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AN ENVIRONMENTAL EVALUATION OF LA PLATA LAKE, TOA ALTA

SECOND QUARTERLY REPORT (JAN.-MAR., 1982)

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH
MARINE ECOLOGY DIVISION
COLLEGE STATION
MAYAGUEZ, PUERTO RICO

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UNIVERSITY OF PUERTO RICO — U.S. DEPARTMENT OF ENERGY

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (cont.)

INTRODUCTION

This document is a report of work accomplished during the second quarter of the restoration-diagnostic/feasibility study of La Plata Lake. Included are the results and preliminary analyses of the data collected during routine sampling excursions to the study area which correspond to the months of January, February and March, 1982, and an additional sampling event performed on 4 February 1982.

The information which resulted from the first quarter of the study (Oct-Dec., 1981) provided a general indication of the major water quality problems of La Plata Lake. These were identified as hypolimnetic oxygen depletion, eutrophication, choking of the lake surface by water hyacinths and bacterial contamination above accepted surface water standards for Puerto Rico. As part of our initial objectives the potential inputs of lake water quality degradation were identified by our approach of measuring concentrations at tributary rivers and at the lake proper. The results evidenced that the loading of nutrients, suspended solids and bacteriological contamination were contributed by the main tributaries of the lake. We also indicated that in view of the fact that more than 90% of the water entering the system comes from the watershed drainage of La Plata River particular attention should be addressed to this tributary in terms of the potential sources of contamination originating from its drainage basin.

Our approach during the second quarter (Jan-Mar.) of the study has followed the original sampling strategy of measuring concentrations at the main tributaries (La Plata River, Guadiana River and Cañas River) and at one station in the lake proper in order to provide the basic characterization of the lake as an input-output system. During this quarter we included in our sampling scheme a special investigation directed to evaluate our present monitoring station (L-I) as indicative of the water quality of the lake proper by comparing the water column average concentrations of L-I with the average water column concentrations at the dam site where the intakes of water for public supply are located. As part of this analysis our ability to detect field differences in concentrations for most of the parameters studied was determined.

In general, the results from this second quarter of investigations provide a more solid indication of what is the natural pattern and structure of some of the most important lake features, such as its thermal and chemical stratification, biological response to nutrient loading and the importance of the morphometric structure in dictating the present lake water quality condition.

METHODS

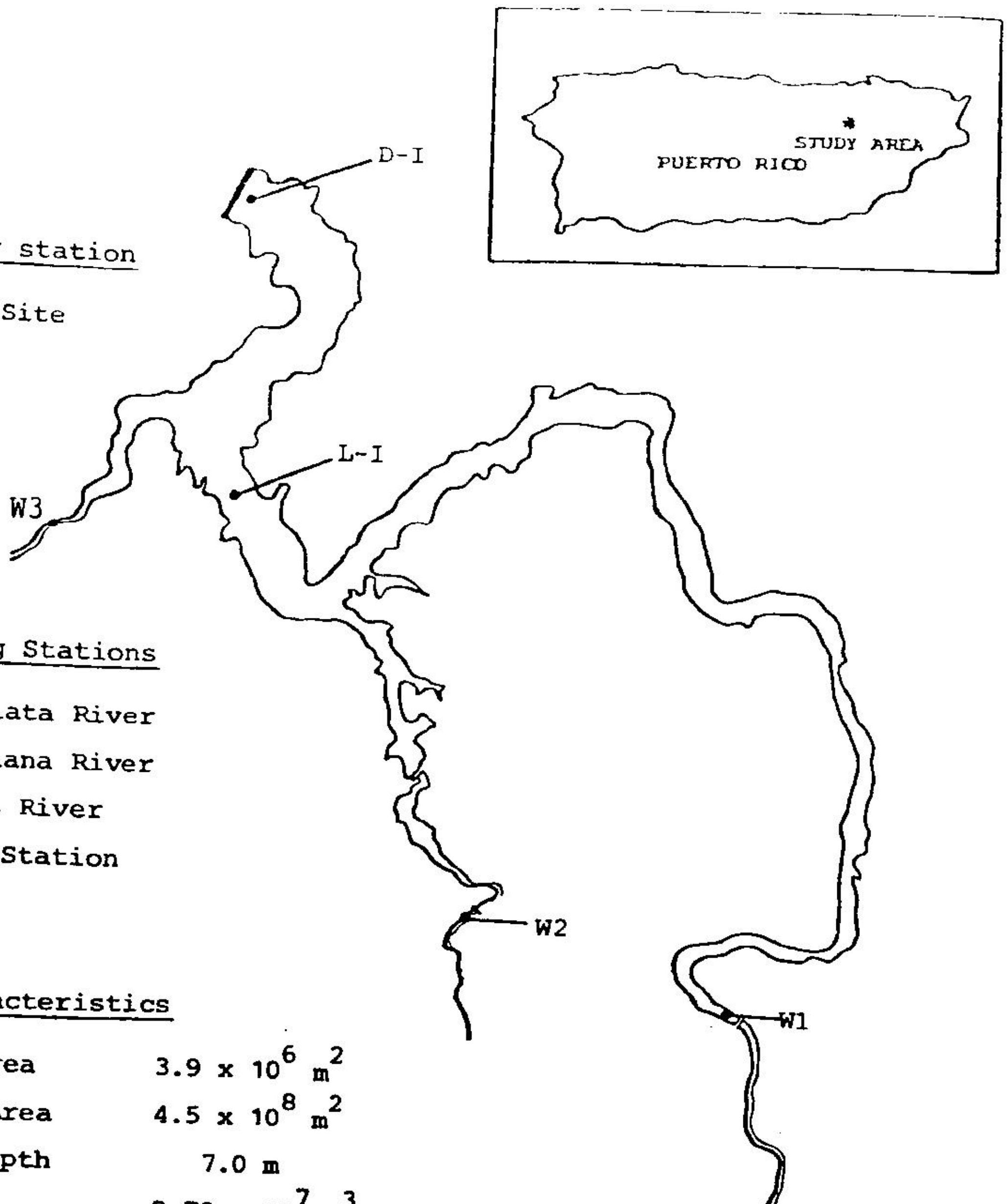
No detailed presentation of methods is made. The reader is referred to the proposal and quality assurance documents for that information.

