ICR Treatment Study Summary Report

Evaluation of Granular Activated Carbon Using Bench-Scale Test for Compliance with the Information Collection Rule

Conducted April 1998 – March 1999

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For:

Upper San Leandro Water Treatment Plant
ICR#139

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Attachments: A diskette containing the *ICR Treatment Study Data Collection Spreadsheets*, the *ICR Treatment Study Summary Spreadsheets*, and the *ICR Treatment Study Summary Report*

Section I – Conclusions and Recommendation

East Bay Municipal Utility District (EBMUD) conducted four seasons of bench-scale study of granular activated carbon (GAC) technology at Upper San Leandro Water Treatment Plant (USLWTP) to remove organic precursors from plant's filtered water prior to chlorination. Based on the results of this study the following conclusions can be reached:

- To meet the Stage 1 DBP MCLs the District should not need to install GAC contactors at USLWTP because without GAC the SDS-HAA5 of the water was below 60 • g/L for all the tests and average SDS-THM4 (82.5 • g/L) was just above 80 • g/L

- The District needs to evaluate and modify its operation to optimize the removal of organic precursors so it can meet the Stage 1 DBP MCLs without building GAC contactors or other capital intensive technologies.

- To meet the proposed Stage 2 THM4, the District most likely has to build GAC contactors or use other technologies to reduce organic precursors below TOC of 1.5 mg/L before chlorination.

- Based on analysis of breakthrough curves for SDS-THM4, a GAC contactor with empty-bed-contact-time (EBCT) of 20-minutes gave 1.7 to 2.8 times longer operation time than EBCT of 10-minutes. Therefore, building GAC contactors with 20-min EBCT is more cost effective than GAC contactors with 10-min EBCT.

- Based on preliminary estimates capital cost of building GAC contactors for USLWTP to meet THM4 goal of 36 • g/L without on-site regeneration facility, is $22 million (1999). This is to meet USLWTP's design flow rate of 55 million-gallons-per-day (MGD) with EBCT of 20-minutes.

- The annual operation (off-site regeneration) and maintenance of the above GAC facility is $16.5 million based on 1999 costs.

Section II - Background Information

The USEPA's Information Collection Rule required that all water treatment plants that serve more than 100,000 persons and have an annual average total organic carbon (TOC) of more than 4.0 mg/l to perform an ICR treatment study.

USLWTP is a conventional water treatment plant with post-sedimentation ozonation system, located in Oakland, California that serves more than 100,000 customers. The plant's raw water has an average TOC of 4.5 mg/L. USLWTP is one of the six water treatment plants that are owned and operated by EBMUD.

To meet the requirements of the ICR Treatment Study, EBMUD conducted a bench-scale treatment study to remove the TOC using granular activated carbon (GAC) technology. These tests were done during the months of April 1998, September 1998, November 1998, and February 1999.

USLWTP receives its raw water from the Upper San Leandro (USL) Reservoir. USL Reservoir is supplied by runoff from local watershed (Figure 1). During the spring and summer seasons, the reservoir is normally supplemented with Mokelumne Aqueduct water of higher quality. EBMUD evaluated the seasonal variability of the water by doing the tests at four different seasons.

Raw and Finished Water Quality - Table 1 shows summary of annual source water quality for the USLWTP, and Table 2 shows summary of annual finished water data. The mineral contents of the plant's raw water can be described as moderately hard with average alkalinity of 108 mg/l as $CaCO_3$, and total hardness of 122 mg/L as $CaCO_3$. Raw water turbidity changes dramatically from season to season as shown by the wide range of turbidity 0.57-49 NTU. The water has very low concentrations of bromide, and fairly constant TOC with annual average of 4.5 mg/L and standard deviation of only 0.19.

The weather during the test period was wetter than normal that caused high local watershed runoff into the USL Reservoir. As a result, the raw water source was more mineralized and had higher than normal organic levels.

Treatment Plant Description - USLWTP was built as a conventional water treatment plant in 1926. In 1993, major plant improvements were completed to accommodate a new ozonation facility, new chemical feed systems, and the automation of the filtration process. Currently, the plant is rated at maximum flow rate of 55 MGD, and an average flow of 19 MGD.

USLWTP is a conventional treatment plant that uses ozone for taste and odor control. The treatment process consists of chlorination, aeration, coagulation, flocculation, sedimentation, ozonation, filtration, and chloramination. Figure 2, shows a schematic of the treatment process at USL. Table 3 describes the design parameters for each unit processes. USLWTP has ten dual-media (sand/GAC) filters.

Treatment Challenges Facing the Plant - Some of the treatment challenges that currently faces USLWTP include:

- Taste and odor control during spring, summer and fall when there is algae bloom in USL Reservoir.
- Reducing disinfection-by-products in the finished water.
- Controlling settled water turbidity during winter storm events.
- Reducing TOC to meet the requirements of enhanced coagulation.

Section III - Materials and Methods

Pretreatment Processes - The pretreatment process prior to the bench-scale GAC study is outlined in Figure 2. First, raw water was aerated to remove some of the taste and odor causing compounds. Then, alum and cationic polymer were added as coagulants to the water as it entered the rapid mix chamber. The water was then sent to flocculation where it went through four stages of flocculation. The flocs were then allowed to settle in the sedimentation basin. After sedimentation, ozone was added to the water for taste and odor control. Then the water was filtered through GAC/sand filters before its collection for the study.

The water for the ICR Treatment Study was collected from one of the filter and placed into 55-gallon polyethelyne tanks. USLWTP normally pre-chlorinates the raw water at the head of the plant; however, for this study pre-chlorination was stopped for at least 24 hours before the water was collected for these tests. Filter effluent was checked for chlorine residual before water was collected for the bench-scale tests.

Bench-Scale Setup **–** The District used rapid small-scale column test (RSSCT) for this study. The RSSCT set-up was designed to meet the requirements specified in the *ICR Manual for Bench and Pilot-Scale Treatment Studies* (EPA 814-B-96-003). Figure 3, shows the RSSCT set-up.

The RSSCT set-up consisted of two glass columns with inner diameter of 15 mm, one for 10-minute empty bed contact time (EBCT), and one for 20-minute EBCT. Each column was equipped with its separate positive displacement pump, pulsation dampner, pressure gauge, pressure relief valve, and manual air release valve. All the tubing and fittings were made of Teflon or stainless steel. Table 4 shows the design parameters for the RSSCT study.

Filtersorb 300, a bituminous coal-based GAC manufactured by Calgon Carbon Corporation, was used for the study. Original GAC with mesh size of 8x30 was crushed, sieved, and washed to mesh size of 100x200 for the study.

To prevent excessive headloss buildup, the batch of RSSCT influent water was pre-filtered with a 1-µm polypropylene cartridge prefilter (Whatman, Polycap HD). A peristaltic pump was used to pump the water across the cartridge filter. Additionally, bottom of each column was fitted with a ceramic frit, as packing support, with about 0.25-inch of glass wool on top of the frit.

Experimental Design **-** Table 5 shows the experimental design for the RSCCT study in which seasonal variability and two empty bed contact times were investigated. The District used the sampling procedure outlined in Section 4.3 of *ICR Manual for Bench- and Pilot-Scale Treatment Studies* (EPA 8141B-96-003).

The District used an on-site TOC analyzer machine (Siever Model 800 with inorganic carbon remover) to measure TOC on-site for estimating sample collection intervals.

Simulated Distribution System (SDS) Test – Table 6 shows the SDS test parameter goals for each quarter of the study. Because USLWTP uses chloramine as residual disinfectant in the distribution system, then according to the EPA's guideline for SDS study, the free chlorine residual at the end of incubation period has to be 0.5-1.0 mg/L. To keep the incubation temperature of the SDS test bottles the same as the water temperature in the distribution system, the District used two water baths to constantly run distribution system water around the bottles.

Analytical Methods **-** EBMUD used its own laboratory for all the analyses. EBMUD laboratory is an ICR approved laboratory. All the analyses were performed using the methods and QA/QC procedures described in the *DBP/ICR Analytical Methods Manual*. Table 7 shows a summary of all the analytical methods and minimum-reporting-levels (MRL) used for the ICR Treatment Study.

Section IV - Results and Discussion

The results of all water quality monitoring and sampling data collected during this study is included the Data Collection Spreadsheet which is attached to this report. The results of this study are summarized in the following sections.

Pretreated Water Data & Seasonal Variation– Table 8, shows the average pretreated feed water quality data for each quarter of the study. The TOC was highest in the first quarter, 3.2 mg/L, and lowest in the fourth quarter, 2.6 mg/L. Figure 4 shows, the SDS-THM4 and SDS-HAA5 formation potential variation for the four quarters. The second quarter had the highest THM and HAA levels, 110 and 38 mg/L, respectively. Second quarter water also had the highest chlorine demand of 3 mg/L.

