ICR Treatment Study Summary Report

Evaluation of Rapid Small Scale Column Testing for Compliance with the Information Collection Rule

Conducted during the period of April 16, 1998 through July 14, 1999

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July 1999

Prepared for:

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Hinckley Reservoir Water Treatment Plant ICR #492

July 7, 1999

Ms. Connie Schreppel
Upper Mohawk Valley Regional Water Board
One Kennedy Plaza
Box 345
Utica, NY 13503

Dear Connie:

Please find enclosed one copy of the draft final report for the ICR RSSCT Treatability Study. The draft report includes printed copies of the summary report, data collection spreadsheets, and laboratory QA/QC summary report. This package contains all of the information required for submission to the EPA. Please review the report and provide comments as soon as possible so that we can edit the report and submit the final version to EPA by July 14, 1999.

Please contact us if there are any questions.

Sincerely,

ENVIRONMENTAL ENGINEERING & TECHNOLOGY, INC.

Michael J. MacPhee, Ph.D.
Process Manager

/wmm

Enclosure

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INTRODUCTION

The Upper Mohawk Valley Regional Water Board (UMVRWB) currently operates the Hinckley Reservoir WTP, a 32-mgd water treatment facility in Prospect, New York. The facility treats raw water from a surface water reservoir for use primarily as a municipal drinking water supply. The UMVRWB was required by the EPA to conduct a bench-scale granular activated carbon (GAC) rapid small scale column test (RSSCT) or a rapid bench-scale membrane test (RBSMT) as directed by the Information Collection Rule (ICR) published in the May 14, 1996 Federal Register. The UMVRWB selected an RSSCT study to satisfy this ICR treatability requirement. The treatment study guidelines are included in EPA's "ICR Manual for Bench- and Pilot-Scale Treatment Studies" (EPA 1996), and the EPA's "ICR Treatment Studies Data Collection Spreadsheets Users Guide" (EPA 1997).

The ICR is a regulatory agreement that is used to determine a course of action for controlling microbial contaminants and disinfection byproducts (DBPs). ICR treatment studies (i.e., the RSSCT) are used to obtain information on the potential options and costs for meeting the Stage I and proposed Stage II regulatory requirements. The UMVRWB was required to perform a year-long DBP precursor removal treatment study using GAC filtration because its historical average distribution system DBPs exceeded 40 μg/L for THMs and its historical annual average raw water TOC concentration exceeded 4.0 mg/L.

BACKGROUND INFORMATION

Treatment Plant Description

The Hinckley WTP uses conventional treatment for purification of drinking water, which includes in-line static mixing for chemical dispersion, contact basins for chemical mixing, adsorption clarification, and filtration. A process schematic of the Hinckley WTP is included in Figure 1. The process schematic shows the different plant treatment processes, locations used for chemical feed injection, and the sampling locations where the RSSCT influent water was collected. The Hinckley

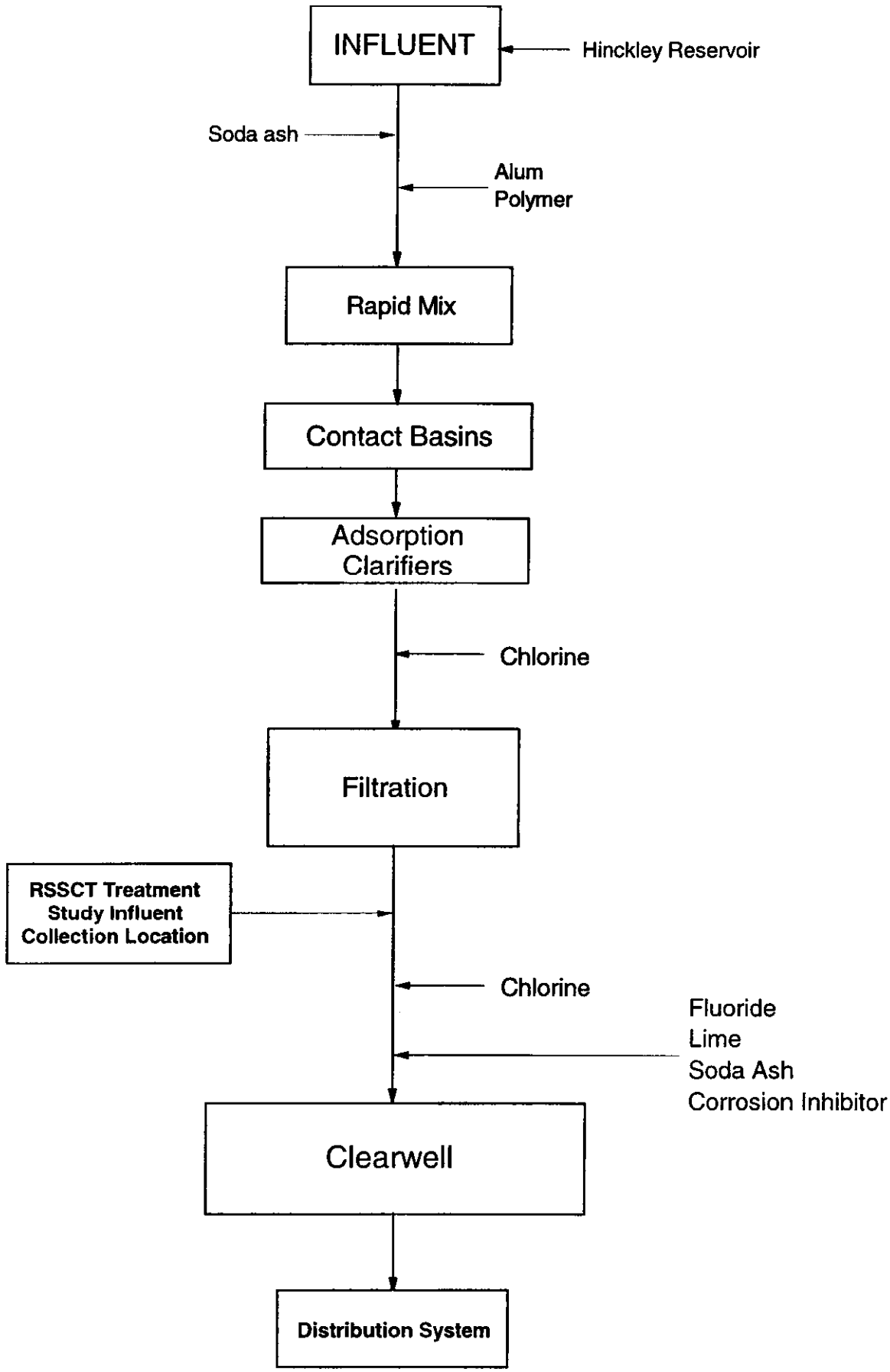

Figure 1 Hinckley WTP process schematic

plant currently uses aluminum sulfate (alum) as the primary coagulant along with a coagulant aid polymer. Chlorine is fed pre- and post-filtration for primary disinfection and distribution system residual maintenance. Other treatment chemicals used are soda ash for raw water pH adjustment, lime or soda ash for corrosion control, fluoride, and a corrosion inhibitor.

Design information for each of Hinckley WTP's unit processes is included in Table 1. The table summarizes each of the plant processes by summarizing mechanical descriptions, basin volumes, media specifications, chemical feed information, etc.

Table 1

Design information

Unit process	Process description	
Rapid mix	Type of mixer Baffling type Liquid volume (gal) Mean velocity gradient (sec^{-1}) Coagulant addition Coagulant dose	In-line static mix Unbaffled 1,127 2.0 Alum 20
Contact basin	Surface area (ft^2) Liquid volume (gal) Detention time (min)	15,000 1,122,000 50 at 32 mgd
Adsorption clarifier	Brand Name Surface area (ft^2) Liquid volume (gal)	Microfloc 2,496 233,376
Disinfection	Disinfection chemical Dose rate (mg/L)	Chlorine 0.10
Filtration	Surface area (ft^2) Liquid volume (gal) Total media depth (in.) Media type Minimum water depth to top of media (ft) Depth from top media of top of backwash trough (ft)	4,992 485,486 30 Anthracite and sand 10.0 6.7
Disinfection	Disinfection chemical Dose rate (mg/L)	Chlorine 1.50
Clearwell	Surface area (ft^2) Liquid volume (gal) Minimum liquid volume (gal) Baffling type	17,987 1,480,000 600,000 None

Unit process	Process description	
	Covered contactor Corrosion control chemical Corrosion chemical dose (mg/L)	Yes Lime or soda ash 10 mg/L (lime) 30 mg/L (soda ash)

Historical Water Quality

Raw Water

The UMVRWB raw water supply source is Hinckley Reservoir. The raw water turbidity is very low averaging approximately 0.9 ntu with a maximum of 1.5 ntu. A summary of the historical raw water quality is provided in Table 2.

Table 2

Summary of raw water quality

Water quality parameter	Average yearly value*	Minimum yearly value*	Maximum yearly value*
Temperature (ºC)	7.0	1.0	20.0
pH	6.6	5.6	7.6
Turbidity (ntu)	0.9	0.6	1.5
Alkalinity (mg/L as $CaCO_3$)	11.0	2.0	20.0
Calcium hardness (mg/L as $CaCO_3$)	15.0	5.0	25.0
Total hardness (mg/L as $CaCO_3$)	18.0	15.0	30.0
TOC (mg/L)	4.14	3.10	6.20
UV_{254} (cm^{-1})	0.150	0.119	0.190
Bromide (µg/L)	0.02	---	---

*Historical data from 1998.

The 1998 historical yearly average total organic carbon (TOC) concentration is approximately 4.14 mg/L, with TOC spikes up to 6.20 mg/L. The raw water alkalinity is also very low. The average alkalinity is 11.0 mg/L as $CaCO_3$ and ranges between 2 and 20 mg/L as $CaCO_3$.

The pH of the raw water ranges between 5.6 and 7.6. The total hardness of the raw water range between 15 and 30 mg/L as $CaCO_3$.

Finished Water

A summary of the UMVRWB finished water quality is provided in Table 3. The finished water turbidity ranges between 0.01 and 0.10 ntu with an average of approximately 0.05 ntu. The finished water TOC concentration 1998 historical yearly average is approximately 1.5 mg/L. Historical finished water DBPs monitored by the UMVRWB include only the distribution system trihalomethanes (THMs). The historical running annual average THM concentration measured in the UMVRWB distribution system sample locations was 53 µg/L. This THM concentration is below the Stage I D/DBP Rule limit of 80 µg/L but is slightly higher than the proposed Stage II D/DBP Rule limit.

Table 3

Summary of finished water quality

Water quality parameter	Average yearly value*	Minimum yearly value*	Maximum yearly value*
Temperature (ºC)	7.0	1.0	20.0
pH	8.6	7.7	9.5
Turbidity (ntu)	0.05	0.01	0.10
TOC (mg/L)	1.50	1.30	1.90
Distribution system THM4 (µg/L)	53	38	69

*Historical data from 1998.

Treatment Challenges

The major treatment challenge is the low alkalinity in the Hinckley Reservoir raw water. The low alkalinity raw water has very little buffering capacity for chemical coagulation. At times the alkalinity fluctuation makes setting the coagulant dosage for achieving optimal coagulation very difficult.

METHODS AND MATERIALS

Influent Pretreatment Process

Influent water used for the RSSCT study was collected from the Hinckley WTP immediately after filtration. The sampling events were coordinated with the plant operators so that pre-chlorination would be stopped for a 24-hr period prior to sample collection. The same full-scale filter effluent sampling location was used for each quarterly sampling event.

A process schematic showing the procedure used during sampling is included in Figure 2. During sampling, the filtered water was pumped directly from the filter effluent pipe through a 1 μm cartridge filter and into a storage tank. The post-filter sample tap was located upstream of any further chemical feed locations. The 1-μm cartridge filter was used to remove any large particulates that could potentially plug the GAC media during RSSCT operation. The filtered water was passed through the cartridge filter at a rate between 1 and 2 gpm. A pre-treatment summary for each quarterly RSSCT test is presented in Table 4.

Table 4

Sample collection pre-treatment for RSSCT study

Test quarter	Pre-treatment	EBCT (min)
Quarter 1	Cartridge filtration (1 μm)	10 and 20
Quarter 2	Cartridge filtration (1 μm)	10 and 20

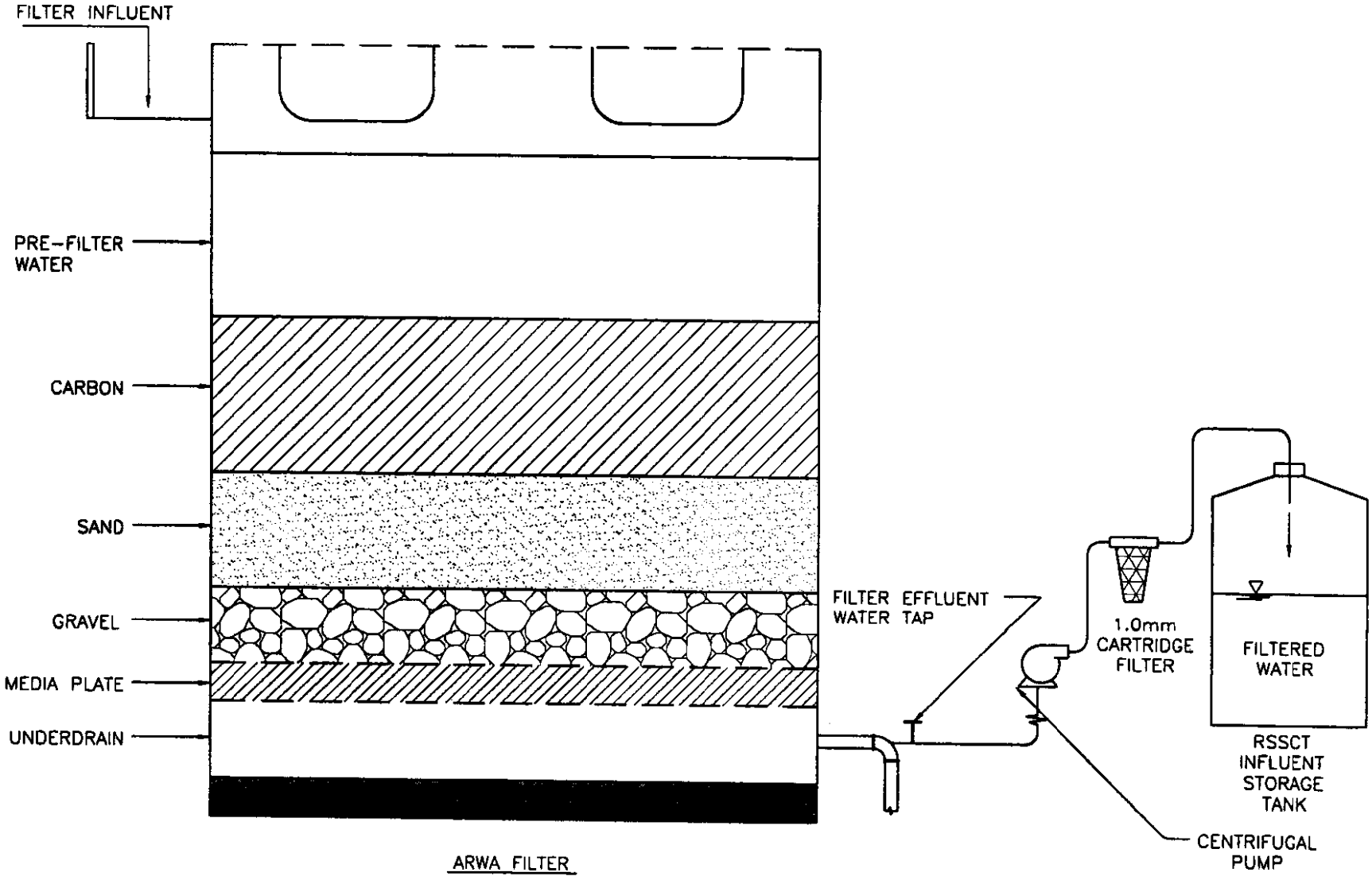

Figure 2. ARWA RSSCT influent sampling pretreatment process

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Quarter 3	Cartridge filtration (1 μm)	10 and 20
Quarter 4	Cartridge filtration (1 μm)	10 and 20

Influent Water Collection

Sample collection for the RSSCT study was performed during periods when the raw water quality was stable and considered representative based on historical seasonal data. In order to verify that the influent sample collected was typical, a series of five analytical tests was performed including:

- TOC
- pH
- Alkalinity (mg/L as $CaCO_3$)
- Total and calcium hardness (mg/L as $CaCO_3$)
- UV_{254}
- Turbidity

Results from these analyses were compared with historical plant filtered water quality data collected by Utica to determine if the sample collected was truly representative. After confirming that the sample was representative, the water was quickly transported to the EE&T test facility to begin the study. At least 160 gal of filtered water were collected for each quarterly RSSCT study.

