Acute Toxic Effects of Chlorinated
Primary Sewage Effluent
on
Brook Trout and Brown Trout
Manchester, Vermont
Batten Kill River

United States Environmental Protection Agency

EPA

Region I

NEW ENGLAND REGIONAL LABORATORY

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Conclusions

1. Chlorinated primary sewage effluent from the Town of Manchester, Vermont is acutely toxic to brown and brook trout.

2. Chlorine toxicity was exhibited over a range of total residual chlorine (TRC) concentrations to both trout species with median survival levels found at the 2 through 96 hour time intervals. Most mortalities occurred during the first 24 hours of exposure.

3. The estimated 96 hour LC_{50}'s for brown and brook trout are .04 mg/l and .06 mg/l TRC respectively.

4. Application of the acute toxicity information gathered in the study together with instream estimates of TRC concentrations derived from low flow data, and projected chlorination levels and discharge volumns indicates that acutely toxic TRC levels may occur in the Batten Kill downstream of the new Manchester waste water facility discharge.

5. Potential for low level chronic chlorine toxicity greatly increases at periods of low river flow. Long term fish productivity could be adversely affected in areas downstream of the chlorinated discharge.

Recommendations

1. To help insure the protection of the aquatic life and the salmonid fishery in the Batten Kill River, a maximum allowable TRC concentration of 0.1 mg/l should be adopted for the new Manchester WWTF secondary discharge during periods of low flow and other critical times such as the fall spawning for the indigenous trout species.

2. A flexible chlorination policy should be developed by the State of Vermont so that "end of the pipe" chlorine limits can be set on a case by case basis which both safeguards public health and protects aquatic life.

3. Dechlorination, seasonal chlorination, adoption of the 200/100ml fecal coliform standard and other disinfection techniques need to be evaluated by the State of Vermont as viable alternatives to across the board chlorine standards particularly for new and planned waste water treatment plants.

Introduction

In the State of Vermont chlorine toxicity has become an issue of concern, particularly in regard to rivers and streams which support Vermont's economically important salmonid sport fishery. Presently in Vermont, several municipalities have new waste water treatment facilities planned or in some phase of development in order to meet state and federal water quality standards. Where municipal waste water is discharged to streams for which the protection of aquatic and fisheries resources is of prime importance, water resource and fish and game authorities are being required to make important policy decisions regarding the usage of chlorine as a waste water disinfectant.

Although several investigations have been conducted (1,2,3) which demonstrate the toxicity of chlorine to aquatic life, no documented study has been performed which discusses the effects of a chlorinated discharge to a native Vermont stream. In view of this, the Vermont Agency of Environmental Conservation requested the assistance of the Environmental Protection Agency, New England Regional Laboratory to investigate the toxicity to trout of chlorinated waste water from the Manchester, Vermont waste water treatment plant located near the Batten Kill River.

On-line continuous flow 96-hour acute bioassays were performed by the Environmental Protection Agency during July 10 - 19, 1978 using brook trout and brown trout as the test animals, chlorinated primary sewage as the toxicant and the Batten Kill River water as diluent.

Coordinated live cage toxicity studies using trout, and analysis of benthic animal populations were performed by the Vermont Water Resources Division. The University of Vermont (D. Merrill) conducted studies on fish exposed to chlorinated waste water to determine mechanisms of chlorine toxicity in trout.

Manchester Waste Water Treatment Facility

The Waste Water Treatment Facility for Manchester, Vermont is an old primary plant consisting of a comminutor and wet well, a single primary clarifier, chlorinators, contact well and discharge pipe. The plant treats approximately 200-250 thousand gallons of domestic waste (little or no industrial waste) daily and operates on a fill and draw principle which results in an intermittent discharge to Bourne Brook, a tributary to the Batten Kill River. Chlorination is achieved by manually set mechanized chlorinators which cycle on and off according to the flow from the primary clarifier. In theory, the rate of chlorination is set based on the discharge volume in order to achieve a total residual chlorine (TRC) of approximately 1 mg/l. The TRC in the effluent was found to vary widely, however, depending on the time of day, and week, whether or not chlorinators were operating properly and to some extent the nature of the sewage. For example, on Sunday, July 16 at 12:50 p.m. the sewage before chlorination had a TRC in excess of 1 mg/l TRC. At present a new secondary waste water treatment facility for Manchester, Vermont is now operating with all construction nearly completed. The new plant disinfects with chlorine and discharges directly into the Batten Kill River. The old plant is to be phased out of operation and become a pumping station for the new plant.

Batten Kill River

The Batten Kill River is the most famous trout stream in the East and is prized by the State of Vermont as its number one blue ribbon trout water. The "Kill" has broad riffle areas, deep pools, narrow swift rips and deep channels with undercut banks. Most of the year it is a moderately flowing river, with peak flows occurring during spring runoff and low flows occurring during the dry summer months at which time the river is subject to a broad range of rise and fall during periods of intermittent heavy precipitation. During the July 1978 study period river temperatures ranged from 14-17°C and dissolved oxygen concentrations ranged from 5.6-8.8 mg/l. Normally, D. O. was in excess of 70% saturation. pH values ranged from 7.6-7.9 and conductivity was approximately 360 umhos/cm .

In addition to the discharge from the new Manchester WWTF, a planned WWTF for Arlington, Vermont will also discharge to the Batten Kill.

Table 1 lists the seven-day low flow data for the river at Arlington and Manchester, Vermont. By back calculation the flow data at Manchester was estimated using 7Q10 data provided by the State of Vermont and the USGS flow data for Arlington. It is assumed that the low flow varies similarly at Manchester and Arlington. Batten Kill water was used as the dilution water source and for fish acclimation.

Methods

EPA's "Methods for Measuring the Acute Toxicity of Effluents to Aquatic Organisms" (4) were generally followed. Bioassays were

Table 1

7 Q Low Flows For Batten Kill River

At Arlington and Manchester, Vermont

Year	Flow at Arlington[1] CFS	Flow at Arlington[1] mgd	Estimated Flow at Manchester CFS	Estimated Flow at Manchester mgd
1.01	129	83.4	45.8	29.6
1.11	94	60.8	33.3	21.5
1.25	84	54.3	30.4	19.6
2	68	43.9	24.1	15.6
5	56	36.2	19.9	12.9
10	51	33.0	18.1[2]	11.7
20	48	31.0	17.0	11.0
50	44	28.4	15.6	10.1
100	42	27.1	14.9	9.6

[1] Source USGS

[2] Source State of Vermont

conducted on location in a 28 foot mobile trailer equipped for continuous flow toxicity studies. (3) Chemical methods used were those recommended by EPA (5,6).

Measurement of total residual chlorine (TRC) in the Manchester primary waste water presented a problem. Apparently, high levels of organic matter cause residual chlorine to exist in a combined state. Considerable residual can exist in this form while chlorine demand simultaneously exists. Reagents added using the recommended procedures for TRC can alter these relationships causing the residual chlorine to be lost during analysis. (6) Although the Iodometric back titration method is recommended for waste water with high organic content, we found this method to give inconsistent TRC measurements.

By modifying the amount of reagents added (excess K I (1g), 4 ml pH 4 buffer) and performing an amperometric forward titration, we were able to achieve consistent TRC measurement with a relatively good accuracy level.

Test Organisms

Young of the year brown trout (*Salmo trutta*) and brook trout (*Salvelinus fontinalis*) were used as the test organisms. Both fishes were supplied by the Vermont Fish and Game from the Bennington State Fish Hatchery. The brown trout used initially, were in fair condition, most suffered from fin rot and some body lesions. The brook trout were in good condition and apparently healthy. Table 2 lists the mean weight and length of the fish including the standing and dynamic loading per exposure chamber.

Table 2

Test Animal Data

Test Species	Mean WT g	STD Dev.	Mean Length cm	STD Dev.	Loading Standing g/l	Loading Dynam. g/l
Brown trout *Salmo trutta*	35.9	11.3	15.6	1.7	18	.7
Brook trout *Salvelinus fontinalis*	33.6	10.8	14.9	1.1	16.8	.65

Test Design

Short-term 24 hour and 96 hour exposure times were used to measure the acute toxic effects of chlorine disinfected primary sewage on brook trout and brown trout. Initially the test was solely designed as a 96 hour bioassay using brown trout, during operation of the assay most of the fish died within the first 24 hours except the controls and those exposed to the lowest chlorine concentrations. The study was then extended into a second phase with some major modifications. Because the brown trout had visible signs of impaired health, they were replaced as the test animal with the healthier appearing brook trout.