Raw Water and Operation Data **-** Table 9 shows USLWTP operation and chemical dose data on the days that the batch water was collected for RSCCT study. The data shows large variation of the raw water turbidity, temperature, ozone, and alum dose during these periods. Figure 5, shows variation in raw water turbidity and alum dose during this period. Higher alum doses corresponds to higher raw water turbidity.

Breakthrough Curves for 10-min EBCT- Figure 6, shows four quarters of normalized TOC breakthrough curves for the10-min EBCT column. In three of the four quarters the 70% TOC breakthrough goal was either surpassed or almost reached. Figure 7, shows the same data for a plant-scaled operation. The data shows that for this pretreated water a plant-scale GAC contactor will become exhausted after 180-200 days of operation.

Figure 8, shows SDS-THM4 data for the four quarters corresponding to GAC column scaled operation time. The curves for first, second, and third quarter exhibits similar trend. None of the curves exceeds MCL of 80 • g/L for Stage 1. The data for the second quarter shows different trend. Although it never reaches MCL of 80 • g/L but it exceeds 60 • g/L level after 65 days of operation. However, all the curves exceed 40 • g MCL proposed for Stage 2 of DBP Rule. The average scaled operation time before breakthrough is 69 days.

Figure 9, shows similar data as Figure 8 but for SDS-HAA5. The HAA concentration never exceeded above MCL of 60 ug/L set for the Stage 1, and proposed MCL of 30 ug/L for the Stage 2 of M/DBP Rule.

Table 10 shows a summary of the run time and number of bed volumes for 10-min EBCT at which Stage 1 DBP MCLs and proposed Stage 2 DBP MCLs, both with 10% safety factor are reached. To meet SDS-THM4 goal of 36 ug/L the GAC must be regenerated after 61 days of operation.

Breakthrough Curves for 20-min EBCT- Figure 10, shows four quarters of normalized TOC breakthrough curves for the 20-min EBCT column. None of the tests reached the 70% TOC breakthrough goal. In the first and third quarters the headloss across the column had reached very high levels (90 psi) so the tests were stopped at that time. For the second and fourth quarters the TOC levels seemed to have reached a steady state. Figure 11, shows the same data for a plant-scaled operation. From this data, it can be extrapolated that a plant scale GAC column will become exhausted after 325-375 days of operation.

Figure 12, shows SDS-THM4 data corresponding to plant-scale operation of GAC column. The curves for first, second, and third quarter exhibits similar trend. None of the curves exceeds MCL of 80 ug/L for Stage 1, or 60 ug/L for proposed Stage 2 of M/DBP Rule. This result is consistent with the SDS-THM4 levels of the column's influent for these quarters (Figure 4). The data for the second quarter shows a different trend. Although it never reaches MCL of 80 ug/L but it exceeds 60 ug/L level after 210 days of operation.

Figure 13, shows similar data as Figure 12 but for SDS-HAA5. The HAA5 concentration never exceeds MCL of 60 ug/L set for the Stage 1, or MCL of 30 ug/L proposed for the Stage 2 of DBP Rule.

Table 11 shows a summary of the run time and number of bed volumes for 20-min EBCT at which Stage 1 DBP MCLs and proposed Stage 2 DBP MCLs, both with 10% safety factor, are exceeded. To meet SDS-THM4 goal of 36 ug/L, the GAC must be regenerated after 102 days of operation.

Section V – QA/QC Summary

All the analyses during this study have been conducted according to QA/QC procedures described in the DBP/ICR Analytical Manual. The District laboratory has performed lab duplicates, fortified matrix samples, and independent QC checks for many analyses that it has analyzed.

A summary of relative performance errors (RPE) of analytical duplicates, percent recovery of laboratory fortified matrix (spike), and percent recovery for performance evaluation (PE) samples is included in the *ICR Summary Study Report Spreadsheets* and is electronically attached to this report. Also a summary of that spreadsheet is shown in Table 12.

Because of large volume of the laboratory duplicate and spiked data, this data is being submitted electronically in a file titled *EBMUD's ICR Treatment Study QA&QC Data* is attached to this report. This file contains six Excel spreadsheets containing all QA/QC data for TOC, HAA, THM, TOX, UV-254, and bromide.

Table 1 – Summary of Annual Source Water Quality (Plant Influent)

Water Quality Parameter	Average Yearly Concentration	Standard Deviation	Maximum Yearly Value	Minimum Yearly Value
Temperature (^{o}C)	19.2	5.7	25.8	10.0
pH	8.33	0.47	9.20	7.60
Turbidity (NTU)	10.79	15.41	49.23	0.57
Alkalinity (mg/L $CaCO_3$)	107.94	14.54	150.00	83.00
Calcium Hardness (mg/L $CaCO_3$)	71.51	6.66	79.00	59.80
Total Hardness (mg/L $CaCO_3$)	121.80	13.71	150.00	95.00
TOC (mg/L)	4.50	0.19	4.90	4.50
UV254 (cm^{-1})	0.16	0.07	0.37	0.11
Bromide (mg/L)	0.04	0.01	0.05	0.04

Table 2 - Summary of Annual Finished Water Quality

Water Quality Parameter	Average Yearly Concentration	Standard Deviation	Maximum Yearly Value	Minimum Yearly Value
Temperature (^{o}C)	15.05	2.95	20.30	11.60
pH	8.66	0.31	9.02	8.32
Turbidity (NTU)	0.05	0.00	0.05	0.04
TOC (mg/L)	2.76	0.34	3.50	2.30
Distribution System THM4 (• g/L)	95.50	27.58	150.00	49.00

Table 3 – Upper San Leandro Water Treatment Design Parameters

Unit Process	Process Description
Chlorination	Pre-chlorination w/sodium hypochlorite, dose=1.4 - 2.8 mg/l
Aeration	Raw water is aerated by hydraulic aspirators
Rapid Mix	Type of Mixer: Mechanical Baffling Type: Baffled - Mixed tank Liquid Volume (gal): 43,000 Waterchamp Mean Velocity Gradient (sec^{-1}): 1000 Coagulant Addition: Alum. Coagulant Dose (mg/L): 18.6 Coagulant Aid: Cationic Polymer. Coagulant Aid Dose (mg/L): 1
Flocculation	Type of Mixer: Mechanical Number of Units: 2 Liquid Volume (gal); 920,000 each Baffling Type: Good - Inlet/Outlet 4 Baffles Stage Mean Velocity Gradient (sec^{-1}): 56/30/12/9 @65 MGD Each Stage Volume (gal): 115,000 Surface Area (ft^2): 14,137
Sedimentation	Number of Units: 2 Liquid Volume (gal): 1,800,000 Baffling Type: Poor - Inlet/Outlet Only Capacity (lbs/day): 1500
Ozone	Ozone Dose (mg/L): 2.4 Surface Area (ft^2): 12,000
Filtration	Number of Filters: 10 Liquid Volume (gal): 388,930 Total Media Depth (in): 26 Media Type: Dual - GAC/Sand Minimum Water Depth to Top Media (in): 14-16 Depth From Top of Media to Top of Backwash Trough (in): 46
Disinfection	**Primary** Chemical Type: Hypochlorite Measured as: Cl_2 Dose Rate (mg/L): 3.2 **Secondary** Chemical Type: Chloramine Measured as: NH_3 Dose Rate (mg/L): 0.51-0.53 Surface Area (ft^2): 100,000
Clear Well	Liquid Volume (gal): 1,000,000 Baffling Type: Poor Covered Contactor: Yes
Corrosion Control	Corrosion Control Chemical: Sodium Hydroxide Dose (mg/L): 8-14

Table 4 – Design Parameters for RSSCT Study

Parameters	EBCT=10 min	EBCT=20 min
Original Mesh Size	8x30	8x30
Diameters of GAC used for RSSCT, mm	0.112	0.112
Scaling Factor	13.6	13.6
$EBCT_{SC}$, min	0.76	1.52
Superficial Velocity, m/hr	8.37	8.37
RSCCT Diameter, mm	15	15
Flow rate, ml/min	24.6	24.6
Mass of dry GAC, grams	9.37	18.74

Table 5 – Experimental Design Summary

Season	Test Date	Pretreatment	EBCT (min)
Spring	April 1998	Conventional filtration with post-sedimentation ozonation	10 & 20
Summer	September 1998	Conventional filtration with post-sedimentation ozonation	10 & 20
Fall	December 1998	Conventional filtration with post-sedimentation ozonation	10 & 20
Winter	February 1999	Conventional filtration with post-sedimentation ozonation	10 & 20