RSSCT Design Information

A bench-scale filter apparatus was constructed that included all of the equipment required to perform the RSSCT study. The filter apparatus contained separate systems for both the 10-min empty bed contact time (EBCT) test and the 20-min EBCT test.

The process schematic for the 10-min EBCT test unit is presented in Figure 3. The 10-min EBCT setup included a positive displacement pump, a Teflon© cartridge filter housing (with 5 μm filter), pressure gauges, and one 8-mm glass chromatography column. The tubing connecting the

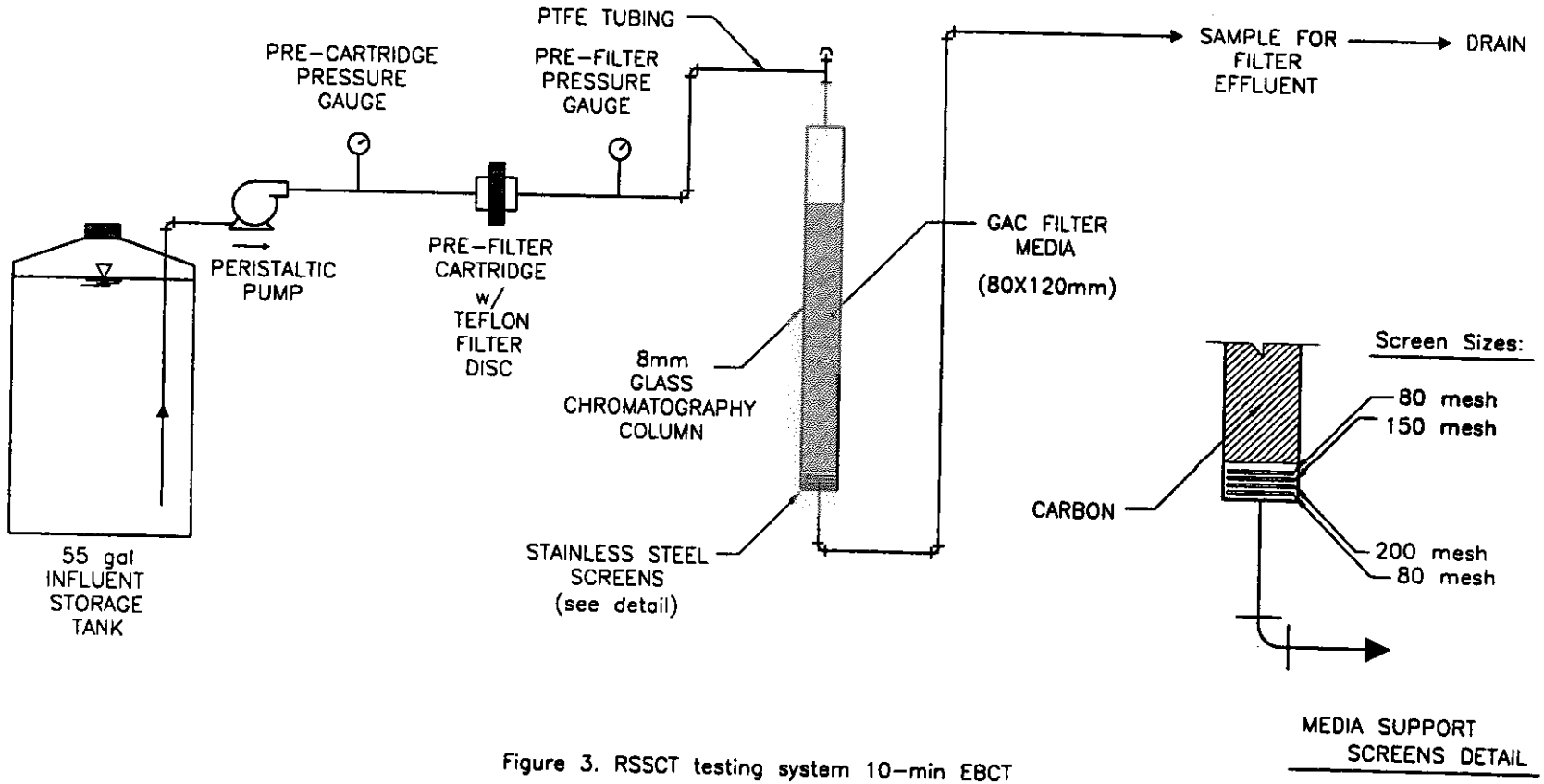

Figure 3. RSSCT testing system 10-min EBCT

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equipment was ⅜-in. O.D. Teflon© and all fittings used were stainless steel. Stainless steel screens were used to support the GAC media in the glass column. The filter effluent was grab sampled downstream of the glass GAC column, and the influent feed water was sampled directly from the storage tank.

A process schematic for the 20-min EBCT test unit is included in Figure 4. The 20-min EBCT apparatus included the same equipment as the 10-min EBCT setup, however, to double the EBCT, two 8-mm glass columns were placed in series to house the additional GAC media.

GAC Media Preparation

A bituminous coal-based GAC media was selected for use in the RSSCT study. The product used was a Calgon F-400 GAC with a U.S. standard mesh size of 12x40. To reduce headloss in the media during testing, a GAC size range of 80x140 was selected for use in the 8-mm I.D. glass columns. To achieve the desired media size, the Calgon F-400 GAC was manually ground using a mortar and pestle and then sieved using 80 mm and 140 mm U.S. standard mesh screens. After sieving was complete, the GAC media was washed according to the procedure provided in Section 5.1 of the ICR Manual for Bench- and Pilot-Scale Treatment Studies (EPA 814-B-96-003).

Prior to loading the 80 mm x 140 mm GAC media into the glass columns, the media was re-sieved to verify the size and remove fines. It was discovered that drying the media after washing caused an excessive amount of GAC fines that significantly increased filter headloss during testing. Once the media preparation was completed and the GAC was added to the columns the test was initiated using the pre-wetting procedure outlined in Section 5.2 of the ICR Treatment Studies Manual (EPA 814-B-96-003). The pre-wetted GAC slurry was added to the 10- and 20-min EBCT columns at depths determined by the RSSCT process projection spreadsheets. The media depths added to the 8-mm glass column(s) to obtain a 10- and 20-min EBCT were as follows:

10-min EBCT: Column 1 media depth (cm) = 12.3

20-min EBCT: Column 1 media depth (cm) = 8.2

Column 2 media depth (cm) = 16.4

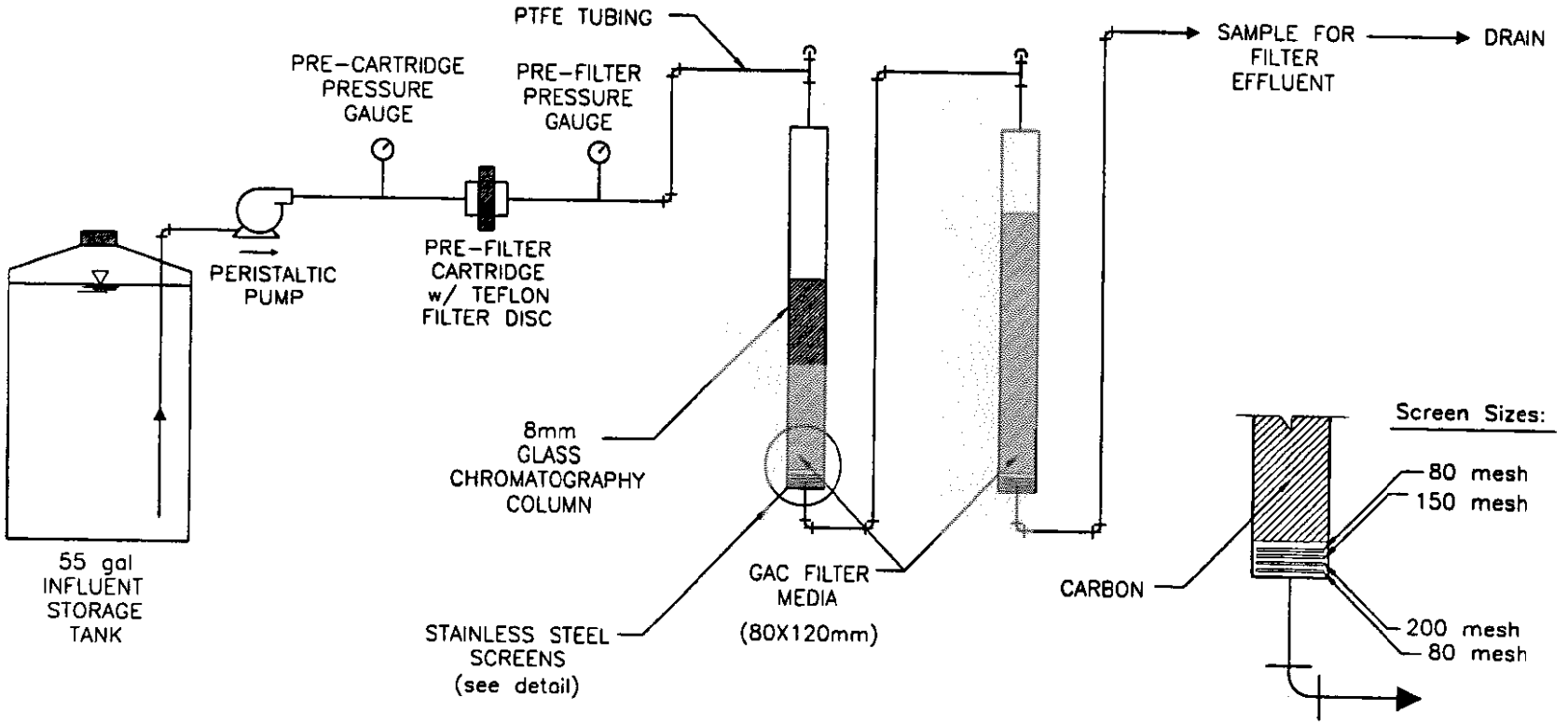

Figure 4. RSSCT testing system 20-min EBCT

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For the 20-min EBCT, one third of the total media volume was placed in column 1, while the balance of the media was placed in Column 2. This was done to reduce headloss build-up through the 20-min EBCT test unit. The media depths were identical for all four quarterly RSSCTs.

Operations Protocol

Process Projections

In order to determine the operational parameters for the RSSCTs, a computer process projection spreadsheet was developed using formulas provided by the ICR Treatment Studies Manual (EPA-814-B-96-003). The process projection was used to determine the mass of GAC media required to obtain a 10- and 20-min EBCT in the GAC columns. The mass of GAC required as well as other pertinent process parameters projected by the computer spreadsheet are shown in Table 5.

Table 5

RSSCT operational parameters

Parameter	RSSCT unit	
	10-min EBCT	20-min EBCT
Mass of GAC (g)	3.1	6.2
Total media depth (cm)	12.3	24.6
System flow rate (mL/min)	4.8	4.8
Scaling factor	7.69	7.69

The scaling factor is the ratio of the mean carbon particle diameter of the full-scale GAC media (1.1 mm) to the particle diameter (0.14 mm) of the crushed GAC used for the RSSCT study. The scaling factor is used to estimate the full-scale equivalent run time based on the measured bench-

scale filter run lengths. To obtain the full-scale equivalent run time, the scaling factor is multiplied by the number of actual RSSCT operation days. For example, one day of RSSCT run time is equal to slightly longer than one full-scale equivalent week. After performing this adjustment, the RSSCT filter run time is referred to as the "scaled operation time".

The process projection provides an estimate of the TOC breakthrough time based on the influent TOC concentration and also is used to estimate the volume of influent water required to complete each test. A copy of the process projections calculated for each quarterly RSSCT are included in Appendix Tables A.1, A.2, A.3, and A.4.

RSSCT Influent Analysis

The influent water was sampled a total of four times for each quarterly RSSCT test. The first influent sample was analyzed prior to collection from the Hinckley WTP. The remaining three influent samples were collected at the beginning, approximate middle, and end of each quarterly RSSCT. Influent analysis for these three samples included the following parameters:

TOC	Turbidity
pH	Bromide*
Alkalinity*	SDS chlorine demand
UV_{254}	SDSTHM4
Total hardness*	SDSHAA6
Calcium hardness*	SDSTOX
Ammonia*	

*Analyses were conducted for first and third influent samples only.

The influent TOC concentration was used to determine the 70 percent TOC breakthrough concentration. During each test, a running average of the beginning and end influent TOC concentrations was used to estimate the 50 and 70 percent breakthrough plateaus, which were used to determine test completion.

RSSCT Effluent Analysis

A total of 12 filter effluent compliance samples were collected during both the 10- and 20-min EBCT tests. Samples 4, 7, and 10 required a duplicate field sampling for each test. Effluent testing included analyses for the following parameters:

TOC	SDS chlorine demand
pH	SDSTHM4
Temperature	SDSHAA6
UV_{254}	SDSTOX

The first compliance sample was collected one hour after initiation of each quarterly test. The remaining 11 samples, however, did not have a specific time schedule for sampling but were collected based on the TOC breakthrough concentrations in the effluent water. The goal for each sampling event was to collect a filter effluent compliance sample at 5 to 8 percent TOC breakthrough increments. To accomplish this, a 10- and 20-min EBCT effluent sample had to be analyzed for TOC daily to determine when to collect each compliance sample. RSSCT study completion was based on at least one of the following ICR Rule 141.144(b)(l)(I) criteria:

a. An effluent TOC concentration $\geq$70 percent of the average influent TOC concentration on two consecutive sample dates that were two full-scale equivalent weeks part.
b. A 50 percent TOC breakthrough is reached and then the effluent concentration does not increase by more than 10 percent of the average influent TOC concentration for the next two full-scale equivalent months.
c. One full-scale equivalent year of testing and completion of sampling for all 12 required compliance samples.

Operational Monitoring

The 10- and 20-min EBCT RSSCT system operational parameters were checked and adjusted on a daily basis. The parameters monitored included the following:

- Pre-treatment cartridge filter pressure
- GAC media pressure
- System flow rate
- Media depth

The system flow rate was controlled by adjusting the rate of the peristaltic feed pump. The flow rate was confirmed daily to maintain the desired flow rate of 4.7 mL/min. Slight changes occurred due to increasing headloss in the pre-filter and GAC media.

Analytical Methods

The laboratory methods used for RSSCT sample analysis are summarized in Table 6. The table also includes the minimum reporting level (MRL), method detection level (MDL), and precision and accuracy criteria. All of the analytical methods used are approved by EPA for ICR testing.

