Information Collection Rule Treatment Study Summary Report

City of Fort Lauderdale, Florida

June, 1999

MONTGOMERY WATSON

ICR TREATMENT STUDY SUMMARY REPORT

Evaluation of Nanofiltration Using the Rapid Bench Scale Membrane Test Methodology for Compliance with the Information Collection Rule

Conducted during the period: February 1998 – March 1999

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Plant Name: Fiveash Water Treatment Plant
Plant ICR #: 296

Section 1
Summary and Conclusions

Four quarters of nanofiltration (NF) testing using pretreated Biscayne Aquifer water were successfully completed. Cartridge filtration was the only NF pretreatment employed. Two NF membranes (TFC-SR and NTR7450) were used to complete Information Collection Rule (ICR) treatment study requirements using the Rapid Bench Scale Membrane Test (RBSMT) methodology.

The Koch-Fluid Systems TFC-SR membrane achieved higher removals of total organic carbon (TOC), and precursor materials to trihalomethanes and haloacetic acids compared to the Hydranautics NTR7450 membrane. For example, the highest recorded TOC concentration in the TFC-SR membrane permeate was only 0.6 mg/L. In comparison, the highest TOC concentration measured in the NTR7450 membrane permeate was 4.3 mg/L.

Under the SDS conditions employed, the highest SDSTTHM and SDSHAA(5) concentrations in the TFC-SR membrane permeate were 37.5 μg/L and 5.9 μg/L, respectively. However, the highest SDSTTHM and SDSHAA(5) concentrations in the NTR7450 membrane permeate were approximately 106 μg/L and 40 μg/L, respectively. Therefore, SDSTTHM and SDSHAA(5) concentrations in the TFC-SR membrane permeate waters were always below the placeholders under Stage II of the D/DBP rule (40 μg/L for TTHMs and 30 μg/L for HAA(5)) even when free chlorine was employed as the final disinfectant. However, on some occasions SDSTHM and SDSHAA(5) concentrations in the NTR7450 membrane permeate waters were above the placeholders under Stage II of the D/DBP rule when free chlorine was used as the final disinfectant.

The TFC-SR membrane also achieved higher removals of a variety of inorganic water quality parameters compared to the NTR7450 membrane. For example, the average total hardness in the TFC-SR membrane permeate at 70% feed water recovery was 182 mg/L as $CaCO_3$, whereas the average total hardness in the NTR7450 membrane permeate at 70% feed water recovery was 244 mg/L as $CaCO_3$.

Simple linear regression analysis suggests that there may be seasonal variations in fouling rates for both membranes. Using the RBSMT methodology, membrane chemical cleaning intervals ranged from ~ 80 h – 240 h at 70% feed water recovery and an initial flux of 14.5 gfd. However, more advanced NF membrane pretreatment may result in longer chemical cleaning intervals. Additionally, more research needs to be done to better establish the validity of the RBSMT methodology in terms of it being able to accurately predict membrane fouling rates (and cleaning intervals) observed in full-scale installations. Hence, these membrane fouling rates and cleaning intervals predicted using bench-scale experiments need to be verified at the pilot-scale.

Finally, because the concentrations of most water quality parameters in the TFC-SR and NTR7450 permeates increased with feed water recovery (at constant flux), the transport of dissolved solutes may be controlled by diffusion across these polymeric membranes.

Section 2
Introduction

Objectives. The primary objective of this Information Collection Rule (ICR) treatment study was to evaluate the ability of two nanofiltration (NF) membranes to remove disinfection by-product (DBP) precursor materials and total organic carbon (TOC). Secondary objectives of this treatment study included evaluating inorganics rejection and membrane fouling. Both membrane operation and permeate water quality data from bench-scale experiments conducted using the rapid bench scale membrane test methodology as specified in the *ICR Manual for Bench- and Pilot-Scale Treatment Studies* (EPA 814-B-96-003) are summarized in this report.

Existing water treatment processes. A schematic of the existing water treatment processes for the City of Fort Lauderdale Fiveash Water Treatment Plant is given in the flow diagram in Appendix A. This schematic was generated earlier during the development of the initial sampling plan for the 18 months of DBP/microbiological monitoring under the ICR. The water for NF testing was obtained directly from the Biscayne Aquifer.

Basic engineering and chemical feed data for each unit process are summarized in Tables A.2 and A.3, respectively, also in Appendix A. These tables were also generated earlier using the *ICR Water Utility Database System* (EPA 814-B-96-004) to report the results from the 18 months of DBP/microbiological monitoring under the ICR.

Full-scale plant influent and finished water quality. Under the 18 months of water quality monitoring requirements of the ICR, samples were collected from July 1997 through December 1998 at the City of Fort Lauderdale Fiveash Water Treatment Plant. The data from the influent and finished water of the full-scale plant have been summarized in Tables 1 and 2, respectively.

Table 1. Full-scale influent water quality data.

Parameter	Units	Average	Std. Dev.	Min.	Max.	Count
Temperature	ºC	25.1	1.01	22.5	26.3	18
pH	-	7.24	0.28	6.77	7.80	18
Turbidity	ntu	0.78	1.10	0.09	4.8	18
Alkalinity	mg/L as $CaCO_3$	225	11.6	200	240	18
Total Hardness	mg/L as $CaCO_3$	248	6.06	240	260	18
Calcium Hardness	mg/L as $CaCO_3$	222	8.49	210	240	18
TOC	mg/L	11.8	0.54	10.4	12.5	18
UV_{254}	1/cm	0.464	0.029	0.422	0.512	18
Bromide	µg/L	150	16	130	180	18
TSUVA*	L/(mg-m)	3.93	0.27	3.41	4.31	18

*TSUVA = [UV_{254} (1/m)] / [TOC (mg/L)] and was calculated using matched-pair data.

Table 2. Full-scale finished water quality data.

Parameter	Units	Average	Std Dev	Min	Max	Count
Temperature	ºC	25.2	0.58	23.9	26.0	18
pH	unit	9.17	0.37	7.90	9.55	18
Turbidity	ntu	0.20	0.11	0.06	0.52	18
TOC	mg/L	9.0	0.76	7.20	10.1	18
UV_{254}	1/cm	0.26	0.023	0.231	0.31	18
DS-THM4 [a]	µg/L	57.8	7.35	47.3	65.6	6
DS-HAA5	µg/L	37.3	8.31	27.6	49.1	6
DS-HAA6	µg/L	40.4	9.15	30.1	54.2	6

[a] DS represents distribution system

Section 3
Materials and Methods

ICR bench-scale treatment study apparatus. All bench-scale ICR experiments were conducted using the Rapid Bench Scale Membrane Test (RBSMT) methodology. For these tests, a pressurized cell using a flat membrane sheet was employed. This cell utilized feed and permeate spacers that are also used in spiral-wound elements. The feed water was pumped tangential to the membrane so as to maintain a shear stress on the membrane surface and thereby, limit concentration polarization. A schematic of the apparatus used to conduct the ICR bench-scale NF experiments is shown in Figure 1. Using positive displacement gear pumps for both feed water and recycle water minimized pressure fluctuations. The feed pump head (Cole-Palmer, Vernon Hills, IL, model # 74011-11) was designed for use at high pressure and low flow, whereas the recirculation pump head (Cole-Palmer, Vernon Hills, IL, model # 07002-23) was designed for use at low pressure and high flow. These pumps used helical gears made of Teflon, a low friction material, to reduce any potential loss due to friction on the gears. All tubing, connections, and the membrane cell were fabricated using stainless steel. Dual float rotameters were used to increase the accuracy of the flow measurements. Further, permeate and waste flows were manually measured using a graduated cylinder and a stopwatch.

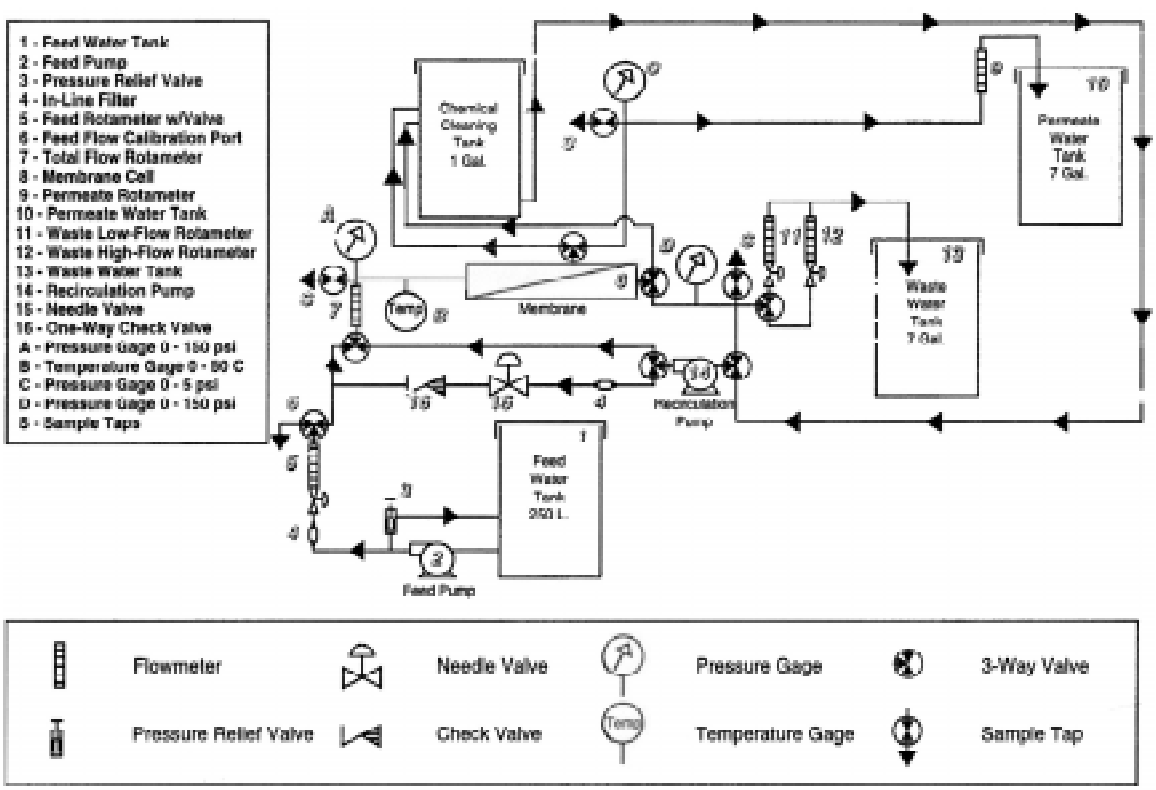


Figure 1. Schematic of the bench-scale NF apparatus

Membranes employed. ICR experiments were conducted using two NF membranes: Hydranautics NTR7450 (Hydranautics Corp., San Diego, CA) and TFC-SR (Koch-Fluid Systems Corp., San Diego, CA). Important characteristics for each membrane (as specified by the manufacturers) are summarized in Table 3.

Table 3. Characteristics of membranes used during ICR testing.

Membrane designation	Manufacturer	Composition	MWCO [a] (Daltons)
NTR7450	Hydranautics Corp.	polysulfone	~ 1,000
TFC-SR	Koch-Fluid Systems	polyamide	300

[a] Denotes Molecular Weight Cut-Off

Membrane cleaning. Membrane cleaning was achieved by circulating a sodium hydroxide solution in deionized water at a pH near 12. In many cases, when the base cleaning was not effective, a sulfuric acid solution in deionized water at a pH of approximately (but not less than) 2.5 was also used. Cleaning was conducted at a temperature of approximately 40 °C. The cleaning solution was initially circulated for 15 minutes at a transmembrane pressure of less than 5 psi. The membrane was then allowed to soak for 30 minutes. Finally, the cleaning solution was circulated again for 10 minutes at a transmembrane pressure of less than 5 psi. The crossflow velocity was maintained near 1 fps during the circulation portion of the cleaning cycle. A pressure-flux profile was also established for both membranes, following chemical cleaning using deionized water. After the base cleaning, the membrane cell was physically removed from the RBSMT apparatus, taken apart, and rinsed with deionized water.

NF feed water and pretreatment. Three, thirty gallon drums were sent to the City of Fort Lauderdale each quarter for feed water sampling for use in ICR testing. Prior to sending the drums, they were cleaned first at high pH (to remove organic and biological contaminants) with sodium hydroxide solution and then at low pH (with sulfuric acid solution) to remove possible metallic deposits After base and acid cleaning, these barrels were thoroughly rinsed with tap water and then dried for a minimum of 24 hours prior to shipment. The drums were then sent to the City of Fort Lauderdale for sampling.

As required by the ICR, water was sampled prior to the first point of continuous oxidant addition. Hence, sample water was taken directly from the Biscayne Aquifer. Prior to the RBSMT experiments, the only pretreatment that was employed on this water was filtration using a 5 µm cartridge filter. A simple schematic of the pretreatment processes employed is given in Figure 2.

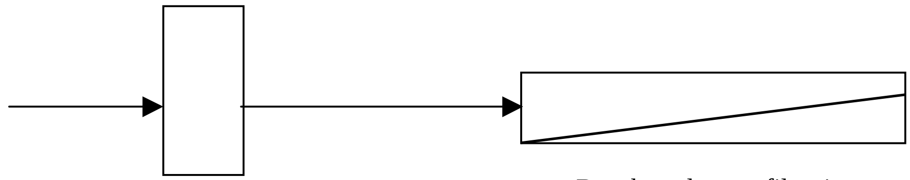


Figure 2. Simple schematic of the pretreatment used prior to bench-scale nanofiltration.