Table 6 – SDS Test Parameter Goals

Incubation Parameter	First Quarter Spring	Second Quarter Summer	Third Quarter Fall	Fourth Quarter Winter
Time (hrs)	96	48	96	96
Temperature (C)	Distribution system temp.	Distribution system temp.	Distribution system temp.	Distribution system temp.
pH (unit)	8.5	9.0	9.0	9.0
Free Chlorine Residual (mg/L)	0.5-1.0	0.5-1.0	0.5-1.0	0.5-1.0

Table 7 - Summary Of Analytical Methods and MRLs Used For ICR Study

Analyte	Method	Minimum Reporting Level
Alkalinity	SM(18)2320B	5 mg/L $CaCO_3$
Ammonia	SM(19)4500-NH_3	0.1 mg/L
Bromide	EPA 300 A	2 • g/L
Calcium Hardness	EPA 200.7	0.025 mg/L $CaCO_3$
Chlorine Residual	Field Data	0.2 mg/L
BCAA	SDS EPA 552.2	0.063 • g/L
DBAA	SDS EPA 552.2	0.087 • g/L
DCAA	SDS EPA 552.2	0.074 • g/L
MBAA	SDS EPA 552.2	0.13 • g/L
MCAA	SDS EPA 552.2	0.34 • g/L
TCAA	SDS EPA 552.2	0.098 • g/L
pH	Field Data	Not Applicable
Temperature	Field Data	Not Applicable
$CHCl_3$	SDS EPA 505.2	0.1 • g/L
BDCM	SDS EPA 505.2	0.1 • g/L
DBCM	SDS EPA 505.2	0.1 • g/L
$CHBr_3$	SDS EPA 505.2	0.15 • g/L
Total Hardness	SM(18)2340C	2 mg/L
TOC	SM(18)5310C	0.09 mg/L
TOX	SDS(18)5320	5 • g/L
Turbidity	Field Data	0.05 ntu
UV_{254}	SM 5910	0.003 abs

Table 8 - Summary of the Average Pretreated Feed Water Quality During Four Quarters of RSSCT study (SD = Standard Deviation)

Water Quality Parameter	First Quarter Average (SD)	Second Quarter Average (SD)	Third Quarter Average (SD)	Fourth Quarter Average (SD)
Temperature (^{o}C)	14 (0.2)	19.6 (0.3)	13.6 (1.6)	12.6 (1.5)
pH	7.34 (0.2)	7.86 (0.1)	8.12 (0.1)	8.06 (0.1)
Turbidity (NTU)	0.11 (0.0)	0.5 (0.6)	0.07 (0.0)	0.08 (0.0)
Alkalinity (mg/L as $CaCO_3$)	79 (1.4)	105 (7.1)	110 (0.0)	100 (0.0)
Calcium Hardness (mg/L $CaCO_3$)	69.6 (0.6)	75 (0.0)	84.5 (0.0)	74.8 (N/R)
Total Hardness (mg/L $CaCO_3$)	115 (7.1)	135 (7.1)	120 (0.0)	120 (0.0)
Bromide (• g/L)	45 (N/R)	45.5 (0.7)	54 (0.0)	37 (1.4)
TOC (mg/L)	3.225 (0.3)	3.0 (0.1)	3.03 (0.1)	2.63 (0.1)
UV_{254} (cm^{-1})	0.055 (0.004)	0.041 (0.001)	0.035 (0.003)	0.028 (0.001)
SDS-THM4 (mg/L)	81.4 (2.7)	109.9 (11.0)	73.9 (7.2)	66.2 (4.3)
SDS-HAA5 (• g/L)	33.4 (5.2)	36.8 (6.5)	30.9 (1.8)	21.5 (3.0)
SDS-HAA6 (• g/L)	39.0 (5.7)	44.7 (8.0)	36.4 (1.8)	25.6 (3.6)
SDS-TOX (• g/L)	240 (52.0)	290 (27.1)	202.5 (20.6)	207.5 (22.2)
SDS-Cl Demand (mg/L)	1.7 (0.5)	3.0 (0.2)	2.2 (0.2)	1.9 (0.3)

Table 9 – Pretreatment Plant Data for Four Quarters of RSSCT Study

Date	**First Quarter** 4/8/98	**Second Quarter** 9/8/98	**Third Quarter** 11/17/98	**Fourth Quarter** 1/10/99
Flow Rate thru Sedimentation Basin, MGD	25	15	10	15
Flow Rate thru Flocculation Basin, MGD	25	15	10	15
Flow Rate thru Filters, MGD	5	5	5	5
Number of Filters on-line	5	3	2	3
Alum Dose, mg/L	27.5	16	12	19
Cationic Polymer Dose, mg/L	1	1	1	1
Ozone, mg/L	1.2	3	2	3.3
Raw Water Turbidity , NTU	9.2	1	0.77	1.68
Raw Water Temperature, degree C	13.7	18	14	10
Raw Water pH	7.52	7.54	7.96	7.93
Settled Water Turbidity, NTU	2	0.4	0.29	0.47
Settled Water Temperature, degree C	13.7	18	14	10
Settled Water pH	7.22	7.51	7.77	7.58

Table 10 - Summary of Times To Reach Various Breakthrough Criteria And The Water Quality Of The GAC Effluent When Those Criteria Are Met For 10-min EBCT

Break-through Criterion	Value of Listed Parameters When Breakthrough Criterion is Met						
	Run Time	**Throughput**	**TOC**	**SDS-THM4**	**SDS-HAA5**	**SDS-HAA6**	**SDS-TOX**
	(days)	**(Bed Vol.)**	**(mg/L)**	**(mg/L)**	**(mg/L)**	**(mg/L)**	**(mg Cl^-/L)**
SDS-THM4 = 90 • g/L	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SDS-THM4 = 72 • g/L	105[1]	15109	2.0	72	18	23	128
SDS-THM4 = 54 • g/L	90[2]	12950	1.9	54	15	18	112
SDS-THM4 = 36 • g/L	61[3]	8777	1.5	36	12	15	90
SDS-HAA5 = 54 • g/L	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SDS-HAA5 = 27 • g/L	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SDS-HAA6 = 54 • g/L	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SDS-HAA6 = 27 • g/L	N/A	N/A	N/A	N/A	N/A	N/A	N/A

1- Results from quarter 2 only
2- Average results from quarters 2-4
3- Average results from all quarters

Table 11 - Summary of Times To Reach Various Breakthrough Criteria And The Water Quality Of The GAC Effluent When Those Criteria Are Met For 20-min EBCT

Break through Criterion	Value of Listed Parameters When Breakthrough Criterion is Met						
	Run Time	Throughput	TOC	SDS-THM4	SDS-HAA5	SDS-HAA6	SDS-TOX
	(days)	(Bed Vol.)	(mg/L)	(• g/L)	(• g/L)	(• g/L)	(• g/L)
SDS-THM4 = 90 • g/L	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SDS-THM4 = 72 • g/L	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SDS-THM4 = 54 • g/L	254[1]	18274	1.8	54	16	20	124
SDS-THM4 = 36 • g/L	102[2]	7338	1.6	36	10	12	70
SDS-HAA5 = 54 • g/L	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SDS-HAA5 = 27 • g/L	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SDS-HAA6 = 54 • g/L	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SDS-HAA6 = 27 • g/L	N/A	N/A	N/A	N/A	N/A	N/A	N/A

1- Average of results from quarters 2 and estimation of quarter 4
2- Average results from all quarters