Table 6

Analytical methods used for the RSSCT study

Test	Method	Reporting units	MRL	MDL	Precision percent RSD*	Accuracy percent response*
Inorganic analytes						
Alkalinity	SM 2320 B	mg/L	3	2	---	---
Bromide	EPA 300.0 B	µg/L	20	0.010	≤10	±10
Chlorine, free, total	SM 4500-Cl G	mg/L	0.1	---	---	---
Hardness, calcium	SM 3500-Ca D	mg/L	4.6	0.09	---	---
Hardness, total	SM 2340 C	mg/L	4.6	0.09	---	---
pH	SM 4500-H+ B	pH	---	---	---	---

Test	Method	Reporting units	MRL	MDL	Precision percent RSD*	Accuracy percent response*
Temperature	SM 2550 B	^{o}C	---	---	---	---
Total organic carbon (TOC)	SM 5310 C	mg/L	0.5	0.50	≤10	±15
Total organic halide (TOX)	SM 5320 B	µg/L	20	25	---	---
Turbidity	SM 2130 B	ntu	0.05	0.015	---	---
UV absorbance at 254 nm	SM 5910 B	cm^{-1}	0.009	0.50 mg/L†	≤10	±15
Organic analytes						
Haloacetic acids (except MCAA)	EPA 552.2 SM 6251 B	µg/L	1.0‡	≤0.50‡	≤20	±15
Monochloroacetic acid	EPA 552.2 SM 6251 B	µg/L	2.0	≤1.0	≤20	±15
Trihalomethanes	EPA 551.1/551	µg/L	1.0‡	≤0.50‡	≤20	±20

*See QC criteria for frequency
†Potassium hydrogen phthalate (KHP) concentration (mg/L) is given as dissolved organic carbon (DOC)
‡Each analyte

The three laboratories used for RSSCT sample analysis are listed in Table 7. Most of the analyses were conducted by the EE&T laboratory. Only the SDSTOX and bromide samples were delivered to outside laboratories for analysis.

Table 7

Laboratory services summary

Laboratory	Dates of service	Analyses performed
EE&T Laboratories	1/98 to 7/99	Alkalinity, Ammonia, Calcium Hardness, Chlorine Residual, HAA6 (EPA 552.2), pH, Temperature, THM4 (EPA 551.1), Total Hardness, Turbidity, UV_{254}
James R. Reed & Associates	1/98 to 7/99	TOX (SM 5320 B)
Utah Department of Health Division of Epidemiology and Laboratory Services	1/98 to 7/99	Bromide (EPA 300.0)

RESULTS AND DISCUSSION

Influent Water Quality

RSSCT influent water was analyzed three separate times during each quarterly test. Samples were collected at the beginning, middle, and end of each test period. A summary of the water quality data obtained for each quarter of testing is shown in Table 8. The table shows that the influent TOC concentration ranged from 1.83 to 2.64 mg/L during RSSCT testing. The influent water quality for each of the four test quarters was very similar. The influent SDSTHM4 concentration averaged 27 µg/L during the study which is somewhat lower than the UMVRWB's historical average distribution system THM concentration of 53 µg/L. The historical range of THM4 in the distribution system was 38 to 69 µg/L

Table 8

Summary of RSSCT influent quality

Water quality parameter	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Temperature (ºC)	23.0	24.0	21.0	20.0
pH	6.90	6.25	7.30	6.82
Turbidity (ntu)	0.51	0.26	0.32	0.12
Alkalinity (mg/L as $CaCO_3$)	9.0	11.0	13.8	33.0
Calcium hardness (mg/L as $CaCO_3$)	7.3	13.8	18.0	34.0
Total hardness (mg/L as $CaCO_3$)	22.5	20.4	24	50.0
Bromide (µg/L)	<0.02	<0.02	<0.02	<0.02
TOC (mg/L)	1.83	2.64	1.96	1.94
UV_{254} (cm^{-1})	0.018	0.050	0.036	0.056
SDSTHM4 (µg/L)	18.4	40.8	22.9	26.1
SDSHAA6 (µg/L)	21.9	73.6	26.4	44.1
SDSTOX (µg/L)	78.8	185.3	119.0	98.0
SDS chlorine demand (mg/L)	1.16	2.36	1.69	0.67

Note: Averages are calculated using only three samples for each parameter except for hardness (total and calcium), bromide, and alkalinity. Each of these included results from only two different sample events.

Quarterly Test Results

Summary

The RSSCT quarterly test findings are summarized in Table 9. The table provides the test dates and the reason why each test was terminated. The table shows that two of the four 10-min tests ended due to 70 percent TOC breakthrough, while none of the first quarter of 20-min EBCT tests was terminated due to 70 percent TOC breakthrough. Data obtained from each of the four quarterly tests are presented in the following sections. The key filter effluent quality parameters monitored include the simulated distribution system TOCs, THMs, HAAs, and TOXs for each quarter. These water quality data are plotted versus the scaled operation time for both the 10- and 20-min EBCT tests.

Each of the four quarterly 10- and 20-min EBCT tests were operated simultaneously with the exception of the first quarter. During the first quarter the 10-min test was terminated and restarted due to equipment failure, therefore, the test dates don't match. For these tests, two separate sets of influent water data was collected during the quarterly tests and are shown in the plots.

Table 9

RSSCT quarterly test summary

Test ID	Test date	Average influent TOC (mg/L)	Average 70 percent breakthrough concentration (mg/L)	Scaled operation time (days)	Reason for ending test
Quarter 1					
10-min	5/22-7/2, 1998	1.83	1.28	314	One full-scale year of run time
20-min	4/16-6/3, 1998	1.83	1.28	363	One full-scale year of run time
Quarter 2					
10-min	8/11-9/8, 1998	2.64	1.85	213	70% TOC breakthrough
20-min	8/11-9/28, 1998	2.64	1.85	366	One full-scale year of run time
Quarter 3					
10-min	11/4-12/17, 1998	1.96	1.37	329	70% TOC breakthrough
20-min	11/4-12/16, 1998	1.96	1.37	329	One full-scale year of run time
Quarter 4					
10-min	3/23-5/7, 1999	1.51	1.06	345	One full-scale year of run time
20-min	3/23-5/7, 1999	1.51	1.06	345	One full-scale year of run time

Quarter 1 Results

TOC Data. The first quarter of RSSCT testing was initiated on April 16, 1998. During this test, the influent TOC averaged approximately 1.80 mg/L for both the 10- and 20-min tests. The 10- and 20-min effluent TOC concentrations versus time is shown in Figure 5. The figure shows that the 10-min EBCT reached the method detection level (MDL) of 0.5 mg/L after approximately 140 scaled operation days, but never reached the 70 percent breakthrough. The 20-min EBCT samples all had TOC concentrations lower than the MDL.

SDSTHM Data. The SDSTHM data are plotted versus scaled operation days in Figure 6. The influent and effluent SDSTHM concentrations were all less than 25 μg/L, which is 15 μg/L lower than the proposed Stage II D/DBP Rule limit.

SDSHAA6 Data. The SDSHAA6 data (Figure 7) for both the RSSCT influent and effluent water. The SDSHAA6 concentrations remained under the proposed Stage II D/DBP Rule limit of 30 μg/L in all samples.

SDSTOX Data. The SDSTOX data presented in Figure 8 show that all samples collected had an SDSTOX concentration below the MDL.

Quarter 2 Results

TOC Data. The second quarter of RSSCT testing began on August 11, 1998. During this quarter the influent TOC averaged 2.59 mg/L. The effluent TOC concentration versus run time for the 10- and 20-min tests are shown in Figure 9. The 10-min effluent EBCT TOC breakthrough reached 70 percent after approximately 150 scaled operation days. The test was then terminated after collection of all compliance samples after 213 scaled operation days. The 20-min EBCT effluent TOC concentration exceeded the MDL and began increasing after approximately 130 scaled operation days. The 20-min TOC concentration reached as high as 1.5 mg/L after approximately 370 scaled operation days at which the test was ended due to time.

