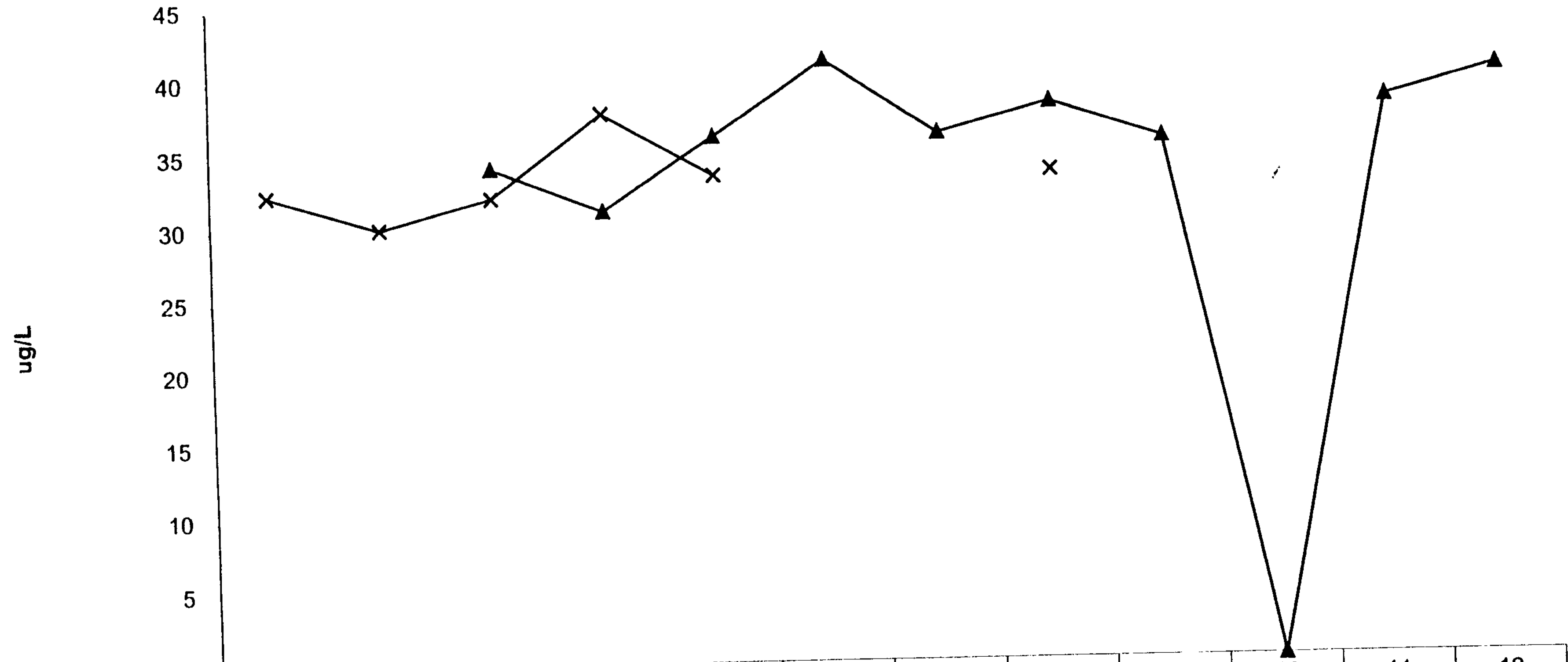
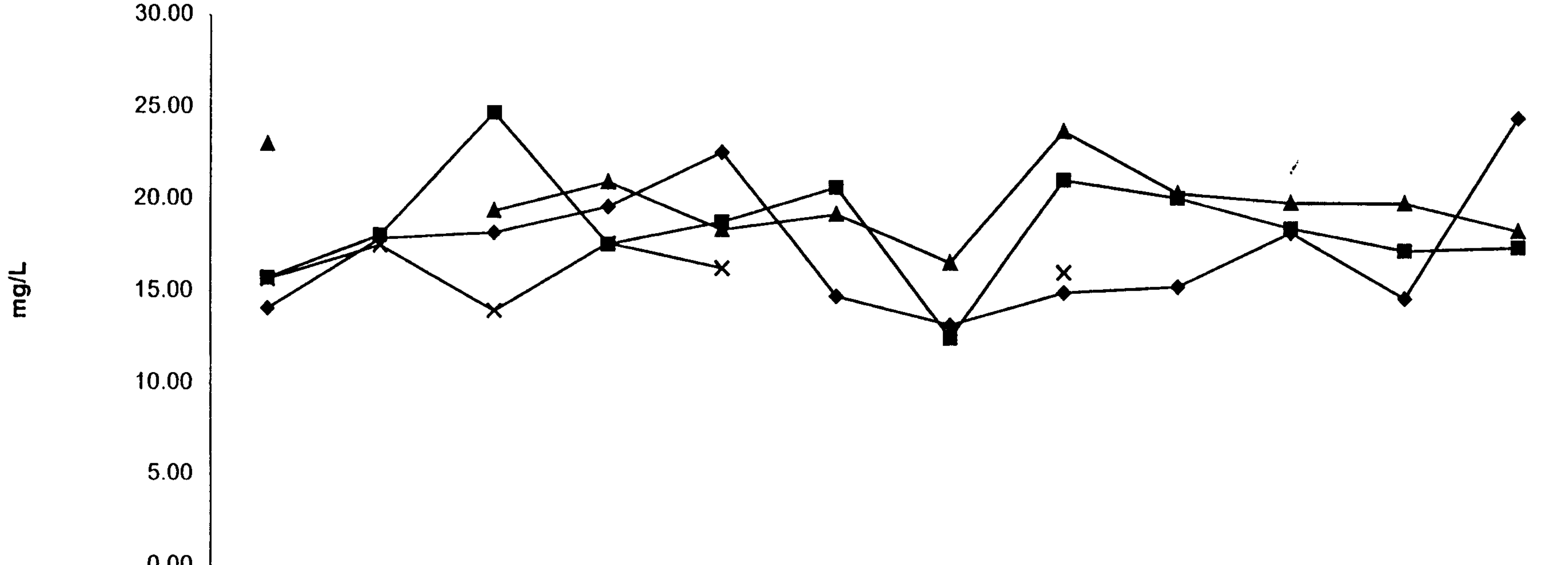
GBRA/USGS Canyon Lake Data
Barium (Monthly Averages)



	1	2	3	4	5	6	7	8	9	10	11	12
8167500			34.00	31.00	36.00	41.00	36.00	38.00	35.50	0.00	38.00	40.00
8167800	32.33	30.00	32.00	37.67	33.33			33.33				

GBRA/USGS Canyon Lake Data
Chloride (Monthly Averages)

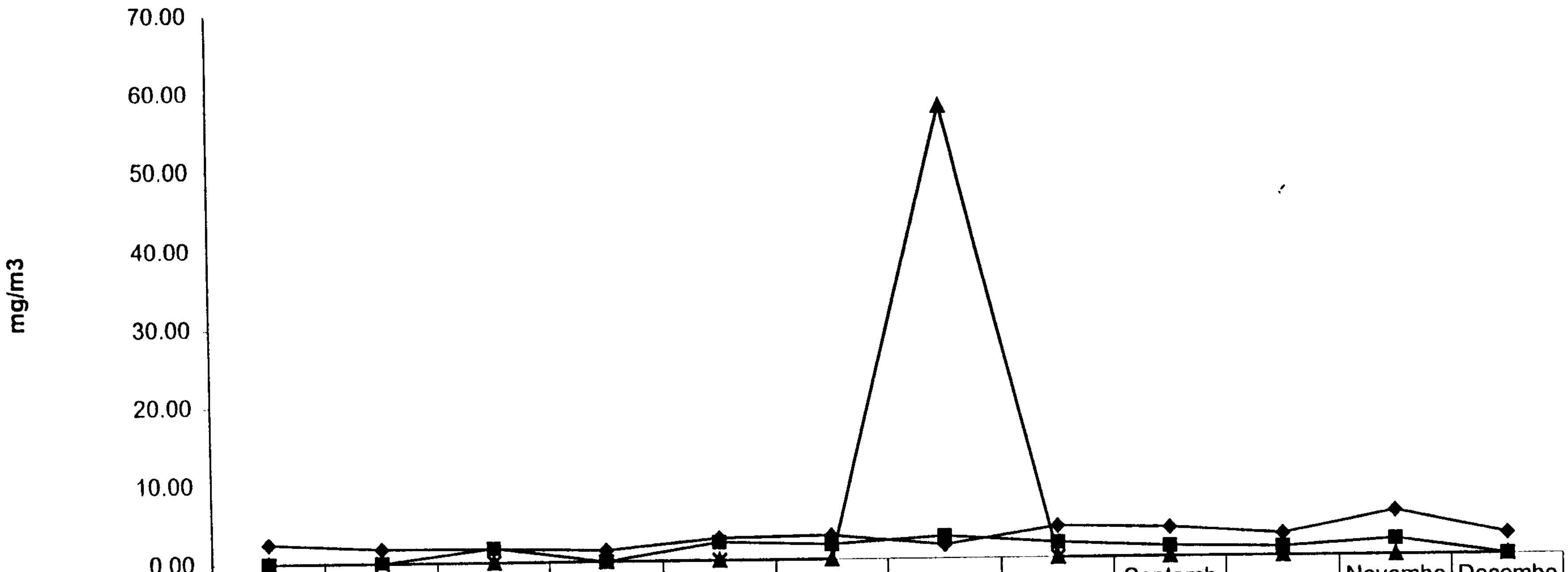


	January	February	March	April	May	June	July	August	September	October	November	December
12598	14.10	17.87	18.20	19.67	22.63	14.87	13.30	15.10	15.43	18.35	14.85	24.67
13700	15.75	18.05	24.75	17.60	18.85	20.75	12.60	21.20	20.25	18.60	17.40	17.60
8167500	23.00		19.40	21.00	18.40	19.29	16.67	23.83	20.50	20.00	20.00	18.50
8167800	15.67	17.50	14.00	17.67	16.33			16.17				

Month

12598 13700 8167500 8167800

GBRA/USGS Canyon Lake Data
Chlorophyll-a (Monthly Averages)

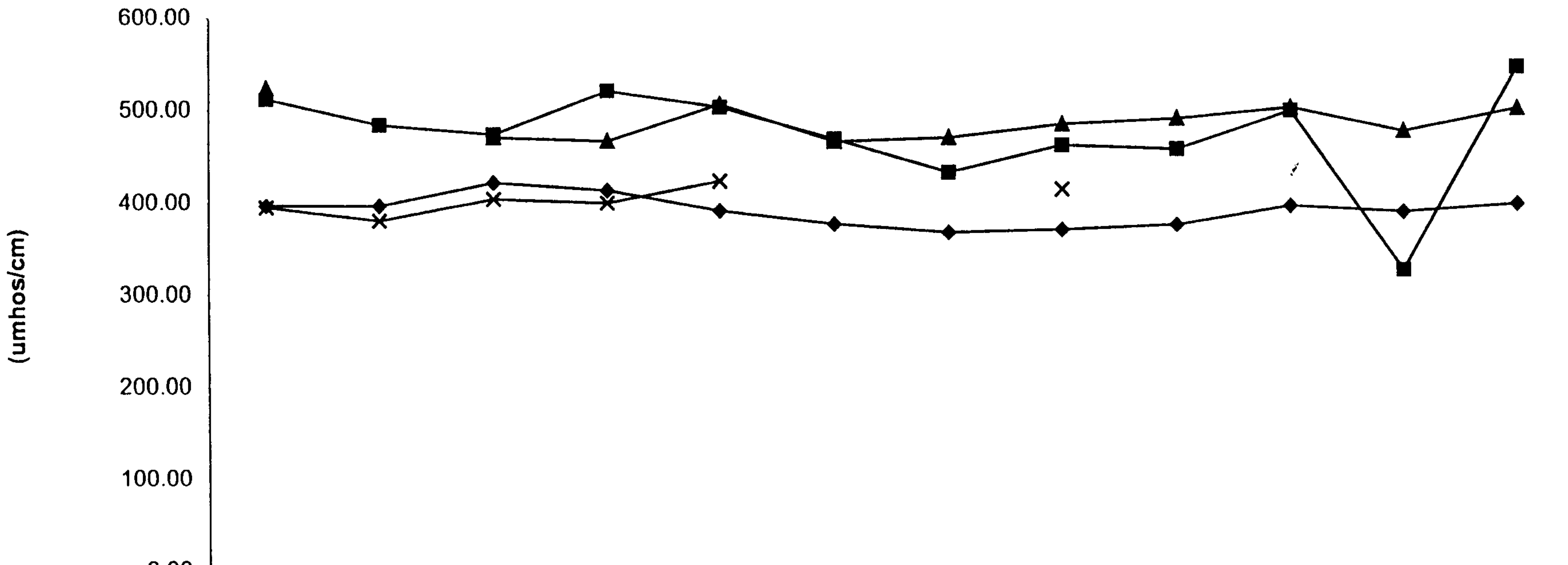


	January	February	March	April	May	June	July	August	September	October	November	December
12598	2.50	1.80	1.75	1.40	2.83	3.07	1.70	4.00	3.70	2.80	5.63	2.66
13700	0.00	0.00	1.80	0.00	2.30	1.90	2.85	1.90	1.30	1.10	2.00	0.00
8167500	0.00		0.00	0.00	0.00	0.00	57.50	0.00	0.00	0.00	0.00	0.00
8167800	0.00	0.00	0.00	0.00	0.00			0.00				

Month

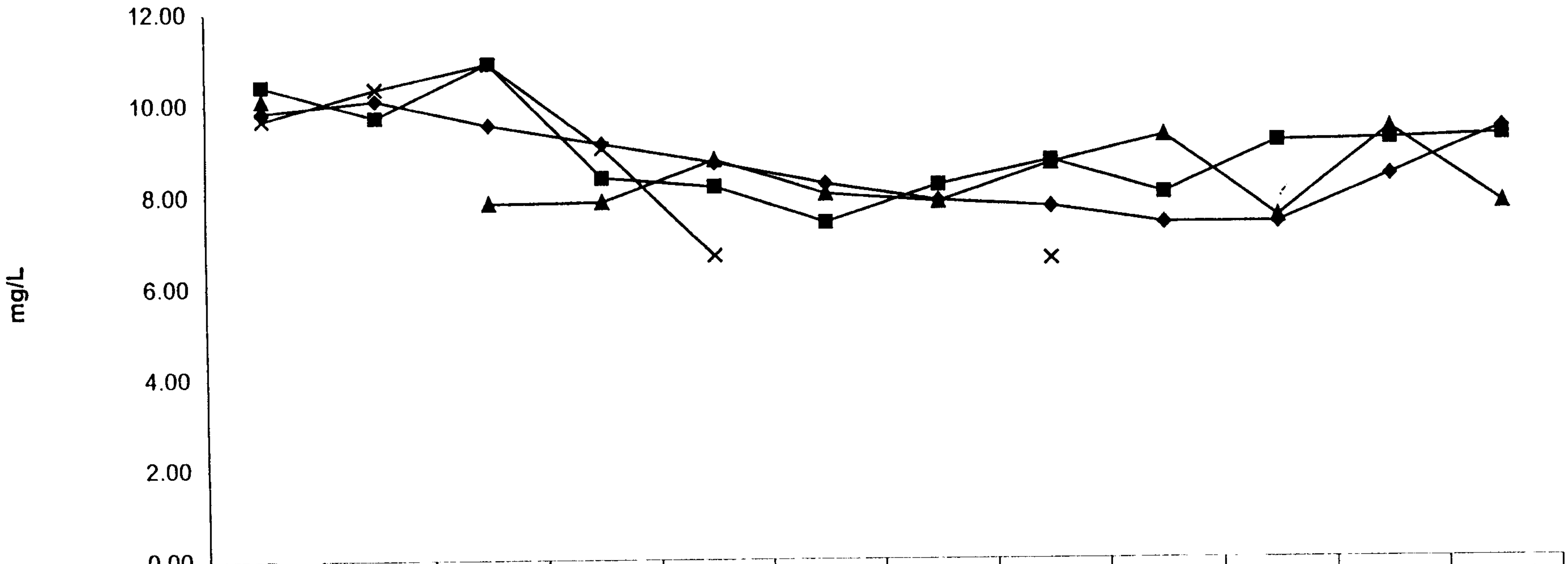
12598 13700 8167500 8167800

GBRA/USGS Canyon Lake Data
Conductivity (Monthly Averages)



	January	February	March	April	May	June	July	August	Septemb er	October	Novembe r	Decembe r
12598	397.08	396.67	421.69	413.23	390.92	376.15	366.92	369.69	374.92	395.08	388.77	397.42
13700	512.00	484.00	473.50	520.50	502.50	468.00	432.00	461.00	456.50	497.50	325.50	545.00
8167500	524.00		470.20	466.33	505.80	465.14	469.33	483.50	489.50	501.00	475.50	500.00
8167800	395.33	380.50	404.00	399.67	423.00			413.67				

GBRA/USGS Canyon Lake Data
Dissolved Oxygen (Monthly Averages)

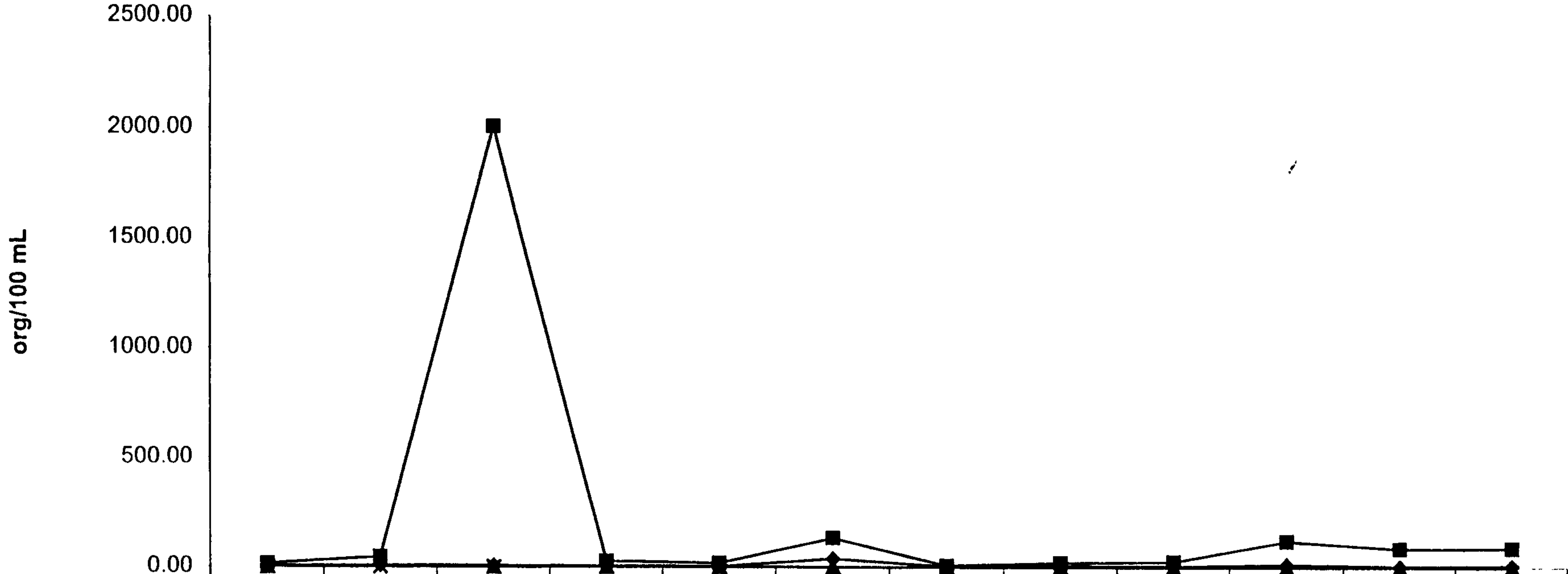


	January	February	March	April	May	June	July	August	September	October	November	December
12598	9.84	10.10	9.54	9.12	8.70	8.23	7.86	7.73	7.37	7.37	8.38	9.41
13700	10.42	9.72	10.91	8.39	8.19	7.41	8.20	8.72	8.01	9.12	9.16	9.24
8167500	10.10		7.84	7.87	8.76	8.01	7.83	8.65	9.25	7.50	9.40	7.78
8167800	9.67	10.35	10.90	9.03	6.70			6.60				

