LIMNOLOGICAL INVESTIGATIONS OF TEXAS IMPOUNDMENTS FOR WATER QUALITY MANAGEMENT PURPOSES-

LIMNOLOGICAL AND WATER QUALITY DATA FOR THE HIGHLAND LAKES, 1968

Technical Report No. 1
to the
Office of Water Resources Research
Department of Interior
Grant 14-01-0001-1554

by

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EHE 69-07
CRWR 40

March 1969

ACKNOWLEDGMENTS

This investigation was supported by funds obtained from the Office of Water Resources Research, Department of Interior, Research Grant 14-01-0001-1554 with matching funds provided by the Center for Research in Water Resources, The University of Texas at Austin. The cooperation of various agencies such as the Lower Colorado River Authority, Texas Water Quality Board, and the City of Austin Water Treatment Department is gratefully acknowledged.

Thanks are also due to the following conscientious and eager group of research personnel and students: Victor Wehman, Margaret McCleskey, Robert Kovar, Randy Smith, Richard Patyrak, Richard Pannell, Grace Barrett, Michael Wyatt, Joe King, Barry Davis and Earl Harriss. We acknowledge the fine work of graduate students, Allan Gravel and Ted Haughton. The data correlation and key punching was handled by Beatrice Mladenka and Agnes Pavliska.

ABSTRACT

A detailed limnological and water quality investigation was conducted on a chain of seven reservoirs located within a 150 mile reach of the Texas Colorado River near Austin. The morphological characteristics of each reservoir as well as its purpose in the chain affected the water quality. The presence of a thermal stratification as well as the location of the penstock in the dam controlled the water quality of the impoundment release.

The most serious water quality problem was the depletion of oxygen in the lower waters of nearly all these impoundments. High numbers of total coliform were found only once in some of the reservoirs, although persistent numbers were found throughout the year in Lakes Town and Decker. The phytoplankton standing crop was small although it increased down the reservoir chain. From chemical measurement of the water, phosphorus or iron or nitrogen could be limiting phytoplankton growth during the summer. Lakes Austin and Town had a high odor content in the summer, during or immediately after an increase in the blue-green algae.

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Chapter I

INTRODUCTION

A complex interaction of a number of physical, chemical and biological phenomena occurs in a reservoir. To achieve an understanding of the water quality changes occurring in an impoundment so as to project future trends as well as to manage the environment for man's benefit, a comprehensive knowledge of these phenomena is essential. However, Cole (1963) and Clark (1966) point out in their reviews that little is known about these phenomena in the artificial impoundments of Texas. In view of this lack of data in a state where the need for greater quantities of water by both the expanding population and industry will force the importation of water from out of state after 1985 (Texas Water Development Board, 1968b), limnological studies are urgently needed on Texas impoundments for water quality management purposes.

The Texas Colorado River was chosen as the system of study for a number of reasons. The seven impoundments, Lakes Buchanan, Inks, Johnson (Granite Shoals), Marble Falls, Travis, Austin and Town differ in volume, depth, surface area, shoreline length, water use and degree of urbanization or shoreline development. Secondly, the deep reservoirs behave as subtropical impoundments (Higgins and Fruh, 1968) about which little data is available in any part of the country. Furthermore, these seven impoundments are located within a 150 mile river reach. Thus, the Texas Colorado River data will serve as a model for future Texas river systems which will be transformed from free-flowing streams to a contiguous series of slack-water pools. In addition, the water quality of the Texas Colorado River is reported to be of high quality (Texas Water Development Board, 1968a). Such data could then be used for models to predict the water quality changes that might occur due to future pollution or river basin water transfer projects.

The objective of the first year of this project was to obtain reliable limnological and water quality data for these seven impoundments. This report also describes the methods and procedures for sampling and analysis, discusses the significance of the findings, and presents the recommendations for the second year's work.

Chapter 2

SAMPLING AND ANALYTICAL PROCEDURES

The purpose of this chapter is to present the sampling locations and procedures as well as the analytical techniques used to measure the various limnological and water quality characteristics. The error inherent in the field and analytical procedures and the effects of storage of the sample before measurement on the accuracy of the results will be discussed.

Samples were obtained at twenty various rivers, impoundment pools, and impoundment releases shown in Figure 1. The limnological and water quality data obtained are outlined in Table 1. Data on the impoundments and their respective dams are outlined in Table 2. The Lower Colorado River Authority supplied information of streamflow, volume, releases, and evaporation. Calculated monthly retention times as well as the rainfall and evaporation data are presented in Appendix A.

Table 1

Analyses

Depth
Surface Light
Secchi Disc
Temperature
Dissolved Oxygen
Total Organic Carbon
pH
Alkalinity
Hardness
Conductivity
Nitrate plus Nitrite
Ammonia
Phosphorus
Silica
Iron
Methylene Blue Extraction
Total Bacteria
Coliform Bacteria
Phytoplankton

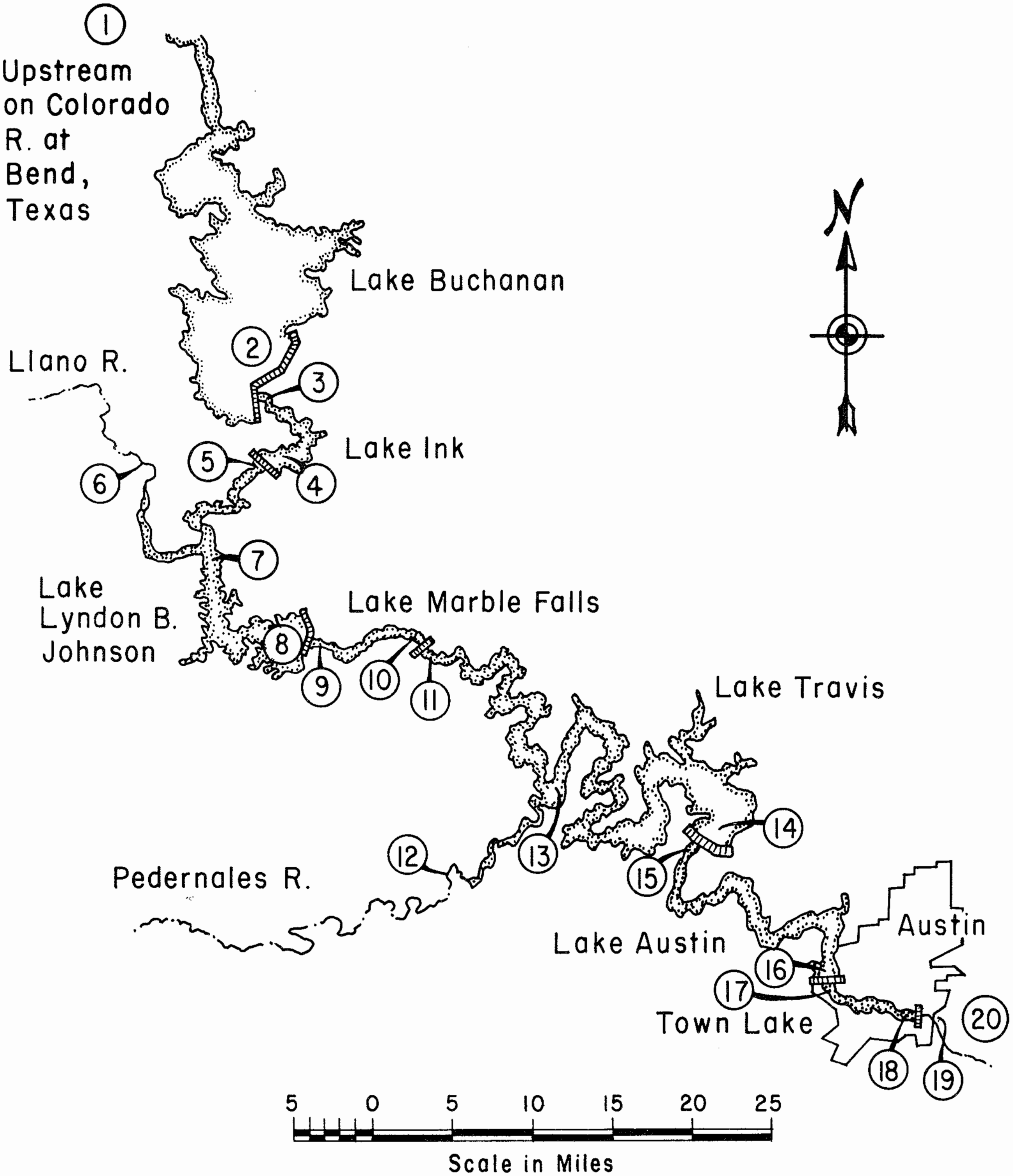


FIG. 1. LOCATION OF SAMPLING STATIONS

Table 2

Physical Characteristics of the Lakes

LAKE	1	2	3	4	5	6	7	8	9	10	11	12
Buchanan	1937	1020.0	23,060	992,475	43.04	105	30.65	5.00	3,665	10,987.5	S,C	42,000
Inks	1938	888.0	803	17,545	21.85	60	4.20	0.57	4,000	1,547.5	S,C	12,000
Lyndon B. Johnson	1950	825.0	6,375	138,460	21.72	85	21.15	2.05	-	5,491.4	C	50,000
Marble Falls	1951	738.0	780	8,760	11.23	55	5.75	0.20	-	859.5	S,C	30,000
Travis	1941	714.1	29,013	1,953,936	67.35	200	63.75	2.18	2,150	7,098.0	S,C,FC	85,000
Austin	1940	492.8	3,000	21,000	7.00	50	20.25	0.25	1,375	1,590.0	S,C	15,000
Town	1960					20						

1. Date completed
2. Spillway elevation (ft. above msl)
3. Area at Spillway elev. (acres)
4. Capacity at spillway elev. (acre-ft.)
5. Mean depth (ft.)
6. Approximate maximum depth (ft.)
7. Length by river channel (miles)
8. Maximum width (miles)
9. Discharge with one foot of head on spillway (cfs)
10. Total length of dam (ft.)
11. Purposes: S - sediment control; C - conservation; FC - Flood control
12. Electrical generation capacity (KW)

Field Measurements

River and impoundment release samples were obtained from shore or from bridges.

The impoundment pool samples were obtained by boat and the water from various depths was brought to the surface by a submerged pump run by means of an electric generator aboard the boat. Temperature and dissolved oxygen probes were inserted at right angles into a plastic cup which was attached to the inlet of the pump. The temperature and dissolved oxygen profiles were obtained as the probes and pump were lowered. Sufficient time was allowed for the temperature and dissolved oxygen readings to attain steady state. All the abrupt changes in the depth profile for these two water quality characteristics were noted. Water samples were obtained from above the sediments, in the hypolimnion (when present), at those depths at which there were significant temperature and/or dissolved oxygen changes, in the epilimnion (when present), and just below the water surface. A mininimum of three minutes was found necessary for the water to pass through the hose at the pumping rate used before a sample could be obtained.

Weather conditions such as air temperature and cloud cover as well as water conditions such as turbidity and turbulence were noted.

Temperature

Temperature was measured at each depth in the impoundment pools by a thermistor probe. A calibration curve was prepared previous to sampling so that the milliampere reading from the thermistor could be converted to actual degrees Centigrade (^{0}C). This calibration curve was obtained by placing the thermistor probe and a standard thermometer in a thoroughly mixed sample and obtaining the responses from each instrument after equilibrium had been reached. The thermistor was stable over long periods of time. As a field check the temperature of the water sample pumped to the boat was immediately measured with the calibrated thermometer. As shown in Table 3, the temperature measured by the thermometer was always slightly higher than the temperature reading obtained by the thermistor because of the warmer air temperature and surface water, and the friction caused by the water traveling through the hose.

The temperature of the river and reservoir release sampling stations was measured using the standard thermometer.

Dissolved Oxygen

The dissolved oxygen in the pumped water sample was measured by the modified Winkler procedure (Standard Methods, 1965). The sample was obtained by placing the pump's outlet tube in the bottom of a BOD bottle and flushing it with a volume of water approximately two to three times the volume of the container to prevent oxygen absorption from the atmosphere. Sodium azide and manganous sulfate were added and the contents mixed in a manner that no oxygen entered the sample. A distilled water seal was used when the bottle was stoppered. When the settling precipitate had produced at least 100 milliters of clear supernatant, sulfuric acid was added. The stopper was replaced, the contents mixed and the water seal replaced. Table 4 shows that the effect of not protecting the sample from sunlight was

Table 3

Comparison of Temperature Measurement Methods

Depth (ft.)	Sample by Thermometer	Temperature Probe
Surface	31.0	30.5
20	30.5	29.5
40	30.0	29.0
50	29.0	28.2
60	26.0	25.6
90	25.0	23.9
130	21.0	20.3
173	14.5	13.8

Table 4

Effect of Protection from Sunlight on Dissolved Oxygen Measurement

Depth (ft.)	Dissolved Oxygen (mg/l)	
	Covered	Uncovered
Surface	6.90	6.80
50	6.70	6.60
100	6.30	6.25

Table 5

Comparison of Winkler and Dissolved Oxygen Probe Measurements

Depth (ft.)	Oxygen (mg/l)	
	Winkler	Probe
Surface	7.10	7.25
15	7.05	7.25
35	5.35	5.25
45	2.00	1.75
60	0.80	0.60
80	0.60	0.00
102	0.15	0.00

small. The samples were returned to the laboratory for titration. For five replicated samples, a 24 hour delay in titration caused a decrease in dissolved oxygen from a mean of 9.92 to a mean of 9.78 mg/l.

Dissolved oxygen was also measured using a lead-silver galvanic cell probe. The probe was calibrated 48 hours after replacing the membrane using water from the particular lake which was to be sampled. At least six BOD bottles were filled with the lake water. Five bottles were generally used to span the temperature range of interest and a sample at one temperature was replicated. The calibration procedure was as follows:

1.) The BOD bottle was placed on a piece of plastic attached to a magnetic stirrer so as to prevent heat transfer.

2.) A stirring bar was placed in the BOD bottle.

3.) The temperature was measured with the standard thermometer while stirring.

4.) The oxygen probe was carefully placed in the mouth of the BOD bottle so that no air bubbles were trapped beneath the probe. The stirrer was started slowly and then increased in speed until there was no further change in the dissolved oxygen reading. After a number of tests this particular stirring rate was always the same.

5.) The oxygen probe was removed and the chemicals added for the modified Winkler test. (The stirring bar was removed after addition of the sulfuric acid.)

6.) The ratio of the probe reading to the modified Winkler measurement (ϕ) was computed and plotted versus the particular temperature of the sample.

To minimize the rate of lead oxide formation on the probe, the probe was placed in a sodium sulfite solution when not in use. Approximately an hour before use, the dissolved oxygen probe was washed and transferred to a distilled water container.