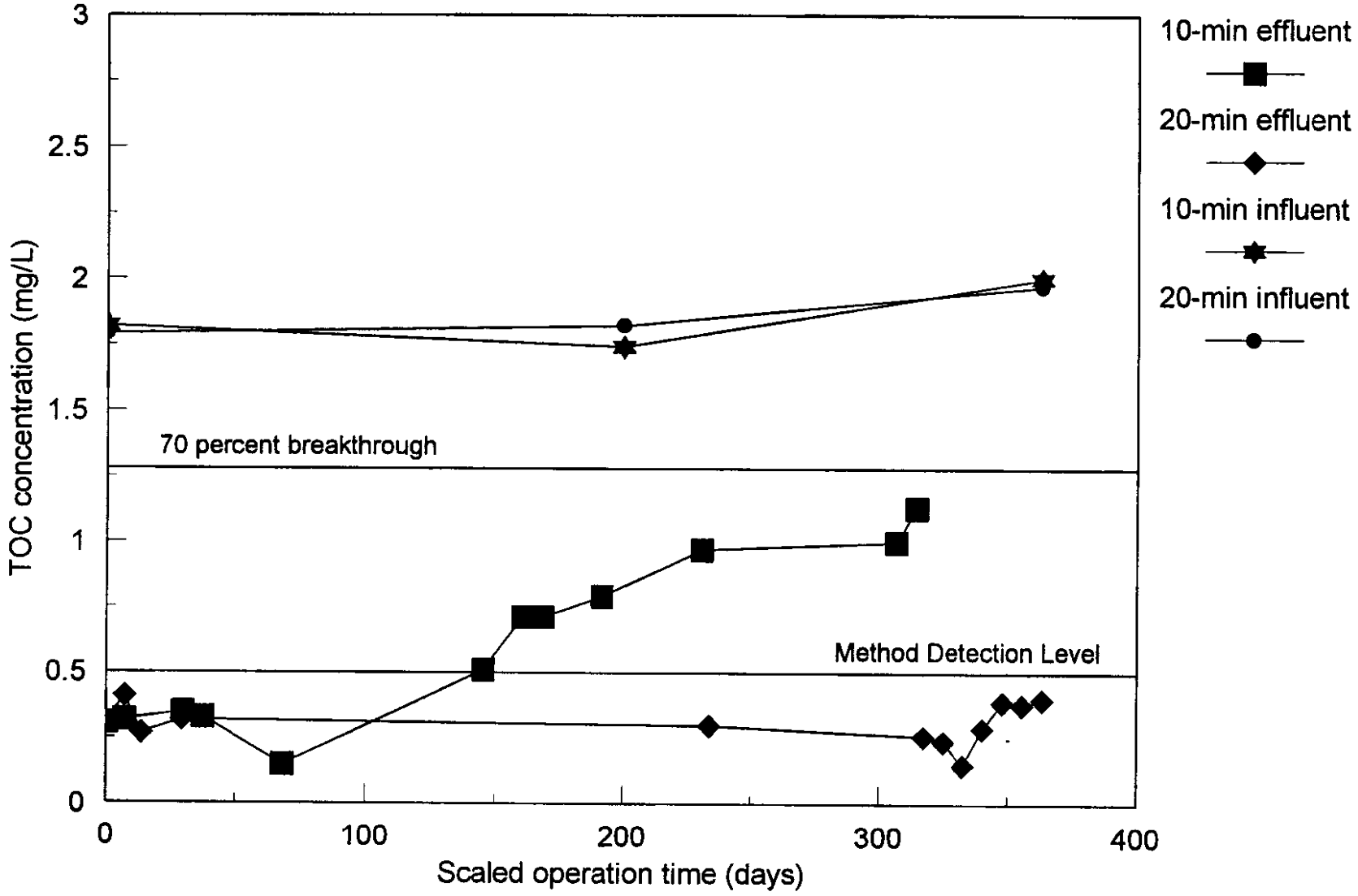

Figure 5 UMVRWB first quarter testing: TOC data

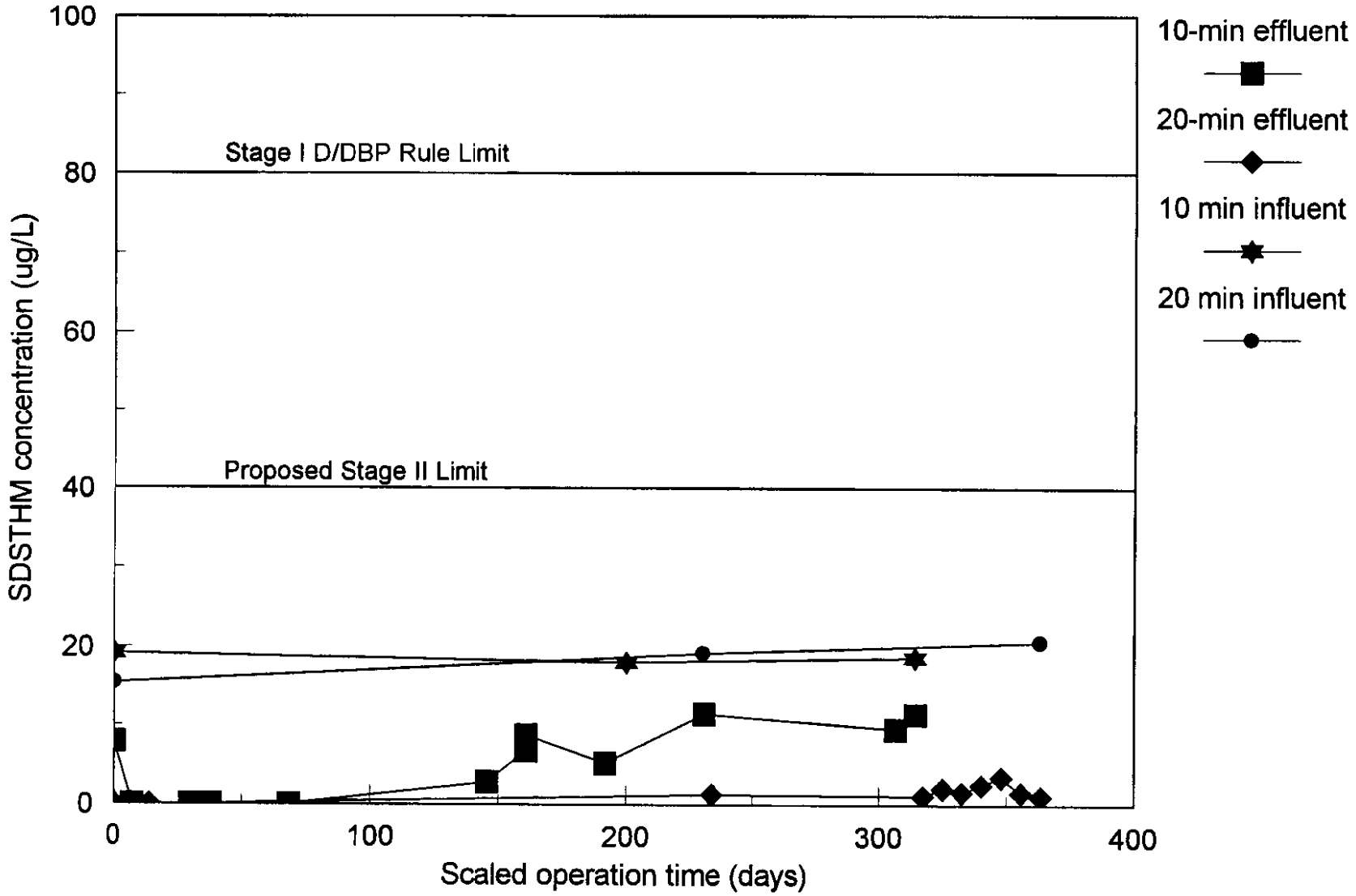

Figure 6 UMVRWB first quarter testing: SDSTHM data

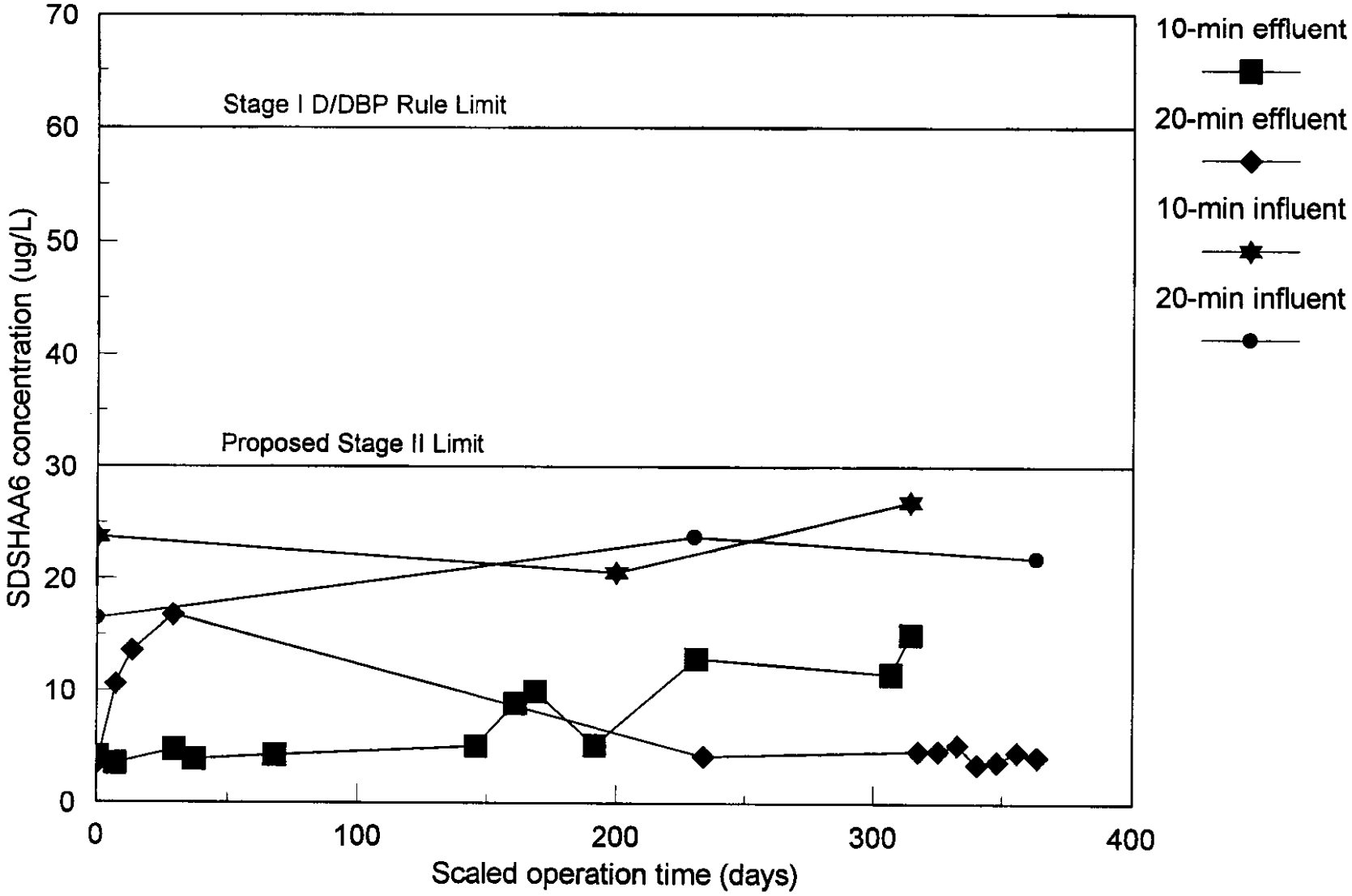

Figure 7 UMVRWB first quarter testing: SDSHAA6 data

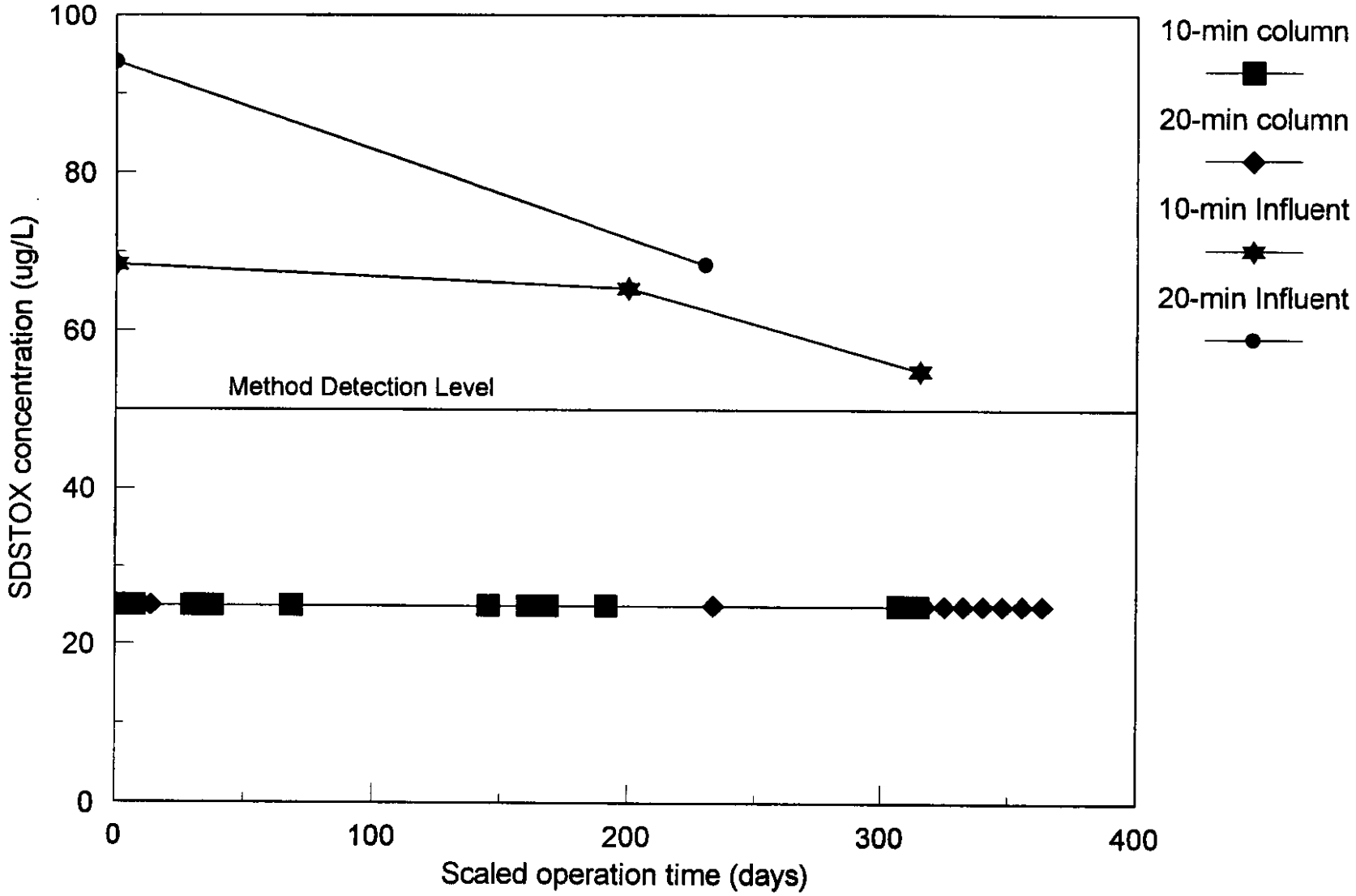

Figure 8 UMVRWB first quarter testing: SDSTOX data

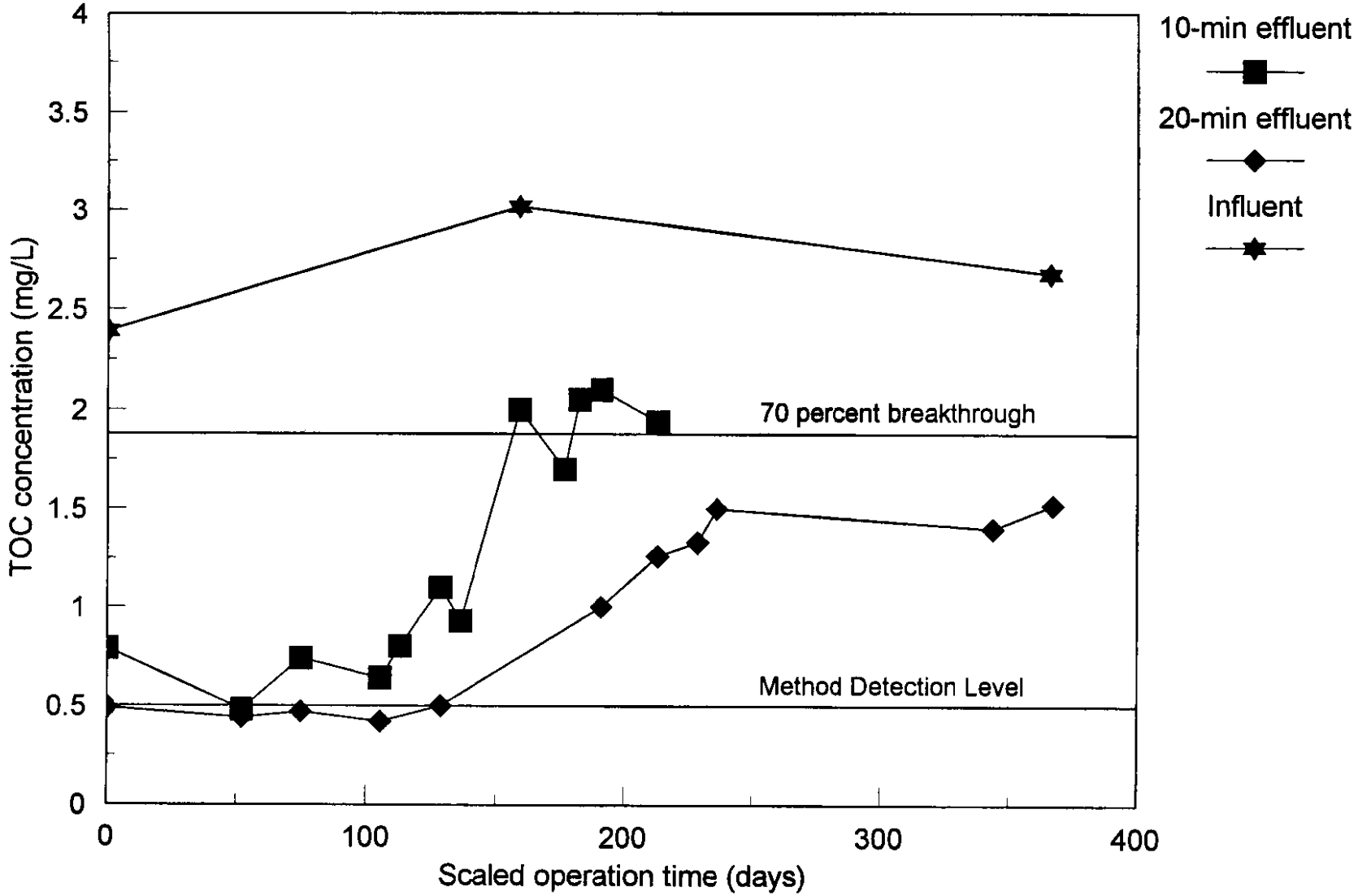

Figure 9 UMVRWB second quarter testing: TOC data

SDSTHM Data. Figure 10 shows the SDSTHM data versus scaled operation days for both the influent and effluent water. The 10-min EBCT effluent SDSTHM concentration reached as high as 30 μg/L, while the 20-min effluent SDSTHM concentration never exceeded 20 μg/L.

SDSHAA6 Data. The second quarter SDSHAA6 data are shown in Figure 11. The influent SDSHAA6 concentrations measured were higher than the concentrations measured during the first quarter testing. The influent concentration exceeded the proposed Stage II limit early in the testing (after approximately 20 scaled operation days) and remained above the Stage II limit for the remainder of testing. The 10-min EBCT SDSHAA6 concentration surpassed the proposed Stage II D/DBP Rule limit after approximately 160 scaled operation days. The 20-min effluent reached as high as 30 μg/L at approximately 130 scaled operation days. Both the 10- and 20-min EBCT effluent samples did not exceed the Stage I D/DBP Rule limit.

SDSTOX Data. The SDSTOX data are shown in Figure 12. The 10-min EBCT effluent SDSTOX concentration ranged between 75 and 125 μg/L. The first detected SDSTOX concentration was measured after 160 scaled operation days. The 20-min effluent SDSTOX concentration did not exceed the method detection level of 50 μg/L at any time.

Quarter 3 Results

TOC Data. The third quarter of RSSCT testing began on November 4, 1998. During this quarter the influent TOC concentration averaged 1.96 mg/L. The 10- and 20-min effluent TOC concentrations versus time are shown in Figure 13. The 10-min EBCT effluent TOC concentration reached 70 percent breakthrough after approximately 190 scaled operation days. This test was allowed to continue, although the test could have been terminated due to the 70 percent breakthrough criteria. The TOC concentration decreased to approximately 1.0 mg/L, or less than 70 percent breakthrough, after approximately 310 scaled operation days. The 20-min EBCT TOC concentration began to increase at approximately 250 scaled operation days and peaked to 2.2 mg/L after approximately 315 scaled operation days.

