TECHNICAL COMPLETION REPORT
OWRR PROJECT NO. A-013-OKLA.

BEHAVIOR OF WATER IN A SOUTHWESTERN IMPOUNDMENT

Submitted to

The Oklahoma Water Resources Research Institute
Oklahoma State University
Stillwater, Oklahoma

by

Edwin H. Klehr, Ph.D.
School of Civil Engineering and Environmental Science
University of Oklahoma
Norman, Oklahoma

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I. Introduction

It was proposed that Lake Thunderbird, its watershed and its effluent, be considered as an integral system; it would be analyzed and studied to gain a better understanding of the behavior of water in a southwestern impoundment. A study of the literature reveals that information regarding basic impoundment behavior is relatively scarce for the Oklahoma region, and yet water supply *via* impoundment is a major fresh-water source in this same area. Lake Thunderbird offers an almost ideal field laboratory with which to make long range studies. This modest program does not claim to fill all the gaps in our information about impoundment behavior. It aims at providing some basic information which will hopefully be applicable to the Southwest in general, and Oklahoma in particular.

A second key goal of this project was to provide theoretical and field experience in water chemistry for the graduate students in our program.

II. Background Information

The location of Lake Thunderbird and its watershed is given in Figure 1. The lake was formed by putting a dam across Little River at the point indicated, and serves as a multipurpose structure, including a surface water supply for Norman, Midwest City and Del City; recreation, flood control and wildlife preservation. The dam itself was funded both locally and federally, and built by the Bureau of Reclamation. It was closed in 1965.

The watershed is approximately 256 square miles, of which some 165 square miles are Garber-Wellington Sandstone, and 75 square miles are Hennessey Shale. Generally, the Garber-Wellington area is forested hills with post oak and blackjack oak; whereas the Hennessey areas are smooth, grass covered hills used for grazing. The soils of the sandstone hills are shallow to moderately deep, and are reddish brown, apparently due to the presence of Goethite. Because of the hilly terraine and shallow soils, surface drainage is rapid and the area is highly susceptible to sheet and gully erosion. The prairie soils overlying the Hennessey shale are moderately deep and have developed mainly from slightly calcerous clay shale and sandy shale. Surface drainage on these soils is slow to rapid. Runoff rates are high, and most sloping surfaces are susceptible to sheet and gully erosion. Relatively little of the area is used for crop farming, and there are no large residential or industrial areas in the watershed. At this time there is no crop irrigation.

The lake is fed entirely from surface runoff in the watershed. Typical runoff figures, taken at a gaging station on Little River just below the dam site, indicate yearly flows as follows:

Year	Flow (acre-feet)	Momentary Peak (cubic feet/second)
1953	24,500	2,640
1954	11,710	2,610
1955	40,900	6,010
1956	5,030	---
1957	149,400	34,600
1958	41,840	6,730
1959	60,540	---

An average runoff value for the period 1952-1963 is estimated to be 45,700 acre-ft./yr. Peak flows generally occur in April-May and September-October. As the data indicate, yearly flows vary considerably, which of course poses a significant resource management problem. The 65 year average rainfall for the watershed area is reported as 33.4 in./yr. Class A Pan evaporation is estimated at 85 in./yr.: lake evaporation for the area is estimated at 59 in./yr. and runoff for the area is estimated at 4 in./yr.

The Army Corps of Engineers has published a table for Lake Thunderbird in which volume (acre-ft.) is indicated as a function of lake elevation. Pertinent points from the table include:

Volume (acre-ft.)	Area	Elevation (feet)	Name
367,500	13,850	1064.7	Maximum pool
196,200	8,600	1049.4	Top flood control pool
119,600	6,070	1039.0	Top conservation pool
13,700	1,680	1010.0	Top dead storage pool

The following water balance for fiscal year 1968-1969 has been worked out:

1. Watershed drainage area: 256 sq. miles.

   (256 sq. miles) (640 acres/sq. mile) = 163,840 acres.

2. Rainfall on watershed (measured at lake pumping station): 37.06 in./yr.

   (37.06 in.)/(12 in./ft.) = 3.08 ft.

   (3.08 ft.) (163,840 acres) = 504,627 acre-ft.

3. Lake volume increase

   Elevation on July 1, 1969: 1032.39 ft. = 83,700 acre-ft.

   Elevation on July 1, 1968: 1024.89 ft. = 52,060 acre-ft.

   Volume increase = 83,700 acre-ft. - 52,060 acre-ft. = 31,640 acre-ft.

4. Lake pumpage: 7,079 acre-ft.

5. Total measured evaporation: 11,971 acre-ft.

6. Leakage through dam: 0.5 cfs average flow = 362 acre-ft.

7. Approximate total lake volume increase:

Measured volume increase	31,640 acre-ft.
Lake pumpage	7,079 acre-ft.
Total measured evaporation	11,971 acre-ft.
Leakage loss through dam	362 acre-ft.
	52,052 acre-ft.

8. Calculation of water transfer from watershed to lake:

Volume of rainfall to watershed	504,627 acre-ft.
Approximate total lake volume increase	51,052 acre-ft.
Water "lost"	453,575 acre-ft.

Based on the above calculations, it seems that only 11% of the water that falls on the watershed actually reaches the lake. The data used in these calculations were obtained from U. S. Geological Survey, Central Oklahoma Master Conservancy District, and the U. S. Army Corps of Engineers. Some assumptions used in the calculations include:

1. Measured rainfall at the lake pumping station was representative of the watershed.
2. Groundwater input to lake and seepage from the lake were negligible.
3. Wastewater input to lake was negligible.
4. Transpiration from the lake was negligible.

III. Water Quality Monitoring

A rough diagram of the lake showing the location of the sampling stations is included as Figure 2.

The parameters chosen for study, at least in initial phases of the project, were:

1. Physical parameters:
   a. Water temperature (degrees Centigrade) measured with a thermistor.
   b. Total dissolved solids (mg/l): Myron conductivity bridge.
   c. Turbidity (JTU): Hack colorimeter.
   d. pH determined using glass-calomel electrodes.

2. Chemical parameters:

a. Dissolved oxygen (mg/l): samples collected in 300 ml BOD bottles and fixed in the field. Determinations made by Winkler Azide method and 0.025N phenyl arsonium oxide with 200 ml aliquots to starch endpoint. Later a Weston-Stack D.O. probe was used.

b. Chloride (mg/l as chloride): mercuric nitrate method as outlined in Standard Methods of Water and Wastewater Analysis (12th Edition).

c. Alkalinity (mg/l as $CaCO_3$) as in Standard Methods, using phenolphthalein and bromcresol green-methyl red as indicators.

d. Total Hardness (mg/l as $CaCO_3$) as in Standard Methods.

e. Calcium Hardness (mg/l as $CaCO_3$) as in Standard Methods.

f. Sulfate (mg/l as sulfate) determined by Turbidimetric method as in Standard Methods.

g. Iron (mg/l as Fe): 1-10 phenanthroline method as in Standard Methods.

h. Manganese (mg/l as Mn): permanganate method as in Standard Methods.

i. Ammonia nitrogen (mg/l as N): Nesslerization method as in Standard Methods.

j. Nitrite (mg/l as N): chromatropic acid method.

k. Nitrite (mg/l as N): sulfonic acid, 1-naphthylamine method as in Standard Methods.

l. Orthophosphate (mg/l as P): ammonium molybdate, stannous fluoride method as in Standard Methods.

m. Total phosphate (mg/l as P): same as above after hydrolyzing in autoclave for 15 minutes at 250°F.

n. BOD (mg/l as O_2): 5-day BOD as in Standard Methods.

o. COD (mg/l as O_2): as in Standard Methods.

3. Biological Procedures:

Bacterial samples were collected in 3 liter Kemmerer Samplers and transfered to sterilized 160 ml milk dilution bottles.

a. Equipment: 0.45 mμ grid filters and pads, disposable plastic petri dishes.

b. Broths: M-F Endo broth (coliform), M-TGE broth (total).

c. Dilution water: Sterilized tap water (Norman).

d. Dilutions (varied): No dilution for coliform 1/100 f; 10 ml sample.

e. Incubation: 37° for 18 hours, 37° for 48 hours.

f. Formulas used:

$$\text{Total} = \frac{\text{No. of colonies X F = total bacteria per ml}}{\text{V}}$$

F = dilution factor

V = volume of sample

The same formula was used for coliform, except that colonies with definite metallic sheen were counted.

4. Sampling and preservation:

a. All sampling was done with either 1200 ml or 3000 ml Kemmerer type samplers.

b. D.O. samples were placed into 300 ml BOD bottles and fixed immediately with $MnSO_4$ - alkaline azide - KI - sulfonic acid.

c. Nitrate and phosphate samples were placed into glass bottles and fixed immediately. Samples were analyzed within 4 hours.

d. Samples for other chemical parameters were placed in plastic bottles and analyzed within 4 hours.

e. Samples for bacterial analysis were iced within 1 hour. Preliminary work started within 4 hours.

f. Plankton counting samples: Kemmerer sampler was flushed through a standardized plankton net (Wildlife, #40).

g. BOD and COD samples were collected in 300 ml BOD bottles and analyzed without dilution.

Summary results of the chemical monitoring are given in Table 1. The lake was found to be essentially homogeneous chemically, and so it is perhaps meaningful to calculate and quote lake averages -- at least for some parameters. The reader is cautioned about hasty interpretations of lake averages for parameters such as temperature, turbidity, and to a lesser extent, dissolved oxygen. There was some evidence of stratification and anaerobic conditions in the hypolimnion during late Summer; however it was too transient for definitive measurement. Consequently, for this period, lake averages for several parameters such as temperature, DO, Fe, Mn, orthophosphate nitrate, ammonia, etc., are certainly suspect.

Partial chemical analysis of the main tributary streams was carried out on 7/25/68 and 8/7/68. Results are summarized in Tables 2 and 3.

Diurnal variations in selected parameters was studied on August 8 and November 21, 1968. Results are included in the Appendix.