NF feed water samples were collected at the start of the first set of experiments and the end of the second set of RBSMT experiments. These samples were then analyzed for a variety of physical, inorganic, and organic parameters. Table 4 summarizes the membrane feed water quality for all four seasons of testing.

As seen in Table 4, after pretreatment the NF feed water can be classified as a slightly alkaline hard water, having high concentrations of total organic carbon (TOC), simulated distribution system (SDS) haloacetic acid 5 (SDSHAA5[1]), SDS haloacetic acid 9 (SDSHAA9[2]), and SDS total trihalomethanes (SDSTTHM[3]).

Table 4. Summary of NF membrane feed water quality for all four seasons of testing.

Parameter	Units	I quarter	II quarter	III quarter	IV quarter
Alkalinity	mg/L as $CaCO_3$	192	230	300	430
Ca hardness	mg/L as $CaCO_3$	207	270	262	214
Total hardness	mg/L as $CaCO_3$	231	291	316	249
TDS	mg/L	296	303	306	300
Bromide	μg/L	140	130	165	180
Ammonia	mg NH_3-N/L	BMRL [a]	0.11	BMRL [a]	BMRL [a]
SDS Cl_2 demand	mg/L	11.49	8.94	12.12	11.55
TOC	mg/L	11.80	12.40	11.10	13.00
SDS TOX	μg/L	980	1030	1100	1180
SDS TTHM	μg/L	284.55	328.45	409.30	346.05
SDS HAA5	μg/L	183.15	192.90	291.90	247.15
SDS HAA9	μg/L	234.65	239.60	333.85	289.75
UV_{254}	cm^{-1}	0.387	0.410	0.409	0.462
pH	-	8.30	8.00	7.83	8.17
Turbidity	NTU	0.31	0.24	0.32	0.33

[a] Denotes Below Minimum Reporting Level

[1] SDSHAA5 denotes the sum of monochloro, dichloro, trichloro, monobromo and dibromo acetic acids
[2] SDSHAA9 denotes the sum of HAA(5) and tribromo, chlorobromo, dichlorobromo, and chlorodibromo acetic acids
[3] SDSTTHM denotes the sum of chloroform, dichlorobromo methane, chlorodibromo methane and bromoform

Membrane setting. Deionized water (TDS concentration less than ~ 1 mg/L) was filtered at the start of each set of RBSMT experiments for approximately 24 hours. This period is sometimes referred to as "membrane setting." All experiments were conducted at room temperature (~23°C). Thus, any effects caused by seasonal variability in temperature were not reflected in the ICR experiments. A pressure-flux profile was conducted at the end of the first day or the beginning of the second day of testing, prior to switching to the feed water. During these measurements, transmembrane pressure was changed in random order in the range of 0 – 80 psi to reduce systematic biases in calculating the membrane resistance. Results from pressure-flux profiles were modeled using Darcy's law (Eq. 1) where J denotes the permeate flux (m/s), R_m (m^{-1}) denotes the membrane resistance, P_{tm} is the transmembrane pressure (Pa), and μ ($N\text{-}s/m^2$) denotes the absolute viscosity of water.

$$J = \frac{P_{tm}}{\mu R_m} \qquad (1)$$

NF experiments using pretreated Biscayne Aquifer water. Table 5 summarizes the sampling and membrane operational dates for RBSMT experiments that were conducted for both membranes.

Table 5. Quarterly dates of RBSMT experiments.

Quarter	Sampling date	Dates of membrane operation	
		NTR-7450	TFC-SR
I	2/16/98	2/26/98 – 3/5/98	3/8/98 – 3/16/98
II	5/20/98	6/3/98 – 6/11/98	6/12/98 – 6/19/98
III	7/22/98	7/27/98 – 8/3/98	7/31/98 – 8/7/98
IV	12/16/98	1/28/99 – 2/4/99	1/4/99 – 1/11/99

During each quarter, experiments using pretreated Biscayne Aquifer water were conducted continuously for a period of approximately 150 hours with each membrane. The feed water recovery, R_f, for the first experiment (~ 78 h duration) was maintained near 70%. This was followed by experiments where R_f was maintained at values near 90%, 50%, and 30%. As required under the ICR, these experiments were run without any cleaning when changing the feed water recovery. The average experimental conditions (net driving pressure, permeate flux, and water mass transfer coefficient) used for the NTR7450 and TFC-SR membranes during all quarters of testing are summarized in Tables 6 and 7 respectively.

Table 6. Summary of quarterly RBSMT experiments using NTR7450 membrane.

Quarter	Recovery (%)	Net driving pressure (psi)	Permeate flux (gfd)	MTC_w [a] (gfd/psi)
I	71	82	12.3	0.152
I	90	83	11.5	0.146
I	49	83	11.5	0.147
I	28	83	11.3	0.147
II	72	70	14.5	0.106
II	90	70	14.8	0.104
II	51	69	13.9	0.100
II	35	69	13.7	0.100
III	69	66	14.2	0.107
III	89	65	13.1	0.100
III	53	65	13.2	0.100
III	31	64	12.6	0.093
IV	67	58	13.6	0.300
IV	87	58	13.2	0.240
IV	55	56	12.7	0.350
IV	31	54	12.0	0.290

[a] denotes water mass transfer coefficient which is also referred to as the specific flux

Table 7. Summary of quarterly RBSMT experiments using TFC-SR membrane.

Quarter	Recovery (%)	Net driving pressure (psi)	Permeate flux (gfd)	MTC_w (gfd/psi)
I	71	40	13.0	0.354
I	89	37	11.9	0.346
I	52	38	11.8	0.335
I	31	39	12.3	0.343
II	71	65	15.0	0.112
II	90	66	11.8	0.088
II	50	66	11.8	0.087
II	32	67	12.5	0.091
III	69	43	14.2	0.163
III	88	41	13.4	0.161
III	51	42	14.4	0.166
III	30	43	14.3	0.165
IV	71	55	13.1	0.260
IV	90	54	12.1	0.240
IV	56	54	11.7	0.230
IV	34	54	11.7	0.240

Membrane fouling analysis. Membrane fouling was analyzed using only the 70% feed water recovery experiment for both membranes. This experiment was selected because of its extended operation time (~ 78 hours) compared to the other three recoveries (~ 24 hours). Further, the rate of fouling appeared to be highly dependent on the feed water recovery. Hence, using data from all four recoveries in each quarter resulted in very low regression coefficients. Additionally, full-scale plants would be operated at one fixed feed water recovery based either on pilot-scale tests or previous design experience. Therefore, fouling rates were calculated using linear regression using permeate flux data obtained at 70% recovery. Results from this regression analysis were then modeled using a simple equation of a straight line (Eq. 2).

$$J = -mt + b \qquad (2)$$

Where J = permeate flux at room temperature (gfd)
m = fouling rate (gfd/h)
t = time (h)
b = initial permeate flux (gfd)

Cleaning intervals (t_{clean}) were calculated assuming a 20% drop in initial specific flux (Eq. 3).

$$t_{clean} = \frac{0.2b}{m} \qquad (3)$$

Similar calculations can be made for 10% and 15% initial flux declines based on manufacturer recommendations or pilot-scale results for full-scale operation.

Monitoring. Routine monitoring for membrane operation and water quality was conducted according to the recommended minimum EPA requirements as described in Tables 8 and 9 respectively. Flow, pressure, and temperature measurements for feed, permeate, concentrate, and influent were recorded hourly during each recovery. TDS, pH, and UV_{254} were monitored at least three times a day for permeate, feed, and concentrate samples. For most analytes, ICR requirements were exceeded and TDS, UV_{254}, and pH were monitored hourly for permeate, feed, and concentrate samples.

Table 8. ICR recommended minimum monitoring frequencies for the RBSMT.

Routine RBSMT Study Monitoring Requirements					
Parameter	**Feed**	**Permeate**	**Concentrate**	**Influent**	**Recycle**
Flow	none	6xD	6xD	6xD	none
Pressure	none	none	6xD	6xD	none
Temperature	none	none	none	6xD	none
TDS	1xD	3xD	1xD	none	none
pH	1xD	3xD	1xD	none	none
UV_{254}	1xD	3xD	1xD	none	none

1xD – once per 24 hours
3xD – three times per 24 hours
6xD – six times per 24 hours

Water quality parameters listed in Table 9 were analyzed on composite samples collected for each recovery.

Table 9. RBSMT water quality monitoring requirements according to the ICR.

Water Quality Parameters to be Evaluated at Each Recovery			
Parameter	**Feed**	**Permeate**	**Concentrate**
pH	TPR	FTPR	FTPR
Total Hardness	TPR	FTPR	FTPR
Calcium Hardness	TPR	FTPR	FTPR
Alkalinity	TPR	FTPR	FTPR
Total Dissolved Solids	TPR	FTPR	FTPR
Turbidity	TPR	FTPR	FTPR
Total Organic Carbon	TPR	FTPR	FTPR
UV_{254}	TPR	FTPR	FTPR
Bromide	TPR	FTPR	none
SDS-THM4	TPR	FTPR	none
SDS-HAA6	TPR	FTPR	none
SDS-TOX	TPR	FTPR	none
SDS-Cl_2 demand	TPR	FTPR	none

TPR – twice per run
FTPR – five times per run

Simulated distribution system tests. One of the important components of ICR treatment studies was the simulated distribution system (SDS) testing of NF feed and permeate waters. Backup permeate samples were collected overnight during the 70% recovery experiment. These samples were then used to conduct a trial chlorine demand experiment with at least 2 different chlorine doses. Using the predetermined quarterly SDS conditions of temperature, pH, and holding time, the samples were then analyzed for chlorine concentrations using the DPD method. Based on these trial SDS experiments, appropriate chlorine dosages were determined for the actual SDS testing. During this test the sample water was dosed with free chlorine after pH adjustment to obtain a free chlorine residual near 1 mg/L at the conclusion of the incubation period. The samples were then incubated under conditions that closely simulated “average” conditions of the existing distribution system. Following incubation, the chlorinated waters were sampled for THMs, HAAs, and TOX. The SDS conditions employed during the four quarters of testing are summarized in Table 10.

Table 10. Simulated distribution system test conditions used in this study.

Parameter	I quarter	II quarter	III quarter	IV quarter
Disinfectant	Free chlorine	Free chlorine	Free chlorine	Free chlorine
Temperature (°C)	24	24	24	24
pH	8.0	8.0	8.0	8.0
Holding time (hour)	24	24	24	24
Free chlorine residual (mg/L)	~1	~1	~1	~1

Analytical methods and laboratories involved. A list of all analytical methods and the corresponding minimum reporting levels is given in Table 11. All analyses were performed using the methods and QA/QC procedures described in the *DBP/ICR Analytical Methods Manual* (EPA 814-B-96-002, April 1996).

All analytical measurements were made by the operator conducting the RBSMT experiments, by Montgomery Watson Laboratories or by Summers and Hooper, Inc. The analyses performed as well as some information regarding these different laboratory sites are provided in Table 12.

Table 11. Summary of analytical methods and MRLs used in this study.

Analyte	Method	Units	Minimum Reporting Level
Alkalinity	SM 2320 B	mg/L as $CaCO_3$	2
Ammonia	EPA 350.1	mg/L	0.05
Bromide	EPA 300	μg/L	40
Calcium hardness	SM 3500 Ca D	mg/L as $CaCO_3$	5
Total hardness	SM 2340 C	mg/L as $CaCO_3$	5
Chlorine residual	SM 4500 Cl G	mg/L	0.5
pH	SM 4500 H^+ B	-	-
TDS	SM 2510 B (probe)	mg/L	10
Temperature	SM 2550 B	°C	-
Turbidity	SM 2130 B	NTU	0.05
TOC	SM 5310 C	mg/L	0.50
UV_{254}	SM 5910 B	cm^{-1}	0.009
$CHCl_3$, BDCM, DBCM, $CHBr_3$	EPA 524.2	μg/L	1 for each analyte
MCAA, DCAA, TCAA, MBAA, DBAA, TBAA, BCAA, BDCAA, DBCAA	SM 6251 B	μg/L	2, 1, 1, 1, 1, 4, 1, 1, and 2 respectively
TOX	SM 5320 B	μg Cl^-/L	25

Table 12. Laboratory information.

Laboratory	Service dates	Analyses performed	Contact information
Field site	Feb. 3, 1998 – March 2, 1999	Alkalinity, calcium and total hardness, pH, Cl_2 residual, TDS, temperature, turbidity, UV_{254}	Dr. Shankar Chellam Montgomery Watson 560 Herndon Pkwy #300 Herndon, VA 20170
Montgomery Watson Labs	Feb. 3, 1998 – March 2, 1999	Bromide, Ammonia, TOC, HAA, THM, TOX	ICR ID #: CA013 Dr. Andrew Eaton 555 E. Walnut St. Pasadena, CA 91101 Phone: (626) 568-6425 Fax: (626) 568-6324
Summers and Hooper Inc.	Feb. 18, 1999 – Feb. 19, 1999	HAA	ICR ID#: OH033 Mr. Stuart Hooper 6 Knollcrest Drive Cincinnati, OH 45237 Phone: (513) 679-2200 Fax: (513) 679-2201

Section 4
Results and Discussion

MEMBRANE OPERATION

New membrane resistances and cleaning. Results from pressure-flux profiles conducted at the start of the experiments for all quarters of testing using new NTR7450 and TFC-SR membranes are given in Figures 3 and 4 respectively. The linearity of the pressure-flux profiles suggests that compaction effects were negligible for these membranes in the range of pressures used.