RESULTS

The analytical results from water samples collected for a total of 22 water quality parameters during the period between January and March, 1982 are presented in Tables I through XXXV. The concentrations of selected water quality parameters resulting from a single hydrocast at the dam site are presented in Table XXXVI. Table XXXVII presents a comparative analysis of average water column concentrations between the lake station L-I and the auxiliary station at the dam site. Surface flow measurements taken at La Plata major tributaries are presented in Table XXXVIII.

Water samples for a preliminary screening of synthetic organics have been collected and the results will be reported as an addendum of the present report. Also included as an addendum of the present report will be the results of Hg concentrations and phytoplankton enumeration and taxonomy for the months of January, February and March, 1982.

Figure I. Sampling stations at La Plata Lake and major tributaries.



Auxiliary station

D-I Dam Site

Monitoring Stations

W-1 La Plata River
W-2 Guadiana River
W-3 Cañas River
L-I Lake Station

Lake Characteristics

Surface Area	3.9×10^6 m^2
Drainage Area	4.5×10^8 m^2
Average Depth	7.0 m
Volume	2.72×10^7 m^3
Maximum Width	500 m
Length	4.5 km
Construction Date	1973

SCALE 1:20,000

TABLE I. Water Temperature vs. Depth at Lake Station L-I

Depth (m)	SAMPLING DATES 1/12/82 °C	2/4/82 °C	2/11/82 °C	3/3/82 °C
0	25.5	25.5	25.0	25.6
1	25.3	25.3	25.0	25.2
2	25.1	25.0	26.0	25.0
3	24.5	24.8	24.8	24.8
4	23.9	24.6	24.4	24.6
5	23.6	24.2	24.2	24.4
6	23.4	23.8	23.8	24.2
7	23.3	23.6	23.6	24.0
8	23.3	23.4	23.6	23.8
9	23.2	23.3	23.4	23.5
10	23.2	23.2	23.3	23.4
11	23.2	23.2	23.3	23.3
12	23.1	23.1	23.2	23.2
13	23.1	23.0	23.2	23.2
14	23.0	23.0	23.1	23.2
15	23.0	23.0	23.1	23.1
16	23.0	22.9	23.0	23.1
17	22.9	22.9	23.0	23.1
18	22.9	22.9	23.0	23.1
19	22.9	22.9	22.9	23.1
20	22.8	22.9	22.9	23.1

TABLE II. Water Temperature at Tributary Stations.

Stations	SAMPLING DATES 1/12/82 °C	2/11/82 °C	3/3/82 °C
W-1 La Plata	23.6	24.0	23.5
W-2 Guadiana	22.8	27.0	23.7
W-3 Cañas	23.0	21.1	20.5

TABLE III. Dissolved Oxygen vs. Depth at Lake Station L-I

Depth (m)	SAMPLING DATES 1/12/82 mg/ℓ	2/4/82 mg/ℓ	2/11/82 mg/ℓ	3/3/82 mg/ℓ
0	7.1	8.4	4.8	7.6
1	5.2	6.7	4.8	7.3
2	4.0	5.0	4.8	6.1
3	1.1	2.9	4.1	4.2
4	0.4	1.4	0.5	0.6
5	0.4	0	0.2	0.2
6	0.4	0	0	0.1
7	0.7	0	0	0.1
8	0.5	0	0	0
9	0.4	0	0	0
10	0.1	0	0	0
11	0.2	0	0	0
12	0.1	0	0	0
13	0.1	0	0	0
14	0.6	0	0	0
15	0.7	0	0	0
16	0.6	0	0	0
17	0.2	0	0	0
18	0.1	0	0	0
19	0	0	0	0
20	0	0	0	0

TABLE IV. Dissolved Oxygen at Tributary Stations.

Stations	**SAMPLING DATES** 1/12/82 mg/ℓ	**2/11/82 mg/ℓ**	**3/3/82 mg/ℓ**
W-I La Plata	**8.6**	**8.0**	7.3
W-2 Guadiana	**9.1**	**10.1**	**10.0**
W-3 Cañas	**8.79**	**9.4**	**8.3**

TABLE V. pH vs. Depth at Lake Station L-I.

Depth (m)	1/12/82 Units	2/4/82 Units	2/11/82 Units	3/3/82 Units
	SAMPLING DATES			
0	6.5	7.6	7.0	7.1
1	6.5	7.5	7.0	7.1
2	6.5	7.5	7.0	7.0
3	6.4	7.2	6.9	6.9
4	6.4	7.1	6.7	6.6
5	6.4	7.0	6.7	6.6
6	6.4	7.0	6.7	6.6
7	6.4	7.1	6.7	6.6
8	6.4	7.1	6.7	6.6
9	6.4	7.1	6.6	6.6
10	6.4	7.1	6.6	6.6
11	6.4	7.1	6.6	6.6
12	6.4	7.1	6.6	6.6
13	6.4	7.1	6.6	6.5
14	6.4	7.0	6.6	6.5
15	6.4	7.0	6.6	6.5
16	6.4	7.0	6.5	6.5
17	6.4	7.0	6.5	6.5
18	6.3	7.0	6.4	6.5
19	6.3	7.0	6.4	6.5
20	6.3	7.0	6.4	6.5

TABLE VI. pH at Tributary Stations

Stations	1/12/82 Units	2/11/82 Units	3/3/82 Units
	SAMPLING DATES		
W-1 La Plata	8.0	7.9	7.9
W-2 Guadiana	7.9	7.8	7.8
W-3 Cañas	7.8	7.7	7.6

TABLE VII. Secchi Disk Readings at L-I and Tributary Stations.

Station	1/12/82 (m)	2/4/82 (m)	2/11/82 (m)	3/3/82 (m)
	SAMPLING DATES			
L-1	1.0	1.75	1.25	1.5
W-1	1.25	1.0	0.3	0.75
W-2	100% (.5m)	Not measured	100% (.5m)	100% (.5m)
W-3	100% (.4m)	Not measured	100% (.4m)	100% (.4m)

Number in parenthesis represents total depth of station.

TABLE VIII. Conductivity vs. Depth at Lake Station L-I.