Table 12 - Summary of QA/QC Data

Analyte	Units	MRL		Count	Average	Std Dev	Percentiles 25th	50th	75th
Bromide	µg/L	0.002	RPE of Analytical Duplicates:	8	3.26	3.90	1.07	1.65	3.88
			% Recovery for Lab Fortified Matrix:	8	106.25	5.18	100.00	110.00	110.00
			% Recovery for PE Samples:	2	103.09	2.16	102.33	103.09	103.85
UV254	1/cm	0.003	RPE of Analytical Duplicates:	180	3.02	4.84	0.00	1.35	4.53
			% Recovery for Lab Fortified Matrix:	N/A	N/A	N/A	N/A	N/A	N/A
			% Recovery for PE Samples:	3	93.21	0.91	92.72	93.06	93.62
TOC	mg/L	0.09	RPE of Analytical Duplicates:	159	3.37	4.04	0.55	2.30	4.20
			% Recovery for Lab Fortified Matrix:	22	99.00	11.65	97.00	100.00	110.00
			% Recovery for PE Samples:	3	99.62	2.36	98.86	100.82	100.98
SDS-TOX	µg Cl-/L	5	RPE of Analytical Duplicates:	182	8.71	6.97	3.03	7.85	12.00
			% Recovery for Lab Fortified Matrix:	88	94.76	18.03	91.00	99.00	100.00
			% Recovery for PE Samples:	3	88.06	9.15	82.85	84.31	91.40
SDS-CHCl3	µg/L	0.1	RPE of Analytical Duplicates:	13	4.14	3.13	1.20	4.10	6.40
			% Recovery for Lab Fortified Matrix:	13	104.69	11.94	99.00	100.00	120.00
			% Recovery for PE Samples:	3	99.55	5.35	96.84	99.41	102.19
SDS-BDCM	µg/L	0.1	RPE of Analytical Duplicates:	13	4.69	3.20	2.80	3.80	5.80
			% Recovery for Lab Fortified Matrix:	13	99.85	7.66	95.00	97.00	110.00
			% Recovery for PE Samples:	3	94.75	1.71	94.13	95.45	95.73
SDS-DBCM	µg/L	0.1	RPE of Analytical Duplicates:	13	4.08	2.79	2.50	3.30	6.60
			% Recovery for Lab Fortified Matrix:	13	101.46	6.45	98.00	100.00	100.00
			% Recovery for PE Samples:	3	106.03	4.51	104.11	107.14	108.52
SDS-CHBr3	µg/L	0.15	RPE of Analytical Duplicates:	13	5.90	6.33	0.86	3.10	8.30
			% Recovery for Lab Fortified Matrix:	13	97.54	7.09	92.00	100.00	100.00
			% Recovery for PE Samples:	3	97.84	4.37	95.47	96.98	99.78
THM4	µg/L		Avg RPE of Indiv Anal Dupl:	13	4.72	1.76	3.50	4.90	6.00
			Avg % Recov for Indiv Lab Fort Matrix:	13	100.91	7.51	96.30	97.30	107.50
			Avg % Recov for Indiv PE Samples:	4	99.55	4.73	97.05	98.70	101.20
SDS-MCAA	µg/L	0.34	RPE of Analytical Duplicates:	12	1.62	3.08	0.00	0.00	1.38
			% Recovery for Lab Fortified Matrix:	11	101.18	9.40	97.50	100.00	105.00
			% Recovery for PE Samples:	3	85.02	7.35	82.80	89.06	89.26
SDS-DCAA	µg/L	0.076	RPE of Analytical Duplicates:	14	8.45	14.94	0.40	4.20	8.23
			% Recovery for Lab Fortified Matrix:	13	91.92	15.32	91.00	95.00	98.00
			% Recovery for PE Samples:	3	84.43	4.56	81.93	83.33	86.38
SDS-TCAA	µg/L	0.099	RPE of Analytical Duplicates:	14	11.39	11.11	3.60	7.60	16.00
			% Recovery for Lab Fortified Matrix:	13	99.38	13.31	89.00	96.00	110.00
			% Recovery for PE Samples:	3	86.43	1.50	85.65	86.30	87.15
SDS-MBAA	µg/L	0.14	RPE of Analytical Duplicates:	14	7.73	12.28	0.00	1.65	7.58
			% Recovery for Lab Fortified Matrix:	13	98.23	7.95	94.00	97.00	100.00
			% Recovery for PE Samples:	3	84.85	5.21	82.27	84.95	87.48
SDS-DBAA	µg/L	0.089	RPE of Analytical Duplicates:	14	13.06	20.97	0.43	4.15	12.75
			% Recovery for Lab Fortified Matrix:	13	102.23	10.84	95.00	100.00	110.00
			% Recovery for PE Samples:	3	89.00	3.03	87.39	88.57	90.40

Table 12 (cont.) - Summary of QA/QC Data

Analyte	Units	MRL		Count	Average	Std Dev	Percentiles 25th	50th	75th
SDS-BCAA	µg/L	0.065	RPE of Analytical Duplicates:	14	12.15	21.51	1.75	5.60	13.73
			% Recovery for Lab Fortified Matrix:	13	97.92	10.50	90.00	98.00	100.00
			% Recovery for PE Samples:	3	84.55	2.13	83.43	84.30	85.54
HAA5	µg/L		Avg RPE of Indiv Anal Dupl:	14	8.74	7.94	2.28	8.50	12.70
			Avg % Recov for Indiv Lab Fort Matrix:	13	98.48	8.48	95.20	101.40	102.60
			Avg % Recov for Indiv PE Samples:	5	85.92	1.88	84.80	85.00	86.40
HAA6	µg/L		Avg RPE of Indiv Anal Dupl:	14	9.32	8.95	2.68	7.55	13.03

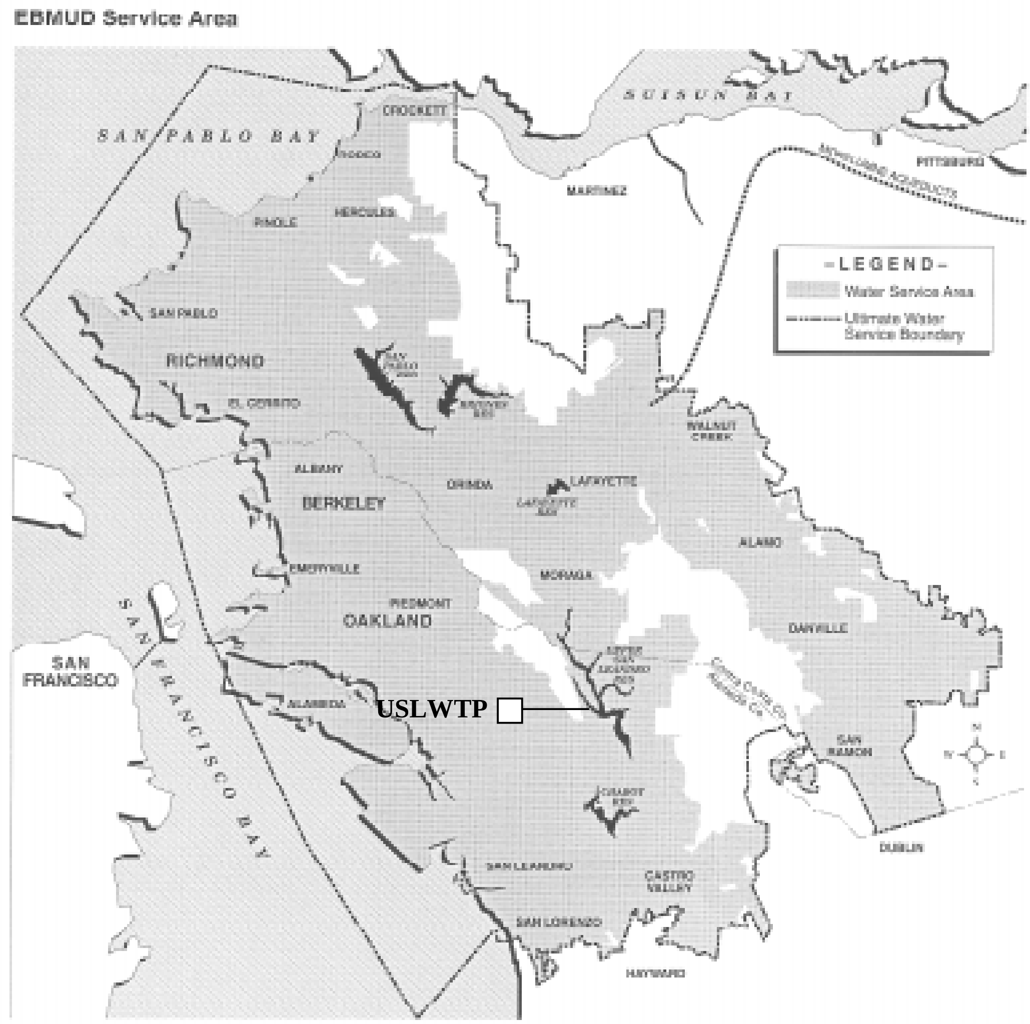

Figure 1 – Location of Upper San Leandro Reservoir and Upper San Leandro Water Treatment plant