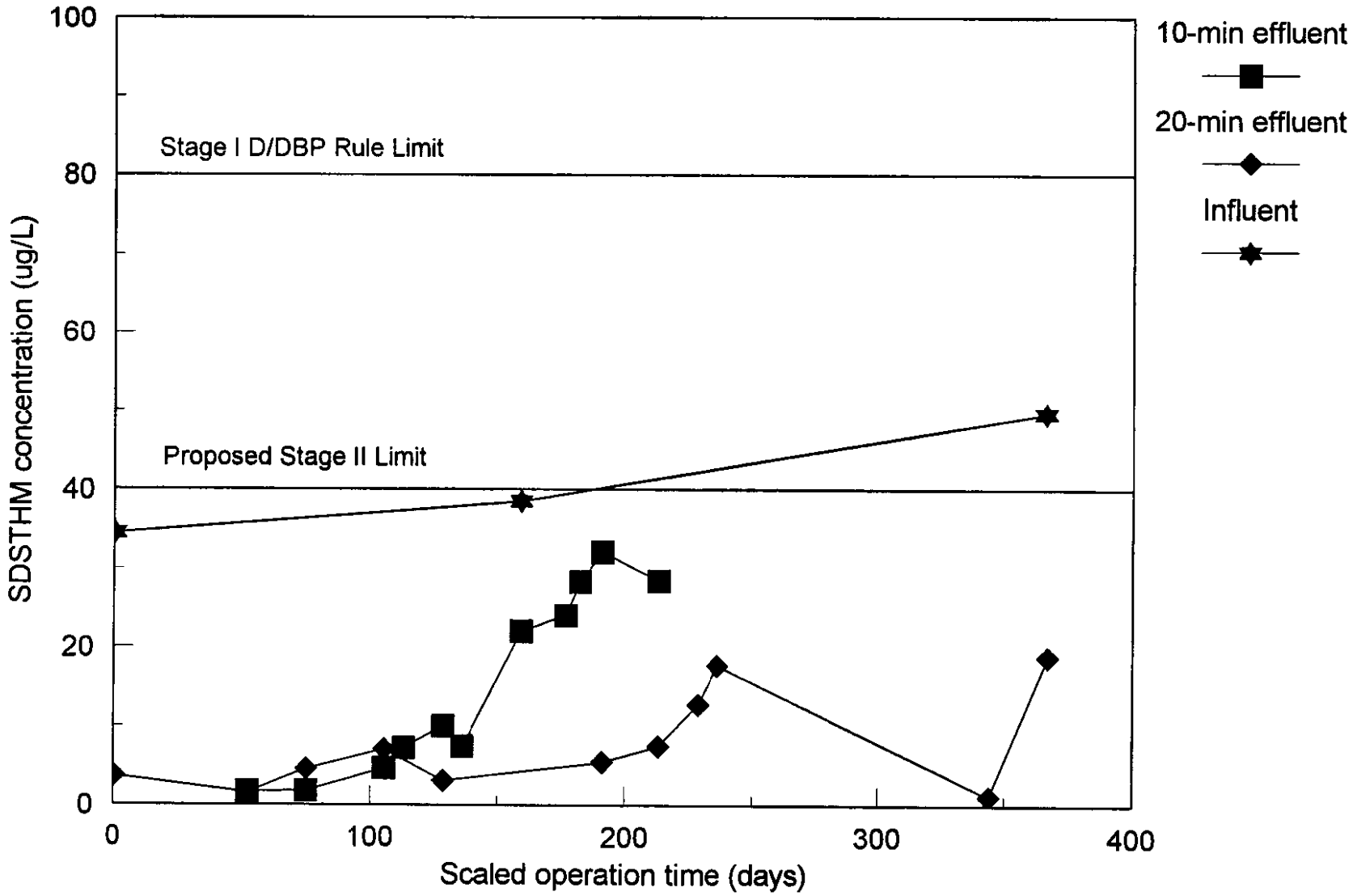

Figure 10 UMVRWB second quarter testing: SDSTHM data

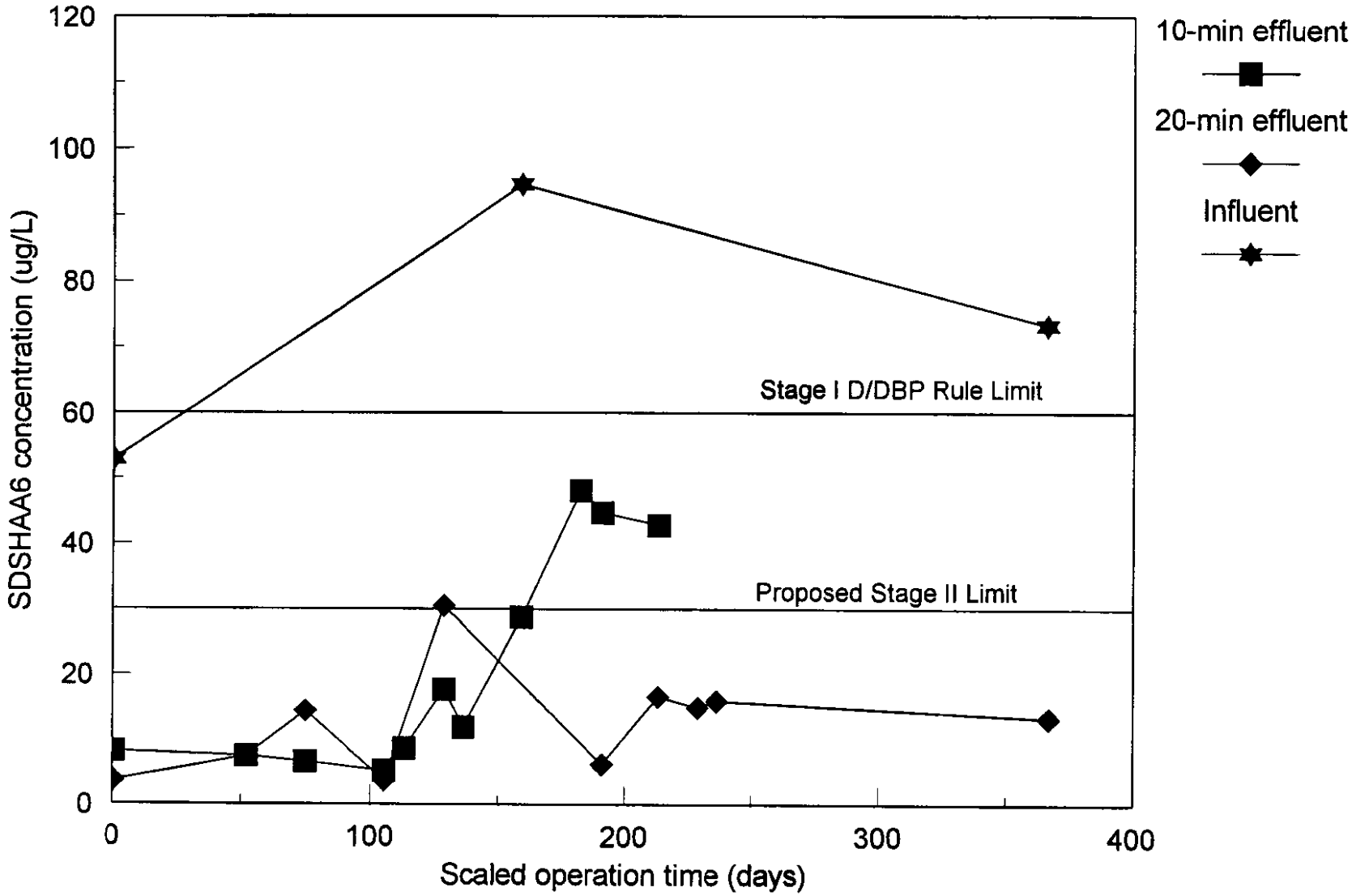

Figure 11 UMVRWB second quarter testing: SDSHAA6 data

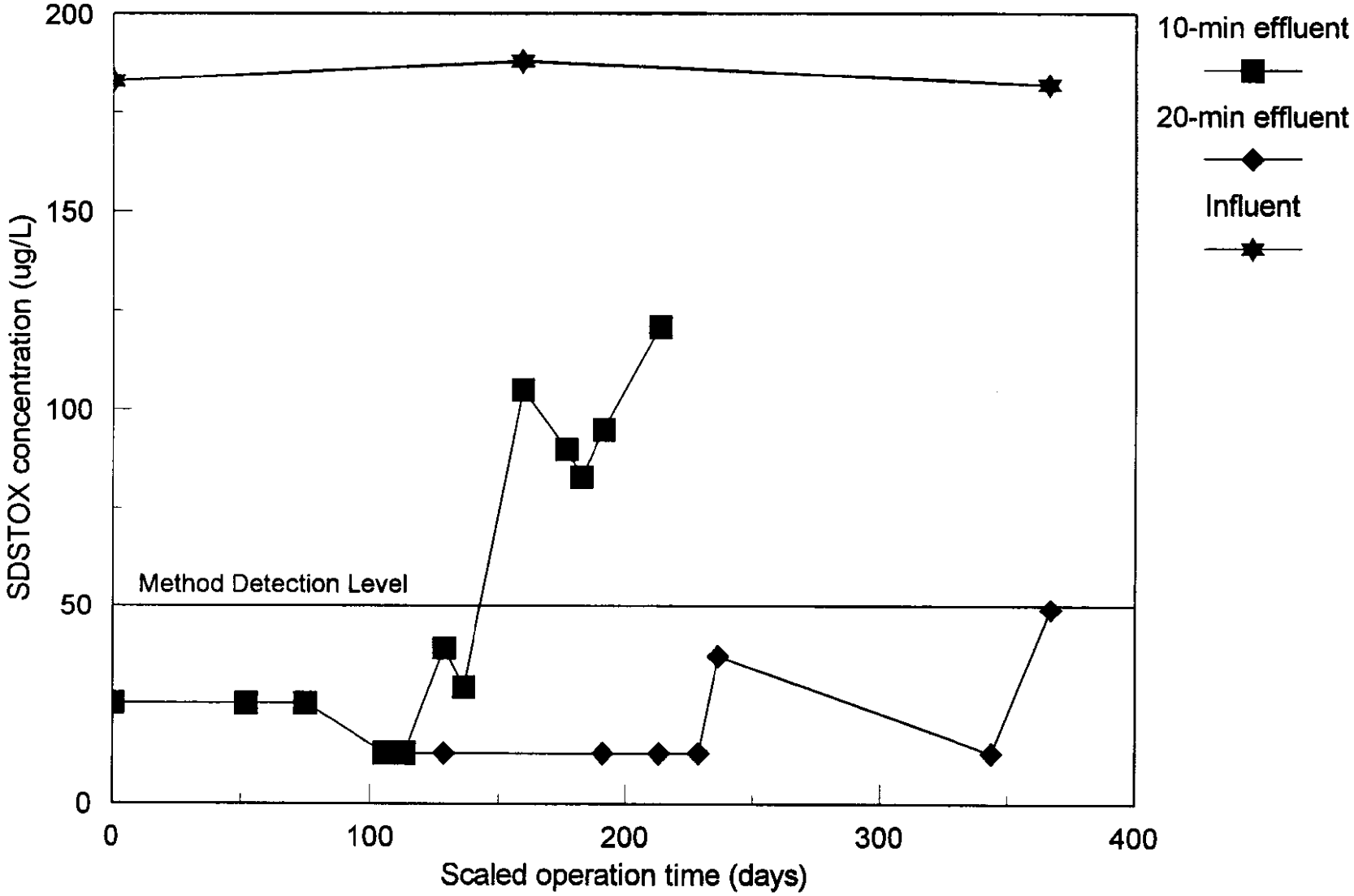

Figure 12 UMVRWB second quarter testing: SDSTOX data

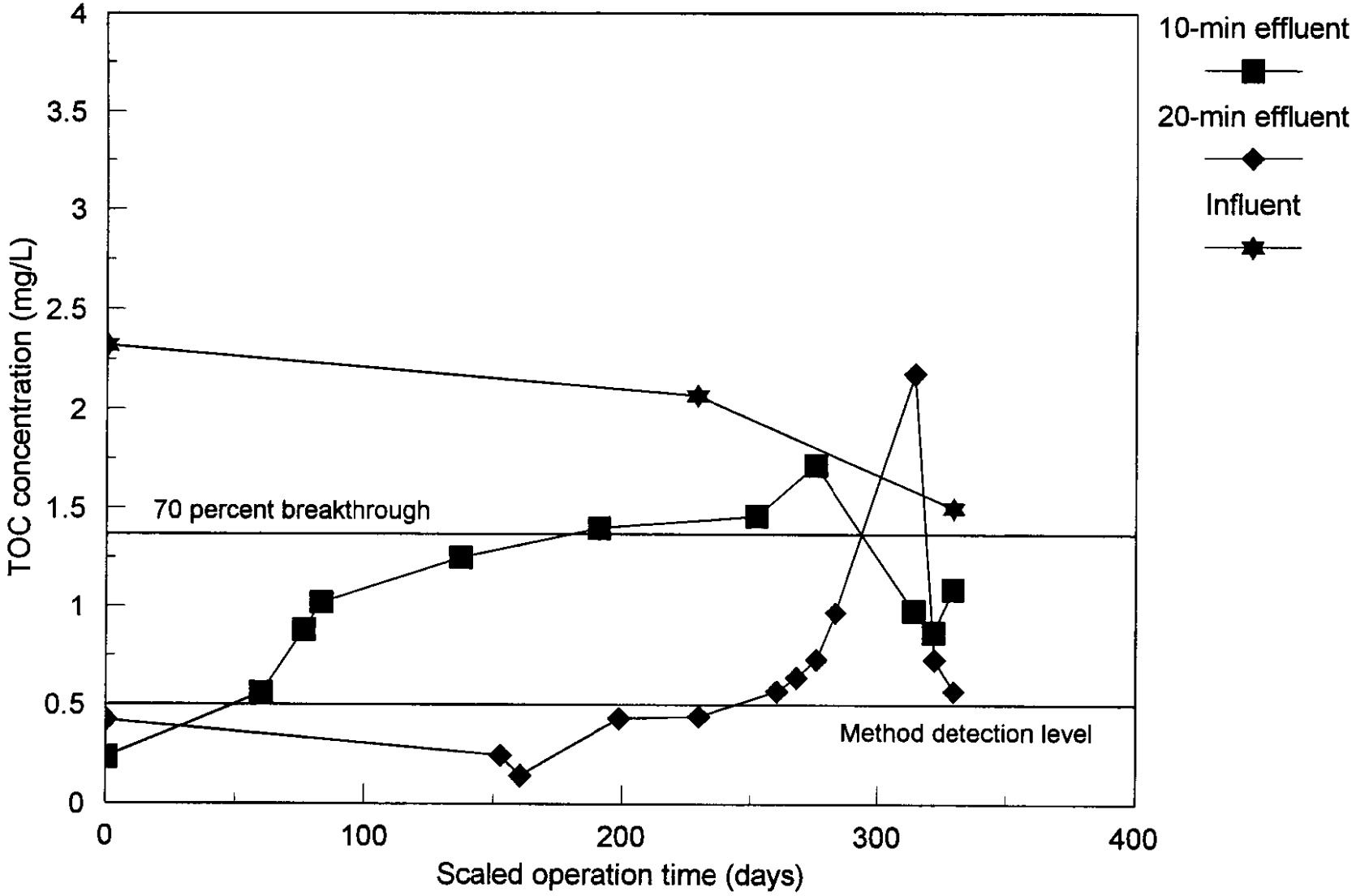

Figure 13 UMVRWB third quarter testing: TOC data

SDSTHM Data. The SDSTHM data are presented in Figure 14. The SDSTHM concentrations measured in the influent and effluent samples were all less than 30 μg/L, which is 10 μg/L lower than the proposed Stage II D/DBP Rule limit.

SDSHAA6 Data. Figure 15 shows the SDSHAA6 results from third quarter testing. The influent SDSHAA6 measured concentration ranged from 15 to 38 μg/L during testing. All 10- and 20-min effluent samples had SDSHAA6 concentrations less than the proposed Stage II D/DBP Rule limit of 30 μg/L.

SDSTOX Data. The influent and effluent SDSTOX data are shown in Figure 16. The first detected 10-min effluent SDSTOX concentration was measured at approximately 135 scaled operation days. The 20-min EBCT effluent SDSTOX remained below the MDL for the entire 325 scaled operation days.

Quarter 4 Results

TOC Data. The fourth quarter of RSSCT testing began on March 23, 1999. During this quarter the influent TOC concentration averaged 1.94 mg/L. The TOC data are presented in Figure 17. The 10-min EBCT effluent ranged between approximately 0.25 and 1.1 mg/L and did not reach 70 percent breakthrough until the final compliance sample. The 20-min EBCT effluent was first detected at approximately 300 scaled operation days.

SDSTHM Data. The SDSTHM results from the fourth quarter are presented in Figure 18. The SDSTHM concentrations for all influent and effluent samples were below the proposed Stage II D/DBP Rule limit of 40 μg/L. The 10-min EBCT effluent samples were under 10 μg/L, while the 20-min EBCT effluent samples were less than 3 μg/L.

SDSHAA6 Data. Figure 19 shows the SDSHAA6 data for both the RSSCT influent and effluent water. All 10- and 20-min effluent SDSHAA6 concentrations fall below the proposed Stage II D/DBP Rule limit for the 345 scaled operation day duration of testing.