Depth (m)	SAMPLING DATES 1/12/82 µmhos/cm	2/4/82 µmhos/cm	2/11/82 µmhos/cm	3/3/82 µmhos/cm
0	262	305	348	314
1	262	305	349	314
2	261	306	349	314
3	252	305	347	313
4	248	294	333	312
5	224	286	327	312
6	217	279	321	308
7	213	263	309	299
8	208	250	300	287
9	201	231	261	265
10	195	214	244	244
11	189	206	234	227
12	184	193	218	219
13	182	188	208	213
14	174	185	198	211
15	170	181	192	206
16	166	179	189	203
17	164	176	183	201
18	161	176	182	196
19	157	172	179	191
20	153	167	177	189

TABLE IX. Conductivity at Tributary Stations.

Stations	SAMPLING DATES 1/12/82 µmhos/cm	2/11/82 µmhos/cm	3/3/82 µmhos/cm
W-1 La Plata	364	290	273
W-2 Guadiana	280	300	305
W-3 Cañas	310	315	320

TABLE X. Total Suspended Solids vs. Depth at Lake Station L-1.

Depth (m)	1/12/82 mg/ℓ	2/4/82 mg/ℓ	2/11/82 mg/ℓ	3/3/82 mg/ℓ
	SAMPLING DATES			
0	6.0	2.4	5.4	3.6
4	6.2	1.4	6.2	3.0
8	231.0	3.2	9.0	2.8
12	236.0	13.0	17.4	2.8
16	243.0	24.0	23.4	9.4
20	474.0	28.8	21.6	10.6

TABLE XI. Total Suspended Solids at Tributary Stations.

Station	1/12/82 mg/ℓ	2/11/82 mg/ℓ	3/3/82 mg/ℓ
	SAMPLING DATES		
W-1	5.1	29.6	9.1
W-2	1.2	5.6	1.6
W-3	55.1	1.6	0

TABLE XII. Total Dissolved Solids vs. Depth at Lake Station L-I

Depth (m)	1/12/82 mg/ℓ	2/4/82 mg/ℓ	2/11/82 mg/ℓ	3/3/82 mg/ℓ
	SAMPLING DATES			
0	203	187	190	198
4	481	174	172	162
8	488	205	186	162
12	213	215	200	164
16	217	236	195	186
20	136	208	202	177

TABLE XIII. Total Dissolved Solids at Tributary Stations.

Stations	SAMPLING DATES 1/12/82 mg/ℓ	2/11/82 mg/ℓ	3/3/82 mg/ℓ
W-1	247	171.5	224
W-2	486	186.5	194
W-3	385	203.5	214

TABLE XIV. Total Alkalinity vs. Depth at Lake Station L-I.

Depth (m)	SAMPLING DATES 1/12/82 mg/ℓ$CaCO_3$	2/4/82 mg/ℓ$CaCO_3$	2/11/82 mg/ℓ$CaCO_3$	3/3/82 mg/ℓ$CaCO_3$
0	94	115	132	120
4	86	114	123	119
8	72	96	120	116
12	115	76	85	93
16	67	66	69	78
20	83	63	66	72

TABLE XV. Total Alkalinity at Tributary Stations.

Stations	SAMPLING DATES 1/12/82 mg/ℓ$CaCO_3$	2/11/82 mg/ℓ$CaCO_3$	3/3/82 mg/ℓ$CaCO_3$
W-1	142	105	143
W-2	102	113	119
W-3	106	115	122.5

TABLE XVI. Ammonia-Nitrogen vs. Depth at Lake Station L-I

Depth (m)	SAMPLING DATES 1/12/82 mg/ℓ	2/4/82 mg/ℓ	2/11/82 mg/ℓ	3/3/82 mg/ℓ
0	.01	.01	.04	.01
4	.04	.03	.03	.02
8	.02	.06	.15	.05
12	.01	.08	.18	.19
16	.01	.15	.16	.32
20	.03	.28	.33	.51

TABLE XVII. Ammonia-Nitrogen at Tributary Stations.

Station	SAMPLING DATES 1/12/82 mg/ℓ	2/11/82 mg/ℓ	3/3/82 mg/ℓ
W-1	.02	.06	.04
W-2	.01	.02	.02
W-3	.01	.01	.02

TABLE XVIII. Nitrite-Nitrate vs. Depth at Lake Station L-I.

Depth (m)	SAMPLING DATES 1/12/82 mg/ℓ	2/4/82 mg/ℓ	2/11/82 mg/ℓ	3/3/82 mg/ℓ
0	.66	.16	.48	.17
4	.85	.13	.47	.20
8	1.23	.38	.58	.24
12	1.21	.79	.72	.35
16	1.07	.61	.73	.24
20	1.19	.56	.41	.04

TABLE XIX. Nitrite-N trate at Tributary Stations.

Stations	/12/82 mg/ℓ	2/11/82 mg/ℓ	3/3/82 mg/ℓ
	SAMPLING DATES		
W-1	1.07	1.11	.09
W-2	1.52	1.82	.15
W-3	1.87	1.62	.14

TABLE XX. Total Kjeldahl Nitrogen vs. Depth at Lake Station L-I.

Depth (m)	1/12/82 mg/ℓ	2/4/82 mg/ℓ	2/11/82 mg/ℓ	3/3/82 mg/ℓ
	SAMPLING DATES			
0	.51	.68	.23	.39
4	.41	.68	.15	.50
8	.65	.68	.26	.38
12	.79	.53	.53	.58
16	.81	.65	.70	.79
20	.75	1.08	.91	.94

TABLE XXI. Total Kjeldahl Nitrogen at Tributary Stations.