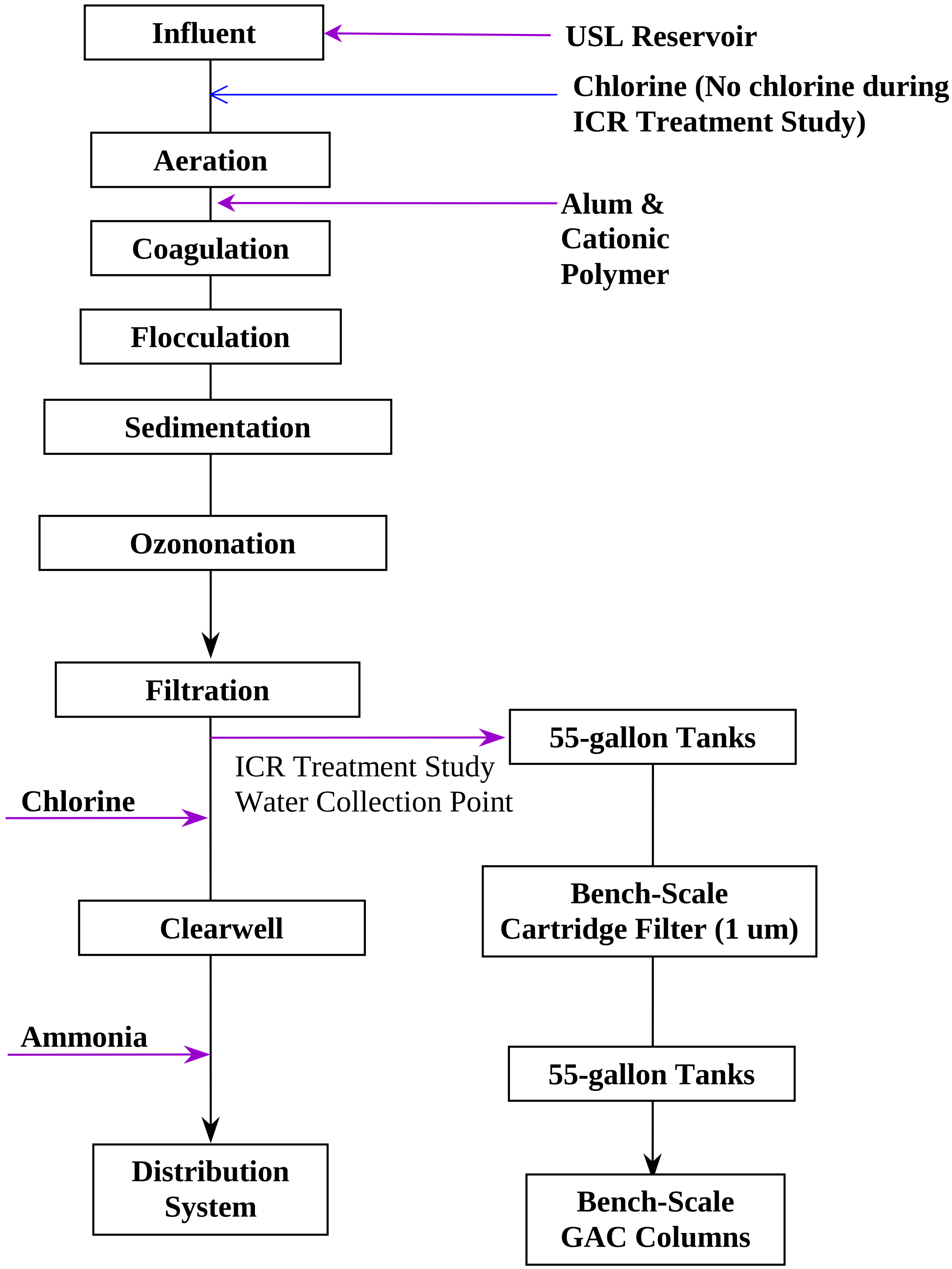
Influent
USL Reservoir
Chlorine (No chlorine during
ICR Treatment Study)
Aeration
Alum &
Cationic
Polymer
Coagulation
Flocculation
Sedimentation
Ozononation
Filtration
55-gallon Tanks
ICR Treatment Study
Water Collection Point
Chlorine
Bench-Scale
Cartridge Filter (1 um)
Clearwell
Ammonia
55-gallon Tanks
Distribution
System
Bench-Scale
GAC Columns

