ICR Treatment Study Summary Report

Evaluation of GAC Technology Using the Rapid Small-Scale Column Test for Compliance with the Information Collection Rule

Conducted during the period of April 1998 through February 1999

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Attachments: 1 diskette containing the *Data Collection Spreadsheets*
1 diskette containing the *Treatment Study Summary Report Sheets*
1 diskette containing the *ICR Treatment Summary Report*

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I. Conclusions and Recommendations

This "Treatment Study Summary Report" provides a supplemental discussion of the data presented in the "Treatment Study Data Collection Spreadsheets" for the Trinity River Authority's Tarrant County Water Supply Project Water Treatment Plant (TCWSP WTP). Major conclusions and recommendations derived from the study include:

TOC Breakthrough:

- For the 1st and 4th quarter sampling (spring and winter), the 20-minute EBCT reached greater than 50 percent total organic carbon (TOC) breakthrough after approximately 70 to 80 days of operation.

- For the 2nd and 3rd quarter sampling (summer and fall), the 20-minute EBCT reached greater than 50 percent total organic carbon (TOC) breakthrough after approximately 50 to 55 days of operation.

- The influent TOC concentration and subsequent breakthrough rate for the 2nd and 3rd quarter sampling was greater than in the 1st and 4th quarter sampling for both the 10 and 20 minute EBCTs, indicating the impact of seasonal variations on GAC adsorption.

DBP Formation Potential:

- As with TOC breakthrough, DBP formation potential for the 2nd and 3rd quarter sampling was greater than in the 1st and 4th quarter sampling for both the 10 and 20 minute EBCTs, indicating a higher potential for DBP formation during the summer and fall seasons

GAC Operation / Run-Times:

- THM4 breakthrough reached THM4 breakthrough criteria (See Section IV) more rapidly than HAA5 breakthrough reached HAA5 breakthrough criteria. Therefore, THM4 breakthrough would likely dictate GAC operation.

- For the 10 minute EBCT, the THM4 concentration reached 72 ug/L after 50, 11, 16, and 41 days of operation for the 1st, 2nd, 3rd, and 4th quarters, respectively. For the 20 minute EBCT, the THM4 concentration reached 72 ug/L after 130, 32, 42, and 90 days of operation for the 1st, 2nd, 3rd, and 4th quarters, respectively.

- Bromodichloromethane breakthrough reached 17 ug/L in less than 60 days.

- Considering the fairly rapid breakthrough rate of THM4 and HAA5 formation potential and the individual THM - bromodichloromethane, the rate of carbon replacement or regeneration would likely be significant for the TCWSP WTP.

Economic Considerations:

Although a cost analysis was not performed as a part of this study, the following conclusions are made with regard to the potential economic feasibility of implementing GAC adsorption with free chlorine disinfection at the TCWSP WTP:

- Implementing GAC adsorption for a 72 MGD facility (the WTP will be expanded from 57 to 72 MGD) would require a significant capital investment. In addition to the GAC filter adsorber units, on-site GAC reactivation facilities may be necessary.

- The potentially high carbon usage rate, when operating based on TOC removal and/or DBP formation potential, could increase costs significantly. On-site reactivation or GAC replacement every few months would likely make the process infeasible.

- Alternative advanced treatment processes may allow the Trinity River Authority to achieve its water quality goals at a lower cost.

Recommendations:

- Evaluate the feasibility of other advanced processes and treatment alternatives that will achieve all of the Trinity River Authority's water quality and operational goals.

II. Background Information

A. Treatment Plant Description

Treatment Plant Schematic: Figure 1 provides a schematic of the full-scale treatment plant.

Raw water from Lake Arlington is pumped through 9 miles of pipeline to the WTP. The WTP (currently 57 MGD) utilizes conventional treatment processes (rapid mix, coagulation, flocculation, and sedimentation) and filtration to treat the water. Raw water flows into the rapid mix basins of the west (12 MGD) and east (45 MGD) plants where alum and polymer are added for coagulation. Coagulated water enters the flocculation/ sedimentation basins through a center flocculation zone equipped with mechanical mixers. Flocculated water passes to the outer portion of the basins where sedimentation occurs. Settled water then flows over a peripheral weir and is transferred to the dual media (sand and anthracite) filters. Filtered water enters a series of clearwells and is sent to distribution.

Combined chlorine is typically the primary disinfectant at the TCWSP plant during summer months. Free chlorine and ammonia are added to form chloramines prior to rapid mixing. During winter months, free chlorine contact time may be increased by moving free chlorine addition further upstream in the raw water pipeline. The increased free chlorine contact time allows the plant to achieve disinfection CT. Chlorine and ammonia may be added before and after filtration to increase the chloramine residual for distribution. Other chemicals added at the plant include chlorine dioxide and PAC (occasionally added for taste and odor), hydrofluorosilicic acid, and filter-aid polymer.

The sample for the ICR study was collected after the west bank filter in front of the treated water clearwell. Chlorinators were turned off before sample collection and residual chlorine was measured to ensure that no residual was present.

Treatment Plant Design Information: Table 1a contains the full-scale plant unit process design and chemical application information; Tables 1 b and 1c contain the bench-scale unit process information.

Treatment challenges facing plant include the following:

- Disinfection: When considering the potential impacts of future regulations, a considerable treatment challenge at the TCWSP WTP is centered around disinfection practices. Currently, free and combined chlorine are used through the plant for primary disinfection. By using this strategy, the TCWSP achieves disinfection requirements for *Giardia* and viruses while limiting THM4 to less than 100 ug/L. However, this disinfection strategy, with GAC adsorption, would not help to achieve potential disinfection requirements for *Cryptosporidium*. Free chlorine and chloramines are not effective for inactivating *Cryptosporidium*. An alternate disinfection strategy may be necessary depending on requirements of the Long Term Enhanced Surface Water Treatment Rule.

- Taste and Odor Control: GAC could provide significant taste and odor control. Currently, the TCWSP adds chlorine dioxide and PAC at the WTP to control taste and odor episodes.

B. Tabular summary of source and finished water quality: Tables 2a and 2b contain the summary of source and finished water quality provided by the water treatment plant.

III. Materials and Methods

A. Pretreatment Processes to the Advanced Treatment Process

Schematics of pretreatment processes: Figure 1 outlines the full-scale process used in the plant prior to the treatment study sampling point.

Design Data: See Figures 2 and 3. In quarters 1, 3, and 4, only bench-scale cartridge filtration was performed at the laboratory prior to the RSSCT. In the second quarter, the water sample could not be taken at the same location. Full-scale coagulation was simulated in the laboratory.

B. Advanced Treatment Process Information

A schematic for the process equipment used for the RSSCT is shown in Figure 4. This schematic shows only one unit, but two identical units were used during the study. This allowed for the simultaneous evaluation of two EBCTs using the same influent water. In most runs during this study, however, they were not started at the exact same time, resulting in two data sets for the influent water. The *ICR Manual for Bench and Pilot-scale Studies* was used as a guide in the set-up of the apparatus.

In general, the procedures outlined in the *ICR Manual for Bench and Pilot-scale Studies* were followed. In order to ensure that no TOC was leaching from our apparatus into the sample, reagent water was passed through the entire system and checked for TOC. Also, the aliquot containers were checked for TOC leaching and/or absorption. Only stainless steel and teflon tubing were used in the apparatus to minimize contamination. The columns were carefully packed according to procedures in the manual.

Headloss buildup was relieved in this study in one of two ways:
a) Slight agitation of the carbon on top of the RSSCT column
b) Complete removal, rinsing, and re-packing of the carbon

C. Experimental Design

Table 3 describes the experimental design used in the study. Seasonal variability was examined as the primary variable at EBCT 10 and 20.

D. Analytical Methods

Table 4 lists the analytical methods and MRLs used for the study. There were no deviations from the QA/QC procedures outlined in the DBP/ICR Analytical Methods Manual.

All analytical services were performed at Environmental Health Laboratories.

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IV. Results and Discussion

A. Problems Encountered

During the second quarter, the water supply could not collect the sample from the same location as in the 1st, 3rd, and 4th quarters. This occurred because of a severe drought in Texas at the time of sampling. The chlorinators could not be turned off at the west plant. Both the east and west plant were needed to supply treated water. As a result, the coagulation step had to be simulated in the laboratory. (See Table 1b and 1c)

During the EBCT 20 run in the second quarter, significant head-loss was observed. The column had to be stirred daily, and on 4 occasions, the carbon was removed from the column, rinsed, and repacked. The EBCT 10 run also experienced some head-loss build-up, but stirring the carbon was all that was necessary. This problem did not occur in the other three quarters.

During the first quarter, an 8mm column ID was used for the RSSCT. An 11 mm column was used for all other quarters. The 11 mm column resulted in less overlap time between effluent sample collections.

Total Organic Halide (TOX) results during the study were generally erratic as several results did not follow the trend of SDS THM and HAA in the effluent water. Also, high percent differences were observed for some samples. The method used and the results meet the QA/QC criteria in the *DBP/ICR Analytical Methods Manual*.

Experimental error: During the 1st quarter, the run at EBCT 10 did not reach 70% TOC breakthrough due to an error in the preparation of the predicted TOC breakthrough tables. Quarter 1 had breakthrough to 65%. Based on complete breakthrough curves obtained during the last three quarters of the study at EBCT 10, the upper portion of the curve can be extrapolated.

B. Water Quality Data

The water quality of the pretreated influent is summarized in Tables 5a and 5b. This table includes a summary of the DBP data obtained at these SDS conditions in the influent water.

Table 6 contains the specific simulated distribution system (SDS) conditions for each quarter in the study.

C. Impact of Seasonal Variability

The data and corresponding figures (described in Paragraph D) show the impacts of seasonal variations in water quality. TOC breakthrough and DBP formation increased from spring to summer summer and decreased from summer through the fall and winter seasons.

D. Impact of Specific Variables on Performance

Included in this final report are several tables and graphs that illustrate important aspects of the study. They are as follows:

1. Breakthrough curves for TOC and UV254

   Figures 5-8: TOC concentration as a function of scaled operation time
   Figures 9-12: UV254 concentration as a function of scaled days

2. SDS Chlorine Dose and Residual Analysis

   Figures 13-16: Chlorine dose / residual effluent / influent vs. operation time
   Figures 17-20: Chlorine dose / residual effluent / influent vs. operation time

3. SDS Breakthrough Curves Analysis (Effluent and Influent)

   Figures 21-24: SDS-THM4 for EBCT 10&20 vs. scaled operation time

Figures 25-32: Individual SDS-THMs for EBCT 10&20 vs. scaled operation time
Figures 33-36: SDS-HAA5 for EBCT 10&20 vs. scaled operation time
Figures 37-40: SDS-HAA6 for EBCT 10&20 vs. scaled operation time
Figures 41-48: Individual SDS-HAAs for EBCT 10&20 vs. scaled operation time
Figures 49-52: SDS-TOX or EBCT 10&20 vs. scaled operation time

4. SDS Influent Analysis

Figures 53-54: Influent for individual THMs vs. scaled operation time
Figures 55-64: Influent for individual HAAs vs. scaled operation time

5. SDS Temperature and pH conditions

Figures 65-68: SDS chlorination pH vs. scaled operation time
Figures 69-72: SDS chlorination temperature vs. scaled operation time

E. Cost Information and Analysis

A cost analysis was not performed for this study. However, cost parameters are included in Field 9 of the Data Collection Spreadsheets.

F. Summary of Significant Results

In general, the breakthrough curves follow the predicted increase in TOC and other SDS parameters as a function of time. There were some points that were outliers, and these are discussed in the QA/QC Summary. Tables 7-10 present a summary of the times to reach various breakthrough criteria along with the water quality data at the given criteria.

V. QA/QC Summary

All QA/QC procedures and requirements were followed as described in the *DBP/ICR Analytical Methods Manual*. Note that Table 4 lists the MRLs, some of which are lower than those listed in the manual. All of the TOC data was used to generate the graphs, even if it was measured below the MRL of 0.50 ug/L. In the *Data Collection Spreadsheets*, these samples were marked BMRL.

All results for lab duplicates and lab fortified matrices are summarized in the *ICR Treatment Study Summary Report Spreadsheets*, along with some miscellaneous data about the public water supply.

PE results: Environmental Health Laboratories is a certified ICR lab that participated in all ICR PE studies. The results for these studies are listed in Tables 11-14.

Calibration Procedures: The calibration procedures used during the study are consistent with the *DBP/ICR Analytical Methods Manual*. Tables 9.1 to 9.4 in this manual were used as guidelines for the frequency and percent recovery requirements.

<u>QC/QA Failures</u>: During the study, some of the chemistry analyses did not meet the ICR QA/QC requirements outlined in the *ICR/DBP Analytical Methods Manual*. These samples were entered as not reported (NR) in the *Data Collection Spreadsheets*. Many of these failures were minor and in the presence of other QC in the analytical run that pass method criteria. As a result, many of these data points are included in the graphs if they seem to fit the data. The following is a summary of QA/QC failures:

Quarter 2

The following samples had DCAA and/or TCAA failures due to results that calculated over the calibration curve range:

DCAA: B1-EBCT-10, B2-EBCT-10, B3-EBCT-10, B1-EBCT-20, B2-EBCT-20, B3-EBCT-20 TCAA: B2-EBCT-10, B2-EBCT-20.

<u>Outliers</u>: Some outlier points were also observed during the study. An NR was used in the *Data Collection Spreadsheets* if a good reason could be determined.

Quarter 1

C1-EBCT-10: TOX result very high, may have been due to contamination.
C7-EBCT-10: SDS HAA data is high. This sample was dosed at the wrong concentration.

Quarter 2

C1-EBCT-10, C1-EBCT-20, C2-ECT-20: TOX result very high, likely due to contamination.

Quarter 3

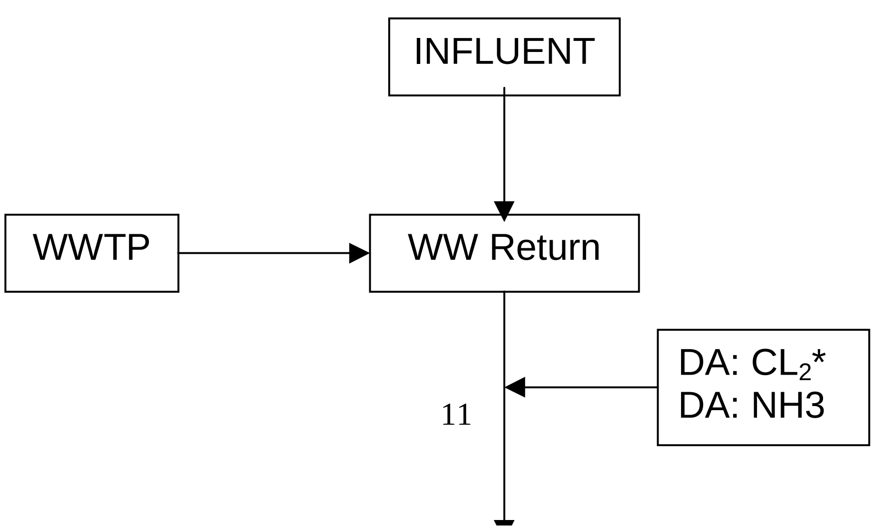
B3-10: Low UV254 observed. This is likely due to an analytical error. C1-EBCT-10, C2-EBCT-10: TOX very high due to contamination. C5-EBCT20: A chlorine residual of 0.05 mg/L remained at the end of SDS incubation.

Quarter 4

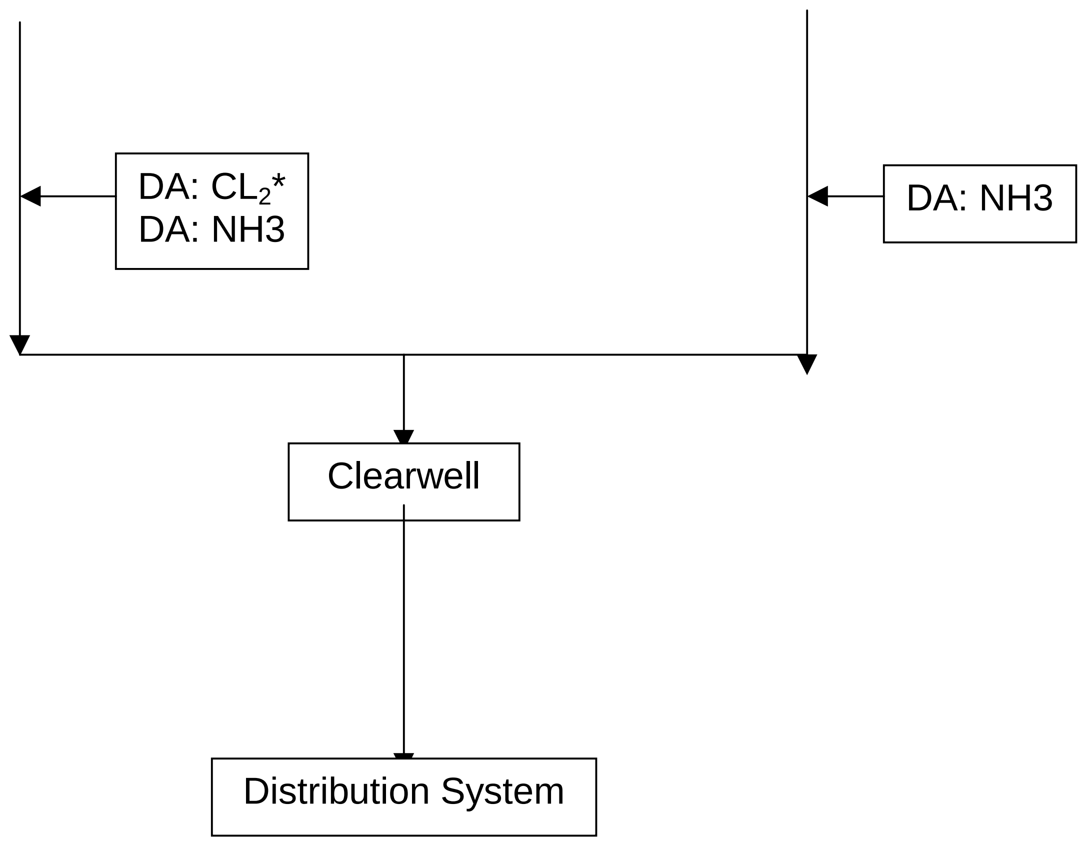
C1-EBCT10, C2-EBCT-10: TOX very high due to contamination.

SDS Testing: Incubation temperature and time measurements - During the bench-scale runs, a high-precision incubator was used. All of the samples in a given batch were taken out of the incubator at the same time and measurements for residual chlorine were taken immediately and quenched using the proper dechlorinating agent. The temperature of the incubator was recorded for the batch. Therefore, the same temperature reading was recorded in the Data Collection Spreadsheets for the entire group of samples. This is why some of the observed standard deviations (SDs) are 0.0. Also, the time recorded for all SDS samples in a given batch was the same, as this was monitored very closely during the study. This will also result in times having SDs of 0.0.

Figure 1: Trinity River Authority of Texas
Full-Scale Treatment Plant Schematic

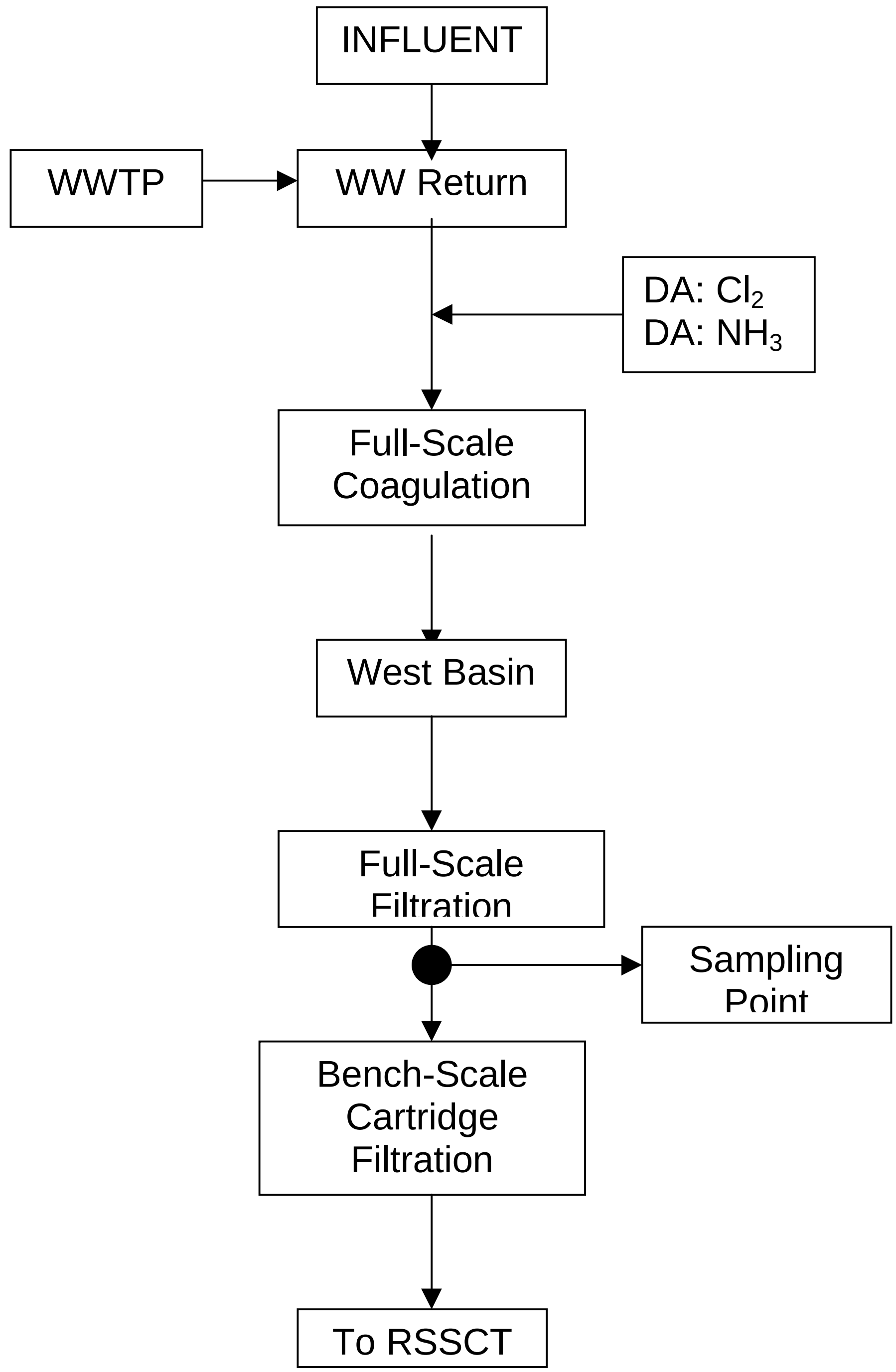


<u>Figure 1 (cont.): Trinity River Authority of Texas</u>
Full-Scale Treatment Plant Schematic



* Note: Sample was taken after chlorinators had been turned off, therefore no chlorine residual was present at the time of collection.

Figure 2: Pretreatment Process Schematic
Quarters 1, 3, 4



<u>Figure 3: Pretreatment Process Schematic</u>
Quarter 2

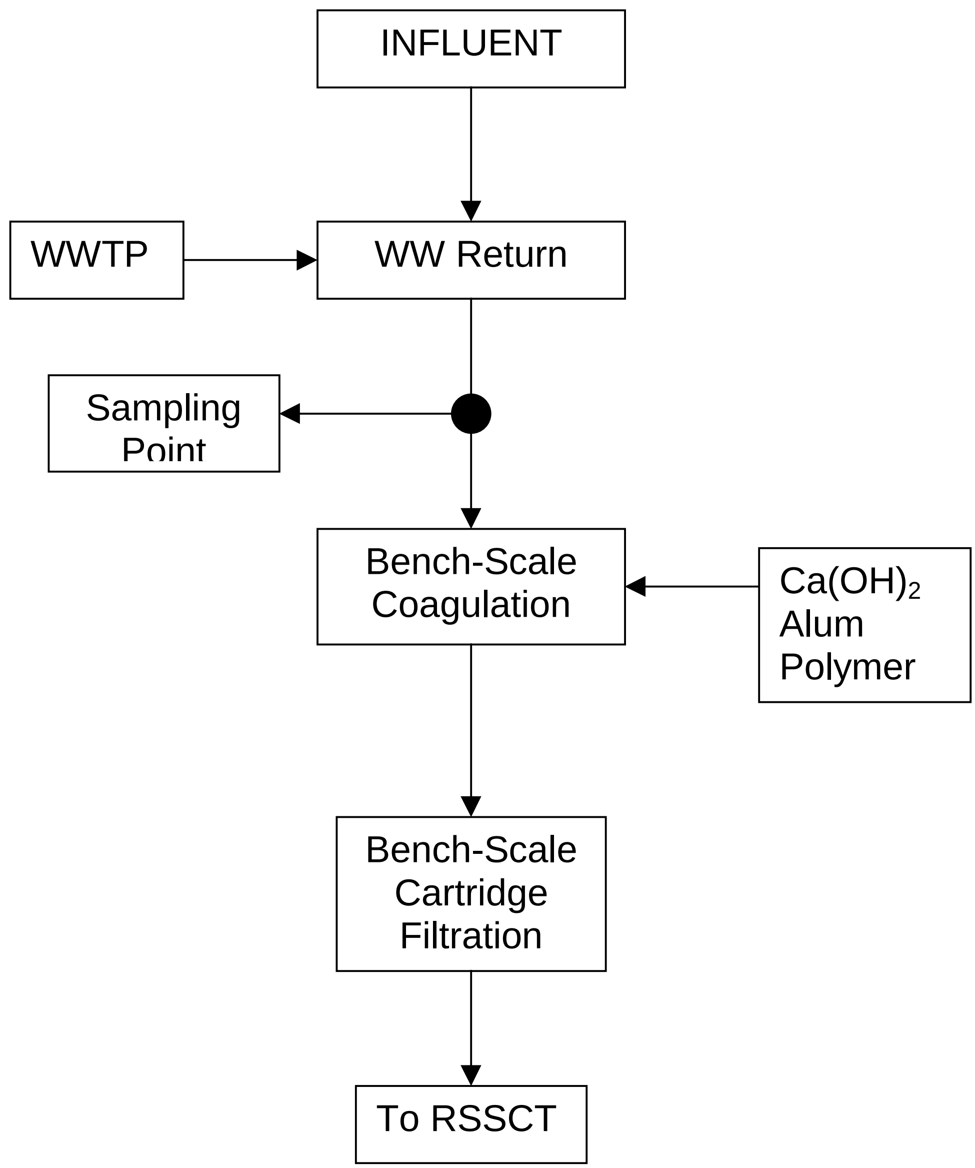


Figure 4: RSSCT Test Apparatus Diagram

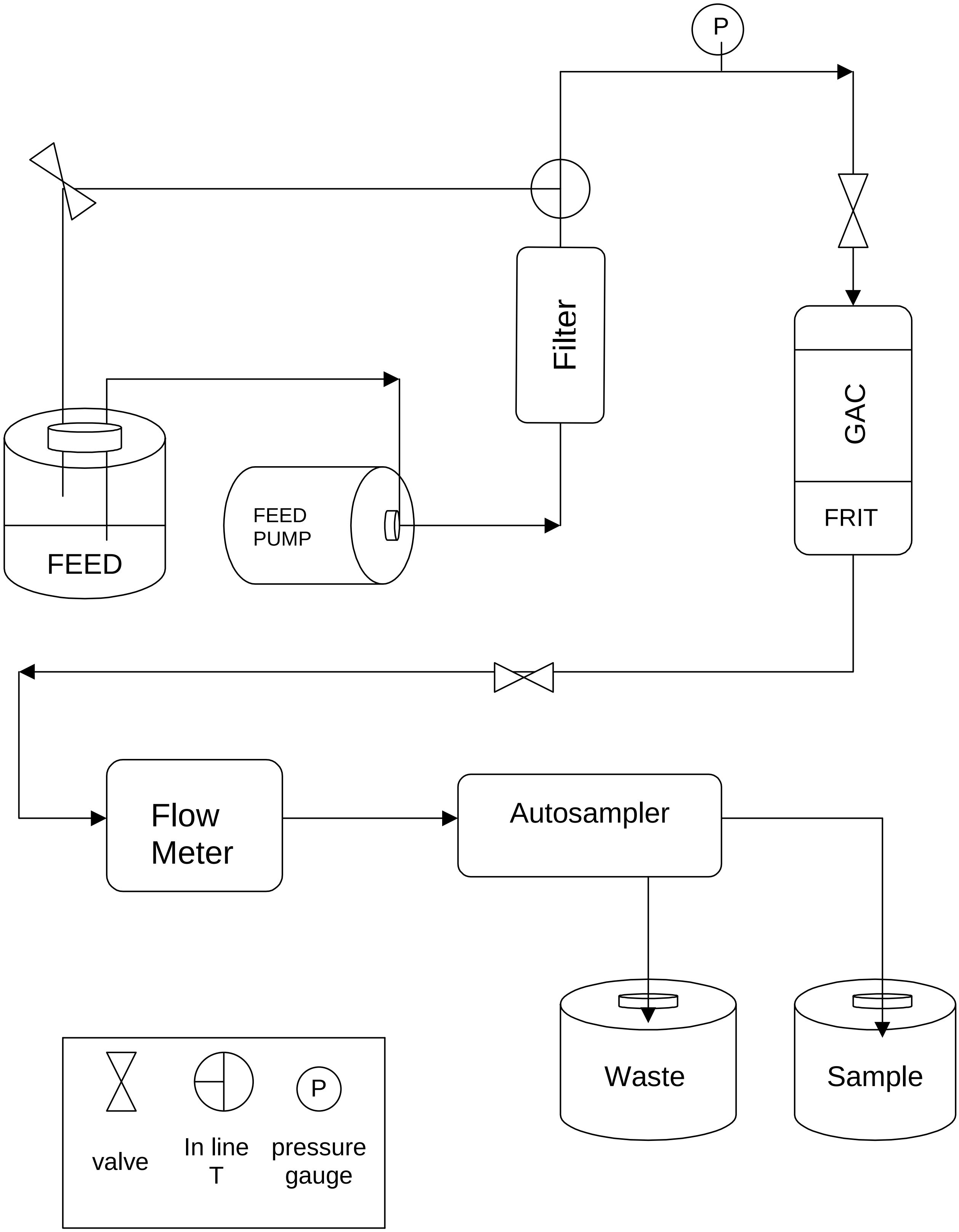


Table 1a: Trinity River Authority of Texas Full-Scale WTP Process Data (Based on Full-Scale ICR Table A.2 and A.3)