To reduce the toxicity of the chlorinated waste water so that a definitive 96 hour bioassay could be performed, the effluent was prediluted. This was accomplished by continuously pumping dilution water and chlorinated effluent into a 280 gallon tank at a ratio of approximately 7 parts diluent to 1 part effluent. This also served the added purpose of smoothing out sudden changes of TRC which would have affected test results. Even with this, broad daily fluctuations in TRC did occur. Figure 1 demonstrates the range of chlorine concentrations to which fish were exposed over a 96 hour period for the 12.5% and 25% prediluted effluent tanks.

Results

The bioassay results for Phase I using brown trout and for Phase II using brook trout are listed in Tables 3 and 4, and 5 and 6, respectively. For each of the studies two data sets are presented, one for each replicate analysis using ten fish and the combined results of the replicates using 20 fish. Also included are the mean values for the chemical and

Figure 1

Fluctuating Total Residual Chlorine Concentrations
At Two Exposure Levels - Manchester, Vermont 7/78

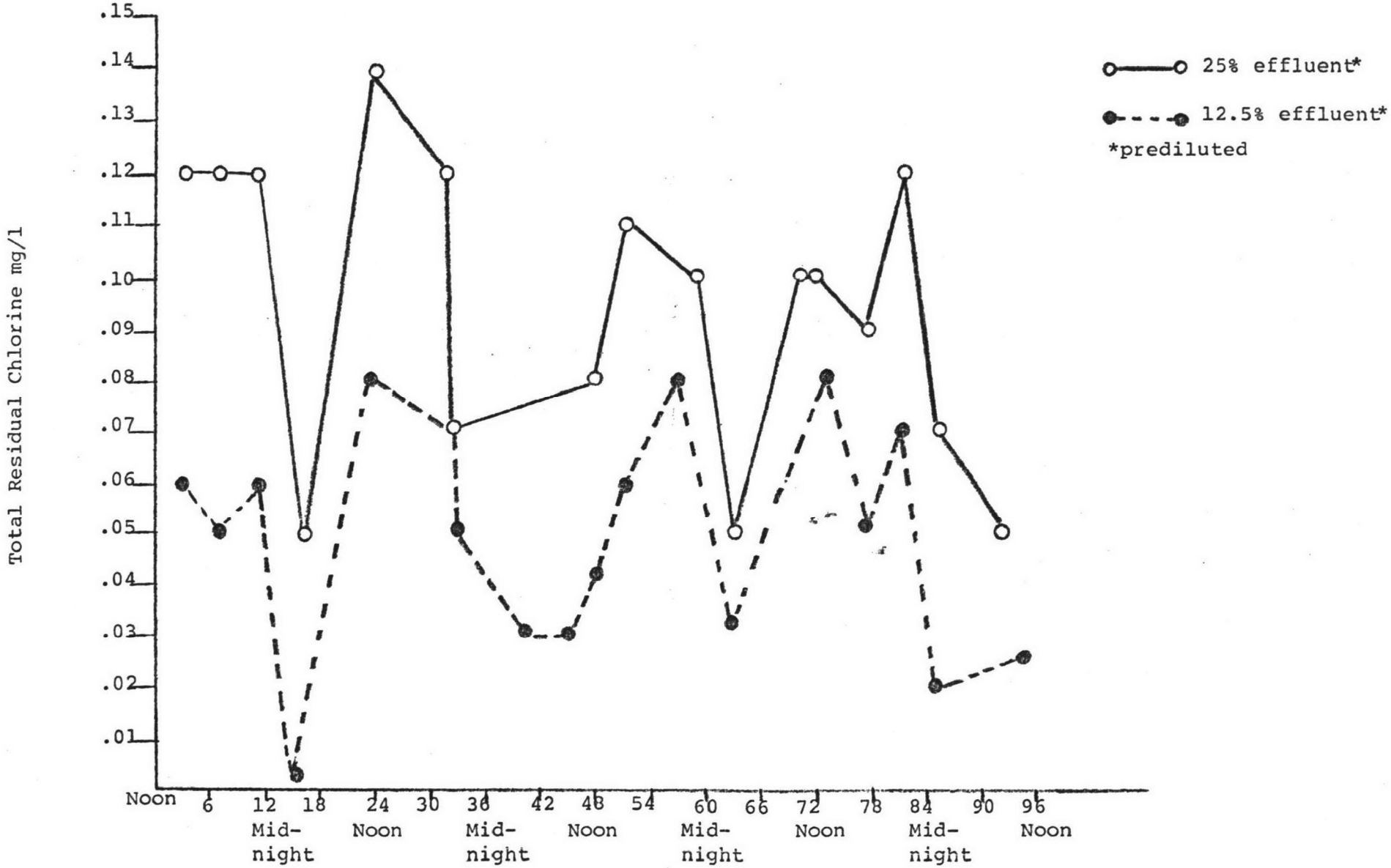


Table 3

Results: Chlorine Toxicity Study Manchester, Vermont, July 1978
Batten Kill River Phase I

Effluent	Tank #	#Test Species	Mean TRC mg/l	Mean T°C	Mean Ph	Mean D.O. ppm	No. of Brown Trout (*Salmo trutta*) Dead At 2hr.	4hr.	6hr.	8hr.	12hr.	24hr.	48hr.	72hr.	96hr.
100	01	10	0.51	17.9	7.68	8.13	10								
100	02	10	0.39	17.5	7.63	8.48	10								
87.5	03	10	0.56	17.3	7.67	8.29	10								
87.5	04	10	0.56	17.4	7.73	8.76	10								
75	05	10	0.49	17.5	7.75	8.32	10								
75	06	10	0.50	17.3	7.75	8.27	10								
66.7	07	10	0.50	16.7	7.72	8.10	10								
66.7	08	10	0.50	17.4	7.59	7.78	10								
50	09	10	0.34	16.4	7.70	7.49	5	10							
50	10	10	0.33	16.5	7.79	7.44	2	10							
33.3	11	10	0.24	16.4	7.73	7.20	0	9	10						
33.3	12	10	0.23	16.0	7.69	6.60	0	4	10						
25	13	10	0.14	16.5	7.80	7.59	0	0	4	6	9	10			
25	14	10	0.17	16.7	7.76	7.86	0	1	4	7	10	10			
12.5	15	10	0.08	16.5	7.70	5.89	0	0	0	0	1	8			
12.5	16	10	0.06	16.5	7.68	5.96	0	0	0	0	1	3			
0	17	10	0.00	16.0	7.84	6.50	0	0	0	0	0	0			
0	18	10	0.00	16.1	7.83	6.01	0	0	0	0	0	0			

Table 4

Combined Results: Chlorine Toxicity Study Manchester, Vermont, July 1978
Batten Kill River Phase I

Effluent	Tank #	#Test Species	Mean TRC mg/l	Mean T°C	Mean Ph	Mean D.O. ppm	No. of Brown Trout (*Salmo trutta*) Dead At 2hr.	4hr.	6hr.	8hr.	12hr.	24hr.	48hr.	72hr.	96hr.
100	01 02	20	0.45	17.7	7.65	8.30	20								
87.5	03 04	20	0.56	17.4	7.70	8.52	20								
75	05 06	20	0.50	17.4	7.75	8.30	20								
66.7	07 08	20	0.50	17.0	7.66	7.94	20								
50	09 10	20	0.34	16.4	7.74	7.46	7	20							
33.3	11 12	20	0.24	16.2	7.71	6.90	0	13	20						
25	13 14	20	0.16	16.6	7.78	7.72	0	1	8	13	19	20			
12.5	15 16	20	0.07	16.5	7.69	5.92	0	0	0	0	2	11			
0	17 18	20	0.00	16.0	7.84	6.26	0	0	0	0	0	0			

Table 5

Results: Chlorine Toxicity Study Manchester, Vermont, July 1978
Batten Kill River Phase II

