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Building 67 at 7th Street
Denver, CO 80225

Dear Bob: . .

Subject: Transmittal of Final Technical Report

On behalf of the City of McAllen, Texas and in accordance with the Cooperative Agreement No. 98FC810073 entitled "Demonstation Testing of ZenoGem and Reverse Osmosis for Indirect Potable Water Reuse – City of McAllen, Texas", please find enclosed five (5) bound copies of the Final Technical Report, one unbound copy, and an electronic copy on compact disk in Word 97 format.

Sincerely,

CH2M HILL

Principal Investigator

Enclosures:

Final Technical Report (5 bound copies; 1 unbound copy)

Compact Disk

Cc:

Bart Hines/City of McAllen

Frank Oudkirk/EPRI Bud Clark/C&SWS Bill Hoffman/TWDB

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Grants and Cooperative Agreements Officer's Technical Representative Stop D-8230
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Dear Bob:

Subject:

Transmittal of Final Technical Report Addendum

Cooperative Agreement No. 98FC810073

On behalf of the City of McAllen, please find enclosed an addendum to the Desalination Research and Development Program Report No. 51, Final Technical Report for *Demonstration Testing of ZenoGem and Reverse Osmosis for Indirect Potable Reuse-City of McAllen, Texas.* Copies of all draft and final report comments are included in this addendum. All comments were either previously incorporated into the final report as appropriate or are enclosed for incorporation. Please replace Page 4-5, Section 6, and Appendix I in each copy of report previously furnished.

Sincerely,

CH2M HILL

Jim Nozier, P.E.

Principal Investigator

Enclosures:

Addendum

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Mr. Robert Jurenka, P.E. Page 2 February 29, 2000

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DEMONSTATION TESTING OF ZENOGEM AND REVERSE OSMOSIS FOR INDIRECT POTABLE REUSE

FINAL TECHNICAL REPORT

City of McAllen, TX

by

James C. Lozier, P.E. and Angela M. Fernandez, E.I.T CH2M HILL

Cooperative Assistance Agreement No. 98-FC-81-0073

Desalination Research and Development Program Report No. 51

January 2000

U.S. DEPARTMENT OF THE INTERIOR
Bureau of Reclamation
Technical Service Center
Water Treatment Engineering and Research Group

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Researcher Disclaimer

The information contained in this report regarding the performance of tested commercial products and the conclusions and recommendations drawn regarding such performance are based on testing conducted on wastewater sources from the City of McAllen, Texas, and are not to be considered an indication of the performance of such products on other water sources either at McAllen, Texas, or at other locations.

Bureau Point of Contact

The Bureau of Reclamation's Water Reuse Task Manager for this work is Robert Jurenka. He can be reached in Denver at (303) 445-2254.

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Acronyms and Abbreviations

ACOE Army Corps of Engineers

ALK alkalinity

ASL Applied Sciences Laboratory

bio-P biological phosphorus

BOD biochemical oxygen demand BOR Bureau of Reclamation

C celsius

CBOD₅ carbonaceous biochemical oxygen demand

cfm cubic feet per minute
CFU colony forming units

CIP clean in place

COD chemical oxygen demand capillary suction time

CSWS Central and Southwest Services

DO dissolved oxygen

DSVI diluted sludge volume index
EPA Environmental Protection Agency
EPRI Electric Power Research Institute

ft² square feet g/L grams per liter

GAC granular activated carbon gfd gallons per square foot per day

gpd gallons per day
gpm gallons per minute
HAA haloacetic acid

HPC heterotrophic plate count
HRT hyraulic residence time
I&C instrumentation and controls

in Hg inches of mercury
IPR indirect potable reuse
KLT King Lee Technologies
MBR membrane bioreactor

MCL maximum contaminant level

MF microfiltration
mg/L milligrams per liter
mgd million gallons per day

mL milliliters
ML million liters

MLSS mixed liquor suspended solids

MLVSS mixed liquor volatile suspended solids

mm millimeter N nitrogen

NH₃-N ammonia nitrogen

NPF normalized product flow
NTU nephelometric turbidity unit
O&M operations and maintenance

OUR oxygen uptake rate

P phosphorus

pCi/L picoCuries per liter
PDC pressure drop coefficient
PLC programmable logic controller

ppm parts per million

psi pounds per square inch

psig pounds per square inch gauge

RO reverse osmosis

scfm standard cubic feet per minute

SDI silt density index

SDS screened degritted sewage SDWA Safe Drinking Water Act

SI solubility index
SRT solids retention time
TDS total dissolved solids
THM trihalomethane
TKN total Kieldahl pitroger

TKN total Kjeldahl nitrogen
TMP transmembrane pressure

TN total nitrogen

TNRCC Texas Natural Resources Conservation Committee

TOC total organic carbon
TP total phosphorus
TSS total suspended solids

TWDB Texas Water Development Board

UF ultrafiltration

UOSA Upper Occoquan Sewage Authority

UV ultraviolet

μg/L micrograms per liter

μm microns

μS/cm microSiemens per centimeter wastewater treatment plant

Introduction and Background

This report documents wastewater reclamation demonstration testing performed at the McAllen, Texas, wastewater treatment plant (WWTP) No. 2. The study was conducted under Task D: Water Recycling and Reuse of the U.S. Bureau of Reclamation's (BOR) Desalination Research and Development Program. The Program sponsors this research in an effort to lower the cost of treatment technologies. Testing was conducted from February 1999 to October 1999.

The results of previous pilot testing conducted for the City of McAllen (*Water Treatment Technology Program Report No. 26*) concluded that treating the City's wastewater with a membrane bioreactor (MBR) system (ZenoGem) followed by reverse osmosis (RO) and final disinfection (chlorination or ultraviolet [UV] light) may provide for a simpler, potentially less costly, treatment process for the reclamation of a portion of the City's wastewater to supplement current water supplies obtained from the Rio Grande River. The reclaimed water produced by the MBR/RO/disinfection process would in most respects contain significantly lower concentrations of most substances currently regulated under the Safe Drinking Water Act (SDWA), and as such, could improve the inorganic quality of the Rio Grande River water. However, unlike microfiltration (MF), which has been used extensively for RO pretreatment of secondary effluent, no testing has been reported on the use of the ZenoGem process to convert wastewater directly to RO feedwater for the purpose of producing a high quality effluent suitable for indirect potable reuse.

The purpose of this study was threefold: 1) to demonstrate the long-term operability and reliability of the ZenoGem system, 2) demonstrate the feasibility of RO treatment of ZenoGem permeate for the production of reclaimed water, and 3) determine if the MBR/RO process has operational, cost, and water quality benefits compared to the conventional WWTP/MF/RO in the context of indirect potable reuse (IPR).

This section addresses the following information:

- Defines indirect potable reuse.
- Explains the City of McAllen's motivations for considering implementation of indirect potable reuse to help solve their water supply problems.
- Describes the regulatory issues associated with implementation, and explains the reasons membrane processes, in particular MF/ultrafiltration (UF) and RO, are integral to its implementation.
- Presents conclusions and recommendations from this study.

1.1 Indirect Potable Reuse—Definition and History

Indirect potable reuse is the recovery of water from wastewater for the purposeful reintroduction into either a surface water or groundwater body that ultimately serves as a drinking water supply. Unplanned IPR has been occurring since humans first began disposing of wastewater into watersheds that are hydrologically connected to raw water supplies. Planned IPR began in the U.S. in the 1960s. A summary of some of the major milestones in the development of potable reuse as a viable component of a water resource management plan is presented below.

The Whittier Narrows Groundwater Replenishment Project, California. In 1962, the County Sanitation Districts of Los Angeles began spreading disinfected secondary effluent from a 10-million-gallon-per-day (mgd) (37.9 million liters [ML]/day) water reclamation plant to an underground potable water supply. The reclaimed water accounts for an annual average of 16 percent of the total inflow to the groundwater basin. The local population is estimated to be exposed to from 0 to 23 percent reclaimed water. An independent scientific advisory panel to the State of California conducted an extensive review of the project data and concluded that the Whittier Narrows Groundwater Replenishment Project was as safe as commonly used surface water supplies.

Orange County, California, Water District. Since 1976, the Orange County, California, Water District's Water Factory 21 has been reclaiming unchlorinated secondary effluent to drinking water quality and recharging it into a heavily used groundwater source to prevent salt water intrusion. The water recovery treatment facility is a 15-mgd (56.8 ML/day) facility that includes lime clarification, air stripping, recarbonation, filtration, carbon adsorption, slip-stream RO, and disinfection. It is estimated that less than 5 percent of the domestic water supply is comprised of the recovered water. The Orange County Water District has not identified any significant risk to users of the groundwater from the indirect potable reuse practice.

Upper Occoquan Sewage Authority Water Reclamation Plant, Virginia. In 1978, the 15-mgd Upper Occoquan Sewage Authority (UOSA) Water Reclamation Plant in northern Virginia began reclaiming wastewater for subsequent discharge to the Occoquan Reservoir. This reservoir is a critical source of drinking water for approximately 1 million people. The reclaimed water has accounted for as much as 90 percent of the flow into the reservoir. Treatment includes primary treatment, secondary treatment, biological nitrification, lime clarification and recarbonation, filtration, activated carbon adsorption, and disinfection. The plant has been expanded to 26 mgd (98.4 ML/day) and will be further expanded to 54 mgd (204 ML/day) by the year 2000. No negative health effects have been attributed to the plant or effluent discharges.

Potomac Estuary Experimental Water Treatment Plant, Washington, D.C. From 1981 to 1983, the 1-mgd (3.8 ML/day) Potomac Estuary Experimental Water Treatment Plant was operated with an influent blend of Potomac Estuary water and nitrified secondary effluent. The blend was designed to simulate influent water quality expected during drought conditions when up to 50 percent of the estuary flow may comprise treated wastewater. Treatment included aeration, coagulation, clarification, pre-disinfection, filtration, carbon adsorption, and post-disinfection. An independent panel reviewed the extensive testing performed by the U.S. Army Corps of Engineers (ACOE) and concluded that the advanced treatment could recover water from a highly contaminated source similar in quality to three major water supplies for the Washington, D.C., metropolitan area.

San Diego Total Resource Recovery Project, California. In 1983, a 1-mgd potable water recovery demonstration facility was commissioned as part of a total resource recovery

program established in San Diego, California. The purpose of the treatment system was to reclaim raw water from raw wastewater. The system included primary treatment, a water hyacinth aquaculture system, coagulation, clarification, filtration, UV disinfection, RO, aeration, carbon adsorption, and disinfection. An extensive chronic toxicity risk analysis showed that the risk associated with use of the recovered water as a raw water supply was less than or equal to the use of the existing raw water entering the City's Miramar Water Treatment Plant. The City is now planning to reclaim up to 20 mgd (75.7 ML/day) of secondary effluent for augmentation of their 90,000 acrefoot San Vicente Reservoir for eventual distribution to water customers.

El Paso, Texas, Fred Hervey Water Reclamation Plant. The 10-mgd (37.9 ML/day) Fred Hervey Water Reclamation Plant began operation in El Paso, Texas, in 1985. The recovered water is recharged to the Hueco Bolson drinking water aquifer where, over a 2-year period, the water travels to one of El Paso's potable water wellfields to become part of the potable water supply. The treatment system includes primary treatment, activated sludge/powdered activated carbon treatment, lime treatment, recarbonation, filtration, ozonation, and granular activated carbon (GAC) adsorption. Although no negative health effects have been correlated with the reuse practice, an increase in the total dissolved solids (TDS) content of the aquifer has occurred because the increased pumping has lowered the aquifer level to the higher salinity water source. Slip-stream demineralization will be included in future plant expansions to address the TDS issue.

Tampa Water Resource Recovery Project, Florida. The City of Tampa's Water Resource Recovery Pilot Plant began operation in 1986 with the purpose of evaluating the feasibility of reclaiming denitrified secondary effluent to a quality suitable for blending with existing surface water and groundwater sources for indirect potable reuse. Several treatments were evaluated, and one was selected for health effects testing. This treatment system consisted of aeration, high pH lime clarification, recarbonation, filtration, GAC adsorption, and ozonation. The results of the health effects testing coupled with the microbiological and chemical analyses performed during the evaluation indicated that the quality of the reuse water was equivalent to or exceeded the quality of the local raw water supply. The City of Tampa intends to develop a 20- to 50-mgd (189 ML/day) water resource recovery plant in the near future.

West Basin Water Recycling Program, California. From 1990 through 1995, the West Basin Municipal Water District conceived, designed, constructed, and began operation of the West Basin Water Recycling Program. This program includes reclaiming 5 mgd (18.9 ML/day) (expandable to 20 mgd, or 75.7 ML/day) of secondary effluent from the City of Los Angeles' Hyperion Treatment Plant for injection into the West Coast Basin Barrier Project. The West Coast Basin Barrier Project has historically received an average of 20 mgd of potable water for injection into the coastal reaches of local South Bay aquifers for mitigation of saltwater intrusion. Substituting reclaimed water for the potable water provides substantially greater water use efficiency in the area. Reclamation treatment includes predecarbonation, lime clarification, recarbonation, filtration, RO, postdecarbonation, and final disinfection. Based on hydrogeologic investigation and modeling of the West Coast Basin, it is anticipated that the reclaimed water will improve groundwater quality along the Barrier because of the high quality of the reclaimed water relative to the imported water and the native groundwater.

Reedy Creek Improvement District, Advanced Water Reclamation Program, Florida. In 1992, the Reedy Creek Improvement District began a pilot program to reduce phosphorus (P) and nitrogen (N) in the effluent from their WWTP to very low levels. Although the goal of treatment was not IPR, this was the first project to evaluate the feasibility of using MF and UF as a replacement to lime clarification, recarbonation, and gravity filtration for RO pretreatment. This approach was shown to be so effective that MF and UF have displaced lime treatment as the preferred means of RO pretreatment on subsequent IPR projects.

City of Scottsdale, Arizona, Water Campus Project. In 1994, the City of Scottsdale began pilot testing MF and RO for the purpose of reclaiming wastewater for groundwater recharge. The testing program, which has culminated in a 6.8-mgd (25.7 ML/day) IPR project currently under construction at the City's Water Campus site, represents the first planned IPR project in Arizona. During periods when demand for non-potable reclaimed water is low, product water from the MF/RO system will be blended with filtered surface water and injected into a potable aquifer using dry wells. The 6.8-mgd facility represents the first phase of a multi-year project designed to have an ultimate capacity of 25 mgd (94.6 ML/day).

City of San Diego, California, Water Repurification Project. As an outgrowth of their Total Resource Recovery Project, the City of San Diego began the Repurification Project to reclaim up to 20 mgd of wastewater for indirect potable use. The program is currently evaluating the feasibility of using the following advanced water treatment processes to re-purify tertiary effluent from the City's new North City Water Reclamation Plant to a quality suitable for direct discharge to the San Vicente Reservoir, one of the City's main raw water reservoirs: MF/UF, RO, ion exchange, and ozonation. The project represents the first surface supply augmentation IPR project in California and must satisfy stringent California Department of Health Services requirements regarding virus removal and real-time monitoring of individual processes for pathogen removal. If successful, the project will result in the construction of the largest IPR plant in the U.S.

1.2 The Need for Indirect Potable Reuse for the City of McAllen

The City of McAllen, Texas, is located in the Lower Rio Grande Valley near the United States-Mexico border, approximately 40 miles upstream from the mouth of the Rio Grande River. The City presently derives its water supply from water rights in the Rio Grande River that it shares with multiple parties, including other cities, water supply corporations, irrigation districts, and Mexico. The Lower Rio Grande Valley is a growing area with an existing water shortage problem. The Texas Water Development Board (TWDB) reports that all surface water resources in the area are 100 percent appropriated. Additionally, this semi-arid area often experiences drought conditions. Projected growth in population and water use indicates that the demand for potable water will exceed the City's authorized water rights by the year 2003. Consequently, alternative water supply strategies are necessary to ensure a safe, reliable source of potable water.

The two most feasible alternative sources are groundwater and re-purified wastewater. Many of the groundwater supplies in the Lower Rio Grande Valley have an elevated

dissolved solids concentration and require demineralization by RO or electrodialysis to make them suitable for potable use. Consequently, wastewater reclamation is considered by the City to be a desirable means of augmenting its water supply.

1.3 Water Quality Considerations and Proposed Treatment Strategy

In general, reclaimed water should be treated to a level where its quality exceeds that of the historical water supply. In Texas, public heath issues related to the use of reclaimed water fall under the purview of the Texas Natural Resources Conservation Commission (TNRCC). The preliminary requirements of the TNRCC with respect to IPR for the City are: 1) reclaimed water must be of equal or better quality than that of the City's current water supply, and 2) RO must be used to treat all of the reclaimed water prior to its reuse. Based on these requirements and in view of the City's desire to reduce the dissolved solids of its finished water to improve consumer acceptability, the following IPR treatment sequence was proposed for the City in 1997 and subsequently demonstrated via testing conducted in that year and reported in *Water Treatment Technology Program Report No. 26*:

- Primary and secondary treatment
- Chlorine disinfection
- MF/UF
- RO
- UV disinfection

This sequence not only satisfies the TNRCC's preliminary requirements, it also provides multiple treatment barriers to the passage of microbial, inorganic, and organic contaminants in the wastewater. The concept of "multiple barriers" has been adopted by the water supply industry to achieve the appropriate level of safety and reliability by providing redundant treatment steps for the removal of wastewater contaminants, primarily pathogens.

1.4 Membrane Technologies in Indirect Potable Reuse

A primary focus of one task of BOR's Desalination Research and Development Program is research on membrane processes for wastewater reclamation. In this context, three membrane processes (MF, UF, and RO) represent key treatment processes in the proposed treatment sequence for IPR at McAllen. RO has been applied for wastewater reclamation for more than two decades and is considered a proven treatment process. RO serves as the "workhorse" for the IPR process because it is efficient in removing nearly all contaminants of public health concern. Cost-effective RO operation on municipal wastewater requires a high degree of preliminary treatment to control membrane fouling. Such treatment is provided through the use of MF/UF to polish secondary effluent.

During the last 5 years, MF has been shown at demonstration- and full-scale to be a reliable process in the context of IPR. Production MF facilities are currently in operation in California and Arizona with additional facilities planned for Pennsylvania, Virginia,

and Georgia. UF technologies have also been demonstrated for the same purpose; however, to date none have been implemented full-scale. All of the MF/UF products at these sites have employed pressure modules.

During the 1997 pilot study at McAllen, pressurized MF was demonstrated for the treatment of effluent from the City's south WWTP using Memcor MF technology. At that time, a novel, immersed MF product (ZeeWeed) was tested and found to provide performance competitive with or somewhat superior to the pressurized MF approach. In addition, ZeeWeed was also evaluated in the context of a membrane bioreactor process (ZenoGem) and found to be feasible for direct treatment of the City's screened, degritted wastewater. Preliminary results indicated that the ZenoGem filtrate was of equivalent quality to both Memcor and ZeeWeed filtrate with respect to general water quality (TDS, total organic carbon [TOC], coliforms, and turbidity) but had significantly higher RO feedwater colloidal fouling potential (as measured by silt density index [SDI]). Longer term testing of ZenoGem coupled with a follow-on RO system was recommended at that time and is the subject of this research.

1.5 Conclusions

Conclusions drawn from the results of this study are presented below.

1.5.1 ZenoGem System

- The ZenoGem membrane bioreactor process successfully treated screened, degritted sewage (SDS) to a quality suitable for RO processing.
- The ZenoGem process produced a permeate (see Tables 5.8 through 5.10) that exceeded the City's effluent discharge requirements for carbonaceous biochemical oxygen demand (CBOD₅<10 milligrams per liter [mg/L]), total suspended solids (TSS <15 mg/L)), and ammonia nitrogen (NH₃-N <3 mg/L). This result was attained at all mixed liquor suspended solids (MLSS) concentrations and with both membrane types.
- The ZeeWeed OKC MF (0.4-micrometer [μm] pore size) membrane exhibited higher sustained permeability than OCP UF (0.035-μm pore size) membrane at high MLSS levels (13 grams per liter [g/L]).
- Permeability of the MF membrane was sensitive to MLSS level. Permeability was stable at 10 g/L but declined at 13 g/L because of increased membrane fouling not adequately controlled by frequent permeate backpulsing or maintenance cleans.
- At an MLSS concentration of 13 g/L, simultaneous nitrification/denitrification and biological phosphorus (bio-P) removal occurred most likely because of the inability to completely transfer oxygen from the bulk liquid to the interior of the bioflocs at the hydraulic residence time (HRT) selected for this study (5.7 hours). The oxygen transfer limitations inhibited complete nitrification but promoted nitrogen removal.

- At an MLSS concentration of 10 g/L, the rate of oxygen transfer was sufficient to maintain complete nitrification and suppress denitrification and bio-P uptake.
- Flow peaking tests (i.e., permeate flowrate increased for a specific duration of time) were conducted over a 24-hour period to simulate the types of peak loading conditions that typically occur in a conventional WWTP. However, peaking significantly increased the rate of permeability decline and accelerated the fouling rate (fouling not reversed by backpulsing or maintenance cleans as defined in Section 3.2.1). As a result, normal diurnal variations in wastewater flow, in which peak hourly flows can equal 300 percent of average daily flow, must be dampened through flow equalization so that the ZenoGem process can operate at more or less a constant hydraulic loading (flux) rate.
- Intermittent aeration (i.e., air cycled at 15 minutes on/15 minutes off) to the aeration tank (at 6 g/L MLSS concentration) produced the greatest degree of total nitrogen removal (optimum simultaneous nitrification and denitrification).
- With respect to RO feedwater quality, ZenoGem permeate quality consistently exceeded goals for turbidity and SDI, and generally exceeded goals for bacterial concentrations.
- Per Table 5.16, compared to the City's existing raw water source, the ZenoGem permeate was of lesser quality with respect to TOC and many inorganic contaminants while the RO permeate was of better quality in nearly all respects.
- Coliform removal by the both membranes was less than 100 percent. MF membrane
 permeate contained significantly greater coliform concentrations at 13 g/L MLSS
 concentration than the UF membrane. Furthermore, coliform removal appeared to be
 a function of MLSS loading for the MF membrane. However, the RO system
 consistently removed any remaining coliform regardless of the MF or UF
 pretreatment.
- Cycled aeration to the membrane tank appeared to significantly increase the rate of membrane fouling (permeability decline) compared with continuous aeration. However, it is difficult to draw firm conclusions regarding aeration given the brief operating time with cycled aeration and its use in combination with other operating modifications (flow peaking, cycled aeration to the aeration tank).
- Footprint for ZenoGem facilities represents about 32 percent of the total area required for a conventional activated sludge plant providing comparable biological treatment and flow equalization.

1.5.2 RO System

- Membrane fouling by particulates and soluble organics in the screened, degritted wastewater was well controlled by the ZenoGem process as illustrated by stable first stage flux and salt rejection. Continuous disinfection, in the predominant form of monochloramine, with a low concentration of combined chlorine (approximately 1 mg/L) was effective in preventing biological fouling of the RO membranes as measured by stability of first stage feed/concentrate differential pressure (see Tables 5.12 through 5.14).
- Elevated concentrations of calcium and phosphate in the City's wastewater (and ZenoGem permeate) most likely caused precipitation of the calcium phosphate salt, hydroxyapatite, in the RO system second stage at feedwater pH levels designed to control calcium carbonate scaling. This precipitation caused rapid increases in RO feed pressures, rapid declines in normalized product flow, and marked increases in salt passage. The precipitate was readily dissolved using citric acid cleaning, and performance declines were consistently reversed by such cleanings. Further acidification of the RO feedwater to pH 5.0 (concentrate pH to 5.6) prevented such precipitation except at design (80 percent) recovery. A better control method may be to precipitate the majority of the soluble phosphorus in the wastewater during MBR treatment using a ferric or aluminum coagulant.
- RO permeate at design (80 percent) recovery was very high quality: TDS <75 mg/L, TOC <0.5 mg/L, and turbidity <0.1 nephelometric turbidity units (NTU). Levels of these and other contaminants monitored for in the RO permeate were significantly less than the maximum concentrations permitted under federal drinking water regulations or indirect potable reuse guidelines established in certain states (e.g., California and Virginia). The exception being coliforms, which were consistently detected at low levels. From this standpoint, the RO permeate is of satisfactory quality for IPR use subject to additional disinfection (chlorination or UV). TNRCC has not established guidelines or regulations for IPR use at McAllen, however, their preliminary position is that RO treatment would be required. On the other hand, TNRCC may consider establishing quality requirements for IPR that use the quality of the existing raw water supply as the benchmark for treatment. In this case, it may be possible that an acceptable quality of reclaimed water can be produced through a blend or ZenoGem and RO permeate with post-disinfection.

1.6 Recommendations for Further Research

The following recommendations are provided with respect to further research involving MBRs and RO in the context of indirect potable reuse.

1.6.1 Membrane Bioreactors

1.6.1.1 MLSS Levels and Membrane Flux

This research illustrated that membrane fouling and permeability is sensitive to MLSS level. Further research is needed to define the optimum combination of these two parameters (MLSS level/membrane flux) as they contribute to both capital and operating cost. Increased MLSS levels permit higher solids retention times (SRTs), reducing sludge yield, however their use may result in higher capital costs and operating costs associated with additional membrane area (reduced flux).

1.6.1.2 Cycled Aeration to Promote Nitrification/Denitrification

Optimize conditions of cycled aeration for the purpose of promoting simultaneous nitrification/denitrification. Testing in this study was conducted at only one on/off cycle (15 minutes on, 15 minutes off) to the aeration tank. No water quality parameters were measured at other cycles to determine if control at other cycles may be more efficient at achieving improved or complete nitrogen removal. Control methods need to be developed in conjunction with such testing.

1.6.1.3 Cycled Aeration to Reduce Membrane Air Scour Requirements

Aeration for control of membrane fouling represents a significant operating (power) cost. Cycling of air to the coarse bubble aerator integral to the membrane module (membrane tank) represents one way to reduce operating cost; however, aeration reductions must not come at the detriment of membrane permeability. Testing is needed to determine optimum airflow rates and cycle times to achieve the optimum balance of these two needs.

1.6.1.4 Alternative MBR Designs

This research tested one MBR product, Zenon Environmental System's ZenoGem using a MF membrane module. Other MBR products are available and have been installed for municipal wastewater reclamation both in Europe and Japan. Testing of these products is needed to assess their performance relative to ZenoGem and to determine if such products represent competitive technologies for application in the U.S. IPR and wastewater treatment market.

The BOR is currently funding research by Montgomery Watson and the City of San Diego to compare the performance of ZenoGem and Mitsubishi systems. Also, the ZenoGem UF system should be retested at $10~\rm g/L$ and $6~\rm g/L$ for comparison to the MF system at these concentrations.

1.6.2 Reverse Osmosis

1.6.2.1 Scale Control

For wastewaters containing elevated concentrations of calcium and phosphate, additional research is needed to determine the most cost-effective and operationally reliable means to control calcium phosphate scaling. Acidification has the advantages of low cost and typically being required for calcium carbonate scale control; however, its use to reduce pH to levels considered effective in this study (see Section 5.0) resulted in an aggressive RO permeate that was supersaturated with carbon dioxide (most likely requiring stripping). Ferric or aluminum coagulant addition to the MBR (or conventional plant) will reduce phosphorus levels in both the RO feedwater and concentrate. However, the doses required in the City's case (approximately 50 mg/L ferric chloride and 91 mg/L alum) produce additional solids in the MBR, potentially increasing membrane fouling and requiring acid maintenance cleans and reducing SRT for a given operating MLSS level.

1.6.2.2 Membrane Flux

RO testing in this study was performed at relatively low flux (10 to 11 gallons per square foot per day [gfd]). Given the low turbidity and SDI of the ZenoGem permeate, higher flux operation (reduced membrane capital cost) may be feasible if scale control can be resolved as discussed herein.

Testing Objectives

The research to be conducted under this program has the following objectives:

- 1. Demonstrate feasibility and benefits of the ZenoGem process:
 - Produce a high quality RO feedwater (i.e., turbidity <0.2 NTU, SDI <3, heterotrophic plate count [HPC] <500 colony forming units [CFU]/milliliter [mL]).
 - Meet the City's effluent discharge permit requirements (i.e., TSS <15 mg/L, CBOD₅ <10 mg/L, NH₃-N <3 mg/L).
 - Operate reliably (i.e., sustained production).
- 2. Demonstrate successful RO treatment on ZenoGem permeate:
 - Reliable operation with minimal fouling and effective membrane cleanings.
 - Meet all drinking water/reuse standards.
- 3. Define design and operation and maintenance (O&M) requirements to develop full-scale ZenoGem and RO plant design criteria.
- 4. Develop cost estimates for current and proposed IPR advanced treatment processes for the City of McAllen.
- 5. Characterize ZenoGem and RO permeates relative to the City's existing raw water supply (i.e., Rio Grande River) based on:
 - Regulated drinking water contaminants.
 - State of Texas secondary drinking water requirement of TDS for 1,000 mg/L.
- 6. Determine impacts of IPR on waste discharges to the City's current discharge location (i.e., Arroyo Colorado/Laguna Madre).

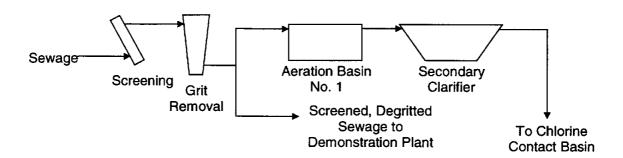
Demonstration Plant Facilities

The demonstration plant facilities consisted of ZenoGem (MBR) and RO treatment systems. The plant also contained ancillary equipment, including a raw water supply pump, chemical feed systems, transfer pump, and associated piping, valves, and fittings for delivery of raw water (i.e., ZenoGem feed), transfer of processed water (i.e., ZenoGem permeate/RO feed), and disposal of discharge flowstreams (i.e., ZenoGem sludge, RO concentrate, and RO permeate) and membrane cleaning solutions to the WWTP. A description of the other components of the demonstration plant facilities is presented in the following sections.

3.1 Raw Water Supply, Abstraction, Pumping, and Screening

The raw water source (feedwater) to the demonstration plant was SDS from the City's South WWTP No. 2. SDS was abstracted from the influent splitter box (located upstream of Aeration Basin No. 1) and transferred to the ZenoGem system via a submersible pump located in the splitter box. The abstraction point relative to the WWTP processes is shown in Figure 3.1.

FIGURE 3.1
Demonstration Plant Feedwater Abstraction Point from WWTP No. 2

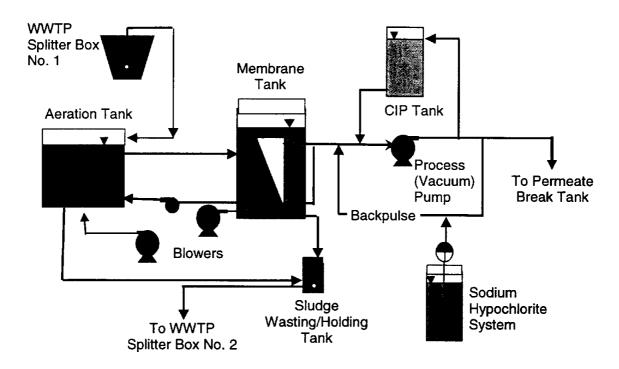


Raw water to the ZenoGem system was screened using a basket strainer and a 3-millimeter (mm) screen. Screening was necessary to prevent clogging of the inlet distributors of the membrane modules.

3.2 ZenoGem Treatment System

The ZenoGem treatment system is comprised of the following components: ZeeWeed Model MSTD ZW-4 unit, a 3,000-gallon aeration tank, auxiliary aeration blower, solids recirculation pump, and sludge wasting system (submersible pump located in aeration tank and 200-gallon calibrated sludge wasting/holding tank). The ZeeWeed unit consists of the following: 185-gallon tank containing the membrane module (membrane tank); one ZW-500 module containing 500 square feet (ft²) of hollow-fiber MF membrane with a nominal pore size of 0.4 microns (OKC membrane); permeate pump; membrane aeration blower; and backpulse/clean-in-place (CIP) tank1. The ZeeWeed ZW-500 membrane module consists of loose fibers connected to a manifold rack system at either end, with the rack/fiber assembly suspended in the membrane tank and submerged in the mixed liquor. Treatment occurs when a vacuum of 1.5 to 9.0 pounds per square inch gage (psig) is applied to the filtrate side of the fibers using the process (vacuum) pump. The vacuum causes the water in the mixed liquor to flow from the feed side to filtrate side of the membrane in a direct filtration mode under a positive transmembrane pressure. A process flow diagram for the ZenoGem treatment system is shown in Figure 3.2. Photographs of the ZenoGem system are presented in Appendix A.

FIGURE 3.2
ZenoGem Treatment System Process Flow Diagram



¹During the commissioning stage of the testing (Stage A), a 0.035-micron UF (OCP) membrane module was installed in the membrane tank. This module was replaced with the 0.4-micron MF (OKC) membrane module to increase flow and reduce fouling.

During ZenoGem operation, biodegradable matter in the sewage (biochemical oxygen demand [BOD] and ammonia) is oxidized by the biomass maintained at high mixed liquor concentrations in the membrane and aeration tanks with air input to these tanks using coarse and fine bubble diffusers, respectively. MLSS levels and SRTs are maintained in the tanks through the frequency and volume of sludge wasted to a calibrated sludge wasting/holding tank. Waste sludge is returned to Splitter Box No. 2 using a submersible pump. The desired HRT is maintained by controlling the rate of permeate flow. Consistency of MLSS concentrations between membrane and aeration tanks is maintained by recirculating MLSS between the tanks using a submersible grinder pump located in the aeration tank.

3.2.1 Methods to Control ZeeWeed Membrane Fouling

Control of solids buildup on the outside surface of the membrane fibers and related increases in permeate side vacuum are achieved in three ways. First, a blower is used to provide continuous air input (in the form of coarse bubbles) at 25 to 30 standard cubic feet per minute (scfm) into the bottom of the membrane tank directly below the membrane fibers. The air bubbles flow upward between the vertically oriented fibers, causing the fibers to agitate against one another. This results in mechanical cleaning through air scour.

Secondly, filtration is interrupted every 10 minutes and the membrane fibers are backpulsed repeatedly for 15 seconds with permeate from the backpulse/CIP tank. The system remains on-line during backpulsing and is in a backpulse mode for a total of 36 minutes per day. Typically, a low concentration of chlorine (<5 parts per million [ppm]) is maintained in the backflush water to inactivate and remove microbes (primarily bacteria) that colonize the outer membrane surface. Hydraulic cleaning via backflushing is accomplished using discharge head from the process pump, and backwash water is retained in the membrane tank.

Thirdly, three times per week, a 100-ppm sodium hypochlorite solution is added to the backpulse/CIP tank, and the membrane module is backpulsed repeatedly for 45 minutes in a procedure called a "maintenance clean." After the 45-minute in situ cleaning, the system is flushed with permeate for 15 minutes. An additional permeate flush to drain is performed for 10 to 15 minutes to purge the system of free chlorine once permeation (i.e., vacuum applied to filtrate side of membrane module) is re-initiated. The total system downtime during a maintenance clean is about 75 minutes.

The combination of air scour, backpulsing, and maintenance cleaning may not be completely effective in controlling membrane fouling, and with time, the pressure differential across the membrane (transmembrane pressure [TMP]) may increase to a maximum of value approximately 17 inches of mercury. When this condition occurs, which is anticipated to be (>3 months) infrequently at full-scale application, the membrane module is chemically cleaned with a 1,500 to 2,000-ppm sodium hypochlorite solution in a procedure called a "recovery clean." Recovery cleaning requires in situ full tank soaking and clean water flux testing. The chemical cleaning dissolves and removes the refractory solids, and reduces TMP to "clean membrane" initial levels (i.e., levels at startup prior to any evidence of fouling).

3.2.2 Permeate Storage, Disinfection, and Pumping

The ZenoGem permeate flows from the ZeeWeed unit to a permeate break tank that serves to balance the intermittent flow of ZenoGem permeate (resulting from backpulsing and maintenance cleans) with the continuous feed flow requirement of the RO system. After the break tank and prior to entering the RO treatment system, the permeate is dosed with combined chlorine (in the predominant form of monochloramine) using a solution tank and metering pump. Combined chlorine is batched using sodium hypochlorite and aqueous ammonia. The dosage is based on maintaining at least 1 to 2 mg/L of total chlorine residual and zero free chlorine residual. The thin film composite RO membrane material is intolerant to free chlorine, and any exposure will reduce the membrane life. Combined chlorine serves to prevent the low levels of bacteria that can be present in the ZenoGem permeate (primarily through contamination) from growing in the RO feed piping and on the membrane elements (biofouling). The addition of combined chlorine is not intended to serve as disinfection to eliminate pathogens. The "disinfected" ZenoGem permeate is pumped from the break tank to the RO system using a transfer pump. Excess ZenoGem permeate overflows the break tank through drain piping.

3.2.3 ZenoGem Operation

The ZenoGem system is designed to operate at a constant flux with the TMP varying over time to maintain the design flux. The rate of filtrate discharge to the break tank is controlled to achieve the desired HRT in the membrane tank (bioreactor). Proper HRT control is required to achieve the desired degree of CBOD₅ and ammonia removal by the biomass maintained in the bioreactor. Solids buildup in the bioreactor is controlled through daily manual wasting to achieve the desired SRT (concentration of MLSS) in the bioreactor. Unlike a conventional WWTP that operates at MLSS levels of 2,000 to 3,000 mg/L, the ZenoGem process is designed to operate at MLSS levels of 10,000 to 15,000 mg/L. This allows for a higher organic loading of wastewater in the ZenoGem treatment system.

Three modes of operation were employed during the study:

- Normal Flow: Permeate flowrate maintained at 6.5 gallons per minute (gpm).
- Peak Flow: Permeate flowrate increased to 9.5 gpm for 6 hours over a 24-hour period.
- Cycled Aeration: Air cycled to membrane tank at 10 seconds on/10 seconds off with or without air cycled to aeration tank at 15 minutes on/15 minutes off.

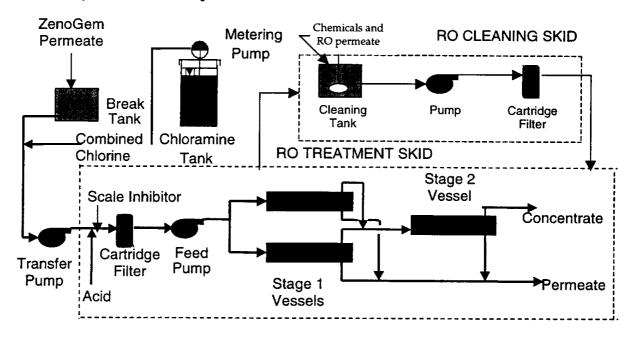
As detailed in Table 5.1, these operating modes are presented as specific operating events during ZenoGem operation.

3.3 RO Treatment System

The RO treatment system is comprised of the following components: a treatment skid and a cleaning skid. The treatment and cleaning skids are provided courtesy of the Bureau of Reclamation's Water Treatment Engineering and Research Group.

The RO treatment skid consists of the following equipment: chemical feed systems for the addition of acid and scale inhibitor, 5 micron cartridge filter, feed (high pressure) pump, two-stage pressure vessel array, programmable logic controller (PLC) and associated instruments and controls, piping, gauges, and valves. The cartridge filter serves as backup in the event of MF pretreatment failure. The RO elements, model LFC1-2540, are manufactured by Hydranautics and contain low fouling composite polyamide membranes. Stage 1 contains four pressure vessels each containing three 2.5-inch-diameter by 40-inch-long spiral wound elements in a "2:2" configuration. Stage 2 contains two pressure vessels of identical design plumbed in a "1:1" configuration. The two-stage array permits operation up to 80 percent recovery and simulates design of a full-scale RO plant using a "2:1" array with six-element vessels. A process flow diagram for the RO treatment skid and associated pretreatment equipment is shown in Figure 3.3. Photographs of the RO treatment system are presented in Appendix A.

FIGURE 3.3
RO Treatment System Process Flow Diagram



3.3.1 RO Feedwater Characterization

Three separate samples of unchlorinated secondary effluent (from the City's WWTP) were collected prior to the start of testing to estimate the inorganic quality of the RO feedwater. (The inorganic quality of the WWTP effluent was considered to be a good simulation of that produced by the ZenoGem system given that both were designed to operate on the same feedwater and provided the same degree of biological treatment and nitrification.) The results are shown in Table 3.1.

TABLE 3.1Results of RO Feedwater Characterization

Parameter	Units	12/14/98	12/16/98	12/18/98	Average
Alkalinity	mg/L as CaCO ₃	153	161	164	159
Bicarbonate	mg/L	187	196	200	194
Chloride	mg/L	388	359	378	375
Reactive Silica	mg/L	13.90	14.70	14.60	14.40
Sulfate	mg/L	327	305	332	321
Anion Sum	mg/L	1,069	1,036	1,089	1,064
Barium	μg/L	78.30	77.60	87.80	81.23
Calcium	μg/L	112,000	127,000	103,000	114,000
/lagnesium	μg/L	29,100	29,700	26,800	28,533
otassium	μg/L	17,100	18,900	19,400	18,467
Sodium	μg/L	236,000	271,000	233,000	246,667
Strontium	μg/L	1,260	1,310	1,380	1,317
Cation Sum	μg/L	395,538	447,988	383,668	409,065
TDS (Sum of lons)	mg/L	1,465	1,484	1,473	1,473

The mean values were then used with two software programs, King Lee Technologies (KLT) WaterWizard and Hydranautics' RODesign, to develop feedwater chemical conditioning requirements and establish product water recovery of the RO system based on the presence and concentration of sparingly soluble salts. The program outputs, shown in Appendix B, indicated the following design condition:

- RO feedwater acidification to pH 6.8 (with sulfuric acid)
- RO feedwater dosing with scale inhibitor at 2 ppm (KLT PreTreat 0100)
- Product water recovery of 80 percent based on 53 times saturation of barium sulfate in the RO concentrate

This condition served as the basis for target operating criteria for the RO system.

3.3.2 RO Feedwater Pretreatment to Control Membrane Fouling

During extended operation, RO membrane elements are subject to fouling caused by both suspended and dissolved matter. Suspended matter includes organic and inorganic colloids and microorganisms. Sparingly soluble salts, such as carbonates, sulfates, and silica, can precipitate from solution because they are concentrated by the RO process. Suspended particles accumulate on the membrane surface causing biofouling and colloidal fouling, and can block feed channels thereby increasing the pressure drop across the system. These phenomenon reduce water permeability through the RO membranes causing flux decline and increased salt passage. The nature and rapidity of fouling depends on the condition of the feedwater. Fouling is progressive, and, if not controlled early, can impair the RO system performance in a relatively short time. For these reasons, fouling must be controlled.

Particulate fouling was addressed through the use of the ZeeWeed MF membrane. Scaling was controlled using acidification and scale inhibitor addition. Chloramines were batched and dosed into the RO feedwater to prevent biological growth (biofouling) on the membranes as discussed in Section 3.2.

The RO feedwater from the transfer pump enters the treatment skid where it is dosed with a scale inhibitor and sulfuric acid prior to entering the cartridge filter. The addition of scale inhibitor prohibits the precipitation of sulfate and carbonate scalants (specifically calcium carbonate and barium sulfate). KLT PreTreat 0100 was used for mineral precipitate control. Acidification further reduces the potential for calcium and carbonate to precipitate from solution. Sulfuric acid was used for feedwater pH control.

Chemically conditioned with King Lee PreTreat 0100 scale inhibitor and sulfuric acid, the filtered water is pumped to the RO vessels at a pressure needed to produce the design permeate flow. Target feedwater recovery is attained by adjustment of the concentrate flow control valve. The system operates in a constant permeate flow/constant recovery mode with feed pressure increasing to compensate for decreases in water mass transfer rate.

The combination of filtration, chloramination, scale inhibition, and acidification may not be completely effective in controlling membrane fouling, and with time, the pressure drop across the stages may increase with simultaneous decreases in permeate flowrate and feedwater recovery. Recirculating a citric acid solution (low pH cleaning) or an alkaline solution (high pH cleaning) containing a mixture of surfactant, detergent, and chelating agent from the cleaning skid through the RO vessels serves to chemically clean the RO system when fouling is apparent. Recirculation is coupled with soak periods to remove the membrane foulants and restore lost performance.

Cleaning was performed five times on the system throughout the study. Low pH cleanings using citric acid and sodium hydroxide (for pH adjustment) were performed to remove inorganic fouling, such as calcium precipitates (e.g., calcium carbonates and phosphates) and hydroxide precipitates (e.g., metal oxides such as ferric hydroxide). High pH cleanings using a caustic solution and sulfuric acid (for pH adjustment) were performed to remove calcium sulfates and organics.

3.4 Criteria for Treatment System Operation

Tables 3.2 and 3.3 present criteria that were established for operation and biological performance, respectively, of the ZenoGem system. Table 3.4 presents the initial operating criteria for the RO system based on RO feedwater analyses and projection results. These criteria reflect the individual manufacturer's experience with the systems. Some of the criteria were modified during the study to improve operability (i.e., reduce potential for membrane fouling) and biological treatment stability and performance. Detailed descriptions of the operating stages for each treatment system are presented in Section 5.1.

TABLE 3.2Operating Criteria for the ZenoGem System

Parameter	Units	Target
Aeration Tank Air	scfm	45
Backpulse Duration	sec	15
Backpulse Frequency	min	10
Biomass Recirculation Rate	gpm	36
Flux	gfd	18.7/27.3ª
Membrane Tank Air	scfm	25/30 ^b
Permeability	gfd/psi	5°
Permeate Flowrate before Backpulse	gpm	6.5/9.5°
ТМР	psi	2.5 - 8.5
Vacuum before Backpulse	in Hg	5.1 - 17.3

^aTarget value during flow peaking.

Applied rate increased to 30 scfm during intermittent aeration.

Expected value based on control variables.

TABLE 3.3Biological Treatment Performance Criteria for the ZenoGem System

		Target				
Parameter	Units	Stage A	Stage B	Stage C	Stage D	
DO	mg/L	> 1.5	> 1.5	> 1.5	> 1.5	
OUR	mg O ₂ /L-min	1.0 - 1.5	1.0 - 1.5	1.0 - 1.5	1.0 - 1.5	
MLSS	mg/L	13,000	13,000	10,000	6,000	
Sludge Wasted Daily	gals	90ª	90 ^a	110 ^a	150 ^a	
HRT	hrs	6.2	6.2	6.2	6.2	
SRT	days	25ª	25ª	20ª	15ª	

^aExpected value based on control variables.

TABLE 3.4 Operating Criteria for the RO System

		Target			
Parameter	Units	Stage A	Stage B	Stage C	Stage D
Acidified Feedwater pH		6.8	6.8	6.8	5.6ª
Feedwater Flowrate	gpm	5	5	3	3 - 5
Feedwater Recovery	%	80	80	50	50 - 80
Permeate Flowrate	gpm	4	4	1.5	1.5 - 4.0
Scale Inhibitor Dose	ppm	2	2	2	2

^aSet target to concentrate pH during this stage (feedwater pH = 5.0).

Testing Approach

The demonstration testing program was divided into two phases:

- Phase I: Operation of ZenoGem treatment system for 1 month to establish stable biological treatment performance and permeate water quality.
- Phase II: Operation of ZenoGem and RO treatment systems for 5 months to demonstrate project goals and objectives.

The demonstration plant operated 24 hours per day, 7 days per week except for chemical cleanings or planned and unplanned maintenance. Equipment was supervised on an 8-hour per day, 5-day per week basis and as required on weekends to ensure proper operation and data collection. Operating data were recorded at the beginning and end of the each shift. Water quality samples were collected at the beginning of the shift. The results of Phase I and Phase II testing are discussed in Section 5.0.

4.1 ZenoGem Treatment System Tasks

The ZenoGem treatment system tasks under Phases I and II were to:

- 1. Operate ZenoGem system to produce a permeate whose quality complies with the City's discharge permit (TSS <15 mg/L; BOD <10 mg/L; NH₄-N <3 mg/L).
- 2. Characterize ZenoGem permeate relative to goals for RO feedwater quality, defined as follows:

Turbidity: < 0.2 NTU

• SDI: <3

Fecal coliforms: < 1 CFU/100 milliliters (mL)

- 3. Characterize ZenoGem permeate relative to IPR water quality requirements and for development of RO feedwater design composition.
- 4. Measure O&M requirements for ZenoGem system (plant efficiency factor, labor hours required, energy consumption, and chemical and other consumable consumption); demonstrate reliable, long-term performance of the ZenoGem process; and develop criteria for design of full-scale ZenoGem system.
- 5. Develop information necessary for design of a full-scale ZenoGem plant. Design criteria to be developed as part of this task include the following:
 - HRT (at average and peak loading)
 - SRT
 - Aeration requirements, separately for maintenance of membrane flux (air scour) and for carbonaceous and nitrogenous removal

- Membrane flux rate
- Duration of operation between chemical cleanings
- Frequency and duration of backpulse
- Backpulse volume
- Chemical type and concentration (if any) needed in backpulse water
- Chemical cleaning regime, including chemical type(s) and concentration(s) and contact time to ensure maintenance of membrane
- Sludge production rate and characteristics to define and assess proper sludge handling, drying, and disposal
- 6. Evaluate the effect of flow peak testing (hydraulic peaking) on the ZenoGem process. The approach is to initially operate the ZenoGem process at a target SRT of 25 days and a HRT of approximately 6 hours to establish baseline performance. After a predetermined period of operation, the HRT will be decreased to about 4 hours. Following this change, system operation (membrane performance) will be monitored at the new HRT by tracking changes in TMP and permeability.
- 7. Evaluate the effect of intermittent aeration on operational (blower) costs and the ability to concurrently nitrify and denitrify in the ZenoGem process. This task includes cycled aeration to the membrane tank and aeration tank to determine the impacts on operational (blower) costs and biological nitrogen removal, respectively.

4.2 RO Treatment System Tasks

The RO treatment system tasks under Phases II were to:

- 1. Characterize RO permeate quality relative to IPR quality requirements.
- 2. Monitor RO system operating performance as measured by the following:
 - Feed and permeate conductivity
 - Feedwater recovery
 - Feed pressure
- 3. Assess changes in RO membrane performance caused by fouling of RO membrane and elements and by chemical oxidation of RO membrane surface by monitoring the following parameters:
 - Normalized permeate flow
 - Normalized conductivity passage
 - Normalized vessel differential pressure
- 4. Perform chemical cleanings as required when normalized performance parameters change by a pre-determined amount. Assess the efficiency of one or more chemical cleaning formulations/regimes to restore RO performance losses.

- 5. Confirm RO membrane manufacturer's projections of attainable feedwater recovery and document RO feedwater chemical conditioning requirements to control mineral precipitation.
- 6. Confirm effectiveness of RO feedwater chloramination as a means to control biological fouling of RO membranes.
- 7. Develop information necessary for design of a full-scale RO plant. Design criteria to be developed as part of this task include the following:
 - Feedwater chemical conditioning
 - Feedwater biological monitoring requirements
 - Feedwater disinfection (chloramination)
 - Feedwater pressure
 - Membrane flux
 - Feedwater recovery
 - Membrane composition
 - Cleaning frequency and regime
 - Post-disinfection requirements

4.3 Additional Testing Activities

Prior to and during the operation of the demonstration plant, several additional activities were required and performed, including RO feedwater characterization, IPR characterization of the ZenoGem permeate and RO permeate, RO concentrate/WWTP effluent characterization, and RO integrity testing. These activities are described below.

4.3.1 RO Feedwater Characterization

Prior to testing, three sets of samples of unchlorinated secondary effluent from the South WWTP were collected to characterize the inorganic quality of the feedwater to the RO system. These analyses were required to estimate RO system operating conditions with respect to acid and scale inhibitor dosage and feedwater recovery. The samples were collected on December 14, 16, and 18, 1998, by the plant operating staff and analyzed by the CH2M HILL's Applied Sciences Laboratory (ASL). Results of these analyses were presented and discussed in Section 3.0.

4.3.2 IPR Characterization

The overall goal of IPR is to produce reclaimed water of suitable quality for supplementing McAllen's current raw water supply. Thus, it was desirable to characterize the quality of the raw water supply as part of this study to compare it with quality of reclaimed water produced by MF treatment (ZenoGem permeate) and by RO treatment (RO permeate).

Raw water characterization of McAllen's current raw water supply was conducted during the previous pilot testing. With respect to the demonstration plant, samples of ZenoGem permeate and RO permeate were collected on August 18 and September 14, 1999, respectively, by the plant operating staff and analyzed by ASL. Results of these analyses are presented and discussed in Section 5.0.

4.3.3 RO Concentrate and WWTP Effluent Characterization

RO will produce a waste stream (concentrate) containing elevated levels of most constituents present in the ZenoGem permeate, most notably TDS, TOC, and nutrients. Based on an assumed rejection of 90 percent for these constituents by RO and a feedwater recovery of 80 percent, the concentrate will contain TDS, TOC, and nutrients at four to five times their concentration in the ZenoGem permeate. It is anticipated that the RO concentrate will be disposed of by blending it with that portion of the South WWTP secondary effluent that is not reclaimed for IPR. This secondary effluent/concentrate blend would be discharged to the current WWTP effluent discharge point, the Arroyo Colorado, which flows into the Laguna Madre, a marine lagoon. Low freshwater inflows and variable salinity characterize the Arroyo Colorado-Laguna Madre system, which has TDS ranging from 3,000 to 10,000 mg/L. It is anticipated that TDS levels of the concentrate/effluent blend (which will be between 1,200 and 7,500 mg/L) will not adversely impact the ecology of the Arroyo Colorado-Laguna Madre system; however, there is concern that elevated nutrient concentrations in the blend could promote eutrophication and could adversely affect marine ecology.

Samples of WWTP effluent and RO concentrate were collected on August 18 and September 14, 1999, by the plant operating staff and analyzed by ASL and the South WWTP laboratory. The concentrations of the following constituents were measured to: 1) determine the suitability of discharge of the WWTP effluent/RO concentrate blend, and 2) develop requirements for treatment of the RO concentrate to ameliorate any constraints on discharge that are identified:

- TDS (gravimetric)
- TOC
- pH
- Total phosphorus
- Total Kjeldahl nitrogen (TKN)
- Nitrite/nitrate nitrogen

Results of these analyses are presented and discussed in Section 5.0.

4.3.4 RO Integrity Testing

The BOR performed an evaluation of RO element integrity test methods. This evaluation was outside of the scope of CH2M HILL's activities under their agreement with the City; however, activities conducted as part of the BOR's evaluation were closely coordinated with those conducted under this study and were, in large part, conducted by the City's operations staff. Furthermore, the results of the integrity method evaluation should provide useful information for future implementation of indirect potable reuse at McAllen and other locations where RO is used. Development of a field-applied integrity test method for RO elements will provide greater assurance that RO treatment is providing contaminant removal to the degree necessary to protect public health in this reuse context. Results of these analyses are presented in Appendix J.

4.4 Treatment System Monitoring

During the demonstration testing, various performance parameters were monitored to evaluate operation of the treatment systems and the quality of the water fed to and produced by the systems. The parameters that were monitored are presented in the following sections.

4.4.1 Operator Training

The City provided two dedicated operators to supervise, operate, and maintain the demonstration plant during the course of the study. The operators were responsible for, but not limited to, equipment maintenance and operation, including manually recording operational data, saving RO system PLC data, batching chemicals, adjusting chemical addition rates, performing chemical cleanings, collecting routine water quality samples, and recording all demonstration plant activities.

Operating parameters for the systems were monitored daily to evaluate treatment: system performance. ZenoGem system operating data were collected from equipment instruments and recorded manually on operations log sheets at least twice daily. RO system operating data were collected by two methods: 1) electronically via a PLC for a specified interval and duration (typically every hour over a 12-hour period), and 2) manually at the end of each operating shift from equipment instruments and panel readouts and recorded on operations log sheets. Method 1 was used for primary data collection; method 2 served as a backup source in the event of difficulties with PLC data downloading. Logbooks for each system were maintained to record all O&M events that occurred during the testing period including, but not limited to, date and time of chemical cleanings; type and amount of chemicals used during cleaning, cleaning temperature, and pH; downtimes; alarms or failures; and changes in any operating conditions.

The operating criteria (targets) were presented in Section 3.0. The actual average operating conditions, along with targets, are presented and discussed in Section 5.0.

4.4.2 Sampling and Analysis

The operators collected water quality samples from each treatment system on a routine basis. The South WWTP laboratory was responsible for performing selected physical/chemical and biological analyses. The WWTP laboratory was also responsible for collecting samples for TOC, chemical oxygen demand (COD), TKN, nitrite/nitrate nitrogen, and total phosphorous, and shipment of these samples to ASL for analyses. The central water laboratory, located at McAllen's Water Treatment Plant No. 1, was responsible for performing microbiological analyses.

Sampling activities commenced on February 8, 1999, for the ZenoGem system and on April 16, 1999, for the RO system. At these times, the operators began routine recording of system operating data and collection of water quality samples for each system. In addition, the water and wastewater treatment plants and ASL began routine sampling analyses. The biological treatment and water quality parameters, sampling location and frequency, and responsible analytical party for each treatment system are presented in Tables 4.1 and 4.2.

TABLE 4.1 Biological Treatment and Water Quality Sampling Schedule for the ZenoGem System

		Loo	Location and Frequency	cy			
Parameter	ZenoGem Feed	Membrane Tank	Aeration Tank	ZenoGem	Aeration Tank	Sample	Responsible
Physical/Chemical					affinic average	Day(s)	Party
Н	2W	2W	SW	MAC	!		
Temperature*	1/0	Ę	: <u>(</u>	M7	NONE	M & W	WWTP
Conductivity		2	2/2	1/D	NONE	M-F	OPERATOR
	Q/1	NONE	NONE	1/D	NONE	ш, 2	22,4641
Lurbidity	NONE	NONE	NONE	1/0	JINCIN	. I	٠ ١
cop	2/M	NONE	NONE	2/W	10NE	¥ ;	WWTP
Total Chlorine	NONE	NONE	HNCN	; ;	AA/)	Σ	CH2M
Free Chlorine	NONE	HNCN	i ii	2 !	NONE	Ā.	WWTP
ALK	1/W			Q/L	NONE	M - F	WWTP
Biological		NOINE	NONE	1/W	NONE	Σ	WTP
,00	Ş	ţ	!				
9) : :	2	0/1	NONE	NONE	Ψ.	OPERATOR
, do	NONE	2/W	2/W	NONE	NONE	M & W	Motoria C
MLSS	NONE	3W	3/W	NONE	J WE	5 N	d MM
MLVSS	NONE	3/W	3/W	HNCN	104	T, W, M	WWTP
DSVI	NONE	3/W	NON	NON E		M or M,W,F	WWTP
CBOD ₅ ^b	3/W	3W	3/W	300	NONE CO	M,W,F	WWTP
TSS	3/W	NONE	LINC N	* **	NON :	M,W,F	WWTP
				M/9	NONE	M,W,F	WWTP

TABLE 4.1
Biological Treatment and Water Quality Sampling Schedule for the ZenoGem System

		Poc	Location and Frequency	cy			
Parameter	ZenoGem Feed	Membrane Tank	Aeration Tank	ZenoGem	Aeration Tank	Sample	Responsible
NH3-Np	3/W	HOME			waste Studge	Day(s)	Party
Q NXI	i	NOME OF THE PERSON OF THE PERS	NONE	3/W	NONE	M W E	CEANA!
	1 %	NONE	NONE	1,00	7		- MM
NO ₂ /NO ₃ -N _p	1/W	NONE	NON		A/I	₹	CH2M
T Phosphorus	1/W	NONE	NON F	W .	NONE	Σ	CH2M
Microbial				AA/1	1/W	Σ	CH2M
Total Coliform	2/W	NONE	HNON				
Fecal Coliform	2W	NONE	ENCN.	M/Z	NONE	M&W	WTP
НРС	NONE		I LNCN	M 7	NONE	M & W	WTP
These samples are to be taken at the same time	ken at the same tir	me.		AW	NONE	M & W	WTP
Operator to analyze at sample location. 1/D=once per day	ple focation.						
2/W=twice per week							
3/W=three times per week							
Z/m=z umes per month ALK=alkalinity							
CH2M HILL=CH2M HILL's Applied Sciences Laboratory	pplied Sciences La	aboratory (ASL)					
UC=dissolved oxygen DSVI=diluted sludge volume in dil	;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;	(===) (
MLVSS=mixed studie volume index	index Suspended solids						
OUR=oxygen uptake rate							
W I P=McAllen's Central Water Treatment Plant Laboratory	er Treatment Plant	Laboratory					
	stewater i reatmen	it Plant Laboratory					

TABLE 4.2Water Quality Sampling Schedule for the RO System

_	Lo	cation and Freque	ency	<u> </u>	
Parameter	RO Feed	RO Permeate	RO Concentrate	Sample Day(s)	Responsible Party
Physical/Chemical		-			
рН	1/W	1/W	1/W	М	WWTP
Conductivity	1/W	1/W	1/W	М	WWTP
Turbidity	1/D	1/D	1/D	M-F	WWTP
SDI ^a	1/D	1/D	NONE	M-F	OPERATOR
TOC ^b	1/D	1/D	NONE	M-F	OPERATOR
тос	2/M	2/M	NONE	М	CH2M
Total Chlorine	1/D	1/D	NONE	M-F	WWTP
Free Chlorine	1/D	1/D	NONE	M - F	WWTP
TDS	1/W	1/ W	1/W	М	WWTP
Microbial			· · · · · · · · · · · · · · · · · · ·		
Total Coliform	NONE	2/W	NONE	M & W	WTP
Fecal Coliform	NONE	2/W	NONE	M & W	WTP
HPC	2/W	2/W	NONE	M & W	WTP

^aOperator to analyze at sample location using auto analyzer.

4.5 Data Evaluation

Several of the operating parameters and water quality parameters presented previously were compiled, reduced, and analyzed to evaluate operational, biological, and membrane performance of the treatment systems. Evaluating the flux, TMP, and permeability characterized ZenoGem membrane performance. The primary water quality parameters used to evaluate the effectiveness of the ZenoGem treatment process in producing a high quality RO feedwater were turbidity and SDI. Evaluating the feedwater recovery, normalized product flow (NPF), and the pressure drop across the vessels characterized RO membrane performance.

^bOperator to analyze at sample location using monitor.

^{1/}D=once per day

^{1/}W=once per week

^{2/}W=twice per week

^{2/}M=twice per month

CH2M=CH2M HILL's Applied Sciences Laboratory (ASL)

WWTP=McAllen's South Wastewater Treatment Plant Laboratory

WTP=McAllen's Central Water Treatment Plant Laboratory

4.5.1 Filtrate Flow and Membrane Flux

Membrane flux is directly proportional to the permeate (filtrate) flow rate as shown in the following equation:

Flux [gfd] = Permeate Flow rate[gpm] x 1440 / Membrane Area [ft²] where [gfd] = gallons per day per ft²

As the filtrate flow rate increases, the membrane flux increases proportionately.

4.5.2 Transmembrane Pressure and Permeability

TMP represents the resistance to flow of water of 1) the membrane, and 2) the materials in the feedwater (foulants) that accumulate at the membrane surface or within the membrane pores. TMP at the start of testing (with a clean membrane) represents only the resistance of the membrane. As foulants accumulate and cannot be effectively removed by backwashing/backpulsing with disinfectant, TMP increases because of the resistance of flow exerted by the foulants. Thus, the rate at which TMP increases is directly proportional to the rate of membrane fouling.

Membrane permeability is inversely proportional to the TMP as shown in the following equation:

Permeability [gfd/psi] = Flux [gfd]*1.024 $^{(25-7)}$ /TMP [pounds per square inch (psi)] where T = feedwater temperature, $^{\circ}$ C

Permeability is a direct measure of the water flow through the membrane fiber and any foulants that have accumulated on the surface or within the membrane pores. The permeability equation includes a temperature correction factor to remove or "normalize for" the effects of changing temperature on membrane permeability. Increases in temperature increase water flow through the membrane because of decreasing viscosity. This effect must be removed to accurately assess changes in permeability with run time.

4.5.3 Turbidity and SDI

Traditionally, the RO membrane manufacturers have established the following as criteria for efficient RO operation:

Turbidity: ≤0.2 NTU

 $SDI: \leq 3$ (based on 15-min test interval)

SECTION 5

Demonstration Testing Results

This section presents the results of demonstration plant testing. All data collected during the study are presented in Appendix C as follows:

Operating data for ZenoGem System	Table C-1
Water quality data for ZenoGem System	Table C-2
Operating data for RO System	Table C-3
Water quality data for RO System	Table C-4

Results for water quality parameters routinely analyzed by the McAllen water and wastewater laboratories were communicated to CH2M HILL by facsimile on daily or weekly sampling logs. These data, along with CH2M HILL laboratory data, were tabulated and incorporated into Tables C-1 through C-4 in Appendix C.

5.1 Operations

A summary of ZenoGem and RO system operating stages and events is presented in Tables 5.1 and 5.2. Additional details regarding the specific operating stages are discussed below.

TABLE 5.1Operating Stages and Events for the ZenoGem System

Stage	Event	Date(s)	Run Time (hrs)	Duration (hrs)	Description
A		2/6/99	0.00		Start of Testing (MLSS concentration at 13 g/L and OCP Membrane)
В		3/20/99	677.58		OKC Membrane
	1	3/31/99 - 4/1/99	915.58 - 941.00	25.42	Peak Flow Testing (9.5 gpm for 6 hrs over 24-hour period)
С		5/6/99	1783.00		Decrease MLSS Concentration to 10 g/L
	2	6/1/99	2406.08	2.42	Bubble Point Test
	3	8/12/99 - 8/13/99	4129.58 - 4158.33	28.75	Peak Flow Testing (9.5 gpm for 6 hrs over 24-hour period)
	4	8/16/99 - 8/20/99	4225.08 - 4326.25	101.17	Peak Flow Testing (9.5 gpm for 6 hrs over 24-hour period)

TABLE 5.1 CONT.Operating Stages and Events for the ZenoGem System

Stage	Event	Date(s)	Run Time (hrs)	Duration (hrs)	Description
	5	8/30/99 - 9/1/99	4561.08	51.50	Recovery (Full Tank) Clean
	6	9/14/99 - 9/16/99	4875.91	50.25	Raise Membranes
	7	9/17/99 - 9/27/99	4894.16 - 5136.25	242.09	Cycled Aeration to the Membrane Tank (10 sec on/off)
	8	9/27/99 - 9/29/99	5136.25 - 5186.91	50.66	Peak Flow Testing without Cycled Aeration
D		10/4/99	5303.41		Decrease MLSS Concentration to 6 g/L
	9	10/7/99 - 10/8/99	5328.75 - 5352.50	23.75	Cycled Aeration to the Membrane Tank (10 sec on/off)
	10	10/8/99 - 10/13/99	5352.50 - 5476.00	123.50	Peak Flow Testing with Cycled Aeration to Membrane Tank
	11	10/14/99 - 10/19/99	5476.00 - 5615.66	139.66	Normal Flow with Cycled Aeration to Membrane Tank
	12	10/19/99 - 11/2/99	5615.66 - 5948.25	332.59	Normal Flow with Cycled Aeration to Both Tanks (Aeration Tank at 15 mir on/off)
	13	11/2/99	5948.25		End of Testing

TABLE 5.2Operating Stages and Events for the RO System

Stage	Event	Date(s)	Run Time (hrs)	Duration (hrs)	Description
A		4/21/99	0.00		Startup
В		5/19/99	0.00		Start of Testing (Target Feed pH = 6.8)
	1	5/24/99 - 5/25/99	114.89 - 147.69	32.80	1st Cleaning (Citric Acid:Stages 1 and 2)
	2	5/30/99	256.41		Decrease Recovery to 50%
	3	6/1/99 - 6/2/99	305.9 - 328.42	22.52 2nd Cleaning (Citric Acid:Stand 2)	
	4	6/8/99 - 6/10/99	475.88 - 526.38	50.50	3rd Cleaning (Citric Acid:Stages 1 and 2 followed by Caustic:Stage 1)
С		6/11/99	544.50		Decrease Recovery to 50% (Stage 2 Removed from Service)
D		7/7/99	1176.51		Stage 2 Returned to Service (50% Recovery)

TABLE 5.2 CONT.Operating Stages and Events for the RO System

Stage Event	Date(s)	Run Time (hrs)	Duration (hrs)	Description
5	7/8/99	1196.78	(1113)	•
Ŭ	170/00	1130.70		Increase Recovery to 60%; Decrease Feed pH to 6.5
6	7/9/99	1208.73		Increase Recovery to 70%; Decrease Feed pH to 6.0
7	7/22/99	1532.92		Set Target pH to Concentrate pH = 5.6 (Feedwater pH = 5.0)
8	7/24/99 - 7/27/99	1578.67 - 1650.27	71.60	4th Cleaning (Citric Acid:Stages 1 and 2)
9	8/10/99	1985.17		Increase Recovery to 75%
10	8/30/99 - 9/1/99	2464.77- 2519.55	54.78	Unit Down due to ZenoGem System Recovery (Full Tank) Clean
11	9/2/99 - 9/8/99	2543.79 - 2687.50	143.71	5th Cleaning (Citric Acid:Stages 1 and 2); Acid Pump Failure
12	9/14/99 - 9/16/99	2830.65 - 2880.25	49.60	Unit Down due to Raising ZenoGem System Membranes
13	9/23/99	3041.97		Increase Recovery to 80%
14	10/4/99 - 10/6/99	3308.51 - 3359.81	51.30	Unit Down due to Decreasing ZenoGem System MLSS
15	10/8/99	3399.11		End of Routine Testing
16	10/21/99	3715.41		End of Special Testing

5.1.1 Startup Activities

ZenoGem Equipment Commissioning. ZENON field service technicians arrived at the plant site on January 11, 1999, and performed commissioning of the ZenoGem system through February 6, 1999. ZenoGem system commissioning included equipment installation; membrane bubble point and clean water flux testing; introduction and concentration of mixed liquor in the bioreactor tank; and operation on SDS to establish steady-state biological treatment (carbonaceous and nitrogenous oxidation) and membrane treatment. Operational activities included establishing target MLSS concentrations in both the membrane (process) and aeration tanks; air flow rates and dissolved oxygen (DO) levels in both tanks; solids recirculation rate between tanks; and membrane permeate flow (flux) rate. The ZenoGem system achieved steady-state operation on March 22, 1999.

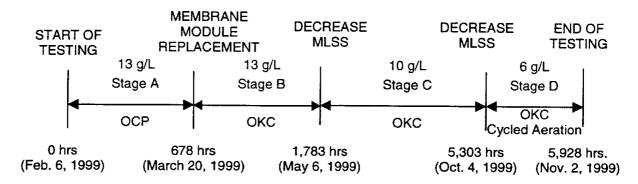
RO Equipment Commissioning. BOR project managers performed commissioning of the RO system during two site visits on February 2 through February 12, 1999, and on March 15 through March 19, 1999. During the first visit, RO system commissioning included installation of plumbing and electrical connections; delivery and storage of chemicals; modifications to the computer recording system; PLC programming; and installation of temporary membranes. During the second visit, additional RO system commissioning

included instrument calibration; SDI auto analyzer installation; system cleaning and disinfection; installation of permanent membranes and integrity tests. At that time, the RO system was scheduled for startup on March 22, 1999, coincident with steady-state operation of ZenoGem system. However, due to ZenoGem system special testing, replacement of defective chloramine metering pump parts, difficulties in attaining stable and effective chloramine stock solutions and residuals, combined with minor RO equipment problems, RO system start of testing was delayed until April 21, 1999.

5.1.2 Operating Stages

ZenoGem System. The ZenoGem operating period has been divided into four separate operating stages as shown in Exhibit 5.1. The ZenoGem operating stages were as follows:

EXHIBIT 5.1 ZenoGem Operating Stages



Stage A represents the start of testing using the OCP UF membrane and a target MLSS concentration of 13 g/L. During this stage, the aeration and membrane tanks were seeded with activated sludge from the WWTP and MLSS levels increased step-wise to the target level. The system accumulated 321 operating hours out of a possible 678 available hours, for an online factor of 0.47 (47 percent). This online factor includes two separate periods when the system was offline due to failure and subsequent replacement of the recirculation pump impeller, feedwater inlet level sensor replacement, and membrane module replacement.

The originally supplied membrane module, which used the OCP membrane, has recently been classified by ZENON as their drinking water membrane and is marketed primarily as an UF membrane for the treatment of natural raw water supplies to produce potable water. This membrane, which has a nominal pore size of 0.035 microns, has been found to have flux limitations when operated on high MLSS wastewaters and consequently is being phased out by ZENON in favor of the OKC MF membrane for wastewater treatment. The OKC membrane is more porous, with a nominal pore size of 0.4 microns. Initial in-house testing by ZENON showed the OKC membrane to operate at higher permeability and to benefit from a lower rate of fouling on wastewater, particularly when operating at peak loading conditions. Consequently, it was decided jointly by ZENON and CH2M HILL that the OKC membrane would be better suited for the

McAllen IPR application. After the OCP module was replaced with a new OKC module, the permeate flow rate was slowly increased to the target 6.5 gpm.

Stage B represents the period of operation using the OKC module and a target MLSS concentration of 13 g/L. During this stage, the system accumulated 1,077 operating hours out of a possible 1,105 available hours, for an online factor of 0.97 (97 percent). This online factor includes a short period of time when the system was offline due to replacement of a valve in the aeration tank. A single-day peak flow test was conducted during the latter part of this stage.

Stage C represents the period of operation at a target MLSS concentration of 10 g/L. During this stage, the system accumulated 3,416 operating hours out of a possible 3,520 available hours, for an online factor of 0.97 (97 percent). This online factor includes three separate periods when the system was offline due to bubble point testing, clean water flux testing/full tank soaking, and to raise the module height (in the membrane tank). During this stage, peak flow testing continued and cycled aeration (to the membrane tank only) was initiated.

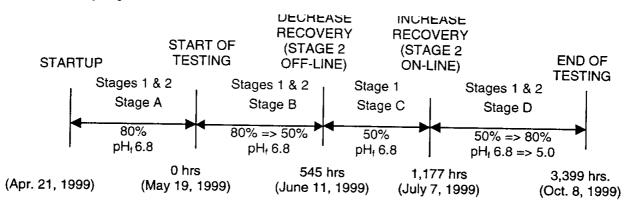
The target MLSS concentration was decreased from an initial target of 13 g/L to 10 g/L after 1,783 total available hours of operation following detailed discussions with ZENON technical personnel. Based on ZENON experience, lowering the MLSS concentration to 10 g/L provides for improved operability (lower membrane fouling) and more stable biological treatment. As discussed later in this section, MLSS reduction also improved oxygen transfer from the bulk fluid to the biomass, thereby improving nitrification efficiency and decreasing the degree of denitrification. Consequently, it was decided jointly by ZENON and CH2M HILL that the decrease in MLSS concentration would be preferred for the McAllen indirect potable reuse application.

Stage D represents the period of operation at a target MLSS concentration of $6\,\mathrm{g/L}$. During this stage, the system accumulated 596 operating hours out of a possible 645 available hours, for an online factor of 0.92 (92 percent). This online factor includes a short period of time when the system was offline to decrease the MLSS concentration (i.e., wasting half the aeration tank volume) and subsequent aeration-only operation to reestablish proper biomass condition. Peak flow testing continued and cyclic aeration to the membrane and aeration tanks was also initiated during this stage.

The MLSS concentration was decreased from 10 g/L to 6 g/L after 5,303 total available hours of operation following detailed discussions with ZENON technical personnel. ZENON indicated that maintenance of stable membrane permeability during flow peaking would most likely depend on sludge filterability characteristics as indicated by the sludge capillary suction time (CST). Sludges with high CSTs are viscous and difficult to filter. The sludge generated in the ZenoGem process had a high CST (exceeding 100 seconds). ZENON indicated that for such sludge, reducing the MLSS concentration reduces the resistance to filtration and would maximize permeability during flow peak peaking. Consequently, it was decided jointly by ZENON and CH2M HILL to perform peak flow tests at a lower MLSS concentration in order to demonstrate maximum performance.

RO System. The RO operating period has been divided into four separate operating stages, as shown in Exhibit 5.2. Since the hour meter on the system was not functional, the online factor for each stage of operation was approximated by system downtimes recorded by the operators. The first two RO operating stages were as follows:

EXHIBIT 5.2 RO Operating Stages



Stage A represents the period of operation from startup to the actual start of steady state testing (commissioning phase). During this stage, the system was off line approximately 70 percent of the time due to numerous downtimes associated with PLC reprogramming and tuning to optimize control of feedwater flow and pH; failure and subsequent replacement of the scale inhibitor feed pump; de-commissioning of automatic sampling valves; and troubleshooting acid feed pump loss of prime. Data collected during this phase was considered representative of continued startup activities and system troubleshooting. By May 19, the system was successfully online, and the actual start of steady state testing was achieved.

Stage B represents the period of operation at a target recovery of 80 percent. During this 545-hour stage, the system was off line approximately 19 percent of the time due to three RO membrane cleanings and maintaining target pH.

RO Feedwater Pretreatment to Control Membrane Fouling. RO membrane elements are subject to fouling during extended operation caused by both suspended and sparingly soluble salts. Suspended matter includes organic and inorganic colloids and microorganisms. Sparingly soluble salts, such as carbonates, sulfates, and silica, can precipitate from solution as the RO process concentrates them. Suspended particles accumulate on the membrane surface causing biofouling and colloidal fouling, and they can block feed channels thereby increasing the pressure drop across the system. These phenomenon reduce water permeability through the RO membranes causing flux decline and increased salt passage. The nature and rapidity of fouling depends on the condition of the feedwater. Fouling is progressive, and, if not controlled early, can impair the RO system performance in a relatively short time. For these reasons, fouling must be controlled.

Particulate fouling is addressed through the use of the ZeeWeed MF membrane. Chloramines were batched and dosed into the RO feedwater at a target dose of 1 to 2 mg/L to prevent biological growth (biofouling) of the RO elements. As described in an

earlier section, mineral precipitation is controlled through a combination of acidification and scale inhibitor addition. The last two RO operating stages are described below.

Stage C represents the period of operation at a target recovery of 50 percent (operating first stage vessels only) to demonstrate that performance losses observed in Stage B resulted from mineral precipitation (as opposed to particulate or colloidal fouling). During this 632-hour stage, the system was online 100 percent of the time.

Stage D represents the period of operation at recovery of 50 to 80 percent (operating first and second stage vessels) and acidification of the concentrate stream to a reduced feedwater pH of 5.0 (concentrate target pH of 5.6) to control calcium phosphate and calcium carbonate precipitation. During this 2,222-hour stage, the system was off line approximately 10 percent of the time due to two RO membrane cleanings. It excludes three downtimes associated with ZenoGem full tank soaking, raising module height, and decreasing the MLSS concentration.

5.2 ZenoGem Testing Results

5.2.1 ZenoGem Operating Conditions

Table 5.3 presents the target and average operating conditions for the ZenoGem system during Stage A operation. The system operated at a target MLSS concentration of 13 g/L using the OCP UF membrane. After 678 hours of startup activities, the membrane was replaced with the OKC MF membrane.

TABLE 5.3
Stage A Average Operating Conditions for the ZenoGem System

Parameter	Target ^a	Normal Flow
Aeration Tank Air (scfm)	> 45	48
Backpulse Duration (sec)	15	15
Backpulse Frequency (min)	10	10
Biomass Recirculation Rate (gpm)	> 36	26.2
Flux (gfd)	18.7	17.3
Membrane Tank Air (scfm)	25	25
Normalized Permeability (gfd/psi)	5	20.8
Permeate Flowrate before Backpulse (gpm)	6.5	6.0
Permeate Flowrate after Backpulse (gpm)		6.0
Temperature (degrees C)		26.2
TMP (psi)	2.5 - 8.5	1.34
Vacuum before Backpulse (in Hg)	5.1 - 17.3	2.73
Vacuum after Backpulse (in Hg)		2.57

^aWhere target left blank, no target was established.

^bValues calculated when permeate flowrate reached 6 gpm.

Table 5.4 presents the target and average operating conditions for the ZenoGem system during Stage B operation. The system continued to operate at a target MLSS concentration of 13 g/L during this stage. After 916 hours of operation (Event 1), the permeate flowrate was increased for 25 hours to determine the short-term impact of higher membrane loading on permeability and TMP.

TABLE 5.4
Stage B Average Operating Conditions for the ZenoGem System

Parameter	Target ^a	Normal Flow	Peak Flow (Event 1)
Aeration Tank Air (scfm)	> 45	43	42
Backpulse Duration (sec)	15	15	15
Backpulse Frequency (min)	10	10	10
Biomass Recirculation Rate (gpm)	> 36	38.3	39.5
Flux (gfd)	18.7/27.3 ^b	18.5	27.3
Membrane Tank Air (scfm)	25	25	25
Normalized Permeability (gfd/psi)	5	17.82	13.19
Permeate Flowrate before Backpulse (gpm)	6.5/9.5 ^b	6.40	9.50
Permeate Flowrate after Backpulse (gpm)		6.40	9.50
Temperature (degrees C)		28	25.8
TMP (psi)	2.5 - 8.5	1.2	2.1
Vacuum before Backpulse (in Hg)	5.1 - 17.3	2.66	4.17
Vacuum after Backpulse (in Hg)		2.59	4.12

^aWhere target left blank, no target was established.

Table 5.5 presents the target and average operating conditions for the ZenoGem system during Stage C operation. At the beginning of this stage (after 1,783 hours of operation), the MLSS concentration was decreased to 10 g/L. From 4,130 to 4,158 hours (Event 3) and from 4,225 and 4,326 hours (Event 4) of operation, the permeate flow rate was increased by 46 percent (6.5 to 9.5 gpm) for a period of 6 hours (flow peaking) over a 24-hour period to simulate the types of hydraulic peak loading that typically occur in a conventional WWTP. This was done to determine if the MBR system could be operational in the same manner or if additional means would be required to ensure slower changes in loading to the system. After 4,876 hours of operation, the membrane module height was raised (Event 6) to minimize sludge accumulation on the module aerators during non-aeration periods. From 4,894 to 5,136 hours (Event 7) of operation, air was cycled to the membrane tank at an applied rate of 30 scfm for 10 seconds on and 10 seconds off to evaluate the effect of intermittent aeration on operations and membrane performance. From 5,136 to 5,187 hours (Event 8) of operation, flux peaking was conducted without intermittent aeration to the membrane tank.

^bTarget value during flow peaking.

TABLE 5.5Stage C Average Operating Conditions for the ZenoGem System

			Peak Flow	Normal Flow with Cycled Aeration to Membrane Tank Only
Parameter	Target ^a	Normal Flow	(Events 3,4,8)	(Event 7)
Aeration Tank Air (scfm)	> 45	59	61	63
Backpulse Duration (sec)	15	15	15	15
Backpulse Frequency (min)	10	10	10	10
Biomass Recirculation Rate (gpm)	> 36	48.2	47.5	44.6
Flux (gfd)	18.7/27.3 ^b	18.7	26.6	18.7
Membrane Tank Air (scfm)	25/30°	25	25	31
Normalized Permeability (gfd/psi)	5	6.61	3.05	8.67
Permeate Flowrate before Backpulse (gpm)	6.5/9.5 ^b	6.50	9.20	6.50
Permeate Flowrate after Backpulse (gpm)		6.70	11.10	7.10
Temperature (degrees C)		31.2	31.9	30.3
TMP (psi)	2.5 - 8.5	2.8	7.5	2.4
Vacuum before Backpulse (in Hg)	5.1 - 17.3	5.70	15.30	4.90
Vacuum after Backpulse (in Hg)		5.10	15.90	4.10

^aWhere target left blank, no target was established.

Per discussions with ZENON, cycled aeration operation to the membrane tank was planned at 10 seconds on and 10 seconds off. However, a cycle time of 15 seconds on and 15 seconds off was implemented at the site due to communication and programming error between ZENON and the demonstration plant operators. ZENON Corporate Technology tested a number of different air cycle times at other pilot locations and concluded that 10 seconds off is the maximum allowable period before a decline in permeability is observed. Longer air OFF periods allow the mixed liquor solids to accumulate in the fiber bundle and are not subsequently removed by the air pulse during the ON cycle. Thus, the error in cycle time implemented is significant enough to cause the permeability decline observed during cycled aeration events as discussed in Section 5.2.2.

^bTarget value during flow peaking.

^cApplied rate increased to 30 cubic feet per minute (cfm) during intermittent aeration.

Table 5.6 presents the target and average operating conditions for the ZenoGem system during Stage D operation. At the beginning of this stage (after 5,303 hours of operation), the MLSS concentration was decreased to 6 g/L. From 5,329 to 5,353 hours (Event 9) of operation, air was again cycled to the membrane tank. From 5,353 to 5,476 hours (Event 10) of operation, flux peaking was conducted; however this time with intermittent aeration to the membrane tank. From 5,476 to 5,616 hours (Event 11) of operation, the flowrate was reduced to normal conditions and air continued to cycle to the membrane tank. From 5,616 hours to the end of testing (Event 12), air was cycled to the aeration tank at an applied rate of 45 scfm for 15 minutes on and 15 minutes off to evaluate the effect of intermittent aeration on biological treatment performance (i.e., to concurrently nitrify and denitrify).

TABLE 5.6
Stage D (Alternative Operating Mode) Average Operating Conditions for the ZenoGem System

		Normal	Normal Flow with Cycled Aeration to Membrane Tank Only	Peak Flow with Cycled Aeration to Membrane Tank Only	Normal Flow with Cycled Aeration to Membrane Tank Only	Normal Flow with Cycled Aeration to Membrane and Aeration Tanks
Parameter	Target	Flow	(Event 9)	(Event 10)	(Event 11)	(Event 12)
Aeration Tank Air (scfm)	> 45	65	66	64	66	65
Backpulse Duration (sec)	15	15	15	15	15	15
Backpulse Frequency (min)	10	10	10	10	10	10
Biomass Recirculation Rate (gpm)	> 36	47.3	48.0	47.0	46.2	43.1
Flux (gfd)	18.7/27.3 ^b	18.7	18.7	27.3	18.7	18.7
Membrane Tank Air (scfm)	25/30°	25	32	32	32	32
Normalized Permeability (gfd/psi)	5	7.27	7.52	3.25	3.86	3.42
Permeate Flowrate before Backpulse (gpm)	6.5/9.5 ^b	6.50	6.50	9.5	6.50	6.50
Permeate Flowrate after Backpulse (gpm)		6.90	6.70	11.50	6.90	6.90
Temperature (degrees C)		30.3	30.0	31.6	29.0	26.4
TMP (psi)	2.5 - 8.5	2.39	2.2	7.37	4.5	5.7
Vacuum before Backpulse (in Hg)	5.1 - 17.3	4.90	4.50	15.0	9.10	11.50
Vacuum after Backpulse (in Hg)		4.30	4.60	16.30	8.20	10.50

^aWhere target left blank, no target was established.

^bTarget value during flow peaking.

^cApplied rate increased to 30 cfm during intermittent aeration.

5.2.2 ZeeWeed Membrane Performance

Permeate Flow and Membrane Flux. Figure 5.1 illustrates changes in ZenoGem permeate flow and flux as a function of operating time. During Stage A (prior to membrane replacement), flow and flux were increased in step-wise increments to "condition" the membrane fibers to the mixed liquor. This was done to prevent the fibers from becoming fouled. Permeate flow was held constant during Stages B through D except for five events:

- Event 1: Flow increased for 25 hours to determine the short-term impact of higher membrane loading on permeability and TMP; and
- Events 3, 4, 8 and 10: Flow increased by 46 percent (6.5 to 9.5 gpm) for a period of 6 hours (flow peaking) over a 24-hour period to simulate WWTP peak hydraulic loading.

The increases caused a corresponding increase in TMP and decrease in permeability; however both changes were reversed once the flow was decreased to the target level. Thus, the temporary flux increase caused only reversible membrane fouling and flow peaking for short (one-day) periods of time can occur in response to actual WWTP loading without causing a permanent increase in fouling.

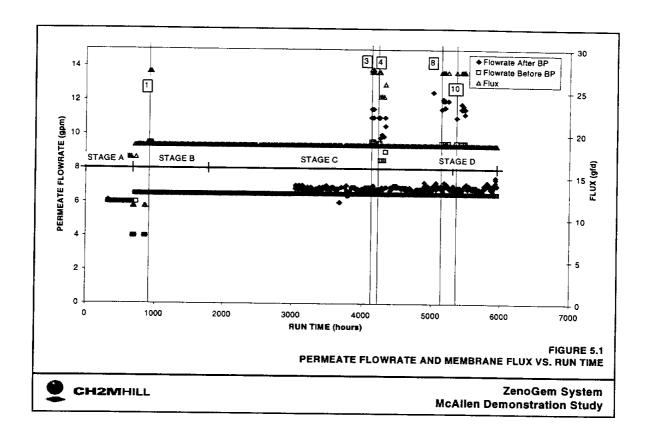
Transmembrane Pressure. Figure 5.2 illustrates changes in ZenoGem TMP as a function of operating time (permeate flow is also shown for reference).

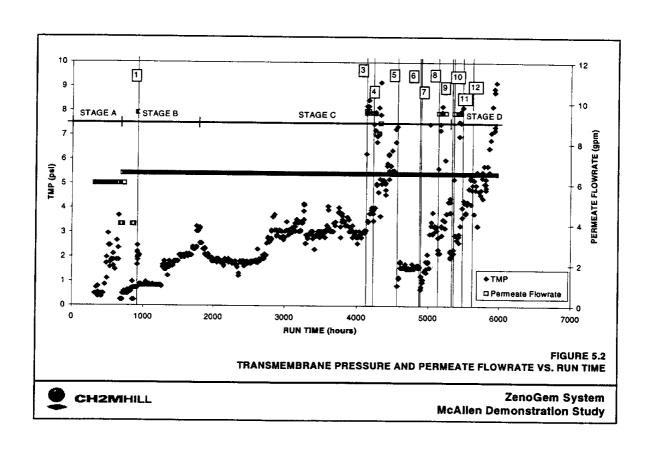
Stage A. TMP increased gradually as permeate flow was increased to the target value. The sharp decline in TMP that occurred at 653 hours was caused by continuous aeration of the module during the 12-day period when the ZenoGem system was offline due to recirculation pump failure and replacement. Continuous aeration in the absence of permeation was very effective in reducing membrane fouling.

Stage B. During the latter part of Stage B, TMP steadily increased even when permeate flowrate (and membrane flux) were held constant. This increase in TMP clearly indicates that membrane fouling was occurring at the higher MLSS concentration. The short-term flow peaking during Stage B (Event 1) caused a temporary increase in TMP that was reversed once flux was reduced.

Stage C. During operation at intermediate (10 g/L) MLSS concentration, TMP first decreased and then increased very gradually over a 1,000-hour period, indicating: 1) a very low rate of fouling, and 2) maintenance cleans were more effective in controlling fouling at the lower MLSS concentration. The step increase in TMP at ~2,700 hours was caused by a temporary loss of air scour in the membrane tank. Flow peaking during Stage C (Events 3 and 4) resulted in a more rapid rate of TMP increase, demonstrating that flow peaking of the membrane on a daily basis over an extended operating period caused a significant increase in fouling rate at the lower MLSS concentration. TMP increased to the maximum value (8 psi) which required a recovery (full tank) clean (Event 5) to reduce TMP to clean membrane levels (0.8 psi). At the end of Stage C, TMP rapidly increased when air was cycled to the membrane tank (Event 7) and again during flow peaking without cycled aeration (Event 8).

Stage D. During this stage, the impact of both flow peaking and cycled (intermittent) aeration was evaluated at low (6 g/L) MLSS concentration. The data in Figure 5.2 shows TMP increases were rapid when flow peaking and cycled aeration was practiced, consistent with flow peaking effect observed in Stage C. The impact of cycled aeration alone (no flow peaking) is more difficult to ascertain. TMP rise rate following Event 11 and the first part of Event 12 was low, but increased rapidly near the end of testing. The latter effect may be the result of operation at high TMP levels (significant fouling present) rather than from intermittent aeration. Future testing using intermittent aeration should be conducted with a clean membrane to more clearly determine its impact on membrane fouling. It should be noted that during flow peaking events, the vacuum after backpulsing was slightly higher than before backpulsing. This indicates that backpulsing had little effect in reducing the TMP (or increasing permeability) during flow peaking. During normal flow operation, post-backpulse TMP was always less than pre-backpulse values.



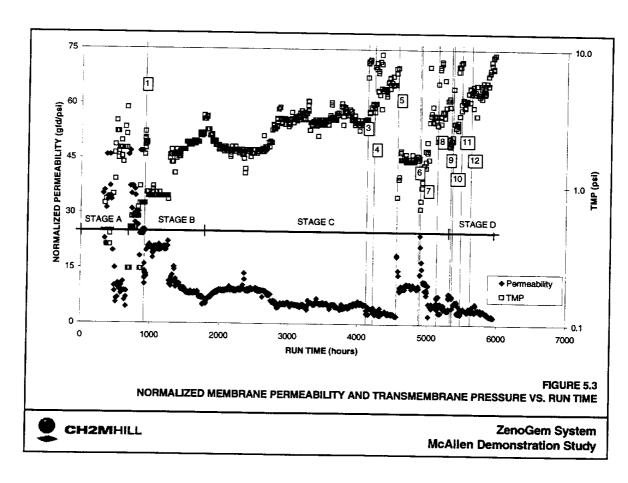


Permeability.

Stages A – C. Figure 5.3 illustrates changes in ZenoGem permeability as a function of operating time (TMP is also shown for reference). During Stage B, permeability (normalized to 20°C) steadily decreased as TMP increased, indicating membrane fouling at the higher MLSS concentration of 13 g/L. In contrast, at the lower MLSS concentration in Stage C, permeability increased and remained relatively constant as TMP very gradually increased. However during the flow peaking test periods (Events 3, 4 and 8), permeability sharply decreased as TMP increased. This showed that the MBR system must be provided with a means of ensuring slow changes in peak loading. The peak loading cannot be raised as quickly over a 24-hour period as in a conventional WWTP. These results also confirm that ZenoGem operation at 10 g/L MLSS concentration and constant flux provides for very stable system operation.

Following raising of the membrane module and subsequent aeration of the membrane tank without operation of the permeate pump (no permeation), permeability decreased (Event 7). Subsequent operation with cycled aeration to the membrane tank produced a rapid and significant decrease in permeability.

Stage D. Operation under conditions of cycled aeration and/or flow peaking generally caused more rapid declines in permeability than operation at normal (steady) flow and continuous aeration, consistent with results under similar conditions during Stage C. This performance indicates that cycled aeration is less effective than continuous aeration in controlling foulant accumulation.



5.2.3 ZenoGem Biological Treatment Performance

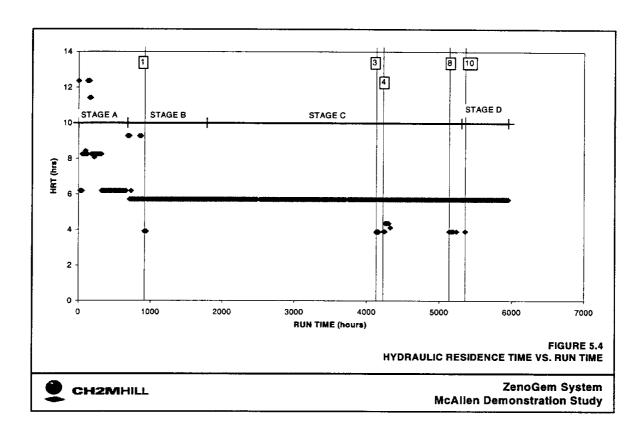
Table 5.7 presents the average conditions within the ZenoGem bioreactor (volume weighted composite of the aeration and membrane tanks) during each stage of operation.

TABLE 5.7 Results of Biological Treatment Performance Analyses for the ZenoGem System

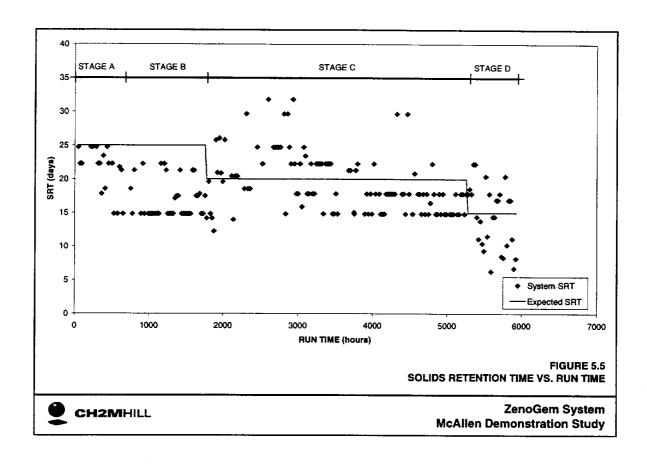
Parameter	Target ^a	Stage A	Stage B	Stage C	Stage D
DO (mg/L)	> 1.5	2.78	1.53	2.00	3.19
OUR (mg O ₂ /L-min)	1.0 - 1.5			0.87	1.34
MLSS (mg/L)	13,000 (Stage A & B) 10,000 (Stage C) 6,000 (Stage D)	11,454	14,070	10,634	6,661
MLVSS (mg/L)		8,339	10,243	7,655	4,873
Sludge Wasted Daily (gals)	90 (Stage A & B) 110 (Stage C) 150 (Stage D)	96	131	114	182
Sludge Yield		1.27	1.50	1.14	2.03
HRT (hrs)	5.7/3.9 ^b	6.2	5.8/3.9 ^b	5.7/4.0 ^b	5.7/3.9 ^b
System SRT (days)	25 (Stage A & B) ^c 20 (Stage C) ^c 15 (Stage D) ^c	21.29	16.79	19.25	14.04

^aWhere target left blank, no target was established. ^bValue during flow peaking. ^cExpected value based on control variables.

Hydraulic Residence Time. Figure 5.4 presents the HRT for the ZenoGem bioreactor. The average HRT for Stage A was slightly higher than the target range due to the step-wise increase in permeate flow to the target value of 6.5 gpm. HRT was held constant and near the target range during subsequent stages, except during flow peaking (Events 1, 3, 4, 8 and 10) when the HRT dropped by 32 percent (from 5.7 hrs at 6.5 gpm down to 3.9 hours at 9.5 gpm). A 6.5-hour HRT was selected to ensure sufficient retention time to achieve complete nitrification based on prior testing at McAllen and other locations. This compares with a HRT of 30 hours for the McAllen WWTP (3 to 4 g/L MLSS) and reflects the greater biochemical oxidation efficiency at the higher MLSS levels.



Solids Retention Time. Figure 5.5 presents the SRT for the ZenoGem bioreactor. The average SRTs were near expected values during each stage, except for Stage B. A higher SRT would be expected for Stage B (versus Stage C) given that the MLSS concentration in the bioreactor was higher and loadings were similar. A lower SRT during Stage B resulted from excess sludge wasting (average 150 gpd compared to the target 110 gpd) in an effort to maintain the target MLSS concentration of 13 g/L. The ZenoGem process has the capability to be operated at a longer SRT (15 to 25 days) than the McAllen WWTP (15 days) because it is not limited by sludge settleability that limits the maximum MLSS concentration that can be accumulated in the system when using clarifiers rather than membranes for biomass retention.

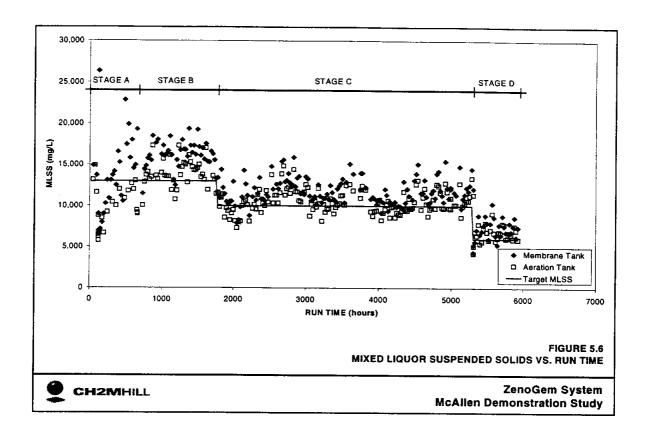


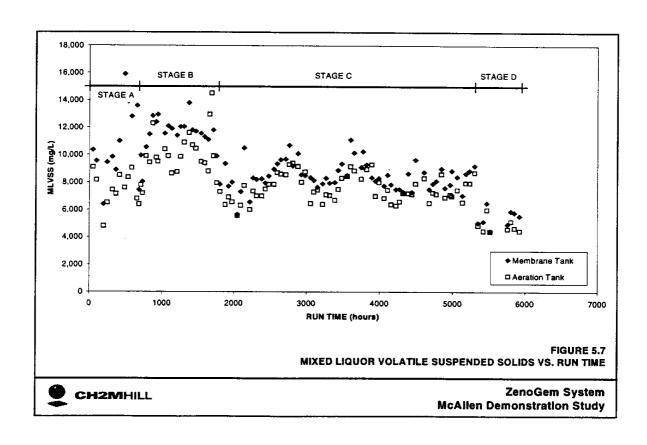
Mixed Liquor Suspended and Volatile Suspended Solids. The McAllen WWTP and the ZenoGem system both use the suspended growth process (activated sludge) to achieve biological treatment. Removal of carbonaceous organic matter in a suspended growth process is directly dependent on the concentration of biomass present in the mixed liquor (activated sludge). Biomass levels can be roughly estimated by measuring the concentration of either the MLVSS or MLSS in the treatment reactor. The latter is more practical for maintaining proper bacterial levels because it is an easier and more rapid method. MLVSS is a more accurate measure of bacterial content because it excludes some of the inert fraction of the suspended solids, however it requires an additional drying and weighing step, which adds time and effort.

MLSS and MLVSS levels measured in the ZenoGem membrane (bioreactor) and aeration tanks are shown in Figures 5.6 and 5.7. The concentration of both parameters should be the same in both tanks under ideal conditions (infinite sludge recirculation rate and exact sludge wasting rates). The average MLSS concentrations in the tanks were at or near target values during each stage. Lower MLSS concentrations in Stage A are representative of startup operations (seeding and MLSS concentration increase to steady-state conditions). Higher than planned MLSS concentrations in Stage B resulted in greater sludge wasting volumes and higher sludge yields. The most common range of MLVSS values for conventional air activated sludge systems is 2,000 to 2,500 mg/L (WEF, 1991). Although air based conventional systems can operate at somewhat higher MLVSS level (up to 3,000 mg/L in practice), sludge settleability decreases as MLSS levels decrease. Settleability is not an issue for the ZenoGem process because separation is not dependent on gravity settling but rather on membrane filtration. However, sludge dewatering characteristics are important as they directly impact observed membrane permeability.

The significance of the greater MLVSS levels is that the ability to remove CBOD $_5$ is directly proportional to bacterial density in the activated sludge tank (or bioreactor). By maintaining higher MLVSS concentrations, the ZenoGem process can attain comparable reduction in CBOD $_5$ at a much lower hydraulic retention time. This is clearly illustrated in Table 5.7, where the average HRT for ZenoGem is about 6 hours versus 30 hours for the WWTP. In fact, as discussed in the following section, CBOD $_5$ removal efficiency was slightly better for the ZenoGem system. In other words, the same, or even greater, degree of treatment can be accomplished in roughly one-fifth of the time or volume used by the extended aeration process used at McAllen. Assuming similar depths for an aeration basin and ZenoGem bioreactor, the tankage area of the ZenoGem process would require only 20 percent of the land area required for the extended aeration basins. It should be noted, however, that it is possible that acceptable treatment could have been achieved in the full-scale McAllen WWTP if another activated sludge process was used.

The average ratio of MLVSS to MLSS for the ZenoGem process was 0.73. This is at the lower end of the typical range (0.7 to 0.9) and reflects the absence of a primary sedimentation step ahead of the ZenoGem process to settle and reduce inerts.



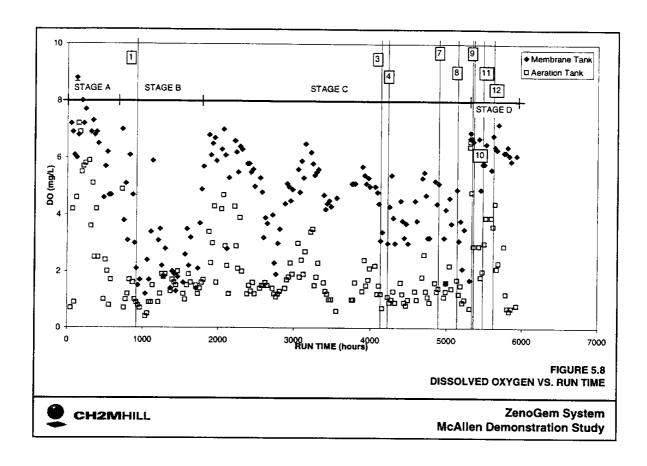


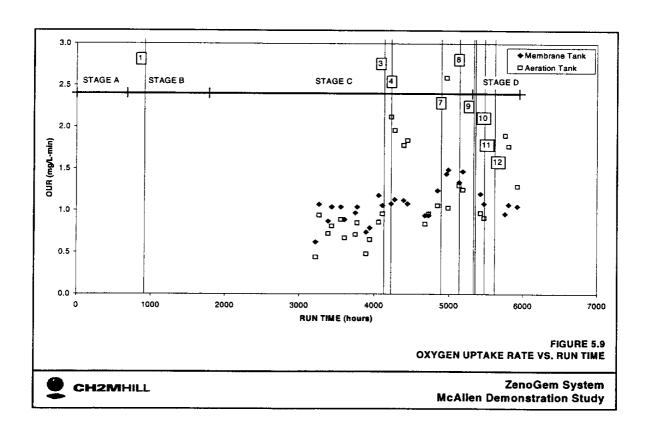
Dissolved Oxygen. Proper DO levels must be maintained in the activated sludge process to enable efficient degradation of both carbonaceous organic matter and organic nitrogen. Generally, DO levels in the activated sludge process should be maintained around 2.0 mg/L or greater to ensure that sufficient oxygen is present to achieve effective BOD₅ removal and nitrification (WEF, 1990). Lower levels will impede nitrification. DO levels of 1.5 mg/L or greater were targeted for the ZenoGem system.

DO levels in the membrane and aeration tanks are presented in Figure 5.8. DO levels were considerably higher than planned during Stage A as the air flowrate was optimized. Lower DO levels in the aeration tank than the membrane tank (38 to 58 percent lower throughout the study) resulted from inadequate air supply. Low DO levels in both tanks during Stage B resulted from high oxygen demand due to high BOD and TSS loading in the feedwater and to the higher MLSS concentration. Periodic increases in the ammonia content of the feedwater resulted in low DO levels during the other stages due to the increased oxygen demand required for nitrification.

Oxygen Uptake Rate. OURs in the membrane and aeration tanks are presented in Figure 5.9. OUR values were less than target from startup to the middle of Stage C due to error in the analytical method used. Samples were held for several hours prior to analysis (rather than being performed immediately), thereby decreasing oxygen uptake potential. After 3,216 hours of operation, OUR analysis was performed correctly and OUR values increased significantly.

Sludge Yield. Sludge yield coefficient, *Y*, is a measure of the amount of biological solids produced by a wastewater treatment process relative to the amount of organic matter removed. Ideally, the sludge yield should be as low as possible to minimize the need to dispose of sludge. For the extended aeration process used at the WWTP, *Y* is typically low because the microorganisms in the activated sludge operate in the endogenous phase based on the long mean SRT for this type of system (15 days). *Y* values for the ZenoGem system should be somewhat lower than the WWTP because the ZenoGem system operated at slightly higher SRTs; however this was not the case. The average sludge yield for the ZenoGem process ranged from 1.14 to 2.03 grams of sludge produced per gram of CBOD₅ removed. Based on the data available from the McAllen WWTP control logs, sludge yield for the McAllen WWTP was 0.73.





5.2.4 ZenoGem Water Quality Impacts

Several water quality parameters were measured to monitor the effectiveness of ZenoGem biological treatment and membrane filtration in improving wastewater quality. Table 5.8 presents the results of water quality analyses of the ZenoGem feed (SDS) and permeate during Stages A and B. The system operated at constant flow/flux during both stages, except for a brief 25-hour flow peaking period at the end of Stage B.

TABLE 5.8
Results of Stages A and B Water Quality Analyses for the ZenoGem System

				Stage B					
Parameter		Sta	Stage A		nal Flow	Peak Flow (Event 1)			
Physical/Chemical	Permeate Target ^a	Feed	Permeate	Feed	Permeate	Feed	Permeate		
рН		7.23	7.33	7.22	7.59	7.12	7.58		
Temperature (degrees C)		25.6	26.3	27.1	28.2	26.0	26.5		
Turbidity (NTU)	< 0.2		0.17		0.24		0.34		
Conductivity (µS/cm)		1,986	1,714	2,138	1,716	1,975	1,765		
COD (mg/L)		300	5.0	620	15.0		·		
CaH (mg/L as CaCO ₃)					331		360		
ALK		391	154	422	203		230		
Biological						···	- <u></u>		
CBOD₅ (mg/L)	< 2	228	1.77	230	0.85	276	1.98		
TSS (mg/L)	< 1	238	0.30	183	0.27	152	0.40		
T-Phosphorus (mg/L as P)		20.65	0.96	14.00	0.18				
NH₃-N (mg/L as N)	< 0.5	26.93	0.16	25.36	5.68	26.50	6.58		
TKN (mg/L as N)		111	3.31	75	9.73				
NO ₂ /NO ₃ -N (mg/L as N)		0.03	19	0.17	5.83				
Total Nitrogen (mg/L as N)		111	22	75	16				
Microbial	·			<u> </u>	····				
Total Coliforms (CFU/100mL)	< 2.2		3.0		109.4		84.0		
Fecal Coliforms (CFU/100 mL)	0		4.5		41.9		175.0		
HPC (CFU/mL)	< 500		1,619		3,276				

 $^{^{}a}$ Where target left blank, no target was established. µS/cm=microSiemens per centimeter.

Table 5.9 presents the results of water quality analyses of the ZenoGem feed and permeate during Stage C. The system operated at constant flow/flux during this stage, except during three flow peaking events and a 242-hour period when air was cycled to the membrane tank.

TABLE 5.9Results of Stage C Water Quality Analyses for the ZenoGem System

				Pea	k Flow	Normał Flow with Cycled Aeration to Membrane Tank Only	
Parameter		Normal Flow		(Ever	its 3,4,8)	(Event 7)	
Physical/Chemical	Permeate Target ^a	Feed	Permeate	Feed	Permeate	Feed	Permeate
pH		7.16	7.42	7.20	7.37	7.20	7.35
Temperature (degrees C)		29.6	30.8	30.6	31.5	28.7	29.9
Turbidity (NTU)	< 0.2		0.15		0.10		0.15
Conductivity (µS/cm)		1,904	1,612	1,669	1,469	1,958	1,678
COD (mg/L)		383.3	15.6	380	13.0		
CaH (mg/L as CaCO ₃)			345		312		322
ALK		352	128	336	158	334	176
Biological							
CBOD ₅ (mg/L)	< 2	164	0.57	161	0.08	156	0.54
TSS (mg/L)	< 1	130	0.28	122	0.20	107	0.24
T-Phosphorus (mg/L as P)		9.55	3.34	5.23	3.15		1.97
NH₃-N (mg/L as N)	< 0.5	23.17	0.56	23.16	0.24	23.18	0.91
TKN (mg/L as N)		47	2.94	37	2.20	38	8.50
NO ₂ /NO ₃ -N (mg/L as N)		0.38	15.47	0.03	6.51	0.04	1.46
Total Nitrogen (mg/L as N)		47	18	37	9	38	10
Microbial							•
Total Coliforms (CFU/100mL)	< 2.2		15.1		17.3		82.2
Fecal Coliforms (CFU/100 mL)	0		8.9		8.8		26.1
HPC (CFU/mL)	< 500		1,383		2,891		3,237

^aWhere target left blank, no target was established.

Table 5.10 presents the results of water quality analyses of the ZenoGem feed and permeate during Stage D. The system operated in an alternative operating mode with a reduced MLSS concentration (6 g/L) and peak flow and/or cycled aeration to one or both tanks.

TABLE 5.10Results of Stage D (Alternative Operating Mode) Water Quality Analyses for the ZenoGern System

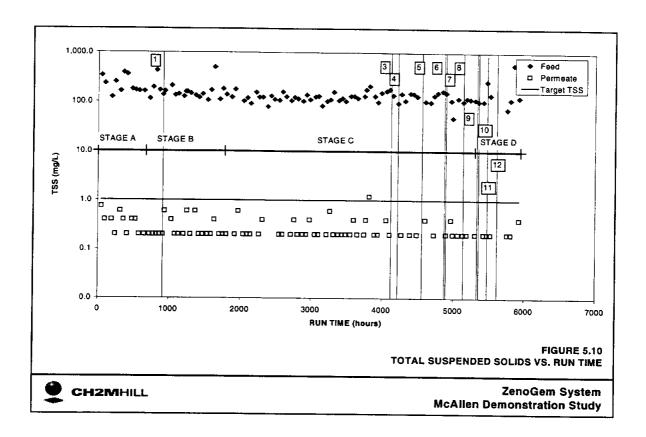
		Normal Flow with Cycled Aeration to Membrane Tank (Event 9)		Peak Flow with Cycled Aeration to Membrane Tank Only (Event 10)		Normal Flow with Cycled Aeration to Membrane Tank Only (Event 11)		Normal Flow with Cycled Aeration to Membrane and Aeration Tanks (Event 12)	
Parameter									
Physical/Chemical	Permeate Target ^a		Permeate	Feed	Permeate	Feed	Permeate	Feed	Permeate
pН				7.06	7.13			7.13	7.33
Temperature (degrees C)		29.3	29.8	29.4	30.3	29.1	31.0	28.1	26.6
Turbidity (NTU)	< 0.2		0.12		0.10		0.13		0.14
Conductivity (µS/cm)		1,796	1,533	1,695	1,487	1,595	1,448	1,575	1,338
COD (mg/L)				448	15.0			292	14.0
CaH (mg/L as CaCO₃)					280		300		316
ALK				360	110	320	124	380	180
Biological			·						
CBOD₅ (mg/L)	< 2	146	0.03	157	0.15	154	0.17	154	0.37
TSS (mg/L)	< 1	104		184	0.20	140	0.20	220	0.27
T-Phosphorus (mg/L as P)		6.07	3.19	5.45	1.44	3.87	2.73	4.94	1.44
NH ₃ -N (mg/L as N)	< 0.5	21.30	0.05	24.85	0.15	17.20	0.14	24.28	0.31
TKN (mg/L as N)		42	2.0	43	2.0	39	2.0	47	2.85
NO ₂ /NO ₃ -N (mg/L as N)		0.01	18.30	0.02	13.5	0.01	20.10	0.01	3.96
Total Nitrogen (mg/L as N)		42	20	43	16	39	22	47	7
Microbial									
Total Coliforms (CFU/100mL)	< 2.2				8.5		9.0		6.4
Fecal Coliforms (CFU/100 mL)	0				2.0				
HPC (CFU/mL)	< 500				2,102		1,600		2,458

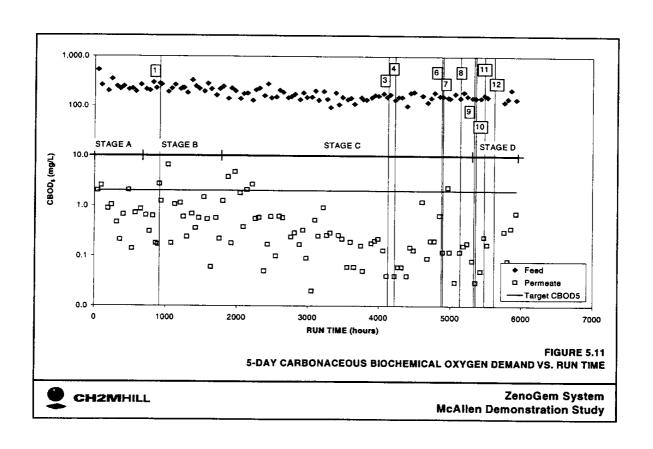
^aWhere target left blank, no target was established.

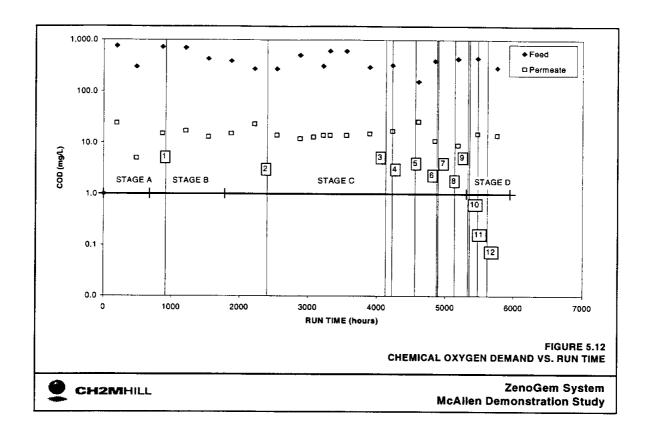
Particle Removal. The ZenoGem system achieved greater than 99 percent removal of TSS and CBOD during all stages of operation and was effective in reducing TSS and CBOD, in the wastewater to below target levels as shown in Figures 5.10 and 5.11. TSS measurement is not sufficiently sensitive to detect potential differences in TSS removal as a function of MLSS concentration. Figure 5.12 illustrates that COD was consistently reduced to less than 20 mg/L in the ZenoGem permeate. COD removal efficiency was not impacted by MLSS concentration.

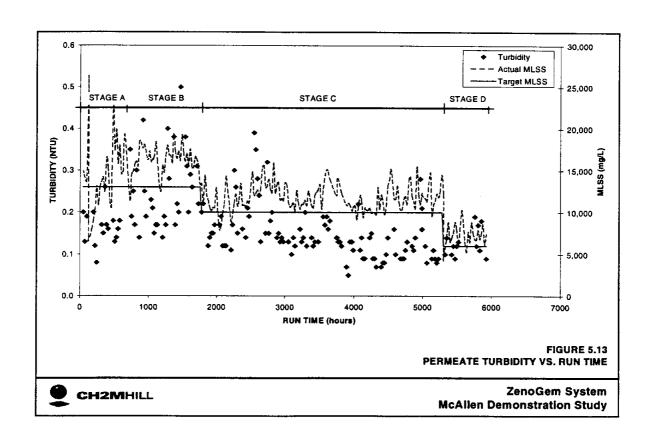
As shown in Figure 5.13 and Table 5.8, the average permeate turbidity was slightly higher in Stage B as compared to Stage A and to the target level of 0.2 NTU established for feedwater to the downstream RO system. This suggests greater particle passage through the OKC MF versus the OCP UF membrane at the higher MLSS concentration. Permeate turbidities were higher during Stage B than Stage C (see Table 5.9), suggesting that particle passage through the OKC membrane is greater at high solids loading (high MLSS concentration).

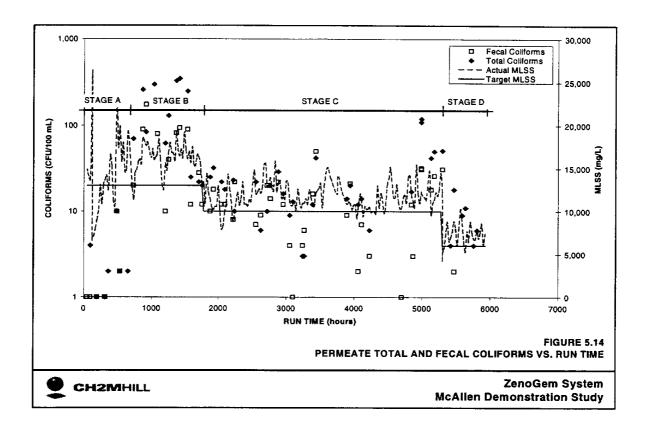
Microbial Removal. Trends observed for turbidity removal were also seen with microbial removal. As shown in Figure 5.14, the average total and fecal coliform levels were higher in Stage B as compared to Stage A. This suggests greater bacteria passage through the MF versus the UF membrane at equal MLSS loadings. The increase coliform levels observed in Stage B compared to Stage C suggest bacteria passage through the MF membrane is a function of MLSS concentration. The high HPC levels may reflect bacterial regrowth in the ZenoGem permeate piping in the absence of a continuous disinfectant. In general, total and fecal coliform levels exceeded the informally adopted goal of State of California "Title 22" regulations pertaining to unrestricted access (2.2 CFU/100 mL for total coliforms and 0 CFU/100 mL, respectively).