Month

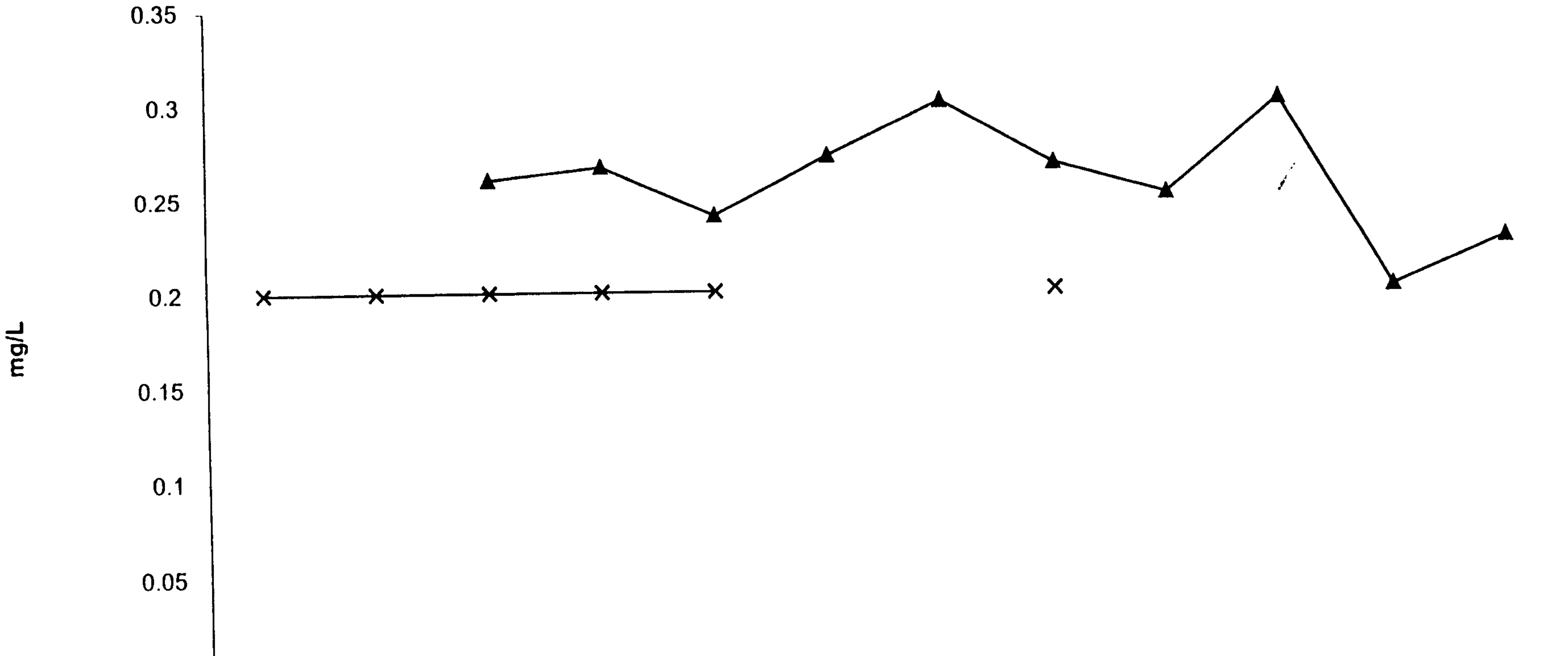
12598 13700 8167500 8167800

GBRA/USGS Canyon Lake Data
E. Coli (Monthly Averages)



	January	February	March	April	May	June	July	August	September	October	November	December
12598	4.33	6.00	6.67	4.00	2.33	39.00	4.00	6.33	5.33	12.75	5.75	8.33
13700	16.00	45.50	2006.00	26.00	18.00	133.00	8.00	21.00	26.50	119.00	86.00	88.00
8167500	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8167800	0.00	0.00	0.00	0.00	0.00			0.00				

GBRA/USGS Canyon Lake Data
Fluoride (Monthly Averages)

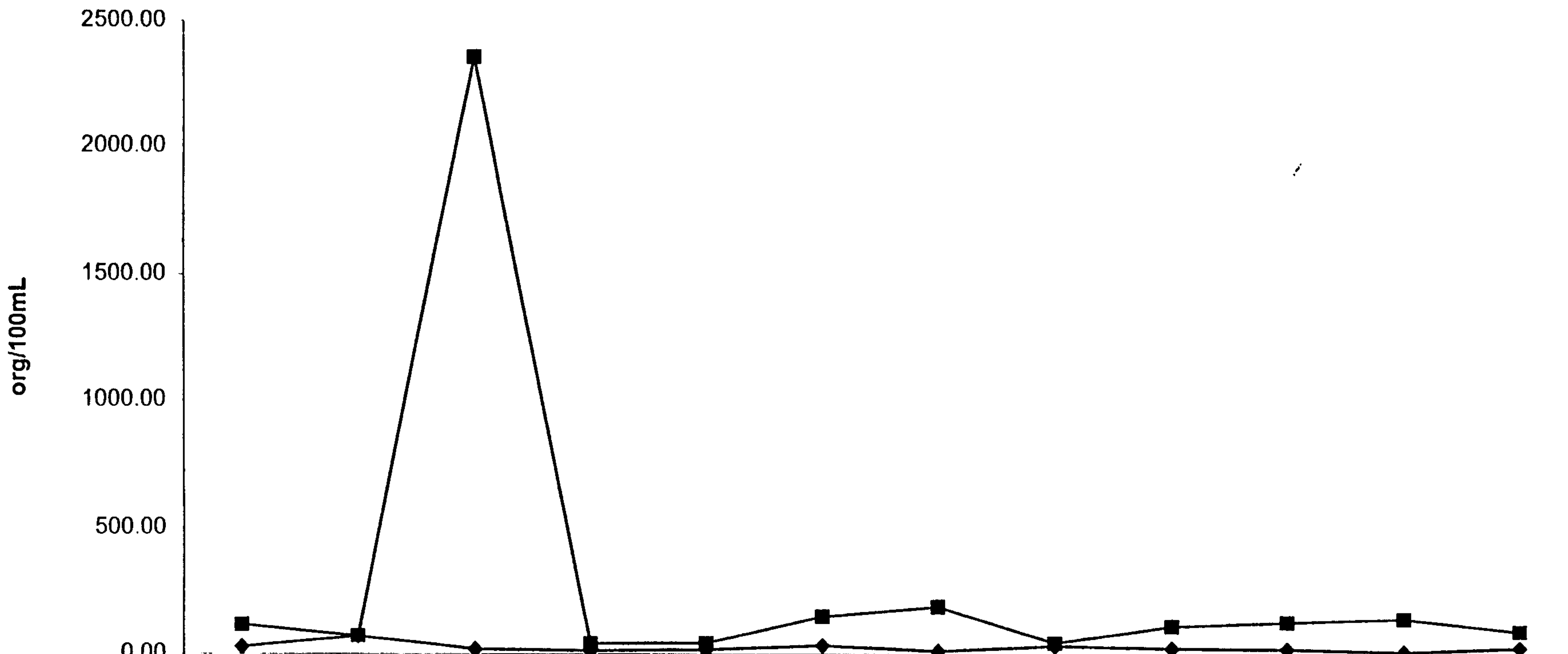


	1	2	3	4	5	6	7	8	9	10	11	12
8167500			0.26	0.27	0.24	0.27	0.30	0.27	0.25	0.30	0.20	0.23
8167800	0.20	0.20	0.20	0.20	0.20			0.20				

Month

8167500 8167800

GBRA/USGS Canyon Lake Data
Fecal Coliform (Monthly Averages)

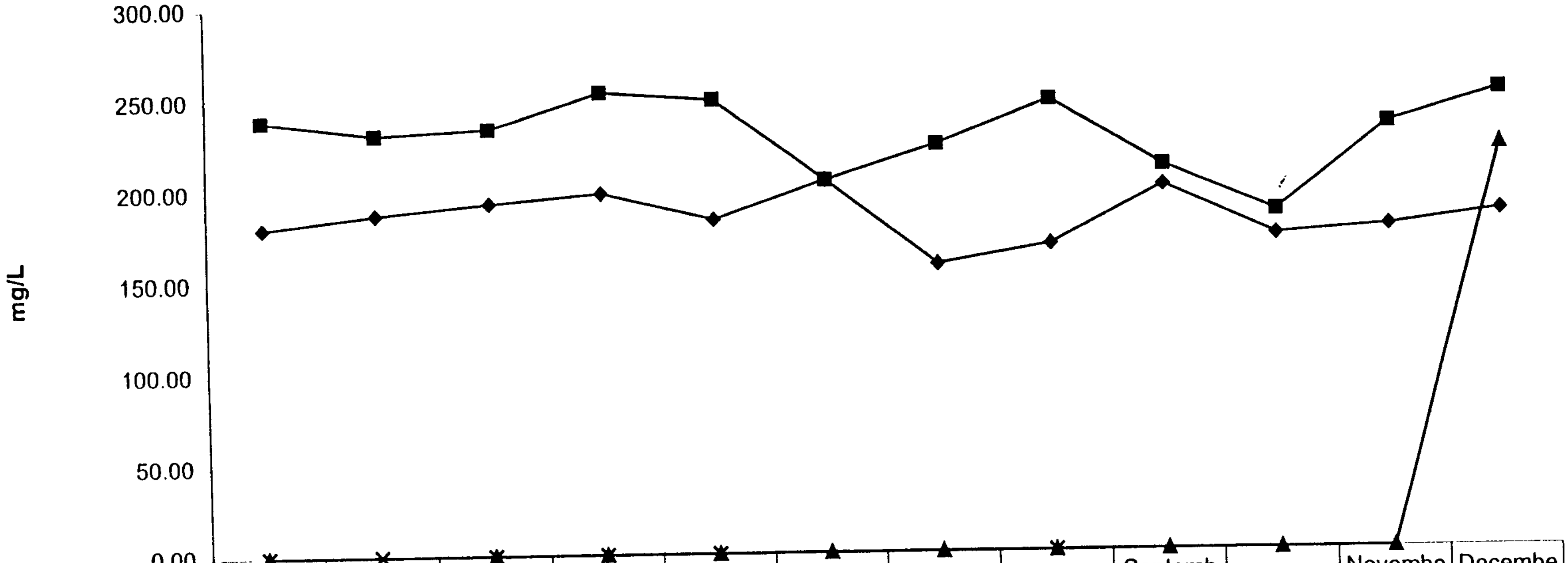


	January	February	March	April	May	June	July	August	September	October	November	December
12598	28.75	70.50	18.00	12.23	15.62	32.92	11.33	31.85	22.92	19.46	8.54	26.17
13700	118.00	71.50	2356.00	39.00	42.00	150.00	190.00	44.00	111.50	128.00	142.00	91.00

Month

12598 13700

GBRA/USGS Canyon Lake Data
Total Hardness (Monthly Averages)

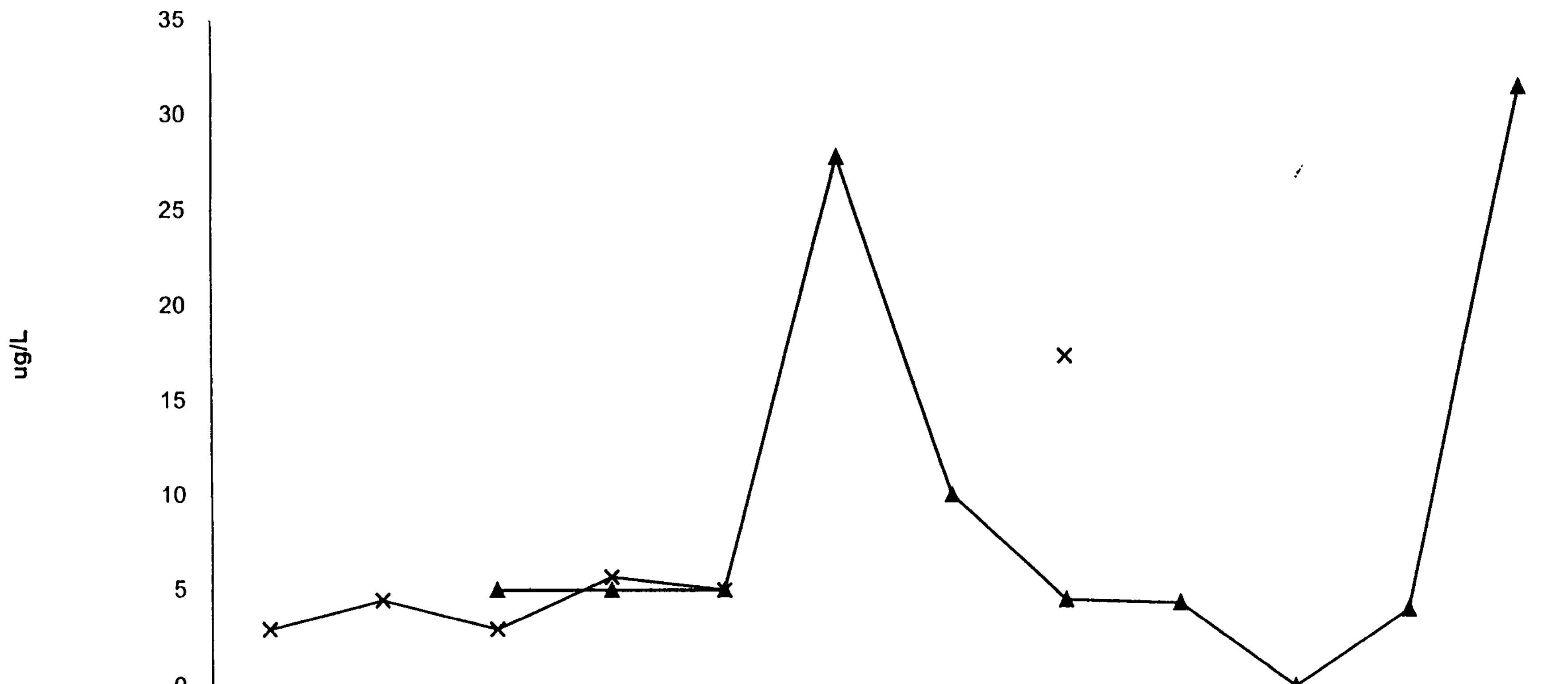


	January	February	March	April	May	June	July	August	September	October	November	December
12598	180.00	187.33	193.33	198.33	183.33	204.33	157.50	167.67	199.67	172.00	176.25	184.00
13700	239.00	231.00	234.00	253.50	249.00	204.00	223.00	247.00	210.50	185.00	232.50	250.00
8167500	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	220.00
8167800	0.00	0.00	0.00	0.00	0.00			0.00				

Month

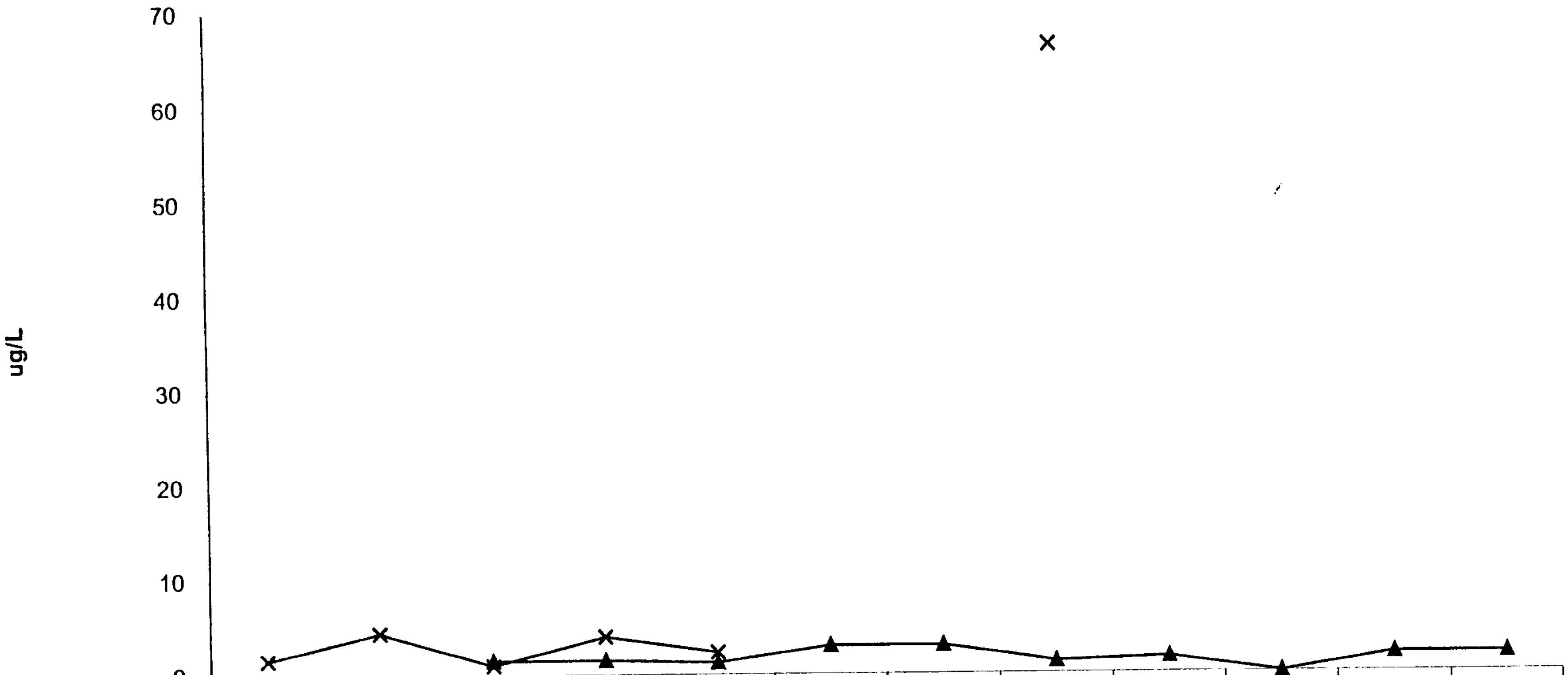
12598 13700 8167500 8167800

GBRA/USGS Canyon Lake Data
Iron (Monthly Averages)



	1	2	3	4	5	6	7	8	9	10	11	12
8167500			5.00	5.00	5.00	27.75	10.00	4.50	4.33	0.00	4.00	31.33
8167800	3.00	4.50	3.00	5.67	5.00			17.33				

GBRA/USGS Canyon Lake Data
Manganese (Monthly Averages)

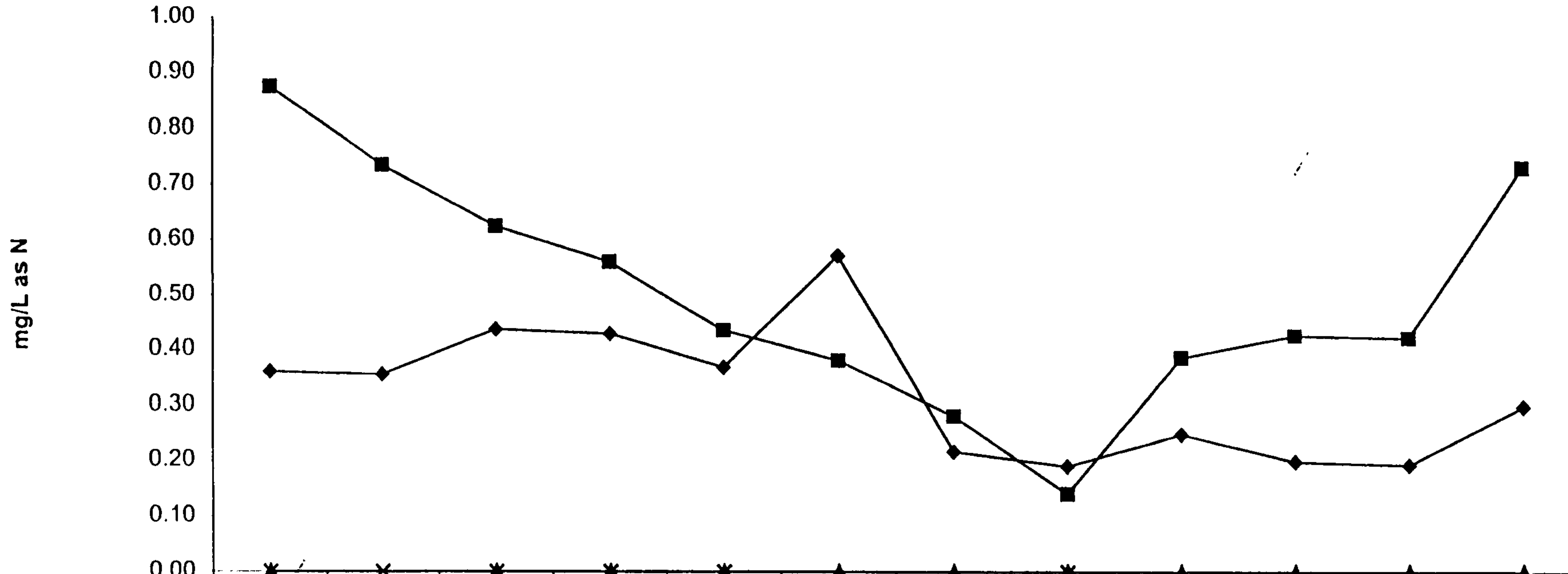


	1	2	3	4	5	6	7	8	9	10	11	12
8167500			1.50	1.50	1.25	3.00	3.00	1.25	1.67	0.00	2.00	2.00
8167800	1.67	4.50	1.00	4.00	2.33			66.33				