A summary of results of the biological monitoring is also included in the Appendix.

IV. Lake Sediment Study

As part of the attempt to correlate the quality of lake water with the characteristics of the watershed, and further, to gather basic data for the possible development of a physical sediment-water mixing model, it was decided to do a preliminary study on the particle size distribution of the sediment in the lake. A sampling and analysis method was developed which seems to give reproducible results, at least for the lake in question. The method finally used for this preliminary study involved core sampling, and slight modifications of the hydrometer, dry sieve technique as described in ASTMD 442-63. The specific gravity of the sediment was estimated to be 2.65, as determined by the procedure outlined in the ASTMD manual.

A summary of the results is included in Table 4 of the Appendix. As expected the middle of the lake showed the greatest percentage of smaller particles, whereas the two arms showed greater percentages of larger particles.

V. <u>The Contribution of the Watershed-soil-rainwater Interaction to the Water Quality of Lake Thunderbird</u>

Any study that concerns itself, even remotely, with the effect of impoundment on water quality must attempt to determine the sources available to the impoundment, especially runoff from the watershed. Lake Thunderbird offers an almost ideal opportunity for such a study. It has a small, well-defined watershed of fairly uniform geologic formation, and rainfall on the watershed is currently the only significant source of water to the lake.

The study essentially involved the percolation of aerated, distilled water through columns of watershed soil in an attempt to simulate watershed runoff. The percolate was collected in a container which served as a model of the lake itself.

The first part of the study involved the use of small (1" x 5") columns filled with soils from various locations (seven) in the watershed. The objective was to gain some insight into the behavior of percolation columns with soils from this region, and to determine the feasibility of representative sampling of the watershed soils. In particular, the initial study was designed to:

1. Conduct a parameter-by-parameter comparison of column effluents from each of the seven soil sample locations.

2. Determine if column effluent retained over a period of time in a lighted, aerated 2000 ml beaker that is continually being fed by additional column effluent approaches Lake Thunderbird in water quality.

The following parameters were chosen for monitoring of both the column effluents and the beakers:

1. Total Dissolved Solids (TDS)
2. pH
3. Turbidity
4. Total Hardness
5. Dissolved Orthophosphate (DOP)
6. Alkalinity
7. Calcium Hardness

Typical results, as given in Table 5, seem to indicate that a laboratory model of Lake Thunderbird and its watershed was possible. It can be seen that the pH and DOP values of soil-beaker #1 compare favorably with those of Thunderbird. Furthermore, if TDS is used as an index of comparison between the two systems, it is seen that the beaker compares quite favorably in all parameters with the lake. Of course, such TDS ratios must be used with a great deal of caution. Other conclusions were drawn from the small column phase of this study. First, percolation columns using soil columns from this area behave as expected; that is TDS, total hardness and DOP column effluent concentrations remained constant with time. Secondly, mean effluent values for each parameter were remarkably similar. It also seemed apparent that effluent retained in the beakers underwent many of the same changes that occur when stream waters are impounded.

On the basis of these results, a larger (5 3/4" x 4') plexiglass column was filled with composite watershed soil. Aerated distilled water was added at a controlled rate, and the effluent was collected in a 20 gallon aquarium. The aquarium contained a bottom layer of lake sediment. More frequent analysis and additional parameters were possible in this phase of the work due to the larger effluent and tank volumes. In addition to the parameters listed in Table 5, the following were incorporated into the study:

1. Dissolved total-phosphate (DTP)
2. Dissolved oxygen (DO)
3. Five-day Biochemical Oxygen Demand (BOD)
4. Chloride
5. Manganese
6. Iron
7. Total Solids
8. Carbon (total)
9. Nitrogen (total)
10. Total bacteria
11. Coliform bacteria
12. Temperature

Some of these parameters were determined only occasionally, and some were used only for special studies. The system was operated under various conditions (including soil replacement) for 250 days, during which time both effluent and tank were monitored for the above parameters. Table 6 compares tank results from 4 different time intervals during the first 250 days with Lake Thunderbird. The actual results and the modified results obtained by multiplying the actual results by the ratio of lake TDS to tank TDS are shown for each time period. A TDS value of 250 mg/l was used for the lake. The results from day 16-60 represent the initial tank steady-state values. The period from days 120-135 was chosen because the lake to tank TDS ratio was one during the period. The interval from 150-152 days represented the maximum values obtained during the first 250 days, and consequently the smallest TDS ratio. Finally, the interval from days 200-250 represented final tank steady-state conditions for the first major period of the study.

Results from further analysis of tank waters at day 250 are shown in Table 7 and are compared to Lake Thunderbird. As can be seen, all tank values with the exception of DTP and chloride fall within the ranges found in Lake Thunderbird.

In general, results from the first 250 days indicated that a column-fed laboratory model of Lake Thunderbird could be established that was remarkably similar to the lake in terms of chemical water quality. Results further indicated that the column was capable of continually supplying biological and chemical constituents to the tank, thus allowing the model to be maintained over relatively long periods of time.

During days 250-450, the second major phase of the study was performed, in which the tank was subjected to environmental changes similar to what happens in a reservoir in an attempt to determine if the artificial laboratory system would behave as the natural system. Figure 3 indicates the program of change, as well as the response of dissolved oxygen. The TDS remained at about 200 mg/l through day 420. Thus tank aeration, concentration of DO, and blackout conditions had no effect on TDS. However, after the addition of the glucose, TDS increased markedly. In general, pH, alkalinity, total hardness, iron, manganese, DTP, DOP all changed in a pattern consistent with the change in dissolved oxygen and associated biological changes. Results during this period indicated that steady-state conditions could be maintained over relatively long periods of time, and this fact is considered to be one of the most important consequences of this research.

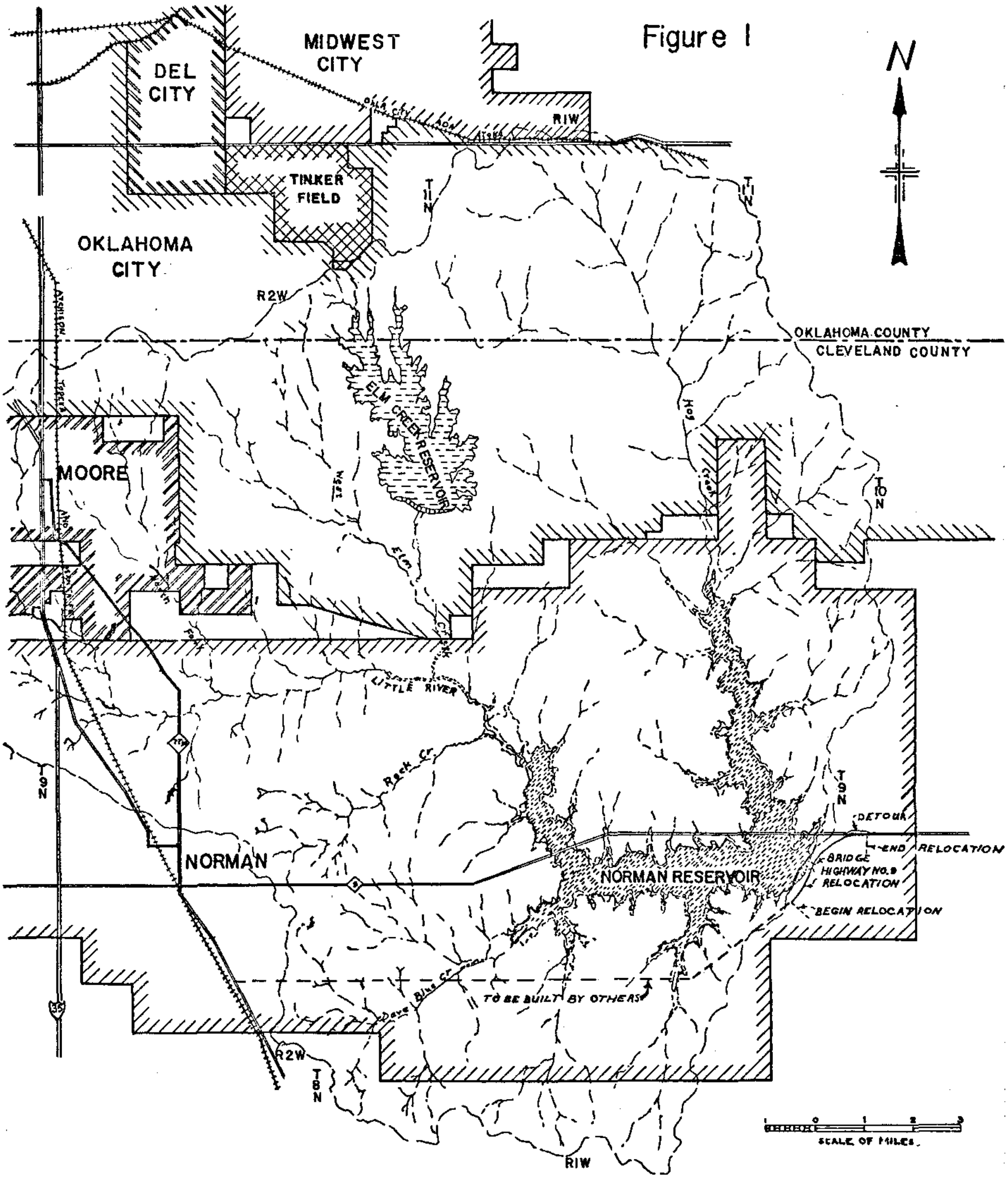
Carbon and nitrogen determinations were done on a periodic basis during the 450 day study period. Results are summarized in Table 8. These results seem to indicate that the laboratory model is functioning in a fashion generally similar to that of the Lake and its watershed.