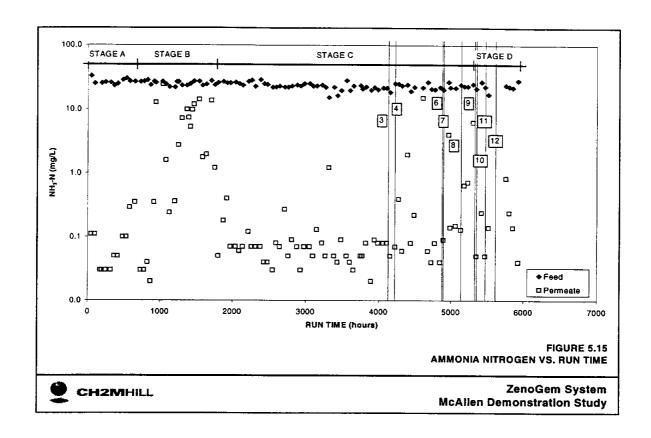
Nutrient Removal.

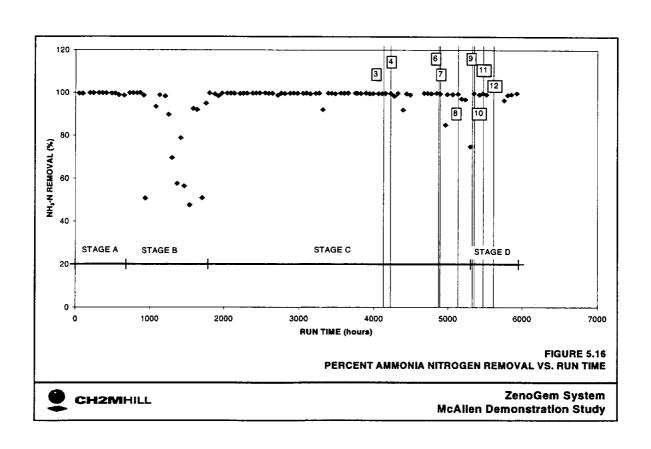
Nitrogen Transformation. At the long SRTs used in this study and the high wastewater temperatures, the activated sludge portion of the ZenoGem process should be able to achieve complete nitrification, i.e., the conversion of ammonia-nitrogen to nitrate-nitrogen. A potential constraint is the ability to supply sufficient oxygen to the process, given the relatively short HRT and the high volumetric organic loading rate. Assuming sufficient DO levels and a well mixed biomass, denitrification should be minimized. These were the expectations at the start of the study.

Ammonia Removal. Ammonia nitrogen feed and permeate levels and percent removal by ZenoGem as a function of operating time are shown in Figures 5.15 and 5.16. Feed levels were relatively constant, ranging from 15 to 30 mg/L. Permeate concentrations were less than the target of 0.5 mg/L at normal flow conditions, except during Stage B. Removals were essentially complete during all stages, except Stage B. Reduced removals (partial/incomplete nitrification) during Stage B most likely reflect impaired efficiency of oxygen transfer to the nitrifiers within the dense flocs present at the higher MLSS concentration (~13 g/L) and high wastewater temperatures. Although dissolved oxygen levels in the bulk liquid were within acceptable range to achieve nitrification (under conventional wastewater MLSS levels), transfer of this oxygen from bulk liquid to bacteria contained within the flocs was not sufficient to achieve complete nitrification at the provided HRT. The reduced nitrification efficiency at higher MLSS levels suggests that MBR operation at such levels may be constrained by oxygen transfer efficiency unless such a constraint can be overcome by increase air input or better gas-to-liquid transfer efficiency than attained in this study.

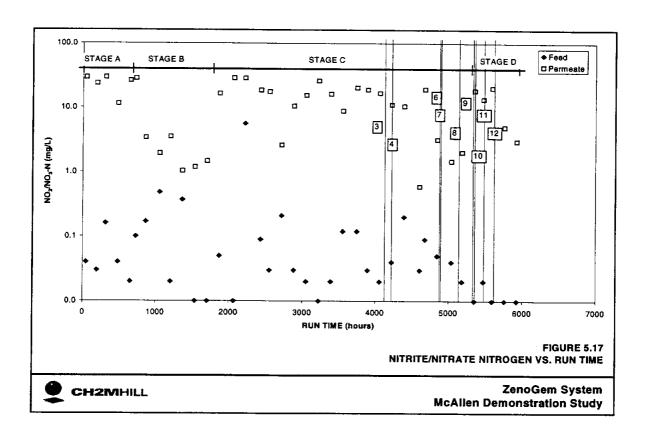
When comparing normal flow versus flow peaking in Stages B and C, nitrification (ammonia removal) was incomplete during peaking due to the decrease in HRT from 5.7 hrs to 3.9 hrs. Cycled aeration to the membrane tank had no real effect on nitrification efficiency in Stage C. Ammonia removal was reduced from 98 to 97 percent only. This result is not surprising as most of the oxygen for biological oxidation is provided in the aeration tank. During Stage D, flow peaking with cycled aeration to both tanks during showed no significant decrease in nitrification when compared to normal flow and full aeration operation.

During all stages, the rate of nitrification was calculated at $0.48~mg/L~NH_3-N~per~mg/L~MLVSS$ per day regardless of MLSS concentration or permeate flowrate. However, during cycled aeration to both tanks in Stage D, the nitrification rate increased to $0.72~mg/L~NH_3-N~per~mg/L~MLVSS$ per day.





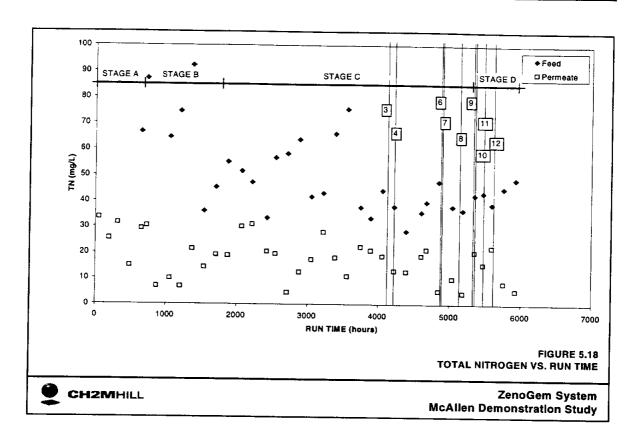
Nitrite/Nitrate Removal. Feed and permeate nitrite/nitrate nitrogen levels for the ZenoGem system as a function of operating time is shown in Figure 5.17. Feed levels were < 0.4 mg/L in all cases, as anticipated. Permeate levels ranged from 15 to 19 mg/L in Stages A and C. During Stage B and the end of Stage D, permeate levels were significantly less. Permeate levels are a function of the amount of ammonia and organic nitrogen converted to nitrite/nitrate (nitrification) and the extent to which this "converted" nitrogen is reduced to nitrogen gas by denitrifiers. In an aerated system, denitrification (nitrite/nitrate conversion to nitrogen gas) is not anticipated as the bacteria responsible for this reduction operate under anoxic conditions. During Stages A and C, denitrification was minimal yielding higher permeate nitrite/nitrate levels. However during Stage B and the end of Stage D, a significant fraction of the nitrite/nitrate generated from nitrification was converted to nitrogen gas, resulting in a condition of "simultaneous nitrification/denitrification" thus yielding lower permeate nitrite/nitrate levels. This result is consistent with the hypothesis offered under the Ammonia Removal discussion where reduced oxygen transfer creates micro anoxic zones within the mixed liquor, providing conditions conducive to the growth of denitrifiers. At the end of Stage D, conditions to produce this effect were put into place through cycled aeration in both treatment tanks. Such conditions were very effective for achieving a high level of both nitrification and denitrification, as illustrated by the data in Table 5.10 (Event 12) where permeate ammonia and nitrite/nitrate nitrogen concentrations were 0.31 and 3.96 mg/L, respectively.

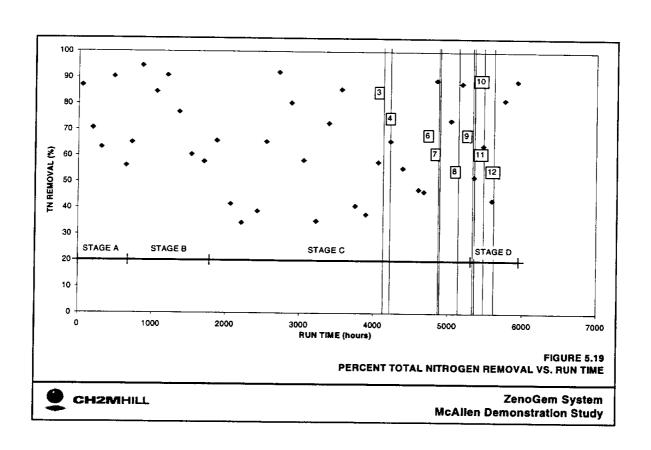


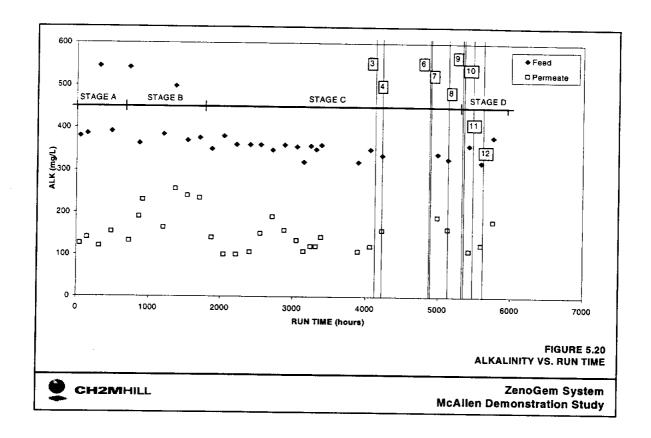
Total Nitrogen Removal. Feed and permeate total nitrogen (TN) levels and percent removal by the ZenoGem system as a function of operating time are shown in Figures 5.18 and 5.19. Feed TN levels were exceptionally high during Stages A and B, decreasing to the 38 to 47 mg/L range during the remainder of testing. As shown in Tables 5.8through 5.10, highest permeate TN levels were observed at normal flow rates and at low to medium MLSS levels. Cycled aeration to the membrane tank had only minor impact on TN levels. TN removal was higher in Stage B as compared to Stage C due to nearly complete denitrification, in spite of the fact that partial nitrification (higher permeate ammonia and lower permeate nitrite/nitrate levels) was observed. TN removal decreased as a result of complete nitrification (lower permeate ammonia and higher permeate nitrite/nitrate levels) and reduced denitrification when the MLSS concentration was decreased in Stage C. The greatest degree of TN removal was observed at the end of Stage D (Event 12) during cycled aeration to both tanks. As previously discussed, such aeration is effective at maximizing simultaneous nitrification/denitrification. With a 15-minute on/off aeration cycle, the ZenoGem system was capable of reducing TN levels to 7 mg/L.

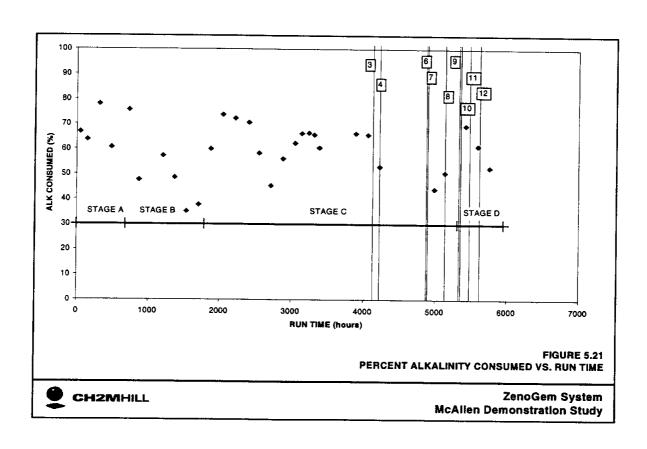
Alkalinity Consumption. During nitrification, alkalinity is consumed. During denitrification alkalinity is created. Assessing alkalinity reductions during the various stages of operation provides a means of "proofing" observed ammonia removals as well as providing a semi-quantitative measure of biological oxidation of non-ammonia organic nitrogen compounds. . Theoretically, 7.1 parts of alkalinity are consumed for each part of ammonia oxidized. As shown in Figure 5.20 during Stage B, alkalinity levels were reduced from an average of 422 mg/L as CaCO3 in the feed to 203 mg/L as CaCO3 in the permeate, yielding an alkalinity consumption of 219 mg/L as CaCO₃. In Stage C, levels were reduced from an average of 352 mg/L as CaCO₃ in the feed to 128 mg/L as $CaCO_3$ in the permeate, yielding an alkalinity consumption of 224 mg/L as $CaCO_3$. Based on an average ammonia nitrogen removal of 20 mg/L in Stage B and 23 mg/L in Stage C, 142 mg/L and 163 mg/L of alkalinity (as CaCO₃) should have been consumed in Stages B and C, respectively. The additional alkalinity consumption (77 mg/L as CaCO₃ in Stage B and 61 mg/L in Stage C) would have resulted from the biological oxidation of (non-ammonia) nitrogen compounds present in the wastewater. Ammonia nitrogen accounted for only 34 percent of the 75 mg/L of organic nitrogen (TKN) in Stage B and only 49 percent of the 47 mg/L of TKN in Stage C. These levels of TKN are unusually high for a domestic wastewater and indicate that nitrogen-rich discharges are present in the McAllen wastewater.

From previous discussions, nitrification was reduced and denitrification was significant during Stage B. Alkalinity changes between ZenoGem feed and permeate should reflect these differences; alkalinity removals during Stage B should be less than during Stage C as less alkalinity is consumed (from nitrification) and more is created (from denitrification). As shown in Figure 5.21, average alkalinity removal was 50 percent for Stage B and 64 percent for Stage C. Another way of comparing alkalinity consumption and nitrogen transformation is to correlate alkalinity consumption with total nitrogen removal. Lesser alkalinity consumption should occur with greater nitrogen removal as the ratio of nitrogen transformed from nitrate to nitrogen gas increases relative to the amount of organic nitrogen oxidized to nitrite/nitrate. Total nitrogen removal was 76 percent for Stage B and 58 percent for Stage C.

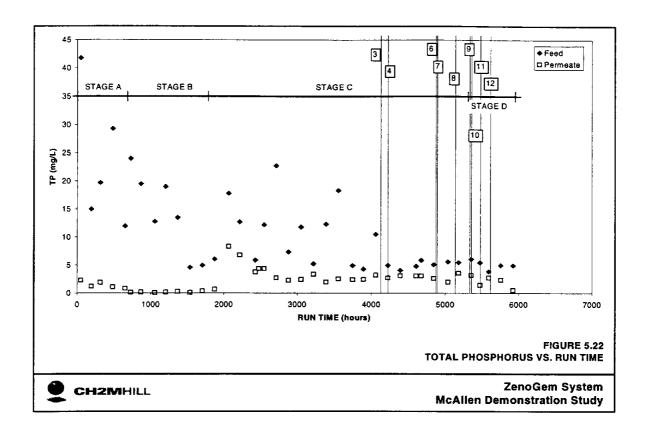


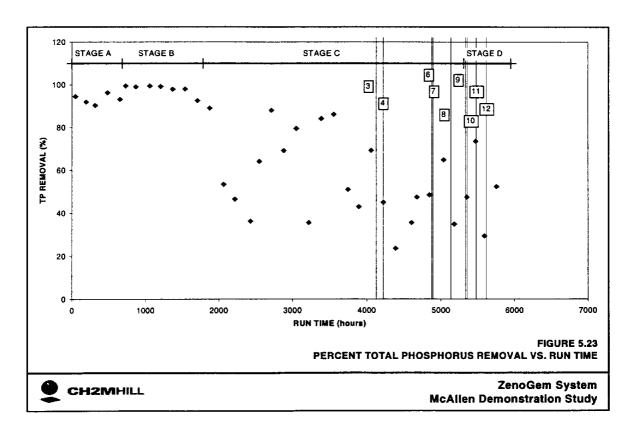






Phosphorus Reduction. Feed and permeate total phosphorus (TP) levels and percent removal by the ZenoGem system as a function of operating time are shown in Figures 5.22 and 5.23. Phosphorus reduction by the ZenoGem process was significantly greater in Stage B than in Stage C at 98 percent and 58 percent, respectively. At the higher MLSS concentration, oxygen transfer to certain zones of the aeration tank was most likely poor, resulting in anaerobic conditions within segments of the biomass producing favorable conditions for biological phosphorus uptake. When the MLSS level was reduced at the beginning of Stage C, these anaerobic zones were eliminated (or greatly reduced) and the phosphorus bound in these organisms was subsequently released, causing phosphorus removal to temporarily increase as shown in Figure 5.23. During the latter part of Stage C, the phosphorus levels in the permeate were in the 2 to 5 mg/L range, which is typical for the conventional wastewater treatment process using secondary treatment and nitrification. Phosphorus removal variability in Figure 5.23 reflects variability in the measured phosphorus levels in the ZenoGem feedwater. Also during Stage C, the phosphorus reduction decreased from 58 percent at normal flow/flux to 40 percent during flow peaking due to the decrease in HRT (insufficient time for phosphorus removal).





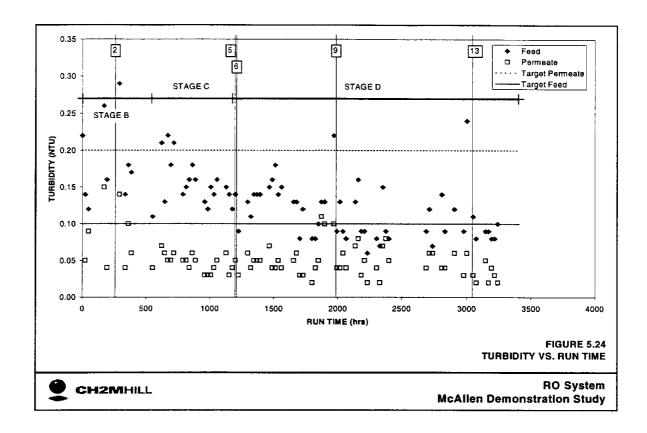
5.3 RO Testing Results

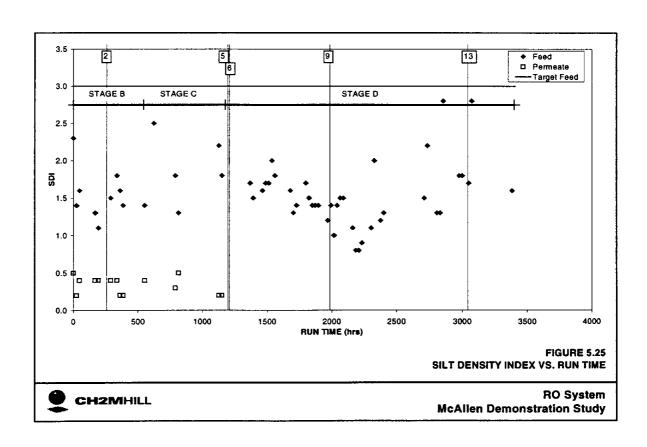
5.3.1 RO Feedwater Quality

Particulate Fouling Potential. Table 5.11 presents the average values for the RO feedwater quality parameters that reflect particulate and colloidal fouling potential (turbidity, SDI and heterotrophic bacteria). For all stages of testing, turbidity and SDI values were less than corresponding target levels, reflecting the low particle water produced by the ZeeWeed membrane. (Turbidity and SDI targets are those established by the spiral wound RO industry based on minimizing RO element fouling and cleaning. With a few exceptions, RO feedwater turbidity averaged less than the 0.2 NTU target (Figure 5.24). As shown in Figure 5.25, the ZenoGem system consistently produced a permeate with a SDI less than the target value of 3. The target of 500 CFU/mL for HPCs is an informal goal that is related to the acceptable level of HPCs in drinking water. There is not established correlation between HPC level in RO feedwater and degree of biological fouling, however, the greater the level the greater the potential to establish biofilms. Actual propensity to form biofilms depends on a number of interrelated factors, including organism type, level of nutrients, water chemistry, membrane material and flow hydraulics through the element. HPC levels were consistently above the target, however, as discussed in a later section of the report, there was no evidence of biological fouling. Taken together, the data in Table 5.11 indicate that the permeate from the ZenoGem permeate should cause little if any particulate fouling of downstream RO membranes.

TABLE 5.11Average RO Feedwater Quality Parameters

Parameter	Target	Stage B	Stage C	Stage D
Turbidity (NTU)	< 0.2	0.18	0.16	0.11
SDI	< 3	1.46	1.83	1.53
HPC (CFU/mL)	< 500	3,274	865	1,444





Mineral Precipitation Potential. Section 3 discussed the need for chemical conditioning of the RO feedwater to prevent the precipitation of calcium carbonate and barium sulfate, based on their levels in the WWTP secondary effluent and the degree to which their coions would be concentrated during RO treatment at target recovery. The mineral saturation calculations provided in the RODesign program (and also by the scale inhibitor suppliers contacted at the beginning of the project) estimate percent saturation for only the following sparingly soluble salts: calcium carbonate, calcium fluoride, barium sulfate, calcium sulfate, strontium sulfate and silica. Consequently, other sparingly soluble salts present in the effluent, including calcium phosphate salts, were not identified as being supersaturated as a result of RO treatment of the ZenoGem permeate. As discussed in Section 5.3.2 of this report, precipitation of calcium phosphate salts occurred during testing and required additional feedwater acidification to control. Analysis of spent cleaning solutions and materials removed from the membrane surface from element autopsies, showed that calcium carbonate and barium sulfate scaling was effectively controlled and that calcium phosphate was the major mineral precipitate.

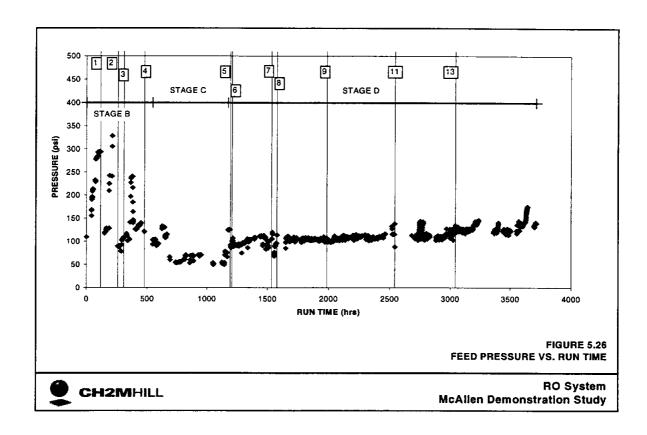
5.3.2 RO Operating Conditions/Membrane Performance

Operating Conditions. Table 5.12 presents the average RO system operating conditions for the following parameters: (recovery, flux, flow, pressure, and conductivity). With the exception of periods during Stage B, the RO system operated at or near target flowrates. Average feed pressure and permeate conductivity was significantly greater during Stage B operation at high recovery because of the increase resistance to flow caused by scaling in the second stage elements during this period. Feed pressure variations as a function of operating time is shown in Figure 5.26. This plot clearly illustrates the high feed pressure periods associated with scaling of the second stage membrane elements during Stage B. These effects were reversed by citric acid cleanings (Events 1, 3 and 4).

TABLE 5.12
Average Operating Conditions for the RO System

	04	Target	Actual	5		Flow (gpm)			Pressure (psi)			Conductivity (µS/cm)		
Stage	Stages in Operation	(%)	Recovery (%)	Flux gfd	Feed	Conc	Permeate	Feed	Interstage	Conc	Feed	Interstage	Conc	Permeate
В	182	80	70.4	10.37	3.98	0.94	2.85	231	220	213	1,608	4,408	3,729	182
B*	182	50	59.0	10.63	5.04	2.29	2.92	132	111	91	1,701	3,544	4,024	150
С	1	50	47.9	9.83	4.11	2.31	2.01	80	NA	65	1,636	3,167	3,330	71
D	1&2	50	48.9	7.71	5.45	2.67	2.95	125	100	63	1,798	2,958	3,520	104
D	1&2	62	63.8	10.03	4.33	2.76	1.45	90	76	63	1,814	3,510	5,017	148
D	1&2	70	68.1	10.50	4.24	2.89	1.41	101	86	74	1,741	3,408	4,998	118
D	1&2	74	72.6	10.62	4.02	2.92	1.12	110	97	87	1,549	3,187	4,970	95
D	1&2	80	79.3	11.89	4.12	3.27	0.86	128	115	107	1,731	3,841	7,210	105

^{*}Target feedwater recovery decreased from 80 to 50 percent after 256 hours of operation (Event 2). NA=Not Applicable



Performance Parameters. Table 5.13 presents RO system target and average actual membrane performance parameters (NPF, salt passage and salt rejection) as a function of operating time. Figure 5.27 illustrates changes in flux as a function of operating time. Membrane flux varied considerably during Stage B, decreasing in proportion to the decline in system productivity. Although testing called for operation at constant flux, the rapid and severe increases in feed pressure make it difficult for the plant operators to provide such control. The step decrease in flux during Stage C was intentional and reflects an attempt to reduce RO fouling potential. Flux was steady during Stage D as mineral precipitation and feed pressure was more effectively controlled.

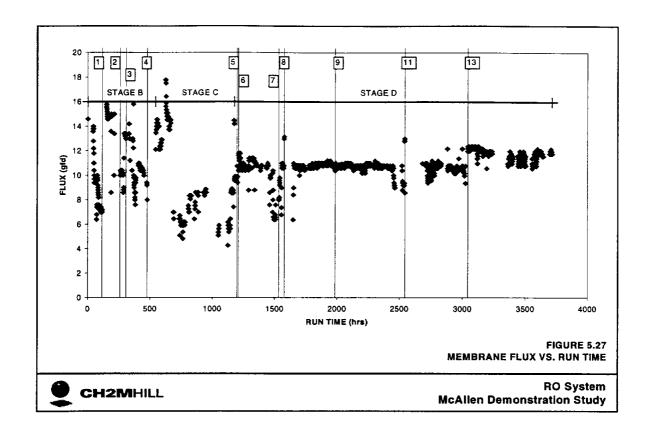
TABLE 5.13Average Membrane Performance Parameters for the RO System

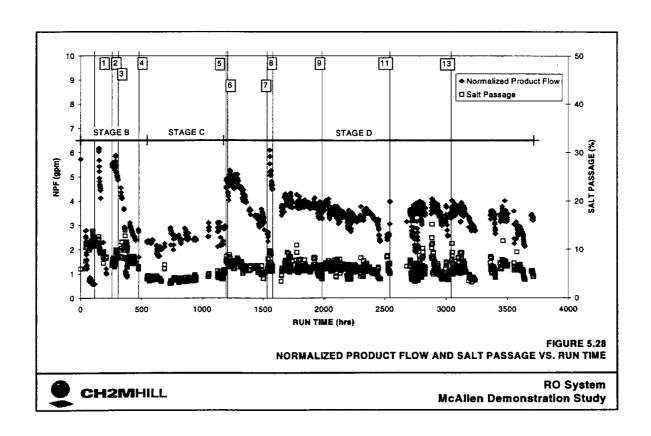
Stage	Stages in Operation	Target Recovery (%)	Normalized Product Flow (gpm)	Salt Rejection (%)	Salt Passage (%)
В	1&2	80	1.88	89.26	10.74
Bª	1&2	50	3.47	91.65	8.30
С	1	50	2.38	95.90	4.10
D	1&2	50	2.92	94.57	5.43
D	1&2	62	4.71	92.27	7.73
D	1&2	70	4.02	93.63	6.37
D	1&2	74	3.36	94.18	5.82
D	1&2	80	3.39	94.24	5.76

^aTarget feedwater recovery decreased from 80 to 50 percent after 256 hours of operation (Event 2).

Similarly, NPF showed severe and rapid declines during Stage B. As shown in Figure 5.28, these declines were readily reversible by citric acid cleanings, however operation at high recovery and feed pH (6.8) was not sustainable on a long-term basis. At lower recovery (Stage C), NPF was quite stable confirming that performance declines were recovery and scaling related. With return to two-stage operation and recovery of 70-75 percent (Stage D), NPF again declined but a lesser rate, reflecting the partial effectiveness of reduced pH (6.0-6.5) operation. However, stable performance could not be achieved until feedwater pH was reduced to 5.0, corresponding to a concentrate pH of 5.6. As recovery was further increased to 80, inability to effectively control concentrate pH at 5.6 again resulted in rapid NPF decline.

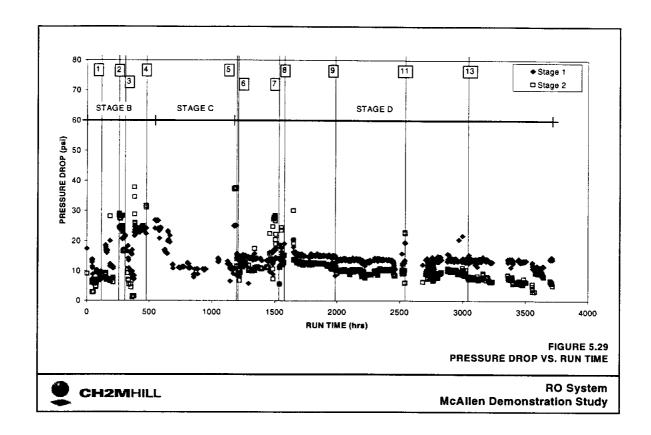
Normalized salt passage was less impacted by scaling than NPF, with the exception of Stage B operation when scaling was worst (Figure 5.28). Normalized salt passage was comparable at the very beginning of Stage B (6 percent at 4 hours) and at the end of routine testing (5 percent at 3,400 hours). This indicates no loss in salt rejecting capability by the RO membranes over the course of this testing despite repeated membrane scaling and citric acid cleaning.

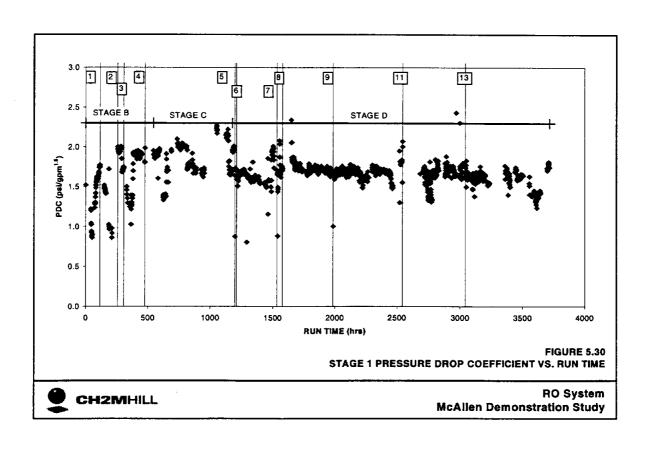




Figures 5.29 and 5.30 present vessel differential pressure (pressure drop) for each RO system stage during the testing as well as pressure drop coefficient for Stage 1 only as a function of operating time. In RO systems operating on MF-treated wastewater effluent or MBR permeate, pressure drop is monitored primarily to indicate the occurrence biological fouling, which causes a characteristic rise in Stage 1 pressure drop. Pressure drop reflects the resistance of water flow through the RO element feed spacer. As material accumulates within the spacer or on the membrane surface, pressure drop increases. Pressure drop coefficient accounts for changes in flow through the pressure and allows for a better comparison of systems operating at different recoveries. In general, the data in the figures indicate the absence of biological fouling. Stage 1 PDC was relatively unchanged, except during the beginning of Stage B. During the period considered most representative of a properly operated RO system (Stage D, 1,500 to 3,000 hours), both pressure drop and PDC were extremely stable. The very gradual decline in pressure drop during Stage C was associated with the decrease in recovery (lower feedwater flow through the feed channels).

¹Pressure drop coefficient (PDC) is defined as follows: PDC = pressure drop /(feed flowrate)^{1,5}





Calcium Phosphate Scaling and Its Impacts on RO System Feed Pressure and Productivity. During Stage B, NPF declined rapidly (see Figure 5.28). Cleanings with citric acid were effective in restoring performance losses (Event 1) but with subsequent operation, NPF again rapidly declined. At this time, mineral precipitation was considered the likely cause for loss of RO performance. Biofouling was unlikely based on stable pressure drop readings. A second citric acid cleaning was then conducted (Event 2) and a portion of the second stage spent cleaning solution was analyzed to better determine the nature of the mineral precipitant. Calcium, aluminum and phosphorus were present in elevated concentrations relative to the other metals. Calcium and aluminum phosphate salts were considered the primary scaling concern, as calcium carbonate precipitation was controlled by feedwater acidification. Appendix E presents results of the cleaning solution analysis.

To determine the exact type of scale, the ZenoGem permeate, which becomes RO feedwater after chloramination, was analyzed twice a week during the period June 9 through June 23, 1999 for ions that can form precipitable salts, including phosphorus and sulfate, and metals, including barium, aluminum, and iron. (Calcium hardness, alkalinity and phosphorus levels in the ZenoGem permeate were routinely analyzed as part of ZenoGem peformance monitoring protocol.) The analysis showed less than detectable levels of the oxidizable metals aluminum and iron (<0.1 mg/L). Barium and sulfate were present at concentrations less than their solubility (as barium sulfate salt) for operation at 80 recovery (0.06 mg/L and 226 mg/L, respectively). Phosphorus levels were significant relative to natural water supplies (14 mg/L). Given the high concentration of calcium hardness in the wastewater (356 mg/L), calcium phosphate scaling was indirectly suspected. Appendix F presents results of ZenoGem permeate ion analyses.

To further confirm that scaling and not fouling caused performance losses, the second stage was removed from service after 546 hours of operation and the first stage was operated at 50 percent recovery (Stage C). At the lower percent recovery and operating only the first stage vessels, the feed pressure and NPF decreased and remained relatively low and constant during Stage C. Performance stabilized at the lower recovery confirming that performance declines were a result of ion concentration and mineral precipitation. Calcium phosphate scaling is not commonly encountered in municipal RO operations because phosphate levels in most natural raw water supplies are not elevated. Furthermore, based on discussions between CH2M HILL and several scale inhibitor manufacturers (i.e., FMC, KLT, Permacare), calcium phosphate precipitation is not effectively prevented by commercially available RO scale inhibitors. Consequently, three scaling mitigation methods were considered to control the precipitation tendency in lieu of a specific inhibitor:

1. **Decrease RO feedwater pH.** The calcium phosphate solubility index² was used to calculate the pH of the RO concentrate at which calcium phosphate concentration in the RO concentrate would be less than solubility ($SI = pH-pH_c$, where SI is <0). By trial and error iteration, the resulting pH was used to calculate corresponding feed

² The calcium phosphate solubility index (SI) is defined as follows: SI = pH - pH_c, where pH_c = 11.755 - (log calcium ions + log of phosphate ions = 2*log temperature)/0.65 (Green and Holmes, 1947).

pH using Hydranautics RODesign and the design conditions discussed in Section 3.3.1. Although this approach would require significant acid dose (~100 mg/L), it has the added benefit of increasing the solubility of both aluminum phosphate and calcium carbonate. This approach was considered the easiest to implement for this study.

- 2. Chemically precipitate excess phosphorus from the screened, degritted wastewater during ZenoGem treatment. Addition of an aluminum or iron salt to the wastewater would produce highly insoluble aluminum or ferric phosphates easily filterable by the ZeeWeed MF membrane. It was calculated that a dose of 45 mg/L of ferric chloride would be required to reduce the phosphate concentration in the ZenoGem permeate to 0.5 mg/L. a level that would reduce the calcium phosphate solubility index to < 0 at 80 percent recovery. This level of coagulant addition would generate more sludge, increase MLSS concentrations, require a reduction in SRT to maintain the 10 g/L target MLSS concentration and potentially increase the fouling rate of the ZeeWeed membrane.
- 3. **Biologically remove phosphorus by creating an anaerobic zone in the membrane bioreactor.** This was done in an uncontrolled manner during ZenoGem Stage B operation but would require extensive testing to develop the necessary operating strategy relative to oxygen input. Such testing was beyond the scope of this project.

The second stage was returned to service after 1,177 hours of operation (Stage D) and the system continued to operate at 50 percent recovery. After 1,533 hours of operation and step-wise increase in recovery to 70 percent, a target pH of 5.6 was established for the RO concentrate (corresponding to feed pH of 5.0) to maintain calcium phosphate solubility (Scaling Mitigation Method 1). However, difficulties with both the acid feed pump and PLC pH control loop caused difficulty in consistently maintaining the pH during the remainder of testing. After 1,579 hours of operation, the fourth acid cleaning was performed. Feed pressure and NPF was reduced by the cleaning and remained relatively constant until feedwater was increased to 75 percent after 1,985 hours of operation. Thereafter, feed pressure increased and NPF decreased until another cleaning was performed at 2,544 hours of operation to restore performance. Increasing the recovery to 80 percent after 3,042 hours of operation resulted in a rapid increase in feed pressure and decrease in NPF. These results indicate that the decrease in RO feedwater pH effectively stabilized system performance and reduced fouling potential when operating at a feedwater recovery up to 70 percent. Stable system performance could not be maintained at the higher recoveries (75 to 80 percent), even with the decrease in RO feedwater pH.

Autopsy of the trailing element(s) from Stage 2 confirmed calcium phosphate as the primary precipitate (see Appendix G).

5.3.3 RO Water Quality Impacts

Control of Major Contaminant Categories. Table 5.14 presents the results of water quality analyses of the RO system feed, permeate, and concentrate during each stage of operation. These data are presented to illustrate the ability of RO treatment to reduce the concentration of particulate, microbial, inorganic and organic contaminants in the ZenoGem permeate (i.e., wastewater effluent). Per the objectives of the study, the following surrogate parameters were monitored through the study to demonstrate such removal capability: turbidity (representing particles), coliforms and HPCs (representing pathogenic bacteria), conductivity and TDS (representing inorganic) and TOC (representing organic).

TABLE 5.14

Average Water Quality Results for the RO System

Parameter			Stage B			Stage C			Stage D		
Physical/Chemical	Permeate Target*	Feed	Permeate	Conc	Feed	Permeate	Conc	Feed	Permeate	Conc	
pH		7.13	6.00	7.32	7.30	6.07	7.44	6.22	5.66	6.06	
Conductivity (uS/cm)		1,651	86	3,420	1,560	63	3,718	1,668	110	5,367	
Turbidity (NTU)	< 0.1	0.18	80.0	0.54	0.16	0.05	0.32	0.11	0.05	0.36	
SDI		1.46	0.33		1.83	0.32		1.53		1.57	
TOC (mg/L)	< 1	6.18	< 0.5		6.77	< 0.5		6.62	< 0.5		
TDS (mg/L)	< 500	999	51	2,341	943	44	1,702	899	73	3,503	
Microbial											
Total Coliform (CFU/100 mL)		2.0	7.0		5.7	2.9		6.0	1.0		
Fecal Coliform (CFU/100 mL)	0				2.0	2.0		3.0	2.0		
HPC (CFU/mL)		3,274	110		865	65		1,444	276		

^aWhere target left blank, no target was established.

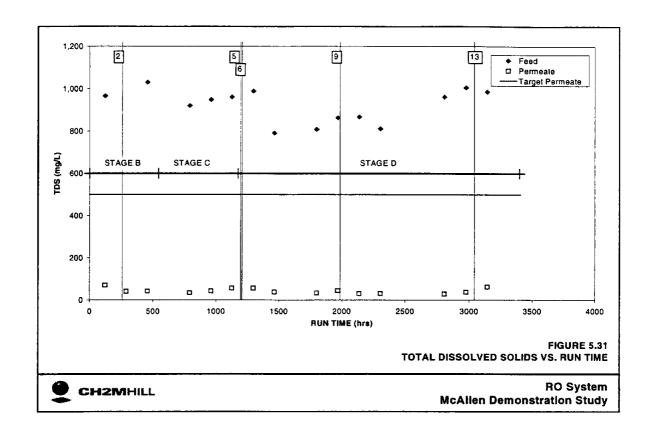
Particulate. As described in earlier in this section, turbidity levels in the RO feedwater were well controlled by ZeeWeed membrane (average of 0.15 NTU). Consequently, only minor improvements in turbidity were possible by the RO system. RO permeate turbidity was consistently measured at to 0.05 NTU. This compares with the target level of 0.1 NTU and the current Environmental Protection Agency (EPA) regulatory level of 0.3 NTU for conventional water treatment plants (95 percent of readings).

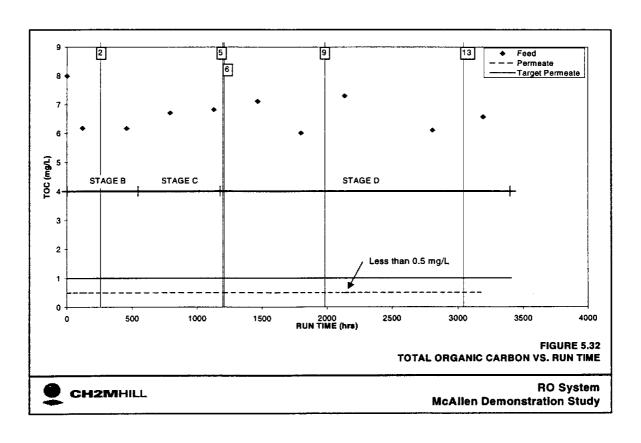
Microbial. The target level of coliforms was established at 0 CFU/mL. Coliforms were routinely measured in the RO permeate, typically at levels of 2 CFU/mL based on similar levels in the feed. This is surprising given the presence of a low level of monochloramines in the RO feed and permeate. HPCs were reduced by more than an order of magnitude by RO treatment, with permeate levels less than the drinking water trigger level of 500 CFU/100mL.

Inorganic. At the target 80 percent recovery (beginning of Stage B and end of Stage D), RO treatment produced an effluent (permeate) having an average TDS of 66 mg/L (in the absence of mineral scaling effects), significantly below both federal and State of Texas secondary drinking water standard for TDS (500 and 1,000 mg/L, respectively). The average RO permeate TDS compares very favorably with the 700 to 800 mg/L TDS level that is typical for the City's existing raw water supply (Lozier, 1998). As shown in Figure 5.31, permeate TDS was consistently < 75 mg/L (greater than 92 percent removal) throughout the study, despite periods of severe membrane scaling.

Organic. As shown in Figure 5.32, TOC levels in the RO permeate grab samples were consistently less than detectable (0.5 mg/L) based on a feedwater TOC range of 6 to 8 mg/L. This represents greater than 92 to 94 percent TOC removals. By comparison, TOC levels in the City's existing raw water supply average 3.8 mg/L (Lozier, 1998) and the California Dept. of Health Services TOC limit for direct injection of reclaimed water is 1 mg/L.

In association with RO membrane integrity studies conducted by the BOR and coincident with these research, permeate TOC levels were measured on-line using two low detection limit (20 ppb) analyzers provided by Sievers and Anatel on a short-term trial basis. Other sites using the Sievers instrument have shown RO systems treating microfiltered secondary effluent contain less than 100 µg/L TOC.





5.4 Impacts of IPR on Waste Discharges

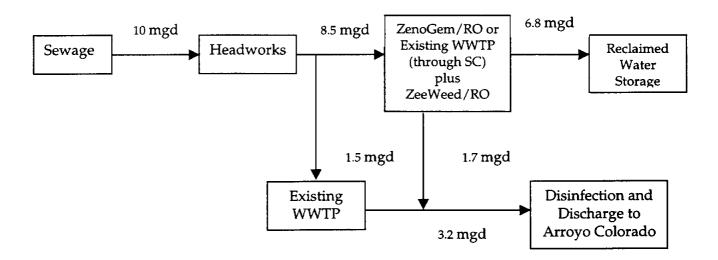
One of the objectives of this testing was to characterize the quality of the ZenoGem permeate and RO concentrate for water quality parameters important to the ecosystems of the Arroyo Colorado and Laguna Madre. The former is a non-perennial waterway to which the City currently discharges the effluent from the South WWTP. Flows into the Arroyo Colorado eventually empty into the Laguna Madre, an estuary that is connected to the Gulf of Mexico. Currently, the City's discharge is regulated with respect to three parameters: CBOD₅, TSS, and ammonia nitrogen. The limits for discharge are as follows:

CBOD₅: 10 mg/L
 TSS: 15 mg/L
 NH₃-N: 3 mg/L

As part of a reuse feasibility study previously conducted for the City, TNRCC expressed concern regarding the presence and concentration of nutrient and TDS in the waste stream(s) from a future IPR treatment system, as it would pertain to discharges to these water bodies. The IPR treatment system evaluated in this research would generate one waste stream, the RO concentrate. Sludge from the ZenoGem system would be dewatered and dried using existing WWTP facilities. For the purpose of this evaluation, it is assumed that 8.5 mgd of wastewater from the WWTP would be diverted to ZenoGem/RO treatment system or, alternatively, 8.5 mgd of WWTP effluent (from the secondary clarifiers) would be diverted for ZeeWeed/RO treatment system. With either alternative, 1.5 mgd (average flow) of undiverted secondary effluent would be disinfected and discharged to the Arroyo Colorado as is currently done. As shown in Exhibit 5.3, these assumed treatment scenarios would result in the following discharges:

- 1.5 mgd of effluent from the South WWTP
- 1.7 mgd of RO concentrate (20% of 8.5 mgd RO feedwater flow)

EXHIBIT 5.3Wastewater Discharge Characterization



In both alternatives, the 8.5 mgd of secondary effluent would be processed by RO to produce 6.8 mgd of final efffluent and 1.7 mgd of RO concentrate (waste). This waste concentrate would then be blended with the remaining 1.5 mgd of WWTP effluent (flow which bypasses IPR treatment), disinfected, and discharged to the current location. As shown in Table 5.15, concentrations of TDS, nutrients and TOC were then calculated for the 47:53 blend of WWTP effluent/RO concentrate using the data collected in Appendix D.

TABLE 5.15
Comparative Loading of Critical Contaminants to Arroyo Colorado/Laguna Madre

	(A)	(B)		
Parameter	RO Concentrate (mg/L) ^a	WWTP Effluent (mg/L) ^a	Composite Stream (Blend) Loading (lbs/day) ^b	Existing WWTP Effluent Discharge Loading (lbs/day) ^c
NO ₂ /NO ₃ -N	29.9	3.45	467	288
T-Phosphorus	10.20	2.38	174	199
TKN	3.16	2	70	167
TDS	3,780	930	65,227	77,562
TOC	28.15	7.25	490	605

Based on average results of two sampling events.

^bCalculated as: 8.34*(1.7*A + 1.5*B) where 1.7=RO concentrate flow (mgd) and 1.5=WWTP effluent flow (mgd).

Calculated as: 8.34*10*B where 10=existing average WWTP effluent flow (mgd).

The comparison shows that for each parameter, the concentration is much higher in the RO concentrate than the WWTP effluent. This reflects the concentration of each parameter by RO treatment and in the case of nitrate, a higher level in the ZenoGem permeate than the WWTP effluent. In some cases, agencies regulate contaminant discharges based on mass loading (pounds of contaminant per day) rather than concentration. Table 5.15 also shows the predicted mass loading for the RO concentrate/WWTP effluent composite stream (blend) verses the current WWTP effluent discharge. In contrast to the concentration comparison, mass loadings for the blend are higher only for nitrate. Consequently, it would be in the City's best interest to work toward establishing mass loading-based discharge regulations versus the current concentration-based regulations if they wish to discharge RO concentrate to the Arroyo Colorado/Laguna Madre ecosystem. If successful, the City could incorporate biological denitrification into the design of the ZenoGem system to control nitrate loadings at the current levels.

5.5 Comparing Reclaimed and Existing Raw Water Quality

No federal regulations exist regarding the quality requirements for reclaimed water to be used in the context of indirect potable reuse. Currently, such requirements are established on a state-by-state basis. To date, the City has had preliminary meetings with TNRCC regarding such requirements. However TNRCC has not yet proposed regulations for McAllen, but have only referenced potential treatment techniques (e.g., treat all the reclaimed water with RO). To provide a basis for development of IPR regulations for this project, all primary and secondary contaminants currently regulated under the SDWA were analyzed in both the ZenoGem and RO permeates. Results of these analyses are presented in Appendix D. The results were then compared with data from similar characterization of the City's existing raw water supply (Rio Grande River) as sampled in 1997 during the Wastewater Reclamation Pilot Study, City of McAllen, Texas (1998).

Comparing the quality of the ZenoGem permeate to the City's existing raw water supply and to federal and state drinking water regulations as shown in Table 5.16, the following conclusions are drawn:

- The ZenoGem permeate contains greater levels (i.e., lower quality) of most inorganic contaminants than the City's raw water supply. The degradation reflects: 1) the inability of the City's water treatment plant and the ZenoGem process to remove such compounds, and 2) increases in these contaminants from the domestic water use/wastewater generation process. Consequently, the ZenoGem permeate, on at least one sampling event, exceeded the maximum contaminant level (MCLs) for chloride, color (APHA) apparent, and TDS.
- The ZenoGem permeate contains lower concentrations of certain metals (i.e., iron, manganese, aluminum, barium, and strontium) than the City's raw water supply and the MCLs as a result of their removal by oxidation or precipitation in both the WWTP and the ZenoGem processes.
- The concentration of dissolved organic matter (as measured by TOC) is significantly greater in the ZenoGem permeate than the City's raw water supply. Although there is not a current MCL for TOC, the greater the TOC level, the greater the potential for formation of trihalomethanes (THMs) and haloacetic acids (HAAs). These chlorinated byproducts have been shown to be carcinogenic and are regulated at very low levels (μg/L levels). This greater potential is illustrated by the significantly higher levels of HAAs in the ZenoGem permeate relative to the raw water supply. Further, the chronic health risks associated with identified organic compounds in wastewater are not well understood. For this reason, respected authorities in the field of IPR recommend that TOC levels be reduced. In the State of California, a TOC guideline of 1 mg/L has been established for reclaimed water used for surface water supplementation IPR projects.

Particle levels in the ZenoGem permeate are significantly lower than the City's raw
water supply based on turbidity measurements. This reflects the very small pore
size of the MF and UF membranes used with ZenoGem, which serves as a effective
barrier to the passage of most particles.

Comparing the quality of the RO permeate to the City's existing raw water supply and to federal and state drinking water regulations as shown in Table 5.16, the following conclusions are drawn:

- The RO permeate meets all established drinking water regulations as well as the TOC guideline of 1 mg/L.
- To produce reclaimed water meeting state and federal drinking water regulations and the State of California TOC guideline, both ZenoGem and RO treatment of the City's wastewater is required. Assuming an RO permeate TOC of 0.5 mg/L, greater than 90 percent of the wastewater would require RO treatment. If the TOC guideline were not considered, RO treatment would still be required, however, the percent of treatment would be reduced depending on the controlling contaminant (e.g., HAAs, nitrate or TDS). Assuming nitrate would be more cost effectively removed through biological denitrification, approximately 80 percent of the wastewater would require RO treatment to control HAA formation.
- Beyond simply meeting the drinking water regulations, experts involved in setting IPR policy strongly recommend the concept of multiple treatment barriers to ensure that the proposed treatment scheme adequately protect public health, particularly with respect to acute health risk from microbes. In this regard, the combination of ZenoGem and RO treatment provides two robust barriers to the passage of viral, bacterial and protozoan pathogens as opposed to relying on only a single barrier (i.e., ZenoGem only). An additional barrier or chlorine/UV disinfection may also be desirable while only marginally increasing costs.
- If TNRCC were to approach IPR guidelines for this project from the viewpoint that the reclaimed water must equal or exceed the quality of the existing raw water supply, a lower percentage of the ZenoGem permeate would require RO treatment. Based on the data shown in Table 5.16, it is estimated that about 50 percent of the wastewater would require RO treatment to have a reclaimed water match the TOC concentration of the raw water.

TABLE 5.16Results of ZenoGem and RO Permeate Sampling for IPR Characterization

	Primary	Existing Raw Water ZenoGe		Gom			
	MCL	_	plya		neate	BO Pe	rmeate
Parameter		3/11/97	6/2/97	8/17/99	9/14/99	8/17/99	9/14/99
General Chemistry						0,17,00	3/14/33
Alkalinity (mg/L as CaCO ₃)		130	106	121	153	14	16
Bromide (mg/L)		0.100	0.54	0.132	0.32	0.02 ^b	0.02 ^b
Chloride (mg/L)	250	155	207	160	281	9.73	15.20
Color Apparent	15	17	10	22	17	5.7 0	5 ^b
Fluoride (mg/L)		0.59	0.99	1.07	1.14	0.32	0.45
NH ₃ -N (mg/L as N)					0.1 ^b	0.01	0.1 ^b
NO ₂ -N (mg/L as N)				9.55	7.90	1.11	1.08
TKN (mg/L as N)				2 ^b	2 ^b	2 ^b	2 ^b
Reactive Silica (mg/L)		6.0	13.5	15.1	16.1	0.65	0.90
Sulfate (mg/L)	250	247	262	150	247	4	5.31
TDS (mg/L)	500 -	720	772	774	1,950	33	72
,	1,000		. –		.,		
TOC (mg/L)	1 ⁹	3.70	3.90	7.48	5.90	0.63	0.52
T-Phos (mg/L)		0.05	0.05 ^b	2.48	2.89	0.10	0.1 ^b
UV-254 (cm ⁻¹)		0.112	0.092	0.129	0.126		
Metals							
Aluminum (mg/L)	0.05 - 0.2	1.22	0.248	0.111	1 ^b	0.046 ^b	0.1 ^b
Arsenic (mg/L)				0.004*	0.01 ^b	0.004 ^b	0.01 ^b
Barium (mg/L)		0.127	0.124	0.056	0.062	0.0008 ^b	0.025*
Cadmium (mg/L)				.003	0.005 ^b	0.0004 ^b	0.005 ^b
Calcium (mg/L)		77	77.7	72.1	86.9	0.714	833
Chromium (mg/L)				0.007 ^b	0.010 ^b	0.008 ^b	0.01 ^b
Iron (mg/L)	0.3°	0.77	0.171	0.032	0.1 ^b	0.01	0.1
Lead (mg/L)				0.028	0.003 ^b	0.002^{b}	0.003 ^b
Magnesium (mg/L)		22.1	27.9	20.4	25.6	0.197	0.5 ^b
Manganese (mg/L)	0.05°	0.025	0.018	0.015	0.017	0.001 ^b	0.01 ^b
Mercury (mg/L)				0.0003^{b}	0.0003 ^b	0.0003 b	0.0003 ^b
Potassium (mg/L)		9	9.58	17.8	29.9	1.36	2*
Selenium (mg/L)				0.007 ^b	0.007 ^b	0.007	0.007 ^b
Silver (mg/L)				0.008 ^b	0.010 ^b	0.008 ^b	0.01 ^b
Sodium (mg/L)		102	140	157	253	13	16.2
Strontium (mg/L)		2.05	2.40	1.87	2	0.029 b	0.1 ^b
Zinc (mg/L)				0.463	0.054	0.007	0.02 ^b
Purgeable Volatiles				,			
Vinyl Chloride				1 ^b	1 ^b	1 ^b	1 ⁶
tran-1,2-Dichloroethene				1 ^b	1 ^b	1 ^b	1 ^b
cis-1,2-Dichloroethene				1 ^b	1 ^b	1 ^b	1 ^b
1,1,1-Trichloroethane				1 ^b	1 ^b	1 ^b	1 ^b
Carbon Tetrachloride				1 ^b	1 ^b	1 ^b	1 ^b
Trichloroethene				1 ^b	1 ^b	1 ^b	1 ^b

TABLE 5.16 Results of ZenoGem and RO Permeate Sampling for IPR Characterization

	Primary	Existing I	Raw Water	Zeno	Gem		
	MCL	Sup	Supply ^a Permeate		RO Per	RO Permeate	
Parameter		3/11/97	6/2/97	8/17/99	9/14/99	8/17/99	9/14/99
1,4-Dichlorobenzene				1 ^b	1 ^b	1 ^b	0.60
Disinfection Byproducts							
Trihalomethanes (SDS THMs) ^c (µg/L)	80	236.00	215.00	198.00	244.00	5.40	8.30
Haloacetic Acids (SDS HAA5) ^d (µg/L)	60	58.00	72.00	119.00	90.60	1.10	1.10
Semi-volatile Organics							
Lindane (µg/L)				0.024	0.011	0.02 ^b	0.02 ^b
Endrin (µg/L)				0.02 ^b	0.01	0.02 ^b	0.02 ^b
Methoxychlor (µg/L)				0.04 ^b	0.04 ^b	0.04 ^b	0.04 ^b
Toxaphene (µg/L)				0.5 ^b	0.5 ^b	0.5 ^b	0.5 ^b
Radiochemicals				,			
Radium-226 (pCi/L)				0.2 ^b	0.2 ^b	0.2 ^b	0.2 ^b
Radium-228 (pCi/L)				1 ^b	1 ^b	1 ^b	1 ^b
Gross Alpha (pCi/L)				1 ^b	1 ^b	1 ^b	1 ^b
Chlorinated Herbicides							
2,4-D (μg/L)				ND	ND	ND	ND
Silvex (2,4,5-TP) (µg/L)				ND	ND	ND	ND

^aSource: Table 5.2 of Water Treatment Technology Program Report No. 26

ND =No Detection

pCi/L=picoCuries per liter

bNot Detected at specified reporting limits.

cSDS THM - Simulated Distribution System Trihalomethanes (4 species)

^dSDS HAA5 - Simulated Distribution System Haloacetic Acids (5 species)

[°]Secondary MCL 'Secondary MCL: Federal = 500 mg/L; State = 1,000 mg/L

⁹Guildeline set by the State of California

SECTION 6

Cost Estimates Using ZenoGem, ZeeWeed, and RO Facilities

This section presents the cost estimates for two advanced treatment systems to produce 6.8 mgd of reclaimed water that would supplement the City of McAllen's drinking water supply by providing a new source of raw water to the City's water treatment plant. The advanced treatment system would be located at the site of the City's south WWTP. The effluent from the advanced treatment system would be of a quality suitable for discharge to a new reclaimed water storage reservoir to be located in the vicinity of the City's existing water treatment plant. It is anticipated that the effluent from the advanced treatment system would receive additional disinfection depending on TNRCC requirements.

UV light disinfection or chlorination are two candidate disinfection methods. The most appropriate may depend on whether the effluent consists of 100 percent RO permeate or a blend of RO permeate and ZenoGem/ZeeWeed permeate¹. In the latter case, UV disinfection may be required because of the increased chlorine disinfection byproduct formation potential of the UF permeate. For the purposes of this exercise, costs for final disinfection have not been included because the method of disinfection has yet to be determined. Costs for disinfection of the UF permeate with chloramines (prior to RO treatment) have been included.

Estimates were developed for two alternatives:

- Treatment Alternative 1: ZenoGem MBR, UF permeate storage/disinfection and RO facilities treating screened, de-gritted wastewater
- Treatment Alternative 2: Extended aeration and clarification (existing), ZeeWeed system, UF permeate storage/disinfection and RO facilities treating secondary effluent from the existing south WWTP

For Alternative 1, a new ZenoGem MBR system would be installed to treat the screened, de-gritted wastewater and produce 8.5 mgd of reclaimed effluent. The UF permeate would be disinfected with monochloramines, stored, and then treated by the RO system (which includes acidification and antiscalant addition to the RO feedwater) to produce 6.8 mgd of RO permeate.

For Alternative 2, 9.4 mgd of effluent from the existing secondary clarifiers would be treated by the ZeeWeed UF system to produce 8.5 mgd of permeate. The UF permeate would then be disinfected, stored, and treated by RO as described for Alternative 1. For either alternative, wastewater flows in excess of those necessary to produce 6.8 mgd of RO permeate and would be processed by the existing WWTP facilities. Concentrate from the ZeeWeed UF system would be recycled back to the aeration basins, while sludge

¹ For purposes of the estimates, the ZenoGem/ZeeWeed permeate is referred to as UF permeate, as both processes use the same UF membranes.

from the ZenoGem system would be digested and dried using existing facilities at the WWTP. Both alternatives use existing headworks facilities for wastewater screening and de-gritting.

Figure 6.1 displays a schematic of the existing WWTP. Figures 6.2 and 6.3 are schematics of the two alternatives including existing facilities.

FIGURE 6.1 Existing WWTP Schematic

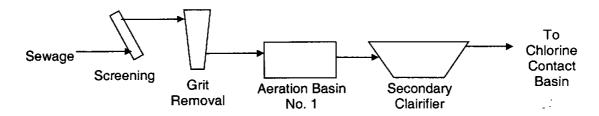


FIGURE 6.2
ZenoGem MBR and RO Facilities

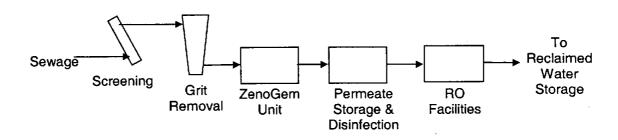
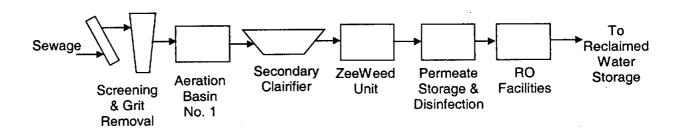


FIGURE 6.3
Conventional WWTP with ZeeWeed and RO Facilities



6.1 Cost Assumptions

The estimates were prepared at an order-of-magnitude level to provide a relative and preliminary cost comparison between the two treatment alternatives and are based on information presently available. Order-of-magnitude cost estimates are defined by the American Association of Cost Engineers as an approximate estimate made without detailed engineering data. Final costs for each alternative will depend on such variables as actual labor and material costs, market conditions, project scope, implementation schedule, and will differ from the estimates presented. The costs are in present day dollars, and annual unit costs are based on ZenoGem/ZeeWeed permeate capacity of 8.5 mgd and RO permeate capacity of 6.8 mgd. The plant availability factor assumed for calculation of unit treatment costs (in \$/1000 gallons) is 95%. A higher availability factor is not required as the plant is intended to operate as a seasonally-average reuse production plant. ZENON budget proposals used in estimating ZenoGem/ZeeWeed and RO equipment costs are presented in Appendix H.

The estimates do not include costs for sewage screening and de-gritting (these facilities are currently being upgraded at the south WWTP) for either alternative. Alternative 2 does not include capital costs for extended aeration or secondary clarification, as these are existing. The costs related to ZenoGem, ZeeWeed, and RO equipment and required ancillaries are included. The ZenoGem system is sized to account for downtime associated with backpulsing and maintenance cleanings while the ZeeWeed system is sized to account for downtimes associated with backpulsing only. At the assumed RO feedwater recovery of 80 percent, 20 percent of the RO feedwater flow (1.7 mgd) becomes waste concentrate requiring appropriate disposal. For purposes of this estimate, RO concentrate is assumed to be discharged without further treatment to the Arroyo Colorado using the City's existing outfall. Consequently, costs are not included for concentrate disposal.

6.2 Cost Estimates

Estimates were prepared for the following cost categories:

- Installed equipment, total construction, total capital, total unit capital, and amortized capital
- Total O&M and total unit O&M
- Total annual and total unit annual

Tables 6.1 and 6.2 present the estimates for the Alternatives 1 and 2, respectively. The tables include the assumptions and references used in developing component capital costs and operating and maintenance costs. Table 6.3 presents design criteria assumptions used in developing the cost estimates for each major process. In addition, a line-item comparison of capital and O&M costs for the ZenoGem and ZeeWeed technologies is presented in Appendix I.

TABLE 6.1Order of Magnitude Cost Estimate for ZenoGem® and RO Alternative Capital and O&M Cost Opinion

Capital and O&M Cost Opinion				
item		Cost	Assumption	Cost Reference
Fine Screening	\$	20,000	3-mm screen	CH2M HILL estimator ^b
ZenoGem® System®	\$	8,620,000		Zenon Budget Proposal
Bioreactor/Equalization Tanks	\$	1,307,808	6 tanks @ 170 ft x 21 ft x 23 ft (1.29 MG for equalization)	CH2M HILL estimator b
Permeate Storage	\$	70,000	180,000 gallons	CH2M HILL estimator ^b
ransfer Pump to RO System	\$	52,500	(2) 2,950 gpm @ 70 ft TDH pumps plus one stand-by	CH2M HILL estimator ^b
Chloramine Feed System				
Chlorinator	\$	30,000	50 lb/day duplex system	CH2M HILL estimator b
Ammoniator	\$	30,000	100 gal/day duplex system	CH2M HILL estimator b
RO System*	\$	2,300,000		Zenon Budget Proposal
nstallation	\$	2,730,000	25% of installed equipment costs	
installed Costs Subtotal	\$	15,160,308		
ZenoGem Equipment Building	\$	288,000	4,800 SF	CH2M HILL estimator ^b
RO Building	\$	390,000	6,500 SF	CH2M HILL estimator ^b
Installed Costs and Building Cost Subtotal	\$	15,838,308	1	
Unit Process Noncomponent Costs				
Yard Piping Allowance (10%)	\$	1,583,831		
Site Electrical Allowance (8%)	\$	1,267,065	;	
Site I&C Allowance (5%)	\$	791,915	5	
Site Civil Allowance (5%)	\$	791,915	5	
Unit Process Subtotal	\$	20,273,034		
Contingency (10%)	\$	2,027,303	3	
Contractor Overhead & Mark-up (10%)	\$	2,027,303	3	
Total Construction Cost	\$	24,327,641	1	
Engineering & Administration (15%)	\$	3,649,146	3	
Total Capital Cost	\$	27,976,787		•
Total Capital Unit Cost (\$/1,000 gallon)	\$			
Amortized Capital Cost (20yr @ 6.5%)	\$	2,539,072		
Operation & Maintenance Costs				
Major Chemical Costs				
Disinfection: Chlorine			O \$610/ton	Hill Brothers Chemical Co
Disinfection: Ammonia		, ,	0 \$370/ton	Hill Brothers Chemical Co
Backpulse Chemicals: Sodium Hypochlorite		, ,	2 \$0.31/Liter	Zenon Budget Proposal
CIP Chemical #1: MC-1			0 \$1.67/Liter	Zenon Budget Proposal
CIP Chemical #2: Sodium Hypochlorite (250 mg/L)		•	4 \$0.31/Liter	Zenon Budget Proposal
RO - Sulfuric Acid			5 \$0.04/lb	Zenon Budget Proposal
RO - Sodium Bisulfite		, ,	4 \$0.25/lb	Zenon Budget Proposal
RO - Antiscalant		\$ 122,35	9 \$3.27/Liter	Zenon Budget Proposal

TABLE 6.1

Order of Magnitude Cost Estimate for ZenoGem® and RO Alternative
Capital and O&M Cost Opinion

Item	(Cost	Assumption	Cost Reference
RO - Organic Acid: MC-1		\$ 8,658	\$2.29/kg	Zenon Budget Proposal
RO - Alkali Surfactant: MC-4		\$ 1,738	\$3.06/kg	Zenon Budget Proposal
RO - Sanitizer: MP-1		\$ 4,748	\$5.01/Liter	Zenon Budget Proposal
Major Power Costs		;	\$0.075/kW-hr	
Screening	\$	• 1	Existing	
Permeate Pumps		\$ 37,392		Zenon Budget Proposal
Recirculation Pumps		\$ 59,068		Zenon Budget Proposal
Sludge Wasting Pumps		\$ 890		Zenon Budget Proposal
Membrane Air Scour Blowers	\$	237,213		Zenon Budget Proposal
Process Air Blowers	\$	119,501		Zenon Budget Proposal
Anoxic Zone Mixers		\$ -		Zenon Budget Proposal
Air Separation System Vacuum Pumps		\$ 2,520		Zenon Budget Proposal
Backpulse Sodium Hypochlorite - Metering		\$ 3		Zenon Budget Proposal
Chemical Feed #1 - Metering		\$ 245		Zenon Budget Proposal
Air Compressors		\$ 2,515		Zenon Budget Proposal
Air Driers		\$ -		Zenon Budget Proposal
Controls & Instrumentation		\$ 657		Zenon Budget Proposal
Miscellaneous		\$ 657		Zenon Budget Proposal
RO - Pretreatment Chemical Mixers, Process Pump, CIP Pump	\$	501,591		Zenon Budget Proposal
Membrane/Cartridge Filter Replacement Costs				
ZenoGem	\$	329,311	1-yr warranty; 8-yr replacement frequency	Zenon Budget Proposal
RO	\$	226,286	5-yr replacement frequency	Zenon Budget Proposal
Cartridge Filter	\$	24,637	Annual replacement	Zenon Budget Proposal
Other Costs				
Maintenance	\$	63,750		Prorated South WWTP Costs
Permit Fees	\$	39,100		Prorated South WWTP Costs
Land Maintenance	\$	12,750	Replacement of sand in drying beds	Prorated South WWTP Costs
Supplies	\$	61,200	Includes land application of sludge (\$31.50/dry ton)	Prorated South WWTP Costs
Labor	\$	436,800	14 O&M personnel @ \$15.00/hr (9 ZenoGem; 5 for RO)	CH2M HILL estimate
Laboratory	\$	141,100	Includes 4 lab techs, analysis, O&M, etc.	Prorated South WWTP Costs
Total Annual Operation & Maintenance Cost	\$	2,482,754		
Total Annual O&M Unit Cost (\$/1,000 gallon)	\$	1.05		

TABLE 6.1Order of Magnitude Cost Estimate for ZenoGem® and RO Alternative Capital and O&M Cost Opinion

Item	Cost	Assumption	Cost Reference
Total Annual Cost	\$ 5,021,826		
Total Unit Cost (\$/1,000 gallon)	\$	on 6.8 MGD product water ant availability factor = 95%	

^a Detailed listing of components comprising ZenoGern and RO systems are presented in Appendix H.

TABLE 6.2

Order of Magnitude Cost Estimate for ZeeWeed® and RO Alternative

Capital and O&M Cost Opinion

Item	Cost	Assumption	Cost Reference
Fine Screening	\$ 20,000	3-mm screen	CH2M HILL estimator b
ZeeWeed [®] Tertiary Treatment System [®]	\$ 5,075,000		Zenon Budget Proposal
ZeeWeed Tanks	\$ 162,468	4 tanks @ 70 ft x 10 ft x 10 ft	CH2M HILL estimator b
Permeate Storage	\$ 70,000	180,000 gallons	CH2M HILL estimator b
Transfer Pump to RO System	\$ 52,500	(2) 2950 gpm @ 70 ft TDH pumps plus one stand-by	CH2M HILL estimator b
Chloramine Feed System			
Chlorinator	\$ 30,000	50 lb/day duplex system	CH2M HILL estimator b
Ammoniator	\$ 30,000	100 gal/day duplex system	CH2M HILL estimator b
RO System*	\$ 2,300,000		Zenon Budget Proposal
Installation	\$ 1,843,750	25% of installed equipment costs	
Installed Costs Subtotal	\$ 9,583,718		
ZeeWeed Equipment Building	\$ 84,000	1,400 SF	CH2M HILL estimator b
RO Building	\$ 390,000	6,500 SF	CH2M HILL estimator ^b
Installed Costs and Building Cost Subtotal	\$ 10,057,718		
Unit Process Noncomponent Costs			
Yard Piping Allowance (10%)	\$ 1,005,772		
Site Electrical Allowance (8%)	\$ 804,617	•	
Site I&C Allowance (5%)	\$ 502,886	i	
Site Civil Allowance (5%)	\$ 502,886	•	
Unit Process Subtotal	\$ 12,873,879	•	
Contingency (10%)	\$ 1,287,388	3	
Contractor Overhead & Mark-up (10%)	\$ 1,287,388	3	
Total Construction Cost	\$ 15,448,655	i	
Engineering & Administration (15%)	\$ 2,317,298	3	
Total Capital Cost	\$ 17,765,953	3	
Total Capital Unit Cost (\$/1,000 gallon)	\$ 7.53	3	
Amortized Capital Cost (20yr @	\$ 1,612,374		

^b ENR CCI reference number 6126.79

TABLE 6.2

Order of Magnitude Cost Estimate for ZeeWeed® and RO Alternative

Capital and O&M Cost Opinion

item	-	Cost	Assumption	Cost Reference
6.5%)				
<u> </u>				
Operation & Maintenance Costs				
Major Chemical Costs	œ	21 250	\$610/ton	Hill Brothers Chemical Co.
Disinfection: Chlorine	\$		\$370/ton	Hill Brothers Chemical Co.
Disinfection: Ammonia	\$,		Zenon Budget Proposal
Backpulse Chemicals: Sodium Hypochlorite	\$	·	\$0.31/Liter	• .
CtP Chemical #1: MC-1	\$	•	\$1.67/Liter	Zenon Budget Proposal
CIP Chemical #2: Sodium Hypochlorite (250 mg/L)	\$	4,435	\$0.31/Liter	Zenon Budget Proposal
CIP Neutralization Chemical #1: Sodium Hydroxide	\$	175	\$0.36/Liter	Zenon Budget Proposal
CIP Neutralization Chemical #2: Sodium Bisulfite	\$	117	\$0.06/Liter	Zenon Budget Proposal
RO - Sulfuric Acid	\$	5,745	\$0.04/lb	Zenon Budget Proposal
RO - Sodium Bisulfite	\$	2,594	\$0.25/lb	Zenon Budget Proposal
RO - Antiscalant	\$	122,359	\$3.27/Liter	Zenon Budget Proposal
RO - Organic Acid: MC-1	\$	8,658	\$2.29/kg	Zenon Budget Proposal
RO - Alkali Surfactant: MC-4	\$	1,738	\$3.06/kg	Zenon Budget Proposal
RO - Sanitizer: MP-1	\$	4,748	\$5.01/Liter	Zenon Budget Proposal
Major Power Costs			\$0.075/kW-hr	
Screening	\$	-	Existing	
Aeration Basins	\$	419,000	18 motors @ 50 HP; 24 hrs/day	South WWTP info
Recirculation Pumps	\$	74,500	4 pumps @ 40 HP; 24 hrs/day	South WWTP info
Permeate Pumps	\$	36,901		Zenon Budget Proposal
Membrane Air Scour Blowers	\$	114,440		Zenon Budget Proposal
Air Separation System Vacuum Pumps	\$	2,520		Zenon Budget Proposal
Backpulse Sodium Hypochlorite Metering	\$	7		Zenon Budget Proposal
Air Compressors	\$	2,515		Zenon Budget Proposal
Air Driers	\$	-		Zenon Budget Proposal
I&C	\$	657	•	Zenon Budget Proposal
Miscellaneous	\$	657	,	Zenon Budget Proposal
RO - Pretreatment Chemical Mixers, Process Pump, CIP Pump	\$	501,591		Zenon Budget Proposal
Membrane/Cartridge Filter Replacement Costs				
ZeeWeed	\$	190,905	i 1-yr warranty; 8-yr replacement frequency	Zenon Budget Proposal
RO	\$	226,286	5 5-yr replacement frequency	Zenon Budget Proposal
Cartridge Filter	\$	24,637	annual replacement	Zenon Budget Proposal
Other Costs				
Maintenance	\$	63,750)	Prorated South WWTP Cos
Permit Fees	\$	39,100)	Prorated South WWTP Cos
Land Maintenance	\$	12,750	replacement of sand in drying beds	Prorated South WWTP Cos

TABLE 6.2Order of Magnitude Cost Estimate for ZeeWeed® and RO Alternative Capital and O&M Cost Opinion

Item	Cost	Assumption	Cost Reference
Supplies	\$ 61,200	includes land application of sludge (\$31.50/dry ton)	Prorated South WWTP Costs
Labor	\$ 655,200	21 O&M personnel @ \$15.00/hr (16 exst. plant w/Zeeweed; 5 for RO)	CH2M HILL estimate
Laboratory	\$ 141,100	includes 4 lab techs, analysis, O&M, etc.	Prorated South WWTP Costs
Total Annual Operation & Maintenance Cost	\$ 2,760,698		
Total Annual O&M Unit Cost (\$/1,000 gallon)	\$ 1.17		•
Total Annual Cost	\$ 4,373,072		
Total Unit Cost (\$/1,000 gallon)	\$ 1.85	Based on 6.8 MGD product water flow; plant availability factor = 95%	÷

^a Detailed listing of components comprising ZeeWeed and RO systems are presented in Appendix H.

TABLE 6.3

Design Criteria Assumptions for ZenoGem, ZeeWeed, and RO Systems

Criterion	Value
ZenoGem System	
Design Permeate Flow, mgd	8.5
Hydraulic Residence Time, hours	6
Solids Retention Time, days	17
Mixed Liquor Suspended Solids Level, g/L	10
Aeration Rate, fine bubble, scfm/mgd	647
Aeration Rate, membrane air scour, scfm/mgd	2,586
Aeration mode (both systems)	Cyclic
Membrane flux, gfd	15.4
No. of membrane trains	6
No. of reactor tanks	6
Backpulse interval, minutes	15
Backpulse duration, seconds	30
Backpulse pressure, psi	8
Maintenance clean interval, hours	168
Maintenance clean duration, minutes	60
ZeeWeed System	
Design Permeate Flow, mgd	8.5
Hydraulic Residence Time, hours	0.56
Feedwater Recovery, percent	95
Aeration Rate, membrane air scour, scfm/mgd	1,207
Aeration Mode	Continuous
Membrane flux, gfd	20.4
Backpulse interval, minutes	15
Backpulse duration, seconds	30

^b ENR CCI reference number 6126.79

TABLE 6.3

Design Criteria Assumptions for ZenoGem, ZeeWeed, and BO Systems

Criterion	Value	
Backpulse pressure, psi	8	
RO System		
Design Permeate Flow, mgd	6.8	
Feedwater pH, units	5	
Antiscalant dose, mg/L	Manufacturer dependent; 3 max	
Feedwater recovery, percent	80	
Membrane flux, gfd	12	
Membrane type	low fouling, aromatic composite	
Vessel array	three stage, concentrate taper	

Estimated total capital cost for the ZenoGem/RO approach (Alternative 1) is significantly higher than for the ZeeWeed/RO approach (Alternative 2), \$28.0MM versus \$17.8MM, a difference of nearly \$10MM. The difference reflects the higher cost of treatment for ZenoGem relative to ZeeWeed. Compared to the requirements for ZeeWeed, ZenoGem requires more membrane modules because a lower flux rate must be used to treat the significantly higher solids concentration of the mixed liquor (relative to the secondary effluent from the existing WWTP); larger tankage to provide wastewater flow equalization and the necessary hydraulic retention time to complete nitrification; and increased blower capacity to achieve carbonaceous and nitrogenous oxidation of the wastewater.

Estimated annual operating and maintenance costs for the ZenoGem-based alternative were slightly lower than for the ZeeWeed alternative (\$2.48MM/year versus \$2.76MM/year). This reflects lower energy and labor costs associated with operating the ZenoGem system versus those for operating costs for the extended aeration basins, secondary clarifiers and ZeeWeed system.

The significantly higher capital cost for Alternative 1 outweighs the slightly lower O&M costs. Consequently, total unit cost for Alternative 1 is higher (\$2.13/1000 gals versus \$1.85/1000 gals). Based on these estimates, it would be more cost-effective for McAllen to implement Alternative 2 (using ZeeWeed and RO to treat existing plant secondary effluent) to achieve their indirect potable reuse treatment goals. This reflects the cost savings of associated with the use of their existing flow equalization and secondary treatment facilities that are a sunk cost.

The disparity in capital cost between the ZenoGem and ZeeWeed alternatives could be reduced somewhat in the instance where a municipality's existing WWTP utilized concrete basins for aeration, rather than the earthen basins used at McAllen. Cost savings in this instance would result from avoiding the costs associated with constructing new concrete basins and instead retrofitting the membrane modules into the existing tankage. For the flow rate assumed in this cost comparison (8.5-mgd), the avoided cost would be \$1.3MM or 5.5% of the total capital cost for the ZenoGem alternative. Actual savings would be somewhat less due to the costs associated with basin retrofit. The \$1.3MM savings would reduce the difference in capital costs between the two alternatives, however, the ZeeWeed alternative would still be significantly less

expensive (by \$8.9MM). Additional capital cost savings could be realized if the blowers used for aeration in the conventional, concrete basin plant could be adapted and used where membrane modules are retrofitted into existing basins.

It was beyond the scope of this study to perform an order-of-magnitude level cost estimate for conventional treatment facilities (primary clarification, secondary [activated sludge] treatment and secondary clarification) followed by ZeeWeed in the case where no conventional wastewater treatment existed. However, based on design and costing of conventional treatment facilities that CH2M HILL has performed over the past 20 years, rule-of-thumb costs for 8.5-mgd of conventional treatment would be in the \$16MM -\$20MM range. Adding ZeeWeed costs of \$12MM results in a cost estimate of \$28-32MM. This compares with ZenoGem cost of \$22MM as estimated in this report. Based on these estimates, constructing a 8.5-mgd ZenoGem treatment plant to treat screened, de-gritted sewage would save \$6-10MM compared with the conventional treatment/ZeeWeed approach using the combination of rule-of-thumb and order-ofmagnitude cost estimates. This represents a significant savings potential and indicates that for municipalities considering indirect potable reuse and who would be starting with raw sewage, it should be considerably less expensive to construct a treatment facility using ZenoGem/RO versus conventional wastewater plant (through secondary treatment)/ZeeWeed/RO.

References

- Green, J and J. Holmes. 1947. Journal American Water Works Association. Volume 39. p. 1090.
- Lozier, Jim. 1998. Water Treatment Technology Program Report No. 26. Wastewater Reclamation Pilot Study, City of McAllen, Texas.
- Water Environment Federation. 1990. Operation of Municipal Wastewater Treatment Plants. Manual of Practice 11, Volume II.
- Water Environment Federation and American Society of Civil Engineers. 1991. Design of Municipal Wastewater Treatment Plants, Volume I. WEF Manual of Practice No. 8. ASCE Manual and Report on Engineering Practice No. 76.

SI Metric Conversions

English Unit	Multiply By	SI Metric Unit
ft²	0.0929	m²
gal	3.785	L
gal	0.003785	m³
gpm	0.06309	L/s
gpd/ft²	1.698	Ľ/m²/hour
in	2.54	cm
lb	454	g
psi	0.0703	kg/cm²

Appendix A. Photographs of Demonstration Plant Facilities and Associated Equipment

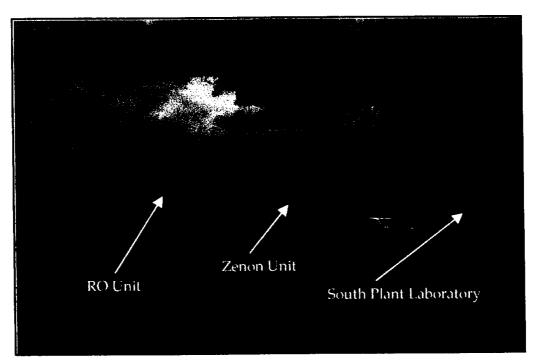


Exhibit A-1. Demonstration plant location (located to the west of the South WWTP laboratory).



Exhibit A-2. ZenoGem $\mbox{\em B}$ and RO treatment systems (looking west).

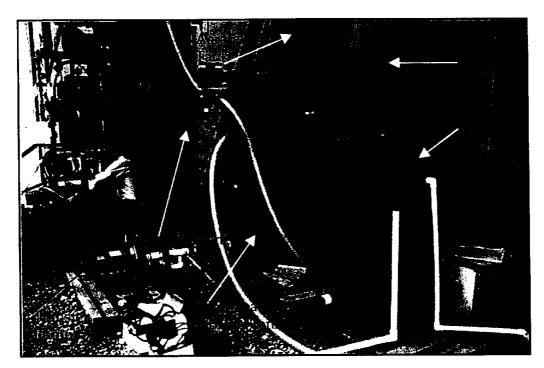


Exhibit A-3. Process tanks for ZenoGem system (operator Henry Perez in background).

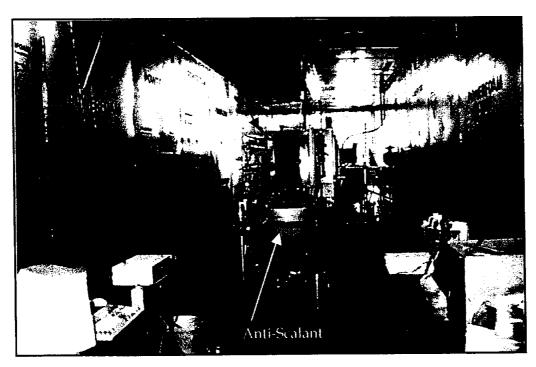


Exhibit A-4. RO system equipment (looking east inside trailer).



Exhibit A-5. RO data acquisition equipment (looking west inside trailer).



```
HYDRANAUTICS RO SYSTEM DESIGN SOFTWARE, VERSION 6.4 (c) 1998
                                                                                                                                             12/12/1999
                                                                BASIC DESIGN
 RO program licensed to:
 Calculation created by: J. Lozier (CH2M HILL)
  Project name: McAllen Phase II
                                                                         Permeate flow:
                                                                                                                                                12.7 gpm
                                                     15.9 gpm
 HP Pump flow:
                                                                                Raw water flow:
                                                                                                                                                15.9 gpm
 Recommended pump press.: 132.2 psi
 Feed pressure: 121.4 psi
Feedwater Temperature: 31.0 C(88F)
                                                                             Permeate recovery ratio: 80.0 % (Stages | $
 Feedwater Temperature: 51.0 C(sor),
Raw water pH: 7.80 Element age: 0.0
Acid dosage, ppm (100%): 56.9 H2SO4 Flux decline % per year: 7.0
Acidified feed CO2: 57.9 Salt passage increase, %/yr: 10.0
Average flux rate: 12.0 gfd Feed type: Wastewater
                                                                                                                                               0.0 years
 Stage Perm. Flow per Vessel Flux Beta Conc.
                                                                                                                  Element
                                                                                                                                     Elem. Arrav
                              Feed Conc Press. Type gpm gpm gfd psi 7.9 5.1 16.2 1.16 111.5 LFC1-4040 5.1 2.8 12.7 1.21 103.6 LFC1-4040 5.7 4.1 8.8 1.10 94.1 LFC1-4040 4.1 3.2 5.3 1.07 86.7 LFC1-4040
               Flow
                                                                                                                                              No.
                 gpm
   1-1
                  5.7
                                                                                                                                                           2x3
  1-2
                4.5
                                                                                                                                                           2x3
                1.6
  1-3
                                                                                                                                                         1x3
  1 - 4
                0.9
                                                                                                               LFC1-4040

        Ca
        140.0
        349.1
        140.0
        349.1
        2.3
        5.7
        690.9
        1723.0

        Mg
        29.1
        119.8
        29.1
        119.8
        0.5
        1.9
        143.6
        591.0

        Na
        332.0
        721.7
        332.0
        721.7
        25.2
        54.8
        1559.2
        3389.5

        K
        17.1
        21.9
        17.1
        21.9
        1.6
        2.1
        79.1
        101.4

        NH4
        1.0
        2.8
        1.0
        2.8
        0.1
        0.3
        4.6
        12.8

        Ba
        0.1
        0.1
        0.1
        0.1
        0.0
        0.0
        0.4
        0.3

        Sr
        1.3
        1.4
        1.3
        1.4
        0.0
        0.0
        0.0
        0.4
        0.3

        Sr
        1.3
        0.5
        0.1
        0.1
        0.0
        0.0
        0.0
        0.2
        7.1

        CO3
        0.3
        0.5
        0.1
        0.1
        0.0
        0.0
        0.0
        0.3
        0.6

        HCO3
        293.0
        240.
 -----
                                                                                                            -----
                                                                                                                                                   -----+
                                              -+------
                                                                         -----
pH 7.8
```

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	8%	10%	73%
SrSO4 / Ksp * 100:	5%	6%	42%
BaSO4 / Ksp * 100:	371%	428%	2994%
SiO2 saturation:	9%	9%	45%
Langelier Saturation Index	0.92	-0.19	1.73
Stiff & Davis Saturation Index	0.95	-0.17	1.35
Ionic strength	0.03	0.03	0.16
Osmotic pressure	13.3 psi	13.1 psi	62.8 psi

HYDR	ANAUT	TICS RO	SYSTE	M DES	IGN SC	FTWARE	. VERS	SION 6.4	(c) 1	.998	1	2/12/	1999
RO p	rogra	um licer	sed t	:0:	T ·								
Proj HP P Reco	ect n ump f mmend	lea pump	Allen pres	Phases: 1	e II 15.9 g 32.2 p	pm si	Perme Raw w	ate flo ater fl	ow:		1	.2.7 g	udu Low
reed	water	. Tember	יא דוו ד בי	•	או הי	/ R R F \		ate rec				0.0 %	;
Raw was Acid	water dosa	pH: ge, ppm	(100	₹): <u></u>	7.80 56.9 H	2SO4	Eleme Flux Salt Feed	nt age: decline passage type:	% per incre	year: ase, % W	/yr: 1 astewa	0.0 y 7.0 0.0 ter	ears
Stage	Fl	ow	Feed	Co	ssel	Flux gfd	Beta	Press.		ement Type		m. A	rray
1-1	5	.7	gpm 7.9	5.	. 1	16.2	1.16	psi 111.5		1-4040			2 x 3
1-2 1-3	1	.5 .6 .9	5.1 5.7	2. 4.		12.7 8.8		103.6 94.1		1-4040 1-4040			2x3
1-4	ō	. 9	4.1	3.		5.3	1.07	86.7		1-4040			1x3 1x3
Stg E n	lem o.		drop	flow	Perm Flux gfd	Beta	Perm sal TDS		Concer CaSO4	ntrate SrSO4	satura BaSO4	ation SiO2	level Lang.
1-1	1	121.4		1.0	17.0	1.13				7	504	10	0.0
1-1 1-1	2	117.4 114.2	3.3 2.6	0.9 0.9	16.1 15.2	1.14 1.16	31.2 34.7			8 10	602 733	12 14	$\begin{array}{c} 0.2 \\ 0.4 \end{array}$
1-2 1-2 1-2	1 2 3	108.5 106.4 104.8	2.1 1.6 1.2	0.8 0.7 0.7	13.7 12.7 11.5	1.17 1.19 1.21	39.3 44.8 51.5	29.1	27	12 16 20	903 1140 1476	17 20 25	0.6 0.8 1.1
1-3 1-3 1-3	1 2 3	100.6 98.1 95.9	2.6 2.2 1.9	0.6 0.5 0.5	9.8 8.6 7.8	1.10	55.9 61.1 66.6	44.0	46	23 26 30	1679 1907 2161	28 31 34	1.2 1.3 1.5
1-4 1-4 1-4	1 2 3	91.0 89.3 87.8	1.7 1.5 1.3	0.4 0.3 0.3	6.1 5.0 4.5		73.4 81.0 88.6	57.3		33 37 41	2410 2665 2925	37 41 44	1.6 1.6 1.8

HYDRANAUTICS RO SYSTEM DESIGN SOFTWARE, VERSION 6.4 (c) 1998 12/12/1999
BASIC DESIGN

RO program licensed to:

Calculation created by: J. Lozier (CH2M HILL)

Project name: McAllen Phase II Permeate flow: 7.2 gpm HP Pump flow: 14.4 gpm Raw water flow: 14.4 gpm

Recommended pump press.: 100.5 psi

Feed pressure: 91.1 psi Permeate recovery ratio: 50.0 %

Feedwater Temperature: 31.0 C(88F)

Raw water pH: 7.80 Element age: 0.0 years (Acid dosage, ppm (100%): 56.9 H2SO4 Flux decline % per year: 7.0

Acidified feed CO2: 57.9 Salt passage increase, %/yr: 10.0 Average flux rate: 10.2 gfd Feed type: Wastewater

Stage	Perm. Flow	Flow per Feed	Vessel Conc	Flux	Beta	Conc. Press.	Element Type	Elem. No.	Array
	gpm	gpm	gpm	gfd		psi			•
1-1	4.1	7.2	5.2	11.5	1.11	81.9	LFC1-4040	6	2x3
1-2	3.1	5.2	3.6	8.8	1.12	73.2	LFC1-4040	6	2x3

+Kaw	water	+Feed	water	+Perme	ate	+Conce:	ntrate+
mg/l	CaCO3	mg/1	CaCO3	mg/l	CaCO3	mg/1	CaCO3
140.0	349.1	140.0	349.1	1.6	4.0	278.4	694.3
332.0	721.7	332.0	721.7	18.0	39.1	646.0	238.1 1404.4
1.0	21.9	1.0	21.9	1.2 0.1	1.5 0.2	33.0 1.9	42.4 5.4
0.1	0.1 1.4	0.1 1.3	$0.1 \\ 1.4$	0.0 0.0	0.0	0.2 2.5	0.1
0.3 293.0	0.5 240.2	0.1 224.0	0.1 183.6	0.0 18.3	0.0	0.1 429 6	0.2
327.0	340.6	382.8	398.7	4.4	4.6	761.1	792.8 1069.4
1.0	2.6	1.0	2.6	0.1	0.2	1.9	5.0
13.9	1.2	13.9	1.2	0.3	0.3	2.7 27.5	2.1
1545.2 7.8	+	1531.8 6.8	+	62.4 5.7	+	3001.1	
	mg/l 140.0 29.1 332.0 17.1 1.0 0.1 1.3 0.3 293.0 327.0 388.0 1.0 1.5 13.9	140.0 349.1 29.1 119.8 332.0 721.7 17.1 21.9 1.0 2.8 0.1 0.1 1.3 1.4 0.3 0.5 293.0 240.2 327.0 340.6 388.0 547.2 1.0 2.6 1.5 1.2 13.9	mg/l CaCO3 mg/l 140.0 29.1 119.8 29.1 332.0 721.7 332.0 17.1 21.9 17.1 1.0 2.8 1.0 0.1 0.1 1.3 1.4 1.3 0.3 0.5 0.1 293.0 240.2 224.0 327.0 340.6 382.8 388.0 547.2 388.0 1.0 2.6 1.0 1.5 1.2 1.5 13.9 13.9 1545.2 1531.8	mg/l CaCO3 mg/l CaCO3 140.0 349.1 140.0 349.1 29.1 119.8 29.1 119.8 332.0 721.7 332.0 721.7 17.1 21.9 17.1 21.9 1.0 2.8 1.0 2.8 0.1 0.1 0.1 0.1 1.3 1.4 1.3 1.4 0.3 0.5 0.1 0.1 293.0 240.2 224.0 183.6 327.0 340.6 382.8 398.7 388.0 547.2 388.0 547.2 1.0 2.6 1.0 2.6 1.5 1.2 1.5 1.2 13.9 13.9	mg/l CaCO3 mg/l CaCO3 mg/l 140.0 349.1 140.0 349.1 1.6 29.1 119.8 29.1 119.8 0.3 332.0 721.7 332.0 721.7 18.0 17.1 21.9 17.1 21.9 1.2 1.0 2.8 1.0 2.8 0.1 0.1 0.1 0.1 0.0 0.0 1.3 1.4 1.3 1.4 0.0 0.3 0.5 0.1 0.1 0.0 293.0 240.2 224.0 183.6 18.3 327.0 340.6 382.8 398.7 4.4 388.0 547.2 388.0 547.2 17.8 1.0 2.6 1.0 2.6 0.1 1.5 1.2 1.5 1.2 0.3 13.9 13.9 0.3	mg/l CaCO3 mg/l CaCO3 mg/l CaCO3 140.0 349.1 140.0 349.1 1.6 4.0 29.1 119.8 29.1 119.8 0.3 1.4 332.0 721.7 332.0 721.7 18.0 39.1 17.1 21.9 17.1 21.9 1.2 1.5 1.0 2.8 1.0 2.8 0.1 0.2 0.1 0.1 0.1 0.0 0.0 1.3 1.4 1.3 1.4 0.0 0.0 0.3 0.5 0.1 0.1 0.0 0.0 293.0 240.2 224.0 183.6 18.3 15.0 327.0 340.6 382.8 398.7 4.4 4.6 388.0 547.2 388.0 547.2 17.8 25.1 1.0 2.6 1.0 2.6 0.1 0.2 1.5 1.2 1.5 1.2 0.3	mg/l CaCO3 mg/l CaCO3 mg/l CaCO3 mg/l 140.0 349.1 140.0 349.1 1.6 4.0 278.4 29.1 119.8 29.1 119.8 0.3 1.4 57.9 332.0 721.7 332.0 721.7 18.0 39.1 646.0 17.1 21.9 17.1 21.9 1.2 1.5 33.0 1.0 2.8 1.0 2.8 0.1 0.2 1.9 0.1 0.1 0.1 0.0 0.0 0.2 1.9 0.3 1.4 1.3 1.4 0.0 0.0 0.2 1.3 1.4 1.3 1.4 0.0 0.0 0.2 1.3 1.4 1.3 1.4 0.0 0.0 0.0 293.0 240.2 224.0 183.6 18.3 15.0 429.6 327.0 340.6 382.8 398.7 4.4 4.6 761.1 </td

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	8%	10%	23%
SrSO4 / Ksp * 100:	5%	6%	13%
BaSO4 / Ksp * 100:	371%	428%	990%
SiO2 saturation:	9%	9%	18%
Langelier Saturation Index	0.92	-0.19	0.65
Stiff & Davis Saturation Index	0.95	-0.17	0.56
Ionic strength	0.03	0.03	0.06
Osmotic pressure	13.3 psi	13.1 psi	25.7 psi

HYDR	ANAUTI	CS RO	SYSTE	M DES	IGN SC	FTWARE	E, VERS	ION 6.4	(c) 1	L998	-	12/12,	/1999
	rogram												
Calc	ulatio	n crea	ated b	у: J.	Lozie	r (CH2	M HILL)					
Proj	ect na	me: Mo	Allen	Phas	e II		Permea Raw wa	ate flo	w:			7.2 9	mm
HP P	ump fl	ow:			14.4 g	pm	Raw wa	ater fl	ow:		1	4.4	nom
Reco.	umende	ս քառը	pres	S.: 1	ם כ.טט	Sl							, , , , ,
Feed	press	ure:		!	91.1 p	si	Permea	ite rec	overy	ratio:	5	0.0 8	
r eea	water '	l'emper	ature	:	31.0 C	(88F)			_		-		
Raw	water page dosage ified :	pH:			7.80		Elemen	it age:				0.0 v	ears
Acid	dosage	e, ppm	ι (100	ቼ): 5	56.9 H	2504	Flux c	lecline	% per	year:		7.0	
Acid	ified :	teed C	:02 :	-	57.9		Salt p	assage	incre	ase, %	/yr: 1	0.0	
Avera	age flu	ıx rat	e:]	L0.2 g	fd	Feed t	ype:	-	W	astewa	ter	
~ .	_	_			_								
Stage	e Peri	n. F	Tow b	er Ves	sel	Flux	Beta	Conc.	El				rray
		V	reed	Co	onc			Press.		Type	N	ο.	_
1 1	gpi	α	gpm	ār	m	gid		psi					
1 2	4.1	_	7.2	5.	2	11.5	1.11	81.9	LFC	1-4040		б	2x3
1-2	3.1	-	5.∠	٤.	6	8.8	1.12	73.2	LFC	1-4040		6	2 x 3
Sta F	:lem	Feed	Drac	Dorm	Dorm.	Poto	Perm	G	G				_
Dug 1	10.	nres	drop	flow	Flux	Deca	sal	Conc	Conce	ntrate	satur	ation	level
•		nsi	nsi	CLOM.	afa			osm	Ca504	SrSO4	BaSO4	S102	Lang.
		Ď31	231	gpm	gra		105	pres					
1-1	1	91.1	3.5	0.7	12.2	1.10	39.0	14.6	11	6	486	10	-0.1
1-1	2	87.5	3.0				42.4	16.2	13	7	555		
1-1			2.6		10.7		46.2			9	638		
							_			,	0.50		0.2
1-2	1		2.2	0.6	9.5	1.11	51.2	20.5	17	10	733	14	0.4
1-2	2		1.9	0.5	8.8	1.11	56.8	22.7		11	848	16	0.5
1-2	3	74.8	1.6	0.5	8.1	1.12	62.7	25.9		13	985	18	0.7

HYDRANAUTICS RO SYSTEM DESIGN SOFTWARE, VERSION 6.4 (c) 1998 12/12/1999 BASIC DESIGN

RO program licensed to:

Calculation created by: J. Lozier (CH2M HILL)

Project name: McAllen Phase II
The Dump flow: 25.4 gpm Permeate flow: 12.7 gpm Raw water flow: 25.4 gpm

Permeate recovery ratio:

Recommended pump press.: 140.9 psi

131.5 psi Feed pressure:

Feedwater Temperature: 31.0 C(88F)

50.0 % (Stages 0.0 years 1 * 2) Raw water pH: 7.80 Element age: Flux decline % per year: Acid dosage, ppm (100%): 56.9 H2SO4

Salt passage increase, %/yr: 10.0 Acidified feed CO2: 57.9 12.0 gfd Feed type: Average flux rate: Wastewater

Stage	Perm. Flow	Flow per Feed	r Vessel Conc	Flux	Beta	Conc. Press.	Element Type	Elem. No.	Array
	gpm	gpm	gpm	gfd		psi			
1-1	6.0	12.7	9.7	17.0	1.09	110.5	LFC1-4040	6	2x3
1-2	4.6	9.7	7.4	13.0	1.09	93.2	LFC1-4040	6	2x3
1-3	1.5	14.8	13.3	8.4	1.03	61.3	LFC1-4040	3	1x3
1-4	0.6	13.3	12.7	3.3	1.01	32.4	LFC1-4040	3	1x3

+	+Raw	water	Feed	water	+Perme	ate		ntrate+
Ion	mg/l	CaCO3	mg/l	CaC03	mg/l	CaCO3	mg/l	CaCO3
Ca	140.0	349.1	140.0	349.1	1.4	3.6	278.6	694.7
Mg	29.1	119.8	29.1	119.8	0.3	1.2	57.9	238.3
Na	332.0	721.7	332.0	721.7	16.2	35.1	647.8	1408.4
K	17.1	21.9	17.1	21.9	1.0	1.3	33.2	42.5
NH4	1.0	2.8	1.0	2.8	0.1	0.2	1.9	5.4
Ba	0.1	0.1	0.1	0.1	0.0	0.0	0.2	0.1
Sr	1.3	1.4	1.3	1.4	0.0	0.0	2.5	2.9
CO3	0.3	0.5	0.1	0.1	0.0	0.0	0.1	0.2
HCO3	293.0	240.2	224.0	183.6	16.7	13.7	431.3	353.5
SO4	327.0	340.6	382.8	398.7	4.0	4.2	761.5	793.2
Cl	388.0	547.2	388.0	547.2	16.2	22.8	759.8	1071.7
F	1.0	2.6	1.0	2.6	0.1	0.2	1.9	5.0
NO3	1.5	1.2	1.5	1.2	0.3	0.3	2.7	2.2
SiO2	13.9		13.9		0.3		27.5	1
TDS	1545.2	+	1531.8		56.5	+	3007.0	
рH	7.8		6.8		5.7		7.1	
++		·			· 			+

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	8%	10%	23%
SrS04 / Ksp * 100:	5%	6%	13%
BaSO4 / Ksp * 100:	371%	428%	990%
SiO2 saturation:	9%	9%	18%
Langelier Saturation Index	0.92	-0.19	0.65
Stiff & Davis Saturation Index	0.95	-0.17	0.56
Ionic strength	0.03	0.03	0.06
Osmotic pressure	13.3 psi	13.1 psi	25.8 psi

HYDRANAUTICS RO SYSTEM DESIGN SOFTWARE, VERSION 6.4 (c) 1998 12/12/1999 BASIC DESIGN RO program licensed to: Calculation created by: J. Lozier (CH2M HILL) Project name: McAllen Phase II Permeate flow: 12.7 gpm 25.4 gpm Raw water flow: 25.4 gpm HP Pump flow: Recommended pump press.: 140.9 psi Permeate recovery ratio: 50.0 % Feed pressure: 131.5 psi 31.0 C(88F) Feedwater Temperature: 7.80 Element age: 0.0 years Raw water pH: Acid dosage, ppm (100%): 56.9 H2SO4 Flux decline % per year: 7.0 Salt passage increase, %/yr: 10.0 Acidified feed CO2: 57.9 Wastewater Average flux rate: 12.0 qfd Feed type: Conc. Element Elem. Array Flux Beta Stage Perm. Flow per Vessel Press. No. Type Flow Feed Conc gfd psi gpm gpm gpm LFC1-4040 6 2x317.0 1.09 110.5 9.7 1-1 6.0 12.7 6 1.09 LFC1-4040 2x37.4 13.0 93.2 4.6 9.7 1-2 1.03 LFC1-4040 3 1x38.4 61.3 1 - 31.5 14.8 13.3 1.01 32.4 LFC1-4040 3 1×3 3.3 12.7 0.6 13.3 1-4 Perm Conc Concentrate saturation level Feed Pres Perm Perm Beta Stg Elem osm CaSO4 SrSO4 BaSO4 SiO2 Lang. pres drop flow Flux sal no. TDS pres psi psi gpm qfd 18.3 25.6 14.3 11 477 10 -0.1 1.08 7.9 131.5 1.1 1-1 1 11 0.0 15.7 532 123.6 7.0 1.0 17.0 1.08 27.9 12 7 1-1 2 8 594 12 0.1 14 30.3 17.1 1-1 3 116.6 6.1 0.9 15.7 1.09 0.3 18.8 15 9 661 13 0.8 14.0 1.08 33.3 107.5 5.4 1 - 217 10 738 14 0.4 36.4 20.4 4.8 0.8 12.9 1.08 102.1 1-2 2 19 823 16 0.5 0.7 11.9 1.09 39.7 22.4 11 97.3 4.2 3 1-2 10.1 23.5 20 12 865 16 0.5 41.8 1.04 1-3 90.1 10.1 0.6 44.2 24.0 21 12 903 17 0.6 0.5 8.3 1.03 80.0 9.6 1-3 2 25.0 22 13 935 17 0.6 70.4 9.2 0.4 6.7 1.03 46.8 1-3 3 0.7 959 4.7 1.02 49.9 25.6 23 13 18 58.2 8.9 0.3 1-4 1 0.6 977 18 53.3 25.6 23 13 8.6 0.2 3.2 1.01 1-4 2 49.4 13 987 18 0.7 26.2 23 1.9 1.01 56.9 40.7 8.5 0.1

(Mare) only	### 000 10	150 AM 24 50 5682 2	7.15 AM 47.28	2-46-PM S4.75 STILT	7.30 AM 71.50 5628.4	215 At 25 At	B30.44 W/50 56633	1 00 PM 101 00 5856 B	127.00	20074 12754 Sept	8 005 AM 148 M 5701 &	144.17 5700.2	117.PM 150.67 5706.2	7.30 AM (48 08 5723.4	2 00 PM 175 56 5729 9	192 60 57574	10 CO AMA 185.54 S748 B	196.75 5750.4	200 54 5754.2	1.20.74 273.0g 5778.7	į	11.00 AM 244.58 5797.5	247 08 5798 9	200 50 502 4	28 58 58 58-62.5	2000	319.00	2 15 PM 319 E3 5472 7 488040 0	33704 3888.2	343 08 5485 1	25 26 25 20 25 20	3617 50144	5017.2	2000	5954.4	7888	41217 5464	433 75 54604	\$ C3853	4 5000 82 357	468.38 8008.3	\$ 120	1	508.08 8043.7
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Table C-1 ZenoGem Operating Data

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Table C-2 ZenoGem Water Quality Data

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	7.490.00				5,600,00		Í						9,200.00				_	9,650 00					10.500 00	_				7,800		9.400.00							-	8.550.00			_	8	+	Waste Studge MLV3S
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* 650 88	6,500 00		S	9			9 200 00				8,850 00		,		800	6 850 00	_	7 854 00		7,600,00		-	900000	- 0	8.100.00			7.50000	. 5	8 750 00			8		96 9.650 90	7,300 00		8 8	: 8	7,300 00	8 8		T	LY88 (impl.)

Table C-2 ZenoGem Water Quality Data

TO ME AND AT EVENT 12)	MORBIAL WITH CYCLED AND	WOMEN WITH CYCLED AND	TO MT-EVENT 19	TO ME CANADAM AND CANADAM AND CANADAM AND CANADAM AND CANADAM AND CANADAM AND CANADAM AND CANADAM AND CANADAM CANADAM AND CANA	TO INTERNENT 7)	CHOCKET MALH CACTED VIL		DEPT.	KHOMMALI	MAT & OPEN		•			n			•			>		= -	ž .	: :	: 5	ü	=	ā	ü	z	.		ä	=	=	
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77.67	29.04 181		¥ \$.	27.53	20.13		L		27.53		24.00	27.46 1		21.00	1		٠.				31 50					_	24.00	20.00						31.36	24.00	WWTP Influent NEG-N (mg/L)
i	2	2			174.73	171.38		1	754.00 1	782.17	280.00 2	142.00		_	8	Ì		8	- [ŀ	8	8	214 00	8	8.00	170.00	8	142.00	5 8	8	2.8	78.00	8	8	WWTP Influent CBOD (mg/L)
5	58,00				153,45	144.67			_	194.00	284.00	-		-	8	- [- 1			8 8	8	8	8	36.00	8	76.00	128 00	28 80	6.00	28.00	80 00 00	56,00	ž	88	WWTP Influent T&S (mg/L)
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Chris Acid (Stage Cody)

Table C-3

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Table C-3
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Table C-3
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Table C-3
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Table C-3
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Table C-3
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Table C-3
RO Operating Data
(Calculations)

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Fr 4/11/90	Thu 6/10/99	Tue 9/1/98	Mon 6/7/98	Sun E-E-FF	34 6/5/98		Day 200 1140	Tue 9/1/98	Hon 5/31/39	Sun 5/30/96	Set \$129.99	Fr. 5/23/09	Wed 5/26/26	Tue 5/25/99	Mon \$/24/96	Sun 5/23/99	Sat 5/22/98	Fri \$23.7	Mer Pan	Tue S/18/9	Sun 5/12/99	Set \$/15/9	Fri 5/149	EVELYS MLI	Wed \$1123	Tue 5/11/89	Mon s/10/9	Set 5/6/99	Fri 5/7/0	Thu 5/8/9	Mad SAM	Tue Side	Sun 5/2/98	Ser Sri A	Fri 47004	Thu 4/29/	Tue 4/27/99	Mon 4/28/	Sun 4255	Fn 4/21/	Thu 4/22/98	+	Tue 4/20/	Sun eray	Set 4/17/		Date
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Table C-4
RO Water Quality Data

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Sat 4/7/98		100	Twe 8/2/99	Mon 8/2/99	Sun 8/1/99	Sal 7/31/99	Fri 7/30/99	Thu 7/29/98	Wed 7/28/99	Tue 7/27/96	Mon 7/26/99	Sun 7/25/09	Set 7/24/98	F# 7/23/89	Thu 7/22/99	Wed 7/21/99	Tue 7/20/99	Mon 7/19/99	Sun 7718/99	Sat 7/17/99	Fri 7/18/59:	Thu 7/15/99	Wed 7/1 4/59	Tue 7/13/99	Mon 7/12/99	Sum 7/11/99	Sat 7/10/99	Fn 7/3/99	Thu 7/8/98	Wed 7/7/99	Mon 7/5/99	Sun 7/4/90	Set 7/2/99	SECTION AND ADDRESS OF THE PERSON AND ADDRES	SEDEN POR	Tue 6/29/99	Mon 4/28/99	Sun 6/27/99	Fri 6/25/98	Thu 6/24/98	Wed 6/23/99	Tue 6/22/99	Sun 6/20/90	Sat 6/19/99	Fri 6/18/39	Thu 6/17/99	86.5 L/S Pe.M.	Tue 6/15/99	Hon 6/14/99	Sat 6/12/98	Date	
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Table C-4
RO Water Quality Data

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7.39	ź	6.22 1	7.46 1	7.00 1	7.30 1	7.13 1	7.13	7.13 1	7.52	7.40	7.46						рн	_	
1.893.00	1,211.00	1,668.44	1,573.00	7.09 1,544.00	7.30 1.560.00	1,651.00	7.13 1.651.00	1,651.00	7.52 1,630.00	7.40 1,483.00	1,556.50	L			_		Conductivity (uS/cm)		
7 30	6.01	6.62	6.82	6.71	6.77		6.17	5	7.93	ŝ	7						TOC (mg/L)		
0.24	0.06	0.11	0.22	<u>.</u>	0.16	0.29	0.12	0.18	0.11	0.16	0.25	Ī	_				Turbidity (NTU)	-	
8	6	5	2.50	3	. 8	1.80	1.	*	2.30	90	2.07		68				SDI	•	
1.71	0.02	0.70	2.64	10	1.71	1.41	0.42	0.92	2.14	1,24	1.62		_	_	_	_	Total Chiorine (mg/L)		
2	0.02	0.11		0.08	0.12	L	8.	0.04	0.15	0.10	0.12	Ĺ	_	_		_	Free Chlorine (mg/L)	FEED	
006.00	791.00	898.67	961.00	920.00	943.33	.031.00	966.00	998.50	929.00	\$29.00	929.00	L					TDS (mg/L)	_	
8	5. 86	8	9.00	8	5.	2.00	2.00	2.00				L		_	_		Tatal Coliform (CFU/100 mL)	_	
8	J.06	8	2.00	2.00	2.00							L					Fecal Coliform (CFU/100 mL)	_	
580000	8	97636	380000	3600	87950	96000	2200	19300	68000	8000	38000						Pseudomonas (1900° CFU/100mL)		
700.00	1,000,00	1,444,35	4,400.00	170.00	864.87	6.000.00	1,500.00	3,274.18		_						1.000.00	HPC (CPU/mL)	-	
7.61	3.10	8.08	7.63	7.13	7.64	ı	7.32	7.12	7.73	7.60	7.67						рH		ROV
6.946.00	4,290.00	5 364 67	4,620.00	2,700.00	3,717.50	3,420.00	3,420.00	3,420.00	6.250.00	3,380.00	4,015.00	[_	_			Conductivity (uS/cm)	8	Table C-4 RO Water Quality Data
Š	0.14	0.34	1.62	0.14		1.46	0.23	2.0	135		0.97		_			_	Turbidity (NTU)	CONCENTRATE	ality Date
8	0.30	1.57											_				SDI	AT.	ш
5 106.00	2,758.00 5.25	3,503,22	2,114.00 6.21	1.41.8	1,702.00	2,796.00	2,016.00	2,341.33	4.776.00	11.00	2,393.50					_	TDS (mg/L)	_	
2					6.07	8	8	6.00	6.35	6.01	6.18	Ĺ		_			pН	-	
56.00	71.00	109.56	72.00	8	62.50	8.00	96.00	86.00	80.00	0.04	#.5	L					Conductivity (uS/cm)	_	
8	0.50	9.50	0.50	0.50		ĺ	0.50	0.50	0.50	0.50	0.50	L				_	TOC (mg/L)		
-	0.02	8	i		0.05	i .	0.04	0.08	0.06	0.04	8.	Ĺ			_		Turbidky (NTU)	-	
9	2	*	ı		22.0	i	0.20		0.50 31		0.47 31	L			_		SDI	-	
	29.00 0.		l	34.00 1.	1.22	l		\$1.00 O.	35.00	5.00	35.00	-	_		_		TDS (mg/L)	- 56	
_	0.02 0.		2.57 0			l		0.90 0				L					Total Chiorine (mg/L)	ERMEATE	
	0.02	_		0.08 2		l	0.04 7	0.06 7				L					Free Chlorine (mg/L) Total Collions	-	
8	8	8	ĺ		2.11	8	8	8				L	_		_		(CFL/100 mL)	-	
ę.			_	8			_	_				-					Fecal Coliform (CPU/100 mL)		
180.00	7.00	64.57	700.00	90	276.75	00.00	30.00	50.25	22.00	9.00	13.50	L				_	Pseudomones (CFU/100mL)	_	
00000	ĕ.	276.43	700.00	8	3	+	10.00	110.28	142.00	32.00	76.67	L				350 00	HPC (CFUML)		
93.15	97. E	92,40	92.67	92.55	92.61	91.91	91.90	91.90	93.74	92.73	93.34	L			_		% TOC Removal	_	
7.93	93.72	8 5.56	30	94.17	1.32	95.93	92.75	11.11	98.23	34 .23	96.23	L	_		_	_	% TDS Ramovai	PEMOV	
7.14	4.47	5.07	52	4.15	5.79	6.51		5.87	7.13	5.58	6.35	L					Log Reduction	VALS	
8	11 11	57.29	0.00	53.05	Ī	75.00	25.00	Ĭ	2	72.73	78.47						% Turbidity Removal		Ì

Table C-4 RO Water Quality Data





CH2M HILL

Applied Sciences Group

2300 NW Walnut Blvd

Corvatlis, OR

97330-3538

P.O. Box 428

Corvallis, OR

97339-0428

Tel 541.752.4271

Fax 541.752.0276

September 22, 1999

McAllen WWTP #2, City of

149462.A1.ZG

RE:

Analytical Data for McAllen WWTP #2, City of

Applied Sciences Group Reference No. 9964

Dear Angie Fernandez/PHX:

On August 18, 1999, CH2M HILL Applied Sciences Group received four samples with a request for analysis of selected parameters.

The analytical results and associated quality control data are enclosed. Any unusual difficulties encountered during the analysis of your samples are discussed in the case narrative. Subcontracted analyses reports are attached.

Under CH2M HILL policy, your samples will be stored for 30 days after reporting. If you have not given us prior instructions for disposal, we will contact you if any samples require disposal as hazardous waste.

CH2M HILL Applied Sciences Group appreciates your business and looks forward to serving your analytical needs again. If you should have any questions concerning the data, or if you need additional information, please call Ms. Kathy McKinley at (541) 758-0235, extension 3120.

Sincerely,

Kelly Ensor

Senior Administrative Assistant

Mugneer

Enclosures

CLIENT SAMPLE CROSS-REFERENCE

CH2M HILL Applied Sciences Group Reference No. 9964

Sample ID	Client Sample ID	Date Collected	Time Collected
996401	ZGP	8/17/99	7:30
996402	ROP	8/17/99	7:30
996403	ROC	8/17/99	7:30
996404	WWTP#2Effluent	8/17/99	7:30

CASE NARRATIVE GENERAL CHEMISTRY

Lab Reference No.: 9964

Client/Project: McAllen WWTP #2, City of

I. Holding Time:

All acceptance criteria were met.

- II. Analysis:
 - A. Calibration:

Bromide recovery (132%) in final calibration verification exceeded acceptance criteria. All other acceptance criteria were met.

B. Blanks:

All acceptance criteria were met.

C. <u>Matrix Spike Sample(s)</u>:

Bromide matrix spike recovery (200%) exceeded acceptance criteria. All other acceptance criteria were met.

D. Duplicate Sample(s):

All acceptance criteria were met.

E. <u>Lab Control Sample(s)</u>:

All acceptance criteria were met.

F. Other:

Not applicable.

IV. Documentation Exceptions:

None.

V. I certify that this data package is in compliance with the terms and conditions agreed to by the client and CH2M HILL, both technically and for completeness, except for the conditions detailed above. Release of the data contained in this hardcopy data package has been authorized by the Laboratory Manager or his designee, as verified by the following signature.

Drenared hy

Reviewed by:

CASE NARRATIVE METALS

Lab Reference No.: 9964

Client/Project:	McAllen	WWTP #2 ,	City of
-----------------	---------	------------------	---------

I. <u>Holding Time</u>:

All acceptance criteria were met.

II. <u>Digestion Exceptions</u>:

None.

III. Analysis:

A. <u>Calibration</u>:

All acceptance criteria were met.

B. Blanks:

All acceptance criteria were met.

C. <u>ICP Interference Check Sample:</u>

All acceptance criteria were met.

D. <u>Spike Sample(s)</u>:

All acceptance criteria were met.

E. <u>Duplicate Sample(s)</u>:

All acceptance criteria were met.

F. <u>Laboratory Control Sample(s)</u>:

All acceptance criteria were met.

G. <u>ICP Serial Dilution</u>:

Not Required.

H. Other:

None

IV. <u>Documentation Exceptions</u>:

None

V. I certify that this data package is in compliance with the terms and conditions agreed to by the client and CH2M HILL, both technically and for completeness, except for the conditions detailed above. Release of the data contained in this hardcopy data package has been authorized by the Laboratory Manager or his designee, as verified by the following signature.