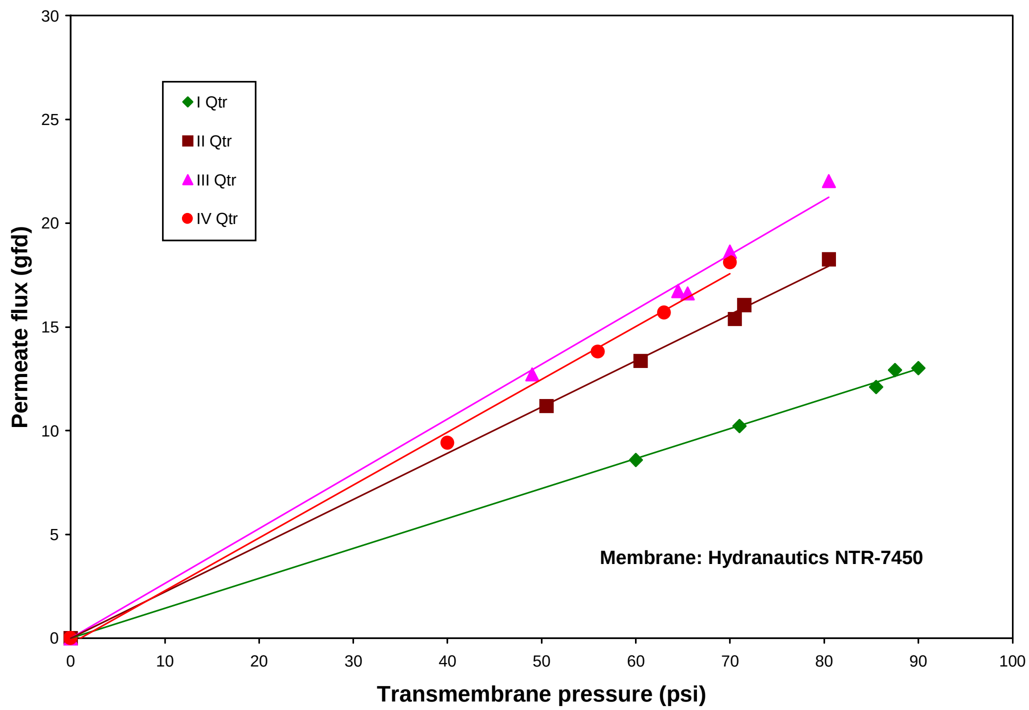


Figure 3. Resistances of the new NTR-7450 membranes used in each quarter.

These data were used to calculate new membrane resistances and the 95% confidence intervals using Eq. 1 and are summarized in Table 13. Table 13 also summarizes membrane resistances calculated following chemical cleaning. New NTR7450 membrane resistance values were in the range of $5.54 \times 10^{13} - 1.01 \times 10^{14}$ m^{-1} with an average value of 6.99×10^{13} m^{-1}. Initial R_m values for the TFC-SR membrane ranged from $4.02 \times 10^{13} - 6.47 \times 10^{13}$ m^{-1} with an average value of 5.09×10^{13} m^{-1}. From Table 13 it is observed that the TFC-SR membrane resistances before and after cleaning were less than ~ 10%. However, large increases in NTR7450 membrane resistances were sometimes observed following chemical cleaning. These data suggest that the cleaning procedure employed was effective only in removing TFC-SR membrane foulants present in the Biscayne Aquifer water. Different cleaning protocols may need to be developed for the NTR7450 membrane.

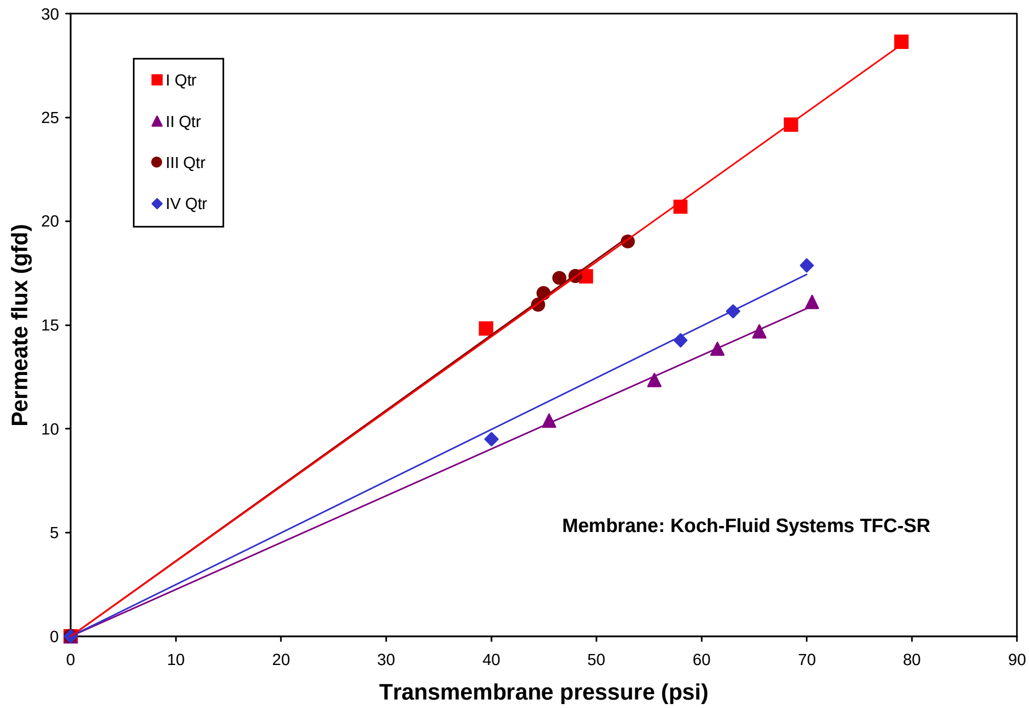


Figure 4. Resistances of the new TFC-SR membranes used in each quarter.

Table 13. Summary of new membrane resistances and after membrane cleaning. [a]

Quarter	Membrane	Initial R_m (m^{-1})	R_m after base cleaning (m^{-1})	R_m after acid cleaning (m^{-1})	Change (%)
I	NTR7450	1.01×10^{14} $\pm 1.9 \times 10^{12}$	9.57×10^{13} $\pm 1.23 \times 10^{13}$		5
I	TFC-SR	4.06×10^{13} $\pm 1.8 \times 10^{12}$	4.34×10^{13} $\pm 2.7 \times 10^{12}$		7
II	NTR7450	6.56×10^{13} $\pm 1.1 \times 10^{12}$	7.65×10^{13} $\pm 8 \times 10^{11}$	9.62×10^{13} $\pm 3.2 \times 10^{12}$	17, 47
II	TFC-SR	6.47×10^{13} $\pm 7 \times 10^{11}$	5.75×10^{13} $\pm 1.4 \times 10^{12}$		11
III	NTR7450	5.54×10^{13} $\pm 1.8 \times 10^{12}$	7.47×10^{13} $\pm 1.0 \times 10^{12}$	8.66×10^{13} $\pm 4.0 \times 10^{12}$	35, 56
III	TFC-SR	4.02×10^{13} $\pm 6 \times 10^{11}$	3.88×10^{13} $\pm 2.4 \times 10^{12}$	3.88×10^{13} $\pm 2.4 \times 10^{12}$	3
IV	NTR7450	5.75×10^{13} $\pm 2.4 \times 10^{12}$	6.67×10^{13} $\pm 2.0 \times 10^{12}$	6.46×10^{13} $\pm 7.0 \times 10^{11}$	16, 11
IV	TFC-SR	5.81×10^{13} $\pm 1.1 \times 10^{12}$	6.63×10^{13} $\pm 6.0 \times 10^{11}$		14

[a] Base cleaning was performed using NaOH solution at 40 ºC. Acid cleaning was performed using H_2SO_4 solution at 40 ºC whenever necessary

Specific flux profiles. Normalized specific flux profiles for the entire duration the experiments using NTR7450 and TFC-SR membranes are depicted in Figures 5 and 6, respectively. It was observed that both membranes experienced a decline in flux initially and during the 90% recovery experiment. However, the flux appeared to stabilize for the duration of the remaining experiments at 30% and 50% recoveries. Overall, both membranes experienced relatively stable operation throughout the duration of the experiments.

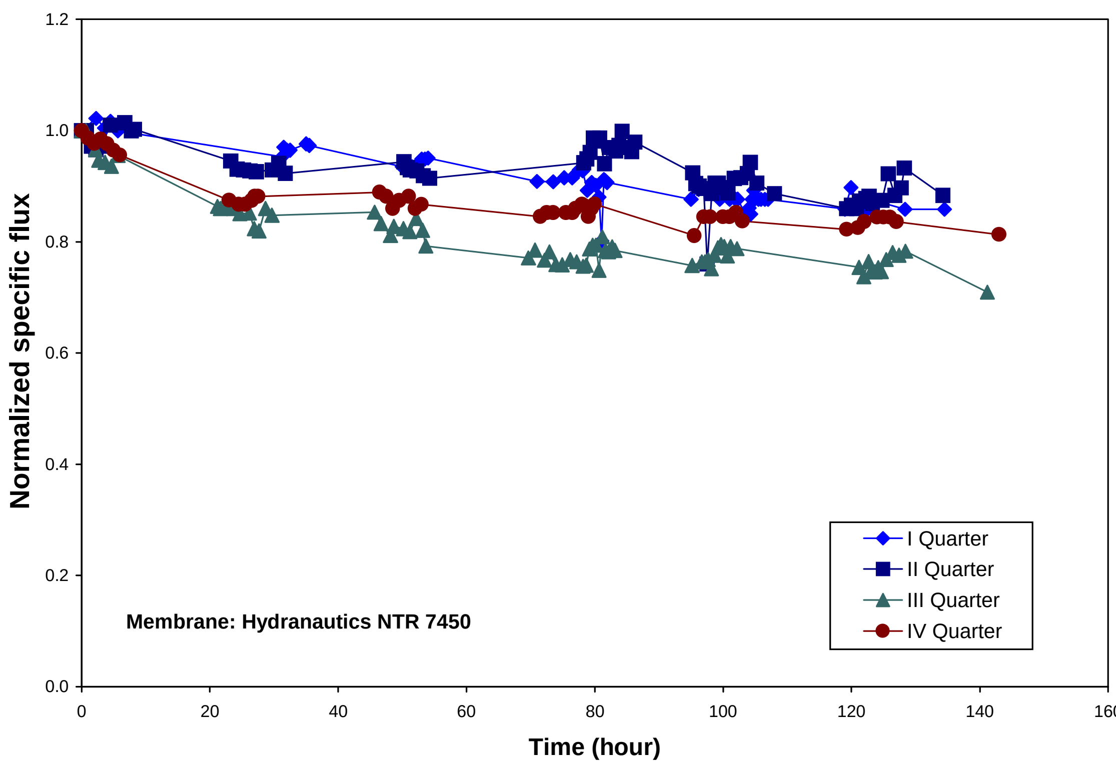


Figure 5. Normalized specific flux profiles for 4 quarters using the NTR7450 membrane

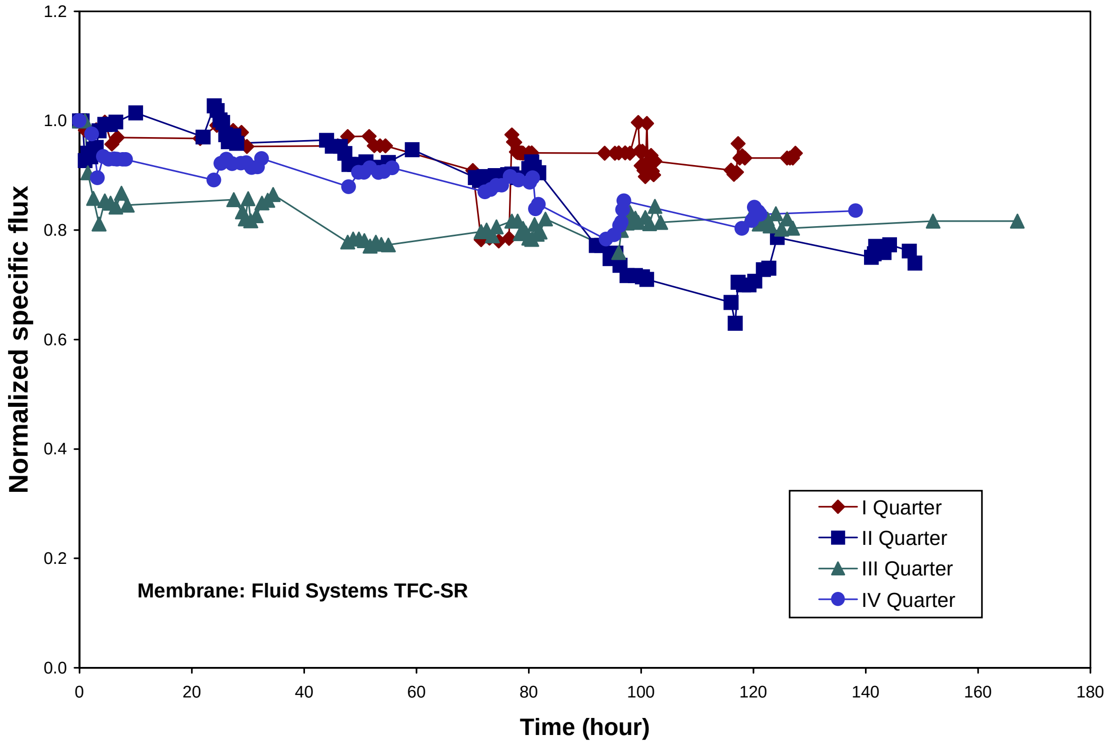


Figure 6. Normalized specific flux profiles for 4 quarters using the TFC-SR membrane

Table 14 summarizes the average permeate flux during membrane setting as well as the lowest recorded permeate flux during each experiment. It was observed that the initial permeate flux ranged from 11.4 – 17.5 gfd with an average value of 14.4 gfd. The lowest recorded permeate flux ranged from 10.3 – 12.7 gfd with an average value of 11.4 gfd. This constituted a decrease of approximately 21% in flux from the membrane setting period to the lowest recorded permeate flux, which always occurred at 90% recovery.