Month

8167500 8167800

GBRA/USGS Canyon Lake Data
Nitrate-N (Monthly Averages)

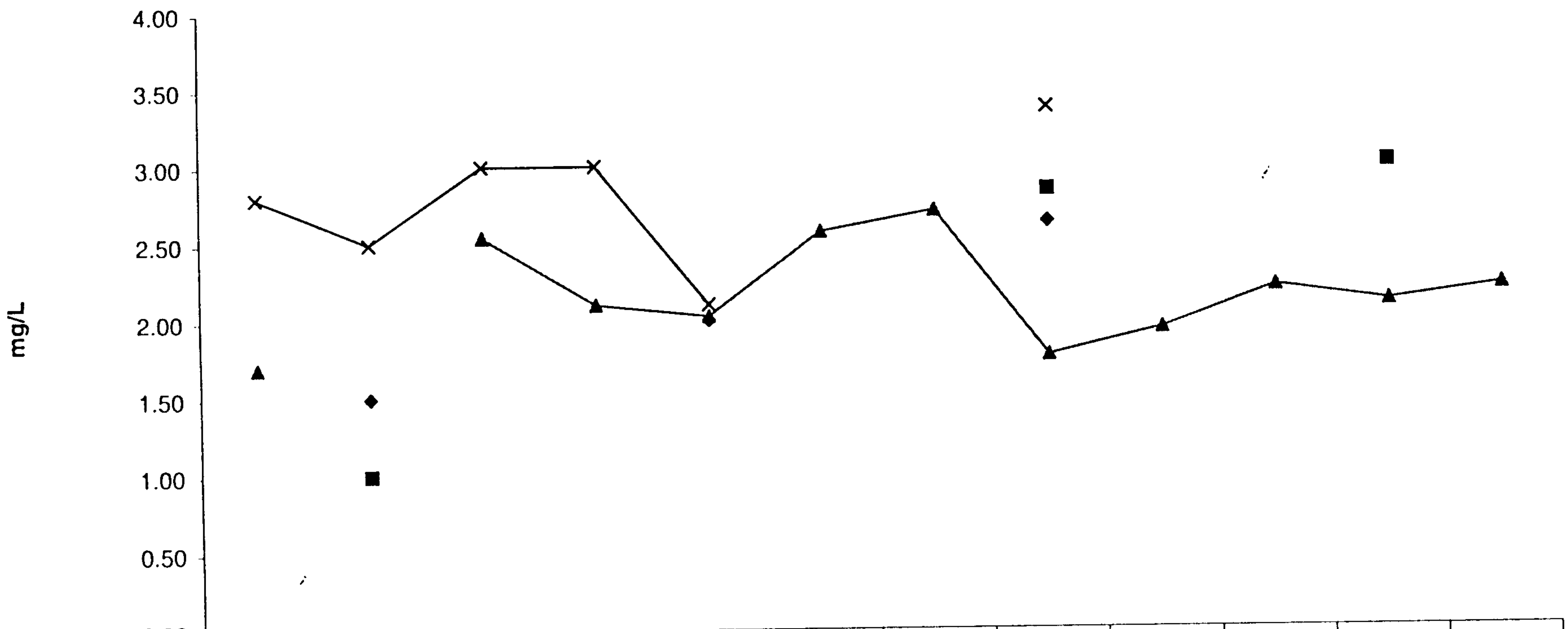


	January	February	March	April	May	June	July	August	Septemb er	October	Novembe r	Decembe r
12598	0.36	0.36	0.44	0.43	0.37	0.57	0.22	0.19	0.25	0.20	0.19	0.30
13700	0.88	0.74	0.63	0.56	0.44	0.38	0.28	0.14	0.39	0.43	0.42	0.73
8167500	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8167800	0.00	0.00	0.00	0.00	0.00			0.00				

Month

12598 13700 8167500 8167800

GBRA/USGS/TNRCC Canyon Lake Data
TOC (Monthly Averages)

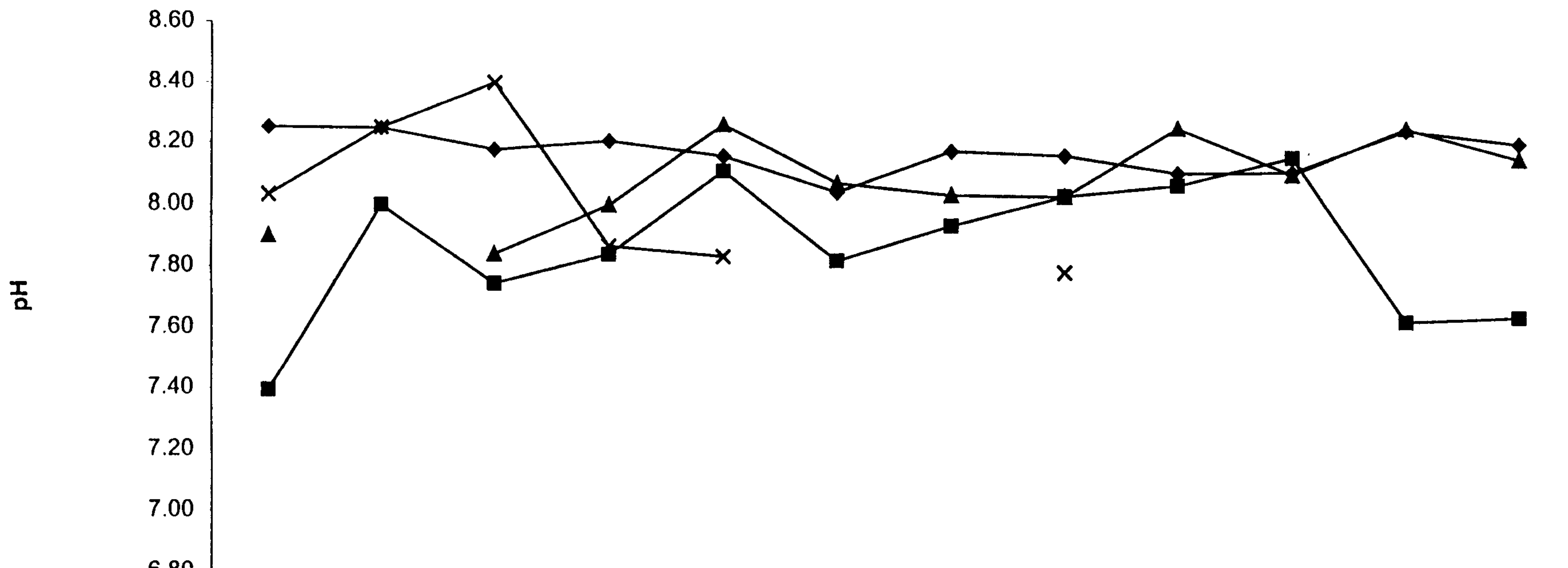


	1	2	3	4	5	6	7	8	9	10	11	12
8167500	1.70		2.54	2.10	2.03	2.57	2.70	1.76	1.93	2.20	2.10	2.20
8167800	2.80	2.50	3.00	3.00	2.10			3.37				
12600		1.5			2			2.625			3	
12601		1						2.833333			3	

Month

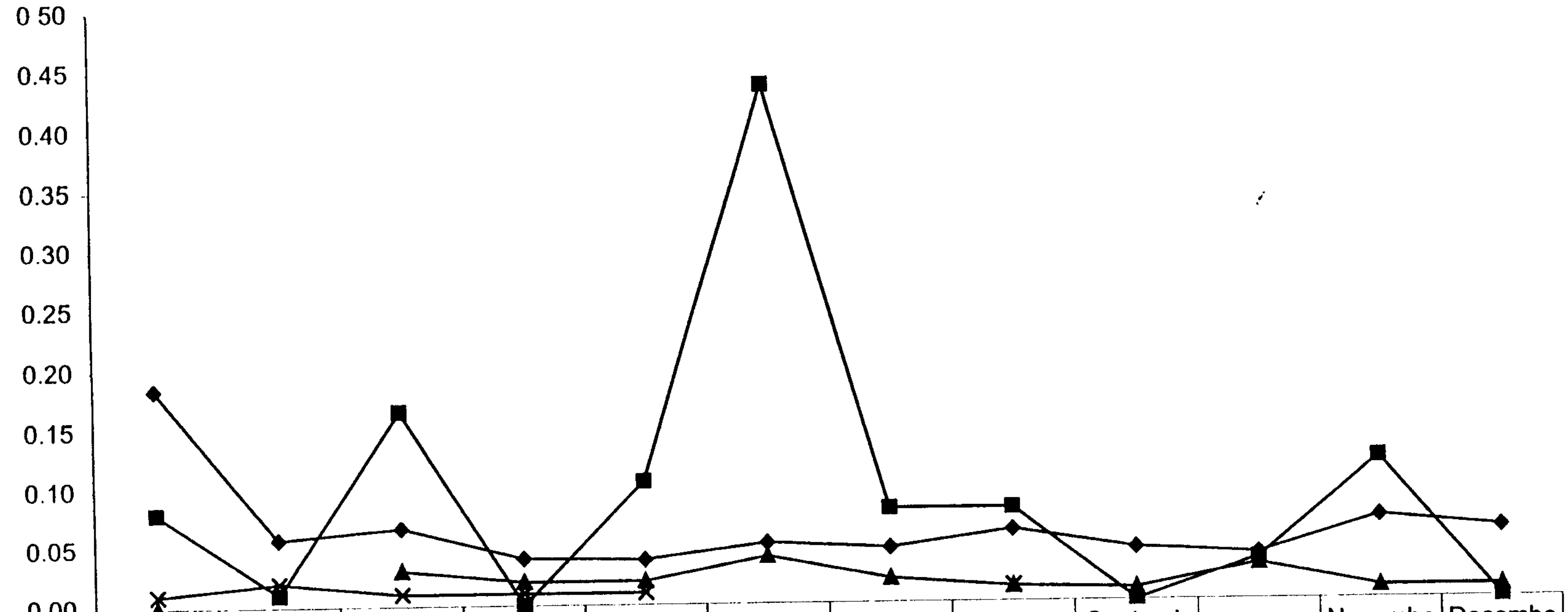
8167500 8167800 12600 12601

GBRA/USGS Canyon Lake Data
pH (Monthly Averages)



	January	February	March	April	May	June	July	August	September	October	November	December
12598	8.25	8.25	8.18	8.21	8.16	8.04	8.17	8.16	8.10	8.11	8.24	8.20
13700	7.40	8.00	7.75	7.84	8.11	7.82	7.94	8.03	8.07	8.16	7.63	7.64
8167500	7.90		7.84	8.00	8.26	8.07	8.03	8.03	8.25	8.10	8.25	8.15
8167800	8.03	8.25	8.40	7.87	7.83			7.78				

GBRA/USGS Canyon Lake Data
Total Phosphorus (Monthly Averages)

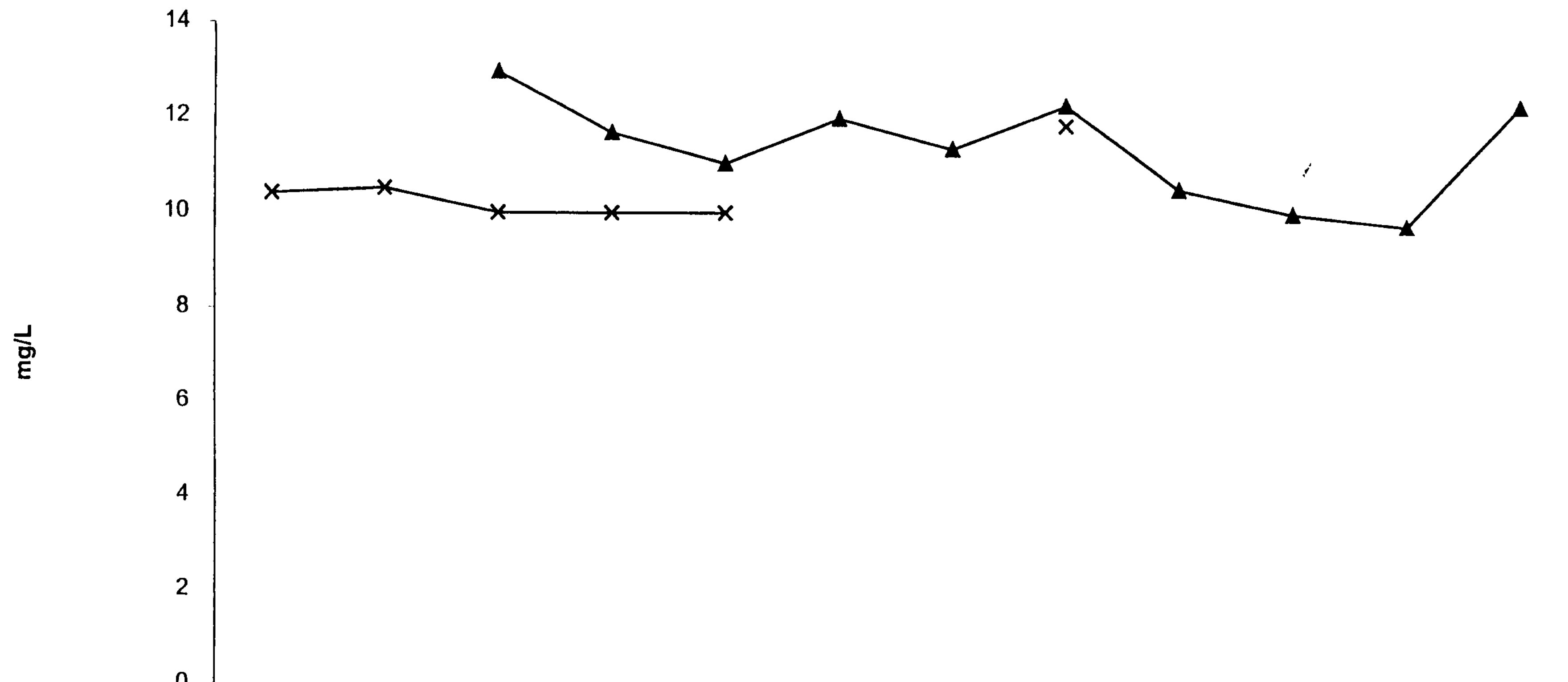


	January	February	March	April	May	June	July	August	Septemb er	October	Novembe r	Decembe r
12598	0.18	0.06	0.07	0.04	0.04	0.05	0.05	0.06	0.04	0.04	0.07	0.06
13700	0.08	0.01	0.17	0.00	0.11	0.44	0.08	0.08	0.00	0.04	0.12	0.00
8167500	0.00		0.03	0.02	0.02	0.04	0.02	0.01	0.01	0.03	0.01	0.01
8167800	0.01	0.02	0.01	0.01	0.01			0.01				

Month

12598 13700 8167500 8167800

GBRA/USGS Canyon Lake Data
Silica (Monthly Averages)

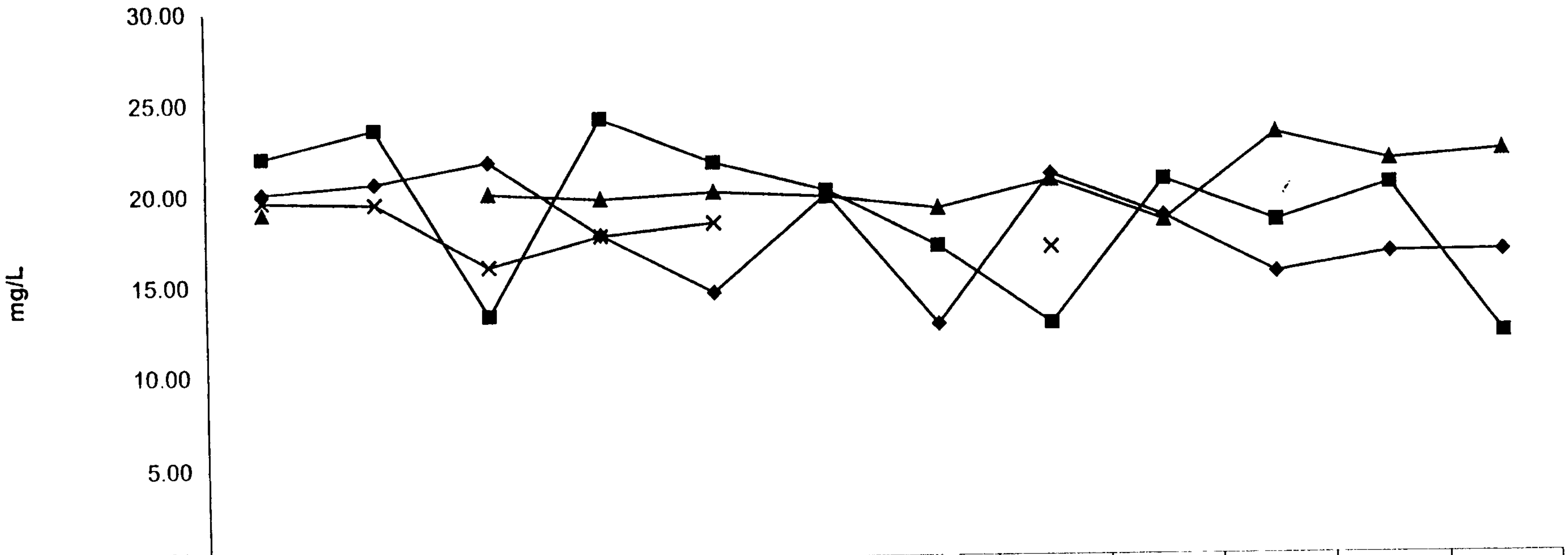


	1	2	3	4	5	6	7	8	9	10	11	12
8167500			12.96	11.67	11.02	11.97	11.33	12.25	10.50	10.00	9.75	12.25
8167800	10.40	10.50	10.00	10.00	10.00			11.83				

Month

8167500 8167800

GBRA/USGS Canyon Lake Data
Sulfate (Monthly Averages)