Prepared by: _	July Day	
Reviewed by:	() () () ()	

 \wedge

Client Information

Lab Information

Client Sample ID: ROC

Lab Sample ID: 996403

Project Name: McAllen WWTP #2, City of Project Manager: Angle Fernandez/PHX

Date Received: 08/18/1999 Report Revision No.: 0

Sampled By: R. Trevino Sampling Date: 08/17/1999 Analyzed By: MG/DK/MS

Sampling Time: 7:30

Reviewed By: ______

Type: Grab Matrix: Water Basis: As Received

Analyte	MRL	Sample Result	Qualifier	Units	Analysis Method	Date Analyzed
General Chemistry						
N-Nitrate	0.20	35.4		mg/L	EPA 353.2	08/19/1999
N-Total Kjeldahl	2.0	2.72		mg/L	EPA 351.4	08/25/1999
Total Dissolved Solids	5	3,230		mg/L	EPA 160.1	08/23/1999
TOC	5.0	33.7		mg/L	EPA 415.1/2	08/19/1999
Total Phosphate-P	0.25	9.89		mg/L	EPA 365.2/4	08/19/1999

Client Information

Lab Information

Client Sample ID: WWTP#2Effluent

Lab Sample ID: 996404

Project Name: McAllen WWTP #2, City of Project Manager: Angie Fernandez/PHX

Date Received: 08/18/1999

Sampled By: R. Trevino

Report Revision No.: 0

Sampling Date: 08/17/1999

Analyzed By: MG/DK/MS
Reviewed By:

Sampling Time: 7:30

Type: Grab Matrix: Water

Basis: As Received

Analyte	MRL	Sample Result	Qualifier	Units	Analysis Method	Date Analyzed
General Chemistry						
N-Nitrate	0.04	2.96		mg/L	EPA 353.2	08/19/1999
N-Total Kjeldahl	2.0	2.0	U	mg/L	EPA 351.4	08/25/1999
Total Dissolved Solids	5	799		mg/L	EPA 160.1	08/24/1999
TOC	0.50	8.39		mg/L	EPA 415.1/2	08/19/1999
Total Phosphate-P	0.25	2.98		mg/L	EPA 365.2/4	08/19/1999

Client Information

Client Sample ID: ZGP

Project Name: McAllen WWTP #2, City of Project Manager: Angle Fernandez/PHX

Sampled By: R. Trevino
Sampling Date: 08/17/1999
Sampling Time: 7:30
Type: Grab
Matrix: Water
Basis: As Received

Lab Information

Lab Sample ID: 996401

Date Received: 08/18/1999

Report Revision No.: 0

Analyzed By: DK/MG/MS/JJB
Reviewed By: -3- 244

Analyte	MRL	Sample Result	Qualifier	Units	Analysis Method	Date Analyzed
General Chemistry						
Alkalinity (as CaCO3)	2.0	121		mg/L	EPA 310.2	08/23/1999 -
Bromide	0.020	0.132		mg/L	EPA 300.0-B	08/19/1999
Chloride	1.0	160		mg/L	EPA 300.0-A	08/23/1999
Color (APHA) Apparent	***	22		color units	EPA 110.2	08/18/1999
Fluoride	0.10	1.07		mg/L	EPA 300.0-A	08/23/1999
N-Nitrate	0.10	9.55		mg/L	EPA 353.2	08/19/1999
N-Total Kjeldahl	2.0	2.0	U	mg/L	EPA 351.4	08/25/1999
Silica-React.	0.40	15.1		mg/L	SM4500-Si D	09/01/1999
Sulfate	1.0	150		mg/L	EPA 300.0-A	08/23/1999
Total Dissolved Solids	5	774		mg/L	EPA 160.1	08/23/1999
roc	0.50	7.48		mg/L	EPA 415.1/2	08/19/1999
Total Phosphate-P	0.25	2.48		mg/L	EPA 365.2/4	08/19/1999
UV-254	0.009	0.129		asb/cm	SM5910	08/19/1999

Client Information Lab Information

Client Sample ID: ZGP Lab Sample ID: 996401

Project Name: McAllen WWTP #2, City of Analysis Me Project Manager: Angie Fernandez/PHX

Sampled By: R. Trevino Date Collected: 8/17/99 Time Collected: 7:30

Type: Grab Matrix: Water Basis: As Received Analysis Method: SW 8260B

Units: µg/L Date Received: 8/18/99 Date Analyzed: 8/27/99

Dilution Factor: 1
Report Revision No.: 0
Reported By: MCB
Reviewed By: >AH

Analyte	CAS#	Reporting Limit	Sample Result	Qualifier
Purgeable Volatiles				
Vinyl Chloride	75-01-4	1.0	1.0	U
trans-1,2-Dichloroethene	156-60-5	1.0	1.0	Ü
cis-1,2-Dichloroethene	156-59-4	1.0	1.0	Ü
1,1,1-Trichloroethane	71-55-6	1.0	1.0	ŭ
Carbon Tetrachloride	56-23-5	1.0	1.0	Ü
Trichloroethene	79-01-6	1.0	1.0	Ü
1,4-Dichlorobenzene	106-46-7	1.0	1.0	Ū
Dibromofluoromethane	1868-53-7		94%	SS
1,2-Dichloroethane-d4	17068-07-0		89%	SS
Toluene-d8	2037-26-5		103%	SS
p-Bromofluorobenzene	460-00-4		103%	SS

E=Estimated value above instrument calibration range

J=Estimated value below reporting limit

U=Not detected at specified reporting limit

SS=Surrogate standard

Client Information

Lab Information

Client Sample ID: ZGP

Lab Sample ID: 996401

Project Name: McAllen WWTP #2, City of Project Manager: Angie Fernandez/PHX

Analysis Method: SM 5710.D

Sampled By: R. Trevino Date Collected: 8/17/99 Time Collected: 7:30 Date Received: 8/18/99 Report Revision No.: 0

Type: Grab Matrix: Water Basis: As Received Analyzed By: BDW
Reviewed By: 2474

SDS-HAA/THM Formation Potential Test Conditions

	Target			Contact	Chlorine	
Set-up Date/Time	Contact Time (h:mm)	Initial pH	Contact pH	Temperature (°C)	Dosage (mg/L)	
8/23/99 9:34	72:00	7.7	7.8	23	10.10	

Chlorine Demand Test Results

Take-off Date/Time	Actual Contact Time (h:mm)	Measured pH	Measured Temperature (°C)	Chlorine Residual (mg/L)	
8/26/99 13:10	75:36	7.8	23	0.68	

Client Information

Lab Information

Client Sample ID: ROP

Lab Sample ID: 996402

Project Name: McAllen WWTP #2, City of Project Manager: Angie Fernandez/PHX

Date Received: 08/18/1999 Report Revision No.: 0

Sampled By: R. Trevino Sampling Date: 08/17/1999 Sampling Time: 7:30

Type: Grab Matrix: Water Basis: As Received

		Sample			Analysis	Date
Analyte	MRL	Result	Qualifier	Units	Method	Analyzed
General Chemistry						
Alkalinity (as CaCO3)	2.0	14		mg/L	EPA 310.2	08/23/1999 -
Bromide	0.020	0.020	U	mg/L	EPA 300.0-B	08/19/1999
Chloride	0.10	9.73		mg/L	EPA 300.0-A	08/23/1999
Color (APHA) Apparent		5	U	color units	EPA 110.2	08/18/1999
Fluoride	0.10	0.32		mg/L	EPA 300.0-A	08/23/1999
N-Nitrate	0.01	1.11		mg/L	EPA 353.2	08/19/1999
N-Total Kjeldahl	2.0	2.0	U	mg/L	EPA 351.4	08/25/1999
Silica-React.	0.40	0.65		mg/L	SM4500-Si D	09/01/1999
Sulfate	0.10	4.00		mg/L	EPA 300.0-A	08/23/1999
Total Dissolved Solids	5	33		mg/L	EPA 160.1	08/23/1999
TOC	0.50	0.63		mg/L	EPA 415.1/2	08/19/1999
Total Phosphate-P	0.05	0.10		mg/L	EPA 365.2/4	08/19/1999

Client Information

Client Sample ID: ROP

Project Name: McAllen WWTP #2, City of Project Manager: Angie Fernandez/PHX

Sampled By: R. Trevino Sampling Date: 08/17/99 Sampling Time: 07:30 Type: Grab

Matrix: Water Basis: As Received

Lab Information

Lab Sample ID: 996402

Date Received: 8/18/99

Report Revision No.: 0
Reported By: JG
Reviewed By: A

By

		Sample			Analysis	Date
Analyte	MRL	Result	Qualifier	Units	Method	Analyzed
Aluminum, Al	45.6	45.6	U	μg/L	SW6010B	08/27/99
Arsenic, As	3.9	3.9	Ü	μg/L	SW6010B	08/27/99
Barium, Ba	0.81	0.81	ΰ	μg/L	SW6010B	08/27/99
Cadmium, Cd	0.38	0.38	Ü	μg/L	SW6010B	08/27/99
Calcium, Ca	21.3	714	-	μg/L	SW6010B	08/27/99
Chromium, Cr	7.2	7.2	U	μg/L	SW6010B	08/27/99
Iron, Fe	2.8	9.9		μg/L	SW6010B	08/27/99
Lead, Pb	2.3	2.3	U	μg/L	SW6010B	08/27/99
Magnesium, Mg	41.0	197		μg/L	SW6010B	08/27/99
Manganese, Mn	1.0	1.0	U	μg/L	SW6010B	08/27/99
Mercury, Hg	0.25	0.25	U	μg/L	SW7470A	08/23/99
Potassium, K	181	1360		μg/L	SW6010B	08/27/99
Selenium, Se	6.8	6.8	U	μg/L	SW6010B	08/27/99
Silver, Ag	8.0	8.0	U	μg/L	SW6010B	08/27/99
Sodium, Na	593	13000		μg/L	SW6010B	08/27/99
Strontium, Sr	28.6	28.6	U	μg/L	SW6010B	08/27/99
Zinc, Zn	2.3	7.2		μg/L	SW6010B	08/27/99

Client Information	Lab Information
Client Sample ID: ROP	Lab Sample ID: 996402
Project Name: McAllen WWTP #2, City of Project Manager: Angie Fernandez/PHX Sampled By: R. Trevino Date Collected: 8/17/99 Time Collected: 7:30 Type: Grab	Analysis Method: SW 8260B Units: µg/L Date Received: 8/18/99 Date Analyzed: 8/27/99 Dilution Factor: 1 Report Revision No.: 0
Matrix: Water Basis: As Received	Reported By: MCB Reviewed By: >474

Analyte	CAS#	Reporting Limit	Sample Result	Qualifier
Purgeable Volatiles				
Vinyl Chloride	75-01-4	1.0	1.0	U
trans-1,2-Dichloroethene	156-60-5	1.0	1.0	Ü
cis-1,2-Dichloroethene	156-59-4	1.0	1.0	Ŭ
1,1,1-Trichloroethane	71-55 - 6	1.0	1.0	Ü
Carbon Tetrachloride	56-23-5	1.0	1.0	Ü
Trichloroethene	79-01-6	1.0	1.0	Ū
1,4-Dichlorobenzene	106-46-7	1.0	1.0	U
Dibromofluoromethane	1868-53-7		96%	SS
1,2-Dichloroethane-d4	17068-07-0		96%	SS
Toluene-d8	2037-26-5		104%	SS
p-Bromofluorobenzene	460-00 - 4		103%	SS

E=Estimated value above instrument calibration range

J=Estimated value below reporting limit

U=Not detected at specified reporting limit

SS=Surrogate standard

Client Information

Lab Information

Client Sample ID: ROP

Lab Sample ID: 996402

Project Name: McAllen WWTP #2, City of Project Manager: Angie Fernandez/PHX

Analysis Method: SM 5710.D

Sampled By: R. Trevino Date Collected: 8/17/99 Time Collected: 7:30

Date Received: 8/18/99 Report Revision No.: 0 Analyzed By: BDW

Type: Grab Matrix: Water Basis: As Received Reviewed By: SAZ

SDS-HAA/THM Formation Potential Test Conditions

Set-up Date/Time	Target Contact Time (h:mm)	Initial pH	Contact pH	Contact Temperature (°C)	Chiorine Dosage (mg/L)	
8/23/99 9:42	72:00	6.0	7.8	23	1.30	

Chlorine Demand Test Results

Take-off Date/Time	Actual Contact Time (h:mm)	Measured pH	Measured Temperature (°C)	Chlorine Residual (mg/L)
8/26/99 13:14	75:32	7.8	23	0.24

				Formati	Formation Potential Test Conditions	st Conditions					
		FP	Free	Free	Total	FP	Measured	FP	FP	FF.	FP
Client ID	Lab ID	Dose	Residual	Demand	Residual	Temp.	Hd	Start	Take-Off	Time H:M	Time (Hour)
McALLEN-ZGP	996401	10.10	89.0	9.42	;	23	81.7	8/23/99 9:34	8/26/99 13:10	75:36	75:36 75.60
McALLEN-ROP	996402	1.30	0.24	1.06	-	23	7.77	8/23/99 9:42	8/26/99 13:14	75:40	75.67

ts, (ug/L.)			CHCl3 = Chloroform	BDCM = Bromodichloromethane	DBCM = Dibromochloromethane	CHBr3 = Bromoform	EPA TTHM Stuge 1 MCL = 80 ug/L	EPA TTHM Stage 2 MCL = 40 ug/L
on Potential Trihalomethanes (THMs) Disinfection By-Products, (ug/L.)	FP	TTHM	861	5.4				
ethanes (THMs	FP	CHBr3	I>	⊽				
ntial Trihalom	FP	DBCM	9.5	⊽				
Formation Pote	g.	BDCM		1.7				
	FP	CHCI3	150	3.7				
		Lab ID	300301	300302				
		Client ID	McALLEN-ZGP-3D	McALLEN-ROP-3D			i	

			Formation Pot	tential Haloace	on Potential Haloacetic Acids (HAAs) Disinfection By-Products (ug/L)) Disinfection	By-Products (u	g/L)			
		FP	FP	FP	FP	FP	FP	FP	FP		
Client ID	Lab ID	MCAA *	MBAA *	DCAA *	TCAA *	BCAA	DBAA *	HAAS	HAA6		
McALLEN-ZGP-3D	300301	8.6	4:1	49.9	57.3	12.8	9.1	611	132		
McALLEN-ROP-3D	300302	8	7	=	⊽	⊽	⊽		-		
									To the second se		***
											:
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		MCAA = Mono	chloroacetic acid		BCAA = Bromochloroacetic acid	thoroacetic a	cid	EPA HAAS Stage 1 MCL = 60 ug/L	ICL = 60 ug/L		
		MBAA = Mono	MBAA = Monobromoacetic acid		DBAA = Dibromoacetic acid	soacetic acid		EPA HAAS Stage 2 MCL = 30 ug/L	fCL = .30 ug/L		-
		DCAA = Dichloroacetic ac	roacetic acid		* These compounds make up the HAA5	rds make up t	he HAAS				
		TCAA = Trichloroacetic acia	roacetic acid		= Estimated value	يو			-		:

Client Information Lab Information

Client Sample ID: McAllen-ZGP-3d

Lab Sample ID: 300301

Project Name: McAllen WWTP #2, City of Project Manager: Angie Fernandez/PHX

Date Received: 8/26/99 Report Revision No.: 0

Sampled By: B. Warloe
Date Collected: 8/26/99
Time Collected: Not Indicated

Analyzed By: DAH Reviewed By: mbos

Type: Grab Matrix: Water Basis: As Received

Analyte	CAS#	MCL*	Reporting Limit	Sample Result	Qualifier	Units	Analysis Method	Date Analyzed
Haloacetic Acids								
Chloroacetic acid	79-11-8		2.0	8.6		μg/L	SM 6251.B	9/3/99
Bromoacetic acid	79-08-3		1.0	1.4		μg/L		9/3/99
Dichloroacetic acid	79-43-6		5.0	51.4		μg/L		9/16/99
Trichloroacetic acid	76-03-9		5.0	56 .0		μg/L		9/16/99
Bromochloroacetic acid	5589-96-3		1.0	12.8		μg/L		9/3/99
Dibromoacetic acid	631-64-1		1.0	1.6		μg/L	SM 6251.B	9/399
HAA5		60	5.0	119		μg/L		9/16/99
2,3-Dibromopropanoic ac	i 600-05-5			116%	SS			
Trihalomethanes								
Chloroform	67-66-3		5.0	150		μg/Ľ	EPA 502.2	9/1/99
Bromodichloromethane	75-27-4		1.0	38.8		μg/L	EPA 502.2	8/31/99
Dibromochloromethane	124-48-1		1.0	9.5		μg/L	EPA 502.2	8/31/99
Bromoform	75-25-2		1.0	1.0	U	μg/L	EPA 502.2	8/31/99
TTHM	10-20-2	80	1.0	198	J	μg/L	EPA 502.2	9/1/99
I I FIIVI		50	1.0	130		µg/L	LFA 302.2	<i>3</i> /1/33
1,2-Dichloroethane-d4	17068-07-0			102%	SS			

U=Not detected at specified reporting limit *=MCL according to Stage 1 of D/DBP rule SS=Surrogate standard

Client Information Lab Information

Client Sample ID: McAllen-ROP-3d Lab Sample ID: 300302

Project Name: McAllen WWTP #2, City of Date Received: 8/26/99
Project Manager: Angie Fernandez/PHX Report Revision No.: 0
Sampled By: B. Warloe Analyzed By: DAH

Date Collected: 8/26/99 Reviewed By: mbos
Time Collected: Not Indicated

Type: Grab
Matrix: Water
Basis: As Received

Analyte	CAS#	MCL*	Reporting Limit	Sample Result	Qualifier	Units	Analysis Method	Date Analyzed
Haloacetic Acids								
Chloroacetic acid	79-11-8		2.0	2.0	U	μg/L	SM 6251.B	9/3/99
Bromoacetic acid	79-08-3		1.0	1.0	υ	μg/L		9/3/99
Dichloroacetic acid	79-43-6		1.0	1.1		μg/L		9/3/99
Trichloroacetic acid	76-03-9		1.0	1.0	U	μg/L	SM 6251.B	9/3/99
Bromochloroacetic acid	5589-96-3		1.0	1.0	U	μg/L		9/3/99
Dibromoacetic acid	631-64-1		1.0	1.0	U	μg/L	SM 6251.B	9/3/99
HAA5		60	1.0	1.1		μg/L	SM 6251.B	9/3/99
2,3-Dibromopropanoic ac	ei 600-05-5			115%	SS			
Trihalomethanes								
Chloroform	67-66-3		1.0	3.7		μg/L	EPA 502.2	8/31/99
Bromodichloromethane	75-27-4		1.0	1.7		μg/L	EPA 502.2	8/31/99
Dibromochloromethane	124-48-1		1.0	1.0	U	μg/L	EPA 502.2	8/31/99
Bromoform	75-25-2		1.0	1.0	U	μg/L	EPA 502.2	8/31/99
TTHM		80	1.0	5.4		μg/L	EPA 502.2	8/31/99
1,2-Dichloroethane-d4	17068-07-0			9 9 %	SS			

U=Not detected at specified reporting limit *=MCL according to Stage 1 of D/DBP rule SS=Surrogate standard

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CVD 2300 NW Walnut Boulevard Corvallis, OR 97330-3638 (541) 752-4271 FAX (541) 752-0278

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Custody Seals Y NNTM LIMS Verification **Custody Review** THIS AREA FOR LAB USE ONLY <u>8</u> Alternate Description e Cooler Temperature N 17/99 17/93 QC Level Log In Lab PN Date/Time | Dette/Time 품 Date/Time Ramm TIEVIAS Posic VillAREP Please sign and print name) Requested Analytical Method # Shipping # 0258-226V 17H Preservative **Empty Bottles** 4052H J 07 HoszH > 01 HossH Q The 174 کار میصما SDOV 0928-Fod-Ex Relinquished By Rellinguished By Shipped Via UPS Fed hoszy Received By しる了 ۷ 2 2 ~ ひのストベース単年の 11/1997:30 18/17/99 7:39 417hg 7:25 98 Sample Disposal: Dispose Return Date/Time Kashu, McKinley Mmtp#21 549/4 bm/4 McMlen Reuse Pilot Study COSIC VI I NP. LEDI (Please sign and print name) CLIENT SAMPLE ID (9 CHARACTERS) Purchase Order # Project Manager or Contact & Phone # | Report Copy to: (Pieses sign and print name) WWTP#2 10/6 0 له 5 Ste ID ∞O--Kathy McKinley Requested Completion Date: **≱∢⊢≝**⊑ **6**44**0** Sampled By and Titte Special Instructions 00**3**0 Voca V AS AP 8/17/9/ 7:30 Relinquished By Company Name 817/M 7:30 1.32 8/17/8/7:30 11/19/1:30 8/17/19/7:30 Received By Project Name 2000 Received By Sampling Project # Date

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AND AGREEMENT TO PERFORM SERVICES

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CHAZMHILL Applied Sciences Lab c CHAIN OF CUSTODY RECORD AND AGREEMENT TO PERFORM SERVICES (6

CV0 2300 NW Weinut Boulevard Corvalls, OR 97330-3838 (541) 752-4271 FAX (541) 752-0278

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Custody Seafe Y N Lab ID Nh (B) **LIMS Verification Custody Raview** THIS AREA FOR LAB USE ONLY Peg (Other Alternate Description 07:39 # 000 000 4964 m Cooler Temperature Date/Time 8 | 1.7 | 9.9 QC Level 8/11/89 Lab PM Log In 돐 Darte/Time, Date/Time Alkalinity, TDS, Color Brimide, Chloride, Fluoride, Sulfede, Bactive Silica Ramin Trevino Posie Villinge EAI Requested Analytical Method # (Please alon and print name) (Please eign and print name) 705, Colo C, Shipping # 46, 45, 5c, Ag, Zn servative FONH Alkalinity, TDS, Color, Branks, Chloride, Fluoride, Swltate, Recative Silice A1, Ba, Ca, Fe, Ma, Mn, K, Wa, Sr, Pe, Ms, Mn, **Empty Bottles** 多 AI) هم هم تحي ٢ لا، ١٩م، حر، ٢٩م، د ١٥) كم الها، هم مع، Mg,1 cd, c EUNH Fed-Ex Refinquished By GOLL Shipped Via Received By 00x-<-z== UPS 3 17/1 7:30 **9**8 K179 87:39 Sample Disposal: Date/Time 8/17/99 <u>2</u> Kashy McKinley Purchase Order # CLIENT SAMPLE ID (9 CHARACTERS) Project Manager or Contact & Phone # Report Copy to: Rosse VIIIn RREA Ranian Trevins (Please eign and print name) (Please sign and print name) MCALLER REUSE PILOT SINGL MWTPHD P 4 9 9 572 0 $\overline{\mathbf{a}}$ City of McAllen Kathy McKinley
Requested Completion Date: Ste 10 **60-**1 7 Z ⋧⋖⊢⋓⋐ 7 7 Z 7 7 0024 Sampled By and Title Special instructions: Company Name 17/95/7:30 11/19/1:30 dt s V E E 17/99 17:30 11/19 7:30 **Relinguished By** Project Name Sampling Received By Received By Male Project # Date

instructions and Agreement Provisions on Reverse Side

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Ms. Anne McKee-Robbins CH2M HILL/CVO 2300 N.W. Walnut Blvd. Corvallis, OR 97330

> Columbia Analytical Services Report City of McAllen D9901502/D1227

> > September 13, 1999

Submitted by:

Leyous forces

Bryan Jones

Project Manager/Client Services

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Sample Identification Cross-Reference	iii
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Case narrative	
Sample results	3
Chain of Custody Documentation	17

Organic Data Qualifiers

- A- This qualifier indicates that a TIC is a suspected aldol-condensation product
- **B--** This flag is used when the analyte is found in the associated blank as well as the sample. This notation indicates possible blank contamination and suggests that the data user evaluate these compounds and their amounts carefully.
- C-- The "C" flag indicates the presence of this compound has been confirmed by the GC/MS analysis.
- **D--** This qualifier is used for all the compounds identified in an analysis at a secondary dilution factor. "D" qualifiers are used only for the samples reported at more than one dilution factor.
- E-- This flag indicates that the value reported exceeds the linear calibration range for that compound. Therefore, the sample should be reanalyzed at the appropriate dilution. The "E" qualified amount is an estimated concentration, and the results of the dilution will be reported on a separate Form I.
- I-- The qualifier indicates that the reporting limit to the "I" qualifier has been raised. It is used when the chromatographic interference prohibits detection of a compound at a level below the concentration expressed on the Form I.
- J- Indicates an estimated value. It is used when the data indicates the presence of a target compound below the reporting limit or the presence of a Tentatively Identified Compound (TIC).
- N-- This qualifier indicates presumptive evidence of a compound. This flag is only used for Tentatively Identified Compounds (TIC), where the identification is based on a mass spectral library research. It is applied to all TIC results. For generic characterization of a TIC, such as chlorinated hydrocarbon, the "N" qualifier is not used.
- P-- This qualifier is used for Pesticide/Aroclor target analytes when there is a greater than 25% difference for detected concentrations between the two columns. The lower of the two values is reported on Form I and flagged with a "P".
- U-- Indicates the compound was analyzed for but not detected. The number adjacent to the "U" qualifier indicates the reporting limit for that compound. The reporting limit can vary from sample to sample depending on dilution factors or percent moisture adjustments when indicated.

Organic Sample ID Qualifiers

The qualifiers that may be appended to the Lab Sample ID and/or the Client Sample ID for organic analysis are defined below:

- **DL--** Diluted reanalysis. Indicates that the results were determined in an analysis of a secondary dilution of a sample or extract. A digit to indicate multiple dilutions of the sample or extract may follow the "DL" suffix. The results of more than one diluted reanalysis may be reported.
- MS-- Matrix spike (may be followed by a digit to indicate multiple matrix spikes within a sample set).
- MSD-Matrix spike duplicate (may be followed by a digit to indicate multiple matrix spikes within a sample set).
- R-- Reanalysis. The extract was reanalyzed without re-extraction. The "R" is not used if the sample was also re-extracted. May be followed by a digit to indicate multiple reanalysis of the sample at the same dilution.
- **RE--** Re-extraction analysis. The sample was re-extracted and reanalyzed. May be followed by a digit to indicate multiple re-extracted analysis of the same sample at the same dilution.

GC ORGANOCHLORINE PESTICIDES

CASE NARRATIVE GC ORGANOCHLORINE PESTICIDES

CAS	Lab	Reference	No./SDG.:	D1227
-----	-----	-----------	-----------	-------

Project: City of McAllen

I. RECEIPT

No exceptions were encountered unless a Sample Receipt Exception Report is attached to the Chain-of-Custody included with this data package.

II. HOLDING TIMES

- Α. Sample Preparation: All holding times were met.
- в. Sample Analysis: All holding times were met.

METHOD III.

Preparation: SW-846 3520C

Cleanup: NA

Analysis: SW-846 8081A

IV. PREPARATION

Sample volume may vary based on the amount of sample received per container.

٧. ANALYSIS

- Calibration. In the ending CCV, toxaphene, exceeded 15%D however the average of all analytes was within therefore no corrective action was taken.
 - 1. Retention Time Windows: All analytes were within criteria.
 - 2. Degradation: All acceptance criteria were met.
- В. Blanks: All acceptance criteria were met.
- Surrogates: All acceptance criteria were met.
- D. Internal Standards: All acceptance criteria were met.
- Ε. Spikes: All acceptance criteria were met.
- F. Samples: Sample analysis proceeded normally.

I certify that this data package is in compliance with the terms and conditions agreed to by the client and Columbia Analytical Services, both technically and for completeness, except for the conditions noted above. Release of the data contained in this hardcopy data package has been authorized by the Laboratory Manager or designated person, as verified by the following signature.

9/10/99 Reviewer: Abun Walker 9-10-99 SIGNED: Jerry Watega

Scientist, GC Organics

Columbia Analytical Services

PWB10820

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Case No.: D1227 SDG No.: D1227

Lab Sample ID: PWB10820

Matrix: WATER Level: LOW Lab File ID: B0904010

Sample Wt/Vol: 1.000 L Date Received:

Extract Vol: 10 ML Date Extracted: 08/20/99

Column: DB5 Date Analyzed: 09/04/99

Extraction Type: Continuous Dilution Factor: 1.0

CAS NO.	COMPOUND	Units: ug/L	MDL	RL	RESULT	Q
72-20-8	gamma-BHC (L Endrin Methoxychlor Toxaphene		0.0032 0.0021 0.017 0.23	0.020 0.020 0.040 0.50	0.020 0.020 0.040 0.50	ט ט ט

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

PWB10820LCS

Case No.: D1227 SDG No.: D1227 Lab Sample ID: PWB10820LCS

Matrix: WATER Level: LOW Lab File ID: B0904008

Sample Wt/Vol: 1.000 L Date Received:

Extract Vol: 10 ML Date Extracted: 08/20/99

Column: DB5 Date Analyzed: 09/04/99

Extraction Type: Continuous Dilution Factor: 1.0

CAS NO.	COMPOUND	Units: ug/L	MDL	RL	RESULT	Q
72-20-8	gamma-BHC (L Endrin Methoxychlor Toxaphene		0.0032 0.0021 0.017 0.23	0.020 0.020 0.040 0.50	0.56 0.52 0.46 0.50	

FORM I

SW846

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

PWB10820LCS

Case No.: D1227 SDG No.: D1227

Lab Sample ID:

PWB10820LCS

Matrix: WATER Level:

LOW

Lab File ID:

B0904009

Sample Wt/Vol: 1.000 L

Date Received:

Extract Vol:

10 ML

Date Extracted: 08/20/99

Column: DB5

Date Analyzed: 09/04/99

Extraction Type: Continuous

Dilution Factor: 1.0

CAS NO.	COMPOUND	Units: ug/L	MDL	RL	RESULT	Q
72-20-8 72-43-5	gamma-BHC (Li Endrin Methoxychlor Toxaphene	ndane)	0.0032 0.0021 0.017 0.23	0.020 0.020 0.040 0.50	0.020 0.090 0.075 5.1	<u>U</u>

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING ZGPERMEATE

Case No.: D1227 SDG No.: D1227 Lab Sample ID: D1227001

Matrix: WATER Level: LOW Lab File ID: B0904011

Sample Wt/Vol: 1.000 L Date Received: 08/18/99

Extract Vol: 10 ML Date Extracted: 08/20/99

Column: DB5 Date Analyzed: 09/04/99

Extraction Type: Continuous Dilution Factor: 1.0

CAS NO.	COMPOUND	Units: ug/L	MDL	RL	RESULT	Q
72-20-8	gamma-BHC (L Endrin Methoxychlor Toxaphene		0.0032 0.0021 0.017 0.23	0.020 0.020 0.040 0.50	0.024 0.020 0.040 0.50	U U

CLIENT ID.

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

ROPERMEATE

Case No.: D1227 SDG No.: D1227 Lab Sample ID: D1227002

Matrix: WATER Level: LOW Lab File ID: B0904012

Sample Wt/Vol: 1.000 L Date Received: 08/18/99

Extract Vol: 10 ML Date Extracted: 08/20/99

Column: DB5 Date Analyzed: 09/04/99

Extraction Type: Continuous Dilution Factor: 1.0

CAS NO. COMPOUND	Units: ug/L	MDL	RL.	RESULT	Q
58-89-9gamma-BHC 72-20-8Endrin 72-43-5Methoxychl 8001-35-2Toxaphene		0.0032 0.0021 0.017 0.23	0.020 0.020 0.040 0.50	0.020 0.020 0.040 0.50	ם ט ט

2C WATER SEMIVOLATILE SURROGATE RECOVERY

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Case No.: D1227 SDG No.: D1227

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	LAB ID	CLIENT ID.	S1 #	S2 #	S2	TOT
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01	PWB10820LCS	DWD100201.CC	102	======	=====	===
02		PWB10820LCS	107	86] 0
	PWB10820LCS	PWB10820LCS	105	72	1	0
03	PWB10820	PWB10820	102	76		l ol
04	D1227001	ZGPERMEATE	105	74		0
05	D1227002	ROPERMEATE	68	47		l ŏl
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QC LIMITS

= Tetrachloro-m-xylene
= Decachlorobiphenyl (45-125)(34-133)

Column to be used to flag recovery values
* Values outside of contract required QC limits
D Surrogates diluted out

3E WATER PESTICIDE LAB CONTROL SAMPLE

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Case No.: D1227 SDG No.: D1227 Column: DB5

LCS - Sample No.: PWB10820

COMPOUND	SPIKE	SAMPLE	LCS	LCS	QC.
	ADDED	CONCENTRATION	CONCENTRATION	%	LIMITS
	(ug/L)	(ug/L)	(ug/L)	REC #	REC.
gamma-BHC (Lindane)	0.5000	0.0000	0.5583	112	73-125
Endrin	0.5000	0.0000	0.5193	104	43-134
Methoxychlor	0.5000	0.0000	0.4603	92	73-142

- # Column to be used to flag recovery and RPD values with an asterisk
- * Values outside of QC limits

RPD: 0 out of 0 outside limits

Spike Recovery: 0 out of 3 outside limits

COMMENTS:			

WATER PESTICIDE LAB CONTROL SAMPLE

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Case No.: D1227 SDG No.: D1227 Column: DB5

LCS - Sample No.: PWB10820

COMPOUND	SPIKE	SAMPLE	LCS	LCS	QC.
	ADDED	CONCENTRATION	CONCENTRATION	%	LIMITS
	(ug/L)	(ug/L)	(ug/L)	REC #	REC.
Toxaphene	5.000	0.0000	5.095	102	41-126

- # Column to be used to flag recovery and RPD values with an asterisk
- * Values outside of QC limits

RPD: 0 out of 0 outside limits

Spike Recovery: 0 out of 1 outside limits

COMMENTS:	

SW846

SEMIVOLATILE METHOD BLANK SUMMARY

Client ID.

PWB10820

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Case No.: D1227 SDG No.: D1227

Lab File ID: B0904010

Lab Sample ID:

PWB10820

Date Extracted: 08/20/99

Extraction Type:

CONT

Date Analyzed:

09/04/99

Time Analyzed:

2010

Matrix:

WATER

Level: (low/med)

LOW

Instrument ID:

GCB

THIS METHOD BLANK APPLIES TO THE FOLLOWING SAMPLES, MS and MSD:

	CLIENT ID.	LAB SAMPLE ID	LAB FILE ID	DATE ANALYZED
01 02 03 04 05 06 07 08 09 11 12 13 14 15 16 17 18 19 20 21		PWB10820LCS PWB10820LCS D1227001 D1227002	B0904008 B0904009 B0904011 B0904012	ANALYZED ===================================
22 23				

PESTICIDE CONTINUING CALIBRATION CHECK

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Instrument ID: GCB Case No.: D1227 SDG No.: D1227

1605

GC Column: DB5

ICAL Date/Time (1st pt): 08/22/99

1725

ICAL Date/Time (Last pt): 08/22/99

2040

Units : ug/mL

COMPOUND	AVERAGE RF	RF	CURVE	%D	MAX %d	
Toxaphene	0.044	0.038	AVG	-12.0	15 A	
(2)	0.047	0.039	AVG	-17.6	15.0	<-
(3)	0.050	0.048	AVG	-4.3	15.0	

7B PESTICIDE CONTINUING CALIBRATION CHECK

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Instrument ID: GCB Case No.: D1227 SDG No.: D1227

Lab File ID: B0904020 CCV Date/Time: 09/05/99 0417

GC Column: DB5 ICAL Date/Time (1st pt): 08/23/99 0959

ICAL Date/Time (Last pt): 08/23/99 1314

Units : ug/mL

	AVERAGE				MAX	i
COMPOUND	RF	RF	CURVE	%D	%d	ł
	=======	========	=======	=====	====	
alpha-BHC	2.751	3.182	AVG		15.0	
beta-BHC	0.871	0.968	AVG		15.0	
delta-BHC	2.640	2.951	AVG		15.0	
gamma-BHC (Lindane)	2.495	2.825	AVG	13.2	15.0	
Heptachlor	2.542	2.917	AVG	14.7	15.0	
Aldrin	2.351	2.658	AVG	13.1	15.0	ĺ
Heptachlor epoxide	2.134	2.365	AVG	10.8	15.0	ļ
Endosulfan I	1.886	1.963	AVG		15.0	
Dieldrin	2.243	2.438	AVG	8.7	15.0	
4,4'-DDE	1.919	1.922	AVG		15.0	1
Endrin	1.972	2.030	AVG		15.0	
Endosulfan II	1.832	1.892	AVG		15.0	
4,4'-DDD	1.503	1.543	AVG		15.0	
Endosulfan sulfate	1.801	1.684	AVG		15.0	
4,4'-DDT	1.717	1.732	AVG		15.0	
Methoxychlor	0.903	0.864	AVG		15.0	1
Endrin ketone	1.951	1.960	AVG		15.0	1
Endrin aldehyde	1.334	1.342	AVG		15.0	1
alpha-Chlordane	2.115	2.222	AVG		15.0	ĺ
gamma-Chlordane	2.117	2.223	AVG		15.0	i
=======================================	=======	======================================	=======		====	ĺ
Tetrachloro-m-xylene	1.075	1.249	AVG	16.2	20.0	
Decachlorobiphenyl	1.920	1.792	AVG	-6.6		

PESTICIDE CONTINUING CALIBRATION CHECK

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Instrument ID: GCB

Case No.: D1227 SDG No.: D1227

0506

GC Column: DB5

ICAL Date/Time (1st pt): 08/22/99

1725

ICAL Date/Time (Last pt): 08/22/99

2040

Units : ug/mL

COMPOUND	AVERAGE RF	RF	CURVE	%D	MAX %d	
Toxaphene (2)	0.044	0.039 0.036	AVG AVG	-10.4 -24.2	15.0	<-
(3)	0.050	0.043	AVG	-12.5	15.0	

$\mathbb{C}3$ PESTICIDE ANALYTICAL SEQUENCE

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Case No.: D1227 SDG No.: D1227

Instrument ID: GCB

	CLIENT SAMPLE NO.	LAB SAMPLE ID	DATE ANALYZED	TIME ANALYZED
01 02 03	PSTD#3 PEST PSTD#3 TOX PWB10820LCS	PSTD#3 PEST PSTD#3 TOX PWB10820LCS	09/04/99 09/04/99 09/04/99	1517 1605
04 05 06	PWB10820LCS PWB10820 ZGPERMEATE	PWB10820LCS PWB10820LCS PWB10820 D1227001	09/04/99 09/04/99 09/04/99	1832 1921 2010 2058
07 08 09 10	ROPERMEATE PSTD#3 PEST PSTD#3 TOX	D1227002 PSTD#3 PEST PSTD#3 TOX	09/04/99 09/05/99 09/05/99	2147 0417 0506
11 12 13				
14 15 16			•	
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20 21 22				
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CHAIN OF CUSTODY DOCUMENTATION

CH2IMHILL Analytical Services CHAIN OF CUSTODY RECORD AND AGREEMENT TO PERFORM SERVICES

UJ LMG 2567 Fairlane Drive Montgomery, AL 36116-1622 (334) 271-1444 FAX (334) 271-3428

☐ LRD 5090 Caterpillar Road Redding, CA 96003-1412 (916) 244-5227 FAX (916) 244-4109

[] LKW Canviro Analytical Laboratories, Inc. 50 Bathurst, Unit 12, Waterloo, Ontario, Canada N2V 2C5 (519) 747-2575 FAX (519) 747-3806

| EVV0 2300 NW Walnut Boulevard Corvallis, OR 97330-3638 (541) 752-4271 FAX (541) 752-0276 COC # 980189

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Instructions:

3. Relinquished by: (signature)

Date N/A

Time NVA

Received by: (signature)

4. Relinquished by: (signature)
Sheryl A. Garling

Date 5-28-95

Time 14:00p

Received at Laboratory by:

Roger A. Garling

1.Sampler: (signature)

Jeff Jones

Date **5-23-95**

Time **12:05p**

Received by: (signature)

2.Relinquished by: (signature) Harry Truckers

Date **5-28-95**

Time **13:15p**

Received by: (signature)
Sheryl A. Garling

Harry Truckers

- 33 A completed Chain-of-Custody must be submitted with all samples Special Requests area can include (but not limited to) the following:

 • Turnaround status, Rush status, Due Date, etc.
- Special mailing instructions:
- send copy of Report and/or Invoice to a second party
 send copy of Report to a Government Agencies (EPA, etc.)
- Public Water System (PWS) Number
 Do you want samples returned to voi Do you want samples returned to you or disposed of?

Scope of Work/Instructions

CH2M HILL Point of Contact for Final report/Invoicing

CH2M HILL Kathy McKinley 2300 NW Walnut Blvd. Corvallis, OR 97330

Phone: 541/758-0235 ext. 3144

FAX: 541/766-2852

Analytical Methods/Prices:

Radium 226 by EPA 903.0 for \$40 per sample Radium 228 by EPA 904.0 for \$50 per sample Gross Alpha by EPA 903.0 for \$35 per sample

Sample Delivery: \$25

Return Cooler/Samples: \$6.40

The laboratory shall clearly and completely document and justify the preparation and analysis procedures when modifications to the methods have been made/requested.

Holding Times: Samples must be analyzed within EPA holding for each analytical method specified. CH2M HILL will deliver samples to the laboratory in a timely manner to facilitate the meeting of holding times.

Quality Assurance/Quality Control Requirements: QA/QC procedures will follow the protocols set forth in the EPA methods.

Data Package: A final data package must be submitted to CH2M HILL. The package will include: a lab narrative and data summary.

The laboratory narrative will include:

A description of any deviation from the prescribed methodologies or protocols as discussed in this SOW.

Summarization of quality control information exceeding the laboratory's acceptance criteria, a discussion of possible reasons for these discrepancies, and a description of corrective action taken.

All blank values exceeding three times the average method blank will be addressed.

A synopsis of all holding times achieved.

A discussion of any other analytical problems that may have been encountered.



Turnaround Time: Standard (3 weeks)

CLIENT SAMPLE CROSS-REFERENCE

CH2M HILL Applied Sciences Group Reference No. 3089

Sample ID	Client Sample ID	Date Collected	Time Collected
308901	ZGP	09/14/1999	08:50
308902	ROP	09/14/1999	08:50
308903	WWTP#2Effluent	09/14/1999	08:50
308904	ROC	09/14/1999	08:50

CASE NARRATIVE VOLATILES

Lab Reference No.: 3089

Client/Project: McAllen WWTP #2, City of

I. **Holding Times**:

All acceptance criteria were met.

II. Analysis:

> A. Calibration:

> > All acceptance criteria were met.

B. Blanks:

All acceptance criteria were met.

C. <u>Duplicate Sample(s)</u>:

All acceptance criteria were met.

D. Spike Sample(s):

All acceptance criteria were met.

E. Surrogate Recoveries:

All acceptance criteria were met.

F. Lab Control Sample(s):

All acceptance criteria were met.

G. Other:

None

Ш. **Documentation Exceptions:**

None

IV. I certify that this data package is in compliance with the terms and conditions agreed to by the client and CH2M HILL, both technically and for completeness, except for the conditions detailed above. Release of the data contained in this hardcopy data package has been authorized by the Laboratory Manager or designee, as verified by the following signature.

Prepared by:

Reviewed by:

A Handy

CASE NARRATIVE GENERAL CHEMISTRY

Lab Reference No.: 3089

Client/Project: McAllen WWTP #2, City of

I. <u>Holding Time</u>:

All acceptance criteria were met.

II. Digestion Exceptions:

None

- III. Analysis:
 - A. <u>Calibration</u>:

All acceptance criteria were met.

B. Blanks:

All acceptance criteria were met.

C. <u>Matrix Spike Sample(s)</u>:

All acceptance criteria were met.

D. Duplicate Sample(s):

All acceptance criteria were met.

E. <u>Lab Control Sample(s)</u>:

All acceptance criteria were met.

F. Other:

Not applicable.

IV. <u>Documentation Exceptions</u>:

None.

V. I certify that this data package is in compliance with the terms and conditions agreed to by the client and CH2M HILL, both technically and for completeness, except for the conditions detailed above. Release of the data contained in this hardcopy data package has been authorized by the Laboratory Manager or his designee, as verified by the following signature.

Prepared by:

Reviewed by:

CASE NARRATIVE METALS

Lab Reference No.: 3089

Client/Project:	McAllen	WWTP #2,	City of
-----------------	---------	-----------------	---------

I. Holding Time:

All acceptance criteria were met.

II. <u>Digestion Exceptions</u>:

None.

- III. Analysis:
 - A. <u>Calibration</u>:

All acceptance criteria were met.

B. Blanks:

All acceptance criteria were met.

C. <u>ICP Interference Check Sample</u>:

All acceptance criteria were met.

D. <u>Spike Sample(s)</u>:

All acceptance criteria were met.

E. <u>Duplicate Sample(s)</u>:

All acceptance criteria were met.

F. <u>Laboratory Control Sample(s)</u>:

All acceptance criteria were met.

G. ICP Serial Dilution:

Not Required.

H. Other:

None

IV. <u>Documentation Exceptions</u>:

None

V. I certify that this data package is in compliance with the terms and conditions agreed to by the client and CH2M HILL, both technically and for completeness, except for the conditions detailed above. Release of the data contained in this hardcopy data package has been authorized by the Laboratory Manager or his designee, as verified by the following signature.

Prepared by:	and Loop	
-	CX0 111 13	
Reviewed by:		



CH2M HILL

Applied Sciences Group

2300 NW Walnut Blvd

Corvallis, OR

97330-3538

P.O. Box 428

Corvallis, OR

97339-0428

Fax 541.752.0276

Tel 541.752.4271

October 26, 1999

McAllen WWTP #2, City of

149462.A1.ZG

RE: Analytical Data for McAllen WWTP #2, City of

Applied Sciences Group Reference No. 3089

Angie Fernandez/PHX:

On September 15, 1999, CH2M HII request for analysis of selected para

The analytical results and associate difficulties encountered during the narrative.

Under CH2M HILL policy, your s have not given us prior instruction disposal as hazardous waste.

CH2M HILL Applied Sciences (serving your analytical needs ag: if you need additional informatic extension 3120.

Sincerely,

Kelly Ensor

Senior Administrative Assistant

Enclosures

Group received four samples with a tached.

> ısual : case

ting. If you nples require

rward to ning the data, or 758-0235,



Applied Sciences Group

2300 NW Watnut Blvd

Corvallis, OR

97330-3538

P.O. Box 428

Corvallis, OR

97339-0428

Tel 541.752.4271

Fax 541.752.0276

October 4, 1999

McAllen WWTP #2, City of

149462.A1.ZG

RE:

Analytical Data for McAllen WWTP #2, City of

Applied Sciences Group Reference No. 3089 & 3113

Angie Fernandez/PHX:

On September 15, 1999, CH2M HILL Applied Sciences Group received four samples with a request for analysis of selected parameters. From two of these samples, CH2M HILL Applied Sciences Group generated two samples with a request for analysis of selected parameters.

The analytical results and associated quality control data are enclosed. Any unusual difficulties encountered during the analysis of your samples are discussed in the case narrative.

Under CH2M HILL policy, your samples will be stored for 30 days after reporting. If you have not given us prior instructions for disposal, we will contact you if any samples require disposal as hazardous waste.

CH2M HILL Applied Sciences Group appreciates your business and looks forward to serving your analytical needs again. If you should have any questions concerning the data, or if you need additional information, please call Ms. Kathy McKinley at (541) 758-0235, extension 3120.

Sincerely,

Kelly Ensor

Senior Administrative Assistant

Mugnes

Enclosures

CLIENT SAMPLE CROSS-REFERENCE

CH2M HILL Applied Sciences Group Reference No. 3089 & 3113

C. LID		Date	Time
Sample ID	Client Sample ID	Collected	Collected
308901	ZGP	9/14/99	8:50
308902	ROP	9/14/99	8:50
308903	WWTP#2Effluent	9/14/99	8:50
308904	ROC	9/14/99	8:50
311301	ZGP-3D	9/20/99	
311302	ROP-3D	9/20/99	

CASE NARRATIVE DBPs/ORGANICS

Lab Reference No.: 3089 & 3113

Client	/Project	: McAllen WWTP #2, City of
I.		g Times: eptance criteria were met.
II.	Analys	<u>is</u> :
	A.	Calibration: All acceptance criteria were met.
	B.	Blanks: All acceptance criteria were met.
	C.	Duplicate Sample(s): All acceptance criteria were met.
	D.	Spike Sample(s): All acceptance criteria were met.
	E.	Surrogate Recoveries: All acceptance criteria were met.
	F.	Lab Control Sample(s): All acceptance criteria were met.
	G.	Other: None
III.	<u>Docum</u> None	entation Exceptions:
clie abo	ent and Cove. Rel	at this data package is in compliance with the terms and conditions agreed to by the CH2M HILL, both technically and for completeness, except for the conditions detailed ease of the data contained in this hardcopy data package has been authorized by the Manager or designee, as verified by the following signature.
Prepare	ed by: _	
Review	ed by: _	·

				Formati	Formation Potential Test Conditions	st Conditions					
		FP	Free	Free	Total	FP	Measured	ď	FP	FP	FP
Client ID	Lab ID	Dose	Residual	Demand	Residual	Temp.	рН	Start	Take-Off	Time H:M	Time H:M Time (Hour)
ZGP	308901	10:00	0.21	62.6	;	23	7.9	9/17/99 12:05	9/20/99 13:17	73:12	73.20
ROP	308902	1.60	0.71	68.0	:	23	7.7	9/17/99 12:12	9/20/99 13:21	73:09	73.15

			Formation Poter	ntial Trihalom	ethanes (THM	s) Disinfection B	Formation Potential Trihalomethanes (THMs) Disinfection By-Products, (ug/L)		
		FP	FP	FP	FP	FP			
Client ID	Lab ID	СНСВ	BDCM	DBCM	CHBr3	TTHM		: 44	-
ZGP-3D	311301	105	97.2	51.5	9.5	244			
ROP-3D	311302	2.9	2.9	2.5	⊽	8.3			
		CHCI3 = Chlon	CHCl3 = Chloroform			EPA TTHM Stag	EPA TTHM Stage I $MCL = 80 \text{ ug/L}$	# # # # # # # # # # # # # # # # # # #	
		BDCM = Brome	odichloromethane	31		EPA TTHM Stag	EPA TTHM Stage 2 MCL = 40 ug/L		
		DBCM = Dibromochlor	uo.						
		CHBr3 = Bromoform	зботт						

			Formation Pol	ential Haloace	Formation Potential Haloacetic Acids (HAAs) Disinfection By-Products (ug/L,)) Disinfection I	3y-Products (ug	g/L.)		
		FP	FP	FP	FP	FP	FP	FP	FP	
Client ID	Lab ID	MCAA *	MBAA *	DCAA *	TCAA *	BCAA	DBAA *	HAA5	HAA6	
ZGP-3D	311301	7.5	3.2	39.8	31.3	22.8	8.8	90.6	113	
ROP-3D	311302	2	7	1.	7	7	7	1.1	-	
		MCAA = Mono.	MCAA = Monochloroacetic acid		BCAA = Bromo	chloroacetic aci		EPA HAAS Stuge 1 A	4CL = 60 ng/L	
		MBAA = Monobromoa	bromoacetic acid		DBAA = Dibromoacetic acid	noacetic acid		EPA HAAS Stage 2 MCL = 30 ug/L	4CL = 30 ug/L	
		DCAA = Dichloroacetic acid	Dichloroacetic acid		* These compou	* These compounds make up the HAAS	IAAS			
		11	proacetic acid						·	

212 Set REC 4NNTPEHIL

Client Information

Client Sample ID: ROC

Project Name: McAllen WWTP #2, City of Project Manager: Angie Fernandez/PHX

Sampled By: R. Villareal Sampling Date: 09/14/1999 Sampling Time: 8:50

Type: Grab Matrix: Water Basis: As Received **Lab Information**

Lab Sample ID: 308904

Date Received: 09/15/1999

Report Revision No.: 0

Analyzed By: MG/MAS/DHK

Reviewed By: ---

		Sample			Analysis	Date
Analyte	MRL	Result	Qualifier	Units	Method	Analyzed
General Chemistry						
N-Nitrate/Nitrite	0.20	24.4		mg/L	EPA 353.2	09/20/99
N-Total Kjeldahl	2.0	3.6		mg/L	EPA 351.4	09/21/99
Total Dissolved Solids	10	4,330		mg/L	EPA 160.1	09/20/99
TOC	5.0	22.6		mg/L	EPA 415.1/2	09/21/99
Total Phosphate-P	1.0	10.5		mg/L	EPA 365.2/4	09/21/99

Client Information

Client Sample ID: WWTP#2Effluent

Project Name: McAllen WWTP #2, City of

Project Manager: Angie Fernandez/PHX

Sampled By: R. Villareal Sampling Date: 09/14/1999 Sampling Time: 8:50

> Type: Grab Matrix: Water Basis: As Received

Lab Information

Lab Sample ID: 308903

Date Received: 09/15/1999

Report Revision No.: 0

Analyzed By: MG/MAS/DHK

Reviewed By:

Analyte	MRL	Sample Result	Qualifier	Units	Analysis Method	Date Analyzed
General Chemistry N-Nitrate/Nitrite N-Total Kjeldahl Total Dissolved Solids TOC Total Phosphate-P	0.04 2.0 10 0.50 0.10	3.94 2.0 1,060 6.10 1.78	U	mg/L mg/L mg/L mg/L mg/L	EPA 353.2 EPA 351.4 EPA 160.1 EPA 415.1/2 EPA 365.2/4	09/20/99 09/21/99 09/20/99 09/20/99 09/21/99

Client Information

Lab Information

Client Sample ID: ZGP

Lab Sample ID: 308901

Project Name: McAllen WWTP #2, City of Project Manager: Angie Fernandez/PHX

Date Received: 09/15/1999

Sampled By: R. Villareal Sampling Date: 09/14/99 Sampling Time: 08:50 Report Revision No.: 0
Reported By: JG
Reviewed By:

Impling Time: 08:50
Type: Grab
Matrix: Water
Basis: As Received

Analyte	MRL	Sample Result	Qualifier	Units	Analysis Method	Date Analyzed
	· · · · · · · · · · · · · · · · · · ·					
Aluminum, Al	100	100	U	μg/L	SW6010B	10/14/99
Arsenic, As	10.0	10.0	U	μg/L	SW6010B	10/14/99
Barium, Ba	25.0	61.6		μg/L	SW6010B	10/14/99
Cadmium, Cd	5.0	5.0	U	μg/L	SW6010B	10/14/99
Calcium, Ca	500	* 86900 /		μg/L	SW6010B	10/14/99
Chromium, Cr	10.0	10.0	U	μg/L	SW6010B	10/14/99
Iron, Fe	100	\$100 g	U	μg/L	SW6010B	10/14/99
Lead, Pb	3.0	3.0	U	μg/L	SW6010B	10/14/99
Magnesium, Mg	500	\$25600 /		μg/L	SW6010B	10/14/99
Manganese, Mn	10.0	17.0		μg/L	SW6010B	10/14/99
Mercury, Hg	0.3	0.3	U	μg/L	SW7470A	09/28/99
Potassium, K	2000	29900		μg/L	SW6010B	10/14/99
Selenium, Se	7.0	7.0	U	µg/L	SW6010B	10/14/99
Silver, Ag	10.0	10.0	U	μg/L	SW6010B	10/14/99
Sodium, Na	1000	253000 🕯		μg/L	SW6010B	10/14/99
Strontium, Sr	100	2000		μg/L	SW6010B	10/14/99
Zinc, Zn	20.0	54.4		μg/L	SW6010B	10/14/99

Era Set IPR

Client Information

Client Sample ID: ZGP

Project Name: McAllen WWTP #2, City of

Project Name: McAllen WWTP #2, City of Project Manager: Angie Fernandez/PHX

Sampled By: R. Villareal Sampling Date: 09/14/1999 Sampling Time: 8:50

Type: Grab Matrix: Water Basis: As Received Lab Information

Lab Sample ID: 308901

Date Received: 09/15/1999

Report Revision No.: 0

Analyzed By: MG/MAS/JJB/DHK Reviewed By: MS/MAS/JJB/DHK

Analyte	MRL	Sample Result	Qualifier	Units	Analysis Method	Date Analyzed
General Chemistry						
Alkalinity (as CaCO3)	2.0	153		mg/L	EPA 310.2	09/24/99
Bromide	0.020	0.322		mg/L	EPA 300.0-B	09/20/99
Chloride	2.0	281		mg/L	EPA 300.0-A	09/22/99
Color (APHA) Apparent		17		color units	EPA 110.2	09/15/99
Fluoride	0.10	1.14		mg/L	EPA 300.0-A	09/22/99
N-Ammonia	0.10	0.10	U	mg/L	EPA 350.3	09/23/99
N-Nitrate/Nitrite	0.04	7.90		mg/L	EPA 353.2	09/20/99
N-Total Kjeldahl	2.0	2.0	U	mg/L	EPA 351.4	09/21/99
Silica-React.	0.4	16.1		mg/L	SM4500-Si D	09/23/99
Sulfate	2.0	247		mg/L	EPA 300.0-A	09/22/99
Total Dissolved Solids	10	1,950		mg/L	EPA 160.1	09/20/99
TOC	0.50	5.90		mg/L	EPA 415.1/2	09/20/99
Total Phosphate-P	0.10	2.89		mg/L	EPA 365.2/4	09/21/99
UV-254	0.009	0.126		asb/cm	SM5910	09/15/99

Client Information Lab Information

Client Sample ID: ZGP Lab Sample ID: 308901

Project Name: McAllen WWTP #2, City of Analysis Method: SW 8260B

Project Manager: Angie Fernandez/PHX Units: μg/L Sampled By: R. Villareal Date Received: 9/15/99 Date Collected: 9/14/99 Date Analyzed: 9/27/99

Time Collected: 8:50 Dilution Factor: 1

Type: Grab Report Revision No.: 0

Matrix: Water Reported By: MCB

Matrix: Water Reported By: MCB
Basis: As Received Reviewed By:

Analyte	CAS#	Reporting Limit	Sample Resuit	Qualifian
Analyte	UA3 #	LIIIIL	Result	Qualifier
Purgeable Volatiles				
Vinyl Chloride	75-01-4	1.0	1.0	U
trans-1,2-Dichloroethene	156-60-5	1.0	1.0	U
cis-1,2-Dichloroethene	156-59-4	1.0	1.0	U
1,1,1-Trichloroethane	71-55-6	1.0	1.0	U
Carbon Tetrachloride	56-23-5	1.0	1.0	U
Trichloroethene	79-01-6	1.0	1.0	U
1,4-Dichlorobenzene	106-46-7	1.0	1.0	U
Dibromofluoromethane	1868-53-7		103%	SS
1,2-Dichloroethane-d4	17068-07-0		94%	SS
Toluene-d8	2037-26-5		115%	SS
p-Bromofluorobenzene	460-00-4		95%	SS

E=Estimated value above instrument calibration range

J=Estimated value below reporting limit

U=Not detected at specified reporting limit

SS=Surrogate standard

Client Information

Lab Information

Client Sample ID: ROP

Lab Sample ID: 308902

Project Name: McAllen WWTP #2, City of

Date Received: 09/15/1999

Project Manager: Angie Fernandez/PHX

Report Revision No.: 0

Sampled By: R. Villareal Sampling Date: 09/14/1999 Analyzed By: MG/MAS/JJB/DHK

Sampling Time: 8:50

Reviewed By:

Type: Grab

Matrix: Water Basis: As Received

Analyte	MRL	Sample Result	Qualifier	Units	Analysis Method	Date Analyzed
General Chemistry						
Alkalinity (as CaCO3)	2.0	16		mg/L	EPA 310.2	09/24/99
Bromide	0.020	0.020	U	mg/L	EPA 300.0-B	09/20/99
Chloride	0.10	15.2		mg/L	EPA 300.0-A	09/22/99
Color (APHA) Apparent		5		color units	EPA 110.2	09/15/99
Fluoride	0.10	0.45		mg/L	EPA 300.0-A	09/22/99
N-Ammonia	0.10	0.10	U	mg/L	EPA 350.3	09/23/99
N-Nitrate/Nitrite	0.01	1.08		mg/L	EPA 353.2	09/20/99
N-Total Kjeldahl	2.0	2.0	U	mg/L	EPA 351.4	09/21/99
Silica-React.	0.4	0.9		mg/L	SM4500-Si D	09/23/99
Sulfate	0.10	5.31		mg/L	EPA 300.0-A	09/22/99
Total Dissolved Solids	10	72		mg/L	EPA 160.1	09/20/99
TOC	0.50	0.52		mg/L	EPA 415.1/2	09/20/99
Total Phosphate-P	0.10	0.10	U	mg/L	EPA 365.2/4	09/21/99

Client Information

Client Sample ID: ROP

Project Name: McAllen WWTP #2, City of Project Manager: Angie Fernandez/PHX

Sampled By: R. Villareal Sampling Date: 09/14/99 Sampling Time: 08:50 Type: Grab Matrix: Water

Basis: As Received

Lab Information

Lab Sample ID: 308902

Date Received: 09/15/1999

Report Revision No.: 0
Reported By: JG

Reviewed By

Analyte	MRL	Sample Result	Qualifier	Units	Analysis Method	Date Analyzed
						
Aluminum, Al	100	100	U	μg/L	SW6010B	10/14/99
Arsenic, As	10.0	10.0	U	μg/L	SW6010B	10/14/99
Barium, Ba	25.0	25.0	U	μg/L	SW6010B	10/14/99
Cadmium, Cd	5.0	5.0	U	μg/L	SW6010B	10/14/99
Calcium, Ca	500	833		μg/L	SW6010B	10/14/99
Chromium, Cr	10.0	10.0	U	μg/L	SW6010B	10/14/99
Iron, Fe	100	₹100 [3	U	μg/L	SW6010B	10/14/99
Lead, Pb	3.0	3.0	U	μg/L	SW6010B	10/14/99
Magnesium, Mg	500	7500 ¥	U	μg/ L	SW6010B	10/14/99
Manganese, Mn	10.0	10.0	U	μg/L	SW6010B	10/14/99
Mercury, Hg	0.3	0.3	U	μg/L	SW7470A	09/28/99
Potassium, K	2000	2000	U	μg/ L	SW6010B	10/14/99
Selenium, Se	7.0	7.0	U	μg/ L	SW6010B	10/14/99
Silver, Ag	10.0	10.0	U	μg/L	SW6010B	10/14/99
Sodium, Na	1000	§ 16200	•	μg/L	SW6010B	10/14/99
Strontium, Sr	100	₹100 <i>™ (</i>	U	μg/L	SW6010B	10/14/99
Zinc, Zn	20.0	20.0	U	μg/L	SW6010B	10/14/99

Client Information	Lab Information

Client Sample ID: ROP Lab Sample ID: 308902

Project Name: McAllen WWTP #2, City of Analysis Method: SW 8260B

Project Manager: Angie Fernandez/PHX

Sampled By: R. Villareal

Date Received: 9/15/99

Date Collected: 9/14/99

Date Analyzed: 9/27/99

Time Collected: 8:50 Dilution Factor: 1
Type: Grab Report Revision No.: 0

Matrix: Water Reported By: MCB Basis: As Received Reviewed By:

Analyte	CAS#	Reporting Limit	Sample Result	Qualifier
				- Godiniei
Purgeable Volatiles				
Vinyl Chloride	75-01-4	1.0	1.0	U
trans-1,2-Dichloroethene	156-60-5	1.0	1.0	U
cis-1,2-Dichloroethene	156-59-4	1.0	1.0	U
1,1,1-Trichloroethane	71-55-6	1.0	1.0	U
Carbon Tetrachloride	56-23-5	1.0	1.0	U
Trichloroethene	79-01-6	1.0	1.0	U
1,4-Dichlorobenzene	106-46-7	1.0	0.6	J
Dibromofluoromethane	1868-53-7		110%	SS
1,2-Dichloroethane-d4	17068-07-0		102%	SS
Toluene-d8	2037-26-5		115%	SS
p-Bromofluorobenzene	460-00-4		104%	SS

E=Estimated value above instrument calibration range

J=Estimated value below reporting limit

U=Not detected at specified reporting limit

SS=Surrogate standard

CHAZMHILL Applied Sciences Lab CV0 2300 NW Welnut Bouleward ChAIN OF CUSTODY RECORD Conveils, OR 97390-3638 AND AGREEMENT TO PERFORM SERVICES (641) 752-4271 FAX (641) 752-0276

Custody Seals Y LIMS Verification MW **Custody Review** THIS AREA FOR LAB USE ONLY Page Other 8 Alternate Description # 000 08:30 08:55 140° 2689 e Cooler Temperature N QC Leyel Lab PM Log in DeterTime 9/14/94 9/14/199 풀 Data/Time コノエ 501 T-Phosphorac , MH3-N TKN, NO2-NO3/N, TONOSPACOUS 4052H Rosie Villandsn' Javier Hinojusa 40541 Requested Analytical Method # TUN, NO2-NO3/N, (Please sign and print name) (Please sign and print name TCe Shipping # 50-1 Preservative T-Phosphorous, NH3-N
505 THMS
TRN, NO3-NO2/N,
TRN, NO3-NO2/N,
TRN, NO3-NO2/N,
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TRN, NO3-NO2/N,
Empty Bottles 4052H D.T. > H 2001 Fedex 457 177 つけ Received By < - Z M € 0 1/4/4 08:32 Sample Disposal: 114993:50 1444 08:55 Plepose Return Date/Time Darba/Time Date/Time Kathu MCKinky WINTPH-2 EFFILLENT 24AI WENT Purchase Order # (9 CHARACTERS) Luneal Hin bjosa Project Manager or Contact & Phone # Report Copy to: (Please sign and print name) (Please sign and print name) McAllen Reuse Pilot Stude 9 **₽** 2 0 0 ď 3 Rathy MKinky
Requested Completion Date: Ste 1D 80-1 ¥≪⊢₩Œ 9648 \mathbf{z} Z 0024 JSAP Sampled By and Titl Company Name 14/199 08:50 114/19 08:50 05:80/64/1/6 08:80 05:80 64/4/16 05:80 6/11/ TIME 05:80 644.1/6 Project Name 10:30/6//// 0:10 64/1/16 202 Relinquished By Sampling Received By Special Instr Project # 700, Received B 66/6//5 Date

DISTRIBUTION: Original - LAB, Yellow - LAB, Pink - Cilent

Instructions and Agreement Provisions on Reverse Side

CH2NHILL Applied Sciences Lab cut 23 CHAIN OF CUSTODY RECORD AND AGREEMENT TO PERFORM SERVICES (841) 78

D CV0 2300 NW Walnut Boulevard Corvallis, OR 97330-3636 (541) 762-4271 FAX (541) 752-0276 # 000 000

Custody Seals Y N اما 1 Nú4 LIMS Verification Custody Review 15 THIS AREA FOR LAB USE ONLY Page 3 Other <u>8</u> Alternate Description 08:30 08:55 P808 Cooler Temperature N QC Leyel Date/Time 9/14/16 Leb PM 64/41/6 Log in 둏 Date/Time Datte/Time Posse don and print name) Savick Hindinsal Requested Analytical Method # (Please sign and print name) Shipping # 2978-500N 174 Preservative Empty Bottles 4052H 701 4053H <u>つの</u> +052H 70 LUNO L 2978 - STON HCI Relinquished By Fed-Ex フの上 TOSZH ماحاق Shipped Via UPS Fed Received By -0-41 4 ひつとてくしと世氏の 2 3 1 2 N C42 25/ 1111/14 OB:30 **PB** 00 1489 08:50 "/// "/// OS:55 Sample Disposal: Propose Talenta Kathy McKinley するに 1/26 P. 16+ Stody Purchase Order # CLIENT SAMPLE ID (9 CHARACTERS) Javiel Hinoissa Project Manager or Contact & Phone # Report Copy to: W.W.T.P.#2 P#2E (Please agon and print name)
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CH2MHILL Applied Sciences Lab CVO CHAIN OF CUSTODY RECORD COM AND AGREEMENT TO PERFORM SERVICES (641)

CVO 2300 NW Wainut Boulevard Corvalls, OR 97330-3638 (541) 752-4271 FAX (541) 752-0276

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Project Manager or Contact & Phone # R Ka My McKinley	Report Copy to: Kathy M.K. 1/64		معي دوي ا مي 3 ري لا المحي 5 و المحي 5 و	الماملي ا مناطع <u>C</u> محاطع ا حازياو يمي رهي د	اهي کري ا اطعي ج	Jinity, Jahm Sides S		Log In	LIMS Verification	cation	
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Instructions and Agreement Provisions on Reverse Side

DISTRIBUTION: Original - LAB, Vellow - LAB, Pink - Client



Ms. Anne McKee-Robbins CH2M HILL/CVO 2300 N.W. Walnut Blvd. Corvallis, OR 97330

> Columbia Analytical Services Report City of McAllen D9901720/D1454

> > October 20, 1999

Submitted by:

Karen Sellers Project Manager/Client Services

TABLE OF CONTENTS

CAS Lab Reference No.: D1454 Level 1

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(This report contains a total of 16 pages.)

Organic Data Qualifiers

- A -- This qualifier indicates that a TIC is a suspected aldol-condensation product
- B -- This flag is used when the analyte is found in the associated blank as well as the sample. This notation indicates possible blank contamination and suggests that the data user evaluate these compounds and their amounts carefully.
- C -- The "C" flag indicates the presence of this compound has been confirmed by the GC/MS analysis.
- D -- This qualifier is used for all the compounds identified in an analysis at a secondary dilution factor. "D" qualifiers are used only for the samples reported at more than one dilution factor.
- E -- This flag indicates that the value reported exceeds the linear calibration range for that compound. Therefore, the sample should be reanalyzed at the appropriate dilution. The "E" qualified amount is an estimated concentration, and the results of the dilution will be reported on a separate Form I.
- I -- The qualifier indicates that the reporting limit to the "I" qualifier has been raised. It is used when the chromatographic interference prohibits detection of a compound at a level below the concentration expressed on the Form I.
- J -- Indicates an estimated value. It is used when the data indicates the presence of a target compound below the reporting limit or the presence of a Tentatively Identified Compound (TIC).
- N -- This qualifier indicates presumptive evidence of a compound. This flag is only used for Tentatively Identified Compounds (TIC), where the identification is based on a mass spectral library research. It is applied to all TIC results. For generic characterization of a TIC, such as chlorinated hydrocarbon, the "N" qualifier is not used.
- P -- This qualifier is used for Pesticide/Aroclor target analytes when there is a greater than 25% difference for detected concentrations between the two columns. The lower of the two values is reported on Form I and flagged with a "P".
- U -- Indicates the compound was analyzed for but not detected. The number adjacent to the "U" qualifier indicates the reporting limit for that compound. The reporting limit can vary from sample to sample depending on dilution factors or percent moisture adjustments when indicated.

Organic Sample ID Qualifiers

The qualifiers that may be appended to the Lab Sample ID and/or the Client Sample ID for organic analysis are defined below:

- **DL** -- Diluted reanalysis. Indicates that the results were determined in an analysis of a secondary dilution of a sample or extract. A digit to indicate multiple dilutions of the sample or extract may follow the "DL" suffix. The results of more than one diluted reanalysis may be reported.
- MS -- Matrix spike (may be followed by a digit to indicate multiple matrix spikes within a sample set).
- **MSD** -- Matrix spike duplicate (may be followed by a digit to indicate multiple matrix spikes within a sample set).
- R -- Reanalysis. The extract was reanalyzed without re-extraction. The "R" is not used if the sample was also re-extracted. May be followed by a digit to indicate multiple reanalysis of the sample at the same dilution.
- **RE** -- Re-extraction analysis. The sample was re-extracted and reanalyzed. May be followed by a digit to indicate multiple re-extracted analysis of the same sample at the same dilution.

Sample ID Cross-reference Table

CAS Lab Sample	ID	Client Sample ID	Collect Date Sample Matrix	Additional	Description	
FS = Field	Samp	ole				
D1454001 D1454002	FS FS	ZGPERMEATE ROPERMEATE	09/23/99 Water 09/23/99 Water	ZGPERMEATE ROPERMEATE		

The above lab sample ID's and cross reference information apply to samples as received by the laboratory. Modifiers to the lab sample ID may be added for internal tracking purposes. Any modified sample ID will be reflected in the appropriate case narrative only.

GC ORGANOCHLORINE PESTICIDES

CASE NARRATIVE GC ORGANOCHLORINE PESTICIDES

CAS	Lab	Reference	No./SDG.:	D1454

Project: <u>City of McAllen</u>

I. RECEIPT

No exceptions were encountered unless a Sample Receipt Exception Report is attached to the Chain-of-Custody included with this data package.

II. HOLDING TIMES

- A. Sample Preparation: All holding times were met.
- B. Sample Analysis: All holding times were met.

III. METHOD

Preparation: SW-846 3520C

Cleanup: NA

Analysis: SW-846 8081A

IV. PREPARATION

Sample volume may vary based on the amount of sample received per container.

V. ANALYSIS

- A. Calibration. All acceptance criteria were met.
 - 1. Retention Time Windows: All analytes were within criteria.
 - 2. Degradation: All acceptance criteria were met.
- B. Blanks: All acceptance criteria were met.
- C. Surrogates: All acceptance criteria were met.
- D. Internal Standards: All acceptance criteria were met.
- E. Spikes: All acceptance criteria were met.
- F. Samples: Sample analysis proceeded normally.

I certify that this data package is in compliance with the terms and conditions agreed to by the client and Columbia Analytical Services, both technically and for completeness, except for the conditions noted above. Release of the data contained in this hardcopy data package has been authorized by the Laboratory Manager or designated person, as verified by the following signature.

SIGNED: J. Jerry Watega Scientist, GC Organics

CLIENT ID.

ZGPERMEATE

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Case No.: D1454 SDG No.: D1454 Lab Sample ID: D1454001

Matrix: WATER Level: LOW Lab File ID: B1001024

Sample Wt/Vol: 1.050 L Jate Received: 09/24/99

Extract Vol: 10 ML Date Extracted: 09/27/99

Column: DB5 Date Analyzed: 10/02/99

Extraction Type: Continuous Dilution Factor: 1.0

CAS NO.	COMPOUND	Units: ug/L	MDL	RL	RESULT	Q
72-20-8 72-43-5	gamma-BHC (I Endrin Methoxychlor Toxaphene		0.0032 0.0021 0.017 0.23	0.020 0.020 0.040 0.50	0.11 0.093 0.140 0.50	מענ

CLIENT ID.

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

ROPERMEATE

Case No.: D1454 SDG No.: D1454

Matrix: WATER Level: LOW V Lab File ID: B1001025

Sample Wt/Vol: 1.050 L Date Received: 09/24/99

Extract Vol: 10 ML Date Extracted: 09/27/99

Column: DB5 Date Analyzed: 10/02/99

Extraction Type: Continuous Dilution Factor: 1.0

CAS NO.	COMPOUND	Units: ug/L	MDL	RL	RESULT	Q
72-20-8 72-43-5	gamma-BHC (L Endrin Methoxychlor Toxaphene		0.0032 0.0021 0.017 0.23	0.020 0.020 0.040 0.50	0.0.0 0.0.0 0.0.0 0.0.0	ם מ ט

CLIENT ID.

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

PWB10927

Case No.: D1454 SDG No.: D1454 Lab Sample ID: PWB10927

Matrix: WATER Level: LOW Lab File ID: B1001023

Sample Wt/Vol: 1.000 L Date Received:

Extract Vol: 10 ML Date Extracted: 09/27/99

Column: DB5 Date Analyzed: 10/02/99

Extraction Type: Continuous Dilution Factor: 1.0

CAS NO.	COMPOUND	Units: ug/L	MDL	RL	RESULT	Q
72-20-8 72-43-5	gamma-BHC (I Endrin Methoxychlor Toxaphene		0.0032 0.0021 0.017 0.23	0.020 0.020 0.040 0.50	0.020 0.020 0.040 0.50	ם ט ט

2C WATER SEMIVOLATILE SURROGATE RECOVERY

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Case No.: D1454 SDG No.: D1454

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		i	S1	S2	S2	TOT
	LAB ID	CLIENT ID.	#	#		OUT
		1	1	l'''	i	1 1
			=====	=====	=====	===
01	PWB10927LCS	PWB10927LCS	93	74		0
02	PWB10927LCS	PWB10927LCS	92	80		0
03	PWB10927	PWB10927	96	89		Ö
04	D1454001	ZGPERMEATE	112	73		0
05	D1454002	ROPERMEATE	106	62		l ol
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QC LIMITS (45-125)

S1 = Tetrachloro-m-xylene (45-125) S2 = Decachlorobiphenyl (34-133)

Column to be used to flag recovery values
* Values outside of contract required QC limits

D Surrogates diluted out

SW846

3E WATER PESTICIDE LAB CONTROL SAMPLE

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Case No.: D1454 SDG No.: D1454 Column: DB5

LCS - Sample No.: PWB10927

COMPOUND	SPIKE	SAMPLE	LCS	LCS	QC.
	ADDED	CONCENTRATION	CONCENTRATION	%	LIMITS
	(ug/L)	(ug/L)	(ug/L)	REC #	REC.
gamma-BHC (Lindane)	0.5000	0.0000	0.5002	100	73-125
Endrin	0.5000	0.0000	0.4876	98	43-134
Methoxychlor	0.5000	0.0000	0.4194	84	73-142

Column to be used to flag recovery and RPD values with an asterisk

* Values outside of QC limits

RPD: 0 out of 0 outside limits

Spike Recovery: 0 out of 3 outside limits

COMMENTS:				
		 	•	

SW846

3E WATER PESTICIDE LAB CONTROL SAMPLE

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Case No.: D1454 SDG No.: D1454 Column: DB5

LCS - Sample No.: PWB10927

COMPOUND	SPIKE	SAMPLE	LCS	LCS	QC.
	ADDED	CONCENTRATION	CONCENTRATION	%	LIMITS
	(ug/L)	(ug/L)	(ug/L)	REC #	REC.
Toxaphene	5.000	0.0000	4.895	98	41-126

- # Column to be used to flag recovery and RPD values with an asterisk
- * Values outside of QC limits

RPD: 0 out of 0 outside limits Spike Recovery: 0 out of 1 outside limits

COMMENTS:	

SW846

CHAIN OF	CUSTODY	DOCUMENTA	TION

CHAIN OF CUSTODY

 $_{\rm coc}$ $^{\circ}$ N $_{\rm 0}$ 990802

5090 Caterpillar Road • Redding, CA 96003 • Phone: (530) 244-5227 • FAX: (530) 244-4109

z () Custody Seals V 00 Lab ID 4 LIMS Verification Custody Review THIS AREA FOR LAB USE ONLY ١ INVOICE INFORMATION Page Other <u>s</u> Date/Time | 99 | 2) 0 h Alternate Description 3 Cooler Temperature OC Level 1 2 7571C P.O. # Bill To 812900725117 품 Posic VillaREGA (Please sign and print name) Encique Perez Preservative (to be filled out by customer) Requested Analytical Method # Shipping # Shipped Via Relinquished By 4054 9-24-99.0934UPS 9/23/99 9/23/99 3:30 Date/Time 9/23/99 8 40 7 OOZ Date/Time Return S S Dispose ð Ø Kastry McKinley Enright 16.562 (Please sign and print name) Rosie Villanke Please sign and print name) CLIENT SAMPLE ID (9 CHARACTERS) mea on mela Semples were collected Purchase Order # Report Copy to: City of mathen WWTP#2 MAHEN RUSE PILOT Study विश 10 P City of Midllow Project Manager or Contact & Phone # Matrix so--Columbia
Analytical
Services "Company Sampled By and Tille Time Sampling Project Name 13/95 9/3/45 Project # Date

Distributions - Original - Lab, Yellow - Lab, Pink - Client

and American Providence on Doubles Side

0010



5090 Caterpillar Road

Redding Ca., 96003

Phone: 530-244-5227

Fax: 530-244-4109

SAMPLE RECEIPT EXCEPTION REPORT

Sampl	le Batch Number: D バタタ	Client/Project: City of McAllen
ور دید در است		
		Comments:
	No custody seal as required by project.	2) No time sampled recorded on COC. Time taken from container
1	2. Analysis, description, date/time of collection not provided.	labels.
	Samples broken or leaking on receipt.	
1 . 14	Temperature of samples inappropriate for analysis requested.	
	Container inappropriate for analysis requested.	
	6. Inadequate sample volume.	en de la companya del companya de la companya del companya de la c
	7. Preservation inappropriate for analysis requested.	
	8. Samples received out of holding time for analysis requested.	
	Descrepencies between COC form and container labels.	
	10. Other	

Corrective Actions Taken:

some Regard

8N 9/28/99

Sound Analytical Services, Inc.

ANALYTICAL & ENVIRONMENTAL CHEMISTS

4813 Pacific Hwy East • Tacoma, WA 98424 (253) 922-2310 • FAX (253) 922-5047 e-mail: sainc1@uswest,net



TRANSMITTAL MEMORANDUM

DATE: September 23, 1999

TO: Kathy McKinley City of McAllen 4100 Idela McAllen, TX 78503

PROJECT: McAllen Re-Use Pilot Study

REPORT NUMBER: 84099

Enclosed are the test results for two samples received at Sound Analytical Services on September 15, 1999.

The report consists of this transmittal memo, analytical results, quality control reports, a copy of the chainof-custody, a list of data qualifiers and analytical narrative when applicable, and a copy of any requested raw data.

Should there be any questions regarding this report, please contact me at (253) 922-2310.

Sincerely,

Darla Powell Project Manager

Client Name

City of McAllen

Client ID:

ZENOGEM PERMEATE

Lab ID:

84099-01

Date Received:

9/15/99

Date Prepared:

9/21/99

Date Analyzed: % Solids

9/22/99

Dilution Factor

Surrogate

Silvex (2,4,5-TP)

10

Chlorinated Herbicides by USEPA Method 8151GC/MS Modified

Result

(ug/L)

Recovery Limits High Low Flags % Recovery 124 48 86.4 2,4-Dichlorophenylacetic acid

Analyte ND 2,4-D ND

PQL 0.096 0.096 MDL 0.084 0.077 Flags

Client Name Client ID:

Lab ID: Date Received:

Date Prepared: Date Analyzed: % Solids

Dilution Factor

City of McAllen

RO PERMEATE 84099-02

> 9/15/99 9/21/99

9/22/99

10

Chlorinated Herbicides by USEPA Method 8151GC/MS Modified

Surrogate % Recovery Flags Low High 48 124

 Result

 Analyte
 (ug/L)
 PQL
 MDL
 Flags

 2,4-D
 ND
 0.1
 0.087

 Silvex (2,4,5-TP)
 ND
 0.1
 0.081

Lab ID:

Method Blank - HB885

Date Received:

9/21/99

Date Prepared: Date Analyzed:

9/22/99

% Solids

-

Dilution Factor

10

Chlorinated Herbicides by USEPA Method 8151GC/MS Modified

			Recov	ery Limits
Surrogate	% Recovery	Flags	Low	High
2,4-Dichlorophenylacetic acid	67.8		48	124

Result

Analyte (ug/L) PQL MDL Flags
2,4-D ND 0.1 0.087
Silvex (2,4,5-TP) ND 0.1 0.081

Blank Spike/Blank Spike Duplicate Report

Lab ID:

Date Prepared: Date Analyzed:

QC Batch ID:

HB885

9/21/99

9/22/99 HB885

Chlorinated Herbicides by USEPA Method 8151GC/MS Modified

	Blank	Spike	BS		BSD			
_	Result	Amount	Result	BS	Result	8SD		
Compound Name	(ug/L)	(ug/L)	(ug/L)	% Rec.	(ug/L)	% Rec.	RPD	Flag
2,4-D	0	5	4.73	94.6	4.48	89.6	-5.4	
Silvex (2,4,5-TP)	0	5	5.44	109	5.17	103	-5.7	

ANALYTICAL & ENVIRONMENTAL CHEMISTS

4813 PACIFIC HIGHWAY EAST, TACOMA, WASHINGTON 98424 - TELEPHONE: (253) 922-2310 - FAX; (253) 922-5047

DATA QUALIFIERS AND ABBREVIATIONS

- B1: This analyte was detected in the associated method blank. The analyte concentration was determined not to be significantly higher than the associated method blank (less than ten times the concentration reported in the blank).
- B2: This analyte was detected in the associated method blank. The analyte concentration in the sample was determined to be significantly higher than the method blank (greater than ten times the concentration reported in the blank).
- C1: Second column confirmation was performed. The relative percent difference value (RPD) between the results on the two columns was evaluated and determined to be ≤ 40%.
- C2: Second column confirmation was performed. The RPD between the results on the two columns was evaluated and determined to be > 40%. The higher result was reported unless anomalies were noted.
- M: GC/MS confirmation was performed. The result derived from the original analysis was reported.
- D: The reported result for this analyte was calculated based on a secondary dilution factor.
- E: The concentration of this analyte exceeded the instrument calibration range and should be considered an estimated quantity.
- J: The analyte was analyzed for and positively identified, but the associated numerical value is an estimated quantity.
- MCL: Maximum Contaminant Level
- MDL: Method Detection Limit
- N: See analytical narrative.
- ND: Not Detected
- PQL: Practical Quantitation Limit
- X1: Contaminant does not appear to be "typical" product. Elution pattern suggests it may be ______.
- X2: Contaminant does not appear to be "typical" product.
- X3: Identification and quantitation of the analyte or surrogate was complicated by matrix interference.
- X4: RPD for duplicates was outside advisory QC limits. The sample was re-analyzed with similar results. The sample matrix may be nonhomogeneous.
- X4a: RPD for duplicates outside advisory QC limits due to analyte concentration near the method practical quantitation limit/detection limit.
- X5. Matrix spike recovery was not determined due to the required dilution.
- X6: Recovery and/or RPD values for matrix spike(/matrix spike duplicate) outside advisory QC limits. Sample was reanalyzed with similar results.
- X7: Recovery and/or RPD values for matrix spike(/matrix spike duplicate) outside advisory QC limits. Matrix interference may be indicated based on acceptable blank spike recovery and/or RPD.
- X7a: Recovery and/or RPD values for this spiked analyte outside advisory QC limits due to high concentration of the analyte in the original sample.
- X8: Surrogate recovery was not determined due to the required dilution.
- X9: Surrogate recovery outside advisory QC limits due to matrix interference.



Sound Analytical Services, Inc.

ANALYTICAL & ENVIRONMENTAL CHEMISTS 4813 Pacific Hwy East • Tacoma, WA 98424 (253) 922-2310 + FAX (253) 922-5047

e mail, saine for uswest net

100		8409
	SAS Lab No.	890 1

TURNAROUND REQUEST-	(business days)
Standard (10 days)	
RUSU: 24 hrs. 48 hrs	5 day

CHAIN OF CUSTODY/REQUEST FOR LABORATORY ANALYSIS

Project Name:						Analyses Requested																
Project Name:																						
McAllen Re-Use Pilot Study Contact: Kashy McKinley - Applied Science, Phone No: 541-758-0235 #3144								σź	ф К													
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1	Signature	Printed Name	Firm	Time/Date	Special Instructions
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ENERGY LABORATORIES, INC.

SHIPPING: 2393 SALT CREEK HIGHWAY • CASPER, WY 82601

MAILING: P.O. BOX 3258 • CASPER, WY 82602

E-mail: energy@trib.com • FAX: (307) 234-1639 • PHONE: (307) 235-0515 • TOLL FREE: (888) 235-0515

CASE NARRATIVE

DATE:

October 5, 1999

TO:

Kathy McKinley

FROM:

Sheryl Garling

RE:

CH2MHill Water Samples

SAMPLE NUMBERS: 32965 001 through 002

Samples Zenogem Permeate and RO Permeate were received on September 15, 1999. Samples were shipped using Energy Laboratories, Inc. contract service with UPS. The overnight option was used for shipping the samples to the laboratory. Samples were in good condition and properly preserved.

No analytical problems were indicated for this sample delivery group.

The methods used are methods published by US EPA for drinking water analyses. The methods used are as follows:

Radium 226 - EPA Method 903.0 (alpha emitting),

Radium 228 - EPA Method 904.0, and

Gross Alpha -EPA Method 900.1 (gross alpha minus uranium and

radon).

The standard detection limits for these methods are 0.2 pCi/L, 1.0 pCi/L, and 1.0 pCi/L, respectively. The initial e-mail response incorrectly identified methods and detection limits.

If additional information is required, please advise.



ENERGY LABORATORIES, INC.

SHIPPING: 2393 SALT CREEK HIGHWAY • CASPER, WY 82601

MAILING: P.O. BOX 3258 • CASPER, WY 82602 E-mail: energy@trib.com • FAX: (307) 234-1639 PHONE: (307) 235-0515 • TOLL FREE: (888) 235-0515

LABORATORY ANALYSIS REPORT - CH2M HILL

Project:
Sample ID:
Laboratory ID:
Sample Matrix:
Sample Date/Time:
Date Received:
Report Date:

e Pilot Study
RO Permeate
32965-002
er
0/0850
-99
4, 1999

Radiometric		Method	Reporting Limit	Units	Res	sults
· · · · · · · · · · · · · · · · · · ·				3		
Radium-226	²²⁶ Ra	903.0	0.2	pCi/L	< 0.2	< 0.2
Radium Precision ±					-	
	. 41					
Radium-228	²²⁸ Ra	904.0	1.0	pCi/L	<1.0	<1.0
Radium Precision ±					-	-
			278 T. P			
Gross Alpha	Gross a	900.1	1.0	pCi/L	<1.0	<1.0
G. Alpha Precision ±					-	-



RADIOCHEMICAL QUALITY ASSURANCE REPORT - CH_2M HILL

Laboratory ID Range: Sample Matrix: Sample Date / Time: Date Received:

Report Date:

32965-001-002 Water 09-14-99/0850 09-15-99 October 4, 1999

	<u>Method</u>	Relative Percent <u>Difference¹</u>	Spike Recovery (Percent) ²	LCS Recovery (Percent)	Method Blank (pCi/L)	Date <u>Analyzed</u>	<u>Analyst</u>
Laboratory #:		32996-002	32880-022		GA-40		
Gross Alpha:	900.1	0.0	104	106	<1.0	10-01-99	RS
Laboratory #:		32880-001	32880-022		RA-206		
Radium-226:	903.0	0.0	100	101	< 0.2	09-29-99	RS
Laboratory #:	yezhiñ area a	32880-010	32880-020		228-235		
Radium-228:	904.0	0.0	79	77	<1.0	10-04-99	LMH

Report Approved By 1 Haila

Reviewed By:

lmh r:\Reports\Clients.99\CH2M_Hill\Water\rc32965-001.xls

Log In No. 99-32965

⁽¹⁾ These values are an assessment of analytical precision. The acceptance range is 0-20% for sample results above 10 times the reporting limit. This range is not applicable to samples with results below 10 times the reporting limit.

⁽²⁾ These values are an assessment of analytical accuracy. They are a percent recovery of the spike addition. ELI performs a matrix spike on 10 percent of all samples for each analytical method.

66-9-01

,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,									66	,			
toll free 1-888-235-0515 voice 307-235-0515 fax 307-234-1639	LES AND INSTRUCTIONS)	Special Requests	1	-	Comments, Special Instructions, etc.								
CUSTODY RECORD • 82602-3258 Casper, WY • 82601	(SEE BACK OF FORM FOR EXAMPLES AND INSTRUCTIONS)	Type of Analyses Requested		887	mily								
CHAIN OF Casper, WY		ne <u>O</u> ther	o V S W	So 19dmu Sold spilos/sliog Area of the sold with the sold of the s	Same Air Waler . Ladium .	7	-				:		
ENERGY LABORATORIES, INC. 'S Mail Only: PO Box 3258 • UPS/FedEx Deliveries: 2393 Salt Creek Hi	For Sample Tracking Purposes, Please Provide Contact Name and Telephone #'s as Indicated	r# / Bid#	-766-25選52	Send Invoice to: Kathy McKinley CH2M HIM Corvallis OK.	Samuel D	Permeate	eate						
• Billings • Casper • Gillette • Rapid City • Rapid City	ing Purposes, Please Provic	Location Purchase Order # Mrs.	541-758-0235 / 54-766-28 ES2 # 3144	อาู่สนาง	Send Send	Zenogen Permente	1 RO Permeate	IV-San					
ENERGY LABORATORIES	For Sample Tracki	Project Name / L McMlen Edse / / Pibt Study / T	ine #	Date Time		05:20 14/41/16	9/14/99 08:50						1 Sampler: (cionature)

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		2/20 11:45 X Distribution Tap	:::3 ::3 ::3 ::3 ::3 ::3 ::3 ::3 ::3 ::	+	Send Report to:	Send Invoice to: Jeff Jones PO Box Nowhere Time composite T	Jeff Jones	Name / Phone # / Fax #	Thunderbasin Town of Hope No PO #	Project Name / Location / Purchase Order # Project Name / Location / Purchase Order #	ENERGY LABOI Mail Only: I UPS/FedEx Deliveries:	
		ар	ribution		Bob Brown PO Box Somewhere USA, WY 81111 Sample I.D.	Jeff Jones FO Box Nowhere Hope, WY 80000	(307) 555-5555 fax		No PO #	rovide Contact Name and Telephone #'S	ENERGY LABORATORIES, INC CHA Mail Only: PO Box 3258 • Caspe MedEx Deliveries: 2393 Salt Creek Highway	
		9	4 ×			Number Sample Type Air Waser Soils/soli Stos - TEN	ds <u>V</u> egetation <u>J</u>	U e	O <u>Q</u> ther		CHAIN OF CUSTODY RECORD Casper, WY • 82602-3258 lighway • Casper, WY •	
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		×			50Cs -	- 504, 50 515, 531.			ested	R EXAMPLE)2	
		ŧ	Phase II SDWA Primary		Comments, Special Instructions, etc.	Thank you.	results as soon as possible	Please fax	Special Requests	(SEE BACK OF FORM FOR EXAMPLES AND INSTRUCTIONS)	voice 307 235-0518 fax 307-234-1639	

3. Relinquished by: (signature) Date Time Received by: (signature) N/A N/A N/A N/A N/A N/A Sheryl A. Garling	1.Sampler: (signature) Jeff Jones	Date Time 5-11-85 12:05p	Time 1 2:05p	Received by: (signature) Harry Truckers	2.Relinquished by: (signature) Harry Truekers
N/A N/A N/A N/A					
	3. Relinquished by: (signature) N/A	Date N/A	Time N/A		4. Relinquished by: (signature) Sheryl A. Garling

Date **5-28-95**

Time 13:15p

Received by: (signature)
Sheryl A. Garling

Date 5-28-95

Tinte 14:00y

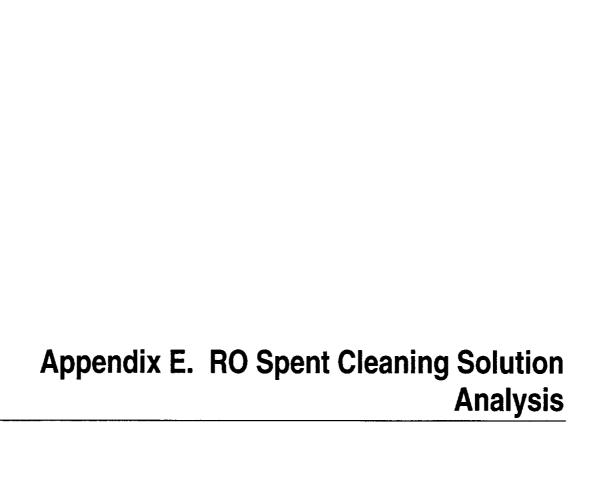
Received at Laboratory by:
Roger A. Garling

instructions:

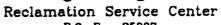
- 9 E A completed Chain-of-Custody must be submitted with all samples Special Requests area can include (but not limited to) the following:

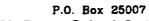
 • Turnaround status, Rush status, Due Date, etc.

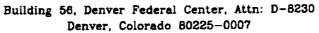
- Special mailing instructions:
 send copy of Report and/or Invoice to a second party
- send copy of Report to a Government Agencies (EPA, etc.)
- Public Water System (PWS) Number
- Do you want samples returned to you or disposed of?



United States Department of the Interior Bureau of Reclamation Water Treatment Engineering and Research Group









FAXOGRAM

Date:
To: Jim Lozier / Angie Formandez
Company: CH2MH1)
Fax Number:
From: Michell USBR
Fax Number: (303) 445-6329 Telephone Number: (303) 445-2245
Number of pages (including cover sheet)
Message: Copy of the Cleaning Solution
analysis. They are sending out
for the SOy, I'll let you know.
mi V Ol
- muio

DATA TRANSMITTAL FAX COVER

ULN-12-1555 1m:54

Environmental Research Chemistry Laboratory, D-8240
US Bureau of Reclamation - Technical Service Center
PO Box 25007, Denver CO 80225-0007
Margaret Lake, Laboratory Manager, 303-445-2181
Douglas Craft, QC Officer, 303-445-2182
FAX 303-445-6326

-manne

DATE: 6/10/99
FROM: Barb Frost PHONE: X2190
TO: Michelle Chapman MAIL CODE:
OFFICE: FAX NUMBER:
PROJECT: McAllen DO LAB NUMBERS: \$5313-1
SAMPLES COLLECTED ON: 61199 NUMBER OF SAMPLES:
ANALYSES PERFORMED BY: BF VM
This is an electronic transmission of analytical results. The final data and memorandum with appropriate formal review and requested QC reports will follow. The data in the attached report has been reviewed by the laboratory QC Officer (or designate) and meets TSC Chemistry Laboratory precision and accuracy requirements unless qualified in the section below. Please review your data and let us know if there are problems that require corrective action.
QUALIFIERS: The following issues may affect the usability of your data:
Ca Diasod low Dy 20.5% CCO
was acceptable.
MESSAGE: Contract 504 and ymal
memo will gollow.
APPROVAL Box Frost Box 500 6/10/90 Client Representative (For QC Officer Date
PAGE 1 OF REVIEWED-QUALIFIED SEE COMMENTS
LAB QC OFFICER DAT

SAMPLE LOG-IN SUMMARY

USBR ENVIRONMENTAL RESEARCH CHEMISTRY LABORATORY

Denver, Colorado

Job Control No: McAllen-99

Project Name: McAllen W-R

Login Date: 6/3/99

Description: Cleaning Solution

Client Reps: Barb Frost

Client Name: M. Chapman-Wilber

Chem Client Lab# SampleID

Sample Sampled Analysis Type Date

Due Date

6/10/99

COC#

K5313-1

McAllen unfiltered/unacidified, SO4/Ca/Fe/Al/Ba/Si

200.7_ICP

ICP Metals

300.0_ANIONS 365.1,365.2_totP

cleaning soln.

ion chromatography of anions

6/1/99

total phosphorous by Perstorp autoanalyzer

12.

SAMPLE SUBMITTAL REQUEST FORM		SHEET 1 OF
Environmental Research Chemistry Laboratory, U.S. Bureau of Reclamation - Technical Service Building 56, Room 2340, Denver Federal Center Margaret Lake, Laboratory Manager, 303-445-2	Center r, PO Box 25007, Denv 181	
Today's Date: $\frac{\sqrt{2}/99}{\sqrt{44}}$	Report Data By:	10/99
Today's Date: 4/2/99 Samples Submitted By: Michele ChomanWi	bettelephone: \XZ24	<i>,</i> 4
Mailing Address: 1) -8 2 30 0	_ FAX/LAN:	
Project Name: McAllen W.R	_ Job Number/WOID): <u>DS9A5</u>
Sample Collection Location: Mallen	_ Sample Collected I	By: Navier.
Sampling Date(s): 6/1/99 Type of Sampl	es: Cleanning So Nu	mber of Samples:
Samples Filtered? No' Samples Preserved?	<u>/V (des</u> cribe) Custo	ody Form Required?
Official Data Report To: Michello C G), bert	· · · · · · · · · · · · · · · · · · ·
Copies To: Special Instructions:	nium, Salfat	Report Requested?
7	Requested	Method or
SAMPLE IDENTIFIERS	Analyses	Det Lim
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11.		

Report	Report of Chemical Analyses	Cilent	McAllen W-R
U.S. Depar	U.S. Department of the Interior - Bureau of Reclamation	Samples C	
PO Box 25 Denver CO	PO Box 25007, Building 56, Room 2300, Denver Federal Center Denver CO 80225-0007	Center	
Laboratory	\$102	47.0	
Number	Sample ID	ma/L	
K5313-1	McAllen 2.53	11.9	
	Detection firmit: 0.02	0.005	
	Date Analyzed: 6/9/99	6/1/18	
	Analyst: bf	Ę	
<i>'</i>	EPA Method: 200.7	365.1	

Chem Lab#: K5313-1

Station ID: McAllen

MoreID:

Sampled Date: 6/1/99

Received Date: 6/2/99

Login Date: 6/3/99

Chain-Of-Custody:

Sample Type: cleaning soln.

Note: unfiltered/unacidified,

SO4/Ca/Fe/Al/Ba/Si

Analyte	Method_Ref	Result	Units Qualifier	MDL	Date Extract	Date Analyzed D	ilution
 Al	200.7 EPA	5530	µg/L	30		6/10/99	1
Ba	200.7 EPA	449	μ g/ L	4		6/10/99	1
Ca	200.7 EPA	26	mg/L	0.03		6/10/99	1

U: Not Detected at Listed MDL.

J: Estimated.

MDL: Method Detection Limit.

Chem Lab#: K5313-1

Station ID: McAllen

Sampled Date: 6/1/99 Received Date: 6/2/99

MoreID:

Login Date: 6/3/99

Chain-Of-Custody:

Sample Type: cleaning soln.

Note: unfiltered/unacidified, SO4/Ca/Fe/Al/Ba/Si

Analyte	Method_Ref	Result	Units Qualifier	MDL	Date Extract	Date Analyzed ^l	Dilution
Fe	200.7 EPA	722	µg/L	4		6/10/99	1

U: Not Detected at Listed MDL.

J: Estimated.

MDL: Method Detection Limit.



Table F-1
ZenoGem Permeate Scale Potential

Parameter	Units	6/9/99	6/11/99	6/14/99	6/16/99	6/21/99	6/23/99	Average
General Chemistry	44.4 图 2000		814					
Alkalinity	mg/L as CaCO ₃	150		190		158		166
Total Phosphorus	mg/L as P			2.72		2.26		2.49
Sulfate	mg/L	250	214	214	ļ			226
Metals 1	精乳 沉默。			6.6				
Aluminum ^a	mg/L	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Barium	mg/L	0.06	0.06	0.06	0.05	0.05	0.06	0.06
Calcium Hardness	mg/L	360		348		360	<u></u>	356
Iron ^a	mg/L	0.1	0.1	0.1	0.1	0.1	0.1	0.1

^aNot dectected at specified reporting limits for each sampling event.



SPIRAL WOUND MEMBRANE ELEMENT AUTOPSY

PURPOSE AND LOCATION OF AUTOPSY

Purpose of Autopsy: McAllen, TX Wastewater Reclamation Project: Determination of scaling in end element.

Date and Place: October 29, 1999, USBR WTER Pilot Plant Lab, Denver, CO.

Date of This Report: 12/30/99

Names of Observers:

Frank Leitz Bill Boegli Michelle Chapman Wilbert Kim Linton Qian Zhang

ELEMENT IDENTIFICATION				
Manufacturer:	Hydranautics			
Element Location:	Housing #6, 2nd element			
Serial Number:	x03529			
Element Dimensions:	2.5 in. x 40 in.			
Number of Leaves:	2			
Size of Leaves:	92.1 cm x 71.1cm Total Area 84.5 cm x 63.5cm Active Area per side (2.1 m² per element or 22.1 ft²)			

OPERATING HISTORY

The RO system was operated for six months on site at the McAllen,TX South Waste Water Treatment Plant. Screened de-gritted sewage was first treated in a Zenogem bioreactor/microfiltration system, then chlorine and ammonia was added and the Zenogem effluent was forwarded to the RO system. The RO element array was a 2x2x1x1 and had 3 elements per vessel for a total of 18 elements in the system. RO recovery rates were set from 50% to 80% of 15.2 L/min feed flow.

Sulfuric acid and antiscalent were added to prevent scaling. However, due to changes in the chemical character of the Zenogem effluent, or excessive gas formation in the acid tank which caused the acid feed pump to loose it's prime, the pH was not controlled well at all times. This resulted in a loss of permeate flow from the last vessel.

Also, traditional constituents used in an RO projection do not include phosphorous compounds. The researchers involved in this project began to suspect that phosphorous salts were the cause of excessive scale problems due to the nature of waste water treatment. Attempts at adjusting the pH to control phosphorous salts included running a projection with non-RO software to determine the potential for phosphate scaling. A range of pH settings and two control points for pH were tested in an attempt to control the scaling problems. The pH ranges tested were from 5.5 to 7 on the feed, and 5.5 to 6 on the concentrate. The lower pH control ranges were in response to this non-RO projected information.

Scaling also caused operators to clean the system approximately 4 times with a low pH solution at a pH of about 3. A high pH solution was not used to clean the membranes as there was no indication of biofouling and the system's performance was recovered using the acid cleanings.

DESCRIPTION OF EVENTS LEADING TO AUTOPSY

This element was subjected to one needle hole to help evaluate the integrity test methods.

Subject element was the second to last element of the last vessel (vessel #6). Permeate recovery flow from the last vessel varied from 1.4 L/min to 0.01 L/min. The last fouling was a result of turning off the acid feed pump for approximately 8 hours.

This autopsy was primarily done to determine how deep the hole in the membrane leaves had penetrated, and to determine the general nature of the scaling composition.

NARRATIVE DESCRIPTION OF AUTOPSY PROCEDURE

Fiberglass wrapping was cut open and peeled or pried off.

Picture shows the compressed air saw and other autopsy materials.



Anti-telescoping devices were removed and tape wrap was unwound.

Unwound membrane and separated spacer material from first leaf.

Measured leaf dimensions and active area.

A squeegee was used to wipe both sides of one leaf. DI water was used to liquefy the fouling substance

Applied congo red dye to the first leaf.

Samples were cut from the feed and reject ends of the second leaf for SEM analysis. Feed side is Sample 2 and the reject side is Sample 3.

OBSERVATIONS

There was a crack, ~ 2 cm long, ~ 10 cm from the feed end.

Sample #1 is the piece of fiberglass with the crack.

The brine seal was in good condition; it was saved as Sample #2

There was extra glue, possibly rubber cement, under the tape at the ends of the element-- probably to keep the end caps tight. Sample #3 is a bit of the glue peeled away from the end.

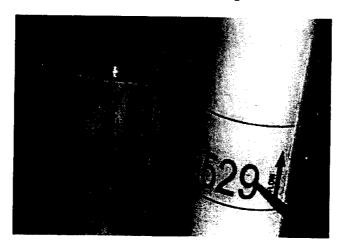
There was no evidence of the crack extending into the membrane material.

Picture was taken of the feed end of the rolled element.





Hole location was marked on the outer fiberglass cover from where a needle had been poked into the membrane. Picture taken of hole location in element. The hole location is shown in the fiberglass wrap and in the number 9 of the tape wrap.



At least 2 leaves had holes which were identified using a

magnifying glass (10x). The hole on the on the outer leaf was a cresent shape which is the same shape that would be formed by the tip of the hypodermic needle used to inflict the damage. The second hole protruded out, which would also be consistent with the direction the needle would penetrate.

The glue line appeared to have attracted more fouling material than the active area of the leaf. This may be due to the excessive use of glue.

Dye test on the second leaf with congo red dye took evenly over the membrane surface. This could be damage from low pH. There was no evidence of the hole extending beyond the tape wrap.

Test and Test Objective: No additional tests were done on this element.

DISCUSSION AND CONCLUSIONS

This element had at least two holes from the needle puncture which penetrated the active area of the membrane. The visible damage was configured in such a way that it can be attributed to the needle. One of the holes was cresent shaped and poked inward. The hole on the opposite leaf protruded outward.

SPIRAL WOUND MEMBRANE ELEMENT AUTOPSY

PURPOSE AND LOCATION OF AUTOPSY

Purpose of Autopsy: McAllen, TX Wastewater Reclamation Project: Determination of scaling in end element.

Date and Place: October 29, 1999, USBR WTER Pilot Plant Lab, Denver, CO.

Date of This Report: 11/21/1999

Names of Observers:

Frank Leitz Michelle Chapman Wilbert Kim Linton

ELEMENT IDENTIFICATION				
Manufacturer:	Hydranautics			
Element Type:	LFC1X 2540			
Element Location:	Housing #3, 2nd element			
Serial Number:	x03531			
Element Dimensions:	2.5 in. x 40 in.			
Number of Leaves:	2			
Size of Leaves:	91.8cm x 72.4cm Total Area 83.8cm x 62.8cm Active Area of one side (2.1 m² per element or 22.6 ft²)			

OPERATING HISTORY

The RO system was operated for six months on site at the McAllen,TX South Waste Water Treatment Plant. Screened de-gritted sewage was first treated in a Zenogem bioreactor/microfiltration system, then chlorine and ammonia was added and the Zenogem effluent was forwarded to the RO system. The RO element array was a 2x2x1x1 and had 3 elements per vessel for a total of 18 elements in the system. RO recovery rates were set from 50% to 80% of 15.2 L/min feed flow.

Sulfuric acid and antiscalent were added to prevent scaling. However, due to changes in the chemical character of the Zenogem effluent, or excessive gas formation in the acid tank which caused the acid feed pump to loose it's prime, the pH was not controlled well at all times. This resulted in a loss of permeate flow from the last vessel.

Also, traditional constituents used in an RO projection do not include phosphorous compounds. The researchers involved in this project began to suspect that phosphorous salts were the cause of excessive scale problems due to the nature of waste water treatment. Attempts at adjusting the pH to control phosphorous salts included running a projection with non-RO software to determine the potential for phosphate scaling. A range of pH settings and two control points for pH were tested in an attempt to control the scaling problems. The pH ranges tested were from 5.5 to 7 on the feed, and 5.5 to 6 on the concentrate. The lower pH control ranges were in response to this non-RO projected information.

Scaling also caused operators to clean the system approximately 4 times with a low pH solution at a pH of about 3. A high pH solution was not used to clean the membranes as there was no indication of biofouling and the system's performance was recovered using the acid cleanings.

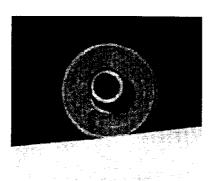
DESCRIPTION OF EVENTS LEADING TO AUTOPSY

Subject element was the second element in housing #3, one of two vessels that received flow first. Permeate recovery flow from this vessel varied from 2.8 L/min to 2.3 L/min. This element was subject to two holes punctured with a hypodermic needle. The fouling on the membrane was a result of turning off the acid feed pump for approximately 8 hours.

This autopsy was primarily done to determine the size and extent of damage resulting from the hypodermic needle. In addition, the general nature of the membrane and scaling composition is of interest.

NARRATIVE DESCRIPTION OF AUTOPSY PROCEDURE

Fiberglass wrapping was cut open and peeled or pried off. Sample #1 is the fiberglass with the 2 holes marked.
Anti-telescoping devices were removed.
Photographed the feed end of the element.



X03531

Tape wrap was unwound.

Measured the total area and active area of one side of one leaf. Applied congo red dye to the first leaf. Photograph of the dye stained membrane.



Sample #2 is a cutting from the leaf with the 2 holes in the glue line.

OBSERVATIONS

There were no cracks in this element fiberglass casing.

Two needle holes were visible in the fiberglass and tape wrap at a distance of 17.75 cm (~ 7 in) from the reject end.

The membrane was wound backwards - which probably makes no difference in performance, but does make autopsy confusing.

There were little black flecks on the membrane surface.

Glue lines were all solid.

Dye test showed no pin hole damage. There were only 2 holes in the glue line, neither of which extended through the hard, thick glue.

Test and Test Objective: Chemical analysis of fouling material on leaf 1

Organization Performing Test: USBR Chemistry Lab

Date: Submitted November 1, 1999

Observations from Test:

The analysis methods used for TDS, TSS, SO4, and Cl do not used acid to digest the samples. The method used for SO4 and Cl was EPA method 300.0A, ion chromatography. The other metals, except for phosphorous were digested with nitric acid and analyzed using the ICP (inductively coupled plasma) EPA method 30.15. Phosphorous is also digested, but under EPA method 365.1.

The results from both housing #3 and #6 are shown for comparison.

Analytes	Housing #3	Equivalent	Equivalent	Housing #6	Anions =>	Cations =>
	concentration	Anions =>	Cations =>	concentration	Ox. State *	Ox. State *
	(mg/L)	Ox. State *	Ox. State *	(mg/L)	Conc. / At.	Conc. / At.
		Conc. / At.	Conc. / At.		Wt.	Wt.
····		Wt.	Wt.			
Total P	36.69	-3.6		135.2	-13.1	
Al	2.52		0.3	9.1		1.0
Ba	7.02		0.1	20.8		0.3
Fe	1.1		0.1	3.8		0.2
Ca	76.5		3.8	298.0		14.9
K	2.7		0.1	4.8		0.1
Mg	4.07		0.3	13.4	***	1.1
Na	21.3		0.9	38.0		1.7
Si	2.46		0.4	7.4		1.1
SO4	15.7	-0.3		20.6		
CI	21.6	-0.6		33.7	-1.0	
Totals		-4.5	5.9		-14.5	

DISCUSSION AND CONCLUSIONS

The holes did not penetrate through the heavy glue line into the permeable membrane surface.

The solids precipitated onto the membrane surface originally come from a saturated solution. When the autopsy is done, de-ionized water is used to rinse the scrapings from the surface of the membrane. Since the samples are scraped from the membrane using DI water, the concentration expressed as a value in milligrams per liter is not meaningful as a concentration unless it is expressed in equivalents.

When the concentrations are interpreted as equivalents, it can then be shown in both housing #3 and housing #6 that there are roughly the same number of equivalents of calcium and phosphorous in each housing. This indicates that the predominant form of what was left on the membrane was most likely calcium phosphate (hydroxy apetite). Housing #6 had a larger amount than housing #3 resulting in the flow almost ceasing in housing #6.

When dye was applied to the element from the 6th housing, it did not That membrane element was the second membrane from the end of adhere. The membrane in the 3rd housing at the front end of the system absorbed the dye indicating damage to the membrane surface. One possible reason why is that the acid solution was stronger at the front end of the system, especially if there was a problem with the chemical feed system and the pH dropped towards 2. Another possible explanation is the phosphate scale acted as a buffer to protect the membrane surface from the sulfuric acid in the end of the system. Phosphoric acid is a weaker acid than sulfuric. Using the 1st ionization constants, phosphoric acid would be a pH of about 3, and sulfuric is less than 2. Using the second ionization constant, phosphoric acid would be a pH of about 8, and sulfuric would still be about 2. As the water became more saturated with calcium phosphorous, the sulfuric acid became buffered significantly.

SPIRAL WOUND MEMBRANE ELEMENT AUTOPSY

PURPOSE AND LOCATION OF AUTOPSY

Purpose of Autopsy: McAllen, TX Wastewater Reclamation Project: Determination of scaling in end element.

Date and Place: October 29, 1999, USBR WTER Pilot Plant Lab, Denver, CO.

Date of This Report: 12/30/1999

Names of Observers:

Frank Leitz Michelle Chapman Wilbert Kim Linton

ELEMENT IDENTIFICATION				
Manufacturer:	Hydranautics			
Element Type:	LFC1X 2540			
Element Location:	Housing #6, final element			
Serial Number:	X03536			
Element Dimensions:	2.5 in. x 40 in.			
Number of Leaves:	2			
Size of Leaves:	92.1cm x 72.7cm Total Area 82.6cm x 62.2cm Active Area per side (2 m² per element or 22.1 ft²)			
OPERATING HISTORY				

The RO system was operated for six months on site at the McAllen,TX South Waste Water Treatment Plant. Screened de-gritted sewage was first treated in a Zenogem bioreactor/microfiltration system, then chlorine and ammonia was added and the Zenogem effluent was forwarded to the RO system. The RO element array was a 2x2x1x1 and had 3 elements per vessel for a total of 18 elements in the system. RO recovery rates were set from 50% to 80% of 15.2 L/min feed flow.

Sulfuric acid and antiscalent were added to prevent scaling. However, due to changes in the chemical character of the Zenogem effluent, or excessive gas formation in the acid tank which caused the acid feed pump to loose it's prime, the pH was not controlled well at all times. This resulted in a loss of permeate flow from the last vessel.

Also, traditional constituents used in an RO projection do not include phosphorous compounds. The researchers involved in this project began to suspect that phosphorous salts were the cause of excessive scale problems due to the nature of waste water treatment. Attempts at adjusting the pH to control phosphorous salts included running a projection with non-RO software to determine the potential for phosphate scaling. A range of pH settings and two control points for pH were tested in an attempt to control the scaling problems. The pH ranges tested were from 5.5 to 7 on the feed, and 5.5 to 6 on the concentrate. The lower pH control ranges were in response to this non-RO projected information.

Scaling also caused operators to clean the system approximately 4 times with a low pH solution at a pH of about 3. A high pH solution was not used to clean the membranes as there was no indication of biofouling and the system's performance was recovered using the acid cleanings.

DESCRIPTION OF EVENTS LEADING TO AUTOPSY

Subject element was the last element of the last vessel (vessel #6). Permeate recovery flow from the last vessel varied from 1.4 L/min to 0.01 L/min. This fouling was a result of turning off the acid feed pump for approximately 8 hours.

This autopsy was primarily done to determine if phosphate salts were of primary concern, or not. In addition, the general nature of the scaling composition is of interest.

NARRATIVE DESCRIPTION OF AUTOPSY PROCEDURE

The membrane was inspected during the autopsy at every step. First, the fiberglass wrapping was cut open using an air-powered cast saw set to cut at a shallow depth. The wrapping was then peeled or pried off. Anti-telescoping devices were removed from both ends of the membrane. Finally, the tape wrap was removed.

A squeegee was used to wipe both sides of the first leaf. DI water was used to liquefy the fouling substance. The material was collected in a sample jar labeled as Sample 1.

Researchers then applied a strong red red dye, congo red, to the second leaf.

Samples were cut from the feed and reject ends of the second leaf for SEM analysis with DI water added to the baggie to keep the membrane supple. Feed side is Sample 2 and the reject side is Sample #3.

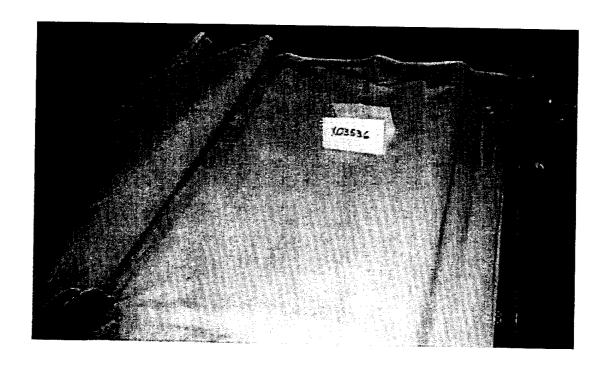
The material was collected from the first leaf was funneled into a sample jar labeled as Sample #4.



OBSERVATIONS

The scrapings from the first element were a brownish pink color. The pink may be dye. No visible scaling was apparent.

Dye test on the second leaf with congo red was negative indicating no structural damage or biofouling on the membrane surface. Dye will highlight biofouling as the dye adheres to a surface ripe with organisms.



Test and Test Objective: Chemical analysis of fouling material on leaf 1

Organization Performing Test: USBR Chemistry Lab

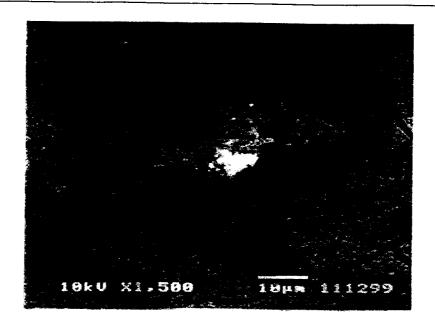
Date: Submitted November 1, 1999

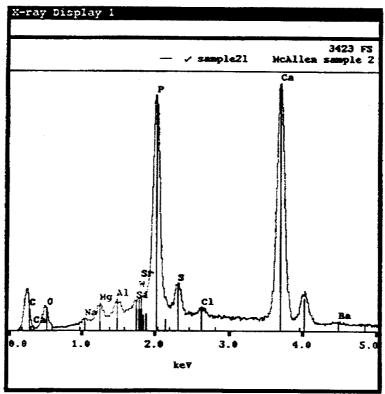
Test Results

Analytes	Housing #3	Equivalent	Cauitalant	11	1.	T
Allalytes				Housing #6		Cations =>
	concentration		Cations =>	concentration	Ox. State *	Ox. State *
	(mg/L)	Ox. State *	Ox. State *	(mg/L)	Conc. / At.	Conc. / At.
		Conc. / At.	Conc. / At.	, ,	Wt.	Wt.
		Wt.	Wt.			****
Total P	36.69	-3.6		135.2	-13.1	
Al	2.52		0.3			1.0
Ba	7.02		0.1	20.8		0.3
Fe	1.1		0.1	3.8		0.2
Ca	76.5		3.8			14.9
K	2.7		0.1	4.8		0.1
Mg	4.07		0.3			1.1
Na	21.3		0.9	38.0		1.7
Si	2.46		0.4			1.1
SO4	15.7	-0.3		20.6	-0.4	
CI	21.6			33.7		
Totals		-4.5	5.9		-14.5	20.3

Observations from Test:

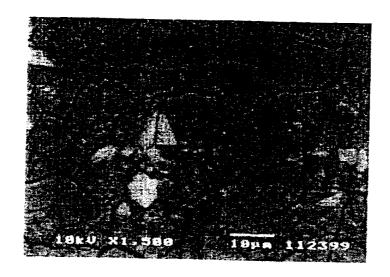
The analysis methods used for TDS, TSS, SO4, and Cl do not used acid to digest the samples. The method used for SO4 and Cl was EPA method 300.0A, ion chromatography. The other metals, except for phosphorous were digested with nitric acid and analyzed using the ICP (inductively coupled plasma) EPA method 30.15. Phosphorous is also digested, but under EPA method 365.1.