Table 14. Summary of worst case permeate fluxes.

Quarter	Membrane	DI water permeate flux (gfd)	Lowest permeate flux [a] (gfd)
I	NTR7450	11.4	10.4
I	TFC-SR	13.0	10.5
II	NTR7450	14.0	11.8
II	TFC-SR	14.1	10.3
III	NTR7450	16.3	11.7
III	TFC-SR	17.5	12.7
IV	NTR7450	16.8	11.8
IV	TFC-SR	12.4	12.1

[a] Recorded always during 90% recovery

Fouling analysis and cleaning intervals. Fouling rate parameters obtained using Eq. 2 for the RBSMT experiments conducted at 70% recovery are listed in Table 15. These data were obtained by linear regression analysis (the 95% confidence intervals are shown following the ± sign). The coefficient of regression ranged from 0.45 to 0.88, indicating a relatively close fit to the data. The corresponding cleaning intervals were obtained using Eq. 3 and ranged from 78 to 243 hours with an average of 151 hours. Therefore, it appears that under the conditions employed, membrane cleaning needs to be conducted approximately every 6 days of operation at 70% recovery. However, it should be understood that no attempt was made to “optimize” membrane operation and to increase the duration between cleanings by pH adjustment, anti-scalent addition, or by incorporating more advanced pretreatment processes such as micro- or ultrafiltration. (It is not the intent of the ICR to determine optimum operating conditions for NF.)

Table 15. Summary of statistical fits to specific flux profiles at 70% recovery.

Quarter	Membrane	Fouling rate (gfd/h)	Initial flux (gfd)	R^2	Cleaning interval (h)*
I	NTR7450	0.0169 ± 0.0027	13.08 ± 0.13	0.88	155
II	NTR7450	0.0138 ± 0.0065	15.24 ± 0.26	0.45	221
III	NTR7450	0.0405 ± 0.0052	15.85 ± 0.25	0.88	78
IV	NTR7450	0.0328 ± 0.0100	15.37 ± 0.44	0.68	94
I	TFC-SR	0.0256 ± 0.011	13.43 ± 0.49	0.51	105
II	TFC-SR	0.0142 ± 0.0047	15.59 ± 0.21	0.49	220
III	TFC-SR	0.032 ± 0.011	15.75 ± 0.48	0.53	98
IV	TFC-SR	0.0111 ± 0.0038	13.50 ± 0.17	0.54	243

*Cleaning interval was calculated assuming a 20% drop in initial flux

PERMEATE WATER QUALITY

Composite sample collection. Permeate water quality was monitored frequently to establish a “steady-state” before collecting composite permeate and concentrate samples. Upon switching recoveries for each experiment, permeate water samples were collected every 20 minutes and analyzed for TDS and UV_{254}. Once consistent readings were achieved, and the experiment reached “steady-state” composite samples were then collected. These composite samples were analyzed for a variety or organic and inorganic water quality parameters. SDS testing was performed on the composite permeate samples and the feed water.

Table 16 and 17 provides a summary of all physical, organic and inorganic permeate water quality parameters obtained using the NTR7450 and TFC-SR membranes, respectively, at 70% feed water recovery for all four quarters of testing.

Table 16. NTR7450 permeate water quality for all 4 quarters of testing at 70% recovery.

Parameter	Units	I quarter	II quarter	III quarter	IV quarter
Alkalinity	mg/L as $CaCO_3$	193	222	214	401
Ca hardness	mg/L as $CaCO_3$	200	253	215	198
Total hardness	mg/L as $CaCO_3$	225	284	235	230
TDS	mg/L	288	288	293	284
Bromide	μg/L	150	140	160	170
Ammonia	mg NH_3-N/L	0.24	0.05	BMRL [a]	BMRL [a]
SDS Cl_2 demand	mg/L	6.00	4.15	4.19	1.97
TOC	mg/L	2.80	3.25	2.45	2.10
TOX	μg/L	195	227.5	212.5	157.5
THM	μg/L	76.75	82.30	97.55	85.35
HAA(5)	μg/L	28.20	39.30	21.45	17.55
HAA(9)	μg/L	36.75	53.30	41.35	33.60
UV_{254}	cm^{-1}	0.068	0.079	0.056	0.052
pH	-	8.50	8.06	7.83	8.27
Turbidity	NTU	0.08	0.08	0.08	0.09

[a] Denotes Below Minimum Reporting Level

Table 17. TFC-SR permeate water quality for all 4 quarters of testing at 70% recovery.

Parameter	Units	I quarter	II quarter	III quarter	IV quarter
Alkalinity	mg/L as $CaCO_3$	150	180	171	319
Ca hardness	mg/L as $CaCO_3$	145	158	166	162
Total hardness	mg/L as $CaCO_3$	185	173	200	171
TDS	mg/L	230	248	235	239
Bromide	μg/L	125	120	150	160
Ammonia	mg NH_3-N/L	BMRL [a]	BMRL [a]	BMRL [a]	BMRL [a]
SDS Cl_2 demand	mg/L	2.29	1.08	2.54	1.55
TOC	mg/L	0.60	0.70	0.60	BMRL [a]
TOX	μg/L	BMRL [a]	24.5	37	BMRL [a]
THM	μg/L	13.8	17.5	24.9	12.9
HAA(5)	μg/L	1.55	1.75	3.45	1.80
HAA(9)	μg/L	2.05	1.75	4.60	1.80
UV_{254}	cm^{-1}	BMRL [a]	BMRL [a]	0.009	0.009
pH	-	8.20	8.14	8.05	8.00
Turbidity	NTU	0.05	0.06	0.08	0.12

[a] Denotes Below Minimum Reporting Level

Total organic carbon removal. TOC removal measured at 70% feed water recovery by both membranes are summarized in Figure 7. Of the two membranes tested at the bench-scale, the TFC-SR membrane achieved higher rejections of total organic carbon (see Tables 18 and 19). Many of the permeate TOC concentrations using the TFC-SR membrane were below the minimum reporting level of 0.5 mg/L. The highest recorded permeate TOC concentration using this membrane was 0.6 mg/L. Thus, the lowest TOC removal percentage using the TFC-SR membrane was 94 %. In contrast, the NTR7450 membrane achieved lower TOC removal (see Table 18). The highest recorded permeate TOC concentration using this membrane was 3.9 mg/L. Thus, the lowest TOC removal percentage using the NTR7450 membrane was 67 %.

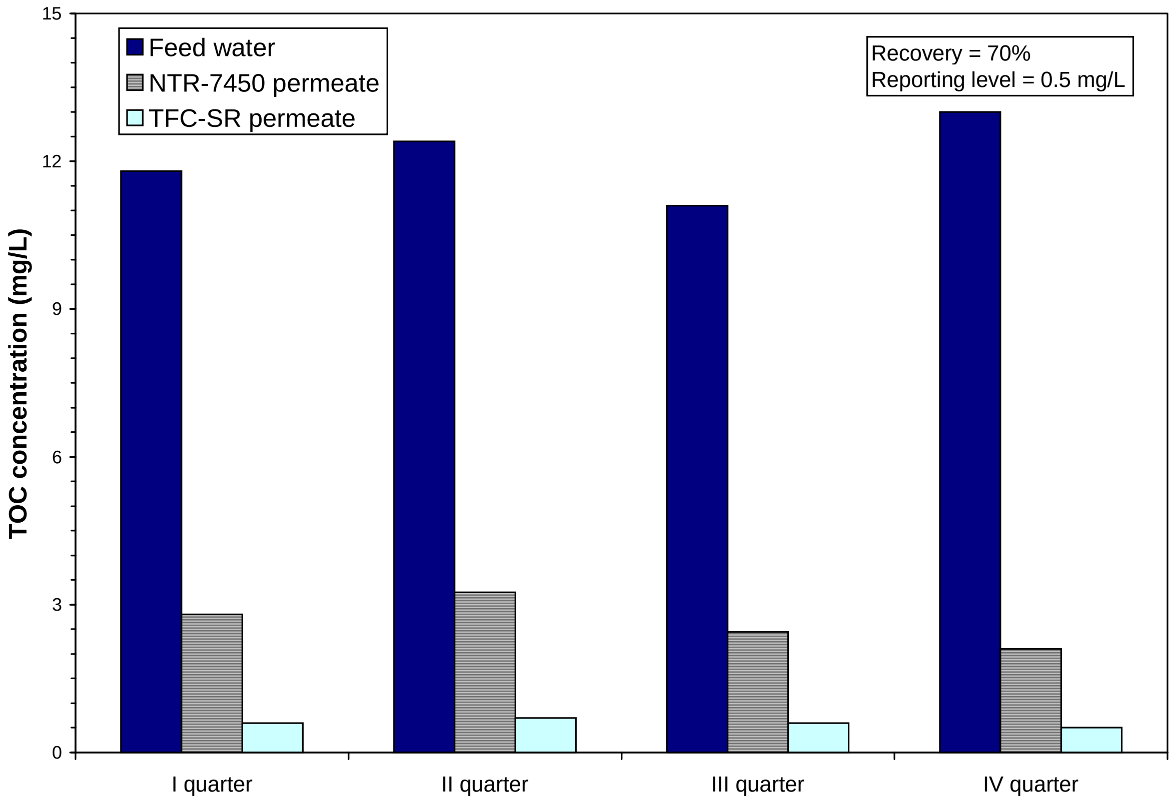


Figure 7. TOC removals by TFC-SR and NTR7450 membranes at 70% recovery.

Table 18. Summary of TOC concentrations in the permeate water using the NTR7450 membrane.

Recovery (%)	I Quarter		II Quarter		III Quarter		IV Quarter	
	Concentration (mg/L)	Removal (%)	Concentration (mg/L)	Removal (%)	Concentration (mg/L)	Removal (%)	Concentration (mg/L)	Removal (%)
30	1.4	88	2.1	83	1.6	86	1.3	90
50	2.2	81	2.1	83	2.1	81	1.8	86
70	2.8	76	3.25	74	2.4	78	2.1	84
90	3.9	67	4.3	65	3.7	67	3.1	76

Table 19. Summary of TOC concentrations in the permeate water using the TFC-SR membrane.

Recovery (%)	I Quarter		II Quarter		III Quarter		IV Quarter	
	Concentration (mg/L)	Removal (%)	Concentration (mg/L)	Removal (%)	Concentration (mg/L)	Removal (%)	Concentration (mg/L)	Removal (%)
30	BMRL [a]	>96%	BMRL [a]	>96%	0.6	95	BMRL [a]	>96%
50	0.6	95	BMRL [a]	>96%	BMRL [a]	>95%	BMRL [a]	>96%
70	0.6	95	0.7	94	0.6	95	BMRL [a]	>96%
90	0.6	95	BMRL [a]	>96%	0.6	95	BMRL [a]	>96%

[a] Calculated using 0.5 mg/L as the TOC minimum reporting level

Disinfection by-product precursor removal. Highest SDSTTHM and SDSHAA(5) concentrations in the TFC-SR membrane permeate were near 37.5 µg/L and 6 µg/L, respectively. Compared to the TFC-SR membrane, higher concentrations of organic constituents were observed in the NTR7450 membrane permeate water. For example, the highest SDSTTHM and SDSHAA(5) concentrations using the NTR7450 membrane were approximately 106 µg/L and 39 µg/L, respectively.

Both membranes achieved high TOC removals, but the TFC-SR membrane achieved higher removals of SDSTTHM and SDSHAA(5) precursors (see Tables 16 and 17). SDSTTHM and SDSHAA(5) concentrations in the TFC-SR membrane permeate waters were always below the placeholders under Stage II of the D/DBP rule (40 µg/L for TTHMs and 30 µg/L for HAA(5)) even when free chlorine was employed as the final disinfectant. However, on some occasions, both TTHM and HAA(5) concentrations in NTR7450 membrane permeate waters were above the placeholders under Stage II of the D/DBP rule when free chlorine was employed as the final disinfectant.

HAA(5) and TTHM precursor removals from pretreated Biscayne Aquifer water by NTR7450 and TFC-SR membranes (at 70% recovery) are summarized in Figures 8 and 9 respectively.