The dissolved oxygen probe was used as a field check method for the oxygen concentrations determined by the modified Winkler method. As shown in Table 5, the probe readings sometimes differed from those attained by the Modified Winkler method. A possible reason for this discrepancy was that the membrane on the probe was affected by the pressure as it was lowered.

pH

Upon arrival at the sampling station, the pH meter was always calibrated using buffers of pH 7.0 and 10.0. Because of the delicacy of the instrument, the pH meter was also recalibrated frequently during sampling. For pH measurement of the sample brought up to the boat by the submerged pump, a plastic container (similar to a BOD bottle) was filled in the same manner as that described for oxygen, the pH electrode immediately placed in the container, and the reading recorded within a few seconds.

Light

Throughout the day, light intensity measurements were obtained at the water surface. Secchi disc readings were obtained at each sampling in the impoundment pool. Light penetration data were obtained from Lakes Buchanan and Town during the fall of 1968 and in January, 1969 for comparison of penetrability of bands which affect photosynthetic productivity.

Samples Obtained for Laboratory Analysis

Samples were obtained from the various impoundment depths for some chemical and biological analyses by filling 64 milliliter test tubes. In the laboratory previous to sampling, the test tubes were washed with a 1 to 10 dilution of concentrated HCl, rinsed and autoclaved. In no case was detergent used. In filling all the test tubes, the same procedure was used (although the bacterial samples were handled with greater care). The plastic caps were removed from the test tubes so that neither the top of the test tube nor the inside of the cap was contaminated. The stream of water emerging from the hose was directed into the test tube without the hose touching the test tube. For samples obtained from rivers and impoundment releases, the test tube was placed approximately at mid-depth, the cap removed, the test tube filled, and the cap replaced all under water. The bacterial samples were placed in an insulated container filled with ice, returned to the laboratory, and placed in a dark 4°C room. The test tubes containing chemical samples were not iced in the field, but were placed in the same dark 4°C room upon return to the laboratory.

Algal and methylene blue extraction samples were obtained using 1000 milliliter plastic containers. Previous to sampling the plastic bottles were acid washed and then rinsed. Algal samples were obtained from above the sediments, at the thermocline and just below the water surface. Samples for methylene blue extraction were obtained only from just below the water surface. All plastic containers were not iced in the field, but were placed in a 4°C refrigerator upon return to the laboratory.

The effects of such preservation procedures will be discussed in detail for each laboratory analysis.

Chemical Analyses

For ease of presentation, the various chemical analyses are divided into three sections:

1.) Alkalinity, hardness and conductivity;
2.) Nutrients (phosphorus, silica, nitrogen and iron); and
3.) Other (total organic carbon and methylene blue extraction.)

Alkalinity, Hardness and Conductivity

The procedures for alkalinity, hardness, and conductivity measurements are the same as those outlined in Standard Methods (1965). The endpoint for the alkalinity titration was standardized at pH 4.8 because the alkalinity was always in the range of 150 mg/l as $CaCO_3$.

Because of the limitations of time and personnel all samples were generally analyzed for these three constituents within three days of sampling and never more than one week after sampling. Because of this delay a preliminary study was conducted to determine the effects of storage upon each constituent. As shown in Table 6, storage had a slight effect upon the hardness and conductivity concentrations. Although these changes were less than 5 per cent of the measurement obtained before storage, more detailed studies were initiated on the reproducibility of the measurements as well as on the effect of storage temperatures.

The reproducibility of the analysis for alkalinity presented in Table 7 shows the reliability of the procedure. However, there was a slight decrease in alkalinity when stored at room temperature. Table 9 shows that even with immediate storage of the sample at 4°C there was also slight decrease in alkalinity. After the first day of storage, there was no further decrease in the alkalinity.

The replicability of the hardness procedure as well as the effect of storage at room temperature is shown in Table 8. There was a decrease of 5 mg/l in the hardness within the first 24 hours. No further statistically significant decrease was found with increased storage time. As shown by Table 9, placement of the samples immediately into a 4°C refrigerator also did not aid.

The conductivity showed only a slight increase with time when stored at either 4°C or room temperature. (See Table 10.)

Because of the inconvenience of titration immediately on the boat as well as the fact that these slight changes in alkalinity, hardness, and conductivity during storage were within sampling error (to be discussed later in this chapter), the procedure for sampling and storage previously outlined was used.

Nutrients

Highly sensitive and accurate procedures were required to measure the low concentrations of nutrients present in the waters of the Highland Lakes. Considering the large number of samples which had to be processed quickly before change occurred in nutrient concentration, automated chemical procedures were desired for use. The only method available was the Technicon

Table 6

Effect of Storage Time at 4 C

Storage Time (Day)	Alkalinity (mg/l $CaCO_3$)	Hardness (mg/l $CaCO_3$)	Conductivity (μMHOS/CM)
0	154	180	496
2	-	-	498
14	-	184	514
21	154	-	-
32	-	190	500

Table 7

Replication and Effect of Storage at Room Temperature on Alkalinity

Storage Time (hr.)	0	24	48	96	192
	151	149	147	147	145
	151	145	145	145	147
	149	147	150	145	145
	151	145	145	145	145
	149	145	145	145	147

Table 8

Replication and Effect of Storage at Room Temperature on Hardness

Storage Time (hr.)	0	24	48	96	192
	168	176	176	172	172
	188	176	172	172	176
	180	176	172	172	176
	180	172	176	172	176
	180	172	176	176	176

Table 9

Effect of Storage for Various Times at Different Temperature on Alkalinity and Hardness

Total Storage Time (Hours)	Hours at the Storage Temperature Room	$4^{\circ}C$	Alkalinity (mg/l as $CaCO_3$)	Hardness (mg/l as $CaCO_3$)
0	0	0	150	179
24	0	24	149	172
48	0	48	145	176
96	0	96	147	172
192	0	192	147	176
0	0	0	150	179
48	24	24	147	176
96	24	72	145	172
192	24	168	145	172
0	0	0	150	179
96	48	48	143	172
192	48	144	145	176

Table 10

Effect of Storage Time and Temperature on Conductivity

Days	Storage Temperature $4^{\circ}C$	Room
0	500	500
3	518	508
6	510	501
7	514	512

autoanalyzer; however, it was found that nearly every nutrient procedure outlined in the Technicon Co. manual was unsuitable for accurate detection of the concentration present. Thus, it became necessary to spend a considerable portion of the research effort of this project in developing modified methods for nutrient analysis. In some cases these methods were successful, while in others it was necessary to revert to established regular methods.

Phosphorus

Total phosphorus is defined here as all of the phosphorus in the sample including both the inorganic and organic forms. Adenosine triphosphate (ATP) was the phosphorylated organic compound utilized as a standard since the difficulty in hydrolyzing the tertiary phosphate on the molecule was considered a good test of the efficiency of the various analytical methods evaluated. The ATP standards used in the experiment were compared to orthophosphate standards to obtain the per cent degradation of the organic phosphate form to orthophosphate. For all procedures evaluated, it was absolutely required that all glassware be thoroughly cleaned. Dichromate cleaning solution followed by repeated rinsing with both tap and distilled water was found reliable.

The autoanalyzer procedure tested was the method developed by D.P. Lundgren (1960). However, as shown in Table 11, only

52 per cent of the ATP was broken down to orthophosphate by this procedure. Modifications in the procedure were attempted which consisted of adding a digester to the system and varying the digestor temperature as well as adding additional oxidizing agents. As shown in Table 11 at least 88% breakdown of ATP to orthophosphate was obtained with three of the modifications. However, while this modified procedure was fairly accurate at phosphorus concentrations above 0.2 mgP/l, it became highly unstable and inaccurate at lower phosphorus concentrations. The time needed by a technician to make this automated system operable at very low phosphorus concentrations brought about abandonment of this procedure.

Basic batch methods for phosphorus measurements outlined in Table 12 were then evaluated. The catalyzed persulfate oxidation gave the best replication of results. However, instability of the reagents used in this procedure limited its usefulness. The persulfate oxidation procedure with stannous chloride reduction and 60 minutes autoclaving was the most efficient of all methods tested.

Unfortunately, because the levels of total phosphorus in the Highland Lakes are extremely low, it was found necessary to utilize the persulfate oxidation procedure in conjunction with methods of precision colorimetry (Willard, et al, 1958). In this particular case, a treated standard of 0.20 mgP/l was used in conjunction with the dark-current adjustment side of the scale on a Baush and Lombe

Table 11

Evaluation of Automated Methods for Phosphorus Measurement
(after Higgins, 1968)

Method	% ATP Breakdown to Orthophosphate
Lundgren Method	52
Lundgren Modified (125°C)	55
Lundgren Modified (260°C)	88
Lundgren Modified (310°C)	86
Lundgren Modified (260°C plus 0.5% Perchloric Acid)	88

Table 12

Evaluation of Batch Methods for Phosphorus Measurement
(After Moore, 1969)

Method	% ATP Breakdown to Orthophosphate
Hydrolyzable	37
Acid Hydrolyzable	72
Sulfuric Acid-Nitric Acid Digestion	84
Persulfate Oxidation with Stannous Chloride Reduction	
a) 30 minute autoclaving	77
b) 60 minute autoclaving	95
Persulfate Oxidation with Ascorbic Acid Reduction	82
Catalyzed Persulfate Oxidation with Ascorbic Acid Reduction	91

Spec 20. Lower concentrations of phosphorus were then read on the spectrophotometer in the normal manner. The result was simply an expansion of the normal calibration curve. Due to deviation from Beer's Law, the expanded calibration curve was not a straight line. For this reason, at least two standard phosphorus concentrations were run with each set of samples to check the accuracy of the calibration curve, operation of the spectrophotometer, and possible decay of reagents.

To determine the error possible in laboratory measurement, five replicates of six different phosphorus concentrations were used and the relative error computed. As shown in Table 13, this relative error was quite high for all phosphorus concentrations less than 0.05 mg/l.

The effect of storage on phosphorus measurement is shown in Table 14. For all methods of storage, the decrease was well within analytical error. Thus, the method of sampling and storage outlined previously in this chapter was followed. All phosphorus analyses were conducted within 24 hours after sampling.

Silica

Automated colorimetric procedures for silica determination are based on the yellow silico-molybdate complex formed by the reaction of orthosilicic acid with ammonium molybdate. However,

Table 13

Internal Replicates of Phosphorus Measurements

P Standards (mg /l)	Concentration (mg/l)	Mean	Standard Deviation	Coefficient of Variance (Std. dev/mean x 100)
0.01	0.00	0.008	0.0084	105
	0.01			
	0.00			
	0.01			
	0.02			
0.03	0.05	0.022	0.0179	81.4
	0.01			
	0.01			
	0.03			
	0.01			
0.05	0.05	0.046	0.0089	19.3
	0.04			
	0.04			
	0.06			
	0.04			
0.10	0.10	0.100	0.00	0.00
	0.10			
	0.10			
	0.10			
	0.10			
0.20	0.20	0.202	0.0045	2.2
	0.20			
	0.20			
	0.21			
	0.20			

Table 14

Effect of Various Sample Storage Procedures on Phosphorus Measurement

Storage Method	Time of Storage Hours	Phosphorus Concentration (mg/l)
Immediately Placed in 4°C Room	0	0.130
	24	0.140
	48	0.130
	96	0.140
	168	0.130
Immediately Placed in Ice of Insulated Container	0	0.140
	24	0.140
	48	0.130
	96	0.120
	168	0.120
Left at Room Temperature for 24 Hours and Then Placed in 4°C Room	0	0.140
	24	0.140
	48	0.130
	96	0.140
	168	0.130
Left at Room Temperature in Darkness	0	0.140
	24	0.130
	48	0.120
	96	0.120
	168	0.120

this procedure was too sensitive for the silica concentrations (5 to 14 mg/l as SiO_2) found in the Highland Lakes. The problem was solved by diluting the sample with distilled water by a ratio of 5 to 3.9. The resulting calibration curve followed Beer's Law. Also precipitation occurred after addition of the reagents to the lake waters. This problem was solved by decreasing the reducing agent (1 amino-2 napthanol-4-sulfonic acid). All other reagents used were the same as recommended by Technicon (1960).

For 18 replicates of a lake sample interdispersed with a number of other samples, a mean of 8.10 mg/l as SiO_2 resulted in a standard deviation of 0.208 mg/l as SiO_2 and a coefficient of variation of 2.57%. Replicates of two standards are presented in Table 15. As shown by the data in Table 16 there was only a slight change in silica with storage, which was within the overall sampling error (to be discussed later in this chapter). Because of the need to determine other nutrients as fast as possible, silica measurements were generally delayed for a time convenient for the analyst.

Nitrate plus Nitrite

Kamphake, et al (1966) optimized pH, temperature, time of reaction, hydrazine concentration and copper sulfate concentration for the reduction of nitrate to nitrite. Technicon (1965) added an acetone solution to keep in solution the large molecules formed in the reactions of the nitrite-hydrazine and color complexes. Spear (1967) indicated

Table 15

Reproducibility of Silica Analyses

Concentration (mg/l SiO_2)	Mean	Standard Deviation	Coefficient of Variance (%)
2.5	2.5	0.00	0.00
7.5	7.53	0.034	0.45

Table 16

Effect of Storage Procedure on Silica (mg/l as SiO_2) for Lake Marble Falls Water

Depth (ft.)	Date of Measurement		
	7-19	1-2	1-16
Surface	7.3	7.8	7.5
15	7.3	7.8	7.5
30	7.2	7.7	7.5
45	7.2	7.7	7.6
63	7.4	7.8	7.7

Table 17

Replication of Nitrate Plus Nitrite Standards

Concentration (mg/l NO_3+NO_2-N)	Mean	Standard Deviation	Coefficient of Variance (%)
0.05	0.05	0.00	0.00
0.40	0.41	0.02	4.5

Table 18

Effect of Storage Procedure on Nitrate Plus Nitrite Measurements for Lake Marble Falls Water

	Date				
Depth (ft.)	3-16	4-5	7-2	12-12	1-14
Surface	0.30	0.30	0.30	0.26	0.29
15	0.29	0.28	0.32	0.28	0.33
30	0.24	0.25	0.27	0.21	0.25
45	0.30	0.27	0.33	0.28	0.30
63	0.27	0.25	0.28	0.23	0.21

that greater sensitivity could be attained by addition of a double time delay external to the heating bath common to both of the other procedures. This modification was adapted and proved successful.

As shown in Table 17, the nitrate plus nitrite reproducibility was quite good. Furthermore, the data in Table 18 indicates that the storage procedure was valid over a long period and hence with the press of other nutrient analyses the nitrate plus nitrite determinations were usually conducted at random times convenient to the analyst.

