. If other parameters of the system remain unchanged, at constant operating pressure, a clean membrane should always yield a constant initial flux. However, the results plotted in this figure shows that at a constant operating pressure of 500 psi, the initial flux varied from 33.1 GFD to 53.0 GFD. Please explain the reason for this variation.	The text of Section 4.2 was modified to discuss flux variations.
49.	b. At 75 percent recovery, the average flux for PT-100/400 20 ppm (8.9 GFD) was lower than that of raw feed (9.7 GFD). Please explain the reason.	The text of Section 4.2 was modified to discuss the flux variations. The revised report discusses the relationship of feedwater conductivity/salinity with flux variation.
50.	c. In a separate table, please show the rate (%) of increase of average flux due to the use of anti-scalants.	Table 4 was added to Section 4.2. All tables thereafter were renumbered.

RWB Tracking No.	TWDB Comment	Proposed Resolution
	<u>4.3 Phase 4 Threshold Concentration Testing (Pages 9 to 16)</u>	
51.	a. The last paragraph of Page 10 stated it clearly that the method used in this experiment was inconsistent, unreliable, and unverifiable. Therefore, the results obtained from this experiment could not be used as a reference for the future design and operation of a VSEP^{TM} system. However, the inconsistent method used in this experiment could be used as a learning experience for the future operation of a VSEP^{TM} system. We recommend that a separate section should be created for discussing the operational challenges of the pilot study and Figure 6 and Figure 7, Tables 5, 6, 7, and 8, and associated text should be moved to the new section.	NLR has revised the text of Section 4.3 to create a separate Section 4.3a discussing anti-scalant dosing. NLR has clarified its position that it does not agree with other team members who questioned the effectiveness of anti-scalant mixing since a tank mixer was not included in the equipment configuration. Consequently, RWB has modified Section 7.2.4 of the RWB report to discuss anti-scalant addition.
52.	b. Figure 6 and Table 5: Please explain the reason for re-running the experiment at 25 ppm anti-scalant. Also, please explain the reason for obtaining different flux rates when the experiment was re-run.	Text of Section 4.3a was revised to explain the reason for re-running the experiment at 25 ppm anti-scalant and the reason for obtaining different flux rates when the experiment was re-run.
53.	c. Table 5: At a constant operating pressure of 500 psi, the initial flux varied from 35.5 GFD to 48.2 GFD. Please explain the reason for this variation.	Text of Section 4.3a was revised to explain the reason for the variation in initial flux from 35.5 GFD to 48.2 GFD.
54.	d. Page 10, first paragraph, second line from the bottom: The words “Figure 4” should be replaced with the words “Figure 7”.	Corrected.

RWB Tracking No.	TWDB Comment	Proposed Resolution
55.	e. According to the pilot test protocol (Page 13 of Appendix B), the primary purpose of Phase 4 testing is to determine the minimum concentration of the anti-scalant capable of producing a significant response. Data plotted in Tables 3 and 9 suggest that 15 ppm anti-scalant produced a significant increase (>25%) in the average flux rate. However, the statement in lines 5-7 of Page 12 indicates that 25 ppm of the anti-scalant was used for the remainder of testing. Please address the reason for selecting 25 ppm (instead of 15 ppm) of the anti-scalant.	Revised the text of Section 4.3a to reference NLR Figure 9 as an explanation for selecting 25 ppm anti-scalant dose.
	<u>Figure 8 (Page 13)</u>	
56.	a. Due to higher concentration polarization, and greater fouling potential, higher recovery should trigger greater flux decline. However, the results plotted in this figure show that lower recovery caused greater flux decline. Please discuss the reason.	Text of NLR Report Section 4.3a was revised to explain the effect of the variation of initial flux and absolute flux decline. Note: RWB normalized the curves for initial flux to resolve this issue in the RWB Report.
57.	b. Same as comment “b” for Phase 4 Threshold Concentration Testing.	The text of Section 4.3a was revised to explain the reason for re-running the experiment at 25 ppm anti-scalant and the reason for obtaining different flux rates when the experiment was re-run.
	<u>Table 9 (Page 13)</u>	
58.	a. To identify the effect of the anti-scalant properly, please copy the data set of raw feed (at 65 percent recovery) from Table 3 to Table 9.	Table 9 was revised to address.

RWB Tracking No.	TWDB Comment	Proposed Resolution
	<u>Figure 9 (Page 15)</u>	
59.	Same as comment "a" for Figure 8 of the pilot study.	The text of NLR Report Section 4.3a was revised to explain the effect of the variation of initial flux and absolute flux decline. Note: RWB normalized the curves for initial flux to resolve this issue in the RWB Report.
60.	**<u>Table 13 (Page 16)</u>**	
61.	Please explain the reason for different initial fluxes at a constant operating pressure.	Section 4.3a was revised to explain reason for different initial fluxes at a constant operating pressure.
62.	**<u>4.4 Recovery Study (Pages 17 and 18)</u>**	
63.	a. Please refer to Tables 6-1 to 6-3 of the main report for obtaining rejection characteristics at different recoveries.	Text of section 4.4 revised to refer to Tables 6-1 to 6-3 of the main report for obtaining rejection characteristics at different recoveries.
64.	b. Figure 10 (Page 17): The same figure number (Figure 10) has been used for two different figures (figures in Page 10 and Page 12). Please correct the figure number for the figure shown in Page 12. The numbers of the subsequent figures should also be corrected accordingly.	Figure numbering revised.
65.	c. Same as comment "a" of Figure 8 of the pilot study.	The text of Section 4.3a was revised to explain the reason for re-running the experiment at 25 ppm anti-scalant and the reason for obtaining different flux rates when the experiment was re-run.
	<u>5.0 Cleaning (Pages 25 and 26)</u>	
66.	a. Please indicate that the operating parameters for cleaning are shown in Table 6-5 of Page 32 in the main report.	The text of Section 5 has been revised.

RWB Tracking No.	TWDB Comment	Proposed Resolution
67.	b. In the text, please mention it clearly that from Figure 16 it is evident that the flux was improved after adding NLR550 at 39th cleaning.	The text in Section 5 was modified to clarify.
68.	c. It is interesting to know how the rejection was affected due to cleaning. Please consider proving the rejection data before and after cleaning the membrane.	The text was modified to indicate that sufficient sampling data was not collected during the test to allow such a determination after each cleaning.
69.	d. Same as comment "b" for section 5.3.1.	Per discussion with TWDB, the name of cleaning materials was already incorporated in Section 5.
	<u>6.0 Summary</u>	
70.	Please define the term "Slipstream".	The text was modified to refer to definition in NLR Report Section 3.0.