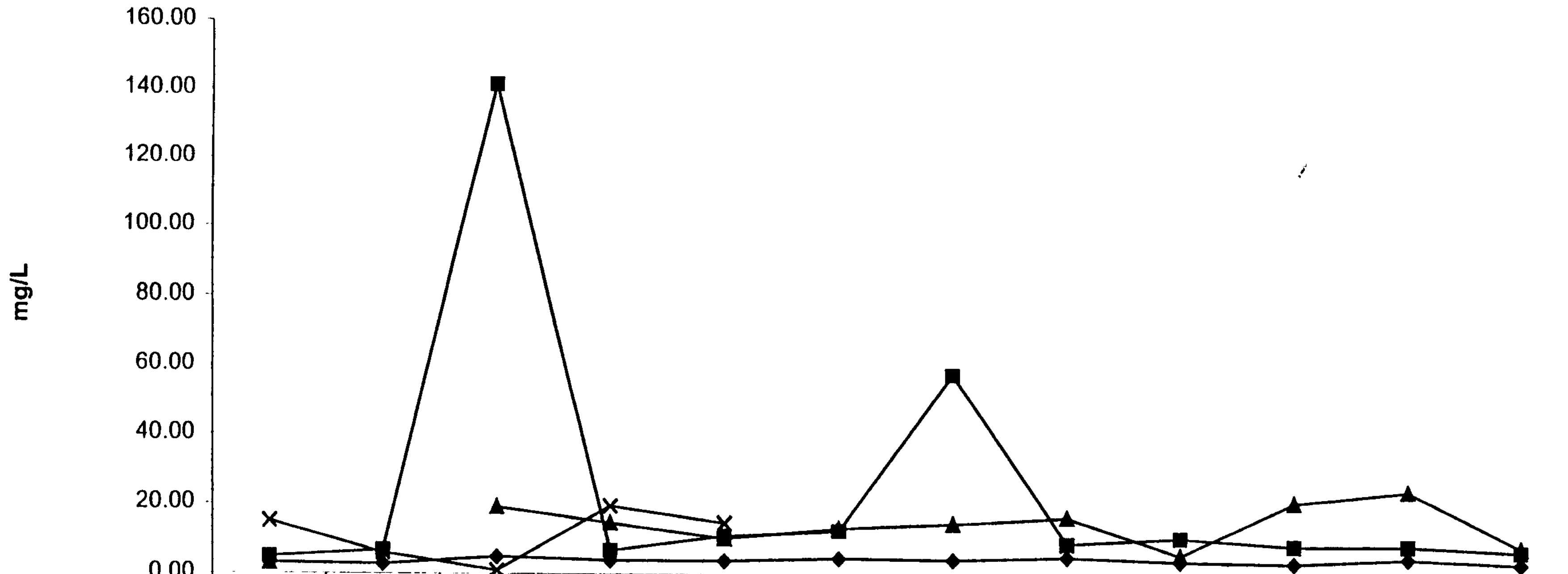


	January	February	March	April	May	June	July	August	September	October	November	December
12598	20.13	20.63	21.77	17.70	14.50	19.83	12.65	20.83	18.50	15.38	16.45	16.50
13700	22.10	23.60	13.30	24.10	21.65	20.05	16.95	12.65	20.50	18.20	20.20	12.00
8167500	19.00		20.00	19.67	20.00	19.71	19.00	20.50	18.25	23.00	21.50	22.00
8167800	19.67	19.50	16.00	17.67	18.33			16.83				

Month

12598 13700 8167500 8167800

GBRA/USGS Canyon Lake Data
TSS (Monthly Averages)

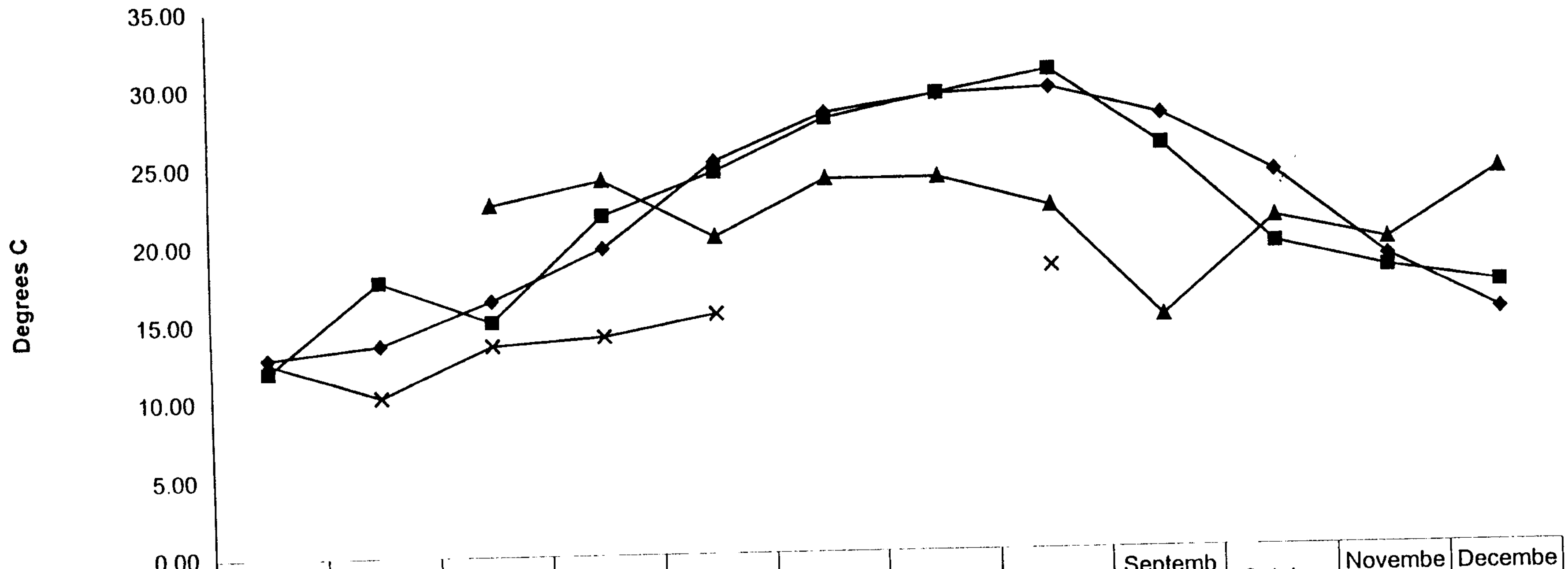


	January	February	March	April	May	June	July	August	September	October	November	December
12598	3.13	2.79	4.88	3.92	4.02	4.78	4.47	5.42	4.25	3.84	5.30	3.94
13700	4.90	6.80	141.45	6.75	11.00	12.50	57.45	9.20	10.85	8.75	9.00	7.40
8167500	3.00		19.00	14.50	10.25	13.33	14.67	16.60	6.00	21.00	24.50	8.50
8167800	15.00	6.00	1.00	19.33	14.67			9.17				

Month

12598 13700 8167500 8167800

GBRA/USGS Canyon Lake Data
Temperature (Monthly Averages)

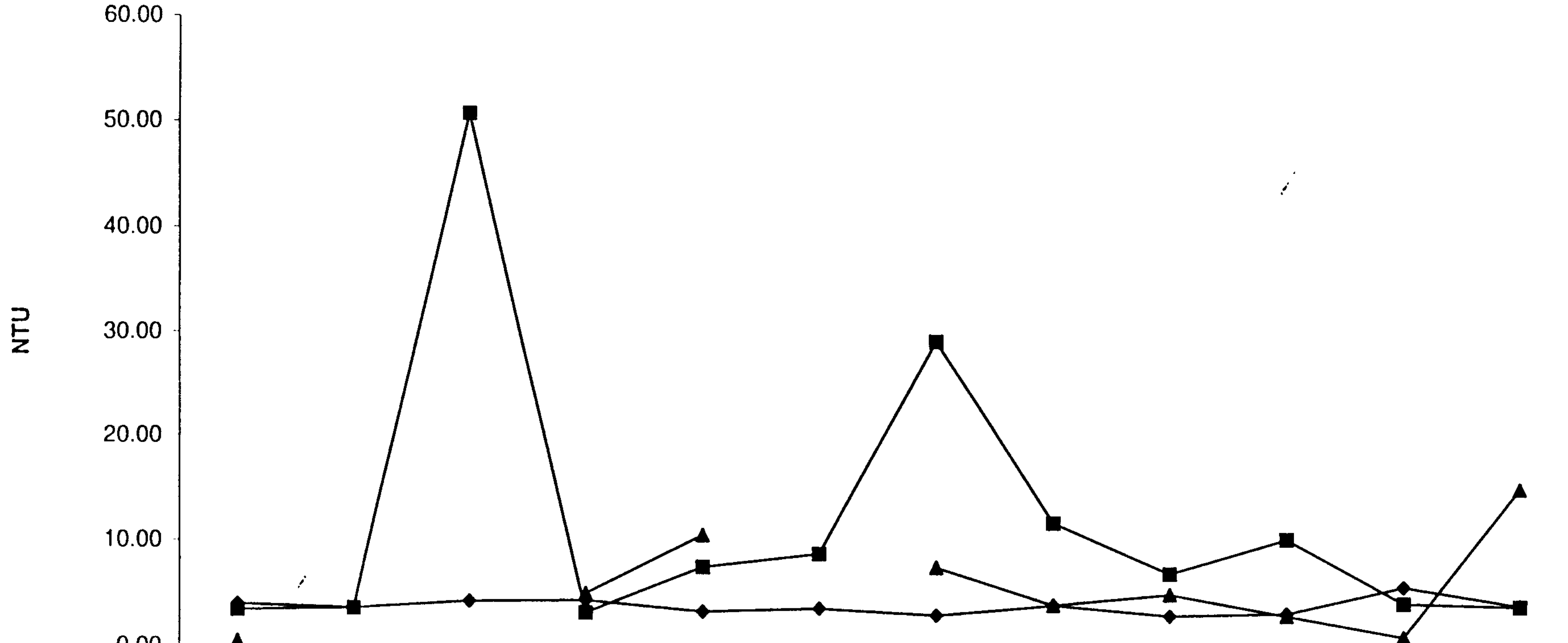


	January	February	March	April	May	June	July	August	September	October	November	December
12598	12.82	13.62	16.40	19.67	25.08	28.04	29.14	29.42	27.64	23.93	18.47	14.91
13700	11.93	17.69	15.04	21.77	24.44	27.70	29.18	30.57	25.74	19.39	17.70	16.62
8167500	12.50		22.51	24.00	20.30	23.86	23.83	21.92	14.75	21.00	19.50	23.88
8167800	12.50	10.25	13.50	14.00	15.33			18.08				

Month

12598 — 13700 — 8167500 — 8167800

GBRA/USGS/TNRCC Canyon Lake Data
Turbidity (Monthly Averages)

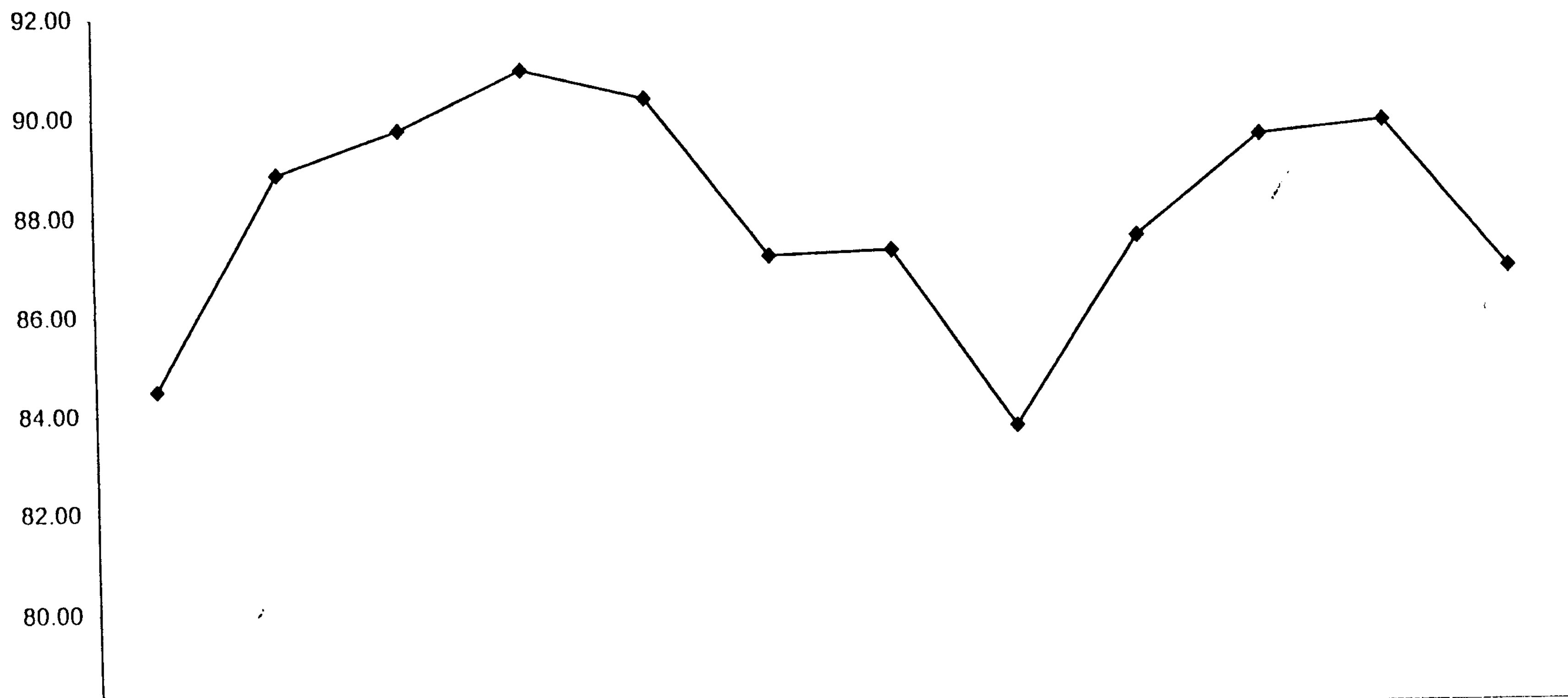


	January	February	March	April	May	June	July	August	September	October	November	December
12598	4.00	3.65	4.26	4.36	3.32	3.62	3.00	3.97	3.02	3.22	5.72	3.98
13700	3.45	3.60	50.75	3.20	7.50	8.75	29.15	11.75	6.95	10.20	4.20	3.90
12601	1			5	11		8	4	5	3	1	15

Month

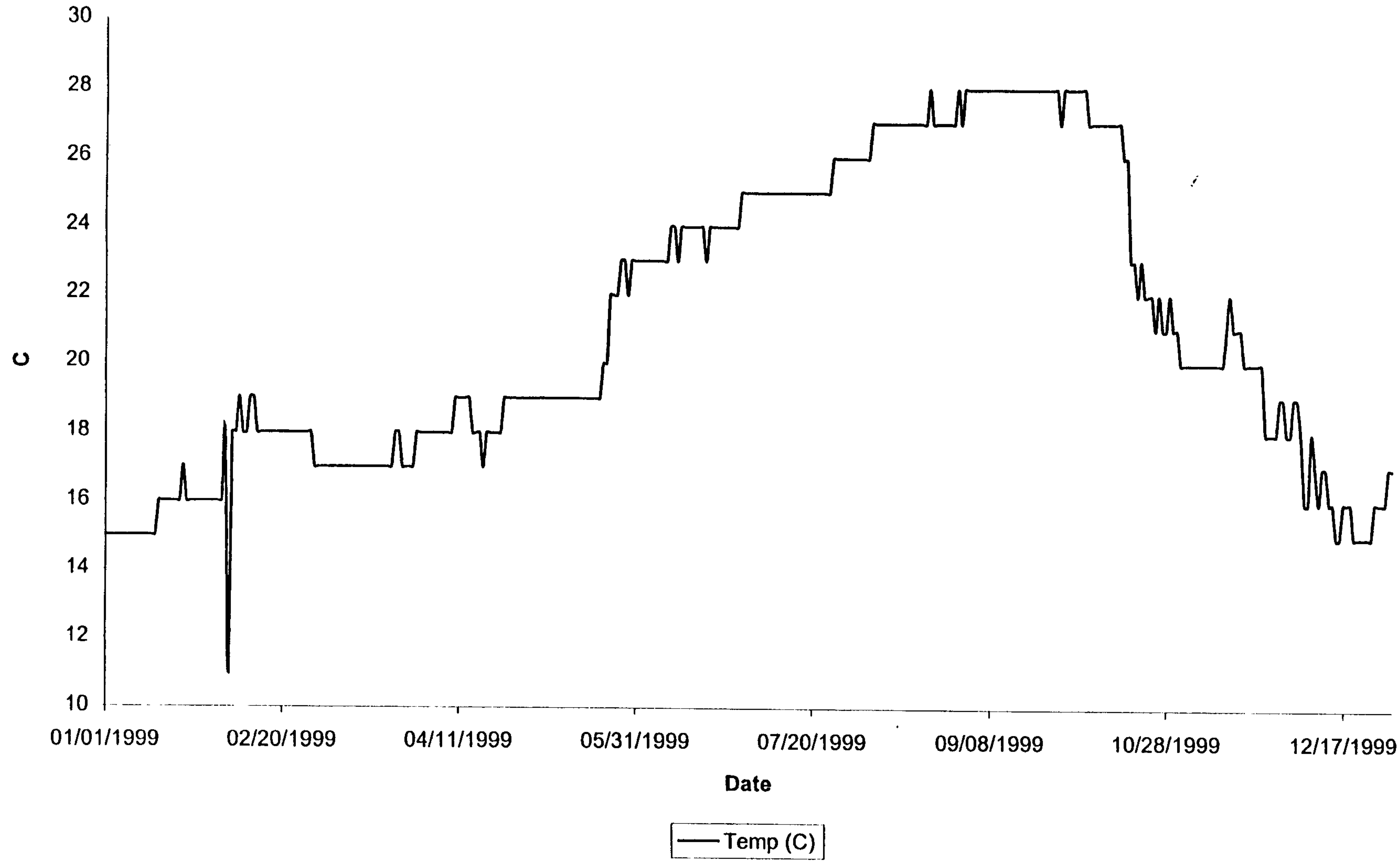
12598 13700 12601

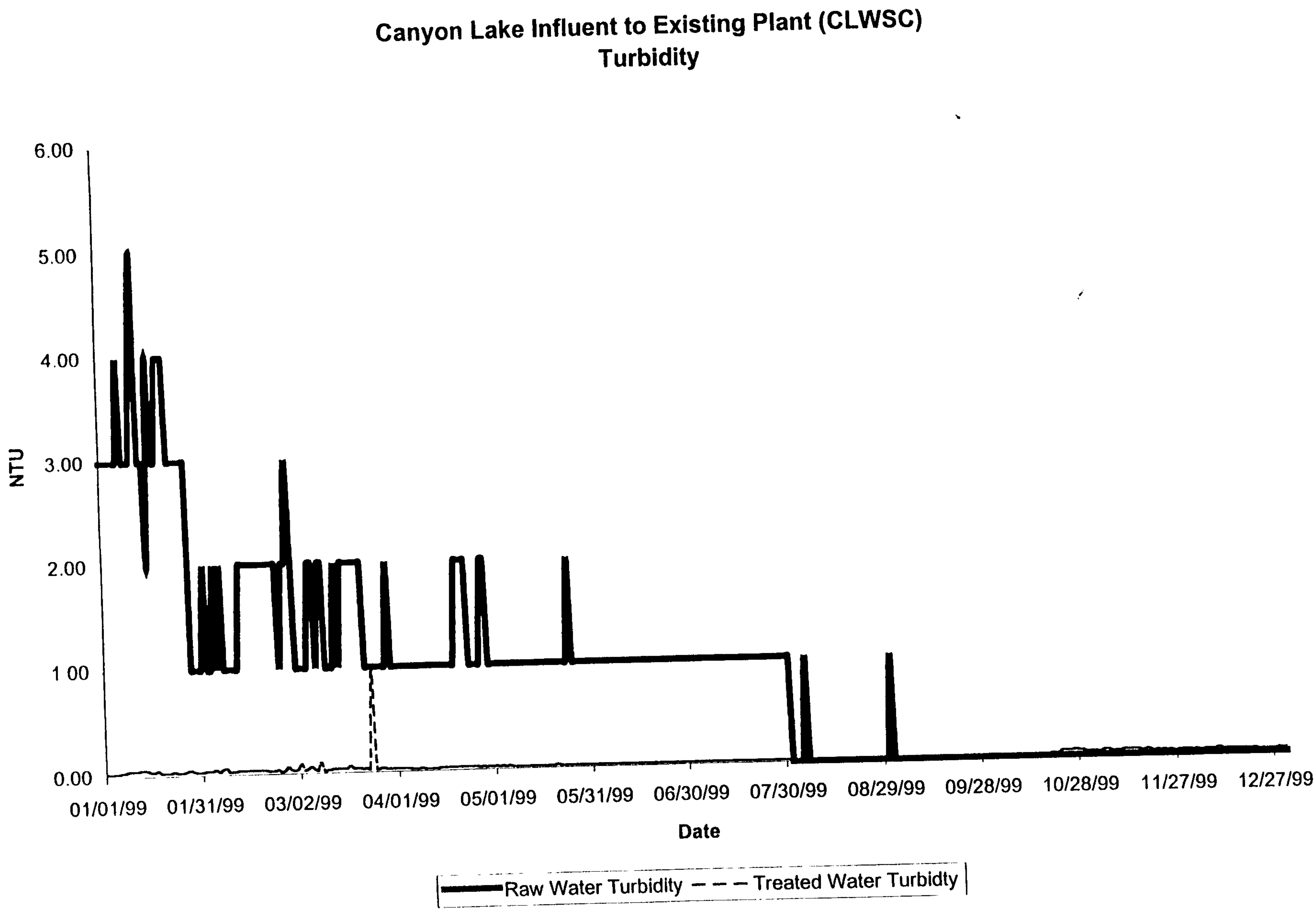
GBRA/USGS Canyon Lake Data
Water Quality (Monthly Averages)