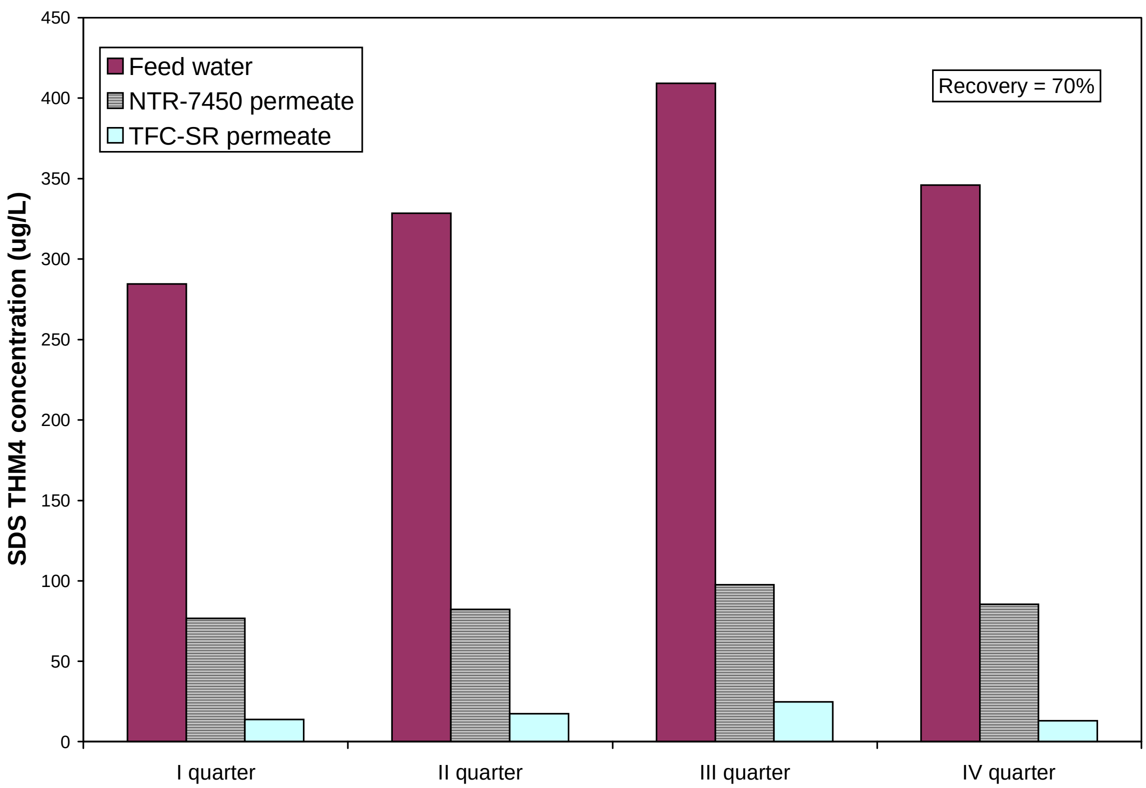


Figure 8. THM precursor removals by TFC-SR and NTR7450 membranes at 70% recovery.

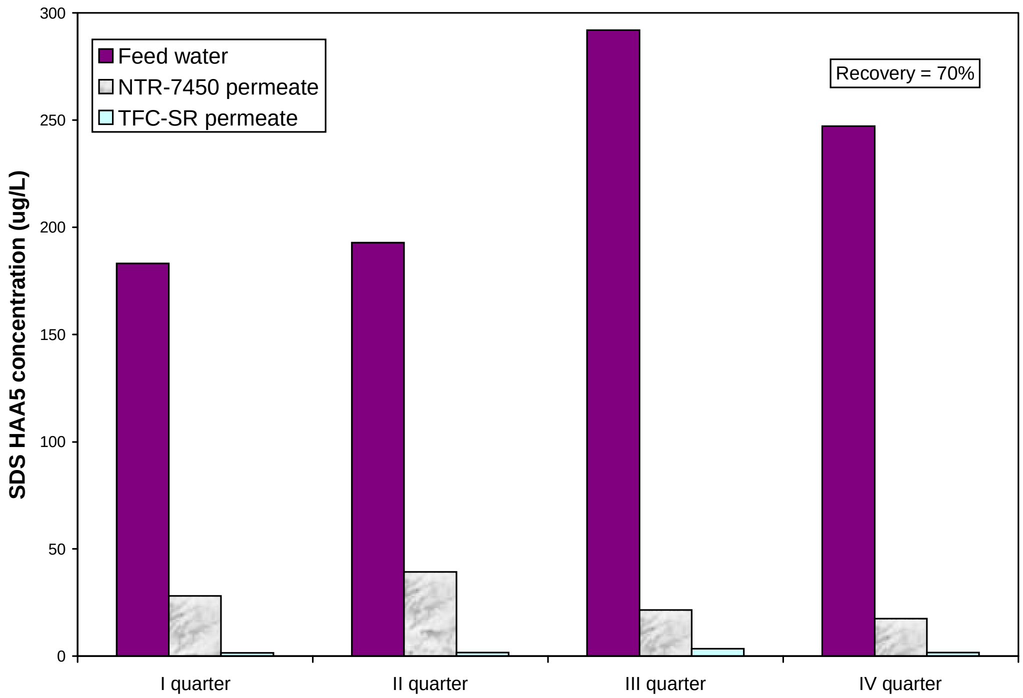


Figure 9. HAA(5) precursor removals by TFC-SR and NTR7450 membranes at 70% recovery.

Effect of nanofiltration on THM speciation. As described in the previous sections, the NF membranes employed achieved high TOC removals. However, these membranes achieved essentially no bromide ion rejection. In other words, these membranes were completely permeable to the bromide ion. Hence, the ratio of the concentration of bromide ion concentration to TOC concentration increased dramatically in the NF permeate water compared to the NF feed water. At the same time, SDS experiments were conducted by employing similar free chlorine concentration to TOC concentration ratios in both the feed and permeate waters so as to achieve a free chlorine concentration ~ 1 mg/L at the end of the SDS incubation period.

Because of these SDS experimental conditions, large changes in the relative concentrations of the individual THM species were detected in the NF feed and permeate waters. This phenomenon is depicted in Figure 10 by expressing each THM species as a mole fraction. As observed, chloroform was dominant in the NF feed water. However, as the ratio of the concentration of bromide ion concentration to TOC concentration increased the mixed chloro-bromo species increased in relative concentrations in the NF permeate water.

Similar observations were also made in haloacetic acid speciation but those data are not depicted in this report for the sake of brevity.

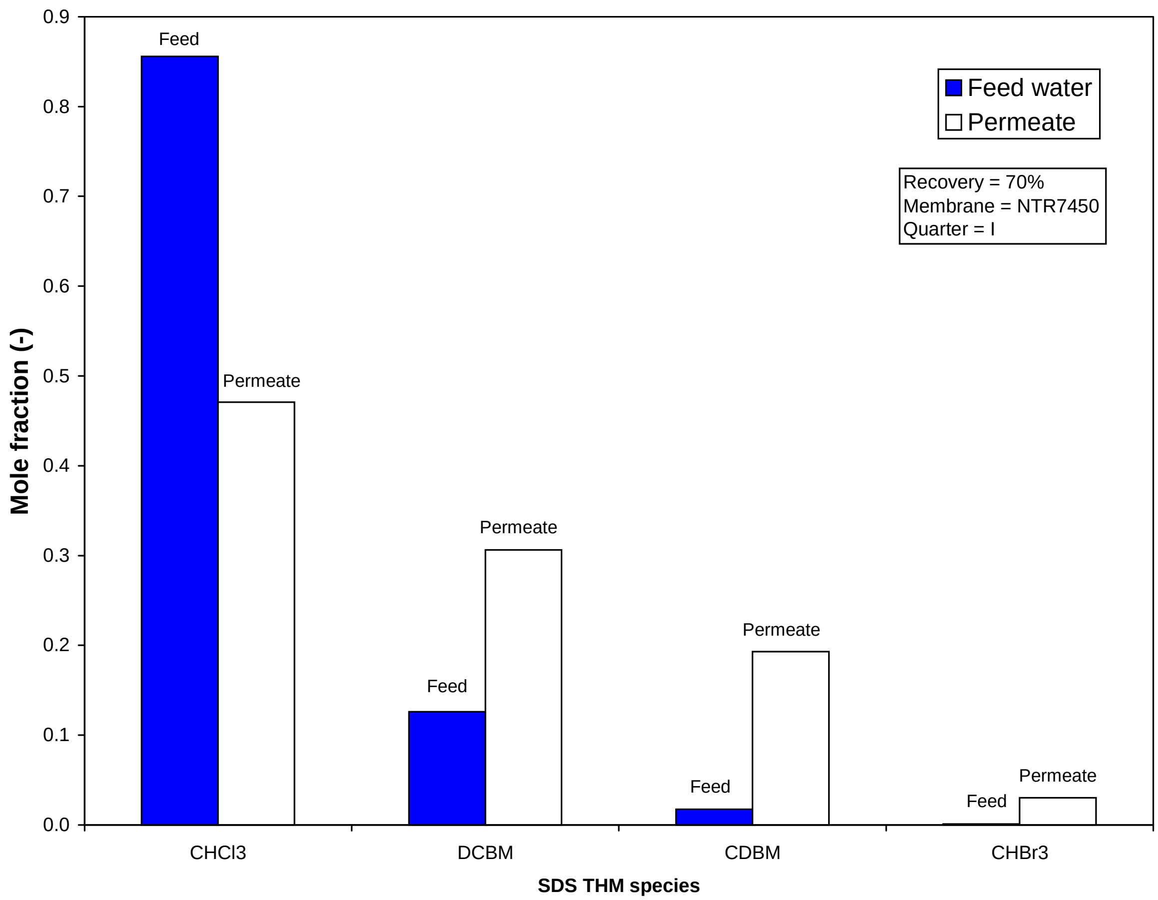


Figure 10. Changes in THM speciation expressed as mole fraction upon nanofiltration (data from I quarter experiments at 70% feed water recovery and NTR-7450 membrane).

Inorganics removal. The NTR7450 membrane achieved only ~ 16% TDS rejection. But the TFC-SR membrane was able to remove ~ 47% TDS from the Biscayne Aquifer water. Additionally, the TFC-SR membrane removed approximately 35% of total hardness at 70% recovery. However, the NTR7450 membrane removed less than 10% of total hardness from the membrane feed water (at 70% recovery). None of the membranes employed in this study were able to achieve substantial removal of the bromide ion. As explained earlier and as shown in Figure 7, this resulted in large changes in trihalomethane and haloacetic acid speciation in the permeate water compared to the feed water.

Effect of feed water recovery on rejection. The concentrations of a variety of inorganic and organic permeate water quality parameters were dependent on feed water recovery for both membranes. Tables 20 and 21 show the effects of recovery on the rejection of selected water quality parameters by the NTR7450 and TFC-SR membranes, respectively. These data were obtained by averaging data from all quarters of testing. The median and range for each parameter are also listed. In general, permeate concentrations increased with increasing feed water recovery suggesting that the transport of many water quality constituents across these polymeric membranes were controlled by diffusion.

The effects of feed water recovery on permeate TDS concentrations and TDS removal using the NTR7450 and the TFC-SR membranes are depicted graphically in Figure 11 for the first quarter of testing. It can be observed that permeate TDS concentrations increased exponentially with feed water recovery (R_f) for both membranes. The following empirical fits were obtained using the first quarter data:

TFC-SR membrane: Permeate TDS (mg/L) = 194 exp(0.0011) (R^2 = 0.81)

NTR7450 membrane: Permeate TDS (mg/L) = 265 exp(0.0011R_f) (R^2 = 0.80)

Empirical correlations relating other organic and inorganic permeate water quality parameters to feed water recovery could be derived using simple linear regression techniques if necessary.

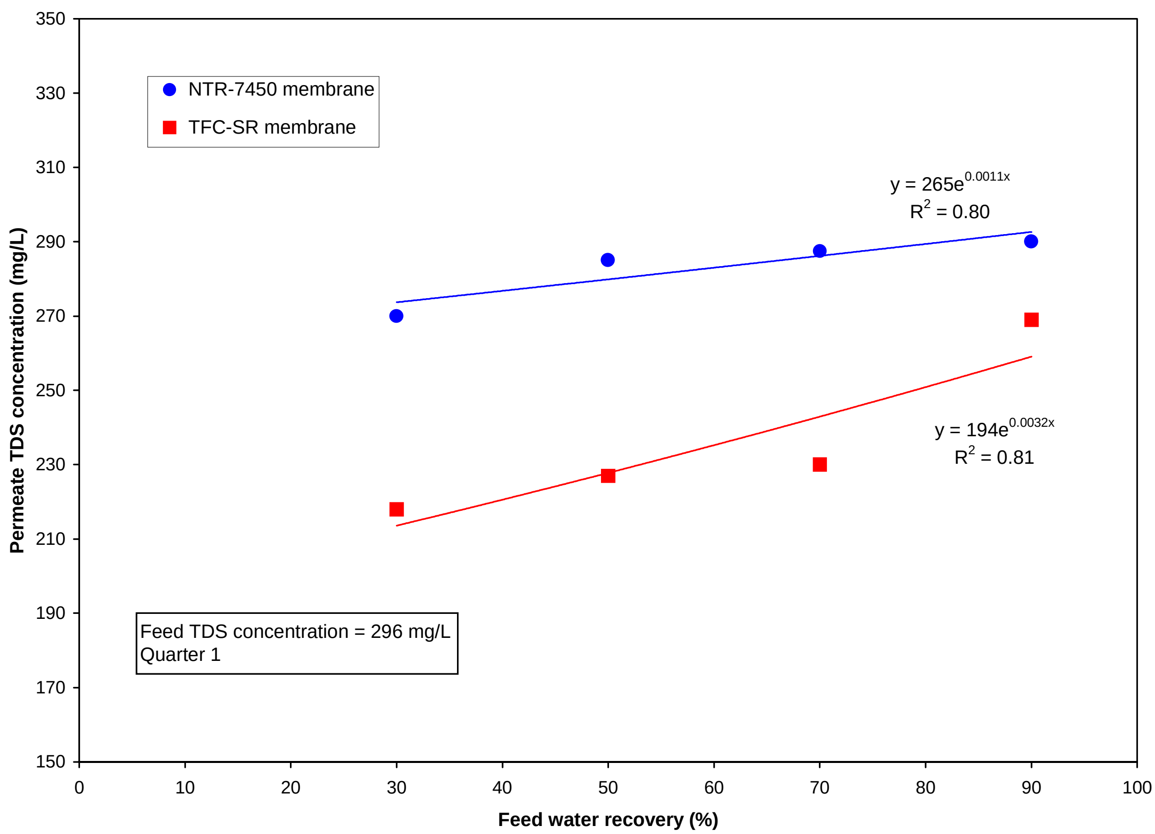


Figure 11. Effect of feed water recovery on permeate TDS concentrations.