Figure 3. Schematic of RSSCT Bench-Scale Configuration

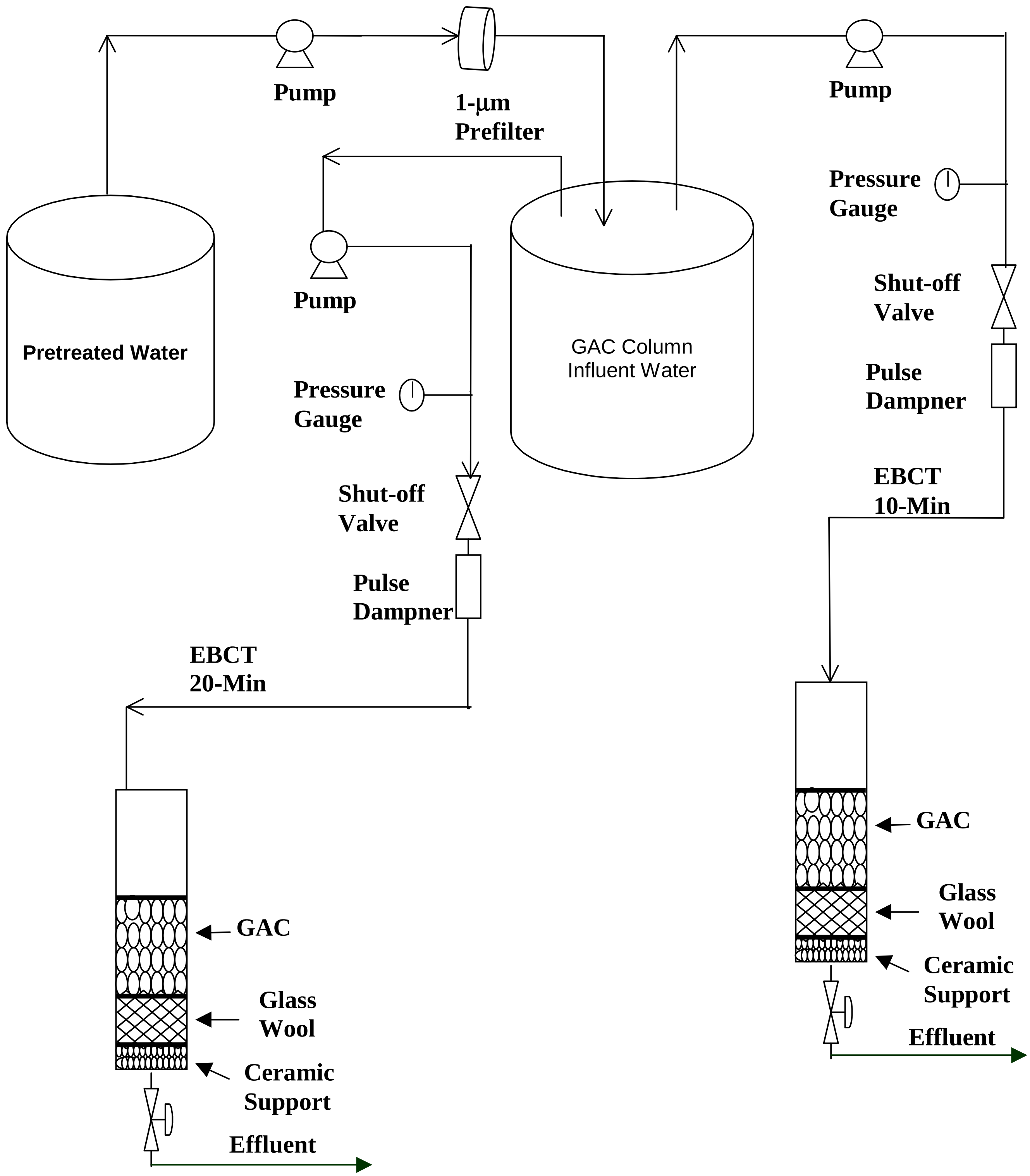

Figure 4 - Seasonal variation of SDS-THM & HAA of Pretreated RSSCT Feed Water

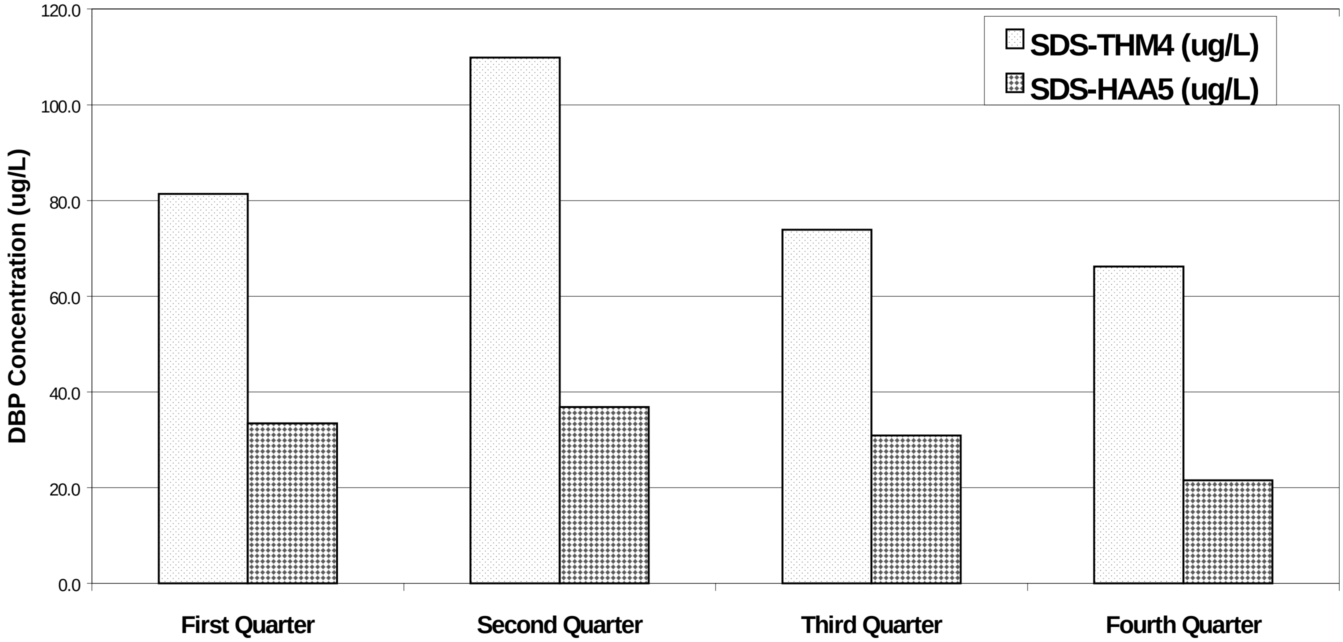

Figure 5 - Raw Water Turbidity and Alum Dose USL Raw Water Variation

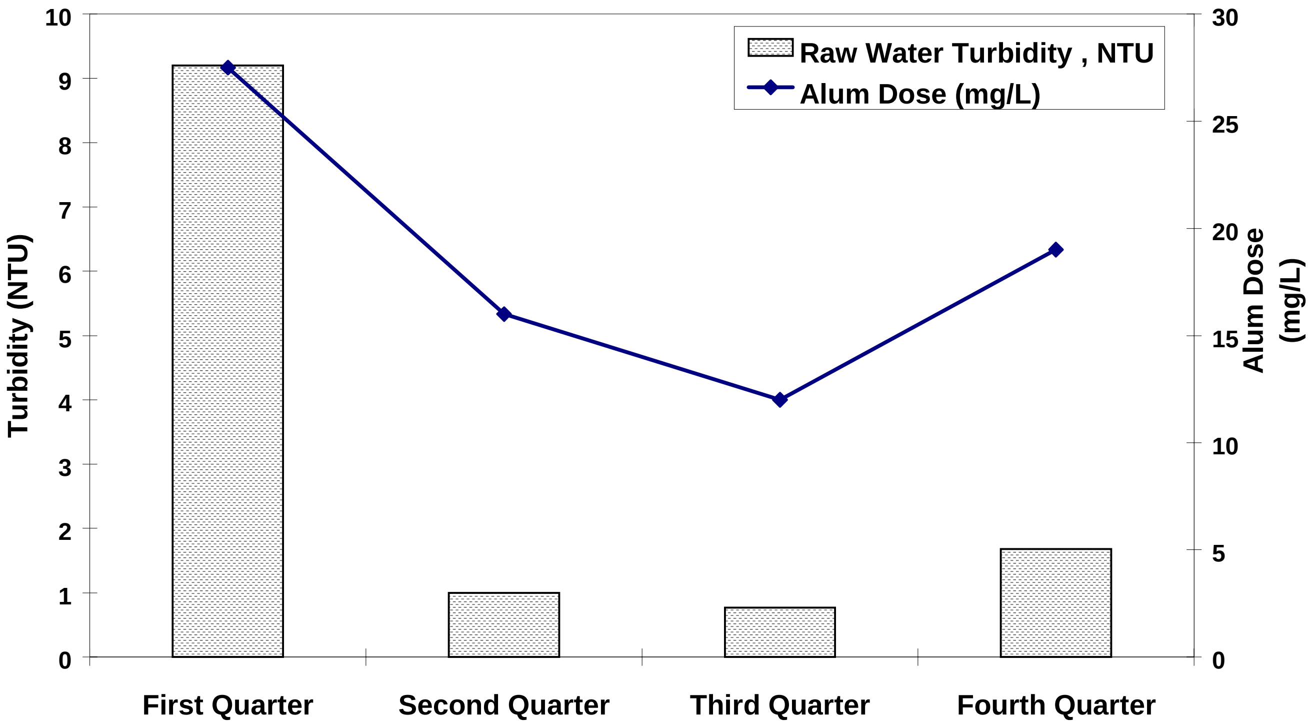

Figure 6 - Normalized TOC Breakthrough Curve for 10-minute EBCT RSSCT Column - ICR Treatment Study

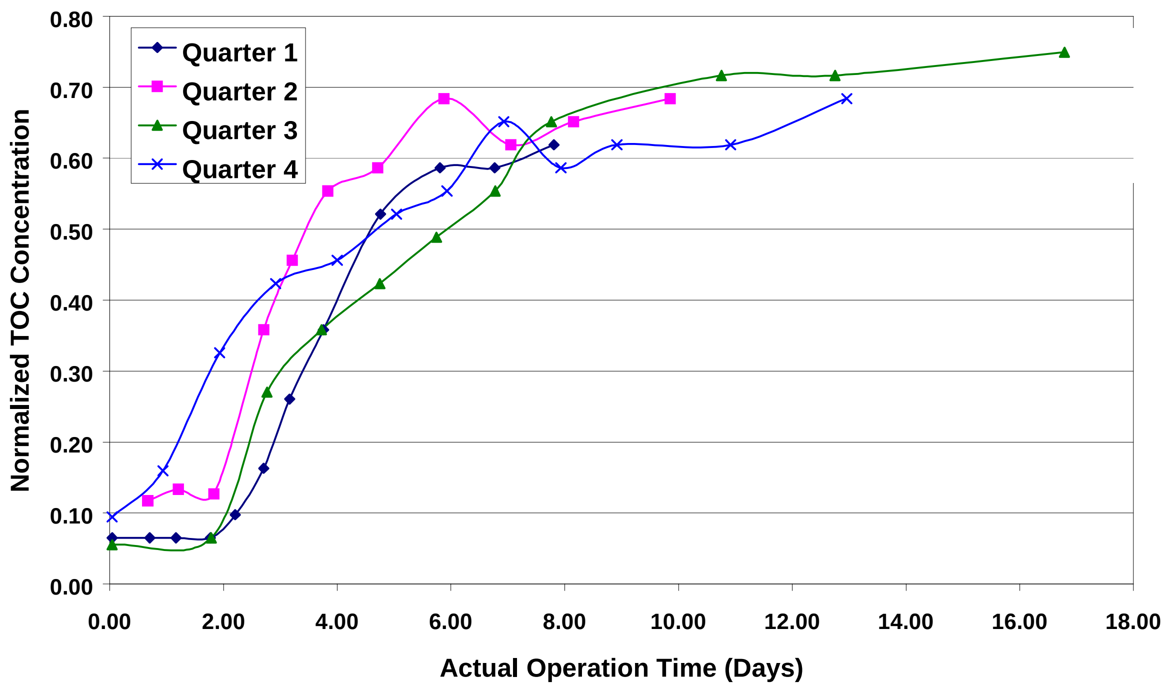

Figure 7 - TOC Breakthrough Curve for 10-minute EBCT RSSCT Column ICR Treatment Study