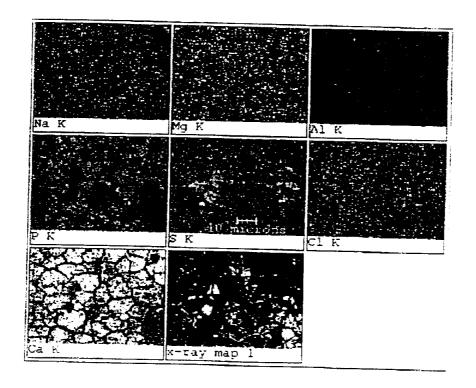




Test and Test Objective: SEM/Elemental Analysis of membrane samples from the second leaf to determine the nature of the scalant for element number X03536.

Organization Performing Test: USBR Date: Submitted November 1, 1999





SEM Distribution map of sampled elements for membrane # X03536

DISCUSSION AND CONCLUSIONS

SEM Test:

The X-ray display peaks should be interpreted as a qualitative analysis, not a quantative one. This analysis captures the energy spikes from the entire picture, not just the particle in the middle. The sample was hit with 10 kV of energy and magnified 3,500 times. Certainly, phosphorous and calcium are prevalent peaks. Barium and sulfur also show strong peaks on other samples not shown as part of this report because they are redundant to the information captured in the body of this report.

Although no visible scaling was apparent to the naked eye, this analysis clearly shows a fine silt-like layer covers the surface of the membrane. It appears from the distribution map that there is an even covering of these elements across the face of the membrane. The particle in the middle does not seem to be of a different character as compared to the rest of the scale layer.

Chemical Analysis of Scraping:

The solids precipitated onto the membrane surface originally come from a saturated solution. When the autopsy is done, de-ionized water is used to rinse the scrapings from the surface of the membrane. Since the samples are scraped from the membrane using DI water, the concentration expressed as a value in milligrams per liter is not meaningful as a concentration unless it is expressed in equivalents.

Using equivalents, it can then be shown in both housing #3 and housing #6 that there are roughly the same number of equivalents of calcium and phosphorous in each housing. This indicates that the predominant form of what was left on the membrane was most likely calcium phosphate (hydroxy apetite). Housing #6 had a larger amount than housing #3 resulting in the flow almost ceasing in housing #6.



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ZeeWeed® Tertiary Treatment System

BUDGET PROPOSAL for a ZeeWeed® Membrane Filtration Tertiary Filtration Treatment System for the City of McAllen, Texas Proposal Number #374-98 Rev. 2.0

Submitted to:

CH2M Hill 1620 W. Fountain Head Pkwy. #550 Tempe, AZ 85282

Attention:

Jim Lozier / Fair Miller

Submitted by:

ZENON Environmental Systems – Municipal Division 845 Harrington Court Burlington, Ontario L7N 3P3

December 7, 1999

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1.0 COMMERCIAL INFORMATION

1.1 Pricing Summary

The budget pricing to supply equipment and services as described in this proposal is as follows:

ZeeWeed[®] Membrane Tertiary Treatment System including membranes, permeate pumps, membrane air scour blowers, instruments and control system & equipment F.O.B. McAllen, Texas.

Four (4) Train ZeeWeed® Membrane Tertiary Treatment System to treat a maximum daily hydraulic capacity of 8.5 MGD.

Process equipment will be supplied loose, i.e. not on skids, for installation by others.

Fixed Capacity Flow

8.5 MGD

Budgetary System Price

US \$5,075,000.00

Validity

Pricing is for budgetary purposes only and does not constitute a final offer of sale.

Taxes and Duties

No taxes or duties or brokerage are included in the above pricing. Any taxes, duties, tariffs of any type are for the account of the Purchaser.

Field Service

The equipment pricing above includes Field Service from ZENON Technicians for assistance with the equipment installation, commissioning, operator training and process start-up assistance.

Any additional days of Field Service required will be at ZENON's Standard per diem rate of US\$650 per day plus living and travelling expenses.

Terms of Payment

The budgetary pricing quoted in this proposal is based on the following payment terms

- 15% with Purchase Order
- 25% on submission of General Arrangement Drawings

- 50% on shipment of equipment or notification that equipment is ready to ship (partial shipments permitted)
- 10% within 30 days of equipment start up or within 60 days of equipment shipment whichever is sooner.

Performance & Maintenance Bonds

The cost of providing performance or maintenance bonds is not included. If required these will be at additional cost.

Equipment Shipment and Delivery

A typical drawing submission and equipment shipment schedule is indicated below. Drawing submission milestones and equipment shipment periods are quoted from the date of acceptance of a formal signed Purchase Order:

Submission of GA Drawings:

8 to 10 weeks from acceptance of P.O

Drawing Approval:

3 weeks from submission of drawings

Equipment Shipment:

24 to 26 weeks from acceptance of P.O. 2 weeks after shipment of equipment to site

Plant Operation Manuals: Operator Training:

When preferred by Customer but no later than

2 weeks prior to the scheduled plant start-up

The above estimated delivery schedule is presented based on current workload backlogs and production capacity. If a formal purchase order is not received within the period of validity of this proposal, the delivery schedule is subject to review and adjustment.

The estimated delivery period quoted is presented based on review <u>and approval</u> of equipment shop drawings within a two (2) week period. Any delay in approval of shop drawings may affect the proposed shipment schedule.

Quality Basis

For the purposes of establishing a quality basis for equipment supply, reference is made herein to particular equipment manufactured by certain suppliers. The term "or equal" where used herein shall be deemed to mean "ZENON Approved Equivalent". ZENON reserves the right to substitute equipment that ZENON considers to be of equal quality and suitability for the intended application from alternative suppliers to those named herein. With regard to determining the suitability or otherwise of any particular manufacturer's equipment for inclusion as part of the ZeeWeed® system, ZENON's decision shall be final.

1.2 Standard Terms and Conditions

ZENON's Standard Terms and Conditions apply.

1.3 ZENON STANDARD TERMS AND CONDITIONS

Seller desires to provide its Customers with prompt and efficient service. However, to negotiate individually the Terms and Conditions of each Sales contract would substantially impair Seller's ability to provide such service. Accordingly, Products and Services furnished by Seller are sold only on the Terms and Conditions stated herein. Notwithstanding any terms or conditions on Customer's order. Seller's performance of any contract is expressly made conditional on Customer's agreement to Seller's Terms and Conditions of Sale unless otherwise specially agreed to in writing by Seller. In the absence of such agreement, commencement of performance and/or shipment shall be for Customer's convenience only and shall not be deemed or construed to be acceptance of Customer's Terms and Conditions, or any of them. If a contract is not earlier formed by mutual agreement in writing, acceptance of any Product or Service shall be deemed acceptance of the Terms and Conditions stated herein. All contracts for the Sale of Products shall be construed under and governed by the law of the location of Seller's plant at Burlington, Ontario, Canada.

QUOTATION AND PRICES

All quotations are subject to the Terms and Conditions stated herein as well as any additional Terms and Conditions that may appear on the face hereof. In the case of a conflict between the Terms and Conditions stated herein and those appearing on the face hereof, the latter shall control. Seller's prices and quotations are subject to the following:

- a) All published prices are subject to change without notice.
- b) UNLESS OTHERWISE SPECIFIED IN WRITING, ALL QUOTATIONS EXPIRE THIRTY (30) DAYS AFTER DATE THEREOF, MAY BE TERMINATED EARLIER BY NOTICE AND CONSTITUTE ONLY SOLICITATIONS FOR OFFER TO PURCHASE; further, budgetary quotations and estimates are for preliminary information only and shall neither constitute offers, nor impose any obligation or liability upon Seller.
- c) Unless otherwise stated in writing by Seller, all prices quoted shall be exclusive of transportation, insurance, taxes (including, without limitation, any sales, use, or similar tax, and any tax levied on or assessed to Seller after Product shipment by reason of Seller's retention of a security interest as provided herein), license fees, customs fees, duties and other charges related thereto and Customer shall report and pay any and all such shipping charges, premiums, taxes, fees, duties and other charges related thereto, and shall hold Seller harmless therefrom, provided that, if Seller, in its sole discretion, chooses to make any such payment, Customer shall reimburse Seller in full upon demand.
- d) Stenographic, typographical and clerical errors are subject to correction.
- e) Prices quoted are for Products only and do not include technical data, proprietary right of any kind, patent rights, qualification, environmental or other than Seller's standard tests and other than Seller's normal domestic commercial packaging unless expressly agreed to in writing by Seller.
- f) Published weights and dimensions are approximate only. Certified dimension drawings can be obtained upon request. Manuals, drawings or other documentation required hereupon must be referenced specifically.

This is merely a quotation, and the technology disclosed herein may be covered by one or more ZENON Environmental Inc. (ZENON) patents or patent applications. Any disclosure in this offer does not hereby grant, and nothing contained in the offer shall obligate ZENON to grant, an option to obtain a license to any technology or any other rights under any patent now or hereafter owned or controlled by ZENON.

TERMS OF PAYMENT

Unless credit is granted or otherwise specified in writing, payment is due upon shipment. All payments on approved credit accounts

shall be due in full thirty (30) days from date of invoice. Past due balances shall be subject to a service charge of 1-1/2% per month (18% per annum), but not more than the amounts allowed by law. Partial shipments will be billed as made and payments therefor are subject to the above terms. Payment shall not be withheld for delay in delivery of required documentation unless a separate price is stated therefor, and then only to the extent of the price stated for such undelivered documentation. Seller may cancel or delay delivery of Products in the event Customer fails to make prompt payment therefor, or in the event of an arrearage in Customer's account with Seller. Seller hereby retains a security interest in the Products finished until Customer has made payment in full in accordance with the terms hereof. Customer shall cooperate fully with Seller to execute such documents and to accomplish such filings and/or recordings thereof as Seller may deem necessary for the protection of Seller's interest in the Products furnished.

TRANSPORTATION AND RISK OF LOSS

Transportation will normally follow Customer's shipping instructions, but Seller reserves the right to ship Products freight collect and to select the means of transportation and routing when Customer's instructions are deemed unsuitable. Unless otherwise advised, Seller may insure to full value of the Products or declare full value thereof to the transportation company at the time of shipment and all freight and insurance costs shall be for Customer's account. Risk of loss and/or damage shall pass to Customer at the FOB point, which shall be the point of manufacture or such other place as Seller shall specify in writing, notwithstanding installation by or under supervision of Seller. Confiscation or destruction of, or damage to, Products shall not release, reduce or in any way affect the liability of Customer therefor. All Products must be inspected upon receipt and claims should be filed with the transportation company when there is evidence of shipping damage, either concealed or external. Notwithstanding any defect or nonconformity, or any other matter, risk or loss and/or damage shall remain with the Customer until the Products are returned at Customer's expense to such place as Seller may designate in writing. Customer, at its expense, shall fully insure Products against all loss and/or damage until Seller has been paid in full therefor, or the Products have been returned, for whatever reason, to Seller.

PERFORMANCE

Seller will make all reasonable effort to observe its dates indicated for performance. However, Seller shall not be liable in any way because of any delay in performance hereupon due to unforeseen circumstances or to causes beyond its control, including, without limitation, strike, lockout, riot, war, fire, act of God, accident, failure or breakdown of components necessary to order completion, subcontractor, supplier or customer caused delays, inability to obtain or substantial rises in the price of labour, materials or manufacturing facilities, curtailment of, or failure to obtain sufficient, electrical or other energy supplies, or compliance with any law, regulation or order, whether valid or invalid of any cognizant governmental body or any instrument thereof whether now existing or hereafter created. Performance shall be deemed suspended during, and extended for, such time as any such circumstances or causes delay its execution. Whenever such circumstances or causes are remedied. Seller will make, and Customer shall accept, performances hereupon. In addition, Seller's inventories and current production must be allocated so as to comply with applicable Government regulations. In the absence of such regulations, Seller reserves the right, in its sole discretion, to allocate inventories and current production and substitute suitable materials when, in its opinion, such allocation or substitution is necessary due to such circumstances or causes. No penalty clause of any kind shall be effective. As used herein, "performance" shall include, without limitations, fabrication, shipment, delivery, assembly, installation, testing, and warranty repair or replacement as applicable.

ACCEPTANCE

The furnishing by Seller of a Product to the Customer shall constitute acceptance of that Product by Customer, unless notice of defect or nonconformity is received by Seller within thirty (30) days of receipt of the Product at Customer's designated receiving address; provided that, for Product for which Seller agrees in writing to perform acceptance testing after installation, the completion of Seller's applicable acceptance tests, or execution of Seller's acceptance form

by Customer, shall constitute acceptance of the Product by Customer. Notwithstanding the foregoing, any use of a Product by Customer, its agents, employees, contractors or licensees for any purpose, after receipt thereof, shall constitute acceptance of that Product by Customer. Seller may repair or, at its option, replace defective or non-conforming parts after receipt of notice of defect or nonconformity.

ASSIGNMENTS AND TERMINATIONS

Any assignment by Customer of any contract hereupon without the express written consent of Seller is void. No order may be terminated by Customer except by mutual agreement in writing. Terminations by mutual agreement are subject to the following conditions:

- Customer will pay, at applicable contract prices, for all Products which are completely manufactured and allocable to Customer at the time of Seller's receipt of notice of termination.
- Customer will pay all costs, direct and indirect, which have been incurred by Seller with regard to Products which have not been completely manufactured at the time of Seller's receipt of notice of termination
- Customer will pay a termination charge on all other determined costs and other charges. To reduce termination charges, Seller will divert completed parts, material or work-in-process from terminated contracts to other Customer's whenever, in Seller's sole discretion, it is practicable to do so.

PATENTS AND OTHER INDUSTRIAL PROPERTY RIGHTS

Seller will hold Customer harmless, as set forth herein, in respect to any claim that the design or manufacture of any Product in Seller's any claim that the design or manufacture of any Product in Seller's commercial line of Products, or manufactured to specifications set by Seller and furnished herein, constitutes an infringement of any patent or other industrial property rights of the United States or Canada. Seller will pay all damages and costs, either awarded in a suit or paid, in Seller's sole discretion, by way of settlement, which are based on such claim of infringement, provided that Seller is notified promptly in writing of such claim of infringement but there is no liability whatsoever herein with respect to any claims settled is no liability whatsoever herein with respect to any claims settled by Customer without Seller's prior written consent. In the event that Seller is required to hold Customer harmless hereupon, Seller will, in its sole discretion and at its own expense, either procure for Customer the right to continue using said Product, replace it with a customer the right to continue using said refound, replace it with a non-infringing product, or remove it and refund an equitable portion of the selling price and transportation costs thereof. THIS SHALL CONSTITUTE SELLER'S ENTIRE LIABILITY FOR ANY CLAIM BASED UPON OR RELATED TO ANY ALLEGED INFRINGEMENT OF ANY PATENT OR OTHER INDUSTRIAL RIGHTS. Customer shall hold Seller harmless against any expense, loss, costs or damages resulting from claimed infringement of patents, trademarks, or other industrial property rights arising out of compliance by Seller with Customer's designs, specifications, or instructions. SELLER DISCLAIMS LIABILITY FOR U.S. OR CANADIAN PATENT OR COPYRIGHT INFRINGEMENT ARISING FROM USE OR MANUFACTURE BY ANYONE OF INVENTIONS IN CONNECTION WITH PRODUCTS OR SERVICES SOLD, USED, OR INTENDED FOR SALE OR USE, IN PERFORMING CONTRACTS WITH THE UNITED STATES OR CANADA. against any expense, loss, costs or damages resulting from claimed

WARRANTY

Unless otherwise agreed to in writing, Seller warrants its Products to be free from defects in material or workmanship for a period of 12 months from the shipment of Product by Seller, provided that such Product are used, cleaned and maintained in accordance with the Seller's instructions. This warranty does not apply to normally replaceable parts or components such as

- filter cartridges, pump seals, membranes etc., (see below for membrane warranties)
- Customer undertakes to give immediate notice to Seller if goods or performance appear defective and to provide Seller with reasonable opportunity to make inspections and tests. If Seller is not at fault. Customer shall pay Seller the costs and expenses of the inspections and tests.
- 3. Seller's obligations under this warranty is limited to the repair or replacement at its factory, or any device or part thereof which shall prove to have been thus defective. If Customer asks Seller to replace defective parts at Customer's premises, Customer agrees to pay for any traveling time and expenses, plus the Seller's labour to complete the replacement/repair.
- Goods shall not be returned to Seller without Seller's permission. Seller will provide Customer with a "Return Material Authorization" number to use for returned goods. All returns are F.O.B. - Burlington, Ontario, Canada.
- 5. Warranty on the membranes applies only if the membrane element(s) has been operated and cleaned according to Seller's instructions. When either permeate or concentrate flow drops by 10% from the original rates at the same operating conditions, cleaning must be initiated or the warranty will be null and void. Elements must be clean and be kept moist. They should be shipped to Seller in water-tight bags and must be protected from freezing. WARNING – if element conditions of use given in Seller's instructions are not followed, the warranty will be null and void.

IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, WARRANTIES OF FITNESS FOR PARTICULAR PURPOSE, USE, OR APPLICATION, AND ALL OTHER OBLIGATIONS OR LIABILITIES ON THE PART OF THE SELLER, UNLESS SUCH OTHER WARRANTIES, OBLIGATIONS OR LIABILITIES ARE EXPRESSLY AGREED TO IN WRITING BY SELLER, ARE NULL AND VOID.

DAMAGES AND LIABILITY

SELLER'S LIABILITY FOR DAMAGES SHALL NOT EXCEED THE PAYMENT, IF ANY, RECEIVED BY SELLER FOR THE UNIT OF PRODUCT OR SERVICE FURNISHED OR TO BE FURNISHED, AS THE CASE MAY BE, WHICH IS THE SUBJECT OF CLAIM OR DISPUTE. IN NO EVENT WILL SELLER BE LIABLE FOR INCIDENTAL, CONSEQUENTIAL OR SPECIAL DAMAGES, OF ANY KIND, HOWEVER CAUSED, ARISING OUT OF, OR IN ANY WAY CONNECTED WITH, THE PRODUCTS FURNISHED BY SELLER TO CUSTOMER.

DISPUTES

All disputes under any contract concerning Products not otherwise resolved between Seller and Customer shall be resolved in a court of competent jurisdiction for the location of Seller's plant at Burlington, Ontario, Canada, and no other place. Provided that, in Seller's sole discretion, such action may be heard in some other place designated by Seller, if necessary to acquire jurisdiction over third persons, so that the dispute can be resolved in one action. Customer hereby consents to the jurisdiction of such court or courts and agrees to appear in any such action upon written notice thereof. No action, regardless of form arising out of, or in any way connected with, the Products or Services furnished by Seller, may be brought by Customer more than one (1) year after the cause of action has occurred. If any part, provision or clause of the Terms and Conditions of Sale, or the application thereof to any person or circumstances, is held invalid, void or unenforceable, such holding shall not affect and shall leave valid all other parts, provisions, clauses or applications of the Terms and Conditions remaining, and to this end the Terms and Conditions shall be treated as severable.

2.0 SYNOPSIS OF THE ZEEWEED® TERTIARY TREATMENT PROCESS

ZeeWeed[®] ultrafiltration system is a proprietary ZENON process technology that produces high quality treated water by drawing raw water through immersed ZeeWeed[®] membrane modules. ZeeWeed[®] "Outside-In", hollow-fibre membranes are manufactured ultrafiltration (UF) pore size. The ZeeWeed[®] UF Membranes have an absolute pore size of 0.1 microns and thus ensure removal of particulate matter greater than 0.1 microns in size such as most particulate matter, including bacteria, solids, Giardia cysts and Cryptosporidium oocysts, cannot enter the treated effluent stream. The ZeeWeed[®] Membrane ensures removal of a large percentage of impurities. The ZeeWeed membranes produce a high quality effluent, optimal for post-treatment by reverse osmosis.

The membranes operate under a slight vacuum created within the hollow membrane fibres by a permeate pump. Treated water is drawn through the membranes, enters the hollow fibres and is pumped out to the treated water storage tank (or distribution system). Air flow is introduced at the bottom of the membrane modules to create turbulence which scrubs and cleans the outside of the membrane fibres allowing them to operate at a high flux. The aeration also oxidizes iron and organic compounds, resulting in a treated water quality that is better than that provided by ultrafiltration alone.

ZeeWeed® membranes are immersed and therefore can tolerate high levels of solids. This is a main advantage when used as a tertiary treatment plant, since the ZeeWeed plant continues to operate well even when the upstream clarifier is upset and rejects solids to the UF. The capacity to handle solids also means that there is no need to pre-treat the clarified effluent, avoiding therefore the costs of sand filters or cartridge filters often required by other membrane technologies.

ZeeWeed® membranes have the additional benefit of being chlorine resistant up to concentrations of 1,000 mg/L. Therefore, influent water can be pre-chlorinated or the membranes can be easily cleaned, even when heavy fouling occurred.

The ZeeWeed[®] Membrane Technology process consistently produces high quality water, as the membranes are not subjected to stress, pressurization or rapid pressure fluctuations. Membrane cleaning by backpulsing is achieved by reversing the permeate flow and backwashing the fibre's lumen with permeate at low pressure (due to the high permeability of the ZeeWeed[®] membrane, the backpressure during backpulsing is low). The small variations in operating pressure occur smoothly over relatively long periods so that at no time is the membrane stressed. This, in turn, results in a membrane filtered permeate with the lowest sustainable particle count on the market.

3.0 FEATURES & BENEFITS OF THE ZEEWEED® SYSTEM

High Treated Effluent Quality

ZENON's ZeeWeed® Membrane Tertiary Treatment System is a cost effective method for membrane filtration removal of solids and is particularly recommended for treatment of the following contaminants in water:

Feed Water Element

Treated Water Quality Suspended Solids ≥6 log removal Average Turbidity ≤ 0.1 NTU

Particle Counts

Average $\leq 5/\text{mL}$, size range > 2 microns

Note: The information provided in this section of the proposal is general only and is intended only to indicate what is capable of being achieved with ZeeWeed® Membrane Water Treatment Technology based on consideration of specific raw water qualities and the type of treatment processes utilized.

Since the presence of air is continuous or semi-continuous in the process tank, materials which will readily oxidize, such as iron in its ferrous state, will be micro-precipitated and separated by the membrane, therefore producing a better quality water than if treated by ultrafiltration alone.

Advantages of an "Outside-In" Immersed Membrane

a) Single Step Treatment

The ZeeWeed® membrane is an outside-in membrane where the flow of water is from the outside of the membrane to the inside of the hollow fibre. This means that the inside of the membrane only comes in contact with clean, filtered water. The solids to be removed remain outside of the membrane where they do not cause fouling and plugging.

b) Low Energy Requirement.

Being immersed allows ZENON's ZeeWeed® Membranes to operate under a slight vacuum instead of under a high positive pressure, as do other membranes on the market. The ZeeWeed® Membrane operates under a differential pressure of 5"Hg to 18"Hg (5-20 ft H₂O) vacuum. This operational energy is very low and to ZENON's knowledge is the lowest in the membrane market.

c) Ability to Operate in a High Solids Environment

The ZeeWeed® membranes are immersed within the process tank, where suspended solids can exist without interfering with membrane operation. The operating flux rates of ZeeWeed® membrane modules are, for all practical purposes, independent of the solids content and turbidity of the raw water supply. This reflects in its capacity to operate well in a solids environment seen when the clarifiers get upset.

d) Stable and Low Particle Counts in the Effluent

The low energy backpulse of an immersed membrane does not produce significant expansion of the membrane pores. Expansion of the membrane pores, which results from high energy air backpulsing of the membranes as utilized in some types of membrane systems, can result in high particle counts immediately following backpulsing. This expansion of the membrane pores may potentially permit the passage of particles of larger sizes through the membranes until the membrane fibre fully relaxed from the expansion induced by the backpulsing process. Such systems cannot reliably use particle counters to verify the membrane integrity.

With the ZeeWeed® Membrane system expansion of the membrane pores is insignificant and the ZeeWeed® process consistently produces high quality treated water, which remains stable at all phases of plant operation.

Resistance to Oxidizing Chemicals

The ZeeWeed® membrane is resistant to chlorine and other typical water treatment plant oxidants (such as chlorine dioxide and potassium permanganate) in concentrations as high as 1,000 mg/L. This means that it is possible to pre-chlorinate the water without having to add a de-chlorination step such as Granular Activated Carbon (GAC) or bisulfite injection, which not only requires periodic chemical filling and maintenance, but also adds an unnecessary compound into the water. Where prechlorination is desired, chemical resistance also provides protection against dechlorination equipment failure, which could lead to severe damage of a chlorine sensitive membrane. Finally, chlorine resistance also allows for easy disinfection of the membrane and the plant should this be required.

Exceptional Membrane Durability

The ZeeWeed® membrane has been designed to be exceptionally durable and resistant to breakage. To achieve a high level of membrane durability ZENON utilizes a patented internal support on which the membrane is caste. This provides resistance to the membrane and protects it against tearing and breakage without reducing its flux capacity.

Simplicity of Operation

The ZeeWeed® process is an easy and inexpensive system to operate both in terms of maintenance costs and personnel requirements. Since treatment is a single stage process, there is no need for coagulants (except for colour and organics removal), clarifiers or sand filters as with some other membrane systems. Instead the plant operators are only required to ensure they maintain proper membrane permeating conditions by maintaining the permeate pumps and blowers in operation.

Ruggedness of Operation / Operational Flexibility

The ZeeWeed® Treatment Process consistently produces high quality treated effleunt irrespective of seasonal, operational and weather related variations in the source raw water quality, since the membranes can operate equally well in low or high solids concentrations and at varying temperatures:

- without clogging

- without the need for pressurized air backpulsing cycles which consistently stress the membranes and lead to premature failure
- without any detrimental effects on the membrane flux since the ZeeWeed® membrane was developed for environments of high solids concentrations
- without breaking since the hollow fibre membrane is a composite developed to be both highly durable structurally as well as chemically resistant to outside elements

4.0 ZEEWEED® TERTIARY TREATMENT PLANT

Design Parameters

The table below summarizes the main design parameters on which the proposed ZeeWeed® Tertiary Treatment System has been designed.

Design Flow
Design Flow
Fixed Capcity Flow
9.435 MGD
Treated Water

8.5 MGD

Note 1: The plant should be able to operate at 95% recovery, however, the recovery equipment has been sized for 90% and the average given above at 90%, is to allow for operations flexibility.

4.0 ZEEWEED® TERTIARY TREATMENT PLANT

Design Philosophy and Equipment Selection

ZENON proposes to offer a four (4) Process Stream Membrane Treatment Plant with each process train designed to produce a continuous treated water output of 1/4 of the required capacity of the plant. In the event of any type of operational problem or failure with one train the plant will function at 75% of the nominal average day flow design capacity, by adjusting the vacuum applied to the operating membrane modules. Future plant expansion, if and when required, can be achieved by adding additional treatment units.

The equipment proposed is designed for simplicity of operation. All plant operations are automatically controlled via a PLC. There are no normal operations that require manual operation of valves, pump speeds, etc. The system design philosophy is to reduce as far as possible the potential for system problems caused by operator error.

The treatment system proposed by ZENON does not include a chlorine dosing system to add residual chlorine to the treated effluent.

CONCRETE, EQUIPMENT LOOSE

The ZeeWeed® Membrane Tertiary Treatment System is designed with major process equipment supplied loose for installation on concrete pads. The ZeeWeed® membranes are supplied for installation in concrete tanks (by others) within Zenon supplied membrane support beams. The membrane air scour blowers are supplied loose for installation within an acoustically insulated blower room to minimize the noise transmission to the rest of the plant. Reject water will flow by gravity to the disposal point. The plant control panel will be supplied loose so that it can be either wall mounted adjacent to the plant or located in a separate control room depending on the Owner's preference.

5.0 MAJOR EQUIPMENT

The list below summarizes the major equipment and the quantities of items included for the ZenoGem® plant design.

SCOPE OF SUPPLY SYNOPSIS for the ZeeWeed® Plant			
Item	Size	Units	Quantity
Raw Water Feed			
Raw Influent Feed Pumps			Not Incl.
Inlet & Discharge Isolating Valves			Not Incl.
Discharge Check Valves			Not Incl.
Piping Manifold			Not Incl.
Wet Well Level Switches			Not Incl.
VFD's			Not Incl.
Raw Water Screening			
Raw Influent Screen			Not Incl.
Raw Influent Grinder			Not Incl.
Raw Influent Flowmeter			Not Incl.
Raw Influent Flow Control Flowmeter			Not Incl.
Raw Influent Flow Control Valve			Not Incl.
Membranes/Membrane Cassettes			
Individual Membrane Modules			640
Membrane Cassettes			80
Process Tanks & Frames			
Membrane Support Frames			Incl.
Process Tanks			Not Included
Permeate Collection Headers			4
Air Scour Headers			4
Permeate Pumps			
Permeate Pumps	2,497	USgpm	5
VFD's/Control Valves	50	HP	4
Piping Manifold			Not Incl.
Valves			Incl.
Air Extraction System			
Air Removal Separation Columns			4
Vacuum Pumps	24	scfm	3
Backpulse System			
Backpulse Water Storage Tank	6,480	USg	2
Hypochlorite Storage Tank	106	USg	1
Hypochlorite Feed Pumps	6.9	USgphr	2
Item	Size	Units	Quantity

Air Blowers			
Membrane Air Scour Blowers incl. Silencers	5,129	Scfm	3
Inlet & Discharge Isolation Valves			6
Discharge Check Valves			3
Inlet Control Valves			Incl.
Chemical Addition System (if required)			
Chemical Storage Tank			Not Incl.
Chemical Feed Pumps			Not Incl.
CIP System			
CIP Chemical Storage Tank			Incl.
CIP Chemical Feed Pump			Incl.
Instruments			
Permeate Flowmeters			4
Permeate Header Pressure Transducers			4
Process Tank Level Transmitters			4
Process Tank Level Switches			16
pH Transmitters			Not Incl.
Turbidimeters			1
Particle Counters			4
Membrane Blower Flow Switches			3
Permeate Pump Pressure Gauges			4
Membrane Air Scour Blower Pressure Gauges			3
Control Panel			
PLC-based Control Panel			1
Back-Up PLC			Not Incl.
Electrical			
MCC Panel			Not Included
Miscellaneous			
Air Compressor			2
Air Drier			1
Monorail for Cassette Removal			Not Incl.
Field Service Allowed			Days
Installation Supervision			5
Mechanical Checkout			5
Operator Training			2
Process Start-Up			3
Commissioning			5
TOTAL MAN-DAYS			20
TOTAL No. TRIPS			3
Freight			
Delivery to Site			Incl.

6.0 ATTACHMENTS

Plant Power Consumption and Estimated Yearly Operating Cost

Table 9.1.1 Connected Power and Estimated Power Consumption at Average Day Flow City of McAllen Eff Filtration Rev 2

m3/day m3/day 32,173 32,173 USgpd **D**Sgpd 8,500,026 8,500,026 Maximum Day Flow Average Day Flow

1 And wide/Wastewater Screen name Blowers etc. 2 4 00 Permission Pumps By Zenon 4 00 1,644.32 USgpm 35.00 ft 81.00 18.44 30.00 3 - 10 Permission Pumps Py Zenon 4 00 1,644.32 USgpm 35.00 ft 81.00 18.44 30.00 4 - 10 Permission Pumps Py Zenon - 10.8gpm 30.00 ft 55.00 - 10.9gpm 110.49 20.00 5 - 10 Permission Pumps Py Zenon 2.00 38.40.00 Schm 4.25 psl 110.49 20.00 - 10.00 psl - 10.00	¥ #	OTAL	# QTY DESCRIPTION			Design Capacity	Discharge Head	Duty Point	Equipment Operating	Motor HP	Total Equipment	Total Connected	Matar Efficiency	Equipment KW	Hours / Day Continuous	Energy Cost
4 00 Permeate Pumps Part Water/Mastewater Screen n/a . 1564 32 USgpm 35 00 ft . 164 32 USgpm 35 00 ft . 164 4 25 . Backcluster Pumps n/a . USgpm 30 00 ft . 165 00 . 164 0	+	1			Blowers etc.			Efficiency	BHP		服	윺	%		Operation	peryear
4 00 Permeate Pumps Parameter Pumps Parameter Pumps Na 1.684.32 USgpm 35.00 ft 81.00 18.44 or 18.4 1 Backpulse Pumps n/a - USgpm 30.00 ft 55.00 - USgpm 10.00 ft 55.00 - Stool 2 Suddge Wasting Pumps n/a - USgpm 30.00 ft 56.00 - Stool - Stool </td <td>-</td> <td>Ϊ,</td> <td></td> <td>6/0</td> <td></td>	-	Ϊ,		6/0												
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Hearciculation Pumps n/a . USgpm 10.00 ft 55.00 . Sludge Wasting Pumps n/a . . USgpm 25.00 ft 55.00 . 3.00 Membrane Air Scoul Blowers n/a . </td <td>ر م</td> <td>,</td> <td></td> <td>n/a</td> <td>,</td> <td>. USgpm</td> <td># 808</td> <td></td> <td></td> <td></td> <td>•</td> <td>•</td> <td>,</td> <td></td> <td>6.40</td> <td>,</td>	ر م	,		n/a	,	. USgpm	# 808				•	•	,		6.40	,
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Select Water Pumps Index	2	1		n/a		- USgpm	30.00 ft	20.00							2002	
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∴ Miscellaneous Alt Blowers n/a · schm 6 00 psi n/a · 3.00 Anoxic Zone Misers n/a . 2.25 acdm 18.00 ina . 2.00 Backpulses Sodium Hypochlorite · Melering By Zenon 100 0.039 USgpm 50.00 it n/a 0.10 . CIP Wash Pump n/a . . USgpm 50.00 it . 2.50 . CIP Wash Pump n/a .	8	•		n/a	٠	- sdm		n/a	,						24 00	
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Total Operating Power Total Operating Cost		- 1	Total Connected Power	4								781.89	운			
Total Operating Cost		. 1	Total Operating Power		TOTAL STATE OF THE						318.09	BHP		255.59	κW	
			Total Operating Cost									Property and a second			\$SN	157,696

Notes

Energy Costs based on

Power Consumption of other plant equipment required (raw water feed pumps, high lift pumps etc.) is not included by ZENON.
Where operating efficiencies are not known, the equipment operating power is assumed to be 75% of the motor nameplate power rating.

The operating hours for the permeate pump are corrected for the downtime during backpulse cycles (and Membrane Pressure Decay Test Cycles if applicable)

Permeate Pump Backpulses every 15 mins for 30 seconds 2,486 USgpm @ 30.00 if TDH = 24.89 BHP
Motor Efficiencies Indicated are typical only. Efficiencies used are usually within 2% of actual when motor is operating within 50-100% of its full load rating Operation of Air Compressor is assumed to be only 25% of time
Operation of the Sodium Hypochtorite Pumps is intermittent - operation for 25% of time is used for energy calculation
Blower Energy Consumption Estimated as: 6.770 BHP per 1,000 scfm per psig.

It must be understood that at the time of proposal preparation, final headlosses or pressure drops in piping systems have not been calculated accurately Motor sizes are subject to confirmation (and if necessary adjustment) during final design. Use of the above information for sizing or selection of any ancillary equipment is entirely at the USER's own risk. Whilst the motor sizes indicated above are ZENON's best estimate based on design criteria assumed during preparation of the proposal, ZENON accepts no responsibility for the absolute accuracy of the information contained herein. The motor sizes in the above table are preliminary only and estimated based on the information evailable at the time of preparing this proposal

Table 9.2.2 Estimated Total Annual Operating Cost
City of McAllen Eff Filtration Rev 2
Average Day Flow 8,500,026 USgpd
Maximum Day Flow 8,500,026 USgpd

32,173 m3/day 32,173 m3/day

tem			Cost per year	
Electrical Equipment - Zenon		Calculated at Average Day Flow	157,696	USS
Electrical Equipment - Others				USS
Backpulse Chemicals	Sodium Hypochlorite	Calculated at Average Day Flow	8,232	USS
CIP Chemical #1	MC-1		3.211	USS
CIP Chemical #2	Sodium Hypochlorite - 250 mg/L		4,435	
CIP Neutralization Chemical #1				
CIP Neutralization Chemical #2			117	USS
Suggested Membrane Accrual			190,905	
Estimated Total Annual Opera	iting Cost		364,772	USS

Notes	Backpulse Chemical Consumption		Sodium Hypor	chlorite
	Sodium Hypochlorite Consumption		71.91	Litres per day
	Sodium Hypochlorite Consumption		26,248	
	Sodium Hypochlorite Cost	US\$	0.31	per Litre
	CIP Cleaning Chemical #1		MC-1	
	Design Dosage		2.000.00	ma/L
	Solution Concentration		50.00	%
	Specific Gravity		1.240	70
	Wash Frequency		1.00	times / year
	Chemical Consumption per Wash (all tar	aka)	1,918.24	Litres
	Total Annual Chemical Consumption	inaj	1,918.24	Litres
	Chemical Cost	US\$	1.67	per Litre
	Chemical Cost	US\$	2.70	per kg
	Gricinion Cost	004	2.10	per kg
	CIP Cleaning Chemical #2		Sodium Hypod	hlorite - 250 mg/L
	Design Dosage		250.00	mg/L
	Solution Concentration		10.80	%
	Specific Gravity		1.168	
	Wash Frequency		12.00	times / year
	Chemical Consumption per Wash (all tan	iks)	1,178.52	Litres
	Total Annual Chemical Consumption		14,142.26	Litres
	Chemical Cost	US\$	0.31	per Litre
	CIP Neutralization Chemical #1		Sodium Hydro	xide
	Design Dosage		625.00	ma/L
	Solution Concentration		50.00%	ū
	Specific Gravity		1.520	
	Wash Frequency		1.00	times / year
	Chemical Consumption per Wash (all tan	iks)	489.02	Litres
	Total Annual Chemical Consumption		489.02	Litres
	Chemical Cost	US\$	0.36	per Litre
	Chemical Cost	U\$ \$ [0.47	per kg
	CIP Neutralization Chemical #2		Sodium Blaulfi	ite
	Design Dosage		146.00	ma/L
	Solution Concentration		38.00%	yc
	Specific Gravity		1.290	
	Wash Frequency		12.00	times / year
	Chemical Consumption per Wash (all tan	ks)	177.11	Litres
	Total Annual Chemical Consumption	,	2,125.32	Litres
	Chemical Cost	US\$ [0.06	per Litre
	Chemical Cost	US\$	0.55	per kg
			<u> </u>	r

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ZenoGem®/ZeeWeed® BUDGET PROPOSAL for the City of McAllen, Texas Wastewater Treatment Plant

BUDGET PROPOSAL #374-98 Rev 1

Submitted to:

CH2M Hill 1620 W. Fountain Head Pkwy. #550 Tempe, AZ 85282

Attention:

Jim Lozier & Fair Miller

Submitted by:

ZENON Environmental Systems – Municipal Division 845 Harrington Court Burlington, Ontario L7N 3P3

December 7, 1999

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1999

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1.0 COMMERCIAL INFORMATION

1.1 PRICING SUMMARY

The budget pricing to supply equipment and services as described in this proposal is as follows:

One (1) ZenoGem® Membrane Bioreactor Waste Treatment System including membranes, aeration system, pumps, blowers, instruments, control system and equipment, FOB McAllen Texas.

Process equipment will be supplied loose, i.e. not on skids, for installation by others.

Fixed Capacity Flow

8.5 MGD

Budgetary System Price

US\$ 8,620,000.00

Validity

Pricing is for budgetary purposes only and does not constitute a final offer of sale.

Taxes and Duties

No taxes or duties or brokerage are included in the above pricing. Any taxes, duties, tariffs of any type are for the account of the Purchaser.

Field Service

The equipment pricing above includes Field Service from ZENON Technicians for assistance with the equipment installation, commissioning, operator training and process start-up assistance.

Any additional days of Field Service required will be at ZENON's Standard per diem rate of US\$650 per day plus living and traveling expenses.

Terms of Payment

The budgetary pricing quoted in this proposal is based on the following payment terms

- 15% with Purchase Order
- 30% on submission of General Arrangement Drawings
- 50% on shipment of equipment or notification that equipment is ready to ship (partial shipments permitted)
- 5% within 30 days of equipment start up or within 60 days of equipment shipment whichever is sooner.

Performance & Maintenance Bonds

The cost of providing performance or maintenance bonds is not included. If required these will be at additional cost.

Equipment Shipment and Delivery

A typical drawing submission and equipment shipment schedule is indicated below. Drawing submission milestones and equipment shipment periods are quoted from the date of acceptance of a formal signed Purchase Order:

Submission of GA Drawings:

8 to 10 weeks from acceptance of P.O.

Drawing Approval:

3 weeks from submission of drawings

Equipment Shipment:

24 to 26 weeks from acceptance of P.O.

Plant Operation Manuals: Operator Training:

2 weeks after shipment of equipment to site When preferred by Customer but no later than

2 weeks prior to the scheduled plant start-up

The above delivery schedule is presented based on current workload backlogs and production capacity. If a formal purchase order is not received within the period of validity of this proposal, the delivery schedule is subject to review and adjustment.

The delivery period quoted is presented based on review and approval of equipment shop drawings within a two (2) week period. Any delay in approval of shop drawings may affect the proposed shipment schedule.

Quality Basis

For the purposes of establishing a quality basis for equipment supply, reference is made herein to particular equipment manufactured by certain suppliers. The term "or equal" where used herein shall be deemed to mean "ZENON Approved Equivalent". ZENON reserves the right to substitute equipment that ZENON considers to be of equal quality and suitability for the intended application from alternative suppliers to those named herein. With regard to determining the suitability or otherwise of any particular manufacturer's equipment for inclusion as part of the ZeeWeed® system, ZENON's decision shall be final.

Definitions

For the purposes of defining milestone dates for payments, commencement of equipment warranties and turnover of responsibility for the operation of equipment from ZENON to the OWNER, the following definitions apply:

Commissioning

Commissioning of the plant is defined as the date when wastewater first flows through the plant.

Substantial Completion Substantial Completion is defined as the date when the equipment supplied first meets the required treatment quality and quantities as defined in accordance with Performance Warranties. In cases where the equipment supplied is designed for a future plant design capacity it is the responsibility of the Owner to provide wastewater in sufficient quantities for the performance tests within the time frame outlined in section 7.0 (Performance Warranties).

On the date Substantial Completion is achieved:

- Equipment and Process Warranties start.
- Responsibility for the plant operation transfers from ZENON to the OWNER. 2...
- 3. Holdbacks become due and payable.

OWNER

For the purposes of this document the term "OWNER" shall be also deemed to include the OWNER's appointed agents or assigns who will be responsible for the operation of the equipment / plant / treatment facility.

Equipment Drawings, Plans & Specifications

Unless otherwise specified, ZENON will furnish as part of this order the following types of drawings:

- 1. Process Flow Diagram
- 2. Process and Instrumentation Diagrams
- General Arrangement Drawings showing equipment dimensions and weights required for 3. the equipment foundations (foundations by others), and the utility requirements for the process equipment being furnished by ZENON with the System being supplied.
- Standard sub-vendors dimensional outline drawings for the items of major process 4. equipment (e.g. pumps, blowers, air compressors) which are necessary for the purchaser to complete its engineering and installation.
- Standard sub-vendors equipment cut sheets for the major process equipment and other 5. equipment items (major instruments and system components)
- 6. Electrical Drawings including Single Line Diagrams, Control Panel Layouts and Interconnecting Wiring Diagrams.
- Assembly Drawings including General Equipment Layouts, deemed necessary by ZENON to 7. be required for the Purchaser's field forces to erect the equipment.

Flow Definitions

For the purposes of defining membrane plant capacity after flow equalization, the following definitions shall apply:

Average daily flow. The average flowrate occurring over a 24-hour period based on total annual flowrate data.

<u>Maximum daily flow</u>. The maximum flowrate that occurs over a 24-hour period based on annual operating data.

<u>Maximum daily four hour flow</u>. The maximum sustained flowrate that occurs over a 4-hour period based on annual operating data.

<u>Peak hourly flow</u>. The peak sustained hourly flowrate occurring during a 24-hour period based on annual operating data.

Minimum daily flow. The minimum flowrate that occurs over a 24-hour period based on annual operating data.

Minimum hourly flow. The minimum sustained hourly flowrate occurring over a 24-hour period based on annual operating data.

<u>Sustained flow.</u> The flowrate value sustained or exceeded for a specified number of consecutive days based on annual operating data.

<u>Maximum monthly average flow</u>. This is the flow that is obtained by taking the month with the highest total flow and dividing by the number of days in that month. It provides information on the highest average flow that can be sustained for a one month period.

1.2 STANDARD TERMS AND CONDITIONS

ZENON's Standard Terms and Conditions apply.

ZENON STANDARD TERMS AND CONDITIONS

Seller desires to provide its Customers with prompt and efficient service. However, to negotiate individually the Terms and Conditions of each Sales contract would substantially impair Seller's ability to provide such service. Accordingly, Products and Services furnished by Seller are sold only on the Terms and Conditions stated herein. Notwithstanding any terms or conditions on Customer's order, Seller's performance of any contract is expressly made conditional on Customer's agreement to Seller's Terms and Conditions of Sale unless otherwise specially agreed to in writing by Seller. In the absence of such agreement, commencement of performance and/or shipment shall be for Customer's convenience only and shall not be deemed or construed to be acceptance of Customer's Terms and Conditions, or any of them. If a contract is not earlier formed by mutual agreement in writing, acceptance of any Product or Service shall be deemed acceptance of the Terms and Conditions stated herein. All contracts for the Sale of Products shall be construed under and governed by the law of the location of Seller's plant at Burlington, Ontario, Canada.

QUOTATION AND PRICES

All quotations are subject to the Terms and Conditions stated herein as well as any additional Terms and Conditions that may appear on the face hereof. In the case of a conflict between the Terms and Conditions stated herein and those appearing on the face hereof, the latter shall control. Seller's prices and quotations are subject to the following:

- a) All published prices are subject to change without notice.
- b) UNLESS OTHERWISE SPECIFIED IN WRITING, ALL QUOTATIONS EXPIRE THIRTY (30) DAYS AFTER DATE THEREOF, MAY BE TERMINATED EARLIER BY NOTICE AND CONSTITUTE ONLY SOLICITATIONS FOR OFFER TO PURCHASE; further, budgetary quotations and estimates are for preliminary information only and shall neither constitute offers, nor impose any obligation or liability upon Seller.
- c) Unless otherwise stated in writing by Seller, all prices quoted shall be exclusive of transportation, insurance, taxes (including, without limitation, any sales, use, or similar tax, and any tax levied on or assessed to Seller after Product shipment by reason of Seller's retention of a security interest as provided herein), license fees, customs fees, duties and other charges related thereto and Customer shall report and pay any and all such shipping charges, premiums, taxes, fees, duties and other charges related thereto, and shall hold Seller harmless therefrom, provided that, if Seller, in its sole discretion, chooses to make any such payment, Customer shall reimburse Seller in full upon demand.
- Stenographic, typographical and clerical errors are subject to correction.
- e) Prices quoted are for Products only and do not include technical data, proprietary right of any kind, patent rights, qualification, environmental or other than Seller's standard tests and other than Seller's normal domestic commercial packaging unless expressly agreed to in writing by Seller.
- f) Published weights and dimensions are approximate only. Certified dimension drawings can be obtained upon request. Manuals, drawings or other documentation required hereupon must be referenced specifically.

This is merely a quotation, and the technology disclosed herein may be covered by one or more ZENON Environmental Inc. (ZENON) patents or patent applications. Any disclosure in this offer does not hereby grant, and nothing contained in the offer shall obligate ZENON to grant, an option to obtain a license to any technology or any other rights under any patent now or hereafter owned or controlled by ZENON.

TERMS OF PAYMENT

Unless credit is granted or otherwise specified in writing, payment is due upon shipment. All payments on approved credit accounts

shall be due in fuil thirty (30) days from date of invoice. Past due balances shall be subject to a service charge of 1-1/2% per month (18% per annum), but not more than the amounts allowed by law. Partial shipments will be billed as made and payments therefor are subject to the above terms. Payment shall not be withheld for delay in delivery of required documentation unless a separate price is stated therefor, and then only to the extent of the price stated for such undelivered documentation. Seller may cancel or delay delivery of Products in the event Customer fails to make prompt payment therefor, or in the event of an arrearage in Customer's account with Seller. Seller hereby retains a security interest in the Products finished until Customer has made payment in full in accordance with the terms hereof. Customer shall cooperate fully with Seller to execute such documents and to accomplish such filings and/or recordings thereof as Seller may deem necessary for the protection of Seller's interest in the Products furnished.

TRANSPORTATION AND RISK OF LOSS

Transportation will normally follow Customer's shipping instructions, but Seller reserves the right to ship Products freight collect and to select the means of transportation and routing when Customer's instructions are deemed unsuitable. Unless otherwise advised. Seller may insure to full value of the Products or declare full value thereof to the transportation company at the time of shipment and all freight and insurance costs shall be for Customer's account. Risk of loss and/or damage shall pass to Customer at the FOB point, which shall be the point of manufacture or such other place as Seller shall specify in writing, notwithstanding installation by or under supervision of Seller. Confiscation or destruction of, or damage to, Products shall not release, reduce or in any way affect the liability of Customer therefor. All Products must be inspected upon receipt and claims should be filed with the transportation company when there is evidence of shipping damage, either concealed or external. Notwithstanding any defect or nonconformity, or any other matter, risk or loss and/or damage shall remain with the Customer until the Products are returned at Customer's expense to such place as Seller may designate in writing. Customer, at its expense, shall fully insure Products against all loss and/or damage until Seller has been paid in full therefor, or the Products have been returned, for whatever reason, to Seller.

PERFORMANCE

Seller will make all reasonable effort to observe its dates indicated for performance. However, Seller shall not be liable in any way because of any delay in performance hereupon due to unforeseen circumstances or to causes beyond its control, including, without limitation, strike, lockout, riot, war, fire, act of God, accident, failure or breakdown of components necessary to order completion, subcontractor, supplier or customer caused delays, inability to obtain or substantial rises in the price of labour, materials or manufacturing facilities, curtailment of, or failure to obtain sufficient, electrical or other energy supplies, or compliance with any law, regulation or order, whether valid or invalid of any cognizant governmental body or any instrument thereof whether now existing or hereafter created. Performance shall be deemed suspended during, and extended for, such time as any such circumstances or causes delay its execution. Whenever such circumstances or causes are remedied, Seller will make, and Customer shall accept, performances hereupon. In addition, Seller's inventories and current production must be allocated so as to comply with applicable Government regulations. In the absence of such regulations, Seller reserves the right, in its sole discretion, to allocate inventories and current production and substitute suitable materials when, in its opinion, such allocation or substitution is necessary due to such circumstances or causes. No penalty clause of any kind shall be effective. As used herein, "performance" shall include, without limitations, fabrication, shipment, delivery, assembly, installation, testing, and warranty repair or replacement as applicable.

ACCEPTANCE

The furnishing by Seller of a Product to the Customer shall constitute acceptance of that Product by Customer, unless notice of defect or nonconformity is received by Seller within thirty (30) days of receipt of the Product at Customer's designated receiving address; provided that, for Product for which Seller agrees in writing to

perform acceptance testing after installation, the completion of Seller's applicable acceptance tests, or execution of Seller's acceptance form by Customer, shall constitute acceptance of the Product by Customer. Notwithstanding the foregoing, any use of a Product by Customer, its agents, employees, contractors or licensees for any purpose, after receipt thereof, shall constitute acceptance of that Product by Customer. Seller may repair or, at its option, replace defective or non-conforming parts after receipt of notice of defect or nonconformity. notice of defect or nonconformity.

ASSIGNMENTS AND TERMINATIONS

Any assignment by Customer of any contract hereupon without the express written consent of Seller is void. No order may be terminated by Customer except by mutual agreement in writing. Terminations by mutual agreement are subject to the following

- Customer will pay, at applicable contract prices, for all Products which are completely manufactured and allocable to Customer at the time of Seller's receipt of notice of termination
- Customer will pay all costs, direct and indirect, which have been incurred by Seller with regard to Products which have not been completely manufactured at the time of Seller's receipt of notice of termination.
- Customer will pay a termination charge on all other determined costs and other charges. To reduce termination charges, Seller will divert completed parts, material or work-in-process from terminated contracts to other Customer's whenever, in Seller's sole discretion, it is practicable to do so.

PATENTS AND OTHER INDUSTRIAL PROPERTY RIGHTS

Seller will hold Customer harmless, as set forth herein, in respect to any claim that the design or manufacture of any Product in Seller's commercial line of Products, or manufactured to specifications set by Seller and furnished herein, constitutes an infringement of any patent or other industrial property rights of the United States or Canada. Seller will pay all damages and costs, either awarded in a suit or paid, in Seller's sole discretion, by way of settlement, which are based on such claim of infringement, provided that Seller is notified promptly in writing of such claim of infringement but there is no liability whatsoever herein with respect to any claims settled by Customer without Seller's prior written consent. In the event that Seller is required to hold Customer harmless hereupon, Seller that Seller is required to hold Customer harmless hereupon, Seller will, in its sole discretion and at its own expense, either procure for Customer the right to continue using said Product, replace it with a non-infringing product, or remove it and refund an equitable portion of the selling price and transportation costs thereof. THIS SHALL CONSTITUTE SELLER'S ENTIRE LIABILITY FOR ANY CLAIM BASED UPON OR RELATED TO ANY ALLEGED INFRINGEMENT OF ANY PATENT OR OTHER INDUSTRIAL RIGHTS. Customer shall hold Seller harmless and standard transportation from claimed INDUSTRIAL RIGHTS. Customer shall hold Seller harmless against any expense, loss, costs or damages resulting from claimed infringement of patents, trademarks, or other industrial property rights arising out of compliance by Seller with Customer's designs, specifications, or instructions. SELLER DISCLAIMS LIABILITY FOR U.S. OR CANADIAN PATENT OR COPYRIGHT INFRINGEMENT ARISING FROM USE OR MANUFACTURE BY ANYONE OF INVENTIONS IN CONNECTION WITH PRODUCTS OR SERVICES SOLD, USED, OR INTENDED FOR SALE OR USE, IN PERFORMING CONTRACTS WITH THE UNITED STATES OR CANADA. OR CANADA.

 Unless otherwise agreed to in writing, Seller warrants its Products to be free from defects in material or workmanship for a period of 12 months from the shipment of Product by Seller, provided that such Product are used, cleaned and maintained in accordance with the Seller's instructions. This warranty does

- not apply to normally replaceable parts or components such as filter cartridges, pump seals, membranes etc., (see below for membrane warranties).
- Customer undertakes to give immediate notice to Seller if goods or performance appear defective and to provide Seller with reasonable opportunity to make inspections and tests. If Seller is not at fault, Customer shall pay Seller the costs and expenses of the inspections and tests.
- 3. Seller's obligations under this warranty is limited to the repair or replacement at its factory, or any device or part thereof which shall prove to have been thus defective. If Customer asks Seller to replace defective parts at Customer's premises, Customer agrees to pay for any traveling time and expenses, plus the Seller's labour to complete the replacement/repair.
- 4. Goods shall not be returned to Seller without Seller's permission. Seller will provide Customer with a "Return Material Authorization" number to use for returned goods. All returns are F.O.B. Burlington, Ontario, Canada.
- Warranty on the membranes applies only if the membrane element(s) has been operated and cleaned according to Seller's instructions. When either permeate or concentrate flow drops by 10% from the original rates at the same operating conditions, cleaning must be initiated or the warranty will be null and void. Elements must be clean and be kept moist. They should be shipped to Seller in water-tight bags and must be protected from freezing. WARNING – if element conditions of use given in Seller's instructions are not followed, the warranty will be null

IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, WARRANTIES OF FITNESS FOR PARTICULAR PURPOSE, USE, OR APPLICATION, AND ALL OTHER OBLIGATIONS OR LIABILITIES ON THE PART OF THE SELLER, UNLESS SUCH OTHER WARRANTIES, OBLIGATIONS OR LIABILITIES ARE EXPRESSLY AGREED TO IN WRITING BY SELLER, ARE NULL AND VOID.

DAMAGES AND LIABILITY

SELLER'S LIABILITY FOR DAMAGES SHALL NOT EXCEED THE PAYMENT, IF ANY, RECEIVED BY SELLER FOR THE UNIT OF PRODUCT OR SERVICE FURNISHED OR TO BE FURNISHED, AS THE CASE MAY BE, WHICH IS THE SUBJECT OF CLAIM OR DISPUTE. IN NO EVENT WILL SELLER BE LIABLE FOR INCIDENTAL, CONSEQUENTIAL OR SPECIAL DAMAGES, OF ANY KIND, HOWEVER CAUSED, ARISING OUT OF, OR IN ANY WAY CONNECTED WITH, THE PRODUCTS FURNISHED BY SELLER TO CUSTOMER. BY SELLER TO CUSTOMER.

All disputes under any contract concerning Products not otherwise resolved between Seller and Customer shall be resolved in a court of competent jurisdiction for the location of Seller's plant at Burlington, Ontario. Canada, and no other place. Provided that, in Seller's sole discretion, such action may be heard in some other place designated by Seller, if necessary to acquire jurisdiction over third persons, so that the dispute can be resolved in one action. Customer hereby consents to the jurisdiction of such court or courts and agrees to appear in any such action upon written notice thereof. No action, regardless of form arising out of, or in any way connected with, the Products or Services furnished by Seller, may be brought by Customer more than one (1) year after the cause of action has occurred. If any part, provision or clause of the Terms and Conditions of Sale, or the application thereof to any person or circumstances, is held invalid, void or unenforceable, such holding shall not affect and shall leave valid all other parts, provisions, clauses or applications of the Terms and Conditions remaining, and to this end the Terms and Conditions shall be treated as severable. to this end the Terms and Conditions shall be treated as severable.

2.0 ZENOGEM® PROCESS DESCRIPTION

The ZenoGem® Process is a proprietary ZENON technology that consists of a suspended growth biological reactor integrated with a microfiltration membrane system, based on the ZeeWeed® hollow fibre membrane. Essentially, the microfiltration system replaces the solids separation function of secondary clarifiers and sand filters in a conventional activated sludge system.

The ZeeWeed® microfiltration membranes are typically submerged in the aeration tank, in direct contact with the mixed liquor. Through the use of a suction duty pump, a vacuum is applied to a header connecting the membranes. The vacuum draws the treated water through the hollow fibre microfiltration membranes and into the pump. Treated water is then discharged by the pump. The energy associated with permeate pumping is relatively small. An airflow is introduced to the bottom of the membrane module producing turbulence which scours the external surface of the hollow fibres transferring rejected solids away from the membrane surface. This airflow also provides a large portion of the process biological oxygen requirements; the remainder is provided by a diffused aeration system. Waste sludge is pumped directly from the aeration tank.

The ZenoGem® technology effectively overcomes the problems associated with poor settling of sludge in conventional activated sludge processes. The ZenoGem® technology permits bioreactor operation with considerably higher mixed liquor solids concentrations than conventional activated sludge systems which are limited by sludge settling. The ZenoGem® process is typically operated at a mixed liquor suspended solids (MLSS) concentration in the range of 8,000 to 12,000 mg/L. The elevated biomass concentrations allow for highly effective removal of both soluble and particulate biodegradable material in the waste stream. The ZenoGem® process combines the unit operations of aeration, secondary clarification and filtration into a single process, simplifying operation and greatly reducing space requirements.

Since the ZenoGem® process can be operated at elevated MLSS concentrations, extended solids retention times (SRTs) are readily attainable. Accurate SRT control is very simple since no solids are lost in the effluent. Many municipal ZenoGem® plants are operated with SRTs exceeding 25 days. These extended SRTs ensure complete nitrification even under extreme cold weather operating conditions. At extended SRTs, sludge yields can be considerably less than conventional aerobic processes, due to endogenous decay.

The ZenoGem® process is readily adapted for denitrification if total nitrogen removal is required. The elevated levels of biomass become readily anoxic in the absence of aeration, ensuring high denitrification rates. An upstream anoxic zone and mixer readily accommodates denitrification; this can be incorporated in the ZenoGem® tank design.

The ZenoGem® process is ideally suited for phosphorus removal, where required. Through the addition of metal salts such as alum or ferric chloride to the raw wastewater or mixed liquor, soluble phosphorus in the waste stream can be precipitated. The ZeeWeed® membranes have a pore size that provides an absolute barrier to the discharge of precipitated phosphorus. The phosphorus is retained in the mixed liquor and removed with the waste activated sludge. The ZenoGem® process can reliably achieve

significantly lower effluent phosphorus concentrations than conventional municipal treatment processes.

3.0 ZENOGEM® ADVANTAGES

Effluent Quality

Depending on the specific application and design requirements, a ZenoGem[®] plant can achieve either high quality nitrified effluent or with the addition of an anoxic zone, high quality denitrified effluent. Phosphorus removal is readily achieved through the addition of metal salts to the feed wastewater or mixed liquor. Typically, ZenoGem[®] systems are capable of achieving the following effluent qualities.

 $\begin{array}{lll} BOD & <2 \text{ mg/L}^{\text{Note 1}} \\ TSS & <2 \text{ mg/L}^{\text{Note 1}} \\ TN & <10 \text{ mg/L}^{\text{Note 1}} \text{ (cool climate)} \\ & <3 \text{ mg/L}^{\text{Note 1}} \text{ (hot climate)} \\ TP & <0.1 \text{ mg/L} \\ Turbidity & <1 \text{ NTU} \\ Total \text{ Coliforms} & <100 \text{ cfu/100 mL} \\ Faecal \text{ Coliforms} & <20 \text{ cfu/} 100 \text{ mL} \end{array}$

Note 1: The information provided in this section of the proposal is general only and is intended only to indicate what is the ZeeWeed®/ZenoGem® Membrane Wastewater Treatment Technology is capable of achieving. For the specific design treated wastewater quality, based on the consideration of specific raw wastewater characteristics and the required discharge criteria for the treated effluent, refer to Section 4.0.

Compact Plant

The ZenoGem® process can operate at mixed liquor suspended solids (MLSS) concentrations in the range of 8,000 to 12,000 mg/L, which is substantially greater than conventional activated sludge processes. This allows for conventional organic loading rates to be achieved with much lower hydraulic residence times. In addition, the ZenoGem® process requires a single tank in which aeration and solids separation are both achieved. If required, sludge digestion can also be accomplished in this tank. This single stage process results in an overall plant footprint substantially smaller than conventional tertiary wastewater treatment plants.

Expandability

Since the ZenoGem® equipment is modular in nature, plant expansion can be phased. Civil works can be designed for ultimate flow while membranes are added in phases as plant operating capacity dictates.

Simple Operation

Since the ZenoGem[®] process uses membranes to perform solid/liquid separation, there is no requirement for sludge to settle and thus no need for a secondary clarifier or polishing filters. Sludge is wasted directly from the aeration tank at a solids concentration in the range of 1.5 to 2.0 percent solids. The result is a single system which is simple to operate.

Lower Sludge Yield

The ZenoGem® plant can be operated at extended solids retention times (SRTs) allowing for lower net solids yields than conventional municipal treatment processes.

Process Reliability

Since the ZenoGem® plant is typically operated at low organic loading rates and the membrane provides an absolute barrier to particulate discharge, ZenoGem® effluent quality is not susceptible to hydraulic or organic surges which can negatively affect effluent quality in conventional activated sludge and fixed film plants. At periods of low flow (and organic load), the sludge within the reactor basin simply digests itself, without affecting the effluent quality.

Advantages of an "Outside-In" Membrane

a) Resistance To Fouling

The ZeeWeed® membrane is an outside-in membrane where the flow of water is from the outside of the membrane to the inside of the hollow fibre, meaning that the inside only sees clean, microfiltered water. The bacteria and inert solids to be removed from the wastewater remain outside the membrane and never enter the membrane to cause fouling.

b) Low Energy

Being immersed allows for the operation of the ZeeWeed[®] membrane under a slight vacuum (suction) instead of under positive pressure like other membranes on the market. The ZeeWeed[®] membrane operates under a vacuum of between -2 to -8 psi. The pump energy requirements to achieve this vacuum are relatively small.

Exceptional Membrane Durability

The ZeeWeed[®] membrane has been designed for exceptional durability and resistance to breakage. To achieve this high level of membrane durability ZENON utilizes a patented internal support to which the membrane is bonded. This support strengthens the membrane and protects it against tearing and breakage without reducing its flux capacity.

4.0 ZENOGEM® PLANT

Firm Capcity Flow

The proposed ZenoGem[®] plant is designed to continuously treat an average daily flow of 8.5 MGD. The ZenoGem[®] plant is a six (6) train system and the capacity of each parallel train is .1.417 MGD.

The ZenoGem® plant is capable of producing an effluent meeting or exceeding the following criteria:

8.5 MGD

Design Parameters

<u>Parameter</u>	<u>Influent</u>		Effluent	
BOD	200	mg/L	≤2	mg/L
TSS	150	mg/L	≤2	mg/L
TKN	46	mg/L	≤3	mg/L
TN	46	mg/L	≤17	mg/L
TP	9	mg/L	≤1	mg/L
Wastewater Temperature	≥20	°C	≥20	$^{\circ}\mathrm{C}$

Equipment Selection

The main process equipment for the ZenoGem® plant, including permeate pumping equipment, membrane air scour blowers and supplemental aeration blowers, CIP membrane cleaning system, air extraction system, controls and other miscellaneous items, is designed for installation within equipment buildings (equipment buildings not included in ZENON's scope of supply).

The sizing of the main process equipment selected is as follows. Section 5.0 gives further details of the equipment items included by ZENON for this project.

Bioreactor (Process) Tank(s)

The bioreactors will consist of concrete tanks (concrete tanks not in ZENON's scope of supply). Six (6) individual process streams are required, each with the minimum dimensions of 160 ft long x 20 ft wide x 17 ft high (15 ft SWD). Each process tank will have an anoxic/aerobic and an aerated membrane zone separated by a baffle (baffle not included in ZENON's scope of supply).

Membrane cassettes will be supported by structural steel beams that will span between the concrete walls of the process tanks and will use the concrete walls as supports.

Process Tanks

Total Bioreactor Volume	2.154	MUS gallons
Design HRT	6	hours
Number of Membrane Trains	6	
Number of Bioreactor Tanks	6	
Volume of Each Bioreactor	359,000	US gallons

Length of Each Bioreactor	160	ft
Width of Each Bioreactor	20	ft
Side Water Depth of Bioreactor	15	ft

Note: Process tanks may be of concrete construction or fabricated steel tanks, whichever suits the client's preferences and are not included in ZENON's scope of supply.

Tank dimensions are preliminary only and may change slightly once final detail design commences.

ZW-500 Micro-Filtration Membrane Modules

Membrane	Design	Flux	11.55	gfd at Fixed Capacity Daily flow
Rate				
Minimum	Design	Liquid	20	°C
Temperature	e			
# Membrane	e Modules	3	1104	
# Membrane	e Cassette	s	138	(8 modules per Cassette)

ZENON is committed to continuous development and invests continuously in research to develop better and higher flux membranes. For this reason ZENON reserves the right to change the number of membranes in its design, if by way of membrane technology improvements the permeability or operating flux rates of the membranes have been improved. This does not change the warranty since ZENON guarantees the design flow capacity and the operational performance of the membrane system.

Aeration System

The design air flow required for the fine bubble aeration system used with the ZenoGem® plant is approximately 5,550 scfm at the plant design capacity.

Aeration Blowers

Three (3) aeration blowers are included - two duty blower and one common stand-by unit. Each blower has a design capacity of 2,775 scfm. The aeration blowers are equipped with variable frequency drives (VFDs) to allow air delivery and dissolved oxygen levels in the wastewater to be controlled according to the system air requirements.

Membrane Air Blowers

Four (4) blowers are included for the membrane air scouring - four duty blower and one common standby unit The total required capacity of membrane air scouring is approximately 21,983 scfm. Each blower has a design capacity of 7,328 scfm.

Permeate Pumps

Seven (7) permeate pumps are included - six duty pumps and two shelf spares. Each pump is designed for a maximum permeate flow of 1,110 USgpm. The pumps will also provide backpulse flow at 2,880 USgpm The speed of the permeate pumps is controlled via VFD units according to the liquid level in the bioreactor tanks.

Sludge Recirculation Pumps

Seven (7) sludge recirculation pumps are included - six duty pumps and one shelf spare. Each pump is designed for a flow of 3,395 USgpm. The recirculation pumps are provided with VFD units to allow flow variation to allow optimization of the system process performance.

Sludge Wasting Pumps

Seven (7) sludge wasting pumps are included – eight duty pumps and one shelf spare. Each pump is designed for a flow of 207 USgpm.

Miscellaneous

No influent screening facilities are included. There must be existing screening and/or primary clarifiers upstream of what will become the ZenoGem® aeration (bioreactor) tanks. The screening equipment must be capable of screening particles down to 3.0 mm to prevent hair and other stringy materials from tangling with the membranes.

Equipment Installation cost is not included.

5.0 MAJOR EQUIPMENT

The list below summarizes the major equipment and the quantities of items included for the ZenoGem® plant design.

SCOPE OF SUPPLY SYNOPSIS	; 121.00		-
for the ZenoGem® Plant			
Item	Size	Units	Quantity
Raw Wastewater Feed	Size	Cinto	Quantity
Raw Influent Feed Pumps		<u> </u>	Not Incl.
Inlet & Discharge Isolating Valves			Not Incl.
Discharge Check Valves			Not Incl.
Piping Manifold			Not Incl.
Wet Well Level Switches			Not Incl.
VFD's			Not Incl.
Raw Water Screening			
Raw Influent Screen	, .		Not Incl.
Raw Influent Grinder			Not Incl.
Raw Influent Flowmeter			Not Incl.
Raw Influent Flow Control Flowmeter			Not Incl.
Raw Influent Flow Control Valve			Not Incl.
Membranes/Membrane Cassettes			
Individual Membrane Modules			1,104
Membrane Cassettes			138
Process Tanks & Frames			
Membrane Support Beam(s)			Included
Process Tanks			Not Incl.
Permeate Collection Headers			6
Air Scour Headers			6
Permeate Pumps			
Permeate Pumps	1,110	USgpm	7
VFD's	50	HP	6
Piping Manifold			Not Incl.
Valves			Incl.
Air Extraction System			
Air Removal Separation Columns			6
Vacuum Pumps	22	scfm	3
Backpulse System			
Backpulse Water Storage Tank	5,160	gallons	_ 2
Hypochlorite Storage Tank	106	gallons	1
Hypochlorite Feed Pumps	6.08	USgphr	3

Item	Size	Units	Quantity
DIP Tank Cleaning System			
DIP Tank			Not Incl.
Chemical Wash Pump			Incl.
Monorail & Pulley/Hoist for membrane removal			Not Incl.
Sludge Recirculation			
Sludge Recirculation Pumps	3,935	USgpm	7
Inlet & Discharge Isolation Valves			N/A
Discharge Check Valves			N/A
Piping			Not Incl.
VFD's	2.5	HP	6
Sludge Wasting			
Sludge Wasting Pumps	206.6	USgpm	7
Inlet & Discharge Isolation Valves			6
Discharge Check Valves			6
Piping			Not Incl.
VFD's			N/A
Air Blowers			
Membrane Air Scour Blowers incl. Silencers	7,328	scfm	4
Inlet & Discharge Isolation Valves			4
Discharge Check Valves			4
Inlet Control Valves			4
Aeration System Blowers incl. Silencers	2,775	scfm	3
Inlet & Discharge Isolation Valves			3
Discharge Check Valves			3
VFD's	200	hp	3
Biological Aeration System			
Fine Bubble Diffuser System			Incl.
Phosphorus Removal System (if required)			
Chemical Storage Tank	9,600	USg	1
Chemical Feed Pumps	112	USgphr	2
Instruments			
Permeate Flowmeters			6
Permeate Header Pressure Transducers			6
Process Tank Level Transmitters			6
Process Tank Level Switches			48
Dissolved Oxygen Sensors			6
pH Transmitters			N/A
Turbidimeters			6
Turbidimeter Calibration Kits			1

Membrane Blower Flow Switches		4	
Aeration Blower Flow Switches		3	ĺ

Item	Size	Units	Quantity
Permeate Pump Pressure Gauges			6
Membrane Air Scour Blower Pressure Gauges			4
Aeration Blower Pressure Gauges			3
Recirculation Pump Pressure Gauges			N/A
Sludge Wasting Pump Pressure Gauges			6
Control Panel			
PLC-based Control Panel			1
Back-Up PLC			Not Incl.
Electrical		-	
MCC Panel			Not Incl.
Miscellaneous			
Air Compressor			2
Air Drier			1
Field Service Allowed			Days
Installation Supervision			10
Mechanical Checkout			6
Operator Training			8
Process Start-Up			3
Commissioning			3
TOTAL MAN-DAYS			30
TOTAL No. TRIPS			3
Freight			
Delivery to Site			Incl.

6.0 ATTACHMENTS

Plant Power Consumption and Estimated Yearly Operating Cost

Table 9.1.1 Connected Power and Estimated Power Consumption at Average Day Flow City of McAilen (ZenoGem) Rev 1

m3/day m3/day 32,173 32,173 USgpd **DSgpd** 8,500,132 8,500,132 Maximum Day Flow Average Day Flow

TEN	TOTAL			# Operating	Design Capacity	Discharge Head	Duty	Equipment	Motor	Total	Total	Motor	Equipment	Hours / Day	Energy
*	5	DESCRIPTION		Pumps Blowers etc.	_		Point Efficiency	Operating	Ē	Equipment BHP	Connected	emiciency %	KW	Continuous	Cost per year
-		Raw Water/Wastewater Screen	n/a											24.00	•
2	00.9	Permeate Pumps	By Zenon	9 00 9	1,109.56 USgpm	35.00 #	81.00	12.29	8 8	73.76	120.00	90.20	86.09	22.40	37,392
m	·		n/a	,	2,880.00 USgpm	30.00	74.00	29.94	40.00				,	6.40	-
4	00.9	Recirculation Pumps	By Zenon	00.9	1	10.00 #	55.00	18.35	25.00	110.08	150.00	91.30	89.91	24.00	59,068
2	9.00	Sludge Wasting Pumps	By Zenon	9 00 9	1	30.00 ft	20.00	3.18	5.00	19.07	30.00	87.50	16.25	2.00	890
9	Ľ		n/a	,		25.00 #	55.00	•			-	-		24.00	
1	4 00	Membrane Air Scour Blowers	By Zenon	3.00	5,520.00 sdm	4.25 psl	n/a	153.32	250.00	459.97	1,000.00	95.00	361.05	24.00	237,213
80	300	Process Air Blowers	By Zenon	2 00	i	ĺ	n/a	11489	150.00	229.77	450.00	94.20	181.89	24 00	119,501
6		Miscellaneous Air Blowers	r/a	-	- sdm	6.00 psi	n/a					-	•	24.00	
2	9	Anoxic Zone Mixers	By Zenon	00.9			1/3					80.00		24.00	
=	300	Air Separation System Vacuum Pumps	By Zenon	2.00	22.25 acfm	18.00 ins Hg	n/a	2.25	300	4.50	9.00	87.50		24 00	2,520
12	300	Backpulse Sodium Hypochlorite - Metering	By Zenon	1.50	0.066 USgpm	\$0.00 #	n/a	0.03	0.03	40.0	60.0	100.00	0.03	320	က
13	-	CIP Wash Pump	n/a	•	5	30.00 #	55.00	,						0.03	•
4		Mering	п⁄а		MSgpm					•			,		•
5	200	Chemical Feed #1 System #1 - Metering	By Zenon	00.1	1.140	\$0.00 ft	n/a	0.50	0.50	0.50	1.00	100.00	0.37	24.00	245
19			n/a		1	\$0.00 #	n/a	•	0.03			100.00		24.00	•
17			n/a	THE RESERVE OF THE PERSON OF T	0.057 USgpm	50.00 ft	n/a		0.03	-		100.00		24 00	
80			n/a		0.065 USgpm	\$0.00 #	n/a		0.02	•	•	100.00	,	24.00	•
8	2.00	Air Compressors	By Zenon	1 00		100.001 isq 00.001	n/a	18.75	25.00	18.75	20.03	91.30	15.31	90.9	2,515
5	- 8	Air Driers	By Zenon	9	75.00 scfm		n/a	,		,		80.00	,	6 00	
ଷ	8	Controls & Instrumentation	By Zenon								1.34		1.80	248	657
2	8	Miscellaneous	By Zenon			***************************************					1.34		1.00	24 00	657
	_														
		Total Connected Power									1,812.77	윺			
		Total Operating Power	AND THE PROPERTY OF THE PROPER	A AND NAVO CONTRACTOR OF THE PROPERTY OF THE P					Andreas de la constitución de la	916.44	ВНР		731.64	ΚW	
		Total Operating Cost												\$SN	460,661

Notes

per kW.hr 0.0750 Energy Costs based on

Power Consumption of other plant equipment required (raw water feed pumps, high lift pumps etc.) is not included by ZENON.
Where operating efficiencies are not known, the equipment operating power is assumed to be 75% of the motor nameplate power rating.
The operating hours for the permeate pump are corrected for the downtime during backpulse cycles (and Membrane Pressure Decay Test Cycles if applicable).

16.59 BHP 1,664 USgpm @ 30.00 ft TDH = Permeate Pump Backputses every 15 mins for 30 seconds

Motor Efficiencies indicated are typical only. Efficiencies used are usually within 2% of actual when motor is operating within 50-100% of its full load rating Operation of Air Compressor is assumed to be only 25% of time

Operation of the Sodium Hypochlorite Pumps is intermittent - operation for 25% of time is used for energy calculation Blower Energy Consumption Estimated as: 6.536 BHP per 1,000 scfm per psig.

It must be understood that at the time of proposal preparation, final headlosses or pressure drops in piping systems have not been calculated accurately criteria assumed during preparation of the proposal, ZENON accepts no responsibility for the absolute accuracy of the information contained herein Motor sizes are subject to confirmation (and if necessary adjustment) during final design. Use of the above information for sking or selection of any ancillary equipment is entirely at the USER's own risk. Whits the motor sizes indicated above are ZENON's best estimate based on design The motor sizes in the above table are preliminary only and estimated based on the information available at the time of preparing this proposal.

Table 9.2.2 Estimated Total Annual Operating Cost
City of McAllen (ZenoGem) Rev 1
Average Day Flow 8,500,132 US
Maximum Day Flow 8,500,132 US 8,500,132 USgpd 8,500,132 USgpd

32,173 m3/day 32,173 m3/day

tem			Cost per year	
Electrical Equipment - Zenon		Calculated at Average Day Flow	460,661	US\$
Electrical Equipment - Others				US\$
Backpulse Chemicals	Sodium Hypochlorite	Calculated at Average Day Flow	8,232	US\$
CIP Chemical #1	MC-1		220	US\$
CIP Chemical #2	Sodium Hypochlorite - 250 mg/L		304	US\$
Chemical #1	Aluminum Sulphate (Liquid @ 48.5%)	Calculated at Average Day Flow	201,764	US\$
Suggested Membrane Accrual			329,311	US\$
Estimated Total Annual Opera	ating Cost		1,000,492	US\$

Cammateu	Total Alliqual Operating Cost			
Votes	Backpulse Chemical Consumption		Sodium Hypoc	
	Sodium Hypochlorite Consumption		71.91	Litres per day
	Sodium Hypochlorite Consumption		26,248	Litres per year
	Sodium Hypochlorite Cost	US\$	0.31	per Litre
	CIP Cleaning Chemical #1		MC-1	
	Design Dosage		2,000.00	mg/L
	Solution Concentration		50.00	%
	Specific Gravity		1.240	
	Wash Frequency		1.00	times / year
	Chemical Consumption per Wash (all tar	nks)	131.54	Litres
	Total Annual Chemical Consumption	,	131.54	Litres
	Chemical Cost	US\$		per Litre
	Chemical Cost	USS		per kg
	Charlica Cost		L	F
	CIP Cleaning Chemical #2			hlorite - 250 mg/L
	Design Dosage		250.00	mg/L
	Solution Concentration		10.80	%
	Specific Gravity		1.168	
	Wash Frequency			times / year
	Chemical Consumption per Wash (all tar	nks)	80.81	Litres
	Total Annual Chemical Consumption		969.76	Litres
	Chemical Cost	US\$	0.31	per Litre
	CIP Neutralization Chemical #1		Sodium Hydro	xide
	Design Dosage		•	mg/L
	Solution Concentration		50.00%	3
	Specific Gravity		1.520	
	Wash Frequency		1.00	times / year
	Chemical Consumption per Wash (all tar	nks)		Litres
	Total Annual Chemical Consumption	,	_	Litres
	Chemical Cost	US\$	0.36	per Litre
	Chemical Cost	US\$	0.47	per kg
	Chermon Cost	004		po
	CIP Neutralization Chemical #2		Sodium Bisulf	
	Design Oosage			mg/L
	Solution Concentration		38.00%	
	Specific Gravity		1.290	
	Wash Frequency		12.00	times / year
	Chemical Consumption per Wash (all tai	nks)	•	Litres
	Total Annual Chemical Consumption			Litres
	Chemical Cost	US\$	0.06	per Litre
	Chemical Cost	US\$	0.55	per kg
	Chemical Feed System #1		Aluminum Sul	phate (Liquid @ 48.5%)
	Design Dosage		90.00	ma/L
	Solution Concentration		48.50	%
	Specific Gravity		1.335	
	Chemical Consumption			Litres per day
	Chemical Consumption		1,632,315	Litres per year
	Chemical Cost	US\$	0.12	per Litre
	Chemical Cost	USS	0.19	per kg
	Chemica Codi			r • •

12/07/1999 : 3:59 PM ZENON - CONFIDENTIAL

PROPOSAL

990212-M



845 Harrington Court, Burlington, Ontario, L7N 3P3 Tel. No.: (905) 639-6320 Fax No.: (905) 639-1812

DATE:

November 29, 1999

PREPARED FOR:

CH2M Hill

ATTENTION:

Mr. Jim Lozier

FROM:

Roland Lamoca

Re:

McAllen South WWTP

ITEMS COVERED:

Packaged water treatment plant incorporating Reverse Osmosis treatment.

The plant is to be designed for three trains, each with an effluent flowrate of 2.3 MGD of final product from the Reverse Osmosis system. The projected recovery rates from each unit operations have been established in the specifications provided CH2M Hill and are estimated at 80% - 85%.

The preliminary design criteria are:

One Reverse Osmosis Train

Effluent Flow (MGD)

2.3 MGD

System Recovery (%)

80 - 85 %

SCOPE OF SUPPLY:

Three Reverse Osmosis System Trains - Each:

- eighty-eight (88) 6 element long membrane pressure vessels, 400 psi rating, arranged in a 50:28:10 array configuration for optimal cross-flow conditions.
- five hundred twenty eight (528) Hydranautics spiral wrap high rejection type membrane modules. Six membrane elements will be installed in each membrane pressure vessel. A total membrane area of 192,720 ft2 is supplied,
- one (1) duplexed 5 micron prefiltration cartridge system, isolatable for cartridge replacement,
- one (1) horizontal, split case centrifugal-type feed supply pump, 1880 USgpm @530 ftH, 1780 rpm TEFC, Goulds or equal,

PROPOSAL



990153-M

845 Harrington Court, Burlington, Ontario, L7N 3P3
Tel. No.: (905) 639-6320 Fax No.: (905) 639-1812

- one (1) sodium metabisulfite chemical injection system with chlorine analyzer, Prominent or equal,
- one (1) antiscalant injection system, Prominent or equal,
- one (1) acid injection system with pH probe and controller, Prominent or equal,
- one (1) lot process instrumentation for the RO system, includes feed conductivity, permeate conductivity, permeate flow transmitter, concentrate flow transmitter, concentrate pressure transmitter, membrane feed pressure transmitter, permeate pressure transmitter, feed supply residual chlorine analyzer, and feed supply pH.
- one (1) lot process valves for the RO system, Bray or equal,
- one (1) lot process low pressure piping Sched. 10 304 SS,
- one (1) lot process high pressure piping Sched. 10 316 SS,
- one (1) NEMA 4 PLC based control panel (Allen Bradley PLC complete with PanelView Operator Interface),

One Reverse Osmosis System Clean In Place Tank:

• one (1) skid mounted membrane cleaning tank with prefiltration cartridge system, and cleaning pump (316SS Goulds, or equal) and controls,

PRICE ESTIMATE:

US\$ 2,300,000.00

TERMS:

- All pricing in Dollars, FOB ZENON Burlington, Ontario.
- Duty, if applicable, is not included. Any Taxes, if applicable, are extra.
- Shipment shall be 20 24 weeks from receipt of order.
- Payment Terms: 15% with order, 25% on submission of drawings, 50% on equipment shipment, 10 % on start-up or thirty days whichever is less, all terms are Net 30.
- ZENON's Terms and Conditions as attached shall apply.
- This is a budgetary estimate only at this time, and does not constitute a binding offer of supply by ZENON.



- RECEIVED -

JAN 18 2000



CH2M HILL PHUENIX Water for the World

Project Number: 990212-M

TO:

CH2M Hill

rengebo: repair tempetation (European E

FAX:

480 966 9450

ATTN.:

Ms. Fair Miller

PHONE:

480 966-8577 x 249

cc:

Jim Lozier - CH2M Hill

Dave Bingham - ZENON

cc FAX:

DATE:

18 January, 2000

OF PAGES

(Including Cover): 5

FROM:

Roland Lamoca

Manager, Technical Support Division

Industrial Wastewater Division

SUBJECT: McAllen Reverse Osmosis Operating Cost Estimates - Revision

Hello Fair and Jim;

The operating costs have been revisied based on our discussions today.

The higher pressure we had included previously accounted for a 5 year operation with a 10% flux decline/year. This is typical of ZENON's experience, but may not reflect recent experiences you have noted. As agreed upon, the following have been based on your experiences.

Please feel free to contact ZENON if you have any questions.

Regards,

Roland Lamoca

If you do not receive all pages, please call Lisa Ashton as soon as possible.

ZENON Environmental Systems Inc.

845 Harrington Court, Burlington, Ontario, L7N 3P3 Telephone: (905) 639-6320 Fax: (905) 639-1812 email: rlamoca@zenonenv.comhttp://www.zenonenv.com

18/01/00

Operating Cost Summary

•	
Assumptions	(based on \$0.07 /kW-hr)
ltem	Power Consumption

(based on \$5.00 /1000 lb)

Steam Consumption

Annual Cost, US\$ \$357,495 /year

\$190,179 /year \$24,637 /year (based on current prices, subject to change) Cartridge Filter Replacement (once per year) (based on current prices, subject to change) Membrane Replacement (every 5 years)

Annual Cleaning Chemical Cost Annual Process Chemical Cost

\$130,698 /year

\$15,144 /year

\$718,152 /year

2,522.9 Million gallons per year

\$0.28 /1000 gallons

Water Volume Produced Annually: (based on 4800 USgpm)

Operating Cost per Thousand Gallons

REHOR		•	
	re-		

18/01/00

Operating Cost - Power

Power Consumption

Total power	1.1 KW 581.9 KW Intermittent use
Power/unit	0.2 kW 194.0 kW 93.3 kW
# of units	total of 6 total of 3 total of 1
Unit	Pre-freatment Chemical Mixers, 0.25 Hp 1st Pass - R.O. Process Pump, 260 Hp Reverse Osmosis CIP Pump, 125 Hp

nenseppinzia TPV adenova elu podvětatu.

RO process pump pressure is 165 psi @ 1883 USgpm each

Total Power	Total Power Requirement	583 KW
Operating period	Days / year Hours / day	365 days 24 hours
Utility	Utility rate (\$/kW-hr)	\$0.07 /kW-hr
Annual Power Consumption Cost	umption Cost	\$357.495 /vear

Operating Cost - Elements

Membrane Replacement (every 5 years)

Membrane Element	

Unit Price, US\$

of elements

Extended price, US\$

8" HYDRANAUTICS 8040-LFC1

\$600 each

total of 1584

\$950,894

Membrane pricing assumes negotiated pre-purchase price and is to be verified.

Membrane Replacement Cost

\$190,179 /year

Cartridge Filter Replacement (once per year)

Cartridge	
Filter	

FILTERITE QMPT050-300USM8 FILTERITE OMPT050-300USM8

total of 324 total of 72

\$62 each \$62 each

\$20,158 \$4,479

Extended price, US\$

Unit Price, US\$

of cartridges

Cartridge Filter Replacement Cost

\$24,637 /year

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Use or disclosure of the information on this page is subject to the restrictions on the lifte page of this proposal.

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Process Chemical Requirements

	1 Unit Cost, US\$ Annual Cost, US\$	ns \$0.04 /lb \$5,745 /year	\$0.25 /lb	
Annai	Chemical Consumption	10374 USgallo	12288 USgallons	9892 USgallor
	Chei	Sulphuric acid	Sodium bisulphite	Antiscalant

Annual Process Chemical Cost

\$130,698 /year

Operating Cost - Cleaning Chemicals

Cleaning Chemicals / Preservative Requirements

	Unit Cost, US\$ Annual Cost, US\$			\$3.06 /kg \$1,738 /year	\$5.01 /litre \$4,748 /year
<u>Annual</u>	Consumption	:	3788 kilograms	568 kilograms	947 litre
	Chemical		Organic Acid: MC-1	Alkali Surfactant: MC-4	Sanitizer: MP-1

Annual Cleaning Chemical Cost

\$15,144 /year

Use or disclosure of the information on this page is subject to the restrictions on the title page of this proposal.

Appendix I. ZenoGem and ZeeWeed Cost Comparison

ltem		ZenoGem*		eeWeed*
Fine Screening	\$	20,000	\$	20,000
ZenoGem* / ZeeWeed* System ^a	\$		\$	5,075,000
Bioreactor/Equalization / ZeeWeed Tanks	\$	1,307,808	\$	162,468
bioreactor/Equalization / Zeeweed Tariks	- -	1,307,606		102,400
Installation	\$	2,155,000	\$	1,268,750
Installed Costs Subtotal	\$	12,102,808	\$	6,526,218
ZenoGem / ZeeWeed Equipment Building	\$	288,000		84,000
Installed Costs and Building Cost Subtotal	\$	12,390,808	\$	6,610,218
Unit Process Noncomponent Costs				
Yard Piping Allowance (10%)	\$	1,239,081	\$	661,022
Site Electrical Allowance (8%)	\$	991,265	\$	528,817
Site I&C Allowance (5%)	\$	619,540	\$	330,511
Site Civil Allowance (5%)	\$	619,540	\$	330,511
Unit Process Subtotal	\$	15,860,234	\$	8,461,079
Contingency (10%)	\$	1,586,023	\$	846,108
Contractor Overhead & Mark-up (10%)	\$	1,586,023	\$	846,108
Total Construction Cost	\$	19,032,281	\$	10,153,295
Engineering & Administration (15%)	\$	2,854,842	\$	1,522,994
Total Capital Cost	\$	21,887,123	\$	11,676,289
Total Capital Unit Cost (\$/1,000 gallon)	\$	9.28	\$	4.95
Amortized Capital Cost (20yr @ 6.5%)	\$	1,986,396	\$	1,059,698
Operation & Maintenance Costs				
Major Chemical Costs	 			
Backpulse Chemicals: Sodium Hypochlorite	\$	8,232	\$	8,232
	\$	220	\$	3,211
CIP Chemical #1: MC-1 CIP Chemical #2: Sodium Hypochlorite (250 mg/L)	\$	304	\$	4,435
	\$	304	\$	175
CIP Neutralization Chemical #1: Sodium Hydroxide	\$	•	\$	117
CIP Neutralization Chemical #2: Sodium Bisulfite	12	-	φ	117
Major Power Costs				
Screening	\$		\$	-
Aeration Basins	\$	-	\$	419,000
Permeate Pumps	\$	37,392		36,901
Recirculation Pumps	\$	59,068	\$	74,500
Sludge Wasting Pumps	\$	890	\$	-
Membrane Air Scour Blowers	\$	237,213		114,440
Process Air Blowers	\$	119,501	\$	<u> </u>
Anoxic Zone Mixers	\$		\$	-
Air Separation System Vacuum Pumps	\$	2,520	\$	2,520
Backpulse Sodium Hypochlorite - Metering	\$	3	\$	
Chemical Feed #1 - Metering	\$	245	\$	•
Air Compressors	\$	2,515	\$	2,515
Air Driers	\$	-	\$	•
Controls & Instrumentation	\$	657	\$	657
Miscellaneous	\$	657	\$	657
Membrane Replacement Costs	\$	329,311	\$	190,905
Labor	\$	280,800		218,400
Total Annual Operation 9 Maintenance Cost	\$	1,079,528	\$	1,076,672
Total Annual Operation & Maintenance Cost		0.46		0.46
Total Annual O&M Unit Cost (\$/1,000 gallon)	\$			2,136,370
Total Annual Cost Total Annual Unit Cost (\$/1,000 gallon)	\$	3,065,924 1.30		2,136,370

DEMONSTATION TESTING OF ZENOGEM AND REVERSE OSMOSIS FOR INDIRECT POTABLE REUSE

FINAL TECHNICAL REPORT ADDENDUM

City of McAllen, TX

by

James C. Lozier, P.E. and Angela M. Fernandez, E.I.T CH2M HILL

Cooperative Assistance Agreement No. 98-FC-81-0073

Desalination Research and Development Program Report No. 51 February 2000

U.S. DEPARTMENT OF THE INTERIOR
Bureau of Reclamation
Technical Service Center
Water Treatment Engineering and Research Group

D-8230 ACM-1.10

Mr. James C. Lozier, P.E. Project Manager, CH2M Hill 1620 Fountainhead Parkway Suite 550 Tempe AZ 85282

Re: Agreement Number 98FC810073, Desalination Research and Development Program Report No. 51, Draft Report Review Comments

Dear Mr. Lozier:

Thank you for presenting the data and results from the project titled "Demonstration Testing of Zenogem and Reverse Osmosis For Indirect Potable Reuse" on December 14, 1999. Ms. Angie Fernandez also deserves to be recognized for her valuable assistance in both the presentation and in overseeing the piloting activities.

Attached, for your consideration are select comments, both editorial and technical, which I believe will strengthen the final report's technology transfer capability.

If you have any questions on these comments, please do not hesitate to call at 303 445-2254.

Sincerely,

Robert A. Jurenka, P.E.

Attachment

cc: D-7810 (Mulligan)

cc: Mr. Wm. Bart Hines, City of McAllen TX,

bc: D-8230 (Price, Jurenka)

WBR:RJurenka:geg:xx/xx/xx:2254 Jurenka/rpt51comltr.wpd

Review Comments, "Demonstration Testing of Zenogem and Reverse Osmosis For Indirect Potable Reuse"

City of McAllen TX,

Cooperative Agreement No. 98-FC-81-0073

The following are suggested editorial comments:

- 1. Complete the acknowledgment page
- 2. Complete all missing appendices
- 3. Page 1-7: Shouldn't the last paragraph be indented?
- 4. Page 1-8 second line: delete "should".
- 5. Page 3-3, section 3.2.1: To the second paragraph:

 Third line, delete "...can (or may)" and replacewith

 "may";
- 4th line: add of after "value" and delete the parentheses;
- 5th line: move ">3 months" ahead of "infrequently" and replace"during" with "at";
 - 7th line: replace "insitu" to "in situ"
- 6. Section 3.2.2, last line: delete the parentheses.
- 7. Page 3-7: section 3.3.2:
- a. second paragraph: The lat 2 sentences seem redundent considering the previous section. Can they be rephrased?
 - b. third paragraph antiscalent is mispelled.
- c. 5^{th} paragrpah: replace in the 3^{rd} line, "can (or may)" with "may".

The following are recommended technical comments:

1. Page 1-1:

- a. To the first paragraph, add: This Program sponsors research in an effort to lower the cost of treatment technologies.
- b. The second paragraph describes UV treatment (also listed on page 1-5), however, there is nothing in the conclusions regarding it. Obviously the decision was made to use chloramines both in the pilot and in the projections of costs at full scale. Add sentences in the report describing why this disinfectant technique was replaced.

- c. Second paragraph, last sentence: define "intended purpose".
- d. Restructure the $4^{\rm th}$ paragraph by either using a colon and numbering the items, or make each point a separate sentence.
- 2. Page 1-3, re: El Paso Texas paragraph: Add to the end of the next to the last sentence... "because the increased pumping is lowering the aquifer level to the higher salinity water source."
- 3. Page 1-4: In section 1-2 the second sentence: It is recommended that "...from the Rio Grande River, water rights that it shares with multiple parties, including..." be replaced with, "...from water rights in the Rio Grande River that it shares with multiple parties including ..."

4. Page 1-6: Section 1.5.1,

- a. second bullet: List the WWTP effluent limits (as shown on page 4-1, section 4.1.1) and reference the table, by table number and page number, of the final values.
- b. The term maintenance clean or acid maintenance clean is used here and on pages 1-7, 1-9, 3-3, etc. Define this term prior to its use or add as a reference the page number where it is defined.

5. Page 1-7:

a. First point: At the start of this point, replace "Flow Peaking" with "Flow peaking tests were run over a 24 hour period of time to simulate the types of peak loading conditions that typically occur in a conventional wastewater treatment plant. However, this (significantly)...

Also, at the end of this point add, "As a result, additional means must be provided such as ?? to ensure that slower changes in loading occur to give the membrane bioreactor system time to react to the change in loading."

- b. Second Bullet: Clarify what "intermittent aeration" is. Delete the words, "treatment conditions resulting in".
 - c. Third bullet: Add a reference to the table of results.
- d. Add a fourth bullet with the following: Per Table 5-16, Zenogem permeate was of lesser quality and the RO permeate was of greatert quality than the City's existing raw water source.
 - e. To the end of the fourth bullet add the following

sentence: However, the RO system always removed any remaining coliform regardless of the MF or UF pretreatment. Also, add the table number and page on which it can be found for the results supporting this conclusion.

- f. Add one last point about how cost effective and how much smaller the footprint area is as compared to a conventional treatment system.
- g. Section 1.5.2 RO System, Bullet 1, $4^{\rm th}$ line: Add "in the predominant form of monochloramine..." after "Continuos disinfection..." Also, add the table numbers and pages on which to be found for the results supporting this conclusion.

6. pages 1-7 and 1-8,

- a. RO System, bullet 2: If 80% is "higher" as stated, state what the normal or target recovery rate is. Also, clarify why the 80% recovery rate is described differently between bullet 2 and bullet 3. (I.E. higher vs design).
- b. RO System, bullet 3: Will blending the RO product water with Zenogem product water be acceptable in terms of final effluent quality? With MF not retaining all viruses, isn't there a concern over exposure to small viruses? Also, specify what type of limits are being described on page 1-8, line 2.
- c. Section 1.6.1.4 Replace the first sentence with: "This research project tested one MBR product, Zenon Corporations ZenoGem MF system The ZenoGem UF system should be retested at the 10g/L MLSS level. Also, other..."
- d. Section 1.6.1.4: Add to the end of this paragraph: "The Bureau of Reclamation is currently funding Montgomery Watson and the City of San Diego to perform research testing of this type, comparing the performance of ZenoGem and Mitsubishi systems.
- e. Section 1.6.2.1: add the approximate concentration of an aluminum based coagulant to complete the words in parentheses.
- f. Section 1.6.2.2 After the last word, "feasible", add "if the scale control can be resolved as discussed herein."
- 7. Section 2: There are many other RO treatment objectives which the Bureau would like to see listed. As shown in Jim's presentation graphic, these include:
- a. RO Feed: RO feed must be < 2 ntu; SDI<3; and heterotrophic plate count <500 cfu/ml.
- b. McAllen discharge limits: TSS<0.5 mg/L; CBOD5 <10 and NH3-n <3 mg/L.

- c. Reliability of Operation
- d. RO concentrate: Determine the impacts of the RO concentrate.
- 8. Page 3-1: Add consistency so that all figures are called figures and not exhibits.
- 9. Can a vacuum pump be added to Exhibit 3.2?
- 10. Page 3-3, section 3.2.1:
- a. State the complete downtime to the system for the backpulsing that occurs every 10 minutes? State the complete downtime for the maintenance cleans described as at least 75 minutes? Add the total downtime from the backpulsing and the maintenance cleans and clarify if a full scale plant must be slightly oversized to produce a given flowrate (ie plant reliability factor of 90-95%).
- b. Define permeation in the first paragrpah, second to the last line.
- c. To the second paragraph's 9th line: delete the first "membrane" in this line. Also, clarify ..." clean membrane initial level". Is the post-chemically cleaned TMP level reduced to a clean membrane level or restored to a new membrane level.
- 11. Page 3-4, 3rd line: Replace "The RO" with "The thin film composite RO". Section 3.2.3: Change the last sentence to read: This allows for a higher organic loading of wastewater in the treatment system.
- 12. Page 3-5: Specify the micron rating of the cartridge filter in the second line of the second paragraph. Also, in the second paragraph's 4th line, delete the first two "ands". Lastly, can the cleaning skid be shown in Exhibit 3.3?
- 13. Page 3-6: Change the TDS sum of ions values for 12/14 and 12/18 to 1465 and 1473. Also, to the second bullet, state the recommended antiscalent from the Hydranautics program.
- 14. Page 3-8: delete the parentheses in the first line. Also, clarify why in the last line, "Zenogem system" is in parentheses.
- 15. Page 3-9: Define stages A through D.
- 16. Page 4-1: Secton 4-1 item 4: Where in the report are the results of each of these tasks? Where are the air requirements summarized for the process for cleaning and for nutrient consumption?

- 17. Tables 4.1 and 4.2: Clarify under responsible party, what WWTP and WTP really means (ie who)?
- 18. Page 5-7: Add a figure, after Exhibit 5.2, of a complete project timeline that shows both the Zenogem and the RO stages. Then to all of the RO performance figures, modify the timeline hours to match this new complete timeline (ie RO start at 1200 hours instead of 0 hours). This will eliminate confusion arising from the fact that stages A-D differ depending on the equipment.
- 19. Section 5: Can a nitrification rate be determined and added? Also, on Page 5-8, from line 6 replace the second paragraph with:
- Table 5.5 presents the target and average operating conditions for th ZenoGem system during Stage C operation. At the beginning of this stage (after 1,783 hours of operation), the MLSS concentration was decreased to 10 g/L. From 4,130 to 4,158 hours (Event 3) and from 4,225 and 4,326 hours (Event 4) of operation, the permeate flow rate was increased by 46 percent (6.5 to 9.5 gpm) for a period of 6 hours (flow peaking) over a 24-hour period to simulate the types of hydraulic peak loading that typically occur in a conventional wastewater plant. This was done to determine if the MBR system could be operational in the same manner or if additional means would have to be provided to ensure slower changes in the loading to give the MBR time to react to the change in loading. After 4,876 hours of operation, the membrane module height was raised (Event 6) to minimize sludge accumulation in the module aerators during non-aeration periods. From 4,894 to 5,136 hours (Event 7) of operation, air was cycled to the membrane tank at an applied rate of 30 scfm for 10 seconds on and 10 seconds off to evaluate the effect of intermittent aeration on operations and membrane performance. From 5,136 to 5,187 hours
- 20. Page 5-14, Permeability Section: Replace the first paragraph with the following:
- Stages A C. Figure 5.3 illustrates changes in ZenoGem permeability as a function of operating time (TMP is also shown for reference). During Stage B, permeability (normalized to 20°C) steadily decreased as TMP increased, indicating membrane fouling at the higher MLSS concentration of 13 g/L. In contrast, at the lower MLSS concentration in Stage C, permeability increased and remained relatively constant as TMP very gradually increased. However during the flow peaking test periods (Events 3, 4 and 8), permeability sharply decreased as TMP increased. This showed that the MBR system must be provided with a means of ensuring slower changes in peak loading. The peak loading can not be raised as quickly over a 24 hour period as fast as a conventional wastewater treatment plant. These results also confirm that ZenoGem operation at 10 g/L MLSS concentration and constant flux provides

for very stable system operation.

- 21. Page 5-48, last paragraph: State why no useful data was obtained from the instruments. Section 5.3.3, RO Water Quality Impacts: Add to this section the table of RO manufacturer's membrane information and data, which Jim had shown in the presentation.
- 22. Page 5-50, section 5.4: Elaborate what is said in the very last paragraph. Define mass loading basis and be very specific here so non-technical readers can understand what is being concluded.
- 23. Page 5-51, section 5-5: change existing to exist in lkine 1. Also, delete the s on parameters in line 7. Lastly add conclusions for the data being displayed in Table 5-16 and for any blending being contemplated.

24. Cost Section 6:

- a. Add text describing the overall conclusions of that can be derived from this study. Would a MBR system be cost effective or not, and under what conditions?
 - b. What labor rate was used in the cost estimates?
- c. Clarify if the costs presented are based to a certain $\mbox{month/year.}$
 - d. Where is the square footage of the building?

P.02

Bob Jurenka'- Re: RE: McAllen Integrity Report Status

Pagn 1

From:

Bob Jurenka

To:

ibr8dm00:jlozier@[CH2M.com]

Date:

Fri, Feb 25, 2000 1:12 PM

Subject:

Re: RE: McAllen Integrity Report Status

Jim: Michelle is wrapping up the integrity report, having received internal review comments.

After receiving the final McAllen report, here are 4 final review comments which will need clarification. After you read these, lets discuss how best to finalize the report.

- 1. Table 6.1: It is not clear why the Zenogem process needs 1.3M of new tankage.

2. Table 6.1: The economic analysis says @ 6.5% was the rate used. My tables of A/P values show a 7 % value was used.

\3. Table 6.1: The total unit cost of \$2.10 per 1,000 is questioned. Explain how this was derived and not 1.98/1000 gallons.

4. Page 6-9, 3rd sentence: Provide more details to better justify the costs associated for new tankage, and the difference between \$1.3M vs \$0.1M for zeeweed.

Thanks

PS: We are still looking at ways to assist with autopsy work for Sherman. Hope the knee is doing better.

Bob Jurenka, 303 445-2254

Fernandez, Angie/PHX

From:

Fboudkirk@cs.com

ົ າt:

December 20, 1999 12:32 PM

Afernand@ch2m.com

Subject:

McAllen

Angie,

Here are a few editorial comments on the December 7, draft report. Bear in mind that the EPRI folks who take the time to read it will be starting from ground zero and the don't know ZeeWeed from break tank.

Page 1-1, UV is mentioned here but nowhere else in the report. I suggest deleting these references to UV as the project did not address its use.

Page 1-3 first paragraph; for the sake of current info, the San Vincente Reservoir recharge project was killed because of politics. It might be resurrected but as of August, 1999 the politicians killed it claiming it was an Anglo plot to make Hispanics drink dirty water!

Page 3-2. Somewhere we need to have a glossary for abbreviations like CIP. I know what it means but a person not informed about membranes might not. Also the term break tank is not is not self explanatory. On this page we have labeled an aerobic tank in the diagram while in the text a "aeration tank" is mentioned as well as "a 200 gallon calibrated receiving tank." These descriptions should be consistent with the diagram.

rege 3-3. In the first and second paragraphs a "process tank" is mentioned. I eve the words "membrane tank" should be used for consistency's sake. Also in the second paragraph it might be helpful to mention that the maintenance cleaning flush liquid is drained to waste.

The last sentence of this paragraph might confuse a first time reader as it seems to imply that maintenance cleaning is not a part of "normal" operation. I would suggest the sentence read "Maintenance cleaning is done insitu and is necessary to sustain the membrane flux." (Is it insitu or in situ?)

Page 3-4, I think adding the words "For pilot testing" to the beginning of the last sentence of the first paragraph sentence would avoid confusion about how a full-scale system would operate. The terms CBOD5, MLSS, MLVSS, SRT, etc., show the need for a glossary.

Page 3-5, The pore size of the cartridge filter would be informative as would be a few words about why the filter is required.

Page 3-6, I believe the samples were taken in 1998 not 1999 as the charts says.

Page 4-4, Again, since my audience is made up mainly of power plant types who are given job assignments outside their technical field of expertise, I would prefer the last sentence of the first paragraph of section 4.33 to "could adversely affect marine ecology." If that is indeed what we mean.

Page 4-5, ASL should be define in a glossary.

 $_{\rm I}$ age 5-18, Here we introduce an other CBOD term which I think is the same as CBOD5. If not it needs to be define in a glossary.

Page 5-52, Some explanation why some chemical element levels in the ZenoGem Permeate are higher than in the raw water would be helpful. Could these be a seasonal variation?

ATTACHMENT 1

Texas Water Development Board Review Comments: City of McAllen Contract No. 99-483-276

Board Staff offers the following comments.

The study shows that effluent, and especially effluent with high hardness and high total dissolved solids, can be brought to drinking water standards for between \$1.24 and \$1.80 per thousand gallons. The study shows that using the Zenon technologies tested, that existing wastewater treatment plant capacities could be significantly increased (doubled or tripled) at costs similar to new plants (under \$1.5 per gallon/day of capacity). Savings may be realized by removing the possible impediments of new construction such as site location and additional distribution lines by utilizing the Zenon technology in existing wastewater treatment plants. The report also shows that Zenon technology can produce a higher quality treated effluent.

Specific recommended changes to the report include:

- 1. Table 5.16 should be modified so that applicable safe drinking water act criteria are included in the table for reference.
- 2. The summary tables of water quality parameters compared to target values shown in the overheads at the Denver meeting should be included in the summary of this report.
- 3. The cost for the micro filtration process, including costs in dollars per thousand gallons should be broken out separately from the RO costs in Chapter 6.
- 4. 4.4.2 Sampling and Analysis: 1st paragraph, 3rd sentence (The WWTP....) mentions one of the samples collected is nitrate/nitrate nitrogen. This is redundant. This should be changed to read nitrate/nitrite nitrogen.
- 5. The Texas Water Development Board should be acknowledged as helping to fund this study.



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JAN 2 4 2000

January 18, 2000

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National Engineers Week 2000

Mr. Robert Jurenka, P.E. Grants and Cooperative Agreements Officer's Technical Representative Stop D-8230 Bureau of Reclamation Denver Federal Center Building 67 at 7th Street Denver, CO 80225

Dear Bob:

Subject: Transmittal of Final Technical Report

On behalf of the City of McAllen, Texas and in accordance with the Cooperative Agreement No. 98FC810073 entitled "Demonstation Testing of ZenoGem and Reverse Osmosis for Indirect Potable Water Reuse - City of McAllen, Texas", please find enclosed five (5) bound copies of the Final Technical Report, one unbound copy, and an electronic copy on compact disk in Word 97 format.

Sincerely,

CH2M HILL

Jim\Lbzier, P.E.

Principal Investigator

Enclosures:

Final Technical Report (5 bound copies; 1 unbound copy)

Compact Disk

Cc:

Bart Hines/City of McAllen

Frank Oudkirk/EPRI Bud Clark/C&SWS Bill Hoffman/TWDB

Doreen Benson/ZENON Environmental Systems

Mike Anglea/CH2M HILL/SAN Angie Fernandez/CH2M HILL/PHX Glen Daigger/CH2M HILL/DEN



Prepared for

City of McAllen, Texas

Prepared by



1620 W. Fountainhead Pkwy. Suite 550 Tempe, AZ 85282



17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ARSTRACT	20. LIMITATION OF ABSTRACT	
membrane technology; indirec	potable reuse; sewage		16. PRICE CODE	
wastewater reclamation; McAllen, Texas; ZenoGem; ZeeWeed; reverse osmosis; microfiltratio				
14. SUBJECT TERMS			15. NUMBER OF PAGES	
13. ABSTRACT (Maximum 200 words) This study involved demonstrator reclaim the City of McAller demonstration testing objective drinking water regulations, (2) to control of membrane fouling processed by composite RO m MBR/RO system. The results while meeting the City's current filtrate that meets all drinking of the control of the city's current filtrate that meets all drinking of the city's current filtrate that meets all drinking of the city's current filtrate that meets all drinking of the city's current filtrate that meets all drinking of the city's current filtrate that meets all drinking of the city's current filtrate that meets all drinking of the city's current filtrate that meets all drinking of the city's current filtrate that meets all drinking of the city of the ci	echnical Information Service, Orfield, Virginia 22161 attion-scale testing of an integrate and include: (1) demonstration the demonstrate reliable operation of through automatic cleaning, (3) embranes with minimal fouling, showed that (1) the ZenoGem principle.	ad membrane bioreactor (MBI ality suitable for use as a new at RO product water meets all of the MBR on screened, degree) demonstrate the MBR filtrat and (4) develop estimates of crocess is capable of producing requirements, and (2) the RO	federal primary and State secondary itted sewage, particularly with respect e (RO feedwater) can be efficiently capital and operating costs for a ga filtrate suitable for RO treatment system is capable of producing a brane cleanings.	
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CH2M HILL 1620 W. Fountainhead Parkway, Suite 550 Tempe, Arizona 85282-1843		Desalination Research and Development Program Report No. 51		
7. PERFORMING ORGANIZATION NAME(S)	LND ADDRESS(ES)		8. PERFORMING ORGANIZATION	
Jim C. Lozier and Angela M.	Fernandez			
Demonstration Testing of Zen of McAllen, Texas	oGem and Reverse Osmosis for	Indirect Potable Reuse, City		
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19. SECURITY CLASSIFICATION OF ARSTRACT

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18. SECURITY CLASSIFICATION OF THIS PAGE

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Standard Form 298 (Nev. 2-89)

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Prescribed by ANSI Std. 235-18 258-102

DEMONSTATION TESTING OF ZENOGEM AND REVERSE OSMOSIS FOR INDIRECT POTABLE REUSE

FINAL TECHNICAL REPORT

City of McAllen, TX

by

James C. Lozier, P.E. and Angela M. Fernandez, E.I.T CH2M HILL

Cooperative Assistance Agreement No. 98-FC-81-0073

Desalination Research and Development Program Report No. 51

January 2000

U.S. DEPARTMENT OF THE INTERIOR
Bureau of Reclamation
Technical Service Center
Water Treatment Engineering and Research Group

Mission Statements

U.S. Department of the Interior

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

Bureau of Reclamation

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

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The information contained in this report was developed for the Bureau of Reclamation: no warranty as to the accuracy, usefulness, or completeness is expressed or implied.

Researcher Acknowledgments

The authors would like to thank the Bureau of Reclamation (Bob Jurenka, Michelle Chapman-Wilbert, and Kim Linton), Texas Water Development Board (Bill Hoffman), Electric Power Research Institute (Frank Oudkirk), and Central and Southwest Energy Services (Bud Clark and Lance Orner) for sponsoring this research.

The authors would also like to thank the City of McAllen, Texas, specifically: Bart Hines, Public Utility Manager, and his Board for their financial and management support; Joe Ibarra, Rey Palomo, Henry Perez and Javier Hinojosa and others at the South WWTP for their assistance in construction, operation, and maintenance of the demonstration plant facilities; and Rosie Villarreal, Ramon Trevino, David Garcia, Juan Morales and their respective staff for sample analysis.

Researcher Disclaimer

The information contained in this report regarding the performance of tested commercial products and the conclusions and recommendations drawn regarding such performance are based on testing conducted on wastewater sources from the City of McAllen, Texas, and are not to be considered an indication of the performance of such products on other water sources either at McAllen, Texas, or at other locations.

Bureau Point of Contact

The Bureau of Reclamation's Water Reuse Task Manager for this work is Robert Jurenka. He can be reached in Denver at (303) 445-2254.

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Acronyms and Abbreviations

ACOE Army Corps of Engineers

ALK alkalinity

ASL Applied Sciences Laboratory

bio-P biological phosphorus

BOD biochemical oxygen demand BOR Bureau of Reclamation

C celsiu

CBOD carbonaceous biochemical oxygen demand

cfm cubic feet per minute CFU colony forming units

CIP clean in place

COD chemical oxygen demand CST capillary suction time

CSWS Central and Southwest Services

DO dissolved oxygen

DSVI diluted sludge volume index
EPA Environmental Protection Agency
EPRI Electric Power Research Institute

 $\begin{array}{ll} \text{ft}^2 & \text{square feet} \\ \text{g/L} & \text{grams per liter} \end{array}$

GAC granular activated carbon gfd gallons per square foot per day

gpd gallons per day gpm gallons per minute HAA haloacetic acid

HPC heterotrophic plate count
HRT hyraulic residence time
I&C instrumentation and controls

in Hg inches of mercury
IPR indirect potable reuse
KLT King Lee Technologies
MBR membrane bioreactor

MCL maximum contaminant level

MF microfiltration mg/L milligrams per liter mgd million gallons per day

mL milliliters
ML million liters

MLSS mixed liquor suspended solids

MLVSS mixed liquor volatile suspended solids

mm millimeter N nitrogen

NH₃-N ammonia nitrogen

NPF normalized product flow
NTU nephelometric turbidity unit
O&M operations and maintenance

OUR oxygen uptake rate

P phosphorus

pCi/L picoCuries per liter
PDC pressure drop coefficient
PLC programmable logic controller

ppm parts per million

psi pounds per square inch

psig pounds per square inch gauge

RO reverse osmosis

scfm standard cubic feet per minute

SDI silt density index

SDS screened degritted sewage SDWA Safe Drinking Water Act

SI solubility index
SRT solids retention time
TDS total dissolved solids
THM trihalomethane

TKN total Kjeldahl nitrogen
TMP transmembrane pressure

TN total nitrogen

TNRCC Texas Natural Resources Conservation Committee

TOC total organic carbon
TP total phosphorus
TSS total suspended solids

TWDB Texas Water Development Board

UF ultrafiltration

UOSA Upper Occoquan Sewage Authority

UV ultraviolet

μg/L micrograms per liter

μm microns

μS/cm microSiemens per centimeter WWTP wastewater treatment plant

Introduction and Background

This report documents wastewater reclamation demonstration testing performed at the McAllen, Texas, wastewater treatment plant (WWTP) No. 2. The study was conducted under Task D: Water Recycling and Reuse of the U.S. Bureau of Reclamation's (BOR) Desalination Research and Development Program. The Program sponsors this research in an effort to lower the cost of treatment technologies. Testing was conducted from February 1999 to October 1999.

The results of previous pilot testing conducted for the City of McAllen (*Water Treatment Technology Program Report No. 26*) concluded that treating the City's wastewater with a membrane bioreactor (MBR) system (ZenoGem) followed by reverse osmosis (RO) and final disinfection (chlorination or ultraviolet [UV] light) may provide for a simpler, potentially less costly, treatment process for the reclamation of a portion of the City's wastewater to supplement current water supplies obtained from the Rio Grande River. The reclaimed water produced by the MBR/RO/disinfection process would in most respects contain significantly lower concentrations of most substances currently regulated under the Safe Drinking Water Act (SDWA), and as such, could improve the inorganic quality of the Rio Grande River water. However, unlike microfiltration (MF), which has been used extensively for RO pretreatment of secondary effluent, no testing has been reported on the use of the ZenoGem process to convert wastewater directly to RO feedwater for the purpose of producing a high quality effluent suitable for indirect potable reuse.

The purpose of this study was threefold: 1) to demonstrate the long-term operability and reliability of the ZenoGem system, 2) demonstrate the feasibility of RO treatment of ZenoGem permeate for the production of reclaimed water, and 3) determine if the MBR/RO process has operational, cost, and water quality benefits compared to the conventional WWTP/MF/RO in the context of indirect potable reuse (IPR).

This section addresses the following information:

- Defines indirect potable reuse.
- Explains the City of McAllen's motivations for considering implementation of indirect potable reuse to help solve their water supply problems.
- Describes the regulatory issues associated with implementation, and explains the reasons membrane processes, in particular MF/ultrafiltration (UF) and RO, are integral to its implementation.
- Presents conclusions and recommendations from this study.

1.1 Indirect Potable Reuse—Definition and History

Indirect potable reuse is the recovery of water from wastewater for the purposeful reintroduction into either a surface water or groundwater body that ultimately serves as a drinking water supply. Unplanned IPR has been occurring since humans first began disposing of wastewater into watersheds that are hydrologically connected to raw water

supplies. Planned IPR began in the U.S. in the 1960s. A summary of some of the major milestones in the development of potable reuse as a viable component of a water resource management plan is presented below.

The Whittier Narrows Groundwater Replenishment Project, California. In 1962, the County Sanitation Districts of Los Angeles began spreading disinfected secondary effluent from a 10-million-gallon-per-day (mgd) (37.9 million liters [ML]/day) water reclamation plant to an underground potable water supply. The reclaimed water accounts for an annual average of 16 percent of the total inflow to the groundwater basin. The local population is estimated to be exposed to from 0 to 23 percent reclaimed water. An independent scientific advisory panel to the State of California conducted an extensive review of the project data and concluded that the Whittier Narrows Groundwater Replenishment Project was as safe as commonly used surface water supplies.

Orange County, California, Water District. Since 1976, the Orange County, California, Water District's Water Factory 21 has been reclaiming unchlorinated secondary effluent to drinking water quality and recharging it into a heavily used groundwater source to prevent salt water intrusion. The water recovery treatment facility is a 15-mgd (56.8 ML/day) facility that includes lime clarification, air stripping, recarbonation, filtration, carbon adsorption, slip-stream RO, and disinfection. It is estimated that less than 5 percent of the domestic water supply is comprised of the recovered water. The Orange County Water District has not identified any significant risk to users of the groundwater from the indirect potable reuse practice.