Table 20. Effect of feed water recovery on rejection of selected water quality parameters using the NTR7450 membrane.

Parameter	Units	30% recovery		50% recovery		70% recovery		90% recovery	
		Median	Range	Median	Range	Median	Range	Median	Range
Ca hardness	mg/L as $CaCO_3$	190	182-214	202	194-228	206	196-254	220	204-294
Total hardness	mg/L as $CaCO_3$	216	208-282	229	216-248	232	224-292	240	222-324
Alkalinity	mg/L as $CaCO_3$	210	178-370	220	194-376	219	192-402	229	200-412
TDS	mg/L	274	270-293	283	251-296	287.5	283-292	292	290-320
Bromide	mg/L	150	130-160	145	130-170	155	140-170	160	130-170
Ammonia	mg NH_3-N/L	0.06	BMRL-0.06	BMRL	BMRL	0.10	BMRL-0.34	0.06	BMRL-0.06
SDS Cl_2 demand	mg/L	3.60	1.40-4.25	3.61	1.72-4.64	4.17	4.13-6.18	4.71	2.39-5.84
TOC	mg/L	1.50	1.30-2.10	2.10	1.8-2.2	2.65	2.1-3.3	3.80	3.1-4.3
TOX	µg/L	112.3	98-170	142.5	140-160	202.5	155-235	257.5	220-280
THM	µg/L	60.1	50.4-67	69.55	64.2-76	84.9	71.6-102.3	102.65	62.4-106.3
HAA(5)	µg/L	12.8	11.4-20.6	16.7	14.1-28	24.3	16.8-39.7	27.2	23.4-29.8
HAA(9)	µg/L	24.5	16.9-262	29.95	26.6-39	39.8	33.6-54.7	48.1	39.7-54.4
UV_{254}	cm^{-1}	0.035	0.031-0.046	0.049	0.045-0.056	0.062	0.05-0.079	0.087	0.071-0.107

Refer to Table 12 for the minimum reporting levels for various water quality parameters

Table 21. Effect of feed water recovery on rejection of selected water quality parameters using the TFC-SR membrane.

Parameter	Units	30% recovery		50% recovery		70% recovery		90% recovery	
		Median	Range	Median	Range	Median	Range	Median	Range
Ca hardness	mg/L as $CaCO_3$	129	120-154	145	138-168	160	144-168	182	172-234
Total hardness	mg/L as $CaCO_3$	144	130-164	163	150-194	179	170-212	220	204-344
Alkalinity	mg/L as $CaCO_3$	144	132-156	160	134-182	177	144-324	260	182-372
TDS	mg/L	216	201-231	226	212-231	236	223-253	266	262-270
Bromide	mg/L	130	120-150	135	120-160	140	120-160	150	130-170
Ammonia	mg NH_3-N/L	BMRL	BMRL	BMRL	BMRL	BMRL	BMRL	BMRL	BMRL
SDS Cl_2 demand	mg/L	1.13	0.35-2.18	1.11	0.27-1.85	2.01	0.15-2.55	1.37	0.49-2.73
TOC	mg/L	0.6	BMRL-0.6	0.6	BMRL-0.6	0.6	BMRL-0.7	0.6	BMRL-0.6
TOX	μg/L	25	BMRL-25	BMRL	BMRL	31	BMRL-39	39	BMRL-39
THM	μg/L	10.2	9.3-18.6	11.2	10.3-19.5	15.45	11.9-25.2	25.15	22-37.5
HAA(5)	μg/L	2.4	1-3.6	2.55	1.3-3.9	2.00	BMRL-3.6	4.7	3.6-5.9
HAA(9)	μg/L	2.4	1-4.7	3.1	1.3-4	1.95	BMRL-4.8	7.75	5.5-13
UV_{254}	cm^{-1}	BMRL	BMRL	BMRL	BMRL	BMRL	BMRL-0.010	0.012	BMRL-0.014

Refer to Table 12 for the minimum reporting levels for various water quality parameters

Permeate and feed water blending. Because of the high rejection capabilities of some nanofiltration membranes employed in water treatment, the concentrations of many water quality parameters in the permeate water are often much lower than regulatory maximum contaminant levels. This may allow the possibility of blending NF feed water with NF permeate thereby reducing membrane area and/or energy requirements for the full-scale membrane plant.

However, because of the high concentrations of THM and HAA9 precursor materials in the NF feed water (average feed water SDSTTHM concentration = 342 μg/L, average feed water SDSHAA9 concentration = 275 μg/L) blending is not expected to be feasible especially to meet the current place holders for THM concentrations under Stage 2 of the Disinfectant/Disinfection By-Products Rule if free chlorine is employed as the disinfectant.

Problems encountered. During the first quarter of testing with the NTR7450 membrane, a leak was detected in the temperature gauge, prompting shutdown of the unit for approximately 2 hours. This event occurred on February 26, 1998 during the membrane setting. A power outage during the second quarter of testing with the TFC-SR membrane caused a delay of approximately two hours. The power outage occurred at 4:30 p.m. on the afternoon of June 15, 1998. The unit was restarted without difficulty during both incidents. Waste flow rates occasionally dropped by approximately 2 – 8% when the RBSMT apparatus was left unattended overnight, most often during the experiment at 90% feed water recovery.

Section 5
QA/QC Summary

Laboratory analyses. As described in Table 12, samples were shipped to two ICR certified laboratories: Montgomery Watson Laboratories, CA and Summers and Hooper Inc., OH. The tables in this section (see next few pages) summarize the QA/QC information provided by these two commercial laboratories using the format required under the ICR.

Quality assurance and quality control (QA/QC) summary data from Montgomery Watson Laboratories reflects not only ICR samples for the City of Fort Lauderdale, but other bench-scale test utilities as well, as per agreement with Mr. Steve Allegeier ICR Technical Coordinator.

Summers and Hooper provided HAA9 analyses only.

ICR RBSMT data collection spreadsheets. To ensure the integrity of the data collected and reported in this treatment study, EPA has previously provided one preliminary review of the ICR Treatment Study Data Collection Spreadsheets for the City of Fort Lauderdale. The comments generated during this preliminary review process are in Appendix B. We have addressed all of the EPA comments into the Data Collection Spreadsheets. Our detailed responses are as described below:

<u>Global Comments Applicable to Both Membrane Worksheets:</u>

1. Missing information in Field 1 has been provided.
2. Cost of an 8x40 TFC-SR membrane element is not available from manufacturer.
3. No water quality parameters (including potential foulants) were measured prior to pretreatment because they were not required under the ICR.
4. Cartridge filtration was the only membrane pretreatment employed.
5. Cost data have been provided.

<u>TFC-SR Membrane 1st Quarter:</u>

1. The relatively high MTC_w values were as measured in the lab. No changes made.
2. TOX and feed THM concentrations were verified and found to be as reported by Montgomery Watson Laboratories. No changes were made.

<u>TFC-SR Membrane 2nd Quarter:</u>

1. TOX and feed THM concentrations were verified and found to be as reported by Montgomery Watson Laboratories. No changes were made.
2. Ca and total hardness values were verified and found to be correct. No changes made.

TFC-SR Membrane 3rd Quarter:

1. The relatively high MTC_w values reflect measurements made during membrane operation in the lab. All entries were verified and found to be correct. No changes made.
2. HAA values were verified and found to be correct. No changes made.
3. TDS and alkalinity values were checked and found to be correct. No changes made.

TFC-SR Membrane 4th Quarter:

1. No comments were generated by you for these data.

NTR-7450 Membrane 1st Quarter:

1. The relatively low MTC_w values reflect measurements made during membrane operation in the lab. All entries were verified and found to be correct. No changes made.
2. TDS values were verified and found to be correct. No changes made.
3. THM and TOX concentrations are as reported by Montgomery Watson lab. No changes made.

NTR-7450 Membrane 2nd Quarter:

1. TDS values were verified and found to be correct. No changes made.
2. THM and TOX concentrations are as reported by Montgomery Watson lab. No changes made.
3. All water quality parameters for the 90% recovery run were verified and found to be correct. No changes made.

NTR-7450 Membrane 3rd Quarter:

1. HAA concentrations were verified and found to be correct. No changes made.
2. Alkalinity, calcium and total hardness concentrations were verified and found to be correct. No changes made.

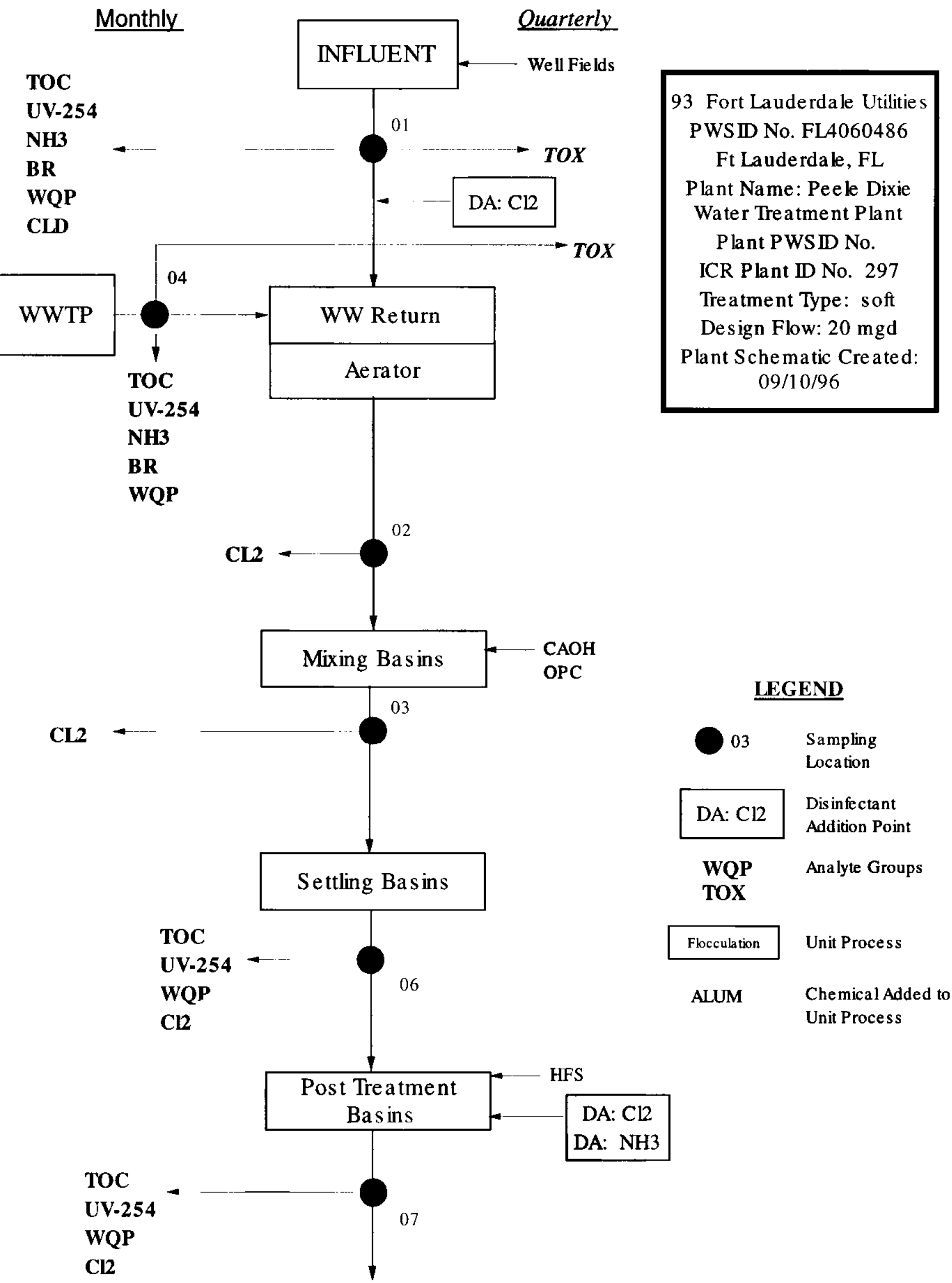
NTR-7450 Membrane 4th Quarter:

1. No comments were generated by EPA for these data.

Section 6
Acknowledgments

The laboratory testing and analysis component of this ICR treatment study would not have been completed without the assistance of Jennifer Abrajano, Dan Bush, Andy Eaton, Jim Hein, and Jason Radgowski. Dr. Dan Askenaizer and David Wilkes provided valuable comments during their review of this summary report. Wayne Welch, Pauline de Rosa, Becky Fierle Hachenburg and Joanne Misiag assisted in project management and other administrative activities.