Effluent	Tank #	#Test Species	Mean TRC mg/l	Mean T°C	Mean Ph	Mean D.O. ppm	No. of Eastern Brook Trout (Salvelinus fontinalis) Dead At: 2hr.	4hr.	6hr.	8hr.	12hr.	24hr.	48hr.	72hr.	96hr.
100	01	10	0.43	15.0	7.58	7.15	1	10							
100	02	10	0.42	15.1	7.52	7.35	4	10							
87.5	03	10	0.50	15.0	7.60	6.9	1	10							
87.5	04	10	0.50	15.2	7.65	6.8	5	10							
75	05	10	0.41	15.2	7.61	6.0	1	9	10						
75	06	10	0.39	14.8	-	6.0	2	9	10						
66.7	07	10	0.36	13.9	7.59	-	1	8	10						
66.7	08	10	0.33	16.2	7.57	6.41	0	6	10						
50.0	09	10	0.26	14.7	7.53	5.7	0	0	5	10					
50.0	10	10	0.26	14.5	7.72	7.31	0	0	1	10					
33.3	11	10	0.18	15.0	7.71	6.8	0	1	1	2	9	10			
33.3	12	10	0.14	15.3	7.76	7.76	0	0	0	0	5	10			
25	13	10	0.11	14.8	7.76	7.28	0	0	0	0	0	0	10		
25	14	10	0.095	15.4	7.76	6.96	0	0	0	0	0	0	7	10	
12.5	15	10	0.048	15.3	7.74	6.63	0	0	0	0	1	1	1	2	2
12.5	16	10	0.044	15.3	7.72	6.41	0	0	0	0	0	0	0	0	0
0	17	10	0.0	15.0	7.81	6.63	0	0	0	0	0	0	0	0	0
0	18	10	0.0	14.9	7.80	6.81	0	0	0	0	0	0	0	0	0

Table 6

Combined Results: Chlorine Toxicity Study Manchester, Vermont, July 1978
Batten Kill River Phase II

Effluent	Tank #	#Test Species	Mean TRC mg/l	Mean T°C	Mean Ph	Mean D.O. ppm	No. of Eastern Brook Trout (*Salvelinus fontinalis*) Dead At: 2hr.	4hr.	6hr.	8hr.	12hr.	24hr.	48hr.	72hr.	96hr.
100	01 02	20	0.42	15.0	7.55	7.25	5	20							
87.5	03 04	20	0.50	15.1	7.62	6.85	6	20							
75	05 06	20	0.40	15.0	7.61	6.00	3	18	20						
66.7	07 08	20	0.34	15.0	7.58	6.41	1	14	20						
50	09 10	20	0.26	14.6	7.62	6.50	0	0	6	20					
33.3	11 12	20	0.16	15.2	7.74	7.28	0	1	1	2	14	20			
25	13 14	20	0.10	15.1	7.76	7.12	0	0	0	0	0	0	17	20	
12.5	15 16	20	0.046	15.3	7.73	6.52	0	0	0	0	1	1	1	2	2
0	17 18	20	0.0	15.0	7.80	6.72	0	0	0	0	0	0	0	0	0

physical parameters tested and mortalities totalled for a specified time interval.

From this data the LC_{50} can be determined for a period of time. Figures A1 - A6 appended are representative plots used to estimate the LC_{50}'s for both Phase I and Phase II.

LC_{50}'s

Table 7 lists the estimated LC_{50} values for Phase I and Phase II using 20 test animals. Brown trout (*Salmo trutta*) overall have lower LC_{50}'s particularly during the first 24 hours of testing. For the 48, 72, and 96 hour time intervals the LC_{50} data for Phase I was extrapolated from the toxicity curve shown in Figure 2, extended from real data plotted for 24 hours. Figure 3 is the toxicity curve drawn for Phase II. The likeness of the two curves indicates that both trout species exhibit a similar toxic response to chlorinated primary sewage although at slightly different concentrations. For both test organisms the greatest toxicity is exhibited during the first 24 hours of exposure. With respect to time both toxicity curves approach the asymptote at 72 hours and reach it at about 96 hours. The concentration at which this occurs is often referred to as the incipient lethal dose or the concentration and time at which 50% of test animals can live indefinitely. This information gives an idea of concentration of TRC at which acute toxicity ceases and sublethal effects begin and can be of practical value for predicting and identifying potential instream problems where fish and aquatic life are endangered.

The somewhat greater sensitivity to TRC by brown trout versus

Table 7

Manchester Vermont, Batten Kill River
LC_{50} Results [1]
Total Residual Chlorine mg/l

Time		Phase I	Phase II
Hours	Days	*Salmo trutta*	*Salvelinus fontinalis*
2		.37	.42
4		.22	.32
6		.17	.28
8		.13	.20
12	.5	.10	.14
24	1	.06	.08
48	2	.05*	.07
72	3	.05*	.06
96	4	.04*	.06

[1] Based on 20 test animals
* Estimated from Phase I toxicity curve

Figure 2

Toxicity Curve From LC_{50}'s
Phase I - Brown Trout

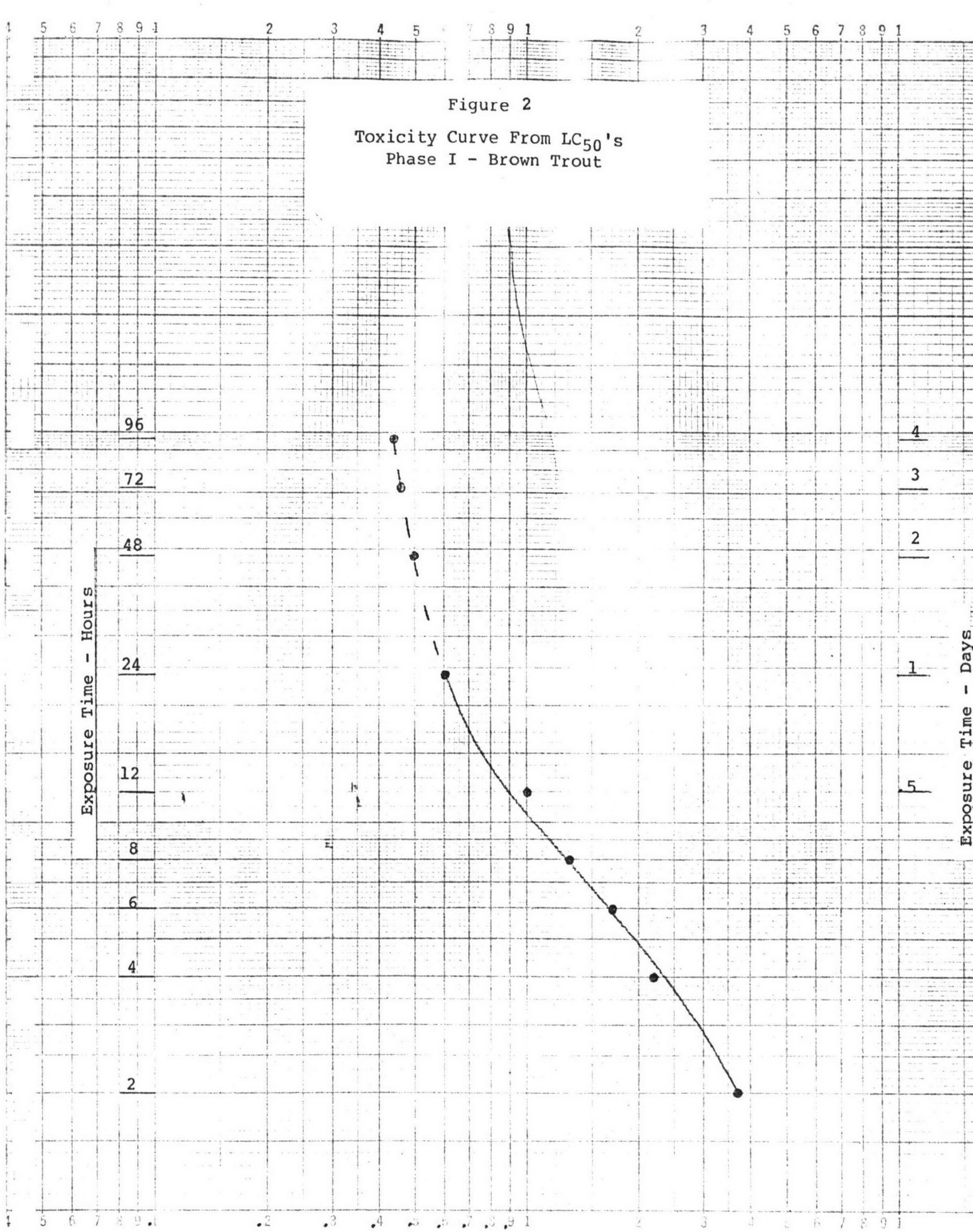
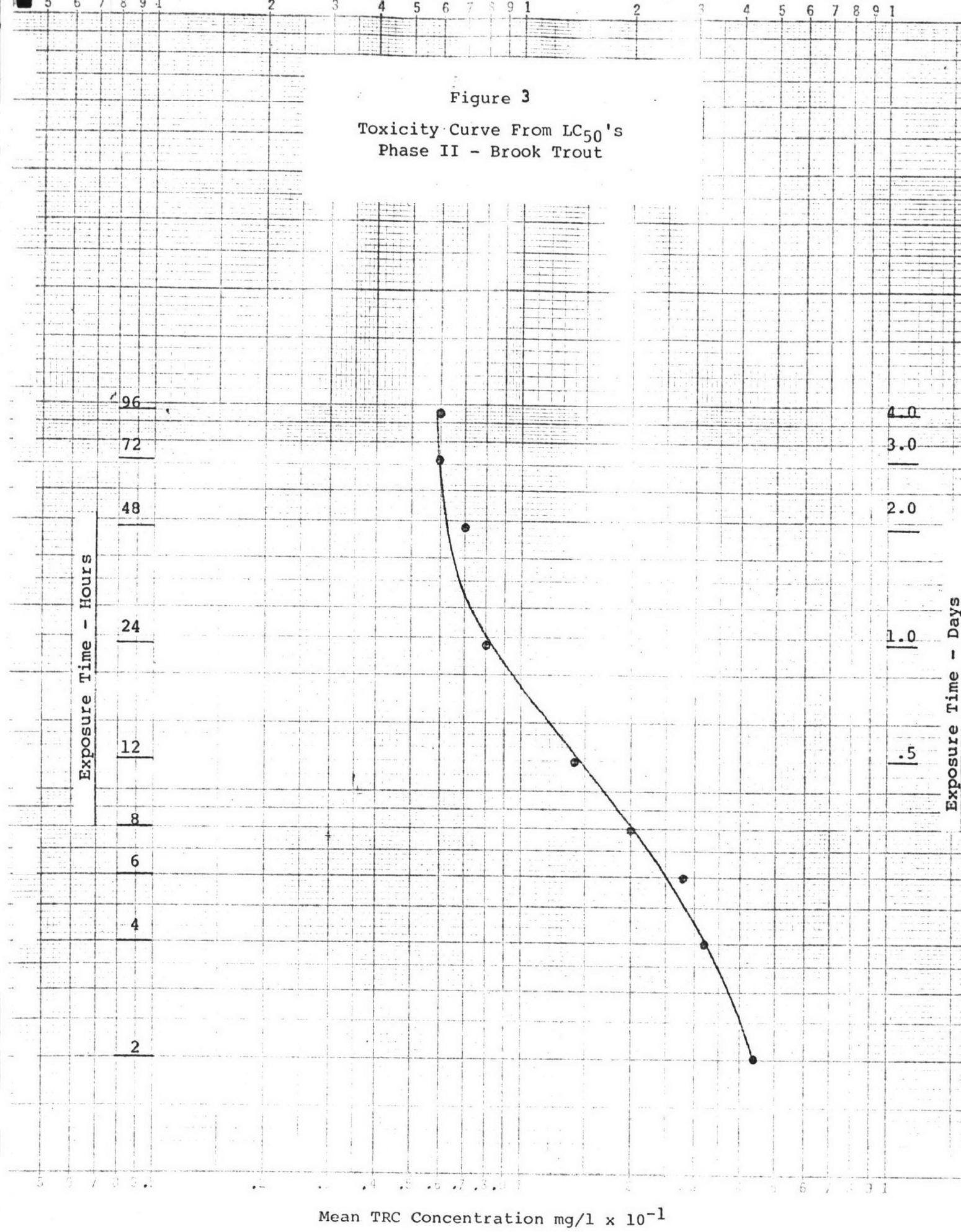