Stations	1/12/82 mg/ℓ	2/11/82 mg/ℓ	3/3/82 mg/ℓ
	SAMPLING DATES		
W-1	.29	.30	.34
W-2	.30	.23	.38
W-3	.28	.18	.28

TABLE XXII. Soluble Reactive Phosphorus vs. Depth at Lake Station L-I

	SAMPLING DATES			
Depth (m)	1/12/82 mg/ℓ	2/4/82 mg/ℓ	2/11/82 mg/ℓ	3/3/82 mg/ℓ
0	.10	.04	.10	.05
4	.12	.04	.08	.06
8	.12	.10	.12	.09
12	.14	.16	.15	.13
16	.13	.16	.15	.13
20	.14	.12	.15	.14

TABLE XXIII. Soluble Reactive Phosphorus at Tributary Stations

	SAMPLING DATES		
Stations	1/12/82 mg/ℓ	2/11/82 mg/ℓ	3/3/82 mg/ℓ
W-1	.19	.26	.26
W-2	.20	.28	.23
W-3	.13	.12	.10

TABLE XXIV. Total Phosphorus vs. Depth at Lake Station L-I

	SAMPLING DATES			
Depth (m)	1/12/82 mg/ℓ	2/4/82 mg/ℓ	2/11/82 mg/ℓ	3/3/82 mg/ℓ
0	.53	.15	.14	.14
4	.58	.11	.15	.15
8	.17	.33	.14	.14
12	.29	.30	.13	.15
16	.20	.20	.17	.12
20	.37	.26	.15	.10

TABLE XXV. Total Phosphorus at Tributary Stations

Stations	SAMPLING DATES 1/12/82 mg/ℓ	2/11/82 mg/ℓ	3/3/82 mg/ℓ
W-1	.17	.20	.26
W-2	.39	.32	.28
W-3	.18	.18	.19

TABLE XXVI. Chlorophyll-a vs. Depth at Lake Station L-I

Depth (m)	SAMPLING DATES 1/12/82 mg/m^3	2/4/82 mg/m^3	2/11/82 mg/m^3	3/3/82 mg/m^3
0	21.13	29.51	34.94	3.07
4	4.65	18.98	17.12	2.69
8	.68	4.18	3.84	3.03
12	.23	1.20	2.03	3.94
16	.32	1.09	1.39	16.60
20	.26	1.46	1.04	13.09

TABLE XXVII. Chlorophyll-a at Tributary Stations

Stations	SAMPLING DATES 1/12/82 mg/m^3	2/11/82 mg/m^3	3/3/82 mg/m^3
W-1	1.12	1.65	1.30
W-2	1.87	1.83	2.03
W-3	3.86	1.52	6.35

TABLE XXVIII. Total Coliforms vs. Depth at Lake Station L-I

Depth (m)	SAMPLING DATES 1/12/82 MPN/100 mls	2/11/82 MPN/100 mls	3/3/82 MPN/100 mls
0	1,400	1,700	790
4	490	790	79
8	230	700	130
12	170	*	230
16	130	700	230
20	50	1,700	130

*Sample bag accidentally torn during transport.

TABLE XXIX. Total Coliforms at Tributary Stations.

Stations	SAMPLING DATES 1/12/82 MPN/100 mls	2/11/82 MPN/100 mls	3/3/82 MPN/100 mls
W-1	1,500	1,815	640
W-2	14,450	7,950	1,300
W-3	3,850	7,650	2,800

TABLE XXX. Fecal Coliforms vs. Depth at Lake Station L-I

Depth (m)	SAMPLING DATES 1/12/82 MPN/100 mls	2/11/82 MPN/100 mls	3/3/82 MPN/100 mls
0	110	230	13
4	490	490	49
8	230	700	33
12	20	*	79
16	80	330	49
20	20	230	79

*Sample bag accidentally torn during transport.

TABLE XXXI. Fecal Coliforms at Tributary Stations

Stations	1/12/82 MPN/100 mls	2/11/82 MPN/100 ms	3/3/82 MPN/100 mls
	SAMPLING DATES		
W-1	220	965	110
W-2	1,400	3,300	300
W-3	640	945	475

TABLE XXXII. Fecal Streptococcus vs. Depth at Lake Station L-I

Depth(m)	1/12/82 MPN/100 mls	2/11/82 MPN/100 mls	3/3/82 MPN/100 mls
	SAMPLING DATES		
0	80	13	≤2
4	≤20	94	≤2
8	≤20	130	23
12	20	*	5
16	≤20	110	5
20	≤20	21	≤2

*Sample bag accidentally torn during transport.

TABLE XXXIII. Fecal Streptococcus at Tributary Stations

Stations	1/12/82 MPN/100 mls	2/11/82 MPN/100 mls	3/3/82 MPN/100 mls
	SAMPLING DATES		
W-1	35	92	18
W-2	465	76	23
W-3	345	360	140

TABLE XXXIV. Concentrations of Heavy Metals vs. Depth at the Lake Station, L-I.

Depth (m)	Cu 1/12/82 µg/ℓ	Cu 3/3/82 µg/ℓ	Cd 1/12/82 µg/ℓ	Cd 3/3/82 µg/ℓ	Cr 1/12/82 µg/ℓ	Cr 3/3/82 µg/ℓ	Pb 1/12/82 µg/ℓ	Pb 3/3/82 µg/ℓ	Zn 1/12/82 µg/ℓ	Zn 3/3/82 µg/ℓ
0	3.0	3.0	1.9	1.9	<10.0	<10.0	18.2	24.2	64.5	33.6
4	3.5	4.5	1.9	1.9	<10.0	<10.0	18.2	18.2	47.4	16.8
8	10.7	3.0	2.1	1.9	<10.0	<10.0	15.2	<6.2	81.2	36.1
12	11.2	3.3	1.9	1.9	<10.0	<10.0	18.2	6.2	488.8	54.1
16	6.4	5.9	1.2	2.2	<10.0	< 5.0	27.2	30.2	126.8	120.0
20	14.9	8.8	1.9	1.2	<10.0	< 5.0	24.2	<6.2	192.8	183.0

TABLE XXXV. Concentrations of Heavy Metals at Tributary Stations.

Station	Cu 1/12/82 µg/ℓ	Cu 3/3/82 µg/ℓ	Cd 1/12/82 µg/ℓ	Cd 3/3/82 µg/ℓ	Cr 1/12/82 µg/ℓ	Cr 3/3/82 µg/ℓ	Pb 1/12/82 µg/ℓ	Pb 3/3/82 µg/ℓ	Zn 1/12/82 µg/ℓ	Zn 3/3/82 µg/ℓ
W-1	3.5	5.6	2.8	0.8	<10.0	<10.0	25.8	13.7	33.2	50.2
W-2	3.2	4.0	1.4	1.9	<10.0	<10.0	15.2	7.6	41.4	21.9
W-3	2.8	3.2	2.0	1.4	<10.0	<10.0	18.2	25.7	39.0	51.4

TABLE XXXVI. Concentrations of Selected Water Quality Parameters vs. Depth at the Dam Site Station during February 4, 1982.