Craig Canning and Maurice Toban from the City of Fort Lauderdale Fiveash Water Treatment Plant assisted during raw water collection and shipment, as well as providing data necessary to complete the ICR Treatment Study Spreadsheets.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Quarterly
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NH3
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WQP
CLD
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TOX
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WWTP
WW Return
Aerator
TOC
UV-254
NH3
BR
WQP
02
CL2
Mixing Basins
CAOH
OPC
03
CL2
Settling Basins
TOC
UV-254
WQP
Cl2
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Post Treatment Basins
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Cl2
07
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03
Sampling Location
DA: Cl2
Disinfectant Addition Point
WQP
TOX
Analyte Groups
Flocculation
Unit Process
ALUM
Chemical Added to Unit Process

Monthly

Quarterly

93 Fort Lauderdale Utilities
PWSID No. FL4060486
Ft Lauderdale, FL
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Plant PWSID No.
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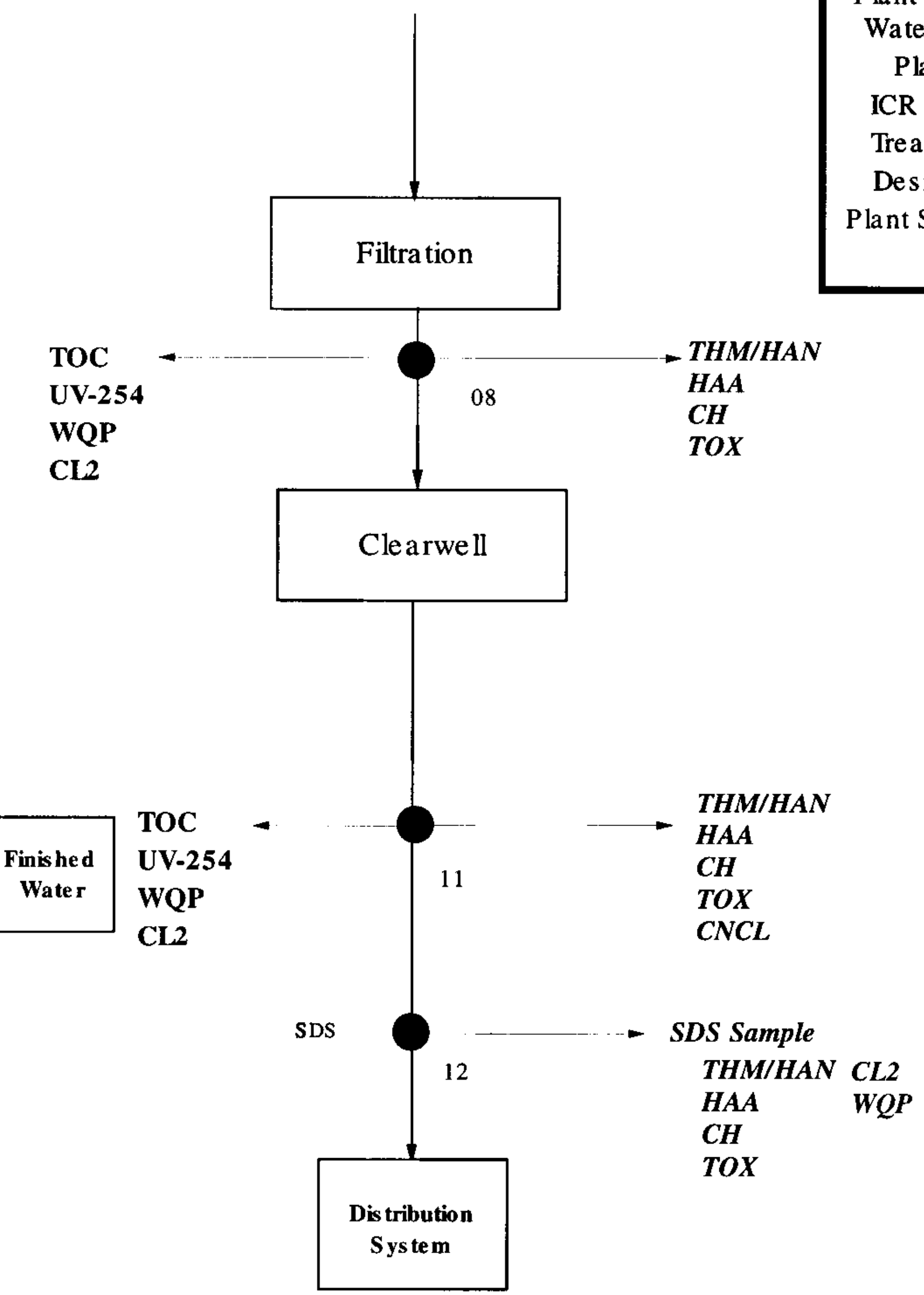
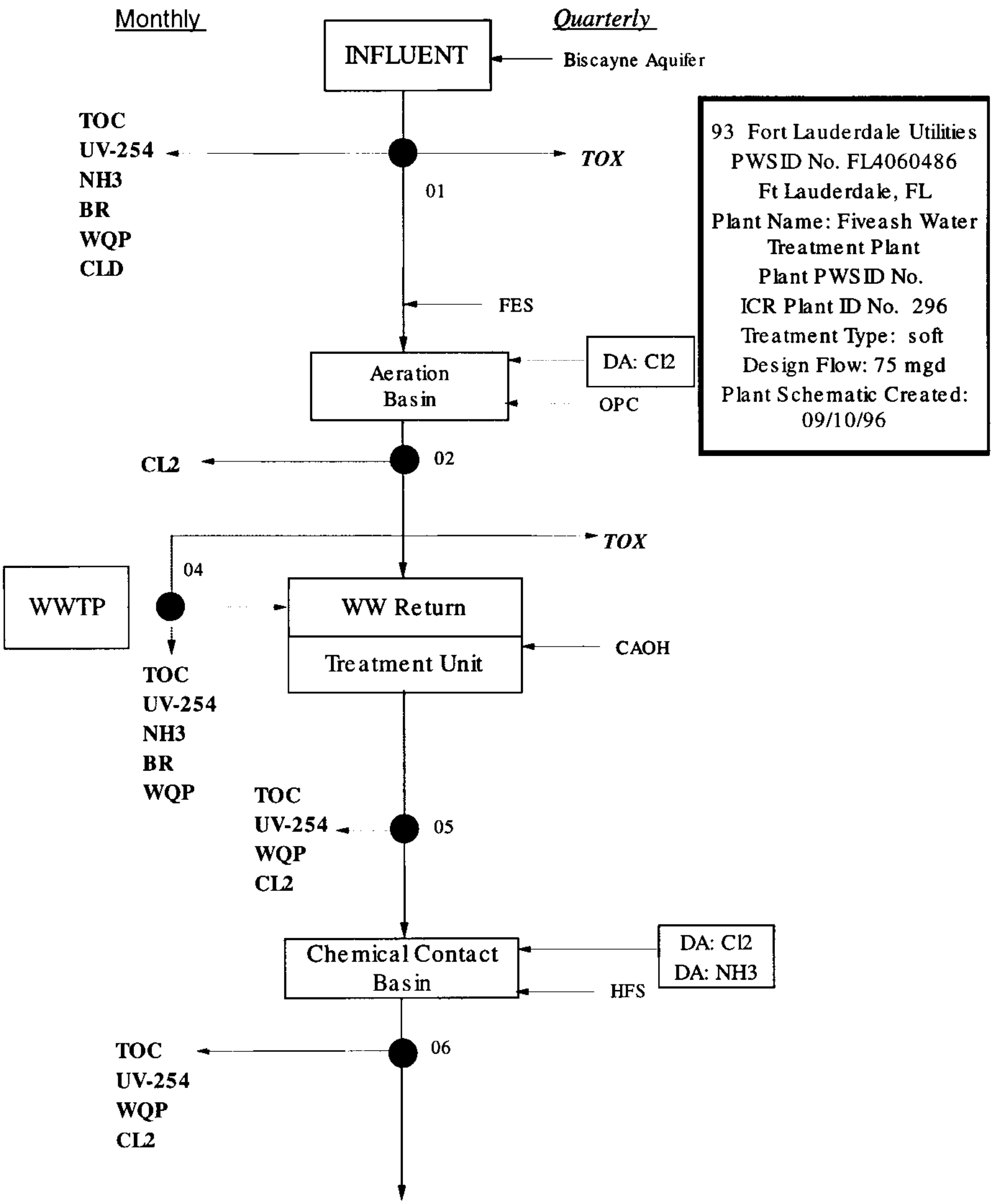
Design Flow: 20 mgd
Plant Schematic Created:
09/10/96

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CL2
02
TOX
04
WWTP
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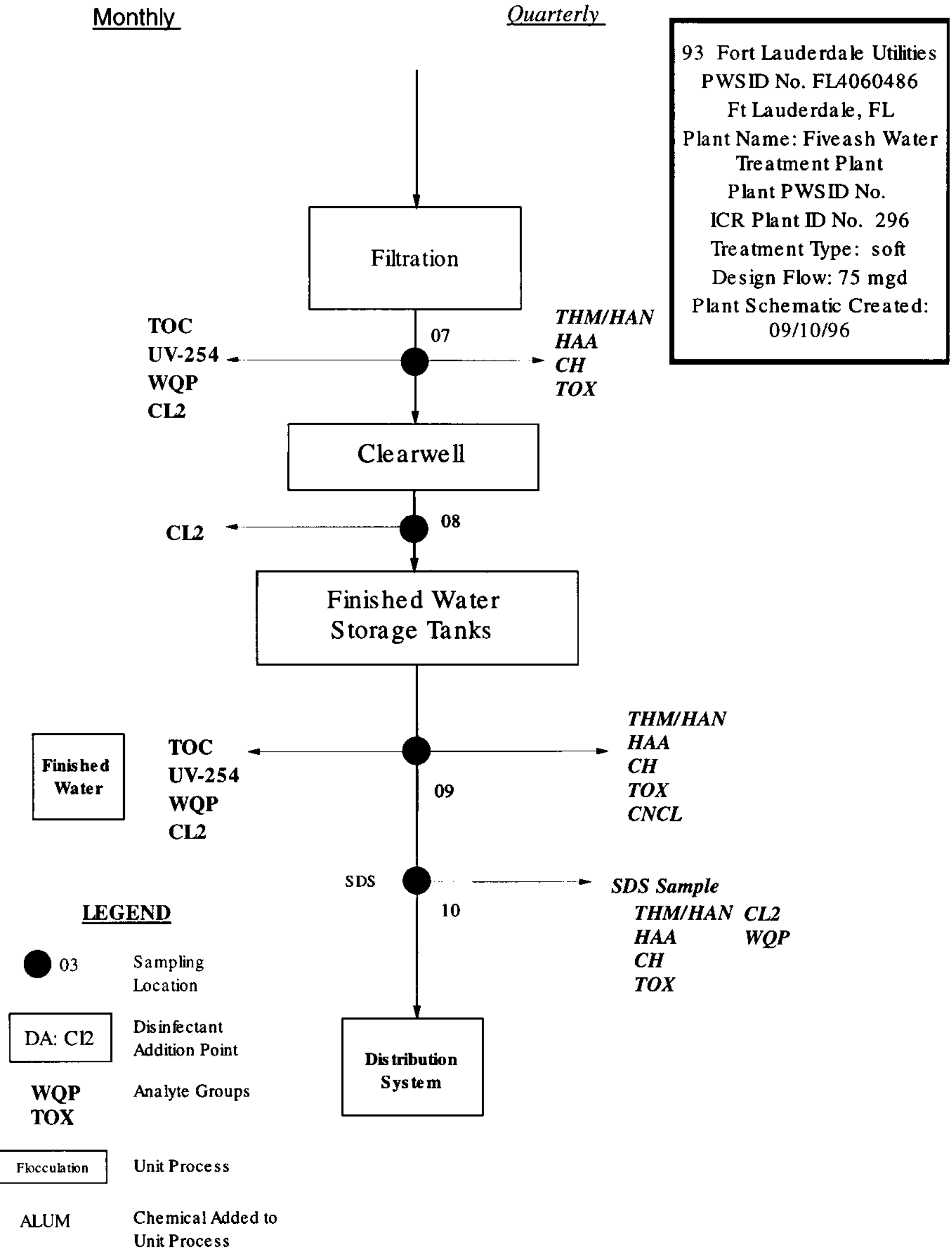
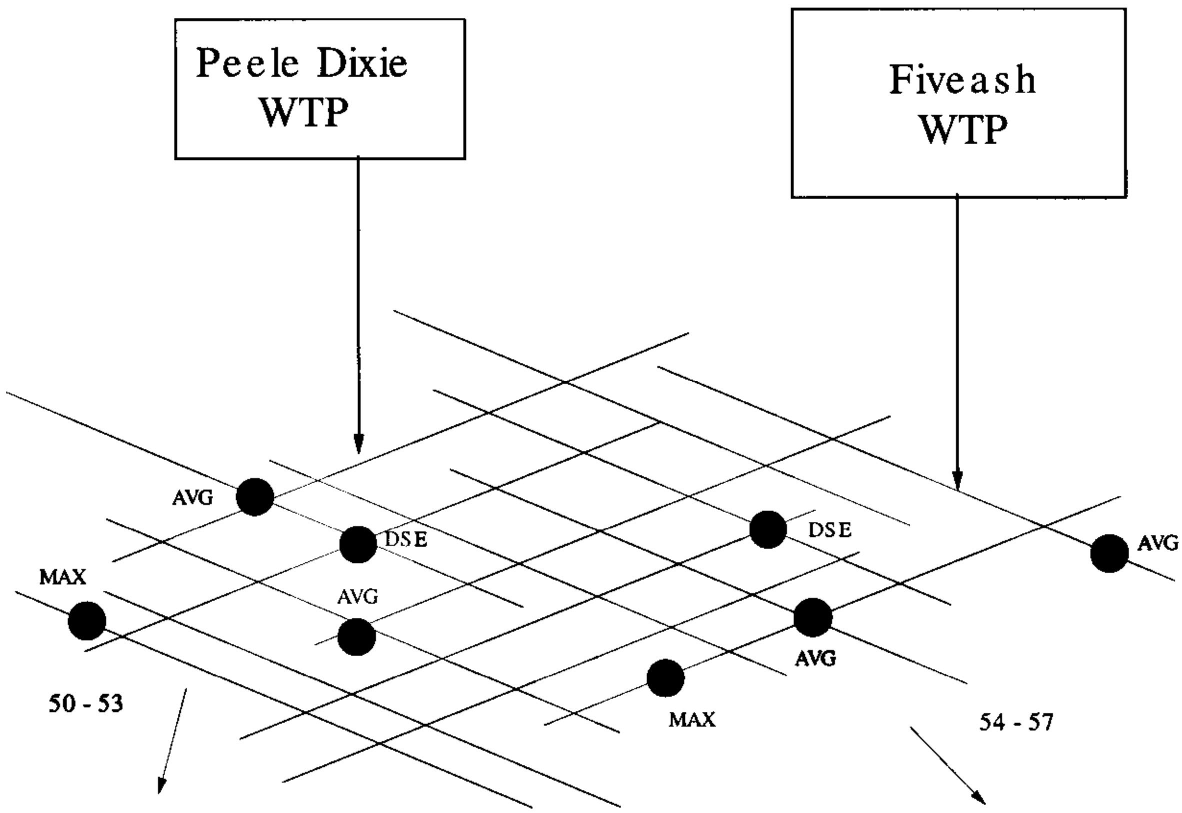
TOC
UV-254
NH3
BR
WQP
TOC
UV-254
WQP
CL2
05
Chemical Contact Basin
DA: Cl2
DA: NH3
HFS
TOC
UV-254
WQP
CL2
06