Upper Occoquan Sewage Authority Water Reclamation Plant, Virginia. In 1978, the 15-mgd Upper Occoquan Sewage Authority (UOSA) Water Reclamation Plant in northern Virginia began reclaiming wastewater for subsequent discharge to the Occoquan Reservoir. This reservoir is a critical source of drinking water for approximately 1 million people. The reclaimed water has accounted for as much as 90 percent of the flow into the reservoir. Treatment includes primary treatment, secondary treatment, biological nitrification, lime clarification and recarbonation, filtration, activated carbon adsorption, and disinfection. The plant has been expanded to 26 mgd (98.4 ML/day) and will be further expanded to 54 mgd (204 ML/day) by the year 2000. No negative health effects have been attributed to the plant or effluent discharges.

Potomac Estuary Experimental Water Treatment Plant, Washington, D.C. From 1981 to 1983, the 1-mgd (3.8 ML/day) Potomac Estuary Experimental Water Treatment Plant was operated with an influent blend of Potomac Estuary water and nitrified secondary effluent. The blend was designed to simulate influent water quality expected during drought conditions when up to 50 percent of the estuary flow may comprise treated wastewater. Treatment included aeration, coagulation, clarification, pre-disinfection, filtration, carbon adsorption, and post-disinfection. An independent panel reviewed the extensive testing performed by the U.S. Army Corps of Engineers (ACOE) and concluded that the advanced treatment could recover water from a highly contaminated source similar in quality to three major water supplies for the Washington, D.C., metropolitan area.

San Diego Total Resource Recovery Project, California. In 1983, a 1-mgd potable water recovery demonstration facility was commissioned as part of a total resource recovery

program established in San Diego, California. The purpose of the treatment system was to reclaim raw water from raw wastewater. The system included primary treatment, a water hyacinth aquaculture system, coagulation, clarification, filtration, UV disinfection, RO, aeration, carbon adsorption, and disinfection. An extensive chronic toxicity risk analysis showed that the risk associated with use of the recovered water as a raw water supply was less than or equal to the use of the existing raw water entering the City's Miramar Water Treatment Plant. The City is now planning to reclaim up to 20 mgd (75.7 ML/day) of secondary effluent for augmentation of their 90,000 acrefoot San Vicente Reservoir for eventual distribution to water customers.

El Paso, Texas, Fred Hervey Water Reclamation Plant. The 10-mgd (37.9 ML/day) Fred Hervey Water Reclamation Plant began operation in El Paso, Texas, in 1985. The recovered water is recharged to the Hueco Bolson drinking water aquifer where, over a 2-year period, the water travels to one of El Paso's potable water wellfields to become part of the potable water supply. The treatment system includes primary treatment, activated sludge/powdered activated carbon treatment, lime treatment, recarbonation, filtration, ozonation, and granular activated carbon (GAC) adsorption. Although no negative health effects have been correlated with the reuse practice, an increase in the total dissolved solids (TDS) content of the aquifer has occurred because the increased pumping has lowered the aquifer level to the higher salinity water source. Slip-stream demineralization will be included in future plant expansions to address the TDS issue.

Tampa Water Resource Recovery Project, Florida. The City of Tampa's Water Resource Recovery Pilot Plant began operation in 1986 with the purpose of evaluating the feasibility of reclaiming denitrified secondary effluent to a quality suitable for blending with existing surface water and groundwater sources for indirect potable reuse. Several treatments were evaluated, and one was selected for health effects testing. This treatment system consisted of aeration, high pH lime clarification, recarbonation, filtration, GAC adsorption, and ozonation. The results of the health effects testing coupled with the microbiological and chemical analyses performed during the evaluation indicated that the quality of the reuse water was equivalent to or exceeded the quality of the local raw water supply. The City of Tampa intends to develop a 20- to 50-mgd (189 ML/day) water resource recovery plant in the near future.

West Basin Water Recycling Program, California. From 1990 through 1995, the West Basin Municipal Water District conceived, designed, constructed, and began operation of the West Basin Water Recycling Program. This program includes reclaiming 5 mgd (18.9 ML/day) (expandable to 20 mgd, or 75.7 ML/day) of secondary effluent from the City of Los Angeles' Hyperion Treatment Plant for injection into the West Coast Basin Barrier Project. The West Coast Basin Barrier Project has historically received an average of 20 mgd of potable water for injection into the coastal reaches of local South Bay aquifers for mitigation of saltwater intrusion. Substituting reclaimed water for the potable water provides substantially greater water use efficiency in the area. Reclamation treatment includes predecarbonation, lime clarification, recarbonation, filtration, RO, postdecarbonation, and final disinfection. Based on hydrogeologic investigation and modeling of the West Coast Basin, it is anticipated that the reclaimed water will improve groundwater quality along the Barrier because of the high quality of the reclaimed water relative to the imported water and the native groundwater.

Reedy Creek Improvement District, Advanced Water Reclamation Program, Florida. In 1992, the Reedy Creek Improvement District began a pilot program to reduce phosphorus (P) and nitrogen (N) in the effluent from their WWTP to very low levels. Although the goal of treatment was not IPR, this was the first project to evaluate the feasibility of using MF and UF as a replacement to lime clarification, recarbonation, and gravity filtration for RO pretreatment. This approach was shown to be so effective that MF and UF have displaced lime treatment as the preferred means of RO pretreatment on subsequent IPR projects.

City of Scottsdale, Arizona, Water Campus Project. In 1994, the City of Scottsdale began pilot testing MF and RO for the purpose of reclaiming wastewater for groundwater recharge. The testing program, which has culminated in a 6.8-mgd (25.7 ML/day) IPR project currently under construction at the City's Water Campus site, represents the first planned IPR project in Arizona. During periods when demand for non-potable reclaimed water is low, product water from the MF/RO system will be blended with filtered surface water and injected into a potable aquifer using dry wells. The 6.8-mgd facility represents the first phase of a multi-year project designed to have an ultimate capacity of 25 mgd (94.6 ML/day).

City of San Diego, California, Water Repurification Project. As an outgrowth of their Total Resource Recovery Project, the City of San Diego began the Repurification Project to reclaim up to 20 mgd of wastewater for indirect potable use. The program is currently evaluating the feasibility of using the following advanced water treatment processes to re-purify tertiary effluent from the City's new North City Water Reclamation Plant to a quality suitable for direct discharge to the San Vicente Reservoir, one of the City's main raw water reservoirs: MF/UF, RO, ion exchange, and ozonation. The project represents the first surface supply augmentation IPR project in California and must satisfy stringent California Department of Health Services requirements regarding virus removal and real-time monitoring of individual processes for pathogen removal. If successful, the project will result in the construction of the largest IPR plant in the U.S.

1.2 The Need for Indirect Potable Reuse for the City of McAllen

The City of McAllen, Texas, is located in the Lower Rio Grande Valley near the United States-Mexico border, approximately 40 miles upstream from the mouth of the Rio Grande River. The City presently derives its water supply from water rights in the Rio Grande River that it shares with multiple parties, including other cities, water supply corporations, irrigation districts, and Mexico. The Lower Rio Grande Valley is a growing area with an existing water shortage problem. The Texas Water Development Board (TWDB) reports that all surface water resources in the area are 100 percent appropriated. Additionally, this semi-arid area often experiences drought conditions. Projected growth in population and water use indicates that the demand for potable water will exceed the City's authorized water rights by the year 2003. Consequently, alternative water supply strategies are necessary to ensure a safe, reliable source of potable water.

The two most feasible alternative sources are groundwater and re-purified wastewater. Many of the groundwater supplies in the Lower Rio Grande Valley have an elevated

dissolved solids concentration and require demineralization by RO or electrodialysis to make them suitable for potable use. Consequently, wastewater reclamation is considered by the City to be a desirable means of augmenting its water supply.

1.3 Water Quality Considerations and Proposed Treatment Strategy

In general, reclaimed water should be treated to a level where its quality exceeds that of the historical water supply. In Texas, public heath issues related to the use of reclaimed water fall under the purview of the Texas Natural Resources Conservation Commission (TNRCC). The preliminary requirements of the TNRCC with respect to IPR for the City are: 1) reclaimed water must be of equal or better quality than that of the City's current water supply, and 2) RO must be used to treat all of the reclaimed water prior to its reuse. Based on these requirements and in view of the City's desire to reduce the dissolved solids of its finished water to improve consumer acceptability, the following IPR treatment sequence was proposed for the City in 1997 and subsequently demonstrated via testing conducted in that year and reported in *Water Treatment Technology Program Report No. 26*:

- Primary and secondary treatment
- Chlorine disinfection
- MF/UF
- RO
- UV disinfection

This sequence not only satisfies the TNRCC's preliminary requirements, it also provides multiple treatment barriers to the passage of microbial, inorganic, and organic contaminants in the wastewater. The concept of "multiple barriers" has been adopted by the water supply industry to achieve the appropriate level of safety and reliability by providing redundant treatment steps for the removal of wastewater contaminants, primarily pathogens.

1.4 Membrane Technologies in Indirect Potable Reuse

A primary focus of one task of BOR's Desalination Research and Development Program is research on membrane processes for wastewater reclamation. In this context, three membrane processes (MF, UF, and RO) represent key treatment processes in the proposed treatment sequence for IPR at McAllen. RO has been applied for wastewater reclamation for more than two decades and is considered a proven treatment process. RO serves as the "workhorse" for the IPR process because it is efficient in removing nearly all contaminants of public health concern. Cost-effective RO operation on municipal wastewater requires a high degree of preliminary treatment to control membrane fouling. Such treatment is provided through the use of MF/UF to polish secondary effluent.

During the last 5 years, MF has been shown at demonstration- and full-scale to be a reliable process in the context of IPR. Production MF facilities are currently in operation in California and Arizona with additional facilities planned for Pennsylvania, Virginia,

and Georgia. UF technologies have also been demonstrated for the same purpose; however, to date none have been implemented full-scale. All of the MF/UF products at these sites have employed pressure modules.

During the 1997 pilot study at McAllen, pressurized MF was demonstrated for the treatment of effluent from the City's south WWTP using Memcor MF technology. At that time, a novel, immersed MF product (ZeeWeed) was tested and found to provide performance competitive with or somewhat superior to the pressurized MF approach. In addition, ZeeWeed was also evaluated in the context of a membrane bioreactor process (ZenoGem) and found to be feasible for direct treatment of the City's screened, degritted wastewater. Preliminary results indicated that the ZenoGem filtrate was of equivalent quality to both Memcor and ZeeWeed filtrate with respect to general water quality (TDS, total organic carbon [TOC], coliforms, and turbidity) but had significantly higher RO feedwater colloidal fouling potential (as measured by silt density index [SDI]). Longer term testing of ZenoGem coupled with a follow-on RO system was recommended at that time and is the subject of this research.

1.5 Conclusions

Conclusions drawn from the results of this study are presented below.

1.5.1 ZenoGem System

- The ZenoGem membrane bioreactor process successfully treated screened, degritted sewage (SDS) to a quality suitable for RO processing.
- The ZenoGem process produced a permeate (see Tables 5.8 through 5.10) that exceeded the City's effluent discharge requirements for carbonaceous biochemical oxygen demand (CBOD₅<10 milligrams per liter [mg/L]), total suspended solids (TSS <15 mg/L)), and ammonia nitrogen (NH₃-N <3 mg/L). This result was attained at all mixed liquor suspended solids (MLSS) concentrations and with both membrane types.
- The ZeeWeed OKC MF (0.4-micrometer [μm] pore size) membrane exhibited higher sustained permeability than OCP UF (0.035-μm pore size) membrane at high MLSS levels (13 grams per liter [g/L]).
- Permeability of the MF membrane was sensitive to MLSS level. Permeability was stable at 10 g/L but declined at 13 g/L because of increased membrane fouling not adequately controlled by frequent permeate backpulsing or maintenance cleans.
- At an MLSS concentration of 13 g/L, simultaneous nitrification/denitrification and biological phosphorus (bio-P) removal occurred most likely because of the inability to completely transfer oxygen from the bulk liquid to the interior of the bioflocs at the hydraulic residence time (HRT) selected for this study (5.7 hours). The oxygen transfer limitations inhibited complete nitrification but promoted nitrogen removal.

- At an MLSS concentration of 10 g/L, the rate of oxygen transfer was sufficient to maintain complete nitrification and suppress denitrification and bio-P uptake.
- Flow peaking tests (i.e., permeate flowrate increased for a specific duration of time) were conducted over a 24-hour period to simulate the types of peak loading conditions that typically occur in a conventional WWTP. However, peaking significantly increased the rate of permeability decline and accelerated the fouling rate (fouling not reversed by backpulsing or maintenance cleans as defined in Section 3.2.1). As a result, normal diurnal variations in wastewater flow, in which peak hourly flows can equal 300 percent of average daily flow, must be dampened through flow equalization so that the ZenoGem process can operate at more or less a constant hydraulic loading (flux) rate.
- Intermittent aeration (i.e., air cycled at 15 minutes on/15 minutes off) to the aeration tank (at 6 g/L MLSS concentration) produced the greatest degree of total nitrogen removal (optimum simultaneous nitrification and denitrification).
- With respect to RO feedwater quality, ZenoGem permeate quality consistently exceeded goals for turbidity and SDI, and generally exceeded goals for bacterial concentrations.
- Per Table 5.16, compared to the City's existing raw water source, the ZenoGem
 permeate was of lesser quality with respect to TOC and many inorganic
 contaminants while the RO permeate was of better quality in nearly all respects.
- Coliform removal by the both membranes was less than 100 percent. MF membrane
 permeate contained significantly greater coliform concentrations at 13 g/L MLSS
 concentration than the UF membrane. Furthermore, coliform removal appeared to be
 a function of MLSS loading for the MF membrane. However, the RO system
 consistently removed any remaining coliform regardless of the MF or UF
 pretreatment.
- Cycled aeration to the membrane tank appeared to significantly increase the rate of membrane fouling (permeability decline) compared with continuous aeration.
 However, it is difficult to draw firm conclusions regarding aeration given the brief operating time with cycled aeration and its use in combination with other operating modifications (flow peaking, cycled aeration to the aeration tank).
- Footprint for ZenoGem facilities represents about 32 percent of the total area required for a conventional activated sludge plant providing comparable biological treatment and flow equalization.

1.5.2 RO System

- Membrane fouling by particulates and soluble organics in the screened, degritted wastewater was well controlled by the ZenoGem process as illustrated by stable first stage flux and salt rejection. Continuous disinfection, in the predominant form of monochloramine, with a low concentration of combined chlorine (approximately 1 mg/L) was effective in preventing biological fouling of the RO membranes as measured by stability of first stage feed/concentrate differential pressure (see Tables 5.12 through 5.14).
- Elevated concentrations of calcium and phosphate in the City's wastewater (and ZenoGem permeate) most likely caused precipitation of the calcium phosphate salt, hydroxyapatite, in the RO system second stage at feedwater pH levels designed to control calcium carbonate scaling. This precipitation caused rapid increases in RO feed pressures, rapid declines in normalized product flow, and marked increases in salt passage. The precipitate was readily dissolved using citric acid cleaning, and performance declines were consistently reversed by such cleanings. Further acidification of the RO feedwater to pH 5.0 (concentrate pH to 5.6) prevented such precipitation except at design (80 percent) recovery. A better control method may be to precipitate the majority of the soluble phosphorus in the wastewater during MBR treatment using a ferric or aluminum coagulant.
- RO permeate at design (80 percent) recovery was very high quality: TDS <75 mg/L, TOC <0.5 mg/L, and turbidity <0.1 nephelometric turbidity units (NTU). Levels of these and other contaminants monitored for in the RO permeate were significantly less than the maximum concentrations permitted under federal drinking water regulations or indirect potable reuse guidelines established in certain states (e.g., California and Virginia). The exception being coliforms, which were consistently detected at low levels. From this standpoint, the RO permeate is of satisfactory quality for IPR use subject to additional disinfection (chlorination or UV). TNRCC has not established guidelines or regulations for IPR use at McAllen, however, their preliminary position is that RO treatment would be required. On the other hand, TNRCC may consider establishing quality requirements for IPR that use the quality of the existing raw water supply as the benchmark for treatment. In this case, it may be possible that an acceptable quality of reclaimed water can be produced through a blend or ZenoGem and RO permeate with post-disinfection.

1.6 Recommendations for Further Research

The following recommendations are provided with respect to further research involving MBRs and RO in the context of indirect potable reuse.

1.6.1 Membrane Bioreactors

1.6.1.1 MLSS Levels and Membrane Flux

This research illustrated that membrane fouling and permeability is sensitive to MLSS level. Further research is needed to define the optimum combination of these two parameters (MLSS level/membrane flux) as they contribute to both capital and operating cost. Increased MLSS levels permit higher solids retention times (SRTs), reducing sludge yield, however their use may result in higher capital costs and operating costs associated with additional membrane area (reduced flux).

1.6.1.2 Cycled Aeration to Promote Nitrification/Denitrification

Optimize conditions of cycled aeration for the purpose of promoting simultaneous nitrification/denitrification. Testing in this study was conducted at only one on/off cycle (15 minutes on, 15 minutes off) to the aeration tank. No water quality parameters were measured at other cycles to determine if control at other cycles may be more efficient at achieving improved or complete nitrogen removal. Control methods need to be developed in conjunction with such testing.

1.6.1.3 Cycled Aeration to Reduce Membrane Air Scour Requirements

Aeration for control of membrane fouling represents a significant operating (power) cost. Cycling of air to the coarse bubble aerator integral to the membrane module (membrane tank) represents one way to reduce operating cost; however, aeration reductions must not come at the detriment of membrane permeability. Testing is needed to determine optimum airflow rates and cycle times to achieve the optimum balance of these two needs.

1.6.1.4 Alternative MBR Designs

This research tested one MBR product, Zenon Environmental System's ZenoGem using a MF membrane module. Other MBR products are available and have been installed for municipal wastewater reclamation both in Europe and Japan. Testing of these products is needed to assess their performance relative to ZenoGem and to determine if such products represent competitive technologies for application in the U.S. IPR and wastewater treatment market.

The BOR is currently funding research by Montgomery Watson and the City of San Diego to compare the performance of ZenoGem and Mitsubishi systems. Also, the ZenoGem UF system should be retested at 10~g/L and 6~g/L for comparison to the MF system at these concentrations.

1.6.2 Reverse Osmosis

1.6.2.1 Scale Control

For wastewaters containing elevated concentrations of calcium and phosphate, additional research is needed to determine the most cost-effective and operationally reliable means to control calcium phosphate scaling. Acidification has the advantages of low cost and typically being required for calcium carbonate scale control; however, its use to reduce pH to levels considered effective in this study (see Section 5.0) resulted in an aggressive RO permeate that was supersaturated with carbon dioxide (most likely requiring stripping). Ferric or aluminum coagulant addition to the MBR (or conventional plant) will reduce phosphorus levels in both the RO feedwater and concentrate. However, the doses required in the City's case (approximately 50 mg/L ferric chloride and 91 mg/L alum) produce additional solids in the MBR, potentially increasing membrane fouling and requiring acid maintenance cleans and reducing SRT for a given operating MLSS level.

1.6.2.2 Membrane Flux

RO testing in this study was performed at relatively low flux (10 to 11 gallons per square foot per day [gfd]). Given the low turbidity and SDI of the ZenoGem permeate, higher flux operation (reduced membrane capital cost) may be feasible if scale control can be resolved as discussed herein.

Testing Objectives

The research to be conducted under this program has the following objectives:

- 1. Demonstrate feasibility and benefits of the ZenoGem process:
 - Produce a high quality RO feedwater (i.e., turbidity <0.2 NTU, SDI <3, heterotrophic plate count [HPC] <500 colony forming units [CFU]/milliliter [mL]).
 - Meet the City's effluent discharge permit requirements (i.e., TSS <15 mg/L, CBOD₅ <10 mg/L, NH₃-N <3 mg/L).
 - Operate reliably (i.e., sustained production).
- 2. Demonstrate successful RO treatment on ZenoGem permeate:
 - Reliable operation with minimal fouling and effective membrane cleanings.
 - Meet all drinking water/reuse standards.
- 3. Define design and operation and maintenance (O&M) requirements to develop full-scale ZenoGem and RO plant design criteria.
- 4. Develop cost estimates for current and proposed IPR advanced treatment processes for the City of McAllen.
- 5. Characterize ZenoGem and RO permeates relative to the City's existing raw water supply (i.e., Rio Grande River) based on:
 - Regulated drinking water contaminants.
 - State of Texas secondary drinking water requirement of TDS for 1,000 mg/L.
- 6. Determine impacts of IPR on waste discharges to the City's current discharge location (i.e., Arroyo Colorado/Laguna Madre).

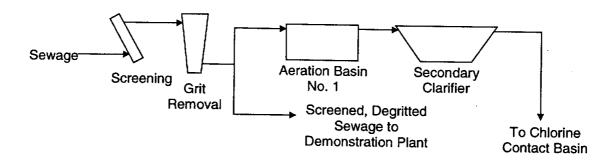
Demonstration Plant Facilities

The demonstration plant facilities consisted of ZenoGem (MBR) and RO treatment systems. The plant also contained ancillary equipment, including a raw water supply pump, chemical feed systems, transfer pump, and associated piping, valves, and fittings for delivery of raw water (i.e., ZenoGem feed), transfer of processed water (i.e., ZenoGem permeate/RO feed), and disposal of discharge flowstreams (i.e., ZenoGem sludge, RO concentrate, and RO permeate) and membrane cleaning solutions to the WWTP. A description of the other components of the demonstration plant facilities is presented in the following sections.

3.1 Raw Water Supply, Abstraction, Pumping, and Screening

The raw water source (feedwater) to the demonstration plant was SDS from the City's South WWTP No. 2. SDS was abstracted from the influent splitter box (located upstream of Aeration Basin No. 1) and transferred to the ZenoGem system via a submersible pump located in the splitter box. The abstraction point relative to the WWTP processes is shown in Figure 3.1.

FIGURE 3.1
Demonstration Plant Feedwater Abstraction Point from WWTP No. 2

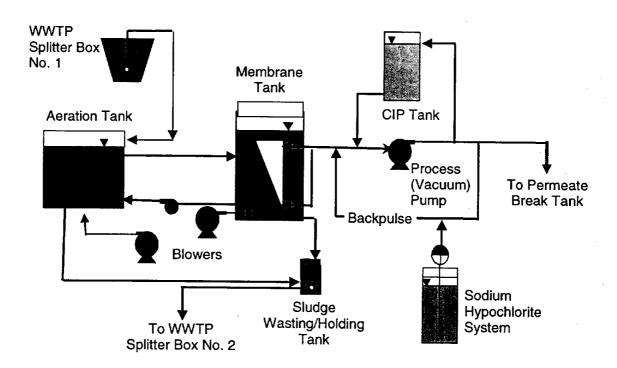


Raw water to the ZenoGem system was screened using a basket strainer and a 3-millimeter (mm) screen. Screening was necessary to prevent clogging of the inlet distributors of the membrane modules.

3.2 ZenoGem Treatment System

The ZenoGem treatment system is comprised of the following components: ZeeWeed Model MSTD ZW-4 unit, a 3,000-gallon aeration tank, auxiliary aeration blower, solids recirculation pump, and sludge wasting system (submersible pump located in aeration tank and 200-gallon calibrated sludge wasting/holding tank). The ZeeWeed unit consists of the following: 185-gallon tank containing the membrane module (membrane tank); one ZW-500 module containing 500 square feet (ft²) of hollow-fiber MF membrane with a nominal pore size of 0.4 microns (OKC membrane); permeate pump; membrane aeration blower; and backpulse/clean-in-place (CIP) tank. The ZeeWeed ZW-500 membrane module consists of loose fibers connected to a manifold rack system at either end, with the rack/fiber assembly suspended in the membrane tank and submerged in the mixed liquor. Treatment occurs when a vacuum of 1.5 to 9.0 pounds per square inch gage (psig) is applied to the filtrate side of the fibers using the process (vacuum) pump. The vacuum causes the water in the mixed liquor to flow from the feed side to filtrate side of the membrane in a direct filtration mode under a positive transmembrane pressure. A process flow diagram for the ZenoGem treatment system is shown in Figure 3.2. Photographs of the ZenoGem system are presented in Appendix A.

FIGURE 3.2
ZenoGem Treatment System Process Flow Diagram



¹During the commissioning stage of the testing (Stage A), a 0.035-micron UF (OCP) membrane module was installed in the membrane tank. This module was replaced with the 0.4-micron MF (OKC) membrane module to increase flow and reduce fouling.

During ZenoGem operation, biodegradable matter in the sewage (biochemical oxygen demand [BOD] and ammonia) is oxidized by the biomass maintained at high mixed liquor concentrations in the membrane and aeration tanks with air input to these tanks using coarse and fine bubble diffusers, respectively. MLSS levels and SRTs are maintained in the tanks through the frequency and volume of sludge wasted to a calibrated sludge wasting/holding tank. Waste sludge is returned to Splitter Box No. 2 using a submersible pump. The desired HRT is maintained by controlling the rate of permeate flow. Consistency of MLSS concentrations between membrane and aeration tanks is maintained by recirculating MLSS between the tanks using a submersible grinder pump located in the aeration tank.

3.2.1 Methods to Control ZeeWeed Membrane Fouling

Control of solids buildup on the outside surface of the membrane fibers and related increases in permeate side vacuum are achieved in three ways. First, a blower is used to provide continuous air input (in the form of coarse bubbles) at 25 to 30 standard cubic feet per minute (scfm) into the bottom of the membrane tank directly below the membrane fibers. The air bubbles flow upward between the vertically oriented fibers, causing the fibers to agitate against one another. This results in mechanical cleaning through air scour.

Secondly, filtration is interrupted every 10 minutes and the membrane fibers are backpulsed repeatedly for 15 seconds with permeate from the backpulse/CIP tank. The system remains on-line during backpulsing and is in a backpulse mode for a total of 36 minutes per day. Typically, a low concentration of chlorine (<5 parts per million [ppm]) is maintained in the backflush water to inactivate and remove microbes (primarily bacteria) that colonize the outer membrane surface. Hydraulic cleaning via backflushing is accomplished using discharge head from the process pump, and backwash water is retained in the membrane tank.

Thirdly, three times per week, a 100-ppm sodium hypochlorite solution is added to the backpulse/CIP tank, and the membrane module is backpulsed repeatedly for 45 minutes in a procedure called a "maintenance clean." After the 45-minute in situ cleaning, the system is flushed with permeate for 15 minutes. An additional permeate flush to drain is performed for 10 to 15 minutes to purge the system of free chlorine once permeation (i.e., vacuum applied to filtrate side of membrane module) is re-initiated. The total system downtime during a maintenance clean is about 75 minutes.

The combination of air scour, backpulsing, and maintenance cleaning may not be completely effective in controlling membrane fouling, and with time, the pressure differential across the membrane (transmembrane pressure [TMP]) may increase to a maximum of value approximately 17 inches of mercury. When this condition occurs, which is anticipated to be (>3 months) infrequently at full-scale application, the membrane module is chemically cleaned with a 1,500 to 2,000-ppm sodium hypochlorite solution in a procedure called a "recovery clean." Recovery cleaning requires in situ full tank soaking and clean water flux testing. The chemical cleaning dissolves and removes the refractory solids, and reduces TMP to "clean membrane" initial levels (i.e., levels at startup prior to any evidence of fouling).

3.2.2 Permeate Storage, Disinfection, and Pumping

The ZenoGem permeate flows from the ZeeWeed unit to a permeate break tank that serves to balance the intermittent flow of ZenoGem permeate (resulting from backpulsing and maintenance cleans) with the continuous feed flow requirement of the RO system. After the break tank and prior to entering the RO treatment system, the permeate is dosed with combined chlorine (in the predominant form of monochloramine) using a solution tank and metering pump. Combined chlorine is batched using sodium hypochlorite and aqueous ammonia. The dosage is based on maintaining at least 1 to 2 mg/L of total chlorine residual and zero free chlorine residual. The thin film composite RO membrane material is intolerant to free chlorine, and any exposure will reduce the membrane life. Combined chlorine serves to prevent the low levels of bacteria that can be present in the ZenoGem permeate (primarily through contamination) from growing in the RO feed piping and on the membrane elements (biofouling). The addition of combined chlorine is not intended to serve as disinfection to eliminate pathogens. The "disinfected" ZenoGem permeate is pumped from the break tank to the RO system using a transfer pump. Excess ZenoGem permeate overflows the break tank through drain piping.

3.2.3 ZenoGem Operation

The ZenoGem system is designed to operate at a constant flux with the TMP varying over time to maintain the design flux. The rate of filtrate discharge to the break tank is controlled to achieve the desired HRT in the membrane tank (bioreactor). Proper HRT control is required to achieve the desired degree of CBOD, and ammonia removal by the biomass maintained in the bioreactor. Solids buildup in the bioreactor is controlled through daily manual wasting to achieve the desired SRT (concentration of MLSS) in the bioreactor. Unlike a conventional WWTP that operates at MLSS levels of 2,000 to 3,000 mg/L, the ZenoGem process is designed to operate at MLSS levels of 10,000 to 15,000 mg/L. This allows for a higher organic loading of wastewater in the ZenoGem treatment system.

Three modes of operation were employed during the study:

- Normal Flow: Permeate flowrate maintained at 6.5 gallons per minute (gpm).
- Peak Flow: Permeate flowrate increased to 9.5 gpm for 6 hours over a 24-hour period.
- Cycled Aeration: Air cycled to membrane tank at 10 seconds on/10 seconds off with or without air cycled to aeration tank at 15 minutes on/15 minutes off.

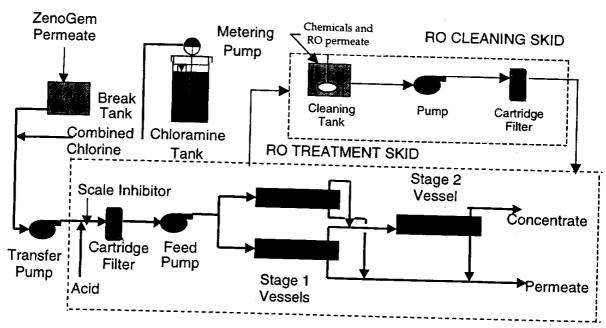
As detailed in Table 5.1, these operating modes are presented as specific operating events during ZenoGem operation.

3.3 RO Treatment System

The RO treatment system is comprised of the following components: a treatment skid and a cleaning skid. The treatment and cleaning skids are provided courtesy of the Bureau of Reclamation's Water Treatment Engineering and Research Group.

The RO treatment skid consists of the following equipment: chemical feed systems for the addition of acid and scale inhibitor, 5 micron cartridge filter, feed (high pressure) pump, two-stage pressure vessel array, programmable logic controller (PLC) and associated instruments and controls, piping, gauges, and valves. The cartridge filter serves as backup in the event of MF pretreatment failure. The RO elements, model LFC1-2540, are manufactured by Hydranautics and contain low fouling composite polyamide membranes. Stage 1 contains four pressure vessels each containing three 2.5-inch-diameter by 40-inch-long spiral wound elements in a "2:2" configuration. Stage 2 contains two pressure vessels of identical design plumbed in a "1:1" configuration. The two-stage array permits operation up to 80 percent recovery and simulates design of a full-scale RO plant using a "2:1" array with six-element vessels. A process flow diagram for the RO treatment skid and associated pretreatment equipment is shown in Figure 3.3. Photographs of the RO treatment system are presented in Appendix A.

FIGURE 3.3
RO Treatment System Process Flow Diagram



3.3.1 RO Feedwater Characterization

Three separate samples of unchlorinated secondary effluent (from the City's WWTP) were collected prior to the start of testing to estimate the inorganic quality of the RO feedwater. (The inorganic quality of the WWTP effluent was considered to be a good simulation of that produced by the ZenoGem system given that both were designed to operate on the same feedwater and provided the same degree of biological treatment and nitrification.) The results are shown in Table 3.1.

TABLE 3.1
Results of RO Feedwater Characterization

	_		Sampling Date		
Parameter	Units	12/14/98	12/16/98	12/18/98	- Average
Alkalinity	mg/L as CaCO ₃	153	161	164	159
Bicarbonate	mg/L	187	196	200	194
Chloride	mg/L	388	359	378	
Reactive Silica	mg/L	13.90	14.70	14.60	375
Sulfate	mg/L	327	305	332	14.40
Anion Sum	mg/L	1,069	1,036	1,089	321
Barium	μg/L	78.30	77.60	87.80	1,064
Calcium	μg/L	112,000	127,000	103,000	81.23
Magnesium	μg/L	29,100	29,700		114,000
Potassium	μg/L	17,100	18,900	26,800	28,533
Sodium	μg/L	236,000	271,000	19,400	18,467
Strontium	µg/L	1,260	1,310	233,000	246,667
Cation Sum	μg/L	395,538	·	1,380	1,317
TDS (Sum of lons)			447,988	383,668	409,065
CO (Suill of folis)	mg/L	1,465	1,484	1,473	1,473

The mean values were then used with two software programs, King Lee Technologies (KLT) WaterWizard and Hydranautics' RODesign, to develop feedwater chemical conditioning requirements and establish product water recovery of the RO system based on the presence and concentration of sparingly soluble salts. The program outputs, shown in Appendix B, indicated the following design condition:

- RO feedwater acidification to pH 6.8 (with sulfuric acid)
- RO feedwater dosing with scale inhibitor at 2 ppm (KLT PreTreat 0100)
- Product water recovery of 80 percent based on 53 times saturation of barium sulfate in the RO concentrate

This condition served as the basis for target operating criteria for the RO system.

3.3.2 RO Feedwater Pretreatment to Control Membrane Fouling

During extended operation, RO membrane elements are subject to fouling caused by both suspended and dissolved matter. Suspended matter includes organic and inorganic colloids and microorganisms. Sparingly soluble salts, such as carbonates, sulfates, and silica, can precipitate from solution because they are concentrated by the RO process. Suspended particles accumulate on the membrane surface causing biofouling and colloidal fouling, and can block feed channels thereby increasing the pressure drop across the system. These phenomenon reduce water permeability through the RO membranes causing flux decline and increased salt passage. The nature and rapidity of fouling depends on the condition of the feedwater. Fouling is progressive, and, if not controlled early, can impair the RO system performance in a relatively short time. For these reasons, fouling must be controlled.

Particulate fouling was addressed through the use of the ZeeWeed MF membrane. Scaling was controlled using acidification and scale inhibitor addition. Chloramines were batched and dosed into the RO feedwater to prevent biological growth (biofouling) on the membranes as discussed in Section 3.2.

The RO feedwater from the transfer pump enters the treatment skid where it is dosed with a scale inhibitor and sulfuric acid prior to entering the cartridge filter. The addition of scale inhibitor prohibits the precipitation of sulfate and carbonate scalants (specifically calcium carbonate and barium sulfate). KLT PreTreat 0100 was used for mineral precipitate control. Acidification further reduces the potential for calcium and carbonate to precipitate from solution. Sulfuric acid was used for feedwater pH control.

Chemically conditioned with King Lee PreTreat 0100 scale inhibitor and sulfuric acid, the filtered water is pumped to the RO vessels at a pressure needed to produce the design permeate flow. Target feedwater recovery is attained by adjustment of the concentrate flow control valve. The system operates in a constant permeate flow/constant recovery mode with feed pressure increasing to compensate for decreases in water mass transfer rate.

The combination of filtration, chloramination, scale inhibition, and acidification may not be completely effective in controlling membrane fouling, and with time, the pressure drop across the stages may increase with simultaneous decreases in permeate flowrate and feedwater recovery. Recirculating a citric acid solution (low pH cleaning) or an alkaline solution (high pH cleaning) containing a mixture of surfactant, detergent, and chelating agent from the cleaning skid through the RO vessels serves to chemically clean the RO system when fouling is apparent. Recirculation is coupled with soak periods to remove the membrane foulants and restore lost performance.

Cleaning was performed five times on the system throughout the study. Low pH cleanings using citric acid and sodium hydroxide (for pH adjustment) were performed to remove inorganic fouling, such as calcium precipitates (e.g., calcium carbonates and phosphates) and hydroxide precipitates (e.g., metal oxides such as ferric hydroxide). High pH cleanings using a caustic solution and sulfuric acid (for pH adjustment) were performed to remove calcium sulfates and organics.

3.4 Criteria for Treatment System Operation

Tables 3.2 and 3.3 present criteria that were established for operation and biological performance, respectively, of the ZenoGem system. Table 3.4 presents the initial operating criteria for the RO system based on RO feedwater analyses and projection results. These criteria reflect the individual manufacturer's experience with the systems. Some of the criteria were modified during the study to improve operability (i.e., reduce potential for membrane fouling) and biological treatment stability and performance. Detailed descriptions of the operating stages for each treatment system are presented in Section 5.1.

TABLE 3.2Operating Criteria for the ZenoGem System

Parameter	Units	Target
Aeration Tank Air	scfm	45
Backpulse Duration	sec	15
Backpulse Frequency	min	10
Biomass Recirculation Rate	gpm	36
Flux	gfd	18.7/27.3ª
Membrane Tank Air	scfm	25/30 ^b
Permeability	gfd/psi	5°
Permeate Flowrate before Backpulse	gpm	6.5/9.5ª
TMP	psi	2.5 - 8.5
Vacuum before Backpulse	in Hg	5.1 - 17.3

^aTarget value during flow peaking.

^cExpected value based on control variables.

Applied rate increased to 30 scfm during intermittent aeration.

TABLE 3.3Biological Treatment Performance Criteria for the ZenoGem System

			Tar	get	
Parameter	Units	Stage A	Stage B	Stage C	Stage D
DO	mg/L	> 1.5	> 1.5	> 1.5	> 1.5
OUR	mg O₂/L-min	1.0 - 1.5	1.0 - 1.5	1.0 - 1.5	1.0 - 1.5
MLSS	mg/L	13,000	13,000	10,000	6,000
Sludge Wasted Daily	gals	90ª	90ª	110 ^a	150 ^a
HRT	hrs	6.2	6.2	6.2	6.2
SRT	days	25ª	25ª	20ª	15ª

^aExpected value based on control variables.

TABLE 3.4 Operating Criteria for the RO System

			Tai	rget	
Parameter	Units	Stage A	Stage B	Stage C	Stage D
Acidified Feedwater pH		6.8	6.8	6.8	5.6ª
Feedwater Flowrate	gpm	5	5	3	3 - 5
Feedwater Recovery	%	80	80	50	50 - 80
Permeate Flowrate	gpm	4	4	1.5	1.5 - 4.0
Scale Inhibitor Dose	ppm	2	2	. 2	2

^aSet target to concentrate pH during this stage (feedwater pH = 5.0).

Testing Approach

The demonstration testing program was divided into two phases:

- Phase I: Operation of ZenoGem treatment system for 1 month to establish stable biological treatment performance and permeate water quality.
- Phase II: Operation of ZenoGem and RO treatment systems for 5 months to demonstrate project goals and objectives.

The demonstration plant operated 24 hours per day, 7 days per week except for chemical cleanings or planned and unplanned maintenance. Equipment was supervised on an 8-hour per day, 5-day per week basis and as required on weekends to ensure proper operation and data collection. Operating data were recorded at the beginning and end of the each shift. Water quality samples were collected at the beginning of the shift. The results of Phase I and Phase II testing are discussed in Section 5.0.

4.1 ZenoGem Treatment System Tasks

The ZenoGem treatment system tasks under Phases I and II were to:

- 1. Operate ZenoGem system to produce a permeate whose quality complies with the City's discharge permit (TSS <15 mg/L; BOD <10 mg/L; NH₃-N <3 mg/L).
- 2. Characterize ZenoGem permeate relative to goals for RO feedwater quality, defined as follows:
 - Turbidity: < 0.2 NTU
 - SDI: <3
 - Fecal coliforms: <1 CFU/100 milliliters (mL)
- 3. Characterize ZenoGem permeate relative to IPR water quality requirements and for development of RO feedwater design composition.
- 4. Measure O&M requirements for ZenoGem system (plant efficiency factor, labor hours required, energy consumption, and chemical and other consumable consumption); demonstrate reliable, long-term performance of the ZenoGem process; and develop criteria for design of full-scale ZenoGem system.
- 5. Develop information necessary for design of a full-scale ZenoGem plant. Design criteria to be developed as part of this task include the following:
 - HRT (at average and peak loading)
 - SRT
 - Aeration requirements, separately for maintenance of membrane flux (air scour) and for carbonaceous and nitrogenous removal

- Membrane flux rate
- Duration of operation between chemical cleanings
- Frequency and duration of backpulse
- Backpulse volume
- Chemical type and concentration (if any) needed in backpulse water
- Chemical cleaning regime, including chemical type(s) and concentration(s) and contact time to ensure maintenance of membrane
- Sludge production rate and characteristics to define and assess proper sludge handling, drying, and disposal
- 6. Evaluate the effect of flow peak testing (hydraulic peaking) on the ZenoGem process. The approach is to initially operate the ZenoGem process at a target SRT of 25 days and a HRT of approximately 6 hours to establish baseline performance. After a predetermined period of operation, the HRT will be decreased to about 4 hours. Following this change, system operation (membrane performance) will be monitored at the new HRT by tracking changes in TMP and permeability.
- 7. Evaluate the effect of intermittent aeration on operational (blower) costs and the ability to concurrently nitrify and denitrify in the ZenoGem process. This task includes cycled aeration to the membrane tank and aeration tank to determine the impacts on operational (blower) costs and biological nitrogen removal, respectively.

4.2 RO Treatment System Tasks

The RO treatment system tasks under Phases II were to:

- 1. Characterize RO permeate quality relative to IPR quality requirements.
- Monitor RO system operating performance as measured by the following:
 - · Feed and permeate conductivity
 - Feedwater recovery
 - Feed pressure
- 3. Assess changes in RO membrane performance caused by fouling of RO membrane and elements and by chemical oxidation of RO membrane surface by monitoring the following parameters:
 - Normalized permeate flow
 - Normalized conductivity passage
 - Normalized vessel differential pressure
- 4. Perform chemical cleanings as required when normalized performance parameters change by a pre-determined amount. Assess the efficiency of one or more chemical cleaning formulations/regimes to restore RO performance losses.

- 5. Confirm RO membrane manufacturer's projections of attainable feedwater recovery and document RO feedwater chemical conditioning requirements to control mineral precipitation.
- 6. Confirm effectiveness of RO feedwater chloramination as a means to control biological fouling of RO membranes.
- 7. Develop information necessary for design of a full-scale RO plant. Design criteria to be developed as part of this task include the following:
 - Feedwater chemical conditioning
 - Feedwater biological monitoring requirements
 - Feedwater disinfection (chloramination)
 - Feedwater pressure
 - Membrane flux
 - Feedwater recovery
 - Membrane composition
 - Cleaning frequency and regime
 - Post-disinfection requirements

4.3 Additional Testing Activities

Prior to and during the operation of the demonstration plant, several additional activities were required and performed, including RO feedwater characterization, IPR characterization of the ZenoGem permeate and RO permeate, RO concentrate/WWTP effluent characterization, and RO integrity testing. These activities are described below.

4.3.1 RO Feedwater Characterization

Prior to testing, three sets of samples of unchlorinated secondary effluent from the South WWTP were collected to characterize the inorganic quality of the feedwater to the RO system. These analyses were required to estimate RO system operating conditions with respect to acid and scale inhibitor dosage and feedwater recovery. The samples were collected on December 14, 16, and 18, 1998, by the plant operating staff and analyzed by the CH2M HILL's Applied Sciences Laboratory (ASL). Results of these analyses were presented and discussed in Section 3.0.

4.3.2 IPR Characterization

The overall goal of IPR is to produce reclaimed water of suitable quality for supplementing McAllen's current raw water supply. Thus, it was desirable to characterize the quality of the raw water supply as part of this study to compare it with quality of reclaimed water produced by MF treatment (ZenoGem permeate) and by RO treatment (RO permeate).

Raw water characterization of McAllen's current raw water supply was conducted during the previous pilot testing. With respect to the demonstration plant, samples of ZenoGem permeate and RO permeate were collected on August 18 and September 14, 1999, respectively, by the plant operating staff and analyzed by ASL. Results of these analyses are presented and discussed in Section 5.0.

4.3.3 RO Concentrate and WWTP Effluent Characterization

RO will produce a waste stream (concentrate) containing elevated levels of most constituents present in the ZenoGem permeate, most notably TDS, TOC, and nutrients. Based on an assumed rejection of 90 percent for these constituents by RO and a feedwater recovery of 80 percent, the concentrate will contain TDS, TOC, and nutrients at four to five times their concentration in the ZenoGem permeate. It is anticipated that the RO concentrate will be disposed of by blending it with that portion of the South WWTP secondary effluent that is not reclaimed for IPR. This secondary effluent discharge point, the Arroyo Colorado, which flows into the Laguna Madre, a marine lagoon. Low freshwater inflows and variable salinity characterize the Arroyo Colorado-Laguna Madre system, which has TDS ranging from 3,000 to 10,000 mg/L. It is anticipated that TDS levels of the concentrate/effluent blend (which will be between 1,200 and 7,500 mg/L) will not adversely impact the ecology of the Arroyo Colorado-Laguna Madre system; however, there is concern that elevated nutrient concentrations in the blend could promote eutrophication and could adversely affect marine ecology.

Samples of WWTP effluent and RO concentrate were collected on August 18 and September 14, 1999, by the plant operating staff and analyzed by ASL and the South WWTP laboratory. The concentrations of the following constituents were measured to: 1) determine the suitability of discharge of the WWTP effluent/RO concentrate blend, and 2) develop requirements for treatment of the RO concentrate to ameliorate any constraints on discharge that are identified:

- TDS (gravimetric)
- TOC
- pH
- Total phosphorus
- Total Kjeldahl nitrogen (TKN)
- Nitrite/nitrate nitrogen

Results of these analyses are presented and discussed in Section 5.0.

4.3.4 RO Integrity Testing

The BOR performed an evaluation of RO element integrity test methods. This evaluation was outside of the scope of CH2M HILL's activities under their agreement with the City; however, activities conducted as part of the BOR's evaluation were closely coordinated with those conducted under this study and were, in large part, conducted by the City's operations staff. Furthermore, the results of the integrity method evaluation should provide useful information for future implementation of indirect potable reuse at McAllen and other locations where RO is used. Development of a field-applied integrity test method for RO elements will provide greater assurance that RO treatment is providing contaminant removal to the degree necessary to protect public health in this reuse context. Results of these analyses are presented in Appendix J.

4.4 Treatment System Monitoring

During the demonstration testing, various performance parameters were monitored to evaluate operation of the treatment systems and the quality of the water fed to and produced by the systems. The parameters that were monitored are presented in the following sections.

4.4.1 Operator Training

The City provided two dedicated operators to supervise, operate, and maintain the demonstration plant during the course of the study. The operators were responsible for, but not limited to, equipment maintenance and operation, including manually recording operational data, saving RO system PLC data, batching chemicals, adjusting chemical addition rates, performing chemical cleanings, collecting routine water quality samples, and recording all demonstration plant activities.

Operating parameters for the systems were monitored daily to evaluate treatment system performance. ZenoGem system operating data were collected from equipment instruments and recorded manually on operations log sheets at least twice daily. RO system operating data were collected by two methods: 1) electronically via a PLC for a specified interval and duration (typically every hour over a 12-hour period), and 2) manually at the end of each operating shift from equipment instruments and panel readouts and recorded on operations log sheets. Method 1 was used for primary data collection; method 2 served as a backup source in the event of difficulties with PLC data downloading. Logbooks for each system were maintained to record all O&M events that occurred during the testing period including, but not limited to, date and time of chemical cleanings; type and amount of chemicals used during cleaning, cleaning temperature, and pH; downtimes; alarms or failures; and changes in any operating conditions.

The operating criteria (targets) were presented in Section 3.0. The actual average operating conditions, along with targets, are presented and discussed in Section 5.0.

4.4.2 Sampling and Analysis

The operators collected water quality samples from each treatment system on a routine basis. The South WWTP laboratory was responsible for performing selected physical/chemical and biological analyses. The WWTP laboratory was also responsible for collecting samples for TOC, chemical oxygen demand (COD), TKN, nitrite/nitrate nitrogen, and total phosphorous, and shipment of these samples to ASL for analyses. The central water laboratory, located at McAllen's Water Treatment Plant No. 1, was responsible for performing microbiological analyses.

Sampling activities commenced on February 8, 1999, for the ZenoGem system and on April 16, 1999, for the RO system. At these times, the operators began routine recording of system operating data and collection of water quality samples for each system. In addition, the water and wastewater treatment plants and ASL began routine sampling analyses. The biological treatment and water quality parameters, sampling location and frequency, and responsible analytical party for each treatment system are presented in Tables 4.1 and 4.2.

TABLE 4.1
Biological Treatment and Water Quality Sampling Schedule for the ZenoGem System

		Loc	Location and Frequency	cy.			
Parameter	ZenoGem Feed	Membrane Tank	Aeration Tank	ZenoGem	Aeration Tank	Sample	Responsible
Physical/Chemical					Waste Sludge	Day(s)	Party
Н	2W	2W	WVC	į			
Temperature*	1/0	<u> </u>	A	2W	NONE	M & W	WWTP
Conductivity	1/D	E N		5	NONE	M.F	OPERATOR
Turbidity	NONE	NONE	ENON CN	\$ \$	NONE	M - F	WWTP
COD	2/M	NONE	NON E	Q/L &	NONE	Α.	WWTP
Total Chlorine	NONE	NONE	NONE	W/Z	1 %	≥	CH2M
Free Chlorine	NONE	NONE	NONE	<u>5</u> ;	NONE	M·F	WWTP
ALK	1/W	NON	NONE NO	Q	NONE	M.F	WWTP
Biological			NOW.	W/L	NONE	Σ	WTP
DO*	1/0	1/0	Ę	!			
OUR	NONE	2W	SW Z	NON FINON	NONE	M - F	OPERATOR
MLSS ^b	NONE	3/W	3/w		NON	M&W	WWTP
MLVSS ^b	NONE	3/W	we.		3We	M,W,F	WWTP
DSVI	NONE	3/W	LINC N	HON A	1W	M or M,W,F	WWTP
CBOD _s ^b	3/W	3/w	3W.	NONE	NONE	M,W,F	WWTP
TSS ^b	3/W	NONE	NONE	aw.	NONE PACIFIC	M,W,F	WWTP
				:	NON NON	M,W,M	WWTP

Biological Treatment and Water Quality Sampling Schedule for the ZenoGem System TABLE 4.1

		Loc	Location and Frequency	٠,			
Parameter	ZenoGem Feed	Membrane Tank	Aeration Tank	ZenoGem Permeate	Aeration Tank Waste Sludge	Sample Day(s)	Responsible Party
NH3-N _p	3/W	NONE	NONE	3/W	NONE	M,W,F	WWTP
TKΝ⁵	1/W	NONE	NONE	1/W	1/W	Σ	CH2M
NO ₂ /NO ₃ -N ^b	1/w	NONE	NONE	1/W	NONE	Σ	CH2M
T Phosphorus	1W	NONE	NONE	1/W	1W	Σ	CH2M
Microbial							
Total Coliform	2W	NONE	NONE	2/W	NONE	M & W	WTP
Fecal Coliform	2W	NONE	NONE	2/W	NONE	M&W	WTP
HPC	NONE	NONE	NONE	2W	NONE	M&W	WTP
*These samples are to be taken at the same time.	taken at the same ti	me.					

Doperator to analyze at sample location.

1/D=once per day 1/W=once per week

2/W=twice per week

3/W=three times per week

2/M=2 times per month

ALK=alkalinity CH2M HILL's Applied Sciences Laboratory (ASL)

DO=dissolved oxygen
DSVI=diluted sludge volume index
MLVSS=mixed liquor volatile suspended solids

OUR=oxygen uptake rate WTP=McAllen's Central Water Treatment Plant Laboratory WWTP=McAllen's South Wastewater Treatment Plant Laboratory

TABLE 4.2
Water Quality Sampling Schedule for the RO System

	Lo	cation and Freque	ency		
Parameter	RO Feed	RO Permeate	RO Concentrate	Sample Day(s)	Responsible Party
Physical/Chemical					
pН	1/W	1/W	1/W	М	WWTP
Conductivity	1/W	1/W	1/W	М	WWTP
Turbidity	1/D	1/D	1/D	M - F	WWTP
SDI ^a	1/D	1/D	NONE	M - F	OPERATOR
TOC ^b	1/D	1/D	NONE	M-F	OPERATOR
тос	2/M	2/M	NONE	М	CH2M
Total Chlorine	1/D	1/D	NONE	M - F	WWTP
Free Chlorine	1/D	1/D	NONE	M - F	WWTP
TDS	1/W	1/W	1/W	М	WWTP
Microbial					
Total Coliform	NONE	2/W	NONE	M & W	WTP
Fecal Coliform	NONE	2/W	NONE	M & W	WTP
HPC	2/W	2/W	NONE	M & W	WTP

^aOperator to analyze at sample location using auto analyzer.

4.5 Data Evaluation

Several of the operating parameters and water quality parameters presented previously were compiled, reduced, and analyzed to evaluate operational, biological, and membrane performance of the treatment systems. Evaluating the flux, TMP, and permeability characterized ZenoGem membrane performance. The primary water quality parameters used to evaluate the effectiveness of the ZenoGem treatment process in producing a high quality RO feedwater were turbidity and SDI. Evaluating the feedwater recovery, normalized product flow (NPF), and the pressure drop across the vessels characterized RO membrane performance.

^bOperator to analyze at sample location using monitor.

^{1/}D=once per day

^{1/}W=once per week

^{2/}W=twice per week

^{2/}M=twice per month

CH2M=CH2M HILL's Applied Sciences Laboratory (ASL)

WWTP=McAllen's South Wastewater Treatment Plant Laboratory

WTP=McAllen's Central Water Treatment Plant Laboratory

4.5.1 Filtrate Flow and Membrane Flux

Membrane flux is directly proportional to the permeate (filtrate) flow rate as shown in the following equation:

Flux [gfd] = Permeate Flow rate[gpm] x 1440 / Membrane Area [ft²]

where [gfd] = gallons per day per ft²

As the filtrate flow rate increases, the membrane flux increases proportionately.

4.5.2 Transmembrane Pressure and Permeability

TMP represents the resistance to flow of water of 1) the membrane, and 2) the materials in the feedwater (foulants) that accumulate at the membrane surface or within the membrane pores. TMP at the start of testing (with a clean membrane) represents only the resistance of the membrane. As foulants accumulate and cannot be effectively removed by backwashing/backpulsing with disinfectant, TMP increases because of the resistance of flow exerted by the foulants. Thus, the rate at which TMP increases is directly proportional to the rate of membrane fouling.

Membrane permeability is inversely proportional to the TMP as shown in the following equation:

Permeability $[gfd/psi] = Flux [gfd]*1.024^{(25-T)}/TMP$ [pounds per square inch (psi)] where T = feedwater temperature, ${}^{\circ}C$

Permeability is a direct measure of the water flow through the membrane fiber and any foulants that have accumulated on the surface or within the membrane pores. The permeability equation includes a temperature correction factor to remove or "normalize for" the effects of changing temperature on membrane permeability. Increases in temperature increase water flow through the membrane because of decreasing viscosity. This effect must be removed to accurately assess changes in permeability with run time.

4.5.3 Turbidity and SDI

Traditionally, the RO membrane manufacturers have established the following as criteria for efficient RO operation:

Turbidity: ≤0.2 NTU

SDI: ≤3 (based on 15-min test interval)

Demonstration Testing Results

This section presents the results of demonstration plant testing. All data collected during the study are presented in Appendix C as follows:

Operating data for ZenoGem System	Table C-1
Water quality data for ZenoGem System	Table C-2
Operating data for RO System	Table C-3
Water quality data for RO System	Table C-4

Results for water quality parameters routinely analyzed by the McAllen water and wastewater laboratories were communicated to CH2M HILL by facsimile on daily or weekly sampling logs. These data, along with CH2M HILL laboratory data, were tabulated and incorporated into Tables C-1 through C-4 in Appendix C.

5.1 Operations

A summary of ZenoGem and RO system operating stages and events is presented in Tables 5.1 and 5.2. Additional details regarding the specific operating stages are discussed below.

TABLE 5.1Operating Stages and Events for the ZenoGem System

Stage	Event	Date(s)	Run Time (hrs)	Duration (hrs)	Description
A		2/6/99	0.00		Start of Testing (MLSS concentration at 13 g/L and OCP Membrane)
В		3/20/99	677.58		OKC Membrane
	1	3/31/99 - 4/1/99	915.58 - 941.00	25.42	Peak Flow Testing (9.5 gpm for 6 hrs over 24-hour period)
С		5/6/99	1783.00		Decrease MLSS Concentration to 10 g/L
	2	6/1/99	2406.08	2.42	Bubble Point Test
	3	8/12/99 - 8/13/99	4129.58 - 4158.33	28.75	Peak Flow Testing (9.5 gpm for 6 hrs over 24-hour period)
	4	8/16/99 - 8/20/99	4225.08 - 4326.25	101.17	Peak Flow Testing (9.5 gpm for 6 hrs over 24-hour period)

TABLE 5.1 CONT.
Operating Stages and Events for the ZenoGem System

Stage	Event	Date(s)	Run Time (hrs)	Duration (hrs)	Description
	5	8/30/99 - 9/1/99	4561.08	51.50	Recovery (Full Tank) Clean
	6	9/14/99 - 9/16/99	4875.91	50.25	Raise Membranes
	7	9/17/99 - 9/27/99	4894.16 - 5136.25	242.09	Cycled Aeration to the Membrane Tank (10 sec on/off)
	8	9/27/99 - 9/29/99	5136.25 - 5186.91	50.66	Peak Flow Testing without Cycled Aeration
D		10/4/99	5303.41		Decrease MLSS Concentration to 6 g/L
	9	10/7/99 - 10/8/99	5328.75 - 5352.50	23.75	Cycled Aeration to the Membrane Tank (10 sec on/off)
	10	10/8/99 - 10/13/99	5352.50 - 5476.00	123.50	Peak Flow Testing with Cycled Aeration to Membrane Tank
	11	10/14/99 - 10/19/99	5476.00 - 5615.66	139.66	Normal Flow with Cycled Aeration to Membrane Tank
	12	10/19/99 - 11/2/99	5615.66 - 5948.25	332.59	Normal Flow with Cycled Aeration to Both Tanks (Aeration Tank at 15 mir on/off)
	13	11/2/99	5948.25		End of Testing

TABLE 5.2Operating Stages and Events for the RO System

Stage	Event	Date(s)	Run Time (hrs)	Duration (hrs)	Description
	·	4/21/99	0.00	<u> </u>	Startup
В		5/19/99	0.00		Start of Testing (Target Feed pH = 6.8)
	1	5/24/99 - 5/25/99	114.89 - 147.69	32.80	1st Cleaning (Citric Acid:Stages 1 and 2)
	2	5/30/99	256.41		Decrease Recovery to 50%
	3	6/1/99 - 6/2/99	305.9 - 328.42	22.52	2nd Cleaning (Citric Acid:Stages 1 and 2)
	4	6/8/99 - 6/10/99	475.88 - 526.38	50.50	3rd Cleaning (Citric Acid:Stages 1 and 2 followed by Caustic:Stage 1)
С		6/11/99	544.50		Decrease Recovery to 50% (Stage 2 Removed from Service)
D		7/7/99	1176.51		Stage 2 Returned to Service (50% Recovery)

TABLE 5.2 CONT.

Operating Stages and Events for the RO System

Stage E	ent	Date(s)	Run Time (hrs)	Duration (hrs)	Description
	5	7/8/99	1196.78		Increase Recovery to 60%; Decrease Feed pH to 6.5
	6	7/9/99	1208.73		Increase Recovery to 70%; Decrease Feed pH to 6.0
	7	7/22/99	1532.92		Set Target pH to Concentrate pH = 5.6 (Feedwater pH = 5.0)
	8	7/24/99 - 7/27/99	1578.67 - 1650.27	71.60	4th Cleaning (Citric Acid:Stages 1 and 2)
	9	8/10/99	1985.17		Increase Recovery to 75%
	10	8/30/99 - 9/1/99	2464.77- 2519.55	54.78	Unit Down due to ZenoGem System Recovery (Full Tank) Clean
	11	9/2/99 - 9/8/99	2543.79 - 2687.50	143.71	5th Cleaning (Citric Acid:Stages 1 and 2); Acid Pump Failure
•	12	9/14/99 - 9/16/99	2830.65 - 2880.25	49.60	Unit Down due to Raising ZenoGem System Membranes
•	13	9/23/99	3041.97		Increase Recovery to 80%
-	14	10/4/99 - 10/6/99	3308.51 - 3359.81	51.30	Unit Down due to Decreasing ZenoGem System MLSS
1	15	10/8/99	3399.11		End of Routine Testing
1	16	10/21/99	3715.41		End of Special Testing

5.1.1 Startup Activities

ZenoGem Equipment Commissioning. ZENON field service technicians arrived at the plant site on January 11, 1999, and performed commissioning of the ZenoGem system through February 6, 1999. ZenoGem system commissioning included equipment installation; membrane bubble point and clean water flux testing; introduction and concentration of mixed liquor in the bioreactor tank; and operation on SDS to establish steady-state biological treatment (carbonaceous and nitrogenous oxidation) and membrane treatment. Operational activities included establishing target MLSS concentrations in both the membrane (process) and aeration tanks; air flow rates and dissolved oxygen (DO) levels in both tanks; solids recirculation rate between tanks; and membrane permeate flow (flux) rate. The ZenoGem system achieved steady-state operation on March 22, 1999.

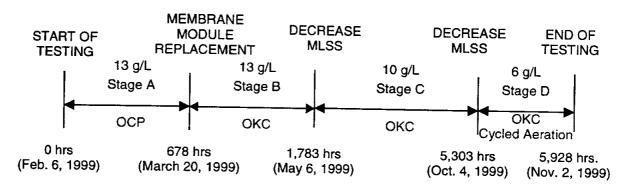
RO Equipment Commissioning. BOR project managers performed commissioning of the RO system during two site visits on February 2 through February 12, 1999, and on March 15 through March 19, 1999. During the first visit, RO system commissioning included installation of plumbing and electrical connections; delivery and storage of chemicals; modifications to the computer recording system; PLC programming; and installation of temporary membranes. During the second visit, additional RO system commissioning

included instrument calibration; SDI auto analyzer installation; system cleaning and disinfection; installation of permanent membranes and integrity tests. At that time, the RO system was scheduled for startup on March 22, 1999, coincident with steady-state operation of ZenoGem system. However, due to ZenoGem system special testing, replacement of defective chloramine metering pump parts, difficulties in attaining stable and effective chloramine stock solutions and residuals, combined with minor RO equipment problems, RO system start of testing was delayed until April 21, 1999.

5.1.2 Operating Stages

ZenoGem System. The ZenoGem operating period has been divided into four separate operating stages as shown in Exhibit 5.1. The ZenoGem operating stages were as follows:

EXHIBIT 5.1 ZenoGem Operating Stages



Stage A represents the start of testing using the OCP UF membrane and a target MLSS concentration of 13 g/L. During this stage, the aeration and membrane tanks were seeded with activated sludge from the WWTP and MLSS levels increased step-wise to the target level. The system accumulated 321 operating hours out of a possible 678 available hours, for an online factor of 0.47 (47 percent). This online factor includes two separate periods when the system was offline due to failure and subsequent replacement of the recirculation pump impeller, feedwater inlet level sensor replacement, and membrane module replacement.

The originally supplied membrane module, which used the OCP membrane, has recently been classified by ZENON as their drinking water membrane and is marketed primarily as an UF membrane for the treatment of natural raw water supplies to produce potable water. This membrane, which has a nominal pore size of 0.035 microns, has been found to have flux limitations when operated on high MLSS wastewaters and consequently is being phased out by ZENON in favor of the OKC MF membrane for wastewater treatment. The OKC membrane is more porous, with a nominal pore size of 0.4 microns. Initial in-house testing by ZENON showed the OKC membrane to operate at higher permeability and to benefit from a lower rate of fouling on wastewater, particularly when operating at peak loading conditions. Consequently, it was decided jointly by ZENON and CH2M HILL that the OKC membrane would be better suited for the

McAllen IPR application. After the OCP module was replaced with a new OKC module, the permeate flow rate was slowly increased to the target 6.5 gpm.

Stage B represents the period of operation using the OKC module and a target MLSS concentration of 13 g/L. During this stage, the system accumulated 1,077 operating hours out of a possible 1,105 available hours, for an online factor of 0.97 (97 percent). This online factor includes a short period of time when the system was offline due to replacement of a valve in the aeration tank. A single-day peak flow test was conducted during the latter part of this stage.

Stage C represents the period of operation at a target MLSS concentration of 10~g/L. During this stage, the system accumulated 3,416 operating hours out of a possible 3,520 available hours, for an online factor of 0.97 (97 percent). This online factor includes three separate periods when the system was offline due to bubble point testing, clean water flux testing/full tank soaking, and to raise the module height (in the membrane tank). During this stage, peak flow testing continued and cycled aeration (to the membrane tank only) was initiated.

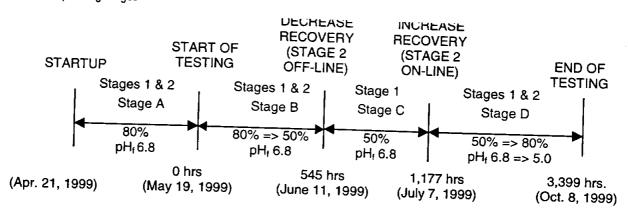
The target MLSS concentration was decreased from an initial target of 13 g/L to 10 g/L after 1,783 total available hours of operation following detailed discussions with ZENON technical personnel. Based on ZENON experience, lowering the MLSS concentration to 10 g/L provides for improved operability (lower membrane fouling) and more stable biological treatment. As discussed later in this section, MLSS reduction also improved oxygen transfer from the bulk fluid to the biomass, thereby improving nitrification efficiency and decreasing the degree of denitrification. Consequently, it was decided jointly by ZENON and CH2M HILL that the decrease in MLSS concentration would be preferred for the McAllen indirect potable reuse application.

Stage D represents the period of operation at a target MLSS concentration of 6 g/L. During this stage, the system accumulated 596 operating hours out of a possible 645 available hours, for an online factor of 0.92 (92 percent). This online factor includes a short period of time when the system was offline to decrease the MLSS concentration (i.e., wasting half the aeration tank volume) and subsequent aeration-only operation to reestablish proper biomass condition. Peak flow testing continued and cyclic aeration to the membrane and aeration tanks was also initiated during this stage.

The MLSS concentration was decreased from 10 g/L to 6 g/L after 5,303 total available hours of operation following detailed discussions with ZENON technical personnel. ZENON indicated that maintenance of stable membrane permeability during flow peaking would most likely depend on sludge filterability characteristics as indicated by the sludge capillary suction time (CST). Sludges with high CSTs are viscous and difficult to filter. The sludge generated in the ZenoGem process had a high CST (exceeding 100 seconds). ZENON indicated that for such sludge, reducing the MLSS concentration reduces the resistance to filtration and would maximize permeability during flow peak peaking. Consequently, it was decided jointly by ZENON and CH2M HILL to perform peak flow tests at a lower MLSS concentration in order to demonstrate maximum performance.

RO System. The RO operating period has been divided into four separate operating stages, as shown in Exhibit 5.2. Since the hour meter on the system was not functional, the online factor for each stage of operation was approximated by system downtimes recorded by the operators. The first two RO operating stages were as follows:

EXHIBIT 5.2 RO Operating Stages



Stage A represents the period of operation from startup to the actual start of steady state testing (commissioning phase). During this stage, the system was off line approximately 70 percent of the time due to numerous downtimes associated with PLC reprogramming and tuning to optimize control of feedwater flow and pH; failure and subsequent replacement of the scale inhibitor feed pump; de-commissioning of automatic sampling valves; and troubleshooting acid feed pump loss of prime. Data collected during this phase was considered representative of continued startup activities and system troubleshooting. By May 19, the system was successfully online, and the actual start of steady state testing was achieved.

Stage B represents the period of operation at a target recovery of 80 percent. During this 545-hour stage, the system was off line approximately 19 percent of the time due to three RO membrane cleanings and maintaining target pH.

RO Feedwater Pretreatment to Control Membrane Fouling. RO membrane elements are subject to fouling during extended operation caused by both suspended and sparingly soluble salts. Suspended matter includes organic and inorganic colloids and microorganisms. Sparingly soluble salts, such as carbonates, sulfates, and silica, can precipitate from solution as the RO process concentrates them. Suspended particles accumulate on the membrane surface causing biofouling and colloidal fouling, and they can block feed channels thereby increasing the pressure drop across the system. These phenomenon reduce water permeability through the RO membranes causing flux decline and increased salt passage. The nature and rapidity of fouling depends on the condition of the feedwater. Fouling is progressive, and, if not controlled early, can impair the RO system performance in a relatively short time. For these reasons, fouling must be controlled.

Particulate fouling is addressed through the use of the ZeeWeed MF membrane. Chloramines were batched and dosed into the RO feedwater at a target dose of 1 to 2 mg/L to prevent biological growth (biofouling) of the RO elements. As described in an

earlier section, mineral precipitation is controlled through a combination of acidification and scale inhibitor addition. The last two RO operating stages are described below.

Stage C represents the period of operation at a target recovery of 50 percent (operating first stage vessels only) to demonstrate that performance losses observed in Stage B resulted from mineral precipitation (as opposed to particulate or colloidal fouling). During this 632-hour stage, the system was online 100 percent of the time.

Stage D represents the period of operation at recovery of 50 to 80 percent (operating first and second stage vessels) and acidification of the concentrate stream to a reduced feedwater pH of 5.0 (concentrate target pH of 5.6) to control calcium phosphate and calcium carbonate precipitation. During this 2,222-hour stage, the system was off line approximately 10 percent of the time due to two RO membrane cleanings. It excludes three downtimes associated with ZenoGem full tank soaking, raising module height, and decreasing the MLSS concentration.

5.2 ZenoGem Testing Results

5.2.1 ZenoGem Operating Conditions

Table 5.3 presents the target and average operating conditions for the ZenoGem system during Stage A operation. The system operated at a target MLSS concentration of 13 g/L using the OCP UF membrane. After 678 hours of startup activities, the membrane was replaced with the OKC MF membrane.

TABLE 5.3
Stage A Average Operating Conditions for the ZenoGem System

Parameter	Target ^a	Normal Flow	
Aeration Tank Air (scfm)	> 45	48	
Backpulse Duration (sec)	15	15	
Backpulse Frequency (min)	10	10	
Biomass Recirculation Rate (gpm)	> 36	26.2	
Flux (gfd)	18.7	17.3	
Membrane Tank Air (scfm)	25	25	
Normalized Permeability (gfd/psi)	5	20.8	
Permeate Flowrate before Backpulse (gpm)	6.5	6.0	
Permeate Flowrate after Backpulse (gpm)		6.0	
Temperature (degrees C)		26.2	
TMP (psi)	2.5 - 8.5	1.34	
Vacuum before Backpulse (in Hg)	5.1 - 17.3	2.73	
Vacuum after Backpulse (in Hg)		2.57	

^aWhere target left blank, no target was established.

^bValues calculated when permeate flowrate reached 6 gpm.

Table 5.4 presents the target and average operating conditions for the ZenoGem system during Stage B operation. The system continued to operate at a target MLSS concentration of 13 g/L during this stage. After 916 hours of operation (Event 1), the permeate flowrate was increased for 25 hours to determine the short-term impact of higher membrane loading on permeability and TMP.

TABLE 5.4
Stage B Average Operating Conditions for the ZenoGem System

Parameter	Target ^a	Normal Flow	Peak Flow (Event 1)	
Aeration Tank Air (scfm)	> 45	43	42	
Backpulse Duration (sec)	15	15	15	
Backpulse Frequency (min)	10	10	10	
Biomass Recirculation Rate (gpm)	> 36	38.3	39.5	
Flux (gfd)	18.7/27.3 ^b	18.5	27.3	
Membrane Tank Air (scfm)	25	25	25	
Normalized Permeability (gfd/psi)	5	17.82	13.19	
Permeate Flowrate before Backpulse (gpm)	6.5/9.5 ^b	6.40	9.50	
Permeate Flowrate after Backpulse (gpm)		6.40	9.50	
Temperature (degrees C)		28	25.8	
FMP (psi)	2.5 - 8.5	1.2	2.1	
/acuum before Backpulse (in Hg)	5.1 - 17.3	2.66	4.17	
/acuum after Backpulse (in Hg)		2.59	4.12	

Where target left blank, no target was established.

Table 5.5 presents the target and average operating conditions for the ZenoGem system during Stage C operation. At the beginning of this stage (after 1,783 hours of operation), the MLSS concentration was decreased to 10 g/L. From 4,130 to 4,158 hours (Event 3) and from 4,225 and 4,326 hours (Event 4) of operation, the permeate flow rate was increased by 46 percent (6.5 to 9.5 gpm) for a period of 6 hours (flow peaking) over a 24-hour period to simulate the types of hydraulic peak loading that typically occur in a conventional WWTP. This was done to determine if the MBR system could be operational in the same manner or if additional means would be required to ensure slower changes in loading to the system. After 4,876 hours of operation, the membrane module height was raised (Event 6) to minimize sludge accumulation on the module aerators during non-aeration periods. From 4,894 to 5,136 hours (Event 7) of operation, air was cycled to the membrane tank at an applied rate of 30 scfm for 10 seconds on and 10 seconds off to evaluate the effect of intermittent aeration on operations and membrane performance. From 5,136 to 5,187 hours (Event 8) of operation, flux peaking was conducted without intermittent aeration to the membrane tank.

^bTarget value during flow peaking.

TABLE 5.5 Stage C Average Operating Conditions for the ZenoGem System

		Normai	Peak Flow	Normal Flow with Cycled Aeration to Membrane Tank Only (Event 7)	
Parameter	Target ^a	Flow	(Events 3,4,8)		
Aeration Tank Air (scfm)	> 45	59	61	63	
Backpulse Duration (sec)	15	15	15		
Backpulse Frequency (min)	10	10	10	15 10	
Biomass Recirculation Rate (gpm)	> 36	48.2	47.5		
Flux (gfd)	18.7/27.3 ^b	18.7	26.6	44.6	
Membrane Tank Air (scfm)	25/30°	25	25.0	18.7	
Normalized Permeability (gfd/psi)	5	6.61	3.05	31	
Permeate Flowrate before Backpulse (gpm)	6.5/9.5 ^b	6.50		8.67	
Permeate Flowrate after Backpulse (gpm)	313.313		9.20	6.50	
Temperature (degrees C)		6.70	11.10	7.10	
·		31.2	31.9	30.3	
ΓMP (psi)	2.5 - 8.5	2.8	7.5	2.4	
/acuum before Backpulse (in Hg)	5.1 - 17.3	5.70	15.30	4.90	
/acuum after Backpulse (in Hg) Where target left blank, no target was establi		5.10	15.90	4.10	

^aWhere target left blank, no target was established.

^bTarget value during flow peaking.

Per discussions with ZENON, cycled aeration operation to the membrane tank was planned at 10 seconds on and 10 seconds off. However, a cycle time of 15 seconds on and 15 seconds off was implemented at the site due to communication and programming error between ZENON and the demonstration plant operators. ZENON Corporate Technology tested a number of different air cycle times at other pilot locations and concluded that 10 seconds off is the maximum allowable period before a decline in permeability is observed. Longer air OFF periods allow the mixed liquor solids to accumulate in the fiber bundle and are not subsequently removed by the air pulse during the ON cycle. Thus, the error in cycle time implemented is significant enough to cause the permeability decline observed during cycled aeration events as discussed in Section 5.2.2.

^cApplied rate increased to 30 cubic feet per minute (cfm) during intermittent aeration.

Table 5.6 presents the target and average operating conditions for the ZenoGem system during Stage D operation. At the beginning of this stage (after 5,303 hours of operation), the MLSS concentration was decreased to 6 g/L. From 5,329 to 5,353 hours (Event 9) of operation, air was again cycled to the membrane tank. From 5,353 to 5,476 hours (Event 10) of operation, flux peaking was conducted; however this time with intermittent aeration to the membrane tank. From 5,476 to 5,616 hours (Event 11) of operation, the flowrate was reduced to normal conditions and air continued to cycle to the membrane tank. From 5,616 hours to the end of testing (Event 12), air was cycled to the aeration tank at an applied rate of 45 scfm for 15 minutes on and 15 minutes off to evaluate the effect of intermittent aeration on biological treatment performance (i.e., to concurrently nitrify and denitrify).

TABLE 5.6 Stage D (Alternative Operating Mode) Average Operating Conditions for the ZenoGem System

•		Normal	Normal Flow with Cycled Aeration to Membrane Tank Only	Peak Flow with Cycled Aeration to Membrane Tank Only	Normal Flow with Cycled Aeration to Membrane Tank Only	Normal Flow with Cycled Aeration to Membrane and Aeration Tanks
Parameter	Target ^a	Flow	(Event 9)	(Event 10)	(Event 11)	(Event 12)
Aeration Tank Air (scfm)	> 45	65	66	64	66	65
Backpulse Duration (sec)	15	15	15	15	15	
Backpulse Frequency (min)	10	10	10	10	10	15
Biomass Recirculation Rate (gpm)	> 36	47.3	48.0	47.0	46.2	10 43.1
Flux (gfd)	18.7/27.3 ^b	18.7	18.7	27.3	40 =	
Membrane Tank Air (scfm)	25/30°	25	32	32	18.7	18.7
Normalized Permeability (gfd/psi)	5	7.27	7.52	3.25	32 3.86	32 3.42
Permeate Flowrate before Backpulse (gpm)	6.5/9.5 ^b	6.50	6.50	9.5	6.50	6.50
Permeate Flowrate after Backpulse (gpm)		6.90	6.70	11.50	6.90	6.90
Temperature (degrees C)		30.3	30.0	21.6		
MP (psi)	2.5 - 8.5	2.39	2.2	31.6	29.0	26.4
acuum before Backpulse	5.1 - 17.3	4.90		7.37	4.5	5.7
in Hg)	0.1 17.0	7.30	4.50	15.0	9.10	11.50
acuum after Backpulse n Hg) Where target left blank, no ta		4.30	4.60	16.30	8.20	10.50

^aWhere target left blank, no target was established.

Target value during flow peaking.

^oApplied rate increased to 30 cfm during intermittent aeration.

5.2.2 ZeeWeed Membrane Performance

Permeate Flow and Membrane Flux. Figure 5.1 illustrates changes in ZenoGem permeate flow and flux as a function of operating time. During Stage A (prior to membrane replacement), flow and flux were increased in step-wise increments to "condition" the membrane fibers to the mixed liquor. This was done to prevent the fibers from becoming fouled. Permeate flow was held constant during Stages B through D except for five events:

- Event 1: Flow increased for 25 hours to determine the short-term impact of higher membrane loading on permeability and TMP; and
- Events 3, 4, 8 and 10: Flow increased by 46 percent (6.5 to 9.5 gpm) for a period of 6 hours (flow peaking) over a 24-hour period to simulate WWTP peak hydraulic loading.

The increases caused a corresponding increase in TMP and decrease in permeability; however both changes were reversed once the flow was decreased to the target level. Thus, the temporary flux increase caused only reversible membrane fouling and flow peaking for short (one-day) periods of time can occur in response to actual WWTP loading without causing a permanent increase in fouling.

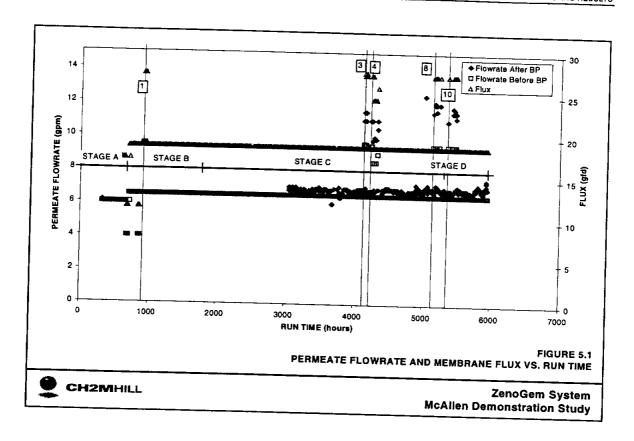
Transmembrane Pressure. Figure 5.2 illustrates changes in ZenoGem TMP as a function of operating time (permeate flow is also shown for reference).

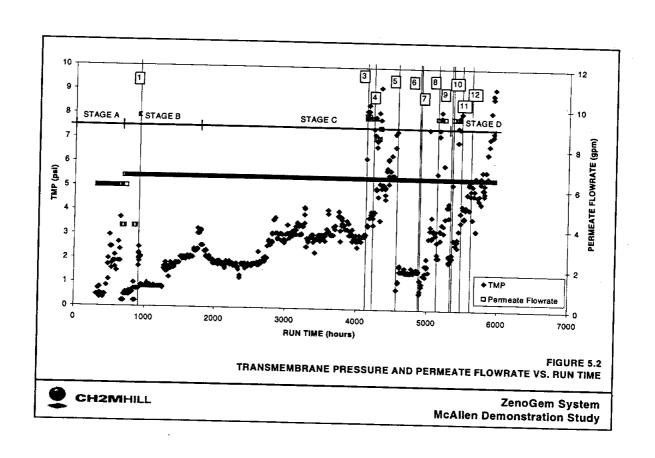
Stage A. TMP increased gradually as permeate flow was increased to the target value. The sharp decline in TMP that occurred at 653 hours was caused by continuous aeration of the module during the 12-day period when the ZenoGem system was offline due to recirculation pump failure and replacement. Continuous aeration in the absence of permeation was very effective in reducing membrane fouling.

Stage B. During the latter part of Stage B, TMP steadily increased even when permeate flowrate (and membrane flux) were held constant. This increase in TMP clearly indicates that membrane fouling was occurring at the higher MLSS concentration. The short-term flow peaking during Stage B (Event 1) caused a temporary increase in TMP that was reversed once flux was reduced.

Stage C. During operation at intermediate (10 g/L) MLSS concentration, TMP first decreased and then increased very gradually over a 1,000-hour period, indicating: 1) a very low rate of fouling, and 2) maintenance cleans were more effective in controlling fouling at the lower MLSS concentration. The step increase in TMP at ~2,700 hours was caused by a temporary loss of air scour in the membrane tank. Flow peaking during Stage C (Events 3 and 4) resulted in a more rapid rate of TMP increase, demonstrating that flow peaking of the membrane on a daily basis over an extended operating period caused a significant increase in fouling rate at the lower MLSS concentration. TMP increased to the maximum value (8 psi) which required a recovery (full tank) clean (Event 5) to reduce TMP to clean membrane levels (0.8 psi). At the end of Stage C, TMP rapidly increased when air was cycled to the membrane tank (Event 7) and again during flow peaking without cycled aeration (Event 8).

Stage D. During this stage, the impact of both flow peaking and cycled (intermittent) aeration was evaluated at low (6 g/L) MLSS concentration. The data in Figure 5.2 shows TMP increases were rapid when flow peaking and cycled aeration was practiced, consistent with flow peaking effect observed in Stage C. The impact of cycled aeration alone (no flow peaking) is more difficult to ascertain. TMP rise rate following Event 11 and the first part of Event 12 was low, but increased rapidly near the end of testing. The latter effect may be the result of operation at high TMP levels (significant fouling present) rather than from intermittent aeration. Future testing using intermittent aeration should be conducted with a clean membrane to more clearly determine its impact on membrane fouling. It should be noted that during flow peaking events, the vacuum after backpulsing was slightly higher than before backpulsing. This indicates that backpulsing had little effect in reducing the TMP (or increasing permeability) during flow peaking. During normal flow operation, post-backpulse TMP was always less than pre-backpulse values.



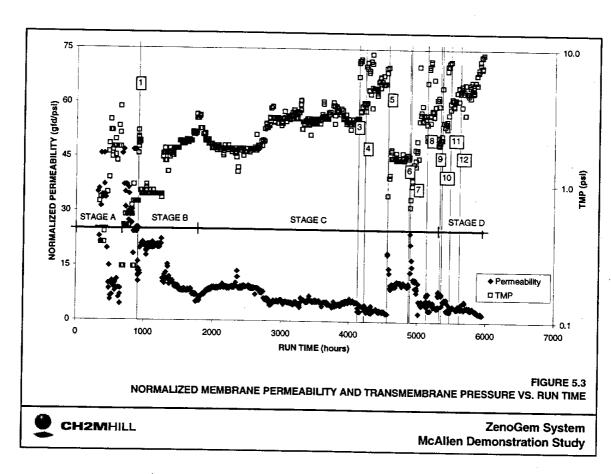


Permeability.

Stages A – C. Figure 5.3 illustrates changes in ZenoGem permeability as a function of operating time (TMP is also shown for reference). During Stage B, permeability (normalized to 20°C) steadily decreased as TMP increased, indicating membrane fouling at the higher MLSS concentration of 13 g/L. In contrast, at the lower MLSS concentration in Stage C, permeability increased and remained relatively constant as TMP very gradually increased. However during the flow peaking test periods (Events 3, 4 and 8), permeability sharply decreased as TMP increased. This showed that the MBR system must be provided with a means of ensuring slow changes in peak loading. The peak loading cannot be raised as quickly over a 24-hour period as in a conventional WWTP. These results also confirm that ZenoGem operation at 10 g/L MLSS concentration and constant flux provides for very stable system operation.

Following raising of the membrane module and subsequent aeration of the membrane tank without operation of the permeate pump (no permeation), permeability decreased (Event 7). Subsequent operation with cycled aeration to the membrane tank produced a rapid and significant decrease in permeability.

Stage D. Operation under conditions of cycled aeration and/or flow peaking generally caused more rapid declines in permeability than operation at normal (steady) flow and continuous aeration, consistent with results under similar conditions during Stage C. This performance indicates that cycled aeration is less effective than continuous aeration in controlling foulant accumulation.



5.2.3 ZenoGem Biological Treatment Performance

Table 5.7 presents the average conditions within the ZenoGem bioreactor (volume weighted composite of the aeration and membrane tanks) during each stage of operation.

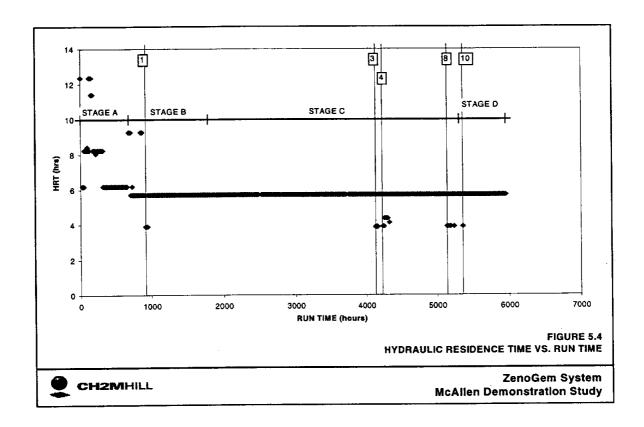
TABLE 5.7 Results of Biological Treatment Performance Analyses for the ZenoGern System

Parameter	Target ^a	Stage A	Stage B	Stage C	Stage [
DO (mg/L)	> 1.5	2.78	1.53	2.00	3.19
OUR (mg O ₂ /L-min)	1.0 - 1.5			0.87	1.34
MLSS (mg/L)	13,000 (Stage A & B) 10,000 (Stage C) 6,000 (Stage D)	11,454	14,070	10,634	6,661
MLVSS (mg/L)		8,339	10,243	7,655	4,873
Sludge Wasted Daily (gals)	90 (Stage A & B) 110 (Stage C) 150 (Stage D)	96	131	114	182
Sludge Yield		1.27	1.50	1.14	2.03
HRT (hrs)	5.7/3.9 ^b	6.2	5.8/3.9 ^b	5.7/4.0 ^b	5.7/3.9 ^b
System SRT (days)	25 (Stage A & B) ^c 20 (Stage C) ^c 15 (Stage D) ^c	21.29	16.79	19.25	14.04

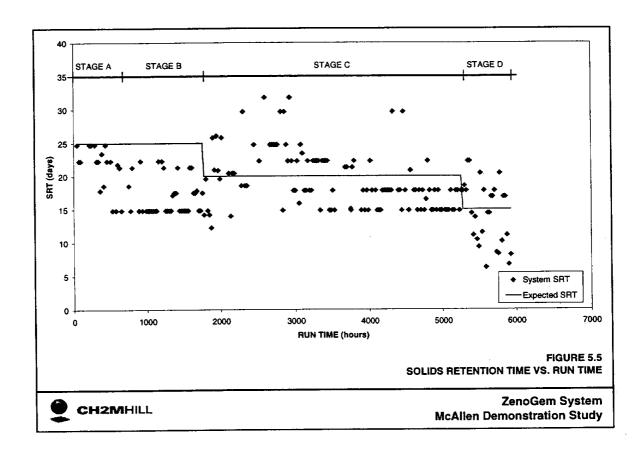
^aWhere target left blank, no target was established.

bValue during flow peaking.
Expected value based on control variables.

Hydraulic Residence Time. Figure 5.4 presents the HRT for the ZenoGem bioreactor. The average HRT for Stage A was slightly higher than the target range due to the step-wise increase in permeate flow to the target value of 6.5 gpm. HRT was held constant and near the target range during subsequent stages, except during flow peaking (Events 1, 3, 4, 8 and 10) when the HRT dropped by 32 percent (from 5.7 hrs at 6.5 gpm down to 3.9 hours at 9.5 gpm). A 6.5-hour HRT was selected to ensure sufficient retention time to achieve complete nitrification based on prior testing at McAllen and other locations. This compares with a HRT of 30 hours for the McAllen WWTP (3 to 4 g/L MLSS) and reflects the greater biochemical oxidation efficiency at the higher MLSS levels.



Solids Retention Time. Figure 5.5 presents the SRT for the ZenoGem bioreactor. The average SRTs were near expected values during each stage, except for Stage B. A higher SRT would be expected for Stage B (versus Stage C) given that the MLSS concentration in the bioreactor was higher and loadings were similar. A lower SRT during Stage B resulted from excess sludge wasting (average 150 gpd compared to the target 110 gpd) in an effort to maintain the target MLSS concentration of 13 g/L. The ZenoGem process has the capability to be operated at a longer SRT (15 to 25 days) than the McAllen WWTP (15 days) because it is not limited by sludge settleability that limits the maximum MLSS concentration that can be accumulated in the system when using clarifiers rather than membranes for biomass retention.

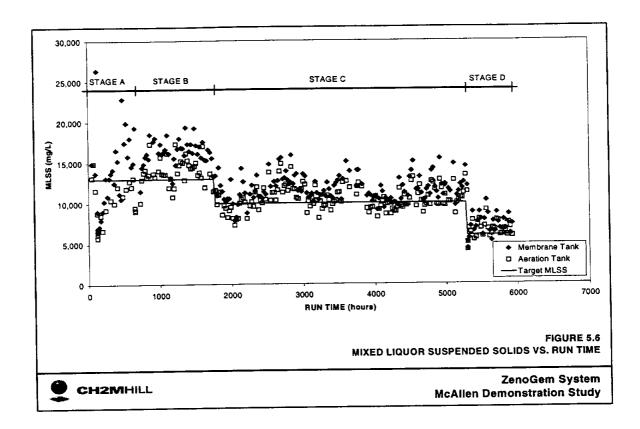


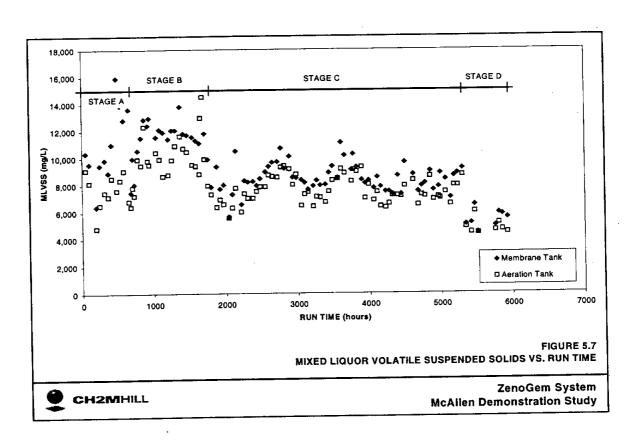
Mixed Liquor Suspended and Volatile Suspended Solids. The McAllen WWTP and the ZenoGem system both use the suspended growth process (activated sludge) to achieve biological treatment. Removal of carbonaceous organic matter in a suspended growth process is directly dependent on the concentration of biomass present in the mixed liquor (activated sludge). Biomass levels can be roughly estimated by measuring the concentration of either the MLVSS or MLSS in the treatment reactor. The latter is more practical for maintaining proper bacterial levels because it is an easier and more rapid method. MLVSS is a more accurate measure of bacterial content because it excludes some of the inert fraction of the suspended solids, however it requires an additional drying and weighing step, which adds time and effort.

MLSS and MLVSS levels measured in the ZenoGem membrane (bioreactor) and aeration tanks are shown in Figures 5.6 and 5.7. The concentration of both parameters should be the same in both tanks under ideal conditions (infinite sludge recirculation rate and exact sludge wasting rates). The average MLSS concentrations in the tanks were at or near target values during each stage. Lower MLSS concentrations in Stage A are representative of startup operations (seeding and MLSS concentration increase to steady-state conditions). Higher than planned MLSS concentrations in Stage B resulted in greater sludge wasting volumes and higher sludge yields. The most common range of MLVSS values for conventional air activated sludge systems is 2,000 to 2,500 mg/L (WEF, 1991). Although air based conventional systems can operate at somewhat higher MLVSS level (up to 3,000 mg/L in practice), sludge settleability decreases as MLSS levels decrease. Settleability is not an issue for the ZenoGem process because separation is not dependent on gravity settling but rather on membrane filtration. However, sludge dewatering characteristics are important as they directly impact observed membrane permeability.

The significance of the greater MLVSS levels is that the ability to remove CBOD5 is directly proportional to bacterial density in the activated sludge tank (or bioreactor). By maintaining higher MLVSS concentrations, the ZenoGem process can attain comparable reduction in CBOD5 at a much lower hydraulic retention time. This is clearly illustrated in Table 5.7, where the average HRT for ZenoGem is about 6 hours versus 30 hours for the WWTP. In fact, as discussed in the following section, CBOD5 removal efficiency was slightly better for the ZenoGem system. In other words, the same, or even greater, degree of treatment can be accomplished in roughly one-fifth of the time or volume used by the extended aeration process used at McAllen. Assuming similar depths for an aeration basin and ZenoGem bioreactor, the tankage area of the ZenoGem process would require only 20 percent of the land area required for the extended aeration basins. It should be noted, however, that it is possible that acceptable treatment could have been achieved in the full-scale McAllen WWTP if another activated sludge process was used.

The average ratio of MLVSS to MLSS for the ZenoGem process was 0.73. This is at the lower end of the typical range (0.7 to 0.9) and reflects the absence of a primary sedimentation step ahead of the ZenoGem process to settle and reduce inerts.



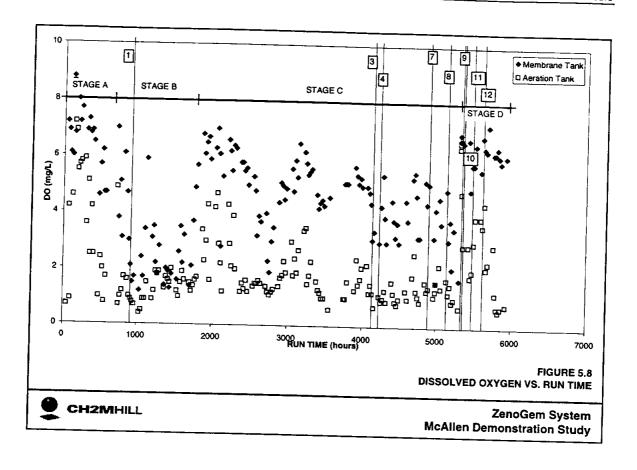


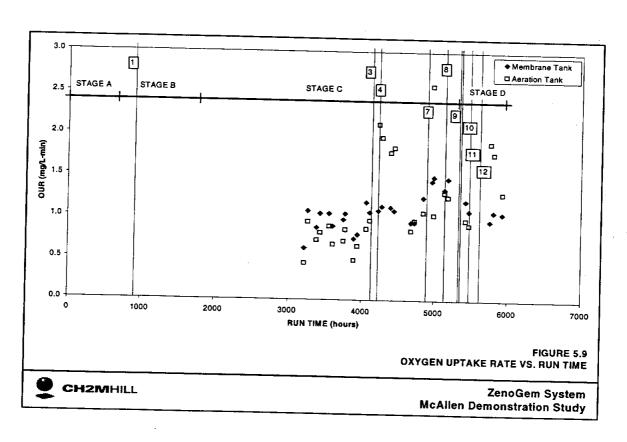
Dissolved Oxygen. Proper DO levels must be maintained in the activated sludge process to enable efficient degradation of both carbonaceous organic matter and organic nitrogen. Generally, DO levels in the activated sludge process should be maintained around 2.0 mg/L or greater to ensure that sufficient oxygen is present to achieve effective BOD₅ removal and nitrification (WEF, 1990). Lower levels will impede nitrification. DO levels of 1.5 mg/L or greater were targeted for the ZenoGem system.

DO levels in the membrane and aeration tanks are presented in Figure 5.8. DO levels were considerably higher than planned during Stage A as the air flowrate was optimized. Lower DO levels in the aeration tank than the membrane tank (38 to 58 percent lower throughout the study) resulted from inadequate air supply. Low DO levels in both tanks during Stage B resulted from high oxygen demand due to high BOD and TSS loading in the feedwater and to the higher MLSS concentration. Periodic increases in the ammonia content of the feedwater resulted in low DO levels during the other stages due to the increased oxygen demand required for nitrification.

Oxygen Uptake Rate. OURs in the membrane and aeration tanks are presented in Figure 5.9. OUR values were less than target from startup to the middle of Stage C due to error in the analytical method used. Samples were held for several hours prior to analysis (rather than being performed immediately), thereby decreasing oxygen uptake potential. After 3,216 hours of operation, OUR analysis was performed correctly and OUR values increased significantly.

Sludge Yield. Sludge yield coefficient, *Y*, is a measure of the amount of biological solids produced by a wastewater treatment process relative to the amount of organic matter removed. Ideally, the sludge yield should be as low as possible to minimize the need to dispose of sludge. For the extended aeration process used at the WWTP, *Y* is typically low because the microorganisms in the activated sludge operate in the endogenous phase based on the long mean SRT for this type of system (15 days). *Y* values for the ZenoGem system should be somewhat lower than the WWTP because the ZenoGem system operated at slightly higher SRTs; however this was not the case. The average sludge yield for the ZenoGem process ranged from 1.14 to 2.03 grams of sludge produced per gram of CBOD₅ removed. Based on the data available from the McAllen WWTP control logs, sludge yield for the McAllen WWTP was 0.73.





5.2.4 ZenoGem Water Quality Impacts

Several water quality parameters were measured to monitor the effectiveness of ZenoGem biological treatment and membrane filtration in improving wastewater quality. Table 5.8 presents the results of water quality analyses of the ZenoGem feed (SDS) and permeate during Stages A and B. The system operated at constant flow/flux during both stages, except for a brief 25-hour flow peaking period at the end of Stage B.

TABLE 5.8
Results of Stages A and B Water Quality Analyses for the ZenoGem System

Danas			,	···	Sta	ge B	
Parameter		St	age A	Norn	nal Flow	Peak Flo	w (Event 1)
Physical/Chemical	Permeate Target ^a	Feed	Permeate	Feed	Permeate	Feed	Permeate
pΗ		7.23	7.33	7.22	7.59	7.12	7.58
Temperature (degrees C)		25.6	26.3	27.1	28.2	26.0	
Turbidity (NTU)	< 0.2		0.17		0.24	20.0	26.5
Conductivity (µS/cm)		1,986	1,714	2,138	1,716	1.075	0.34
COD (mg/L)		300	5.0	620	15.0	1,975	1,765
CaH (mg/L as CaCO₃)				020			
ALK		391	154	422	331		360
Biological			104	422	203		230
CBOD₅ (mg/L)	< 2	228	1.77	230	0.85	270	
TSS (mg/L)	< 1	238	0.30	183		276	1.98
T-Phosphorus (mg/L as P)		20.65	0.96	14.00	0.27	152	0.40
NH₃-N (mg/L as N)	< 0.5	26.93	0.16	25.36	0.18		
ΓKN (mg/L as N)		111	3.31		5.68	26.50	6.58
NO₂/NO₃-N (mg/L as N)		0.03	19	75	9.73		
Fotal Nitrogen (mg/L as N)		111		0.17	5.83		
Microbial			22	75 ———	16		
Total Coliforms (CFU/100mL)	< 2.2		3.0		109.4		
ecal Coliforms (CFU/100 mL)	0 .		4.5				84.0
IPC (CFU/mL)	< 500		1,619		41.9 3,276		175.0

 $[^]a\mbox{Where target left blank, no target was established.}$ $\mu\mbox{S/cm=microSiemens per centimeter}.$

Table 5.9 presents the results of water quality analyses of the ZenoGem feed and permeate during Stage C. The system operated at constant flow/flux during this stage, except during three flow peaking events and a 242-hour period when air was cycled to the membrane tank.

TABLE 5.9Results of Stage C Water Quality Analyses for the ZenoGem System

				Pea	k Flow	Normal Flow wit Cycled Aeration Membrane Tank Only		
Parameter		Normal Flow		(Even	nts 3,4,8)	(Ev	rent 7)	
Physical/Chemical	Permeate Target ^a	Feed	Permeate	Feed	Permeate	Feed	Permeate	
рН		7.16	7.42	7.20	7.37	7.20	7.35	
Temperature (degrees C)		29.6	30.8	30.6	31.5	28.7	29.9	
Turbidity (NTU)	< 0.2		0.15		0.10		0.15	
Conductivity (µS/cm)		1,904	1,612	1,669	1,469	1,958	1,678	
COD (mg/L)		383.3	15.6	380	13.0	,,,,,,,,	1,070	
CaH (mg/L as CaCO ₃)			345		312		322	
ALK		352	128	336	158	334	176	
Biological			 					
CBOD₅ (mg/L)	< 2	164	0.57	161	0.08	156	0.54	
TSS (mg/L)	< 1	130	0.28	122	0.20	107	0.24	
T-Phosphorus (mg/L as P)		9.55	3.34	5.23	3.15		1.97	
NH ₃ -N (mg/L as N)	< 0.5	23.17	0.56	23.16	0.24	23.18	0.91	
TKN (mg/L as N)		47	2.94	37	2.20	38	8.50	
NO ₂ /NO ₃ -N (mg/L as N)		0.38	15.47	0.03	6.51	0.04	1.46	
Total Nitrogen (mg/L as N)		47	18	37	9	38	10	
Microbial		- · · · · ·		-				
Total Coliforms (CFU/100mL)	< 2.2		15.1		17.3		82.2	
Fecal Coliforms (CFU/100 mL)	0		8.9		8.8		•	
HPC (CFU/mL)	< 500		1,383		2,891		26.1 3,237	

^aWhere target left blank, no target was established.

Table 5.10 presents the results of water quality analyses of the ZenoGem feed and permeate during Stage D. The system operated in an alternative operating mode with a reduced MLSS concentration (6 g/L) and peak flow and/or cycled aeration to one or both tanks.

TABLE 5.10Results of Stage D (Alternative Operating Mode) Water Quality Analyses for the ZenoGem System

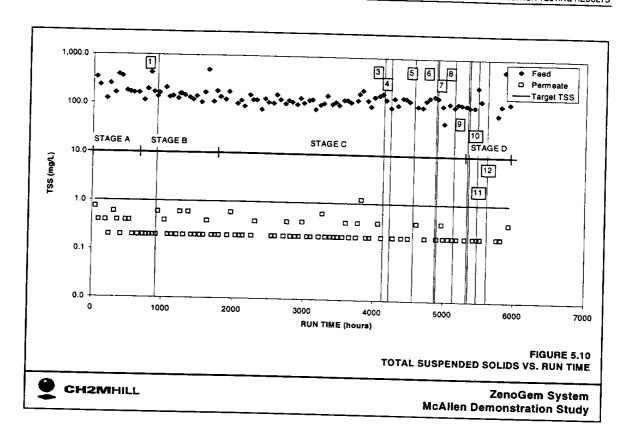
		Normal Flow with Cycled Aeration to Membrane Tank (Event 9)		Peak Flow with Cycled Aeration to Membrane Tank Only		with A to M	mal Flow n Cycled eration embrane nk Only	Normal Flow with Cycled Aeration to Membrane and Aeration Tanks		
Parameter				(Ev	vent 10)	(E	/ent 11)	(Ev	ent 12)	
Physical/Chemical	Permeate Target ^a		Permeate	Feed	Permeate	Feed	Permeate	Feed	Permeate	
pН				7.06	7.13			7.13	7.33	
Temperature (degrees C)		29.3	29.8	29.4	30.3	29.1	31.0	28.1	26.6	
Turbidity (NTU)	< 0.2		0.12		0.10		0.13		0.14	
Conductivity (µS/cm)		1,796	1,533	1,695	1,487	1,595	1,448	1,575	1,338	
COD (mg/L)				448	15.0			292	14.0	
CaH (mg/L as CaCO₃)					280		300		316	
ALK				360	110	320	124	380	180	
Biological										
CBOD ₅ (mg/L)	< 2	146	0.03	157	0.15	154	0.17	154	0.37	
TSS (mg/L)	< 1	104		184	0.20	140	0.20	220	0.27	
T-Phosphorus (mg/L as P)		6.07	3.19	5.45	1.44	3.87	2.73	4.94	1.44	
NH ₃ -N (mg/L as N)	< 0.5	21.30	0.05	24.85	0.15	17.20	0.14	24.28	0.31	
TKN (mg/L as N)		42	2.0	43	2.0	39	2.0	47	2.85	
NO_2/NO_3 -N (mg/L as N)		0.01	18.30	0.02	13.5	0.01	20.10	0.01	3.96	
Total Nitrogen (mg/L as N)		42	20	43	16	39	22	47	7	
Microbial										
Total Coliforms (CFU/100mL)	< 2.2	,			8.5		9.0		6.4	
Fecal Coliforms (CFU/100 mL)	0				2.0					
HPC (CFU/mL)	< 500				2,102		1,600		2,458	

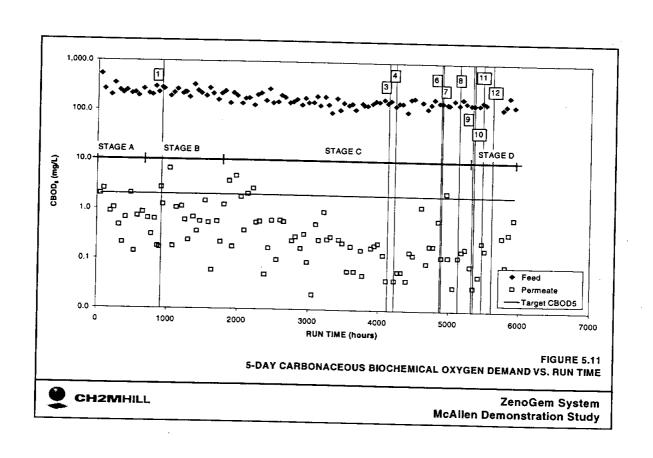
^aWhere target left blank, no target was established.

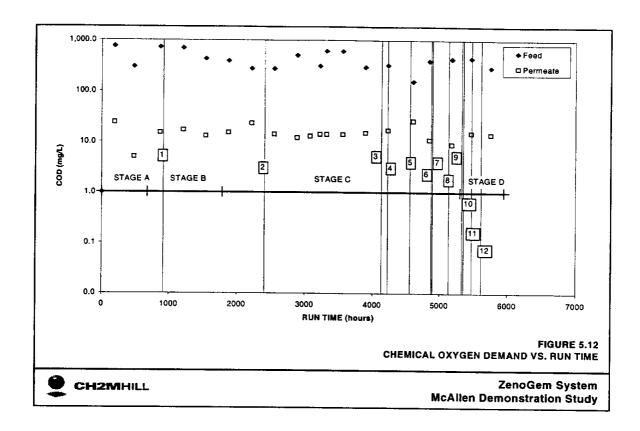
Particle Removal. The ZenoGem system achieved greater than 99 percent removal of TSS and CBOD during all stages of operation and was effective in reducing TSS and CBOD $_5$ in the wastewater to below target levels as shown in Figures 5.10 and 5.11. TSS measurement is not sufficiently sensitive to detect potential differences in TSS removal as a function of MLSS concentration. Figure 5.12 illustrates that COD was consistently reduced to less than 20 mg/L in the ZenoGem permeate. COD removal efficiency was not impacted by MLSS concentration.

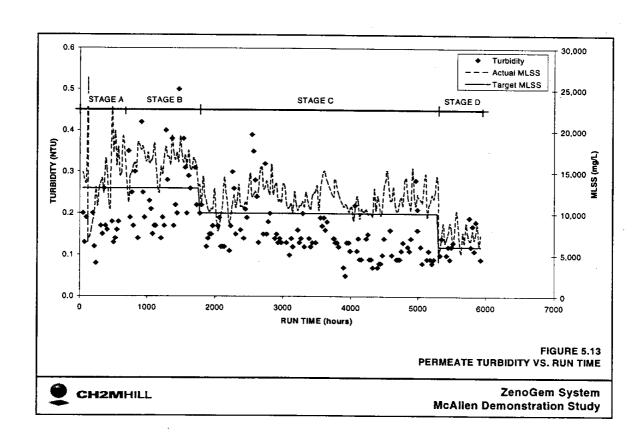
As shown in Figure 5.13 and Table 5.8, the average permeate turbidity was slightly higher in Stage B as compared to Stage A and to the target level of 0.2 NTU established for feedwater to the downstream RO system. This suggests greater particle passage through the OKC MF versus the OCP UF membrane at the higher MLSS concentration. Permeate turbidities were higher during Stage B than Stage C (see Table 5.9), suggesting that particle passage through the OKC membrane is greater at high solids loading (high MLSS concentration).

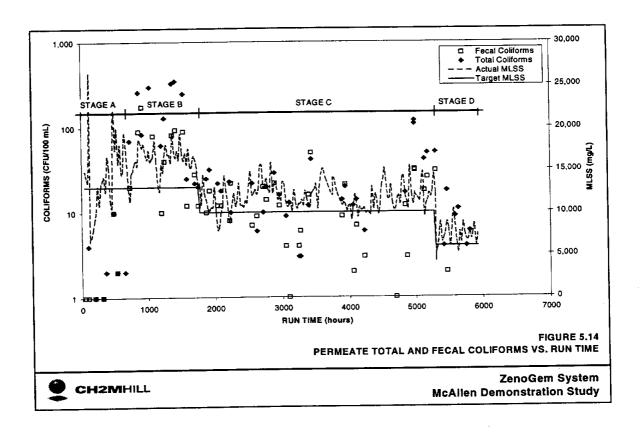
Microbial Removal. Trends observed for turbidity removal were also seen with microbial removal. As shown in Figure 5.14, the average total and fecal coliform levels were higher in Stage B as compared to Stage A. This suggests greater bacteria passage through the MF versus the UF membrane at equal MLSS loadings. The increase coliform levels observed in Stage B compared to Stage C suggest bacteria passage through the MF membrane is a function of MLSS concentration. The high HPC levels may reflect bacterial regrowth in the ZenoGem permeate piping in the absence of a continuous disinfectant. In general, total and fecal coliform levels exceeded the informally adopted goal of State of California "Title 22" regulations pertaining to unrestricted access (2.2 CFU/100 mL for total coliforms and 0 CFU/100 mL, respectively).











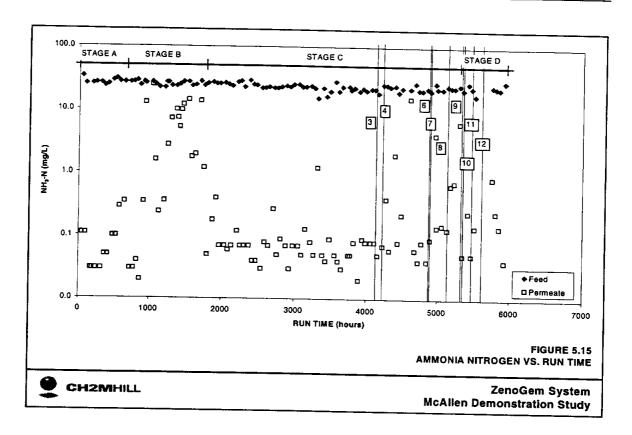
Nutrient Removal.

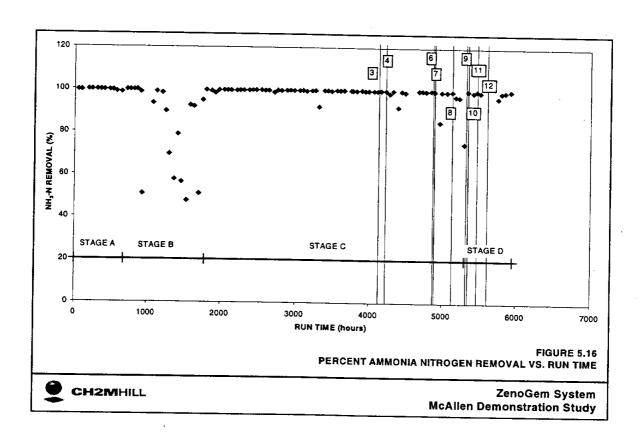
Nitrogen Transformation. At the long SRTs used in this study and the high wastewater temperatures, the activated sludge portion of the ZenoGem process should be able to achieve complete nitrification, i.e., the conversion of ammonia-nitrogen to nitrate-nitrogen. A potential constraint is the ability to supply sufficient oxygen to the process, given the relatively short HRT and the high volumetric organic loading rate. Assuming sufficient DO levels and a well mixed biomass, denitrification should be minimized. These were the expectations at the start of the study.

Ammonia Removal. Ammonia nitrogen feed and permeate levels and percent removal by ZenoGem as a function of operating time are shown in Figures 5.15 and 5.16. Feed levels were relatively constant, ranging from 15 to 30 mg/L. Permeate concentrations were less than the target of 0.5 mg/L at normal flow conditions, except during Stage B. Removals were essentially complete during all stages, except Stage B. Reduced removals (partial/incomplete nitrification) during Stage B most likely reflect impaired efficiency of oxygen transfer to the nitrifiers within the dense flocs present at the higher MLSS concentration (~13 g/L) and high wastewater temperatures. Although dissolved oxygen levels in the bulk liquid were within acceptable range to achieve nitrification (under conventional wastewater MLSS levels), transfer of this oxygen from bulk liquid to bacteria contained within the flocs was not sufficient to achieve complete nitrification at the provided HRT. The reduced nitrification efficiency at higher MLSS levels suggests that MBR operation at such levels may be constrained by oxygen transfer efficiency unless such a constraint can be overcome by increase air input or better gas-to-liquid transfer efficiency than attained in this study.

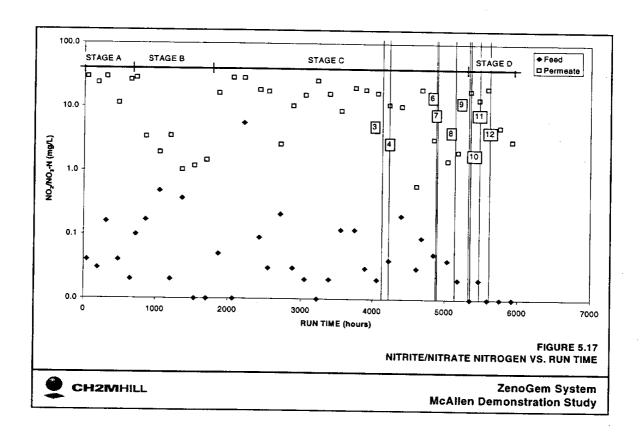
When comparing normal flow versus flow peaking in Stages B and C, nitrification (ammonia removal) was incomplete during peaking due to the decrease in HRT from 5.7 hrs to 3.9 hrs. Cycled aeration to the membrane tank had no real effect on nitrification efficiency in Stage C. Ammonia removal was reduced from 98 to 97 percent only. This result is not surprising as most of the oxygen for biological oxidation is provided in the aeration tank. During Stage D, flow peaking with cycled aeration to both tanks during showed no significant decrease in nitrification when compared to normal flow and full aeration operation.

During all stages, the rate of nitrification was calculated at $0.48~mg/L~NH_3-N~per~mg/L~MLVSS$ per day regardless of MLSS concentration or permeate flowrate. However, during cycled aeration to both tanks in Stage D, the nitrification rate increased to $0.72~mg/L~NH_3-N~per~mg/L~MLVSS$ per day.





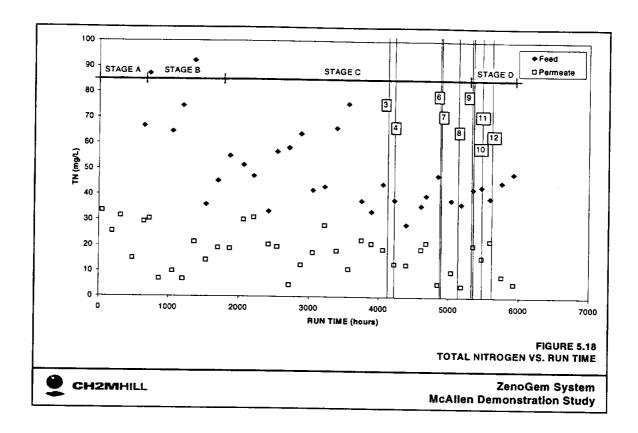
Nitrite/Nitrate Removal. Feed and permeate nitrite/nitrate nitrogen levels for the ZenoGem system as a function of operating time is shown in Figure 5.17. Feed levels were < 0.4 mg/L in all cases, as anticipated. Permeate levels ranged from 15 to 19 mg/L in Stages A and C. During Stage B and the end of Stage D, permeate levels were significantly less. Permeate levels are a function of the amount of ammonia and organic nitrogen converted to nitrite/nitrate (nitrification) and the extent to which this "converted" nitrogen is reduced to nitrogen gas by denitrifiers. In an aerated system, denitrification (nitrite/nitrate conversion to nitrogen gas) is not anticipated as the bacteria responsible for this reduction operate under anoxic conditions. During Stages A and C, denitrification was minimal yielding higher permeate nitrite/nitrate levels. However during Stage B and the end of Stage D, a significant fraction of the nitrite/nitrate generated from nitrification was converted to nitrogen gas, resulting in a condition of "simultaneous nitrification/denitrification" thus yielding lower permeate nitrite/nitrate levels. This result is consistent with the hypothesis offered under the Ammonia Removal discussion where reduced oxygen transfer creates micro anoxic zones within the mixed liquor, providing conditions conducive to the growth of denitrifiers. At the end of Stage D, conditions to produce this effect were put into place through cycled aeration in both treatment tanks. Such conditions were very effective for achieving a high level of both nitrification and denitrification, as illustrated by the data in Table 5.10 (Event 12) where permeate ammonia and nitrite/nitrate nitrogen concentrations were 0.31 and 3.96 mg/L, respectively.

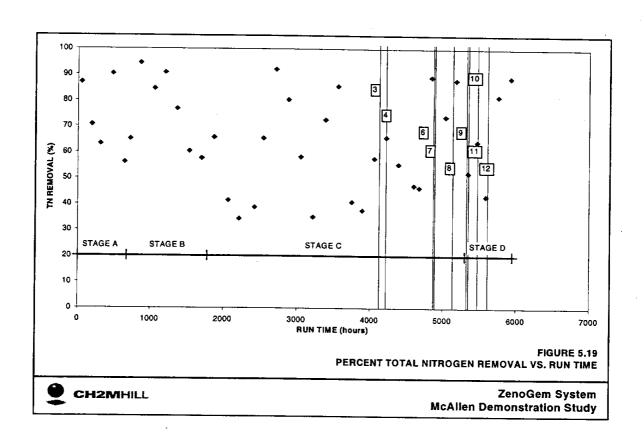


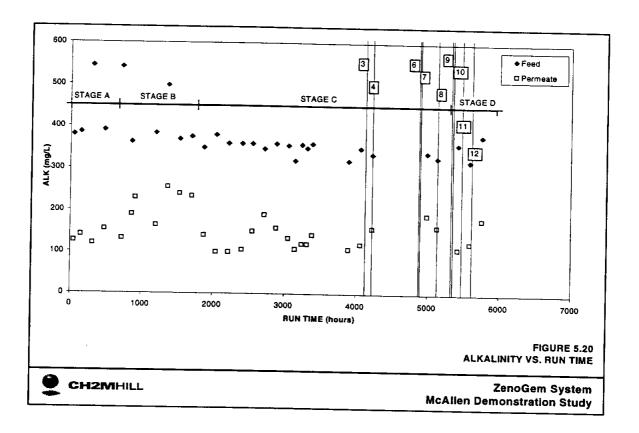
Total Nitrogen Removal. Feed and permeate total nitrogen (TN) levels and percent removal by the ZenoGem system as a function of operating time are shown in Figures 5.18 and 5.19. Feed TN levels were exceptionally high during Stages A and B, decreasing to the 38 to 47 mg/L range during the remainder of testing. As shown in Tables 5.8 through 5.10, highest permeate TN levels were observed at normal flow rates and at low to medium MLSS levels. Cycled aeration to the membrane tank had only minor impact on TN levels. TN removal was higher in Stage B as compared to Stage C due to nearly complete denitrification, in spite of the fact that partial nitrification (higher permeate ammonia and lower permeate nitrite/nitrate levels) was observed. TN removal decreased as a result of complete nitrification (lower permeate ammonia and higher permeate nitrite/nitrate levels) and reduced denitrification when the MLSS concentration was decreased in Stage C. The greatest degree of TN removal was observed at the end of Stage D (Event 12) during cycled aeration to both tanks. As previously discussed, such aeration is effective at maximizing simultaneous nitrification/denitrification. With a 15-minute on/off aeration cycle, the ZenoGem system was capable of reducing TN levels to 7 mg/L.