Ammonia

Automated procedures for ammonia measurement were found to be inadequate for detection of the very low ammonia concentrations present in the majority of the samples from the Highland Lakes. From previous research on Kjeldahl nitrogen (which utilizes the ammonia determination as part of its overall system) by Technicon (1965), Mann (1963), and Kemmerer, et al (1967), it appeared that considerable differences in opinion existed regarding optimum methodology and reagent concentrations. From Mann's (1963) work on a manual method for Kjeldahl nitrogen determination, it appeared that the alkaline phenol solution needed to be more concentrated and the hypochlorite concentration less concentrated in comparison to the methodology of the other two investigators using the automated procedure. Therefore, it became evident that a study was needed to determine the concentration of reagents required to obtain an optimum methodology.

The first two variables studied were the concentration of alkaline phenol and hypochlorite. The concentration of phenol denoted on Table 19 as 1.0 was made up of 250 grams of phenol crystals dissolved in a 20 per cent solution of sodium hydroxide. The alkaline phenol concentrations were varied by 50 per cent increments throughout the subsequent experiment. The initial concentration of hypochlorite in a commercial bleach was 5.25 per cent and is denoted as 1.0. This hypochlorite solution was varied by 25 per cent dilutions during the experiment. The transmittances for the 0.5 mg/l NH_3-N standard per cented in Table 19 were approximately ten times those previously obtained using procedures in the literature. The optimum sensitivity was obtained using an alkaline phenol solution consisting of 375 grams of phenol dissolved in a 30 per cent solution of sodium hydroxide and a solution consisting of 2.66 per cent hypochlorite.

However, it was quite difficult to prevent precipitation in the alkaline phenol reagent flask during a run. Thus, it was found necessary to determine which component, sodium hydroxide or phenol, was responsible for the major shift in sensitivity. It is obvious from the data in Table 20 that the phenol was the sensitive component. The lowering of the sodium hydroxide to a 20 per cent solution solved the problem of reagent precipitation.

Also at times, negative results were obtained indicating that the ammonia in the lake samples was lower than that found in the

Table 19

Effect of Alkaline Phenol and Sodium Hypochlorite Concentrations on the Transmittance of a 0.5 mg/l NH_3-N Standard

Alkaline Phenol Solution	Sodium Hypochlorite Solution			
	0.25	0.50	0.75	1.00
1.50	64	68	66	60
1.25				
1.00			35	39
0.75				
0.50		21	24	27
0.25				20
0				

Table 20

Effect of Phenol and Sodium Hydroxide on Sensitivity of Ammonia Measurement

Phenol Concentration (mg/l)	NaOH Concentration (mg/l)	Deflection for 0.4 mg/l NH_3-N
250	200	30.5
250	250	21.0
250	300	14.0
375	150	37.5
375	200	51.0
375	250	39.0

Table 21

Reproducibility of Ammonia Analyses

Concentration (mg/l NH_3-N)	Mean	Standard Deviation	Coefficient of Variance (%)
0.10	0.0975	0.0056	5.64
0.40	0.385	0.0258	6.73

Table 22

Effects of Storage at $4^{o}C$ on Ammonia Concentration

Time (days)	NH_3-N (mg/l)
0	0.50
3	0.50
10	0.52
13	0.52

laboratory distilled water. Amines, resulting from the addition of chlorine and ammonia for disinfection at the city's water treatment plant, were sufficiently volatile to distill over. Attempts to remove ammonia by addition of folin to batches of water were unsuccessful and an ion exchange column had to be used. However, some of the folin particles of near microscopic size were lost from the ion exchange and entered the ammonia-free distilled water. Filtration through millipore membranes was thus also needed.

An added difficulty was that small particles from the natural water samples oscillated back and forth in the colorimeter's flow cell causing irregularities in the transmittance patterns. A continuous filter was placed before the colorimeter to reduce the "noise."

The ammonia analysis was not perfected until after the fall sampling period. Thus, only the data obtained during the last winter sampling can be considered accurate.

The reproducibility of ammonia analyses are presented in Table 21. The effects of storage on the ammonia concentration are presented in Table 22. Ammonia was usually determined within 48 hours after sampling.

Iron

Excessive back pressure in the autoanalyzer procedure (Technicon, 1965) caused instability. This problem was solved by reducing the quantity of sample flowing through the system and decreasing the normality of HCl used for digestion. In addition it was found that particles present in the natural water samples were not removed adequately by the filtration system and, thus, results were not reproducible. This problem was avoided by allowing the particles to settle out in the sample test tubes, then carefully decanting the sample into the system's sample cups. Thus, the system measured total soluble iron and not total iron. Reproducibility for iron is shown in Table 23.

The analysis for iron was not started until after it was found by Floyd, et al (1969) that iron might be in such low concentrations so as to limit algal growth. However, as shown in Table 24, the iron concentration did not remain the same after two months storage. Thus, only the data obtained during the last sampling period was accurate. The data for the first five sampling periods are presented in this report to give an indication of the low iron concentration present.

Other Analyses

The purpose of the other two chemical analyses, total organic carbon and methylene blue extraction, was to indicate the quantity of organic matter in the Highland Lakes.

Table 23

Reproducibility of Iron Analysis

Concentration (mgFe/l)	Mean	Standard Deviation	Coefficient of Variance (%)
0.030	0.0295	0.0013	4.41
0.070	0.0696	0.0018	2.58

Table 24

Effects of Storage at Various Temperatures on Iron Concentration

Time (days)	Storage Temperature	
	Room	4°C
0	0.052	0.052
23	<0.010	0.052
33	0.013	0.061
36	0.017	0.061
60	0.0025	0.024
78	<0.0025	0.025

Total Organic Carbon

The recently developed carbon analyzer procedure (Van Hall, et al, 1965) utilizes the concept of complete combustion of all carbonaceous organic matter to carbon dioxide and water, then allowing the gas stream to pass through an infrared analyzer sensitized for carbon dioxide, and recording the response on a strip chart. Although this method is rapid, simple, and free of the many variables which plague the COD and BOD analyses, certain limitations are associated with the concept of correlating total organic carbon values with the oxygen-based analyses of BOD and COD (Ford, 1968).

The internal replication of various TOC standards and the effect of storage on TOC measurement are presented in Tables 25 and 26 , respectively. In comparison to the sampling error (discussed later in this chapter), all analyses are sufficiently accurate above 5 mg/l TOC. All storage procedures appeared valid. The TOC was determined usually within 48 hours of sampling and never more than 96 hours after sampling.

Methylene Blue Extraction

The analysis was conducted only during the fall sampling period following the procedure outlined in Standard Methods (1965). The reproducibility of the analysis is outlined in Table 27 . As shown in Table 28 , there was an increase in the concentration of the

Table 25

Internal Replicates of TOC Standards

TOC Standard (mg/l)	Concentration (mg/l)	Mean	Standard Deviation $(x10^2)$	Coefficient of Variance Std. Dev./Mean x 100
0	0	0.4	0.548	137
	0			
	0			
	1			
	1			
5	4	4.8	0.838	17.5
	4			
	6			
	5			
	5			
10	10	9.6	0.894	9.3
	8			
	10			
	10			
	10			
	10			
15	15	15.8	1.095	6.9
	15			
	15			
	17			
	17			
20	20	20.6	0.548	2.7
	20			
	21			
	21			
	21			
25	25	25.8	1.305	5.1
	24			
	26			
	27			
	27			

Table 26

Effect of Various Storage Methods on TOC Measurement

Time of Storage (Hours)	Storage Methods Immediately 4°C	First 24 hr. at Room Temp., then 4°C	Insulated Container	Room Temp.
0	18	17	18	17
24	18	18	18	17
48	17	18	18	18
96	18	17	17	18
168	17	17	18	17

Table 27

Reproducibility of Methylene Blue Extraction Measurement

Concentration (mg/l)	Mean	Standard Deviation	Coefficient of Variance (Std. Dev/mean x 100)
0.138	0.135	0.005	3.7
0.138			
0.130			

Table 28

Effect of Storage Conditions on the Methylene Blue Extraction

Time (days)	Storage Methods 4°C	Room Temp.
0	0.196	0.206
15	0.200	0.220
22	0.196	0.236
70	0.200	0.225

sample stored at room temperature, but not in those samples stored in the normal manner at 4°C.

Biological Analyses

Biological analyses consisted of testing for both total and coliform bacteria, identification and counting of phytoplankton, and other related analyses such as chlorophyll extraction and threshold odor values.

Bacterial Enumeration

Total and coliform bacteria were tested for and enumerated by use of the membrane filter technique (Standard Methods, 1965). As previously outlined, bacterial samples were obtained from the sampling sites in autoclaved presterilized 68 ml screw-capped test tubes which were stored in an insulated container filled with ice until arrival in the laboratory where they were stored at 4°C. Enumeration was accomplished within twenty-four hours of sampling.

Determination of the effect of various methods of storage on and the reproducibility of total and coliform bacteria counts are presented in Table 29. In some cases the error was quite large as indicated by the data omitted in averaging. No appreciable changes in total coliform counts enumeration occurred within twenty-four hours in those samples stored in the insulated container or in the 4°C room

Table 29

An Example of the Effects of Three Storage Techniques on Reproducibility of Total and Coliform Bacterial Enumeration

Samples kept at room temperature (22-24° C)

Time (hrs.)	0.00		12.25		23.50		36.00		49.50		61.75		76.25		84.50	
Sample No.	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C
1	1,020	5.8	3,330	7.8	8,640	9.9	9,300	8.8	4,000	11.7	9,300	7.0	9,200	2.8	4,800	3.6
2	1,440	4.9	3,210	4.4	8,640	8.1	8,100	7.8	12,600	10.8	10,000	3.2	6,800	2.8	4,900	3.6
3	750	4.2	2,220	6.6	5,760	9.9	7,300	16.2	16,000	12.4	1,200*	4.8	11,100	8.8	4,600	3.6
4	47*	5.3	3,500	4.4	7,680	11.5	13,200	15.8	13,700	17.8	10,500	7.8	8,100	7.0	7,900	5.8
5	1,280	5.5	4,250	7.0	10,560	9.5	11,100	11.2	11,000	12.4	10,600	10.0	10,900	5.4	9,000	4.0
Avg.	1,120	5.1	3,310	6.0	8,250	9.7	9,800	11.9	11,460	13.0	10,100	6.4	9,250	5.4	6,250	4.1

Samples kept in insulated container filled with ice

Time (hrs.)	0.00		9.15		20.5		32.50		48.25		57.25		70.25	
Sample No.	T	C	T	C	T	C	T	C	T	C	T	C	T	C
1	780	9.3	110	16.0	1,020	14.8	510	3.2*	4,800	12.4	1,490	14.8	3,570	15.6
2	1,050	13.3	830	16.4	1,040	14.5	720	24.0	990	14.2	1,140	14.4	1,010	15.2
3	1,130	4.1*	930	9.4	830	15.6	580	15.2	1,540	14.8	2,260	16.2	560	10.2
4	1,210	12.9	1,100	13.9	940	13.7	750	19.6	560*	19.8	520	14.2	1,110	14.4
5	1,050	15.0	10*	9.0	820	13.9	300	16.8	4,090	23.2	1,410	14.8	480*	15.4
Avg.	1,045	12.6	990	12.9	930	14.5	572	18.9	2,890	16.8	1,365	14.9	1,563	14.2

Samples kept at 4°C

Time (hrs.)	0.00		14.75		23.00		35.75		47.00		61.50	
Sample No.	T	C	T	C	T	C	T	C	T	C	T	C
1	1,030	6.9	390	5.8	328	7.1	259	8.6	620	7.2	240	5.3
2	1,040	7.5	410	3.0	327	0.0*	178	11.8	550	4.6	260	3.6
3	850	7.7	550	7.7	295	7.0	173	6.2	650	9.0	260	7.4
4	1,060	7.8	640	7.9	262	9.6	177	6.6	460	7.6	350	6.0
5	860	8.1	760	1.1	278	7.3	197	7.2	530	5.8	5*	3.2
Avg.	968	7.6	550	6.1	298	7.8	185	8.1	562	6.8	302	5.1

All counts are no. per milliliter.

* Inconsistent data omitted on averaging.

such that one might assume that the gross effects of storage were causative. The total bacteria counts were apparently affected to a slightly significant degree in a much shorter time. Thus, the data on total bacteria presented in this report should be considered as those total bacteria present in the water twenty-four hours after sampling. It should be remembered, however, that two primary factors affect this time dieoff phenomenon. Subtle changes in the water quality, varying with sample dates, and changes in the species of total bacteria with time alter any storage effect data. The time from sampling to testing in the laboratory is universally recognized to yield the most accurate data when that time is at a minimum.

Phytoplankton Enumeration

Enumeration of the standing crop of phytoplankton was made by total counts and by the Areal Standard Unit (ASU) of Measurement described in Standard Methods (1965). The relationship between the two-dimensional measure (ASU) of phytoplankton and their numbers has long been sought after. The closest approximation is that of the Cubic Standard Unit (CSU) outlined in Standard Methods (1965). However, in the analyses of the phytoplankton from the Highland Lakes the CSU method falls short of its function due to the significant variance of the phytoplankton from the true geometric shape upon which the application of the third dimension for the CSU method is based. Thus, comparison of the ASU and number of phytoplankton found in the Highland Lakes revealed more significantly the limnological and water quality characteristics of these waters.

All phytoplankton enumeration was conducted using the Sedquick Rafter funnel concentration procedure in which 500 ml of sample water was concentrated to 5 ml. One milliliter of this concentrate was subsequently analyzed by counting ten fields in the cell. The error in concentration and enumeration was found to be well within 5 per cent for all samples replicated.

The effect of various storage procedures on the ASU and number of phytoplankton enumerated is presented in Table 30. No significant effect of any storage method was obvious up to 72 hours. The importance of this result lies not so much in the phytoplankton dieoff concept but in the fact that none of the samples were subjected to any chemical preservation. Thus, all enumeration results presented in this report include motile phytoplankton genera which would have been extremely difficult to identify if a chemical such as formaldehyde had been applied for preservation purposes.

Other Analyses

Chlorophyll - A measurements were initiated near the end of this year's sampling period to determine if this measurement was

Table 30

Effects of Three Storage Techniques on Phytoplankton Enumeration

	Storage Methods		
Time (hours)	4°C Throughout	Room Temp. (24°C) Throughout	Room Temp. for 24 Hrs. 4°C Thereafter
0	113.9/84	113.9/84	113.9/84
24	107.3/104	105.1/91	100.8/87
48	116/113	91.9/114	137.2/149
72	118.4/105	100.7/101	111/106
96	81.1/81	35.6/55	78.2/112

All values shown are Areal Standard Units per ml/No. organisms per milliliter.

a reliable method of estimating the standing crop of phytoplankton. Appropriate volumes of lake water were membrane filtered and extracted with 10 ml of 90% acetone for 24 hours. The optical density of the resulting solution was measured at 665 mμ. The optical density was then multiplied by the predetermined factor of 14.3 to determine the exact chlorophyll - A concentration (Odum and Hoskins, 1958).