Monthly
Quarterly
93 Fort Lauderdale Utilities
PWSID No. FL4060486
Ft Lauderdale, FL
Plant Name: Fiveash Water Treatment Plant
Plant PWSID No.
ICR Plant ID No. 296
Treatment Type: soft
Design Flow: 75 mgd
Plant Schematic Created: 09/10/96
Filtration
TOC
UV-254
WQP
CL2
07
THM/HAN
HAA
CH
TOX
Clearwell
CL2
08
Finished Water Storage Tanks
Finished Water
TOC
UV-254
WQP
CL2
09
THM/HAN
HAA
CH
TOX
CNCL
SDS
10
SDS Sample
THM/HAN CL2
HAA WQP
CH
TOX
Distribution System
LEGEND
03 Sampling Location
DA: Cl2 Disinfectant Addition Point
WQP
TOX
Analyte Groups
Flocculation Unit Process
ALUM Chemical Added to Unit Process

Quarterly

93 Fort Lauderdale Utilities
PWSID No. FL4060486
Ft Lauderdale, FL
System Schematic Created:
09/10/96



THM/HAN ***CL2***
HAA ***WQP***
CH ***CNCL(MAX)***
TOX

THM/HAN ***CL2***
HAA ***WQP***
CH ***CNCL(MAX)***
TOX

LEGEND

●	50 - 53	Sampling Locations
DSE		Distribution System Equivalent--Corresponds to SDS Residence Time
AVG		Average Residence Time in the Distribution System
MAX		Maximum Residence Time in the Distribution System

A.2 -- Design Plant Parameters

Date: 7/9/97

PWS Name: City of Fort Lauderdale
PWS ID: FL4060486
WIDB:
ICR Contact Person: Mr. Craig Canning

Sampling Period: Design
Design Sampling Start Date: 7/21/97
Design Sampling End Date: 12/31/98

Treatment Plant Name: Fiveash Water Treatment Plant
ICR Treatment Plant ID: 296
Treatment Plant PWS ID:
Treatment Plant Category: SOFT

State Approved Plant Capacity (MGD): 75.0
Historical Min. Water Temperature (deg C): 20.0
Installed Sludge Handling Capacity (GPD): 475,200.00
Blending Indicator: N

Water Resource Name: Prospect Wellfield
Water Resource Type: Ground water
Intake Name: Prospect Transmission Pipeline
Wellhead Protection: Y

Hydrologic Unit Code:
Latitude (degrees, minutes, seconds): +26°11'43.2"
Longitude (degrees, minutes, seconds): -80°11'12"

Seq. No.	Sample Location Name	Sample Location Type	Sample Loc. No.	
	Influent	INF	1	

Process Train Name: Fiveash
Process Train Category: SOFT

Seq. No.	Sample Location Name	Sample Location Type	Sample Loc. No.	
1	Aeration	Other Treatment Process		Surface Area (ft2): 1,058 Liquid Volume (gal): 146,464

Seq. No.	Sample Location Name	Sample Location Type	Sample Loc. No.	
				Short Circuiting Factor:
2	Chlorine gas	Disinfectant Addition	2	Chemical Code: CL2 Measurement Formula: Cl2 Dose Rate (mg/L): 6.00
3	Fiveash wshwtr	Washwater Return Sample Point		
4	Fiveash wshwtr	Washwater Return	15	Washwater Treated: N Coagulation/Sedimentation: N Filtration: N Disinfectant Addition: N Plain Sedimentation: N Other Treatment: 24 hr average Water flow Returned (MGD): 0.8
5	Hydrotreater 4	Solids Contact Clarifier	4	Clarifier Type: SB Clarifier Type: UP Brand Name: Dorr-Oliver Surface Area (ft2): 14,798 Liquid Volume (gal): 2,468,000 Short Circuiting Factor: Baffling Type: AV Plate Settler Surface Area (ft2): Tube Settler Surface Area (ft2):

Seq. No.	Sample Location Name	Sample Location Type	Sample Loc. No.	
				Plate Settler Brand Name: Tube Settler Brand Name:
6	Chlorine gas	Disinfectant Addition		Chemical Code: CL2 Measurement Formula: Cl2 Dose Rate (mg/L): 6.00
7	Anhydrous ammon	Disinfectant Addition		Chemical Code: NH3A Measurement Formula: NH3 Dose Rate (mg/L): 1.10
8	Recarb Basin 4	Disinfection Contact Basin	5	Surface Area (ft2): 1,800 Liquid Volume (gal): 300,605 Baffling Type: AV Short Circuiting Factor:
9	No 11	Filtration	6	Surface Area (ft2): 15,400 Liquid Volume (gal): 806,344 Total Media Depth (in): 36 Depth of GAC (in): Media Type: DUAL Type of Activated Carbon: Minimum Water Depth To Top of Media (ft): 6.0 Depth From Top of Media to Top of Backwash Trough (ft): 2.8
10	Clearwell #1	Clearwell	14	Surface Area (ft2): 27,500

Seq. No.	Sample Location Name	Sample Location Type	Sample Loc. No.	
				Liquid Volume (gal): 2,057,000 Minimum Liquid Volume (gal): 1,200,000 Baffling Type: UN Short Circuiting Factor: Covered Indicator Code: Y
11	Fin. Wtr. Stor.	Other Treatment Process		Surface Area (ft2): 59,328 Liquid Volume (gal): 14,000,000 Short Circuiting Factor:
	Finished Water	FIN	7	

Treatment Plant Name: Peele Dixie Water Treatment Plant
ICR Treatment Plant ID: 297
Treatment Plant PWS ID:
Treatment Plant Category: SOFT

State Approved Plant Capacity (MGD): 20.0
Historical Min. Water Temperature (deg C): 20.0
Installed Sludge Handling Capacity (GPD): 57,600.00
Blending Indicator: N

Water Resource Name: Peele Dixie Wellfield
Water Resource Type: Ground water
Intake Name: Peele Dixie Transmission Pipeline
Wellhead Protection: Y

Hydrologic Unit Code:
Latitude (degrees, minutes, seconds): +26°6'24.9"
Longitude (degrees, minutes, seconds): -80°12'19.3"

Seq. No.	Sample Location Name	Sample Location Type	Sample Loc. No.	
	Influent	INF	1	
Process Train Name: Peele Dixie				
Process Train Category: SOFT				
1	Chlorine gas	Disinfectant Addition		Chemical Code: CL2 Measurement Formula: Cl2 Dose Rate (mg/L): 6.00
2	Aeration	Other Treatment Process		Surface Area (ft2): 400 Liquid Volume (gal): 36,000 Short Circuiting Factor:
3	Peele wshwtr	Washwater Return Sample Point	2	
4	Dixie wshwtr	Washwater Return	15	Washwater Treated: N

Seq. No.	Sample Location Name	Sample Location Type	Sample Loc. No.	
				Coagulation/Sedimentation: N Filtration: N Disinfectant Addition: N Plain Sedimentation: N Other Treatment: WW returned to Mix Basin 24 hr average Water flow Returned (MGD): 0.39
5	Flocculation	Flocculation Basin	4	Type of Mixer: ME Liquid Volume (gal): 288,000 Short Circuiting Factor: Baffling Type: AV Stage Sequence Number: 1 Stage Mean Velocity Gradient (sec-1): 20 Stage Liquid Volume (gal): 288,000
6	Sedimentation	Sedimentation	5	Surface Area (ft2): 26,550 Liquid Volume (gal): 2,383,350 Baffling Type: PR Short Circuiting Factor: Plate Settler Surface Area (ft2): Plate Settler Brand Name: Tube Settler Surface Area (ft2): Tube Settler Brand Name:
7	Chlorine gas	Disinfectant Addition		Chemical Code: CL2

Seq. No.	Sample Location Name	Sample Location Type	Sample Loc. No.	
				Measurement Formula: Cl2 Dose Rate (mg/L): 6.00
8	Anhydrous ammon	Disinfectant Addition		Chemical Code: NH3A Measurement Formula: NH3 Dose Rate (mg/L): 1.10
9	North Recarb	Disinfection Contact Basin	6	Surface Area (ft2): 1,690 Liquid Volume (gal): 142,800 Baffling Type: AV Short Circuiting Factor:
10	#5	Filtration	7	Surface Area (ft2): 5,632 Liquid Volume (gal): 337,000 Total Media Depth (in): 30 Depth of GAC (in): Media Type: DUAL Type of Activated Carbon: Minimum Water Depth To Top of Media (ft): 5.5 Depth From Top of Media to Top of Backwash Trough (ft): 3.0
11	Clearwell #1	Clearwell	14	Surface Area (ft2): 27,000 Liquid Volume (gal): 2,000,000 Minimum Liquid Volume (gal): 1,000,000 Baffling Type: UN Short Circuiting Factor:

Seq. No.	Sample Location Name	Sample Location Type	Sample Loc. No.	
				Covered Indicator Code: Y
12	Fin. Wtr. Stor.	Other Treatment Process		Surface Area (ft2): 21,785 Liquid Volume (gal): 4,090,000 Short Circuiting Factor:
	Finished Water	FIN	8	

End of Report A.2 -Design Plant Parameters

A.3 -- Design Plant Chemical Parameters

Date: 7/9/97

PWS Name: City of Fort Lauderdale
PWS ID: FL4060486
WIDB:
ICR Contact Person: Mr. Craig Canning

Sampling Period: Design
Sampling Start Date: 7/21/97
Sampling End Date: 12/31/98

Treatment Plant Name: Fiveash Water Treatment Plant
ICR Treatment Plant ID No: 296
Treatment Plant Category: SOFT

Process Train Name: Fiveash
Process Train Category: SOFT

Sep. No.	Sample Location Name	Sample Location Type	Sample Location Number	Chemical Name	Measurement Formula	Dose (mg/L)
1	Aeration	Other Treatment Process				
				Organic polymer - coagulant aid	OPC	0.15
				Ferric sulfate	FES	7.00
2	Chlorine gas	Disinfectant Addition	2			
				Chlorine gas	Cl2	6.00
3	Fiveash wshwtr	Washwater Return Sample Point				
4	Fiveash wshwtr	Washwater Return	15			
5	Hydrotreater 4	Solids Contact Clarifier	4			
				Calcium hydroxide	CaOH	150.00

Sep. No.	Sample Location Name	Sample Location Type	Sample Location Number	Chemical Name	Measurement Formula	Dose (mg/L)
6	Chlorine gas	Disinfectant Addition		Chlorine gas	Cl2	6.00
7	Anhydrous ammon	Disinfectant Addition		Anhydrous ammonia	NH3	1.10
8	Recarb Basin 4	Disinfection Contact Basin	5	Hydrofluorosilic acid	HFS	0.50
9	No 11	Filtration	6			
10	Clearwell #1	Clearwell	14			
11	Fin. Wtr. Stor.	Other Treatment Process				

Treatment Plant Name: Peele Dixie Water Treatment Plant
ICR Treatment Plant ID No: 297
Treatment Plant Category: SOFT

Process Train Name: Peele Dixie
Process Train Category: SOFT

Sep. No.	Sample Location Name	Sample Location Type	Sample Location Number	Chemical Name	Measurement Formula	Dose (mg/L)
1	Chlorine gas	Disinfectant Addition				
				Chlorine gas	Cl2	6.00
2	Aeration	Other Treatment Process				
3	Peele wshwtr	Washwater Return Sample Point	2			
4	Dixie wshwtr	Washwater Return	15			
5	Flocculation	Flocculation Basin	4			
				Organic polymer - coagulant aid	OPC	0.12
				Calcium hydroxide	CaOH	150.00
6	Sedimentation	Sedimentation	5			
7	Chlorine gas	Disinfectant Addition				
				Chlorine gas	Cl2	6.00
8	Anhydrous ammon	Disinfectant Addition				
				Anhydrous ammonia	NH3	1.10
9	North Recarb	Disinfection Contact Basin	6			
				Hydrofluorosilic acid	HFS	0.50
10	#5	Filtration	7			

Sep. No.	Sample Location Name	Sample Location Type	Sample Location Number	Chemical Name	Measurement Formula	Dose (mg/L)
11	Clearwell #1	Clearwell	14			
12	Fin. Wtr. Stor.	Other Treatment Process				

End of Report A.3 --Design Plant Chemical Parameters