Depth (m)	Temp. °C	Cond. µmhos/cm	pH Units	DO mg/ℓ	Alk mg/ℓ	TSS mg/ℓ	TDS mg/ℓ	TKN mg/ℓ	NO_2-NO_3 mg/ℓ	NH_3-N mg/ℓ	SRP mg/ℓ	TP mg/ℓ	Chl-a mg/m^3
0	24.8	286	6.9	0.5	109	2.4	172	.26	.08	.02	.03	-	5.54
4	24.0	258	7.25	0	110	1.8	173	.53	.06	.03	.04	.20	[illegible]
8	23.3	203	7.2	0.0	74	21.8	218	.52	.85	.06	.06	.11	[illegible].05
12	23.1	179	7.2	0.0	62	9.8	237	.74	.79	.06	.06	.19	[illegible]
16	22.9	164	7.1	0.0	56	24.8	213	1.91	.92	.07	.06	.12	.26
20	22.9	159	7.1	0.0	56	15.6	250	.73	.82	.14	.16	.20	.20
$\bar{x}$	23.5	208	7.1		78	12.7	210	.78	.59	.06	.07	.16	2.18

TABLE XXXVII. Comparative Analysis of Average Water Column Concentrations of Selected Water Quality Parameters Between L-I and the Dam Site.

Parmaeters	Units	$\bar{X}$ L-I	$\bar{X}$ Dam	Coefficent of Variation from duplicate samples	T Value*
Temperature	°C	23.7	23.5	0.17%	- 33.3 ⊕
Conductivity	µmhos/cm	231	208	0.71%	- 9.34
pH	Units	7.15	7.125	0.70%	- 0.33
D.O.	mg/ℓ	1.2	0.05	11.4 %	- 5.47
T. Alkalinity	mg/ℓ as $CaCO_3$	88	78	1.66%	- 4.56
TSS	mg/ℓ	12.1	12.7	26.09%	0.13
TDS	mg/ℓ	204	210	13.9 %	0.14
TKN	mg/ℓ	0.72	0.78	10.8 %	0.5
NO_2-NO_3	mg/ℓ	0.44	0.59	11.9 %	2.0
NH_3-N	mg/ℓ	0.10	0.06	13.02%	2.7
SRP	mg/ℓ	0.10	0.07	6.5 %	3.0
TP	mg/ℓ	0.22	0.16	13.2 %	1.3
Chl-a	mg/m^3	9.40	2.18	54.1 %	-0.95

*Comparison of a single observation (Dam average concentrations) with the mean of a sample (L-I average concentrations).

⊕Significantly different at p ~ .05
t .05[1] = 12.71.

TABLE XXXVIII. Surface Flow Measurements of the Major Tributaries of La Plata Lake.

Month	W-1 La Plata River m^3/month	W-2 Guadiana River m^3/month	W-3 Cañas River m^3/month
October '81	1.769×10^7	-	-
November '81	1.863×10^7	2.041×10^6	5.503×10^5
December '81	7.205×10^7	2.23×10^6	2.215×10^5
January '82	1.601×10^7	1.123×10^6	1.129×10^5
February '82	7.955×10^6	7.163×10^5	2.63×10^5
March '82	1.277×10^7	1.62×10^6	3.181×10^5

- Not measured.

DISCUSSION

Temperature

The vertical profile of water temperature evidenced a gradual decline with depth at the lake station L-I (see Table I) with an average ΔT of 0.15°C per meter. The maximum differences in water temperature between surface and 20 m depths were 2.7°C in January, 1982 and averaged 2.5°C during this quarter (Jan.-Mar., 1982). The plane of highest rate of change with depth fluctuated between surface and 6 m depths. The presence of a classical thermocline (i.e., $\Delta T \geq 1°/M$) was not evident at any depth in the water column; however, the temperature profiles reveal a weak thermal stratification.

Water temperatures at the main tributaries ranged between 23.5°C and 24°C in La Plata River (W-1), 22.8°C and 27.0°C in Guadiana River and 20.5°C and 23.0°C in Cañas River (see Table II).

Dissolved Oxygen

A clinograde oxygen profile was maintained at the lake station L-I during the period between January and March 1982. A strong chemocline fluctuated between 2-4 m (see Table III). Oxygen depletion with zero values in the hypolimnion has been shown to be a recurrent lake feature in La Plata Lake (see First Quarterly Report).

The structure of oxygen distribution in La Plata Lake is dictated by complex biochemical, physical and hydrodynamic factors. The major features are probably: lake morphometry, nutrient loading and biological response, possible organic loading, and the tropical setting.

The lake has a relatively low surface to volume relationship (relative depth is .04) and its location protected by high hills tends to prevent wind mixing and reaeration. Loading of the lake by N and P via rain-runoff is high and sustains a higher internal primary productivity. Phytoplankton respond with densities so high in surface waters that light penetration is restricted. Water hyacinth crops are high and cover more than 50% of the lake surface. Where present, they virtually screen out all the light. Organic materials discharged to the lake in rain events and sedimenting phytoplankton and dead particles of hyacinths support the growth of microbes which consume available oxygen in the layers of the lake below 4-6 meters and render it anaerobic and reducing. Such reducing conditions, in general, are unfavorable for the growth of phytoplankton and other aerobic life. Thus photosynthetic oxygen renewal does not occur either.

The large seasonal reductions in temperature, which in more temperate areas result in convective mixing of the water column, do not occur here and the higher and less variable temperature regime keeps metabolism high while preventing physical reaeration.

Tributary discharge and runoff of well-oxygenated waters have shown to be a significant factor in the oxygenation of the water column in Lake La Plata; however, it appears possible that only rainstorm events or extremely strong winds will be capable of mixing the lake restoring oxygen to the depths. Some restoration of oxygen to the hypolimnion was evidenced following the rains of

December, 1981 but proved to be of short duration as clinograde profiles again appeared from January through March, 1982.