To determine the effect of the algae and other microbes upon water quality, threshold odor values were determined for two reservoirs following the procedure outlined in Standard Methods (1965).

Evaluation of Overall Sampling and Analytical Accuracy

The purpose of this section is to evaluate if one sampling station was representative of an entire particular area investigated; if one sample obtained during a particular day was representative of the entire day; and if obtaining one sample was sufficient for accurate quantitative data. In all cases the worst situation possible was analyzed.

Sampling Station

To determine if one sampling station was representative of an entire area investigated, a study was conducted on June 2 in a stratified impoundment pool, Lake Travis, as shown in Figure 2. Station 1 was the regular sampling station located in the old river channel at the

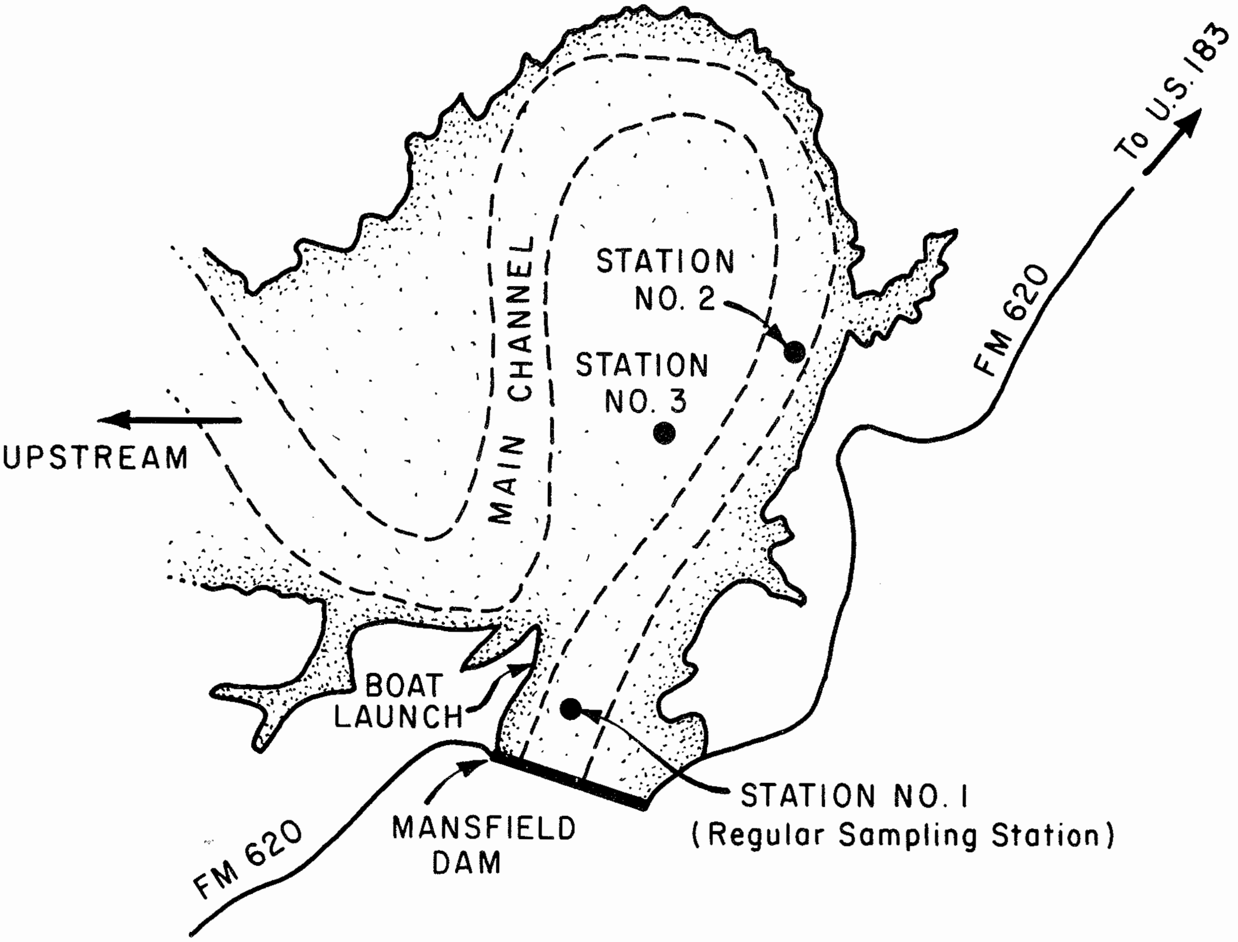


FIG. 2. SAMPLING STATIONS IN LAKE TRAVIS POOL

Table 31

Comparison of Data Obtained from Three Sampling Stations in a Stratified Impoundment Pool

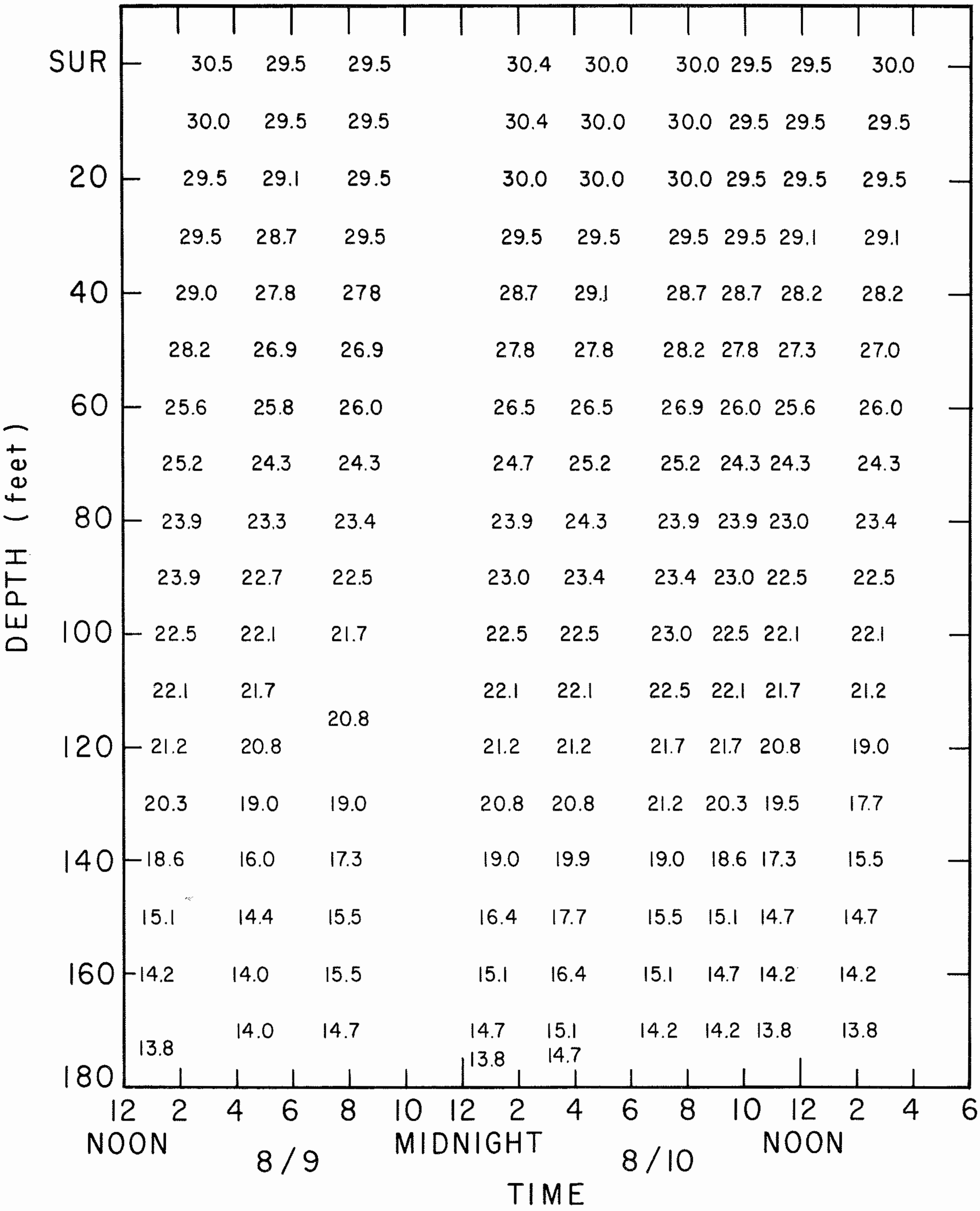
Station	Depth (ft.)	Temp. (^oC)	DO (mg/l)	pH	Alkalinity (mg/1 $CaCO_3$)	Hardness (mg/1 $CaCO_3$)	Conductivity (μMHO/CM)	P (mg/l)	$NO_2 + NO_3$ (mg/1 N)	NH_3 (mg/1 N)	Silica (mgSiO_2/l)	Iron (mg/l)	TOC (mg/l)
1	Surf.	29.2	7.25	8.3	130	167	424	0.010	0.10	0.000	6.7		2.6
	40	27.3	6.50	8.1	135	162	424	0.000	0.13	0.000	6.9		2.0
	55	24.4	2.50	7.6	142	183	445	0.003	0.26	0.000	7.0	<0.01	2.0
	70	22.5	2.25	7.5	147	175	448	0.003	0.30	0.010		<0.01	2.6
	140	17.5	1.60	7.3	151	183	466	0.001	0.38	0.000			1.3
	150	14.2	0.70	7.3	151	187	475	0.001	0.39	0.000	7.5		1.3
	160	12.2	0.30	7.3	158	191	475	0.000	0.37	0.025	7.7	0.02	1.3
	180	11.7	0.00	7.3	160	187	473	0.003	0.30	0.175	8.3	0.05	1.3
2	Surf.	28.8	7.30	8.2	135	171	424	0.000	0.12	0.000	7.8		2.6
	55	23.5	2.25	7.6	144	175	445	0.001	0.29	0.000	7.0		2.6
	150	13.2	0.55	7.3	154	183	473	0.014	0.42	0.005	7.4	0.014	2.0
	176	10.7	0.00	7.3	156	187	476	0.008	0.26	0.000	8.1		3.3
3	Surf.	29.2	7.50	8.3	132	196	420	0.008	0.12	0.000	6.9	0.01	2.0
	20	27.8	7.10	8.2	137	175	429	0.003	0.12	0.027	6.9		2.6
	50	25.8	2.80	7.6	142	179	445	0.000	0.26	0.030	7.1	0.01	1.3
	80	22.0	2.00	7.6	147	175	454	0.000	0.31	0.030	7.0		3.3

deepest point in the pool behind Mansfield Dam. Station 2 was located in the old river channel but further upstream from Mansfield Dam. Station 3 was located in the middle of the impoundment pool. However, it was not located in the old river channel and, hence, the water depth was much less than that of the other two sampling stations. The data obtained are presented in Table 31.

Temperature, dissolved oxygen, pH, alkalinity, hardness, conductivity, nitrate plus nitrite and silica appear similar at the same depths for the three sampling stations. However, phosphorus, ammonia, iron and TOC concentrations are so close to the lower limits of detectability that no valid comparison could be made.

Time of Day

To determine the effect of sampling time on the accuracy of the data, a twenty-four study was conducted at the regular sampling station in Lake Travis during August when the impoundment was stratified. Temperature, dissolved oxygen and pH were measured because these characteristics would have the greatest change due to the duirnal heating and photosynthetic processes. The data are presented in Figures 3 to 5. Eventually the temperature, dissolved oxygen and pH remain constant throughout the day except in two unstable areas. One was the thermocline which constantly changes a few feet because of internal waves. The second was in the hypolimnion where the flow



SUR	30.5	29.5	29.5	30.4	30.0	30.0	29.5	29.5	30.0
	30.0	29.5	29.5	30.4	30.0	30.0	29.5	29.5	29.5
20	29.5	29.1	29.5	30.0	30.0	30.0	29.5	29.5	29.5
	29.5	28.7	29.5	29.5	29.5	29.5	29.5	29.1	29.1
40	29.0	27.8	278	28.7	29.1	28.7	28.7	28.2	28.2
	28.2	26.9	26.9	27.8	27.8	28.2	27.8	27.3	27.0
60	25.6	25.8	26.0	26.5	26.5	26.9	26.0	25.6	26.0
	25.2	24.3	24.3	24.7	25.2	25.2	24.3	24.3	24.3
80	23.9	23.3	23.4	23.9	24.3	23.9	23.9	23.0	23.4
	23.9	22.7	22.5	23.0	23.4	23.4	23.0	22.5	22.5
100	22.5	22.1	21.7	22.5	22.5	23.0	22.5	22.1	22.1
	22.1	21.7	20.8	22.1	22.1	22.5	22.1	21.7	21.2
120	21.2	20.8		21.2	21.2	21.7	21.7	20.8	19.0
	20.3	19.0	19.0	20.8	20.8	21.2	20.3	19.5	17.7
140	18.6	16.0	17.3	19.0	19.9	19.0	18.6	17.3	15.5
	15.1	14.4	15.5	16.4	17.7	15.5	15.1	14.7	14.7
160	14.2	14.0	15.5	15.1	16.4	15.1	14.7	14.2	14.2
	13.8	14.0	14.7	14.7 13.8	15.1 14.7	14.2	14.2	13.8	13.8