Treatment Plant Name: Tarrant County Water Supply		State Approved Plant Capacity (MGD): 57.0	
ICR Treatment Plant ID: 650		Historical Min.Water Temperature (deg C): --	
Treatment Plant PWS ID: TX2200199		Installed Sludge Handling Capacity (DPD): 60,000.00	
Treatment Plant Category: CONV		Blending Indicator: N	
Water Resource Name: Lake Arlington		Hydrologic Unit Code: 1203.010	
Water Resource Type: Reservoir/lake		River Reach: NA	
Average Residence Time (Days): 876		Latitude (degrees, minutes, seconds): +32 43'2"	
Intake Name: ICR Plant ID 643		Longitude (degrees, minutes, seconds): -97 11'35"	
Watershed Control: Y		River Reach Miles: 0.0	
Seq. Sample No. Location Name	**Sample Location Type**	**Sample Location No.**	**Characteristics**
Influent	INF	12	
East WW Recovery	Washwater Return	10	Washwater Treated: N Coagulation/Sedimentation: N Filtration: N Disinfectant Addition: N Plain Sedimentation: N Other Treatment: 24 hr average Water flow Returned (MGD): 4.0
East WW Recovery	Washwater Return	11	
Chlorine gas	Disinfectant Addition	2	Chemical Code: Cl2 Measurement Formula: Cl2 Dose Rate (mg/L): 4.00
Anhydrous ammonia	Disinfectant Addition	3	Chemical Code: NH3A Measurement Formula: NH3 Dose Rate (mg/L): 1.00
Rapid Mix	Rapid Mix	4	Type of Mixer: ME Baffling Type: SP Liquid Volume (gal): 25,843 Short Circuiting Factor: Mean Velocity Gradient (sec-1): 500.0
Flocculation	Flocculation Basin	5	Type of Mixer: ME Liquid Volume (gal): 79,309 Short Circuiting Factor: 0.1 Baffling Type: AV Stage Sequence Number: 2 Stage Mean Velocity Gradient (sec-1): 1 Stage Liquid Volume (gal): 563,979 Stage Sequence Number: 3 Stage Mean Velocity Gradient (sec-1): 1 Stage Liquid Volume (gal): 563,979 Stage Sequence Number: 4 Stage Mean Velocity Gradient (sec-1): 1 Stage Liquid Volume (gal): 563,979

Flocculation	Flocculation Basin	5	Stage Sequence Number: 5 Stage Mean Velocity Gradient (sec-1): 1 Stage Liquid Volume (gal): 2,834,325 Stage Sequence Number: 6 Stage Mean Velocity Gradient (sec-1): 1 Stage Liquid Volume (gal):2,834,325 Stage Sequence Number: 7 Stage Mean Velocity Gradient (sec-1): 1 Stage Liquid Volume (gal):2,834,325
Sedimentation	Sedimentation	6	Surface Area (ft2): 550,252 Liquid Volume (gal): 10,757,747 Baffling Type: AV Short Circuiting Factor: 0.7 Plate Settler Surface Area (ft2): Plate Settler Brand Name: Tube Settler Surface Area (ft2): Tube Settler Brand Name:
East Filter Bank	Filtration	7	Surface Area (ft2): 10,368 Liquid Volume (gal): 442,832 Total Media Depth (in): 48 Depth of Anthracite (in): 18 Media Type: TRIM Type of Activated Carbon: G4 Min.Water Depth to Top of Media (ft): 5.6 Depth From Top of Media to Top of Backwash Trough (ft): 3.0
Clearwell	Clearwell		Surface Area (ft2): 53,093 Liquid Volume (gal): 7,000,000 Minimum Liquid Volume (gal): Baffling Type: AV Short Circuiting Factor: 0.1 Covered Indicator Code: Y

Sample Location Name	Sample Location Type and Number	Chemical Name and Measurement Formula	Dose (mg/L)
Chlorine gas	Disinfectant Addition - 2	Chlorine gas - Cl2	4.00
Anhydrous ammonia	Disinfectant Addition - 3	Anhydrous ammonia - NH3	1.00
Rapid Mix	Rapid Mix	Aluminum sulfate - $Al_3(SO4)_2$* $14H_2O$ Organic polymer-coagulant aid - OPC Organic polymer-filter aid - OPF Powdered Activated Carbon - PAC Hydrofluorosilicic Acid - HFS	25.00 0.50 0.25 20.00 3.00

Table 1b: Bench-Scale Pretreatment Data - Quarters 1, 3, 4

Unit Process	Process Description
Scale Control (Bench-Scale)	Chemical Type: NA
	Adjusted pH: NA
	Dose Rate (mg/L): NA
Cartridge Filtration (Bench-Scale)	Surface Area (ft2): 4.5
	Nominal Pore Size (mm): 1.0
	Filter Material: polypropylene
	Filter Life (gallons of processed water): NA

Table 1c: Bench-Scale Pretreatment Data - Quarter 2

Unit Process	Process Description
Coagulation (Bench-Scale)	Chemical Type: Alum, Dose: 36 mg/L
	Chemical Type: Polymer, Dose: 0.5 mg/L
	Chemical Type: Lime, Dose: 14.0 mg/L
Cartridge Filtration (Bench-Scale)	Surface Area (ft2): 4.5
	Nominal Pore Size (mm): 1.0
	Filter Material: polypropylene
	Filter Life (gallons of processed water): NA

Table 2a: Tabular Summary of Source Water Quality

Water Quality Parameter	Average Yearly Concentration	Standard Deviation	Maximum Yearly Value	Minimum Yearly Value
Temperature (°C)	23.7	7.2	33.4	13.6
pH	7.5	0.3	7.9	6.7
Turbidity (ntu)	9.2	9.3	30	1.18
Alkalinity (mg/L as $CaCO_3$)	96.3	8.5	114	84
Total Hardness (mg/L as $CaCO_3$)	113.7	17.2	150	96
Calcium Hardness (mg/L as $CaCO_3$)	86.9	11	104	69
TOC (mg/L)	4.6	0.4	5.3	4
UV254 (cm^{-1})	0.166	0.075	0.304	0.107
Bromide (µg/L)	5.5	1	6.9	3.7
TSUVA (L/mg*m)	3.43	1.77	6.33	2.06

Table 2b: Tabular Summary of Finished Water Quality

Water Quality Parameter	Average Yearly Concentration	Standard Deviation	Maximum Yearly Value	Minimum Yearly Value
Temperature (°C)	24.5	6.4	32.8	14.8
pH	7.5	0.4	8.2	6.8
Turbidity (ntu)	0.76	0.82	2.8	0.14
TOC (mg/L)	3.9	0.5	4.5	3.1
UV254 (cm^{-1})	0.078	0.007	0.093	0.064
DS-THM4 (µg/L)	29.6	12.9	40.1	12.9
DS-HAA5 (µg/L)	20.4	5.7	26.7	12.9
DS-HAA6 (µg/L)	26.6	6	33.7	19.4

Table 3: Experimental Design For The RSSCT Study

Season	Pretreatment	EBCT, min
Spring	Coagulation/Conventional filtration	10 & 20
Summer	Coagulation/Conventional filtration	10 & 20
Fall	Coagulation/Conventional filtration	10 & 20
Winter	Coagulation/Conventional filtration	10 & 20

Table 4: Summary of Analytical Methods and MRLs Used During the Study

Analyte	Method	Minimum Reporting Level
Alkalinity	SM 2320 B	1.0 mg/L $CaCO_3$
Ammonia	SM 4500-NH_3 D	0.30 mg/L NH_3-N
Bromide	EPA 300.0	20 μg/L
Calcium Hardness	SM 2340 B	0.25 mg/L $CaCO_3$
Chlorine Residual	SM 4500-Cl G	0.1 mg/L
BCAA, DBAA, DCAA, MBAA, MCAA, TCAA	EPA 552.2	2.0 μg/L for MCAA 1.0 μg/L for all others
pH	SM 4500-H^+	Not Applicable
TDS	SM 2510 B (TDS meter)	5.0 mg/L
Temperature	SM 2550 B	Not Applicable
CHCl3, BDCM, DBCM, $CHBr_3$	EPA 524.2	1.0 μg/L for each analyte
Total Hardness	SM 2340 B	0.33 mg/L $CaCO_3$
TOC	SM 5310 C	0.50 mg/L
TOX	SM 5320 B	25.0 μg/L
Turbidity	EPA 180.1	0.05 ntu
UV_{254}	SM 5910	0.001 cm^{-1}

Table 5a: Average Pretreated Feed Water Quality During 4 Seasons of the 10 minute RSSCT Study

Water Quality Parameter	Units	Spring Average	Spring S.D.	Summer Average	Summer S.D.	Fall Average	Fall S.D.	Winter Average	Winter S.D.
pH	---	7.61	0.36	8.20	0.08	8.07	0.05	8.26	0.04
Temperature	°C	20.3	1.2	20.3	1.2	21.0	0.0	23.0	1.0
Alkalinity	mg/L as $CaCO_3$	75.8	0.4	98.8	1.8	83.6	3.5	93.3	2.5
Total hardness	mg/L as $CaCO_3$	102.2	2.9	114.8	2.4	91.6	4.5	109.6	4.9
Calcium hardness	mg/L as $CaCO_3$	86.0	3.0	89.9	0.4	74.4	3.5	95.3	4.0
Turbidity	ntu	0.20	0.01	0.58	0.17	0.29	0.08	0.37	0.08
Ammonia	mg NH_3-N / L	BMRL	BMRL	BMRL	BMRL	BMRL	BMRL	BMRL	BMRL
Total organic carbon	mg/L	3.05	0.09	4.88	0.08	3.67	0.15	3.37	0.08
UV_{254}	cm^{-1}	0.068	0.008	0.089	0.003	0.062	0.003	0.062	0.001
SUVA	L/(mg*m)	2.22	0.21	1.83	0.03	1.30	0.61	1.85	0.06
Bromide	µg/L	72.0	1.4	125.0	35.4	100.0	0.0	75.0	2.8
SDS-Cl_2 dose	mg/L	5.30	0.75	7.00	0.00	7.62	0.00	5.87	0.36
SDS-Free Cl_2 residual	mg/L	0.89	0.27	0.47	0.08	0.66	0.05	1.12	0.19
SDS-Cl_2 demand	mg/L	4.41	0.79	6.53	0.08	6.96	0.05	4.74	0.40
SDS-Chlorination temp.	°C	17.0	0.0	27.6	0.0	27.4	0.1	18.8	0.1
SDS-Chlorination pH	---	7.69	0.07	6.95	0.03	8.02	0.01	7.97	0.01
SDS-Incubation time	hours	119.3	0.3	120.0	0.0	120.0	0.0	120.0	0.0
SDS-TOX	µg Cl^-/L	300.00	8.66	385.00	91.79	361.67	10.41	291.67	12.58
SDS-CHCl3	µg/L	73.23	3.80	120.17	4.71	110.73	2.78	83.80	5.35
SDS-BDCM	µg/L	29.58	2.34	46.14	1.27	39.50	0.49	29.71	1.33
SDS-DBCM	µg/L	9.35	0.93	14.02	0.41	16.73	0.27	11.07	0.33
SDS-CHBr3	µg/L	BMRL	BMRL	0.77	0.04	1.86	0.17	1.01	0.01
SDS-THM4	µg/L	112.16	6.97	180.84	5.90	168.82	3.25	125.26	6.60
SDS-MCAA*	µg/L	4.20	0.24	6.86	0.95	7.77	0.66	4.11	1.10
SDS-DCAA*	µg/L	33.70	4.19	53.62	2.66	46.32	3.09	43.14	4.69
SDS-TCAA*	µg/L	21.10	6.58	49.69	6.76	17.42	2.85	23.66	0.77
SDS-MBAA*	µg/L	BMRL	BMRL	1.64	0.19	1.78	0.32	1.39	0.36
SDS-DBAA*	µg/L	1.98	0.30	3.02	0.47	3.82	0.61	3.43	0.71
SDS-BCAA*	µg/L	10.41	0.71	17.09	2.62	16.36	1.56	14.50	0.48
SDS-HAA5	µg/L	60.98	10.80	114.83	8.88	77.11	7.45	74.36	2.44
SDS-HAA6	µg/L	71.39	11.25	131.91	10.55	93.47	8.99	88.87	2.89

Table 5b: Average Pretreated Feed Water Quality During 4 Seasons of the 20 minute RSSCT Study

Water Quality Parameter	Units	Spring Average	Spring S.D.	Summer Average	Summer S.D.	Fall Average	Fall S.D.	Winter Average	Winter S.D.
pH	---	7.78	0.26	8.13	0.06	8.07	0.05	8.27	0.04
Temperature	°C	21.0	1.73	23.0	0.00	21.0	0.00	21.3	2.31
Alkalinity	mg/L as $CaCO_3$	71.5	2.83	100.3	3.18	83.6	3.46	96.3	1.77
Total hardness	mg/L as $CaCO_3$	100.3	0.21	116.9	4.17	91.6	4.45	111.2	0.42
Calcium hardness	mg/L as $CaCO_3$	84.9	1.41	92.6	4.24	74.4	3.54	98.0	0.57
Turbidity	ntu	0.20	0.01	0.81	0.14	0.29	0.08	0.28	0.12
Ammonia	mg NH_3-N / L	BMRL	BMRL	BMRL	BMRL	BMRL	BMRL	BMRL	BMRL
Total organic carbon	mg/L	3.08	0.08	4.83	0.23	3.67	0.15	3.40	0.10
UV_{254}	cm^{-1}	0.069	0.01	0.090	0.01	0.048	0.02	0.060	0.00
SUVA	L/(mg*m)	2.23	0.22	1.87	0.06	1.30	0.61	1.76	0.07
Bromide	µg/L	74.5	4.95	84.6	5.02	100.0	0.00	64.5	10.61
SDS-Cl_2 dose	mg/L	5.30	0.75	7.33	0.58	7.62	0.00	5.67	0.05
SDS-Free Cl_2 residual	mg/L	1.13	0.36	0.59	0.24	0.66	0.05	1.24	0.16
SDS-Cl_2 demand	mg/L	4.17	1.10	6.75	0.34	6.96	0.05	4.43	0.11
SDS-Chlorination temp.	°C	17.0	0.00	27.5	0.06	27.1	0.06	18.8	0.10
SDS-Chlorination pH	---	7.80	0.05	7.00	0.02	8.02	0.01	7.90	0.01
SDS-Incubation time	hours	119.5	0.50	120.0	0.00	120.0	0.00	120.0	0.00
SDS-TOX	µg Cl^-/L	321.67	23.09	511.67	68.25	361.67	10.41	266.67	31.75
SDS-CHCl3	µg/L	74.73	7.66	120.24	8.69	110.73	2.78	89.66	13.67
SDS-BDCM	µg/L	30.59	2.46	46.24	1.26	39.50	0.49	32.43	3.53
SDS-DBCM	µg/L	9.97	0.68	13.61	0.20	16.73	0.27	11.15	0.69
SDS-CHBr3	µg/L	BMRL	BMRL	BMRL	BMRL	1.86	0.17	BMRL	BMRL
SDS-THM4	µg/L	115.29	10.56	180.10	9.82	168.82	3.25	133.23	16.56
SDS-MCAA*	µg/L	3.92	0.46	6.49	3.52	7.77	0.66	3.92	1.95
SDS-DCAA*	µg/L	38.01	3.22	60.78	3.53	46.32	3.09	44.52	1.61
SDS-TCAA*	µg/L	28.99	9.38	52.15	5.84	17.42	2.85	28.26	2.88
SDS-MBAA*	µg/L	BMRL	BMRL	1.54	0.20	1.78	0.32	1.63	0.28
SDS-DBAA*	µg/L	2.23	0.09	3.28	0.50	3.82	0.61	3.35	0.73
SDS-BCAA*	µg/L	11.27	0.82	18.88	2.25	16.36	1.56	14.95	1.02
SDS-HAA5	µg/L	73.15	12.10	124.23	11.79	77.11	7.45	81.14	7.06
SDS-HAA6	µg/L	84.41	12.77	143.11	14.03	93.47	8.99	96.09	8.04

Table 6: SDS Conditions

Parameters	Units	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
pH	-	7.6	6.93	8.0	7.95
Temperature	°C	17.0	27.6	27.0	18.8
Target residual	mg/L	0.5 - 1.0	0.5 - 1.0	0.5 - 1.0	0.5 - 1.0
Retention Time	hours	120.00	120.00	120.00	120.00

Table 7a: Summary of Breakthrough Criteria (10 Min EBCT) — 1st Quarter

Breakthrough Criterion	Value of Listed Parameter When Breakthrough Criterion is Met						
	Run Time (Days)	Throughput (Bed Vol.)	TOC (mg/L)	SDS-THM4 (μg/L)	SDS-HAA5 (μg/L)	SDS-HAA6 (μg/L)	SDS-TOX (μg Cl⁻/L)
SDS-THM4 = 90 μg/L	NA	NA	NA	NA	NA	NA	NA
SDS-THM4 = 72 μg/L	50	7200	1.75	72	23	30	140
SDS-THM4 = 54 μg/L	32	4608	1.40	54	18	19	70
SDS-THM4 = 36 μg/L	25	3600	0.99	36	9	14	45
SDS-HAA5 = 54 μg/L	NA	NA	NA	NA	NA	NA	NA
SDS-HAA5 = 27 μg/L	65	9360	1.92	80	27	33	175
SDS-HAA6 = 54 μg/L	NA	NA	NA	NA	NA	NA	NA
SDS-HAA6 = 27 μg/L	45	6480	1.55	63	20	27	105

Table 7b: Summary of Breakthrough Criteria (20 Min EBCT) — 1st Quarter

Breakthrough Criterion	Value of Listed Parameter When Breakthrough Criterion is Met						
	Run Time (Days)	Throughput (Bed Vol.)	TOC (mg/L)	SDS-THM4 (μg/L)	SDS-HAA5 (μg/L)	SDS-HAA6 (μg/L)	SDS-TOX (μg Cl⁻/L)
SDS-THM4 = 90 μg/L	NA	NA	NA	NA	NA	NA	NA
SDS-THM4 = 72 μg/L	130	9360	2.10	72	32	41	173
SDS-THM4 = 54 μg/L	73	5256	1.20	54	12	19	99
SDS-THM4 = 36 μg/L	55	3960	0.55	36	4	9	50
SDS-HAA5 = 54 μg/L	NA	NA	NA	NA	NA	NA	NA
SDS-HAA5 = 27 μg/L	110	7920	1.95	73	27	33	170
SDS-HAA6 = 54 μg/L	NA	NA	NA	NA	NA	NA	NA
SDS-HAA6 = 27 ug/L	95	6840	1.75	65	20	27	130

Table 8a: Summary of Breakthrough Criteria (10 Min EBCT) — 2nd Quarter

Breakthrough Criterion	Value of Listed Parameter When Breakthrough Criterion is Met						
	Run Time (Days)	Throughput (Bed Vol.)	TOC (mg/L)	SDS-THM4 (µg/L)	SDS-HAA5 (µg/L)	SDS-HAA6 (µg/L)	SDS-TOX (µg Cl^-/L)
SDS-THM4 = 90 µg/L	17	2448	2.39	90	35	54	250
SDS-THM4 = 72 µg/L	11	1584	1.61	72	27	36	150
SDS-THM4 = 54 µg/L	6	864	1.25	54	19	27	92
SDS-THM4 = 36 µg/L	4.5	648	1.00	36	18	20	91
SDS-HAA5 = 54 µg/L	27	3888	3.00	104	54	65	290
SDS-HAA5 = 27 µg/L	11	1584	1.61	72	27	36	150
SDS-HAA6 = 54 µg/L	17	2448	2.39	90	35	54	250
SDS-HAA6 = 27 µg/L	6	864	1.25	54	19	27	92

Table 8b: Summary of Breakthrough Criteria (20 Min EBCT) — 2nd Quarter

Breakthrough Criterion	Value of Listed Parameter When Breakthrough Criterion is Met						
	Run Time (Days)	Throughput (Bed Vol.)	TOC (mg/L)	SDS-THM4 (µg/L)	SDS-HAA5 (µg/L)	SDS-HAA6 (µg/L)	SDS-TOX (µg Cl^-/L)
SDS-THM4 = 90 µg/L	49	3528	2.2	90	45	60	205
SDS-THM4 = 72 µg/L	32	2304	1.99	72	31	27	150
SDS-THM4 = 54 µg/L	23	1656	1.40	54	19	30	100
SDS-THM4 = 36 µg/L	16	1152	0.88	36	12	17	100
SDS-HAA5 = 54 µg/L	52	3744	2.35	97	54	62	210
SDS-HAA5 = 27 µg/L	30	2160	1.80	63	27	40	140
SDS-HAA6 = 54 µg/L	39	2808	2.00	79	43	54	160
SDS-HAA6 = 27 µg/L	32	2304	1.99	72	31	27	150

Table 9a: Summary of Breakthrough Criteria (10 Min EBCT) — 3rd Quarter

Breakthrough Criterion	Value of Listed Parameter When Breakthrough Criterion is Met						
	Run Time (Days)	Throughput (Bed Vol.)	TOC (mg/L)	SDS-THM4 (µg/L)	SDS-HAA5 (µg/L)	SDS-HAA6 (µg/L)	SDS-TOX (µg Cl^-/L)
SDS-THM4 = 90 µg/L	20	2880	1.90	90	27.5	40	190
SDS-THM4 = 72 µg/L	15.5	2232	1.50	72	20	30	130
SDS-THM4 = 54 µg/L	13	1872	0.90	54	12	18	61
SDS-THM4 = 36 µg/L	9	1296	0.13	36	8	9	48
SDS-HAA5 = 54 µg/L	41	5904	2.50	119	54	62	201
SDS-HAA5 = 27 µg/L	19	2736	1.80	89	27	39	175
SDS-HAA6 = 54 µg/L	37	5328	2.50	110	45	54	200
SDS-HAA6 = 27 µg/L	14	2016	1.25	60	19	27	75

Table 9b: Summary of Breakthrough Criteria (20 Min EBCT) — 3rd Quarter

Breakthrough Criterion	Value of Listed Parameter When Breakthrough Criterion is Met						
	Run Time (Days)	Throughput (Bed Vol.)	TOC (mg/L)	SDS-THM4 (µg/L)	SDS-HAA5 (µg/L)	SDS-HAA6 (µg/L)	SDS-TOX (µg Cl^-/L)
SDS-THM4 = 90 µg/L	56	4032	2.20	90	32	42	190
SDS-THM4 = 72 µg/L	42	3024	1.65	72	22	27	125
SDS-THM4 = 54 µg/L	39	2808	1.60	54	16	23	94
SDS-THM4 = 36 µg/L	31	2232	1.00	36	11	14	50
SDS-HAA5 = 54 µg/L	92	6624	1.70	120	54	64	260
SDS-HAA5 = 27 µg/L	46	3312	2.00	83	27	37	130
SDS-HAA6 = 54 µg/L	85	6120	2.55	119	45	54	210
SDS-HAA6 = 27 µg/L	42	3024	1.65	72	22	27	110

Table 10a: Summary of Breakthrough Criteria (10 Min EBCT) — 4th Quarter

Breakthrough Criterion	Value of Listed Parameter When Breakthrough Criterion is Met						
	Run Time (Days)	Throughput (Bed Vol.)	TOC (mg/L)	SDS-THM4 (µg/L)	SDS-HAA5 (µg/L)	SDS-HAA6 (µg/L)	SDS-TOX (µg Cl^-/L)
SDS-THM4 = 90 µg/L	NA	NA	NA	NA	NA	NA	NA
SDS-THM4 = 72 µg/L	41	5904	2.30	72	31	42	120
SDS-THM4 = 54 µg/L	20	2880	1.60	54	20	27	145
SDS-THM4 = 36 µg/L	13	1872	0.80	36	10	17	20
SDS-HAA5 = 54 µg/L	NA	NA	NA	NA	NA	NA	NA
SDS-HAA5 = 27 µg/L	28	4032	2.00	65	27	38	145
SDS-HAA6 = 54 µg/L	59	8496	2.60	83	45	54	180
SDS-HAA6 = 27 µg/L	20	2880	1.60	54	20	27	145

Table 10b: Summary of Breakthrough Criteria (20 Min EBCT) — 4th Quarter

Breakthrough Criterion	Value of Listed Parameter When Breakthrough Criterion is Met						
	Run Time (Days)	Throughput (Bed Vol.)	TOC (mg/L)	SDS-THM4 (µg/L)	SDS-HAA5 (µg/L)	SDS-HAA6 (µg/L)	SDS-TOX (µg Cl^-/L)
SDS-THM4 = 90 µg/L	NA	NA	NA	NA	NA	NA	NA
SDS-THM4 = 72 µg/L	90	6480	2.25	72	25	37	75
SDS-THM4 = 54 µg/L	68	4896	1.75	54	19	26.7	90
SDS-THM4 = 36 µg/L	28	2016	0.80	36	8	12	71
SDS-HAA5 = 54 µg/L	NA	NA	NA	NA	NA	NA	NA
SDS-HAA5 = 27 µg/L	91	6552	2.25	72	27	37	75
SDS-HAA6 = 54 µg/L	NA	NA	NA	NA	NA	NA	NA
SDS-HAA6 = 27 ug/L	76	5472	1.90	59	20	27	110

Table 11: PE Study for 1st Quarter (PE Study #6)

Parameter	Units	True Value	Measured Value	RPD
UV_{254}	cm^{-1}	0.101	0.090	10.89
TOC	mg/L	2.69	3.01	11.90
TOX	µg Cl^-/L	135	102.0	24.44
Bromide	mg/L	0.059	0.056	5.08
Inorganic DBPs:				
ClO_2^-	µg/L	73.6	63.0	14.40
BrO_3^-	µg/L	16.2	17.10	5.56
ClO_3^-	µg/L	141	140.0	0.71
HAAs:				
MCAA	µg/L	9.04	7.86	13.05
MBAA	µg/L	8.10	6.84	15.56
DCAA	µg/L	18.1	16.60	8.29
TCAA	µg/L	26.2	26.80	2.29
BCAA	µg/L	11.1	8.50	23.42
DBAA	µg/L	4.97	4.36	12.27
THMs:				
$CHCl_3$	µg/L	16.2	15.10	6.79
BDCM	µg/L	22.8	23.20	1.75
DBCM	µg/L	28.6	29.70	3.85
$CHBr_3$	µg/L	20.2	20.20	0.00
HANs:				
TCAN	µg/L	-	5.97	-
DCAN	µg/L	10.9	9.02	17.25
DCP	µg/L	9.00	8.30	7.78
BCAN	µg/L	13.0	12.00	7.69
TCP	µg/L	8.01	6.90	13.86
DBAN	µg/L	15.9	15.20	4.40
CH	µg/L	12.2	13.80	13.11

Table 12a: PE Study for 2nd Quarter (PE Study #7)

Parameter	Units	True Value	Measured Value	RPD
UV_{254}	cm^{-1}	0.361	0.339	6.09
TOC	mg/L	1.22	1.29	5.74
TOX	μg Cl^-/L	188	149.0	20.74
Inorganic DBPs:				
ClO_2^-	μg/L	483	449.0	7.04
BrO_3^-	μg/L	26.1	24.50	6.13
ClO_3^-	μg/L	375	352.0	6.13
HAAs:				
MCAA	μg/L	5.94	5.07	14.65
MBAA	μg/L	11.1	7.50	32.43
DCAA	μg/L	24.0	17.10	28.75
TCAA	μg/L	15.0	12.90	14.00
BCAA	μg/L	12.1	7.37	39.09
DBAA	μg/L	14.0	9.03	35.50
THMs:				
$CHCl_3$	μg/L	17.0	16.00	5.88
BDCM	μg/L	11.0	11.30	2.73
DBCM	μg/L	28.1	28.00	0.36
$CHBr_3$	μg/L	18.2	18.20	0.00
HANs:				
TCAN	μg/L	12.1	12.00	0.83
DCAN	μg/L	19.0	18.60	2.11
DCP	μg/L	5.06	5.22	3.16
BCAN	μg/L	9.10	8.69	4.51
TCP	μg/L	11.1	11.80	6.31
DBAN	μg/L	14.0	14.30	2.14
CH	μg/L	22.1	20.10	9.05

Table 12b: Makeup PE Study for 2nd Quarter

Parameter	Units	True Value	Measured Value	RPD
Bromide	mg/L	0.091	0.090	1.10

Table 13a: PE Study for 3rd Quarter (PE Study #8)

Parameter	Units	True Value	Measured Value	RPD
UV_{254}	cm^{-1}	0.072	0.066	8.33
TOC	mg/L	2.62	3.14	19.85
TOX	μg Cl^-/L	80.3	62.8	21.79
Bromide	mg/L	0.325	0.296	8.92
Inorganic DBPs:				
ClO_2^-	μg/L	687	635.0	7.57
BrO_3^-	μg/L	13.1	12.30	6.11
ClO_3^-	μg/L	768	700.0	8.85
HAAs:				
MCAA	μg/L	13.0	12.60	3.08
MBAA	μg/L	16.0	14.30	10.63
DCAA	μg/L	14.2	12.60	11.27
TCAA	μg/L	8.03	6.76	15.82
BCAA	μg/L	5.07	4.77	5.92
DBAA	μg/L	18.0	17.90	0.56
HANs:				
TCAN	μg/L	6.92	5.52	20.23
DCAN	μg/L	6.16	4.51	26.79
DCP	μg/L	4.09	4.38	7.09
BCAN	μg/L	10.0	7.44	25.60
TCP	μg/L	2.99	3.61	20.74
DBAN	μg/L	5.07	4.52	10.85
CH	μg/L	9.08	10.60	16.74

Table 13b: Makeup PE Study for 3rd Quarter

Parameter	Units	True Value	Measured Value	RPD
THMs:				
$CHCl_3$	μg/L	17.1	17.10	0.00
BDCM	μg/L	11.0	11.00	0.00
DBCM	μg/L	28.1	26.70	4.98
$CHBr_3$	μg/L	18.2	18.10	0.55