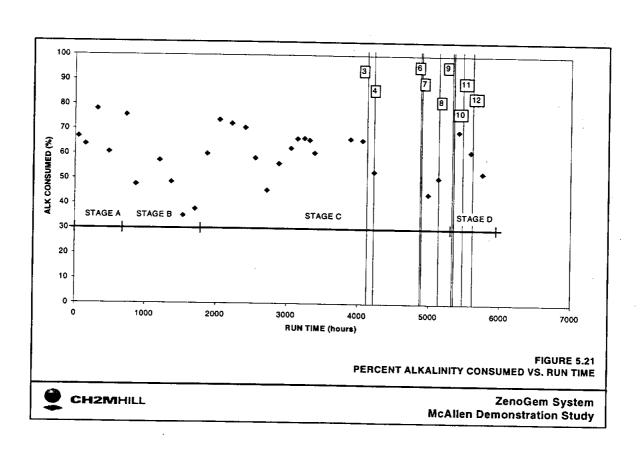
Alkalinity Consumption. During nitrification, alkalinity is consumed. During denitrification alkalinity is created. Assessing alkalinity reductions during the various stages of operation provides a means of "proofing" observed ammonia removals as well as providing a semi-quantitative measure of biological oxidation of non-ammonia organic nitrogen compounds. . Theoretically, 7.1 parts of alkalinity are consumed for each part of ammonia oxidized. As shown in Figure 5.20 during Stage B, alkalinity levels were reduced from an average of 422 mg/L as CaCO3 in the feed to 203 mg/L as CaCO3 in the permeate, yielding an alkalinity consumption of 219 mg/L as CaCO₃. In Stage C, levels were reduced from an average of 352 mg/L as CaCO3 in the feed to 128 mg/L as CaCO₃ in the permeate, yielding an alkalinity consumption of 224 mg/L as CaCO₃.Based on an average ammonia nitrogen removal of 20 mg/L in Stage B and 23 mg/L in Stage C, 142 mg/L and 163 mg/L of alkalinity (as CaCO₃) should have been consumed in Stages B and C, respectively. The additional alkalinity consumption (77 mg/L as CaCO₃ in Stage B and 61 mg/L in Stage C) would have resulted from the biological oxidation of (non-ammonia) nitrogen compounds present in the wastewater. Ammonia nitrogen accounted for only 34 percent of the 75 mg/L of organic nitrogen (TKN) in Stage B and only 49 percent of the 47 mg/L of TKN in Stage C. These levels of TKN are unusually high for a domestic wastewater and indicate that nitrogen-rich discharges are present in the McAllen wastewater.

From previous discussions, nitrification was reduced and denitrification was significant during Stage B. Alkalinity changes between ZenoGem feed and permeate should reflect these differences; alkalinity removals during Stage B should be less than during Stage C as less alkalinity is consumed (from nitrification) and more is created (from denitrification). As shown in Figure 5.21, average alkalinity removal was 50 percent for Stage B and 64 percent for Stage C. Another way of comparing alkalinity consumption and nitrogen transformation is to correlate alkalinity consumption with total nitrogen removal. Lesser alkalinity consumption should occur with greater nitrogen removal as the ratio of nitrogen transformed from nitrate to nitrogen gas increases relative to the amount of organic nitrogen oxidized to nitrite/nitrate. Total nitrogen removal was 76 percent for Stage B and 58 percent for Stage C.

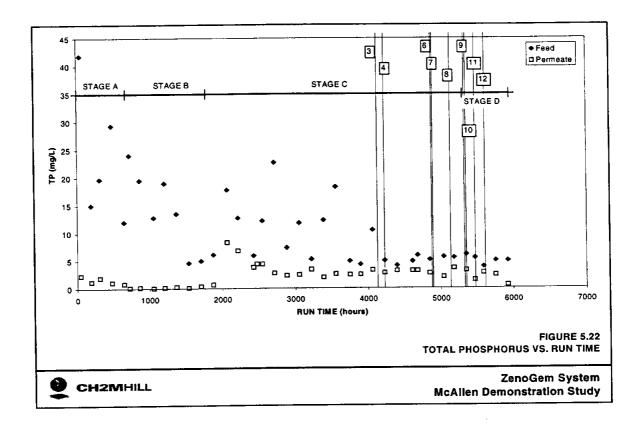


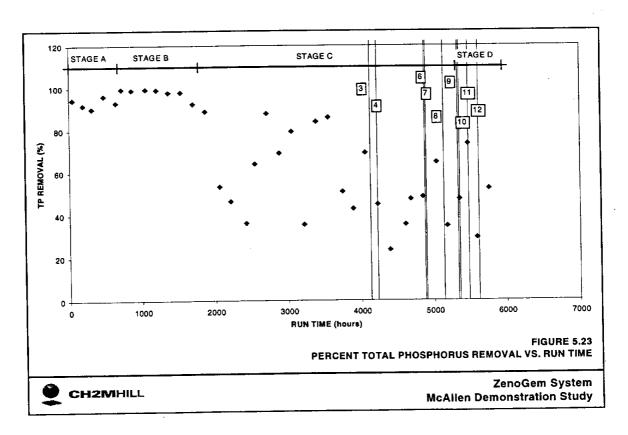






Phosphorus Reduction. Feed and permeate total phosphorus (TP) levels and percent removal by the ZenoGem system as a function of operating time are shown in Figures 5.22 and 5.23. Phosphorus reduction by the ZenoGem process was significantly greater in Stage B than in Stage C at 98 percent and 58 percent, respectively. At the higher MLSS concentration, oxygen transfer to certain zones of the aeration tank was most likely poor, resulting in anaerobic conditions within segments of the biomass producing favorable conditions for biological phosphorus uptake. When the MLSS level was reduced at the beginning of Stage C, these anaerobic zones were eliminated (or greatly reduced) and the phosphorus bound in these organisms was subsequently released, causing phosphorus removal to temporarily increase as shown in Figure 5.23. During the latter part of Stage C, the phosphorus levels in the permeate were in the 2 to 5 mg/L range, which is typical for the conventional wastewater treatment process using secondary treatment and nitrification. Phosphorus removal variability in Figure 5.23 reflects variability in the measured phosphorus levels in the ZenoGem feedwater. Also during Stage C, the phosphorus reduction decreased from 58 percent at normal flow/flux to 40 percent during flow peaking due to the decrease in HRT (insufficient time for phosphorus





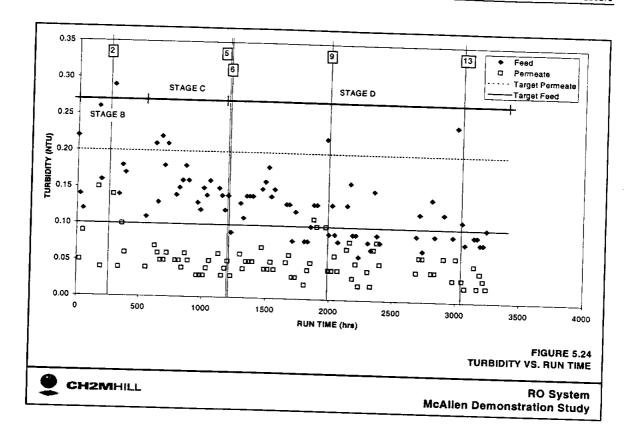
5.3 RO Testing Results

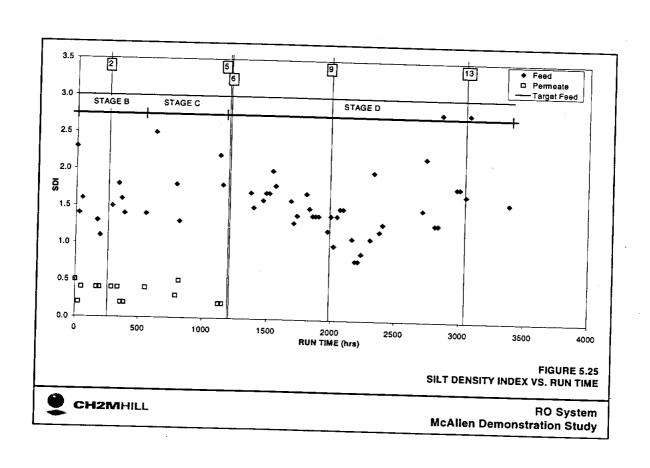
5.3.1 RO Feedwater Quality

Particulate Fouling Potential. Table 5.11 presents the average values for the RO feedwater quality parameters that reflect particulate and colloidal fouling potential (turbidity, SDI and heterotrophic bacteria). For all stages of testing, turbidity and SDI values were less than corresponding target levels, reflecting the low particle water produced by the ZeeWeed membrane. (Turbidity and SDI targets are those established by the spiral wound RO industry based on minimizing RO element fouling and cleaning. With a few exceptions, RO feedwater turbidity averaged less than the 0.2 NTU target (Figure 5.24). As shown in Figure 5.25, the ZenoGem system consistently produced a permeate with a SDI less than the target value of 3. The target of 500 CFU/mL for HPCs is an informal goal that is related to the acceptable level of HPCs in drinking water. There is not established correlation between HPC level in RO feedwater and degree of biological fouling, however, the greater the level the greater the potential to establish biofilms. Actual propensity to form biofilms depends on a number of interrelated factors, including organism type, level of nutrients, water chemistry, membrane material and flow hydraulics through the element. HPC levels were consistently above the target, however, as discussed in a later section of the report, there was no evidence of biological fouling. Taken together, the data in Table 5.11 indicate that the permeate from the ZenoGem permeate should cause little if any particulate fouling of downstream RO membranes.

TABLE 5.11
Average RO Feedwater Quality Parameters

Parameter	Target	Stage B	Stage C	Stage D
Turbidity (NTU)	< 0.2	0.18	0.16	0.11
SDI	< 3	1.46	1.83	1.53
HPC (CFU/mL)	< 500	3,274	865	1,444





Mineral Precipitation Potential. Section 3 discussed the need for chemical conditioning of the RO feedwater to prevent the precipitation of calcium carbonate and barium sulfate, based on their levels in the WWTP secondary effluent and the degree to which their coions would be concentrated during RO treatment at target recovery. The mineral saturation calculations provided in the RODesign program (and also by the scale inhibitor suppliers contacted at the beginning of the project) estimate percent saturation for only the following sparingly soluble salts: calcium carbonate, calcium fluoride, barium sulfate, calcium sulfate, strontium sulfate and silica. Consequently, other sparingly soluble salts present in the effluent, including calcium phosphate salts, were not identified as being supersaturated as a result of RO treatment of the ZenoGem permeate. As discussed in Section 5.3.2 of this report, precipitation of calcium phosphate salts occurred during testing and required additional feedwater acidification to control. Analysis of spent cleaning solutions and materials removed from the membrane surface from element autopsies, showed that calcium carbonate and barium sulfate scaling was effectively controlled and that calcium phosphate was the major mineral precipitate.

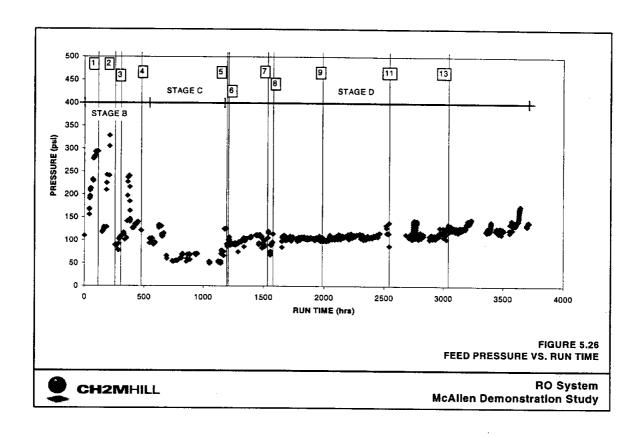
5.3.2 RO Operating Conditions/Membrane Performance

Operating Conditions. Table 5.12 presents the average RO system operating conditions for the following parameters: (recovery, flux, flow, pressure, and conductivity). With the exception of periods during Stage B, the RO system operated at or near target flowrates. Average feed pressure and permeate conductivity was significantly greater during Stage B operation at high recovery because of the increase resistance to flow caused by scaling in the second stage elements during this period. Feed pressure variations as a function of operating time is shown in Figure 5.26. This plot clearly illustrates the high feed pressure periods associated with scaling of the second stage membrane elements during Stage B. These effects were reversed by citric acid cleanings (Events 1, 3 and 4).

TABLE 5.12
Average Operating Conditions for the RO System

	Stages in	Target Recovery	Actual Recovery	Flux	Flow (gpm)				Pressure (ps			Conductivity (µS/cm)		
Stage	Operation	(%)	(%)	gfd	Feed	Conc	Permeate	Feed	Interstage	Conc	Feed			<u> </u>
В	1&2	80	70.4	10.37	3.98	0.94	2.85	231	<u>_</u>			Interstage	Conc	Permeate
-						0.54	2.00	231	220	213	1,608	4,408	3,729	182
B*	182	50	59.0	10.63	5.04	2.29	2.92	132	111	91	1,701	3,544	4,024	150
С	1	50	47.9	9.83	4.11	2.31	2.01	80	NA	65	1,636	3,167	3,330	71
D	1&2	50	48.9	7.71	5.45	2.67	2.95	125	100	63	1,798	2,958	3,520	
D	182	62	63.8	10.03	4.33	2.76	1.45	90	76	63	1,814	3,510	5,017	104
D	1&2	70	68.1	10.50	4.24	2.89	1.41	101	86	74	1,741	3,408		148
D	182	74	72.6	10.62	4.02	2.92	1.12	110	97	87	·	,	4,998	118
D	100							•	31	01	1,549	3,187	4,970	95
	182	80	79.3	11.89	4.12	3.27	0.86	128	115	107	1,731	3,841	7,210	105

^{*}Target feedwater recovery decreased from 80 to 50 percent after 256 hours of operation (Event 2). NA=Not Applicable



Performance Parameters. Table 5.13 presents RO system target and average actual membrane performance parameters (NPF, salt passage and salt rejection) as a function of operating time. Figure 5.27 illustrates changes in flux as a function of operating time. Membrane flux varied considerably during Stage B, decreasing in proportion to the decline in system productivity. Although testing called for operation at constant flux, the rapid and severe increases in feed pressure make it difficult for the plant operators to provide such control. The step decrease in flux during Stage C was intentional and reflects an attempt to reduce RO fouling potential. Flux was steady during Stage D as mineral precipitation and feed pressure was more effectively controlled.

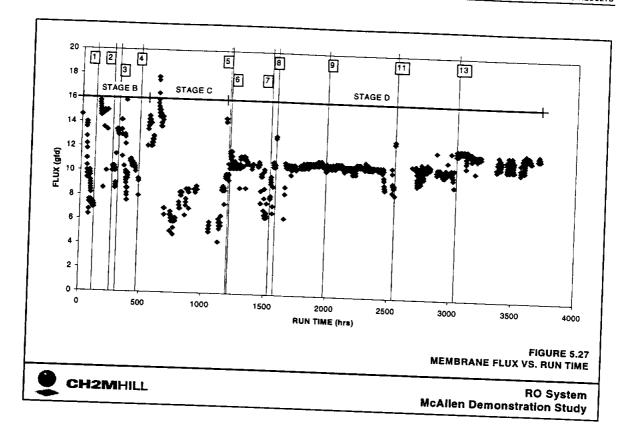
TABLE 5.13
Average Membrane Performance Parameters for the RO System

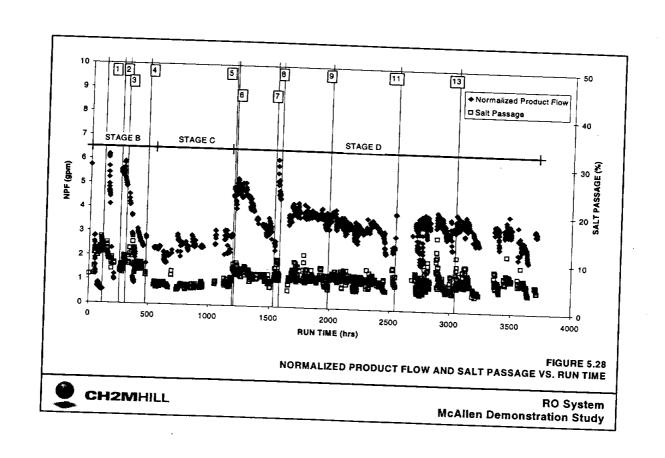
Stage	Stages in Operation	Target Recovery (%)	Normalized Product Flow (gpm)	Salt Rejection (%)	Salt Passage (%)
В	1&2	80	1.88	89.26	10.74
B^{a}	1&2	50	3.47	91.65	8.30
С	1	50	2.38	95.90	4.10
D	1&2	50	2.92	94.57	5.43
D	1&2	62	4.71	92.27	7.73
D	1&2	70	4.02	93.63	6.37
D	1&2	74	3.36	94.18	5.82
D	1&2	80	3.39	94.24	5.76

^aTarget feedwater recovery decreased from 80 to 50 percent after 256 hours of operation (Event 2).

Similarly, NPF showed severe and rapid declines during Stage B. As shown in Figure 5.28, these declines were readily reversible by citric acid cleanings, however operation at high recovery and feed pH (6.8) was not sustainable on a long-term basis. At lower recovery (Stage C), NPF was quite stable confirming that performance declines were recovery and scaling related. With return to two-stage operation and recovery of 70-75 percent (Stage D), NPF again declined but a lesser rate, reflecting the partial effectiveness of reduced pH (6.0-6.5) operation. However, stable performance could not be achieved until feedwater pH was reduced to 5.0, corresponding to a concentrate pH of 5.6. As recovery was further increased to 80, inability to effectively control concentrate pH at 5.6 again resulted in rapid NPF decline.

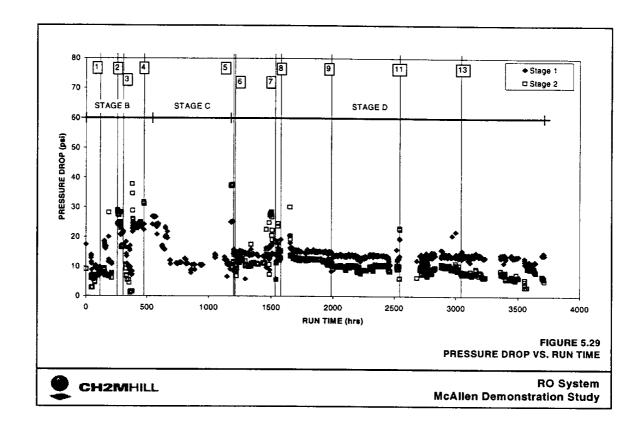
Normalized salt passage was less impacted by scaling than NPF, with the exception of Stage B operation when scaling was worst (Figure 5.28). Normalized salt passage was comparable at the very beginning of Stage B (6 percent at 4 hours) and at the end of routine testing (5 percent at 3,400 hours). This indicates no loss in salt rejecting capability by the RO membranes over the course of this testing despite repeated membrane scaling and citric acid cleaning.

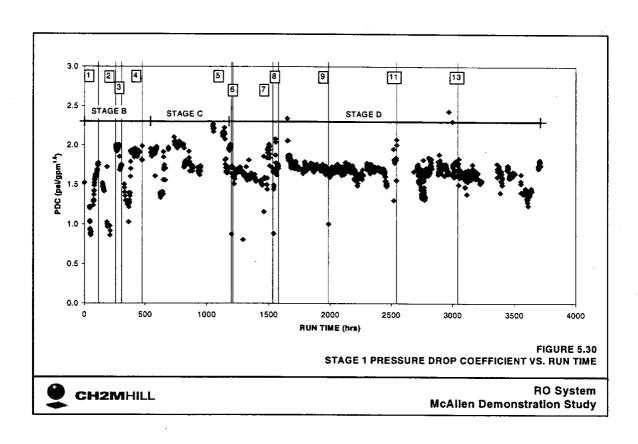




Figures 5.29 and 5.30 present vessel differential pressure (pressure drop) for each RO system stage during the testing as well as pressure drop coefficient for Stage 1 only as a function of operating time. In RO systems operating on MF-treated wastewater effluent or MBR permeate, pressure drop is monitored primarily to indicate the occurrence biological fouling, which causes a characteristic rise in Stage 1 pressure drop. Pressure drop reflects the resistance of water flow through the RO element feed spacer. As material accumulates within the spacer or on the membrane surface, pressure drop increases. Pressure drop coefficient accounts for changes in flow through the pressure and allows for a better comparison of systems operating at different recoveries. In general, the data in the figures indicate the absence of biological fouling. Stage 1 PDC was relatively unchanged, except during the beginning of Stage B. During the period considered most representative of a properly operated RO system (Stage D, 1,500 to 3,000 hours), both pressure drop and PDC were extremely stable. The very gradual decline in pressure drop during Stage C was associated with the decrease in recovery (lower feedwater flow through the feed channels).

¹Pressure drop coefficient (PDC) is defined as follows: PDC = pressure drop /(feed flowrate)¹.5





Calcium Phosphate Scaling and Its Impacts on RO System Feed Pressure and Productivity. During Stage B, NPF declined rapidly (see Figure 5.28). Cleanings with citric acid were effective in restoring performance losses (Event 1) but with subsequent operation, NPF again rapidly declined. At this time, mineral precipitation was considered the likely cause for loss of RO performance. Biofouling was unlikely based on stable pressure drop readings. A second citric acid cleaning was then conducted (Event 2) and a portion of the second stage spent cleaning solution was analyzed to better determine the nature of the mineral precipitant. Calcium, aluminum and phosphorus were present in elevated concentrations relative to the other metals. Calcium and aluminum phosphate salts were considered the primary scaling concern, as calcium carbonate precipitation was controlled by feedwater acidification. Appendix E presents results of the cleaning solution analysis.

To determine the exact type of scale, the ZenoGem permeate, which becomes RO feedwater after chloramination, was analyzed twice a week during the period June 9 through June 23, 1999 for ions that can form precipitable salts, including phosphorus and sulfate, and metals, including barium, aluminum, and iron. (Calcium hardness, alkalinity and phosphorus levels in the ZenoGem permeate were routinely analyzed as part of ZenoGem peformance monitoring protocol.) The analysis showed less than detectable levels of the oxidizable metals aluminum and iron (<0.1 mg/L). Barium and sulfate were present at concentrations less than their solubility (as barium sulfate salt) for operation at 80 recovery (0.06 mg/L and 226 mg/L, respectively). Phosphorus levels were significant relative to natural water supplies (14 mg/L). Given the high concentration of calcium hardness in the wastewater (356 mg/L), calcium phosphate scaling was indirectly suspected. Appendix F presents results of ZenoGem permeate ion analyses.

To further confirm that scaling and not fouling caused performance losses, the second stage was removed from service after 546 hours of operation and the first stage was operated at 50 percent recovery (Stage C). At the lower percent recovery and operating only the first stage vessels, the feed pressure and NPF decreased and remained relatively low and constant during Stage C. Performance stabilized at the lower recovery confirming that performance declines were a result of ion concentration and mineral precipitation. Calcium phosphate scaling is not commonly encountered in municipal RO operations because phosphate levels in most natural raw water supplies are not elevated. Furthermore, based on discussions between CH2M HILL and several scale inhibitor manufacturers (i.e., FMC, KLT, Permacare), calcium phosphate precipitation is not effectively prevented by commercially available RO scale inhibitors. Consequently, three scaling mitigation methods were considered to control the precipitation tendency in lieu of a specific inhibitor:

1. Decrease RO feedwater pH. The calcium phosphate solubility index² was used to calculate the pH of the RO concentrate at which calcium phosphate concentration in the RO concentrate would be less than solubility ($SI = pH-pH_c$, where SI is <0). By trial and error iteration, the resulting pH was used to calculate corresponding feed

² The calcium phosphate solubility index (SI) is defined as follows: SI = $pH - pH_c$, where $pH_c = 11.755 - (log calcium ions + log of phosphate ions = 2*log temperature)/0.65 (Green and Holmes, 1947).$

pH using Hydranautics RODesign and the design conditions discussed in Section 3.3.1. Although this approach would require significant acid dose (\sim 100 mg/L), it has the added benefit of increasing the solubility of both aluminum phosphate and calcium carbonate. This approach was considered the easiest to implement for this study.

- 2. Chemically precipitate excess phosphorus from the screened, degritted wastewater during ZenoGem treatment. Addition of an aluminum or iron salt to the wastewater would produce highly insoluble aluminum or ferric phosphates easily filterable by the ZeeWeed MF membrane. It was calculated that a dose of 45 mg/L of ferric chloride would be required to reduce the phosphate concentration in the ZenoGem permeate to 0.5 mg/L. a level that would reduce the calcium phosphate solubility index to < 0 at 80 percent recovery. This level of coagulant addition would generate more sludge, increase MLSS concentrations, require a reduction in SRT to maintain the 10 g/L target MLSS concentration and potentially increase the fouling rate of the ZeeWeed membrane.
- 3. Biologically remove phosphorus by creating an anaerobic zone in the membrane bioreactor. This was done in an uncontrolled manner during ZenoGem Stage B operation but would require extensive testing to develop the necessary operating strategy relative to oxygen input. Such testing was beyond the scope of this project.

The second stage was returned to service after 1,177 hours of operation (Stage D) and the system continued to operate at 50 percent recovery. After 1,533 hours of operation and step-wise increase in recovery to 70 percent, a target pH of 5.6 was established for the RO concentrate (corresponding to feed pH of 5.0) to maintain calcium phosphate solubility (Scaling Mitigation Method 1). However, difficulties with both the acid feed pump and PLC pH control loop caused difficulty in consistently maintaining the pH during the remainder of testing. After 1,579 hours of operation, the fourth acid cleaning was performed. Feed pressure and NPF was reduced by the cleaning and remained relatively constant until feedwater was increased to 75 percent after 1,985 hours of operation. Thereafter, feed pressure increased and NPF decreased until another cleaning was performed at 2,544 hours of operation to restore performance. Increasing the recovery to 80 percent after 3,042 hours of operation resulted in a rapid increase in feed pressure and decrease in NPF. These results indicate that the decrease in RO feedwater pH effectively stabilized system performance and reduced fouling potential when operating at a feedwater recovery up to 70 percent. Stable system performance could not be maintained at the higher recoveries (75 to 80 percent), even with the decrease in RO feedwater pH.

Autopsy of the trailing element(s) from Stage 2 confirmed calcium phosphate as the primary precipitate (see Appendix G).

5.3.3 RO Water Quality Impacts

Control of Major Contaminant Categories. Table 5.14 presents the results of water quality analyses of the RO system feed, permeate, and concentrate during each stage of operation. These data are presented to illustrate the ability of RO treatment to reduce the concentration of particulate, microbial, inorganic and organic contaminants in the ZenoGem permeate (i.e., wastewater effluent). Per the objectives of the study, the following surrogate parameters were monitored through the study to demonstrate such removal capability: turbidity (representing particles), coliforms and HPCs (representing pathogenic bacteria), conductivity and TDS (representing inorganic) and TOC (representing organic).

TABLE 5.14
Average Water Quality Results for the RO System

Parameter			Stage B			Stage C			Stage D	
Physical/Chemical	Permeate Target	Feed	Permeate	Conc	Feed	Permeate	Conc	Feed	Permeate	Conc
pН		7.13	6.00	7.32	7.30	6.07	7.44	6.22	5.66	6.06
Conductivity (uS/cm)		1,651	86	3,420	1,560	63	3,718	1,668	110	5,367
Turbidity (NTU)	< 0.1	0.18	0.08	0.54	0.16	0.05	0.32	0.11	0.05	0.36
SDI		1.46	0.33		1.83	0.32		1.53		1.57
TOC (mg/L)	< 1	6.18	< 0.5		6.77	< 0.5		6.62	< 0.5	
TDS (mg/L)	< 500	999	51	2,341	943	44	1.702	899	73	3,503
Microbial							·			0,000
Total Coliform (CFU/100 mL)		2.0	7.0		5.7	2.9		6.0	1.0	
Fecal Coliform (CFU/100 mL)	0				2.0	2.0		3.0	2.0	
HPC (CFU/mL)		3,274	110		865	65		1,444	276	

^aWhere target left blank, no target was established.

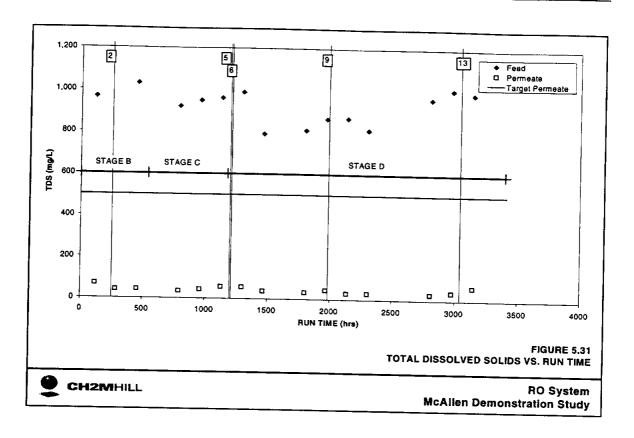
Particulate. As described in earlier in this section, turbidity levels in the RO feedwater were well controlled by ZeeWeed membrane (average of 0.15 NTU). Consequently, only minor improvements in turbidity were possible by the RO system. RO permeate turbidity was consistently measured at to 0.05 NTU. This compares with the target level of 0.1 NTU and the current Environmental Protection Agency (EPA) regulatory level of 0.3 NTU for conventional water treatment plants (95 percent of readings).

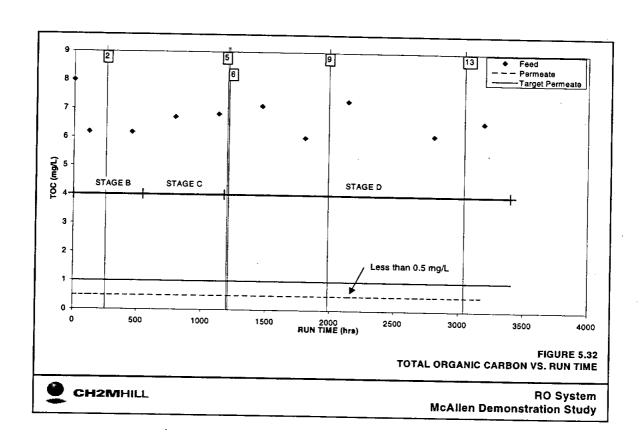
Microbial. The target level of coliforms was established at 0 CFU/mL. Coliforms were routinely measured in the RO permeate, typically at levels of 2 CFU/mL based on similar levels in the feed. This is surprising given the presence of a low level of monochloramines in the RO feed and permeate. HPCs were reduced by more than an order of magnitude by RO treatment, with permeate levels less than the drinking water trigger level of 500 CFU/100mL.

Inorganic. At the target 80 percent recovery (beginning of Stage B and end of Stage D), RO treatment produced an effluent (permeate) having an average TDS of 66 mg/L (in the absence of mineral scaling effects), significantly below both federal and State of Texas secondary drinking water standard for TDS (500 and 1,000 mg/L, respectively). The average RO permeate TDS compares very favorably with the 700 to 800 mg/L TDS level that is typical for the City's existing raw water supply (Lozier, 1998). As shown in Figure 5.31, permeate TDS was consistently < 75 mg/L (greater than 92 percent removal) throughout the study, despite periods of severe membrane scaling.

Organic. As shown in Figure 5.32, TOC levels in the RO permeate grab samples were consistently less than detectable (0.5 mg/L) based on a feedwater TOC range of 6 to 8 mg/L. This represents greater than 92 to 94 percent TOC removals. By comparison, TOC levels in the City's existing raw water supply average 3.8 mg/L (Lozier, 1998) and the California Dept. of Health Services TOC limit for direct injection of reclaimed water is 1 mg/L.

In association with RO membrane integrity studies conducted by the BOR and coincident with these research, permeate TOC levels were measured on-line using two low detection limit (20 ppb) analyzers provided by Sievers and Anatel on a short-term trial basis. Other sites using the Sievers instrument have shown RO systems treating microfiltered secondary effluent contain less than 100 μ g/L TOC.





5.4 Impacts of IPR on Waste Discharges

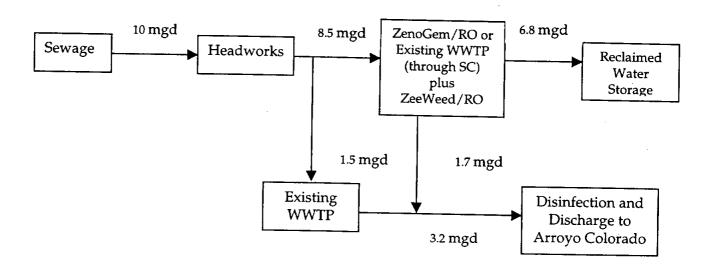
One of the objectives of this testing was to characterize the quality of the ZenoGem permeate and RO concentrate for water quality parameters important to the ecosystems of the Arroyo Colorado and Laguna Madre. The former is a non-perennial waterway to which the City currently discharges the effluent from the South WWTP. Flows into the Arroyo Colorado eventually empty into the Laguna Madre, an estuary that is connected to the Gulf of Mexico. Currently, the City's discharge is regulated with respect to three parameters: CBOD₅, TSS, and ammonia nitrogen. The limits for discharge are as follows:

CBOD₅: 10 mg/L
 TSS: 15 mg/L
 NH₃-N: 3 mg/L

As part of a reuse feasibility study previously conducted for the City, TNRCC expressed concern regarding the presence and concentration of nutrient and TDS in the waste stream(s) from a future IPR treatment system, as it would pertain to discharges to these water bodies. The IPR treatment system evaluated in this research would generate one waste stream, the RO concentrate. Sludge from the ZenoGem system would be dewatered and dried using existing WWTP facilities. For the purpose of this evaluation, it is assumed that 8.5 mgd of wastewater from the WWTP would be diverted to ZenoGem/RO treatment system or, alternatively, 8.5 mgd of WWTP effluent (from the secondary clarifiers) would be diverted for ZeeWeed/RO treatment system. With either alternative, 1.5 mgd (average flow) of undiverted secondary effluent would be disinfected and discharged to the Arroyo Colorado as is currently done. As shown in Exhibit 5.3, these assumed treatment scenarios would result in the following discharges:

- 1.5 mgd of effluent from the South WWTP
- 1.7 mgd of RO concentrate (20% of 8.5 mgd RO feedwater flow)

EXHIBIT 5.3Wastewater Discharge Characterization



In both alternatives, the 8.5 mgd of secondary effluent would be processed by RO to produce 6.8 mgd of final efffluent and 1.7 mgd of RO concentrate (waste). This waste concentrate would then be blended with the remaining 1.5 mgd of WWTP effluent (flow which bypasses IPR treatment), disinfected, and discharged to the current location. As shown in Table 5.15, concentrations of TDS, nutrients and TOC were then calculated for the 47:53 blend of WWTP effluent/RO concentrate using the data collected in Appendix D.

TABLE 5.15 Comparative Loading of Critical Contaminants to Arroyo Colorado/Laguna Madre

	(A)	(B)		
Parameter	RO Concentrate (mg/L) ^a	WWTP Effluent (mg/L) ^a	Composite Stream (Blend) Loading (Ibs/day) ^b	Existing WWTP Effluent Discharge Loading (lbs/day) ^c
NO ₂ /NO ₃ -N	29.9	3.45	467	288
T-Phosphorus	10.20	2.38	174	199
TKN	3.16	2	70	167
TDS	3,780	930	65,227	77,562
TOC	28.15	7.25	490	605

^aBased on average results of two sampling events.

^bCalculated as: 8.34*(1.7*A + 1.5*B) where 1.7=RO concentrate flow (mgd) and 1.5=WWTP effluent flow

cCalculated as: 8.34*10*B where 10=existing average WWTP effluent flow (mgd).

The comparison shows that for each parameter, the concentration is much higher in the RO concentrate than the WWTP effluent. This reflects the concentration of each parameter by RO treatment and in the case of nitrate, a higher level in the ZenoGem permeate than the WWTP effluent. In some cases, agencies regulate contaminant discharges based on mass loading (pounds of contaminant per day) rather than concentration. Table 5.15 also shows the predicted mass loading for the RO concentrate/WWTP effluent composite stream (blend) verses the current WWTP effluent discharge. In contrast to the concentration comparison, mass loadings for the blend are higher only for nitrate. Consequently, it would be in the City's best interest to work toward establishing mass loading-based discharge regulations versus the current concentration-based regulations if they wish to discharge RO concentrate to the Arroyo Colorado/Laguna Madre ecosystem. If successful, the City could incorporate biological denitrification into the design of the ZenoGem system to control nitrate loadings at the current levels.

5.5 Comparing Reclaimed and Existing Raw Water Quality

No federal regulations exist regarding the quality requirements for reclaimed water to be used in the context of indirect potable reuse. Currently, such requirements are established on a state-by-state basis. To date, the City has had preliminary meetings with TNRCC regarding such requirements. However TNRCC has not yet proposed regulations for McAllen, but have only referenced potential treatment techniques (e.g., treat all the reclaimed water with RO). To provide a basis for development of IPR regulations for this project, all primary and secondary contaminants currently regulated under the SDWA were analyzed in both the ZenoGem and RO permeates. Results of these analyses are presented in Appendix D. The results were then compared with data from similar characterization of the City's existing raw water supply (Rio Grande River) as sampled in 1997 during the Wastewater Reclamation Pilot Study, City of McAllen, Texas (1998).

Comparing the quality of the ZenoGem permeate to the City's existing raw water supply and to federal and state drinking water regulations as shown in Table 5.16, the following conclusions are drawn:

- The ZenoGem permeate contains greater levels (i.e., lower quality) of most inorganic contaminants than the City's raw water supply. The degradation reflects: 1) the inability of the City's water treatment plant and the ZenoGem process to remove such compounds, and 2) increases in these contaminants from the domestic water use/wastewater generation process. Consequently, the ZenoGem permeate, on at least one sampling event, exceeded the maximum contaminant level (MCLs) for chloride, color (APHA) apparent, and TDS.
- The ZenoGem permeate contains lower concentrations of certain metals (i.e., iron, manganese, aluminum, barium, and strontium) than the City's raw water supply and the MCLs as a result of their removal by oxidation or precipitation in both the WWTP and the ZenoGem processes.
- The concentration of dissolved organic matter (as measured by TOC) is significantly greater in the ZenoGem permeate than the City's raw water supply. Although there is not a current MCL for TOC, the greater the TOC level, the greater the potential for formation of trihalomethanes (THMs) and haloacetic acids (HAAs). These chlorinated byproducts have been shown to be carcinogenic and are regulated at very low levels (µg/L levels). This greater potential is illustrated by the significantly higher levels of HAAs in the ZenoGem permeate relative to the raw water supply. Further, the chronic health risks associated with identified organic compounds in wastewater are not well understood. For this reason, respected authorities in the field of IPR recommend that TOC levels be reduced. In the State of California, a TOC guideline of 1 mg/L has been established for reclaimed water used for surface water supplementation IPR projects.

Particle levels in the ZenoGem permeate are significantly lower than the City's raw
water supply based on turbidity measurements. This reflects the very small pore
size of the MF and UF membranes used with ZenoGem, which serves as a effective
barrier to the passage of most particles.

Comparing the quality of the RO permeate to the City's existing raw water supply and to federal and state drinking water regulations as shown in Table 5.16, the following conclusions are drawn:

- The RO permeate meets all established drinking water regulations as well as the TOC guideline of 1 mg/L.
- To produce reclaimed water meeting state and federal drinking water regulations and the State of California TOC guideline, both ZenoGem and RO treatment of the City's wastewater is required. Assuming an RO permeate TOC of 0.5 mg/L, greater than 90 percent of the wastewater would require RO treatment. If the TOC guideline were not considered, RO treatment would still be required, however, the percent of treatment would be reduced depending on the controlling contaminant (e.g., HAAs, nitrate or TDS). Assuming nitrate would be more cost effectively removed through biological denitrification, approximately 80 percent of the wastewater would require RO treatment to control HAA formation.
- Beyond simply meeting the drinking water regulations, experts involved in setting IPR policy strongly recommend the concept of multiple treatment barriers to ensure that the proposed treatment scheme adequately protect public health, particularly with respect to acute health risk from microbes. In this regard, the combination of ZenoGem and RO treatment provides two robust barriers to the passage of viral, bacterial and protozoan pathogens as opposed to relying on only a single barrier (i.e., ZenoGem only). An additional barrier or chlorine/UV disinfection may also be desirable while only marginally increasing costs.
- If TNRCC were to approach IPR guidelines for this project from the viewpoint that the reclaimed water must equal or exceed the quality of the existing raw water supply, a lower percentage of the ZenoGem permeate would require RO treatment. Based on the data shown in Table 5.16, it is estimated that about 50 percent of the wastewater would require RO treatment to have a reclaimed water match the TOC concentration of the raw water.

TABLE 5.16
Results of ZenoGem and RO Permeate Sampling for IPR Characterization

	Primary		Raw Water	Zen	oGem		
Parameter	MCL		oplya		neate		ermeate
General Chemistry		3/11/97	6/2/97	8/17/99	9/14/99	8/17/99	9/14/99
Alkalinity (mg/L as CaCO ₃)		400					
Bromide (mg/L)		130	106	121	153	14	16
Chloride (mg/L)	050	0.100	0.54	0.132	0.32	0.02 ^b	0.02 ^b
· = •	250	155	207	160	281	9.73	15.20
Color Apparent	15	17	10	22	17	5 ^b	5 ^b
Fluoride (mg/L)		0.59	0.99	1.07	1.14	0.32	0.45
NH ₃ -N (mg/L as N)					0.1 ^b		0.1 ^b
NO ₂ -N (mg/L as N)				9.55	7.90	1.11	1.08
TKN (mg/L as N)				2 ^b	2 ^b	2 ^b	2 ^b
Reactive Silica (mg/L)		6.0	13.5	15.1	16.1	0.65	0.90
Sulfate (mg/L)	250	247	262	150	247	4	5.31
TDS (mg/L)	500 -	720	772	774	1,950	33	72
TOC (ma/l)	1,000	_			·		
TOC (mg/L)	1 ^g	3.70	3.90	7.48	5.90	0.63	0.52
T-Phos (mg/L)		0.05	0.05 ^b	2.48	2.89	0.10	0.1 ^b
UV-254 (cm ⁻¹)		0.112	0.092	0.129	0.126		
Metals						· · · · · · · · · · · · · · · · · · ·	
Aluminum (mg/L)	0.05 - 0.2	1.22	0.248	0.111	1 ^b	0.046 ^b	0.1 ^b
Arsenic (mg/L)				0.004*	0.01 ^b	0.004 ^b	0.01 ^b
Barium (mg/L)		0.127	0.124	0.056	0.062	0.0008b	0.025*
Cadmium (mg/L)				.003	0.005 ^b	0.0004 ^b	0.005 ^b
Calcium (mg/L)		77	77.7	72.1	86.9	0.714	833
Chromium (mg/L)				0.007 ^b	0.010 ^b	0.008 ^b	0.01 ^b
lron (mg/L)	0.3°	0.77	0.171	0.032	0.1 ^b	0.01	0.1
Lead (mg/L)				0.028	0.003 ^b	0.002 ^b	0.003 ^b
Magnesium (mg/L)		22.1	27.9	20.4	25.6	0.197	0.5 ^b
Manganese (mg/L)	0.05°	0.025	0.018	0.015	0.017	0.001 b	0.01 ^b
Mercury (mg/L)				0.0003b	0.0003 ^b	0.0003 b	0.0003 ^b
Potassium (mg/L)		9	9.58	17.8	29.9	1.36	2*
Selenium (mg/L)				0.007 ^b	0.007 ^b	0.007	0.007 ^b
Silver (mg/L)				0.008 ^b	0.010 ^b	0.008 ^b	0.007 0.01 ^b
Sodium (mg/L)		102	140	157	253	13	16.2
Strontium (mg/L)		2.05	2.40	1.87	2	0.029 b	0.1 ^b
Zinc (mg/L)				0.463	0.054	0.007	0.1 0.02 ^b
Ourgeable Volatiles						0.007	0.02
/inyl Chloride				1 ^b	1 ^b	1 ^b	1 ^b
ran-1,2-Dichloroethene				, 1 ^b	1 ^b	1 ^b	1 1 ^b
cis-1,2-Dichloroethene				1 ^b	1 ^b	1 ^b	1 b
,1,1-Trichloroethane				1 ^b	1 ^b	1 ^b	1 b
Carbon Tetrachloride				1 ^b	1 ^b	1 ^b	1 ^b
richloroethene				1 ^b	1 ^b	1 ^b	1 ^b

TABLE 5.16 Results of ZenoGem and RO Permeate Sampling for IPR Characterization

	Primary	Existing I	Raw Water	Zeno	Gem		·····
	MCL	Sup	plya		eate	RO Pe	rmeate
Parameter		3/11/97	6/2/97	8/17/99	9/14/99	8/17/99	9/14/99
1,4-Dichlorobenzene				1 ^b	1 ^b	1 ^b	0.60
Disinfection Byproducts							- 1
Trihalomethanes (SDS THMs) ^c (µg/L)	80	236.00	215.00	198.00	244.00	5.40	8.30
Haloacetic Acids (SDS HAA5) ^d (µg/L)	60	58.00	72.00	119.00	90.60	1.10	1.10
Semi-volatile Organics							- 1
Lindane (µg/L)				0.024	0.011	0.02 ^b	0.02 ^b
Endrin (µg/L)				0.02 ^b	0.01	0.02 ^b	0.02 ^b
Methoxychlor (µg/L)				0.04 ^b	0.04 ^b	0.04 ^b	0.04 ^b
Toxaphene (µg/L)				0.5 ^b	0.5 ^b	0.5 ^b	0.5 ^b
Radiochemicals							
Radium-226 (pCi/L)				0.2 ^b	0.2 ^b	0.2 ^b	0.2 ^b
Radium-228 (pCi/L)				1 ^b	1 ^b	1 ^b	1 ^b
Gross Alpha (pCi/L)				1 ^b	1 ⁵	1 ^b	1 ^b
Chlorinated Herbicides							
2,4-D (µg/L)				ND	ND	ND	ND
Silvex (2,4,5-TP) (µg/L)				ND	ND	ND	ND

^aSource: Table 5.2 of Water Treatment Technology Program Report No. 26

ND =No Detection

pCi/L=picoCuries per liter

bNot Detected at specified reporting limits.

[°]SDS THM - Simulated Distribution System Trihalomethanes (4 species)

dSDS HAA5 - Simulated Distribution System Haloacetic Acids (5 species)

Secondary MCL: Federal = 500 mg/L; State = 1,000 mg/L

⁹Guildeline set by the State of California

Cost Estimates Using ZenoGem, ZeeWeed, and RO Facilities

This section presents the cost estimates for two advanced treatment systems to produce 6.8 mgd of reclaimed water that would supplement the City of McAllen's drinking water supply by providing a new source of raw water to the City's water treatment plant. The advanced treatment system would be located at the site of the City's south WWTP. The effluent from the advanced treatment system would be of a quality suitable for discharge to a new reclaimed water storage reservoir to be located in the vicinity of the City's existing water treatment plant. It is anticipated that the effluent from the advanced treatment system would receive additional disinfection depending on TNRCC requirements.

UV light disinfection or chlorination are two candidate disinfection methods. The most appropriate may depend on whether the effluent consists of 100 percent RO permeate or a blend of RO permeate and ZenoGem/ZeeWeed permeate¹. In the latter case, UV disinfection may be required because of the increased chlorine disinfection byproduct formation potential of the UF permeate. For the purposes of this exercise, costs for final disinfection have not been included because the method of disinfection has yet to be determined. Costs for disinfection of the UF permeate with chloramines (prior to RO treatment) have been included.

Estimates were developed for two alternatives:

- Treatment Alternative 1: ZenoGem MBR, UF permeate storage/disinfection and RO facilities treating screened, de-gritted wastewater
- Treatment Alternative 2: Extended aeration and clarification (existing), ZeeWeed system, UF permeate storage/disinfection and RO facilities treating secondary effluent from the existing south WWTP

For Alternative 1, a new ZenoGem MBR system would be installed to treat the screened, de-gritted wastewater and produce 8.5 mgd of reclaimed effluent. The UF permeate would be disinfected with monochloramines, stored, and then treated by the RO system (which includes acidification and antiscalant addition to the RO feedwater) to produce 6.8 mgd of RO permeate.

For Alternative 2, 9.4 mgd of effluent from the existing secondary clarifiers would be treated by the ZeeWeed UF system to produce 8.5 mgd of permeate. The UF permeate would then be disinfected, stored, and treated by RO as described for Alternative 1. For either alternative, wastewater flows in excess of those necessary to produce 6.8 mgd of RO permeate and would be processed by the existing WWTP facilities. Concentrate from the ZeeWeed UF system would be recycled back to the aeration basins, while sludge

¹ For purposes of the estimates, the ZenoGem/ZeeWeed permeate is referred to as UF permeate, as both processes use the same UF membranes.

from the ZenoGem system would be digested and dried using existing facilities at the WWTP. Both alternatives use existing headworks facilities for wastewater screening and de-gritting.

Figure 6.1 displays a schematic of the existing WWTP. Figures 6.2 and 6.3 are schematics of the two alternatives including existing facilities.

FIGURE 6.1 Existing WWTP Schematic

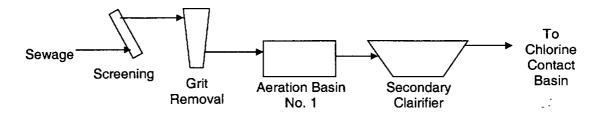


FIGURE 6.2
ZenoGem MBR and RO Facilities

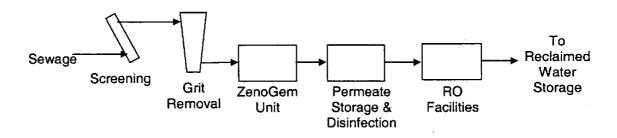
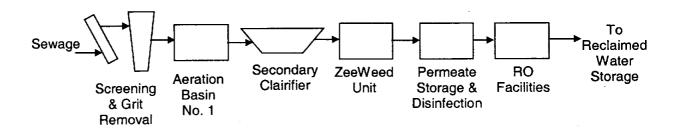


FIGURE 6.3
Conventional WWTP with ZeeWeed and RO Facilities



6.1 Cost Assumptions

The estimates were prepared at an order-of-magnitude level to provide a relative and preliminary cost comparison between the two treatment alternatives and are based on information presently available. Order-of-magnitude cost estimates are defined by the American Association of Cost Engineers as an approximate estimate made without detailed engineering data. Final costs for each alternative will depend on such variables as actual labor and material costs, market conditions, project scope, implementation schedule, and will differ from the estimates presented. The costs are in present day dollars, and annual unit costs are based on ZenoGem/ZeeWeed permeate capacity of 8.5 mgd and RO permeate capacity of 6.8 mgd. The plant availability factor assumed for calculation of unit treatment costs (in \$/1000 gallons) is 95%. A higher availability factor is not required as the plant is intended to operate as a seasonally-average reuse production plant. ZENON budget proposals used in estimating ZenoGem/ZeeWeed and RO equipment costs are presented in Appendix H.

The estimates do not include costs for sewage screening and de-gritting (these facilities are currently being upgraded at the south WWTP) for either alternative. Alternative 2 does not include capital costs for extended aeration or secondary clarification, as these are existing. The costs related to ZenoGem, ZeeWeed, and RO equipment and required ancillaries are included. The ZenoGem system is sized to account for downtime associated with backpulsing and maintenance cleanings while the ZeeWeed system is sized to account for downtimes associated with backpulsing only. At the assumed RO feedwater recovery of 80 percent, 20 percent of the RO feedwater flow (1.7 mgd) becomes waste concentrate requiring appropriate disposal. For purposes of this estimate, RO concentrate is assumed to be discharged without further treatment to the Arroyo Colorado using the City's existing outfall. Consequently, costs are not included for concentrate disposal.

6.2 Cost Estimates

Estimates were prepared for the following cost categories:

- Installed equipment, total construction, total capital, total unit capital, and amortized capital
- Total O&M and total unit O&M
- Total annual and total unit annual

Tables 6.1 and 6.2 present the estimates for the Alternatives 1 and 2, respectively. The tables include the assumptions and references used in developing component capital costs and operating and maintenance costs. Table 6.3 presents design criteria assumptions used in developing the cost estimates for each major process. In addition, a line-item comparison of capital and O&M costs for the ZenoGem and ZeeWeed technologies is presented in Appendix I.

TABLE 6.1
Order of Magnitude Cost Estimate for ZenoGem® and RO Alternative Capital and O&M Cost Opinion

ltem		Cost	Assumption	Cost Reference
Fine Screening	\$	20,000	3-mm screen	CH2M HILL estimator b
ZenoGem® System®	\$	8,620,000		Zenon Budget Proposal
Bioreactor/Equalization Tanks	\$	1,307,808	6 tanks @ 170 ft x 21 ft x 23 ft (1.29 MG for equalization)	CH2M HILL estimator ^b
Permeate Storage	\$	70,000	180,000 gallons	CH2M HILL estimator ^b
Transfer Pump to RO System	\$	52,500	(2) 2,950 gpm @ 70 ft TDH pumps plus one stand-by	
Chloramine Feed System				
Chlorinator	\$	30,000	50 lb/day duplex system	CH2M HILL estimator b
Ammoniator	\$		100 gai/day duplex system	CH2M HILL estimator b
RO System*	\$	2,300,000	g y p y	Zenon Budget Proposal
Installation	\$		25% of installed equipment costs	addar i Johosai
Installed Costs Subtotal	\$	15,160,308	· ·	
ZenoGem Equipment Building	\$	288,000	4,800 SF	CH2M HILL estimator b
RO Building	\$		6,500 SF	CH2M HILL estimator b
installed Costs and Building Cost Subtotal	\$	15,838,308		
Unit Process Noncomponent Costs				
Yard Piping Allowance (10%)	\$	1,583,831		
Site Electrical Allowance (8%)	\$	1,267,065		
Site I&C Allowance (5%)	\$	791,915		
Site Civil Allowance (5%)	\$	791,915		
Unit Process Subtotal	\$	20,273,034		
Contingency (10%)	\$	2,027,303		
Contractor Overhead & Mark-up (10%)	\$	2,027,303		÷
Total Construction Cost	\$	24,327,641		
Engineering & Administration (15%)	\$	3,649,146		
Total Capital Cost	\$	27,976,787		•
Total Capital Unit Cost (\$/1,000 gallon)	\$	11.87		
Amortized Capital Cost (20yr @ 6.5%)	\$	2,539,072		
Operation & Maintenance Costs				·
Major Chemical Costs				
Disinfection: Chlorine		\$ 21,350 \$	\$610/ton	Hill Brothers Chemical Co
Disinfection: Ammonia		\$ 9,620 \$	\$370/ton	Hill Brothers Chemical Co
Backpulse Chemicals: Sodium Hypochlorite		\$ 8,232 \$	\$0.31/Liter	Zenon Budget Proposal
CIP Chemical #1: MC-1		\$ 220 \$	\$1.67/Liter	Zenon Budget Proposal
CIP Chemical #2: Sodium Hypochlorite (250 mg/L)		\$ 304 \$		Zenon Budget Proposal
RO - Sulfuric Acid		\$ 5,745 \$	\$0.04/lb	Zenon Budget Proposal
RO - Sodium Bisulfite		\$ 2,594 \$		Zenon Budget Proposal
RO - Antiscalant	,	\$ 122,359 \$		Zenon Budget Proposal

TABLE 6.1Order of Magnitude Cost Estimate for ZenoGem® and RO Alternative Capital and O&M Cost Opinion

ltem	(Cost	Assumption	Cost Reference
RO - Organic Acid: MC-1		\$ 8,658	3 \$2.29/kg	Zenon Budget Proposal
RO - Alkali Surfactant: MC-4		\$ 1,738	3 \$3.06/kg	Zenon Budget Proposal
RO - Sanitizer: MP-1		\$ 4,748	3 \$5.01/Liter	Zenon Budget Proposal
Major Power Costs			\$0.075/kW-hr	
Screening	\$	-	Existing	
Permeate Pumps		\$ 37,392	!	Zenon Budget Proposal
Recirculation Pumps		\$ 59,068	ı	Zenon Budget Proposal
Sludge Wasting Pumps		\$ 890	•	Zenon Budget Proposal
Membrane Air Scour Blowers	\$	237,213	i .	Zenon Budget Proposal
Process Air Blowers	\$	119,501		Zenon Budget Proposal
Anoxic Zone Mixers		\$ -		Zenon Budget Proposal
Air Separation System Vacuum Pumps		\$ 2,520	,	Zenon Budget Proposal
Backpulse Sodium Hypochlorite - Metering		\$ 3		Zenon Budget Proposal
Chemical Feed #1 - Metering		\$ 245		Zenon Budget Proposal
Air Compressors		\$ 2,515		Zenon Budget Proposal
Air Driers		\$ -		Zenon Budget Proposal
Controls & Instrumentation		\$ 657		Zenon Budget Proposal
Miscellaneous		\$ 657		Zenon Budget Proposal
RO - Pretreatment Chemical Mixers, Process Pump, CIP Pump	\$	501,591		Zenon Budget Proposal
Membrane/Cartridge Filter Replacement Costs				
ZenoGem	\$	329,311	1-yr warranty; 8-yr replacement frequency	Zenon Budget Proposal
RO	\$	226,286	5-yr replacement frequency	Zenon Budget Proposal
Cartridge Filter	\$	24,637	Annual replacement	Zenon Budget Proposal
Other Costs				
Maintenance	\$	63,750		Prorated South WWTP Costs
Permit Fees	\$	39,100		Prorated South WWTP Costs
Land Maintenance	\$	12,750	Replacement of sand in drying beds	Prorated South WWTP Costs
Supplies	\$	61,200	Includes land application of sludge (\$31.50/dry ton)	Prorated South WWTP Costs
Labor	\$	436,800	14 O&M personnel @ \$15.00/hr (9 ZenoGem; 5 for RO)	CH2M HILL estimate
Laboratory	\$		Includes 4 lab techs, analysis, O&M, etc.	Prorated South WWTP Costs
Total Annual Operation & Maintenance Cost	\$ 2	2,482,754		
Total Annual O&M Unit Cost (\$/1,000 gallon)	\$	1.05		

TABLE 6.1Order of Magnitude Cost Estimate for ZenoGem® and RO Alternative Capital and O&M Cost Opinion

ltem	_	Cost	Assumption	Cost Reference
Total Annual Cost	\$	5,021,826		
Total Unit Cost (\$/1,000 gallon)	\$	2.13 Based or flow; plan	n 6.8 MGD product water nt availability factor = 95°	r %

^a Detailed listing of components comprising ZenoGem and RO systems are presented in Appendix H.

TABLE 6.2Order of Magnitude Cost Estimate for ZeeWeed® and RO Alternative Capital and O&M Cost Opinion

Item	Cost	Assumption	Cost Reference
Fine Screening	\$ 20,000	3-mm screen	CH2M HILL estimator ^b
ZeeWeed® Tertiary Treatment System®	\$ 5,075,000		Zenon Budget Proposal
ZeeWeed Tanks	\$ 162,468	4 tanks @ 70 ft x 10 ft x 10 ft	CH2M HILL estimator ^b
Permeate Storage	\$ 70,000	180,000 gallons	CH2M HILL estimator b
Transfer Pump to RO System	\$ 52,500	(2) 2950 gpm @ 70 ft TDH pumps plus one stand-by	CH2M HILL estimator ^b
Chloramine Feed System			
Chlorinator	\$ 30,000	50 lb/day duplex system	CH2M HILL estimator b
Ammoniator	\$ 30,000	100 gal/day duplex system	CH2M HILL estimator b
RO System ^a	\$ 2,300,000	•	Zenon Budget Proposal
Installation	\$ 1,843,750	25% of installed equipment costs	
Installed Costs Subtotal	\$ 9,583,718	(, _p	
ZeeWeed Equipment Building	\$ 84,000	1,400 SF	CH2M HILL estimator b
RO Building	\$ 390,000	6,500 SF	CH2M HILL estimator b
Installed Costs and Building Cost Subtotal	\$ 10,057,718		
Unit Process Noncomponent Costs			
Yard Piping Allowance (10%)	\$ 1,005,772		
Site Electrical Allowance (8%)	\$ 804,617		
Site I&C Allowance (5%)	\$ 502,886		
Site Civil Allowance (5%)	\$ 502,886		
Unit Process Subtotal	\$ 12,873,879		
Contingency (10%)	\$ 1,287,388		•
Contractor Overhead & Mark-up (10%)	\$ 1,287,388		
Total Construction Cost	\$ 15,448,655		
Engineering & Administration (15%)	\$ 2,317,298		
Total Capital Cost	\$ 17,765,953		
Total Capital Unit Cost (\$/1,000 gallon)	\$ 7.53		
Amortized Capital Cost (20yr @	\$ 1,612,374		

^b ENR CCI reference number 6126.79

TABLE 6.2Order of Magnitude Cost Estimate for ZeeWeed® and RO Alternative Capital and O&M Cost Opinion

Item	Cost	Assumption	Cost Reference
6.5%)			
Operation & Maintenance Costs	 		
Major Chemical Costs			
Disinfection: Chlorine	\$ 21,350	\$610/ton	Hill Brothers Chemical Co.
Disinfection: Ammonia	\$ 9,620	\$370/ton	Hill Brothers Chemical Co.
Backpulse Chemicals: Sodium Hypochlorite	\$ 8,232	\$0.31/Liter	Zenon Budget Proposal
CIP Chemical #1: MC-1	\$ 3,211	\$1.67/Liter	Zenon Budget Proposal
CIP Chemical #2: Sodium Hypochlorite (250 mg/L)	\$ 4,435	\$0.31/Liter	Zenon Budget Proposal
CIP Neutralization Chemical #1: Sodium Hydroxide	\$ 175	\$0.36/Liter	Zenon Budget Proposal
CIP Neutralization Chemical #2: Sodium Bisulfite	\$ 117	\$0.06/Liter	Zenon Budget Proposal
RO - Sulfuric Acid	\$ 5,745	\$0.04/lb	Zenon Budget Proposal
RO - Sodium Bisulfite	\$ 2,594	\$0.25/lb	Zenon Budget Proposal
RO - Antiscalant	\$ 122,359	\$3.27/Liter	Zenon Budget Proposal
RO - Organic Acid: MC-1	\$ 8,658	\$2.29/kg	Zenon Budget Proposal
RO - Alkali Surfactant: MC-4	\$ 1,738	\$3.06/kg	Zenon Budget Proposal
RO - Sanitizer: MP-1	\$ 4,748	\$5.01/Liter	Zenon Budget Proposal
flajor Power Costs		\$0.075/kW-hr	
Screening	\$ -	Existing	
Aeration Basins	\$ 419,000	18 motors @ 50 HP; 24 hrs/day	South WWTP info
Recirculation Pumps	\$ 74,500	4 pumps @ 40 HP; 24 hrs/day	South WWTP info
Permeate Pumps	\$ 36,901		Zenon Budget Proposal
Membrane Air Scour Blowers	\$ 114,440		Zenon Budget Proposal
Air Separation System Vacuum Pumps	\$ 2,520		Zenon Budget Proposal
Backpulse Sodium Hypochlorite – Metering	\$ 7		Zenon Budget Proposal
Air Compressors	\$ 2,515		Zenon Budget Proposal
Air Driers	\$ -		Zenon Budget Proposal
I&C	\$ 657		Zenon Budget Proposal
Miscellaneous	\$ 657		Zenon Budget Proposal
RO Pretreatment Chemical Mixers, Process Pump, CIP Pump	\$ 501,591		Zenon Budget Proposal
Membrane/Cartridge Filter Replacement Costs			
ZeeWeed	\$ 190,905	1-yr warranty; 8-yr replacement frequency	Zenon Budget Proposal
RO	\$ 226,286	5-yr replacement frequency	Zenon Budget Proposal
Cartridge Filter	\$ 24,637	annual replacement	Zenon Budget Proposal
Other Costs			
Maintenance	\$ 63,750		Prorated South WWTP Cos
Permit Fees	\$ 39,100		Prorated South WWTP Cost
Land Maintenance	\$ 12,750	replacement of sand in drying beds	Prorated South WWTP Cost

TABLE 6.2

Order of Magnitude Cost Estimate for ZeeWeed® and RO Alternative Capital and O&M Cost Opinion

Item	Cost		Assumption	Cost Reference	
Supplies	\$	61,200	includes land application of sludge (\$31.50/dry ton)	Prorated South WWTP Costs	
Labor	\$	655,200	21 O&M personnel @ \$15.00/hr (16 exst. plant w/Zeeweed; 5 for RO)	CH2M HILL estimate	
Laboratory	\$	141,100	includes 4 lab techs, analysis, O&M, etc.	Prorated South WWTP Costs	
Total Annual Operation & Maintenance Cost	\$	2,760,698			
Total Annual O&M Unit Cost (\$/1,000 gallon)	\$	1.17			
Total Annual Cost	\$	4,373,072			
Total Unit Cost (\$/1,000 gallon)	\$	1.85	Based on 6.8 MGD product water flow; plant availability factor = 95%		

^a Detailed listing of components comprising ZeeWeed and RO systems are presented in Appendix H.

TABLE 6.3Design Criteria Assumptions for ZenoGem, ZeeWeed, and RO Systems

Criterion	Value
ZenoGem System	
Design Permeate Flow, mgd	8.5
Hydraulic Residence Time, hours	6
Solids Retention Time, days	. 17
Mixed Liquor Suspended Solids Level, g/L	10
Aeration Rate, fine bubble, scfm/mgd	647
Aeration Rate, membrane air scour, scfm/mgd	2,586
Aeration mode (both systems)	Cyclic
Membrane flux, gfd	15.4
No. of membrane trains	6
No. of reactor tanks	6
Backpulse interval, minutes	15
Backpulse duration, seconds	30
Backpulse pressure, psi	8
Maintenance clean interval, hours	168
Maintenance clean duration, minutes	60
ZeeWeed System	
Design Permeate Flow, mgd	8.5
Hydraulic Residence Time, hours	0.56
Feedwater Recovery, percent	95
Aeration Rate, membrane air scour, scfm/mgd	1,207
Aeration Mode	Continuous
Membrane flux, gfd	20.4
Backpulse interval, minutes	15
Backpulse duration, seconds	30

^b ENR CCI reference number 6126.79

TABLE 6.3Design Criteria Assumptions for ZenoGem, ZeeWeed, and RO Systems

Criterion	Value
Backpulse pressure, psi	8
RO System	
Design Permeate Flow, mgd	6.8
Feedwater pH, units	5
Antiscalant dose, mg/L	Manufacturer dependent; 3 max
Feedwater recovery, percent	80
Membrane flux, gfd	12
Membrane type	low fouling, aromatic composite
Vessel array	three stage, concentrate taper

Estimated total capital cost for the ZenoGem/RO approach (Alternative 1) is significantly higher than for the ZeeWeed/RO approach (Alternative 2), \$28.0MM versus \$17.8MM, a difference of nearly \$10MM. The difference reflects the higher cost of treatment for ZenoGem relative to ZeeWeed. Compared to the requirements for ZeeWeed, ZenoGem requires more membrane modules because a lower flux rate must be used to treat the significantly higher solids concentration of the mixed liquor (relative to the secondary effluent from the existing WWTP); larger tankage to provide wastewater flow equalization and the necessary hydraulic retention time to complete nitrification; and increased blower capacity to achieve carbonaceous and nitrogenous oxidation of the wastewater.

Estimated annual operating and maintenance costs for the ZenoGem-based alternative were slightly lower than for the ZeeWeed alternative (\$2.48MM/year versus \$2.76MM/year). This reflects lower energy and labor costs associated with operating the ZenoGem system versus those for operating costs for the extended aeration basins, secondary clarifiers and ZeeWeed system.

The significantly higher capital cost for Alternative 1 outweighs the slightly lower O&M costs. Consequently, total unit cost for Alternative 1 is higher (\$2.13/1000 gals versus \$1.85/1000 gals). Based on these estimates, it would be more cost-effective for McAllen to implement Alternative 2 (using ZeeWeed and RO to treat existing plant secondary effluent) to achieve their indirect potable reuse treatment goals. This reflects the cost savings of associated with the use of their existing flow equalization and secondary treatment facilities that are a sunk cost.

The disparity in capital cost between the ZenoGem and ZeeWeed alternatives could be reduced somewhat in the instance where a municipality's existing WWTP utilized concrete basins for aeration, rather than the earthen basins used at McAllen. Cost savings in this instance would result from avoiding the costs associated with constructing new concrete basins and instead retrofitting the membrane modules into the existing tankage. For the flow rate assumed in this cost comparison (8.5-mgd), the avoided cost would be \$1.3MM or 5.5% of the total capital cost for the ZenoGem alternative. Actual savings would be somewhat less due to the costs associated with basin retrofit. The \$1.3MM savings would reduce the difference in capital costs between the two alternatives, however, the ZeeWeed alternative would still be significantly less

expensive (by \$8.9MM). Additional capital cost savings could be realized if the blowers used for aeration in the conventional, concrete basin plant could be adapted and used where membrane modules are retrofitted into existing basins.

It was beyond the scope of this study to perform an order-of-magnitude level cost estimate for conventional treatment facilities (primary clarification, secondary [activated sludge] treatment and secondary clarification) followed by ZeeWeed in the case where no conventional wastewater treatment existed. However, based on design and costing of conventional treatment facilities that CH2M HILL has performed over the past 20 years, rule-of-thumb costs for 8.5-mgd of conventional treatment would be in the \$16MM -\$20MM range. Adding ZeeWeed costs of \$12MM results in a cost estimate of \$28-32MM. This compares with ZenoGem cost of \$22MM as estimated in this report. Based on these estimates, constructing a 8.5-mgd ZenoGem treatment plant to treat screened, de-gritted sewage would save \$6-10MM compared with the conventional treatment/ZeeWeed approach using the combination of rule-of-thumb and order-ofmagnitude cost estimates. This represents a significant savings potential and indicates that for municipalities considering indirect potable reuse and who would be starting with raw sewage, it should be considerably less expensive to construct a treatment facility using ZenoGem/RO versus conventional wastewater plant (through secondary treatment)/ZeeWeed/RO.

References

- Green, J and J. Holmes. 1947. Journal American Water Works Association. Volume 39. p. 1090.
- Lozier, Jim. 1998. Water Treatment Technology Program Report No. 26. Wastewater Reclamation Pilot Study, City of McAllen, Texas.
- Water Environment Federation. 1990. Operation of Municipal Wastewater Treatment Plants. Manual of Practice 11, Volume II.
- Water Environment Federation and American Society of Civil Engineers. 1991. Design of Municipal Wastewater Treatment Plants, Volume I. WEF Manual of Practice No. 8. ASCE Manual and Report on Engineering Practice No. 76.

SI Metric Conversions

English Unit	Multiply By	SI Metric Unit
ft²	0.0929	m²
gal	3.785	L
gai	0.003785	m³
gpm	0.06309	L/s
gpd/ft²	1.698	L/m²/hour
in	2.54	cm
lb	454	g
psi	0.0703	kg/cm²

Appendix A. Photographs of Demonstration Plant Facilities and Associated Equipment

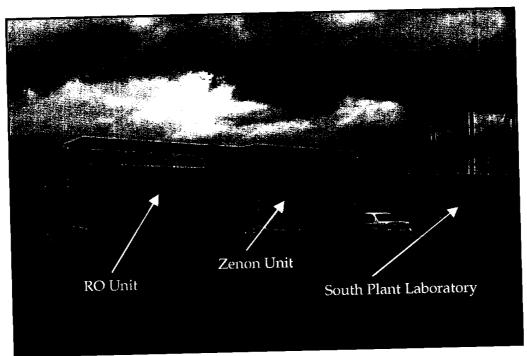


Exhibit A-1. Demonstration plant location (located to the west of the South WWTP laboratory).

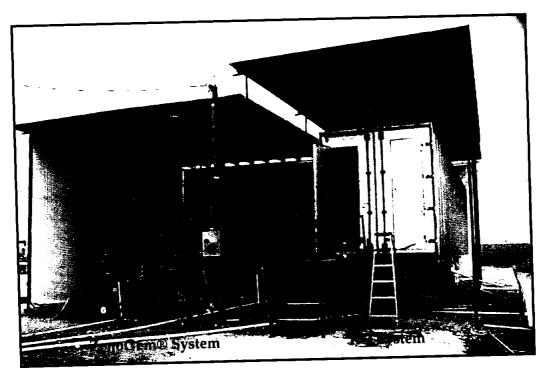


Exhibit A-2. ZenoGem® and RO treatment systems (looking west).

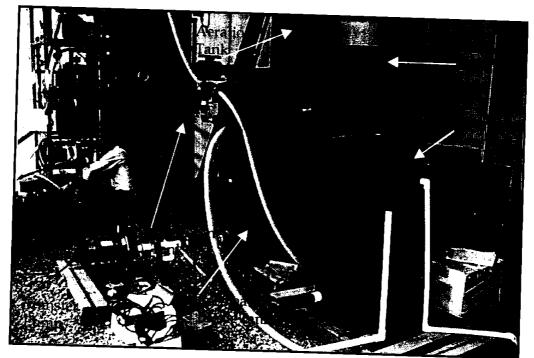


Exhibit A-3. Process tanks for ZenoGem system (operator Henry Perez in background).

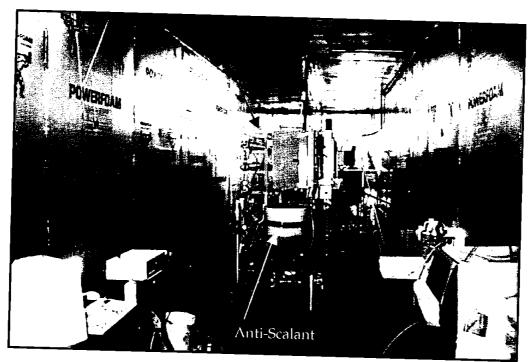


Exhibit A-4. RO system equipment (looking east inside trailer).



Exhibit A-5. RO data acquisition equipment (looking west inside trailer).

RO program licensed to: Calculation created by: J. Lozier (CH2M HILL) 12.7 gpm Permeate flow: Project name: McAllen Phase II 15.9 gpm Raw water flow: 15.9 gpm HP Pump flow: 80.0 & (Stages! Recommended pump press.: 132.2 psi Permeate recovery ratio: 121.4 psi Feed pressure: 31.0 C(88F) Feedwater Temperature: 0.0 years Element age: 7.80 Raw water pH: 7.0

Raw water ph:

Acid dosage, ppm (100%): 56.9 H2SO4

Acidified feed CO2: 57.9

Average flux rate: 12.0 gfd

Array

Stage	Perm.	Flow per Feed	Vessel Conc	Flux	Beta	Conc. Press.	Element Type	Elem. No.	Array
1-1 1-2 1-3 1-4	flow gpm 5.7 4.5 1.6 0.9	gpm 7.9 5.1 5.7 4.1	gpm 5.1 2.8 4.1 3.2	gfd 16.2 12.7 8.8 5.3	1.16 1.21 1.10 1.07	psi 111.5 103.6 94.1 86.7	LFC1-4040 LFC1-4040 LFC1-4040 LFC1-4040	6 6 3 3	2x3 2x3 1x3 1x3
++ Ion	Raw	water CaCO3	+Feed mg/l	water- CaC	03	Permea		ncentra g/l (te+ CaCO3

++	Raw mg/l	water	Feed mg/l	water+ CaCO3	Perme mg/l	CaCO3	mg/l	CaCO3
Ca Mg Na K NH4 Ba Sr CO3 HCO3 SO4 C1 F NO3 SiO2	140.0 29.1 332.0 17.1 1.0 0.1 1.3 0.3 293.0 327.0 388.0 1.0 1.5 13.9	349.1 119.8 721.7 21.9 2.8 0.1 1.4 0.5 240.2 340.6 547.2 2.6 1.2	140.0 29.1 332.0 17.1 1.0 0.1 1.3 0.1 224.0 382.8 388.0 1.0 1.5 13.9	349.1 119.8 721.7 21.9 2.8 0.1 1.4 0.1 183.6 398.7 547.2 2.6 1.2	2.3 0.5 25.2 1.6 0.1 0.0 0.0 25.5 6.3 25.0 0.1 0.5	5.7 1.9 54.8 2.1 0.3 0.0 0.0 20.9 6.6 35.3 0.3	690.9 143.6 1559.2 79.1 4.6 0.4 6.2 0.3 1017.8 1888.6 1839.8 4.5 5.7 67.7	1723.0 591.0 3389.5 101.4 12.8 0.3 7.1 0.6 834.3 1967.3 2594.9 11.8 4.6
TDS	1545.2 7.8		1531.8 6.8		87.6 5.9		7308.5 7.4	+

CaSO4 / Ksp * 100: SrSO4 / Ksp * 100: BaSO4 / Ksp * 100: SiO2 saturation: Langelier Saturation Index Stiff & Davis Saturation Index Ionic strength Osmotic pressure	Raw water 8% 5% 371% 9% 0.92 0.95 0.03 13.3 psi	Feed water 10% 6% 428% 9% -0.19 -0.17 0.03 13.1 psi	Concentrate 73% 42% 2994% 45% 1.73 1.35 0.16 62.8 psi
		c	n Andrated

These calculations are based on nominal element performance when operated on a feed water of acceptable quality. No guarantee of system performance is expressed or implied unless provided in writing by Hydranautics.

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Hydranautics (Europe) Ph: 31 5465 49335 Fax: 31 5465 49337

HYDRANAI	UTICS RO	SYSTEM DES	IGN SOFTWAR	E, VERS	ION 6.4	(c) 1	998	1	2/1 2 /	1999
Calculat Project HP Pump	name: Mo	ated by: J. CAllen Phas	Lozier (CH2 e II 15.9 gpm	M HILL Perme		-			2.7 g 5.9 g	-
Feed pre Feedwate Raw wate Acid dos	essure: er Temper er pH: sage, ppm ed feed C	rature: n (100%): NO2:	21.4 psi 31.0 C(88F) 7.80 56.9 H2SO4	Elemen Flux o	ate reco nt age: decline passage type:	t per	year: ase, %	(0.0	
	low		onc		Conc. Press. psi		ement Type	Eler No		rray
1-1 1-2 1-3	5.7 4.5 1.6	7.9 5 5.1 2 5.7 4	pm gfd .1 16.2 .8 12.7 .1 8.8 .2 5.3	1.16	111.5	LFC1 LFC1	-4040 -4040 -4040 -4040	6 3 3	5 :	2x3 2x3 1x3 1x3
Stg Elem no.	pres	Pres Perm drop flow psi gpm	Perm Beta Flux gfd	Perm sal TDS				satura BaSO4		
1-1 1 1-1 2 1-1 3	121.4 117.4 114.2	3.3 0.9	17.0 1.13 16.1 1.14 15.2 1.16	31.2	17.3	12 14 17	7 8 10	504 602 733	10 12 14	0.0 0.2 0.4
1-2 1 1-2 2 1-2 3	108.5 106.4 104.8	1.6 0.7	13.7 1.17 12.7 1.19 11.5 1.21	44.8	29.1	21 27 35	12 16 20	903 1140 1476	17 20 25	0.6 0.8 1.1
1-3 1 1-3 2 1-3 3	100.6 98.1 95.9	2.2 0.5	9.8 1.10 8.6 1.10 7.8 1.10	55.9 61.1 66.6	44.0	40 46 52	23 26 30	1679 1907 2161	28 31 34	1.2 1.3 1.5
1-4 1 1-4 2 1-4 3	91.0 89.3 87.8	1.7 0.4 1.5 0.3 1.3 0.3	6.1 1.08 5.0 1.08 4.5 1.07	73.4 81.0 88.6	57.3	58 65 71	33 37 41	2410 2665 2925	37 41 44	1.6 1.6 1.8

These calculations are based on nominal element performance when operated on a feed water of acceptable quality. No guarantee of system performance is expressed or implied unless provided in writing by Hydranautics. Hydranautics (USA) Ph: (619) 901-2500 Fax: (619) 901-2578 Hydranautics (Europe) Ph: 31 5465 49335 Fax: 31 5465 49337

HYDRANAUTICS RO SYSTEM DESIGN SOFTWARE, VERSION 6.4 (c) 1998 12/12/1999
BASIC DESIGN

RO program licensed to:

Stage Perm.

1-1

Flow

gpm

4.1

Calculation created by: J. Lozier (CH2M HILL)

Flow per Vessel

Conc

gpm

5.2

Project name: McAllen Phase II Permeate flow: 7.2 gpm HP Pump flow: 14.4 gpm Raw water flow: 14.4 gpm

50.0 %

Array

2x3

Elem.

No.

6

Recommended pump press.: 100.5 psi

Feed pressure: 91.1 psi Permeate recovery ratio:

Feedwater Temperature: 31.0 C(88F) Raw water pH: 7.80

Feed

gpm

7.2

Raw water pH: 7.80 Element age: 0.0 years
Acid dosage, ppm (100%): 56.9 H2SO4 Flux decline % per year: 7.0
Acidified feed CO2: 57.9 Salt passage increase, %/yr: 10.0
Avorage flux rate: 10.2 gfd Feed type: Waterster

Acidified feed CO2: 57.9 Salt passage increase, %/yr: 10.0 Average flux rate: 10.2 gfd Feed type: Wastewater

gfd

11.5

Flux Beta

1.11

Conc.

psi 81.9

Press.

Element

LFC1-4040

Type

1-2	3.1	5.2	3.6	8.8 1	.12 73.2	LFC1-		6	2x3
Ion	+Raw mg/l	water CaCO3	+Feed mg/l	water CaCO3	-+Perme		+Conce mg/l		:e+ iCO3
Ca Mg Na K NH4 Ba Sr CO3 HCO3 SO4 C1 F NO3 SiO2	140.0 29.1 332.0 17.1 1.0 0.1 1.3 0.3 293.0 327.0 388.0 1.0 1.5 13.9	349.1 119.8 721.7 21.9 2.8 0.1 1.4 0.5 240.2 340.6 547.2 2.6 1.2	140.0 29.1 332.0 17.1 1.0 0.1 1.3 0.1 224.0 382.8 388.0 1.0 1.5 13.9	349.1 119.8 721.7 21.9 2.8 0.1 1.4 0.1 183.6 398.7 547.2 2.6 1.2	0.3 18.0 1.2 0.1 0.0 0.0 0.0 18.3 4.4	4.0 1.4 39.1 1.5 0.2 0.0 0.0 0.0 4.6 25.1 0.2 0.3	278.4 57.9 646.0 33.0 1.9 0.2 2.5 0.1 429.6 761.1 758.2 1.9 2.7 27.5	23 140 4 35 79 106	
TDS	1545.2 7.8	· +	1531.8 6.8	***********	62. 4 5.7	+	3001.1		+

CaSO4 / Ksp * 100:	Raw water 8%	Feed water 10%	Concentrate 23%
SrSO4 / Ksp * 100:	5%	6%	13%
BaSO4 / Ksp * 100:	371%	428%	990%
SiO2 saturation:	9%	9%	18%
Langelier Saturation Index	0.92	-0.19	0.65
Stiff & Davis Saturation Index	0.95	-0.17	0.56
Ionic strength	0.03	0.03	0.06
Osmotic pressure	13.3 psi	13.1 psi	25.7 psi

These calculations are based on nominal element performance when operated on a feed water of acceptable quality. No guarantee of system performance is expressed or implied unless provided in writing by Hydranautics. Hydranautics (USA) Ph: (619) 901-2500 Fax: (619) 901-2578 Hydranautics (Europe) Ph: 31 5465 49335 Fax: 31 5465 49337

нут	DRANAUT:	ICS RO	SYST	EM DE	SIGN S	OFTWAR BASI	E, VERS C DESIG	ION 6.4	l (c)	1998		12/12	/1999
Cal	program	n lice	nsed	to:									
Pro	culatio	on cre	ated										
HP	ject na Pump fl	OW:	CATIE	n Phas	14 4 .		Permea Raw wa	ate flo	w:			7.2	arom
Rec	ommende	d pum	p pre	ss.: 1	00 5	gpm osi	Raw wa	ater fl	ow:		:	14.4	abw as
ree	a press	ure:			91 1 +	nei	Perme	ato woo					
ree	dwater.	Tempe:	rature	≘:	31 0 0	'/ <i>ዩዩ</i> ሮነ		ate rec	overy	ratio:	5	50.0	€
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	Flot	v	Feed	Co	onc		beca	Press.		Type	Ele	m. <i>A</i> O.	rray
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1-2	4.1	_	7.2 5.2	3	. 4	11.5	1.11	81.9	LFC	1-4040		6	2x3
													2x3
Stg	Elem no.	Feed	Pres	Perm	Perm	Beta	Perm	Conc	Concer	strata			
	no.						sal	osm	CaSO4	SrS04	Bacos	gion	level Lang.
		psı	psi	gpm	gfd		TDS	pres		01004	Dasou	3102	Lang.
1-1	1	91 1	3 5	0.7	12 2	1.10	20.						
1-1	2	87.5	3.0	0.7	11 4	1.10	39.0 42.4	14.6	11	•		10	-0.1
1-1	3	84.5	2.6	0.6	10.7	1.11	46.4	18.1		•	555	11	0.1
1 0								10.1	15	9	638	13	0.2
1-2 1-2	_		2.2	-		1.11		20.5	17	10	733	14	0.4
1-2	3	74.8	1.9 1.6	0.5 0.5		1.11		22.7		11	848		0.5
_ •	_	73.0	4.0	U.5	8.1	1.12	62.7	25.9	23	13	985	18	0.7

These calculations are based on nominal element performance when operated on a feed water of acceptable quality. No guarantee of system performance is expressed or implied unless provided in writing by Hydranautics. Hydranautics (USA) Ph: (619) 901-2500 Fax: (619) 901-2578 Hydranautics (Europe) Ph: 31 5465 49335 Fax: 31 5465 49337

of section or and

HYDRANAUTICS RO SYSTEM DESIGN SOFTWARE, VERSION 6.4 (c) 1998 12/12/1999 BASIC DESIGN RO program licensed to: Calculation created by: J. Lozier (CH2M HILL) Project name: McAllen Phase II Permeate flow: 12.7 gpm HP Pump flow: 25.4 gpm Raw water flow: 25.4 gpm Recommended pump press.: 140.9 psi Feed pressure: 131.5 psi
Feedwater Temperature: 31.0 C(88F) 50.0 8 (Stage Permeate recovery ratio: Raw water pH: 0.0 years | \$2 7.80 Element age: Acid dosage, ppm (100%): 56.9 H2SO4 Flux decline % per year: 7.0 Acid dosage, ppm (1500).
Acidified feed CO2: 57.9 Salt passage increase,
Average flux rate: 12.0 gfd Feed type: Salt passage increase, %/yr: 10.0 Wastewater Stage Perm. Flow per Vessel Flux Beta Conc. Element Elem. Array Flow Feed Conc Press. Туре No. gpm gpm gpm 6.0 12.7 9.7 4.6 9.7 7.4 1.5 14.8 13.3 0.6 13.3 12.7 gfd psi 17.0 1.09 110.5 13.0 1.09 93.2 8.4 1.03 61.3 1-1 LFC1-4040 6 2x3 LFC1-4040 6 2x3 LFC1-4040 3 1x3 LFC1-4040 3 1x3 1-2 1-3 3.3 1.01 32.4 +----+----Raw water---+---Feed water----+---Permeate------Concentrate---+ | Ion | mg/1 CaC03 | mg/1 CaC03 | mg/1 CaC03 |
 140.0
 349.1
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 ------Mg Na K NH4 Ba Sr CO3 HCO3 SO4 | Cl F NO3 SiO2 -----TDS | 1545.2 1531.8 56.5 pH | 7.8 6.8 5.7 3007.0

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	8%	10%	23%
SrSO4 / Ksp * 100:	5%	6%	13%
BaSO4 / Ksp * 100:	371%	428%	990%
SiO2 saturation:	9%	9%	18%
Langelier Saturation Index	0.92	-0.19	0.65
Stiff & Davis Saturation Index	0.95	-0.17	0.56
Ionic strength	0.03	0.03	0.06
Osmotic pressure	13.3 psi	13.1 psi	25.8 psi

These calculations are based on nominal element performance when operated on a feed water of acceptable quality. No guarantee of system performance is expressed or implied unless provided in writing by Hydranautics. Hydranautics (USA) Ph: (619) 901-2500 Fax: (619) 901-2578 Hydranautics (Europe) Ph: 31 5465 49335 Fax: 31 5465 49337

HYDRANAUTICS RO SYSTEM DESIGN SOFTWARE, VERSION 6.4 (c) 1998 12/12/1999 BASIC DESIGN RO program licensed to: Calculation created by: J. Lozier (CH2M HILL) 12.7 qpm Permeate flow: Project name: McAllen Phase II 25.4 gpm 25.4 gpm Raw water flow: HP Pump flow: Recommended pump press.: 140.9 psi 50.0 % Permeate recovery ratio: 131.5 psi Feed pressure: 31.0 C(88F) Feedwater Temperature: 0.0 years Element age: 7.80 Raw water pH: Acid dosage, ppm (100%): 56.9 H2SO4 Flux decline % per year: 7.0 Salt passage increase, %/yr: 10.0 57.9 Acidified feed CO2: Wastewater 12.0 gfd Feed type: Average flux rate: Elem. Array Conc. Element Flux Beta Flow per Vessel Stage Perm. No. Type Press. Feed Conc Flow gfd psi gpmgpm gpm 2x36 1.09 110.5 LFC1-4040 17.0 9.7 12.7 6.0 1 - 1LFC1-4040 6 2x393.2 13.0 1.09 7.4 9.7 1-2 4.6 LFC1-4040 3 1x38.4 1.03 61.3 13.3 14.8 1.5 1-3 1x3LFC1-4040 12.7 32.4 1.01 3.3 0.6 13.3 1-4 Perm Conc Concentrate saturation level Feed Pres Perm Perm Beta Stg Elem osm CaSO4 SrSO4 BaSO4 SiO2 Lang. pres drop flow Flux sal no. gfd TDS pres psi psi gpm 10 -0.1 477 11 6 25.6 14.3 18.3 1.08 131.5 7.9 1.1 1 1-1 7 532 11 0.0 15.7 12 27.9 1.08 1.0 17.0 7.0 1-1 2 123.6 0.1 14 594 12 8 1.09 30.3 17.1 15.7 0.9 116.6 6.1 1-1 3 0.3 q 661 13 15 33.3 18.8 14.0 1.08 5.4 0.8 107.5 1-2 1 14 0.4 10 738 20.4 17 1.08 36.4 4.8 0.8 12.9 102.1 2 1-2 0.5 16 19 823 11 11.9 1.09 39.7 22.4 4.2 0.7 97.3 1-2 3 0.5 865 16 12 23.5 20 41.8 0.6 10.1 1.04 90.1 10.1 1-3 1 0.6 12 903 17 21 24.0 1.03 44.2 80.0 9.6 0.5 8.3 1-3 2 17 0.6 25.0 22 13 935 46.8 1.03 6.7 9.2 0.4 70.4 1-3 3 18 0.7 959 23 13 25.6 49.9 4.7 1.02 8.9 0.3 58.2 1 - 41 0.6 977 18 13 1.01 23 53.3 25.6 3.2 8.6 0.2 49.4 1 - 42 18 0.7 13 987 23 56.9 26.2 1.9 1.01 8.5 0.1 40.7 3 1-4

These calculations are based on nominal element performance when operated on a feed water of acceptable quality. No guarantee of system performance is expressed or implied unless provided in writing by Hydranautics.

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Hydranautics (Europe) Ph: 31 5465 49335 Fax: 31 5465 49337

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١.	(Tulina) N-EGNACON					8										3		67.0						6							;	3				200							;	60			8	!		
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	eted	(10) soil and stancoff described (even)	H-EIGH Installed 9TWN	WITP Infance CBOD	SET Insulhir STWN	mori beteelt agbuil mori beteelt agbuil (age) zineT notterak	mori betselli egbulë (teg) AreT ameridmeki	Total Meas Produced (yahla)	Total State 900,	MolY appute	(cyab) TAS malaya	GGO egades essevi	MXT sebude essew	TT egbuite steew (Jigm)	(mgt.)	S2V.Mi egbuit elenW (Agm)	Hq	Conductivity (using)	COD (war)	Atta (mg/L)	(Agm) DO	Feed CBODS (mg/L)	(Jen) 651 bee?	(Jam) H-DHN	MHS-N (mgA.) (ASL	(Jen) N-EOMEON	(Agm) KNT	(Agen) nagothik late)	(7 6 4)	Temperature (degrees	(Jew) od	(nimi.Aso ym) MUO (Agm) 88.94		(Jem) 88V.M
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D MT-EVENT 3)		6.50	27.53	174.73	153.45	125.00	143.18	16.90	12.15	1.14	15.65	17100.00	1260.00	215.00	12670.00	9425.00	7 20 24	28.71 1958.29	29	334.00	1.03	158.20	107.20	23.18		PC:0	38.00	38.04	7 188	7.05 30.04	3.9	1.42 12100.00		7950.00
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D MT-EVENT 10)		8.	28.60	173.60	180.00	150.00	225.00	23.77	12.25	2.00	14.40	13400.00	979.00	108.00	9450.00	7450.00	7.08	29.40 1694.67		448.00 360.00	00 0.93	157.00	184.00	24.85		0.02	43.30	43.32	5.45	7.03 31.00	5.80	1.14 777	7770.00 58	5825.00
D MT-EVENT 11)		0.30	29.05	181.83	158.00	191.67	237.50	28.57	12.02	1.24	13.29	14400.00	1004.00	155.00	7650.00		6	29.05 1595.00	8	320.00	08:0	154.00	140.00	17.20		16.0	38.90	38.91	3.87	30.65	61.9	787	7875.00 44	4450.00
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	et#Q	BAPLP POM		Set 417/88	Sun estable	Tue 4/2008	Wed 421/99	Thu 4223	Fri 422/80	200	Hon 4/24/91	Tue 427/M	Wed 4/29/99		Set 57178	Sun \$2.70	Mon SOV	746 644.00	1000	Fel 5778	Set Sylver	Sun Sarre	Tue (11/19)	Wed \$12/99	WET'S MIT	F1 574/8	M2174 M2	Mon 57.77	744 5/18/7	Wed Sribible	The S/20/98	F4 521/M	MC25 uns	Mon \$72478	144 M234	Thu 5/27/80	Frt 5/28/99	Sec 570/0	Mon \$731/80	Tue 6/1/78	Mad 6/2/9	The 6259	Frt 6/4/86	Mon 6/7/88	Tue END/90	Ward Comm	Thu Critical	Sec 6/12/80	Sum 6713/89	Mon 6/14/99 Tue 6/15/99
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	900	Tue ext	Med by		See 877.	M234 mg	Mon M23A	Wad B/25/8	Thu 6/26/8	F1 8277	Ser 67278	Non 8707	Tue BOTA	Ned Wil	Fe Sale	24 145	Sun BRA	Non Man		The SME	Fri Bridge	See 1871.A	Sen W12A	Tue Bridge	Wed 9/15/8	Thu British	Ser Ser Ser	Sun Willer	Mon BZO	Tue 8/21/8	The 9/23/B	F-1 10247	Sun 920m	Mon \$27/8	Tue 9/28/9	Thu \$20%	Fri 1971/36	Set 102/	Mon 1944	Tue 1845/R	SEARCE POW	The 1977	Set 10/8/09	Sun 10/10/98	Mon 1071/79	MAC TOT DAY	Thu 10/14/90	F4 10/15/86	Sun 10/17/89
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	essi proff ma	#) \$GOE	н) emperatu	(76m) O	Sem) RU	/6w) 587	m) gsa7	m) BOO	l Menedm	hettaubri	n) Álipiqi	(Agm) (H	ictum Ha	940) 9 40	(Jen) 8	3-N (mgA (304)	T CHOS	chiedro e	7402-M	(TVStu)	egoriM is		il Coliton A100 mt	1440142) 		omeR Ei	MW 9001	A Minorm	K Consu	godini hal Isve	No spirot co
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2.	Thu 10/21/86 5660.25	¥p.		_	2.10		6.850 00					_			_					_		_	-	8	26.	00 000"					_	
22	Frt 16/72/88 5683.00	P			5.30	_	8,700 00												_								_					
ņ	See 10/23/96 5708:00	P		_		^	7.050.00												_			_										
=	Sun 18/24/88 5731 50	۰	_	_			7,750 00	_							_											_	_				_	
2	Men 19/25/76 5756.50	0 632.00	7 16	25.40	8	96	6.000:00	4,600 00	612.00	7.33 25.00	1,414,00	9	90	316.00		- 5		-		_		_								_	_	
2	Tue 10/26/26 \$780.50	6	_	27 50	29	_	90 0019	_	_					_	3			2 :	8	2	8	824	- 38 - 38	8	930	99	12 96 21	89 75	*	22.63	6918	52.42
7.	Wed 18/27/98 5804.50	984.00	7.21	26.10	0.70	1.7	6.750 00 5	5,150 00	982 00	7.32 26.00		- 1				-		8	8.0	_				_	_		_					_
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=	2	830.00		38.00	0+0	0.49 10	10.050 00 6,400.00	_			9			3 3	8 8	// 6 97.0	6 9	0.0	_						.,	99 92	12 97.50	99 55	62.63	30 35	78.72	78.78
	MAX	2,630.00 7.47		30.00	8.4	0.73	00:000:41 00:000:41		8		8				3	-		5 6										\$	47.60	35.14	\$7.71	92.56
	MEAN	932.19	7.13	31.14	1.73	0.87 10,	7.175.7 25.022.01		115.37		1	1	1		1		!		П	ı		1	1		-1	+	15 97.95	29.97	99.92	75.65	8.50	99.50
O	Ŧ	620.00		27.50	0.60	0.40	7,300.00 5,3	5,550.00	_		122						50.0	g :							-	_	2.8	29 63	ĭ	61 02	60.57	58.93
	MAX	1,460.00 7.36		33.00	4.70	2.59 14,	14,850.00 9,4	9,400.00	_		1,982				2			0.02	6.6	65.0			79.0	3.00		-			7	4.12	34.35	23.65
	MEAN	781.50 7.14		28.95			6,609.36 4,4	4,818 75	669.13	7.25 28.62	1,419.15	0.13	14.50 138.00	t		1	1	1	!	1	ı	ı	1		1	┿	- 1		8	73.68	12.09	89.00
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MINORWALL		1,536.67 7.31		1	-		1 010 00 7.5	_	8	*	- 1	\$ 110	5.00 154.00	١	1 1	0.30 0.16		0.03	l		ļ			1	!	┰				2 2	16 21	2 2
B(PEAK)		1.13.00 7.37		25.52	7 2	20.00	13,863.33 9,875.50		205.28	7.59 20.18			15.00 202.67				61.9	90.0	_	5.63 9				L	Ι.,	╁	F	ı				
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C(PEAK-EVENTS 1,4,8)		870.80	7.19	31.91			9,416.67 6,8		768.80	7.37 31.46	•		2			0.20 0.24	50.0	8 5	3 5	547	12.	18.42	3.34 15	15.09 8.90	X	6			80.82	63.59	58.03	16.82
TO LET EVENT 71		862.00	2.05	20.80	121	2.	00 24301	200000	5									3								1.37 99.85	86.34	99.98	2	52.98	76.89	39.98
CONCOMINE WITH CITCLED AND TO ATTEMPTON		_				1	1		+	7 35 29 87		0.15	176.00	322.00	2.0	0.24 0.91		0.04	30	9	6.50	9.96	1.97 82.	82.15 26.14	3236.64	64 99.7	'n	99.64	86.85	47.36	73.62	88.88
DOPEAN WITH CYCLED AND					392	2			960.00	29.80	1533.00	0.12			0.03	0.05		0.07	10.04	16.30 2	2.00	20.30	3.19			├		8	1		:	:
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TO INT-EVENT 11)		\$80.00		30.60	3.60	69	\$900.00	4400.00	545.00	31,00	1447.50		124.00	900	2												29.65	5	5 5	1	2	73.58
TO ME AND AT-EVEN. 12!		95.150	7 22 2	**	1 74	165	11 1000	, ,	-	1								n n		20.10	22	22.10 2.)	2.73 9.00	8	1600.00	99.88		69 66	99.19	61.25	43.20	29.46
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0.06		000					129 040			_					1 58	_				121				.71	┺-		_			1 47			136	2 2	214	284		773	38	174	1.28		Total Chlorine (mg
			809		_	5 e	. S	-	-			<u> </u>	0 4	3 6	29 791		2	3 3	š	0.08	_	_	=	5 1	+			900	3 8		9		007	: 8	_			0 16	2	0.10	0.00	_	Free Chlorina (mg/
			8				_							_	8			_	_		989 00					8100				3	8					920 00							TDS (mg/L)
					_	_		_	_	_	_			_					_					_	_			_	_				8	3	,					3			Total Collins (CPU/100 mL)
_						_	_	61	_	_								_						_	_								8	<u> </u>									Fecel Colliorm (CFU/100 mL)
1000 —		74000			- Constitution			280000		_		49000		8			70000			17000			5000		3600			17000		DRONDING		-	Second		14000			57000		150000			Pseudomones (1000° CFU/100mL)
		_													_		_	_																		170.00			4,400,00				HPC (CFU/mL)
	_	_	3 88 5						_		_				6.92					è						713				7.35					ž	-					7 63		pH
	_	_	5.460 00		_					_					290.00					95					.000	9				3.550 00						7					4,620.00		Conductivity (ut/or
0 0	_		0.21				0.27	95			8	2 4	033	5	0.35		029	0.35	1	0 0	· -	_ {	2 3	0 22	0 6	3		9 6	0.14	0 20		025	0.36	25.0	020			0.27	2			_	Turbidity (NTU)
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	_		3.066.00								_				2,758 00	_				3,320.00					1,444,00	_				2,114.00					1,548 00								TDS (mg/L)
_	_	_	5	_		_				_			_		5.75		_		_	6.26					603			_		8		_			621		_				6.02	_	рН
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	_				-		_	_	_		_	υ <b>5</b>	- T	3 1		_	-	3 5		ŏ			10	0 11	9		5	2 1	ē ē		_		_	3 5	8		2	013	0.12	0.00	<u> </u>	_	ree Chiorine (mg/L)
	_					_		_	_		_													+				<u>-</u>	_	3			8		_				8			_	otal Coliform CFU/100 mL)
	_			_		_		_						_						-			_	$\downarrow$	_	_									200							_	ecal Cofform CFU/100 mL)
_	9				\$ 3.	_	33.95	_				7 00	Š	7		-	3	_	30.6			8		33 93			10 00		700 00			27 00		9 00			8		90.00	3		*	seudomonae CFU/199mL)
00 00		600 00							_									000		200 00			ge sa	8 8				8		700 00					600				350			-	PC (CFU/mL)
_	_	91.68						_	_	_				92 97											92 67		_			_		•			92 55			_				<b>\</b>	TOC Removal
		20												95.20						14 14 14					94 17		_			9 5				-	£			_	_			+	TDS Removal
	697		_		-		6 93				_		5.1			6.33	<u> </u>		6.33			6.27		5 0.4			6.23		6. Us			6.33		6.19			6 10	_	5.71	_		-	TDS Removal
5 38 5 38	50 00	75 00			3 8	53 85	61 54				ಪ : ಪ :	54 29	75.00	53 33		29	64 29	55 129	63 64	53 65		66 67		78.57	 8 8		9	80 00	75 00	76 92		68 75	7 7	8	<b>2</b>		71 53	72.2	1 5	8		+	Turbidity Removal

Page 2 of 4

Sings/Event																																			_											_	=														-
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TDS (mg/L)	864.00							3	88							812.00																				8	****						3	,008.00								987.00									_
Total Collins CPU/100 mil.)																																				8	9.5																			_					_
CFU/100 mL)																																				8	8										_														_
seudomones 1000° CPLI100ns		110000				2000			-	32000			40000																				84000	ş																											
IPC /CE!!TU	$\dashv$	-	_				_	_	_		_						_					_	_								_	_				į	, j	_	_					_	_				_		_	Ş		-	<u>.</u>	_					_

TDS (mg/L)	2,936.00				3						. 188.00								752.00		1.012.00			.786.00						
pH .	S S				Š						5 25								5.40		1			5.69						
Constructivity (utilizar)	128.00				3						89.00								127.00		93.00			107.00				_		
TOC (mgA.)					8														0.50						ŝ	ģ				
Turbidity (NTU)	0.1	Ş	Ş	9 9	3	9	00	0.05	0.02		2		2 6	0.08	0.05			8 8	P 0	8	0.03	8	0.03	0.05	0 0	9 9	0.02			
SCH				_															 											
TDS (mg/L)	‡ 8				\$	ģ					31.08					 			 8		38 38			82.08						
Total Chiorina (mg/L)	ş	8	8	025	3	0.24	90	0.02	8		2	2	3 2	0.22	9.02			5 8	 0.50	9.02	9	0.08	0.73	8	3 3	\$ 5	\$ 8			
Free Chlorina (mg/L)	ê	92	8	2 8	1	0.00	000	2	2		8	0.03	2 8	0.04	2			3 2 3	 9 9	0.02	6	0.04	9.12	002	2 2	0.03	0.08			
Total Colliona (CFL/100 mL)																			8										İ	
Fecal Coliforn (CPU/100 mi.)	_																													
Pseudomonge (CPU/100mL)		130.00		87.00		<b>%</b>			<b>5</b> 6.08															_						
HPC (CFUINL)	11,000.00		1,000.00			- 29													 <b>8</b> 00 00					330 00		340.00				
% TOC Removal			<u> </u>			8													91 88						;	8			• :	•
% TDS Removal	ž.		_	•		2					28						-3111		98		<b>8</b> 23			93.72	,					
Log Reduction		5		\$		in T			5.90	1																				
% Turbidity Removal	¥	8	<b>8</b>	\$0.00		8 8	98.67	1	86.67	1	50 00	71.63	53.33	=	37 50			8 % 8 %	71.43 55.56	8	66 67	75 00	72.73 75.00	1	77.78	8	80 S			

_			_	_	_		_		_									
	•			n						*							Slage/Event	
WAX.		MEAN	MAX	<b>E</b>	WEAH	WAX	2	MEAN	MAX	Ī	MEAN	94/94	Thu 10/7/90 334	NCC BEARDS POAK	Tue 10/5/90 33:	Morn (0/4/98 33)	Coto	_
7			7	-	7.	7	7	7	7	-	_	3408.00	3384.00	3360.00	3336.00	3312.00	Plan Time (hrs.)	_
3	4.83 1,21	8.22 1,64	40 1.51	08 1,54	30 1,54	7.13 1,68	7.13 1,61	7.13 1,88	7.52 1,63	160 1.4	7.88	┝				_	pH	-
893.00	211.00	668.44	\$73.00	544.00	,560.00	,681.00	651.00	.651.00	,630.00	483.00	554.50	L					Conductivity (uS/cm)	
7.30	9	6.53	5.53	77	77	8.18	8.17		7.99	2	7	L	••••				TOC (mg/L)	
0.24	0.06	2	0.22	0.11	9. #	0.29	0.12	0.1	4	0.16	2	L					Turbidity (NTV)	
2.80	8	:5	2.50	1.30	<b>.</b>	1.80	1.10	 \$	2.30	8	2.07	L	.60				SDI	
\$	0.02	0.70	2	1.	17	1,41	0,42	0.92	2.14	ĭ	82						Total Chlorine (mg/L)	
1.29	0.02	0.13	0.1	0.04	0.12	0.12	<b>3</b>	0.0	0.15	0.10	0.12						Free Chiorine (mg/L)	FEED
1,006.00	791.00	898.67	<b>961</b> .00	920.00	943.33	1,031.00	968.00	998.50	929.00	929.00	929.00						TDS (mg/L)	
8	6.00	6.00	8	6	ž	2.00	2.00	2.00									Total Coliform (CPU/100 mL)	-
1.00	3.00	3.00	2.00	2.00	2.00												Fecal Colliform (CFU/100 ml.)	-
580000	900	97636	380000	3600	87950	96000	2200	39300	68000	9000	38000						Pseudomonas (1980° CFU/190mL)	
1,700.00	1,000.00	1,444.35	4,400.00	170.00	864.87	6,000.00	1,500.00	3,274.18								1.000 00	HPC (CFU/mL)	•
7.61	3.10	5.05	7.63	7.13	14.5	7.32	7.32	7.32	7.73	7.66	7.67						pH	
6,940.00	4,290.00	5,366.67	4,620.00	2,700.00	3,717.50	3,420.00	3,420.00	3,420.00	6,250.00	3,380,00	4,815.00						Conductivity (u5/cm)	င္ခဲ့
.5	0.14	96.	1.62	9.14	0.32	1.40	0.23	9.54	1.35	9.70	0.97	L					Turbidity (MTU)	CONCENTRA
3.00	0.30	1.57															SDI	á
5,186.00	2,758.00	3,503.22	2,114.00	1.444.00	1,702.00	2,796.00	2,016.00	2,341.33	4,778.00	11.88	2,383.50						TDS (mg/L)	
6.26	5.25	5.86	6.21	6.00	6.07	5.00	8	8	6.35	9	=	L					рн	
50.00	71.00	9.54	72.00	46.00	62.50	86.00	8.00	86.00	80.00	2	2						Conductivity (uti/cm)	
0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50						TOC (mg/L)	
0.1	0.02	8		0.03	93	0.15	0.04	0.08	0.0	0.04	0.05	L	_				Turbidity (NTU)	
					0.32	0.46	20		0.50		0.47	L					SDI	
52.00	29.00		56.00	34.00	23	70.00		\$1.00	35.00	35.00	35.00	_					TDB (mg/L)	<u>.</u>
1.69	0.02	0.72	2.57	2	17	1.37	0.46	90.90				L					Total Chiorine (mg/L)	PERMEATE
0.54	0.02	9.1	0.19	0.06	2.1	0.09	9	9.06				_		_			Free Chlorine (mg/L)	
8	8	1.00	9.00	2.00	2.88	7.00	7.00	7.00				L					Total Coliform (CFU100 mL)	-
			2.00	2.00	2.00							_		_			Fecal Coliforn (CPU/100 mL)	
380.00	7.00	66.57	,700.00	9.00	276.75	100.00	30.00	50.25	22.00	5.00	13.50	_					Pseudomonae (CFU/100mL)	-
1,000.00	10.00	276.43	700.00	5.00	65.18	1,200.00	10.00	110.29	142.00	32.00	76.67					350 00	HPC (CFU/mL)	
13.15	31.66	92.40	92.67	92.55	92.61	91.91	91.90	91.90	93.74	92.73	23.54	L					% TOC Removal	
96.99	93.72	95.56	96.30	94.17	95,32	95.93	92.75	94.34	96.23	96.23	96.23	L			_		% TDS Removal	REMOVALS
714	4.47	5.97	ŝ	15	5.79	6.51	ŝ	5.67	7.13	2	6.35	L		_			Log Reduction	STAY
80.00	Ξ	57.29	80.00	53.85	9	75.00	25.00	54.26	86.36	72,73	78.47						% Turbidity Removal	

**Appendix D. Laboratory Reports** 



CH2M HILL

Applied Sciences Group

2300 NW Walnut Blvd

Corvallis, OR

97330-3538

P.O. Box 428

Corvallis, OR

97339-0428

Tel 541.752.4271 Fax 541.752.0274

September 22, 1999

McAllen WWTP #2, City of

149462.A1.ZG

RE:

Analytical Data for McAllen WWTP #2, City of

Applied Sciences Group Reference No. 9964

Dear Angie Fernandez/PHX:

On August 18, 1999, CH2M HILL Applied Sciences Group received four samples with a request for analysis of selected parameters.

The analytical results and associated quality control data are enclosed. Any unusual difficulties encountered during the analysis of your samples are discussed in the case narrative. Subcontracted analyses reports are attached.

Under CH2M HILL policy, your samples will be stored for 30 days after reporting. If you have not given us prior instructions for disposal, we will contact you if any samples require disposal as hazardous waste.

CH2M HILL Applied Sciences Group appreciates your business and looks forward to serving your analytical needs again. If you should have any questions concerning the data, or if you need additional information, please call Ms. Kathy McKinley at (541) 758-0235, extension 3120.

Sincerely,

Kelly Ensor

Senior Administrative Assistant

**Enclosures** 

### CLIENT SAMPLE CROSS-REFERENCE

## CH2M HILL Applied Sciences Group Reference No. 9964

Sample ID	Client Sample ID	Date Collected	Time Collected
996401	ZGP	8/17/99	7:30
996402	ROP	8/17/99	7:30
996403	ROC	8/17/99	7:30
996404	WWTP#2Effluent	8/17/99	7:30

# CASE NARRATIVE VOLATILES

Lab Reference No.: 9964

#### Client/Project: McAllen WWTP #2, City of

I. <u>Holding Times</u>:

All acceptance criteria were met.

- II. Analysis:
  - A. Calibration:

All acceptance criteria were met.

B. Blanks:

All acceptance criteria were met.

C. <u>Duplicate Sample(s)</u>:

Not Applicable.

D. Spike Sample(s):

Not Applicable.

E. Surrogate Recoveries:

All acceptance criteria were met.

F. <u>Lab Control Sample(s)</u>:

All acceptance criteria were met.

G. Other:

None

III. Documentation Exceptions:

None

IV. I certify that this data package is in compliance with the terms and conditions agreed to by the client and CH2M HILL, both technically and for completeness, except for the conditions detailed above. Release of the data contained in this hardcopy data package has been authorized by the Laboratory Manager or designee, as verified by the following signature.

Prepared by:

Reviewed by:

#### CASE NARRATIVE GENERAL CHEMISTRY

Lab Reference No.: 9964

### Client/Project: McAllen WWTP #2, City of

I. <u>Holding Time</u>:

All acceptance criteria were met.

- II. Analysis:
  - A. Calibration:

Bromide recovery (132%) in final calibration verification exceeded acceptance criteria. All other acceptance criteria were met.

B. Blanks:

All acceptance criteria were met.

C. <u>Matrix Spike Sample(s)</u>:

Bromide matrix spike recovery (200%) exceeded acceptance criteria. All other acceptance criteria were met.

D. <u>Duplicate Sample(s)</u>:

All acceptance criteria were met.

E. <u>Lab Control Sample(s)</u>:

All acceptance criteria were met.

F. Other:

Not applicable.

IV. <u>Documentation Exceptions:</u>

None.

V. I certify that this data package is in compliance with the terms and conditions agreed to by the client and CH2M HILL, both technically and for completeness, except for the conditions detailed above. Release of the data contained in this hardcopy data package has been authorized by the Laboratory Manager or his designee, as verified by the following signature.

Prepared by:

Reviewed by

#### CASE NARRATIVE METALS

Lab Reference No.: 9964

Client/Project:	McAllen	<b>WWTP #2</b> ,	City of
-----------------	---------	------------------	---------

I. <u>Holding Time</u>:

All acceptance criteria were met.

II. <u>Digestion Exceptions</u>:

None.

- III. Analysis:
  - A. <u>Calibration</u>:

All acceptance criteria were met.

B. Blanks:

All acceptance criteria were met.

- C. <u>ICP Interference Check Sample</u>: All acceptance criteria were met.
- D. <u>Spike Sample(s)</u>:
  All acceptance criteria were met.
- E. <u>Duplicate Sample(s)</u>:
  All acceptance criteria were met.
- F. <u>Laboratory Control Sample(s)</u>: All acceptance criteria were met.
- G. <u>ICP Serial Dilution</u>: Not Required.
- H. Other:
- IV. <u>Documentation Exceptions</u>: None
- V. I certify that this data package is in compliance with the terms and conditions agreed to by the client and CH2M HILL, both technically and for completeness, except for the conditions detailed above. Release of the data contained in this hardcopy data package has been authorized by the Laboratory Manager or his designee, as verified by the following signature.