FIG. 3. DIURNAL TEMPERATURE VARIATION IN LAKE TRAVIS

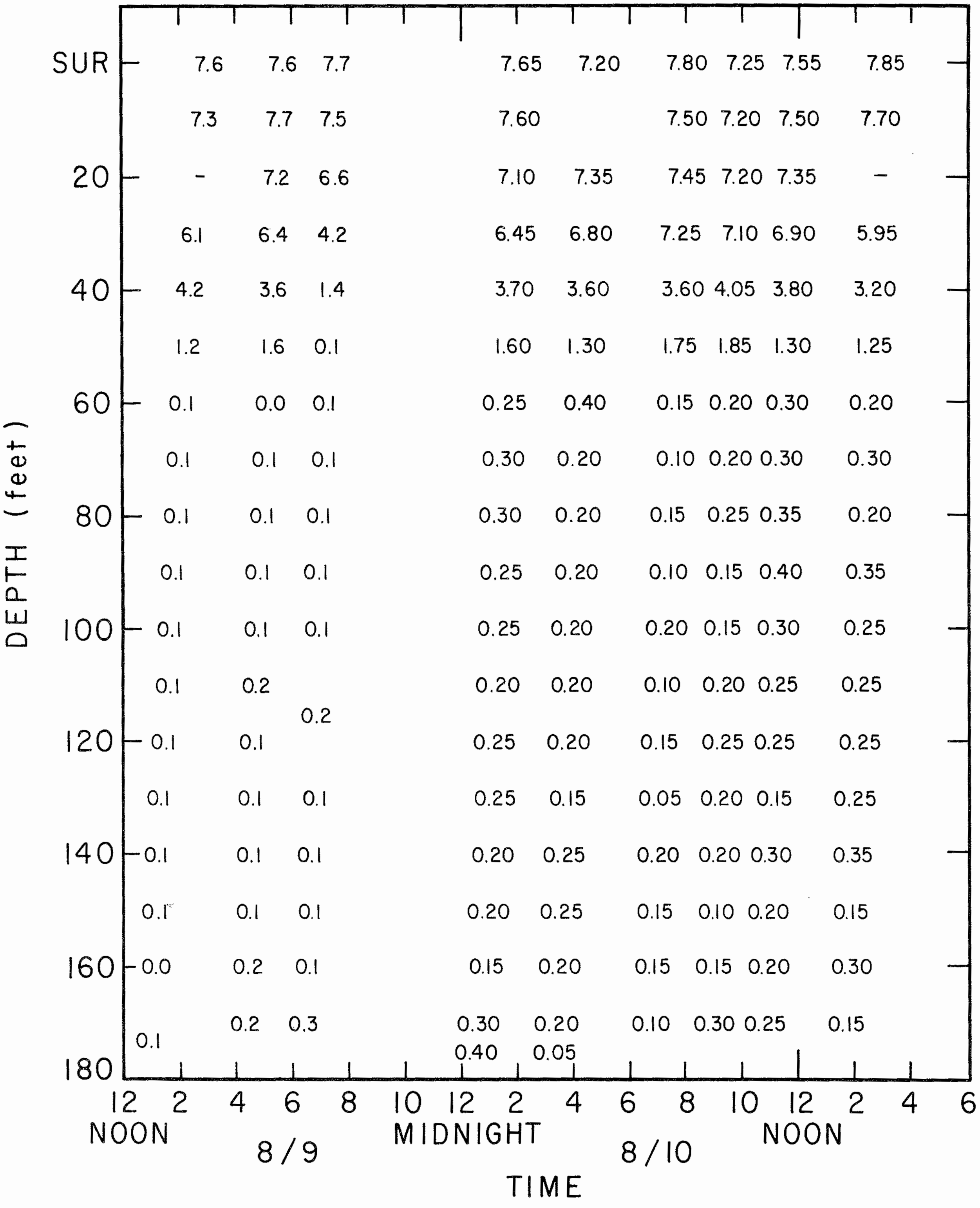


FIG. 4. DIURNAL DISSOLVED OXYGEN VARIATION IN LAKE TRAVIS

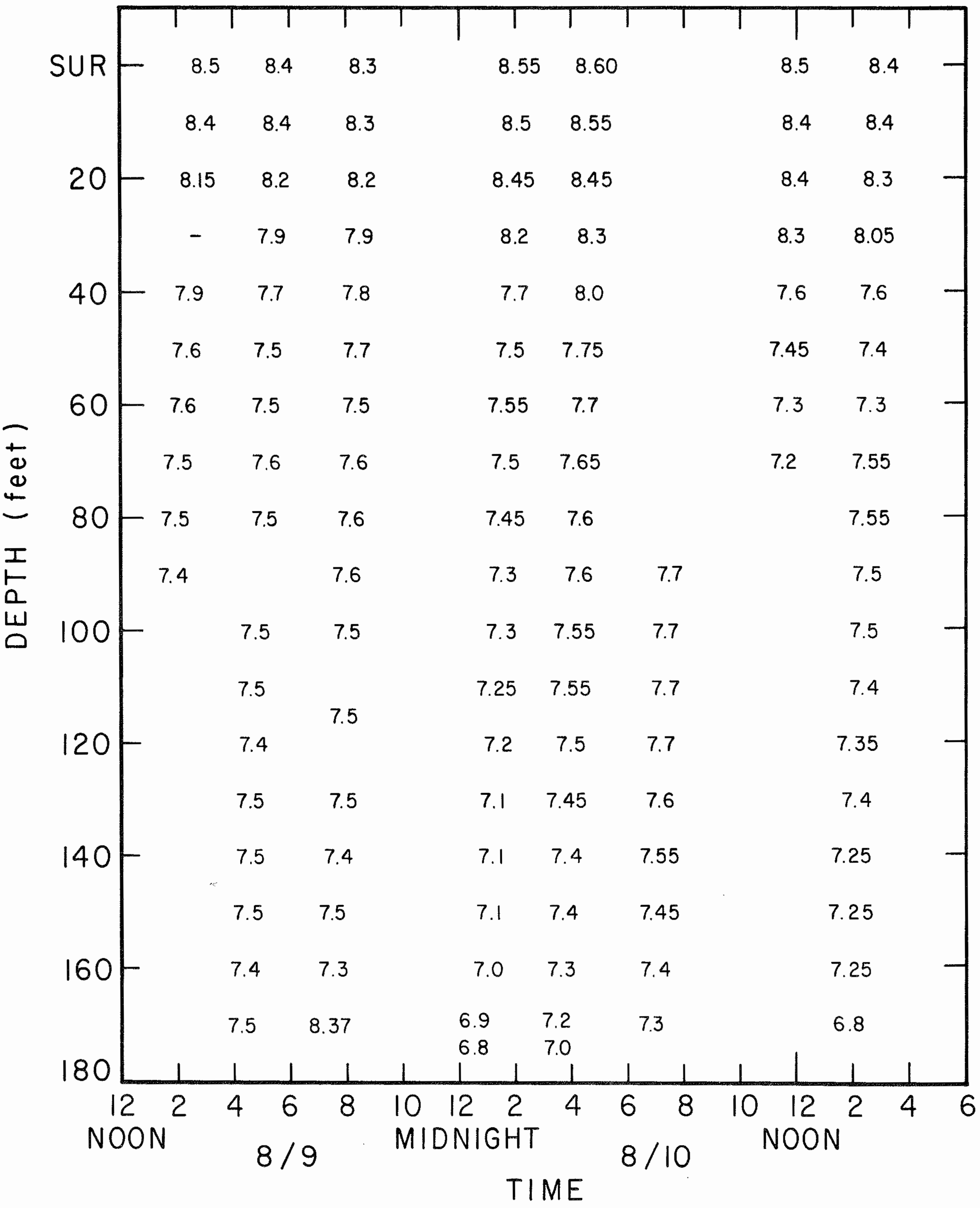


FIG. 5. DIURNAL pH VARIATION IN LAKE TRAVIS

was released through the penstock. These changes were not significant enough to increase the sampling procedure.

Replicate Field Sampling

A study was undertaken to determine the reproducibility attained when measuring the quality of water at a particular depth. The pump and probes were lowered to a depth 18 inches above the sediments. Measurements and samples were obtained. The pump and probes were brought up to the boat and then lowered again to the same depth. This procedure was repeated five times. In one part of the study the sediments were disturbed by the flow in the river while in the second part the sediments appeared undisturbed. The results are presented in Table 32. The variance in results was higher when the sediments were disturbed. However, during sampling of the impoundment pools the sample obtained from above the sediments was seldom turbid indicating undisturbed sediment conditions.

Table 32

Replicate Field Samples for Determination of Error

		Temp. (°C)	DO (mg/l)	pH	Total Bacteria (No/ml)	Total Coliform (No/ml)	Phosphorus (mg/l P)	TOC (mg/l C)	Hardness (mg/l $CaCO_3$)	Alkalinity (mg/l $CaCO_3$)	Conductivity (μMHO/CM)	NH_3 (mg/l N)	NO_2 + NO_3 (mg/l N)	Iron (mg/l)	Silica ($mgSiO_2$/l)
Disturbed Sediments		28.5	5.20	8.20	9,000	30	0.006	6.5	182	151	485	0.02	0.03	0.046	9.9
		28.5	5.50	8.20	8,000	10	0.003	4.5	182	151	486	0.04	0.03	0.014	9.9
		28.5	5.50	8.25	-	10	0.020	3.9	178	151	486	0.02	0.04	0.014	9.6
		28.5	5.30	8.25	10,000	60	0.037	6.5	186	149	489	0.02	0.03	-	9.8
		28.5	5.70	8.20	-	10	0.016	5.8	178	151	489	0.02	0.03	-	9.9
		28.5	5.60	8.20	8,000	50	0.020	4.5	186	154	489	0.02	0.04	-	9.6
	Mean	28.5	5.45	8.22	8,750	27	0.017	5.3	179	151	487	0.023	0.033	0.025	9.8
	Std.Dev.	0.00	0.19	0.02	4,560	24	0.012	1.1	5.8	1.6	1.9	0.008	0.003	0.017	0.14
Undisturbed Sediments		25.5	5.05	7.50	1,000	1	0.005	3.0	180	145	515	0.07	0.01	0.006	10.2
		25.5	5.05	7.50	1,000	1	0.005	3.0	175	147	515	0.08	0.02	0.006	10.2
		25.5	5.10	7.50	1,000	4	0.005	3.0	175	145	515	0.09	0.01	0.005	10.0
		25.5	5.35	7.50	400	1	0.005	3.0	-	147	515	0.09	0.01	0.005	10.2
		25.5	4.95	7.50	1,300	4	0.005	4.0	-	147	511	0.06	0.01	0.006	10.0
	Mean	25.5	5.10	7.50	940	2.2	-	3.2	177	146	514	0.08	0.01	0.006	10.1
	Std. Dev.	0.00	0.15	0.00	415	1.6	-	0.45	2.0	1.1	1.8	0.013	0.003	0.002	0.11

Chapter 3

LIMNOLOGICAL DATA

Before presenting in Chapter 4 the water quality changes that occurred at each sampling station throughout this 150 mile Colorado River reach, it is necessary to discuss the variation in water quality that occurs in these impoundments because of their different morphological characteristics as well as their purpose in the chain. Following this the effect of physical characteristics (such as of thermal stratification in the impoundment pool and the depth at which the penstock is located) on the water quality of the impoundment release will be discussed.

General Classification of Impoundments

Mackenthum and Ingram (1967) have described the interrelationship between morphology and purpose. They classified impoundments into natural lakes and reservoirs and divided reservoirs into main stream ("run of the river") and storage types. Because most of our knowledge of limnological phenomena are based on data obtained from natural lakes, it is important that the differences between natural lakes and reservoirs as well as between reservoir types be briefly reviewed.

Mackenthum and Ingram (1967) state that the inlets and outlets of natural lakes are near the surface while water can leave a reservoir at any depth incorporated in the dam's design. The maximum depth of a natural lake is usually near the middle of the impoundment and the bottom slope is generally non-uniform. The maximum depth of a reservoir is near the dam and the reservoir has a uniform slope that was established by the river before impoundment.

A storage reservoir is used to retain water when surface runoff is high. Thus, the dam must be high. The stored water extends far beyond the former river channel into numerous coves to provide a large surface area. Vertical cross-sections of the reservoir are large in relation to stream flow and, thus, flow velocities are small. Water may be retained in the reservoir for many months and passage of water may be discontinuous. However, when surface runoff is low, waters are released for various downstream uses. As a result, the surface water level varies over a wide range. The drawdown of the reservoir requires that the discharge point from the dam be located deep in the reservoir below the minimum level to which the water will be drawn.

The main stream reservoir is typically an impoundment formed by a relatively low dam. Much of the impounded water is restricted to the original channel and water retention ranges from a few days to a number of weeks. The water surface fluctuations usually are controlled within a few feet. Releases can be from any depth although they are usually from mid-depth. Such impoundments are used primarily for power production.

Limnological Characteristics

Temperature

Thermal stratification in the Colorado River impoundments assumes many patterns depending on the location of the reservoir in the chain of impoundments, impoundment depth, penstock location and power use as indicated by the data in Appendix B.

Lakes Buchanan and Travis are storage reservoirs. Because of the high surface runoff throughout 1968 the water levels only fluctuated about 10 feet in Lake Buchanan and 20 feet in Lake Travis. The average water retention time based on monthly calculations of inflow and outflow varied in Lake Buchanan from approximately 200 to 4500 days while in Lake Travis from approximately 80 to 1800 days.

Representative temperature stratification for a storage reservoir is shown by the Lake Travis data presented in Figure 6. In February and March water temperatures showed only 2 to 3°C differences from water surface to sediments. The temperature did not drop below approximately 8°C as is typical of a subtropical impoundment. During the spring the surface waters rapidly warmed and a permanent thermal stratification formed which for many months prevented mixing of the hypolimnion with the atmosphere. At this time the thermocline was located approximately 30 feet below the surface. During the summer the surface waters were further warmed producing a more stable condition. The depth of the epilimnion increased somewhat probably because of water release from the hypolimnion. This water withdrawal also probably caused the second thermocline present at approximately the 150 foot depth. During the fall the impoundment cools and the epilimnion increases in thickness driving the thermocline downward. During the winter the cooling continues until stratification is broken, although the temperature never becomes uniform.

Lakes Inks, Marble Falls, Austin and Town are main stream reservoirs. Typical of the temperature stratification cycle are the data presented in Figure 7 for Lake Inks. The temperature profile consisted of a small but fairly regular temperature gradient of up to 7°C from top to bottom during the summer. Temporary thermoclines were sometimes found when the temperature gradient was steep through a rather narrow depth of water. The probable cause of these temporary thermoclines was the release of cold hypolimnetic waters from an upstream impoundment during peaking power generation.

Lake Johnson had the characteristics of both a main stream and storage reservoir as shown in Figure 8.