	January	February	March	April	May	June	July	August	September	October	November	December
12598	84.50	88.82	89.69	90.88	90.28	87.09	87.18	83.59	87.42	89.42	89.67	86.73

Canyon Lake Influent to Existing Plant (CLWSC)
Temperature





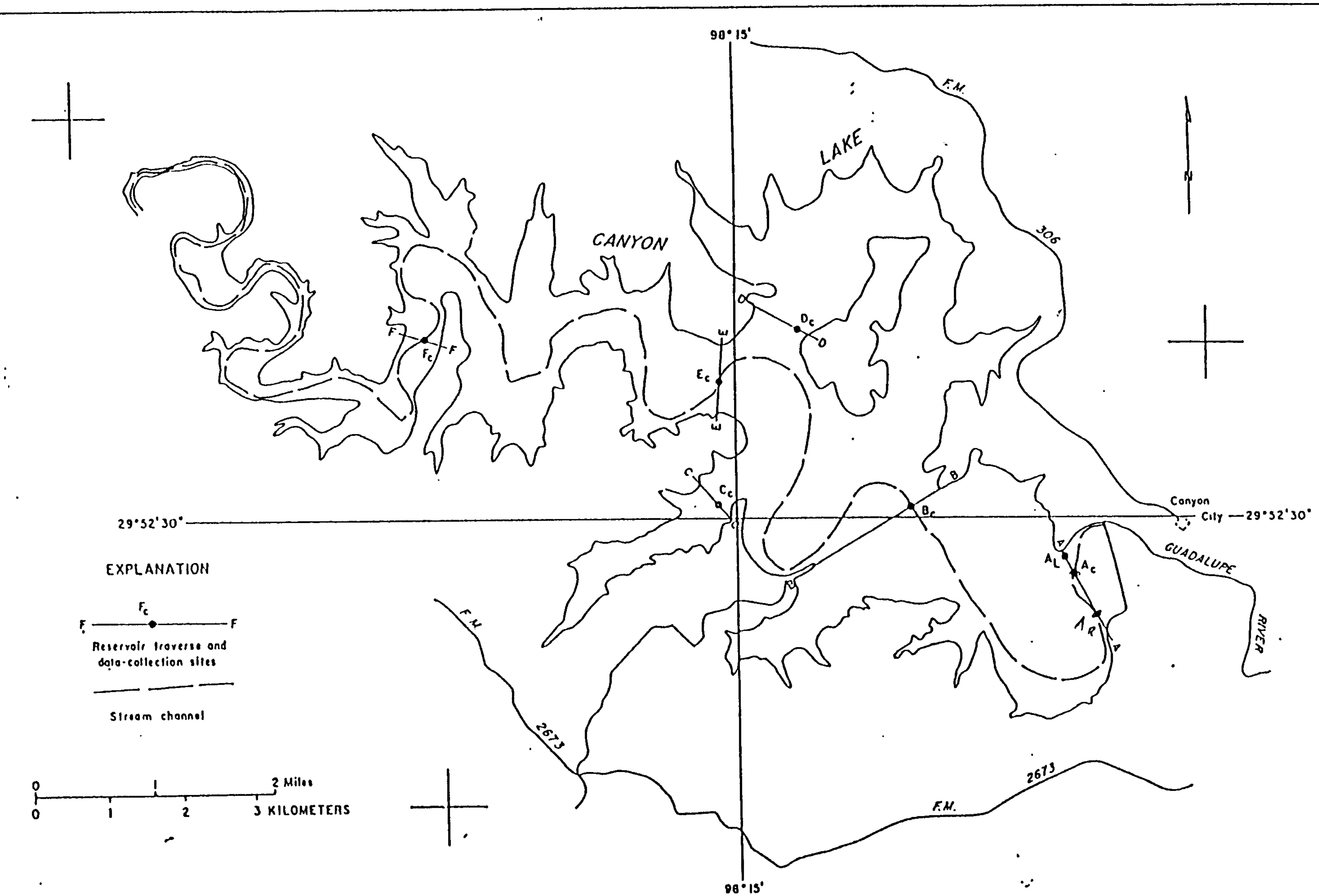
Canyon Lake Influent to Existing Plant (CLWSC)
Turbidity
6.00
5.00
4.00
3.00
2.00
1 00
0.00
NTU
01/01/99
01/31/99
03/02/99
04/01/99
05/01/99
05/31/99
06/30/99
07/30/99
08/29/99
09/28/99
10/28/99
11/27/99
12/27/99
Date
Raw Water Turbidity
Treated Water Turbidty

Table A-1
USGS Water Quality Data

Constituent	Units	Site AC @ 1' Depth 2/5/90	4/24/90	8/13/90	1/31/91	5/16/91	8/12/91	3/12/92	5/13/92	8/6/92	1/20/93	4/15/93	8/10/93
pH	SU	8.50	8.40	8.40	8.30	8.30	8.20	8.40	8.20	8.00	8.20	8.20	8.20
Temperature	°C	12.00	20.00	28.50	11.00	24.00	28.50	16.50	24.50	29.00	12.50	17.50	29.00
Transparency	M	3.50	3.00	4.10	1.80	2.20	3.80	3.20	3.20	2.80	2.00	3.20	4.00
DO	mg/l	8.20	7.40	6.60	8.60	7.90	7.00	8.20	7.70	7.2	8.8	8.70	7.20
Hardness Total	mg/l	170.00	170.00	160.00	180.00	180.00	180.00	220.00	230.00	180.00	200.00	200.00	160.00
Sulfate	mg/l	19.00	20.00	18.00	23.00	22.00	20.00	17.00	18.00	19.00	20.00	18.00	19.00
Chloride	mg/l	18.00	19.00	17.00	16.00	19.00	18.00	14.00	15.00	15.00	15.00	17.00	15.00
Fluoride	mg/l	0.20	0.20	0.20	0.20	0.30	0.20	0.20	<0.10	0.20	0.20	0.30	0.20
Dissolved Solids	mg/l	210.00	215.00	188.00	213.00	213.00	201.00	241.00	255.00	214.00	230.00	236.00	188.00
N - Organic	mg/l	0.40	0.30	0.60	0.30	0.40	0.30	0.30	<0.20	<.20	0.33		
N - Inorganic	mg/l	<0.100	<0.100	<0.100	0.10	0.06	<0.050	0.20	0.74	--	0.34	0.37	0.06
Iron	μg/l	4.00	7.00	<3	4.00	3.00	<3	20.00	<3	<3	6.00	10.00	<3
Manganese	μg/l	<1	<1	<1	<1	<1	<1	20.00	<1	1.00	<1	<1	<1

Table A-2
GBRA Water Quality Data
Raw Water Turbidity (NTU) at Cayon Park Marina

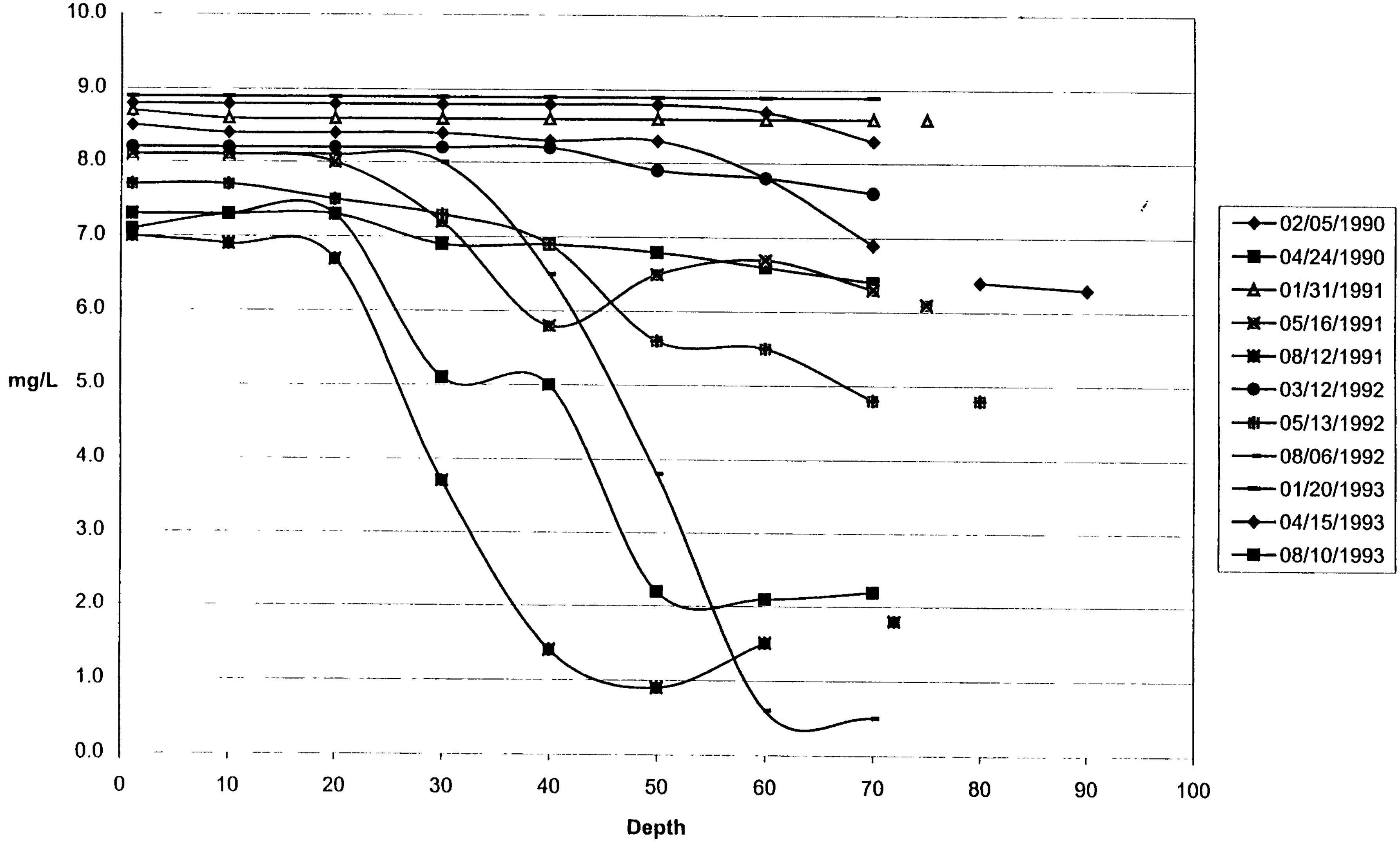
Year	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Min	Max	Avg
1987	8.4	1.6	4.5	4.6	3.6	6.5	4.2	7.9	6.2	5.55	4.8	5.2	1.6	8.4	5.3
1988	3.8	4.4	3.2	4.8	2.3	4.4	4.8	3.4	3.2	4.6	2.7	2.5	2.3	4.8	3.7
1989	2.2	4.1	5.2	4	3.5	3.6	4.4	2.9	3	4.8	1.6	3.4	1.6	5.2	3.6
1990	3.9	3	2.2	4.2	3	1.7	2	3.1	1.8	2.6	3.4	2	1.7	4.2	2.7
1991	2.4	2.8	4	5	3.4	4.9	3	2.4	9	8.5	11	2	2	11	4.9
1992	8	18	3.8	1.5	4.3	5.8	4.5	3.5	17	1.5	6.6	5.4	1.5	18	6.7
1993	7.8	2.3	2.2	2.4	3	3	1.8	1.5	2.4	2.3	2.3	10	1.5	10	3.4
1994	3.7	7.5	3.4	2	4.4	4.9	3.8						2	7.5	4.2
															4.3



Base from U.S. Geolo[...]rvey
topographic quadrang[...]

Raw Water from Canyon Lake
(USGS)

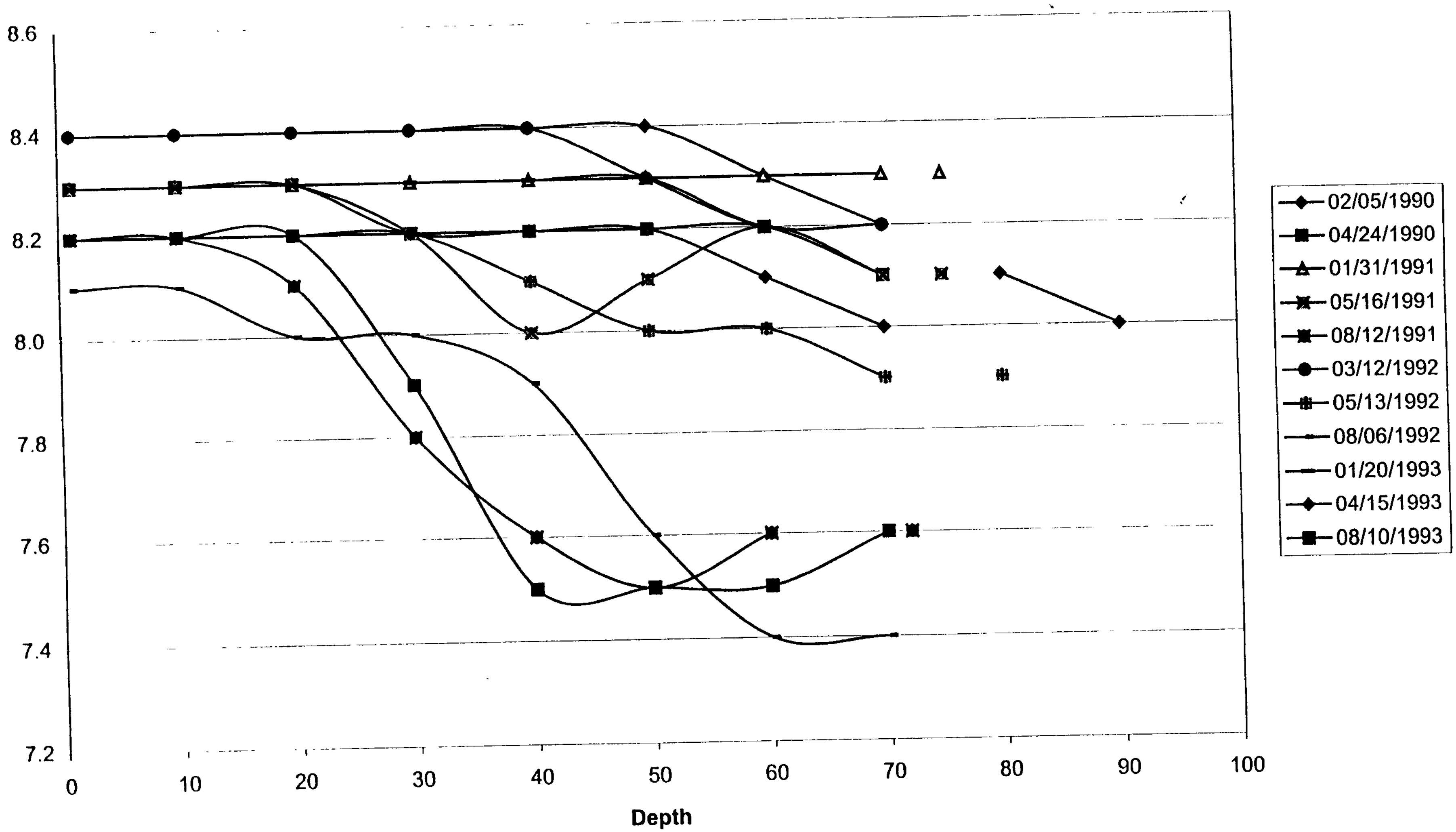
CLWSC Canyon Lake Depth Variation Data ('90 - '93)
Dissolved Oxygen



 Information taken from Hogan Corp. CLWSC Engineering Report (1994)

Raw Water from Canyon Lake
(USGS)

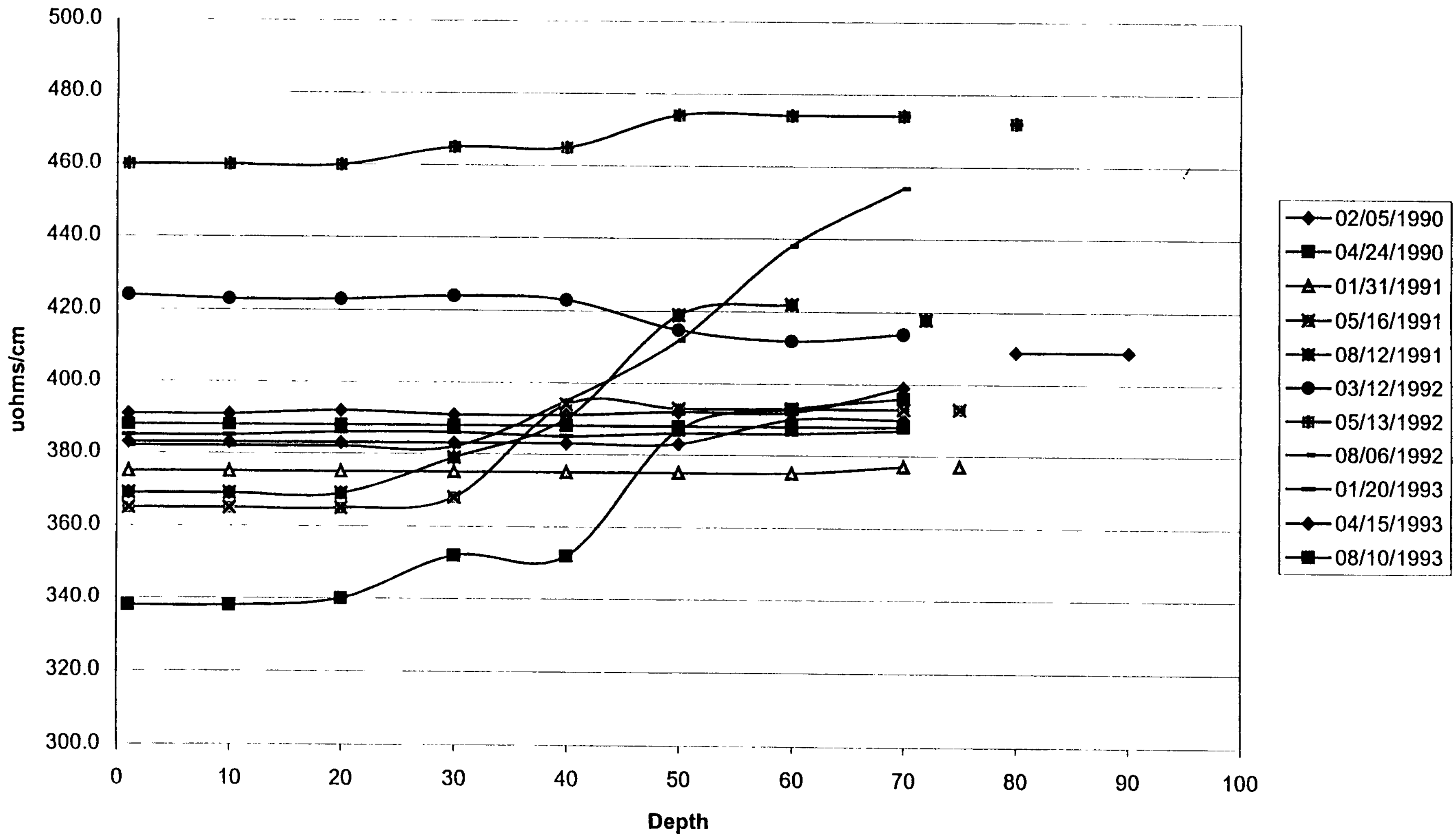
CLWSC Canyon Lake Depth Variation Data ('90 - '93)
pH



Information taken from Hogan Corp. CLWSC Engineering Report (1994)