Oxygen depletion in lake waters represents a serious water quality and recreational problem in La Plata Lake. Heavy metals such as Mn^{++} and Fe^{+-} are more soluble under anoxic conditions and could be detrimental to the system as a drinking water supply; also, fisheries of any sort are limited by oxygen deficiences. In view of this finding increased attention will be addressed to dissolved oxygen structure and lake metabolism in the next quarter of the study.

Dissolved oxygen concentrations at tributary stations were all well-oxygenated with values near to saturation (see Table IV).

pH

Profiles of pH at the lake station L-I are presented in Table V. The pH was consistently higher in the first two meters with an average of 7.0, then declined gradually with depth to mean values of 6.55 at 20 m. The phytosynthetic removal of CO_2 from the uppermost (lighted) layers of the lake are postulated to be involved in the maximum values observed. However, tributary rivers gave higher pH values than the lake (means of 7.9 in La Plata, 7.8 in Guadiana and 7.7 m in Cañas, (see Table VI) allowing the alternate explanation that those input waters simply dominate the upper layers of the lake.

Secchi Transparency

The average secchi transparency at the lake station L-I was 1.4 m. Monthly secchi readings at L-I reflected a significant inverse relationship with mean epilimnion zone (0-4 m) values of total suspended solids (r= -.96). Secchi disk readings at L-I and tributary stations are presented in Table VII.

Conductivity

The average conductivity of the water column at the lake station (L-I) was 233 µmhos/cm per meter. The maximum rate of change was found between 7 - 11 m ($\bar{x}$ = 13.4 µmhos/cm/m). The vertical gradient continues to show no relation to total dissolved solids suggesting that vertical differences in ionic species must exist in the water column. The relationship of specific conductance to TDS will vary depending on the distribution of the major chemical species present (Water Quality Criteria, 1973) and conductivity is, to some extent, influenced by the size and nature of suspended particles as well.

Special sampling and analyses will be performed in the next quarter to examine the possibility that non-ionic dissolved organics contribute a larger fraction of TDS at depths than near the surface.

The specific conductance of the tributaries continue to be higher than the lake. Tributary rivers (Table IX) had mean conductivities of 309 µmhos/cm at La Plata (W-I), 295 µmhos/cm at Guadiana and 315 µmhos/cm at Cañas River.

Total Suspended Solids

The water column mean of TSS for the period between January and March, 1982 was 58.6 mg/ℓ. The vertical profile maintained a consistent increase with depth during this quarter (see Table X). Considerable variation resulted between the month of January and the months of February and March, 1982. Higher concentrations of TSS in January were associated with high sediment loading to the lake during December rainstorms. Tributary rivers presented mean concentrations of TSS of 14.6 mg/ℓ in La Plata, 2.8 mg/ℓ in Guadiana and 18.9 mg/ℓ in Cañas (see Table XI). Although Cañas River presented higher concentrations of TSS, the loading of sediments via La Plata was greater by virtue of relatively much larger flow. As previously shown by spatial variability studies (see First Quarterly Report) horizontal gradients develop in the La Plata arm of the lake apparently as a result of La Plata River inputs.

Total Dissolved Solids

TDS averaged 215 mg/ℓ in the water column at L-I. The vertical profiles of February and March, 1982 presented higher concentrations of TDS at the surface and at the deeper portions of the water column. The month of January presented maximum values at depths of 4 and 8 m (see Table XII) evidencing substantially higher concentrations of TDS than the months of February and March, 1982.

Tributary stations averaged 214 mg/ℓ at La Plata River, 289 mg/ℓ at Guadiana River and 267.5 mg/ℓ at Cañas River (see Table XIII). The apparent disparities of TDS with conductivity relationships have already been noted.

Total Alkalinity

Total alkalinity measurements (see Table XIX) ranged between 132 mg/ℓ as $CaCO_3$. The profile of total alkalinity at the lake station L-I presented, in general, higher alkalinities in the upper strata where aerobic conditions prevail and pH values are higher. Lower alkalinities result below the oxygen chemocline.

Tributary stations averaged 130 mg/ℓ as $CaCO_3$ at La Plata River, 111 mg/ℓ as $CaCO_3$ at Guadiana River and 114 mg/ℓ as $CaCO_3$ at Cañas River during this quarter (see Table XV).

Nutrient Concentrations:

Ammonia-Nitrogen (NH_3-N

Water column average concentrations of NH_3-N ranged between .02 mg/ℓ in January and .18 mg/ℓ in March, 1982. The profile of NH_3-N maintained a pattern of increase with depth during this period (Jan.-March, 1982) at L-I (see Table XVI). Ammonia-nitrogen is generated by heterothrophic bacteria as the primary end product of decomposition of organic matter, either directly from proteins or from other nitrogenous compounds (Wetzel, 1975). High concentrations of NH_3-N in the hypolimnion may be the result of accumulation under anoxic conditions in the bottom strata. Under aerobic conditions in the trophogenic zone NH_3-N is assimilated and metabolized by phytosynthetic algae and floating macrophytes.

Tributary rivers averaged .04 mg/ℓ at La Plata, .02 mg/ℓ at Guadiana and .01 mg/ℓ at Cañas (see Table XVII). As previously noted in the profile of December, 1981 at L-I (see First Quarterly Report) NO_3-NO_2 was higher after high precipitation and watershed runoff. It appears likely that the maximum values observed in January resulted from December rainstorm events. Watershed input is evidenced during this period by the higher concentrations measured at tributary stations (see Table XIX) where NO_2-NO_3 concentrations averaged .76 mg/ℓ at La Plata River, 1.16 mg/ℓ at Guadiana River and 1.21 mg/ℓ at Cañas River.

The profile of NO_2-NO_3 vs. depth evidences, in general, lower concentrations in the trophogenic zone and higher concentrations fluctuating between depths from 8-20 m. As in the case of ammonia-nitrogen profiles indicate assimilation by photosynthetic organisms in the upper layer of the water column.

Total Kjeldahl Nitrogen

The water column average of TKN for the quarter (Jan.-Mar., 1982) was .61 mg/ℓ (range .46-.72 mg/ℓ) at L-I (see Table XX). The vertical distribution of TKN concentrations indicate higher values in the deeper portions of the water column (16-20 m). The origin of these higher concentrations near the bottom is possibly associated to the sedimentation and accumulation of organic compounds. The lower concentrations of TKN at tributary rivers (see Table XXI) tend to support the hypothesis that inorganic sources of nitrogen such as NH_3-N and NO_2-NO_3 are being incorporated by autochthonous lake organisms which contribute to the organic matter load of the sediments after death.