The results obtained from this initial laboratory and field study were, of course, far more qualitative than quantitative. Consequently, no mathematical treatment of the data was attempted. However, it is possible at least for the parameters involved, to make several comments about the Lake Thunderbird system based on the results of the model studies. That the chemical water quality of the model, under steady-state conditions, was remarkably similar to that of the lake was encouraging. This indicates that the percolation column was a source of the same type constituents as were available to the lake <u>via</u> watershed-rainfall-runoff. Additional significance was attributed to the fact that the model responded to manipulation of various environmental control factors in a more or less predictable manner; that is, the model behaved similarly to known impoundment behavior. It was encouraging to note that long-term steady-state conditions could be maintained by keeping the various environmental factors constant.

Several inherent weaknesses in the experimental design utilized became apparent during the course of the study. The column presented considerable operational problems. Then too, in order to have a sufficient volume of water delivered to the tank, the soil in the column stayed almost completely saturated with water. This can only be overcome by increasing the ratio of column surface area to tank area. Further, the glass sides of the tank resulted in a surface area to volume ratio that was highly unrealistic, and consequently heavy growth of organisms (mostly blue-green algae) was noted on the sides of the tank. Also, due to the shallow depth of the tank waters, no volume of water was representative of that found beneath the zone of light penetration in nature.

Nevertheless, it was concluded from this research that a laboratory simulation of an impoundment system as a study/predictive tool is possible. This conclusion is based on results that indicated such a model could be established and dynamically maintained over considerable periods of time, at least for the parameters studied.

WATERSHED OF NORMAN RESERVOIR (LAKE THUNDERBIRD)



LOCATION OF MONITORING STATIONS

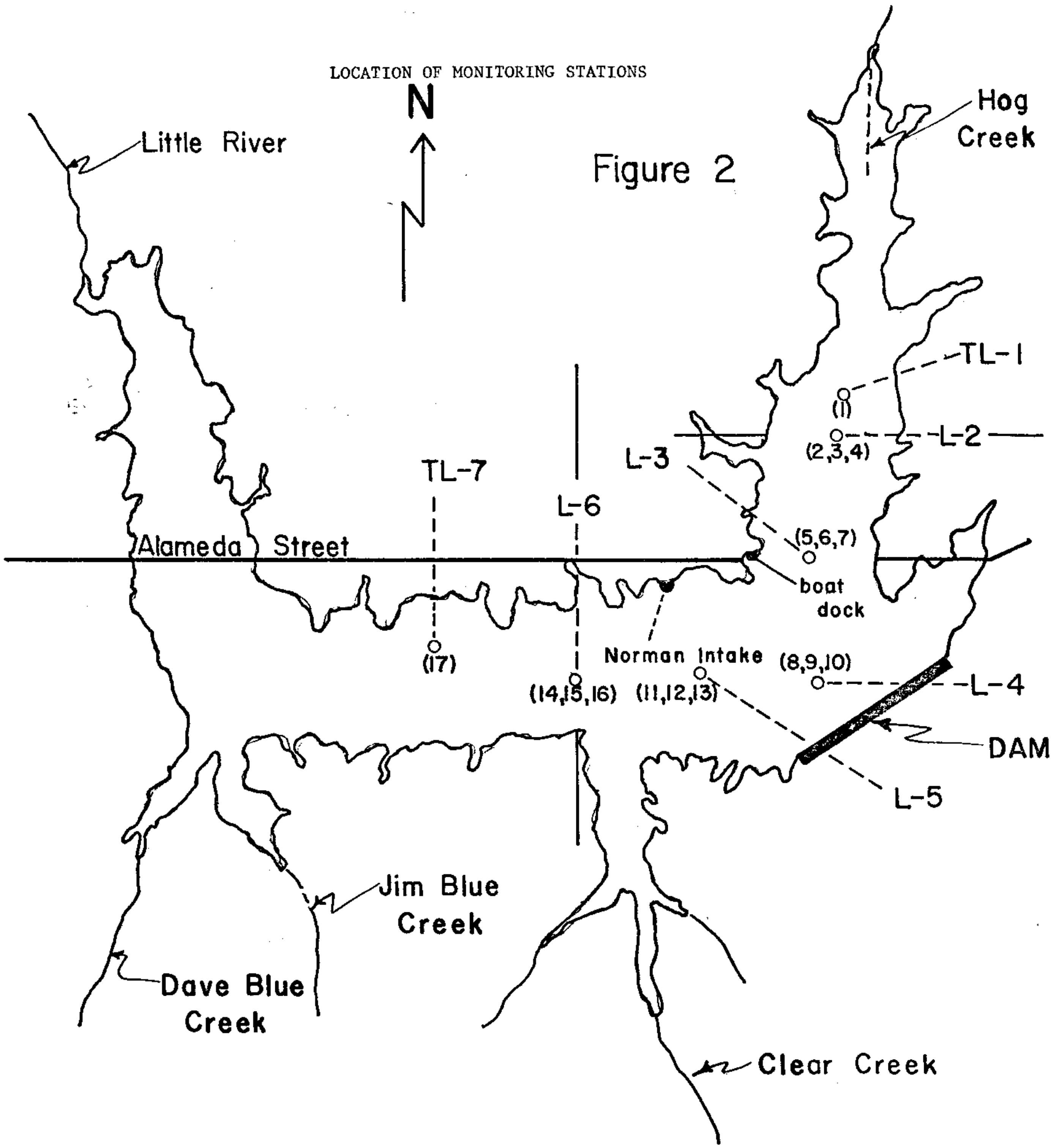


Table 1 Summary of Chemical Analysis - Lake Thunderbird

Period	pH	Turbidity	TDS	SO_4	Fe	Mn	NH_3	NO_3	NO_2	$O-PO_4$	Tot - PO_4	Cl	Alk.	Tot-Hard.	Ca-Hard.	DO	BOD	COD	Na	H_2O Temp.	
Fall, 1967	8.6	25	277	16	<.1	.43	.61	.32	.01	.02	.26	26	$\frac{0}{180}$	193	100	11	-	-	-	12	
Winter, 1967	8.2	18	305	15	.06	.17	.54	.31	.01	.10	.15	25	$\frac{0}{185}$	197	102	13	-	-	-	4	32
Spring, 1968	7.8	200	267	--	---	---	1.0	.44	---	.01	---	--	$\frac{0}{174}$	214	---	8	-	-	-	17	
Summer, 1968	8.6	29	242	--	---	---	.9	.50	---	.12	---	--	$\frac{0}{215}$	183	---	8	2	13	17	28	82
Fall, 1968	7.6	65	231	17	.3	.41	---	.14	---	.17	---	--	$\frac{0}{173}$	176	---	7	1	13	--	23	
Summer, 1969	7.8	24	270	15	.06	---	.01	.18	---	---	---	--	$\frac{0}{204}$	194	---	7	3	44	16	26	79
Fall, 1969	8.0	26	272	--	---	---	---	.37	---	.25	---	--	$\frac{0}{202}$	198	---	11	2	37	--	13	
Winter, 1969	8.0	5	282	10	<.1	---	---	0.1	---	.19	---	25	$\frac{0}{181}$	202	108	14	4	--	--	--	

Table 2 July 25, 1968 Watershed

Station	Time	Air Temperature	H_2O Temperature	pH	Turbidity	TDS	DO	NO_3	$O-PO_4$	Alkalinity	Total Hardness	BOD	COD	Na	NH_3
	A.M.														
2	7:30	24.5	23	8.7	35	370	8.5	0.2	0.06	284	308	2.6	42	10	0.6
4	8:15	26.5	24.5	8.6	35	440	4.6	0.3	0.07	448	358		49	31	1.0
5	8:35	24.5	26	8.7	75	600	4.5	0.4	0.19	412	378		50	70	0.7
6	8:50	24.5	24	8.7	35	350	7.6	0.4	0.11	340	310	2.8	4	14	0.9
7	9:00	24.0	24	8.6	20	380	7.0	0.2	0.14	344	298	4.6	9	23	0.7

2. Clear Creek
4. Dave Blue Creek
5. Little River
6. Elm Creek
7. Little River

Table 3 August 7, 1968 Watershed

Station	Time	Air Temperature	H_2O Temperature	pH	Turbidity	TDS	DO	NO_3	$O\text{-}PO_4$	Alkalinity	Total Hardness	BOD	COD	Na	NH_3
	A.M.														
2	8:15	25.5	23	8.5	25	330	8.5	0.1	0.11	288	290	1	--	10	---
4	8:45	26	24.5	8.4	20	450	1.5	0.2	0.06	436	356	4	--	42	---
5	9:15	27	26	8.2	30	550	4.5	0.1	0.26	388	376	3	--	42	---
6	9:30	27	24	8.4	8	330	7.4	0.1	0.21	280	278	2	--	14	---
7	10:00	31	25.5	8.4	12	340	7.6	0.2	0.21	304	290	2	--	16	---

2. Clear Creek
4. Dave Blue Creek
5. Little River
6. Elm Creek
7. Little River

Table 4 Summary of Particle Size Distribution of Sediment

Location	Percent of sediment with diameter less than (millimeters)						
	0.001	0.005	0.01	0.05	0.01	0.15	1.0
TL-1	24	35	41	67	90	100	100
L-2	14	21	26	41	62	100	100
L-3	44	61	70	83	90	100	100
L-4	66	85	90	99	100	100	100
L-5	61	82	90	99	100	100	100
L-6	14	16	22	60	90	100	100
TL-7	14	15	18	65	92	100	100

Table 5 Comparison of Beaker No. 1 after 65 Days of Percolation with Lake Thunderbird

	Beaker No. 1	Lake Thunderbird	Beaker No. 1 x $\frac{250}{210}$
pH	8.5	8.0 - 8.5	-------
Alkalinity	160	180 - 200	190
Total Hardness	164	170 - 230	195
Calcium Hardness	84	90 - 120	100
Magnesium Hardness	86	80 - 110	102
DOP	0.12	0.01 - 0.15	0.14
TDS	210	250	------

Table 6 Comparison of Tank (Actual) and Tank (TDS Modified) with Lake Thunderbird for Days 0 - 250