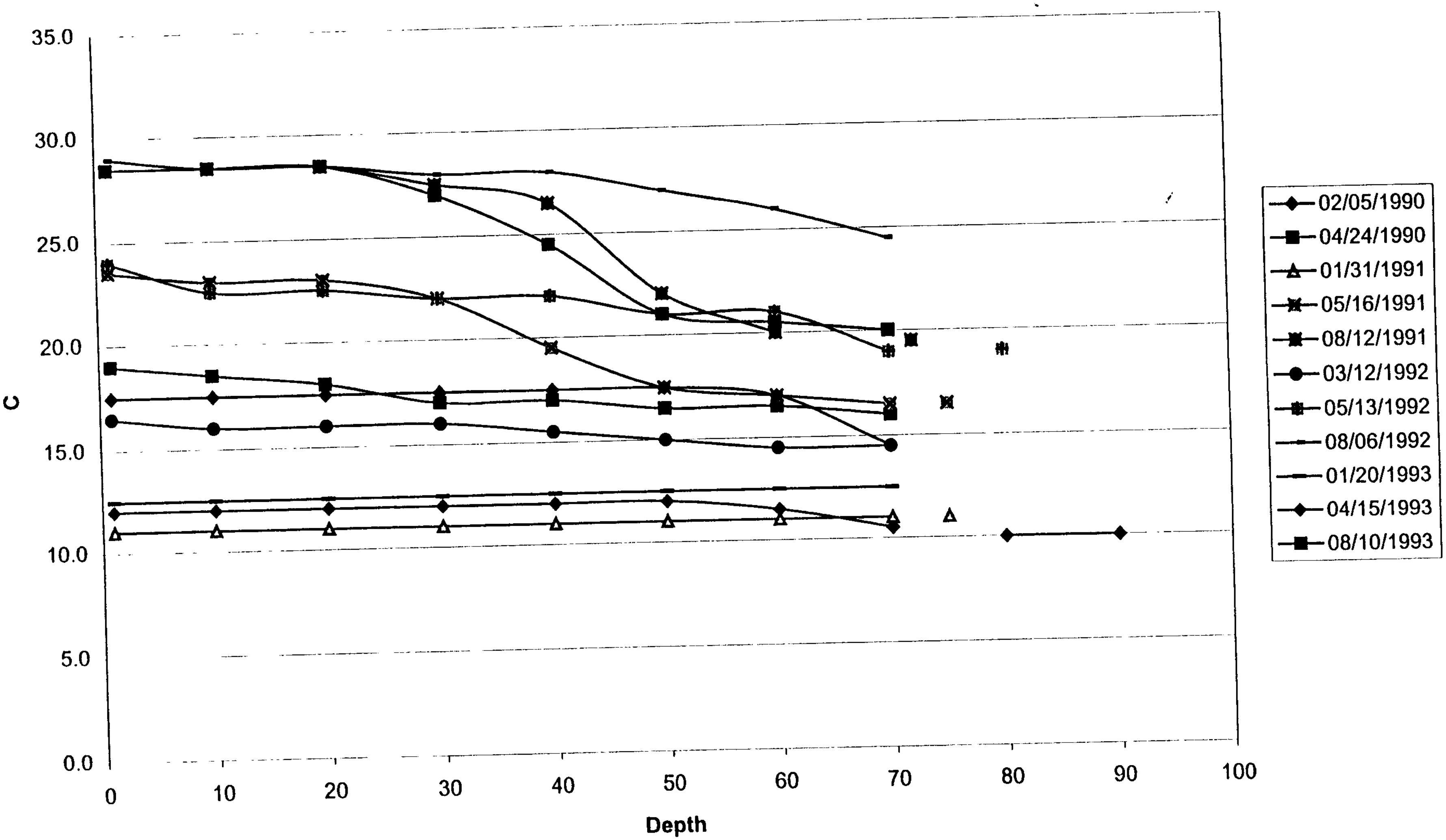
Raw Water from Canyon Lake
(USGS)

CLWSC Canyon Lake Depth Variation Data ('90 - '93)
Specific Conductance

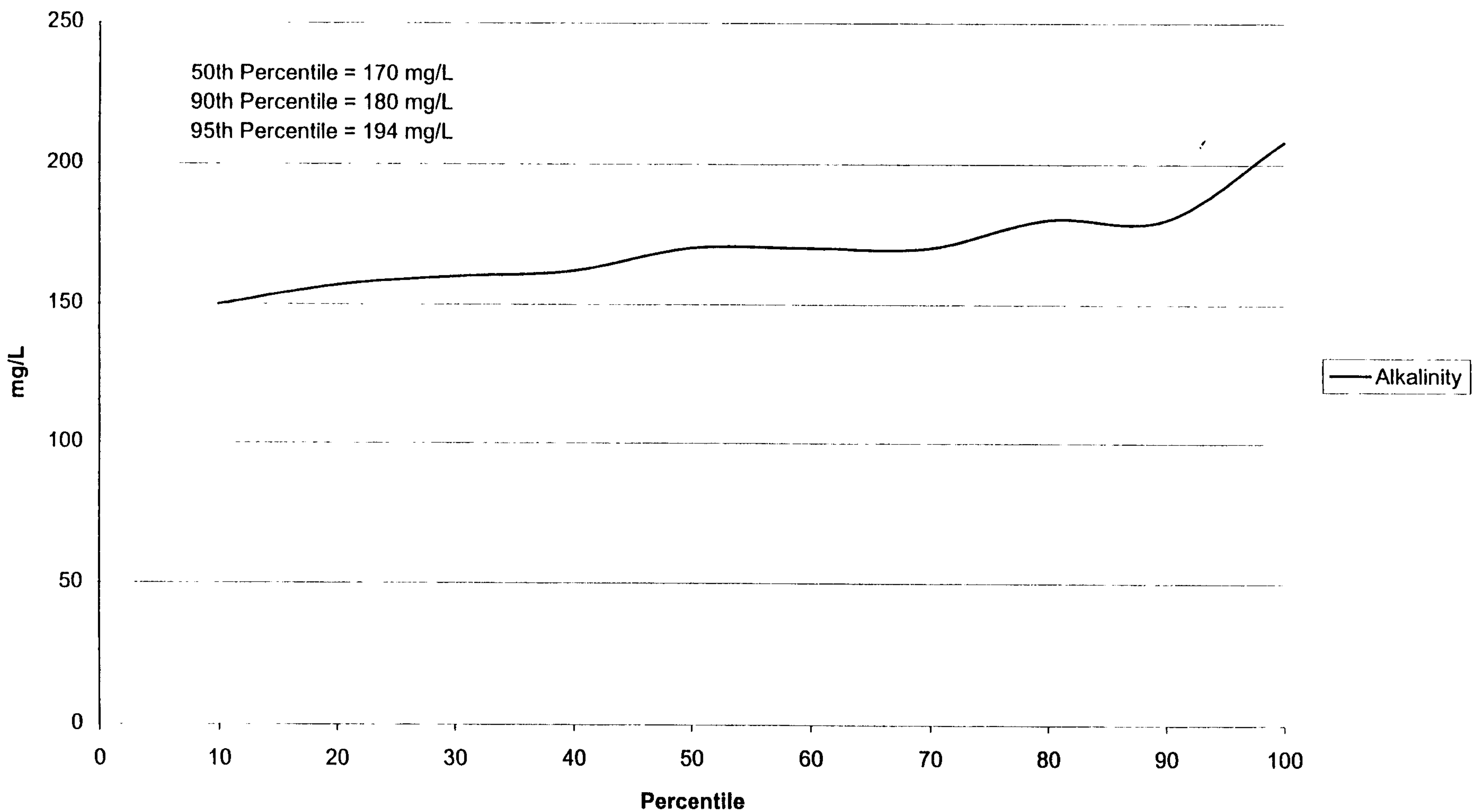


 Information taken from Hogan Corp. CLWSC Engineering Report (1994)

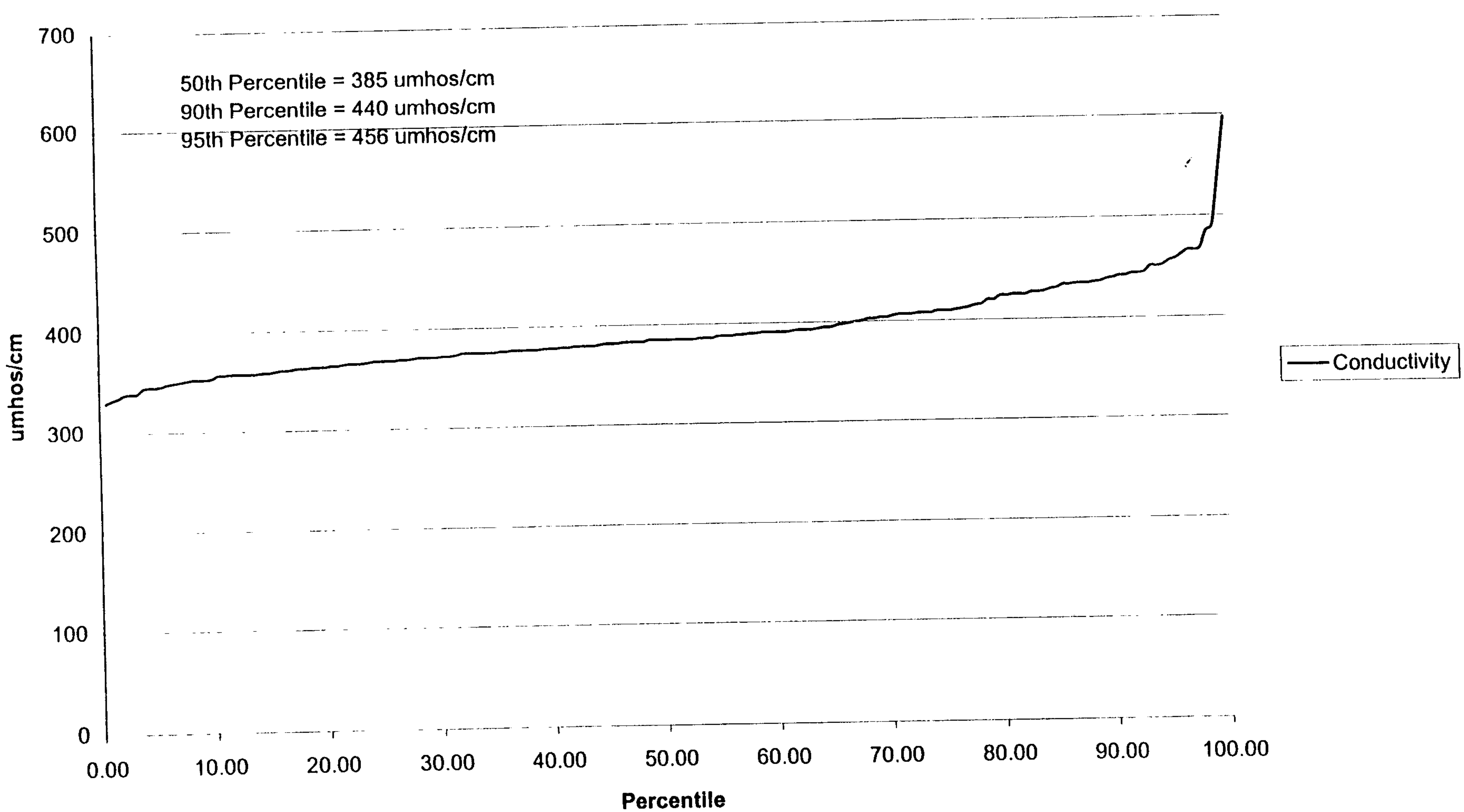
CLWSC Canyon Lake Depth Variation Data ('90 - '93)
Temperature



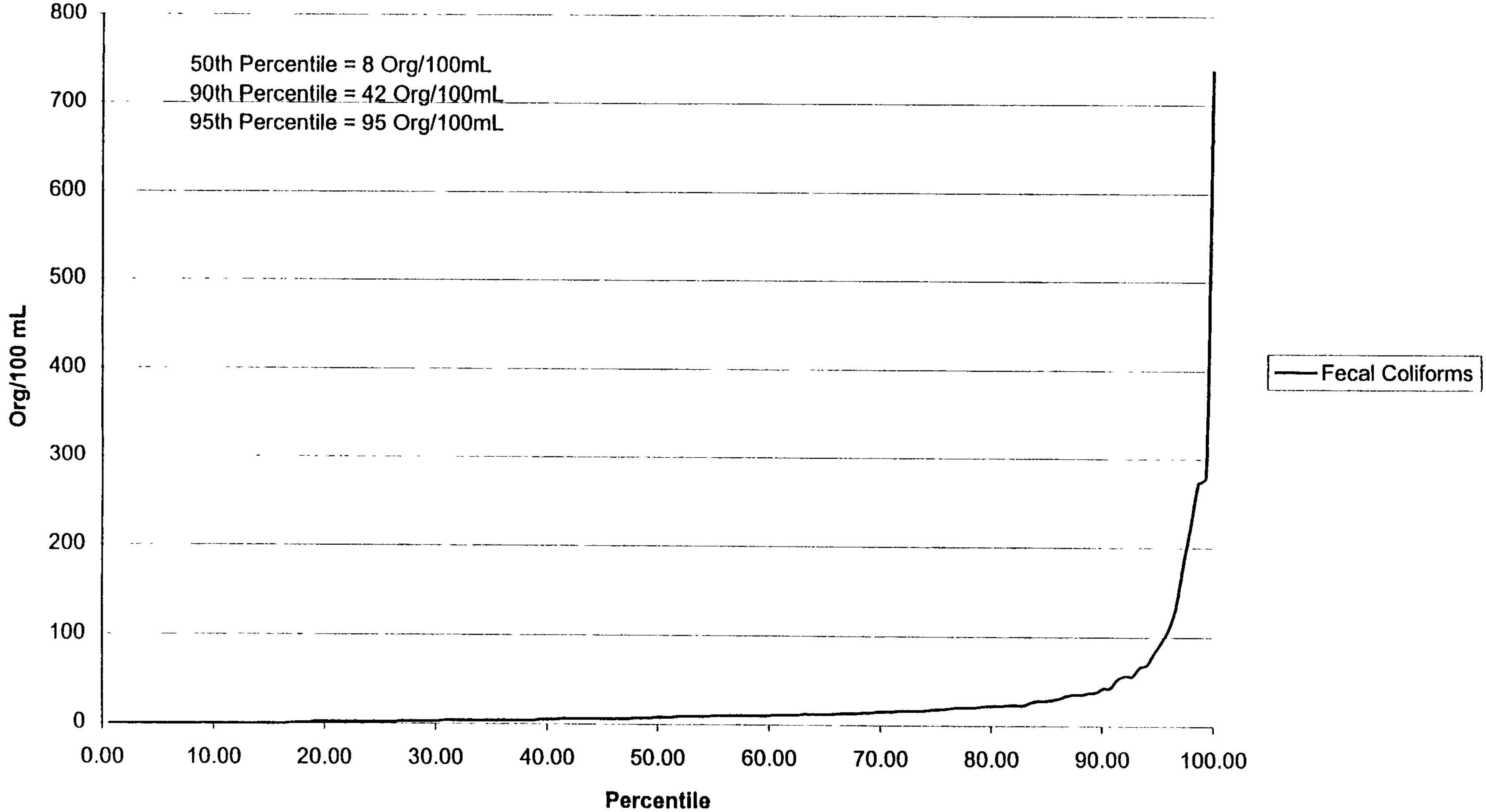
Cumulative Plot of Alkalinity (using data from sampling location 08167800; n = 10)

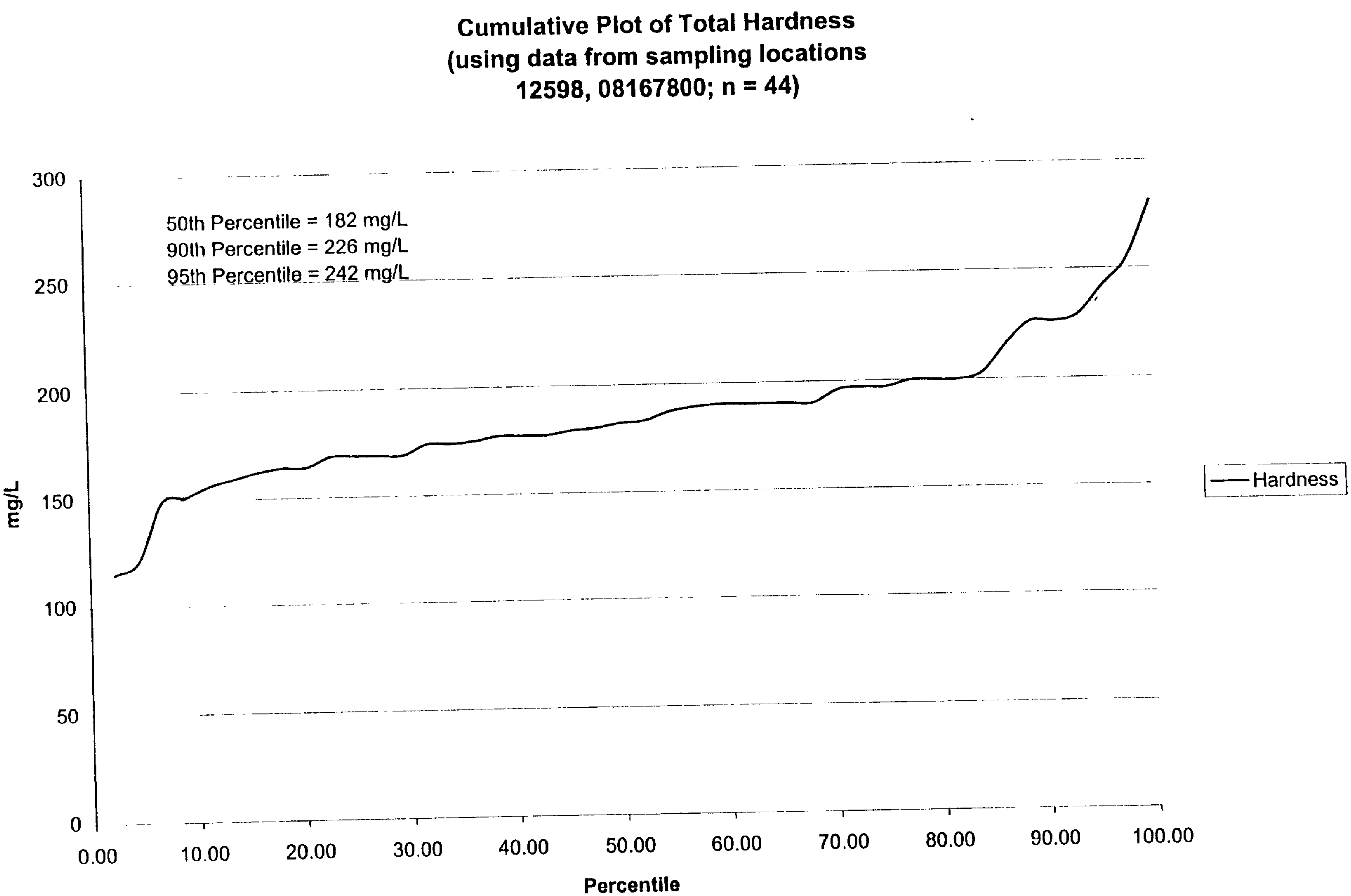


Cumulative Plot of Conductivity (using data from sampling locations 12598, 08167800; n = 180)