Figure 3

Toxicity Curve From LC_{50}'s
Phase II - Brook Trout



brook trout may be the result of many factors. The weakened condition of the browns, because of fin rot and body lesions, the test design - where Phase II exposures using brook trout were made with prediluted waste and Phase I was not, and a species specific response are among the possible explanations.

Discussion

In Vermont, fishing and related activities generates approximately sixty-three million dollars to the general economy of the State. (7) The Batten Kill River reportedly realizes some $50,000.00 per fishable mile, (8) and is the State's top rated trout stream. Presently, a new secondary waste water treatment facility is on line in Manchester, Vermont. Treated effluent is discharged into the Batten Kill River and chlorination is used for disinfection. A new WWTF is currently in the planning stage for the Town of Arlington, Vermont, located approximately 14.4 kilometers (9 miles) downstream. This plant as well will discharge into the Batten Kill and chlorination is being considered for disinfection.

When chlorine enters a stream its fate is not entirely known, some is lost through dilution, dissapation and volatilization. Other chlorine complexes such as chloramines and haloforms formed during chlorination may persist in time at low concentrations. In actual field conditions measurement of total residual chlorine below .01 mg/l is not easily accomplished with conventional methods. Often, estimates of instream chlorine concentrations are only possible by calculation. Figure 4 and 5 illustrate instream TRC values calculated for the Batten Kill at

Figure 4

Theoretical In Stream TRC Concentrations VS. 7Q Low Flows for Three WWTP Discharge Volumes at 1 mg/l TRC-Battenkill River at Arlington, Vermont