Light

The maximum daily sustained Langleys measured by the U.S. Weather Bureau with a calibrated pyroheliometer are presented in Appendix A. These data demonstrate the variance between seasons and the change from day to day because of cloud cover. Although the surface light intensity affects the photosynthetic productivity of the

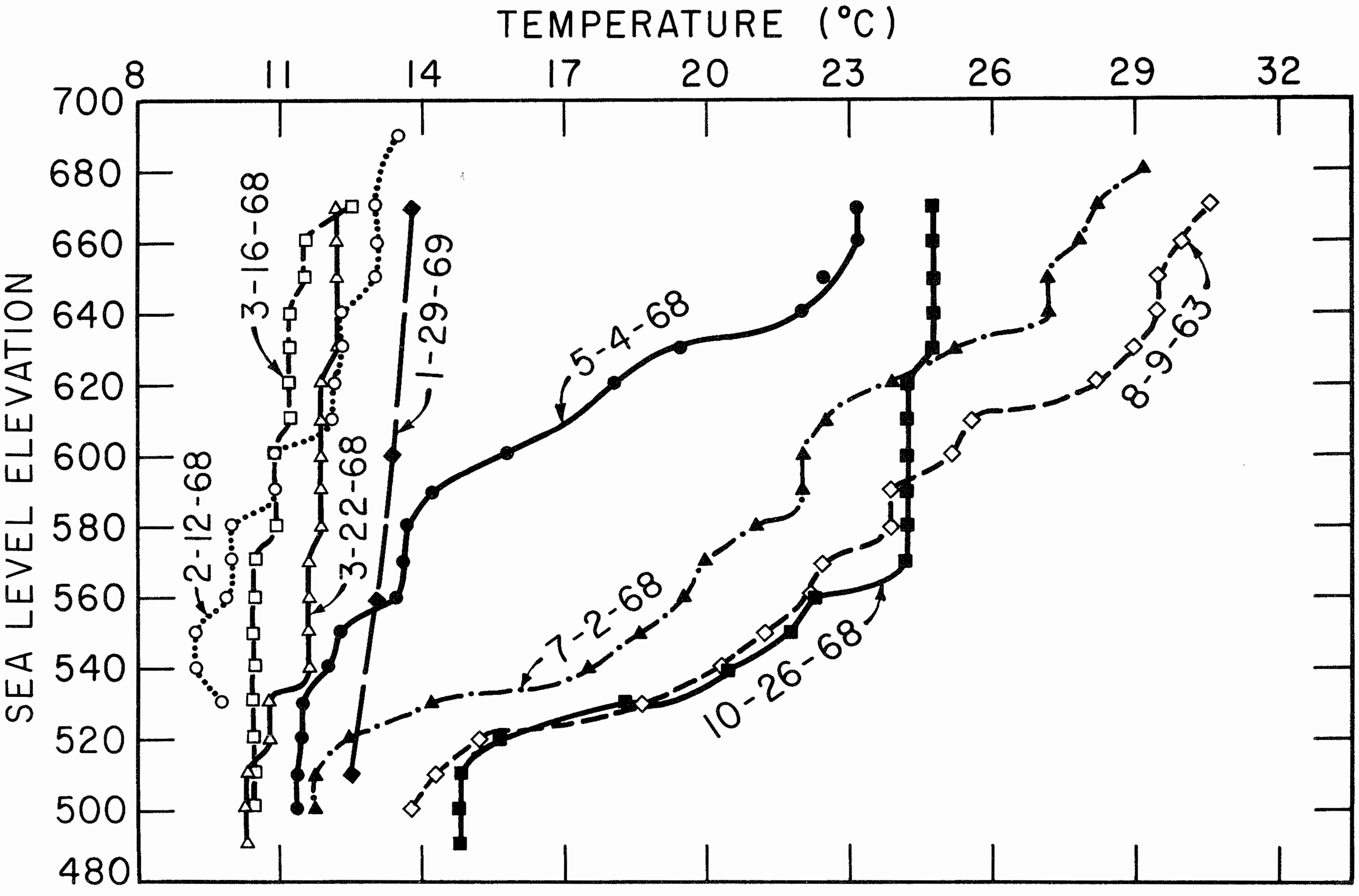


FIG. 6. TEMPERATURE DATA FOR LAKE TRAVIS

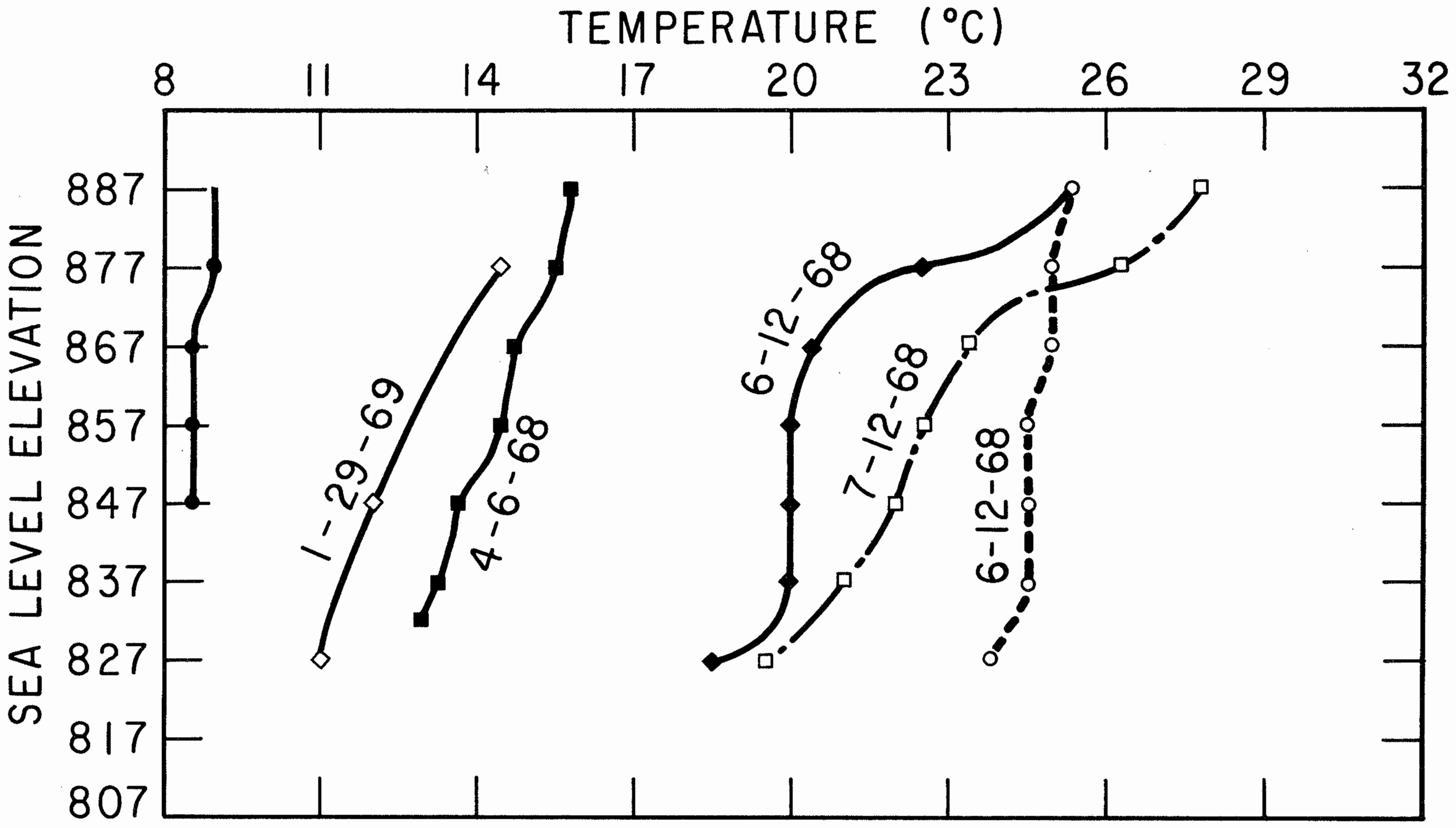


FIG. 7. TEMPERATURE DATA FOR LAKE INKS

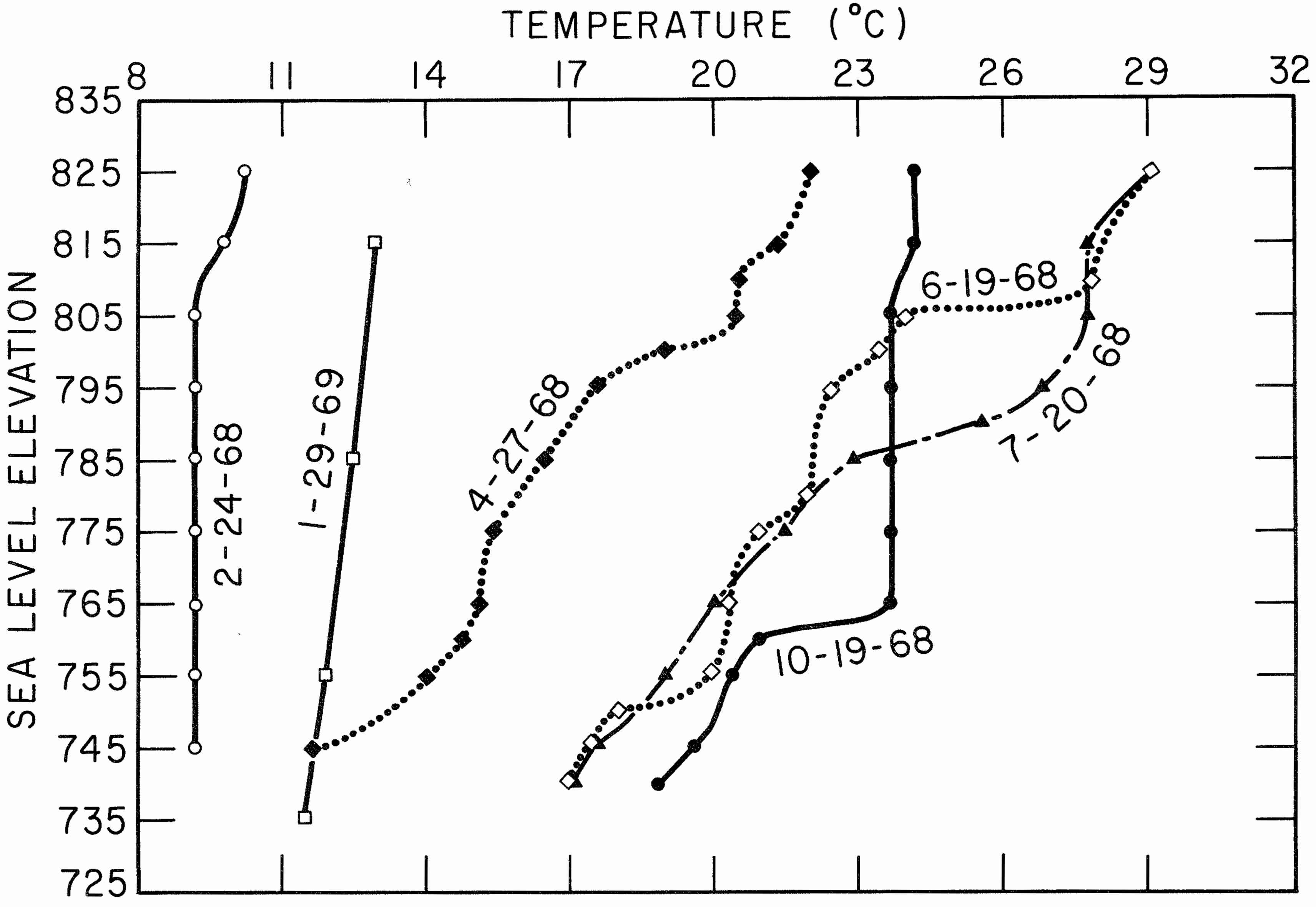


FIG. 8. TEMPERATURE DATA FOR LAKE JOHNSON

algae, of paramount importance to the overall photosynthetic productivity of these or any other impounded waters is the depth to which light of various wavelengths penetrate.

Two impoundments, Lakes Buchanan and Town, were selected for light penetrability studies because they are located at the extreme ends of the reservoir chain. Due to the population increase from Lake Buchanan to Town Lake, there probably is a downstream increase in the overall chemical-biological content which can be termed eutrophication potential. Figures 9, 10, 11, and 12 present light penetration data for

1. the visible spectrum (no approximation of filter);
2. approximation near 660 millimicrons (red filter);
3. approximation near 540 millimicrons (green filter); and
4. approximation near 470 millimicrons (blue filter).

Examination of these data reveal several interesting points. Naturally, the season of the year plays an important part insofar as the total quantity of light available. The light penetration was greater in late summer than in the winter months. The limit of the photic zone in Lake Buchanan in summer is limited to the first 28 feet of water while in the winter that limit is reduced to 18 - 19 feet. Comparatively, the highly important red and blue spectra penetrate to 17 feet in late summer and only to about 8 feet in winter. The waters in Town Lake show a markedly increased capability to absorb the light energies above the capability of the waters of Lake Buchanan. Due to the shallow depth of Town Lake the photic limiting depth was indiscernable in the fall. It appeared to be