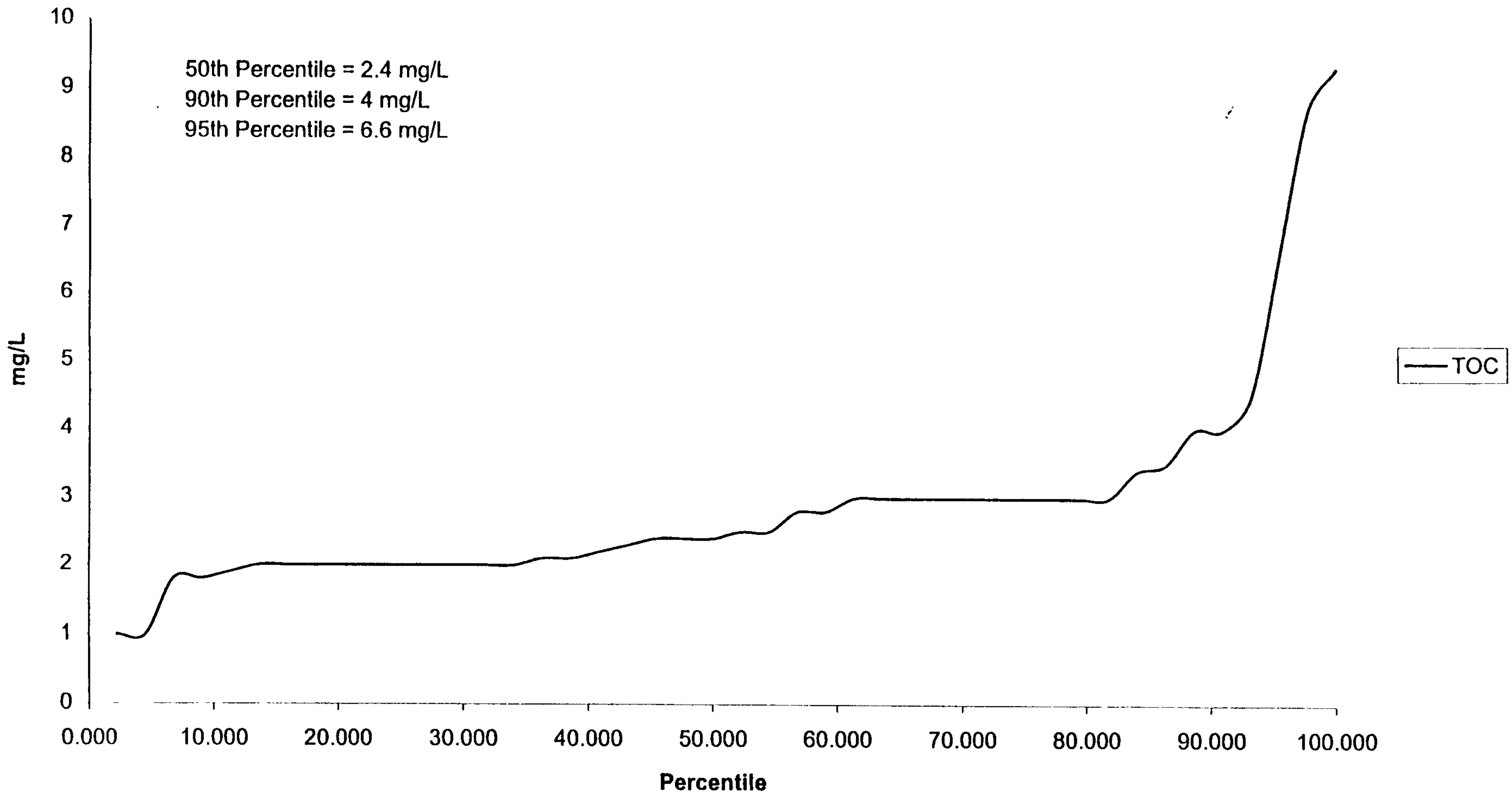


Cumulative Plot of Fecal Coliforms (using data from sampling location 12598; n = 152)

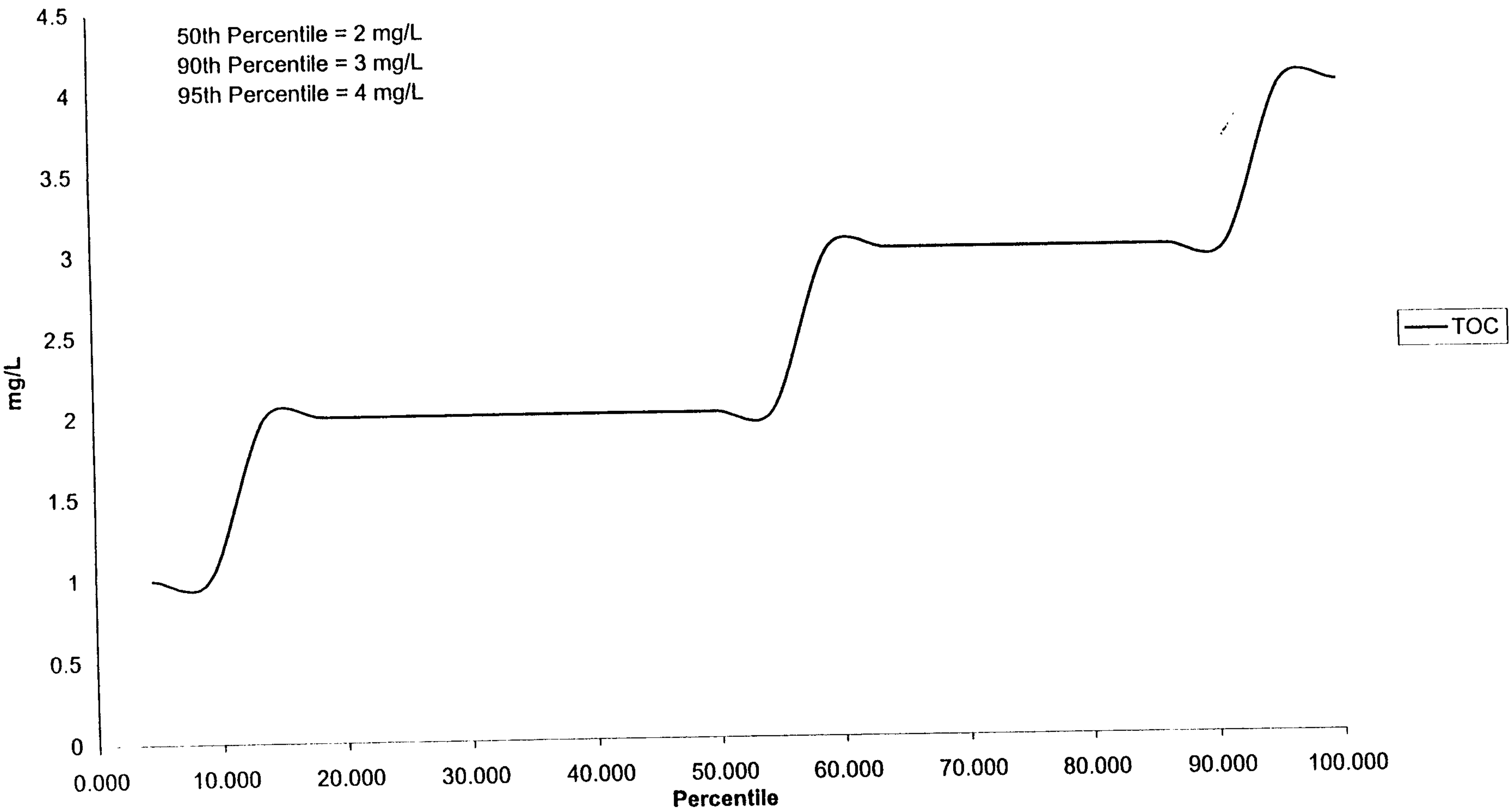



Cumulative Plot of Total Hardness
(using data from sampling locations
12598, 08167800; n = 44)
50th Percentile = 182 mg/L
90th Percentile = 226 mg/L
95th Percentile = 242 mg/L
mg/L
300
250
200
150
100
50
0
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
Percentile
Hardness

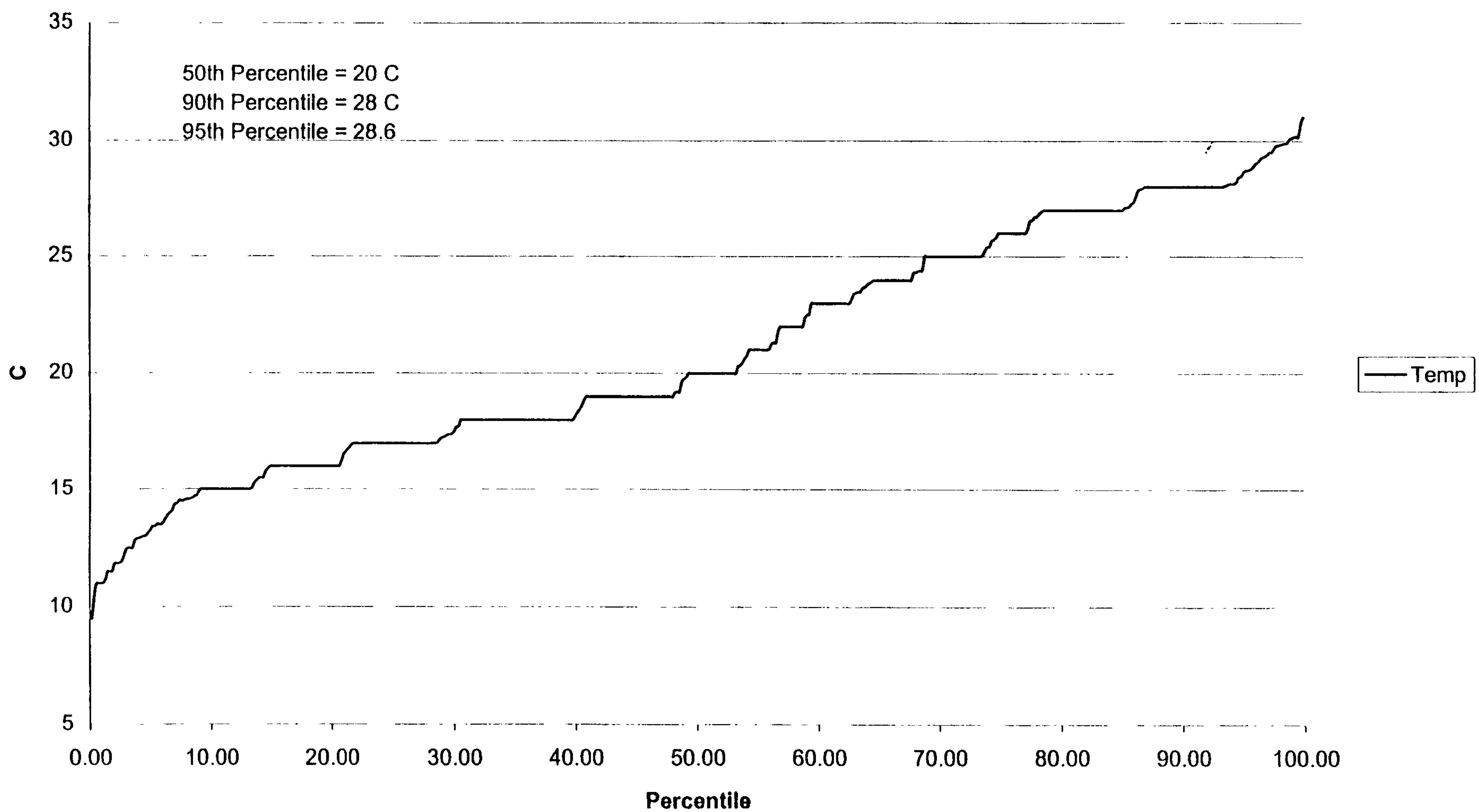
Cumulative Plot of Total Organic Carbon (using data from sampling location 08167800 (downstream), 12598 (in-lake),12600 (in-lake) and 12601 (lake headwaters); n = 44; 1989-1998 data)



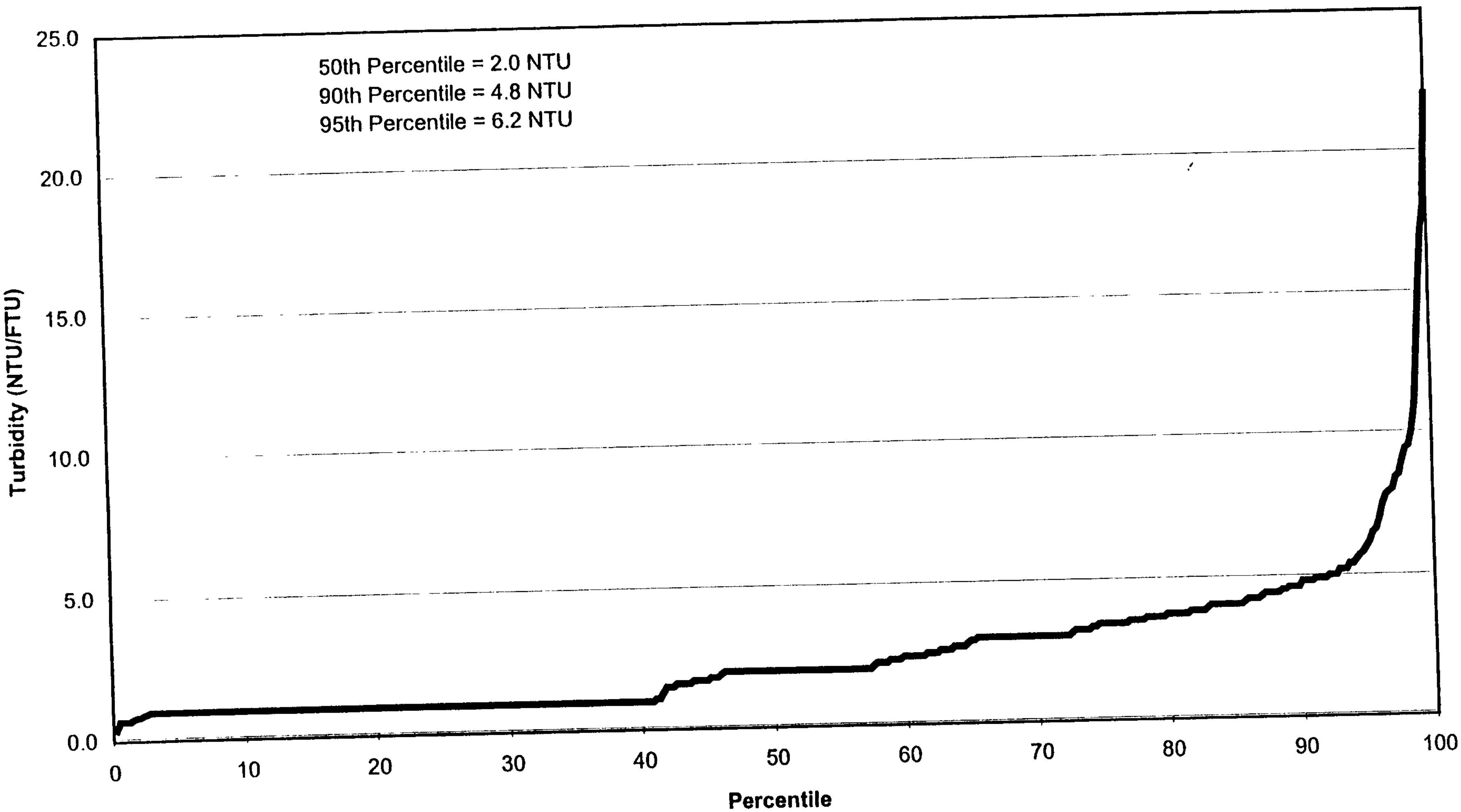
Cumulative Plot of Total Organic Carbon
(using data from sampling location
12598 (in-lake),12600 (in-lake),12601 (lake headwaters); n = 22; 1989-1998 data)



Cumulative Plot of Temperature (using data from 3 sampling locations including 12598, 08167800, and CLWSC Raw Water; n = 543)



Cumulative Plot of Turbidity
(using data from 3 sampling locations including 12598, 08167800, and CLWSC Raw Water; excluding 0 values; n = 390)



Additional Sampling Data
Taken on 01/24/2000

TABLE 7-1: CANYON LAKE ADDITIONAL SAMPLING RESULTS

Sample ID#	Depth (ft)	ph (S.U.)	Alkalinity (mg/L)	Bromide (mg/L)	Calcium Hardness (mg/L)	Total Hardness (mg/L)	Turbidity (NTU)	TOC (mg/L)	UV254 (cm-1)	T. Arsenic (mg/L)
1	20	7.10	144	1.10	102	163	<0.01	2.00	0.0352	<0.01
3	5	8.20	144	1.20	101	170	<0.01	2.0	0.032	<0.01
5	20	8.18	144	1.19	100	168	<0.01	2.0	0.025	<0.01
6	5	8.2	140	1.12	101	167	<0.01	2.0	0.026	<0.01
Method #		150.1	310.1	4500	6010B	-	180.1	415.1	5910B	6010B
MDL		-	1.00	0.20	0.10	1.00	0.01	1.00	0.005	0.01

Notes: 1. Sample Date: 1/24/2000
2. Location: Proposed Intake location (approximately 300 feet off shore from Comal Park).

APPENDIX B
FINISHED WATER BLENDING TESTS

1.1 INTRODUCTION

This protocol describes the bench-scale testing process for the finished water blending study. The testing background is discussed in Sections 1.2 through 1.4 and details of the tests are presented in Section 1.5. The objective of these blending tests is to assess specific water quality characteristics that may potentially impact blended water compatibility and individual customer acceptance.

1.2 TEST WATERS

The new Western Comal WTP will treat water from Canyon Lake, located on the Guadalupe River, and supply treated water to multiple customers, many of whom have different existing water supplies. Treated Canyon Lake water will blend with three other waters, upon delivery to customers:

- Groundwater pumped from the Edwards Aquifer (eg. SAWS and part of BMWD).
- Groundwater pumped from the Trinity Aquifer (eg. BWMD and Fair Oaks Ranch).
- Combined Trinity Aquifer groundwater and treated Cibolo Creek Surface Water (eg. City of Boerne).

1.3 TESTING TIMES

Seasonally varying parameters such as temperature and TOC may impact blending test results. Since it is frequently not feasible to perform blending tests several times throughout the year, these variances should be addressed to the extent possible during analysis.

1.4 TREATED WATER SIMULATION AND CHARACTERIZATION

Alternatives for simulating the treated surface water include using water from the existing Canyon Lake Water Supply Corporation WTP or taking raw water samples directly from the lake. The existing WTP uses a Robert's filtration package plant, applying aluminum chloride and chlorine to the water. Raw water samples would require preparation for testing by running through a cartridge filter to remove particulate matter and adding chlorine. The cartridge filter represent conventional treatment.

A historical review of Canyon Lake raw water and the existing water supplies of GBRA customers indicates that the waters are very similar in composition. To characterize the basic organic and inorganic nature of test waters several water quality parameters should be measured prior to blending:

- pH
- turbidity
- total alkalinity

- TOC
- UV_{254}
- total hardness
- temperature

1.5 *TESTING PROTOCOL FOR BLEND TEST*

The objective of the blend test protocol is to outline the basic test procedures for the laboratory technician.

1.5.1 Sampling Points

Twenty gallons of simulated treated water will be produced for the blending tests. Five-gallon samples will be extracted from each of three customers' existing water systems from points representative of the water to be blended. For example, water from the Edwards Aquifer would be taken from the SAWS Wurzbach pump station and Trinity Aquifer water would be taken from the BMWD Bulverde Hills Water District or Fair Oaks Ranch system.

1.5.2 Blending Percentages

Blending percentages are based on the approximate size and composition of the actual systems. In light of the variable nature of the blending scenarios amongst the customers, this test protocol evaluates water blends of treated Canyon Lake water and the existing water sources between 0 and 100%. Table 1-1 lists the requested delivery quantities of water to be supplied to the customer and anticipated blending range.

Table 1-1: Blending Percentages

Water Source (Customer sampled)	Designed GBRA Flow (Initial/Ultimate, mgd)	Current Water Source Flow (Avg.Day/Max Day, mgd)	Estimated Blending Range (%)	Tested Blending Range (%)
Edwards (SAWS) (BMWD)	 4.15/1.62 2.87/1.91*	Primary SA: 3.7/6.5 Secondary SA: 14.4/24.3** *	65-100% 0-35% 0-50%	0-100%
Trinity (BMWD) (Fair Oaks)	 2.87/1.91* 0.71/1.25	 1.5/4.3	 40-100% 40-100%	0-100%
Cibalo Crk/ Trinity (Boerne)	0.45/1.66	1.1/2.3	40-90%	0-100%

*BMWD delivered water will be distributed into several isolated water systems and blended with Edwards and Trinity waters.
**SA = Service Area

In addition, several smaller customers will receive delivered water quantities totaling up to 100% of their system demands, supplementing supplies with groundwater wells.

1.5.3 Procedure

Mix each blend at 100 rpm for 30 minutes in a 2-liter beaker using a jar test gang mixer apparatus to determine if any precipitate will form.

1.5.4 Analysis

Record values for pH, chlorine (free and total) and temperature at the time of sample collection. Send samples of all four waters to San Antonio Testing Laboratories for analysis of silica, nitrate-nitrogen, total hardness, calcium, TDS, TOC and total alkalinity. Measure pH, temperature, turbidity, UV 254 and conductivity again prior to mixing.

Measure turbidity and conductivity at 5, 15, and 30 minutes during mixing. Following mixing, allow water to settle for 30-minutes to allow any precipitates to settle. Following this settling period, measure pH, turbidity, UV254, and conductivity. Collect samples from the blended beakers and send to the San Antonio Testing Laboratory for testing of total hardness, total alkalinity, calcium, and TOC.

1.5.5 Equipment Requirements

Necessary equipment for testing is listed as follows:

- One or two 6-place gang mixer with 2-liter square beakers.
- pH meter
- Turbidimeter
- UV spectrophotometer
- 0.45 μm syringe filters
- Colorimetric residual chlorine analyzer
- Sample bottles
- Beakers and/or BOD bottles

BENCH-SCALE DISTRIBUTION PIPE COMPATIBILITY TESTS

1.1 INTRODUCTION

The objective of the pipe tests is to assess the effects of the anticipated blended water quality characteristics on existing distribution system (in particular, the possibility for release of corrosion by-products).