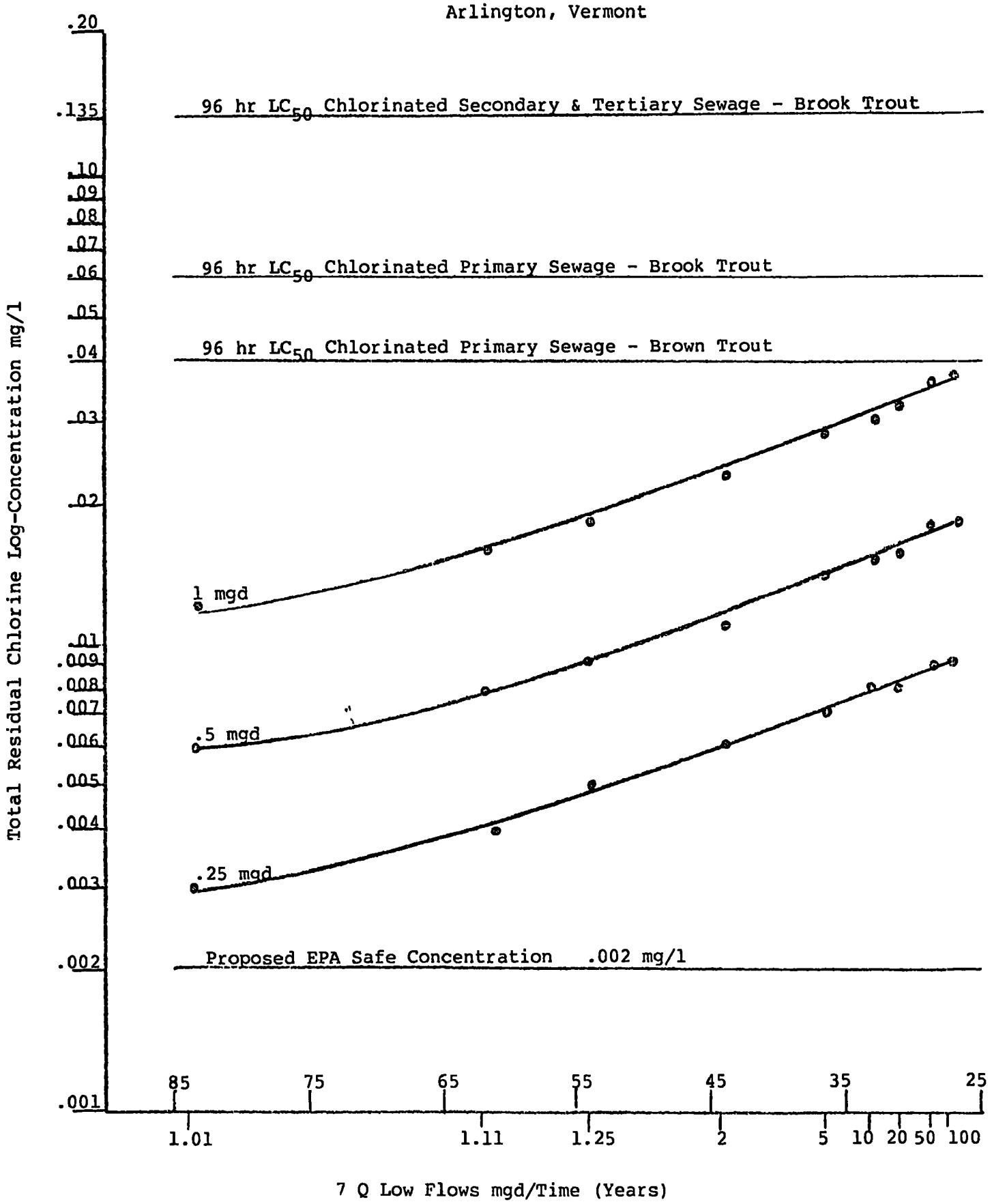
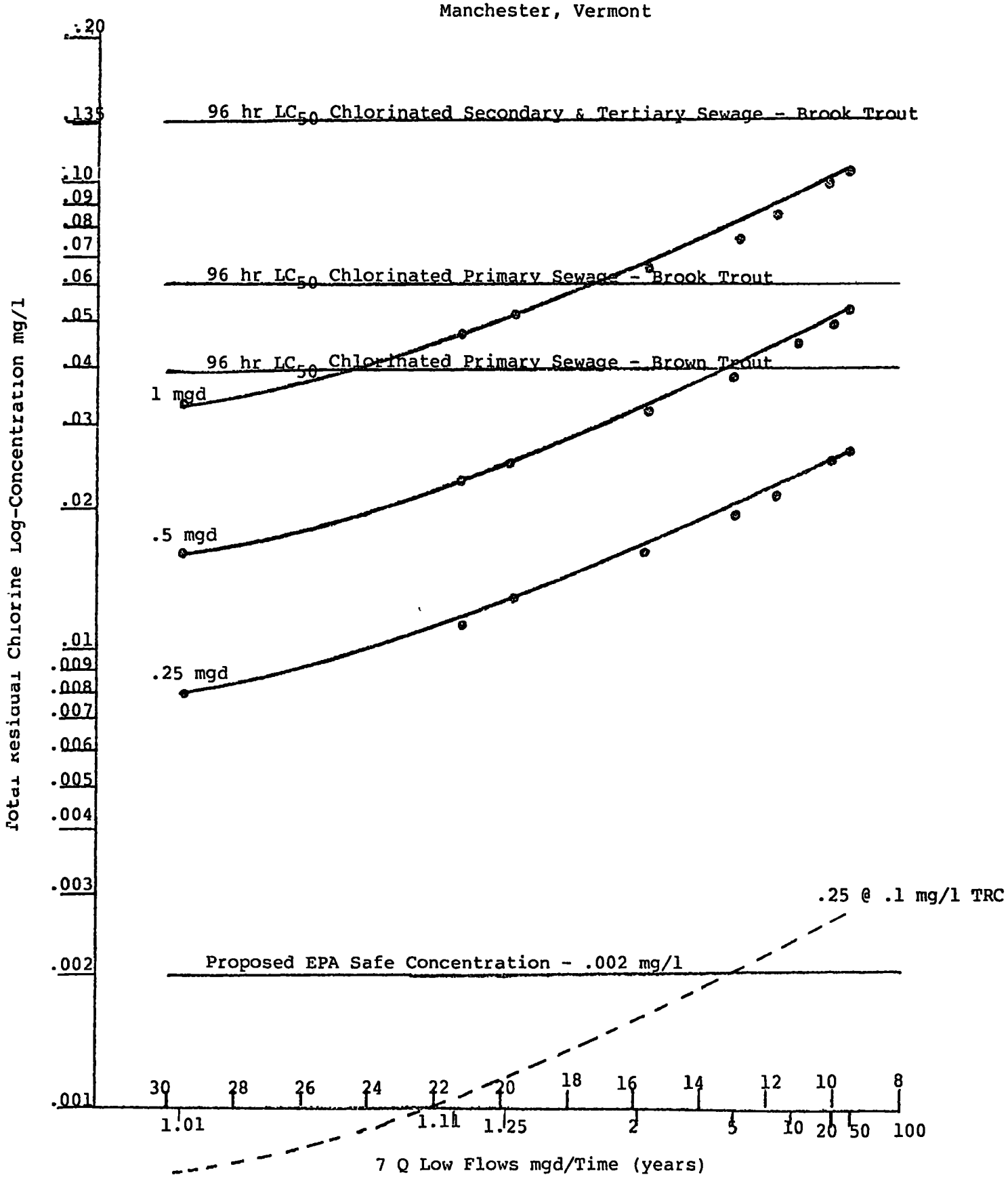


Figure 5

Theoretical In Stream TRC Concentrations VS. 7Q Low Flows for Three WWTP Discharge Volumes at 1 mg/l TRC-Battenkill River at Manchester, Vermont



Arlington and Manchester, Vermont using a total residual chlorine standard of 1 mg/l, discharge volumes of .25, .5 and 1 mgd, and the 1.01 - 100 year 7 day low flows. Acute toxic responses of trout to chlorinated secondary (2) and tertiary (3) waste water are delineated with the toxicity information generated for this study. The recommended EPA criteria of .002 mg/l (2.0 ug/l) for salmonid fish is also delineated.

Under Vermont's existing chlorination regulations total residual chlorine discharged from the new Manchester plant would likely be in the range of 1-4 mg/l. Using TRC values of this magnitude with the above flow and discharge volumes, instream concentrations of TRC are given in Table 8 specifically for the Batten Kill River at Manchester.

Figures 4 and 5 and Table 8 are intended to serve as guidelines with which to predict potential impact on aquatic life in the Batten Kill caused by total residual chlorine and as well to assist in making judgements regarding chlorination policy. Practical application of the LC_{50} data generated using primary chlorinated sewage, Batten Kill water and brown and brook trout with the theoretical instream TRC values, indicates that acutely toxic levels of TRC may be approached under low flow conditions. It is also apparent that during most periods of low flow sub-acute and chronic TRC concentrations exist. Fish populations can be affected by low levels of chlorine through decreased reproduction, reduced growth rates and eventual death. Fish egg and larval stages tend to be most sensitive to chronic levels of TRC with hatchability and survivability being affected.

The Vermont Fish and Game presently does not stock trout into the

Table 8

Calculated Instream Total Residual Chlorine Concentrations for 7Q Low Flows at Various Discharge Volumes and TRC Values - Batten Kill River, Manchester, Vt.

Flow			.25 mgd Discharge .15			.5 mgd Discharge TRC mg/l			1.0 mgd Discharge TRC mg/l		
Year	CFS	mgd	TRC mg/l			1.0	2.0	4.0	1.0	2.0	4.0
			1.0	2.0	4.0						
1.01	45.8	33.0 29.6	.005 .008	.009 .016	.032	.017	.034	.068	.034	.068	.136
1.11	33.3	21.5	.012	.024	.048	.023	.046	.092	.046	.092	.184
1.25	30.4	19.6	.013	.026	.052	.025	.050	.110	.05	.10	.20
2	24.1	15.6	.016	.032	.064	.032	.064	.128	.064	.128	.256
5	19.9	12.9	.019	.038	.076	.039	.078	.156	.077	.154	.308
10	18.1	11.7	.021	.042	.084	.043	.086	.172	.085	.170	.34
20	17.0	11.0	.023	.046	.092	.045	.090	.180	.090	.180	.36
50	15.6	10.1	.025	.050	.10	.05	.10	.20	.10	.20	.40
100	14.9	9.6	.026	.052	.104	.052	.104	.208	.104	.208	.416

Batten Kill River. Fish populations are sustained totally through natural propagation. This together with the economic considerations involved, indicates that even a small loss in the stream's fish productivity because of chlorine toxicity would have an unacceptable impact on the sport fishery in the Batten Kill River.

EPA's proposed safe TRC concentration of .002 mg/l for salmonid fish should be applied to the Batten Kill River because of the naturally reproducing trout population that exists there. A TRC discharge limit for the new Manchester facility not to exceed .1 mg/l at a projected discharge volume of .5 mgd would place estimated instream TRC values within the same magnitude as the recommended safe concentration. This effluent limit should be applied during periods of low flow and at other critical times such as the fall spawning time for brown and brook trout. The .1mg/l TRC level should be manageable from both an operational point of view and it is well within the detection limits of most approved and commonly used analytical methods. (6)

From the foregoing, accomplishments in this direction will require the development of a flexible chlorination policy by the State of Vermont so that "end of the pipe" chlorine limits can be set on a case by case basis which both safeguard public health and protect aquatic life. Dechlorination, seasonal chlorination, adoption of the 200/100 ml fecal coliform standard, and alternative disinfection techniques used separately or in some combination need to be evaluated for implementation into the operation of not only Manchester's new treatment plant but for all others as well where chlorine toxicity in receiving waters is considered a potential hazard.