Table 14: PE Study for 4th Quarter (PE Study #9)

Parameter	Units	True Value	Measured Value	RPD
UV_{254}	cm^{-1}	0.223	0.206	7.62
TOC	mg/L	4.19	4.25	1.43
TOX	µg Cl^-/L	92.9	62.5	32.72
Bromide	mg/L	0.091	0.092	1.10
Inorganic DBPs:				
ClO_2^-	µg/L	167	170.0	1.80
BrO_3^-	µg/L	9.17	9.68	5.56
ClO_3^-	µg/L	211	209.0	0.95
HAAs:				
MCAA	µg/L	11.1	12.10	9.01
MBAA	µg/L	9.11	8.54	6.26
DCAA	µg/L	8.01	7.39	7.74
TCAA	µg/L	12.0	9.47	21.08
BCAA	µg/L	7.05	5.60	20.57
DBAA	µg/L	5.00	3.85	23.00
THMs:				
$CHCl_3$	µg/L	32.2	32.10	0.31
BDCM	µg/L	15.0	14.90	0.67
DBCM	µg/L	9.10	8.73	4.07
$CHBr_3$	µg/L	2.98	2.91	2.35
HANs:				
TCAN	µg/L	17.0	18.30	7.65
DCAN	µg/L	16.2	16.20	0.00
DCP	µg/L	8.13	9.73	19.68
BCAN	µg/L	14.1	11.50	18.44
TCP	µg/L	14.1	14.50	2.84
DBAN	µg/L	12.1	9.64	20.33
CH	µg/L	19.1	15.30	19.90

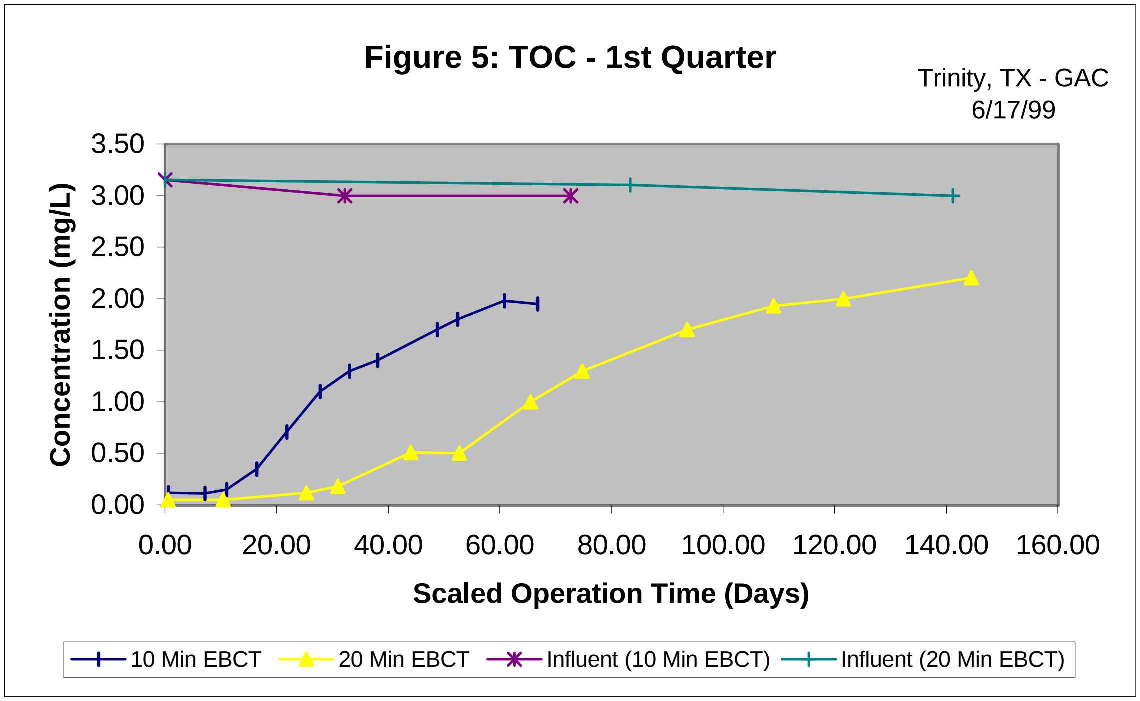


Figure 5: TOC - 1st Quarter
Trinity, TX - GAC
6/17/99
Concentration (mg/L)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Scaled Operation Time (Days)
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

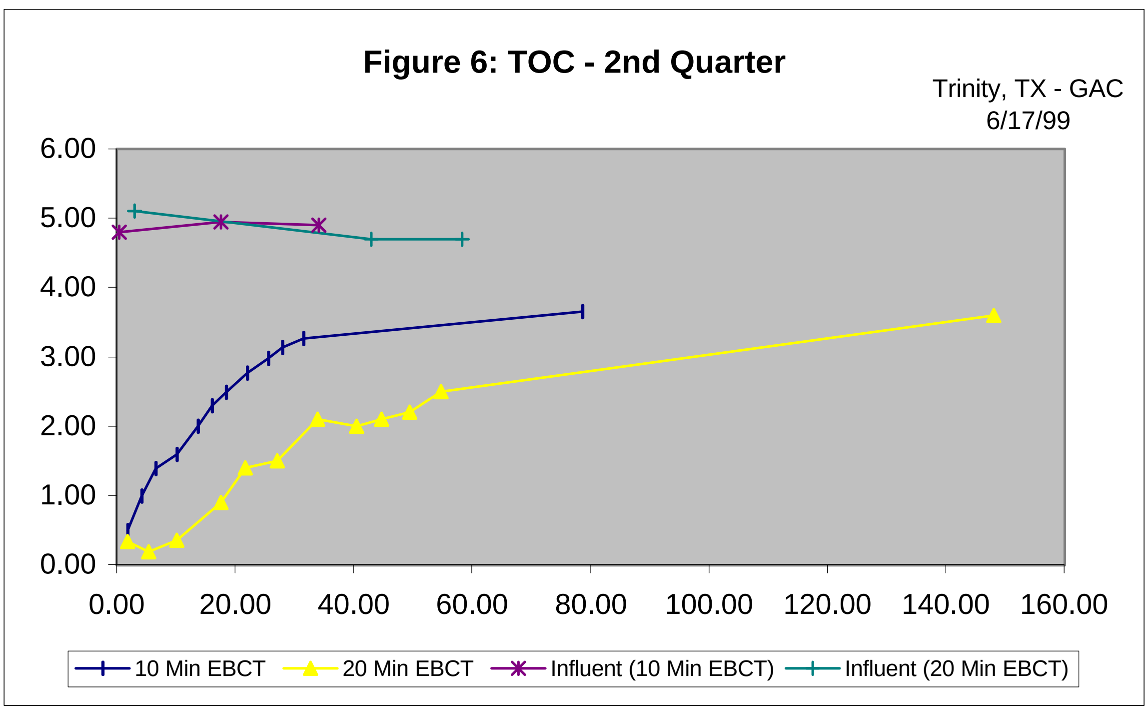


Figure 6: TOC - 2nd Quarter
Trinity, TX - GAC
6/17/99
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

Figure 7: TOC - 3rd Quarter

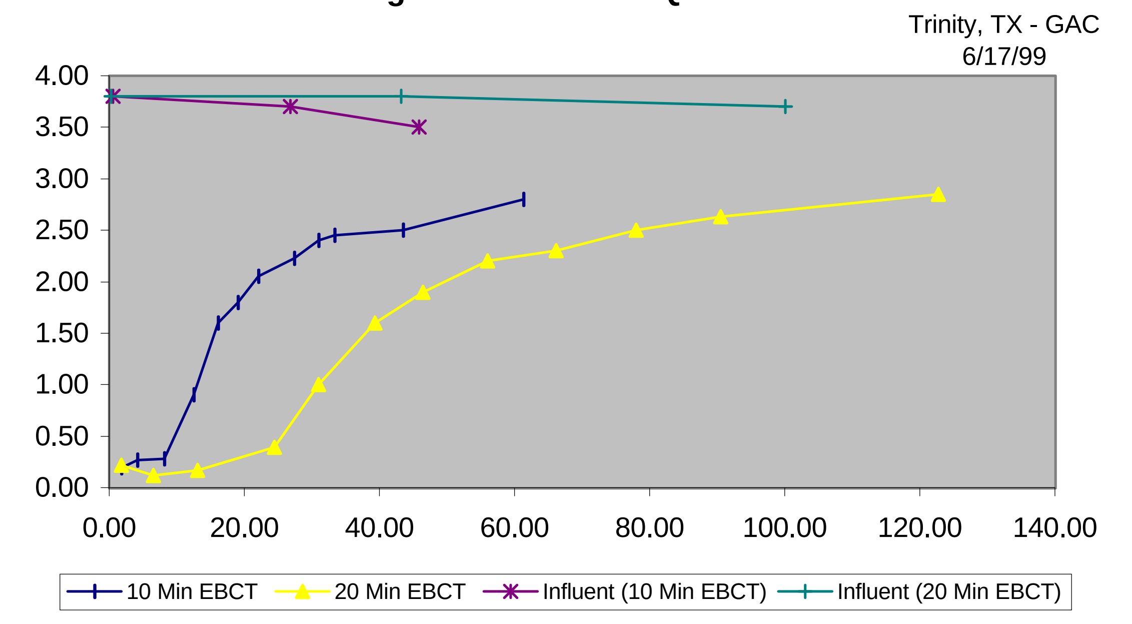


Figure 8: TOC - 4th Quarter

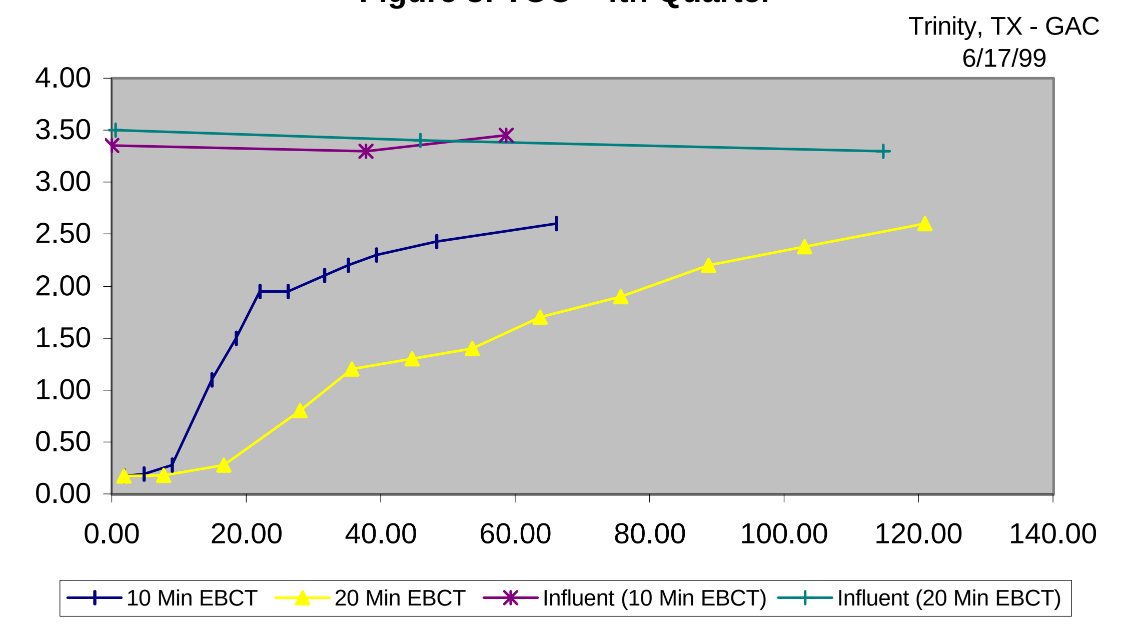


Figure 9: UV-254 -- 1st Quarter

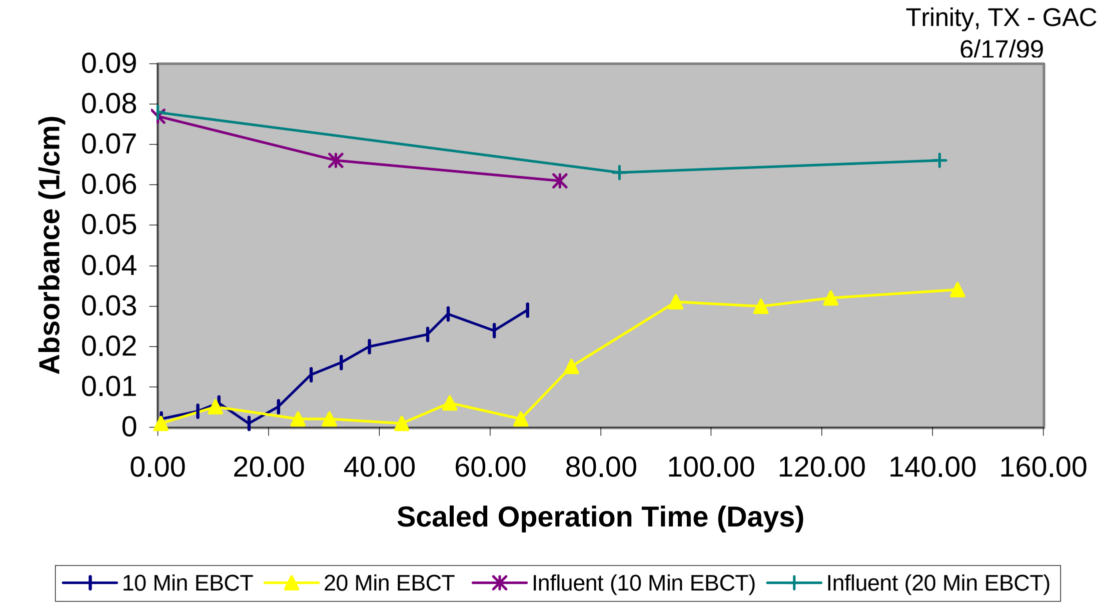
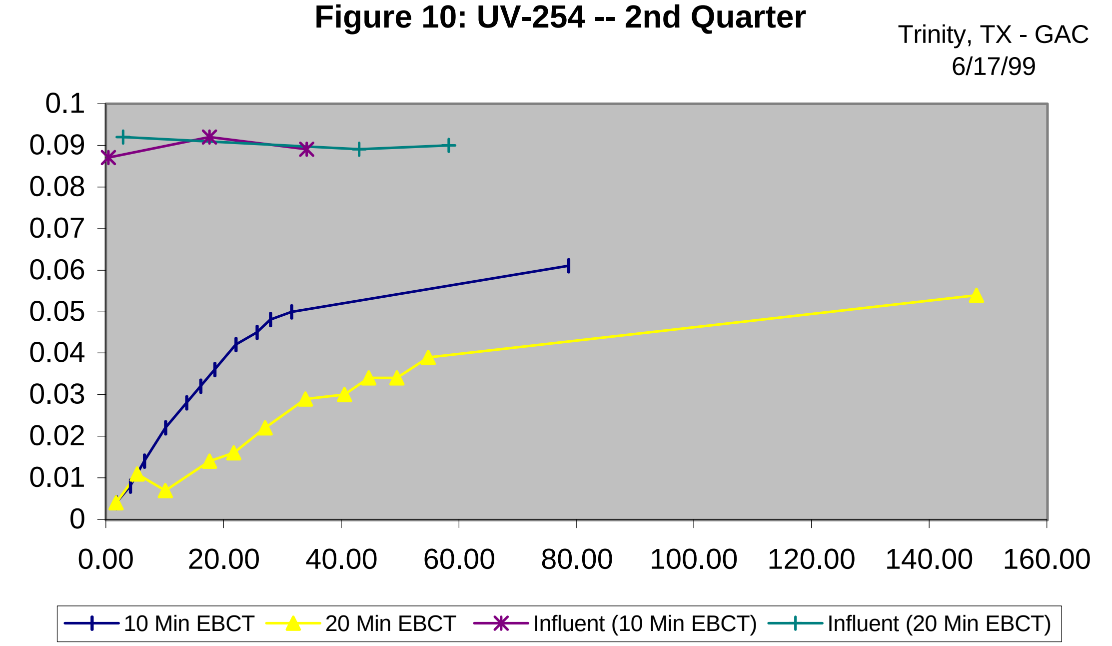


Figure 10: UV-254 -- 2nd Quarter



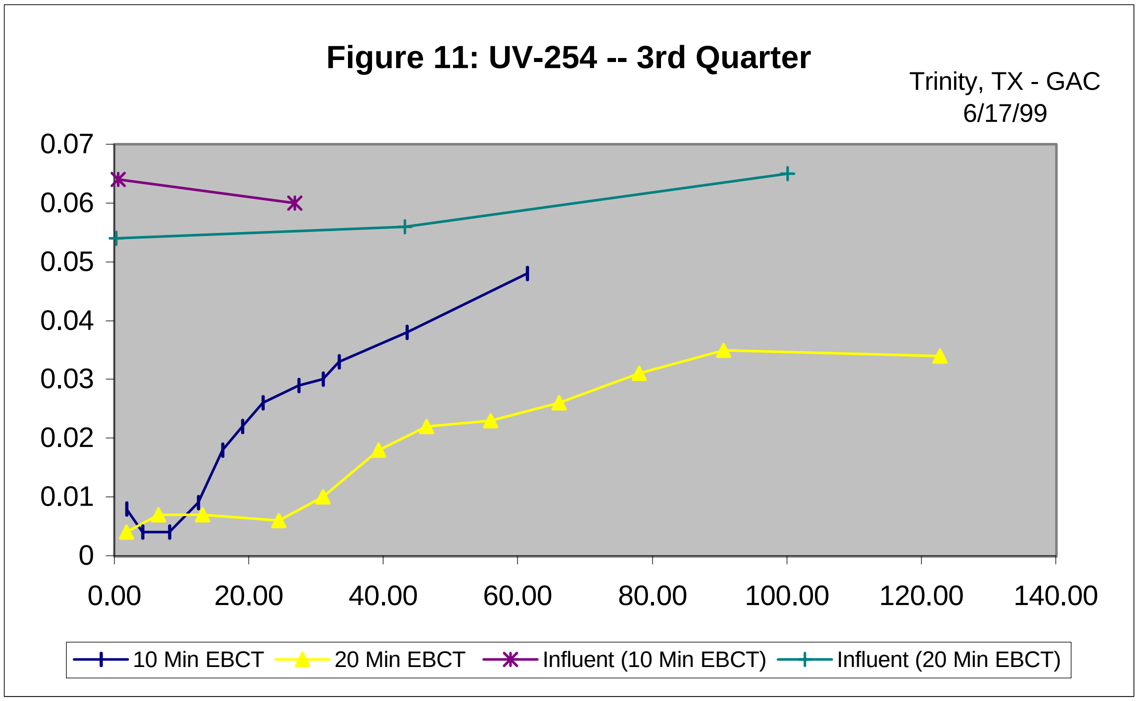


Figure 11: UV-254 -- 3rd Quarter
Trinity, TX - GAC
6/17/99
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

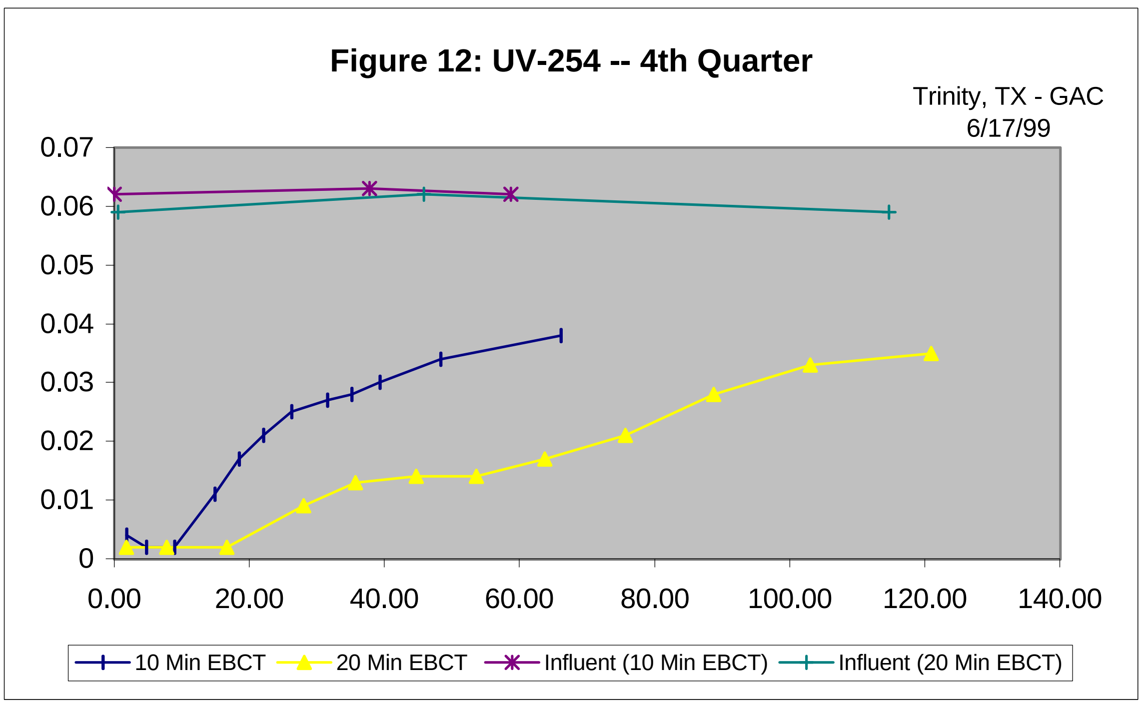


Figure 12: UV-254 -- 4th Quarter
Trinity, TX - GAC
6/17/99
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

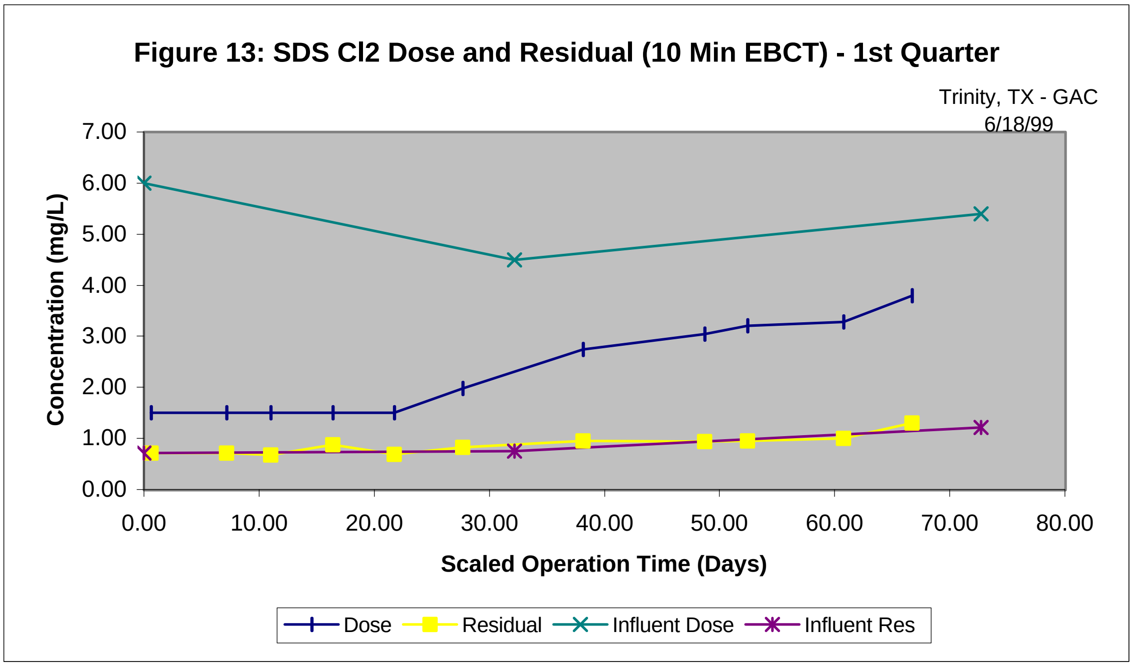


Figure 13: SDS Cl2 Dose and Residual (10 Min EBCT) - 1st Quarter
Trinity, TX - GAC
6/18/99
Concentration (mg/L)
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
Scaled Operation Time (Days)
Dose
Residual
Influent Dose
Influent Res

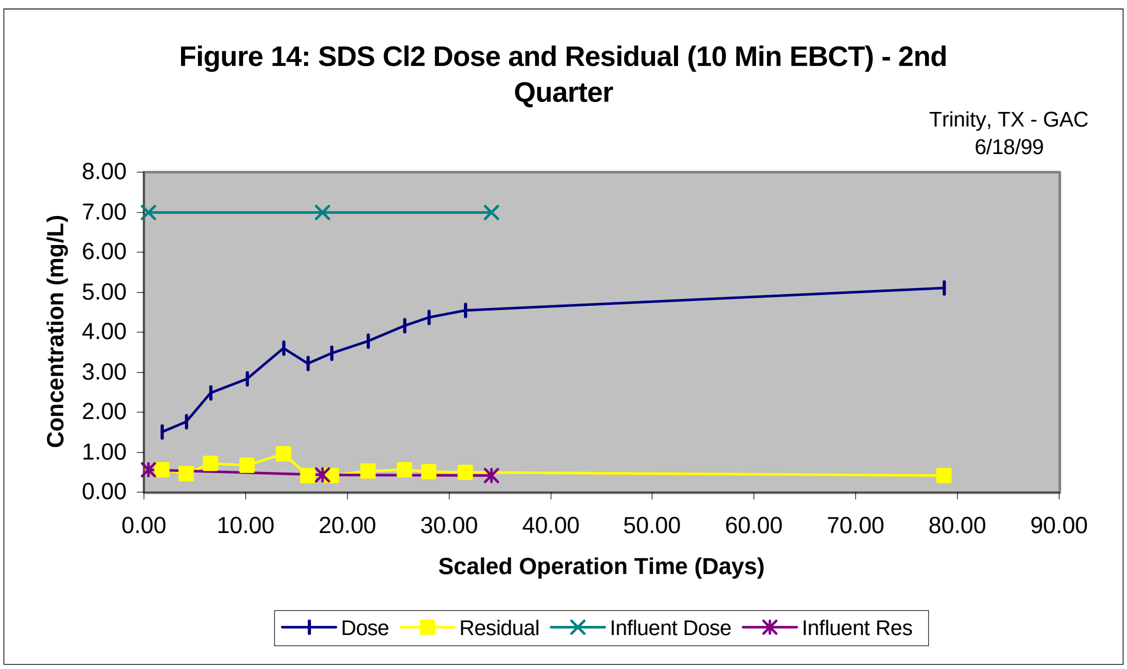


Figure 14: SDS Cl2 Dose and Residual (10 Min EBCT) - 2nd Quarter
Trinity, TX - GAC
6/18/99
Concentration (mg/L)
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
Scaled Operation Time (Days)
Dose
Residual
Influent Dose
Influent Res

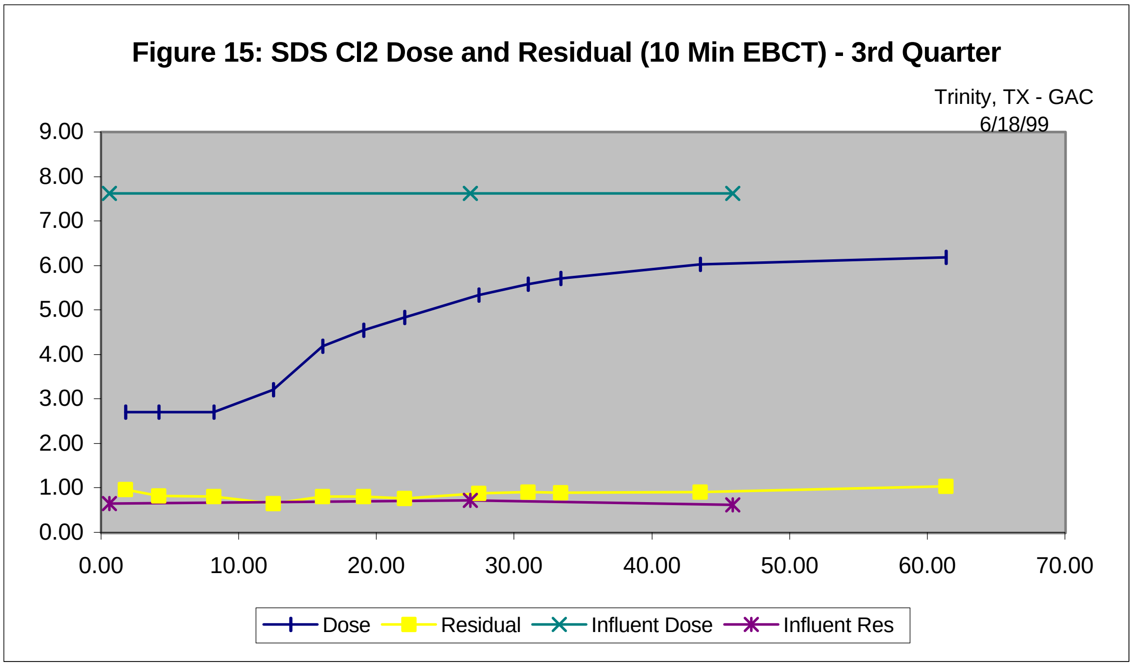


Figure 15: SDS Cl2 Dose and Residual (10 Min EBCT) - 3rd Quarter
Trinity, TX - GAC
6/18/99
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
Dose
Residual
Influent Dose
Influent Res