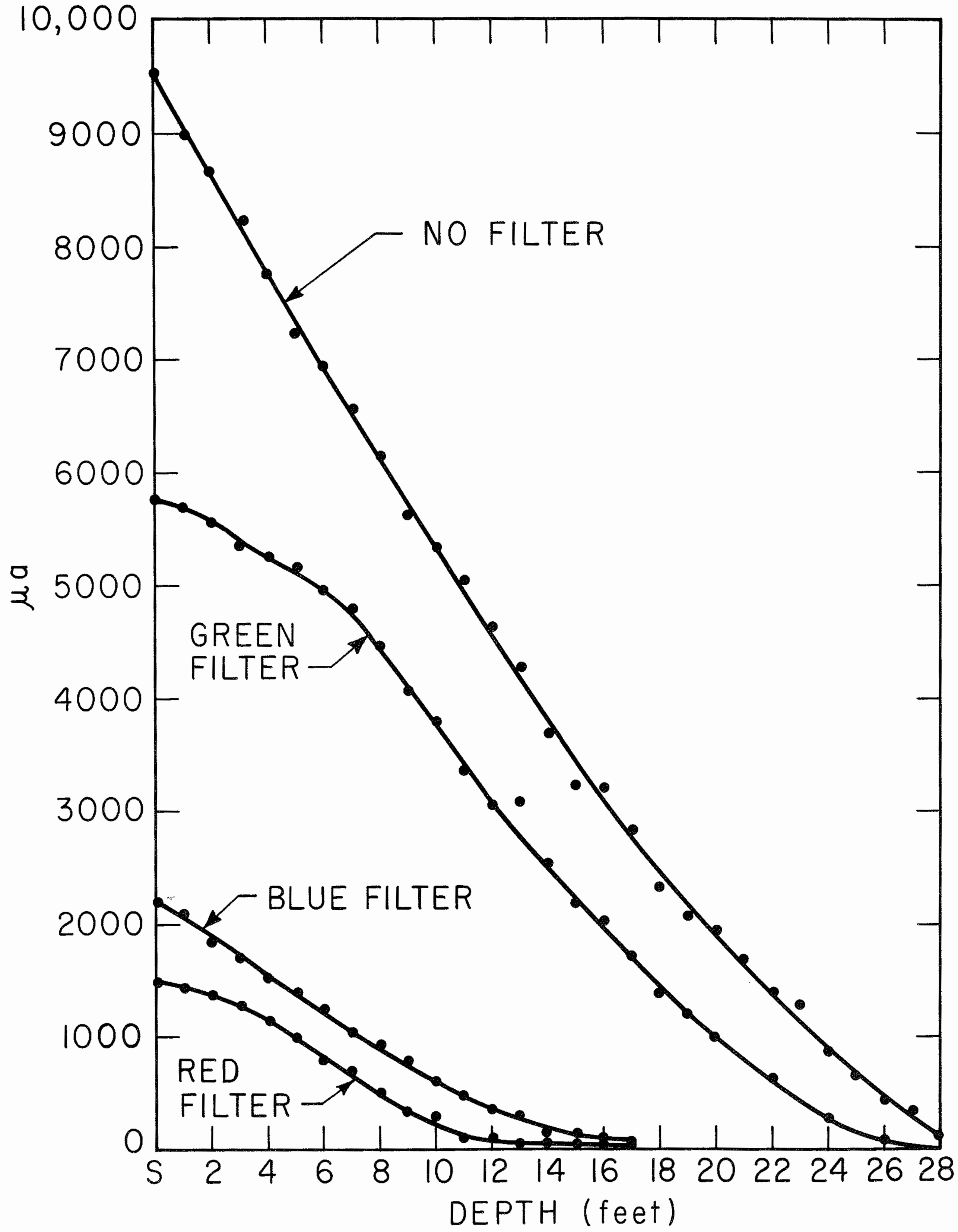


FIG. 9. LIGHT PENETRATION, LAKE BUCHANAN, 9-11-68

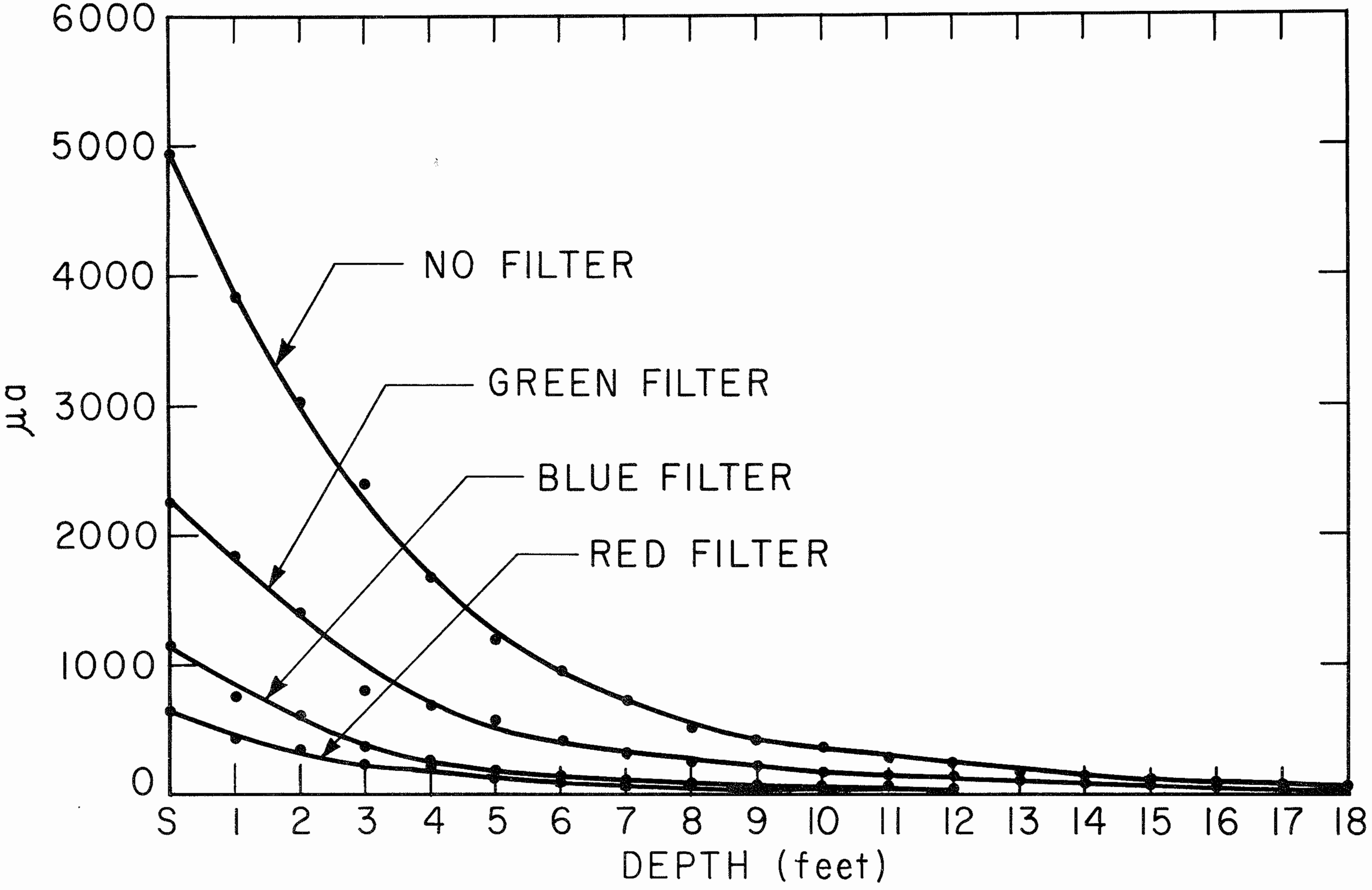


FIG. 10. LIGHT PENETRATION, LAKE BUCHANAN, 1-8-69

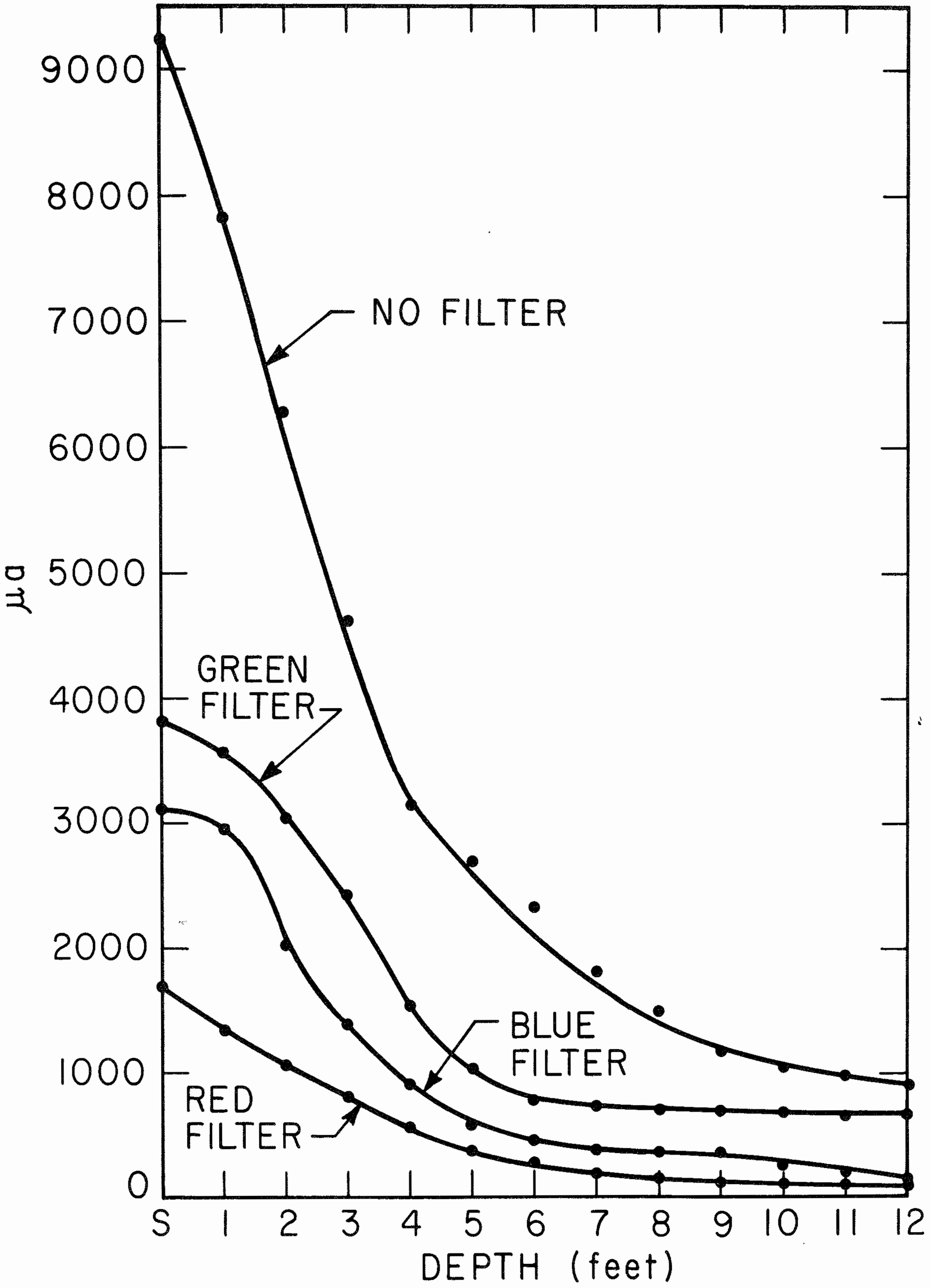


FIG. 11. LIGHT PENETRATION, TOWN LAKE, 9-10-68

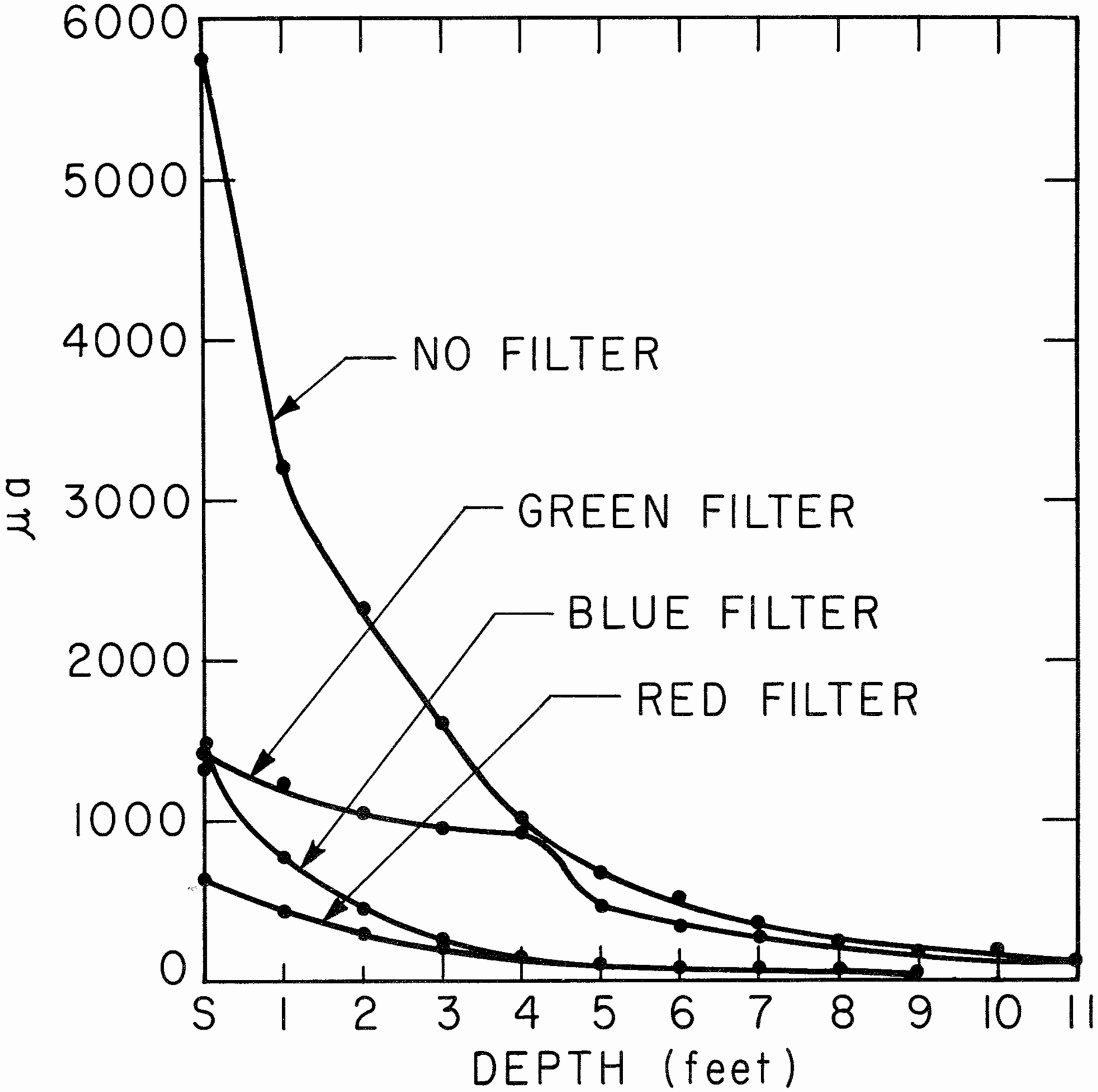


FIG. 12. LIGHT PENETRATION, TOWN LAKE, 1-9-69

between 11 and 12 feet in January. Of considerable importance is the apparent ability of the red and blue segments of the spectrum to penetrate to the bottom in sufficient intensity to stimulate photosynthetic activity. This was not the case in January. The limit (picked here at or below 100 microamperes) was in the 5 to 6 foot depth range.

Compared to Lake Buchanan, therefore, Town Lake waters do absorb greater percentages of different spectra with depth. Photosynthesis can, and in all probability, does occur at the bottom of most of Town Lake during the greater part of the year. The implication is that because of the higher nutrients and due to the shallow depth, coupled with a classically defined mesotrophic basin, this body of water tends to be the most eutrophic and, thus, the most productive.

Phytoplankton

In any impoundment, the phytoplankton should show seasonal trends over a period of years of data accumulation. Typically the subtropical (semitropical) environs of the southwestern United States are suitable for high concentrations of phytoplanktonic populations, provided there are sufficient nutrients to support and sustain said populations. A detailed enumeration of the phytoplankton counts for the intensified study of 1968 is presented in Appendix C. This appendix also lists, with their periodicity, the genera of phytoplankton found in Lakes Travis, Austin, and Town. These data can be applied to all of the

Highland Lakes, per se. Table 33 presents data on extracts of chlorophyll from a few of the sample stations. These analyses were conducted for the purpose of comparing the chlorophyll with the corresponding algal counts in ASU and numbers of cells per milliliter. There should naturally be a direct relationship between the numbers of algal cells and the chlorophyll concentration. It must be remembered that the different algal species, genera, and divisions classically contain different concentrations of chlorophyll, which cause erratic results in correlation attempts. Based on these data for chlorophyll concentration at the indicated points in time, the overall photosynthetic capacity of those surface waters was quite small.