References

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3. Nolan, P.M. , A. Johnson, 1977. Chlorine Toxicity Study, Mad River, Waterville Valley, N. H., U.S. Environmental Protection Agency, Region I, New England Regional Laboratory, Lexington, Mass. April 1977, 48 pp.

4. U.S. Environmental Protection Agency, 1978, Methods for Measuring the Acute Toxicity of Effluents to Aquatic Organisms. U.S. Environmental Protection Agency, Environmental Monitoring & Support Laboratory, Cincinnati, EPA-600/4-78-012, July 1978, 52 pp.

5. U.S. Environmental Protection Agency. 1974 Methods for Chemical Analysis of Water and Wastes. U.S. Environmental Protection Agency, National Environmental Research Center, Methods Development and Quality Assurance Research Laboratory, Cincinnati, 298 pp.

6. American Public Health Association 1976. Standard Methods for the Examination of Water and Wastewater, 14th Edition, Washington, D.C. 1193 pp.

7. Correspondence File, Vermont Department of Fish and Game, Letter Dated January 19, 1978.

8. Personal Communication, Vermont Fish and Game 3/28/79.

9. U.S. Environmental Protection Agency, 1976. Quality Criteria for Water, U. S. Environmental Protection Agency, Washington, D. C. EPA-440/9-76-023, 501 pp.