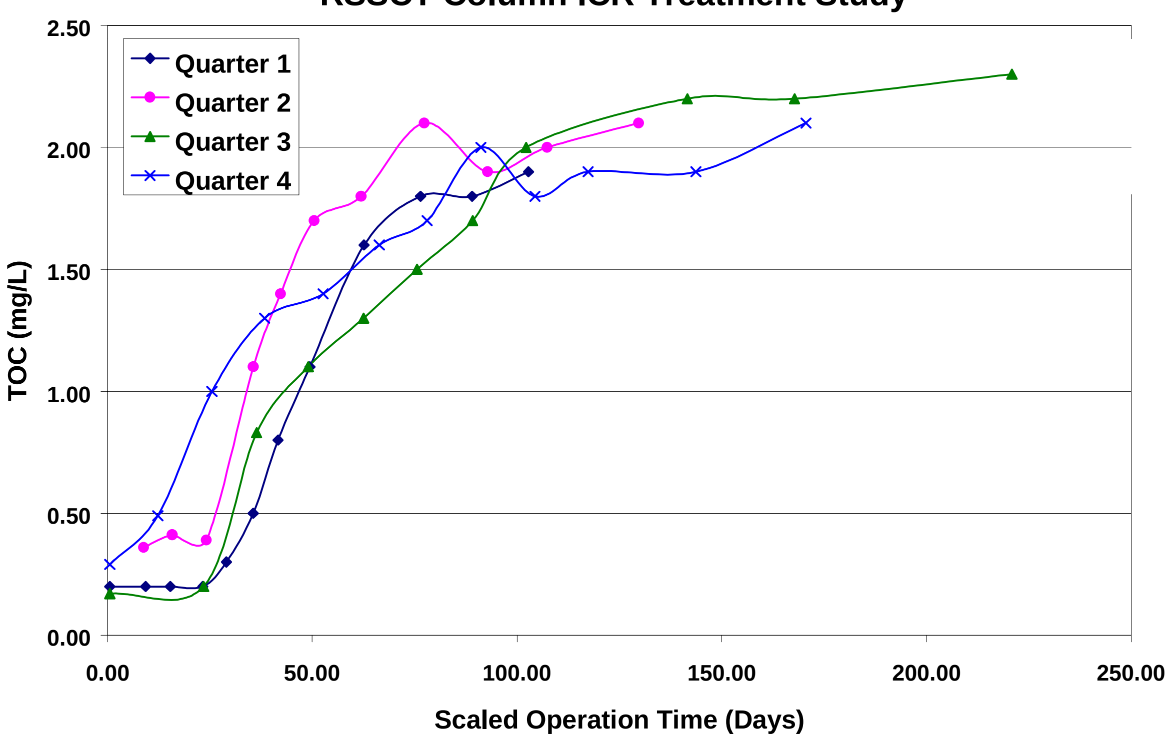

Figure 8 - THM Breakthrough Curves for 10-min EBCT

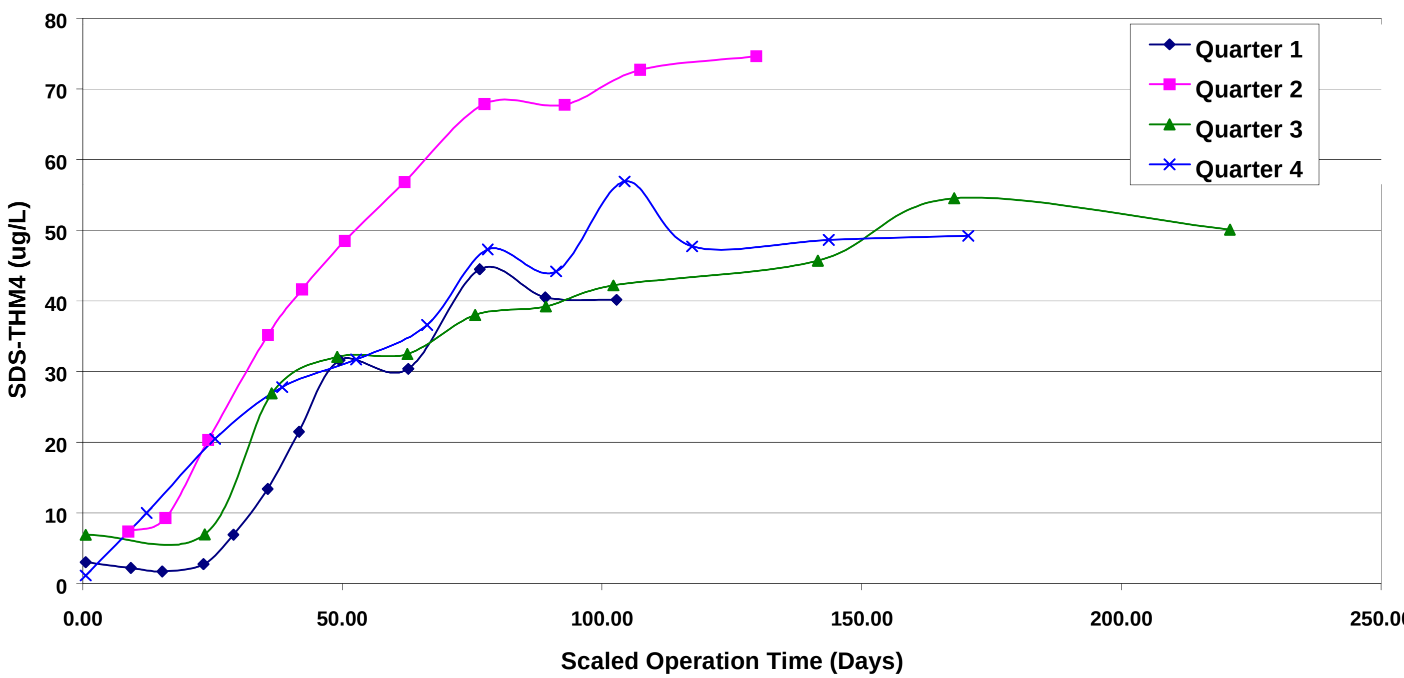

Figure 9 - HAA5 Breakthrough 10-min EBCT

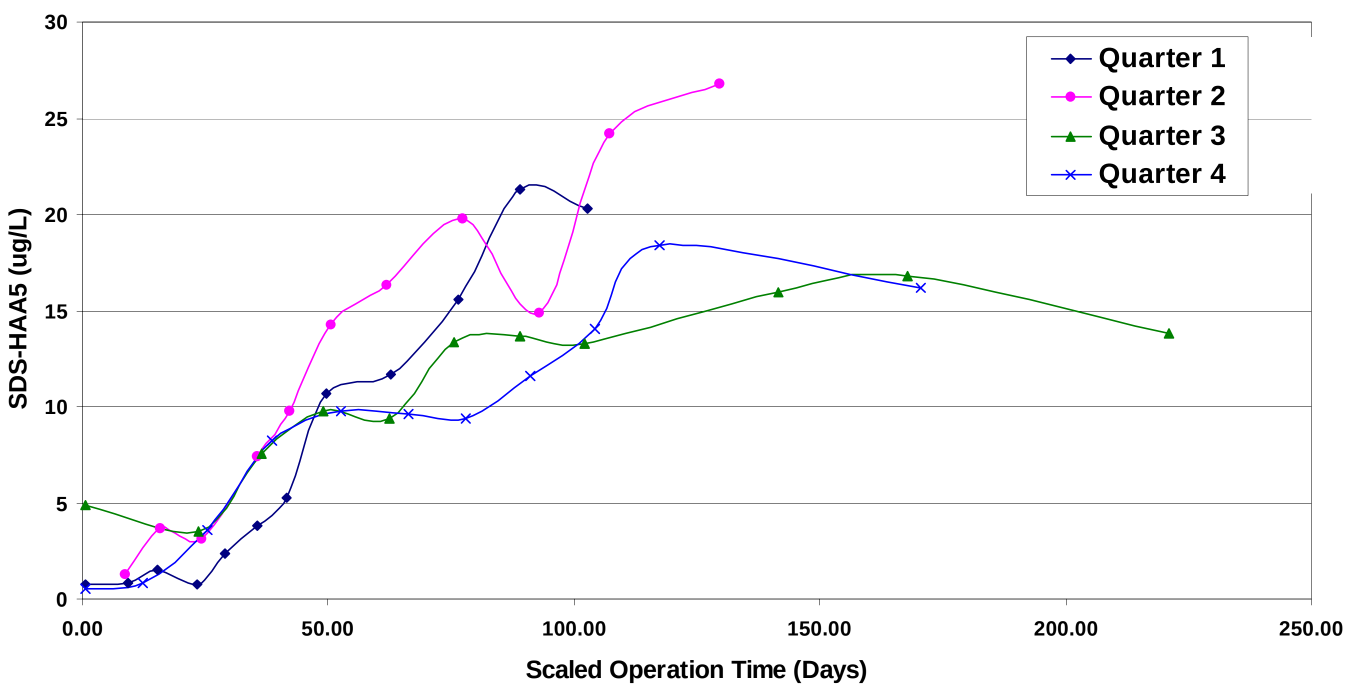

Figure 10 - Normalized TOC Breakthrough Curve for 20-minute EBCT RSSCT Column - ICR Treatment Study