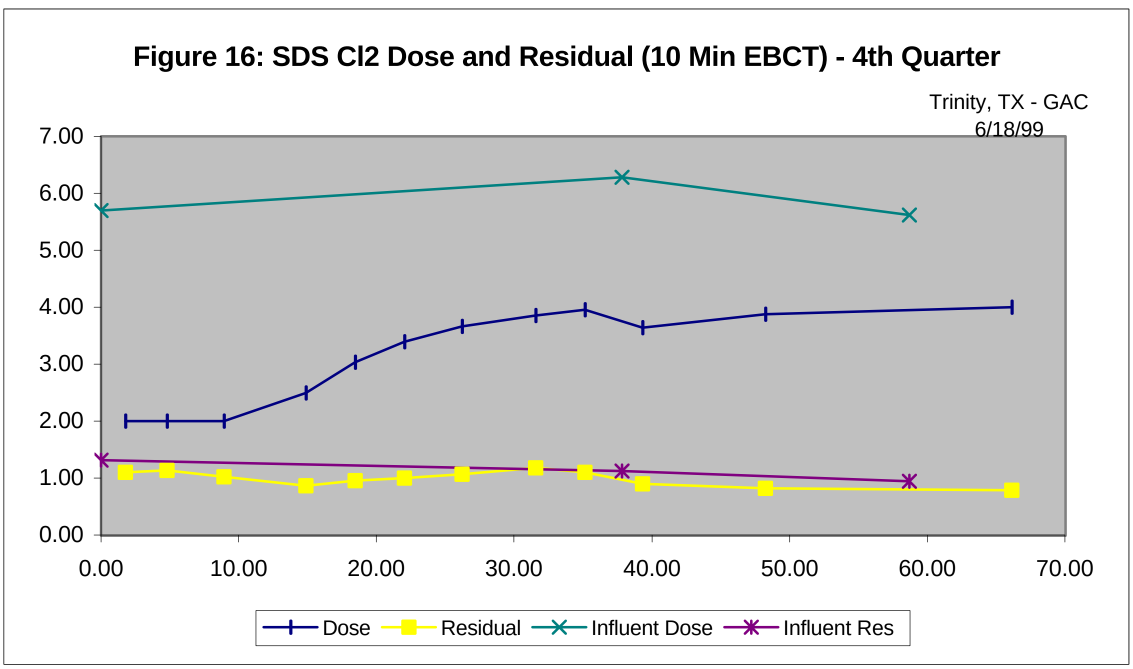


Figure 16: SDS Cl2 Dose and Residual (10 Min EBCT) - 4th Quarter
Trinity, TX - GAC
6/18/99
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
Dose
Residual
Influent Dose
Influent Res

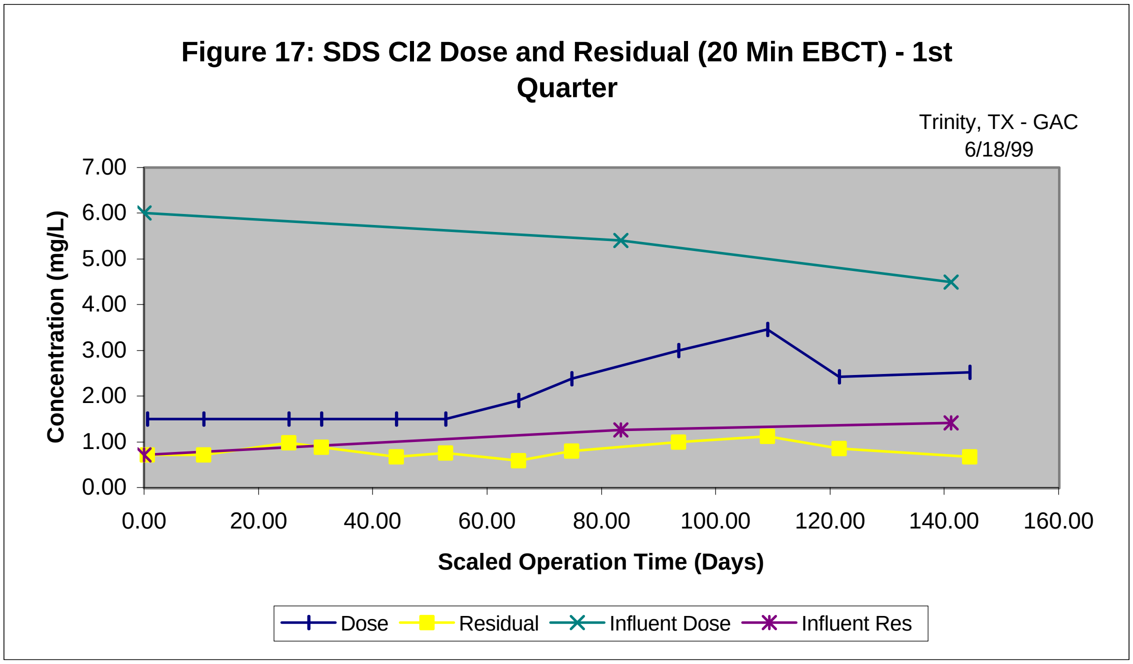


Figure 17: SDS Cl2 Dose and Residual (20 Min EBCT) - 1st Quarter
Trinity, TX - GAC
6/18/99
Concentration (mg/L)
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Scaled Operation Time (Days)
Dose
Residual
Influent Dose
Influent Res

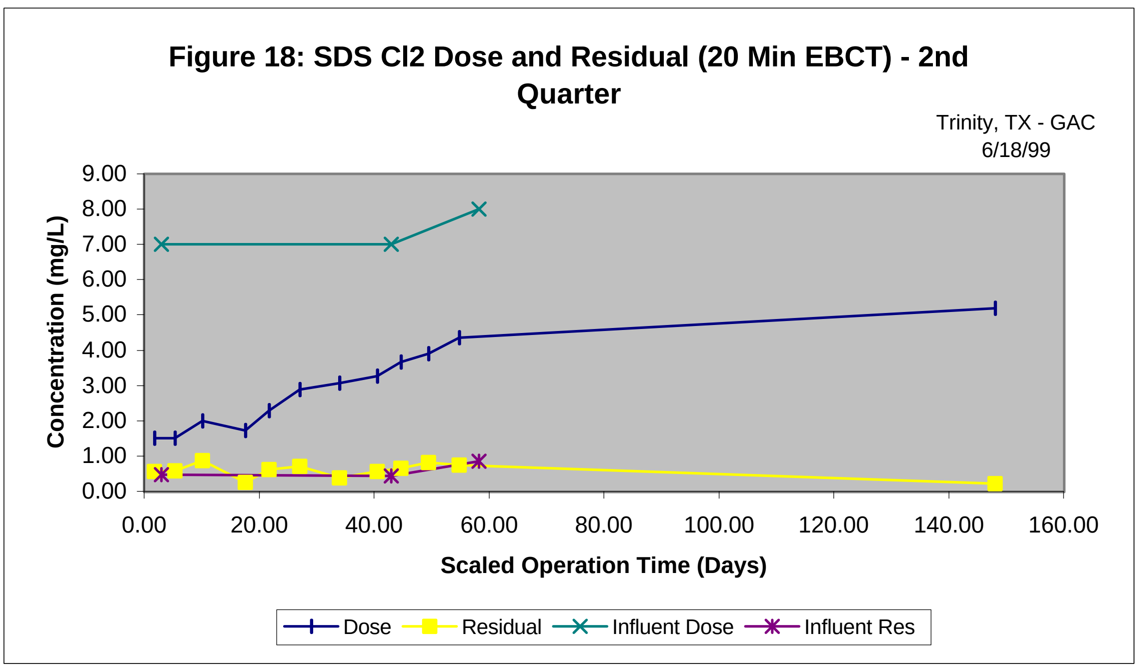


Figure 18: SDS Cl2 Dose and Residual (20 Min EBCT) - 2nd Quarter
Trinity, TX - GAC
6/18/99
Concentration (mg/L)
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Scaled Operation Time (Days)
Dose
Residual
Influent Dose
Influent Res

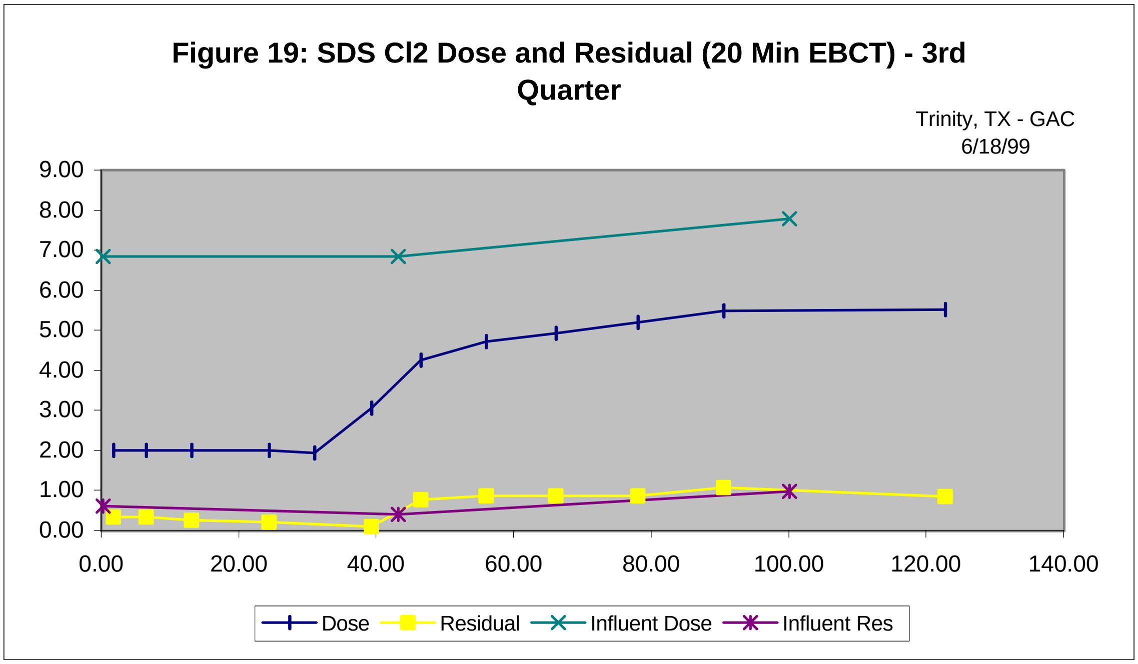


Figure 19: SDS Cl2 Dose and Residual (20 Min EBCT) - 3rd Quarter
Trinity, TX - GAC
6/18/99
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
Dose
Residual
Influent Dose
Influent Res

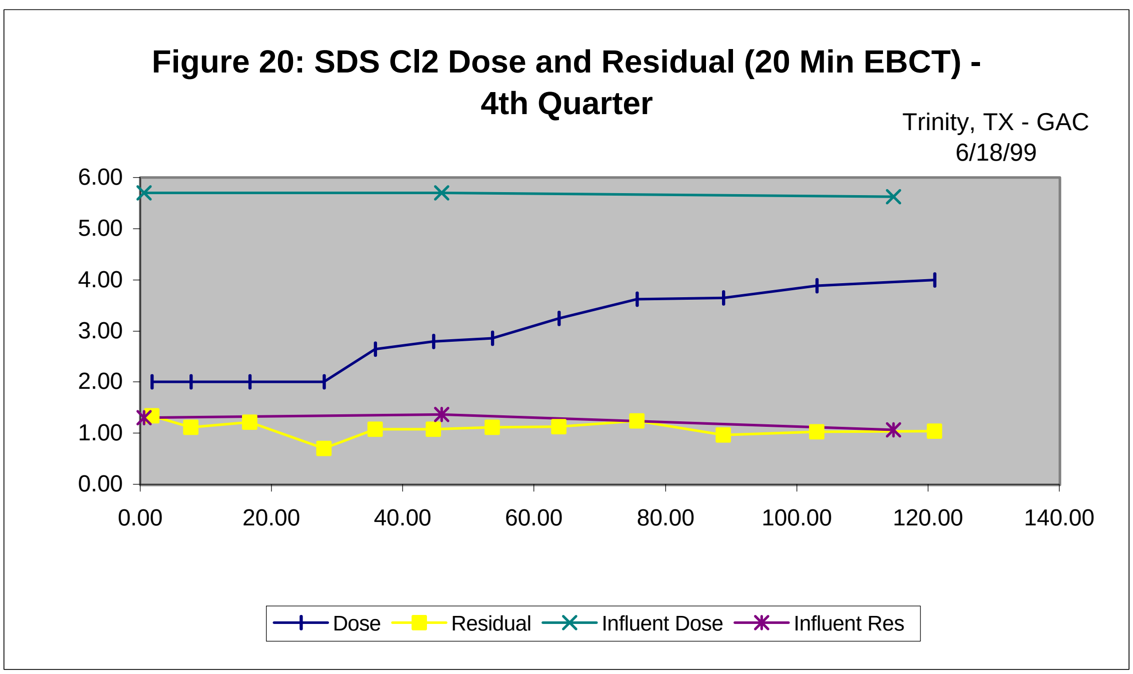


Figure 20: SDS Cl2 Dose and Residual (20 Min EBCT) - 4th Quarter
Trinity, TX - GAC
6/18/99
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
Dose
Residual
Influent Dose
Influent Res

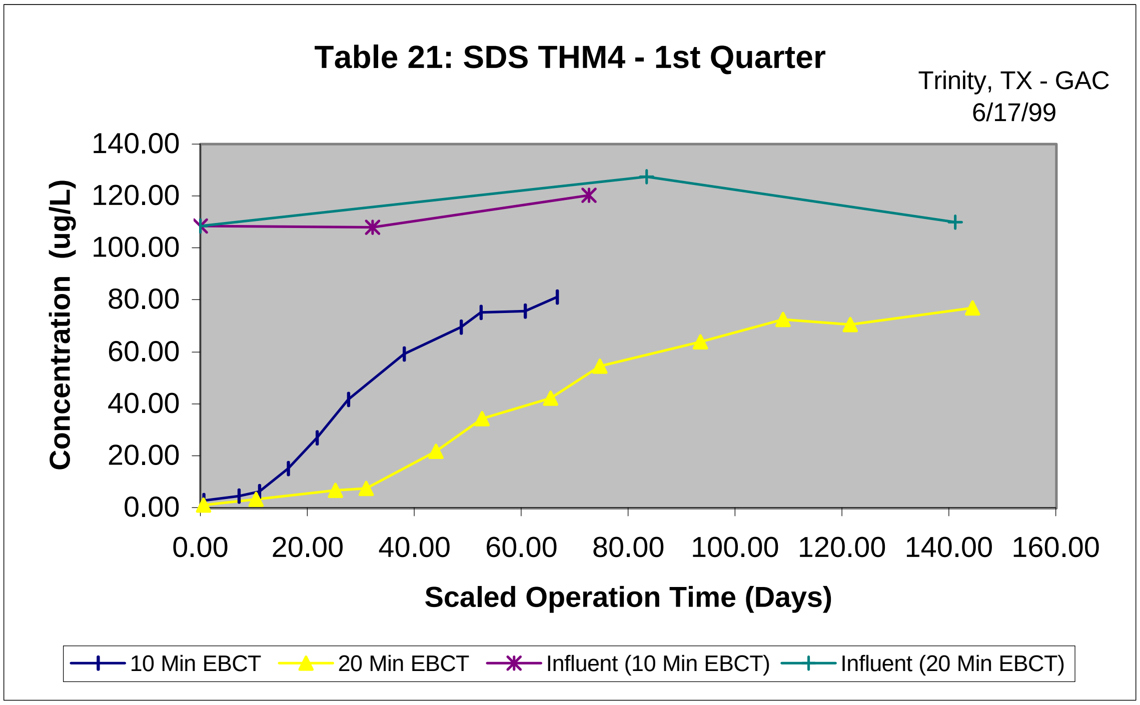


Table 21: SDS THM4 - 1st Quarter
Trinity, TX - GAC
6/17/99
Concentration (ug/L)
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Scaled Operation Time (Days)
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

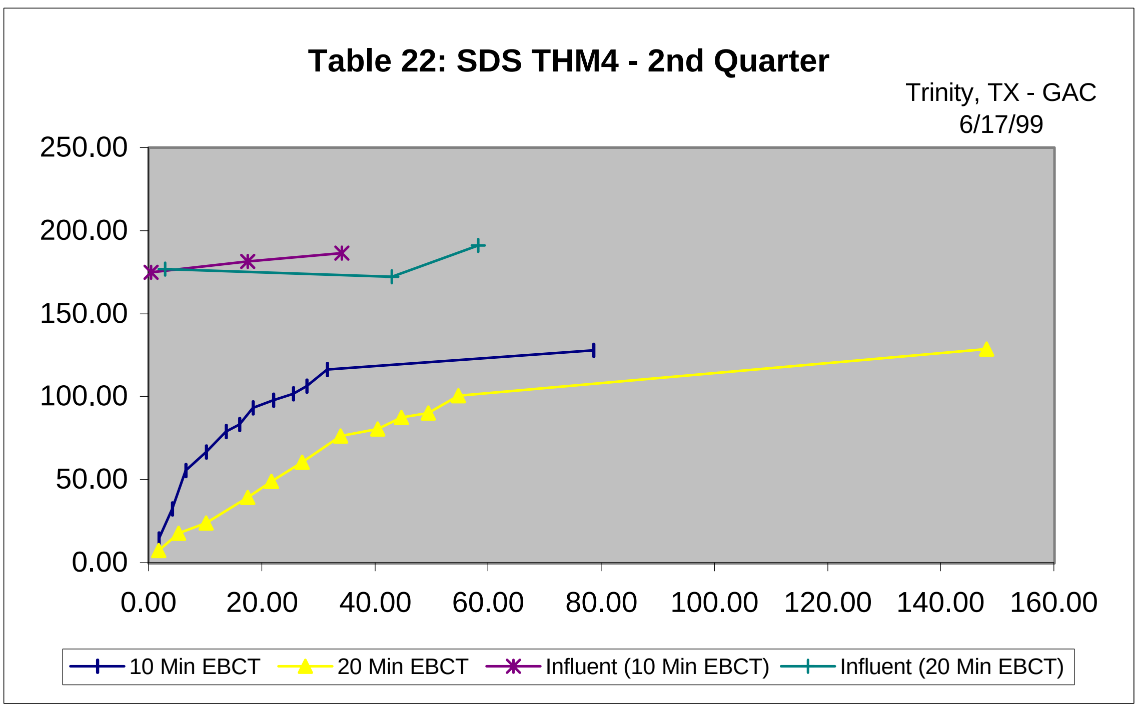


Table 22: SDS THM4 - 2nd Quarter
Trinity, TX - GAC
6/17/99
250.00
200.00
150.00
100.00
50.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

Figure 23: SDS THM4 - 3rd Quarter

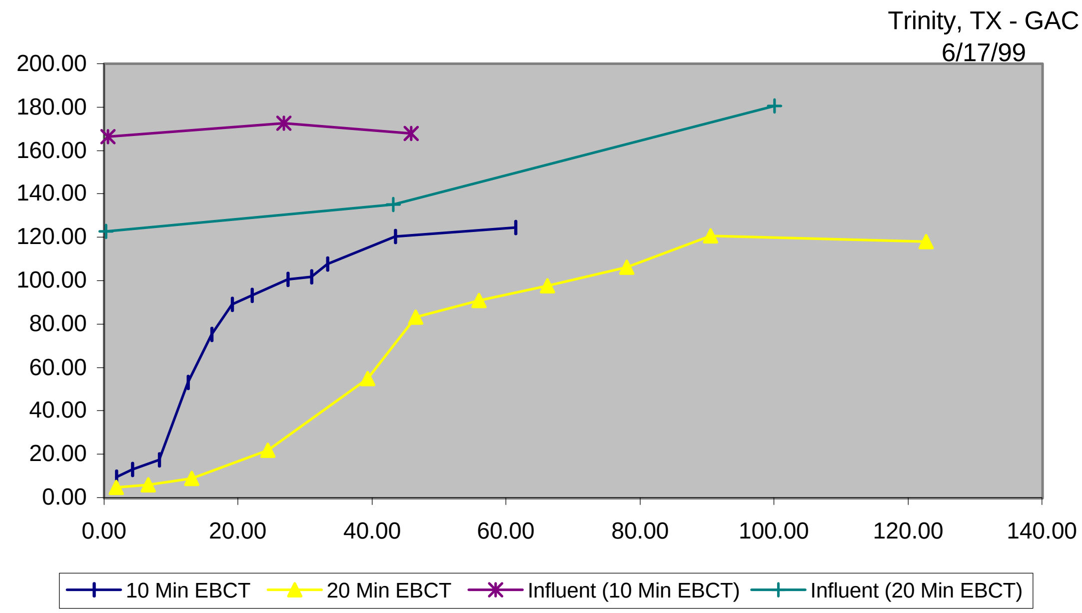
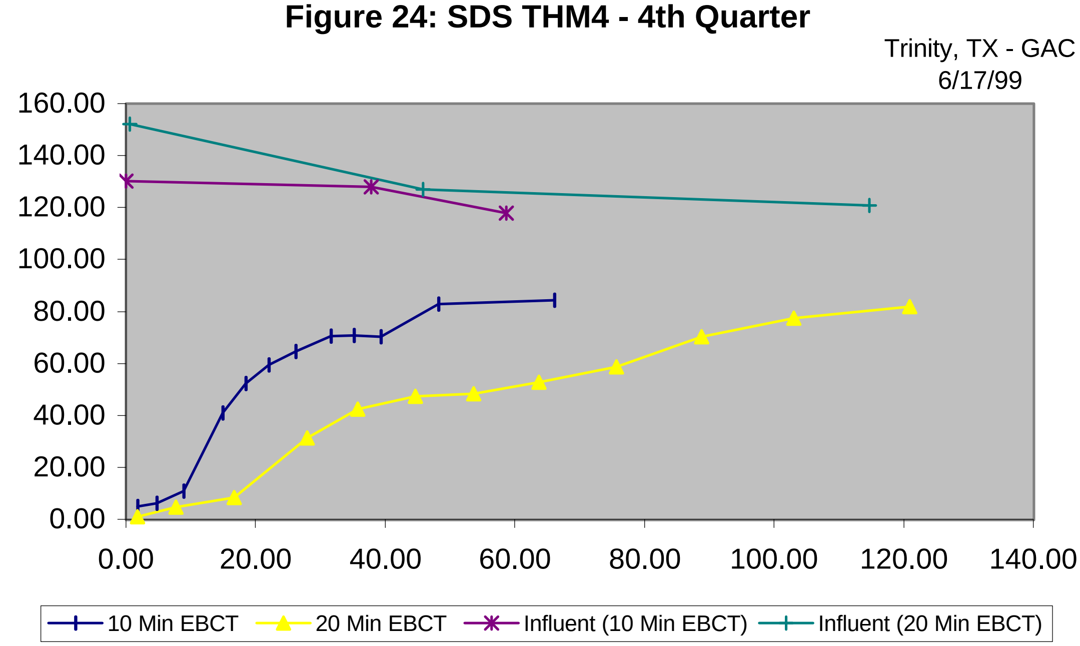


Figure 24: SDS THM4 - 4th Quarter



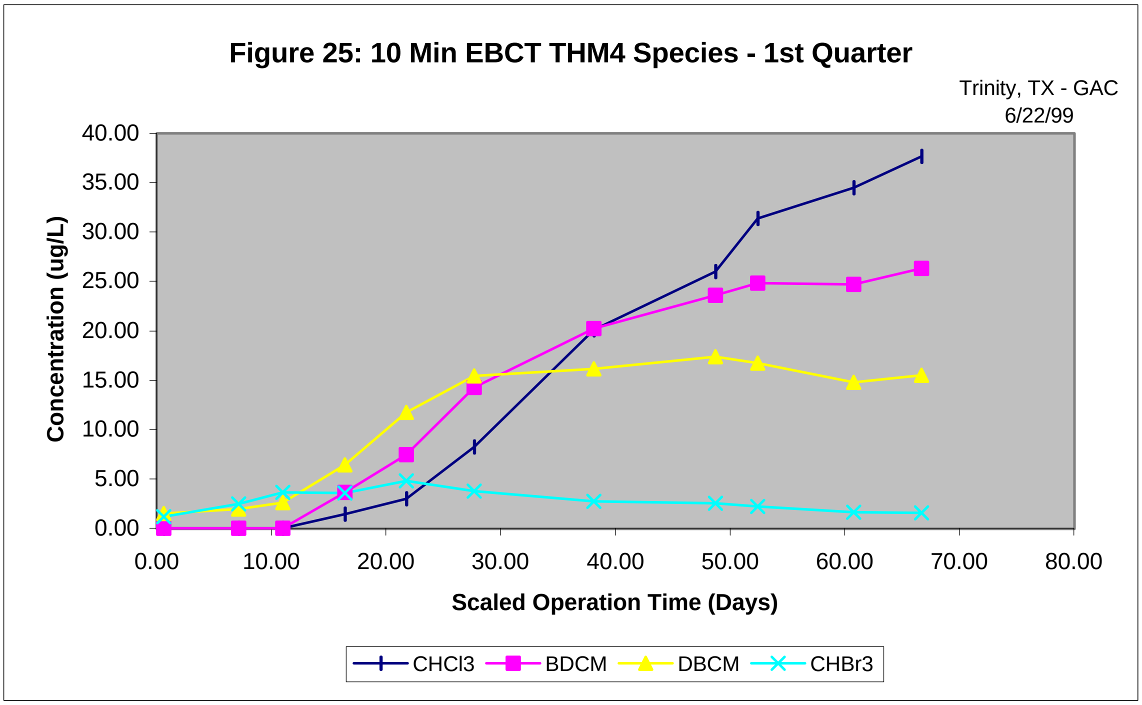


Figure 25: 10 Min EBCT THM4 Species - 1st Quarter
Trinity, TX - GAC
6/22/99
Concentration (ug/L)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
Scaled Operation Time (Days)
CHCl3
BDCM
DBCM
CHBr3

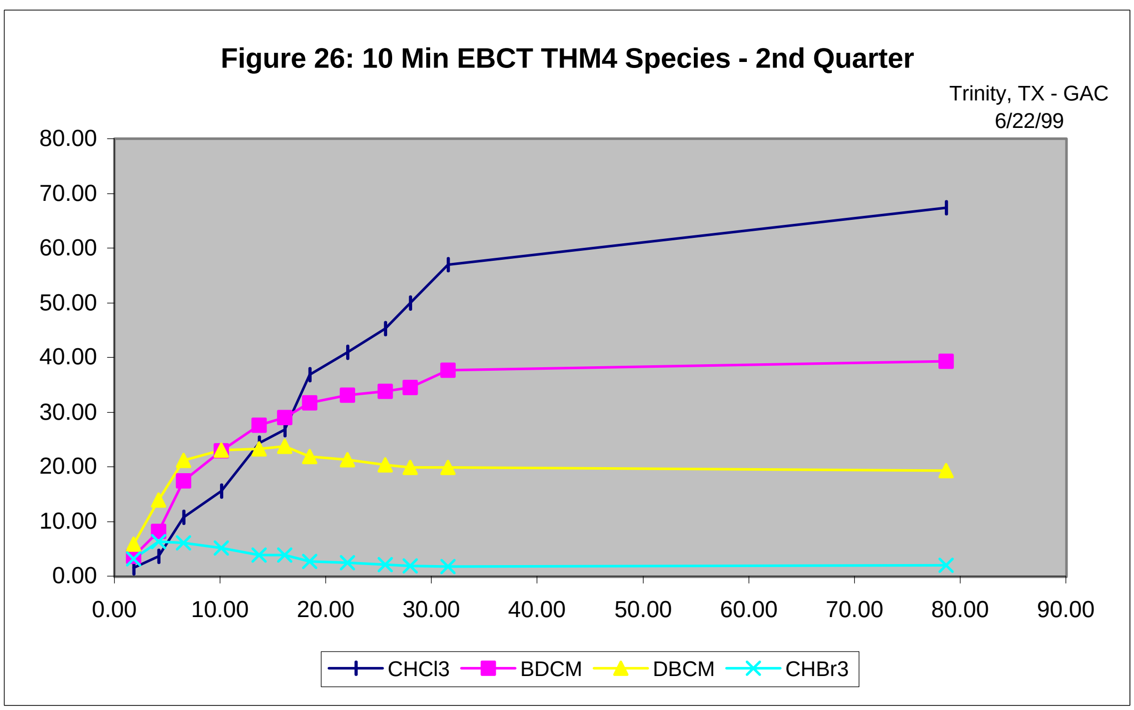


Figure 26: 10 Min EBCT THM4 Species - 2nd Quarter
Trinity, TX - GAC
6/22/99
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
CHCl3
BDCM
DBCM
CHBr3

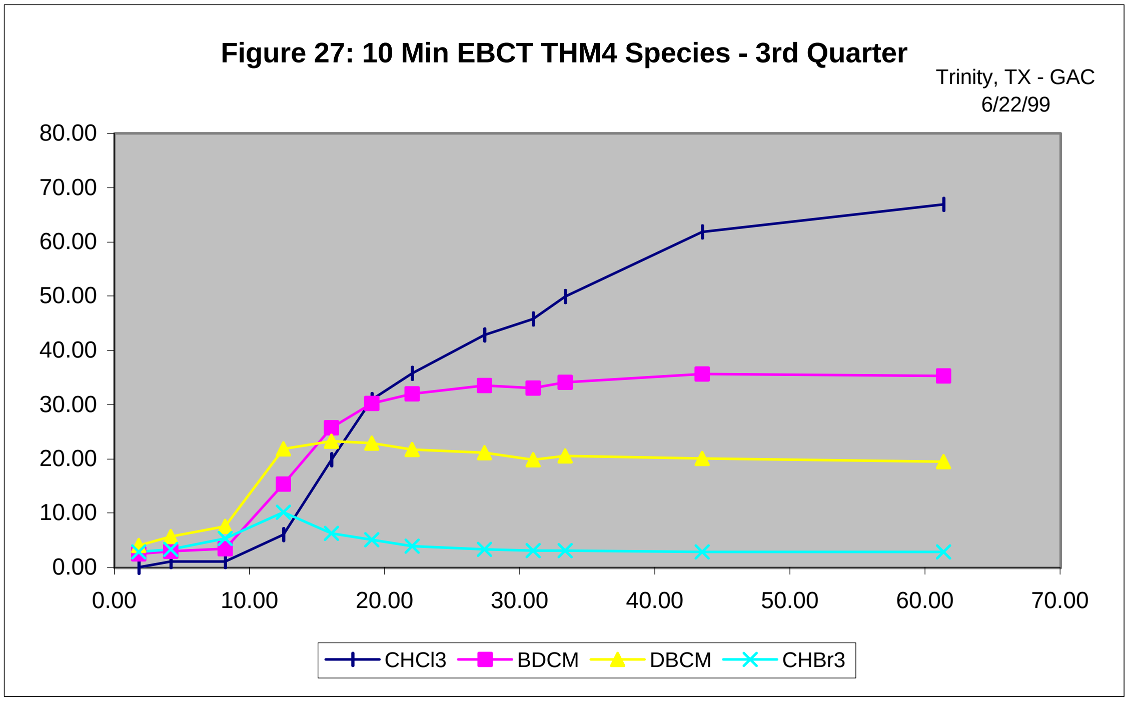


Figure 27: 10 Min EBCT THM4 Species - 3rd Quarter
Trinity, TX - GAC
6/22/99
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
CHCl3
BDCM
DBCM
CHBr3