APPENDIX

Figure A1

Plotted Data Phase I @ 12 hr.
Log-Concentration vs. % Survival

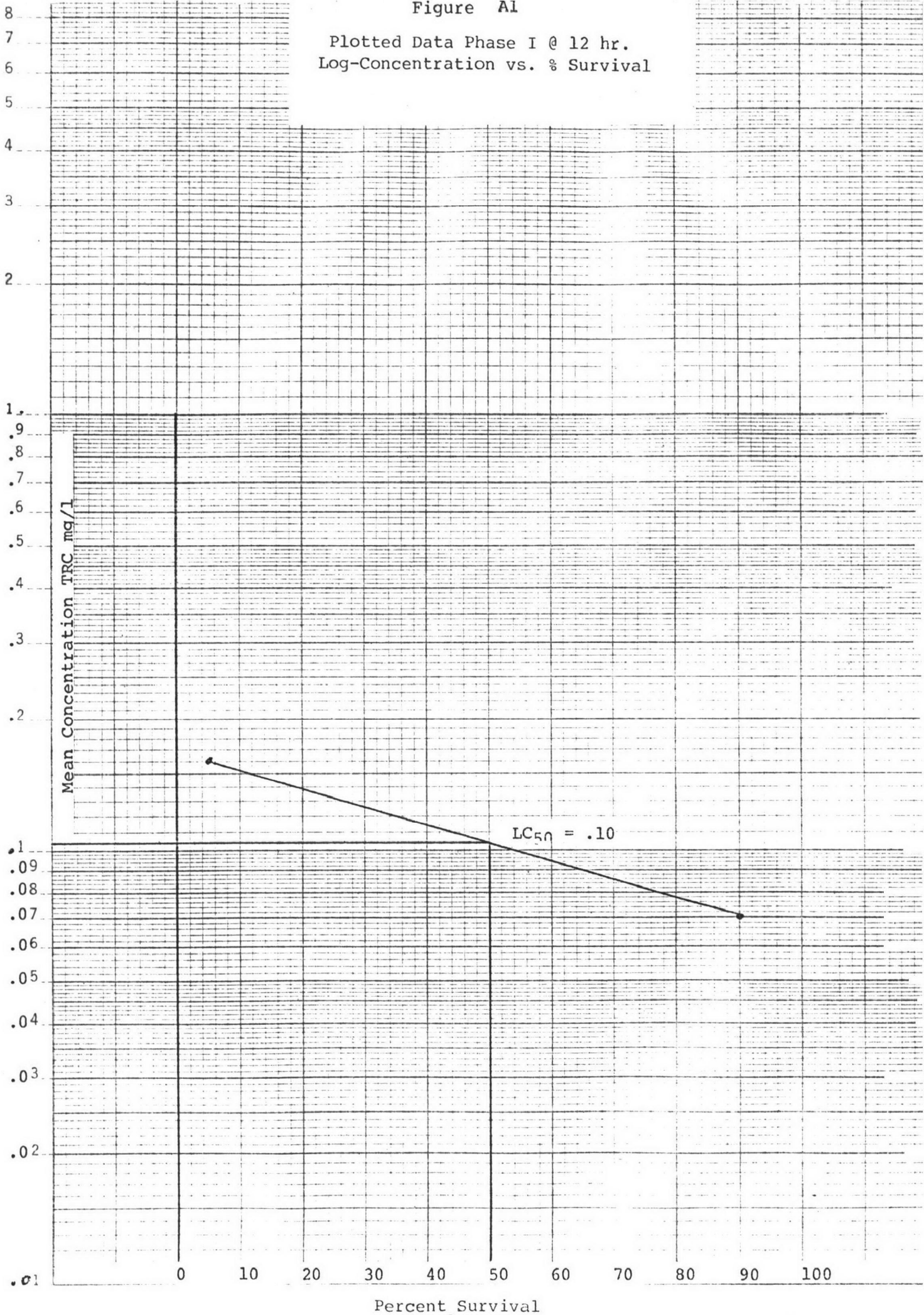


Figure A2

Plotted Data Phase I @ 24 hr.
Log-Concentration vs. % Survival

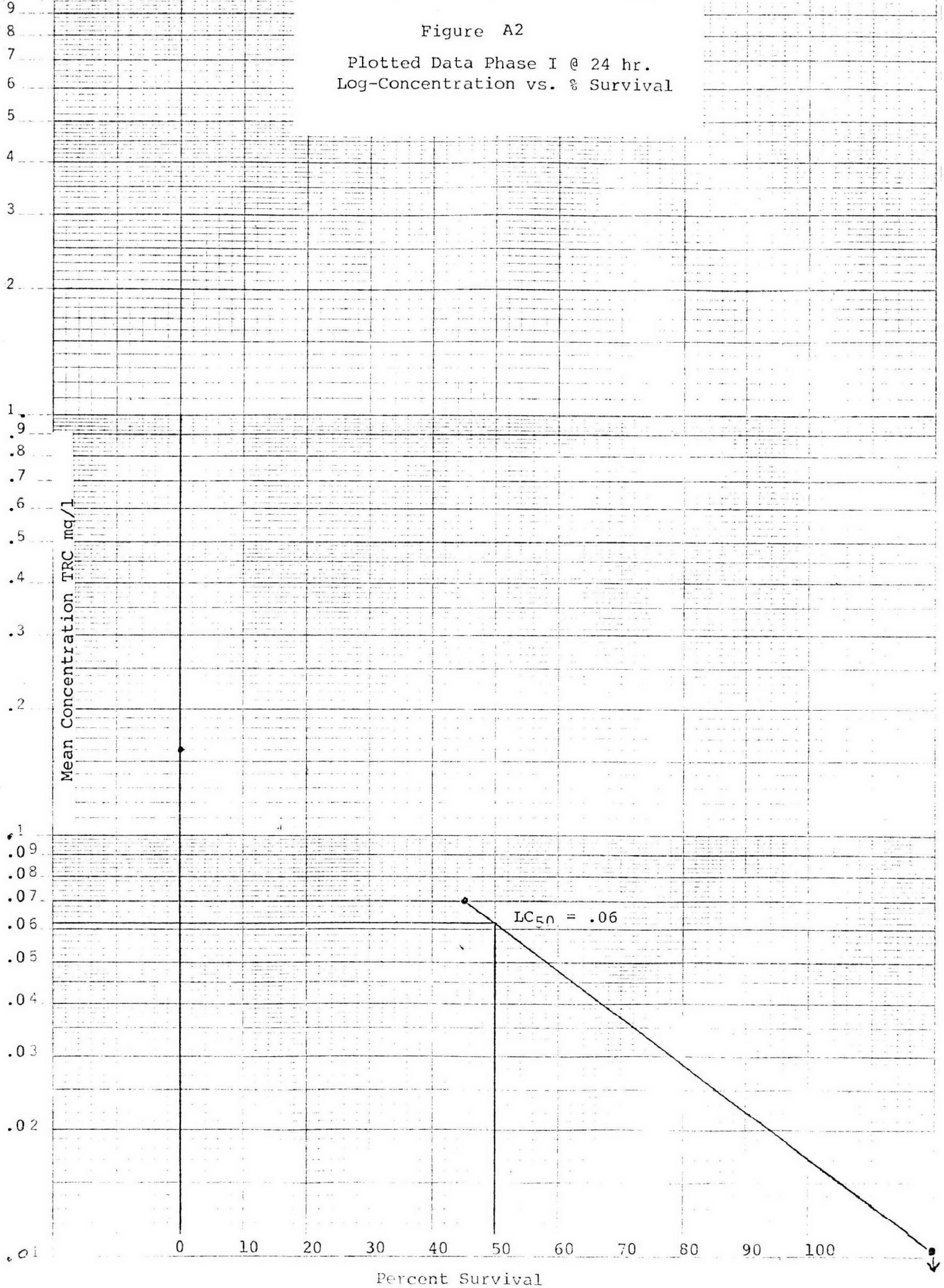


Figure A3

Plotted Data Phase II @ 12 hr.
Log-Concentration vs. % Survival

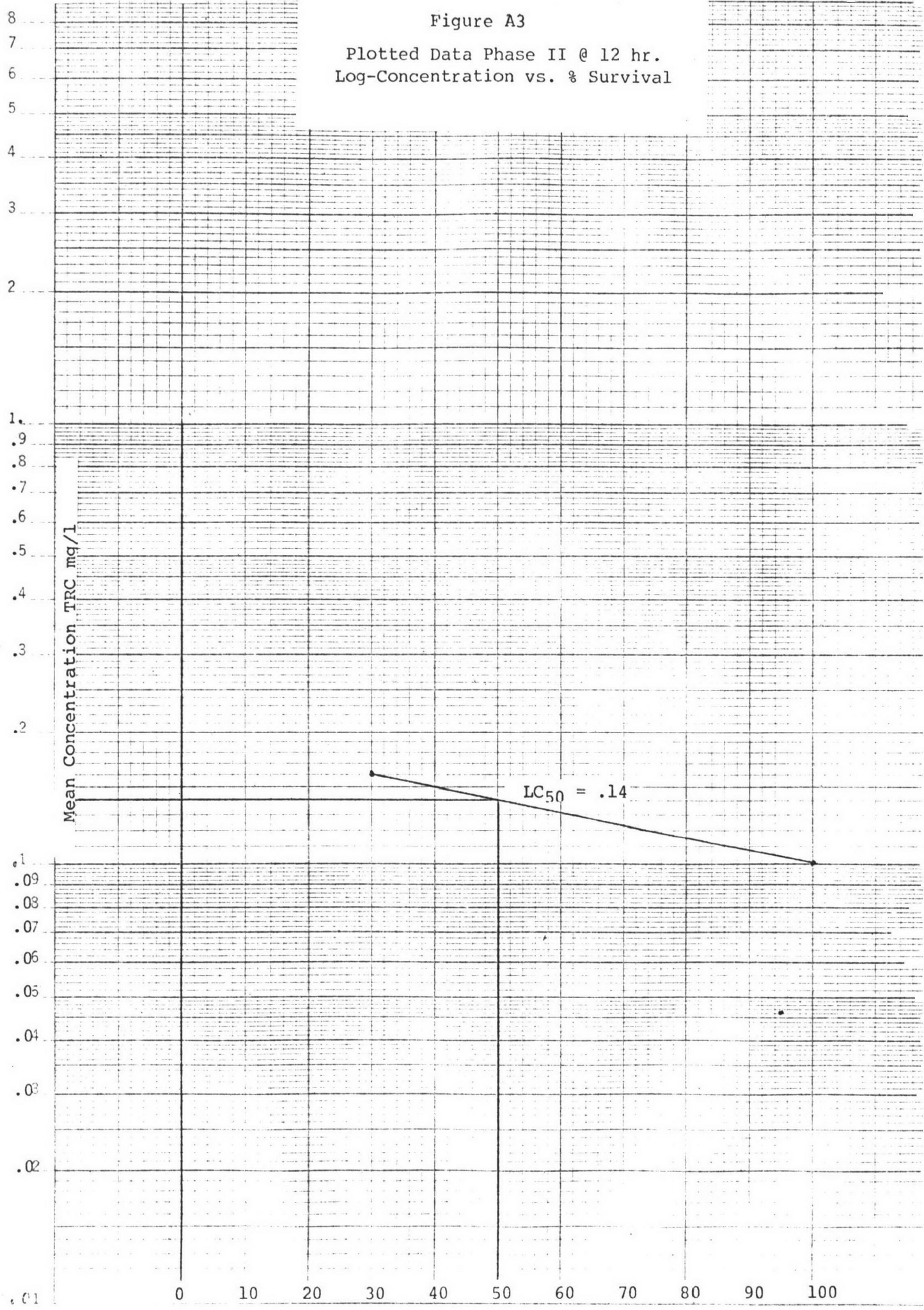
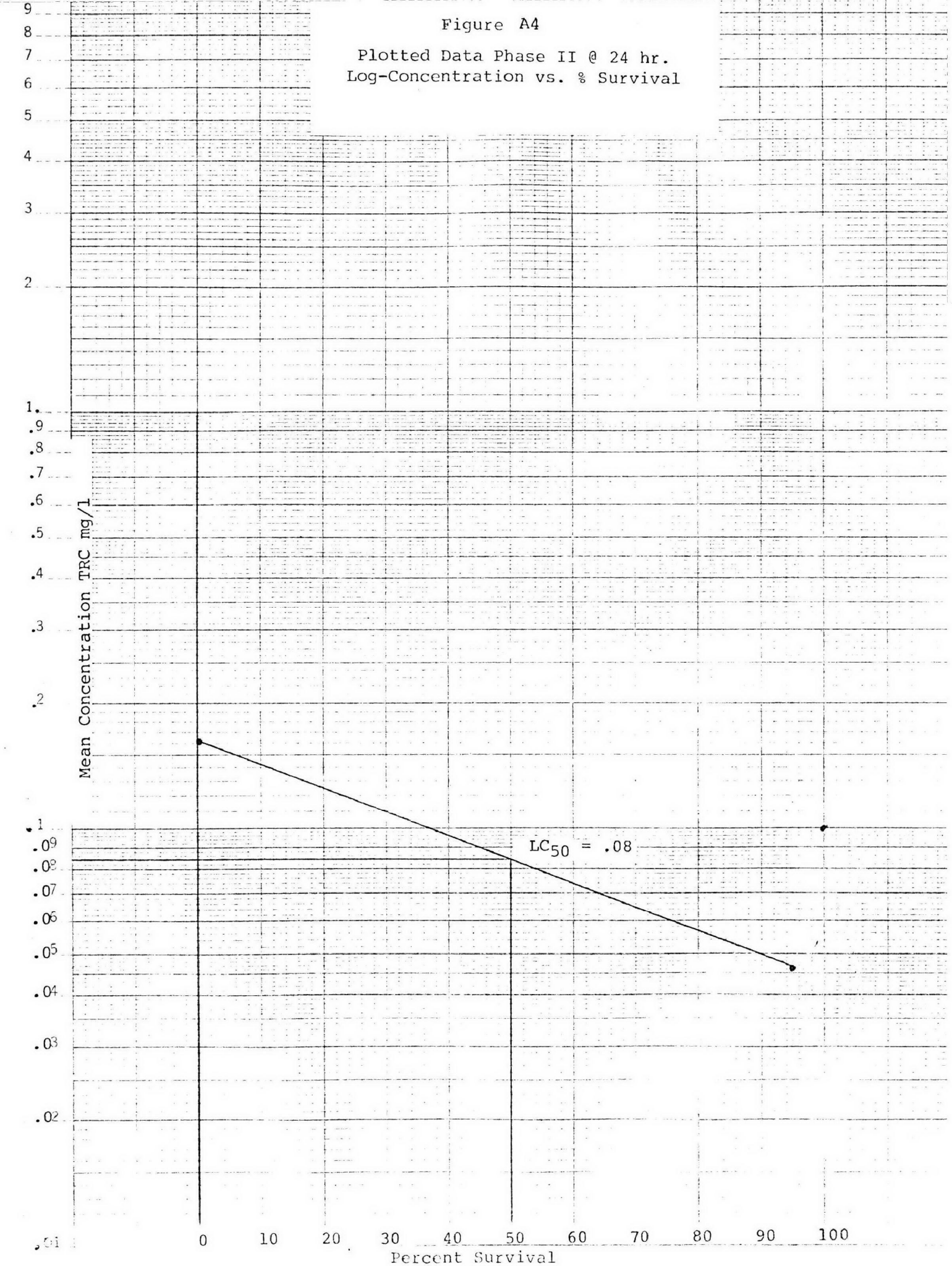
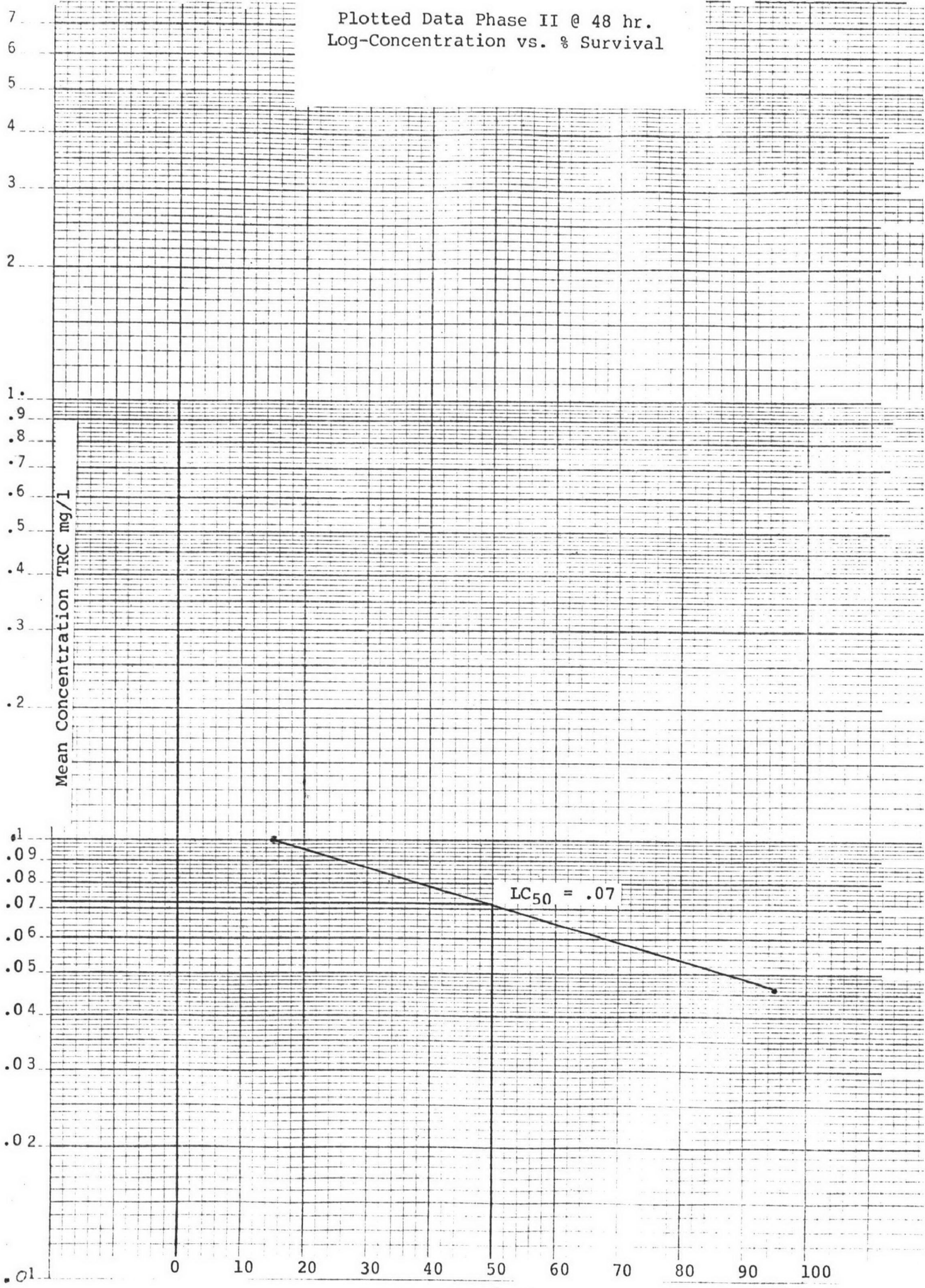