Parameter	Day 16-60		Day 120-135		Day 150-152		Day 200-250		Lake Thunderbird
	Tank	Tank × $\frac{250}{140}$	Tank	Tank × $\frac{250}{250}$	Tank	Tank × $\frac{250}{365}$	Tank	Tank × $\frac{250}{200}$	
TDS	140	250	250	250	365	250	200	250	250 - 300
Total Hardness	125	223	230	230	318	216	160	200	170 - 230
Calcium Hardness	80	142	160	160	213	145	110	138	90 - 120
Magnesium Hardness	45	80	70	70	105	71	50	63	80 - 110
Alkalinity	110	196	185	185	216	147	100	125	180 - 200

Table 7 Comparison of Tank at Day 250 with Lake Thunderbird

Parameter	Tank	Lake
pH	8.5	8.0 - 8.5
DOP	0.06	0.01 - 0.15
DTP	0.90	0.20 - 0.30
Turbidity	35	low of 40
COD	12	10 - 15
BOD	3	1 - 3
Manganese	0.05	0 - 0.25
Iron	0.03	0 - 0.10
Chloride	12	25
Total bacteria (colonies/ml)	200	95 - 350
Coliform bacteria (colonies/ml)	0-1.2	0 - 1.5

Table 8 Comparison of %C and %N in Various Phases of Lake and Model

		%C	%N
Soil	(1969)	9	0.2
Lake sediment	(Dec., 1969)	12	0.3
Tank sediment	(Day 237)	9	0.2
Column effluent	(Day 237)	25	2.3
Lake	(Dec., 1969)	55	0.6
Tank	(Day 237)	63	3.1
Lake sediment	(June, 1970)	10	0.2
Lake total	(June, 1970)	56	0.4
Lake dissolved	(June, 1970)	54	0.3
Tank total	(Day 357)	63	2.9
Tank dissolved	(Day 357)	61	2.7
Tank sediment	(Day 399)	12	0.2
Tank total	(Day 399)	57	3.1
Tank dissolved	(Day 399)	54	3.0

TABLE 9
TANK DISSOLVED OXYGEN DAY 250-450

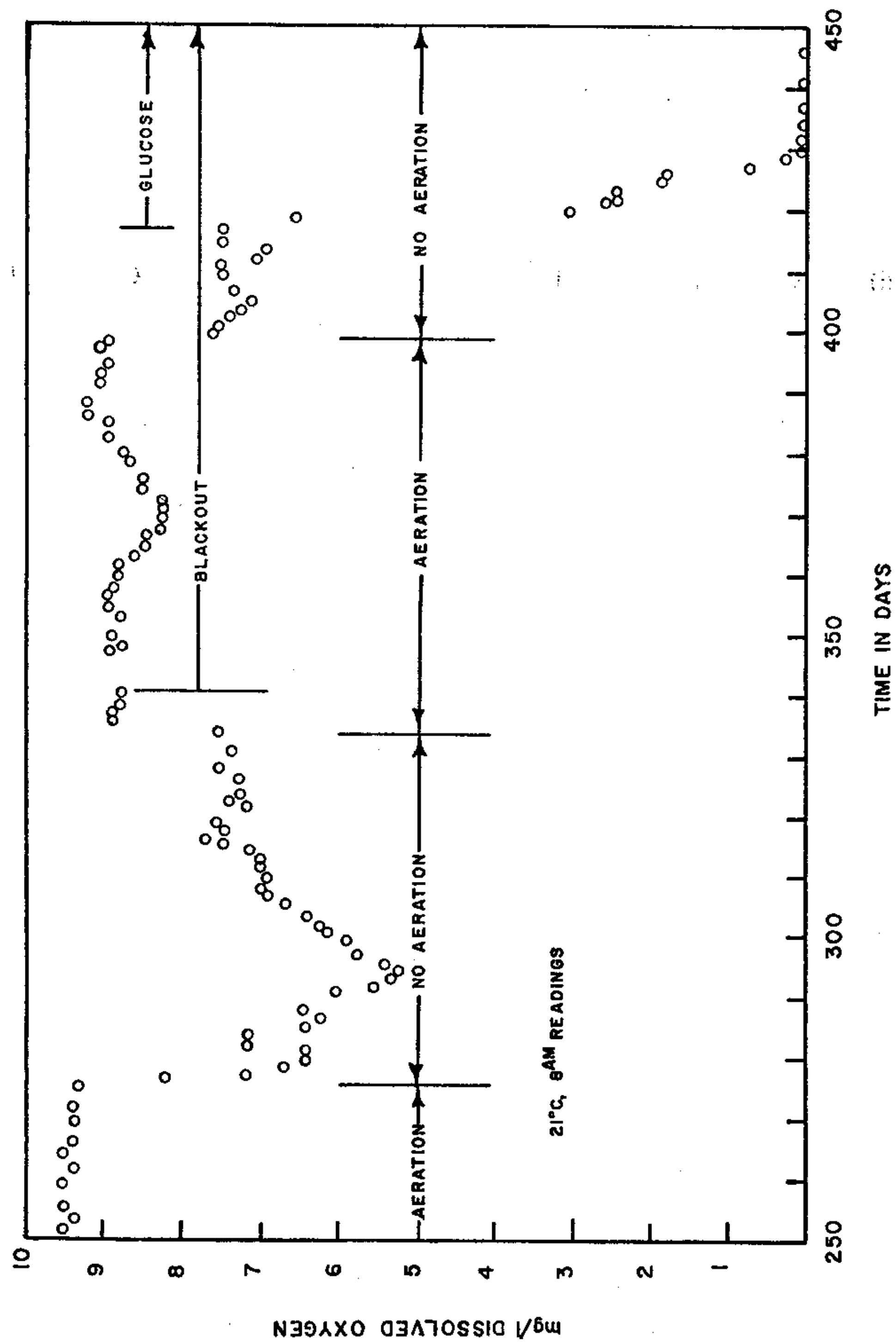


TABLE 10
DIURNAL LAKE STUDIES STATION L-4

—— = D.O.
- - - - = Temp.