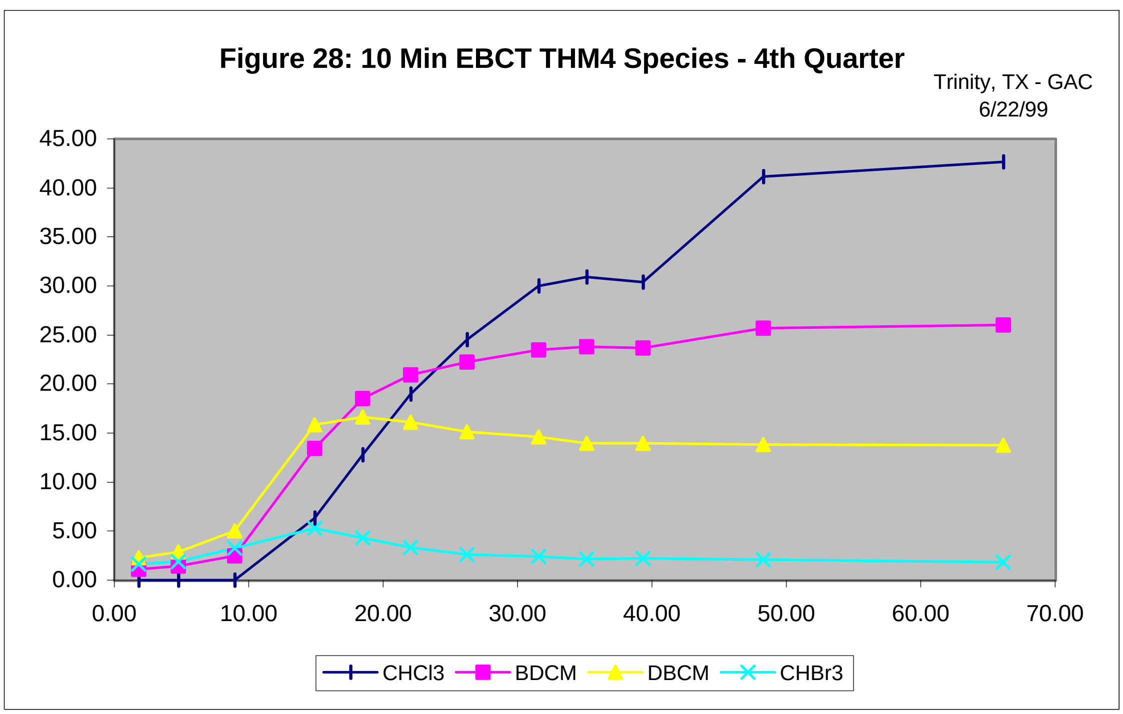


Figure 28: 10 Min EBCT THM4 Species - 4th Quarter
Trinity, TX - GAC
6/22/99
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
CHCl3
BDCM
DBCM
CHBr3

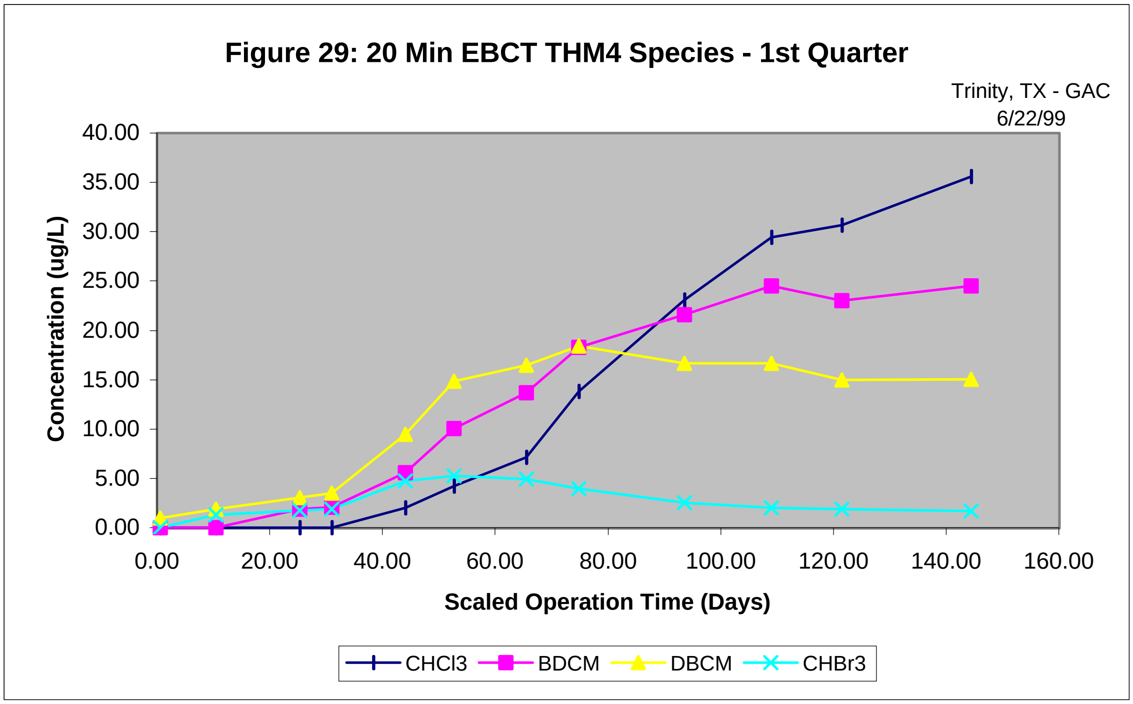


Figure 29: 20 Min EBCT THM4 Species - 1st Quarter
Trinity, TX - GAC
6/22/99
Concentration (ug/L)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Scaled Operation Time (Days)
CHCl3
BDCM
DBCM
CHBr3

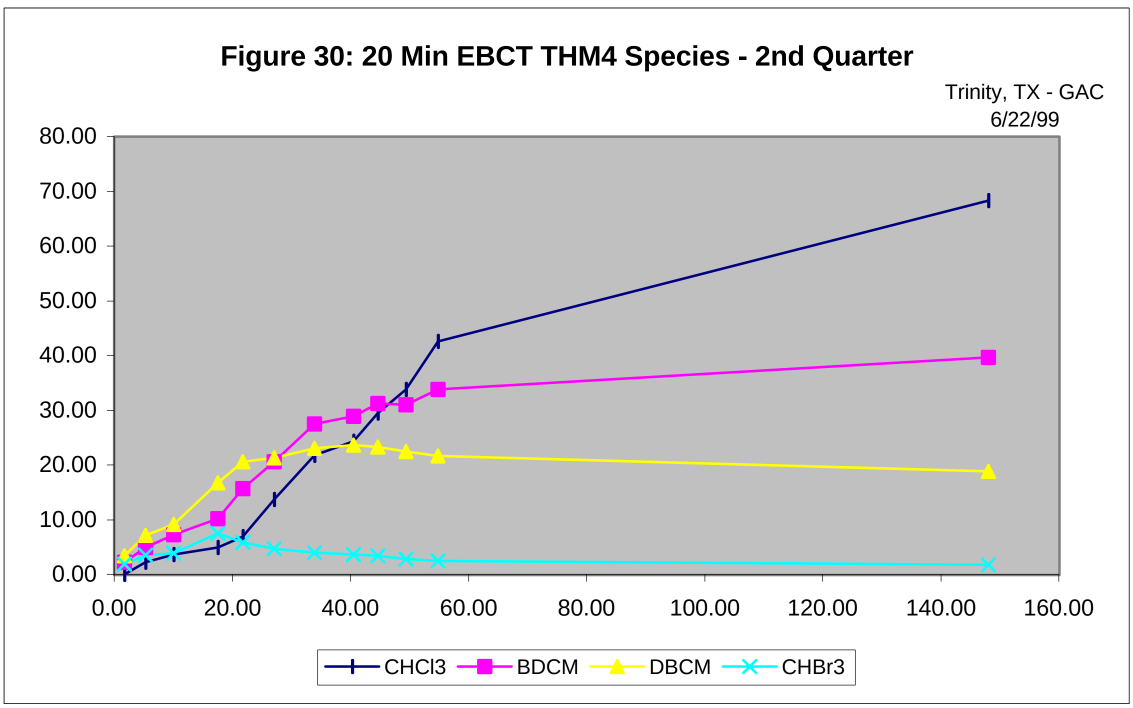


Figure 30: 20 Min EBCT THM4 Species - 2nd Quarter
Trinity, TX - GAC
6/22/99
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
CHCl3
BDCM
DBCM
CHBr3

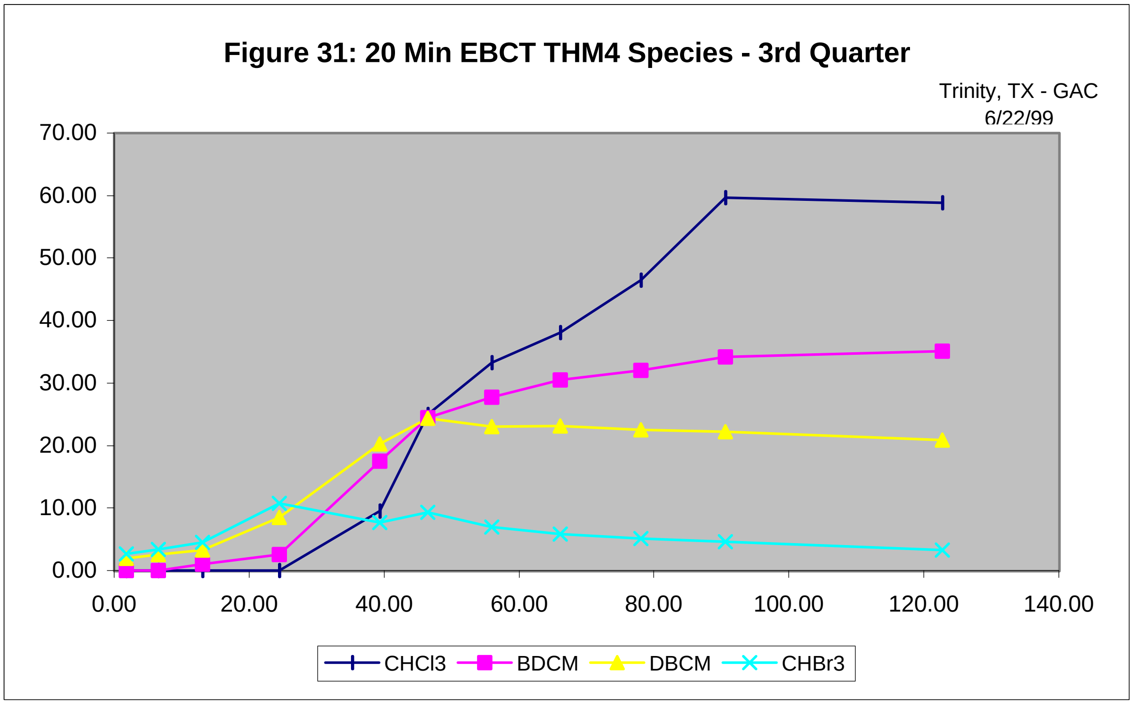


Figure 31: 20 Min EBCT THM4 Species - 3rd Quarter
Trinity, TX - GAC
6/22/99
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
CHCl3
BDCM
DBCM
CHBr3

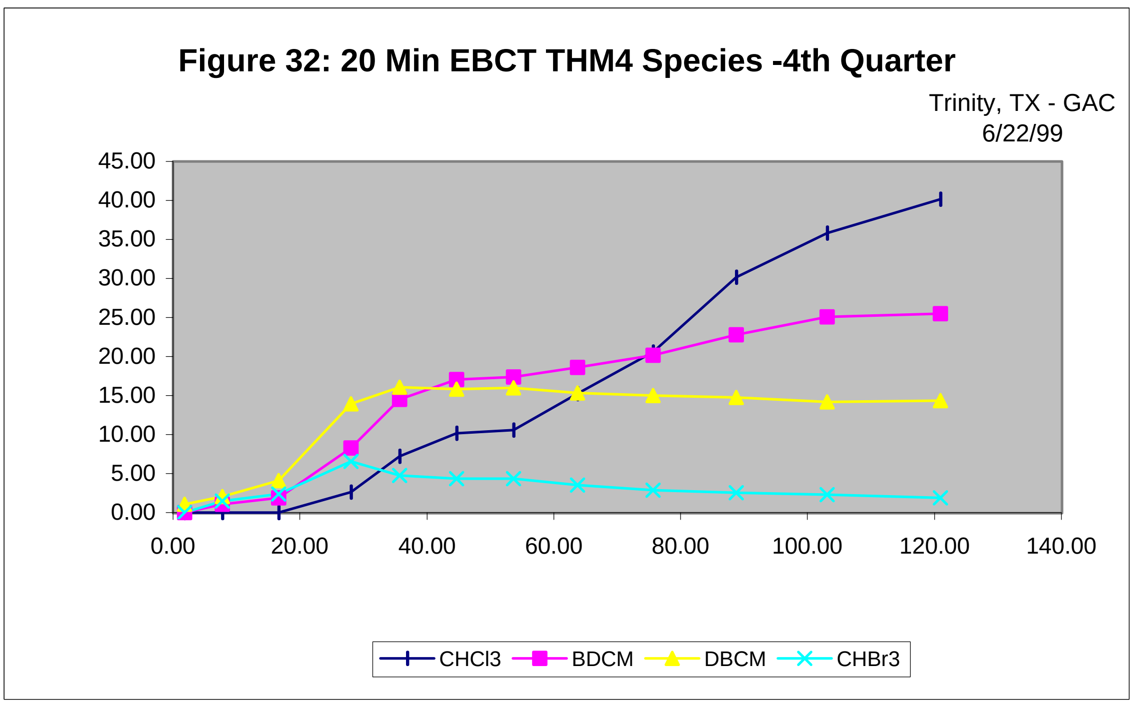


Figure 32: 20 Min EBCT THM4 Species -4th Quarter
Trinity, TX - GAC
6/22/99
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
CHCl3
BDCM
DBCM
CHBr3

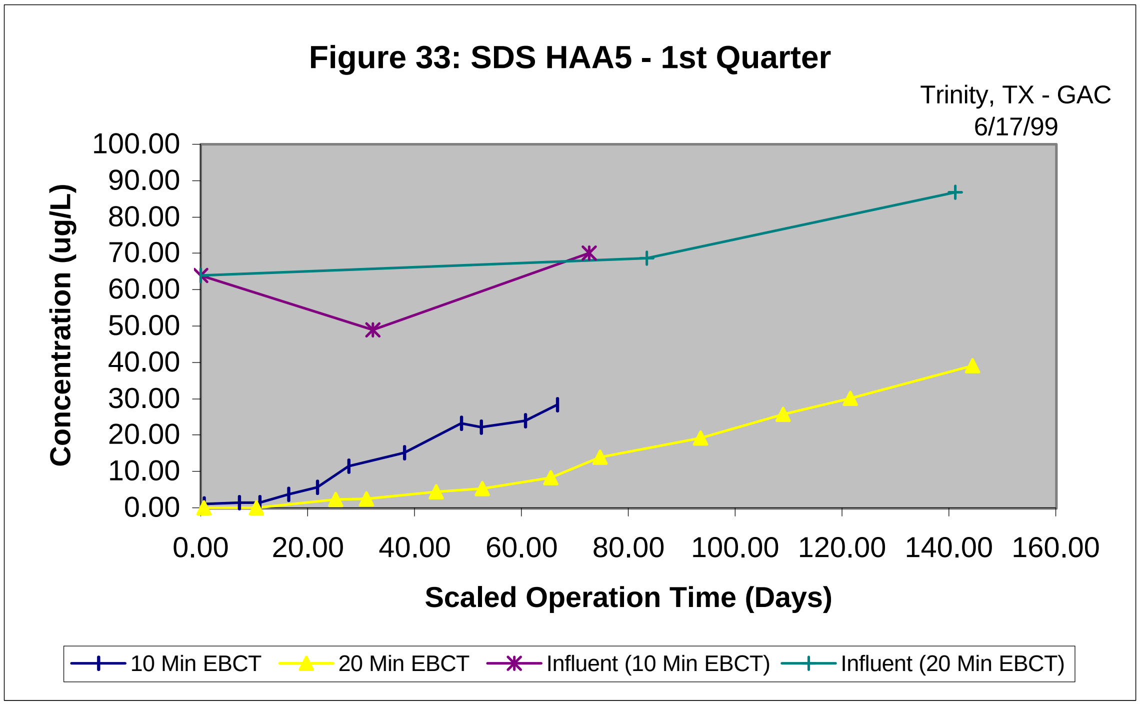


Figure 33: SDS HAA5 - 1st Quarter
Trinity, TX - GAC
6/17/99
Concentration (ug/L)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Scaled Operation Time (Days)
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

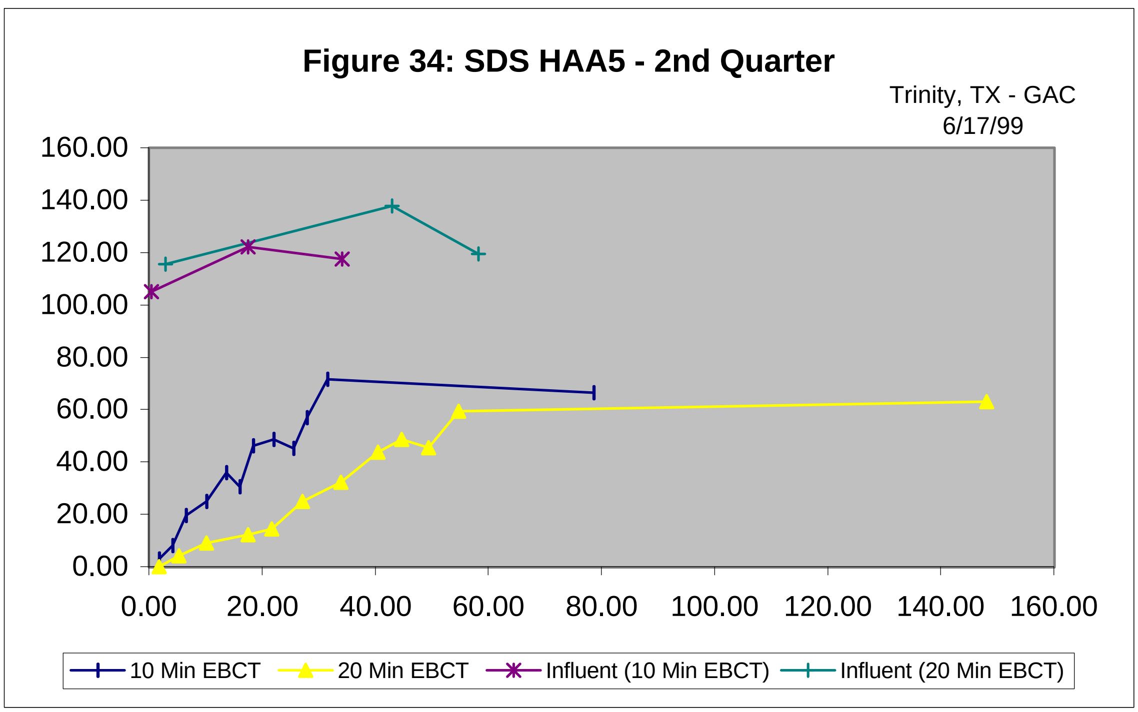


Figure 34: SDS HAA5 - 2nd Quarter
Trinity, TX - GAC
6/17/99
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

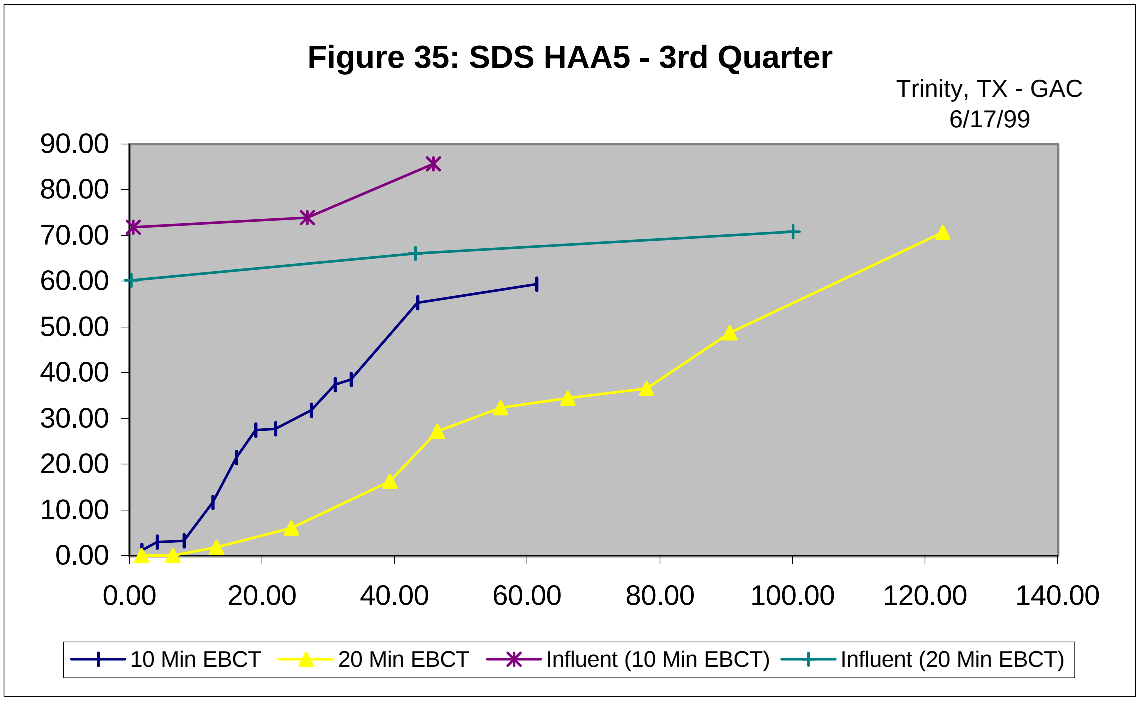


Figure 35: SDS HAA5 - 3rd Quarter
Trinity, TX - GAC
6/17/99
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

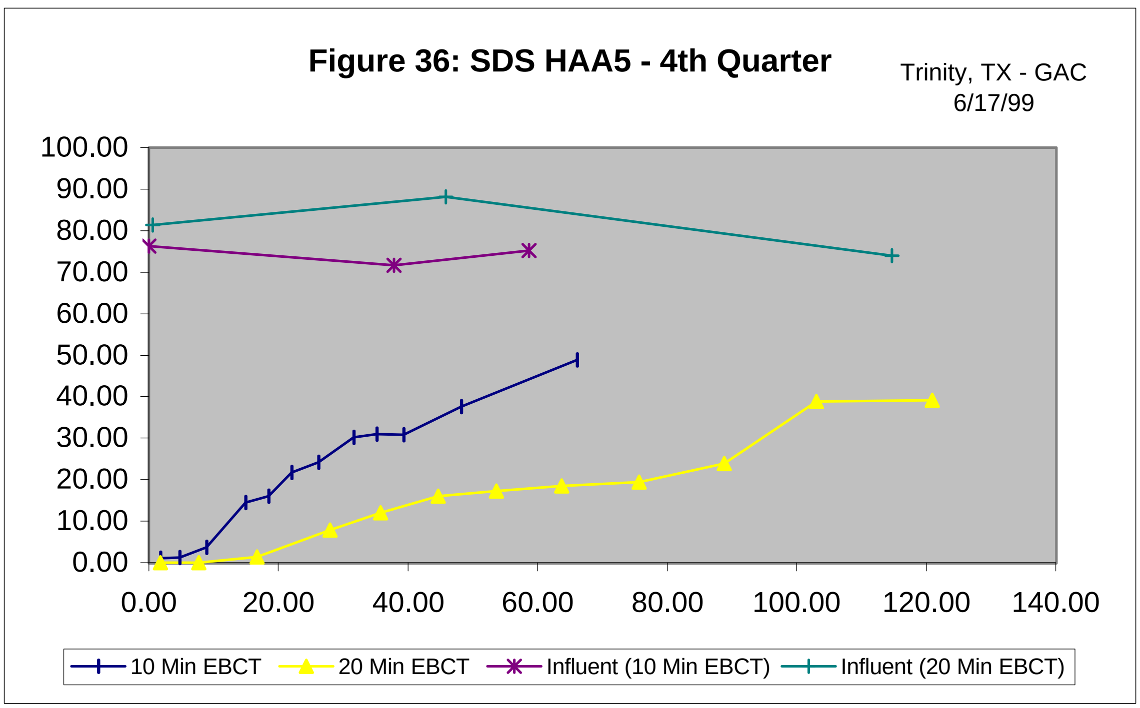


Figure 36: SDS HAA5 - 4th Quarter
Trinity, TX - GAC
6/17/99
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

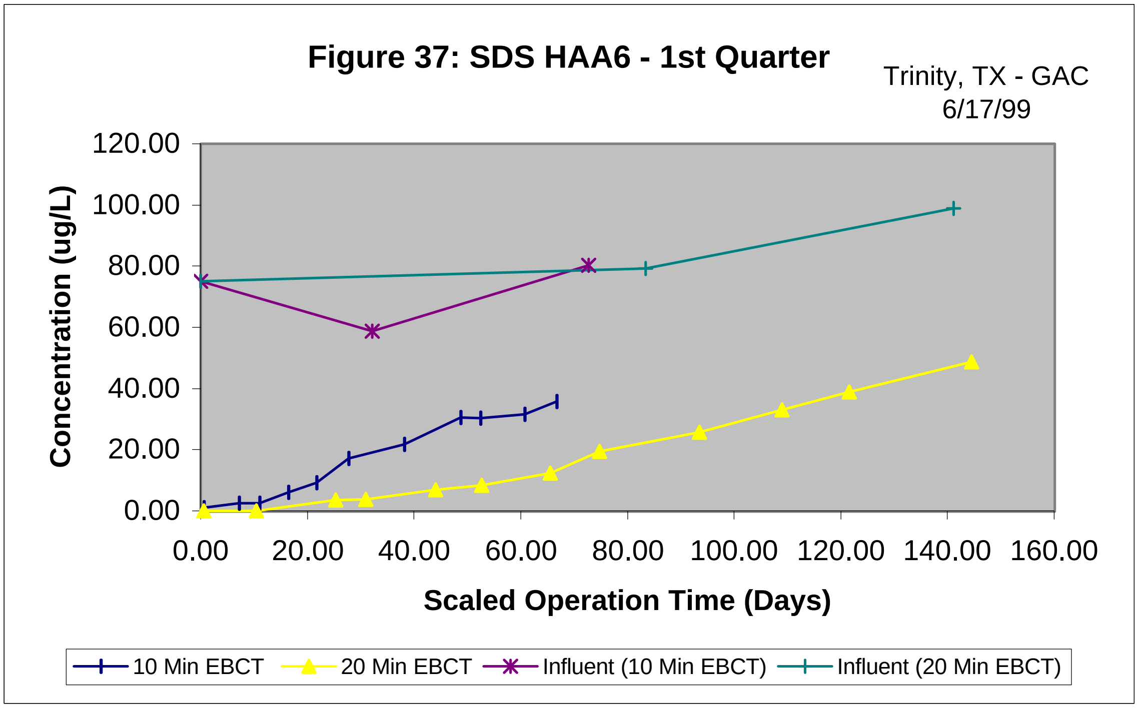


Figure 37: SDS HAA6 - 1st Quarter
Trinity, TX - GAC
6/17/99
Concentration (ug/L)
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Scaled Operation Time (Days)
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

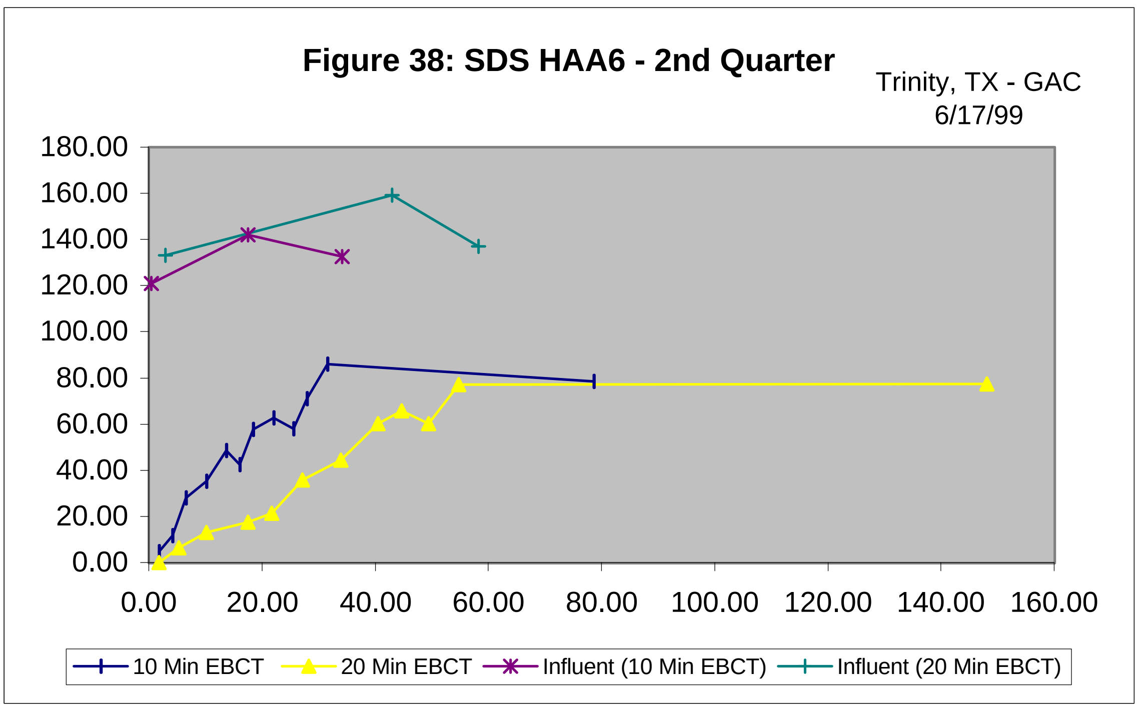


Figure 38: SDS HAA6 - 2nd Quarter
Trinity, TX - GAC
6/17/99
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