Prepared by:	Outo !	A_1~	
Reviewed by:		WUSY	

Client Information

Client Sample ID: ROC

Project Name: McAllen WWTP #2, City of Project Manager: Angle Fernandez/PHX

Sampled By: R. Trevino Sampling Date: 08/17/1999 Sampling Time: 7:30 Type: Grab

Matrix: Water Basis: As Received Lab Information

Lab Sample ID: 996403

Date Received: 08/18/1999

Report Revision No.: 0

Analyzed By: MG/DK/MS

Reviewed By: ______

Analyte	MRL	Sample Result	Qualifier	Units	Analysis Method	Date Analyzed
General Chemistry N-Nitrate N-Total Kjeldahl Total Dissolved Solids TOC Total Phosphate-P	0.20 2.0 5 5.0 0.25	35.4 2.72 3,230 33.7 9.89		mg/L mg/L mg/L mg/L mg/L	EPA 353.2 EPA 351.4 EPA 160.1 EPA 415.1/2 EPA 365.2/4	08/19/1999 08/25/1999 08/23/1999 08/19/1999 08/19/1999

**Client Information** 

Client Sample ID: WWTP#2Effluent

Project Name: McAllen WWTP #2, City of Project Manager: Angie Fernandez/PHX

Sampled By: R. Trevino Sampling Date: 08/17/1999 Sampling Time: 7:30

Type: Grab Matrix: Water Basis: As Received Lab Information

Lab Sample ID: 996404

Date Received: 08/18/1999

Report Revision No.: 0

Analyzed By: MG/DK/MS

Reviewed By:

Analyte	MRL	Sample Result	Qualifier	Units	Analysis Method	Date Analyzed
General Chemistry N-Nitrate N-Total Kjeldahl Total Dissolved Solids TOC Total Phosphate-P	0.04 2.0 5 0.50 0.25	2.96 2.0 799 8.39 2.98	U	mg/L mg/L mg/L mg/L mg/L	EPA 353.2 EPA 351.4 EPA 160.1 EPA 415.1/2 EPA 365.2/4	08/19/1999 08/25/1999 08/24/1999 08/19/1999 08/19/1999

**Client Information** 

Client Sample ID: ZGP

Project Name: McAllen WWTP #2, City of Project Manager: Angie Fernandez/PHX

Sampled By: R. Trevino
Sampling Date: 08/17/1999
Sampling Time: 7:30
Type: Grab
Matrix: Water

Basis: As Received

**Lab Information** 

Lab Sample ID: 996401

Date Received: 08/18/1999

Report Revision No.: 0

			_			
Analyte	MRL	Sample Result	Qualifier	Units	Analysis Method	Date Analyzed
General Chemistry Alkalinity (as CaCO3) Bromide Chloride Color (APHA) Apparent Fluoride N-Nitrate N-Total Kjeldahl Silica-React. Sulfate Total Dissolved Solids TOC Total Phosphate-P UV-254	2.0 0.020 1.0  0.10 0.10 2.0 0.40 1.0 5 0.50 0.25 0.009	121 0.132 160 22 1.07 9.55 2.0 15.1 150 774 7.48 2.48 0.129	U	mg/L mg/L mg/L color units mg/L mg/L mg/L mg/L mg/L mg/L asb/cm	EPA 310.2 EPA 300.0-B EPA 300.0-A EPA 110.2 EPA 353.2 EPA 351.4 SM4500-Si D EPA 300.0-A EPA 160.1 EPA 415.1/2 EPA 365.2/4 SM5910	08/23/1999 - 08/19/1999 08/23/1999 08/23/1999 08/25/1999 08/23/1999 08/23/1999 08/23/1999 08/19/1999 08/19/1999 08/19/1999

Client Information

Client Sample ID: ZGP

Project Name: McAllen WWTP #2, City of Project Manager: Angie Fernandez/PHX

Sampled By: R. Trevino Sampling Date: 08/17/99 Sampling Time: 07:30 Type: Grab

Matrix: Water

Basis: As Received

**Lab Information** 

Lab Sample ID: 996401

Date Received: 8/18/99

Report Revision No.: 0 Reported By: JG

Reviewed By:

Analyte	MRL	Sample Result	Qualifier	Units	Analysis Method	Date Analyzed
Aluminum, Al Arsenic, As Barium, Ba Cadmium, Cd Calcium, Ca Chromium, Cr Iron, Fe Lead, Pb Magnesium, Mg Manganese, Mn Mercury, Hg Potassium, K Selenium, Se Silver, Ag Sodium, Na Strontium, Sr Zinc, Zn	45.6 3.9 0.81 0.38 21.3 7.2 2.8 2.3 41.0 1.0 0.25 1810 6.8 8.0 5930 28.6 2.3	111 3.9 56.2 2.7 72100 7.2 31.9 28.4 20400 14.5 0.25 17800 6.8 8.0 157000 1870 46.3	UUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU	µg/L µg/L µg/L µg/L µg/L µg/L µg/L µg/L	SW6010B SW6010B SW6010B SW6010B SW6010B SW6010B SW6010B SW6010B SW6010B SW6010B SW6010B SW6010B SW6010B SW6010B SW6010B	08/27/99 08/27/99 08/27/99 08/27/99 08/27/99 08/27/99 08/27/99 08/27/99 08/27/99 08/27/99 08/27/99 08/27/99 08/27/99 08/27/99

## Client Information Lab Information

Project Name: McAllen WWTP #2, City of

Project Manager: Angie Fernandez/PHX

Sampled By: R. Trevino Date Collected: 8/17/99 Time Collected: 7:30 Type: Grab Matrix: Water

Client Sample ID: ZGP

Basis: As Received

Lab Sample ID: 996401

Analysis Method: SW 8260B

Units: µg/L Date Received: 8/18/99 Date Analyzed: 8/27/99

Dilution Factor: 1
Report Revision No.: 0
Reported By: MCB
Reviewed By:

Analyte	CAS#	Reporting Limit	Sample Result	Qualifier
Purgeable Volatiles				
Vinyl Chloride	75-01-4	1.0		
trans-1,2-Dichloroethene		1.0	1.0	U
	156-60-5	1.0	1.0	Ü
cis-1,2-Dichloroethene	156-59-4	1.0	1.0	U
1,1,1-Trichloroethane	71-55-6	1.0	1.0	Ü
Carbon Tetrachloride	56-23-5	1.0	1.0	Ŭ
Trichloroethene	79-01-6	1.0	1.0	U
1,4-Dichlorobenzene	106-46-7	1.0	1.0	Ü
Dibromofluoromethane	1868-53-7		94%	SS
1,2-Dichloroethane-d4	17068-07-0		89%	
Toluene-d8	2037-26-5			SS
			103%	SS
p-Bromofluorobenzene	460-00-4		103%	SS

E=Estimated value above instrument calibration range J=Estimated value below reporting limit U=Not detected at specified reporting limit SS=Surrogate standard

**Client Information** 

Client Sample ID: ZGP

Project Name: McAllen WWTP #2, City of Project Manager: Angie Fernandez/PHX

Sampled By: R. Trevino Date Collected: 8/17/99 Time Collected: 7:30 Type: Grab

Matrix: Water
Basis: As Received

Lab Information

Lab Sample ID: 996401

Analysis Method: SM 5710.D

Date Received: 8/18/99

Report Revision No.: 0 Analyzed By: BDW

Reviewed By: 5494

SDS-HAA/THM Formation Potential Test Conditions

Set-up Date/Time	Target Contact Time (h:mm)	Initial pH	Contact pH	Contact Temperature (°C)	Chlorine Dosage (mg/L)
8/23/99 9:34	72:00	7.7	7.8	23	10.10

#### Chlorine Demand Test Results

Take-offDate/Time	Actual Contact Time (h:mm)	Measured pH	Measured Temperature (°C)	Chlorine Residual (mg/L)
8/26/99 13:10	75:36	7.8	23	0.68

**Client Information** 

Client Sample ID: ROP

Project Name: McAllen WWTP #2, City of Project Manager: Angle Fernandez/PHX

Sampled By: R. Trevino
Sampling Date: 08/17/1999
Sampling Time: 7:30
Type: Grab
Matrix: Water
Basis: As Received

**Lab Information** 

Lab Sample ID: 996402

Date Received: 08/18/1999

Report Revision No.: 0

Analyte	MRL	Sample Result	Qualifier	Units	Analysis Method	Date Analyzed
General Chemistry						
Alkalinity (as CaCO3)	2.0	14		mg/L	EPA 310.2	08/23/1999
Bromide	0.020	0.020	U	mg/L	EPA 300.0-B	08/19/1999
Chloride	0.10	9.73		ma/L	EPA 300.0-A	08/23/1999
Color (APHA) Apparent		5	U	color units	EPA 110.2	08/18/1999
Fluoride	0.10	0.32		ma/L	EPA 300.0-A	08/23/1999
N-Nitrate	0.01	1.11		mg/L	EPA 353.2	08/19/1999
N-Total Kjeldahl	2.0	2.0	U	mg/L	EPA 351.4	08/25/1999
Silica-React.	0.40	0.65		mg/L	SM4500-Si D	09/01/1999
Sulfate	0.10	4.00		mg/L	EPA 300.0-A	08/23/1999
Total Dissolved Solids	5	33		mg/L	EPA 160.1	08/23/1999
TOC	0.50	0.63		mg/L	EPA 415.1/2	08/19/1999
Total Phosphate-P	0.05	0.10		mg/L	EPA 365.2/4	08/19/1999

**Client Information** 

Client Sample ID: ROP

Project Name: McAllen WWTP #2, City of Project Manager: Angie Fernandez/PHX

Sampled By: R. Trevino Sampling Date: 08/17/99 Sampling Time: 07:30 Type: Grab Matrix: Water

Basis: As Received

#### **Lab Information**

Lab Sample ID: 996402

Date Received: 8/18/99 Report Revision No.: 0 Reported By: JG

Reviewed By:

Analyte	MRL	Sample Result	Qualifier	Units	Analysis Method	Date Analyzed
Aluminum, At	45.6	45.6	U	μg/L	SW6010B	08/27/99
Arsenic, As	3.9	3.9	Ŭ	μg/L	SW6010B	08/27/99
Barium, Ba	0.81	0.81	Ŭ	μg/L	SW6010B	08/27/99
Cadmium, Cd	0.38	0.38	Ü	μg/L	SW6010B	08/27/99
Calcium, Ca	21.3	714	J	μg/L	SW6010B	08/27/99
Chromium, Cr	7.2	7.2	U	μg/L	SW6010B	08/27/99
Iron, Fe	2.8	9.9	J	μg/L μg/L	SW6010B	08/27/99
Lead, Pb	2.3	2.3	U	μg/L	SW6010B	08/27/99
Magnesium, Mg	41.0	197	ŭ	μg/L	SW6010B SW6010B	08/27/99
Manganese, Mn	1.0	1.0	U	μg/L μg/L	SW6010B	
Mercury, Hg	0.25	0.25	Ü	μg/L μg/L	SW7470A	08/27/99
Potassium, K	181	1360	Ü			08/23/99
Selenium, Se	6.8	6.8	U	μg/L	SW6010B	08/27/99
Silver, Ag	8.0	8.0	Ü	μg/L	SW6010B	08/27/99
Sodium, Na	593	13000	U	μg/L	SW6010B	08/27/99
Strontium, Sr	28.6	28.6	U	µg/L	SW6010B	08/27/99
Zinc, Zn			U	μg/L	SW6010B	08/27/99
Z.111C, Z.11	2.3	7.2		μg/L	SW6010B	08/27/99

Client Information

Lab Information

Client Sample ID: ROP

Lab Sample ID: 996402

Project Name: McAllen WWTP #2, City of

Project Manager: Angle Fernandez/PHX

Sampled By: R. Trevino Date Collected: 8/17/99 Time Collected: 7:30

> Type: Grab Matrix: Water Basis: As Received

Units: µg/L

Date Received: 8/18/99 Date Analyzed: 8/27/99

Analysis Method: SW 8260B

Dilution Factor: 1 Report Revision No.: 0

Reported By: MCB Reviewed By: >47

Analyte	CAS#	Reporting Limit	Sample Result	Qualifier
Purgeable Volatiles				
Vinyl Chloride	75-01-4	1.0	1.0	U
trans-1,2-Dichloroethene	156-60-5	1.0	1.0	U
cis-1,2-Dichloroethene	156-59-4	1.0	1.0	U
1,1,1-Trichloroethane	71-55-6	1.0	1.0	U
Carbon Tetrachloride	56-23-5	1.0	1.0	U
Trichloroethene	79-01-6	1.0	1.0	U
1,4-Dichlorobenzene	106-46-7	1.0	1.0	U
Dibromofluoromethane	1868-53-7		96%	SS
1,2-Dichloroethane-d4	17068-07-0		96%	SS
·	2037-26-5		104%	SS
Toluene-d8 p-Bromofluorobenzene	460-00-4		103%	SS

E=Estimated value above instrument calibration range

CH2M HILL

J=Estimated value below reporting limit

U=Not detected at specified reporting limit

SS=Surrogate standard

**Client Information** 

Client Sample ID: ROP

Project Name: McAllen WWTP #2, City of

Project Manager: Angie Fernandez/PHX

Sampled By: R. Trevino Date Collected: 8/17/99 Time Collected: 7:30

Type: Grab Matrix: Water Basis: As Received **Lab Information** 

Lab Sample ID: 996402

Analysis Method: SM 5710.D

Date Received: 8/18/99

Report Revision No.: 0

Analyzed By: BDW Reviewed By: 242

SDS-HAA/THM Formation Potential Test Conditions

	Target			Contact	Chlorine
Set-up Date/Time	Contact Time (h:mm)	Initial pH	Contact pH	Temperature (°C)	Dosage (mg/L)
8/23/99 9:42	72:00	6.0	7.8	23	1.30

#### Chlorine Demand Test Results

Take-off Date/Time	Actual Contact Time (h:mm)	Measured pH	Measured Temperature (°C)	Chlorine Residual (mg/L)
8/26/99 13:14	75:32	7.8	23	0.24

				Format	Formation Potential Test Conditions	st Conditions					_
		퍔	Free	Free	Total	Q.J	Mac				
Client ID	Lab ID	Dose	Residual	Demand	Residual	Tenn	Measured	1	d	FP.	FP
McALLEN-ZGP	006401	01 01	070	0,0				Start	1ake-Off	Time H:M	Time (Hour)
	101011	10.10	0.00	7.47	!	23	7.78	8/21/99 9:34	01.51.00/90/8	26.26	
McALLEN-ROP	996402	1 30	100	20				1000000	01.01.77.10	73:30	09:0/
		2	1.0.64	DO: 1	-	23	7.77	8/23/99 9:42	8/26/99 13:14	75.40	75.67
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			Formation Po	tential Haloace	tic Acide (HAAe	Formation Potential Halageetic Acids (HAAs) Nictracotton B.: Dandania	Dood of					
					TO THE PERSON	a) Manufection in	y-r roducts (ug	Ē				<u> </u>
			Œ.	£	FP	F	ПP	03	100			
Client ID	Lab ID	MCAA *	MBAA *	DCAA *	TCAA *	A A C			11		-	
McALLEN. ZGP. 3D	1000	7.0				DCAA	DDAA .	HAAS	HAA6			
	10030	0.0	4.	49.9	57.3	12.8	9"	110	133			Ī
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	<b>8</b>	MCAA = Monochioroace	Horoacette acid		BCAA = Bromochloroacetic acid	hloroacetic acid		FPA HAAS Stree I MCI - 60!	101 - 60		i T	
	~	MBAA = Monobromogce	omoacetic acid		DR44 - Dibrom	Line with the		900	1/8 - 00 mg/L	-	i I	
					WOOD - SOO	מערבוור מכומ		EFA HAAS Stage 2 MCL = 30 ug/l,	4CL = 30  ug/L		_	
	2	DCAA = Dichloroacetic acid	sacetic acid		* These compour	* These compounds make up the HAA5	1445			1 1 1 1 1 1		į
		TCAA = Trichloroacetic acid	vacetic acid		Ferimated value	,				į	:	_
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**Client Information** 

Client Sample ID: McAllen-ZGP-3d

Project Name: McAllen WWTP #2, City of Project Manager: Angie Fernandez/PHX

Sampled By: B. Warloe Date Collected: 8/26/99 Time Collected: Not Indicated

Type: Grab Matrix: Water Basis: As Received Lab Information

Lab Sample ID: 300301

Date Received: 8/26/99 Report Revision No.: 0

Analyzed By: DAH

Reviewed By: mbos

Analyte	CAS#	MCL*	Reporting Limit	Sample Result	Qualifier	Units	Analysis Method	Date Analyzed
Haloacetic Acids Chloroacetic acid Bromoacetic acid Dichloroacetic acid Trichloroacetic acid Bromochloroacetic acid Dibromoacetic acid HAA5	79-11-8 79-08-3 79-43-6 76-03-9 5589-96-3 631-64-1	60	2.0 1.0 5.0 5.0 1.0 1.0	8.6 1.4 51.4 56.0 12.8 1.6 119		µg/L µg/L µg/L µg/L µg/L µg/L	SM 6251.B SM 6251.B SM 6251.B SM 6251.B SM 6251.B SM 6251.B SM 6251.B	9/3/99 9/3/99 9/16/99 9/16/99 9/3/99 9/399 9/16/99
2,3-Dibromopropanoic aci	600-05-5			116%	SS			0, 10,00
Trihalomethanes Chloroform Bromodichloromethane Dibromochloromethane Bromoform TTHM  1,2-Dichloroethane-d4	67-66-3 75-27-4 124-48-1 75-25-2	80	5.0 1.0 1.0 1.0 1.0	150 38.8 9.5 1.0 198	U SS	μg/L μg/L μg/L	EPA 502.2 EPA 502.2 EPA 502.2 EPA 502.2 EPA 502.2	9/1/99 8/31/99 8/31/99 8/31/99 9/1/99

U=Not detected at specified reporting limit *=MCL according to Stage 1 of D/DBP rule SS=Surrogate standard

**Client Information** 

Client Sample ID: McAllen-ROP-3d

Lab Sample ID: 300302

Project Name: McAllen WWTP #2, City of Project Manager: Angie Fernandez/PHX

Date Received: 8/26/99 Report Revision No.: 0 Analyzed By: DAH

Lab Information

Sampled By: B. Warloe Date Collected: 8/26/99 Time Collected: Not Indicated

Reviewed By: mbos

Type: Grab Matrix: Water Basis: As Received

Analyte	CAS#	MCL*	Reporting Limit	Sample Result	Qualifier	Units	Analysis Method	Date Analyzed
Haloacetic Acids Chloroacetic acid Bromoacetic acid Dichloroacetic acid Trichloroacetic acid Bromochloroacetic acid Dibromoacetic acid HAA5  2,3-Dibromopropanoic ac	79-11-8 79-08-3 79-43-6 76-03-9 5589-96-3 631-64-1	60	2.0 1.0 1.0 1.0 1.0 1.0	2.0 1.0 1.1 1.0 1.0 1.0 1.1	U U U U U SS	ha/r ha/r ha/r ha/r	SM 6251.B SM 6251.B SM 6251.B SM 6251.B SM 6251.B SM 6251.B SM 6251.B	9/3/99 9/3/99 9/3/99 9/3/99 9/3/99 9/3/99 9/3/99
Trihalomethanes Chloroform Bromodichloromethane Dibromochloromethane Bromoform TTHM	67-66-3 75-27-4 124-48-1 75-25-2	80	1.0 1.0 1.0 1.0 1.0	3.7 1.7 1.0 1.0 5.4	U	μg/L μg/L μg/L	EPA 502.2 EPA 502.2 EPA 502.2 EPA 502.2 EPA 502.2	8/31/99 8/31/99 8/31/99 8/31/99 8/31/99
1,2-Dichioroethane-d4	17068-07-0			99%	SS			•

U=Not detected at specified reporting limit *=MCL according to Stage 1 of D/DBP rule SS=Surrogate standard

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AND AGREEMENT TO PERFORM SERVICES	ERVICES (641) /52-42/1 FAX (841) /82-02/8	V. (D41) / D2-	9/30							# 202	CIICOM
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CH2MHILL Applied Sciences Lab CV0 22 CHAIN OF CUSTODY RECORD
AND AGREEMENT TO PERFORM SERVICES (541) 7

CVO 2300 NW Walnut Bouleward Corvalis, OR 97330-3638 (541) 752-4271 FAX (541) 752-0278

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19 흡 LIMS Verification Custody Review THIS AREA FOR LAB USE ONLY Custody Seai E C Other Per <u>8</u> Alternate Description # 000 COC 07:39 4 Cooler Temperature で で で で で で Date/Time 8 | 17 | 99 QC Level 66/11 8/11/89 Log In 품 Dete/Time Datte/Time Alkalinity, TDS, Colo C. Branides, Chloride, Fluoride, Sulfede, Celfico. Fluoride, Sulfede, Casestive Silico. I CE Rosie Villareen Ramin Trevino Requested Analytical Method # (Please sign and print name) (Please sign and print name) Shipping # 45, 5c, A312n FINGS Alkalinity, TDS, Color, Branide, Chloride, Fluoride, Switchtes Rective Silice Al, Ba, Ca, Fe, Ma, Mn, R, Wa, Sr, Hs, Cd, Cr, **Empty Bottles** ğ Other AI) BAJ CAJ FEJ MG,I K, NA, SC, AS, CAJ C Pb, Hg, Se, AS, Zn EUNH > Fed-Ex  $\langle \lambda \rangle$ Relinquished By Shipped Via UPS Fed Received By **₽**20 Samplé Disposal 8 17/11 7:30 t Jr7 bg 67:35 Date/Time Datte/Time Date/Time E/17/99 Date/Time Kashy McKinley Purchase Order # CLIENT SAMPLE ID (9 CHARACTERS) Project Manager or Contact & Phone # | Report Copy to: Posse VILLARREA (Please sign and print name) (Please eign and print name) (Please eign and print name) MCAILEN REUSE PINT STANDLY MWTOHO 9 9 RO 6 5 City of McAllen Kathy McKin ley Requested Completion Deta: Site ID **<-**Œ ~O-J **≱∢⊢ш**∉ 7 G K < B 7 7 7 Z COZL Sampled By and Title Special Instructions: Company Name 5/17/99/7:30 dt/sW 8/1199 7:30 08:17 PATIS TIME 11/19/17:30 Project Name Relinquished By Sampling 0100 Project # Received By Received By 200 Date

DISTRIBUTION: Original - LAB, Yellow - LAB. Pink - Cileni



Ms. Anne McKee-Robbins CH2M HILL/CVO 2300 N.W. Walnut Blvd. Corvallis, OR 97330

> Columbia Analytical Services Report City of McAllen D9901502/D1227

> > September 13, 1999

Submitted by:

Luyan force

Bryan Jones

Project Manager/Client Services

## TABLE OF CONTENTS

### CAS Lab Reference No.: D1227 Level 1

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Organic Data Qualifiers	:
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Sample results	3
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## **Organic Data Qualifiers**

- A-- This qualifier indicates that a TIC is a suspected aldol-condensation product
- **B--** This flag is used when the analyte is found in the associated blank as well as the sample. This notation indicates possible blank contamination and suggests that the data user evaluate these compounds and their amounts carefully.
- C-- The "C" flag indicates the presence of this compound has been confirmed by the GC/MS analysis.
- **D--** This qualifier is used for all the compounds identified in an analysis at a secondary dilution factor. "D" qualifiers are used only for the samples reported at more than one dilution factor.
- E-- This flag indicates that the value reported exceeds the linear calibration range for that compound. Therefore, the sample should be reanalyzed at the appropriate dilution. The "E" qualified amount is an estimated concentration, and the results of the dilution will be reported on a separate Form I.
- I— The qualifier indicates that the reporting limit to the "I" qualifier has been raised. It is used when the chromatographic interference prohibits detection of a compound at a level below the concentration expressed on the Form I.
- J- Indicates an estimated value. It is used when the data indicates the presence of a target compound below the reporting limit or the presence of a Tentatively Identified Compound (TIC).
- N-- This qualifier indicates presumptive evidence of a compound. This flag is only used for Tentatively Identified Compounds (TIC), where the identification is based on a mass spectral library research. It is applied to all TIC results. For generic characterization of a TIC, such as chlorinated hydrocarbon, the "N" qualifier is not used.
- P-- This qualifier is used for Pesticide/Aroclor target analytes when there is a greater than 25% difference for detected concentrations between the two columns. The lower of the two values is reported on Form I and flagged with a "P".
- U-- Indicates the compound was analyzed for but not detected. The number adjacent to the "U" qualifier indicates the reporting limit for that compound. The reporting limit can vary from sample to sample depending on dilution factors or percent moisture adjustments when indicated.

## Organic Sample ID Qualifiers

The qualifiers that may be appended to the Lab Sample ID and/or the Client Sample ID for organic analysis are defined below:

- **DL--** Diluted reanalysis. Indicates that the results were determined in an analysis of a secondary dilution of a sample or extract. A digit to indicate multiple dilutions of the sample or extract may follow the "DL" suffix. The results of more than one diluted reanalysis may be reported.
- MS-- Matrix spike (may be followed by a digit to indicate multiple matrix spikes within a sample set).
- MSD-- Matrix spike duplicate (may be followed by a digit to indicate multiple matrix spikes within a sample set).
- Reanalysis. The extract was reanalyzed without re-extraction. The "R" is not used if the sample was also re-extracted. May be followed by a digit to indicate multiple reanalysis of the sample at the same dilution.
- **RE--** Re-extraction analysis. The sample was re-extracted and reanalyzed. May be followed by a digit to indicate multiple re-extracted analysis of the same sample at the same dilution.

### Sample ID Cross-reference Table

CAS Lab Sample	Client ID Sample ID	Collect Date Sample Matrix	Additional Desc	cription	
FS = Field D1227001 D1227002	FS ZGPERMEATE FS ROPERMEATE	08/17/99 Water			

The above lab sample ID's and cross reference information apply to samples as received by the laboratory. Modifiers to the lab sample ID may be added for internal tracking purposes. Any modified sample ID will be reflected in the appropriate case narrative only.

GC ORGANOCHLORINE PESTICIDES

## CASE NARRATIVE GC ORGANOCHLORINE PESTICIDES

CAS Lab Reference No./SDG.: D1227

Project: City of McAllen

#### I. RECEIPT

No exceptions were encountered unless a Sample Receipt Exception Report is attached to the Chain-of-Custody included with this data package.

#### II. HOLDING TIMES

- A. Sample Preparation: All holding times were met.
- B. Sample Analysis: All holding times were met.

#### III. METHOD

Preparation: SW-846 3520C

Cleanup: NA

Analysis: SW-846 8081A

#### IV. PREPARATION

Sample volume may vary based on the amount of sample received per container.

#### V. ANALYSIS

- A. Calibration. In the ending CCV, toxaphene, exceeded 15%D however the average of all analytes was within therefore no corrective action was taken.
  - 1. Retention Time Windows: All analytes were within criteria.
  - Degradation: All acceptance criteria were met.
- B. Blanks: All acceptance criteria were met.
- C. Surrogates: All acceptance criteria were met.
- D. Internal Standards: All acceptance criteria were met.
- E. Spikes: All acceptance criteria were met.
- F. Samples: Sample analysis proceeded normally.

I certify that this data package is in compliance with the terms and conditions agreed to by the client and Columbia Analytical Services, both technically and for completeness, except for the conditions noted above. Release of the data contained in this hardcopy data package has been authorized by the Laboratory Manager or designated person, as verified by the following signature.

SIGNED: Jerry Watega 9/10/99 Reviewer: Make 9-10-99

Scientist, GC Organics

Phone: (530) 244-5227

Fax: (530) 244-4109

PWB10820

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Case No.: D1227 SDG No.: D1227

Lab Sample ID:

PWB10820

Matrix: WATER

Level: LOW Lab File ID:

B0904010

Sample Wt/Vol: 1.000 L

Date Received:

Date Extracted: 08/20/99

Extract Vol:

Date Analyzed: 09/04/99

Column: DB5

Dilution Factor: 1.0 Extraction Type: Continuous

CAS NO.	COMPOUND	Units: ug/L	MDL	RL	RESULT	Q 
72-20-8	gamma-BHC ( Endrin Methoxychlo Toxaphene		0.0032 0.0021 0.017 0.23	0.020 0.020 0.040 0.50	0.020 0.020 0.040 0.50	ם ט ט

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

PWB10820LCS

Case No.: D1227

SDG No.: D1227

Lab Sample ID:

PWB10820LCS

Matrix: WATER

Level:

LOW

Lab File ID:

B0904008

Sample Wt/Vol: 1.000 L

Date Received:

Extract Vol:

10 ML

Date Extracted: 08/20/99

Column: DB5

Date Analyzed:

09/04/99

Extraction Type: Continuous

CAS NO.	COMPOUND	Units: ug/L	MDL	RL	RESULT	Q
72-43-5	gamma-BHC (L Endrin Methoxychlor Toxaphene		0.0032 0.0021 0.017 0.23	0.020 0.020 0.040 0.50	0.56 0.52 0.46 0.50	

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

PWB10820LCS

Case No.: D1227 SDG No.: D1227

Lab Sample ID:

PWB10820LCS

Matrix: WATER

Level: LOW

Lab File ID:

B0904009

Sample Wt/Vol: 1.000 L

Date Received:

Extract Vol:

10 ML

Date Extracted: 08/20/99

Column: DB5

Date Analyzed: 09/04/99

Extraction Type: Continuous

CAS NO.	COMPOUND	Units: ug/L	MOL	RL	RESULT	Q
72-43-5	gamma-BHC Endrin Methoxychlo		0.0032 0.0021 0.017 0.23	0.020 0.020 0.040 0.50	0.020 0.090 0.075 5.1	U 

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

ZGPERMEATE

Case No.: D1227

SDG No.: D1227

Lab Sample ID:

D1227001

Matrix: WATER

Level:

Lab File ID:

B0904011

Sample Wt/Vol: 1.000 L

LOW

Extract Vol:

Date Received:

08/18/99

10 ML

Date Extracted: 08/20/99

Column: DB5

Date Analyzed: 09/04/99

Extraction Type: Continuous

CAS NO.	COMPOUND	Units: ug/L	MDL	RL	RESULT	Q
72-20-8	gamma-BHC (L Endrin Methoxychlor Toxaphene		0.0032 0.0021 0.017 0.23	0.020 0.020 0.040 0.50	0.024 0.020 0.040 0.50	ָ ט ט

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

ROPERMEATE

Case No.: D1227

Lab Sample ID: D1227002

SDG No.: D1227

Matrix: WATER

Level: LOW

Lab File ID:

B0904012

Sample Wt/Vol: 1.000 L

Date Received:

Extract Vol:

10 ML

08/18/99 Date Extracted: 08/20/99

Column: DB5

Date Analyzed: 09/04/99

Extraction Type: Continuous

CAS NO.	COMPOUND	Units: ug/L	MDL	RL	RESULT	Q
72-20-8	gamma-BHC (I Endrin Methoxychlor Toxaphene		0.0032 0.0021 0.017 0.23	0.020 0.020 0.040 0.50	0.020 0.020 0.040 0.50	ט ט ט

#### 2C WATER SEMIVOLATILE SURROGATE RECOVERY

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Case No.: D1227 SDG No.: D1227

	I —					
	LAB ID	CLIENT ID.	S1 #	S2 #	S2	TOT
01 02 03	PWB10820LCS PWB10820LCS PWB10820	PWB10820LCS PWB10820LCS PWB10820	107 105 102	86 72 76		0 0
04 05 06 07	D1227001 D1227002	ZGPERMEATE ROPERMEATE	105 68	74 47		0
08 09 10						
11 12 13 14						
15 16 17						
18 19 20 21						
22 23 24						
25 26 27 28						
29 30						

QC LIMITS
S1 = Tetrachloro-m-xylene (45-125)
S2 = Decachlorobiphenyl (34-133)

# Column to be used to flag recovery values
* Values outside of contract required QC limits

D Surrogates diluted out

## WATER PESTICIDE LAB CONTROL SAMPLE

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Case No.: D1227

SDG No.: D1227

Column: DB5

LCS -

Sample No.: PWB10820

COMPOUND	SPIKE	SAMPLE	LCS	LCS	QC.
	ADDED	CONCENTRATION	CONCENTRATION	%	LIMITS
	(ug/L)	(ug/L)	(ug/L)	REC #	REC.
gamma-BHC (Lindane)	0.5000	0.0000	0.5583	112	73-125
Endrin	0.5000	0.0000	0.5193	104	43-134
Methoxychlor	0.5000	0.0000	0.4603	92	73-142

RPD: 0 out of 0 outside limits Spike Recovery: 0 out of 3 outside limits

COMMENTS:			
	 <del></del>	 	

[#] Column to be used to flag recovery and RPD values with an asterisk

^{*} Values outside of QC limits

## WATER PESTICIDE LAB CONTROL SAMPLE

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Case No.: D1227

SDG No.: D1227

Column: DB5

LCS -

Sample No.: PWB10820

|--|

# Column to be used to flag recovery and RPD values with an asterisk

* Values outside of QC limits

RPD: 0 out of 0 outside limits Spike Recovery: 0 out of 1 outside limits

COMMENTS:	

FORM III

SW846

#### 4B SEMIVOLATILE METHOD BLANK SUMMARY

Client ID.

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

PWB10820

Case No.: D1227 SDG No.: D1227

Lab File ID:

B0904010

Lab Sample ID:

PWB10820

Date Extracted:

08/20/99

Extraction Type:

CONT

Date Analyzed:

09/04/99

Time Analyzed:

2010

Matrix:

WATER

Level: (low/med)

LOW

Instrument ID:

GCB

THIS METHOD BLANK APPLIES TO THE FOLLOWING SAMPLES, MS and MSD:

	CLIENT ID.	LAB SAMPLE ID	LAB FILE ID	DATE ANALYZED
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21	PWB10820LCS	PWB10820LCS PWB10820LCS D1227001 D1227002	FILE ID  ===================================	ANALYZED
22				

## PESTICIDE CONTINUING CALIBRATION CHECK

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Instrument ID: GCB

Case No.: D1227 SDG No.: D1227

Lab File ID: B0904004 CCV Date/Time:

09/04/99

1517

GC Column: DB5

ICAL Date/Time (1st pt): 08/23/99

0959

ICAL Date/Time (Last pt): 08/23/99 1314

COMPOUND	AVERAGE RF	DE.			MAX
Tetrachloro-m-xylene	2.751 0.871 2.640 2.495 2.542 2.351 2.134 1.886 2.243 1.919 1.972 1.832 1.503 1.801 1.717 0.903 1.951 1.334 2.115 2.117	RF ====================================	CURVE  AVG AVG AVG AVG AVG AVG AVG AVG AVG AV	0.2 3.1 7.5 3.7 4.8 5.7 2.5 -4.4 -1.3 -3.8 -11.5 -0.4 -4.2 -6.1 -4.2 2.9 -1.4 ====================================	15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0

## PESTICIDE CONTINUING CALIBRATION CHECK

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Instrument ID: GCB

Case No.: D1227

SDG No.: D1227

Lab File ID: B0904005

CCV Date/Time:

09/04/99

1605

GC Column: DB5

ICAL Date/Time (1st pt): 08/22/99

1725

ICAL Date/Time (Last pt): 08/22/99

2040

/	AVERAGE RF ======== 0.044	RF ======= 0.038	CURVE ====== AVG	%D ===== -12.0	MAX %d ====	
/2\	0.047 0.050	0.039	AVG AVG AVG	-12.0 -17.6 -4.3	15.0	<-

## 7B PESTICIDE CONTINUING CALIBRATION CHECK

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Instrument ID: GCB

Case No.: D1227

SDG No.: D1227

Lab File ID: B0904020

CCV Date/Time:

09/05/99

0417

GC Column: DB5

ICAL Date/Time (1st pt): 08/23/99

0959

ICAL Date/Time (Last pt): 08/23/99

1314

GOLGOOT	AVERAGE				MAX	1
COMPOUND	RF	RF	CURVE	%D	%d	
alpha-BHC	2.751	3.182	3170	======	====	1
beta-BHC	0.871	0.968	AVG	15.7	15.0	<-
delta-BHC	2.640	2.951	AVG AVG		15.0	1
gamma-BHC (Lindane)	2.495	2.825	AVG		15.0	
Heptachlor	2.542	2.917	AVG		15.0	
Aldrin	2.351	2.658	AVG		15.0	
Heptachlor epoxide	2.134	2.365	AVG		15.0	1
Endosulfan I	1.886	1.963	AVG		15.0	
Dieldrin	2.243	2.438	AVG		15.0	i
4,4'-DDE	1.919	1.922	AVG		15.0	
Endrin	1.972	2.030	AVG		15.0	-
Endosulfan II	1.832	1.892	AVG		15.0 15.0	1
4,4'-DDD	1.503	1.543	AVG		15.0	
Endosulfan sulfate	1.801	1.684	AVG		15.0	
4,4'-DDT	1.717	1.732	AVG		15.0	ł
Methoxychlor	0.903	0.864	AVG		15.0	
Endrin ketone	1.951	1.960	AVG		15.0	
Endrin aldehyde	1.334	1.342	AVG		15.0	
alpha-Chlordane	2.115	2.222	AVG		15.0	
gamma-Chlordane	2.117	2.223	AVG			
=======================================	========	========	======		====	
Tetrachloro-m-xylene	1.075	1.249	AVG	16.2	20.0	ĺ
Decachlorobiphenyl	1.920	1.792	AVG	-6.6	20.0	
<u> </u>				ا ۵.۰	20.0	l

## PESTICIDE CONTINUING CALIBRATION CHECK

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Instrument ID: GCB

Case No.: D1227

SDG No.: D1227

Lab File ID: B0904021

CCV Date/Time:

09/05/99

0506

GC Column: DB5

1725

ICAL Date/Time (1st pt): 08/22/99

ICAL Date/Time (Last pt): 08/22/99

2040

COMPOUND	AVERAGE RF	RF	CURVE	%D	MAX %d	
Toxaphene (2) (3) (3)	0.044 0.047 0.050	0.039 0.036 0.043	AVG AVG AVG	-10.4 -24.2 -12.5	15.0	

## PESTICIDE ANALYTICAL SEQUENCE

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Case No.: D1227

SDG No.: D1227

GC Column: DB5 ID: 0.53 (mm) ICAL Date(s): 08/22/99 08/23/99

Instrument ID: GCB

	CLIENT SAMPLE NO.	LAB SAMPLE ID	DATE ANALYZED	TIME ANALYZED
01	PSTD#3 PEST	PSTD#3 PEST	09/04/99	========
02	PSTD#3 TOX	PSTD#3 TOX	09/04/99	1517 1605
03 04	PWB10820LCS PWB10820LCS	PWB10820LCS PWB10820LCS	09/04/99 09/04/99	1832 1921
05 06	PWB10820 ZGPERMEATE	PWB10820 D1227001	09/04/99	2010
07	ROPERMEATE	D1227002	09/04/99 09/04/99	2058 2147
08 09	PSTD#3 PEST PSTD#3 TOX	PSTD#3 PEST PSTD#3 TOX	09/05/99 09/05/99	0417 0506
10 11				0306
12				
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33				
35				

## CHAIN OF CUSTODY DOCUMENTATION

71.75 . 2.37 工用型

CH2MHILL Analytical Services CHAIN OF CUSTODY RECORD AND AGREEMENT TO PERFORM SERVICES

L LMG 2567 Fairlane Drive Montgomery, AL 36116-1622 (334) 271-1444 FAX (334) 271-3428

[ ] LRD 5090 Caterpillar Road Redding, CA 96003-1412 (916) 244-5227 FAX (916) 244-4109

| ILKW Canviro Analytical Laboratories, Inc. 50 Bathurst, Unit 12, Waterloo, Onlario, Canada N2V 2C5 (519) 747-2575 FAX (519) 747-3806

| 1000 2300 NW Walnut Boulevard Corvalis, OR 97330-3638 (541) 752-4271 FAX (541) 752-0276 COC # 9801827

Project #	# Topace Order #	3					200	001001-1000	
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				7°4		Lab#		Page	ō
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12	101 Oraay		qه د ۲	Xo[		Lab PM	-	Custody Review	yview
City of McAllen	New		*	יישן: ישן: ישן:				A 8/18/99	8/49
Project Manager or Contact & Phone # Report Copy to:  Rathy McKinley  Syl / 759-0235 # 3144 Syt-759-0235	Hone # Report Copy to: 164 Kayhy M.J. 3/44 Syt-758-00	Kioley 235	ריטין	HANY UCI		200	120 Buffe   199	LIMS Verification	ation
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M SAP W	NWTP#2	Dispose Return		7	Preservative			lce	X X
Type Ma			ш е .			QC Level	1 2 3	Other	
Sampling C G W S A	CLIENT SAMPLE ID	LAB	so			Cooler	Cooler Temperature	2°C	
Date Time B E L						<u> </u>	Alternate Description	lon	Lab ID
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8/17/19/07:30	ROPErmeate	4	7	>					7
									1
									:
Relinquished By . , ,	Empty Bottles	Date/Time	Received By		Empty Bottles	Date/Time			
lopi Villanoch		14/21	XRI	ل	4	8/11/8	75.25	•	
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Received By	/ 1	Date/Time	Relinquished By	1By. 1044.	(Please sign and print name)	Date/Time	i		
			Shipped Via		Shipping #	01111	//		
Serial Instructions:		10001 C6/81/8	JPS Fee	(Fed-Ex) Other	812900725209	25200			

DISTRIBUTION: Original - LAB, Yellow - LAB, Pink - Client



5090 Caterpillar Road

Redding Ca., 96003

Phone: 530-244-5227

Fax: 530-244-4109

## SAMPLE RECEIPT EXCEPTION REPORT

Sample Batch Number: 1227	Client/Project: CITY & McALLEN
	Comments:
No custody seal as required by project.	
Analysis, description, date/time of collection not provided.	1
Samples broken or leaking on receipt.	
Temperature of samples inappropriate for analysis requested.	
<ol><li>Container inappropriate for analysis requested.</li></ol>	
6. Inadequate sample volume.	
Preservation inappropriate for analysis requested.	
Samples received out of holding time for analysis requested.	
9. Descrepencies between COC form and container labels.	
10. Other	
	fraction was affected by the exceptions detailed above by writing
Unpreserved: Metals:	GC Volatiles: GC/MS Volatiles:
Cyanide: Extractables:	Extractables: Other (specify):
Corrective Actions Taken:  NOT Required  SW 8/19/99	
Notified:ClientClient Services	By: Blutton Date: 8/18/99

### Sound Analytical Services, Inc.

ANALYTICAL & ENVIRONMENTAL CHEMISTS

4813 Pacific Hwy East • Tacoma, WA 98424 (253) 922-2310 • FAX (253) 922-5047

e-mail: saincl@uswest.net



#### TRANSMITTAL MEMORANDUM

DATE: September 13, 1999

TO: Kathy McKinley CH2M Hill 2300 NW Walnut Blvd. Corvallis, OR 97330-3538

PROJECT: McAllen Reuse Pilot Study

REPORT NUMBER: 83466

Enclosed are the test results for two samples received at Sound Analytical Services on August 18, 1999.

The report consists of this transmittal memo, analytical results, quality control reports, a copy of the chain-of-custody, a list of data qualifiers and analytical narrative when applicable, and a copy of any requested raw data.

Should there be any questions regarding this report, please contact me at (253) 922-2310.

Sincerely,

Katie Downie
Project Manager

## Sound Analytical Services, Inc.

ANALYTICAL & ENVIRONMENTAL CHEMISTS

4813 Pacific Hwy East • Tacoma, WA 98424 (253) 922-2310 • FAX (253) 922-5047 e-mail: saincl@uswest.net



#### **ANALYTICAL NARRATIVE**

Client:

CH2M Hill

Date: September 13, 1999

Project: McAllen Reuse Pilot Study

Lab No.: 83466

Delivered By: Federal Express

Condition of samples upon receipt: Samples were received in good condition. Chain of custody was in order.

#### Sample Identification:

Lab. No.	Client_ID	Date Sampled	<u>Matrix</u>
83466-1	Zenogem Permeate	08-17-99	Liquid
83466-2	RO Permeate	08-17-99	Liquid

#### SAMPLE PREPARATION AND ANALYSIS

#### ORGANOCHLORINE HERBICIDES

Samples 83466-1 and 83466-2 were analyzed for organochlorine herbicides in accordance with EPA SW-846 Method 8151A GC/MS Modified. Samples 83466-1 and 83466-2 were extracted in accordance with EPA SW-846 Method 3510C on 8-24-99 and analyzed on 08-24-99. The samples were extracted and analyzed within the required holding time.

EPA SW-846 Method 8151A has been modified to include the use of a mass spectrometer (MS) for quantitation of the herbicides. The introduction to Method 8151A allows the use of the MS as a qualitative confirmation of detected compounds.

The relative percent difference (RPD) between the percent recoveries of Silvex in the blank spike and blank spike duplicate exceeded the quality control; acceptance limits. No corrective action was taken because there was no remaining sample volume for reextraction. The RPD has been flagged "N".

All other quality control parameters were within the acceptance limits.

No difficulties were encountered during the organochlorine herbicide analyses.

Client Name

Client ID:

Name CH2M Hill
t ID: ZENOGEM PERMEATE

Lab ID: Date Received:

Date Prepared:
Date Analyzed:

% Solids
Dilution Factor

83466-01 8/18/99 8/24/99 8/24/99

10

### Chlorinated Herbicides by USEPA Method 8151GC/MS Modified

			Recov	ery Limits
Surrogate 2,4-Dichlorophenylacetic acid	<b>% Recovery</b> 100	Flags	<b>Low</b> 48	High 124

 Result

 Analyte
 (ug/L)
 PQL
 MDL
 Flags

 - 2,4-D
 ND
 0.095
 0.083

 Silvex (2,4,5-TP)
 ND
 0.095
 0.077

Client Name

Client ID:

Lab ID: Date Received: Date Prepared: Date Analyzed: % Solids

**Dilution Factor** 

CH2M Hill

**RO PERMEATE** 

83466-02 8/18/99 8/24/99

> 8/24/99 10

### Chlorinated Herbicides by USEPA Method 8151GC/MS Modified

			Recov	ery Limits
Surrogate 2,4-Dichlorophenylacetic acid	% Recovery 102	Flags	Low 48	High 124

		Result			
	Analyte	(ug/L)	PQL	MDL	Flags
_	2,4-D	ND	0.1	0.09	
	Silvex (2,4,5-TP)	ND	0.1	0.083	

Lab ID:

Method Blank - HB876

Date Received:

Date Prepared: Date Analyzed: 8/24/99 8/24/99

% Solids

_ -

Dilution Factor

10

## Chlorinated Herbicides by USEPA Method 8151GC/MS Modified

Surramata			Recov	ery Limits
Surrogate 2,4-Dichlorophenylacetic acid	% Recovery 97.6	Flags	Low 48	High 124

	Result			
Analyte	(ug/L)	PQL	MDL	Flags
2,4-D	ND	0.1	0.087	i iags
Silvex (2,4,5-TP)	ND	0.1	0.081	

## Blank Spike/Blank Spike Duplicate Report

Lab ID: Date Prepared: Date Analyzed: QC Batch ID:

HB876 8/24/99 8/24/99 HB876

Chlorinated Herbicides by USEPA Method 8151GC/MS Modified

Compound Name Dalapon Dicamba	Blank Result (ug/L) 0 0	Spike Amount (ug/L) 5 5	BS Result (ug/L) 2.91 3.65	<b>BS</b> % Rec. 58.2 73	Result (ug/L) 3.07 4.42	<b>BSD % Rec.</b> 61.4 88.4	<b>RPD</b> 5.4 19	Flag
2,4-D	0	5	5.24	105	4.81	96.2	-8.7	
Pentachlorophenol Silvex (2,4,5-TP)	0	5	5.3	106	5.77	115	8.1	
Dinoseb	0	5	4.36	87.2	3.2	64	-31	N
MCPA	0	5 5	4.44 5.43	88.8 109	4.11 4.63	82.2 92.6	-7.7	
		-	0.10	100	4.03	92.0	-16	

### Chlorinated Herbicides by USEPA Method 8151A GC/MS Modified

Aquired 6/12/1999 Valid until12/12/99

### 8151 SURROGATE ACCEPTANCE CRITERIA

	Water	Water high	Soil Low	Soil High
Surrogate	%Rec	%Rec	%Rec	%Rec
2.4.6 - Tribromophenol	48	124	65	131
2.4-Dichlorophenylacetic Acid	48	142	60	142

### 8151 SPIKE ADVISORY LIMITS FOR %RECOVERY AND RPD

Compound Name Dalapon Dicamba	Water low %Rec 23 31	Water high %Rec 114 148	Water RPD %Rec 27 45	Soil Low %Rec 22 25 21	Soil High %Rec 87 150 152	Soil RPD %Rec 22 24 28
2,4-D Pentachlorophenol	29 56	149 146	24 28	31	156 149	25 22
Silvex (2,4,5-TP) Dinoseb	42 50	129 155	19 40	54 54	148	27
2,4-DB MCPA	29 65	125 127	25 26	31 46	123 154	32 41

### 8151 SPIKE ADVISORY LIMITS FOR TCLP % RECOVERY AND RPD

	Leachate Low	Leachate high	Leachate RPD
Compound Name	%Rec	%Rec	
2.4-D	36	137	36
Silvex (2,4,5-TP)	42	149	36

ANALYTICAL & ENVIRONMENTAL CHEMISTS

4813 PACIFIC HIGHWAY EAST, TACOMA, WASHINGTON 98424 - TELEPHONE: (253) 922-2310 - FAX: (253) 922-5047

### DATA QUALIFIERS AND ABBREVIATIONS

- This analyte was detected in the associated method blank. The analyte concentration was determined not to be **B**1: significantly higher than the associated method blank (less than ten times the concentration reported in the blank).
- This analyte was detected in the associated method blank. The analyte concentration in the sample was determined B2: to be significantly higher than the method blank (greater than ten times the concentration reported in the blank).
- Second column confirmation was performed. The relative percent difference value (RPD) between the results on **C**1: the two columns was evaluated and determined to be  $\leq 40\%$ .
- Second column confirmation was performed. The RPD between the results on the two columns was evaluated and C2: determined to be > 40%. The higher result was reported unless anomalies were noted.
- GC/MS confirmation was performed. The result derived from the original analysis was reported. M:
- The reported result for this analyte was calculated based on a secondary dilution factor. D:
- The concentration of this analyte exceeded the instrument calibration range and should be considered an estimated E: quantity.
- The analyte was analyzed for and positively identified, but the associated numerical value is an estimated quantity. J.
- Maximum Contaminant Level MCL:
- MDL: Method Detection Limit
  - See analytical narrative.
- Not Detected ND:
- Practical Quantitation Limit PQL:
- Contaminant does not appear to be "typical" product. Elution pattern suggests it may be ______. X1:
- Contaminant does not appear to be "typical" product. X2:
- Identification and quantitation of the analyte or surrogate was complicated by matrix interference. **X**3:
- RPD for duplicates was outside advisory QC limits. The sample was re-analyzed with similar results. The sample X4: matrix may be nonhomogeneous.
- RPD for duplicates outside advisory QC limits due to analyte concentration near the method practical quantitation X4a: limit/detection limit.
- Matrix spike recovery was not determined due to the required dilution. X5:
- Recovery and/or RPD values for matrix spike(/matrix spike duplicate) outside advisory QC limits. Sample was re-X6: analyzed with similar results.
- Recovery and/or RPD values for matrix spike(/matrix spike duplicate) outside advisory QC limits. Matrix **X**7: interference may be indicated based on acceptable blank spike recovery and/or RPD.
- Recovery and/or RPD values for this spiked analyte outside advisory QC limits due to high concentration of the X7a: analyte in the original sample.
- Surrogate recovery was not determined due to the required dilution. X8:
- Surrogate recovery outside advisory QC limits due to matrix interference. **'**9:



Sound Analytical Services, Inc.
ANALYTICAL & ENVIRONMENTAL CHEMISTS 4813 Pacific Hwy East • Tacoma, WA 98424 (253) 922-2310 • FAX (253) 922-5047 e-mail: saincl@uswest.net

SAS Lab No	83466
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ΤŲ	RNAROUND	REQUEST	(business	days

Standard (10 days) _______ 5 day _____ 5 day _____ 5

CHAIN OF CUSTODY/REQUEST FOR LABORATORY ANALYSIS  Client: City of McAllen  Project Name:  McAllen Reuse Pilot Study  Contact: ** Kathy mcKinkey-Applied Sciences  Phone No: 541 / 758-0235 art, 3144  Fax No: 541 / 766-2852  Email: KmcKinle a ch2m. com  Use Only  Sample ID  Date Time Matrix # 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	
McAllen Reuse Pilot Study  Contact: ** Kathy McKintey-Applied Sciences  Phone No.: 541/758-0235 ext. 3144  Fax No.: 541/766-2852  Email: KmcKinte D ch2m.com  Lab Use Sample ID  Date Time Matrix # 2 2 7 7 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	
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Zenogem Permente 8/17/99 07:30 1:44.21 /	
2 RO Permeate 8/17/19/07:30 Lianid 1 1	
Signature Printed Name Firm Time/Date Special Instructions	

	Signature	Printed Name	Firm	Time/Date	Special Instructions	<del></del>
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COC No.	 



#### **ENERGY LABORATORIES, INC.**

SHIPPING: 2393 SALT CREEK HIGHWAY . CASPER, WY 82601

MAILING: P.O. BOX 3258 • CASPER, WY 82602

E-mail: energy@trib.com • FAX: (307) 234-1639 • PHONE: (307) 235-0515 • TOLL FREE: (888) 235-0515

#### **CASE NARRATIVE**

DATE:

September 21, 1999

TO:

Kathy McKinley

FROM:

Sheryl Garling

RE:

CH2MHill Water Samples

SAMPLE NUMBERS: 32370 001 through 002

Samples Zenogem Permeate and RO Permeate were received on August 18, 1999. Samples were shipped using Energy Laboratories, Inc. contract service with UPS. The overnight option was used for shipping the samples to the laboratory. Samples were in good condition and properly preserved.

No analytical problems were indicated for this sample delivery group.

The methods used are methods published by US EPA for drinking water analyses. The methods used are as follows:

Radium 226 - EPA Method 903.0 (alpha emitting),

Radium 228 - EPA Method 904.0, and

Gross Alpha -EPA Method 900.1 (gross alpha minus uranium and

radon).

The standard detection limits for these methods are 0.2 pCi/L, 1.0 pCi/L, and 1.0 pCi/L, respectively. The initial e-mail response incorrectly identified methods and detection limits.

If additional information is required, please advise.



### **ENERGY LABORATORIES, INC.**

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MAILING: P.O. BOX 3258 • CASPER, WY 82602 E-mail: energy@trib.com • FAX: (307) 234-1639 • PHONE: (307) 235-0515 • TOLL FREE: (888) 235-0515

### LABORATORY ANALYSIS REPORT - CH₂M HILL

Project: Sample ID: Laboratory ID: Sample Matrix: Sample Date/Time: Date Received: Report Date:

McAllen Reuse	Pilot Study
Zenogem Permeate	RO Permeate
32370-001	32370-002
Wat	ег
08-17-99	@ 07:30
08-18	3-99
September	12, 1999

Radiometric		Method	Reporting Limit	Units	Results	
	7/5		<del></del>	G:/I	<0.1	< 0.2
Radium-226	²²⁶ Ra	903.0	0.2	pCi/L	< 0.2	
Radium Precision ±					-	<u> </u>
Radium-228	²²⁸ Ra	904.0	1.0	pCi/L	<1.0	<1.0
Radium Precision ±					-	
	Gross α	000.1	1.0	pCi/L	<1.0	< 1.0
Gross Alpha	Gross a	900.1	1.0	PCI/E		
G. Alpha Precision ±					<u> </u>	<u> </u>



# RADIOCHEMICAL QUALITY ASSURANCE REPORT - CH₂M HILL

Laboratory ID Range:
Sample Matrix:
Sample Date / Time:
Date Received:
Report Date:

32370-001-002
 Water
 08-17-99 @ 07:30
 08-18-99
 September 12, 1999

	Method	Relative Percent <u>Difference¹</u>	Spike Recovery (Percent) ²	LCS Recovery (Percent)	Method Blank (pCi/L) ³	Date <u>Analyzed</u>	Analyst
Y . L		56010-001	90156-001		GA-18633		T DC
Laboratory #:	900.1	0.0	92	98	<1.0	08-24-99	RS
Gross Alpha:		32627-001	32428-003		RA-186		
Laboratory #:	903.0	0.8	98	104	< 0.2	09-07-99	RS
Radium-226:		32443-001	32443-002		228-212		
Laboratory #: dium-228:	904.0	0.0	117	119	< 1.0	09-10-99	LMH
Gidin 220.			_				

(3) Uranium is reported in mg/L.

lmh r:\Reports\Clients.99\CH2M_Hill\Water\rc32370-001.xls

Reviewed By: LOLL

Log In No. 32370

⁽¹⁾ These values are an assessment of analytical precision. The acceptance range is 0-20% for sample results above 10 times the reporting limit. This range is not applicable to samples with results below 10 times the reporting limit.

⁽²⁾ These values are an assessment of analytical accuracy. They are a percent recovery of the spike addition. ELI performs a matrix spike on 10 percent of all samples for each analytical method.

CHAIN OF CUSTODY RECORD ENERGY LABORATORIES, INL BillingsCasperGilletteRapid City

PO Box 3258 UPS/FedEx Deliveries: Mail Only:

82602-3258 Casper, WY 2393 Salt Creek Highway

toll free 1 \\ \)235-0515 voice

99CHSHOULC

(SEE BACK OF FORM FOR EXAMPLES AND INSTRUCTIONS) For Sample Tracking Purposes, Please Provide Contact Name and Telephone #'s as Indicated Project Name / Location / Purchase Order # / Bid #

82601 Casper, WY

307-235-0515 307-234-1639

Comments, Special Special Requests Instructions, etc. 147 Lats Type of Analyses Requested MQIASSOND Gross Alpha Kad ium Sand V We see that V is a sum V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V of V158-038-41-18/ hhls # 5820-851-1hs Send Invoice to: Kathy McKinby, CH2M Hill Applied Sciences Growp call a obove plan number Same as above Zenogem Permeate Sample 1.D. / NO. P.O.# Permeate Send Report to: / McAllen, Name / Phone # / Fax # MuAller Reuse Pilit Sup samble Kathy McKinley omposite Study 8/17/9/07:30 3/17/99/07:30 Time Date

1. Sampler: (signature)	Date	Time	Received by: (signature)	2. Relinquished by: (signature)	Date	Time	Received by: (signature)
R-9.	8/17/99 07:30 RODIE	07.30	Rosie Villangal	Baie Villaneal	8/11/89		
3. Relinquished by: (signature)	Date	Time	Received by: (signature)	4. Relinquished by: (signature)	Date	Time	Received at Laboratory by:
					8-18-8	10:15	8-189 10:15 Krighature

#### Scope of Work/Instructions

### CH2M HILL Point of Contact for Final report/Invoicing

CH2M HILL Kathy McKinley 2300 NW Walnut Blvd. Corvallis, OR 97330

Phone: 541/758-0235 ext. 3144

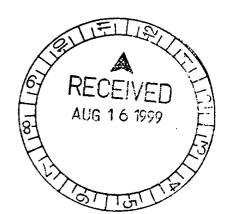
FAX: 541/766-2852

### Analytical Methods/Prices:

Radium 226 by EPA 903.0 for \$40 per sample Radium 228 by EPA 904.0 for \$50 per sample Gross Alpha by EPA 903.0 for \$35 per sample

Sample Delivery: \$25

Return Cooler/Samples: \$6.40



The laboratory shall clearly and completely document and justify the preparation and analysis procedures when modifications to the methods have been made/requested.

**Holding Times:** Samples must be analyzed within EPA holding for each analytical method specified. CH2M HILL will deliver samples to the laboratory in a timely manner to facilitate the meeting of holding times.

**Quality Assurance/Quality Control Requirements:** QA/QC procedures will follow the protocols set forth in the EPA methods.

**Data Package**: A final data package must be submitted to CH2M HILL. The package will include: a lab narrative and data summary.

The laboratory narrative will include:

A description of any deviation from the prescribed methodologies or protocols as discussed in this SOW.

Summarization of quality control information exceeding the laboratory's acceptance criteria, a discussion of possible reasons for these discrepancies, and a description of corrective action taken.

All blank values exceeding three times the average method blank will be addressed.

A synopsis of all holding times achieved.

A discussion of any other analytical problems that may have been encountered.

Turnaround Time: Standard (3 weeks)



October 26, 1999

McAllen WWTP #2, City of

149462.A1.ZG

RE:

Analytical Data for McAllen WWTP #2, City of Applied Sciences Group Reference No. 3089

Angie Fernandez/PHX:

On September 15, 1999, CH2M HII request for analysis of selected para

The analytical results and associate difficulties encountered during the narrative.

Under CH2M HILL policy, your shave not given us prior instruction disposal as hazardous waste.

CH2M HILL Applied Sciences ( serving your analytical needs agif you need additional information extension 3120.

Sincerely,

Kelly Ensor

Senior Administrative Assistant

**Enclosures** 

Group received four samples with a tached.

ısual ; case

CH2M HILL

Fax 541.752.0276

Applied Sciences Group 2300 NW Walnut Bivd Corvallis, OR 97330-3538 P.O. Box 428 Corvallis, OR 97339-0428 Tel 541.752.4271

ting. If you nples require

rward to rning the data, or 758-0235,

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(SEE BACK OF FORM FOR EXAMPLES AND INSTRUCTIONS) 307-235-0515 307-234-1639 Comments, Special Instructions, etc. Special Requests 上も できび 99CHSHBY6C toll free I fax Type of Analyses Requested CHAIN OF CUSTODY RECORD 82602-3258 Casper, WY MQIA SSOND Gross Alpha Rodium 226, Res Radium 226, Radium 228 Casper, WY For Sample Tracking Purposes, Please Provide Contact Name and Telephone #'s as Indicated UPS/FedEx Deliveries: 2393 Salt Creek Highway ENERGY LABORATORIES, INC Kathy McKinley / 541-758-0235 # 3144/541-766-2852 PO Box 3258 Send Invoice to: Kathy McKinby CHOWP Call a obove plux number Same as above Mail Only: Purchase Order # / Bid # Sample I.D. NO. P.O.# Send Report to: / McAllen, · Rapid City BillingsCasperGillette Name / Phone # / Fax # Project Name / Location McAllen Reuse Pilot grab sample əṇsodwoə Time Date

Permeate

Zeno Gam

80

8/17/9/07:30

3/17/99/07:30

1. Sampler: (signature)	Date	Time	Received by: (signature)	2. Relinquished by: (signature)	Date	Time	Received by: (signature)
	01-190	40.70	Jan 11 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	Mice VIlland	8/11/89		
	8111117	00.70					The transfer of a later of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the transfer of the
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S. Neilliquisited by Contract					0-18-9	10.15	0-10-2 10:15 10 , 00.0
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UPS/FedEx Deliveries: ENERGY LABORATORIES, INC. 'S CHAIN OF CUSTODY RECORD Mail Only: PO Box 3258 2393 Salt Creek Highway Casper, WY Casper, WY 82602.3258 82602 AMOL fur 307-235-0515 307 234-1639

5/28 5/28 1995 Date Name Project Name / Location T Purchase Order # For Sample Tracking Purposes, Please Provide Contact Name and Telephone #'S As Indicated / Phone # / Fax # 11:45 11:35 Time Thunderbasin Town of Hope Jeff Jones @ (307) 555-1515, (307) 555-5555 fax composite × grab sample Distribution Tap Entry to Distribution Send Report to: Send Invoice to: Jeff Jones No PO# Bob Brown Hope, WY 80000 USA, WY 81111 PO Box Somewhere PO Box Nowhere Sample I.D. Number of containers Sample Type: A W S V U O Air <u>W</u>ater <u>S</u>oils/solids <u>Y</u>egetation <u>U</u>rine <u>O</u>ther ø 4 Asbestos - TEM (SEE BACK OF FORM FOR EXAMPLES AND INSTRUCTIONS) Type of Analyses Requested 10C's - RADs NO₂, NO₃, F × YOCs - 502.2 50Cs - 504,505,508 × 515, 531.1 50Cs -Phase If SDWA Primary Comments, Special instructions, etc. Special Requests as soon as Please fax Thank you, possible results

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3. Relinquished by: (signature)
N/A

Date N/A

Time

Received by: (signature)

4. Relinquished by: (signature)

Sheryl A. Garling

Date 5-28-95

Time 14:00p

Received at Laboratory by

Roger A. Garling

1.Sampler: (signature)

Jeff Jones

Date **5-28-95** 

Time **12:05p** 

Received by: (signature)

2.Relinquished by: (signature)

Harry Truckers

Date **5-21-95** 

Time **13:15**p

Received by: (signature)

Sheryl A. Garling

Harry Truckers

- 33 Special Requests area can include (but not limited to) the following: A completed Chain-of-Custody must be submitted with all samples
- Turnaround status, Rush status, Due Date, etc
- Special mailing instructions:
- send copy of Report and/or Invoice to a second party - send copy of Report to a Government Agencies (EPA, etc.)
- Public Water System (PWS) Number
- Do you want samples returned to you or disposed of?

#### Scope of Work/Instructions

#### CH2M HILL Point of Contact for Final report/Invoicing

CH2M HILL Kathy McKinley 2300 NW Walnut Blvd. Corvallis, OR 97330

Phone: 541/758-0235 ext. 3144

FAX: 541/766-2852

#### **Analytical Methods/Prices:**

Radium 226 by EPA 903.0 for \$40 per sample Radium 228 by EPA 904.0 for \$50 per sample Gross Alpha by EPA 903.0 for \$35 per sample

Sample Delivery: \$25

Return Cooler/Samples: \$6.40

The laboratory shall clearly and completely document and justify the preparation and analysis procedures when modifications to the methods have been made/requested.

**Holding Times:** Samples must be analyzed within EPA holding for each analytical method specified. CH2M HILL will deliver samples to the laboratory in a timely manner to facilitate the meeting of holding times.

**Quality Assurance/Quality Control Requirements:** QA/QC procedures will follow the protocols set forth in the EPA methods.

**Data Package**: A final data package must be submitted to CH2M HILL. The package will include: a lab narrative and data summary.

The laboratory narrative will include:

A description of any deviation from the prescribed methodologies or protocols as discussed in this SOW.

Summarization of quality control information exceeding the laboratory's acceptance criteria, a discussion of possible reasons for these discrepancies, and a description of corrective action taken.

All blank values exceeding three times the average method blank will be addressed.

A synopsis of all holding times achieved.

A discussion of any other analytical problems that may have been encountered.



Turnaround Time: Standard (3 weeks)



CH2M HILL

Applied Sciences Group

2300 NW Walnut Blvd

Corvallis, OR

97330-3538

P.O. Box 428 Corvallis, OR

97339-0428

Tel 541.752.4271

Fax 541.752.0276

October 26, 1999

McAllen WWTP #2, City of

149462.A1.ZG

RE:

Analytical Data for McAllen WWTP #2, City of Applied Sciences Group Reference No. 3089

Angie Fernandez/PHX:

On September 15, 1999, CH2M HII request for analysis of selected para

The analytical results and associate difficulties encountered during the narrative.

Under CH2M HILL policy, your shave not given us prior instruction disposal as hazardous waste.

CH2M HILL Applied Sciences ( serving your analytical needs agif you need additional information extension 3120.

Sincerely,

Kelly Ensor

Senior Administrative Assistant

**Enclosures** 

Group received four samples with a

tached.

isual case

ting. If you nples require

rward to ming the data, or 758-0235,

### CLIENT SAMPLE CROSS-REFERENCE

### CH2M HILL Applied Sciences Group Reference No. 3089

		Date	Time
Sample ID	Client Sample ID	Collected	Collected
308901	ZGP	09/14/1999	08:50
308902	ROP	09/14/1999	08:50
308903	WWTP#2Effluent	09/14/1999	08:50
308904	ROC	09/14/1999	08:50

# CASE NARRATIVE VOLATILES

Lab Reference No.: 3089

Client/Project: McAllen WWTP #2, City of

I. <u>Holding Times</u>:

All acceptance criteria were met.

- II. Analysis:
  - A. <u>Calibration</u>:
    All acceptance criteria were met.
  - B. <u>Blanks</u>: All acceptance criteria were met.
  - C. <u>Duplicate Sample(s)</u>:
    All acceptance criteria were met.
  - D. <u>Spike Sample(s)</u>:
    All acceptance criteria were met.
  - E. <u>Surrogate Recoveries</u>:
    All acceptance criteria were met.
  - F. <u>Lab Control Sample(s)</u>: All acceptance criteria were met.
  - G. Other:
- III. <u>Documentation Exceptions</u>: None

IV. I certify that this data package is in compliance with the terms and conditions agreed to by the client and CH2M HILL, both technically and for completeness, except for the conditions detailed above. Release of the data contained in this hardcopy data package has been authorized by the Laboratory Manager or designee, as verified by the following signature.

Jungh A Handy

Prepared by:

Reviewed by:

# CASE NARRATIVE GENERAL CHEMISTRY

Lab Reference No.: 3089

Client/Project: McAllen WWTP #2, City of

I. <u>Holding Time</u>:

All acceptance criteria were met.

II. <u>Digestion Exceptions</u>:

None

III. Analysis:

A. Calibration:

All acceptance criteria were met.

B. Blanks:

All acceptance criteria were met.

C. <u>Matrix Spike Sample(s)</u>:

All acceptance criteria were met.

D. <u>Duplicate Sample(s)</u>:

All acceptance criteria were met.

E. Lab Control Sample(s):

All acceptance criteria were met.

F. Other:

Not applicable.

IV. <u>Documentation Exceptions</u>:

None.

V. I certify that this data package is in compliance with the terms and conditions agreed to by the client and CH2M HILL, both technically and for completeness, except for the conditions detailed above. Release of the data contained in this hardcopy data package has been authorized by the Laboratory Manager or his designee, as verified by the following signature.

Prepared by:

Reviewed by:

#### CASE NARRATIVE METALS

Lab Reference No.: 3089

Client/Project:	McAllen	<b>WWTP #2,</b>	City of
-----------------	---------	-----------------	---------

- I. <u>Holding Time</u>:
  All acceptance criteria were met.
- II. <u>Digestion Exceptions</u>: None.
- III. Analysis:
  - A. <u>Calibration</u>:
    All acceptance criteria were met.
  - B. <u>Blanks</u>: All acceptance criteria were met.
  - C. <u>ICP Interference Check Sample</u>: All acceptance criteria were met.
  - D. <u>Spike Sample(s)</u>: All acceptance criteria were met.
  - E. <u>Duplicate Sample(s)</u>:
    All acceptance criteria were met.
  - F. <u>Laboratory Control Sample(s)</u>: All acceptance criteria were met.
  - G. <u>ICP Serial Dilution</u>: Not Required.
  - H. Other: None
- IV. <u>Documentation Exceptions:</u> None
- V. I certify that this data package is in compliance with the terms and conditions agreed to by the client and CH2M HILL, both technically and for completeness, except for the conditions detailed above. Release of the data contained in this hardcopy data package has been authorized by the Laboratory Manager or his designee, as verified by the following signature.

Prepared by:	Gudyland on	
Reviewed by:	: CAUM'	



CH2M HILL

Applied Sciences Group

2300 NW Walnut Blvd

Corvallis, OR

97330-3538

P.O. Box 428

Corvallis, OR

97339-0428

Tel 541.752.4271

Fax 541.752.0276

October 4, 1999

McAllen WWTP #2, City of

149462.A1.ZG

RE:

Analytical Data for McAllen WWTP #2, City of

Applied Sciences Group Reference No. 3089 & 3113

Angie Fernandez/PHX:

On September 15, 1999, CH2M HILL Applied Sciences Group received four samples with a request for analysis of selected parameters. From two of these samples, CH2M HILL Applied Sciences Group generated two samples with a request for analysis of selected parameters.

The analytical results and associated quality control data are enclosed. Any unusual difficulties encountered during the analysis of your samples are discussed in the case narrative.

Under CH2M HILL policy, your samples will be stored for 30 days after reporting. If you have not given us prior instructions for disposal, we will contact you if any samples require disposal as hazardous waste.

CH2M HILL Applied Sciences Group appreciates your business and looks forward to serving your analytical needs again. If you should have any questions concerning the data, or if you need additional information, please call Ms. Kathy McKinley at (541) 758-0235, extension 3120.

Sincerely,

Kelly Ensor

Senior Administrative Assistant

**Enclosures** 

### CLIENT SAMPLE CROSS-REFERENCE

### CH2M HILL Applied Sciences Group Reference No. 3089 & 3113

		Date	Time
Sample ID	Client Sample ID	Collected	Collected
308901	ZGP	9/14/99	8:50
308902	ROP	9/14/99	8:50
308903	WWTP#2Effluent	9/14/99	8:50
308904	ROC	9/14/99	8:50
311301	ZGP-3D	9/20/99	
311302	ROP-3D	9/20/99	

# CASE NARRATIVE DBPs/ORGANICS

Lab Reference No.: 3089 & 3113

Client	Project	: McAllen WWTP #2, City of
I.		g Times: eptance criteria were met.
II.	Analys	<u>is</u> :
	A.	Calibration: All acceptance criteria were met.
	B.	Blanks: All acceptance criteria were met.
	C.	Duplicate Sample(s): All acceptance criteria were met.
	D.	Spike Sample(s): All acceptance criteria were met.
	E.	Surrogate Recoveries: All acceptance criteria were met.
	F.	Lab Control Sample(s): All acceptance criteria were met.
	G.	Other: None
III.	<u>Docun</u> None	nentation Exceptions:
cli ab	ient and ove. Re	at this data package is in compliance with the terms and conditions agreed to by the CH2M HILL, both technically and for completeness, except for the conditions detailed lease of the data contained in this hardcopy data package has been authorized by the Manager or designee, as verified by the following signature.
Prepar	red by: _	
Revie	wed by:	

				Formati	Pormation Potential Test Conditions	st Conditions					
		Ŧ	Free	Free	Total	FP	Measured	FP	FP	FP	en GP
Client ID	Lab ID	Dose	Residual	Demand	Residual	Temp.	Ha	Start	Take-Off	Time H.M Time (House)	Time (House)
ZGP	308901	00 01	0.21	97.0		3	9,0	20 01 001 010	11. 0. 00 00 0	1 11 11 11 11 11 11 11 11 11 11 11 11 1	Time (Tions)
aOa	COOOL			50.5		27	5.7	CO:71 66/11/6	7/20/99 L5:17	73:12	73.20
TO TO	20%00C	OO	0.71	0.89	1	23	7.7	9/17/99 12:12	9/20/99 13:21	73.00	73.15

			Formation Pote	ential Trihalom	ethanes (THM	c) Disinfaction H	Formation Potential Trihalomethanes (THMs) Disinfection Ry. Products (und)				
		d.	GG	100			Jan Comerce				
		-	14	7.	ī	<u>.</u>					
Client ID	Lab ID	CHCI3	BDCM	DBCM	CHBr3	TTHM					
ZGP-3D	311301	105	77.6	51.5	9.5	244					
ROP-3D	311302	2.9	2.9	2.5	⊽	883	+ -		: :		
							-				
		CHC13 = Chloroform	Jorm			EPA TTHM State	EPA TTHM Stage 1 MCL = 80 uv/l.				
		BDCM = Bromodichloromethune	dichloromethan	e e		EPA TTHM Star	EPA TTHM Stage 2 MCL = 40 ug/l.	"			
		DBCM = Dibron	nochloromethan	22			Ċ				
		CHBr3 = Bromo	form								

			Formation Potential Haloacetic Acids (HAAs) Disinfection By-Products (ug/L)	Ellitai matoace	HC ACIOS (HAA	s) Disinfection E	ty-Products (L	(T/A)			
		FP	FP	FP	FP	FP	FР	FP	FP		
Client ID	Lab ID	MCAA *	MBAA *	DCAA *	TCAA *	BCAA	DBAA *	HAAS	HAAK		
ZGP-3D	311301	7.5	3.2	39.8	31.3	22.8	**	908	113		
OP-3D	311302	2	⊽		7		7				
						;	;	:	=		
				!							
		MCAA = Monoc	chloroacetic acid		BCAA = Brome	schloroacetic acia		EPA HAAS Stage I A	MCL = 60  up/L		
		MBAA = Monob	romoacetic acid		DBAA = Dibro	DBAA = Dibromoacetic acid		EPA HAAS Stude 2 MCI = 30 mm/l	MCI = 10/I	i :	
		DCAA = Dichloroacetic acid	roacetic acid		* These compor	* These compounds make up the HAAS	445		1,8		
		TCAA = Trichloroace	roacetic acid								

**Client Information** 

Lab Information

Client Sample ID: ROC

Lab Sample ID: 308904

Project Name: McAllen WWTP #2, City of Project Manager: Angie Fernandez/PHX

Date Received: 09/15/1999

Sampled By: R. Villareal Sampling Date: 09/14/1999 Report Revision No.: 0

Analyzed By: MG/MAS/DHK

Sampling Time: 8:50

Reviewed By: ~~~

Type: Grab Matrix: Water Basis: As Received

		Sample			Analysis	Date
Analyte	MRL	Result	Qualifier	Units	Method	Analyzed
General Chemistry						
N-Nitrate/Nitrite	0.20	24.4		mg/L	EPA 353.2	09/20/99
N-Total Kjeldahl	2.0	3.6		mg/L	EPA 351.4	09/21/99
Total Dissolved Solids	10	4,330		mg/L	EPA 160.1	09/20/99
TOC	5.0	22.6		mg/L	EPA 415.1/2	09/21/99
Total Phosphate-P	1.0	10.5		mg/L	EPA 365.2/4	09/21/99

**Client Information** 

Client Sample ID: WWTP#2Effluent

Project Name: McAllen WWTP #2, City of Project Manager: Angie Fernandez/PHX

Sampled By: R. Villareal Sampling Date: 09/14/1999 Sampling Time: 8:50

> Type: Grab Matrix: Water Basis: As Received

**Lab Information** 

Lab Sample ID: 308903

Date Received: 09/15/1999

Report Revision No.: 0

Analyzed By: MG/MAS/DHK

Reviewed By: ------

		Sample			Analysis	Date
Analyte	MRL	Result	Qualifier	Units	Method	Analyzed
General Chemistry						
N-Nitrate/Nitrite	0.04	3.94		mg/L	EPA 353.2	09/20/99
N-Total Kjeldahl	2.0	2.0	U	mg/L	EPA 351.4	09/21/99
Total Dissolved Solids	10	1,060		mg/L	EPA 160.1	09/20/99
TOC	0.50	6.10		mg/L	EPA 415.1/2	09/20/99
Total Phosphate-P	0.10	1.78		mg/L	EPA 365.2/4	09/21/99

grad Six IPR

**Client Information** 

Lab Information

Client Sample ID: ZGP

Project Name: McAllen WWTP #2, City of Date Received: 09/15/1999

Project Manager: Angie Fernandez/PHX

Sampled By: R. Villareal Sampling Date: 09/14/1999

Sampling Time: 8:50 Type: Grab Matrix: Water Basis: As Received Report Revision No.: 0

Lab Sample ID: 308901

Analyzed By: MG/MAS/JJB/DHK Reviewed By: ~ 3

Analyte	MRL	Sample Result	Qualifier	Units	Analysis Method	Date Analyzed
General Chemistry						
Alkalinity (as CaCO3)	2.0	153		mg/L	EPA 310.2	09/24/99
Bromide	0.020	0.322		mg/L	EPA 300.0-B	09/20/99
Chloride	2.0	281		mg/L	EPA 300.0-A	09/22/99
Color (APHA) Apparent		17		color units	EPA 110.2	09/15/99
Fluoride	0.10	1.14		mg/L	EPA 300.0-A	09/22/99
N-Ammonia	0.10	0.10	U	mg/L	EPA 350.3	09/23/99
N-Nitrate/Nitrite	0.04	7.90		mg/L	EPA 353.2	09/20/99
N-Total Kjeldahl	2.0	2.0	U	mg/L	EPA 351.4	09/21/99
Silica-React.	0.4	16.1		mg/L	SM4500-Si D	09/23/99
Sulfate	2.0	247		mg/L	EPA 300.0-A	09/22/99
Total Dissolved Solids	10	1,950		mg/L	EPA 160.1	09/20/99
TOC	0.50	5.90		mg/L	EPA 415.1/2	09/20/99
Total Phosphate-P	0.10	2.89		mg/L	EPA 365.2/4	09/21/99
UV-254	0.009	0.126		asb/cm	SM5910	09/15/99

**Client Information** 

Client Sample ID: ZGP

Project Name: McAllen WWTP #2, City of Project Manager: Angie Fernandez/PHX

Sampled By: R. Villareal
Sampling Date: 09/14/99
Sampling Time: 08:50
Type: Grab

Matrix: Water Basis: As Received Lab Information

Lab Sample ID: 308901

Date Received: 09/15/1999

Report Revision No.: 0
Reported By: JG
Reviewed By:

Analyte	MRL	Sample Result	Qualifier	Units	Analysis Method	Date Analyzed
Aluminum, Al Arsenic, As Barium, Ba Cadmium, Cd Calcium, Ca Chromium, Cr Iron, Fe Lead, Pb Magnesium, Mg Manganese, Mn Mercury, Hg Potassium, K Selenium, Se	100 10.0 25.0 5.0 500 10.0 100 3.0 500 10.0 0.3 2000 7.0	100 10.0 61.6 5.0 86990 10.0 100 3.0 25600 17.0 0.3 29900 7.0	ט ט ט ט ט ט ט ט ט ט ט	Units  µg/L µg/L µg/L µg/L µg/L µg/L µg/L µg/	•	
Silver, Ag Sodium, Na Strontium, Sr Zinc, Zn	10.0 1000 100 20.0	10.0 <b>253000</b> 2000 54.4	U	μg/L μg/L μg/L μg/L	SW6010B SW6010B SW6010B SW6010B	10/14/99 10/14/99 10/14/99 10/14/99

#### Client Information

Client Sample ID: ZGP

Project Name: McAllen WWTP #2, City of Project Manager: Angle Fernandez/PHX

Sampled By: R. Villareal Date Collected: 9/14/99 Time Collected: 8:50 Type: Grab

> Matrix: Water Basis: As Received

#### Lab Information

Lab Sample ID: 308901

Analysis Method: SW 8260B

Units: µg/L

Date Received: 9/15/99 Date Analyzed: 9/27/99

Dilution Factor: 1
Report Revision No.: 0
Reported By: MCB

Reviewed By:

Analyte	CAS#	Reporting Limit	Sample Result	Qualifier
	OAO #		Nesuit	Quanner
Purgeable Volatiles				
Vinyl Chloride	75-01-4	1.0	1.0	U
trans-1,2-Dichloroethene	156-60-5	1.0	1.0	U
cis-1,2-Dichloroethene	156-59-4	1.0	1.0	U
1,1,1-Trichloroethane	71-55-6	1.0	1.0	U
Carbon Tetrachloride	56-23-5	1.0	1.0	U
Trichloroethene	79-01-6	1.0	1.0	U
1,4-Dichlorobenzene	106-46-7	1.0	1.0	U
Dibromofluoromethane	1868-53-7		103%	SS
1,2-Dichloroethane-d4	17068-07-0		94%	SS
Toluene-d8	2037-26-5		115%	SS
p-Bromofluorobenzene	460-00-4		95%	SS

E=Estimated value above instrument calibration range

J=Estimated value below reporting limit

U=Not detected at specified reporting limit

SS=Surrogate standard

**Client Information** 

**Lab Information** 

Client Sample ID: ROP

Lab Sample ID: 308902

Project Name: McAllen WWTP #2, City of

Date Received: 09/15/1999

Project Manager: Angie Fernandez/PHX Sampled By: R. Villareal

Report Revision No.: 0

Sampling Date: 09/14/1999

Analyzed By: MG/MAS/JJB/DHK Reviewed By:

Sampling Time: 8:50 Type: Grab

Matrix: Water Basis: As Received

Analyte	MRL.	Sample Result	Qualifier	Units	Analysis Method	Date Analyzed
General Chemistry						
Alkalinity (as CaCO3)	2.0	16		mg/L	EPA 310.2	09/24/99
Bromide	0.020	0.020	U	mg/L	EPA 300.0-B	09/20/99
Chloride	0.10	15.2		mg/L	EPA 300.0-A	09/22/99
Color (APHA) Apparent		5		color units	EPA 110.2	09/15/99
Fluoride	0.10	0.45		mg/L	EPA 300.0-A	09/22/99
N-Ammonia	0.10	0.10	U	mg/L	EPA 350.3	09/23/99
N-Nitrate/Nitrite	0.01	1.08		mg/L	EPA 353.2	09/20/99
N-Total Kjeldahl	2.0	2.0	U	mg/L	EPA 351.4	09/21/99
Silica-React.	0.4	0.9		mg/L	SM4500-Si D	09/23/99
Sulfate	0.10	5.31		mg/L	EPA 300.0-A	09/22/99
Total Dissolved Solids	10	72		mg/L	EPA 160.1	09/20/99
TOC	0.50	0.52		mg/L	EPA 415.1/2	09/20/99
Total Phosphate-P	0.10	0.10	U	mg/L	EPA 365.2/4	09/21/99

**Client Information** 

Client Sample ID: ROP

Project Name: McAllen WWTP #2, City of

Project Manager: Angie Fernandez/PHX

Sampled By: R. Villareal Sampling Date: 09/14/99 Sampling Time: 08:50

> Type: Grab Matrix: Water Basis: As Received

Lab Information

Lab Sample ID: 308902

Date Received: 09/15/1999

Report Revision No.: 0 Reported By: JG

Reviewed By

Analyte	MRL	Sample Result	Qualifier	Units	Analysis Method	Date Analyzed
-			<del></del>	·		7.1.1.7,2.5 4
Aluminum, Al	100	100	U	μg/L	SW6010B	10/14/99
Arsenic, As	10.0	10.0	U	μg/L	SW6010B	10/14/99
Barium, Ba	25.0	25.0	U	µg/L	SW6010B	10/14/99
Cadmium, Cd	5.0	5.0	U	μg/L	SW6010B	10/14/99
Calcium, Ca	500	833		μg/L	SW6010B	10/14/99
Chromium, Cr	10.0	10.0	U	μg/L	SW6010B	10/14/99
Iron, Fe	100	· 100	U	μg/L	SW6010B	10/14/99
Lead, Pb	3.0	3.0	U	μg/L	SW6010B	10/14/99
Magnesium, Mg	500	500	Ü	μg/L	SW6010B	10/14/99
Manganese, Mn	10.0	10.0	U	μg/L	SW6010B	10/14/99
Mercury, Hg	0.3	0.3	U	μg/L	SW7470A	09/28/99
Potassium, K	2000	2000	U	μg/L	SW6010B	10/14/99
Selenium, Se	7.0	7.0	U	μg/L	SW6010B	10/14/99
Silver, Ag	10.0	10.0	U	μg/L	SW6010B	10/14/99
Sodium, Na	1000	16200	-	μg/L	SW6010B	10/14/99
Strontium, Sr	100	100	U	μg/L	SW6010B	10/14/99
Zinc, Zn	20.0	20.0	Ū	μg/L	SW6010B	10/14/99

Client Information

Lab Information

Client Sample ID: ROP

Lab Sample ID: 308902

Project Name: McAllen WWTP #2, City of Project Manager: Angie Fernandez/PHX

Analysis Method: SW 8260B

Project Manager: Angle Females Sampled By: R. Villareal

Units: µg/L Date Received: 9/15/99

Date Collected: 9/14/99 Time Collected: 8:50 Date Received: 9/15/99
Date Analyzed: 9/27/99
Dilution Factor: 1

Type: Grab Matrix: Water Report Revision No.: 0

Basis: As Received

Reported By: MCB Reviewed By: >474

		Reporting	Sample	
Analyte	CAS#	Limit	Result	Qualifier
Purgeable Volatiles				
Vinyl Chloride	75-01-4	1.0	1.0	U
trans-1,2-Dichloroethene	156-60-5	1.0	1.0	U
cis-1,2-Dichloroethene	156-59-4	1.0	1.0	U
1,1,1-Trichloroethane	71-55-6	1.0	1.0	U
Carbon Tetrachloride	56-23-5	1.0	1.0	U
Trichloroethene	79-01-6	1.0	1.0	U
1,4-Dichlorobenzene	106-46-7	1.0	0.6	J
Dibromofluoromethane	1868-53-7		110%	SS
1,2-Dichloroethane-d4	17068-07-0		102%	SS
Toluene-d8	2037-26-5		115%	SS
p-Bromofluorobenzene	460-00-4		104%	SS

E=Estimated value above instrument calibration range

J=Estimated value below reporting limit

U=Not detected at specified reporting limit

SS=Surrogate standard

CH2IV. ILL Applied Sciences Lab CHAIN OF CUSTODY RECORD AND AGREEMENT TO PERFORM SERVICES

CVD 2300 NW Walnut Boulevard Corvalle, OR 97330-3838 (541) 752-4271 FAX (541) 752-0276

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CH2N-/ILL Applied Sciences Lab CHAIN OF CUSTODY RECORD AND AGREEMENT TO PERFORM SERVICES

CVD 2300 NW Walnut Boulevard Corvallia, OR 97330-3638 (541) 752-4271 FAX (541) 752-0276

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Instructions and Agreement Provisions on Reverse Side

DISTRIBUTION: Original - LAB, Yellow - LAB, Pink - Client



Ms. Anne McKee-Robbins CH2M HILL/CVO 2300 N.W. Walnut Blvd. Corvallis, OR 97330

> Columbia Analytical Services Report City of McAllen D9901720/D1454

> > October 20, 1999

Submitted by:

Karen Sellers

Project Manager/Client Services

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(This report contains a total of 16 pages.)	

### **Organic Data Qualifiers**

- A -- This qualifier indicates that a TIC is a suspected aldol-condensation product
- B -- This flag is used when the analyte is found in the associated blank as well as the sample. This notation indicates possible blank contamination and suggests that the data user evaluate these compounds and their amounts carefully.
- C -- The "C" flag indicates the presence of this compound has been confirmed by the GC/MS analysis.
- This qualifier is used for all the compounds identified in an analysis at a secondary dilution factor. "D" qualifiers are used only for the samples reported at more than one dilution factor.
- E -- This flag indicates that the value reported exceeds the linear calibration range for that compound. Therefore, the sample should be reanalyzed at the appropriate dilution. The "E" qualified amount is an estimated concentration, and the results of the dilution will be reported on a separate Form I.
- I -- The qualifier indicates that the reporting limit to the "I" qualifier has been raised. It is used when the chromatographic interference prohibits detection of a compound at a level below the concentration expressed on the Form I.
- Indicates an estimated value. It is used when the data indicates the presence of a target compound below the reporting limit or the presence of a Tentatively Identified Compound (TIC).
- N -- This qualifier indicates presumptive evidence of a compound. This flag is only used for Tentatively Identified Compounds (TIC), where the identification is based on a mass spectral library research. It is applied to all TIC results. For generic characterization of a TIC, such as chlorinated hydrocarbon, the "N" qualifier is not used.
- P -- This qualifier is used for Pesticide/Aroclor target analytes when there is a greater than 25% difference for detected concentrations between the two columns. The lower of the two values is reported on Form I and flagged with a "P".
- Indicates the compound was analyzed for but not detected. The number adjacent to
  the "U" qualifier indicates the reporting limit for that compound. The reporting limit
  can vary from sample to sample depending on dilution factors or percent moisture
  adjustments when indicated.

# **Organic Sample ID Qualifiers**

The qualifiers that may be appended to the Lab Sample ID and/or the Client Sample ID for organic analysis are defined below:

- DL Diluted reanalysis. Indicates that the results were determined in an analysis of a secondary dilution of a sample or extract. A digit to indicate multiple dilutions of the sample or extract may follow the "DL" suffix. The results of more than one diluted reanalysis may be reported.
- MS -- Matrix spike (may be followed by a digit to indicate multiple matrix spikes within a sample set).
- **MSD** -- Matrix spike duplicate (may be followed by a digit to indicate multiple matrix spikes within a sample set).
- R -- Reanalysis. The extract was reanalyzed without re-extraction. The "R" is not used if the sample was also re-extracted. May be followed by a digit to indicate multiple reanalysis of the sample at the same dilution.
- **RE** -- Re-extraction analysis. The sample was re-extracted and reanalyzed. May be followed by a digit to indicate multiple re-extracted analysis of the same sample at the same dilution.

### Sample ID Cross-reference Table

CAS Lab Sample	Client Co ID Sample ID Da	llect te Sample Matri	K Additional Description	
FS = Field				
D1454001 D1454002		/23/99 Water /23/99 Water	ZGPERMEATE ROPERMEATE	

The above lab sample ID's and cross reference information apply to samples as received by the laboratory. Modifiers to the lab sample ID may be added for internal tracking purposes. Any modified sample ID will be reflected in the appropriate case narrative only.

GC ORGANOCHLORINE PESTICIDES

# CASE NARRATIVE GC ORGANOCHLORINE PESTICIDES

CAS Lab Reference No./SDG.: D1454

Project: <u>City of McAllen</u>

#### I. RECEIPT

No exceptions were encountered unless a Sample Receipt Exception Report is attached to the Chain-of-Custody included with this data package.

#### II. HOLDING TIMES

- A. Sample Preparation: All holding times were met.
- B. Sample Analysis: All holding times were met.

#### III. METHOD

Preparation: SW-846 3520C

Cleanup: NA

Analysis: SW-846 8081A

#### IV. PREPARATION

Sample volume may vary based on the amount of sample received per container.

#### V. ANALYSIS

- A. Calibration. All acceptance criteria were met.
  - 1. Retention Time Windows: All analytes were within criteria.
  - 2. Degradation: All acceptance criteria were met.
- B. Blanks: All acceptance criteria were met.
- C. Surrogates: All acceptance criteria were met.
- D. Internal Standards: All acceptance criteria were met.
- E. Spikes: All acceptance criteria were met.
- F. Samples: Sample analysis proceeded normally.

I certify that this data package is in compliance with the terms and conditions agreed to by the client and Columbia Analytical Services, both technically and for completeness, except for the conditions noted above. Release of the data contained in this hardcopy data package has been authorized by the Laboratory Manager or designated person, as verified by the following signature.

SIGNED: J. J. Reviewer: Reviewer: Jerry Watega Scientist, GC Organics

Phone: (530) 244-5227

Fax: (530) 244-4109

CLIENT ID.

ZGPERMEATE

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Case No.: D1454 SDG No.: D1454

Lab Sample ID: D1454001

Matrix: WATER Level: LOW

Lab File ID: B1001024

Sample Wt/Vol: 1.050 L

Date Received: 09/24/99

Extract Vol:

10 ML

Date Extracted: 09/27/99

Date Analyzed: 10/02/99

Column: DB5

Extraction Type: Continuous

Dilution Factor: 1.0

CAS NO.	COMPOUND	Units: ug/L	MDL	RL	RESULT	Q
72-20-8	gamma-BHC (L Endrin Methoxychlor Toxaphene		0.0032 0.0021 0.017 0.23	0.020 0.020 0.040 0.50	0.011 0.0093 0.040 0.50	J U U

CLIENT ID.

_ Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

ROPERMEATE

Case No.: D1454

SDG No.: D1454

Matrix: WATER

Level:

Lab Sample ID:

D1454002

LOW

Lab File ID:

B1001025

Sample Wt/Vol: 1.050 L

Date Received:

09/24/99

Extract Vol:

10 ML

Date Extracted: 09/27/99

Column: DB5

Date Analyzed:

10/02/99

Extraction Type: Continuous

Dilution Factor: 1.0

CAS NO.	COMPOUND	Units: ug/L	MDL	RL	RESULT	Q
72-20-8	gamma-BHC (L Endrin Methoxychlor Toxaphene		0.0032 0.0021 0.017 0.23	0.020 0.020 0.040 0.50	0.020 0.020 0.040 0.50	U U U

LOW

CLIENT ID.

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

10 ML

PWB10927

Case No.: D1454 SDG No.: D1454

Lab Sample ID:

PWB10927

Matrix: WATER Level:

Lab File ID:

B1001023

Sample Wt/Vol: 1.000 L

Date Received:

Date Extracted: 09/27/99

Column: DB5

Extract Vol:

Date Analyzed: 10/02/99

Extraction Type: Continuous

Dilution Factor: 1.0

CAS NO.	COMPOUND	Units: ug/L	MDL	RL	RESULT	Q
72-20-8	gamma-BHC (L Endrin Methoxychlor Toxaphene		0.0032 0.0021 0.017 0.23	0.020 0.020 0.040 0.50	0.020 0.020 0.040 0.50	น น บ

# WATER SEMIVOLATILE SURROGATE RECOVERY

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

SDG No.: D1454 Case No.: D1454

LAB ID					I m/	<del></del> 1
PWB10927LCS	LAB ID	CLIENT ID.	1 _1	ŀ	JO	TI
29	01 PWB10927LCS 02 PWB10927LCS 03 PWB10927 04 D1454001 05 D1454002 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27	PWB10927LCS PWB10927LCS PWB10927LCS PWB10927 ZGPERMEATE	93 92 96 112	====== 74 80 89 73		0 0 0
	29		_	_\		

QC LIMITS

= Tetrachloro-m-xylene
= Decachlorobiphenyl (45-125) (34-133)

# Column to be used to flag recovery values
* Values outside of contract required QC limits
D Surrogates diluted out

# WATER PESTICIDE LAB CONTROL SAMPLE

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

SDG No.: D1454 Column: DB5 Case No.: D1454

Sample No.: PWB10927 LCS -

COMPOUND  ===================================	SPIKE ADDED (ug/L) ======= 0.5000 0.5000 0.5000	SAMPLE CONCENTRATION (ug/L) ====================================	LCS CONCENTRATION (ug/L) ====================================	REC #	QC. LIMITS REC. ===== 73-125 43-134 73-142
-----------------------------------------------	-------------------------------------------------------------------	------------------------------------------------------------------	------------------------------------------------------------------------	-------	--------------------------------------------------------------

- # Column to be used to flag recovery and RPD values with an asterisk
- * Values outside of QC limits

RPD: 0 out of 0 outside limits Spike Recovery: 0 out of 3 outside limits

=	
COMMENTS:	

#### 3E WATER PESTICIDE LAB CONTROL SAMPLE

Lab Name: COLUMBIA ANALYTICAL SERVICES - REDDING

Case No.: D1454

SDG No.: D1454

Column: DB5

LCS - Sample No.: PWB10927

COMPOUND	SPIKE	SAMPLE	LCS	LCS	QC.
	ADDED	CONCENTRATION	CONCENTRATION	%	LIMITS
	(ug/L)	(ug/L)	(ug/L)	REC #	REC.
Toxaphene	5.000	0.0000	4.895	98	41-126

- # Column to be used to flag recovery and RPD values with an asterisk
- * Values outside of QC limits

RPD: 0 out of 0 outside limits Spike Recovery: 0 out of 1 outside limits

COMMENTS:	

FORM III

SW846

# CHAIN OF CUSTODY DOCUMENTATION

Col·mbia
A ytical
Services *** 5000 Catamillar Boa

# CHAIN OF CUTODY

30808

00 # 000

5090 Caterpillar Road • Redding, CA 96003 • Phone: (530) 244-5227 • FAX: (530) 244-4109

z O Custody Seals (V) N 00 Lab ID 1 LIMS Verification 1 Custody Review THIS AREA FOR LAB USE ONLY INVOICE INFORMATION Page ď 90 Other 9 9 Date/Time Alternate Description Cooler Temperature QC Level (1) 2 Date/Time 75710 P.O. Bill To Shipping # 812900725117 Enrique 16.62 (Please sign and print name) (Please sign and print name) Preservative (to be filled out by customer) Requested Analytical Method # Pate/Time Shipped Via Fed-Ex Other Relinquished By 4054 9/23/99 9/23/99840 9/249 3:30 7 Date/Time Dispose Return 8 PB S Sample Disposal: ð Ø Kathy Ackinley Sile ID Samp Posie VillARLER Edmle la H Semples were collected on (Please sign and print name) Enrique Perez CLIENT SAMPLE ID (9 CHARACTERS) mea Purchase Order # Report Copy to: City of mallen wwrp#2 MAHLA RUSE PIPT Study ۵. 0 5 CATY OF MCA 10M Project Manager or Contact & Phone # 58-7 9 Kally Mekinley or35 Matrix Requested Completion Bate: Sampled By and Tille Special Instructions: Time Sampling Project Name 1/13/95 9/345 Date Project # <del>0010</del>

char an Davarea Sida

Distributions - Original - Lab, Yellow - Lab, Pink - Client

1 4 - ... Droughous on Bourses Side



5090 Caterpillar Road

Redding Ca., 96003

Phone: 530-244-5227

Fax: 530-244-4109

#### SAMPLE RECEIPT EXCEPTION REPORT

	SAMPLE NEOL				
Samp	le Batch Number: D 1454	Client/Project:	City of	McAllen	
		Comments:			
	No custody seal as required by project.	<del>  \                                   </del>	me sample Time take	d Record	led on
••••	2. Analysis, description, date/time of collection not provided.	labels.			
	Samples broken or leaking on receipt.				
	Temperature of samples inappropriate for analysis requested.				
	Container inappropriate for analysis requested.	<u> </u>			
	6. Inadequate sample volume.				
	7. Preservation inappropriate for analysis requested.				
	Samples received out of holding time for analysis requested.				
	Descrepencies between COC form and container labels.				
	10. Other				
	rando. Pandos	2 25 3	and Annual and the second		
Corre	octive Actions Taken: NONE Regured	W	9/28/99		

# Sound Analytical Services, Inc.

ANALYTICAL & ENVIRONMENTAL CHEMISTS 4813 Pacific Hwy East • Tacoma, WA 98424 (253) 922-2310 • FAX (253) 922-5047

e-mail; saincl@uswest,net



#### TRANSMITTAL MEMORANDUM

DATE: September 23, 1999

TO: Kathy McKinley City of McAllen 4100 Idela McAllen, TX 78503

PROJECT: McAllen Re-Use Pilot Study

**REPORT NUMBER: 84099** 

Enclosed are the test results for two samples received at Sound Analytical Services on September 15, 1999.

The report consists of this transmittal memo, analytical results, quality control reports, a copy of the chainof-custody, a list of data qualifiers and analytical narrative when applicable, and a copy of any requested raw data.

Should there be any questions regarding this report, please contact me at (253) 922-2310.

Sincerely,

Daria Powell
Project Manager

Client Name

City of McAllen

Client ID:

ZENOGEM PERMEATE

Lab ID:

84099-01

Date Received: Date Prepared:

9/15/99

Date Analyzed:

9/21/99

% Solids

9/22/99

**Dilution Factor** 

10

#### Chlorinated Herbicides by USEPA Method 8151GC/MS Modified

			Recov	ery Limits
Surrogate	% Recovery	Flags	Low	High
2,4-Dichlorophenylacetic acid	86.4		48	124

Result

**Analyte** 2,4-D

(ug/L)

PQL

MDL

Flags

Silvex (2,4,5-TP)

ND ND 0.098 0.096 0.084 0.077

Client Name
Client ID:
Lab ID:
Date Received:
Date Prepared:
Date Analyzed:
% Solids

**Dilution Factor** 

City of McAllen RO PERMEATE 84099-02 9/15/99 9/22/99

10

## Chlorinated Herbicides by USEPA Method 8151GC/MS Modified

			Recov	ery Limits
Surrogate 2,4-Dichlorophenylacetic acid	% Recovery 73.6	Flags	Low 48	High 124

Analyte	Result (ug/L) ND	<b>PQL</b> 0.1	MDL Flags 0.087
2,4-D Silvex (2,4,5-TP)	ND	0.1	0.081

Lab ID:

Method Blank - HB885

Date Received:

9/21/99

Date Prepared: Date Analyzed:

9/22/99

% Solids

**Dilution Factor** 

10

#### Chlorinated Herbicides by USEPA Method 8151GC/MS Modified

D			Recov	ery Limits
Surrogate 2,4-Dichlorophenylacetic acid	% Recovery 67.8	Flags	Low 48	High 124

	Result		
Analyte	(u <b>g</b> /L)	PQL	MDL Flags
2,4-D	ND	0.1	0.087
Silvex (2,4,5-TP)	ND	0.1	0.081

#### Blank Spike/Blank Spike Duplicate Report

Lab ID: Date Prepared:

Date Prepared: Date Analyzed: QC Batch ID: HB885

9/21/99

9/22/99

HB885

#### Chlorinated Herbicides by USEPA Method 8151GC/MS Modified

	Blank	Spike	BS		BSD			
	Result	Amount	Result	88	Result	8SD		
Compound Name	(ug/L)	(ug/L)	(ug/L)	% Rec.	(ug/L)	% Rec.	RPD	Flag
2,4-D	0	5	4.73	94.6	4.48	89.6	-5.4	
Silvex (2,4,5-TP)	0	5	5.44	109	5.17	103	-5.7	

ANALYTICAL & ENVIRONMENTAL CHEMISTS
4813 PACIFIC HIGHWAY EAST, TACOMA, WASHINGTON 98424 - TELEPHONE: (253) 922-2310 - FAX; (253) 922-5047

#### DATA QUALIFIERS AND ABBREVIATIONS

- B1: This analyte was detected in the associated method blank. The analyte concentration was determined not to be significantly higher than the associated method blank (less than ten times the concentration reported in the blank).
- B2: This analyte was detected in the associated method blank. The analyte concentration in the sample was determined to be significantly higher than the method blank (greater than ten times the concentration reported in the blank).
- C1: Second column confirmation was performed. The relative percent difference value (RPD) between the results on the two columns was evaluated and determined to be ≤ 40%.
- C2: Second column confirmation was performed. The RPD between the results on the two columns was evaluated and determined to be > 40%. The higher result was reported unless anomalies were noted.
- M: GC/MS confirmation was performed. The result derived from the original analysis was reported.
- D: The reported result for this analyte was calculated based on a secondary dilution factor.
- E: The concentration of this analyte exceeded the instrument calibration range and should be considered an estimated quantity.
- J: The analyte was analyzed for and positively identified, but the associated numerical value is an estimated quantity.
- MCL: Maximum Contaminant Level
  - MDL: Method Detection Limit
  - N: See analytical narrative.
  - ND: Not Detected
  - POL: Practical Quantitation Limit
  - X1: Contaminant does not appear to be "typical" product. Elution pattern suggests it may be ______.
  - X2: Contaminant does not appear to be "typical" product.
  - X3: Identification and quantitation of the analyte or surrogate was complicated by matrix interference.
  - X4: RPD for duplicates was outside advisory QC limits. The sample was re-analyzed with similar results. The sample matrix may be nonhomogeneous.
  - X4a: RPD for duplicates outside advisory QC limits due to analyte concentration near the method practical quantitation limit/detection limit.
  - X5: Matrix spike recovery was not determined due to the required dilution.
  - X6: Recovery and/or RPD values for matrix spike(/matrix spike duplicate) outside advisory QC limits. Sample was reanalyzed with similar results.
  - X7: Recovery and/or RPD values for matrix spike(/matrix spike duplicate) outside advisory QC limits. Matrix interference may be indicated based on acceptable blank spike recovery and/or RPD.
  - X7a: Recovery and/or RPD values for this spiked analyte outside advisory QC limits due to high concentration of the analyte in the original sample.
  - X8: Surrogate recovery was not determined due to the required dilution.
  - X9: Surrogate recovery outside advisory QC limits due to matrix interference.

SAS-QAM REV 11 3/99

	TOTAL .
700	

#### Sound Analytical Services, Inc.

ANALYTICAL & ENVIRONMENTAL CHEMISITS 4813 Pacific Hwy East + Tacoma, WA 98424 (253) 922-2310 + FAX (253) 922-5047 e mail, saine bir uswest net

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TURNAROUND REQUEST	(business days)
Standard (10 days)	
RUSH: 24 hrs 48 hrs	5 day

CHAIN OF	CUSTODY/REQUEST FOR LABORATORY	<b>ANALYSIS</b>
	A	

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Project	Client: City OF McAlleys Project Name:			oiect Name:							r						
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Contac	t Kathy McKipley - AD	ilical S	1 12 12146 12			۲ >	િં રૂ	1					1				
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Use	Sample ID	Date	Time	Матліх	<b>™</b>	2,4-D; 2,45-TP	2,4-0,										
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7/	Ro Permeate	9/14	03:50	Liquid	1		V										
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	Signature	Printed Name	Firm	Time/Date	Special Instructions	
Relinquished By:	ta- Him	Janet Hinojosa	City of Not llen	08:55		
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#### **ENERGY LABORATORIES, INC.**

SHIPPING: 2393 SALT CREEK HIGHWAY • CASPER, WY 82601 MAILING: P.O. BOX 3258 • CASPER, WY 82602

E-mail: energy@trib.com • FAX: (307) 234-1639 • PHONE: (307) 235-0515 • TOLL FREE: (888) 235-0515

#### **CASE NARRATIVE**

DATE:

October 5, 1999

TO:

Kathy McKinley

FROM:

Sheryl Garling

RE:

CH2MHill Water Samples

SAMPLE NUMBERS: 32965 001 through 002

Samples Zenogem Permeate and RO Permeate were received on September 15, 1999. Samples were shipped using Energy Laboratories, Inc. contract service with UPS. The overnight option was used for shipping the samples to the laboratory. Samples were in good condition and properly preserved.

No analytical problems were indicated for this sample delivery group.

The methods used are methods published by US EPA for drinking water analyses. The methods used are as follows:

Radium 226 - EPA Method 903.0 (alpha emitting),

Radium 228 - EPA Method 904.0, and

Gross Alpha -EPA Method 900.1 (gross alpha minus uranium and

radon).

The standard detection limits for these methods are 0.2 pCi/L, 1.0 pCi/L, and 1.0 pCi/L, respectively. The initial e-mail response incorrectly identified methods and detection limits.

If additional information is required, please advise.



#### **ENERGY LABORATORIES, INC.**

SHIPPING: 2393 SALT CREEK HIGHWAY • CASPER, WY 82601 MAILING: P.O. BOX 3258 • CASPER, WY 82602

MAILING: P.O. BOX 3258 • CASPER, WY 82602 E-mail: energy@trib.com • FAX: (307) 234-1639 PHONE: (307) 235-0515 • TOLL FREE: (888) 235-0515

#### LABORATORY ANALYSIS REPORT - CH2M HILL

Project:
Sample ID:
Laboratory ID:
Sample Matrix:
Sample Date/Time:
Date Received:
Report Date:

Pilot Study
RO Permeate
32965-002
er
/0850
-99
4, 1999
֡

Radiometric		Method	Reporting Limit	Units	R	esults
Radium-226	²²⁶ Ra	903.0	0.2	pCi/L	< 0.2	< 0.2
Radium Precision ±					-	
			- <del>1</del>			
Radium-228	²²⁸ Ra	904.0	1.0	pCi/L	<1.0	<1.0
Radium Precision ±					-	-
		1	<del></del>			
ross Alpha	Gross a	900.1	1.0	pCi/L	<1.0	<1.0
G. Alpha Precision ±		7/14			-	



#### RADIOCHEMICAL QUALITY ASSURANCE REPORT - CH2M HILL

Laboratory ID Range: Sample Matrix: Sample Date / Time: Date Received:

Report Date:

32965-001-002 Water 09-14-99/0850 09-15-99 October 4, 1999

	Method	Relative Percent <u>Difference</u> ¹	Spike Recovery (Percent) ²	LCS Recovery (Percent)	Method Blank (pCi/L)	Date <u>Analyzed</u>	Analyst
Laboratory #:		32996-002	32880-022		GA-40		
Gross Alpha:	900.1	0.0	104	106	< 1.0	10-01-99	RS
Laboratory #:		32880-001	32880-022		RA-206		
Radium-226:	903.0	0.0	100	101	< 0.2	09-29-99	RS
boratory #:		32880-010	32880-020		228-235		
adium-228:	904.0	0.0	79	<b>7</b> 7	< 1.0	10-04-99	LMH

Report Approved By DI Raida

Reviewed By:

lmh r:\Reports\Clients.99\CH2M_Hill\Water\rc32965-001.xls

Log In No. 99-32965

⁽¹⁾ These values are an assessment of analytical precision. The acceptance range is 0-20% for sample results above 10 times the reporting limit. This range is not applicable to samples with results below 10 times the reporting limit.

⁽²⁾ These values are an assessment of analytical accuracy. They are a percent recovery of the spike addition. ELI performs a matrix spike on 10 percent of all samples for each analytical method.

66-9-01

Received at Laboratory

Time

16001

Date [7/5/95]

ENERGY LABORATORIES	• Billings • Casper • Gillette • Rapld City	ENERGY LABORATORIES, INC CHA Mail Only: PO Box 3258 • Casper UPS/FedEx Deliveries: 2393 Salt Greek Highway	IN OF C	RECORD 3258	~
For Sample Tracking F	Purposes, Ple	le al		10078	fax 307-234-1639
Project Name / Location	tion / Purch	Purchase Order # / Bid #		UF FUKM FUK EXAM	(SEE DACA OF FORM FOR EXAMPLES AND INSTRUCTIONS)
7	<u> </u>			Type of Analyses Requested	Special Requests
- 1 × 1	-5/		o n	naisanhau sas finin	
Name / Phone # / I	/ Fax# 541-758-0235	35/54-74.	onint V S To noin Johan		Ī
CA2M H1/1 / #	3744		86101 M		
		Send Invoice to: Kathy Mckinley.	5500 0,15 1 0,15 1		•
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# Instructions:

3. Relinquished by: (signature)

Date N/A

Time

Received by: (signature)

4. Relinquished by: (signature)
Sheryl A. Garling

Date 5-28-95

Time 14:00y

Received at Laboratory by:
Roger A. Garling

1.Sampler: (signature)

Date 5-23-95

Time 12:05p

Received by: (signature) Harry Truckers

2.Relinquished by: (signature) Harry Truckers

Date **5-28-95** 

Time **13:15p** 

Received by: (signature) Sheryl A. Garling

Jeff Jones

- 3 E A completed Chain-of-Custody must be submitted with all samples Special Requests area can include (but not limited to) the following:
- Turnaround status, Rush status, Due Date, etc.
- Special mailing instructions: send copy of Report and/or Invoice to a second party
   send copy of Report to a Government Agencies (EPA, etc.)
- Public Water System (PWS) Number
- Do you want samples returned to you or disposed of?

# United States Department of the Interior Bureau of Reclamation Water Treatment Engineering and Research Group Reclamation Service Center



P.O. Box 25007

Building 56, Denver Federal Center, Attn: D-8230

Denver, Colorado 80225-0007



#### **FAXOGRAM**

Date:
To: <u>Sim Lozier</u> / Angre Fornandez
Company: CH2MH1)
Fax Number:
From: Michell USBR
Fax Number: (303) 445-6329 Telephone Number: (303) 445-2245
Number of pages (including cover sheet)
Message: Copy of the Cleaning Solution
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# DATA TRANSMITTAL FAX COVER

Environmental Research Chemistry Laboratory, D-8240
US Bureau of Reclamation - Technical Service Center
PO Box 25007, Denver CO 80225-0007
Margaret Lake, Laboratory Manager, 303-445-2181
Douglas Craft, QC Officer, 303-445-2182
FAX 303-445-6326

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TO: VIIICA CITY	FAX NUMBER:
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formal review and requested QC reports will follow. The the laboratory QC Officer (or designate) and meets TSC requirements unless qualified in the section below. Plea	se review your data and let us know if there are
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#### SAMPLE LOG-IN SUMMARY

# USBR ENVIRONMENTAL RESEARCH CHEMISTRY LABORATORY

Denver, Colorado

Job Control No: McAllen-99

Project Name: McAllen W-R

**Description:** Cleaning Solution

Client Reps: Barb Frost

Client Name: M. Chapman-Wilber

Login Date: 6/3/99 Sample Sampled Due Analysis COC# Client Chem Type Date Date Lab# SampleID 6/10/99 6/1/99 cleaning soin. K5313-1 McAllen 200.7_ICP ICP Metals unfiltered/unacidified, SO4/Ca/Fe/Al/Ba/Si Ion chromatography of anions 300.0_ANIONS total phosphorous by Perstorp autoanalyzer 365.1,365.2_totP

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SAMPLE SUBMITTAL REQUEST FORM		SHEET 1 OF	
Environmental Research Chemistry Laboratory, D	)-8240		
U.S. Bureau of Reclamation - Technical Service C Building 56, Room 2340, Denver Federal Center,	enier	ver, CO 80225-007	
Today's Date: 4/2/99	Report Data By: 🚄	110/99	
Margaret Lake, Laboratory Manager, 303-443-216 Today's Date: 4/2/99 Samples Submitted By: Michelle Choman William Address: 28230	whelephone: \\\ \\ \\ \\ \\ \\ \\ \ \ \ \ \ \ \ \	64	
Mailing Address: D-8>30	FAX/LAN:		
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PO Box 25007, Building Denver CO 80225-0007	PO Box 25007, Building 56, Room 2300, Denver Federal Center Denver CO 80225-0007	al Center	
Laboratory	SiO2	441	0
Number	Sample (D mg/L		
K5313-1	McAlten 2.53	11.9	
	Detection limit: 0.02	0.005	9
	Date Analyzed: 6/9/99	66/1/9	
	Analyst: bf	Ę	
·	EPA Method: 200.7	365.1	

Chem Lab#: K5313-1

Station ID: McAllen

MoreID:

Sampled Date: 6/1/99

Received Date: 6/2/99

Login Date: 6/3/99

Chain-Of-Custody:

Sample Type: cleaning soln.

Note: unfiltered/unacidified,

SO4/Ca/Fe/Al/Ba/Si

Analy	te Method_Re	ef Result	Units Qu	alifier MDL	Date Extract	Date Analyzed	Dilution
A	200.7 EPA	5530	µg/L	30		6/10/99	1
Ba	200.7 EPA	449	μg/L	4		6/10/99	1
Ca	200.7 EPA	26	mg/L	0.03		6/10/99	1

U: Not Detected at Listed MDL.

J: Estimated.

MDL: Method Detection Limit.

Chem Lab#: K5313-1

Station ID: McAllen

MoreID:

Received Date: 6/2/99

Sampled Date: 6/1/99

Login Date: 6/3/99

Chain-Of-Custody:

Sample Type: cleaning soln.

Note: unfiltered/unacidified,

SO4/Ca/Fe/Al/Ba/Si

Analyte	Method_Ref	Result	Units Qu	alifier MDL	Date Extract	Date Analyzed Dil	ution
Fe	200.7 EPA	722	µg/L	4		6/10/99	1

U: Not Detected at Listed MDL.

J: Estimated.

MDL: Method Detection Limit.

Table F-1
ZenoGem Permeate Scale Potential

Parameter	Units	6/9/99	6/11/99	6/14/99	6/16/99	6/21/99	6/23/99	Average
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Alkalinity	mg/L as CaCO ₃	150		190		158		166
Total Phosphorus	mg/L as P			2.72		2.26		2.49
Sulfate	mg/L	250	214	214				226
Modele				100				
Aluminum ^a	mg/L	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Barium	mg/L	0.06	0.06	0.06	0.05	0.05	0.06	0.06
Calcium Hardness	mg/L	360		348		360		356
lron ^a	mg/L	0.1	0.1	0.1	0.1	0.1	0.1	0.1

^aNot dectected at specified reporting limits for each sampling event.

#### PURPOSE AND LOCATION OF AUTOPSY

Purpose of Autopsy: McAllen, TX Wastewater Reclamation Project: Determination of scaling in end element.

Date and Place: October 29, 1999, USBR WTER Pilot Plant Lab, Denver, CO.

Date of This Report: 12/30/99

#### Names of Observers:

Frank Leitz Bill Boegli Michelle Chapman Wilbert Kim Linton Qian Zhang

ELEMENT IDENTIFICATION	V
Manufacturer:	Hydranautics
Element Location:	Housing #6, 2nd element
Serial Number:	X03529
Element Dimensions:	2.5 in. x 40 in.
Number of Leaves:	2
Size of Leaves:	92.1 cm x 71.1cm Total Area 84.5 cm x 63.5cm Active Area per side (2.1 m² per element or 22.1 ft²)

#### OPERATING HISTORY

The RO system was operated for six months on site at the McAllen,TX South Waste Water Treatment Plant. Screened de-gritted sewage was first treated in a Zenogem bioreactor/microfiltration system, then chlorine and ammonia was added and the Zenogem effluent was forwarded to the RO system. The RO element array was a 2x2x1x1 and had 3 elements per vessel for a total of 18 elements in the system. RO recovery rates were set from 50% to 80% of 15.2 L/min feed flow.

Sulfuric acid and antiscalent were added to prevent scaling. However, due to changes in the chemical character of the Zenogem effluent, or excessive gas formation in the acid tank which caused the acid feed pump to loose it's prime, the pH was not controlled well at all times. This resulted in a loss of permeate flow from the last vessel.

Also, traditional constituents used in an RO projection do not include phosphorous compounds. The researchers involved in this project began to suspect that phosphorous salts were the cause of excessive scale problems due to the nature of waste water treatment. Attempts at adjusting the pH to control phosphorous salts included running a projection with non-RO software to determine the potential for phosphate scaling. A range of pH settings and two control points for pH were tested in an attempt to control the scaling problems. The pH ranges tested were from 5.5 to 7 on the feed, and 5.5 to 6 on the concentrate. The lower pH control ranges were in response to this non-RO projected information.

Scaling also caused operators to clean the system approximately 4 times with a low pH solution at a pH of about 3. A high pH solution was not used to clean the membranes as there was no indication of biofouling and the system's performance was recovered using the acid cleanings.

#### DESCRIPTION OF EVENTS LEADING TO AUTOPSY

This element was subjected to one needle hole to help evaluate the integrity test methods.

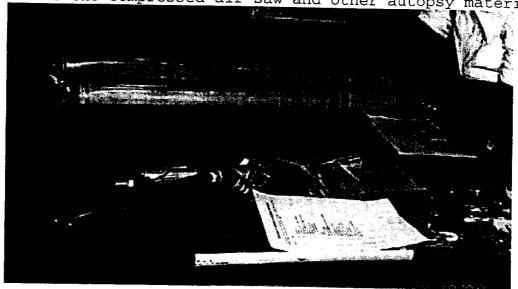
Subject element was the second to last element of the last vessel (vessel #6). Permeate recovery flow from the last vessel varied from 1.4 L/min to 0.01 L/min. The last fouling was a result of turning off the acid feed pump for approximately 8 hours.

This autopsy was primarily done to determine how deep the hole in the membrane leaves had penetrated, and to determine the general nature of the scaling composition.

## NARRATIVE DESCRIPTION OF AUTOPSY PROCEDURE

Fiberglass wrapping was cut open and peeled or pried off.

Picture shows the compressed air saw and other autopsy materials.



Anti-telescoping devices were removed and tape wrap was unwound.

Unwound membrane and separated spacer material from first leaf.

Measured leaf dimensions and active area.

A squeegee was used to wipe both sides of one leaf. DI water was used to liquefy the fouling substance

Applied congo red dye to the first leaf.

Samples were cut from the feed and reject ends of the second leaf for SEM analysis. Feed side is Sample 2 and the reject side is Sample 3.

#### **OBSERVATIONS**

There was a crack, ~2 cm long, ~10 cm from the feed end.

Sample #1 is the piece of fiberglass with the crack.

The brine seal was in good condition; it was saved as Sample #2

There was extra glue, possibly rubber cement, under the tape at the ends of the element-- probably to keep the end caps tight. Sample #3 is a bit of the glue peeled away from the end.

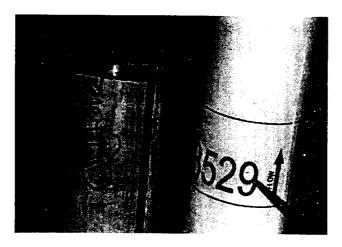
There was no evidence of the crack extending into the membrane material.

Picture was taken of the feed end of the rolled element.





Hole location was marked on the outer fiberglass cover from where a needle had been poked into the membrane. Picture taken of hole location in element. The hole location is shown in the fiberglass wrap and in the number 9 of the tape wrap.



At least 2 leaves had holes which were identified using a

magnifying glass (10x). The hole on the on the outer leaf was a cresent shape which is the same shape that would be formed by the tip of the hypodermic needle used to inflict the damage. The second hole protruded out, which would also be consistent with the direction the needle would penetrate.

The glue line appeared to have attracted more fouling material than the active area of the leaf. This may be due to the excessive use of glue.

Dye test on the second leaf with congo red dye took evenly over the membrane surface. This could be damage from low pH. There was no evidence of the hole extending beyond the tape wrap.

Test and Test Objective: No additional tests were done on this element.

## DISCUSSION AND CONCLUSIONS

This element had at least two holes from the needle puncture which penetrated the active area of the membrane. The visible damage was configured in such a way that it can be attributed to the needle. One of the holes was cresent shaped and poked inward. The hole on the opposite leaf protruded outward.

## PURPOSE AND LOCATION OF AUTOPSY

Purpose of Autopsy: McAllen, TX Wastewater Reclamation Project: Determination of scaling in end element.

Date and Place: October 29, 1999, USBR WTER Pilot Plant Lab, Denver, CO.