Diurnal Lake Study
Station L-4

Nelson, Hansen, Keeley

8-21-68

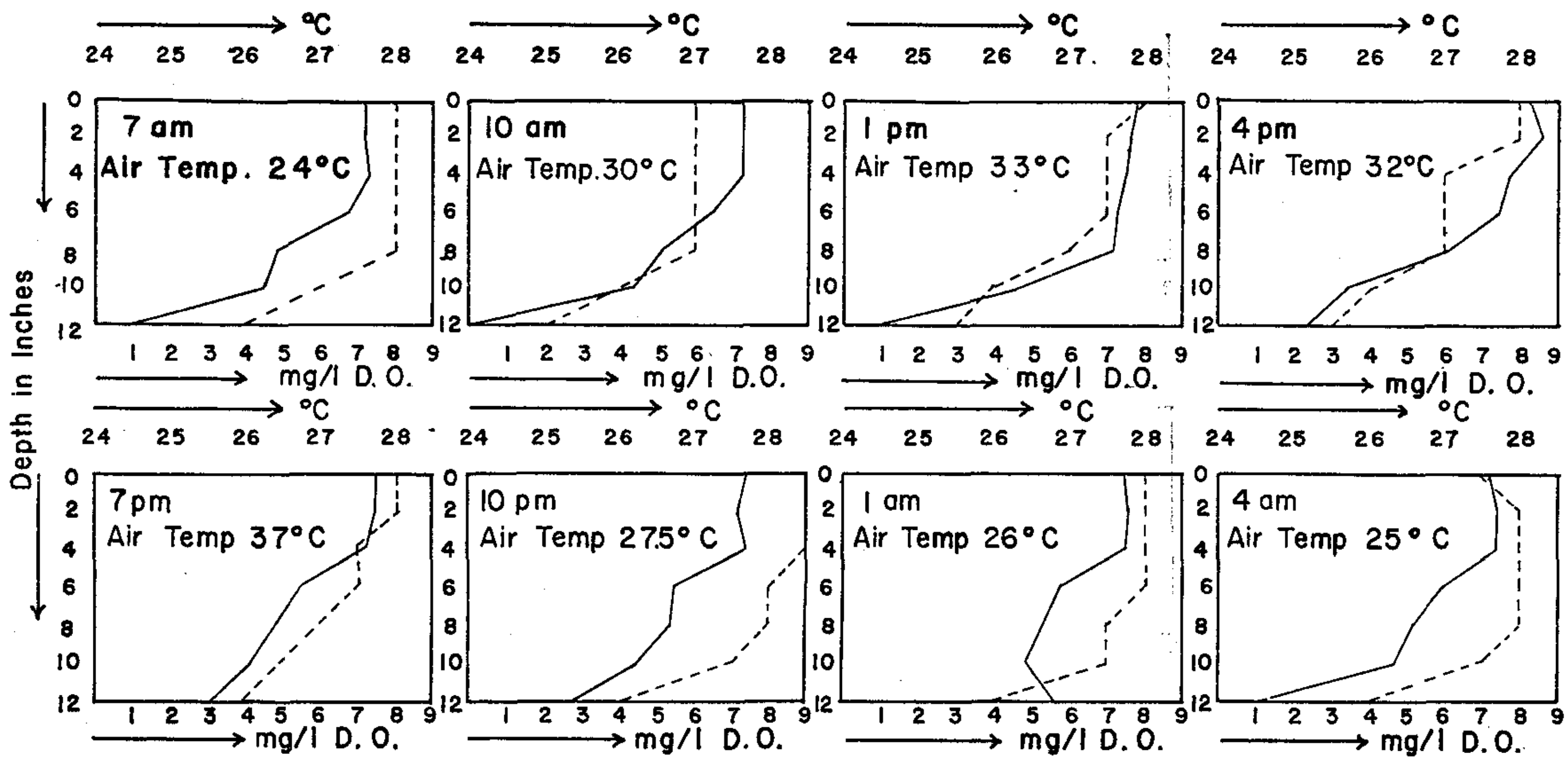


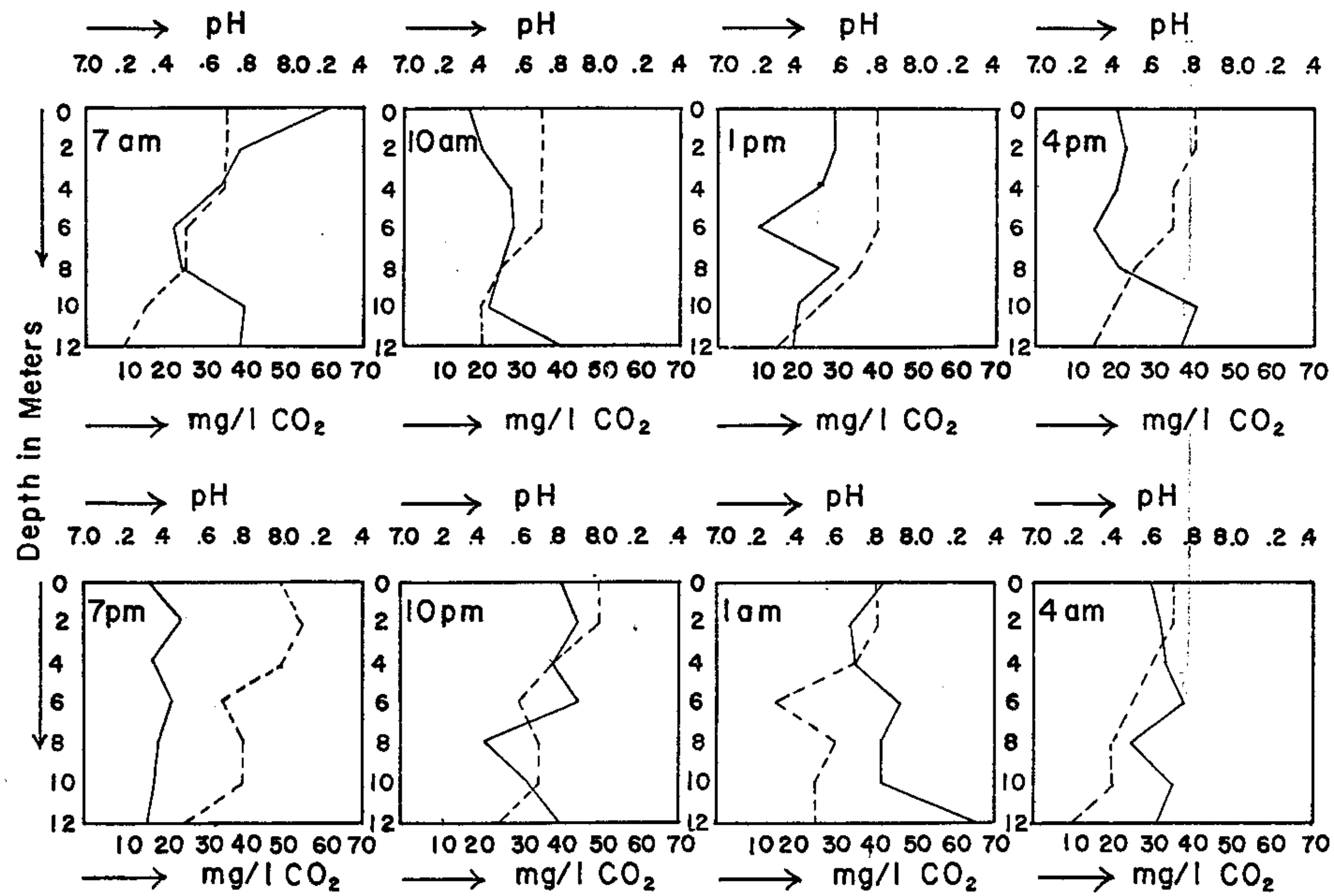
TABLE 11

DIURNAL LAKE STUDIES STATION L-4

Diurnal Lake Study
Station L-4
8-21-68

—— CO_2
- - - - pH

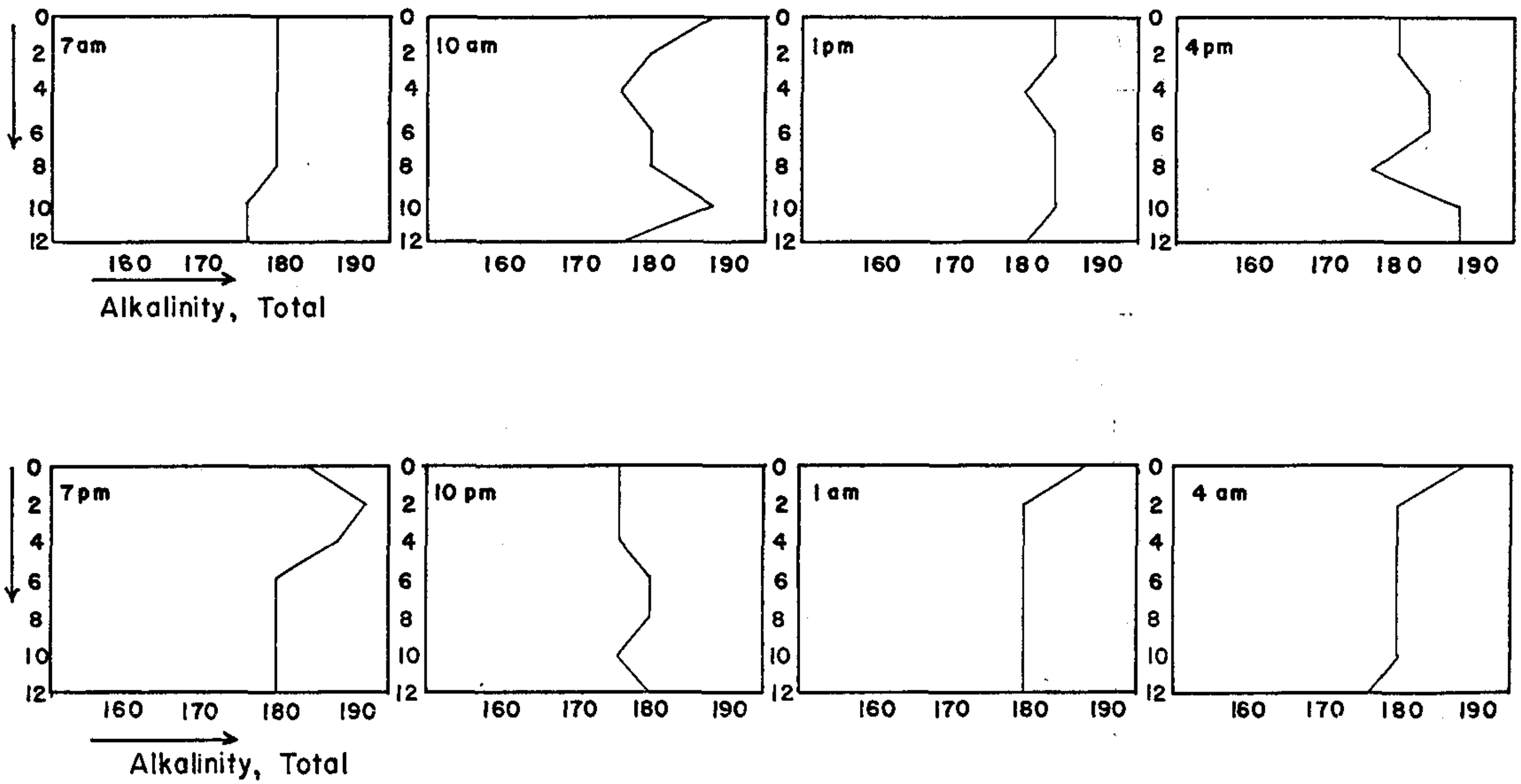
Nelson, Keeley, Hansen



— = Alk.