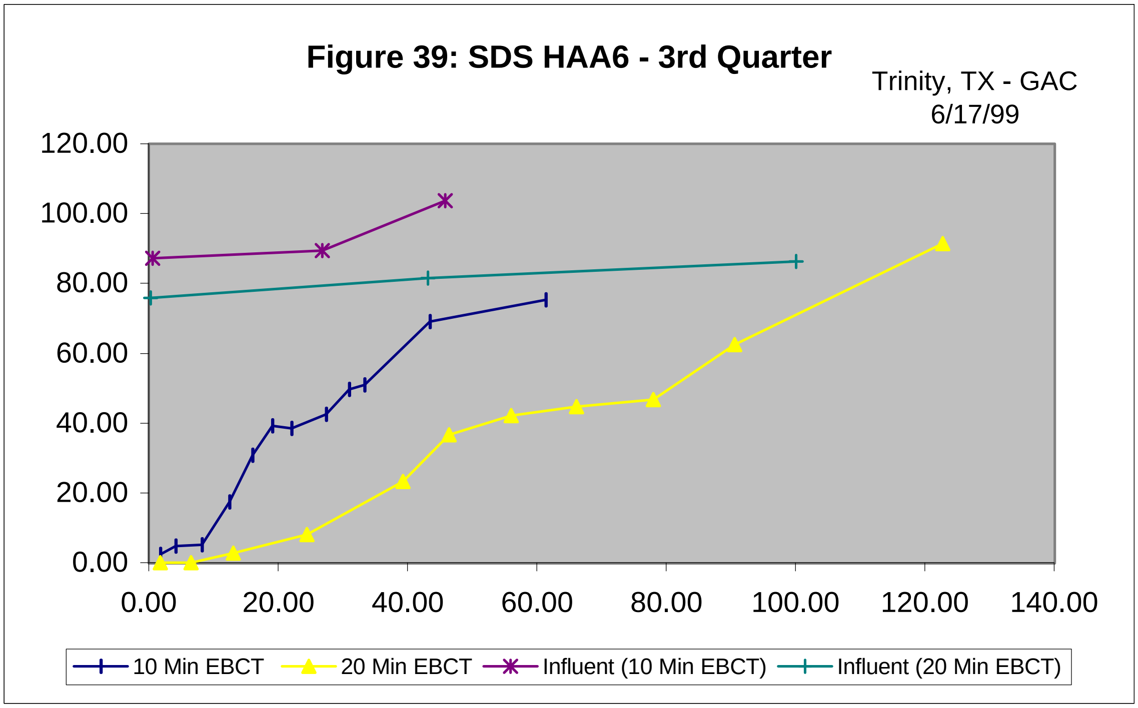


Figure 39: SDS HAA6 - 3rd Quarter
Trinity, TX - GAC
6/17/99
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

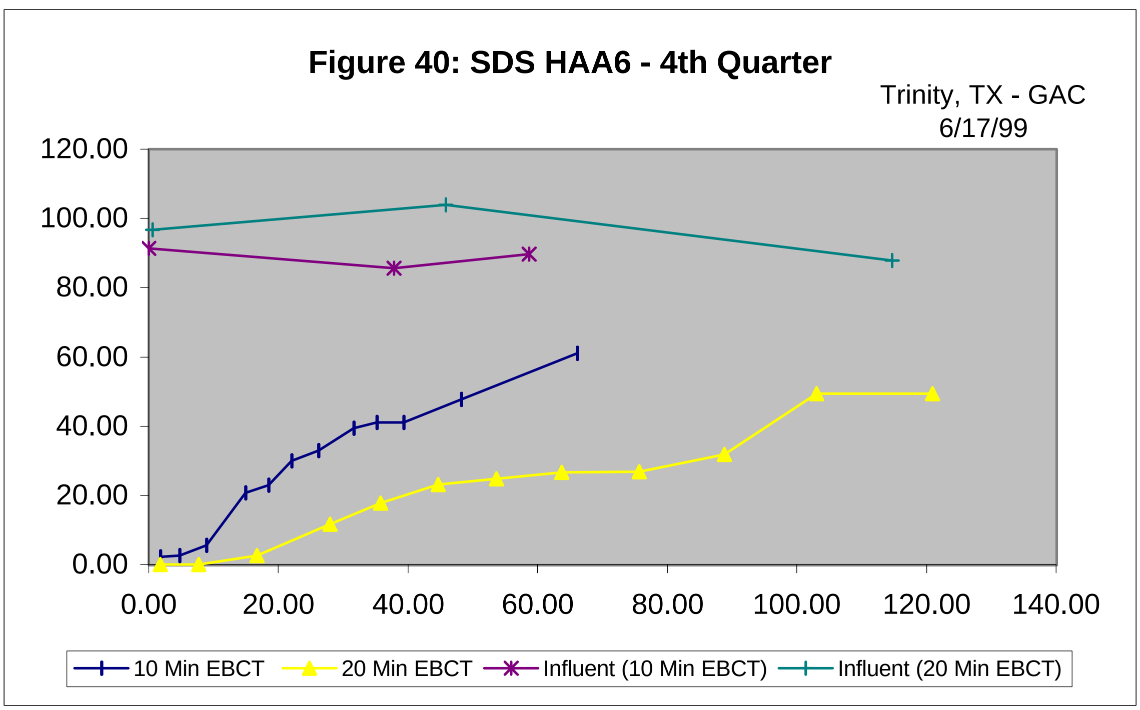


Figure 40: SDS HAA6 - 4th Quarter
Trinity, TX - GAC
6/17/99
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

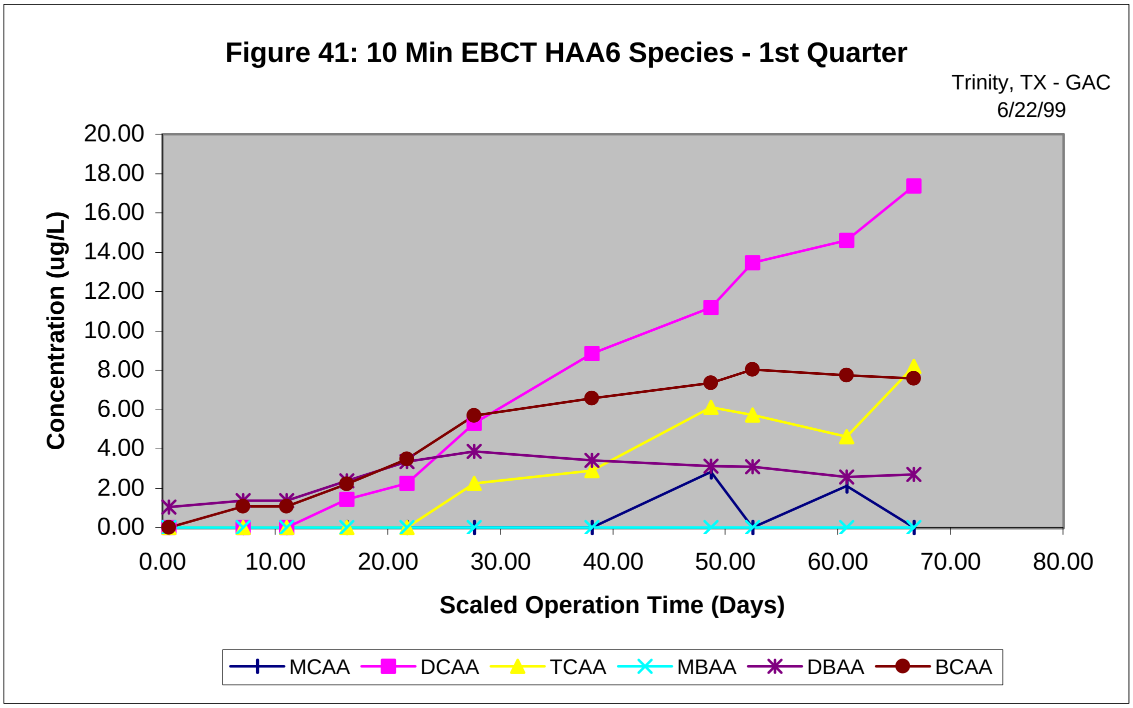


Figure 41: 10 Min EBCT HAA6 Species - 1st Quarter
Trinity, TX - GAC
6/22/99
Concentration (ug/L)
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
Scaled Operation Time (Days)
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

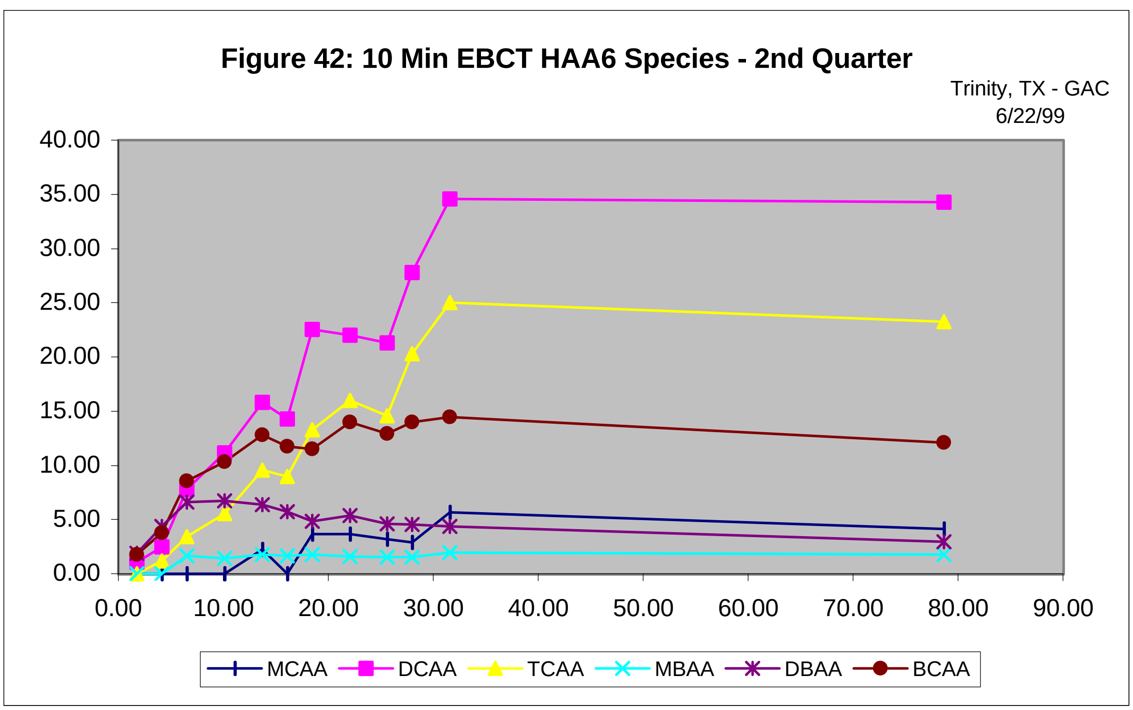


Figure 42: 10 Min EBCT HAA6 Species - 2nd Quarter
Trinity, TX - GAC
6/22/99
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

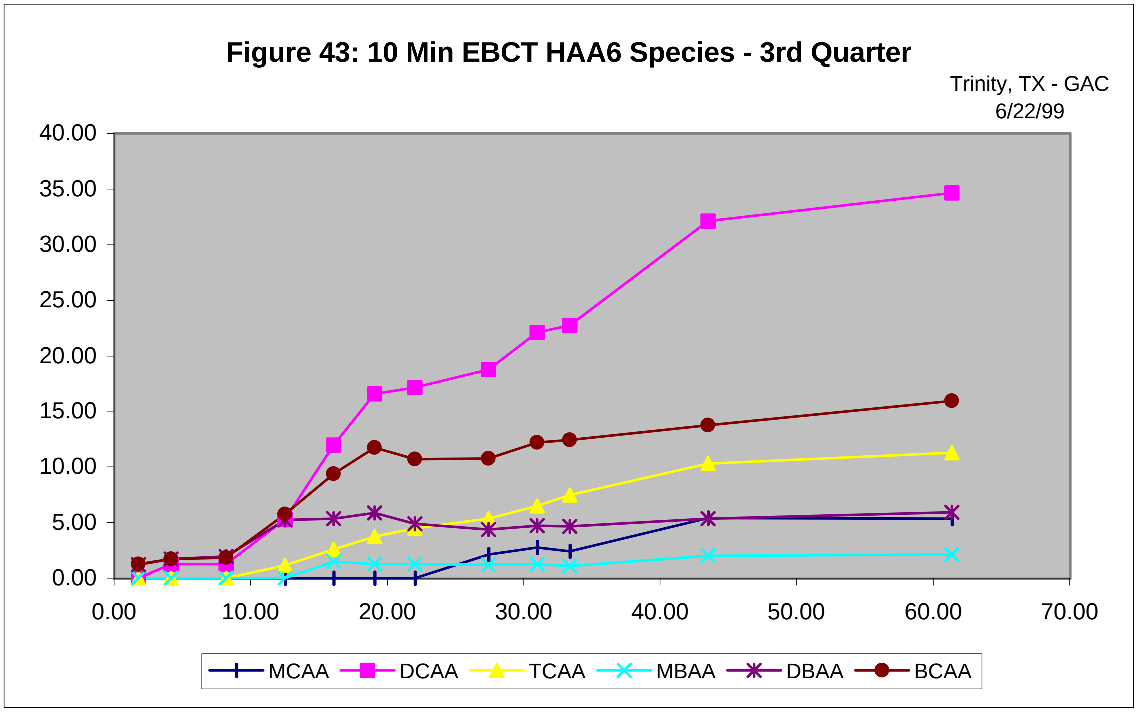


Figure 43: 10 Min EBCT HAA6 Species - 3rd Quarter
Trinity, TX - GAC
6/22/99
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

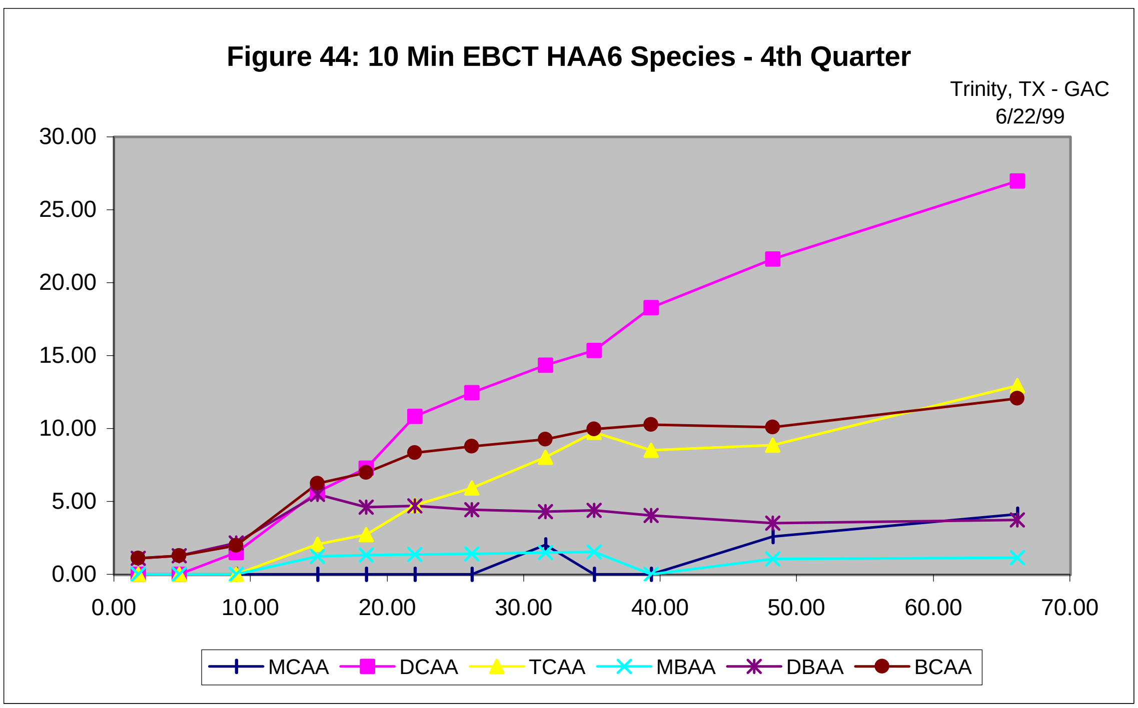


Figure 44: 10 Min EBCT HAA6 Species - 4th Quarter
Trinity, TX - GAC
6/22/99
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

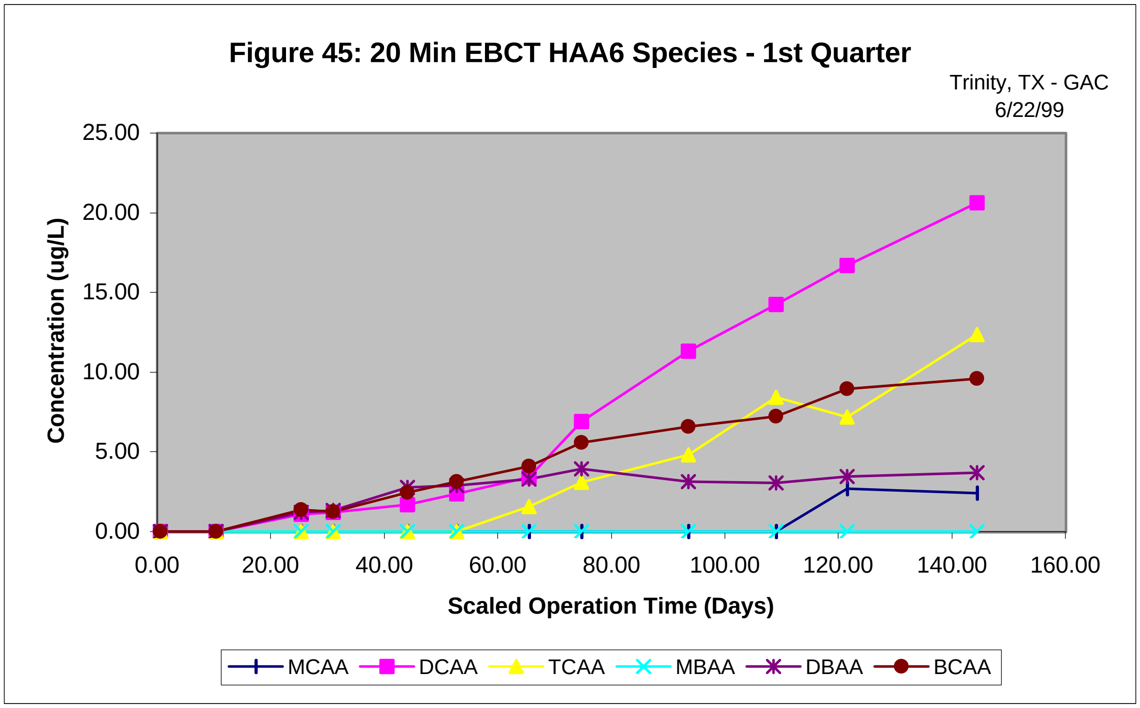


Figure 45: 20 Min EBCT HAA6 Species - 1st Quarter
Trinity, TX - GAC
6/22/99
Concentration (ug/L)
25.00
20.00
15.00
10.00
5.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Scaled Operation Time (Days)
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

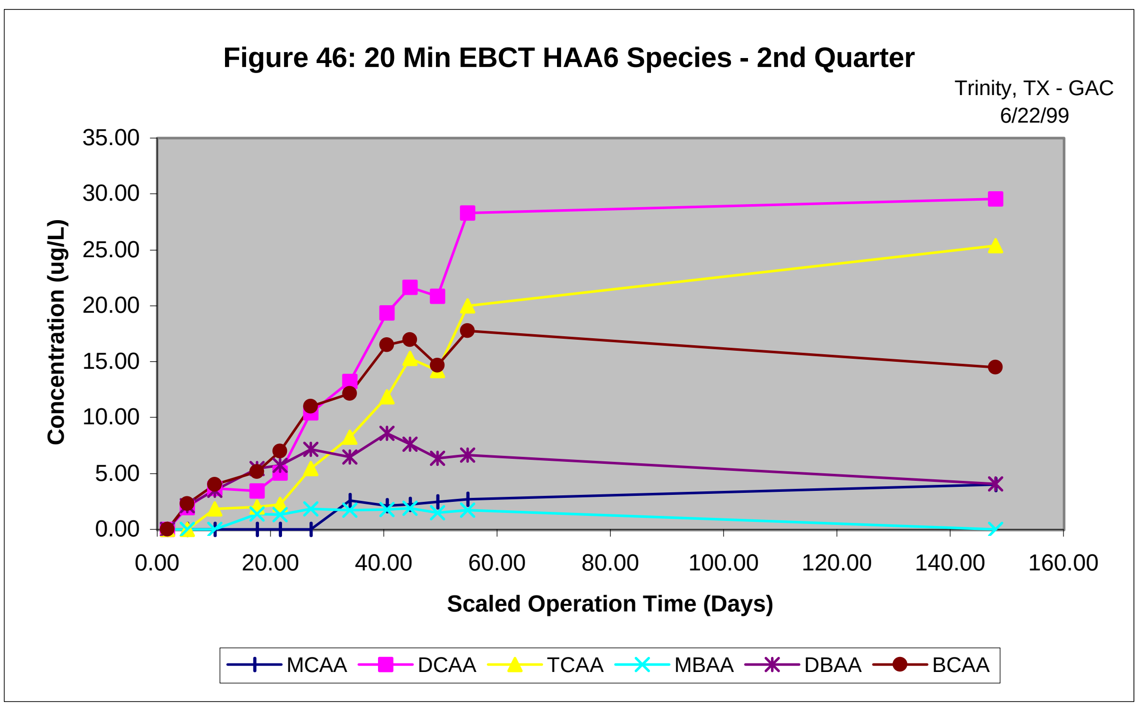


Figure 46: 20 Min EBCT HAA6 Species - 2nd Quarter
Trinity, TX - GAC
6/22/99
Concentration (ug/L)
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Scaled Operation Time (Days)
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

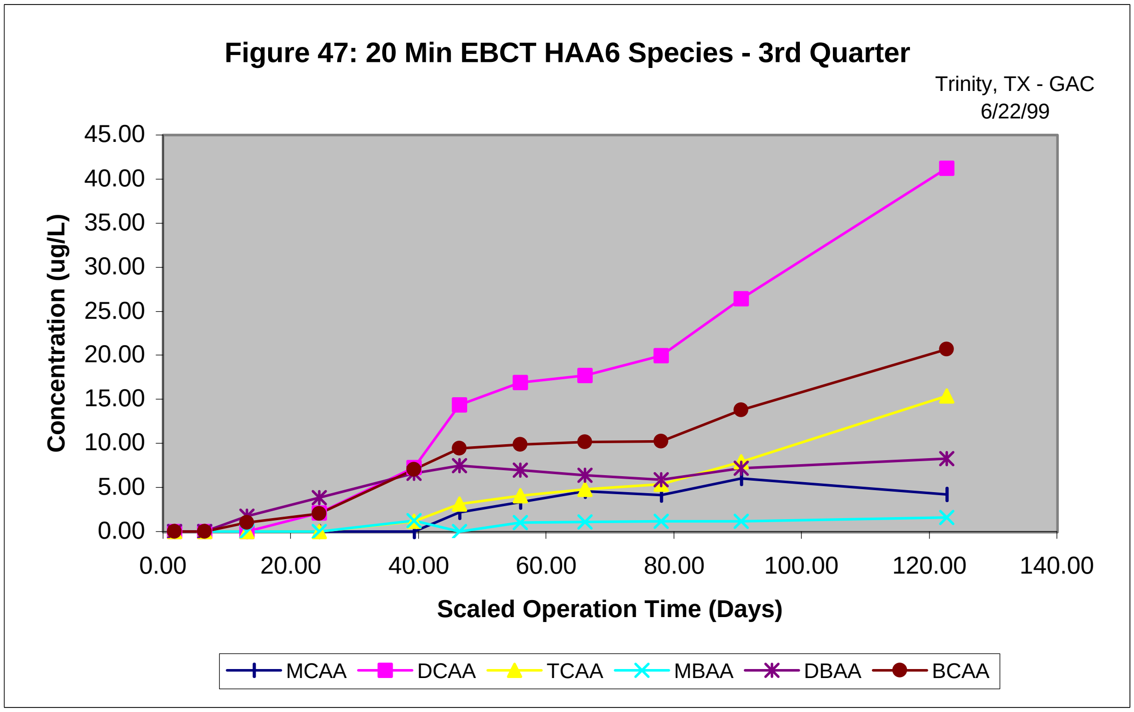


Figure 47: 20 Min EBCT HAA6 Species - 3rd Quarter
Trinity, TX - GAC
6/22/99
Concentration (ug/L)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
Scaled Operation Time (Days)
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

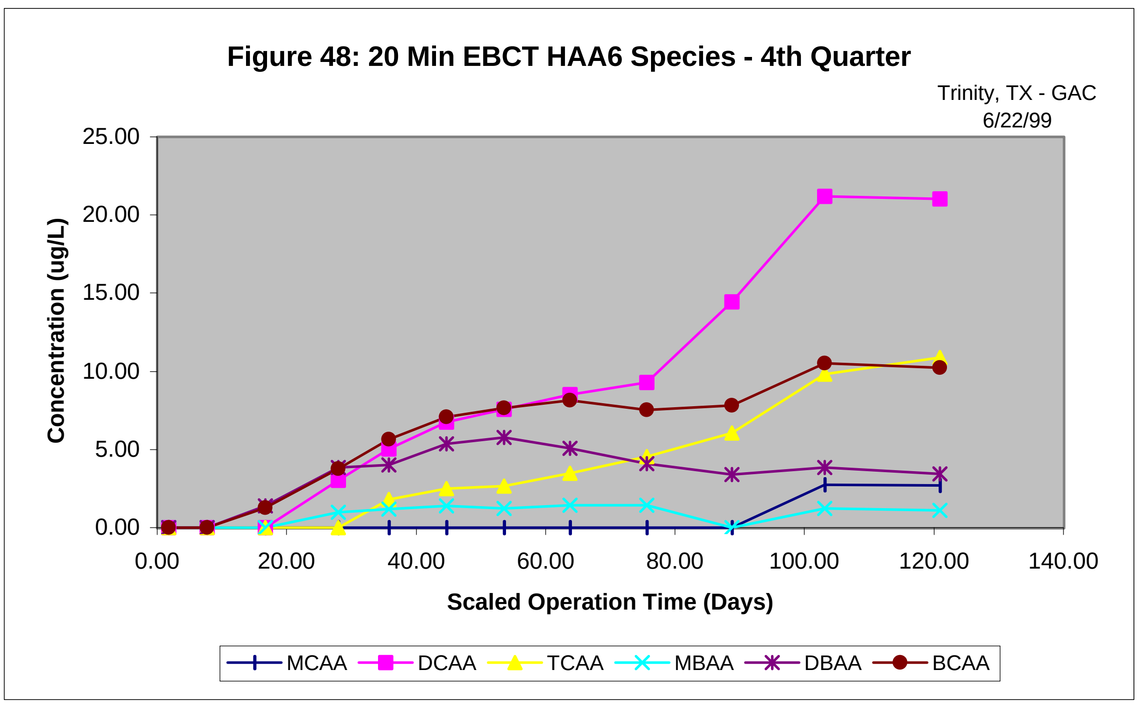


Figure 48: 20 Min EBCT HAA6 Species - 4th Quarter
Trinity, TX - GAC
6/22/99
Concentration (ug/L)
25.00
20.00
15.00
10.00
5.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
Scaled Operation Time (Days)
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

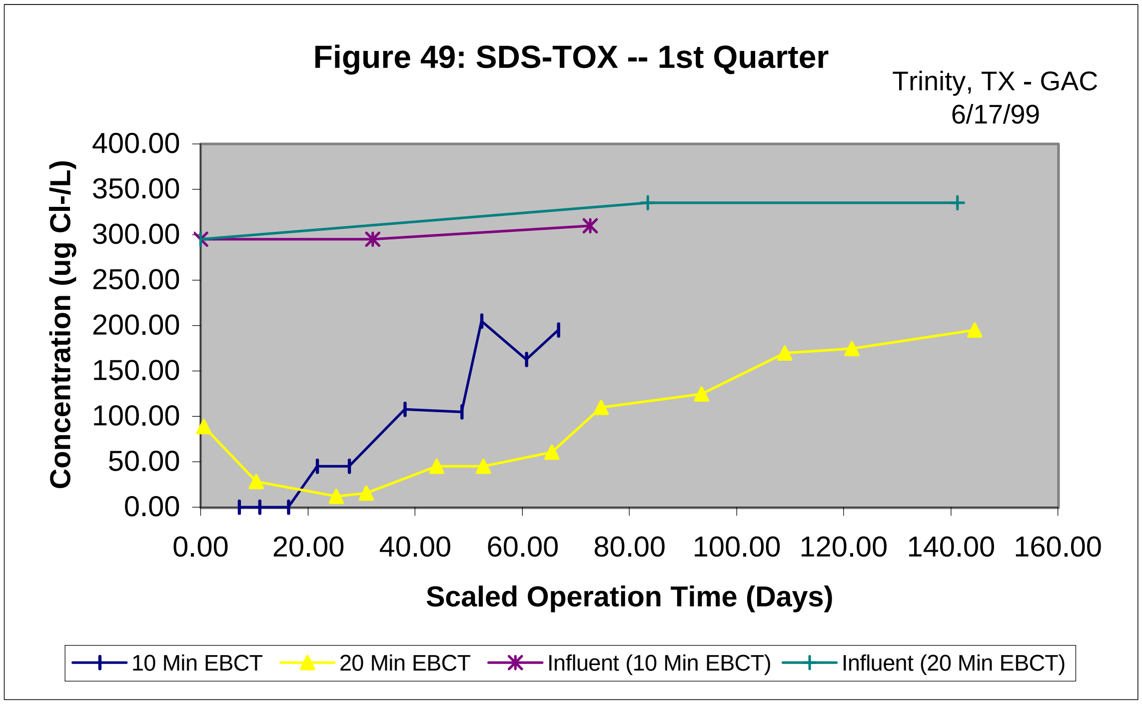


Figure 49: SDS-TOX -- 1st Quarter
Trinity, TX - GAC
6/17/99
Concentration (ug Cl-/L)
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Scaled Operation Time (Days)
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