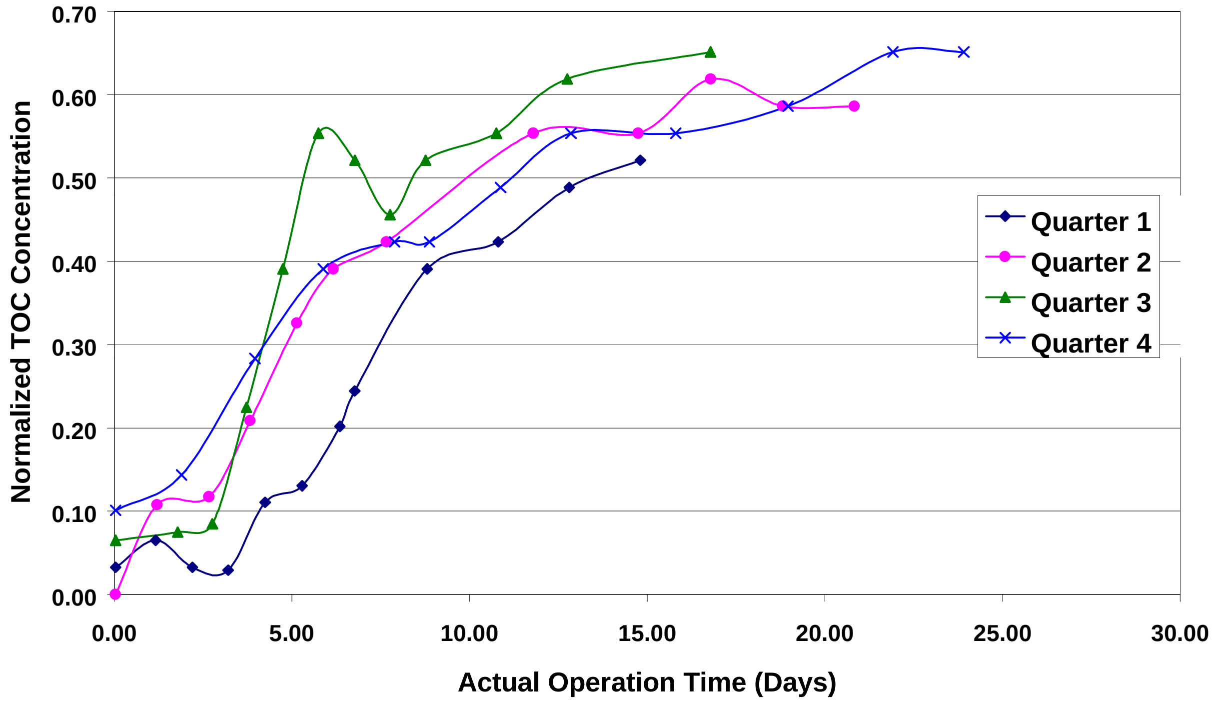

Figure 11 - TOC Breakthrough Curve for 20-minute EBCT RSSCT Column ICR Treatment Study

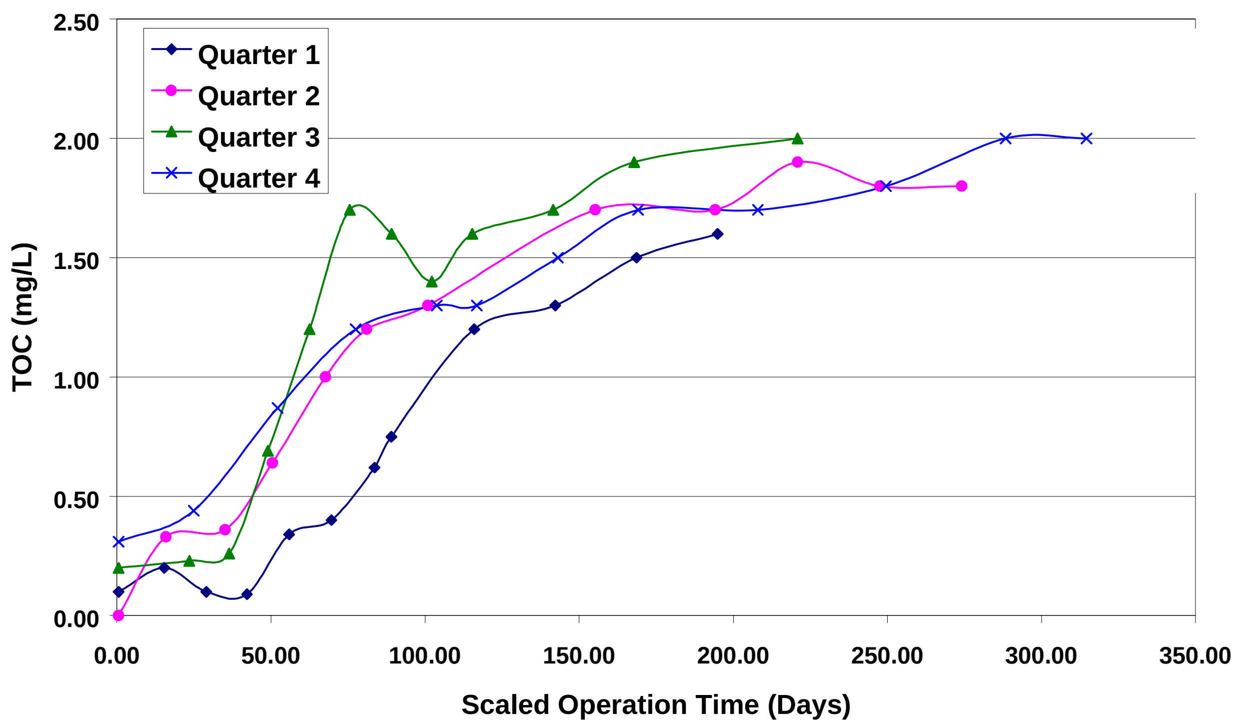

Figure 12 - THM Breakthrough Curves for 20-min EBCT

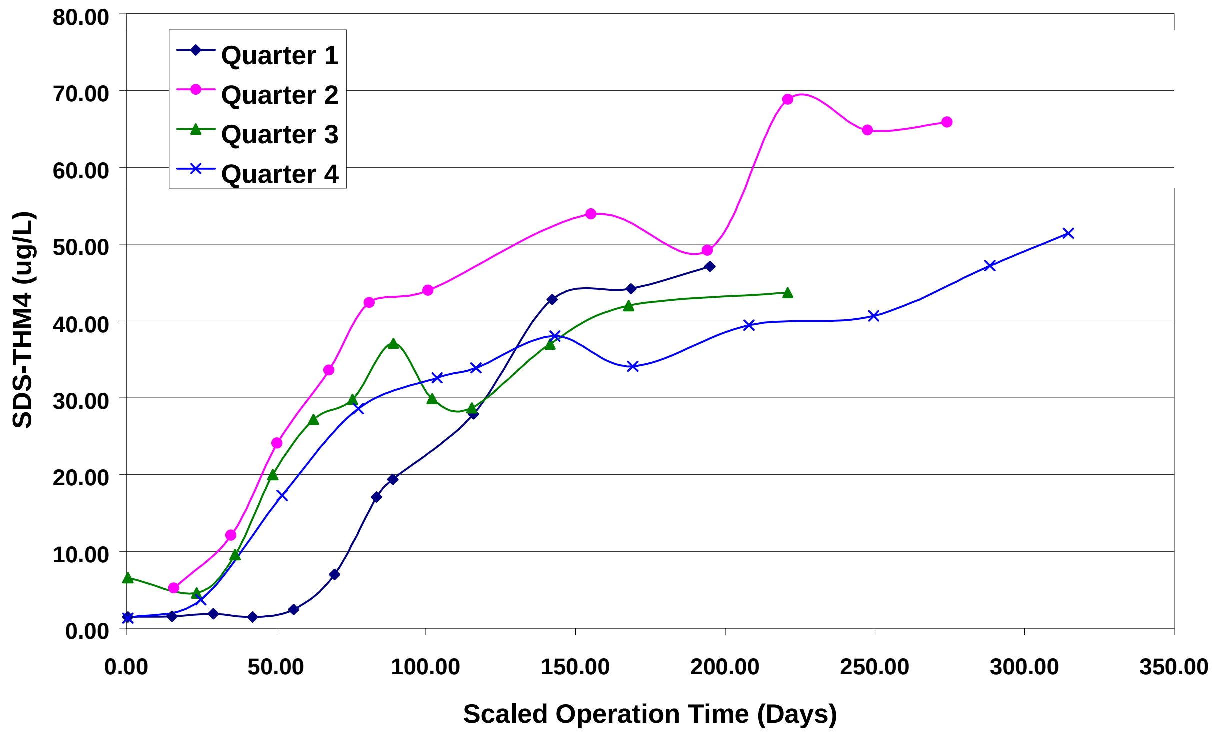

Figure 13 - HAA5 Breakthrough 20-min EBCT