Diurnal Lake Study　　Keeley, Hansen, Nelson
Station L-4

8-21-68



DIURNAL LAKE STUDIES STATION L-4
TABLE 12

TABLE 13

DIURNAL LAKE STUDIES STATION L-4

—— = TDS

Diurnal Lake Study   Keeley, Hansen, Nelson

Station L-4

8-21-68

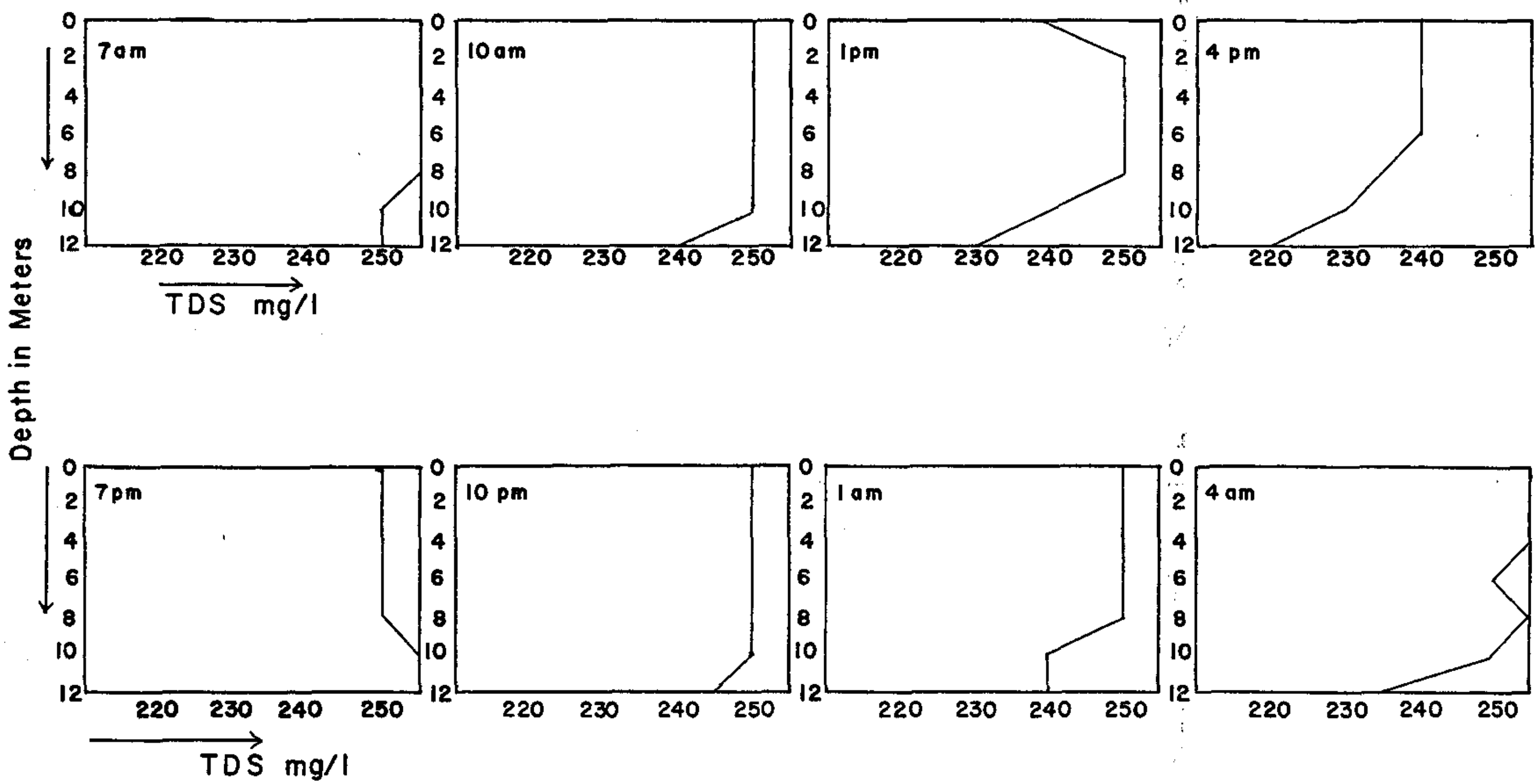


TABLE 14

DIURNAL LAKE STUDIES STATION L-4

Diurnal Lake Study — Keeley, Hansen, Nelson
Station L-4

8-21-68

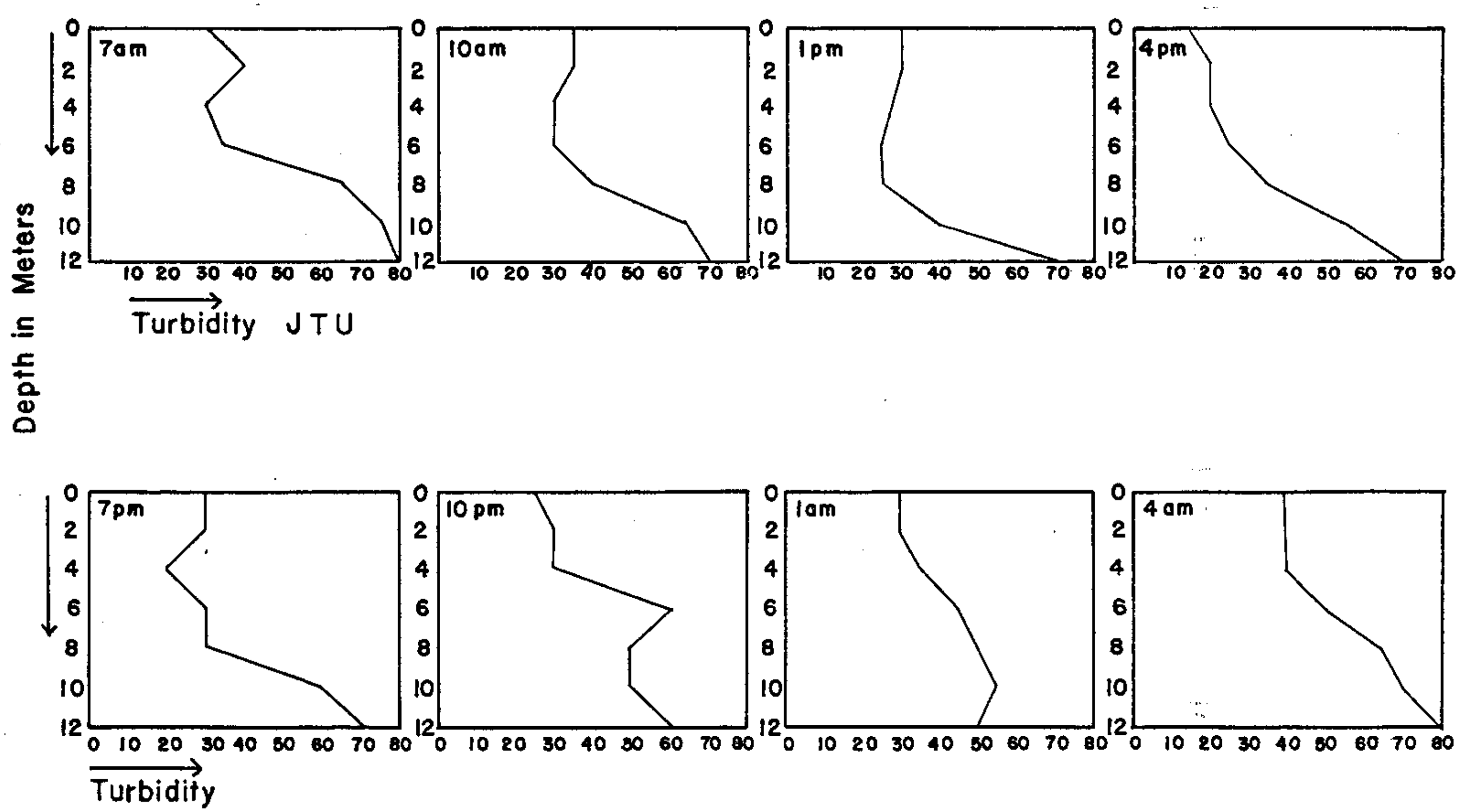


TABLE 15

DIURNAL LAKE STUDIES STATION L-4

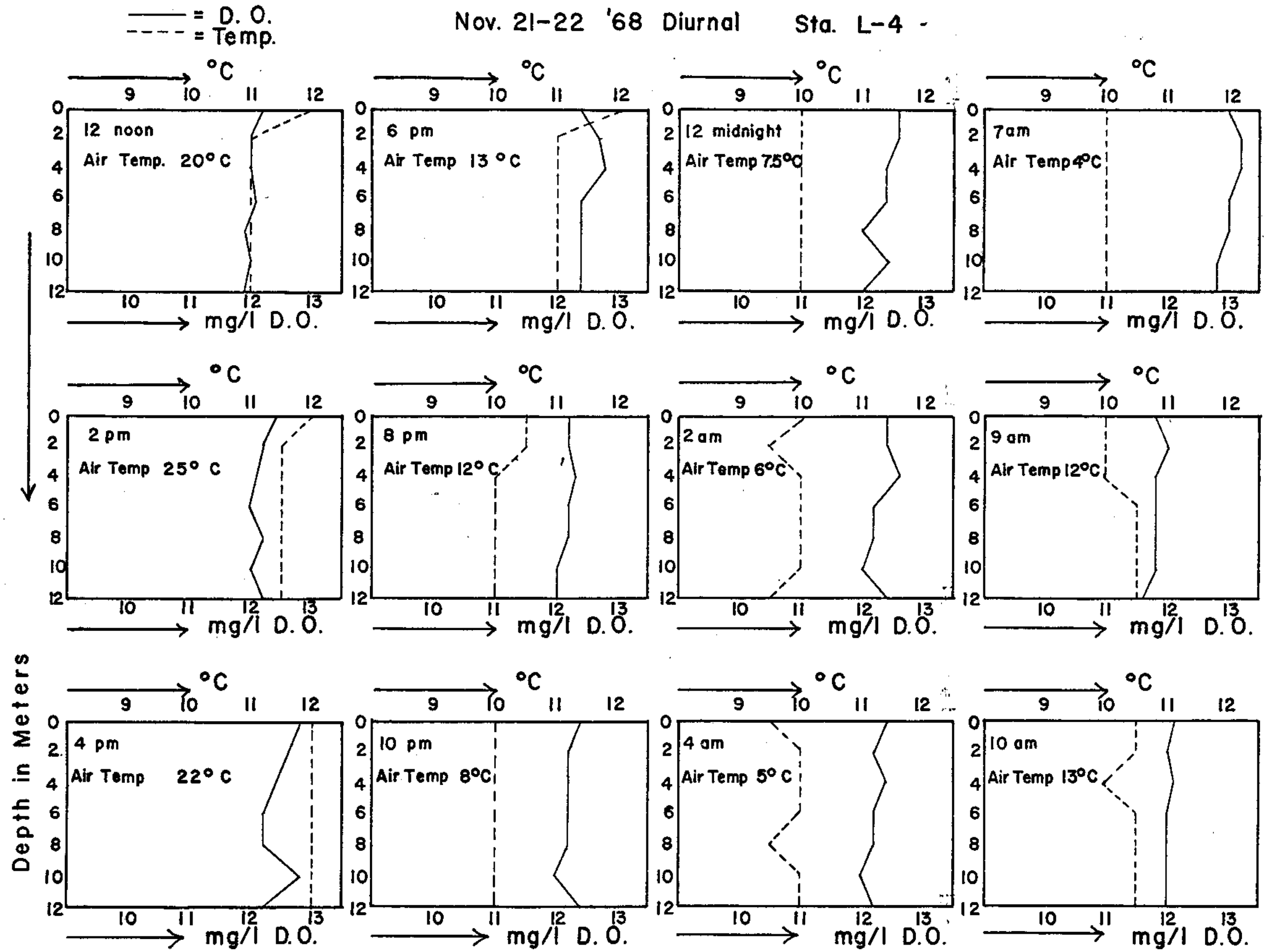
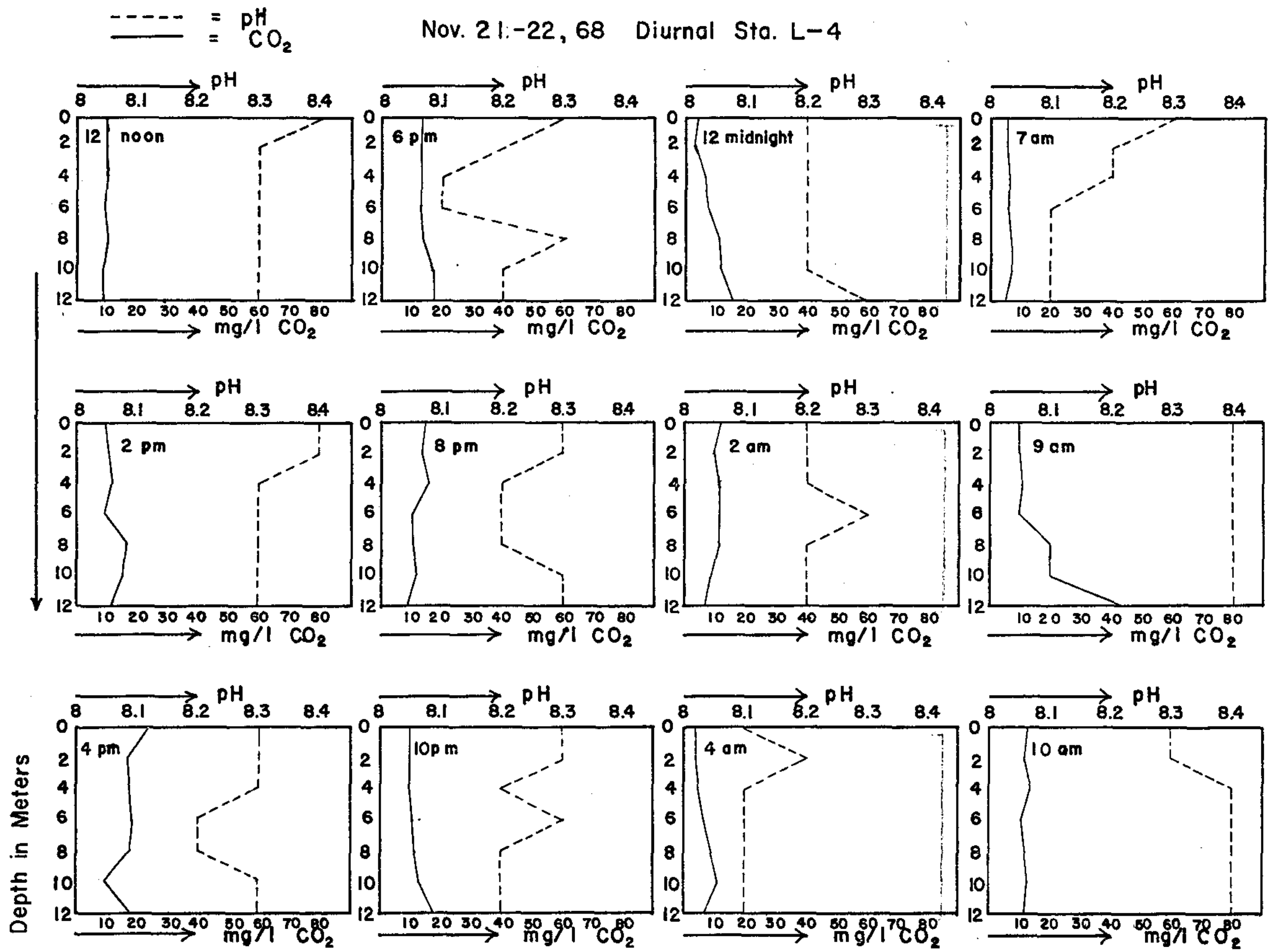