SDSTOX Data. The SDSTOX data collected during the fourth quarter are presented in Figure 20. All 10- and 20-min EBCT effluent samples were not detected.

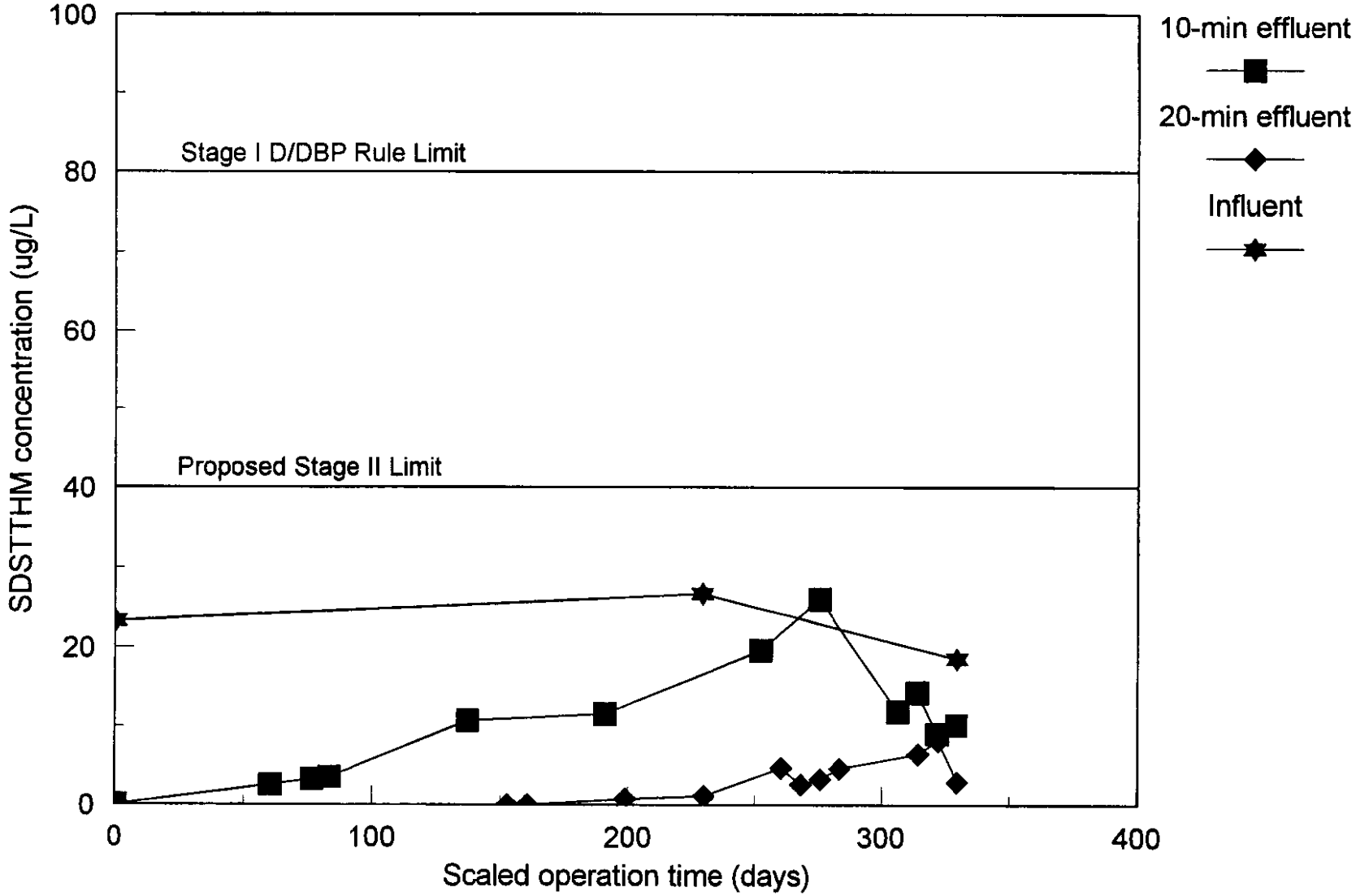

Figure 14 UMVRWB third quarter testing: SDSTTHM data

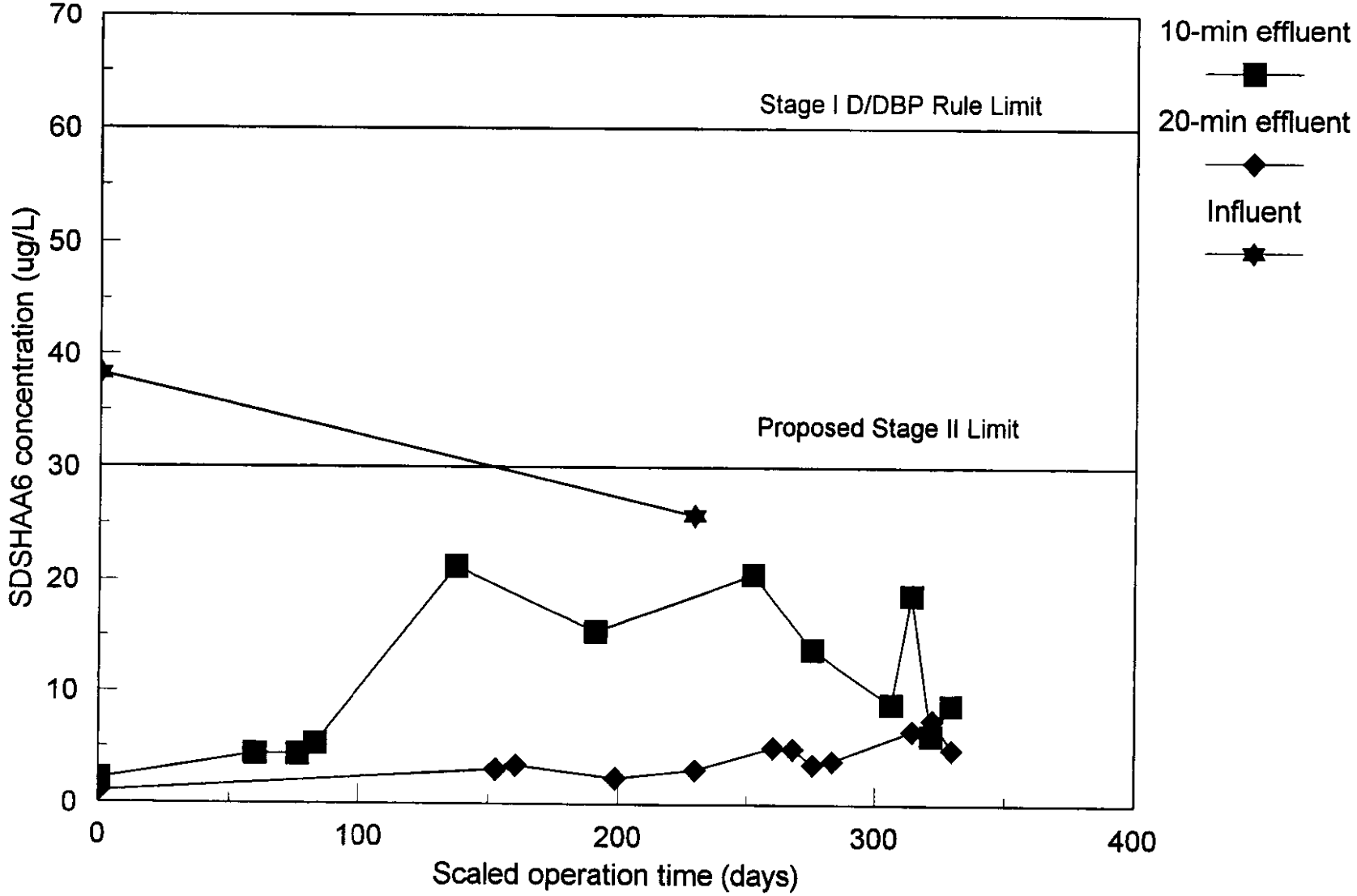

Figure 15 UMVRWB third quarter testing: SDSHAA6 data

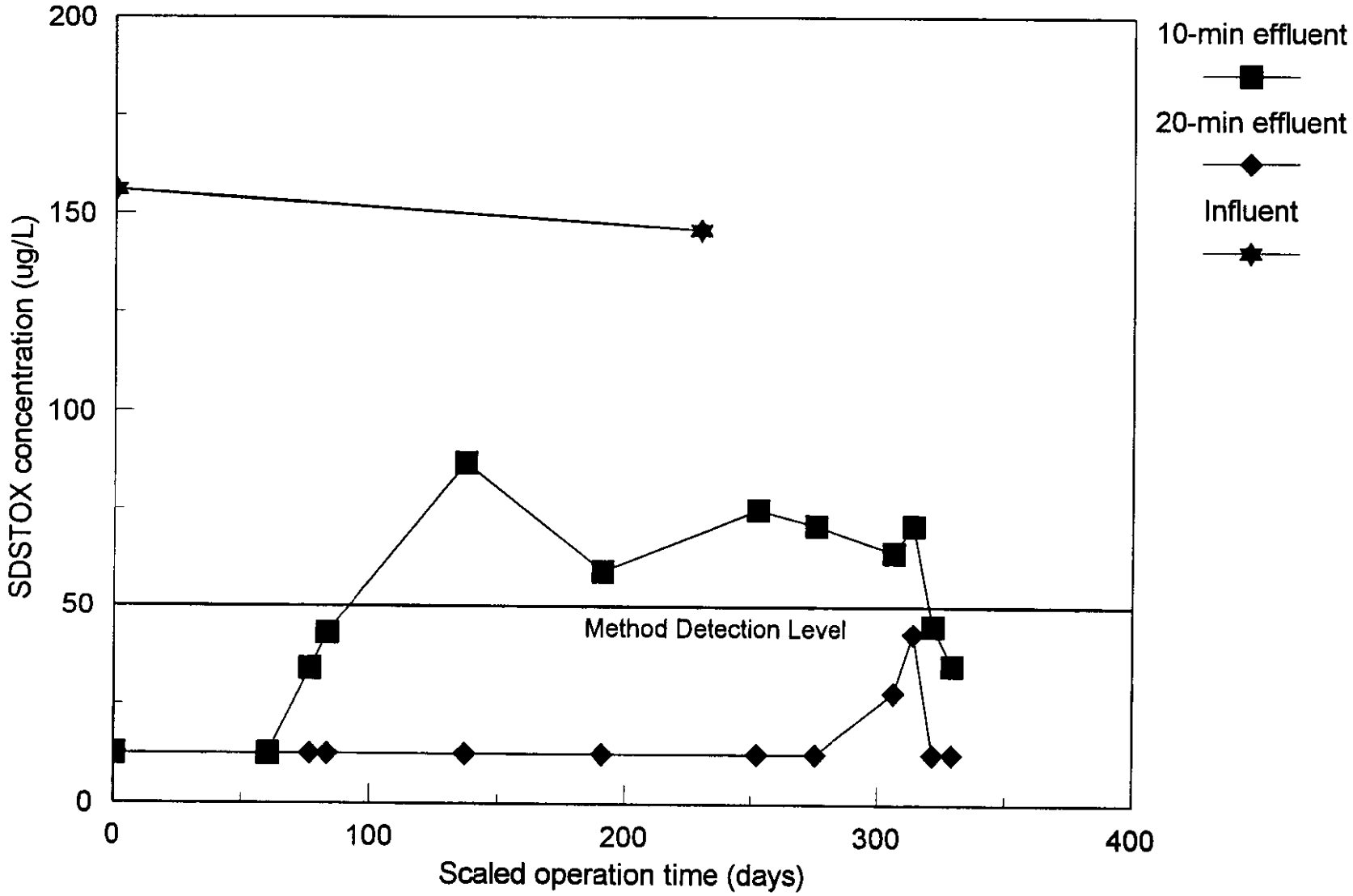

Figure 16 UMVRWB third quarter testing: SDSTOX data

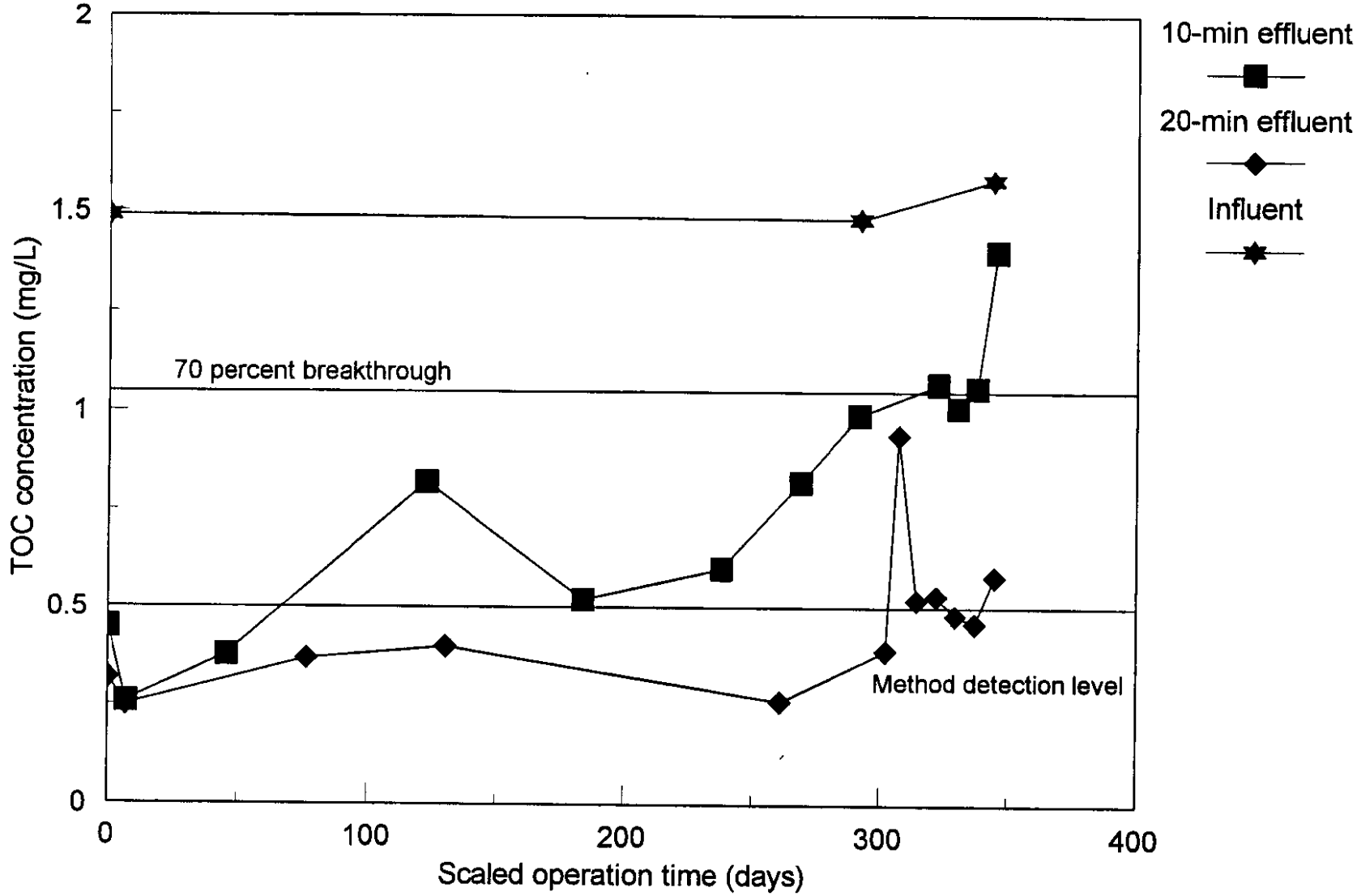

Figure 17 UMVRWB fourth quarter testing: TOC data

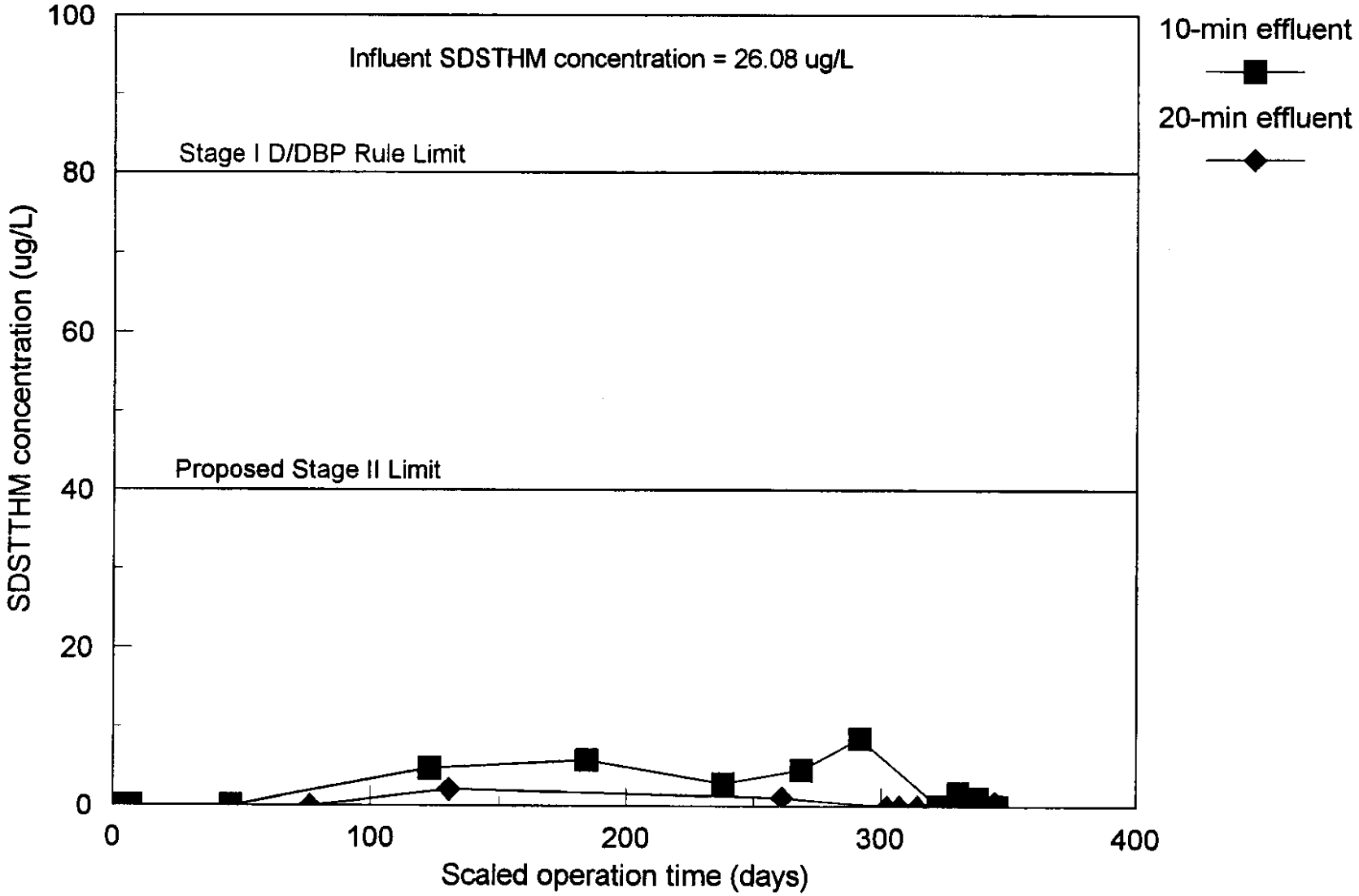

Figure 18 UMVRWB fourth quarter testing: SDSTTHM data

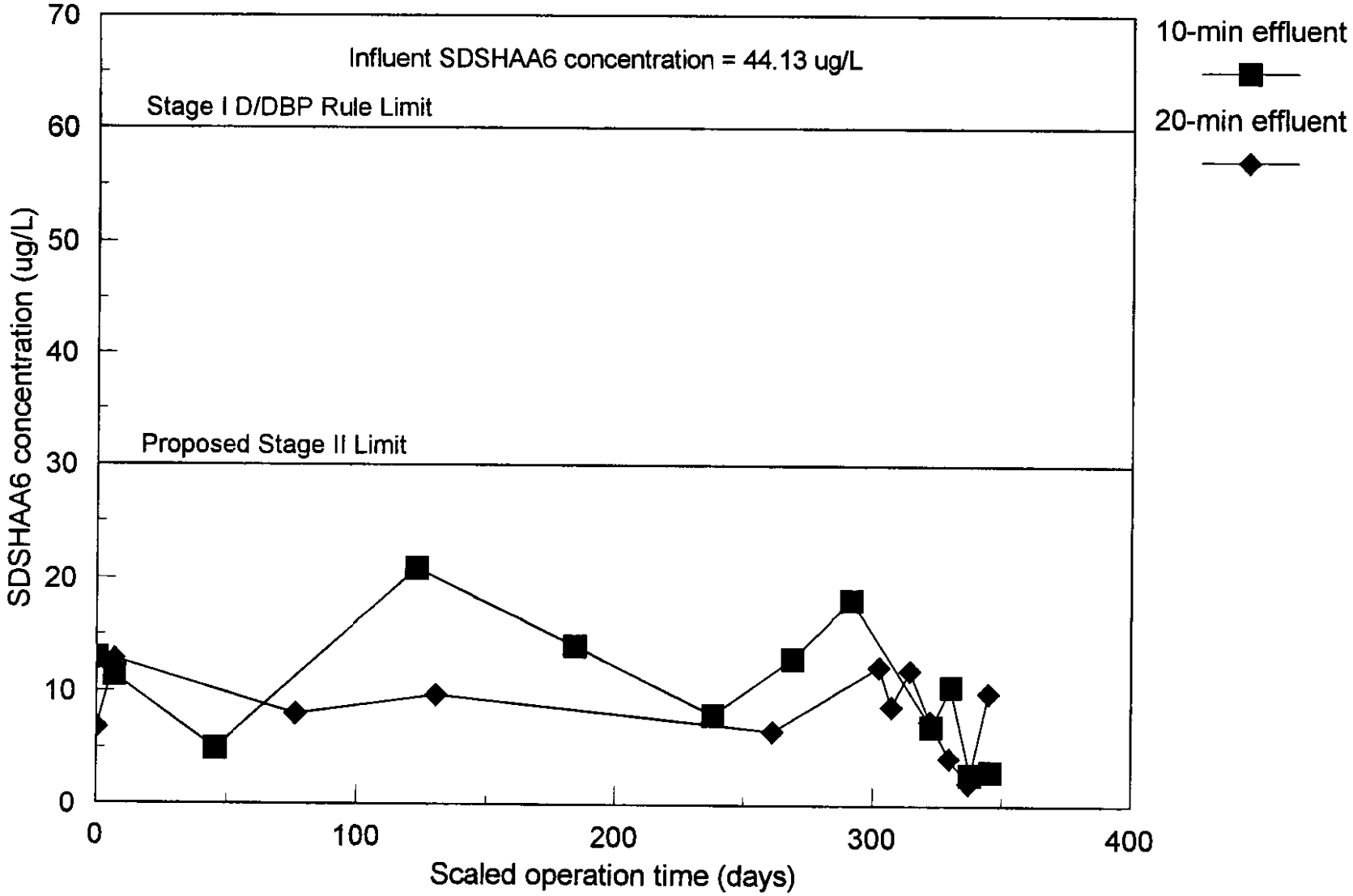

Figure 19 UMVRWB fourth quarter testing: SDSHAA6 data

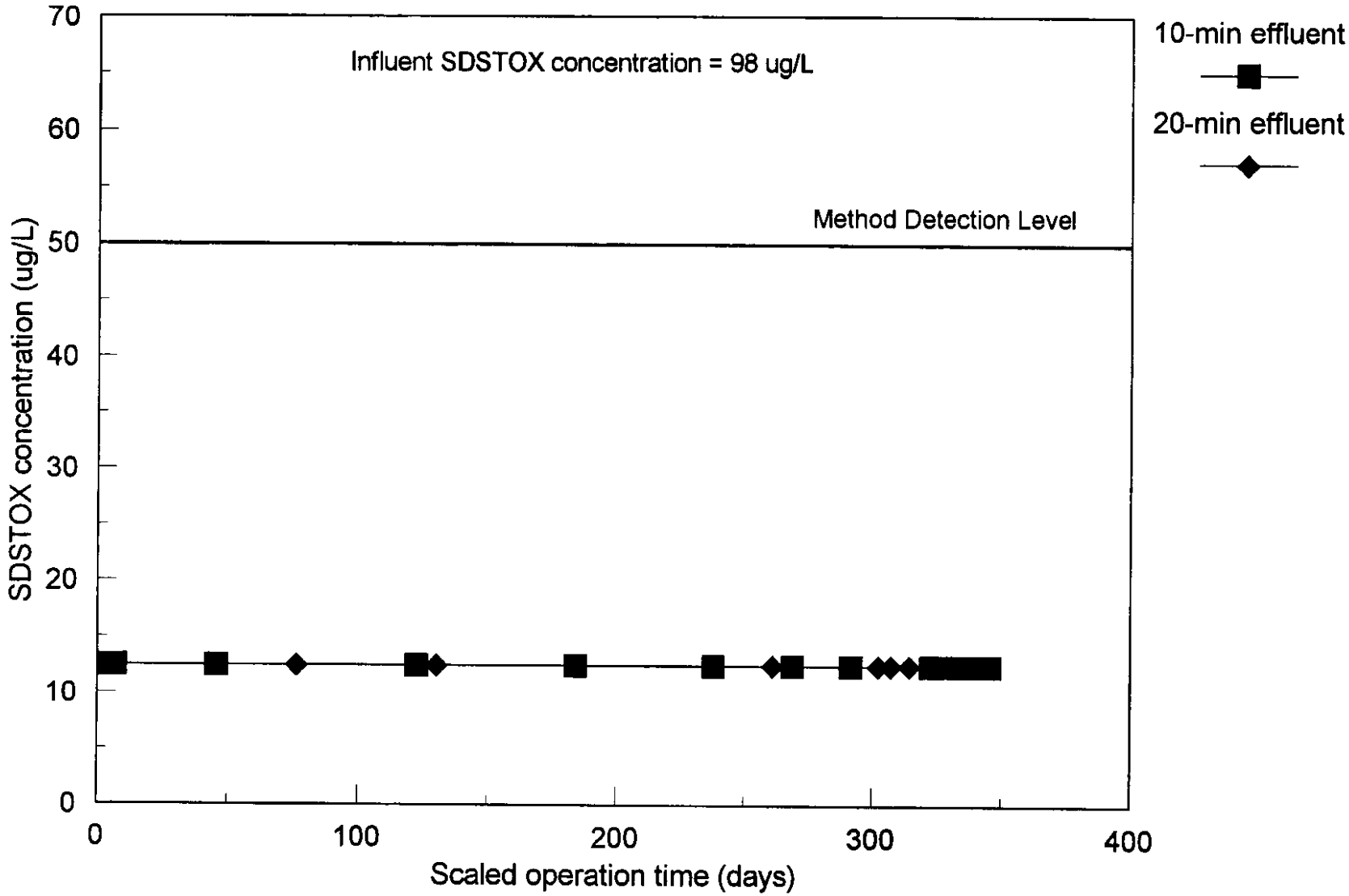

Figure 20 UMVRWB fourth quarter testing: SDSTOX data

Summary of TOC Breakthrough

In order to compare the TOC breakthrough curves for the four quarterly tests, the 10-min and 20-min EBCT tests results were plotted together. The four quarterly 10-min TOC breakthrough curves are shown in Figure 21. This figure confirms that the TOC breakthrough was more rapid when filtering an influent water with a higher average TOC concentration demonstrated by the second quarter data. Quarter 4 had a higher TOC loading rate and, as a result, increased to above 70 percent breakthrough after 150 scaled operation days. The TOC effluent for Quarter 3 testing also reached 70 percent breakthrough at approximately 200 scaled operation days. Quarters 1 and 4 effluent TOC concentrations remained below 70 percent breakthrough throughout these tests.

The 20-min EBCT quarterly breakthrough curves are shown in Figure 22. The majority of the effluent TOC samples analyzed were below the MDL of 0.5 mg/L. Only the effluent TOC concentrations from Quarters 2 and 3 sampling demonstrated significant TOC breakthrough. The Quarter 2 effluent TOC concentration reached as high as 57 percent breakthrough, while the Quarter 3 breakthrough concentration was approximately 50 percent.

Problems Encountered

There were a number of problems encountered during the year-long RSSCT study, however, most were easily resolved. The most significant difficulties encountered were as follows:

- Rapid headloss development caused by both the pre-treatment cartridge filter and GAC media headloss.
- Long run time for each quarterly RSSCT study and the extensive amount of sampling required.
- Determination of when to collect compliance samples.
- Minor leaks and equipment failures.