Soluble Reactive Phosphorus

The water column average of SRP concentrations at L-I was .11 mg/ℓ. SRP is the most available source of phosphorus for phytoplankton and aquatic vegetation in their metabolic processes. Lower concentrations of SRP above the chemocline (<4m) indicate rapid epilimnetic removal by algal and floating vascular plants there. Table XXII presents the water column profiles of SRP at L-I. All tributary stations evidenced higher concentrations of SRP indicating their importance in delivering nutrients to the lake (see Table XXIII).

Total Phosphorus

Total phosphorus concentrations presented a water column average of .22mg/ℓ at L-I (see Table XXV). This concentration characterizes the lake as hypereutrophic according to EPA 440/5-80-11 document. As previously established, the main vehicle of phosphorus loading appears to be La Plata River with average concentrations of .21 mg/ℓ, see Table XXVI. Guadiana River evidenced higher concentrations of total phosphorus ($\bar{x}$= .33 mg/ℓ) but the discharge of this tributary represents less than 5% of the total tributary discharge into the lake. A spatial variability analysis of the distribution of total phosphorus (at surface and 4m) performed during the first quarter (Oct.-Dec., 1981) indicated that a gradient of higher surface concentrations is found from La Plata River to L-I (see 1st Quarterly Report).

BIOLOGICAL PARAMETERS

Chlorophyll-a : The profiles of chlorophyll-a concentrations at L-I are presented in Table XXVI. Water column concentrations averaged 7.77 mg/m^3 with surface concentrations representing a 49% of the total chlorophyll-a crop. In general, the profiles show a marked decline of chlorophyll-a below depths of 4 meters. This appears to be associated with higher phytoplankton crops in the surface layers and the presence of undecomposed fragments of macrophytes. According to EPA-440/5-79-015 (1979) such surface concentrations of chlorophyll-a define La Plata Lake as an eutrophic system.

A spatial variability study of surface chlorophyll-a concentrations has shown that higher concentrations are found at the lake stations and diminish toward the La Plata arm of the lake (see 1st Quarterly Report). Tributary stations were conspicuously lower than the lake station (L-I) in chlorophyll during this period (see Table XXVII) confirming the endogenous origin of the lake values.

Total Coliforms

Table XXVIII presents the profile of total coliform concentrations at L-I. The average water column concentration was 598 MPN/100 mℓs (range 265 1118 MPN/100 mℓs). Standard regulations of water quality (EQB, 1973) recommend an upper limit of 10,000 MPN/100 mℓs for superficial waters of Puerto Rico.

Tributary rivers (see Table XXIX) evidenced higher concentrations than lake waters, however, none of the resulting concentrations surpass superficial water standards during this period (Jan.-Mar., 1982).

Fecal Coliforms

Fecal coliforms averaged 20 MPN/100 mℓs at L-I (range 50-396 MPN/100 mℓs), see Table XXX. Tributary rivers presented higher concentrations of fecal coliforms (see Table XXXI). Standard regulations of water quality (EQB, 1973) recommend an upper limit of 2,000 MPN/100 mℓs for superficial waters of Puerto Rico. Guadiana River evidenced concentrations above the limit recommended during the month of February, 1982.

Fecal Streptococcus

Table XXXII presents the concentrations of fecal streptococcus at L-I. Water column averages ranged between 6-74 MPN/100 mℓs. Evidence of fecal streptococcus was found on all sampling dates.

Concentrations were higher at tributary stations (see Table XXXIII) with means of 48 MPN/100 mℓs at La Plata River, 188 MPN/100 mℓs at Guadiana River and 282 MPN/100 mℓs at Cañas River.

HEAVY METALS

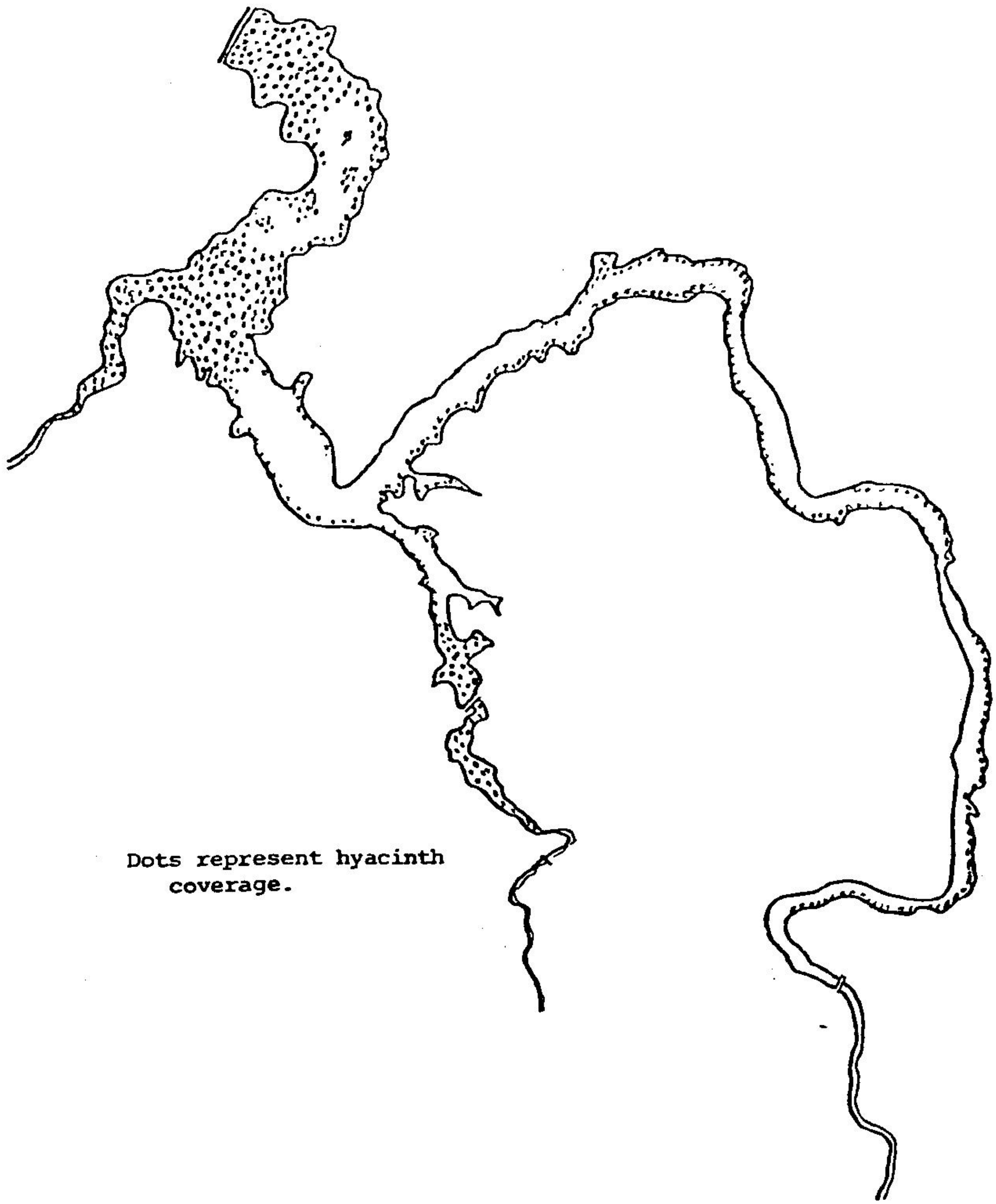
The concentrations of Cu, Cd, Pb, and Zn in μg/ℓ at the lake station L-I and the main tributaries are presented in Tables XXXIV and XXXV. Among the concentrations of heavy metals examined the only one which was found to exceed surface water quality standards was zinc. The average water column concentration of Zn was 120 μg/ℓ at the lake station L-I. The limit reccomended by EQB regulations of water quality (EQB, 1976) for surface waters in 50 μg/ℓ.