Date of This Report: 11/21/1999

## Names of Observers:

Frank Leitz Michelle Chapman Wilbert Kim Linton

ELEMENT IDENTIFICATION	ELEMENT IDENTIFICATION					
Manufacturer:	Hydranautics					
Element Type:	LFC1X 2540					
Element Location:	Housing #3, 2nd element					
Serial Number:	x03531					
Element Dimensions:	2.5 in. x 40 in.					
Number of Leaves:	2					
Size of Leaves:	91.8cm x 72.4cm Total Area 83.8cm x 62.8cm Active Area of one side (2.1 m² per element or 22.6 ft²)					

## OPERATING HISTORY

The RO system was operated for six months on site at the McAllen, TX South Waste Water Treatment Plant. Screened de-gritted sewage was first treated in a Zenogem bioreactor/microfiltration system, then chlorine and ammonia was added and the Zenogem effluent was forwarded to the RO system. The RO element array was a 2x2x1x1 and had 3 elements per vessel for a total of 18 elements in the system. RO recovery rates were set from 50% to 80% of 15.2 L/min feed flow.

Sulfuric acid and antiscalent were added to prevent scaling. However, due to changes in the chemical character of the Zenogem effluent, or excessive gas formation in the acid tank which caused the acid feed pump to loose it's prime, the pH was not controlled well at all times. This resulted in a loss of permeate flow from the last vessel.

Also, traditional constituents used in an RO projection do not include phosphorous compounds. The researchers involved in this project began to suspect that phosphorous salts were the cause of excessive scale problems due to the nature of waste water treatment. Attempts at adjusting the pH to control phosphorous salts included running a projection with non-RO software to determine the potential for phosphate scaling. A range of pH settings and two control points for pH were tested in an attempt to control the scaling problems. The pH ranges tested were from 5.5 to 7 on the feed, and 5.5 to 6 on the concentrate. The lower pH control ranges were in response to this non-RO projected information.

Scaling also caused operators to clean the system approximately 4 times with a low pH solution at a pH of about 3. A high pH solution was not used to clean the membranes as there was no indication of biofouling and the system's performance was recovered using the acid cleanings.

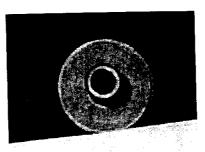
## DESCRIPTION OF EVENTS LEADING TO AUTOPSY

Subject element was the second element in housing #3, one of two vessels that received flow first. Permeate recovery flow from this vessel varied from 2.8 L/min to 2.3 L/min. This element was subject to two holes punctured with a hypodermic needle. The fouling on the membrane was a result of turning off the acid feed pump for approximately 8 hours.

This autopsy was primarily done to determine the size and extent of damage resulting from the hypodermic needle. In addition, the general nature of the membrane and scaling composition is of interest.

## NARRATIVE DESCRIPTION OF AUTOPSY PROCEDURE

Fiberglass wrapping was cut open and peeled or pried off. Sample #1 is the fiberglass with the 2 holes marked.
Anti-telescoping devices were removed.
Photographed the feed end of the element.



## X03531

Tape wrap was unwound. Measured the total area and active area of one side of one leaf. Applied congo red dye to the first leaf. Photograph of the dye stained membrane.



Sample #2 is a cutting from the leaf with the 2 holes in the glue line.

## **OBSERVATIONS**

There were no cracks in this element fiberglass casing.

Two needle holes were visible in the fiberglass and tape wrap at a distance of 17.75 cm ( $\sim$ 7 in) from the reject end.

The membrane was wound backwards - which probably makes no difference in performance, but does make autopsy confusing.

There were little black flecks on the membrane surface.

Glue lines were all solid.

Dye test showed no pin hole damage. There were only 2 holes in the glue line, neither of which extended through the hard, thick glue.

Test and Test Objective: Chemical analysis of fouling material on leaf 1
Organization Performing Test: USBR Chemistry Lab
Date: Submitted November 1, 1999

## Observations from Test:

The analysis methods used for TDS, TSS, SO4, and Cl do not used acid to digest the samples. The method used for SO4 and Cl was EPA method 300.0A, ion chromatography. The other metals, except for phosphorous were digested with nitric acid and analyzed using the ICP (inductively coupled plasma) EPA method 30.15. Phosphorous is also digested, but under EPA method 365.1.

The results from both housing #3 and #6 are shown for comparison.

Analytes	concentration (mg/L)	Ox. State * Conc. / At.	Equivalent Cations => Ox. State * Conc. / At. Wt.	Housing #6 concentration (mg/L)	Anions => Ox. State * Conc. / At. Wt.	Cations => Ox. State * Conc. / At. Wt.
Total P	36.69	-3.6		135.2	-13.1	
Al	2.52		0.3		10.1	1.0
Ba	7.02		0.1	20.8		0.3
Fe	1.1		0.1	3.8	<del></del>	0.3
Ca	76.5		3.8		L	14.9
K	2.7		0.1	4.8		0.1
Mg	4.07		0.3			1.1
Na	21.3		0.9	38.0		1.7
Si	2.46		0.4			1.1
SO4	15.7	-0.3		20.6		
CI	21.6	-0.6		33.7	-1.0	
Totals		-4.5	5.9		-14.5	

## DISCUSSION AND CONCLUSIONS

The holes did not penetrate through the heavy glue line into the permeable membrane surface.

The solids precipitated onto the membrane surface originally come from a saturated solution. When the autopsy is done, de-ionized water is used to rinse the scrapings from the surface of the membrane. Since the samples are scraped from the membrane using DI water, the concentration expressed as a value in milligrams per liter is not meaningful as a concentration unless it is expressed in equivalents.

When the concentrations are interpreted as equivalents, it can then be shown in both housing #3 and housing #6 that there are roughly the same number of equivalents of calcium and phosphorous in each housing. This indicates that the predominant form of what was left on the membrane was most likely calcium phosphate (hydroxy apetite). Housing #6 had a larger amount than housing #3 resulting in the flow almost ceasing in housing #6.

When dye was applied to the element from the 6th housing, it did not adhere. That membrane element was the second membrane from the end of the system. The membrane in the 3rd housing at the front end of the system absorbed the dye indicating damage to the membrane surface. One possible reason why is that the acid solution was stronger at the front end of the system, especially if there was a problem with the chemical feed system and the pH dropped towards 2. Another possible explanation is the phosphate scale acted as a buffer to protect the membrane surface from the sulfuric acid in the end of the system. Phosphoric acid is a weaker acid than sulfuric. Using the 1st ionization constants, phosphoric acid would be a pH of about 3, and sulfuric is less than 2. Using the second ionization constant, phosphoric acid would be a pH of about 8, and sulfuric would still be about 2. As the water became more saturated with calcium phosphorous, the sulfuric acid became buffered significantly.

## SPIRAL WOUND MEMBRANE ELEMENT AUTOPSY

## PURPOSE AND LOCATION OF AUTOPSY

Purpose of Autopsy: McAllen, TX Wastewater Reclamation Project: Determination of scaling in end element.

Date and Place: October 29, 1999, USBR WTER Pilot Plant Lab, Denver, CO.

Date of This Report: 12/30/1999

### Names of Observers:

Frank Leitz Michelle Chapman Wilbert Kim Linton

ELEMENT IDENTIFICATION	
Manufacturer:	Hydranautics
Element Type:	LFC1X 2540
Element Location:	Housing #6, final element
Serial Number:	x03536
Element Dimensions:	2.5 in. x 40 in.
Number of Leaves:	2
Size of Leaves:	92.1cm x 72.7cm Total Area 82.6cm x 62.2cm Active Area per side (2 m ² per element or 22.1 ft ² )
	OPERATING HISTORY

The RO system was operated for six months on site at the McAllen, TX South Waste Water Treatment Plant. Screened de-gritted sewage was first treated in a Zenogem bioreactor/microfiltration system, then chlorine and ammonia was added and the Zenogem effluent was forwarded to the RO system. The RO element array was a 2x2x1x1 and had 3 elements per vessel for a total of 18 elements in the system. RO recovery rates were set from 50% to 80% of 15.2 L/min feed flow.

Sulfuric acid and antiscalent were added to prevent scaling. However, due to changes in the chemical character of the Zenogem effluent, or excessive gas formation in the acid tank which caused the acid feed pump to loose it's prime, the pH was not controlled well at all times. This resulted in a loss of permeate flow from the last vessel.

Also, traditional constituents used in an RO projection do not include phosphorous compounds. The researchers involved in this project began to suspect that phosphorous salts were the cause of excessive scale problems due to the nature of waste water treatment. Attempts at adjusting the pH to control phosphorous salts included running a projection with non-RO software to determine the potential for phosphate scaling. A range of pH settings and two control points for pH were tested in an attempt to control the scaling problems. The pH ranges tested were from 5.5 to 7 on the feed, and 5.5 to 6 on the concentrate. The lower pH control ranges were in response to this non-RO projected information.

Scaling also caused operators to clean the system approximately 4 times with a low pH solution at a pH of about 3. A high pH solution was not used to clean the membranes as there was no indication of biofouling and the system's performance was recovered using the acid cleanings.

### DESCRIPTION OF EVENTS LEADING TO AUTOPSY

Subject element was the last element of the last vessel (vessel #6). Permeate recovery flow from the last vessel varied from 1.4 L/min to 0.01 L/min. This fouling was a result of turning off the acid feed pump for approximately 8 hours.

This autopsy was primarily done to determine if phosphate salts were of primary concern, or not. In addition, the general nature of the scaling composition is of interest.

## NARRATIVE DESCRIPTION OF AUTOPSY PROCEDURE

The membrane was inspected during the autopsy at every step. First, the fiberglass wrapping was cut open using an air-powered cast saw set to cut at a shallow depth. The wrapping was then peeled or pried off. Anti-telescoping devices were removed from both ends of the membrane. Finally, the tape wrap was removed.

A squeegee was used to wipe both sides of the first leaf. DI water was used to liquefy the fouling substance. The material was collected in a sample jar labeled as Sample 1.

Researchers then applied a strong red red dye, congo red, to the second leaf.

Samples were cut from the feed and reject ends of the second leaf for SEM analysis with DI water added to the baggie to keep the membrane supple. Feed side is Sample 2 and the reject side is Sample #3.

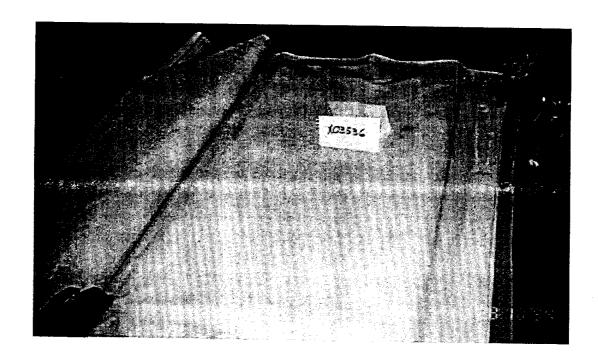
The material was collected from the first leaf was funneled into a sample jar labeled as Sample #4.



## **OBSERVATIONS**

The scrapings from the first element were a brownish pink color. The pink may be dye. No visible scaling was apparent.

Dye test on the second leaf with congo red was negative indicating no structural damage or biofouling on the membrane surface. Dye will highlight biofouling as the dye adheres to a surface ripe with organisms.



Test and Test Objective: Chemical analysis of fouling material on leaf 1 Organization Performing Test: USBR Chemistry Lab

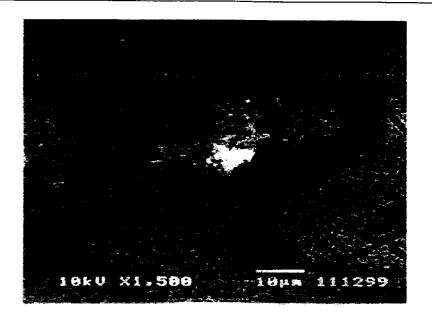
Date: Submitted November 1, 1999

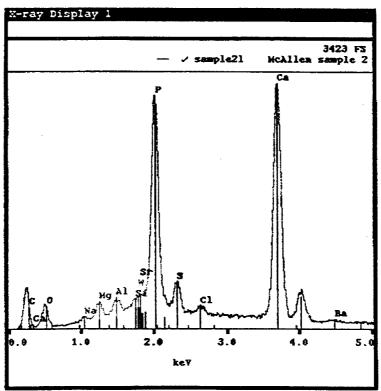
### Test Results

Analytes	Housing #3	Equivalent	Equivalent	Housing #6	Anions =>	Cations
,	concentration				1	Cations =>
	1	į	!	concentration	Ox. State *	Ox. State *
	(mg/L)	Ox. State *	Ox. State *	(mg/L)	Conc. / At.	Conc. / At.
		Conc. / At.	Conc. / At.		Wt.	Wt.
		Wt.	Wt.			
Total P	36.69	-3.6		135.2	-13.1	
Al	2.52	÷	0.3	9.1		1.0
Ba	7.02		0.1	20.8		0.3
Fe	1.1		0.1	3.8		0.2
Ca	76.5		3.8	298.0		14.9
K	2.7		0.1	4.8		0.1
Mg	4.07		0.3		<u> </u>	1.1
Na	21.3		0.9	38.0		1.7
Si	2.46		0.4			1.1
SO4	15.7	-0.3		20.6	-0.4	
CI	21.6	-0.6		33.7		
Totals		-4.5	5.9		-14.5	i

## Observations from Test:

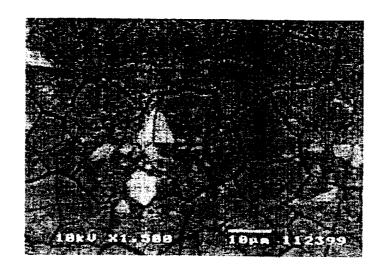
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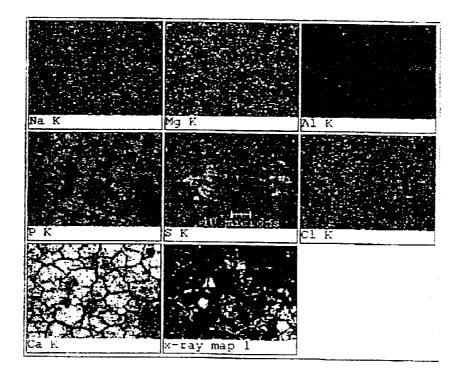




Test and Test Objective: SEM/Elemental Analysis of membrane samples from the second leaf to determine the nature of the scalant for element number X03536.

Organization Performing Test: USBR Date: Submitted November 1, 1999





SEM Distribution map of sampled elements for membrane # X03536

## DISCUSSION AND CONCLUSIONS

### SEM Test:

The X-ray display peaks should be interpreted as a qualitative analysis, not a quantative one. This analysis captures the energy spikes from the entire picture, not just the particle in the middle. The sample was hit with 10 kV of energy and magnified 3,500 times. Certainly, phosphorous and calcium are prevalent peaks. Barium and sulfur also show strong peaks on other samples not shown as part of this report because they are redundant to the information captured in the body of this report.

Although no visible scaling was apparent to the naked eye, this analysis clearly shows a fine silt-like layer covers the surface of the membrane. It appears from the distribution map that there is an even covering of these elements across the face of the membrane. The particle in the middle does not seem to be of a different character as compared to the rest of the scale layer.

## Chemical Analysis of Scraping:

The solids precipitated onto the membrane surface originally come from a saturated solution. When the autopsy is done, de-ionized water is used to rinse the scrapings from the surface of the membrane. Since the samples are scraped from the membrane using DI water, the concentration expressed as a value in milligrams per liter is not meaningful as a concentration unless it is expressed in equivalents.

Using equivalents, it can then be shown in both housing #3 and housing #6 that there are roughly the same number of equivalents of calcium and phosphorous in each housing. This indicates that the predominant form of what was left on the membrane was most likely calcium phosphate (hydroxy apetite). Housing #6 had a larger amount than housing #3 resulting in the flow almost ceasing in housing #6.

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## **ZeeWeed® Tertiary Treatment System**

# BUDGET PROPOSAL for a ZeeWeed® Membrane Filtration Tertiary Filtration Treatment System for the City of McAllen, Texas Proposal Number #374-98 Rev. 2.0

Submitted to:

CH2M Hill 1620 W. Fountain Head Pkwy. #550 Tempe, AZ 85282

Attention:

Jim Lozier / Fair Miller

Submitted by:

ZENON Environmental Systems – Municipal Division 845 Harrington Court Burlington, Ontario L7N 3P3

**December 7, 1999** 

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## 1.0 COMMERCIAL INFORMATION

## 1.1 Pricing Summary

The budget pricing to supply equipment and services as described in this proposal is as follows:

ZeeWeed[®] Membrane Tertiary Treatment System including membranes, permeate pumps, membrane air scour blowers, instruments and control system & equipment F.O.B. McAllen, Texas.

Four (4) Train ZeeWeed® Membrane Tertiary Treatment System to treat a maximum daily hydraulic capacity of 8.5 MGD.

Process equipment will be supplied loose, i.e. not on skids, for installation by others.

**Fixed Capacity Flow** 

8.5 MGD

## **Budgetary System Price**

US \$5,075,000.00

## Validity

Pricing is for budgetary purposes only and does not constitute a final offer of sale.

## **Taxes and Duties**

No taxes or duties or brokerage are included in the above pricing. Any taxes, duties, tariffs of any type are for the account of the Purchaser.

### Field Service

The equipment pricing above includes Field Service from ZENON Technicians for assistance with the equipment installation, commissioning, operator training and process start-up assistance.

Any additional days of Field Service required will be at ZENON's Standard per diem rate of US\$650 per day plus living and travelling expenses.

## **Terms of Payment**

The budgetary pricing quoted in this proposal is based on the following payment terms

- 15% with Purchase Order
- 25% on submission of General Arrangement Drawings

- 50% on shipment of equipment or notification that equipment is ready to ship (partial shipments permitted)
- 10% within 30 days of equipment start up or within 60 days of equipment shipment whichever is sooner.

## **Performance & Maintenance Bonds**

The cost of providing performance or maintenance bonds is not included. If required these will be at additional cost.

## **Equipment Shipment and Delivery**

A typical drawing submission and equipment shipment schedule is indicated below. Drawing submission milestones and equipment shipment periods are quoted from the date of acceptance of a formal signed Purchase Order:

Submission of GA Drawings:

8 to 10 weeks from acceptance of P.O

Drawing Approval:

3 weeks from submission of drawings

Equipment Shipment:

24 to 26 weeks from acceptance of P.O. 2 weeks after shipment of equipment to site

Plant Operation Manuals: Operator Training:

When preferred by Customer but no later than

2 weeks prior to the scheduled plant start-up

The above estimated delivery schedule is presented based on current workload backlogs and production capacity. If a formal purchase order is not received within the period of validity of this proposal, the delivery schedule is subject to review and adjustment.

The estimated delivery period quoted is presented based on review <u>and approval</u> of equipment shop drawings within a two (2) week period. Any delay in approval of shop drawings may affect the proposed shipment schedule.

## **Quality Basis**

For the purposes of establishing a quality basis for equipment supply, reference is made herein to particular equipment manufactured by certain suppliers. The term "or equal" where used herein shall be deemed to mean "ZENON Approved Equivalent". ZENON reserves the right to substitute equipment that ZENON considers to be of equal quality and suitability for the intended application from alternative suppliers to those named herein. With regard to determining the suitability or otherwise of any particular manufacturer's equipment for inclusion as part of the ZeeWeed® system, ZENON's decision shall be final.

## 1.2 Standard Terms and Conditions

ZENON's Standard Terms and Conditions apply.

## 1.3 ZENON STANDARD TERMS AND CONDITIONS

Seller desires to provide its Customers with prompt and efficient service. However, to negotiate individually the Terms and Conditions of each Sales contract would substantially impair Seller's ability to provide such service. Accordingly, Products and Services furnished by Seller are sold only on the Terms and Conditions stated herein. Notwithstanding any terms or conditions on Customer's order, Seller's performance of any contract is expressly made conditional on Customer's agreement to Seller's Terms and Conditions of Sale unless otherwise specially agreed to in writing by Seller. In the absence of such agreement, commencement of performance and/or shipment shall be for Customer's convenience only and shall not be deemed or construed to be acceptance of Customer's Terms and Conditions, or any of them. If a contract is not earlier formed by mutual agreement in writing, acceptance of any Product or Service shall be deemed acceptance of the Terms and Conditions stated herein. All contracts for the Sale of Products shall be construed under and governed by the law of the location of Seller's plant at Burlington, Ontario, Canada.

## QUOTATION AND PRICES

All quotations are subject to the Terms and Conditions stated herein as well as any additional Terms and Conditions that may appear on the face hereof. In the case of a conflict between the Terms and Conditions stated herein and those appearing on the face hereof, the latter shall control. Seller's prices and quotations are subject to the following:

- a) All published prices are subject to change without notice.
- b) UNLESS OTHERWISE SPECIFIED IN WRITING, ALL QUOTATIONS EXPIRE THIRTY (30) DAYS AFTER DATE THEREOF, MAY BE TERMINATED EARLIER BY NOTICE AND CONSTITUTE ONLY SOLICITATIONS FOR OFFER TO PURCHASE; further, budgetary quotations and estimates are for preliminary information only and shall neither constitute offers, nor impose any obligation or liability upon Seller.
- c) Unless otherwise stated in writing by Seller, all prices quoted shall be exclusive of transportation, insurance, taxes (including, without limitation, any sales, use, or similar tax, and any tax levied on or assessed to Seller after Product shipment by reason of Seller's retention of a security interest as provided herein), license fees, customs fees, duties and other charges related thereto and Customer shall report and pay any and all such shipping charges, premiums, taxes, fees, duties and other charges related thereto, and shall hold Seller harmless therefrom, provided that, if Seller, in its sole discretion, chooses to make any such payment, Customer shall reimburse Seller in full upon demand.
- d) Stenographic, typographical and clerical errors are subject to correction.
- e) Prices quoted are for Products only and do not include technical data, proprietary right of any kind, patent rights, qualification, environmental or other than Seller's standard tests and other than Seller's normal domestic commercial packaging unless expressly agreed to in writing by Seller.
- f) Published weights and dimensions are approximate only. Certified dimension drawings can be obtained upon request. Manuals, drawings or other documentation required hereupon must be referenced specifically.

This is merely a quotation, and the technology disclosed herein may be covered by one or more ZENON Environmental Inc. (ZENON) patents or patent applications. Any disclosure in this offer does not hereby grant, and nothing contained in the offer shall obligate ZENON to grant, an option to obtain a license to any technology or any other rights under any patent now or hereafter owned or controlled by ZENON.

## TERMS OF PAYMENT

Inless credit is granted or otherwise specified in writing, payment is due upon shipment. All payments on approved credit accounts

shall be due in full thirty (30) days from date of invoice. Past due balances shall be subject to a service charge of 1-1/2% per month (18% per annum), but not more than the amounts allowed by law. Partial shipments will be billed as made and payments therefor are subject to the above terms. Payment shall not be withheld for delay in delivery of required documentation unless a separate price is stated therefor, and then only to the extent of the price stated for such undelivered documentation. Seller may cancel or delay delivery of Products in the event Customer fails to make prompt payment therefor, or in the event of an arrearage in Customer's account with Seller. Seller hereby retains a security interest in the Products finished until Customer has made payment in full in accordance with the terms hereof. Customer shall cooperate fully with Seller to execute such documents and to accomplish such filings and/or recordings thereof as Seller may deem necessary for the protection of Seller's interest in the Products furnished.

## TRANSPORTATION AND RISK OF LOSS

Transportation will normally follow Customer's shipping instructions, but Seller reserves the right to ship Products freight collect and to select the means of transportation and routing when Customer's instructions are deemed unsuitable. Unless otherwise advised, Seller may insure to full value of the Products or declare full value thereof to the transportation company at the time of shipment and all freight and insurance costs shall be for Customer's account. Risk of loss and/or damage shall pass to Customer at the FOB point, which shall be the point of manufacture or such other place as Seller shall specify in writing, notwithstanding installation by or under supervision of Seller. Confiscation or destruction of, or damage to, Products shall not release, reduce or in any way affect the liability of Customer therefor. All Products must be inspected upon receipt and claims should be filed with the transportation company when there is evidence of shipping damage, either concealed or external. Notwithstanding any defect or nonconformity, or any other matter, risk or loss and/or damage shall remain with the Customer until the Products are returned at Customer's expense to such place as Seller may designate in writing. Customer, at its expense, shall fully insure Products against all loss and/or damage until Seller has been paid in full therefor, or the Products have been returned, for whatever reason, to Seller.

## PERFORMANCE

Seller will make all reasonable effort to observe its dates indicated for performance. However, Seller shall not be liable in any way because of any delay in performance hereupon due to unforeseen circumstances or to causes beyond its control, including, without limitation, strike, lockout, riot, war, fire, act of God, accident, failure or breakdown of components necessary to order completion, subcontractor, supplier or customer caused delays, inability to obtain or substantial rises in the price of labour, materials or manufacturing facilities, curtailment of, or failure to obtain sufficient, electrical or other energy supplies, or compliance with any law, regulation or order, whether valid or invalid of any cognizant governmental body or any instrument thereof whether now existing or hereafter created. Performance shall be deemed suspended during, and extended for, such time as any such circumstances or causes delay its execution. Whenever such circumstances or causes are remedied, Seller will make, and Customer shall accept, performances hereupon. In addition, Seller's inventories and current production must be allocated so as to comply with applicable Government regulations. In the absence of such regulations, Seller reserves the right, in its sole discretion, to allocate inventories and current production and substitute suitable materials when, in its opinion, such allocation or substitution is necessary due to such circumstances or causes. No penalty clause of any kind shall be effective. As used herein, "performance" shall include, without limitations, fabrication, shipment, delivery, assembly, installation, testing, and warranty repair or replacement as applicable.

## ACCEPTANCE

The furnishing by Seller of a Product to the Customer shall constitute acceptance of that Product by Customer, unless notice of defect or nonconformity is received by Seller within thirty (30) days of receipt of the Product at Customer's designated receiving address; provided that, for Product for which Seller agrees in writing to perform acceptance testing after installation, the completion of Seller's applicable acceptance tests, or execution of Seller's acceptance form

by Customer, shall constitute acceptance of the Product by Customer. Notwithstanding the foregoing, any use of a Product by Customer, its agents, employees, contractors or licensees for any purpose, after receipt thereof, shall constitute acceptance of that Product by Customer. Seller may repair or, at its option, replace defective or non-conforming parts after receipt of notice of defect or

## ASSIGNMENTS AND TERMINATIONS

Any assignment by Customer of any contract hereupon without the express written consent of Seller is void. No order may be terminated by Customer except by mutual agreement in writing. Terminations by mutual agreement are subject to the following

- Customer will pay, at applicable contract prices, for all Products which are completely manufactured and allocable to Customer at the time of Seller's receipt of notice of termination.
- Customer will pay all costs, direct and indirect, which have been incurred by Seller with regard to Products which have not been completely manufactured at the time of Seller's receipt of notice of termination.
- c) Customer will pay a termination charge on all other determined costs and other charges. To reduce termination charges, Seller will divert completed parts, material or work-in-process from terminated contracts to other Customer's whenever, in Seller's sole discretion, it is practicable to do so.

## PATENTS AND OTHER INDUSTRIAL PROPERTY RIGHTS

Seller will hold Customer harmless, as set forth herein, in respect to Seller will hold Customer harmless, as set forth herein, in respect to any claim that the design or manufacture of any Product in Seller's commercial line of Products, or manufactured to specifications set by Seller and furnished herein, constitutes an infringement of any patent or other industrial property rights of the United States or Canada. Seller will pay all damages and costs, either awarded in a it or paid, in Seller's sole discretion, by way of settlement, which re based on such claim of infringement, provided that Seller is notified promptly in writing of such claim of infringement but there is no liability whatsoever herein with respect to any claims settled by Customer without Seller's prior written consent. In the event that Seller is required to hold Customer harmless hereupon, Seller will, in its sole discretion and at its own expense, either procure for Seller is required to hold Customer harmless hereupon, Seller will, in its sole discretion and at its own expense, either procure for Customer the right to continue using said Product, replace it with a non-infringing product, or remove it and refund an equitable portion of the selling price and transportation costs thereof. THIS SHALL CLAIM BASED UPON OR RELATED TO ANY ALLEGED INFRINGEMENT OF ANY PATENT OR OTHER INDUSTRIAL RIGHTS. Customer shall hold Seller harmless against any expense, loss, costs or damages resulting from claimed infringement of patents, trademarks, or other industrial property rights arising out of compliance by Seller with Customer's designs, specifications, or instructions. SELLER DISCLAIMS LIABILITY FOR U.S. OR CANADIAN PATENT OR COPYRIGHT INFRINGEMENT ARISING FROM USE OR MANUFACTURE BY ANYONE OF INVENTIONS IN CONNECTION WITH PRODUCTS OR SERVICES SOLD, USED, OR INTENDED FOR SALE OR USE, IN PERFORMING CONTRACTS WITH THE UNITED STATES OR CANADA.

### WARRANTY

1. Unless otherwise agreed to in writing, Seller warrants its Products to be free from defects in material or workmanship for a period of 12 months from the shipment of Product by Seller, provided that such Product are used, cleaned and maintained in accordance with the Seller's instructions. This warranty does not apply to normally replaceable parts or components such as

- filter cartridges, pump seals, membranes etc., (see below for membrane warranties).
- Customer undertakes to give immediate notice to Seller if goods or performance appear defective and to provide Seller with reasonable opportunity to make inspections and tests. If Seller is not at fault, Customer shall pay Seller the costs and expenses of the inspections and tests.
- Seller's obligations under this warranty is limited to the repair or replacement at its factory, or any device or part thereof which shall prove to have been thus defective. If Customer asks Seller to replace defective parts at Customer's premises, Customer agrees to pay for any traveling time and expenses, plus the Seller's labour to complete the replacement/repair.
- 4. Goods shall not be returned to Seller without Seller's permission. Seller will provide Customer with a "Return Material Authorization" number to use for returned goods. All returns are F.O.B. - Burlington, Ontario, Canada.
- 5. Warranty on the membranes applies only if the membrane element(s) has been operated and cleaned according to Seller's instructions. When either permeate or concentrate flow drops by instructions. When either permeate or concentrate flow drops by 10% from the original rates at the same operating conditions, cleaning must be initiated or the warranty will be null and void. Elements must be clean and be kept moist. They should be shipped to Seller in water-tight bags and must be protected from freezing. WARNING – if element conditions of use given in Seller's instructions are not followed, the warranty will be null and void.

IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, WARRANTIES OF FITNESS FOR PARTICULAR PURPOSE, USE, OR APPLICATION, AND ALL OTHER OBLIGATIONS OR LIABILITIES ON THE PART OF THE SELLER, UNLESS SUCH OTHER WARRANTIES, OBLIGATIONS OR LIABILITIES ARE EXPRESSLY AGREED TO IN WRITING BY SELLER, ARE NULL AND VOID.

## DAMAGES AND LIABILITY

SELLER'S LIABILITY FOR DAMAGES SHALL NOT EXCEED THE PAYMENT, IF ANY, RECEIVED BY SELLER FOR THE UNIT OF PRODUCT OR SERVICE FURNISHED OR TO BE FURNISHED, AS THE CASE MAY BE, WHICH IS THE SUBJECT OF CLAIM OR DISPUTE. IN NO EVENT WILL OR SPECIAL DAMAGES, OF ANY KIND, HOWEVER CAUSED, ARISING OUT OF, OR IN ANY WAY CONNECTED WITH, THE PRODUCTS FURNISHED BY SELLER TO CUSTOMER.

### DISPUTES

All disputes under any contract concerning Products not otherwise resolved between Seller and Customer shall be resolved in a court of competent jurisdiction for the location of Seller's plant at Burlington, Ontario, Canada, and no other place. Provided that, in Seller's sole discretion, such action may be heard in some other place designated by Seller, if necessary to acquire jurisdiction over third persons, so that the dispute can be resolved in one action. Customer hereby consents to the jurisdiction of such court or courts and agrees to appear in any such action upon written notice thereof. No action, regardless of form arising out of, or in any way connected with, the Products or Services furnished by Seller, may be brought by Customer more than one (1) year after the cause of action has occurred. If any part, provision or clause of the Terms and Conditions of Sale, or the application thereof to any person or circumstances, is held invalid, void or unenforceable, such holding shall not affect and shall leave valid all other parts, provisions, clauses or applications of the Terms and Conditions remaining, and to this end the Terms and Conditions shall be treated as severable.

## 2.0 SYNOPSIS OF THE ZEEWEED® TERTIARY TREATMENT PROCESS

ZeeWeed[®] ultrafiltration system is a proprietary ZENON process technology that produces high quality treated water by drawing raw water through immersed ZeeWeed[®] membrane modules. ZeeWeed[®] "Outside-In", hollow-fibre membranes are manufactured ultrafiltration (UF) pore size. The ZeeWeed[®] UF Membranes have an absolute pore size of 0.1 microns and thus ensure removal of particulate matter greater than 0.1 microns in size such as most particulate matter, including bacteria, solids, Giardia cysts and Cryptosporidium oocysts, cannot enter the treated effluent stream. The ZeeWeed[®] Membrane ensures removal of a large percentage of impurities. The ZeeWeed membranes produce a high quality effluent, optimal for post-treatment by reverse osmosis.

The membranes operate under a slight vacuum created within the hollow membrane fibres by a permeate pump. Treated water is drawn through the membranes, enters the hollow fibres and is pumped out to the treated water storage tank (or distribution system). Air flow is introduced at the bottom of the membrane modules to create turbulence which scrubs and cleans the outside of the membrane fibres allowing them to operate at a high flux. The aeration also oxidizes iron and organic compounds, resulting in a treated water quality that is better than that provided by ultrafiltration alone.

ZeeWeed® membranes are immersed and therefore can tolerate high levels of solids. This is a main advantage when used as a tertiary treatment plant, since the ZeeWeed plant continues to operate well even when the upstream clarifier is upset and rejects solids to the UF. The capacity to handle solids also means that there is no need to pre-treat the clarified effluent, avoiding therefore the costs of sand filters or cartridge filters often required by other membrane technologies.

ZeeWeed® membranes have the additional benefit of being chlorine resistant up to concentrations of 1,000 mg/L. Therefore, influent water can be pre-chlorinated or the membranes can be easily cleaned, even when heavy fouling occurred.

The ZeeWeed[®] Membrane Technology process consistently produces high quality water, as the membranes are not subjected to stress, pressurization or rapid pressure fluctuations. Membrane cleaning by backpulsing is achieved by reversing the permeate flow and backwashing the fibre's lumen with permeate at low pressure (due to the high permeability of the ZeeWeed[®] membrane, the backpressure during backpulsing is low). The small variations in operating pressure occur smoothly over relatively long periods so that at no time is the membrane stressed. This, in turn, results in a membrane filtered permeate with the lowest sustainable particle count on the market.

## 3.0 FEATURES & BENEFITS OF THE ZEEWEED® SYSTEM

## High Treated Effluent Quality

ZENON's ZeeWeed® Membrane Tertiary Treatment System is a cost effective method for membrane filtration removal of solids and is particularly recommended for treatment of the following contaminants in water:

Feed Water Element
Suspended Solids
Average Turbidity
Particle Counts

**Treated Water Quality** 

≥ 6 log removal ≤ 0.1 NTU

Average  $\leq 5/\text{mL}$ , size range > 2 microns

Note: The information provided in this section of the proposal is general only and is intended only to indicate what is capable of being achieved with ZeeWeed® Membrane Water Treatment Technology based on consideration of specific raw water qualities and the type of treatment processes utilized.

Since the presence of air is continuous or semi-continuous in the process tank, materials which will readily oxidize, such as iron in its ferrous state, will be micro-precipitated and separated by the membrane, therefore producing a better quality water than if treated by ultrafiltration alone.

## Advantages of an "Outside-In" Immersed Membrane

## a) Single Step Treatment

The ZeeWeed® membrane is an outside-in membrane where the flow of water is from the outside of the membrane to the inside of the hollow fibre. This means that the inside of the membrane only comes in contact with clean, filtered water. The solids to be removed remain outside of the membrane where they do not cause fouling and plugging.

## b) Low Energy Requirement.

Being immersed allows ZENON's ZeeWeed[®] Membranes to operate under a slight vacuum instead of under a high positive pressure, as do other membranes on the market. The ZeeWeed[®] Membrane operates under a differential pressure of 5"Hg to 18"Hg (5-20 ft H₂O) vacuum. This operational energy is very low and to ZENON's knowledge is the lowest in the membrane market.

## c) Ability to Operate in a High Solids Environment

The ZeeWeed® membranes are immersed within the process tank, where suspended solids can exist without interfering with membrane operation. The operating flux rates of ZeeWeed® membrane modules are, for all practical purposes, independent of the solids content and turbidity of the raw water supply. This reflects in its capacity to operate well in a solids environment seen when the clarifiers get upset.

## d) Stable and Low Particle Counts in the Effluent

The low energy backpulse of an immersed membrane does not produce significant expansion of the membrane pores. Expansion of the membrane pores, which results from high energy air backpulsing of the membranes as utilized in some types of membrane systems, can result in high particle counts immediately following backpulsing. This expansion of the membrane pores may potentially permit the passage of particles of larger sizes through the membranes until the membrane fibre fully relaxed from the expansion induced by the backpulsing process. Such systems cannot reliably use particle counters to verify the membrane integrity.

With the ZeeWeed[®] Membrane system expansion of the membrane pores is insignificant and the ZeeWeed[®] process consistently produces high quality treated water, which remains stable at all phases of plant operation.

## Resistance to Oxidizing Chemicals

The ZeeWeed® membrane is resistant to chlorine and other typical water treatment plant oxidants (such as chlorine dioxide and potassium permanganate) in concentrations as high as 1,000 mg/L. This means that it is possible to pre-chlorinate the water without having to add a de-chlorination step such as Granular Activated Carbon (GAC) or bisulfite injection, which not only requires periodic chemical filling and maintenance, but also adds an unnecessary compound into the water. Where prechlorination is desired, chemical resistance also provides protection against dechlorination equipment failure, which could lead to severe damage of a chlorine sensitive membrane. Finally, chlorine resistance also allows for easy disinfection of the membrane and the plant should this be required.

## **Exceptional Membrane Durability**

The ZeeWeed® membrane has been designed to be exceptionally durable and resistant to breakage. To achieve a high level of membrane durability ZENON utilizes a patented internal support on which the membrane is caste. This provides resistance to the membrane and protects it against tearing and breakage without reducing its flux capacity.

## Simplicity of Operation

The ZeeWeed® process is an easy and inexpensive system to operate both in terms of maintenance costs and personnel requirements. Since treatment is a single stage process, there is no need for coagulants (except for colour and organics removal), clarifiers or sand filters as with some other membrane systems. Instead the plant operators are only required to ensure they maintain proper membrane permeating conditions by maintaining the permeate pumps and blowers in operation.

## Ruggedness of Operation / Operational Flexibility

The ZeeWeed® Treatment Process consistently produces high quality treated effleunt irrespective of seasonal, operational and weather related variations in the source raw water quality, since the membranes can operate equally well in low or high solids concentrations and at varying temperatures:

- without clogging

- without the need for pressurized air backpulsing cycles which consistently stress the membranes and lead to premature failure
- without any detrimental effects on the membrane flux since the ZeeWeed[®] membrane was developed for environments of high solids concentrations
- without breaking since the hollow fibre membrane is a composite developed to be both highly durable structurally as well as chemically resistant to outside elements

## 4.0 ZEEWEED® TERTIARY TREATMENT PLANT

## Design Philosophy and Equipment Selection

ZENON proposes to offer a four (4) Process Stream Membrane Treatment Plant with each process train designed to produce a continuous treated water output of 1/4 of the required capacity of the plant. In the event of any type of operational problem or failure with one train the plant will function at 75% of the nominal average day flow design capacity, by adjusting the vacuum applied to the operating membrane modules. Future plant expansion, if and when required, can be achieved by adding additional treatment units.

The equipment proposed is designed for simplicity of operation. All plant operations are automatically controlled via a PLC. There are no normal operations that require manual operation of valves, pump speeds, etc. The system design philosophy is to reduce as far as possible the potential for system problems caused by operator error.

The treatment system proposed by ZENON does not include a chlorine dosing system to add residual chlorine to the treated effluent.

## CONCRETE, EQUIPMENT LOOSE

The ZeeWeed® Membrane Tertiary Treatment System is designed with major process equipment supplied loose for installation on concrete pads. The ZeeWeed® membranes are supplied for installation in concrete tanks (by others) within Zenon supplied membrane support beams. The membrane air scour blowers are supplied loose for installation within an acoustically insulated blower room to minimize the noise transmission to the rest of the plant. Reject water will flow by gravity to the disposal point. The plant control panel will be supplied loose so that it can be either wall mounted adjacent to the plant or located in a separate control room depending on the Owner's preference.

## 5.0 MAJOR EQUIPMENT

The list below summarizes the major equipment and the quantities of items included for the  $ZenoGem^{@}$  plant design.

Item	Size	Units	Quantity
Raw Water Feed	1.0.00		
Raw Influent Feed Pumps			Not Incl.
Inlet & Discharge Isolating Valves			Not Incl.
Discharge Check Valves			Not Incl.
Piping Manifold			Not Incl.
Wet Well Level Switches			Not Incl.
VFD's			Not Incl.
Raw Water Screening			
Raw Influent Screen			Not Incl.
Raw Influent Grinder			Not Incl.
Raw Influent Flowmeter	· · · ·		Not Incl.
Raw Influent Flow Control Flowmeter			Not Incl.
Raw Influent Flow Control Valve			Not Incl.
Membranes/Membrane Cassettes			
Individual Membrane Modules			640
Membrane Cassettes			80
Process Tanks & Frames			
Membrane Support Frames			Incl.
Process Tanks			Not Included
Permeate Collection Headers			4
Air Scour Headers			4
Permeate Pumps			
Permeate Pumps	2,497	USgpm	5
VFD's/Control Valves	50	HP	4
Piping Manifold			Not Incl.
Valves			Incl.
Air Extraction System			
Air Removal Separation Columns			4
Vacuum Pumps	24	scfm	3
Backpulse System			
Backpulse Water Storage Tank	6,480	USg	2
Hypochlorite Storage Tank	106	USg	1
Hypochlorite Feed Pumps	6.9	USgphr	2
Item	Size	Units	Quantity

Air Blowers	]		
Membrane Air Scour Blowers incl. Silencers	5,129	Scfm	3
Inlet & Discharge Isolation Valves			6
Discharge Check Valves			3
Inlet Control Valves			Incl.
Chemical Addition System (if required)			
Chemical Storage Tank			Not Incl.
Chemical Feed Pumps			Not Incl.
CIP System	•		
CIP Chemical Storage Tank			Incl.
CIP Chemical Feed Pump	ļ		Incl.
Instruments			
Permeate Flowmeters			4
Permeate Header Pressure Transducers			4
Process Tank Level Transmitters			4
Process Tank Level Switches			16
pH Transmitters			Not Incl.
Turbidimeters			1
Particle Counters			4
Membrane Blower Flow Switches			3
Permeate Pump Pressure Gauges			4
Membrane Air Scour Blower Pressure Gauges			3
Control Panel			
PLC-based Control Panel			1
Back-Up PLC			Not Incl.
Electrical			
MCC Panel			Not Included
Miscellaneous			
Air Compressor		<u> </u>	2
Air Drier			1
Monorail for Cassette Removal			Not Incl.
Field Service Allowed			Days
Installation Supervision			5 .
Mechanical Checkout			5
Operator Training			2
Process Start-Up			3
Commissioning			5
TOTAL MAN-DAYS			20
TOTAL No. TRIPS			3
Freight			
Delivery to Site			Incl.

## 6.0 ATTACHMENTS

Plant Power Consumption and Estimated Yearly Operating Cost

Table 9.1.1 Connected Power and Estimated Power Consumption at Average Day Flow

City of McAllen Eff Filtration Rev 2 Average Day Flow

8,500,026 USgpd 8,500,026 Maximum Day Flow

m3/day m3/day 32,173 32,173 NSgpd

Ľ *	M TOTAL	# QTY DESCRIPTION			Design Capacity	Discharge Head	Duty Point	Equipment Operating	Motor	Total Equipment	Total	Motor	Equipment	Hours / Day	Energy
				Diowers etc.			Efficiency	ВНР		윮	£	, %		Operation	Der year
-	'	Raw Water/Wastewater Screen	e/u												
N	4.00	1	Ry Zenon		011 00 100 1				•			٠		24.00	
m	ŀ	Backbulse Pumps	10.102 (0	20.	- i	- 1	81.00	18.44	88	73.76	120.00	91.40	60.18	22 40	36.901
4		Recirculation Pumps	5/2		mdbso -	# 00 05 #	,		,	•				6.40	-
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9	ŀ		- Na		USgpm	- 1	8.8			•				2.00	
_	300	Membrana Air Scour Blowers	D. 7.	, ,	- 1	- į	55.00		•		•		-	24.00	
80	+-	Process Air Blowara	Dy 28non	2.00	3,840.00 sctm	- 1	n/a	110.49	200.00	220.97	00.009	94.60	174.19	24 00	114 440
6		OWA Pro	170	,	. sctm	- 1	n⁄a	ʻ	•		,			24 00	
9	L		174		. sofm	6.00 psi	r/a	1	•			,		24.0	
=	6	Air Separation States Version 1	EA.				n/a		,					888	
-	+	Racker les Sodiem Librachlode 11	Dy Zenon	2.00	ន	18.00 ins Hg	π⁄a	2 2 5	300	4 50	00.6	87.50	3.84	24 00	0 500
1 5	+-	Clowner South Hypochione - Metenno	Dy Zenon	1.00	0.099 USgpm	\$0.00 #	n/a	0.10	0.10	010	021	100.001	800	3 6	2,320
2 7			n/a		. USgpm	30.00 #	55.00					200	3	250	,
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9			n/a	,	1	# 00 05	9/2		200		,	100.00		24.00	•
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2	_		By Zenon								1.34		8	24.00	657
			1000						1		1.34		1.00	24.00	657
		Total Connected Power							$\dashv$						
		Total Operating Donor									781.89	무			
_		Total Operating Cost								318.09	ВНР		255.59 k	κW	
		1000 Gum 00 - 1110							į					SSO	157 696
														4	,,,,,,,

Notes

Power Consumption of other plant equipment required (raw water feed pumps, high lift pumps etc.) is not included by ZENON
Where operating efficiencies are not known, the equipment operating power is assumed to be 75% of the motor nameplate power rating.
The operating hours for the permeate pump are corrected for the downtime during backpulse cycles (and Membrane Pressure Decay Test Cycles if applicable)
Permeate Pump Backpulses every 15 mins for 30 seconds 2,496 USgpm @ 30.00 if TDH = 24.89 BHP
Motor Efficiencies indicated are typical only. Efficiencies used are usually within 2% of actual when motor is operating within 50-100% of its full load rating Operation of Air Compressor is assumed to be only 25% of time

Operation of the Sodium Hypochlorite Pumps is intermittent - operation for 25% of time is used for energy calculation Blower Energy Consumption Estimated as: 6.770 BHP per 1,000 scfm per psig

It must be understood that at the time of proposal preparation, final headlosses or pressure drops in piping systems have not been calculated accurately Motor sizes are subject to confirmation (and if necessary adjustment) during final design. Use of the above information for sizing or selection of any ancillary equipment is entirely at the USER's own risk. Whilst the motor sizes indicated above are ZENON's best estimate based on design criteria assumed during preparation of the proposal, ZENON accepts no responsibility for the absolute accuracy of the information contained herein. The motor sizes in the above table are preliminary only and estimated based on the information available at the time of preparing this proposal.

Table 9.2.2 Estimated Total Annual Operating Cost

City of McAllen Eff Filtration Rev 2

Average Day Flow Maximum Day Flow

8,500,026 USgpd 8,500,026 USgpd

32,173 m3/day 32,173 m3/day

					Cost per year	
Electrica	i Equipment - Zenon			Calculated at Average Day Flow		
	si Equipment - Others			Carculated at Average Day Flow	157,696	
	se Chemicals Sodium Hype	ochlorite		Calculated at Average Day Flow	<del>-</del>	_ ι
CIP Che				The state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the state of the s	8,232	
CIP Che	mical #2 Sodium Hype trailzation Chemical #1	ochlorite • 250 mg	/L		3,211	<u>.</u>
CIP Neut	tralization Chemical #1				4,435 175	
Suggest	ed Membrane Accrual				117	
ougges.	eo membrane Accruar				190.905	
Estima	ted Total Annual Operating Cost					_
Notes	Product of the second				364,772	
voles	Backpulse Chemical Consumption	Sodium Hyp				
	Sodium Hypochlorite Consumption	71.91	Litres per day			
	Sodium Hypochlorite Consumption		Litres per year			
	Sodium Hypochlorite Cost U:	S\$ 0.31	per Litre			
	CIP Cleaning Chemical #1	MC-1				
	Design Dosage	2,000.00	mo/l			
	Solution Concentration	50.00				
	Specific Gravity	1,240				
	Wash Frequency	1.00	times / year			
	Chemical Consumption per Wash (all tanks)	1,918.24				
	Total Annual Chemical Consumption	1,918.24				
	Chemical Cost Us		per Litre			
	Chemical Cost US	\$ 2.70				
	CIP Cleaning Chemical #2	Sodium Hypo	chlorite - 250 mg	an a		
	Design Dosage	250.00	ma/L	,_		
	Solution Concentration	10.80				
	Specific Gravity	1.168				
	Wash Frequency	12.00	times / year			
	Chemical Consumption per Wash (all tanks)	1,178.52				
	Total Annual Chemical Consumption	14,142.26				
	Chemical Cost US		per Litre			
	CIP Neutralization Chemical #1	Sodium Hydri	oxide			
	Design Dosage	625.00	mg/L			
	Solution Concentration	50.00%	<u> </u>			
	Specific Gravity	1.520				
	Wash Frequency	1.00	times / year			
	Chemical Consumption per Wash (all tanks)	489.02	Litres			
	Total Annual Chemical Consumption	489.02	Litres			
	Chemical Cost US Chemical Cost 115		per Litre			
	Chemical Cost US:	0.47	per kg			
	CIP Neutralization Chemical #2	Sodium Bisuli	ite			
	Design Dosage	146.00	mg/L			
	Solution Concentration	38.00%				
	Specific Gravity	1.290				
	Wash Frequency	12.00	times / year			
	Chemical Consumption per Wash (all tanks)	177.11	Litres			
	Total Annual Chemical Consumption	2,125.32	Litres			
	Chemical Cost USS	0.00	per Litre			
	Chemical Cost USS	0.55	per kg			

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ZenoGem[®]/ZeeWeed[®]
BUDGET PROPOSAL
for the City of McAllen, Texas
Wastewater Treatment Plant

## **BUDGET PROPOSAL #374-98 Rev 1**

Submitted to:

CH2M Hill 1620 W. Fountain Head Pkwy. #550 Tempe, AZ 85282

Attention:

Jim Lozier & Fair Miller

Submitted by:

ZENON Environmental Systems – Municipal Division 845 Harrington Court Burlington, Ontario L7N 3P3

**December 7, 1999** 

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### 1.0 COMMERCIAL INFORMATION

### 1.1 PRICING SUMMARY

The budget pricing to supply equipment and services as described in this proposal is as follows:

One (1) ZenoGem® Membrane Bioreactor Waste Treatment System including membranes, aeration system, pumps, blowers, instruments, control system and equipment, FOB McAllen Texas.

Process equipment will be supplied loose, i.e. not on skids, for installation by others.

**Fixed Capacity Flow** 

8.5 MGD

### **Budgetary System Price**

US\$ 8,620,000.00

### Validity

Pricing is for budgetary purposes only and does not constitute a final offer of sale.

### Taxes and Duties

No taxes or duties or brokerage are included in the above pricing. Any taxes, duties, tariffs of any type are for the account of the Purchaser.

### **Field Service**

The equipment pricing above includes Field Service from ZENON Technicians for assistance with the equipment installation, commissioning, operator training and process start-up assistance.

Any additional days of Field Service required will be at ZENON's Standard per diem rate of US\$650 per day plus living and traveling expenses.

### **Terms of Payment**

The budgetary pricing quoted in this proposal is based on the following payment terms

- 15% with Purchase Order
- 30% on submission of General Arrangement Drawings
- 50% on shipment of equipment or notification that equipment is ready to ship (partial shipments permitted)
- 5% within 30 days of equipment start up or within 60 days of equipment shipment whichever is sooner.

### Performance & Maintenance Bonds

The cost of providing performance or maintenance bonds is not included. If required these will be at additional cost.

### **Equipment Shipment and Delivery**

A typical drawing submission and equipment shipment schedule is indicated below. Drawing submission milestones and equipment shipment periods are quoted from the date of acceptance of a formal signed Purchase Order:

Submission of GA Drawings:

8 to 10 weeks from acceptance of P.O

Drawing Approval:

3 weeks from submission of drawings

Equipment Shipment:

24 to 26 weeks from acceptance of P.O.

Plant Operation Manuals:

2 weeks after shipment of equipment to site

Operator Training:

When preferred by Customer but no later than

2 weeks prior to the scheduled plant start-up

The above delivery schedule is presented based on current workload backlogs and production capacity. If a formal purchase order is not received within the period of validity of this proposal, the delivery schedule is subject to review and adjustment.

The delivery period quoted is presented based on review <u>and approval</u> of equipment shop drawings within a two (2) week period. Any delay in approval of shop drawings may affect the proposed shipment schedule.

### **Quality Basis**

For the purposes of establishing a quality basis for equipment supply, reference is made herein to particular equipment manufactured by certain suppliers. The term "or equal" where used herein shall be deemed to mean "ZENON Approved Equivalent". ZENON reserves the right to substitute equipment that ZENON considers to be of equal quality and suitability for the intended application from alternative suppliers to those named herein. With regard to determining the suitability or otherwise of any particular manufacturer's equipment for inclusion as part of the ZeeWeed® system, ZENON's decision shall be final.

### **Definitions**

For the purposes of defining milestone dates for payments, commencement of equipment warranties and turnover of responsibility for the operation of equipment from ZENON to the OWNER, the following definitions apply:

Commissioning

Commissioning of the plant is defined as the date when wastewater first flows through the plant.

Substantial Completion Substantial Completion is defined as the date when the equipment supplied first meets the required treatment quality and quantities as defined in accordance with Performance Warranties. In cases where the equipment supplied is designed for a future plant design capacity it is the responsibility of the Owner to provide wastewater in sufficient quantities for the performance tests within the time frame outlined in section 7.0 (Performance Warranties).

On the date Substantial Completion is achieved:

- 1. Equipment and Process Warranties start.
- Responsibility for the plant operation transfers from ZENON to the OWNER. 2.
- 3. Holdbacks become due and payable.

**OWNER** 

For the purposes of this document the term "OWNER" shall be also deemed to include the OWNER's appointed agents or assigns who will be responsible for the operation of the equipment / plant / treatment facility.

### **Equipment Drawings, Plans & Specifications**

Unless otherwise specified, ZENON will furnish as part of this order the following types of drawings:

- 1. Process Flow Diagram
- Process and Instrumentation Diagrams 2.
- General Arrangement Drawings showing equipment dimensions and weights required for 3. the equipment foundations (foundations by others), and the utility requirements for the process equipment being furnished by ZENON with the System being supplied.
- Standard sub-vendors dimensional outline drawings for the items of major process 4. equipment (e.g. pumps, blowers, air compressors) which are necessary for the purchaser to complete its engineering and installation.
- Standard sub-vendors equipment cut sheets for the major process equipment and other 5. equipment items (major instruments and system components)
- Electrical Drawings including Single Line Diagrams, Control Panel Layouts and 6. Interconnecting Wiring Diagrams.
- Assembly Drawings including General Equipment Layouts, deemed necessary by ZENON to 7. be required for the Purchaser's field forces to erect the equipment.

### Flow Definitions

For the purposes of defining membrane plant capacity after flow equalization, the following definitions shall apply:

Average daily flow. The average flowrate occurring over a 24-hour period based on total annual flowrate data.

Maximum daily flow. The maximum flowrate that occurs over a 24-hour period based on annual operating data.

<u>Maximum daily four hour flow</u>. The maximum sustained flowrate that occurs over a 4-hour period based on annual operating data.

<u>Peak hourly flow</u>. The peak sustained hourly flowrate occurring during a 24-hour period based on annual operating data.

Minimum daily flow. The minimum flowrate that occurs over a 24-hour period based on annual operating data.

Minimum hourly flow. The minimum sustained hourly flowrate occurring over a 24-hour period based on annual operating data.

<u>Sustained flow.</u> The flowrate value sustained or exceeded for a specified number of consecutive days based on annual operating data.

<u>Maximum monthly average flow</u>. This is the flow that is obtained by taking the month with the highest total flow and dividing by the number of days in that month. It provides information on the highest average flow that can be sustained for a one month period.

### 1.2 STANDARD TERMS AND CONDITIONS

ZENON's Standard Terms and Conditions apply.

### ZENON STANDARD TERMS AND CONDITIONS

Seller desires to provide its Customers with prompt and efficient service. However, to negotiate individually the Terms and Conditions of each Sales contract would substantially impair Seller's ability to provide such service. Accordingly, Products and Services furnished by Seller are sold only on the Terms and Conditions stated herein. Notwithstanding any terms or conditions on Customer's order, Seller's performance of any contract is expressly made conditional on Customer's agreement to Seller's Terms and Conditions of Sale unless otherwise specially agreed to in writing by Seller. In the absence of such agreement, commencement of performance and/or shipment shall be for Customer's convenience only and shall not be deemed or construed to be acceptance of Customer's Terms and Conditions, or any of them. If a contract is not earlier formed by mutual agreement in writing, acceptance of any Product or Service shall be deemed acceptance of the Terms and Conditions stated herein. All contracts for the Sale of Products shall be construed under and governed by the law of the location of Seller's plant at Burlington, Ontario, Canada.

### **QUOTATION AND PRICES**

All quotations are subject to the Terms and Conditions stated herein as well as any additional Terms and Conditions that may appear on the face hereof. In the case of a conflict between the Terms and Conditions stated herein and those appearing on the face hereof, the latter shall control. Seller's prices and quotations are subject to the following:

- a) All published prices are subject to change without notice.
- b) UNLESS OTHERWISE SPECIFIED IN WRITING, ALL QUOTATIONS EXPIRE THIRTY (30) DAYS AFTER DATE THEREOF, MAY BE TERMINATED EARLIER BY NOTICE AND CONSTITUTE ONLY SOLICITATIONS FOR OFFER TO PURCHASE; further, budgetary quotations and estimates are for preliminary information only and shall neither constitute offers, nor impose any obligation or liability upon Seller.
- c) Unless otherwise stated in writing by Seller, all prices quoted shall be exclusive of transportation, insurance, taxes (including, without limitation, any sales, use, or similar tax, and any tax levied on or assessed to Seller after Product shipment by reason of Seller's retention of a security interest as provided herein), license fees, customs fees, duties and other charges related thereto and Customer shall report and pay any and all such shipping charges, premiums, taxes, fees, duties and other charges related thereto, and shall hold Seller harmless therefrom, provided that, if Seller, in its sole discretion, chooses to make any such payment, Customer shall reimburse Seller in full upon demand.
- Stenographic, typographical and clerical errors are subject to correction.
- e) Prices quoted are for Products only and do not include technical data, proprietary right of any kind, patent rights, qualification, environmental or other than Seller's standard tests and other than Seller's normal domestic commercial packaging unless expressly agreed to in writing by Seller.
- f) Published weights and dimensions are approximate only. Certified dimension drawings can be obtained upon request. Manuals, drawings or other documentation required hereupon must be referenced specifically.

This is merely a quotation, and the technology disclosed herein may be covered by one or more ZENON Environmental Inc. (ZENON) patents or patent applications. Any disclosure in this offer does not hereby grant, and nothing contained in the offer shall obligate ZENON to grant, an option to obtain a license to any technology or any other rights under any patent now or hereafter owned or controlled by ZENON.

### TERMS OF PAYMENT

Unless credit is granted or otherwise specified in writing, payment is due upon shipment. All payments on approved credit accounts

shall be due in full thirty (30) days from date of invoice. Past due balances shall be subject to a service charge of 1-1/2% per month (18% per annum), but not more than the amounts allowed by law. Partial shipments will be billed as made and payments therefor are subject to the above terms. Payment shall not be withheld for delay in delivery of required documentation unless a separate price is stated therefor, and then only to the extent of the price stated for such undelivered documentation. Seller may cancel or delay delivery of Products in the event Customer fails to make prompt payment therefor, or in the event of an arrearage in Customer's account with Seller. Seller hereby retains a security interest in the Products finished until Customer has made payment in full in accordance with the terms hereof. Customer shall cooperate fully with Seller to execute such documents and to accomplish such filings and/or recordings thereof as Seller may deem necessary for the protection of Seller's interest in the Products furnished.

### TRANSPORTATION AND RISK OF LOSS

Transportation will normally follow Customer's shipping instructions, but Seller reserves the right to ship Products freight collect and to select the means of transportation and routing when Customer's instructions are deemed unsuitable. Unless otherwise advised, Seller may insure to full value of the Products or declare full value thereof to the transportation company at the time of shipment and all freight and insurance costs shall be for Customer's account. Risk of loss and/or damage shall pass to Customer at the FOB point, which shall be the point of manufacture or such other place as Seller shall specify in writing, notwithstanding installation by or under supervision of Seller. Confiscation or destruction of, or damage to, Products shall not release, reduce or in any way affect the liability of Customer therefor. All Products must be inspected upon receipt and claims should be filed with the transportation company when there is evidence of shipping damage, either concealed or external. Notwithstanding any defect or nonconformity, or any other matter, risk or loss and/or damage shall remain with the Customer until the Products are returned at Customer's expense to such place as Seller may designate in writing. Customer, at its expense, shall fully insure Products against all loss and/or damage until Seller has been paid in full therefor, or the Products have been returned, for whatever reason, to Seller.

### PERFORMANCE

Seller will make all reasonable effort to observe its dates indicated for performance. However, Seller shall not be liable in any way because of any delay in performance hereupon due to unforeseen circumstances or to causes beyond its control, including, without limitation, strike, lockout, riot, war, fire, act of God, accident, failure or breakdown of components necessary to order completion, subcontractor, supplier or customer caused delays, inability to obtain or substantial rises in the price of labour, materials or manufacturing facilities, curtailment of, or failure to obtain sufficient, electrical or other energy supplies, or compliance with any law, regulation or order, whether valid or invalid of any cognizant governmental body or any instrument thereof whether now existing or hereafter created. Performance shall be deemed suspended during, and extended for, such time as any such circumstances or causes delay its execution. Whenever such circumstances or causes are remedied. Seller will make, and Customer shall accept, performances hereupon. In addition, Seller's inventories and current production must be allocated so as to comply with applicable Government regulations. In the absence of such regulations, Seller reserves the right, in its sole discretion, to allocate inventories and current production and substitute suitable materials when, in its opinion, such allocation or substitution is necessary due to such circumstances or causes. No penalty clause of any kind shall be effective. As used herein, "performance" shall include, without limitations, fabrication, shipment, delivery, assembly, installation, testing, and warranty repair or replacement as applicable.

### ACCEPTANCE

The furnishing by Seller of a Product to the Customer shall constitute acceptance of that Product by Customer, unless notice of defect or nonconformity is received by Seller within thirty (30) days of receipt of the Product at Customer's designated receiving address; provided that, for Product for which Seller agrees in writing to

erform acceptance testing after installation, the completion of deller's applicable acceptance tests, or execution of Seller's acceptance form by Customer, shall constitute acceptance of the Product by Customer. Notwithstanding the foregoing, any use of a Product by Customer, its agents, employees, contractors or licensees for any purpose, after receipt thereof, shall constitute acceptance of that Product by Customer. Seller may repair or, at its option, replace defective or non-conforming parts after receipt of notice of defect or nonconformity.

### ASSIGNMENTS AND TERMINATIONS

Any assignment by Customer of any contract hereupon without the express written consent of Seller is void. No order may be terminated by Customer except by mutual agreement in writing. Terminations by mutual agreement are subject to the following

- Customer will pay, at applicable contract prices, for all Products which are completely manufactured and allocable to Customer at the time of Seller's receipt of notice of
- Customer will pay all costs, direct and indirect, which have been incurred by Seller with regard to Products which have not been completely manufactured at the time of Seller's receipt of notice of termination.
- Customer will pay a termination charge on all other determined costs and other charges. To reduce termination charges, Seller will divert completed parts, material or work-in-process from terminated contracts to other Customer's whenever, in Seller's sole discretion, it is practicable to do so.

### PATENTS AND OTHER INDUSTRIAL PROPERTY

Seller will hold Customer harmless, as set forth herein, in respect to any claim that the design or manufacture of any Product in Seller's commercial line of Products, or manufactured to specifications set y Seller and furnished herein, constitutes an infringement of any atent or other industrial property rights of the United States or Canada. Seller will pay all damages and costs, either awarded in a suit or paid, in Seller's sole discretion, by way of settlement, which are based on such claim of infringement, provided that Seller is notified promptly in writing of such claim of infringement but there is no liability whatsoever herein with respect to any claims settled by Customer without Seller's prior written consent. In the event that Seller is required to hold Customer harmless hereupon, Seller that Seller is required to hold Customer harmless hereupon, Seller will, in its sole discretion and at its own expense, either procure for Customer the right to continue using said Product, replace it with a non-infringing product, or remove it and refund an equitable portion of the selling price and transportation costs thereof. THIS SHALL CONSTITUTE SELLER'S ENTIRE LIABILITY FOR ANY CLAIM BASED UPON OR RELATED TO ANY ALLEGED INFRINGEMENT OF ANY PATENT OR OTHER INDUSTRIAL RIGHTS. Customer shall hold Seller harmless against any expense, loss, costs or damages resulting from claimed infringement of patents, trademarks, or other industrial property rights arising out of compliance by Seller with Customer's designs, specifications. Or instructions. SELLER DISCLAIMS LIABILITY FOR U.S. OR CANADIAN PATENT OR COPYRIGHT INFRINGEMENT ARISING FROM USE OR MANUFACTURE BY ANYONE OF INVENTIONS IN CONNECTION WITH PRODUCTS OR SERVICES SOLD, USED, OR INTENDED FOR SALE OR USE, IN PERFORMING CONTRACTS WITH THE UNITED STATES OR CANADA. OR CANADA.

### WARRANTY

1. Unless otherwise agreed to in writing, Seller warrants its Products to be free from defects in material or workmanship for a period of 12 months from the shipment of Product by Seller, provided that such Product are used, cleaned and maintained in accordance with the Seller's instructions. This warranty does

- not apply to normally replaceable parts or components such as filter cartridges, pump seals, membranes etc., (see below for membrane warranties).
- 2. Customer undertakes to give immediate notice to Seller if goods or performance appear defective and to provide Seller with reasonable opportunity to make inspections and tests. If Seller is not at fault, Customer shall pay Seller the costs and expenses of the inspections and tests.
- 3. Seller's obligations under this warranty is limited to the repair or replacement at its factory, or any device or part thereof which shall prove to have been thus defective. If Customer asks Seller to replace defective parts at Customer's premises. Customer agrees to pay for any traveling time and expenses, plus the Seller's labour to complete the replacement/repair.
- 4. Goods shall not be returned to Seller without Seller's permission. Seller will provide Customer with a "Return Material Authorization" number to use for returned goods. All returns are F.O.B. - Burlington, Ontario, Canada.
- 5. Warranty on the membranes applies only if the membrane element(s) has been operated and cleaned according to Seller's instructions. When either permeate or concentrate flow drops by 10% from the original rates at the same operating conditions, cleaning must be initiated or the warranty will be null and void. Elements must be clean and be kept moist. They should be shipped to Seller in water-tight bags and must be protected from freezing. WARNING – if element conditions of use given in Seller's instructions are not followed, the warranty will be null and void. and void.

IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, WARRANTIES OF FITNESS FOR PARTICULAR PURPOSE, USE, OR APPLICATION, AND ALL OTHER OBLIGATIONS OR LIABILITIES ON THE PART OF THE SELLER, UNLESS SUCH OTHER WARRANTIES, OBLIGATIONS OR LIABILITIES ARE EXPRESSLY AGREED TO IN WRITING BY SELLER, ARE NULL AND VOID.

### DAMAGES AND LIABILITY

SELLER'S LIABILITY FOR DAMAGES SHALL NOT EXCEED THE PAYMENT, IF ANY, RECEIVED BY SELLER FOR THE UNIT OF PRODUCT OR SERVICE FURNISHED OR TO BE FURNISHED, AS THE CASE MAY BE, WHICH IS THE SUBJECT OF CLAIM OR DISPUTE. IN NO EVENT WILL SELLER BE LIABLE FOR INCIDENTAL, CONSEQUENTIAL OR SPECIAL DAMAGES, OF ANY KIND, HOWEVER CAUSED, ARISING OUT OF, OR IN ANY WAY CONNECTED WITH, THE PRODUCTS FURNISHED BY SELLER TO CUSTOMER.

### DISPUTES

All disputes under any contract concerning Products not otherwise resolved between Seller and Customer shall be resolved in a court of competent jurisdiction for the location of Seller's plant at Burlington, Ontario, Canada, and no other place. Provided that, in Seller's sole discretion, such action may be heard in some other place designated by Seller, if necessary to acquire jurisdiction over third persons, so that the dispute can be resolved in one action. Customer hereby consents to the jurisdiction of such court or courts and agrees to appear in any such action upon written notice thereof. No action, regardless of form arising out of, or in any way connected with, the Products or Services furnished by Seller, may be brought by Customer more than one (1) year after the cause of action has occurred. If any part, provision or clause of the Terms and Conditions of Sale, or the application thereof to any person or circumstances, is held invalid, void or unenforceable, such holding shall not affect and shall leave valid all other parts, provisions, clauses or applications of the Terms and Conditions remaining, and clauses or applications of the Terms and Conditions remaining, and to this end the Terms and Conditions shall be treated as severable.

### 2.0 ZENOGEM® PROCESS DESCRIPTION

The ZenoGem® Process is a proprietary ZENON technology that consists of a suspended growth biological reactor integrated with a microfiltration membrane system, based on the ZeeWeed® hollow fibre membrane. Essentially, the microfiltration system replaces the solids separation function of secondary clarifiers and sand filters in a conventional activated sludge system.

The ZeeWeed[®] microfiltration membranes are typically submerged in the aeration tank, in direct contact with the mixed liquor. Through the use of a suction duty pump, a vacuum is applied to a header connecting the membranes. The vacuum draws the treated water through the hollow fibre microfiltration membranes and into the pump. Treated water is then discharged by the pump. The energy associated with permeate pumping is relatively small. An airflow is introduced to the bottom of the membrane module producing turbulence which scours the external surface of the hollow fibres transferring rejected solids away from the membrane surface. This airflow also provides a large portion of the process biological oxygen requirements; the remainder is provided by a diffused aeration system. Waste sludge is pumped directly from the aeration tank.

The ZenoGem® technology effectively overcomes the problems associated with poor settling of sludge in conventional activated sludge processes. The ZenoGem® technology permits bioreactor operation with considerably higher mixed liquor solids concentrations than conventional activated sludge systems which are limited by sludge settling. The ZenoGem® process is typically operated at a mixed liquor suspended solids (MLSS) concentration in the range of 8,000 to 12,000 mg/L. The elevated biomass concentrations allow for highly effective removal of both soluble and particulate biodegradable material in the waste stream. The ZenoGem® process combines the unit operations of aeration, secondary clarification and filtration into a single process, simplifying operation and greatly reducing space requirements.

Since the ZenoGem® process can be operated at elevated MLSS concentrations, extended solids retention times (SRTs) are readily attainable. Accurate SRT control is very simple since no solids are lost in the effluent. Many municipal ZenoGem® plants are operated with SRTs exceeding 25 days. These extended SRTs ensure complete nitrification even under extreme cold weather operating conditions. At extended SRTs, sludge yields can be considerably less than conventional aerobic processes, due to endogenous decay.

The ZenoGem[®] process is readily adapted for denitrification if total nitrogen removal is required. The elevated levels of biomass become readily anoxic in the absence of aeration, ensuring high denitrification rates. An upstream anoxic zone and mixer readily accommodates denitrification; this can be incorporated in the ZenoGem[®] tank design.

The ZenoGem® process is ideally suited for phosphorus removal, where required. Through the addition of metal salts such as alum or ferric chloride to the raw wastewater or mixed liquor, soluble phosphorus in the waste stream can be precipitated. The ZeeWeed® membranes have a pore size that provides an absolute barrier to the discharge of precipitated phosphorus. The phosphorus is retained in the mixed liquor and removed with the waste activated sludge. The ZenoGem® process can reliably achieve

significantly lower effluent phosphorus concentrations than conventional municipal treatment processes.

### 3.0 ZENOGEM® ADVANTAGES

### Effluent Quality

Depending on the specific application and design requirements, a ZenoGem[®] plant can achieve either high quality nitrified effluent or with the addition of an anoxic zone, high quality denitrified effluent. Phosphorus removal is readily achieved through the addition of metal salts to the feed wastewater or mixed liquor. Typically, ZenoGem[®] systems are capable of achieving the following effluent qualities.

 $\begin{array}{lll} BOD & <2 \text{ mg/L}^{\text{Note 1}} \\ TSS & <2 \text{ mg/L}^{\text{Note 1}} \\ TN & <10 \text{ mg/L}^{\text{Note 1}} \text{ (cool climate)} \\ & <3 \text{ mg/L}^{\text{Note 1}} \text{ (hot climate)} \\ TP & <0.1 \text{ mg/L} \\ Turbidity & <1 \text{ NTU} \\ Total \text{ Coliforms} & <100 \text{ cfu/100 mL} \\ Faecal \text{ Coliforms} & <20 \text{ cfu/ 100 mL} \end{array}$ 

Note 1: The information provided in this section of the proposal is general only and is intended only to indicate what is the ZeeWeed®/ZenoGem® Membrane Wastewater Treatment Technology is capable of achieving. For the specific design treated wastewater quality, based on the consideration of specific raw wastewater characteristics and the required discharge criteria for the treated effluent, refer to Section 4.0.

### Compact Plant

The ZenoGem® process can operate at mixed liquor suspended solids (MLSS) concentrations in the range of 8,000 to 12,000 mg/L, which is substantially greater than conventional activated sludge processes. This allows for conventional organic loading rates to be achieved with much lower hydraulic residence times. In addition, the ZenoGem® process requires a single tank in which aeration and solids separation are both achieved. If required, sludge digestion can also be accomplished in this tank. This single stage process results in an overall plant footprint substantially smaller than conventional tertiary wastewater treatment plants.

### Expandability

Since the ZenoGem[®] equipment is modular in nature, plant expansion can be phased. Civil works can be designed for ultimate flow while membranes are added in phases as plant operating capacity dictates.

### Simple Operation

Since the ZenoGem® process uses membranes to perform solid/liquid separation, there is no requirement for sludge to settle and thus no need for a secondary clarifier or polishing filters. Sludge is wasted directly from the aeration tank at a solids concentration in the range of 1.5 to 2.0 percent solids. The result is a single system which is simple to operate.

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### Lower Sludge Yield

The ZenoGem® plant can be operated at extended solids retention times (SRTs) allowing for lower net solids yields than conventional municipal treatment processes.

### **Process Reliability**

Since the ZenoGem® plant is typically operated at low organic loading rates and the membrane provides an absolute barrier to particulate discharge, ZenoGem® effluent quality is not susceptible to hydraulic or organic surges which can negatively affect effluent quality in conventional activated sludge and fixed film plants. At periods of low flow (and organic load), the sludge within the reactor basin simply digests itself, without affecting the effluent quality.

### Advantages of an "Outside-In" Membrane

### a) Resistance To Fouling

The ZeeWeed® membrane is an outside-in membrane where the flow of water is from the outside of the membrane to the inside of the hollow fibre, meaning that the inside only sees clean, microfiltered water. The bacteria and inert solids to be removed from the wastewater remain outside the membrane and never enter the membrane to cause fouling.

### b) Low Energy

Being immersed allows for the operation of the ZeeWeed® membrane under a slight vacuum (suction) instead of under positive pressure like other membranes on the market. The ZeeWeed® membrane operates under a vacuum of between -2 to -8 psi. The pump energy requirements to achieve this vacuum are relatively small.

### **Exceptional Membrane Durability**

The ZeeWeed® membrane has been designed for exceptional durability and resistance to breakage. To achieve this high level of membrane durability ZENON utilizes a patented internal support to which the membrane is bonded. This support strengthens the membrane and protects it against tearing and breakage without reducing its flux capacity.

### 4.0 ZENOGEM® PLANT

The proposed ZenoGem® plant is designed to continuously treat an average daily flow of 8.5 MGD. The ZenoGem® plant is a six (6) train system and the capacity of each parallel train is .1.417 MGD.

The ZenoGem® plant is capable of producing an effluent meeting or exceeding the following criteria:

### Design Parameters

Firm Capcity Flow	8.5 MG	D		
Parameter BOD TSS TKN TN TP	Influent 200 150 46 46 9	mg/L mg/L mg/L mg/L mg/L	<u>Effluent</u>	mg/L mg/L mg/L mg/L mg/L
Wastewater Temperature	≥20	°C	≥20	°C

### **Equipment Selection**

The main process equipment for the ZenoGem® plant, including permeate pumping equipment, membrane air scour blowers and supplemental aeration blowers, CIP membrane cleaning system, air extraction system, controls and other miscellaneous items, is designed for installation within equipment buildings (equipment buildings not included in ZENON's scope of supply).

The sizing of the main process equipment selected is as follows. Section 5.0 gives further details of the equipment items included by ZENON for this project.

### Bioreactor (Process) Tank(s)

The bioreactors will consist of concrete tanks (concrete tanks not in ZENON's scope of supply). Six (6) individual process streams are required, each with the minimum dimensions of 160 ft long x 20 ft wide x 17 ft high (15 ft SWD). Each process tank will have an anoxic/aerobic and an aerated membrane zone separated by a baffle (baffle not included in ZENON's scope of supply).

Membrane cassettes will be supported by structural steel beams that will span between the concrete walls of the process tanks and will use the concrete walls as supports.

### Process Tanks

Total Bioreactor Volume	2.154	MUS gallons
Design HRT	6	hours
Number of Membrane Trains	6	
Number of Bioreactor Tanks	6	
Volume of Each Bioreactor	359,000	US gallons

Length of Each Bioreactor	160	ft
Width of Each Bioreactor	20	ft
Side Water Depth of Bioreactor	15	ft

Note: Process tanks may be of concrete construction or fabricated steel tanks, whichever suits the client's preferences and are not included in ZENON's scope of supply.

Tank dimensions are preliminary only and may change slightly once final detail design commences.

### ZW-500 Micro-Filtration Membrane Modules

Membrane Design Flux	11.55	gfd at Fixed Capacity Daily flow
Rate Minimum Design Liquid	20	°C
Temperature # Membrane Modules # Membrane Cassettes	1104 138	(8 modules per Cassette)

ZENON is committed to continuous development and invests continuously in research to develop better and higher flux membranes. For this reason ZENON reserves the right to change the number of membranes in its design, if by way of membrane technology improvements the permeability or operating flux rates of the membranes have been improved. This does not change the warranty since ZENON guarantees the design flow capacity and the operational performance of the membrane system.

### Aeration System

The design air flow required for the fine bubble aeration system used with the ZenoGem® plant is approximately 5,550 scfm at the plant design capacity.

### Aeration Blowers

Three (3) aeration blowers are included - two duty blower and one common stand-by unit. Each blower has a design capacity of 2,775 scfm. The aeration blowers are equipped with variable frequency drives (VFDs) to allow air delivery and dissolved oxygen levels in the wastewater to be controlled according to the system air requirements.

### Membrane Air Blowers

Four (4) blowers are included for the membrane air scouring - four duty blower and one common standby unit The total required capacity of membrane air scouring is approximately 21,983 scfm. Each blower has a design capacity of 7,328 scfm.

### Permeate Pumps

Seven (7) permeate pumps are included - six duty pumps and two shelf spares. Each pump is designed for a maximum permeate flow of 1,110 USgpm. The pumps will also provide backpulse flow at 2,880 USgpm The speed of the permeate pumps is controlled via VFD units according to the liquid level in the bioreactor tanks.

### Sludge Recirculation Pumps

Seven (7) sludge recirculation pumps are included - six duty pumps and one shelf spare. Each pump is designed for a flow of 3,395 USgpm. The recirculation pumps are provided with VFD units to allow flow variation to allow optimization of the system process performance.

### Sludge Wasting Pumps

Seven (7) sludge wasting pumps are included – eight duty pumps and one shelf spare. Each pump is designed for a flow of 207 USgpm.

### Miscellaneous

No influent screening facilities are included. There must be existing screening and/or primary clarifiers upstream of what will become the ZenoGem® aeration (bioreactor) tanks. The screening equipment must be capable of screening particles down to 3.0 mm to prevent hair and other stringy materials from tangling with the membranes.

Equipment Installation cost is not included.

### 5.0 MAJOR EQUIPMENT

The list below summarizes the major equipment and the quantities of items included for the ZenoGem[®] plant design.

SCOPE OF SUPPLY SYNOPSIS  for the ZenoGem® Plant	***	train to the second second second second second second second second second second second second second second	
Item	Size	Units	Quantity
Raw Wastewater Feed	Gize	Units	Quantity
Raw Influent Feed Pumps			Not Incl.
Inlet & Discharge Isolating Valves			Not Incl.
Discharge Check Valves			Not Incl.
Piping Manifold			Not Incl.
Wet Well Level Switches			Not Incl.
VFD's			Not Incl.
Raw Water Screening			1,001,001
Raw Influent Screen			Not Incl.
Raw Influent Grinder			Not Incl.
Raw Influent Flowmeter			Not Incl.
Raw Influent Flow Control Flowmeter			Not Incl.
Raw Influent Flow Control Valve			Not Incl.
Membranes/Membrane Cassettes			
Individual Membrane Modules			1,104
Membrane Cassettes			138
Process Tanks & Frames			
Membrane Support Beam(s)			Included
Process Tanks			Not Incl.
Permeate Collection Headers			6
Air Scour Headers			6
Permeate Pumps			
Permeate Pumps	1,110	USgpm	7
VFD's	50	HP	6
Piping Manifold			Not Incl.
Valves			Incl.
Air Extraction System			
Air Removal Separation Columns			6
Vacuum Pumps	22	scfm	3
Backpulse System			
Backpulse Water Storage Tank	5,160	gallons	2
Hypochlorite Storage Tank	106	gallons	1
Hypochlorite Feed Pumps	6.08	USgphr	3

Item  DID To L. Cl. 100	Size	Units	Quantity
DIP Tank Cleaning System			
DIP Tank			Not Incl.
Chemical Wash Pump			Incl.
Monorail & Pulley/Hoist for membrane removal			Not Incl.
Sludge Recirculation			1 vot mor.
Sludge Recirculation Pumps	3,935	USgpm	7
Inlet & Discharge Isolation Valves			N/A
Discharge Check Valves			N/A
Piping			Not Incl.
VFD's	2.5	HP	6
Sludge Wasting		111	- 0
Sludge Wasting Pumps	206.6	USgpm	7
Inlet & Discharge Isolation Valves	200.0	OSgpin	6
Discharge Check Valves		<del></del>	
Piping	<del></del>		6 Not Incl.
VFD's	<del></del>		
Air Blowers			N/A
Membrane Air Scour Blowers incl. Silencers	7,328		
Inlet & Discharge Isolation Valves	7,320	scfm	4
Discharge Check Valves		<del>                                     </del>	4
Inlet Control Valves			4
Aeration System Blowers incl. Silencers	2 775		4
Inlet & Discharge Isolation Valves	2,775	scfm	3
Discharge Check Valves		<del> </del>	3
VFD's	200		3
Biological Aeration System	200	hp	3
Fine Bubble Diffuser System	<del></del>		
hosphorus Removal System (if required)			Incl.
Chemical Storage Tank	0.600	TIC	<del></del>
Chemical Feed Pumps	9,600	USg	1
nstruments	112	USgphr	2
Permeate Flowmeters		<del>  </del>	<u> </u>
Permeate Header Pressure Transducers			6
Process Tank Level Transmitters			6
Process Tank Level Transmitters  Process Tank Level Switches		1	6
Dissolved Oxygen Sensors			48
pH Transmitters			6
Turbidimeters			N/A
			6
Turbidimeter Calibration Kits			1

Membrane Blower Flow Switches	1 4	1
Aeration Blower Flow Switches		
		- 1

Item	Size	Units	Quantita
Permeate Pump Pressure Gauges	- Size	Units	Quantity 6
Membrane Air Scour Blower Pressure Gauges		<del></del>	4
Aeration Blower Pressure Gauges		-	3
Recirculation Pump Pressure Gauges		<del> </del>	<del>+</del> -
Sludge Wasting Pump Pressure Gauges			N/A
Control Panel	<del> </del>		6
PLC-based Control Panel		<u> </u>	<u> </u>
Back-Up PLC			<del></del>
Electrical		<del>                                     </del>	Not Incl.
MCC Panel		<u> </u>	NI . I
Miscellaneous		<u> </u>	Not Incl.
Air Compressor	<del></del>		
Air Drier		<u> </u>	2
Field Service Allowed			1
Installation Supervision		<del></del>	Days
Mechanical Checkout		<u> </u>	10
Operator Training			6
Process Start-Up			8
Commissioning	<del>-  </del>		3
TOTAL MAN-DAYS			3
TOTAL No. TRIPS			30
Freight			3
Delivery to Site			<del></del>
			Incl.

### 6.0 ATTACHMENTS

Plant Power Consumption and Estimated Yearly Operating Cost

Table 9.1.1 Connected Power and Estimated Power Consumption at Average Day Flow

32,173 m3/day	32,173 m3/dey
nSgpd	nSgpd
8,500,132	8,500,132
Average Day Flow	Maximum Day Flow
	32,173

								ŀ			-	Motor	Equipment	Hours / Day	Energy
FEM TOTAL	OTAL	EQUIPMENT		# Operating	Design Capacity	Discharge Head	ort.		Motor	Fautoment	Connected	Efficiency	KW	Continuous	Cost
*	ΔŢ			Pumps			Efficiency	GHE BHE	<u> </u>	BHP	Ŧ	, %		Operation	per year
				Blowers etc.											
H		***************************************							,	-			•	24.00	
-		Raw Water/Wastewater Screen	n/a		- 1	7 00 10	8	12.20	20.00	73.76	120.00	90.20	86 09	22.40	37,392
~	9	Permeate Pumps	By Zenon	9.00	1	- 1	8.5	67.71	3 5					6 40	
1 0		Backwilse Pumos	n/a		2,880.00 USgpm	- 1	3	10.00	3 8	00 000	150.00	9.30	16 68	24.00	890'68
,	00	Decironistion Pumps	By Zenon	00.9	3,935.25 USgpm	10:00 #	25.00		3 3	10.00	8	27.50	16.25	200	890
4 4	3 8	Chidae Wasting Pilmas	By Zenon	6.00	206.60 USgpm	30.00 #	80.08	3.18	200	/O.8L	33.08	3	2.0	24.00	
0	3	Situação Vrascing Lamba	e/u	-	i	25.00 #	55.00					, 10	201.00	8 8	237 213
٥	,	Heleci water Funks	Dy Zanon	300	5 520 00 sdm	4.25 psi	r/a	153.32	250.00	459.97	1,000:00	ON CR	CD 105	3 3	110 671
7	4.00	Membrane Air Scour Blowers	Dy Zenon	000			n/a	114.89	150.00	229 77	450.00	94.20	181 89	3 3	100,611
80	300		D) 291011	20.3	1		n/a			•				3 8	
_ თ		Miscellaneous Air Blowers	DAL			1	6/4				٠	80.00	,	24.00	,
2	9		By Zenon	00.9	- 1	- 1	_	205	300	4.50	00.6	87.50	3.84	24.00	2,520
-	3.00		By Zenon	2.00	- 1	- 1	1	27.3	200	200	000	100 00	003	3.20	n
- (	3 6		By Zenon	1.50	0.066 USgpm	20 00 #	n/a	0.03	300	500	3	200		0.03	
7 9	3.00		0/9		- USgpm	30.00 ft	55.00			-					
2		Constant and Constant	6/4		USgpm							0000		20.45	245
4		CIP Chemical Meterning			4 140   ISanm	50.00 tt	n/a	0.50	0.50	0.50	8	3	200	3	1
5	2.00		By Zenon	30.1	1	# 00.03	e/u		0.03	,	,	100.00		8	
91		Chemical Feed #1 System #2 - Metering	n/a		- 1.	1			0.03			100.00	,	24.00	-
17		Chemical Feed #1 System #3 - Metering	n/a		- 1	- 1	174		200			100.00		24.00	
18		Chemical Feed #1 System #4 - Metering	n/a	1	. 1	- 1	TVS.	76 76	2 2	18 75	20 00	_	15.31	9 9	2,515
18	200		By Zenon	1.00	_	100.00	Iva	2	3					9 9	•
19	100		By Zenon	1.00	75.00 sdm		Z/A				1.34		9.1	24.00	657
8	100	O Controls & Instrumentation	By Zenon								134		100	24.00	657
21/2	100	0 Miscellaneous	By Zenon												
											181277	  £			
		Total Connected Power								010 44	0		731.64	κ×	
		Total Operating Power								210.44				SCO NSS	460,661
		Total Operating Cost													

Notes

per kW.hr

Power Consumption of other plant equipment required (raw water feed pumps, high lift pumps etc.) is not included by ZENON.
Where operating efficiencies are not known, the equipment operating power is assumed to be 75% of the motor nameplate power rating.
The operating hours for the permeate pump are corrected for the downtime during backpulse cycles (and Membrane Pressure Decay Test Cycles if applicable).

Motor Efficiencies indicated are typical only. Efficiencies used are usually within 2% of actual when motor is operating within 50-100% of its full load rating Operation of Air Compressor is assumed to be only 25% of time 16.59 BHP 1,664 USgpm @ 30.00 ft TDH = Permeate Pump Backpulses every 15 mins for 30 seconds

Operation of the Sodium Hypochiorite Pumps is intermittent operation for 25% of time is used for energy calculation 6.536 BHP per 1,000 scfm per psig. Blower Energy Consumption Estimated as The motor sizes in the above table are preliminary only and estimated based on the information available at the time of preparing this proposal. It must be understood that at the time of proposal preparation, final headlosses or pressure drops in piping systems have not been calculated accurately Motor sizes are subject to confirmation (and if necessary adjustment) during final design. Use of the above information for sking or selection of any ancillary equipment is entirely at the USER's own risk. Whilst the motor sizes indicated above are ZENON's best estimate based on design criteria assumed during preparation of the proposal, ZENON accepts no responsibility for the absolute accuracy of the information contained herein.

Table 9.2.2 Estimated Total Annual Operating Cost
City of McAllen (ZenoGem) Rev 1
Average Day Flow 8,500,132 USgpd
Maximum Day Flow 8,500,132 USgpd 32,173 m3/day 32,173 m3/day

tem		<u>,</u>	Cost per year	
Electrical Equipment - Zenon		Calculated at Average Day Flow	460,661	US\$
Electrical Equipment - Others				US\$
Backpulse Chemicals	Sodium Hypochlorite	Calculated at Average Day Flow	8,232	US\$
CIP Chemical #1	MC-1		220	US\$
CIP Chemical #2	Sodium Hypochlorite - 250 mg/L		304	US\$
Chemical #1	Aluminum Sulphate (Liquid @ 48.5%)	Calculated at Average Day Flow	201,764	US\$
Suggested Membrane Accrual			329,311	US\$
Estimated Total Annual Opera	ating Cost		1,000,492	US\$

Notes	Backpuise Chemical Consumption		Sodium Hypoc	hlorite
140100	Sodium Hypochlorite Consumption		71.91	Litres per day
	Sodium Hypochlorite Consumption		26,248	Litres per year
	Sodium Hypochlorite Cost	US\$	0.31	per Litre
	Social Trypochione Cost	-	0.0.	po
	CIP Cleaning Chemical #1		MC-1	_
	Design Dosage		2,000.00	mg/L
	Solution Concentration		50.00	%
	Specific Gravity		1.240	
	Wash Frequency		1.00	times / year
	Chemical Consumption per Wash (all tan	ks)	131.54	Litres
	Total Annual Chemical Consumption		131.54	
	Chemical Cost	US\$	1.67	per Litre
	Chemical Cost	US\$	2.70	per kg
	CtP Cleaning Chemical #2		Sodium Hypoc	:hlorite - 250 mg/L
	Design Dosage		250.00	
	Solution Concentration		10.80	%
	Specific Gravity		1,168	
	Wash Frequency		12.00	times / year
	Chemical Consumption per Wash (all tan	ks\	80.81	Litres
	Total Annual Chemical Consumption	,	969.76	Litres
	Chemical Cost	US\$		per Litre
	Charlica Cook			F
	CIP Neutralization Chemical #1		Sodium Hydro	
	Design Dosage		•	mg/L
	Solution Concentration		50.00%	
	Specific Gravity		1.520	
	Wash Frequency		1.00	times / year
	Chemical Consumption per Wash (all tar	iks)	-	Litres
	Total Annual Chemical Consumption			Litres
	Chemical Cost	US\$		per Litre
	Chemical Cost	US\$	0.47	per kg
	CIP Neutralization Chemical #2		Sodium Bisuli	ite
	Design Dosage			mg/L
	Solution Concentration		38.00%	-
	Specific Gravity		1.290	
	Wash Frequency		12.00	times / year
	Chemical Consumption per Wash (all tar	iks)	•	Litres
	Total Annual Chemical Consumption	•		Litres
	Chemical Cost	US\$	0.06	per Litre
	Chemical Cost	US\$	0.55	per kg
	Chemical Feed System #1		Aluminum Su	lphate (Liquid @ 48.5%)
	Design Dosage			mg/L
	Solution Concentration		48.50	
	Specific Gravity		1.335	
	Chemical Consumption		4,472.10	Litres per day
	Chemical Consumption		1,632,315	
	Chemical Cost	USS		
	Chemical Cost	USS		
	Original Cost	004	·	1 ha

12/07/1999 : 3:59 PM

### **PROPOSAL**

990212-M



845 Harrington Court, Burlington, Ontario, L7N 3P3 Tel. No.: (905) 639-6320 Fax No.: (905) 639-1812

DATE:

November 29, 1999

PREPARED FOR:

CH2M Hill

ATTENTION:

Mr. Jim Lozier

FROM:

Roland Lamoca

Re:

McAllen South WWTP

### ITEMS COVERED:

Packaged water treatment plant incorporating Reverse Osmosis treatment.

The plant is to be designed for three trains, each with an effluent flowrate of 2.3 MGD of final product from the Reverse Osmosis system. The projected recovery rates from each unit operations have been established in the specifications provided CH2M Hill and are estimated at 80% - 85%.

The preliminary design criteria are:

One Reverse Osmosis Train

Effluent Flow (MGD)

2.3 MGD

System Recovery (%)

80 - 85 %

### SCOPE OF SUPPLY:

### Three Reverse Osmosis System Trains - Each:

- eighty-eight (88) 6 element long membrane pressure vessels, 400 psi rating, arranged in a 50:28:10 array configuration for optimal cross-flow conditions.
- five hundred twenty eight (528) Hydranautics spiral wrap high rejection type membrane modules. Six membrane elements will be installed in each membrane pressure vessel. A total membrane area of 192,720 ft2 is supplied,
- one (1) duplexed 5 micron prefiltration cartridge system, isolatable for cartridge replacement,
- one (1) horizontal, split case centrifugal-type feed supply pump, 1880 USgpm @530 ftH, 1780 rpm TEFC, Goulds or equal,

### **PROPOSAL**



990153-M

845 Harrington Court, Burlington, Ontario, L7N 3P3 Tel. No.: (905) 639-6320 Fax No.: (905) 639-1812

- one (1) sodium metabisulfite chemical injection system with chlorine analyzer, Prominent or equal,
- one (1) antiscalant injection system, Prominent or equal,
- one (1) acid injection system with pH probe and controller, Prominent or equal,
- one (1) lot process instrumentation for the RO system, includes feed conductivity, permeate conductivity, permeate flow transmitter, concentrate flow transmitter, concentrate pressure transmitter, membrane feed pressure transmitter, permeate pressure transmitter, feed supply residual chlorine analyzer, and feed supply pH.
- one (1) lot process valves for the RO system, Bray or equal,
- one (1) lot process low pressure piping Sched. 10 304 SS,
- one (1) lot process high pressure piping Sched. 10 316 SS,
- one (1) NEMA 4 PLC based control panel (Allen Bradley PLC complete with PanelView Operator Interface),

### One Reverse Osmosis System Clean In Place Tank:

 one (1) skid mounted membrane cleaning tank with prefiltration cartridge system, and cleaning pump (316SS Goulds, or equal) and controls,

### PRICE ESTIMATE:

US\$ 2,300,000.00

### **TERMS:**

- All pricing in Dollars, FOB ZENON Burlington, Ontario.
- Duty, if applicable, is not included. Any Taxes, if applicable, are extra.
- Shipment shall be 20 24 weeks from receipt of order.
- Payment Terms: 15% with order, 25% on submission of drawings, 50% on equipment shipment, 10 % on start-up or thirty days whichever is less, all terms are Net 30.
- ZENON's Terms and Conditions as attached shall apply.
- This is a budgetary estimate only at this time, and does not constitute a binding offer of supply by ZENON.





JAN 18 2000



CH2M HILL PHUENIX Water for the World

Project Number: 990212-M

TO:

CH2M Hill

FAX:

480 966 9450

ATTN.:

Ms. Fair Miller

PHONE:

480 966-8577 x 249

cc:

Jim Lozier - CH2M Hill Dave Bingham - ZENON cc FAX:

DATE:

18 January, 2000

# OF PAGES

(Including Cover): 5

FROM:

Roland Lamoca

Manager, Technical Support Division

Industrial Wastewater Division

SUBJECT: McAllen Reverse Osmosis Operating Cost Estimates - Revision

Hello Fair and Jim;

The operating costs have been revisied based on our discussions today.

The higher pressure we had included previously accounted for a 5 year operation with a 10% flux decline/year. This is typical of ZENON's experience, but may not reflect recent experiences you have noted. As agreed upon, the following have been based on your experiences.

Please feel free to contact ZENON if you have any questions.

Regards,

Roland Lamoca

If you do not receive all pages, please call Lisa Ashton as soon as possible.

ZENON Environmental Systems Inc.

845 Harrington Court, Burlington, Ontario, L7N 3P3 Telephone: (905) 639-6320 Fax: (905) 639-1812 email: rlamoca@zenonenv.comhttp://www.zenonenv.com

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## Operating Cost Summary

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	Cons
	ower
	Ъ

### Annual Cost, US\$

### Steam Consumption

Assumptions (based on \$0.07 /kW-hr)

\$357,495 /year

(based on \$5.00 /1000 lb)

(based on current prices, subject to change)

\$190,179 /year

Membrane Replacement (every 5 years)

Cartridge Filter Replacement (once per year) (based on current prices, subject to change)

\$130,698 /year \$24,637 /year

Annual Process Chemical Cost

Annual Cleaning Chemical Cost

\$15,144 /year

# TOTAL ANNUAL OPERATING COSTS

Water Volume Produced Annually:

(based on 4800 USgpm)

Operating Cost per Thousand Gallons

### \$718,152 /year

2,522.9 Million gallons per year

\$0.28 /1000 gallons

: 835838465

## Operating Cost - Power

### Power Consumption

Total power	1.1 kW 581.9 kW Intermittent use
<b>Power/unit</b>	0.2 kW 194.0 kW 93.3 kW
# of units	total of 6 total of 3 total of 1
Unit	Pre-treatment Chemical Mixers, 0.25 Hp 1st Pass - R.O. Process Pump, 260 Hp Reverse Osmosis CIP Pump, 125 Hp

RO process pump pressure is 165 psi @ 1883 USgpm each

Total Power	Total Power Requirement	583 kW
Operating period	Days / year	365 days
	Hours / day	24 hours
Utility	Utility rate (\$/kW-hr)	\$0.07 /kW-hr
Annual Power Consumption Cost	umption Cost	\$357,495 /year

:0010088466

	- 45	,

18/01/00

# Operating Cost - Process Chemicals

## **Process Chemical Requirements**

Annual Cost, US\$	\$5,745 /year \$2,594 /year \$122,359 /year
Unit Cost, US\$	\$0.04 /lb \$0.25 /lb \$3.27 /litre
Annual Consumption	10374 USgallons 12288 USgallons 9892 USgallons
Chemical	Sulphuric acid Sodium bisulphite Antiscalant

Annual Process Chemical Cost \$130,698 /year

# Operating Cost - Cleaning Chemicals

# Cleaning Chemicals / Preservative Requirements

Annual Cost, US\$	\$8,658 /year \$1,738 /year \$4,748 /year
Unit Cost, US\$	\$2.29 /kg \$3.06 /kg \$5.01 /litre
Annual Consumption	3788 kilograms 568 kilograms 947 litre
Chemical	Organic Acid: MC-1 Alkali Surfactant: MC-4 Sanitizer: MP-1

Annual Cleaning Chemical Cost \$15,144 /year

Use or disclosure of the Information on this page is subject to the restrictions on the title page of this proposal.

Item		ZenoGem '		7
Fine Screening	\$			ZeeWeed*
ZenoGem* / ZeeWeed* System*	S	20,000		20,0
Bioreactor/Equalization / ZeeWeed Tanks	\$	8,620,000		5,075,0
		1,307,808	\$	162,4
Installation	\$	2 155 000	-	
		2,155,000	\$_	1,268,
Installed Costs Subtotal	\$	12,102,808	-	
ZenoGem / ZeeWeed Equipment Building	\$	288,000		6,526,2
Installed Costs and Building Cost Subtotal	\$	12,390,808		84,0
Unit Process Noncomponent Costs			+	6,610,2
Yard Piping Allowance (10%)	\$	1,239,081	\$	664
Site Electrical Allowance (8%) Site I&C Allowance (5%)	\$	991,265		661,0 528,8
Site Civil Allowance (5%)	\$	619,540	\$	330,5
Unit Process Subtotal	\$	619,540		330,5
Contingency (10%)	\$	15,860,234	\$	8,461,0
Contractor Overhead & Mark-up (10%)	\$	1,586,023		846,1
Total Construction Cost	\$	1,586,023		846,1
Ingineering & Administration (15%)	\$	19,032,281		10,153,2
Total Capital Cost	\$	2,854,842	\$	1,522,9
Total Capital Unit Cost (\$/1,000 gallon)	\$	21,887,123	\$	11,676,2
Amortized Capital Cost (20yr @ 6.5%)	\$	9.28		4.
3-5-1- (20)1 & 6.5%)	\$	1,986,396	\$	1,059,6
peration & Maintenance Costs				
Major Chemical Costs				
Backpulse Chemicals: Sodium Hypochlorite			<u></u>	
CIP Chemical #1: MC-1	\$	8,232		8,2
CIP Chemical #2: Sodium Hypochlorite (250 mg/L)	\$	220		3,2
Oir Neutralization Chemical #1. Sodium Hydrovida	\$	304		4,4
CIP Neutralization Chemical #2: Sodium Bisulfite	\$		\$	1
			\$	1
ajor Power Costs				
Screening	\$		_	
Aeration Basins	\$		\$	
Permeate Pumps	\$	37,392	\$	419,00
Recirculation Pumps	\$	59,068		36,90
Sludge Wasting Pumps	\$	890		74,50
Membrane Air Scour Blowers	\$	237,213		
Process Air Blowers	\$	119,501	\$	114,44
Anoxic Zone Mixers	\$	- 10,001	\$	
Air Separation System Vacuum Pumps	\$	2,520	<u> </u>	
Backpulse Sodium Hypochlorite - Metering	\$		\$	2,52
Chemical Feed #1 - Metering Air Compressors	\$	245		<del></del>
Air Driers	\$	2,515		2,51
Controls & Instrumentation	\$		\$	2,31
Miscellaneous	\$		\$	65
viiscellalieous	\$		\$	65
embrane Replacement Costs				
bor	\$	329,311	\$	190,90
	\$		\$	218,40
tal Annual Operation & Maintenance Cost				
tal Annual O&M Unit Cost (\$/1,000 gallon)	- \$	1,079,528	\$	1,076,672
tal Annual Cost	\$	0.46	\$	0.46
tal Annual Unit Cost (\$/1,000 gallon)	\$		\$	2,136,370
etailed listing of components comprising ZenoGem and Zee	\$	1.30	:	

### DEMONSTATION TESTING OF ZENOGEM AND REVERSE OSMOSIS FOR INDIRECT POTABLE REUSE

### FINAL TECHNICAL REPORT ADDENDUM

City of McAllen, TX

by

James C. Lozier, P.E. and Angela M. Fernandez, E.I.T CH2M HILL

Cooperative Assistance Agreement No. 98-FC-81-0073

Desalination Research and Development Program Report No. 51 February 2000

U.S. DEPARTMENT OF THE INTERIOR
Bureau of Reclamation
Technical Service Center
Water Treatment Engineering and Research Group

**Draft and Final Report Comments** 

D-8230 ACM-1.10

Mr. James C. Lozier, P.E. Project Manager, CH2M Hill 1620 Fountainhead Parkway Suite 550 Tempe AZ 85282

Re: Agreement Number 98FC810073, Desalination Research and Development Program Report No. 51, Draft Report Review Comments

Dear Mr. Lozier:

Thank you for presenting the data and results from the project titled "Demonstration Testing of Zenogem and Reverse Osmosis For Indirect Potable Reuse" on December 14, 1999. Ms. Angie Fernandez also deserves to be recognized for her valuable assistance in both the presentation and in overseeing the piloting activities.

Attached, for your consideration are select comments, both editorial and technical, which I believe will strengthen the final report's technology transfer capability.

If you have any questions on these comments, please do not hesitate to call at 303 445-2254.

Sincerely,

Robert A. Jurenka, P.E.

Attachment

cc: D-7810 (Mulligan)

cc: Mr. Wm. Bart Hines, City of McAllen TX,

bc: D-8230 (Price, Jurenka)

Review Comments, "Demonstration Testing of Zenogem and Reverse Osmosis For Indirect Potable Reuse"

City of McAllen TX,
Cooperative Agreement No. 98-FC-81-0073

The following are suggested editorial comments:

- 1. Complete the acknowledgment page
- 2. Complete all missing appendices
- 3. Page 1-7: Shouldn't the last paragraph be indented?
- 4. Page 1-8 second line: delete "should".
- 5. Page 3-3, section 3.2.1: To the second paragraph:

  Third line, delete "...can (or may)" and replacewith
  "may";

4th line: add of after "value" and delete the parentheses;

5th line: move ">3 months" ahead of "infrequently" and replace"during" with "at";

7th line: replace "insitu" to "in situ"

- 6. Section 3.2.2, last line: delete the parentheses.
- 7. Page 3-7: section 3.3.2:
- a. second paragraph: The lat 2 sentences seem redundent considering the previous section. Can they be rephrased?
  - b. third paragraph antiscalent is mispelled.
- c.  $5^{\text{th}}$  paragrpah: replace in the  $3^{\text{rd}}$  line, "can (or may)" with "may".

The following are recommended technical comments:

### 1. Page 1-1:

- a. To the first paragraph, add: This Program sponsors research in an effort to lower the cost of treatment technologies.
- b. The second paragraph describes UV treatment (also listed on page 1-5), however, there is nothing in the conclusions regarding it. Obviously the decision was made to use chloramines both in the pilot and in the projections of costs at full scale. Add sentences in the report describing why this disinfectant technique was replaced.

- c. Second paragraph, last sentence: define "intended purpose".
- d. Restructure the  $4^{th}$  paragraph by either using a colon and numbering the items, or make each point a separate sentence.
- 2. Page 1-3, re: El Paso Texas paragraph: Add to the end of the next to the last sentence..."because the increased pumping is lowering the aquifer level to the higher salinity water source."
- 3. Page 1-4: In section 1-2 the second sentence: It is recommended that "...from the Rio Grande River, water rights that it shares with multiple parties, including..." be replaced with, "...from water rights in the Rio Grande River that it shares with multiple parties including ..."

### 4. Page 1-6: Section 1.5.1,

- a. second bullet: List the WWTP effluent limits (as shown on page 4-1, section 4.1.1) and reference the table, by table number and page number, of the final values.
- b. The term maintenance clean or acid maintenance clean is used here and on pages 1-7, 1-9, 3-3, etc. Define this term prior to its use or add as a reference the page number where it is defined.

### 5. Page 1-7:

a. First point: At the start of this point, replace "Flow Peaking" with "Flow peaking tests were run over a 24 hour period of time to simulate the types of peak loading conditions that typically occur in a conventional wastewater treatment plant. However, this (significantly)...

Also, at the end of this point add, "As a result, additional means must be provided such as ?? to ensure that slower changes in loading occur to give the membrane bioreactor system time to react to the change in loading."

- b. Second Bullet: Clarify what "intermittent aeration" is. Delete the words, "treatment conditions resulting in".
  - c. Third bullet: Add a reference to the table of results.
- d. Add a fourth bullet with the following: Per Table 5-16, Zenogem permeate was of lesser quality and the RO permeate was of greatert quality than the City's existing raw water source.
  - e. To the end of the fourth bullet add the following

sentence: However, the RO system always removed any remaining coliform regardless of the MF or UF pretreatment. Also, add the table number and page on which it can be found for the results supporting this conclusion.

- f. Add one last point about how cost effective and how much smaller the footprint area is as compared to a conventional treatment system.
- g. Section 1.5.2 RO System, Bullet 1,  $4^{\rm th}$  line: Add "in the predominant form of monochloramine..." after "Continuos disinfection..." Also, add the table numbers and pages on which to be found for the results supporting this conclusion.

### 6. pages 1-7 and 1-8,

- a. RO System, bullet 2: If 80% is "higher" as stated, state what the normal or target recovery rate is. Also, clarify why the 80% recovery rate is described differently between bullet 2 and bullet 3. (I.E. higher vs design).
- b. RO System, bullet 3: Will blending the RO product water with Zenogem product water be acceptable in terms of final effluent quality? With MF not retaining all viruses, isn't there a concern over exposure to small viruses? Also, specify what type of limits are being described on page 1-8, line 2.
- c. Section 1.6.1.4 Replace the first sentence with: "This research project tested one MBR product, Zenon Corporations ZenoGem MF system The ZenoGem UF system should be retested at the 10g/L MLSS level. Also, other..."
- d. Section 1.6.1.4: Add to the end of this paragraph: "The Bureau of Reclamation is currently funding Montgomery Watson and the City of San Diego to perform research testing of this type, comparing the performance of ZenoGem and Mitsubishi systems.
- e. Section 1.6.2.1: add the approximate concentration of an aluminum based coagulant to complete the words in parentheses.
- f. Section 1.6.2.2 After the last word, "feasible", add "if the scale control can be resolved as discussed herein."
- 7. Section 2: There are many other RO treatment objectives which the Bureau would like to see listed. As shown in Jim's presentation graphic, these include:
- a. RO Feed: RO feed must be < 2 ntu; SDI<3; and heterotrophic plate count <500 cfu/ml.
- b. McAllen discharge limits: TSS<0.5 mg/L; CBOD5 <10 and NH3-n <3 mg/L.

- c. Reliability of Operation
- d. RO concentrate: Determine the impacts of the RO concentrate.
- 8. Page 3-1: Add consistency so that all figures are called figures and not exhibits.
- 9. Can a vacuum pump be added to Exhibit 3.2?
- 10. Page 3-3, section 3.2.1:
- a. State the complete downtime to the system for the backpulsing that occurs every 10 minutes? State the complete downtime for the maintenance cleans described as at least 75 minutes? Add the total downtime from the backpulsing and the maintenance cleans and clarify if a full scale plant must be slightly oversized to produce a given flowrate (ie plant reliability factor of 90-95%).
- b. Define permeation in the first paragrpah, second to the last line.
- c. To the second paragraph's 9th line: delete the first "membrane" in this line. Also, clarify ..." clean membrane initial level". Is the post-chemically cleaned TMP level reduced to a clean membrane level or restored to a new membrane level.
- 11. Page 3-4, 3rd line: Replace "The RO" with "The thin film composite RO". Section 3.2.3: Change the last sentence to read: This allows for a higher organic loading of wastewater in the treatment system.
- 12. Page 3-5: Specify the micron rating of the cartridge filter in the second line of the second paragraph. Also, in the second paragraph's 4th line, delete the first two "ands". Lastly, can the cleaning skid be shown in Exhibit 3.3?
- 13. Page 3-6: Change the TDS sum of ions values for 12/14 and 12/18 to 1465 and 1473. Also, to the second bullet, state the recommended antiscalent from the Hydranautics program.
- 14. Page 3-8: delete the parentheses in the first line. Also, clarify why in the last line, "Zenogem system" is in parentheses.
- 15. Page 3-9: Define stages A through D.
- 16. Page 4-1: Secton 4-1 item 4: Where in the report are the results of each of these tasks? Where are the air requirements summarized for the process for cleaning and for nutrient consumption?

- 17. Tables 4.1 and 4.2: Clarify under responsible party, what WWTP and WTP really means (ie who)?
- 18. Page 5-7: Add a figure, after Exhibit 5.2, of a complete project timeline that shows both the Zenogem and the RO stages. Then to all of the RO performance figures, modify the timeline hours to match this new complete timeline (ie RO start at 1200 hours instead of 0 hours). This will eliminate confusion arising from the fact that stages A-D differ depending on the equipment.
- 19. Section 5: Can a nitrification rate be determined and added? Also, on Page 5-8, from line 6 replace the second paragraph with:
- Table 5.5 presents the target and average operating conditions for th ZenoGem system during Stage C operation. At the beginning of this stage (after 1,783 hours of operation), the MLSS concentration was decreased to 10 g/L. From 4,130 to 4,158 hours (Event 3) and from 4,225 and 4,326 hours (Event 4) of operation, the permeate flow rate was increased by 46 percent (6.5 to 9.5 gpm) for a period of 6 hours (flow peaking) over a 24-hour period to simulate the types of hydraulic peak loading that typically occur in a conventional wastewater plant. This was done to determine if the MBR system could be operational in the same manner or if additional means would have to be provided to ensure slower changes in the loading to give the MBR time to react to the change in loading. After 4,876 hours of operation, the membrane module height was raised (Event 6) to minimize sludge accumulation in the module aerators during non-aeration periods. From 4,894 to 5,136 hours (Event 7) of operation, air was cycled to the membrane tank at an applied rate of 30 scfm for 10 seconds on and 10 seconds off to evaluate the effect of intermittent aeration on operations and membrane performance. From 5,136 to 5,187 hours
- 20. Page 5-14, Permeability Section: Replace the first paragraph with the following:
- Stages A C. Figure 5.3 illustrates changes in ZenoGem permeability as a function of operating time (TMP is also shown for reference). During Stage B, permeability (normalized to  $20^{\circ}\text{C}$ ) steadily decreased as TMP increased, indicating membrane fouling at the higher MLSS concentration of 13 g/L. In contrast, at the lower MLSS concentration in Stage C, permeability increased and remained relatively constant as TMP very gradually increased. However during the flow peaking test periods (Events 3, 4 and 8), permeability sharply decreased as TMP increased. This showed that the MBR system must be provided with a means of ensuring slower changes in peak loading. The peak loading can not be raised as quickly over a 24 hour period as fast as a conventional wastewater treatment plant. These results also confirm that ZenoGem operation at 10 g/L MLSS concentration and constant flux provides

for very stable system operation.

- 21. Page 5-48, last paragraph: State why no useful data was obtained from the instruments. Section 5.3.3, RO Water Quality Impacts: Add to this section the table of RO manufacturer's membrane information and data, which Jim had shown in the presentation.
- 22. Page 5-50, section 5.4: Elaborate what is said in the very last paragraph. Define mass loading basis and be very specific here so non-technical readers can understand what is being concluded.
- 23. Page 5-51, section 5-5: change existing to exist in lkine 1. Also, delete the s on parameters in line 7. Lastly add conclusions for the data being displayed in Table 5-16 and for any blending being contemplated.

### 24. Cost Section 6:

- a. Add text describing the overall conclusions of that can be derived from this study. Would a MBR system be cost effective or not, and under what conditions?
  - b. What labor rate was used in the cost estimates?
- c. Clarify if the costs presented are based to a certain month/year.
  - d. Where is the square footage of the building?

Bob Jurenka' - Re: RE: McAllen Integrity Report Status

Pagn 1

From:

Bob Jurenka

To:

ibr8dm00;jlozier@[CH2M.com]

Date:

Fri, Feb 25, 2000 1:12 PM

Subject:

Re: RE: McAllen Integrity Report Status

Jim: Michelle is wrapping up the integrity report, having received internal review comments.

After receiving the final McAllen report, here are 4 final review comments which will need clarification. After you read these, lets discuss how best to finalize the report.

-1. Table 6.1: It is not clear why the Zenogem process needs 1.3M of new tankage.

2. Table 6.1: The economic analysis says @ 6.5% was the rate used. My tables of A/P values show a 7 % value was used.

3. Table 6.1: The total unit cost of \$2.10 per 1,000 is questioned. Explain how this was derived and not 1.98/1000 gallons.

4. Page 6-9, 3rd sentence: Provide more details to better justify the costs associated for new tankage, and the difference between \$1.3M vs \$0.1M for zeeweed.

Thanks

PS: We are still looking at ways to assist with autopsy work for Sherman. Hope the knee is doing better.

Bob Jurenka, 303 445-2254

### Fernandez, Angie/PHX

From:

Fboudkirk@cs.com

ે ૧t:

December 20, 1999 12:32 PM

Afernand@ch2m.com

Subject:

McAllen

Angie,

Here are a few editorial comments on the December 7, draft report. Bear in mind that the EPRI folks who take the time to read it will be starting from ground zero and the don't know ZeeWeed from break tank.

Page 1-1, UV is mentioned here but nowhere else in the report. I suggest deleting these references to UV as the project did not address its use.

Page 1-3 first paragraph; for the sake of current info, the San Vincente Reservoir recharge project was killed because of politics. It might be resurrected but as of August, 1999 the politicians killed it claiming it was an Anglo plot to make Hispanics drink dirty water!

Page 3-2. Somewhere we need to have a glossary for abbreviations like CIP. I know what it means but a person not informed about membranes might not. Also the term break tank is not is not self explanatory. On this page we have labeled an aerobic tank in the diagram while in the text a "aeration tank" is mentioned as well as "a 200 gallon calibrated receiving tank." These descriptions should be consistent with the diagram.

ge 3-3. In the first and second paragraphs a "process tank" is mentioned. I eve the words "membrane tank" should be used for consistency's sake. Also in the second paragraph it might be helpful to mention that the maintenance cleaning flush liquid is drained to waste.

The last sentence of this paragraph might confuse a first time reader as it seems to imply that maintenance cleaning is not a part of "normal" operation. I would suggest the sentence read "Maintenance cleaning is done insitu and is necessary to sustain the membrane flux." (Is it insitu or in situ?)

Page 3-4, I think adding the words "For pilot testing" to the beginning of the last sentence of the first paragraph sentence would avoid confusion about how a full-scale system would operate. The terms CBOD5, MLSS, MLVSS, SRT, etc., show the need for a glossary.

Page 3-5, The pore size of the cartridge filter would be informative as would be a few words about why the filter is required.

Page 3-6, I believe the samples were taken in 1998 not 1999 as the charts says.

Page 4-4, Again, since my audience is made up mainly of power plant types who are given job assignments outside their technical field of expertise, I would prefer the last sentence of the first paragraph of section 4.33 to "could adversely affect marine ecology." If that is indeed what we mean.

Page 4-5, ASL should be define in a glossary.

rage 5-18, Here we introduce an other CBOD term which I think is the same as CBOD5. If not it needs to be define in a glossary.

Page 5-20, Ditto for BOD5.

Page 5-52, Some explanation why some chemical element levels in the ZenoGem Permeate are higher than in the raw water would be helpful. Could these be a seasonal variation?

### **ATTACHMENT 1**

Texas Water Development Board Review Comments: City of McAllen Contract No. 99-483-276

Board Staff offers the following comments.

The study shows that effluent, and especially effluent with high hardness and high total dissolved solids, can be brought to drinking water standards for between \$1.24 and \$1.80 per thousand gallons. The study shows that using the Zenon technologies tested, that existing wastewater treatment plant capacities could be significantly increased (doubled or tripled) at costs similar to new plants (under \$1.5 per gallon/day of capacity). Savings may be realized by removing the possible impediments of new construction such as site location and additional distribution lines by utilizing the Zenon technology in existing wastewater treatment plants. The report also shows that Zenon technology can produce a higher quality treated effluent.

### Specific recommended changes to the report include:

- 1. Table 5.16 should be modified so that applicable safe drinking water act criteria are included in the table for reference.
- The summary tables of water quality parameters compared to target values shown in the overheads at the Denver meeting should be included in the summary of this report.
- The cost for the micro filtration process, including costs in dollars per thousand gallons should be broken out separately from the RO costs in Chapter 6.
- 4.4.2 Sampling and Analysis: 1st paragraph, 3rd sentence (The WWTP....) mentions one of the samples collected is nitrate/nitrate nitrogen. This is redundant. This should be changed to read nitrate/nitrite nitrogen.
- The Texas Water Development Board should be acknowledged as helping to fund this study.