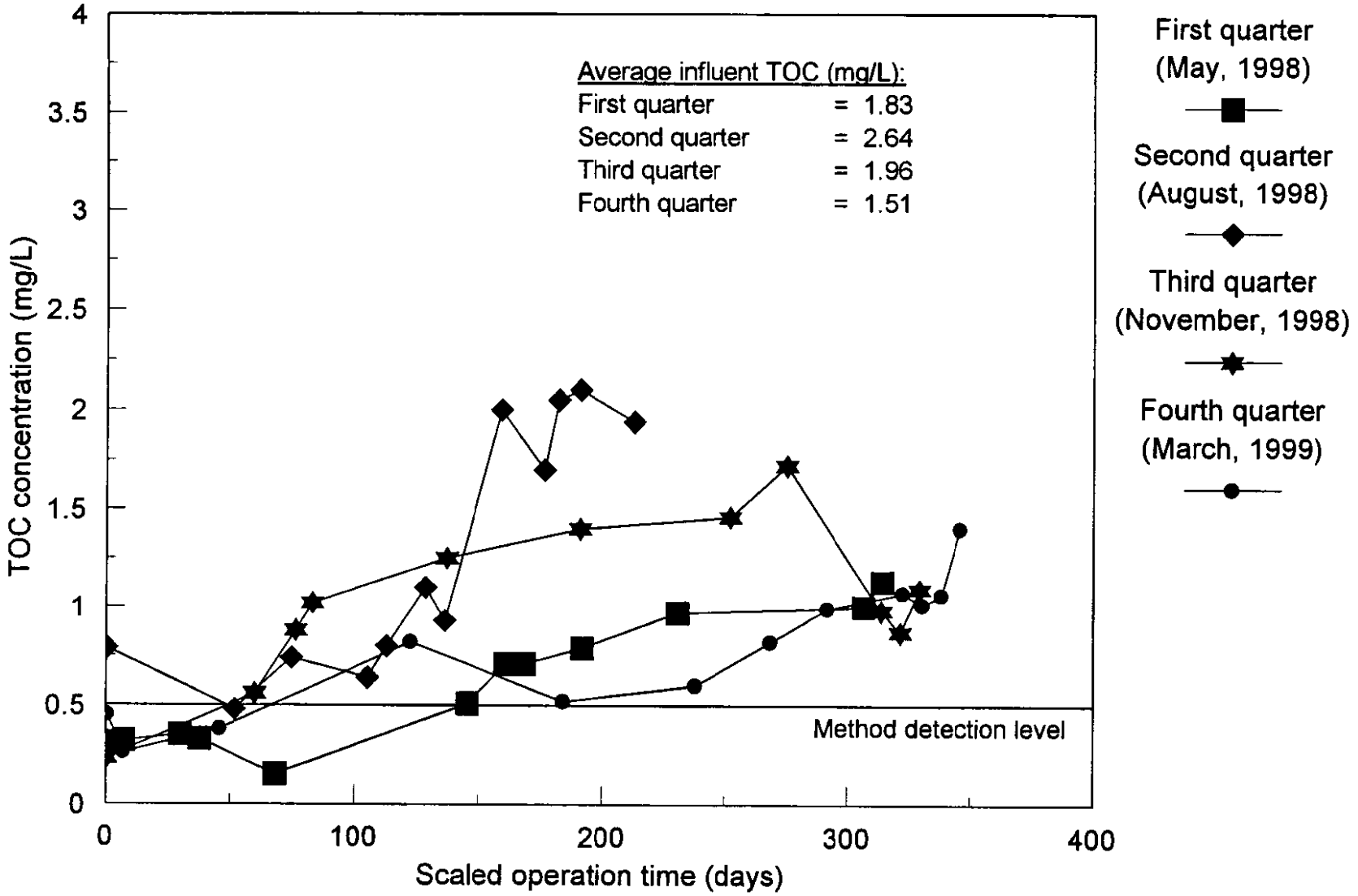

Figure 21 UMVRWB RSSCT testing: TOC data (10-min EBCT)

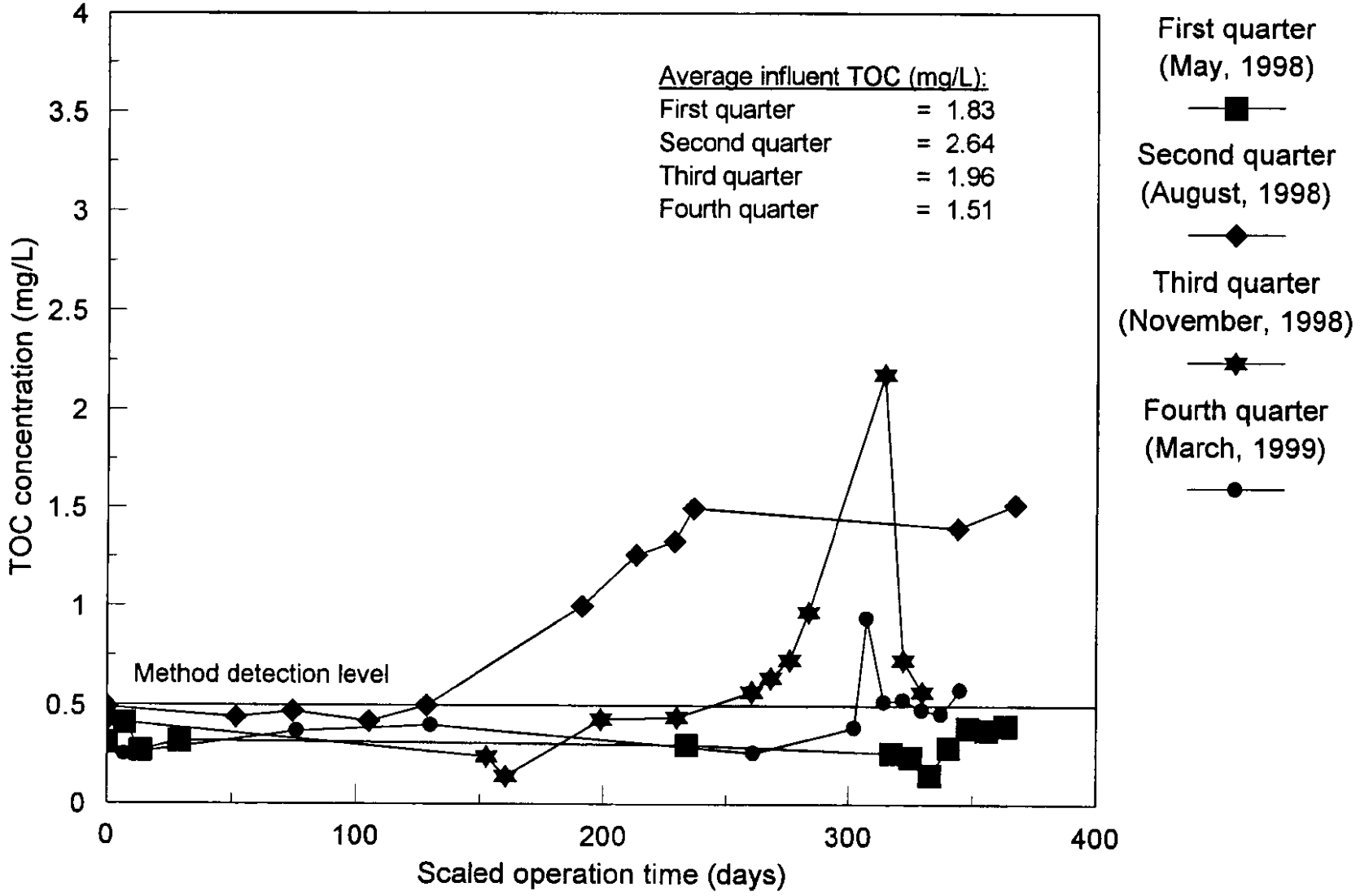

Figure 22 UMVRWB RSSCT testing: TOC data (20-min EBCT)

The most significant problem encountered was the rapid rate of headloss accumulation caused by the pre-treatment filters. Teflon© filter disks were used to remove suspended solids from the feed water prior to entering the GAC columns. Teflon© filter sizes used were 1 μm, 5 μm , and 10 μm. These filter disks needed to be replaced at least two times per week due to plugging. Replacement of the disks was a simple process and involved very little operational downtime.

GAC media plugging was not a significant problem initially during a filter run, however, due to the very long run times needed for most of the quarterly tests, media headloss became a problem towards the end of a run. This problem was overcome by gently scraping the GAC media surfaces to break-up the plugged GAC as necessary.

During testing, only two of the 10-min EBCT tests and one 20-min EBCT test was completed prior to one full-scale equivalent year of testing. The tests that were not stopped due to TOC breakthrough had filter runs that lasted for at least 48 real time tests days. TOC sampling for each test had to be performed daily to determine the breakthrough concentrations.

Daily TOC sampling was necessary to determine when a compliance sample should be collected. It was difficult to collect the compliance samples at 5 to 8 percent TOC increments as required by RSSCT guidelines. Many of the quarterly tests did not show significant breakthrough during one full-scale equivalent year, therefore, compliance samples had to be collected at evenly spaced time intervals during the last few weeks of testing. These samples did not always have TOC concentrations that met the 5 to 8 percent TOC increment criteria for sampling.

As usual, with any pilot- or bench-scale test system, there were minor leaks and equipment failures. Only one of the RSSCT tests, the Quarter no. 1 10-min study, had to be terminated and restarted due to equipment failure. Most of the equipment problems were easily corrected.

QA/QC SUMMARY

Most of the EPA required QA/QC data is included in the treatment summary spreadsheets, however, the calibration procedure for the following parameters are included in Table 10. These parameters are as follows:

- THMs
- HAAs
- TOC
- UV_{254}
- Bromide
- TOX

The table provides the method used and a description of the percent recovery calibration check, method blank, field/laboratory duplicates, lab fortified sample, and internal and surrogate standards.

Table 10

QC criteria for ICR samples

Method	Percent recovery calibration check	Method blank	Field/laboratory duplicate	Laboratory fortified sample	Internal std.	Surrogate std.
SM-6251 B EPA 552.2 Non-MCAA	1,20,40 µg/L 1 µg/L Response +/- 50% 20,40 µg/L Response +/- 20%	1/batch [8-10 hours] <0.5 µg/L per analyte				
SM 6251 B EPA 552.2 MCAA	2 µg/L Response +/- 50% 20, 40 µg/L Response +/- 20%	<1.0 µg/L per analyte	1 laboratory/batch of each extraction set	1/batch of samples	Within 30% of mean for all samples processed with same batch of diazomethane	Within 30% of mean for all samples processed with same batch of diazomethane
EPA-551.1 THMs	1 µg/L Response +/- 50% 20, 40 µg/L Response +/- 20%	1/batch [8-10 hours] <0.5 µg/L per analyte	1 field/batch of samples	1/batch of samples	Within 30% of daily calibration std.	Within 30% of mean for all samples within the same extraction set
SM-5910 UV_{254}	0.5 cm^{-1}* Response +/- 25% 6, 60 cm^{-1} Response +/-15%	Initial zero, with organic free water every 10^{th} sample	Laboratory dup. All samples ≤20% RSD ≤0.045 ≤10% RSD >0.045	No Requirement	No Requirement	No Requirement
300.0 Br^-	0.02 µg/L Response +/- 50% 0.1, 0.3 Response +/- 10%	1/batch [8-10 hours] <10 µg/L per analyte	Laboratory dup 5%/batch of samples	5% of sample in each batch	No requirement	No requirement
SM-5320-B TOX	50 µg/L Response +/- 25% 250, 500 µg/L Cl^- /L Response +/- 15%	<0.8 µg/L Cl^-/40 mg of activated carbon	All samples laboratory dup.	5% all samples analyzed each quarter	No requirement	No requirement
SM-5310 C TOC†	0.5 mg/L Response +/- 50% 4, 10 Response +/- 10%	1/batch [8-10 hours] <0.25 mg/L	Laboratory dup. (all samples) ≤10% RSD >2.0 mg/L ≤20% RSD ≤2.0 mg/L	5% of sample in each batch	No Requirement	No Requirement

*Potassium hydrogen phthalate (KHP) concentration (mg/L) is given as dissolved organic carbon (DOC)

†QC criteria during ICR treatment studies

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Table A.1

ICR RSSCT process projections

Utility Name:	City of Utica, NY		
Quarter number:	1		
Test date (start):	05/22/98		
Test date (end):	06/03/98		
Parameter	Variables	10-min EBCT	20-min EBCT
Diameter (large column)	d lc	1.1	1.1
Diameter (small column)	d sc	0.143	0.143
Scaling factor	SF	7.69	7.69
Empty bed contact time (small column)	EBCT sc	1.30	2.60
Reynolds number	Re sc	0.5	0.5
	bed porosity	0.45	0.45
	kinematic viscosity	1.002E-06	1.002E-06
Superficial velocity (small column)	v sc (m/h)	5.68	5.68
Media height (small column)	1 sc (cm)	12.3	24.6
Diameter (small column)	DC sc (cm)	0.8	0.8
Flow	Q sc (mL/min)	4.75	4.75
Mass of GAC	m sc (g)	3.1	6.2
Total organic carbon	TOC (mg/L)	1.83	1.83
Bed volumes to 50% breakthrough	BV 50	9,892	9,892
Time to 50% breakthrough	t 50 (days)	68.7	137.4
	t int (days	9.8	19.6
Full-scale breakthrough	t lc (days)	137.4	274.8
Bench-scale breakthrough	t sc (days)	17.9	35.7
Volume of water	V sc (L)	122.24	244.57
Excess volume	Total GAC volume (L)	158.91	317.95

Table A.2

ICR RSSCT process projections

Utility Name:	City of Utica, NY		
Quarter number:	2		
Test date (start):	08/11/98		
Test date (end):	09/28/98		
Parameter	Variables	10-min EBCT	20-min EBCT
Diameter (large column)	d lc	1.1	1.1
Diameter (small column)	d sc	0.143	0.143
Scaling factor	SF	7.69	7.69
Empty bed contact time (small column)	EBCT sc	1.30	2.60
Reynolds number	Re sc	0.5	0.5
	bed porosity	0.45	0.45
	kinematic viscosity	1.002E-06	1.002E-06
Superficial velocity (small column)	v sc (m/h)	5.68	5.68
Media height (small column)	1 sc (cm)	12.3	24.6
Diameter (small column)	DC sc (cm)	0.8	0.8
Flow	Q sc (mL/min)	4.75	4.75
Mass of GAC	m sc (g)	3.1	6.2
Total organic carbon	TOC (mg/L)	2.64	2.64
Bed volumes to 50% breakthrough	BV 50	6,143	6,143
Time to 50% breakthrough	t 50 (days)	42.7	85.3
	t int (days	6.1	12.2
Full-scale breakthrough	t lc (days)	85.3	170.6
Bench-scale breakthrough	t sc (days)	11.1	22.2
Volume of water	V sc (L)	75.91	151.88
Excess volume	Total GAC volume (L)	98.69	197.45

Table A.3

ICR RSSCT process projections

Utility Name:	City of Utica, NY		
Quarter number:	3		
Test date (start):	11/04/98		
Test date (end):	12/16/98		
Parameter	Variables	10-min EBCT	20-min EBCT
Diameter (large column)	d lc	1.1	1.1
Diameter (small column)	d sc	0.143	0.143
Scaling factor	SF	7.69	7.69
Empty bed contact time (small column)	EBCT sc	1.30	2.60
Reynolds number	Re sc	0.5	0.5
	bed porosity	0.45	0.45
	kinematic viscosity	1.002E-06	1.002E-06
Superficial velocity (small column)	v sc (m/h)	5.68	5.68
Media height (small column)	1 sc (cm)	12.3	24.6
Diameter (small column)	DC sc (cm)	0.8	0.8
Flow	Q sc (mL/min)	4.75	4.75
Mass of GAC	m sc (g)	3.1	6.2
Total organic carbon	TOC (mg/L)	1.96	1.96
Bed volumes to 50% breakthrough	BV 50	9,047	9,047
Time to 50% breakthrough	t 50 (days)	62.8	125.7
	t int (days	9.0	18.0
Full-scale breakthrough	t lc (days)	125.7	251.3
Bench-scale breakthrough	t sc (days)	16.3	32.7
Volume of water	V sc (L)	111.81	223.70
Excess volume	Total GAC volume (L)	145.35	290.81

Table A.4

ICR RSSCT process projections

Utility Name:	City of Utica, NY		
Quarter number:	4		
Test date (start):	03/23/99		
Test date (end):	05/07/99		
Parameter	Variables	10-min EBCT	20-min EBCT
Diameter (large column)	d lc	1.1	1.1
Diameter (small column)	d sc	0.143	0.143
Scaling factor	SF	7.69	7.69
Empty bed contact time (small column)	EBCT sc	1.30	2.60
Reynolds number	Re sc	0.5	0.5
	bed porosity	0.45	0.45
	kinematic viscosity	1.002E-06	1.002E-06
Superficial velocity (small column)	v sc (m/h)	5.68	5.68
Media height (small column)	1 sc (cm)	12.3	24.6
Diameter (small column)	DC sc (cm)	0.8	0.8
Flow	Q sc (mL/min)	4.75	4.75
Mass of GAC	m sc (g)	3.1	6.2
Total organic carbon	TOC (mg/L)	1.94	1.94
Bed volumes to 50% breakthrough	BV 50	9,169	9,169
Time to 50% breakthrough	t 50 (days)	63.7	127.3
	t int (days	9.1	18.2
Full-scale breakthrough	t lc (days)	127.3	254.7
Bench-scale breakthrough	t sc (days)	16.6	33.1
Volume of water	V sc (L)	113.31	226.70
Excess volume	Total GAC volume (L)	147.30	294.71

APPENDIX

DATA COLLECTION SPREADSHEETS

SUMMARY REPORT SPREADSHEETS