TABLE 16

DIURNAL LAKE STUDIES STATION L-4



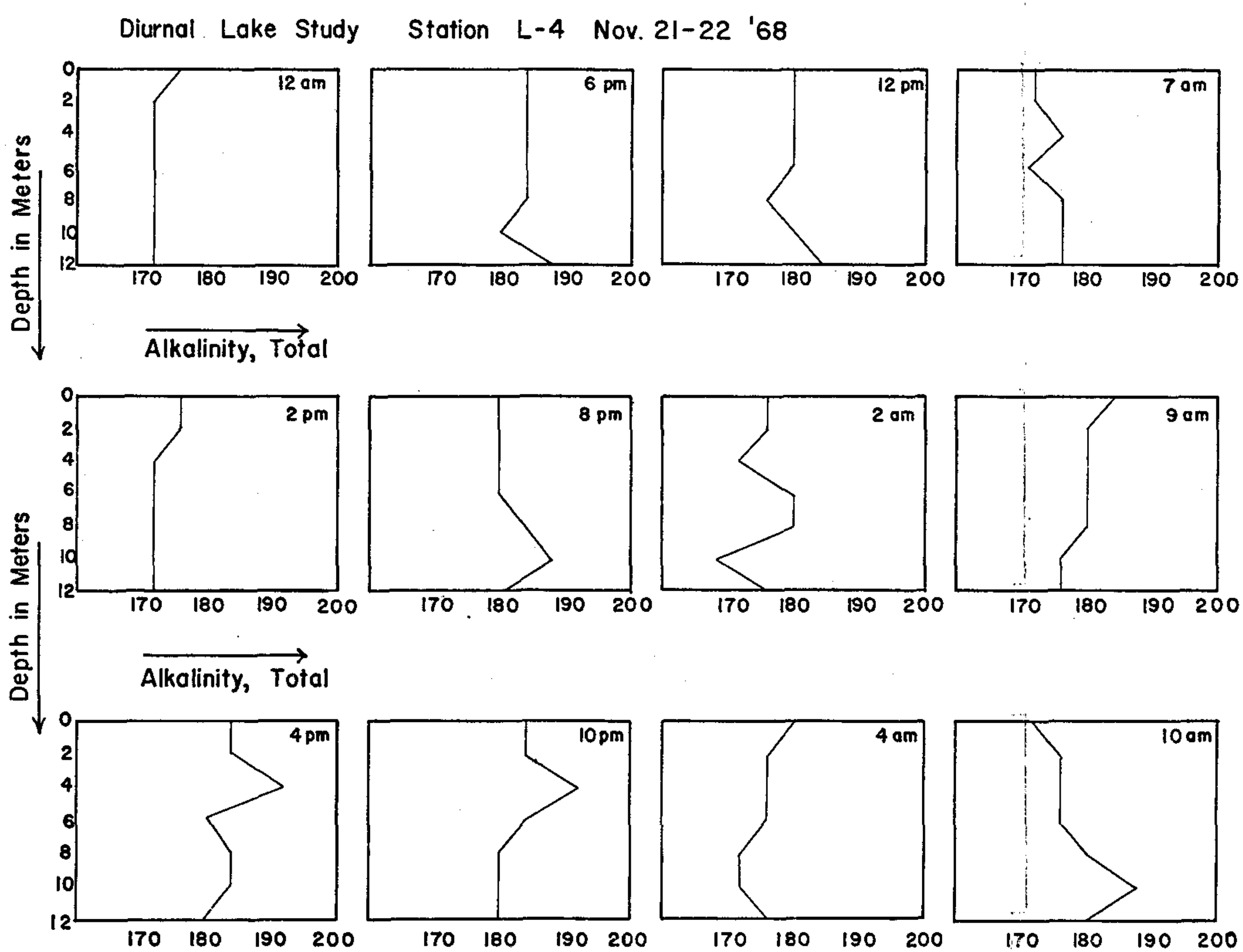


TABLE 17

DIURNAL LAKE STUDIES STATION L-4

Diurnal Lake Study Station L-4 Nov. 21-22 '68

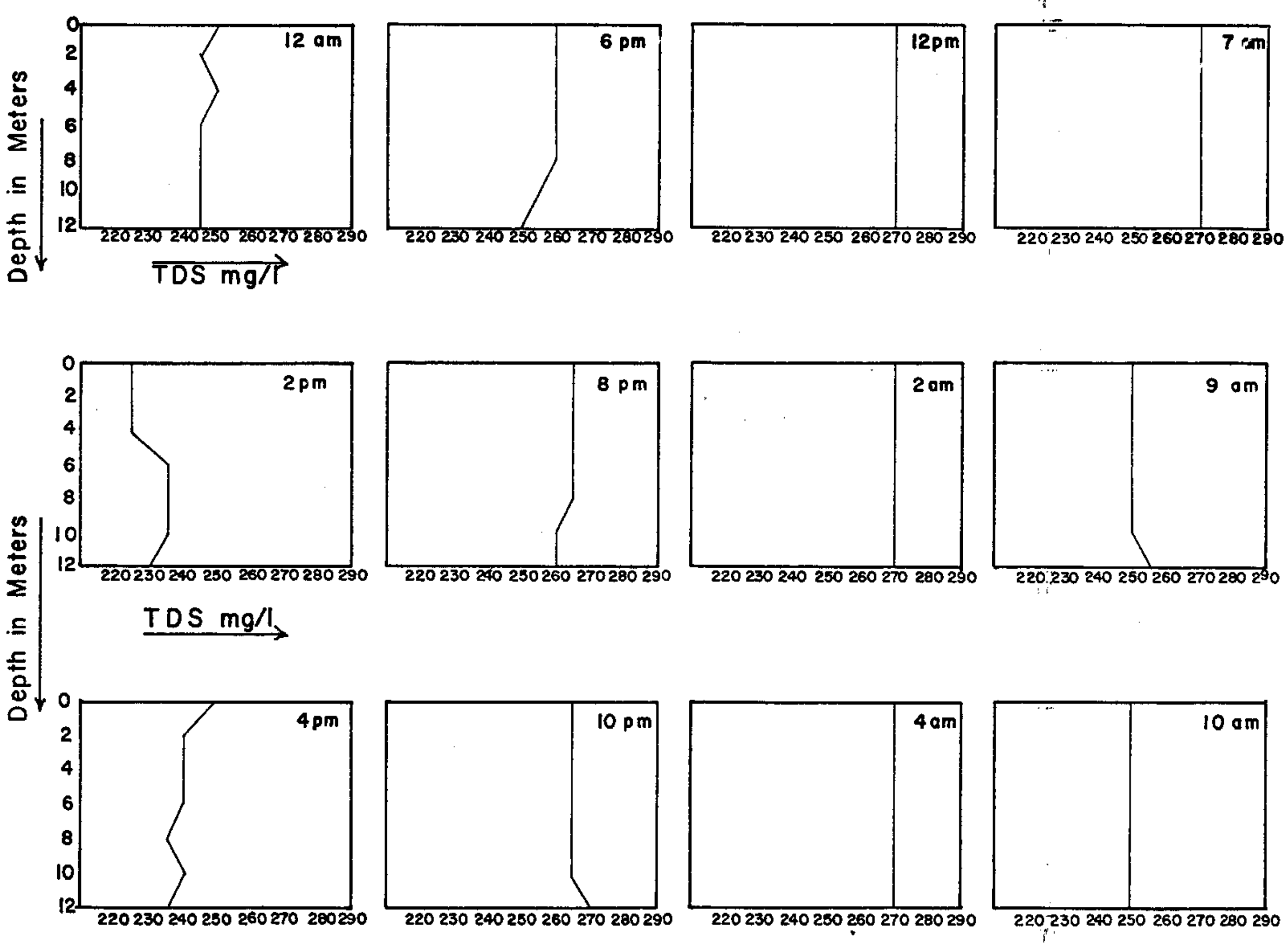


TABLE 18

DIURNAL LAKE STUDIES STATION L-4

TABLE 19
DIURNAL LAKE STUDIES STATION L-4

Diurnal Lake Study Station L-4 Nov. 21-22 '68

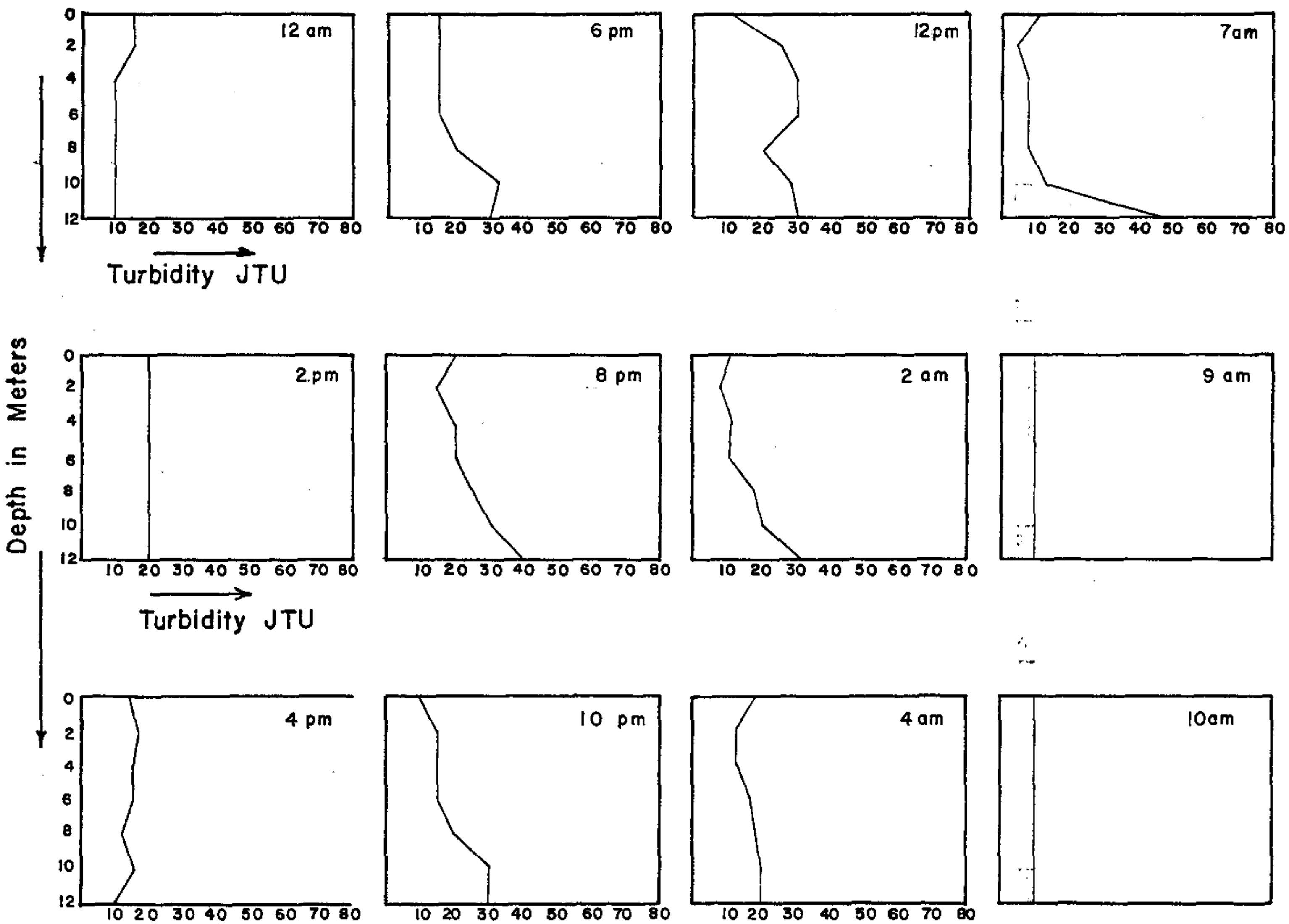


TABLE 20

BACTERIA

Sample Point	Colonies per 100 milliliter Coliform	Total Bacteria	Sample Point	Colonies per 100 milliliter Coliform	Total Bacteria
November 15, 1967			December 18, 1967		
1	8	16,000	1	30	5,000
2	5	14,000	2	8	4,000
3	2	8,000	3	9	21,000
4	1	9,000	4	0	11,000
5	68	5,000	5	37	6,000
6	3	7,000	6	8	4,000
7	0	6,000	7	8	1,000
8	2	8,000	8	7	3,000
9	3	12,000	9	3	5,000
10	3	37,000	10	7	13,000
11	4	11,000	11	15	1,000
12	2	8,000	12	16	5,000
13	7	13,000	13	12	3,000
14	0	overgrown	14	6	3,000
16	0	32,000	16	96	2,000
17	0	32,000	17	overgrown	7,000

Sample Point	Coliform	Total Bacteria	Sample Point	Coliform	Total Bacteria
January 20, 1968			April 24, 1968		
1	20	19,000	1	20	3,000
2	70	18,000	2	40	5,000
3	17	8,000	3	18	5,000
4	15	5,000	4	20	14,000
5	72	4,000	5	50	6,000
5-A (L-3-A)	128	5,000	6	60	9,000
5-B (L-3-B)	27	1,000	7	28	8,000
6	45	4,000	8	35	4,000
7	32	2,444	9	20	2,000
8	34	24,000	10	35	8,000
9	16	5,000	11	21	10,000
10	46	11,000	12	15	6,000
11	22	2,111	13	9	6,000
12	34	9,000	14	70	11,000
13	32	15,000	16	65	10,000
14	overgrown	4,000	17	150	14,000
14-A (L-6-A)	67	0			
14-B (L-6-B)	43	11,000			
16	800	3,000			
17	2900	34,000			

TABLE 21

BACTERIA

Sample Point	Colonies per 100 Milliliters	