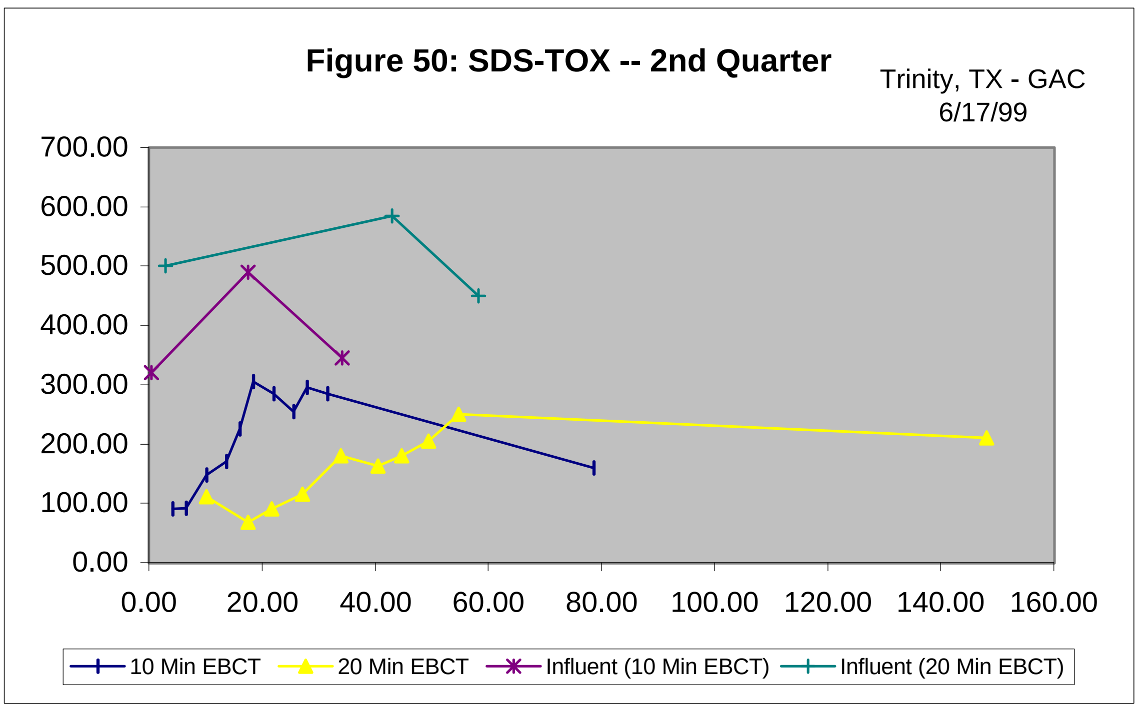


Figure 50: SDS-TOX -- 2nd Quarter
Trinity, TX - GAC
6/17/99
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

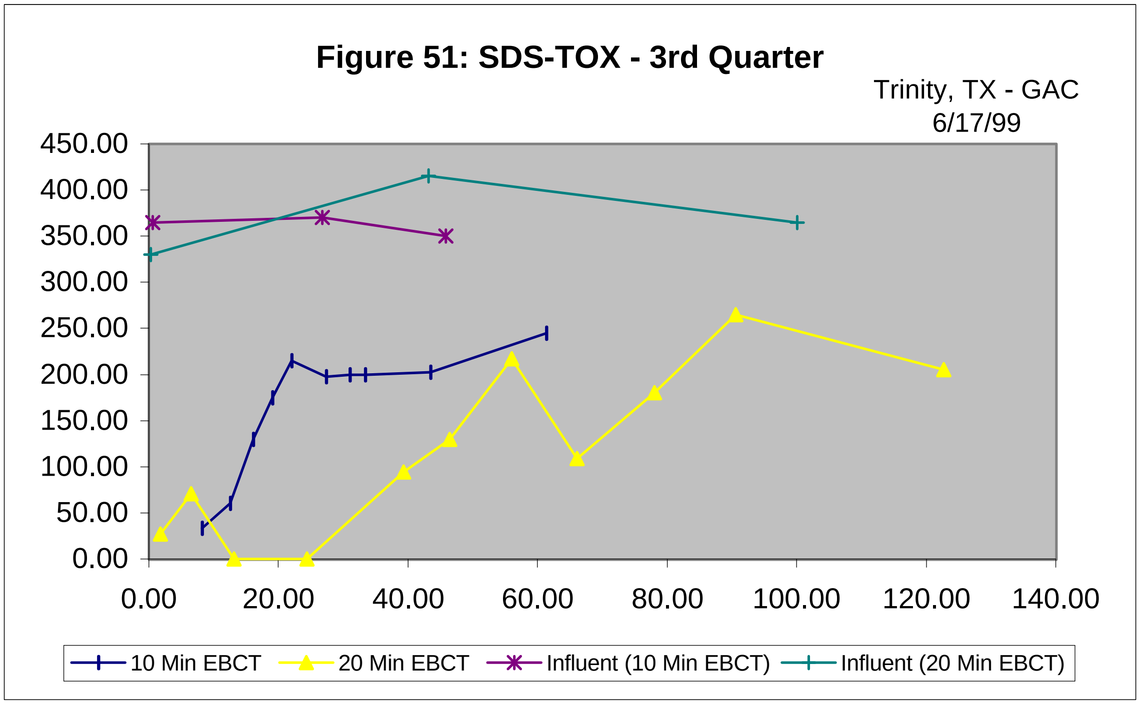


Figure 51: SDS-TOX - 3rd Quarter
Trinity, TX - GAC
6/17/99
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

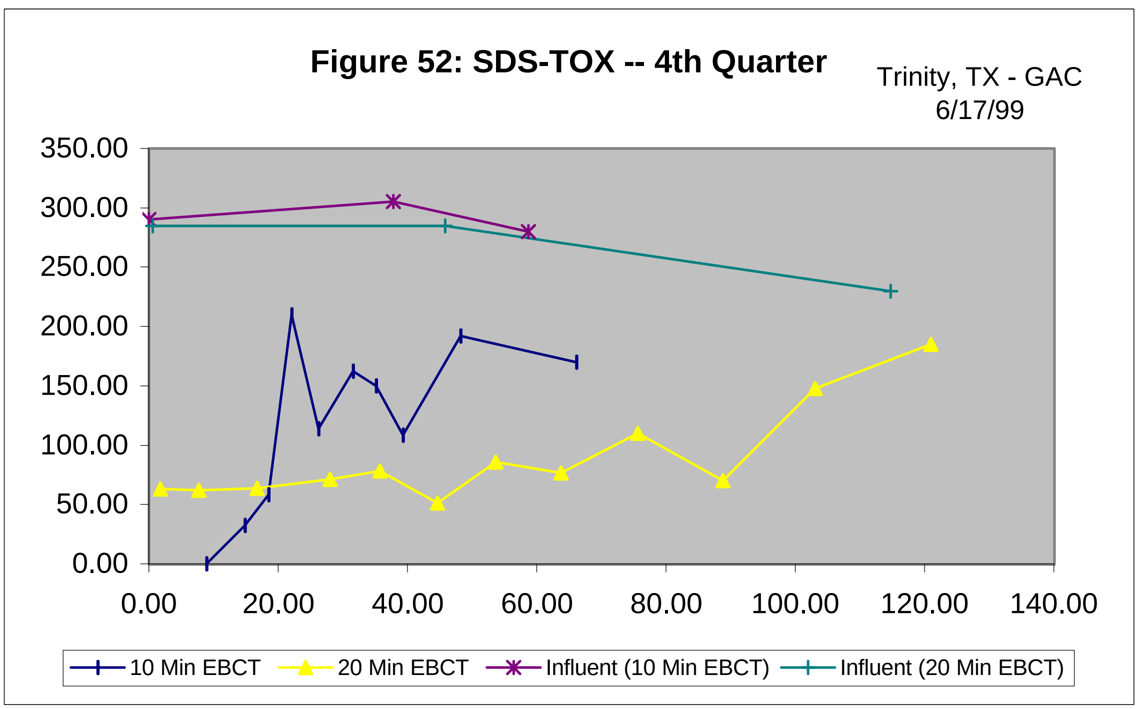


Figure 52: SDS-TOX -- 4th Quarter
Trinity, TX - GAC
6/17/99
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

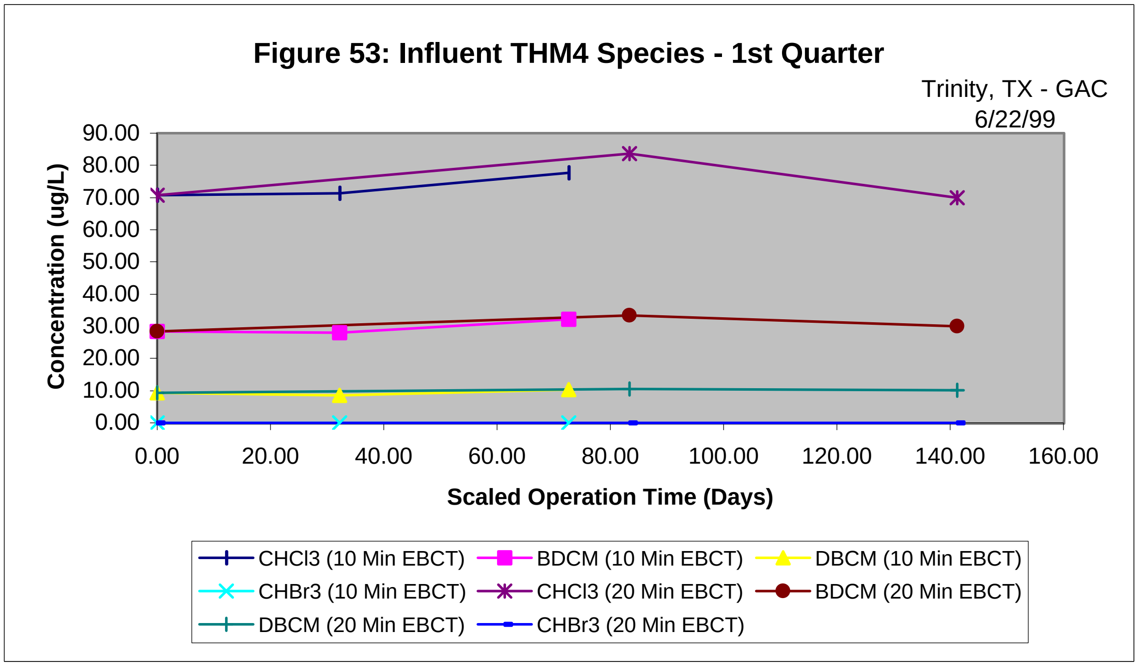


Figure 53: Influent THM4 Species - 1st Quarter
Trinity, TX - GAC
6/22/99
Concentration (ug/L)
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Scaled Operation Time (Days)
CHCl3 (10 Min EBCT)
BDCM (10 Min EBCT)
DBCM (10 Min EBCT)
CHBr3 (10 Min EBCT)
CHCl3 (20 Min EBCT)
BDCM (20 Min EBCT)
DBCM (20 Min EBCT)
CHBr3 (20 Min EBCT)

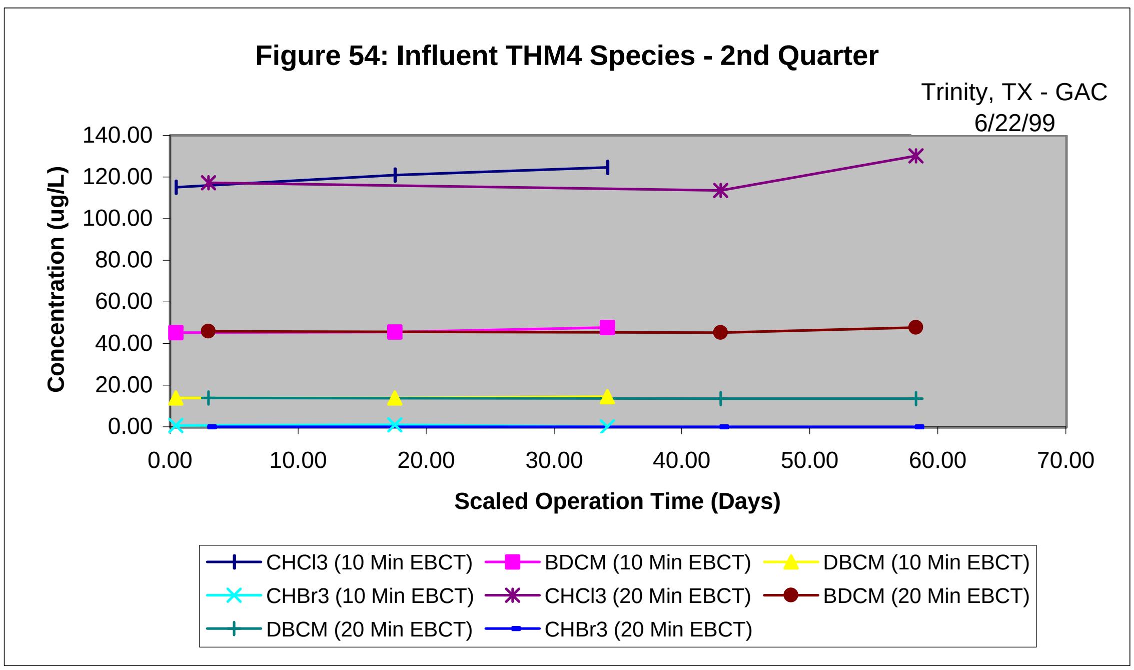


Figure 54: Influent THM4 Species - 2nd Quarter
Trinity, TX - GAC
6/22/99
Concentration (ug/L)
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
Scaled Operation Time (Days)
CHCl3 (10 Min EBCT)
BDCM (10 Min EBCT)
DBCM (10 Min EBCT)
CHBr3 (10 Min EBCT)
CHCl3 (20 Min EBCT)
BDCM (20 Min EBCT)
DBCM (20 Min EBCT)
CHBr3 (20 Min EBCT)

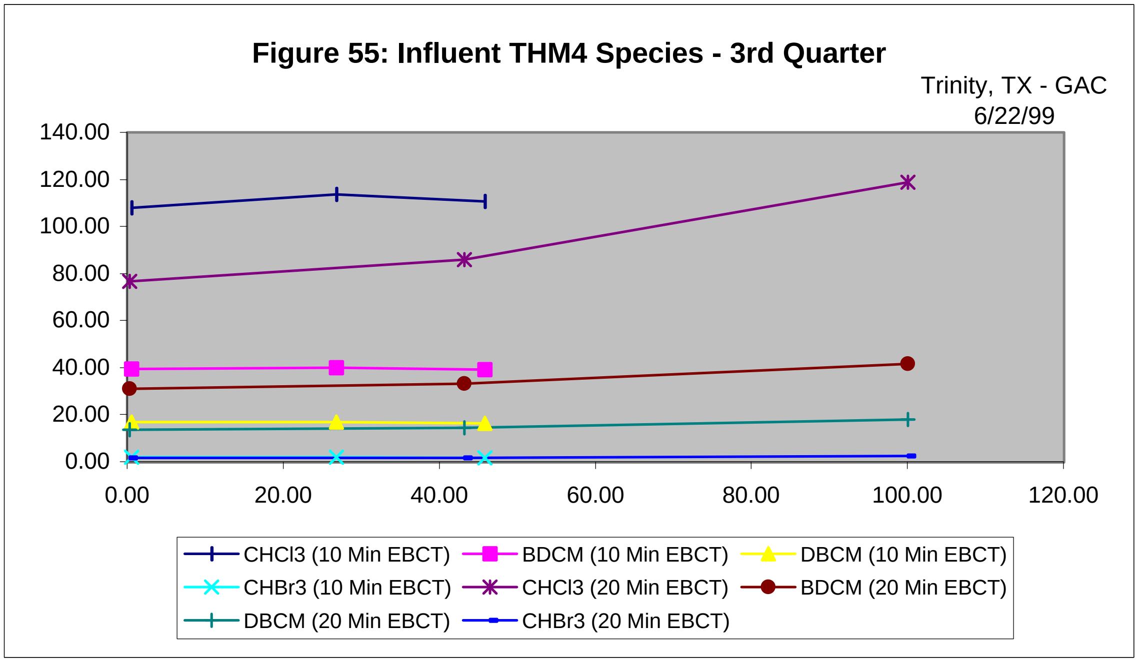


Figure 55: Influent THM4 Species - 3rd Quarter
Trinity, TX - GAC
6/22/99
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
CHCl3 (10 Min EBCT)
BDCM (10 Min EBCT)
DBCM (10 Min EBCT)
CHBr3 (10 Min EBCT)
CHCl3 (20 Min EBCT)
BDCM (20 Min EBCT)
DBCM (20 Min EBCT)
CHBr3 (20 Min EBCT)

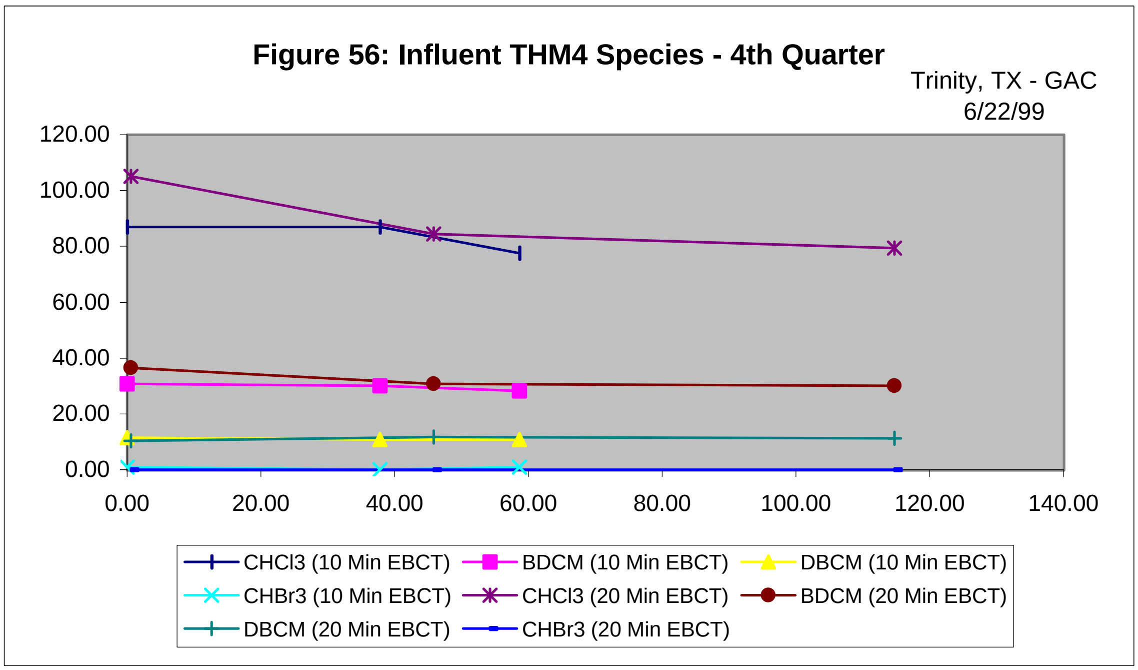


Figure 56: Influent THM4 Species - 4th Quarter
Trinity, TX - GAC
6/22/99
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
CHCl3 (10 Min EBCT)
BDCM (10 Min EBCT)
DBCM (10 Min EBCT)
CHBr3 (10 Min EBCT)
CHCl3 (20 Min EBCT)
BDCM (20 Min EBCT)
DBCM (20 Min EBCT)
CHBr3 (20 Min EBCT)

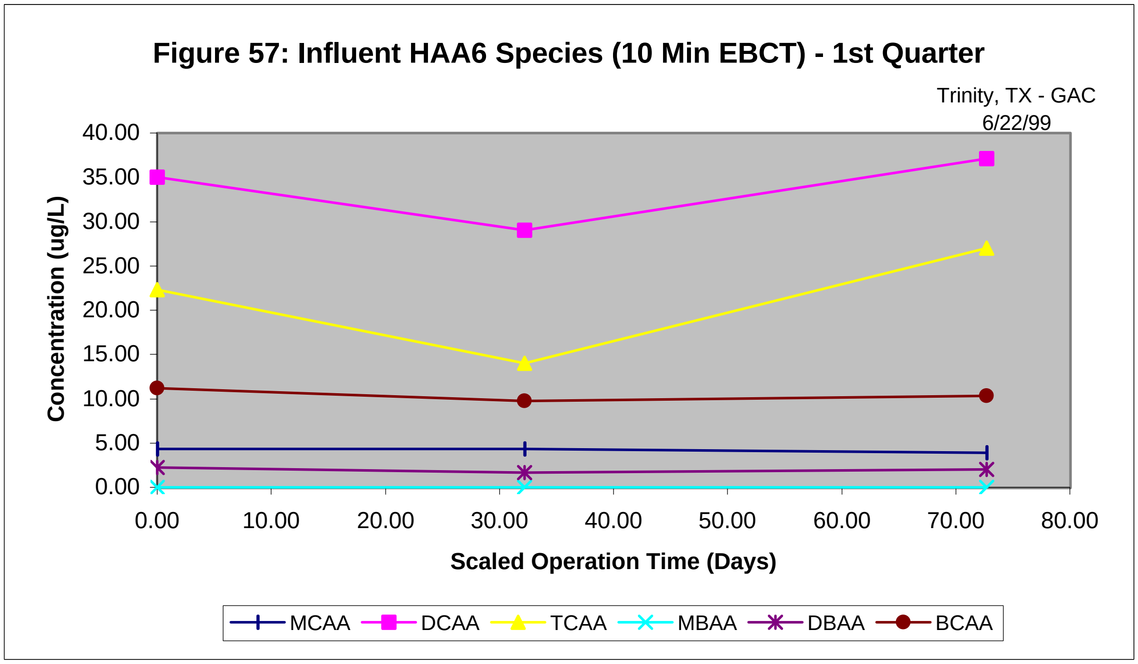


Figure 57: Influent HAA6 Species (10 Min EBCT) - 1st Quarter
Trinity, TX - GAC
6/22/99
Concentration (ug/L)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
Scaled Operation Time (Days)
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

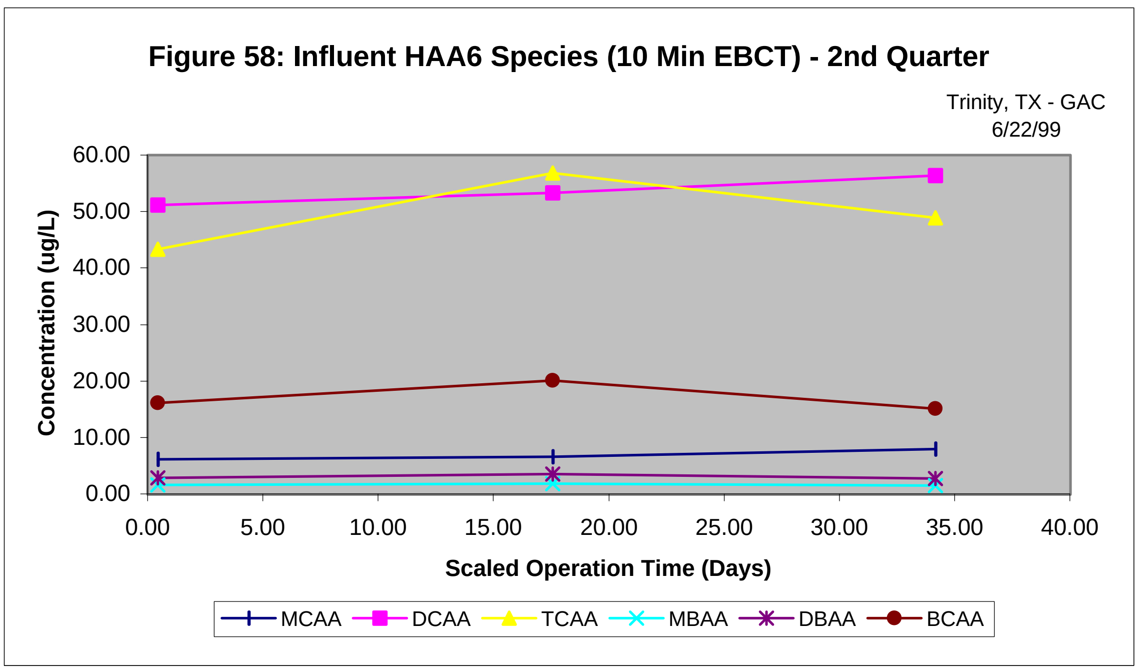


Figure 58: Influent HAA6 Species (10 Min EBCT) - 2nd Quarter
Trinity, TX - GAC
6/22/99
Concentration (ug/L)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
Scaled Operation Time (Days)
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

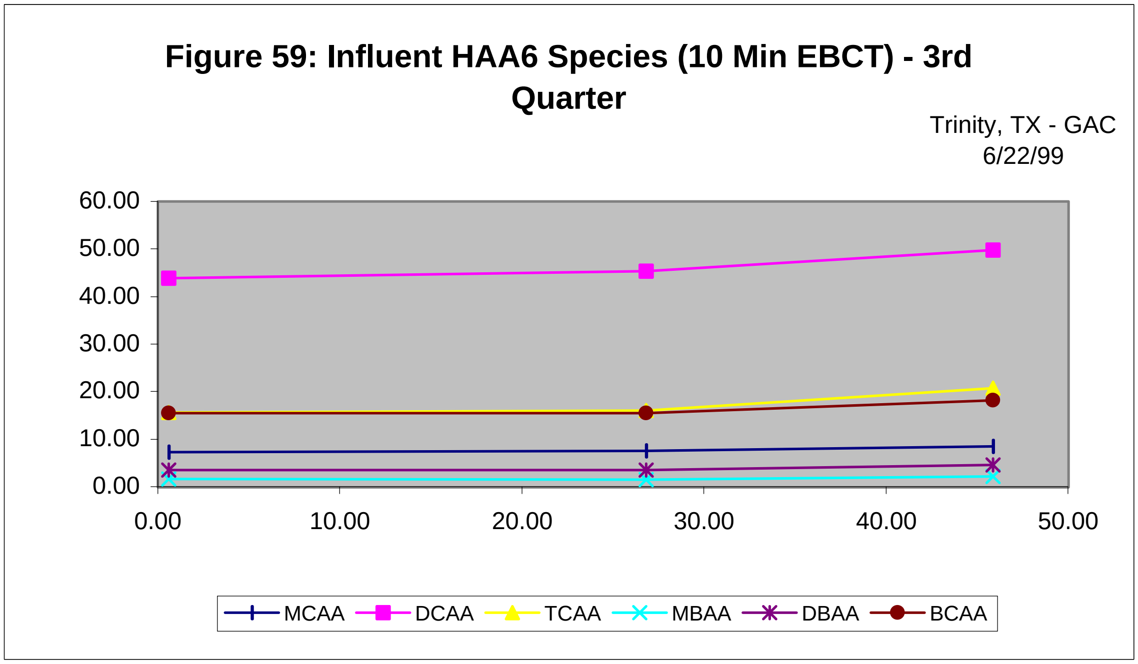


Figure 59: Influent HAA6 Species (10 Min EBCT) - 3rd Quarter
Trinity, TX - GAC
6/22/99
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

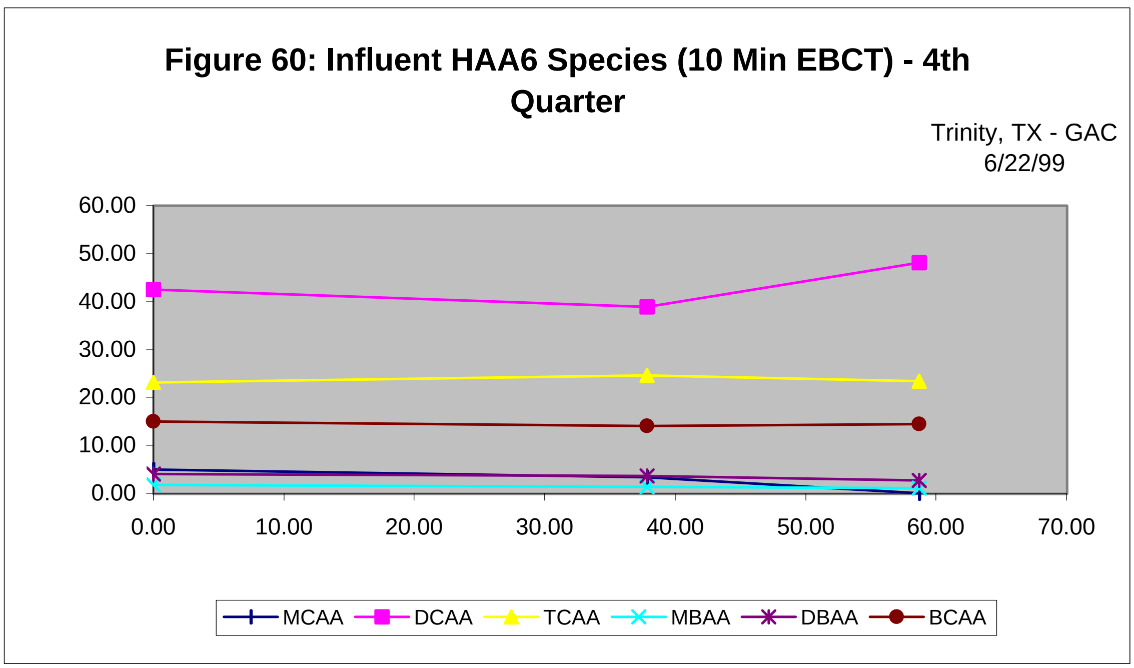


Figure 60: Influent HAA6 Species (10 Min EBCT) - 4th Quarter
Trinity, TX - GAC
6/22/99
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