Macrophyte Coverage

The dominant macrophyte species present in Lake La Plata is the water hyacinth *Eichhornia crassipes*. An estimated percentage coverage of $\geq$50% of the total lake surface area is impacted by water hyacinths. The criteria in evaluating the area impacted within 2x secchi disk depth was not considered in view of the fact that *E. crassipes* is a floating macrophyte species which invades lake surface waters and is not limited by light penetration.

Water hyacinths may induce or enhance the proper conditions for dissolved oxygen deficiencies in the water column by limiting light penetration and subsequent photosynthesis inhibition. They also represent a recreational problem by obstructing navigation and fishing. An illustration of hyacinth cover in La Plata Lake is presented in Figure II.

Figure II. Water hyacinth coverage at La Plata Lake.



SUMMARY

Four sampling excursions to the study area were performed during the second quarter (January-March, 1982) of the diagnostic-restoration/feasibility study of La Plata Lake. These included three regular (monthly) sampling activities at monitoring (fixed) stations in the lake and tributary rivers and one special investigation designed to evaluate our present monitoring lake station (L-I) as representative of the water quality condition at the dam site where the intakes for public water supplies are located.

After completion of six months of investigations, the most important findings may be summarized as follows:

a. Temperature profiles decrease gradually from the surface evidencing a weak stratification in the absence of a well defined thermocline.

b. The dissolved oxygen profile is clinograde with a strong chemocline fluctuating between 2-5 meters.

c. Total alkalinity, pH and specific conductance decrease with depth at the lake station.

d. The concentrations of total dissolved solids vary independently from specific conductance distribution.

e. Available micronutrients such as SRP, NH_3-N and NO_2-NO_3 evidence higher concentrations in the hypolimnion reflecting epilimnetic-removal by photosynthetic organisms and accumulation under the anoxic strata of the water column.

f. Loading of nutrients, TSS, bacteriological contamination and dissolved oxygen are largely contributed by tributary inputs.

g. Chlorophyll, phytoplankton abundance and water hyacinths coverage increase downstream from La Plata arm of the lake.

h. During the first quarter, the lake and tributaries showed evidence of bacteriological contamination concentrations above the recommended surface water standards. During the second quarter of the study only the Guadiana River station (W-2) was above the limits.

i. Among the trace metal concentrations studied (Hg, Cu, Cd, Pb, Cr and Zn), zinc was the only one that exceeded surface water standards for P.R.

j. The measured concentrations of total phosphorus and chlorophyll-a continue to be high and consistent with the classification of La Plata Lake as an eutrophied system.

k. Special close time interval sampling indicates that the standard lake station L-I is essentially the same (within a normal acceptable sampling error) as a station adjacent to the dam and may therefore fairly represent the main body of the lake.

l. Surface flow measurements and watershed drainage area indicate that La Plata River accounts for more than 90% of the total water that enters La Plata Reservoir.

In view of these findings, several hypotheses have been postulated in order to understand some of the basic structural and functional features of the lake.

Hypotheses to be further examined:

1. The lake is oligomictic (mixing occurs rarely and probably aperiodically during storms, high rain and runoff conditions or under strong wind circumstances).

2. The thermal stratification of the water column within any strong thermocline is of low stability.

3. The morphometric features of the lake, especially its high volume to surface area ratio tend to isolate the hypolimnion from mixing forces such as normal winds and river discharge.

4. Dissolved oxygen consumed in the hypolimnion is in equilibrium with that entering from the epilimnion.

5. Low dissolved oxygen prevents the establishment and maintenance of producers in hypolimnion.

6. Higher concentrations of TKN and total phosphorus in the deeper portions of the water column result from accumulation of organic matter which originates at the surface of the lake such as water hyacinths fragments and phytoplankton and zooplankton sedimentation.

The special investigations directed to test hypotheses 4 and 5 will be focused on primary productivity experiments at various epilimnetic depths, BOD analyses and 24 hr measurements of pH, O_2, temperature, conductance and total alkalinity. Hypotheses 1, 2 and 3 will have to be approached by sampling during or immediately after rainstorm events capable of changing the stratified structure of the water column. Testing of hypothesis 6 will be attempted by analyzing TOC samples in a vertical profile.

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