1.2 TEST WATERS

This bench-scale testing program evaluates blended waters with pipes from two distribution systems: City of Boerne and SAWS. The City of Boerne's distribution system is the oldest of all customer systems and includes higher-risk areas of unlined cast-iron piping. SAWS' system is anticipated to experience the highest level of customer sensitivity to slight changes in delivered water aesthetics.

1.3 TESTING PROGRAM

Bench-scale test protocol will be developed upon selection of treatment technology.

APPENDIX C
JAR TESTING PROGRAM

1.0 INTRODUCTION

This section presents the testing philosophy and details of the bench-scale testing program for the enhanced coagulation study. The raw water source for the new GBRA WTP is Canyon Lake. Canyon Lake is located on the Guadalupe River. Based on a review of historical information, the raw water appears to be of high quality and amenable to either conventional or direct membrane filtration treatment. This testing program evaluated 1) the level of TOC that can be removed through enhanced coagulation and 2) the rate of DBP formation after disinfection with free chlorine.

2.0 TESTING TIMES

To develop complete enhanced coagulation results, it is necessary to account for seasonal raw water quality variations. Such variations can be especially pronounced for surface water sources. Since raw water alkalinity and TOC levels directly impact enhanced coagulation TOC removal requirements (and hence, necessary coagulant dosages), the seasonal variations in these parameters are critical. Figures 1 and 2 present seasonal variations of alkalinity and TOC in Canton Lake water during the 1989 to 1998 period. The alkalinity trends shown in Figure 1 clearly illustrate seasonal variations for the lake water. Figure 2 shows that TOC also fluctuates for the water, but not in a regular, seasonal pattern. Since the quantity of TOC varies unpredictably, the GBRA should ideally track the raw water quality and conduct the testing to cover the ranges of alkalinity and TOC. Based on our review of the data, the following potential target range testing dates would be ideal:

- December to January 2000
- May 2000
- August 2000

Figure 1a
Canyon Lake Alkalinity

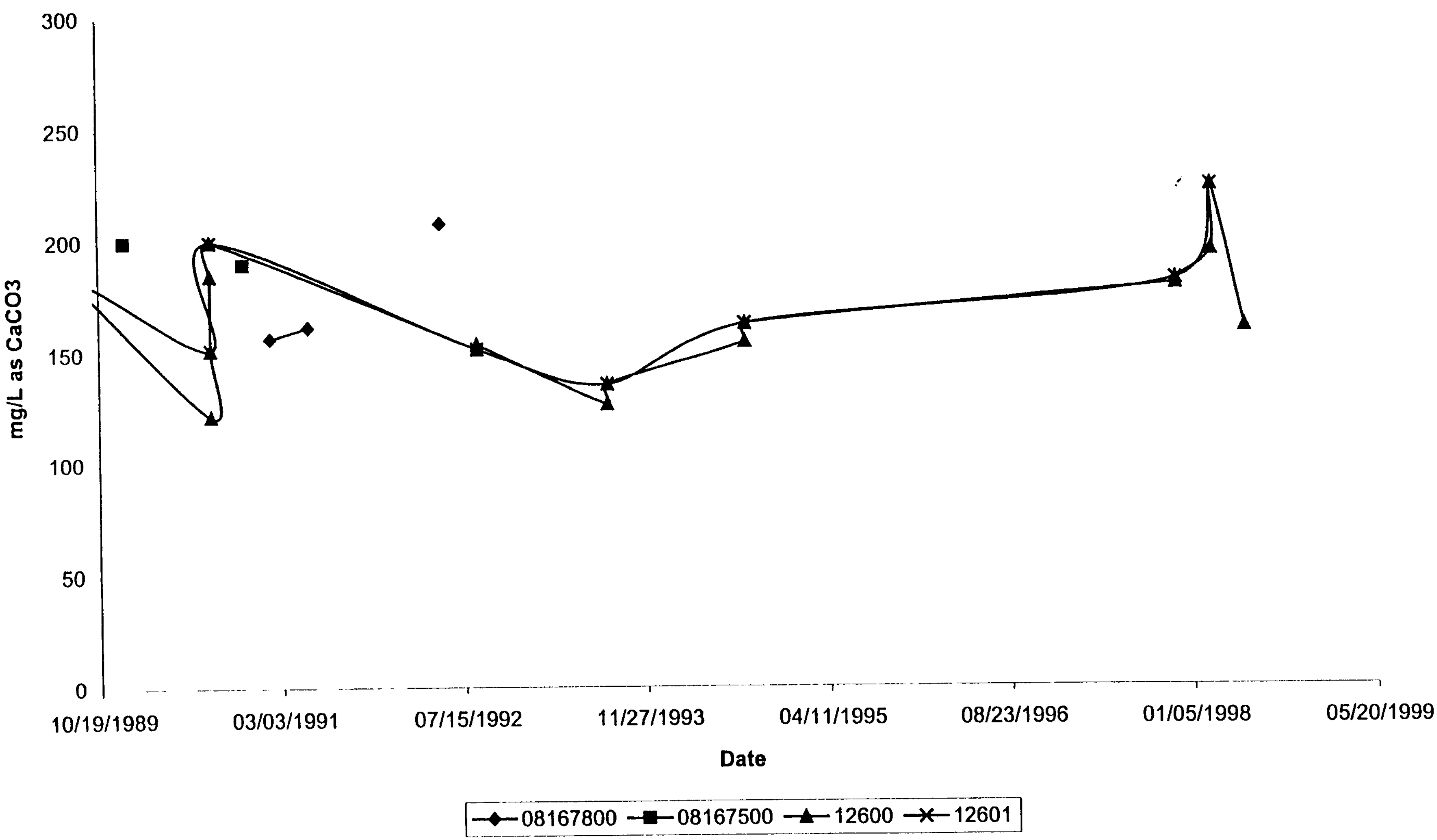
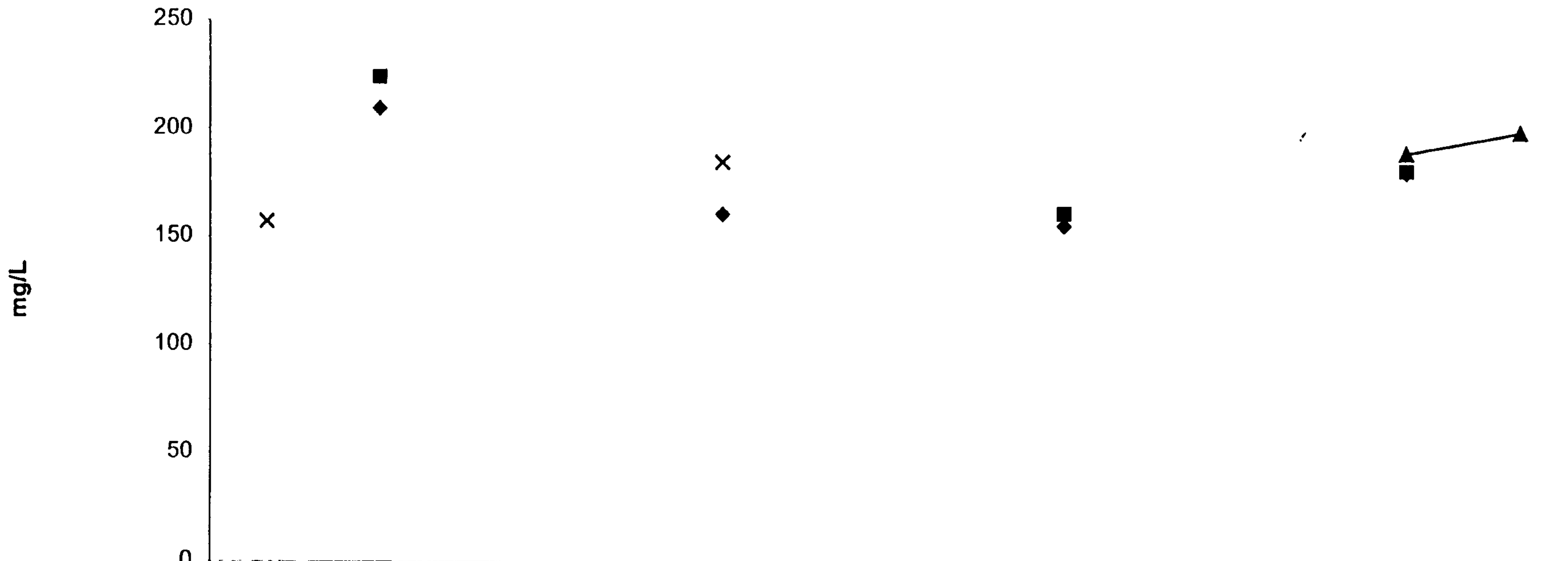


Figure 1b
Canyon Lake Data
Alkalinity (Monthly Averages)



	1	2	3	4	5	6	7	8	9	10	11	12
8167500											190	200
8167800	157				185							
12600		209.5			161			156.1429			181	
12601		224						161.8571			182	

Month

8167500 8167800 12600 12601

Figure 2a
Canyon Lake Total Organic Carbon (as mg/L C)

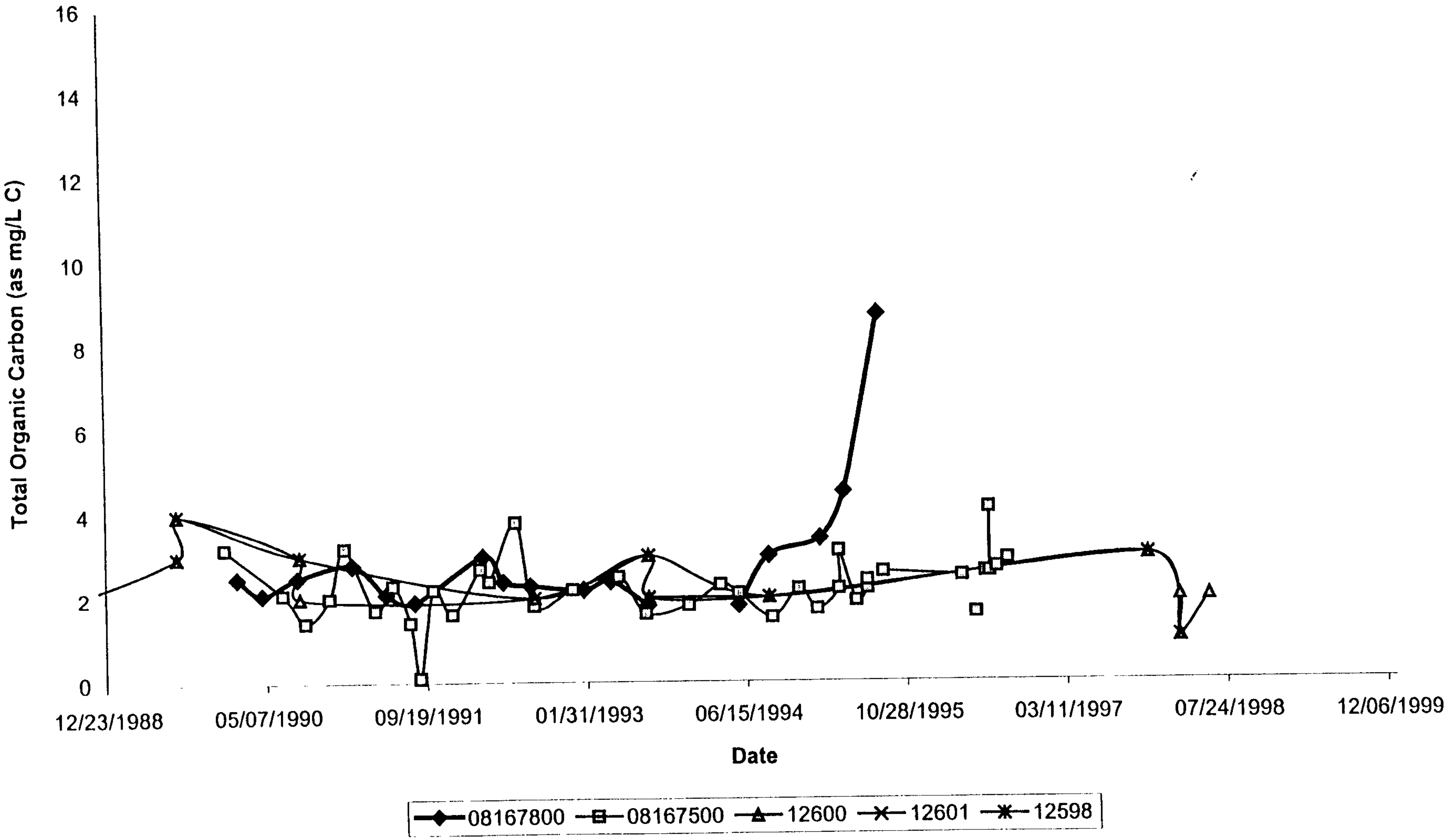
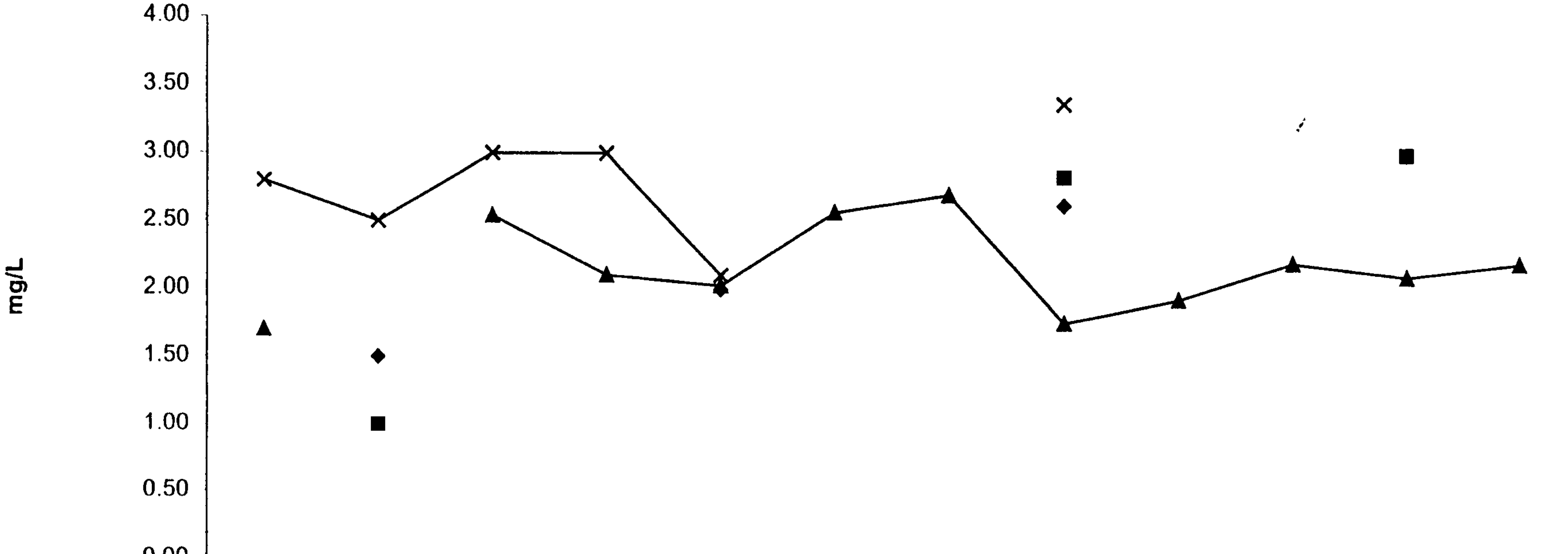


Figure 2b
Canyon Lake Data
TOC (Monthly Averages)



	1	2	3	4	5	6	7	8	9	10	11	12
8167500	1.7		2.54	2.1	2.025	2.566667	2.7	1.76	1.933333	2.2	2.1	2.2
8167800	2.8	2.5	3	3	2.1			3.366667				
12600		1.5			2			2.625			3	
12601		1						2.833333			3	

Month

8167500 8167800 12600 12601

However, due to the accelerated schedule for design of the WTP, the only feasible testing period was February, 2000. Typically, TOC levels are lower during winter months. Thus, this testing period would likely present a worst-case scenario for TOC removal through enhanced coagulation. Low influent TOC levels would not represent worst-case for DBP formation during distribution because less free chlorine is required for disinfection. Because of the lower raw water TOC levels, TOC removal will be assessed on a percent (%) removal basis, rather than on the post coagulation TOC levels.

3.0 RAW WATER CHARACTERIZATION

To characterize the basic organic and inorganic nature of test waters several raw water quality parameters should be measured:

- pH
- turbidity
- alkalinity
- TOC
- UV_{254}
- hardness
- bromide

Of these parameters, TOC and alkalinity are required to determine the Step 1 TOC removal criteria according to the enhanced coagulation requirements. UV absorbance at 254 nanometers (UV_{254}) is an easily measured parameter that provides an estimate of DBP precursor levels. The other parameters indicated above are useful to determine either the particulate concentration of the water sample (turbidity), implications for DBP speciation (bromide), or basic inorganic quality and buffer capacity of the water (pH, alkalinity, and hardness).

4.0 TESTING PROTOCOL DISCUSSION

This section contains a discussion of the test protocol for the laboratory technician to develop an understanding of the basic procedure. A detailed protocol for conducting the tests is also attached.

4.1 Bench-Scale Jar Test Conditions

Mixing and settling conditions during jar testing should be selected to represent these parameters in the full-scale facilities. The objective of rapid mixing is to disperse the added chemicals to the entire body of the water in the jar as quickly and efficiently as possible. The full-scale rapid mixing facilities are typically more efficient compared to what can be achieved in jar testing. Consequently, rapid mixing during jar testing should consist of mixing at full speed (>200 rpm) for one minute. Flocculation conditions at WTPs typically consist of a center well at the clarifiers at an estimated 30 minutes of slow mixing at an approximate mixing intensity (G value) of 30 to 50 per second. For a conventional jar test apparatus with 2 liter square jars, a one-to-one relationship between rotational speed of the paddle and resulting G value can be used.

The settling condition chosen for jar testing should include quiescent settling for a minimum of 30 minutes. For the given depth of jars, this time will represent a much smaller overflow rate compared to full-scale WTPs. However, due to the configuration of the full-scale facilities, the much larger sedimentation basins are often significantly more efficient. A 30-minute settling period can be used for jar testing to represent full-scale settling in large sedimentation basins.

4.2 Coagulant Dosages

Three coagulants will be included in the enhanced coagulation tests. They are Aluminum sulfate (alum), Ferric Chloride, and Aluminum Chlorohydrate. Throughout this document all dosages are in mg/L of dry product. To provide sufficient data from which to determine the effectiveness of TOC removal through enhanced coagulation, four dosages (10, 20, 50, and 80mg/L) were selected for jar testing. Results of this testing may allow a narrower range of coagulant dosages to be used in subsequent tests, if necessary. Enhanced coagulation will also be tested with a reduced pH level (6.5) and at a realistic dose (50 mg/L) for all three coagulants.

4.3 Use of Powdered Activated Carbon

Powered activated carbon (PAC) can be used during enhanced coagulation to improve the removal of TOC. Two alternative PAC dosages (20 and 30 mg/L) should be tested along with two alternative coagulants (alum and ferric) at a dose of 50 mg/L. A PAC dose of 20 mg/L should also be analyzed with an alum and ferric coagulant dose of 50 mg/L, where the pH has been reduced to 6.5. PAC should be added to the jars prior to coagulant addition and should be kept suspended by slowly mixing in the jars for a period representing the full-scale conditions in the raw water pipeline (about 3 hours). Mixing conditions after coagulant addition and sampling from these jars should be identical to those discussed in Section 4.1.

4.4 Treated Water Analyses

Key water quality parameters should be measured in settled water to determine the effectiveness of enhanced coagulation. Table 1 summarizes these parameters. Simulated distribution system (SDS) conditions for the settled water DBP analyses should consist of the following:

- 30 minutes of free chlorine contact time
- target residual of 0.5 mg/L after 72 hours, simulating 3 days residence time in the pipe.
- 24-hour and 72-hour contact time with free chlorine at room temperature. (24 hours is the anticipated maximum residence time of the water in the GBRA transmission line. 72 hours (3 days) is the average residence time including the customer distribution systems. (Free chlorine was evaluated as the secondary disinfectant to assess whether enhanced coagulation would provide enough DBP precursor removal to allow it to replace chloramines without forming excessive DBPs).