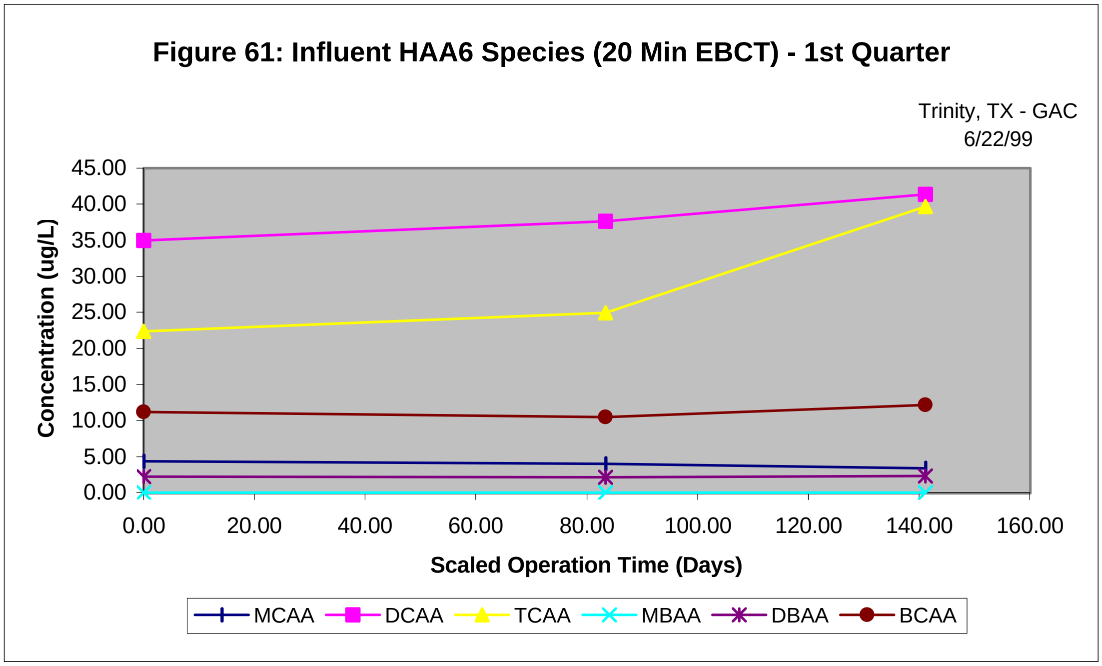


Figure 61: Influent HAA6 Species (20 Min EBCT) - 1st Quarter
Trinity, TX - GAC
6/22/99
Concentration (ug/L)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Scaled Operation Time (Days)
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

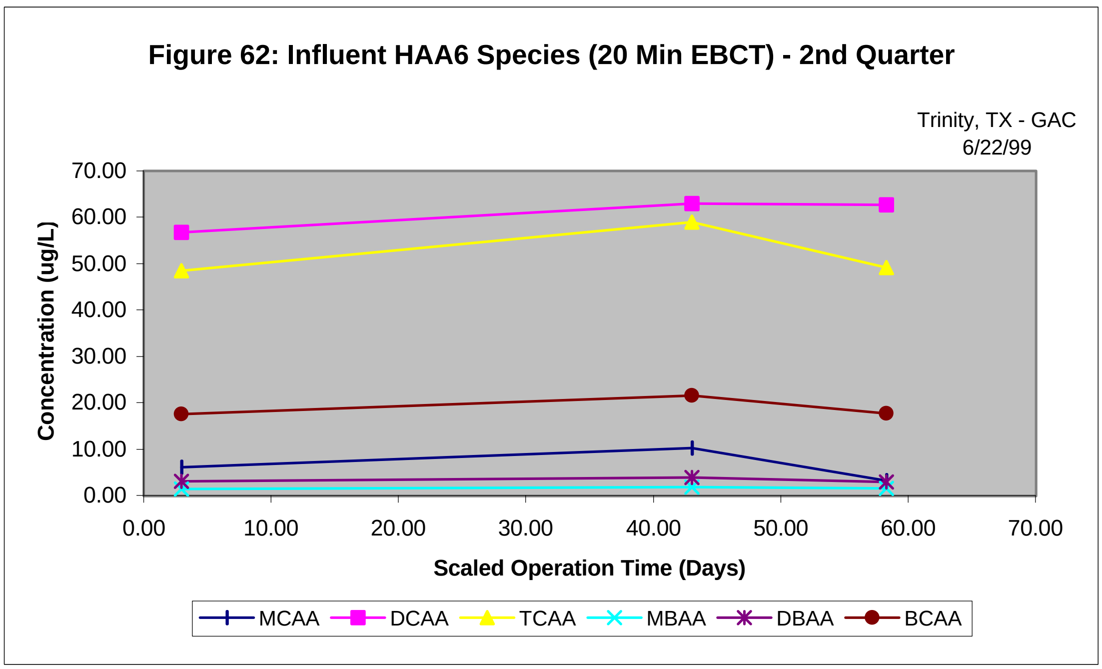


Figure 62: Influent HAA6 Species (20 Min EBCT) - 2nd Quarter
Trinity, TX - GAC
6/22/99
Concentration (ug/L)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
Scaled Operation Time (Days)
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

Figure 63: Influent HAA6 Species (20 Min EBCT) - 3rd Quarter

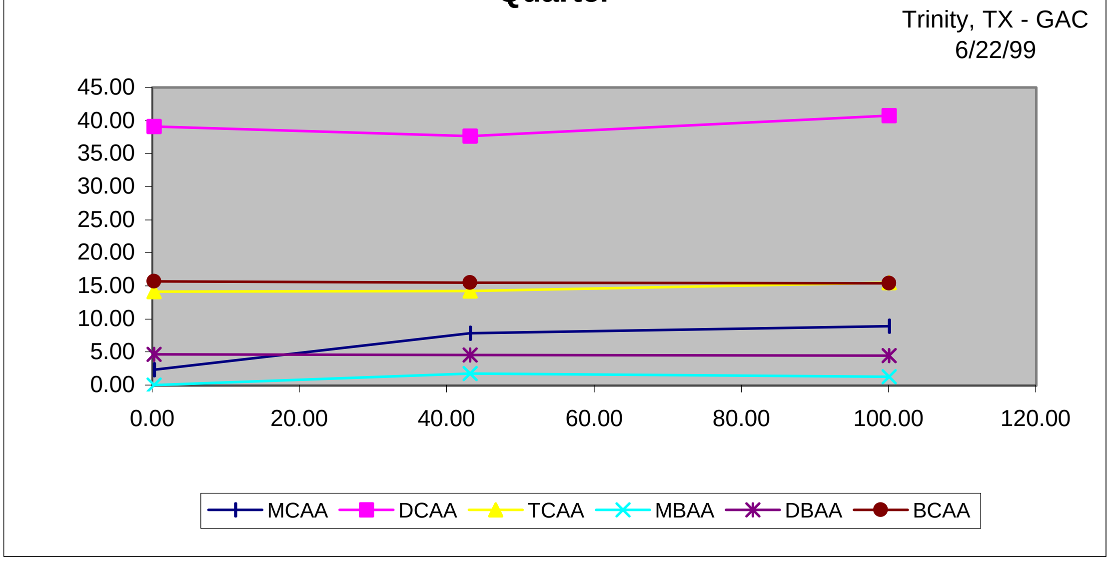
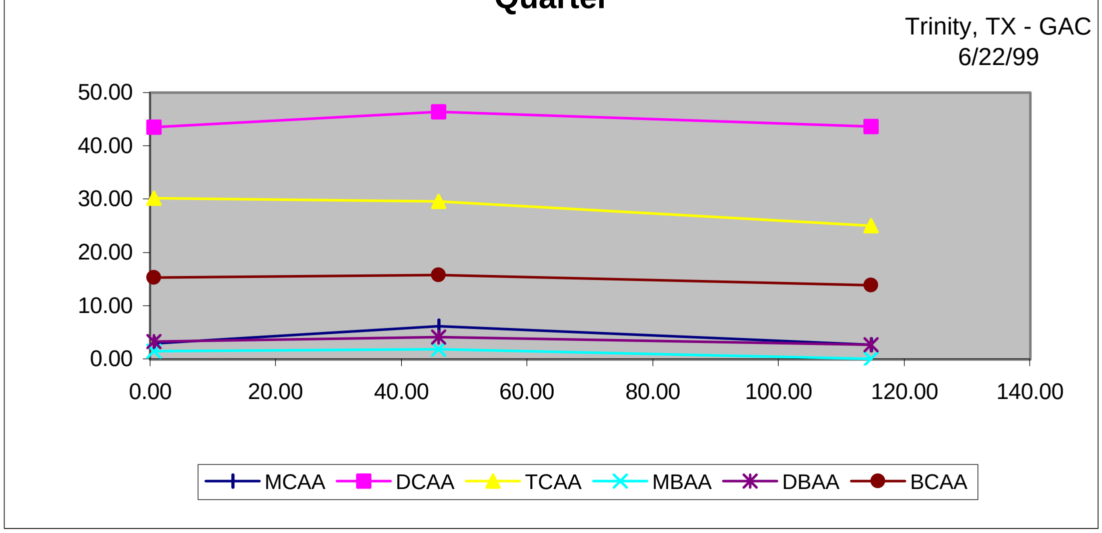


Figure 64: Influent HAA6 Species (20 Min EBCT) - 4th Quarter



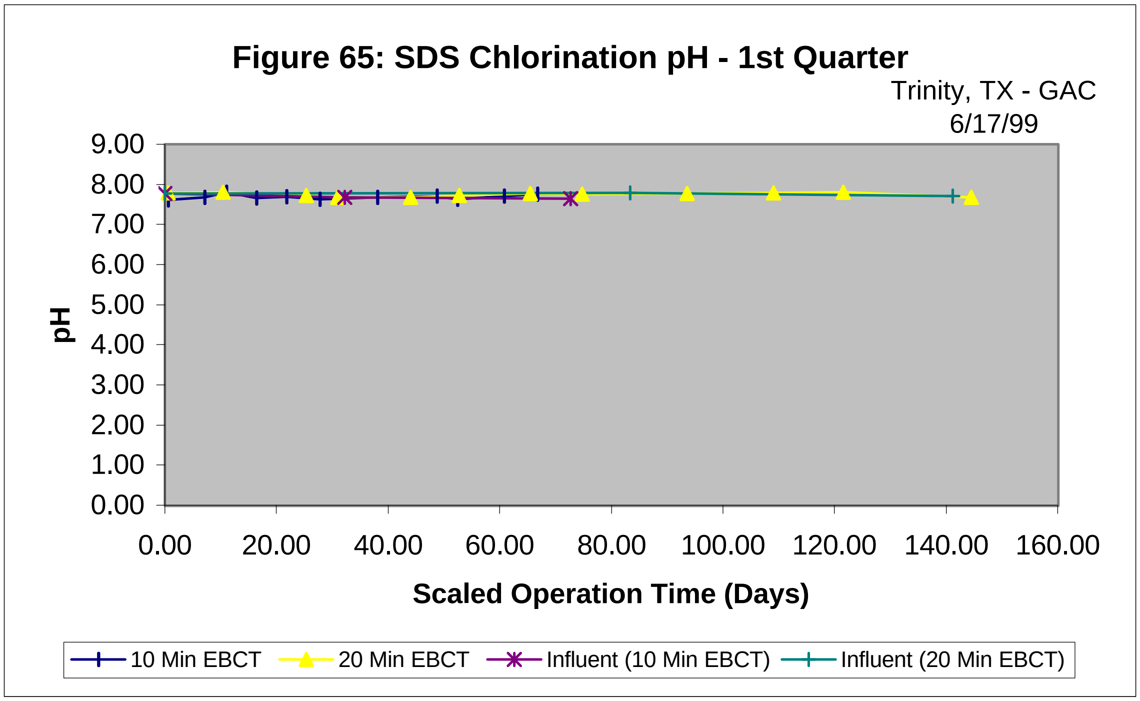


Figure 65: SDS Chlorination pH - 1st Quarter
Trinity, TX - GAC
6/17/99
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
pH
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Scaled Operation Time (Days)
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

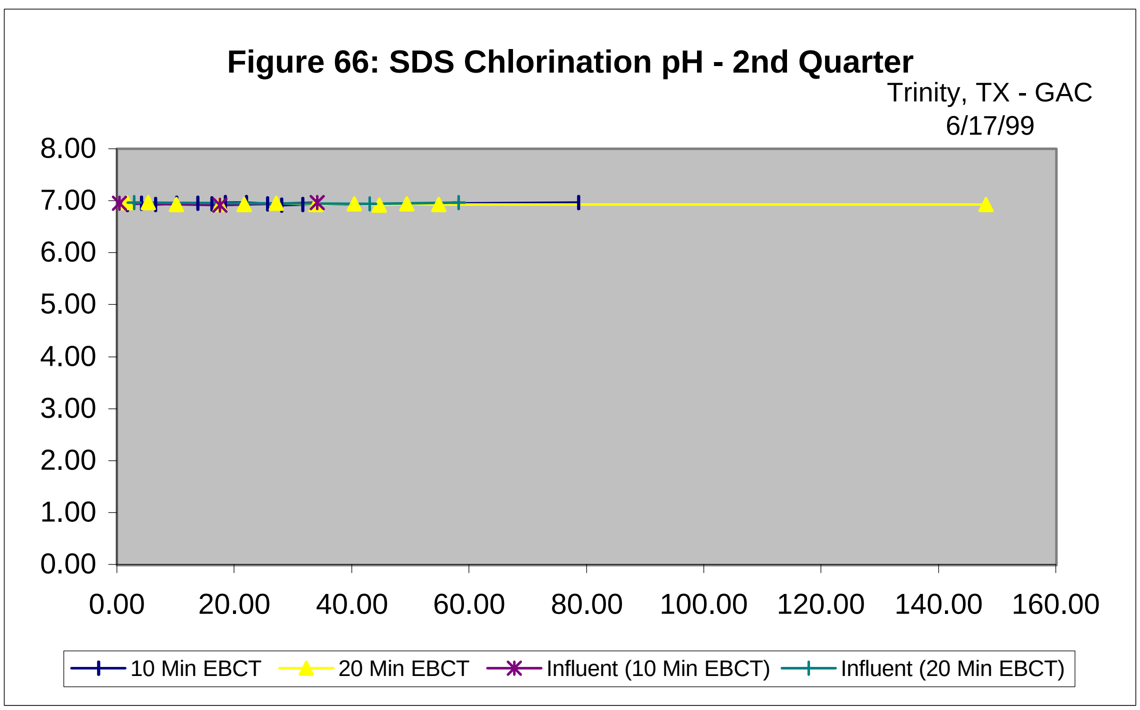


Figure 66: SDS Chlorination pH - 2nd Quarter
Trinity, TX - GAC
6/17/99
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

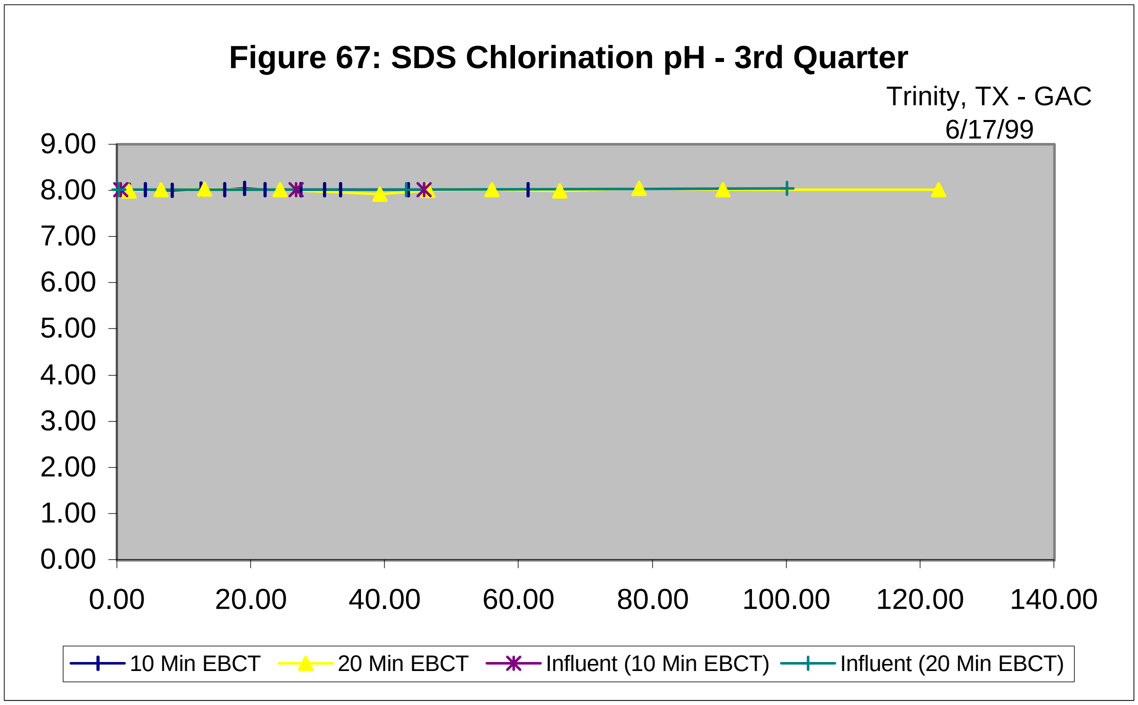


Figure 67: SDS Chlorination pH - 3rd Quarter
Trinity, TX - GAC
6/17/99
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

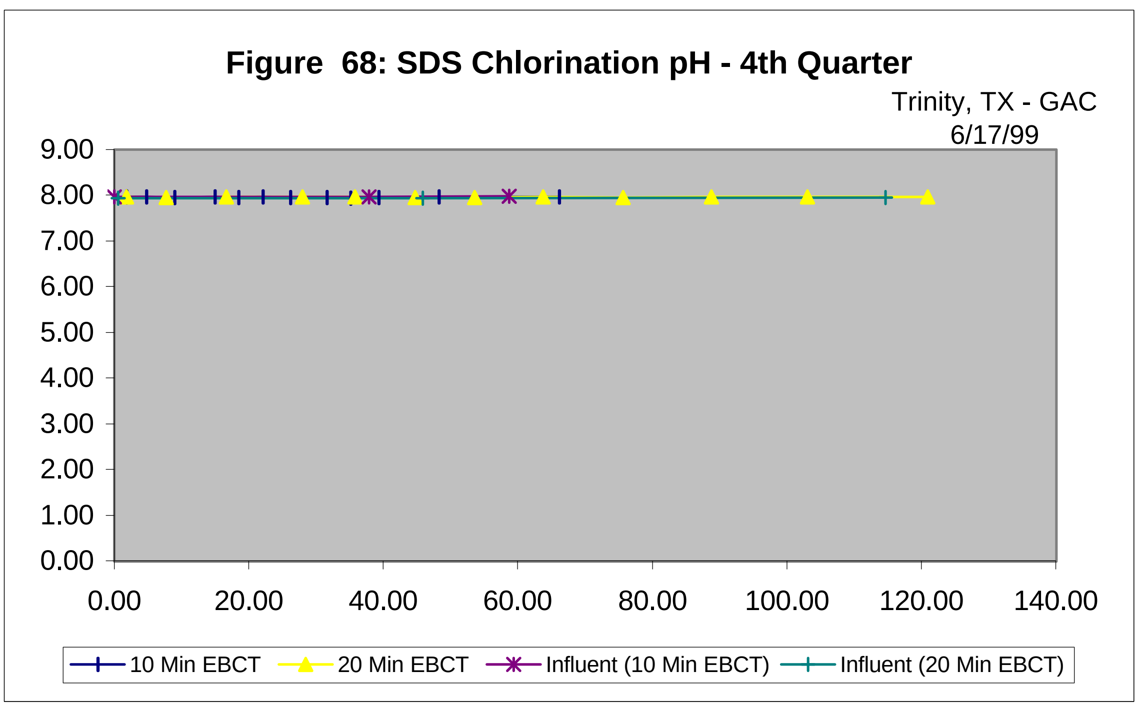


Figure 68: SDS Chlorination pH - 4th Quarter
Trinity, TX - GAC
6/17/99
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

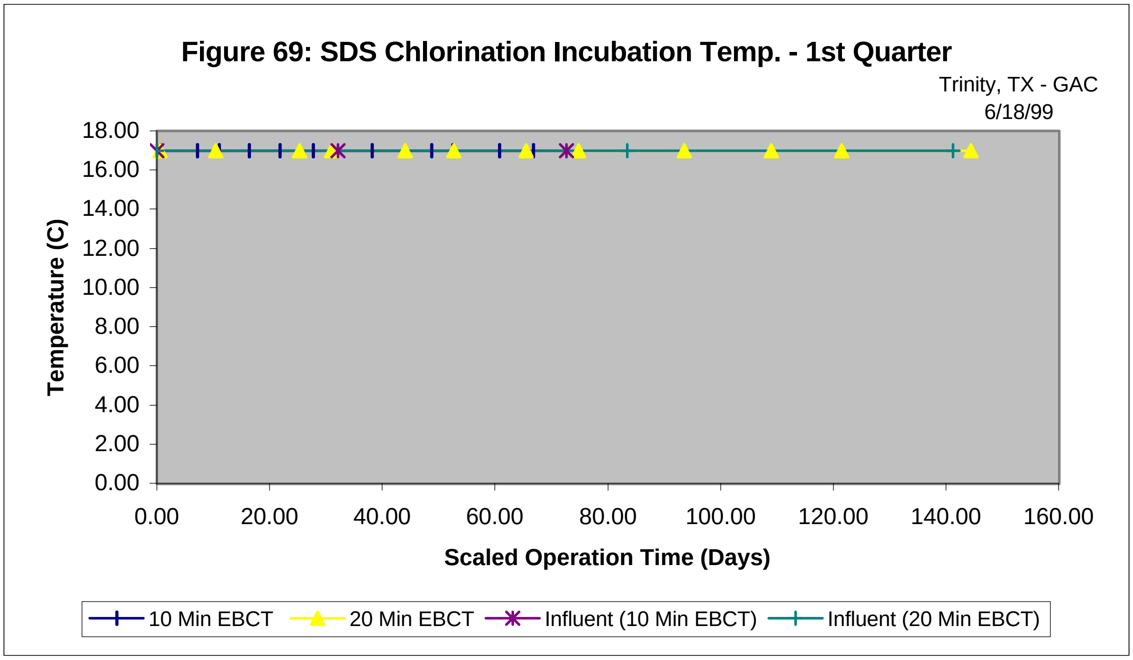


Figure 69: SDS Chlorination Incubation Temp. - 1st Quarter
Trinity, TX - GAC
6/18/99
Temperature (C)
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Scaled Operation Time (Days)
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

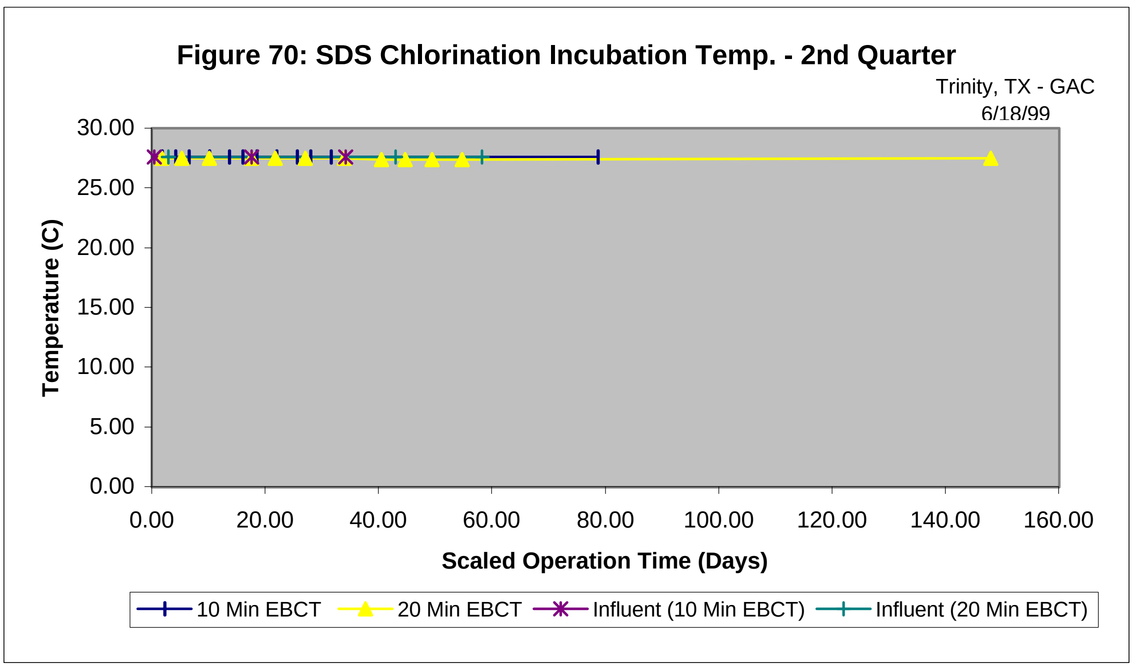


Figure 70: SDS Chlorination Incubation Temp. - 2nd Quarter
Trinity, TX - GAC
6/18/99
Temperature (C)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Scaled Operation Time (Days)
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

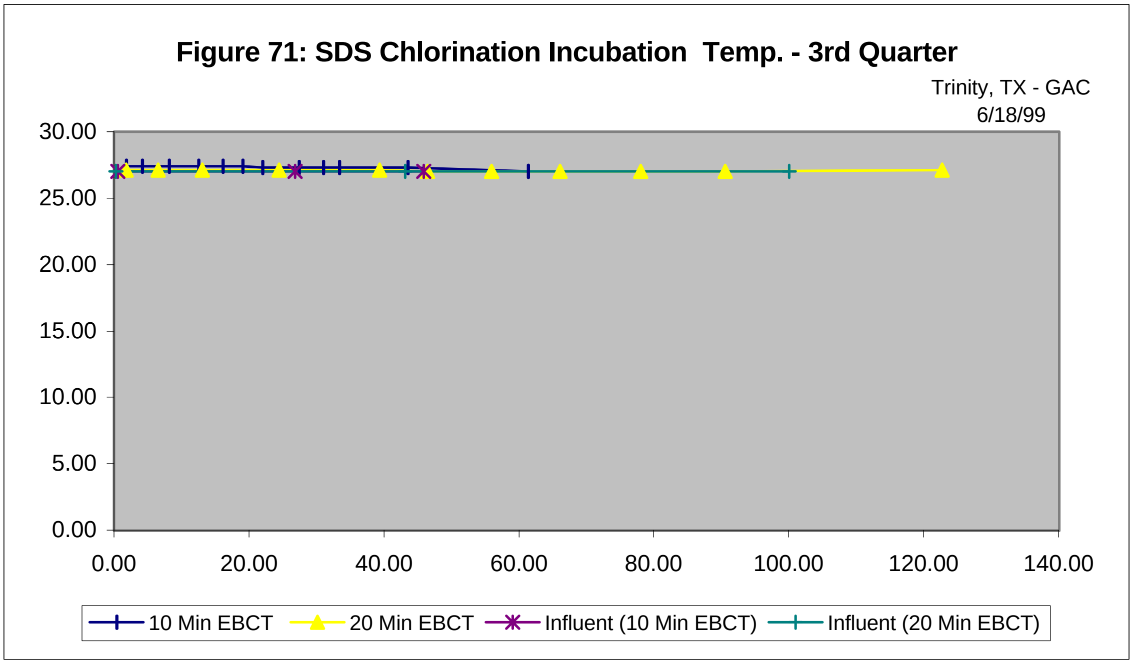


Figure 71: SDS Chlorination Incubation Temp. - 3rd Quarter
Trinity, TX - GAC
6/18/99
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)

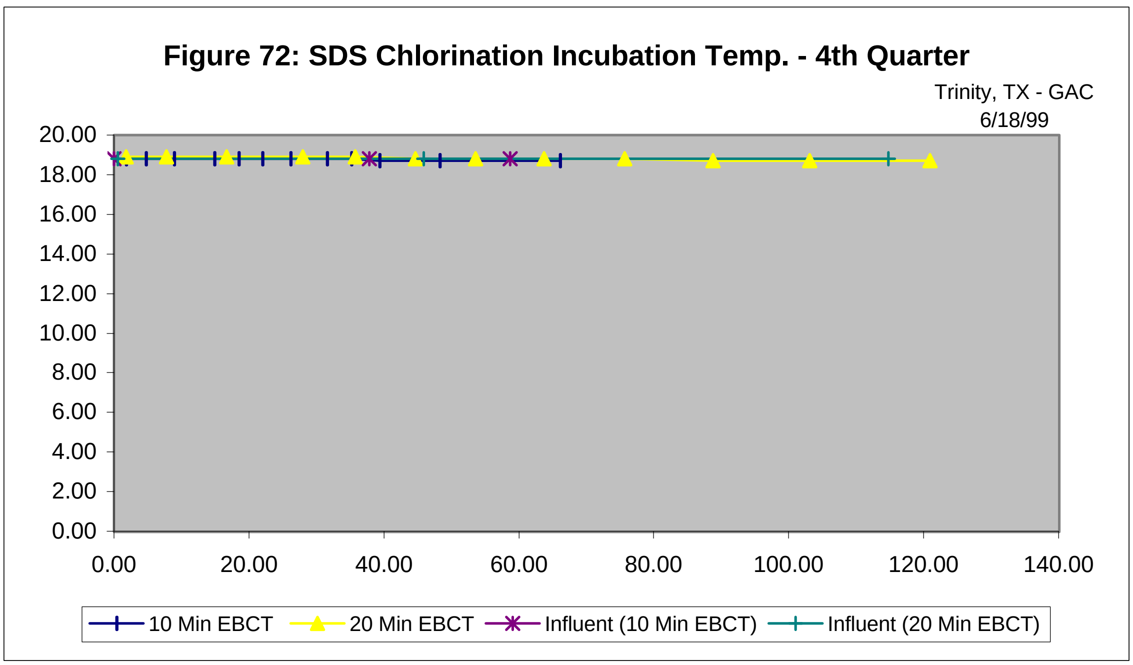


Figure 72: SDS Chlorination Incubation Temp. - 4th Quarter
Trinity, TX - GAC
6/18/99
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
10 Min EBCT
20 Min EBCT
Influent (10 Min EBCT)
Influent (20 Min EBCT)