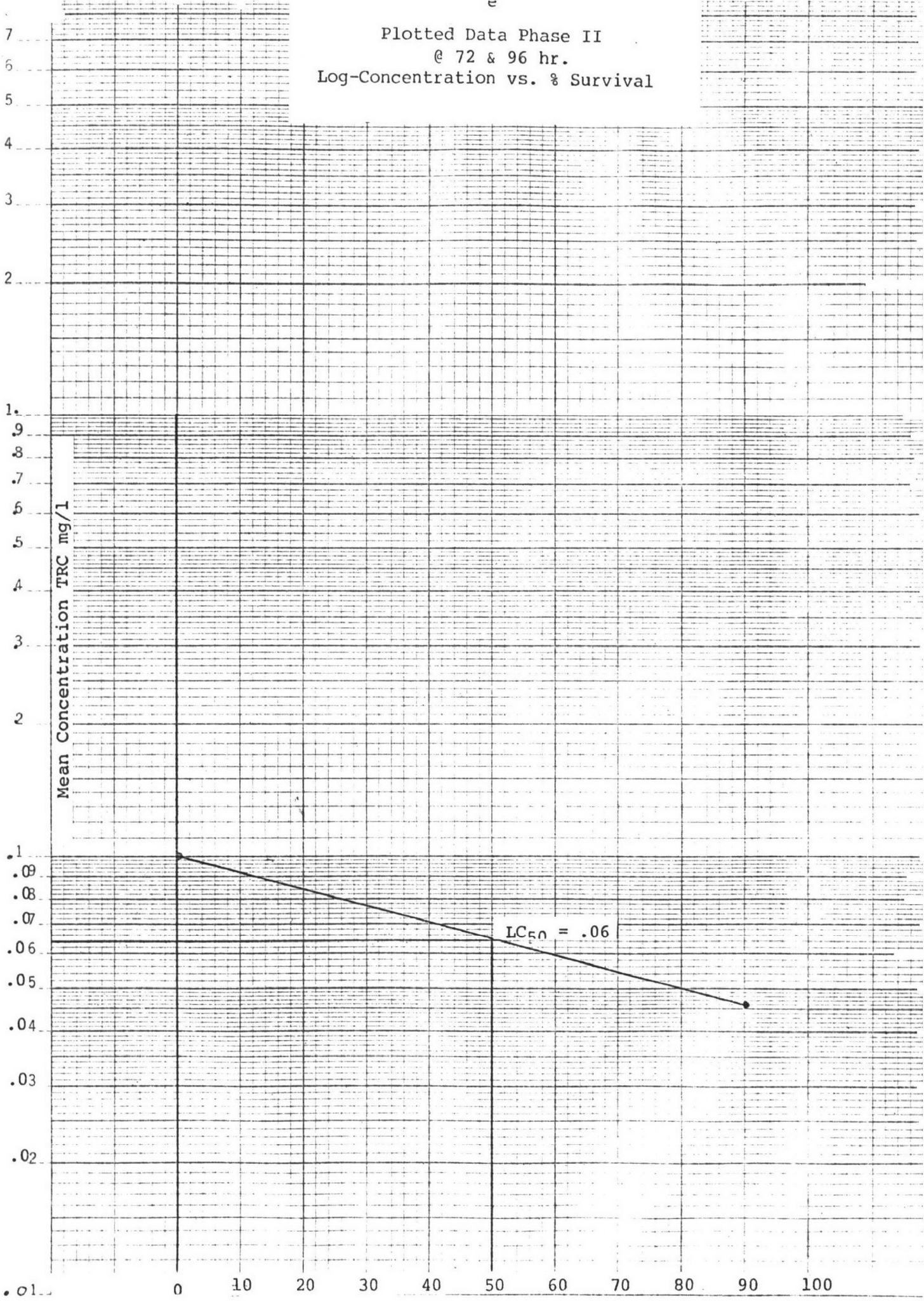


Figure A4

Plotted Data Phase II @ 24 hr.
Log-Concentration vs. % Survival




Plotted Data Phase II @ 48 hr.
Log-Concentration vs. % Survival
Mean Concentration TRC mg/l
7
6
5
4
3
2
1.
.9
.8
.7
.6
.5
.4
.3
.2
.1
.09
.08
.07
.06
.05
.04
.03
.02
.01
LC50 = .07
0
10
20
30
40
50
60
70
80
90
100
Percent Survival

Plotted Data Phase II
@ 72 & 96 hr.
Log-Concentration vs. % Survival