	Coliform	Total Bacteria
(Lake)		
July 25, 1968		
1	140	9,500
5	10	11,500
7	30	3,500
8	0	7,500
10	0	12,500
16	0	15,000
17	40	35,500

Sample Point		
(Watershed)		
2	1350	58,500
4	240	37,500
5	260	72,000
6	170	40,500
7	440	64,000

Sample Point		
(Watershed)		
August 7, 1968		
2	800	42,000
4	120	14,000
5	10	56,500
6	1500	156,500
7	220	25,500

Sample Point	Colonies per 100 Milliliters	
	Coliform	Total Bacteria
(Lake)		
September 26, 1968		
1	40	31,500
2	10	21,500
3	30	20,000
4	50	5,500
5	60	2,500
6	30	28,000
7	20	56,500
8	60	49,500
9	60	63,500
10	130	115,000
11	150	13,000
12	60	10,000
13	10	14,000
14	130	101,500
15	40	13,000
16	overgrown	138,000
17	600	53,500

TABLE 22

BACTERIA

Colonies per 100 Milliliters

Diurnal - Sampling Station L-4

Total Bacteria

Depth	Date and Time November 2, 1968 2PM	November 21, 1968 8PM	November 22, 1968 8AM
Surface	7,500	6,000	11,500
6 meters	6,000	4,000	9,000
12 meters	5,500	7,500	6,500

Coliform

Depth	November 2, 1968 2PM	November 21, 1968 8PM	November 22, 1968 8AM
Surface	0	30	40
6 meters	20	50	20
12 meters	30	20	20

TABLE 23

Zooplankton

Net Plankton Count per 9 liter

July 25, 1968

Sample Point (lake)

Genus

1	25	1	7	20	23	0	
5	19	0	8	0	6	11	
7	25	2	6	17	21	0	
8	3	2	3	0	1	9	
10	2	3	8	9	11	1	
16	58	2	4	37	34	0	
17	32	7	35	24	22	4	

September 26, 1968

1	517	1	19	2	0		
2	19	6	6	1	3		3
3	171	26	14	1	1		12
4	53	13	42	8	34		
5	147	129	54	5	6		16
6	156	29	36	27	43		
7	226	3	79	4	1		
8	104	4	23	5	0		
9	97	15	33	20	87	3	
10	248	32	78	9	0	3	
11	102	57	74	37	1	1	13
12	124	43	95	19	12	1	
13	128	0	64	6	17	1	
14	28	0	35	48	0		
15	29	5	15	25	6		
16	25	2	23	14	4		
17	22	1	10	11	19		