Figures 13, 14, and 15 represent the population trends for Lakes Travis, Austin and Town, respectively. The bar shown in Figure 14 for Lake Austin depicts the time period during which the lake was deliberately lowered to facilitate dock repairs, construction, and other needed maintenance. During this period the water content of the lake adheres to the river bed, leaving an estimated 70% to 80% of the lake bed exposed. The sharp drop in total ASU's in February 1968 may have been caused by the lowering process; however, the trend appears to be one of recovery on the part of the phytoplankton population because of it.

The interesting factor which is apparent from all three graphs is that the surface waters of the pools of all three lakes did not show

Table 33

Chlorophyll-A Concentrations in Various Samples of Highland Lakes Waters

Compared to ASU/No. Phytoplankton Counts of Those Waters

Sampling Station		Chlorophyll-A (mg/l)	ASU/No.
Lake Buchanan, surface			
10-5-68		0.0343	94.9/39
1-9-69		0.0229	35.2/46
Lakes Inks, surface			
10-5-68		0.0586	59.8/55
1-9-69		0.0195	65.4/36
Lake Johnson, surface			
10-19-68		0.0249	62.8/26
1-9-69		0.0241	53.2/14
Lake Marble Falls, surface			
10-19-68		0.0172	106.5/51
1-9-69		0.0072	48.8/26
Pedernales & Colorado confluence			
10-26-68		0.0109	132.8/38
Lake Travis			
10-26-68	Surface	0.0039	12.8/16
10-26-68	190'	0.0070	11.6/34
1-9-69	Surface	0.0037	6.6/8
Lake Austin, surface			
1-9-69		0.0048	69/18
Town Lake, surface			
1-9-69		0.0225	95.2/22

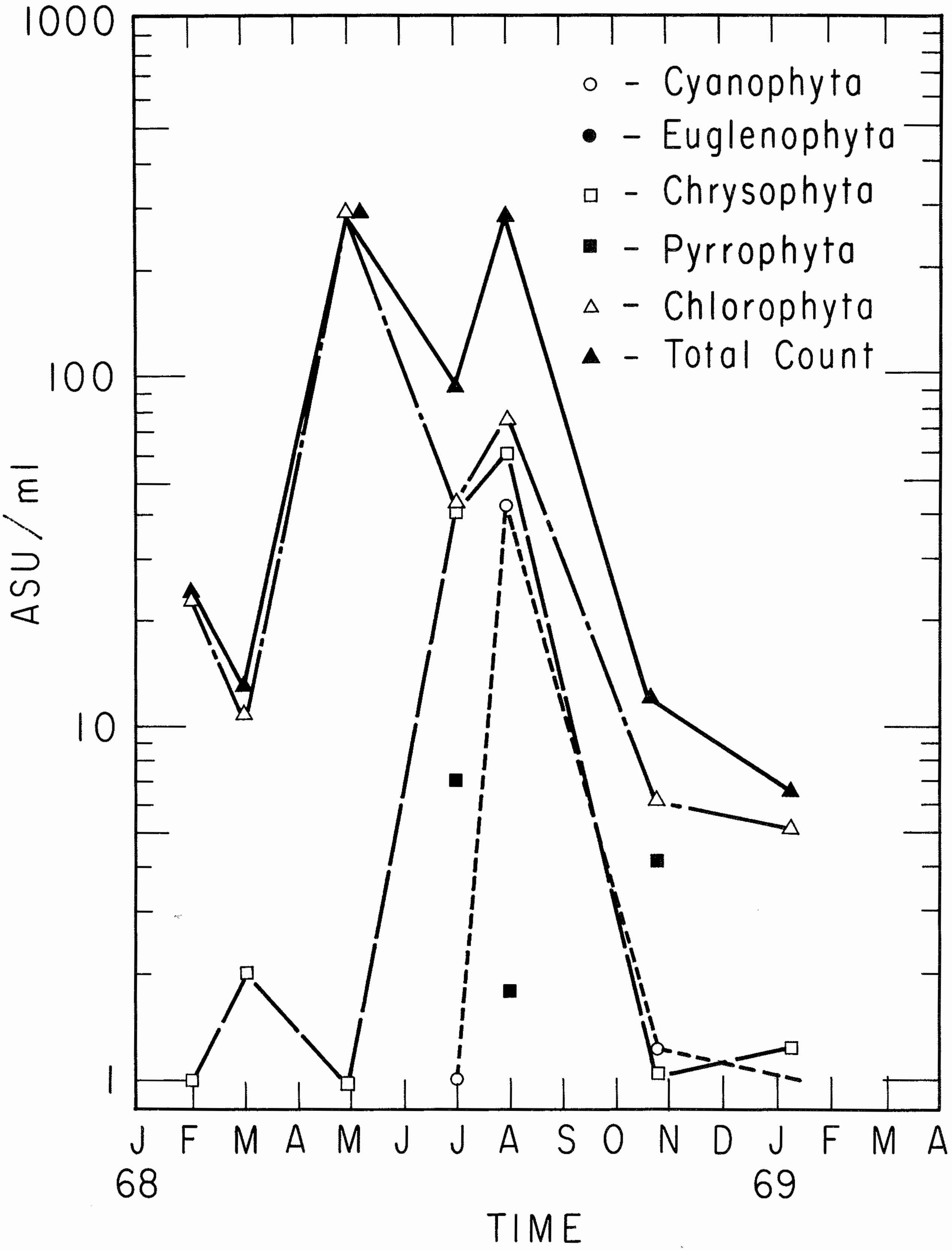


FIG. 13. PHYTOPLANKTON, SURFACE WATERS, LAKE TRAVIS

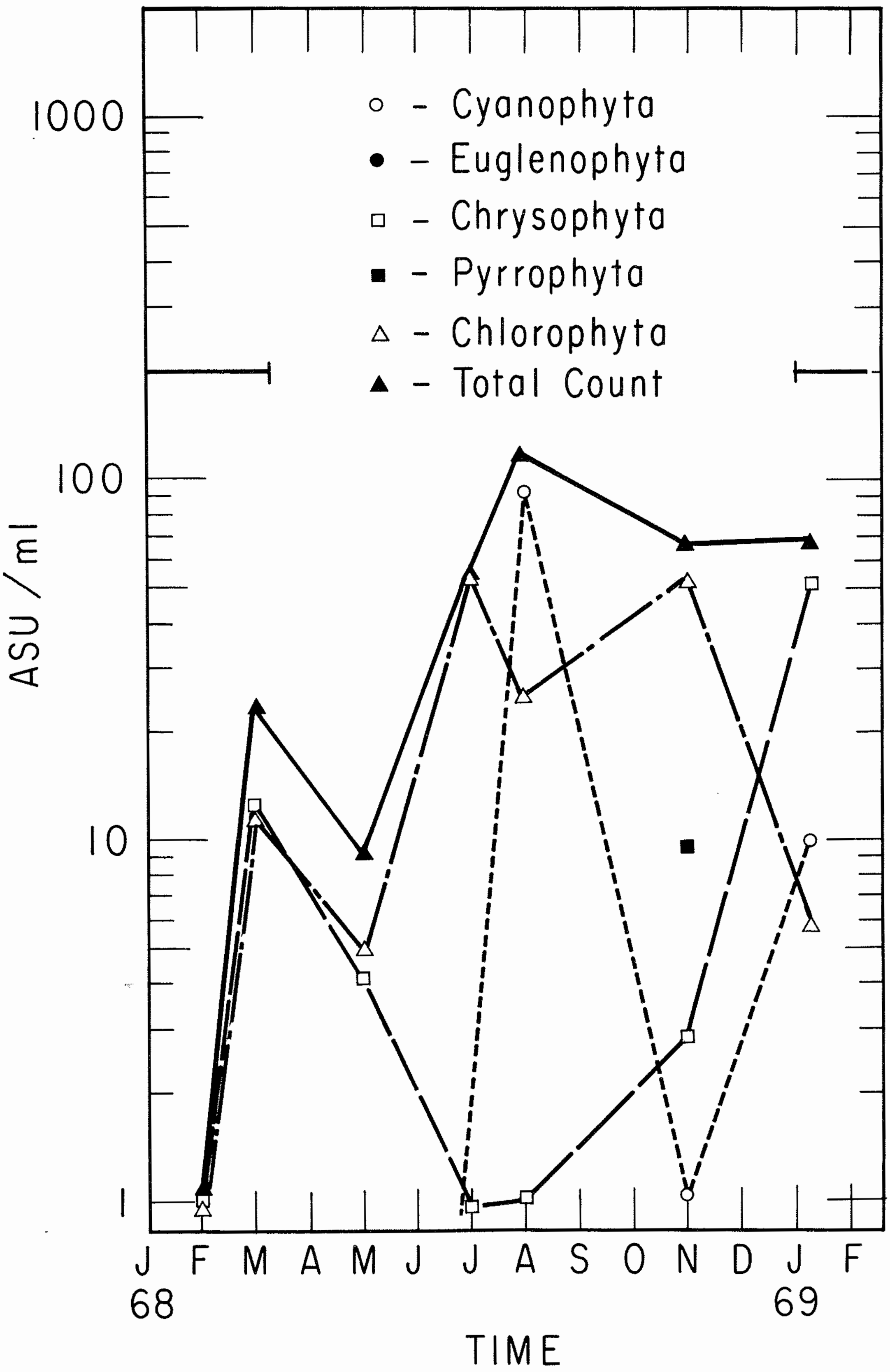


FIG. 14. PHYTOPLANKTON, SURFACE WATERS, LAKE AUSTIN

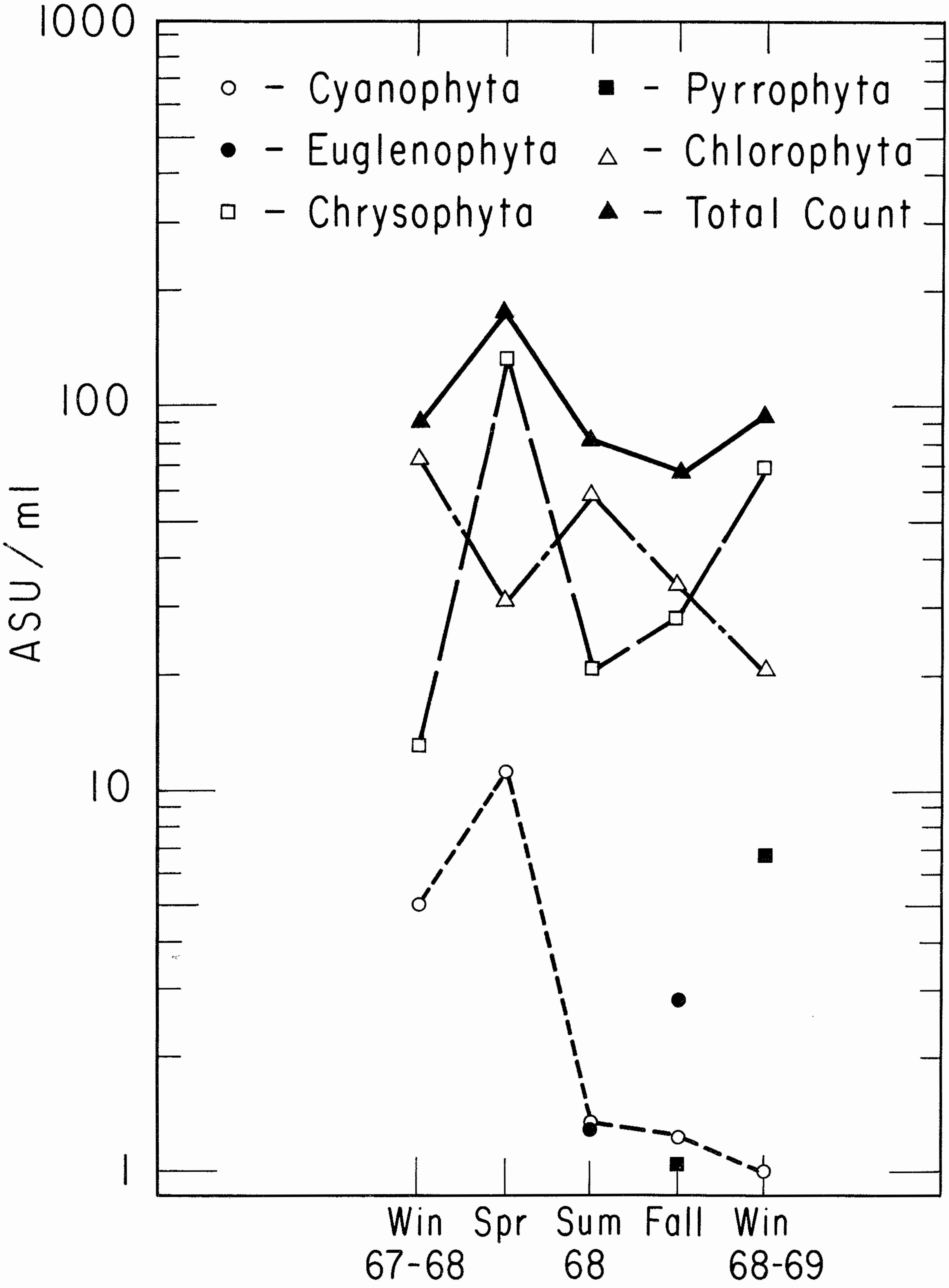


FIG. 15. PHYTOPLANKTON, SURFACE WATERS, TOWN LAKE

concentrations which are classed at "bloom" concentrations. Typically, 500 ASU's is taken here as that number, when exceeded, constitutes the algal "bloom". The peaking of blue-green algae in Lake Austin, and to a less pronounced extent in Lakes Travis and Town, will be recalled in Chapter 4, when the taste and odor characteristics are discussed with regard to water quality. Blue-green algae usually showed peak growth in the latter part of the summer and into early fall. Their growth was followed by a sharp increase in the diatom population which sometimes lasted through the winter months but commonly declined in early to late December. Species of green algae persisted throughout the year and in impoundments which more closely resemble true lakes, these organisms showed a propensity to peak during winter or late summer. The uneven periodicity of the population trends can be attributed to several factors. The prime factor here appears to be the irregular flows of the three impoundments which tend to resemble more of a modified river than truly impounded bodies of water.

Attempts to establish the relationships between the retention times in the Highland Lakes, the temperature of the pool surface waters, and the total ASU of phytoplankton are shown in Figures 16 through 21. Log base 10 of the retention time is plotted on the abscissa. The following compares the six lakes and the point of maximum

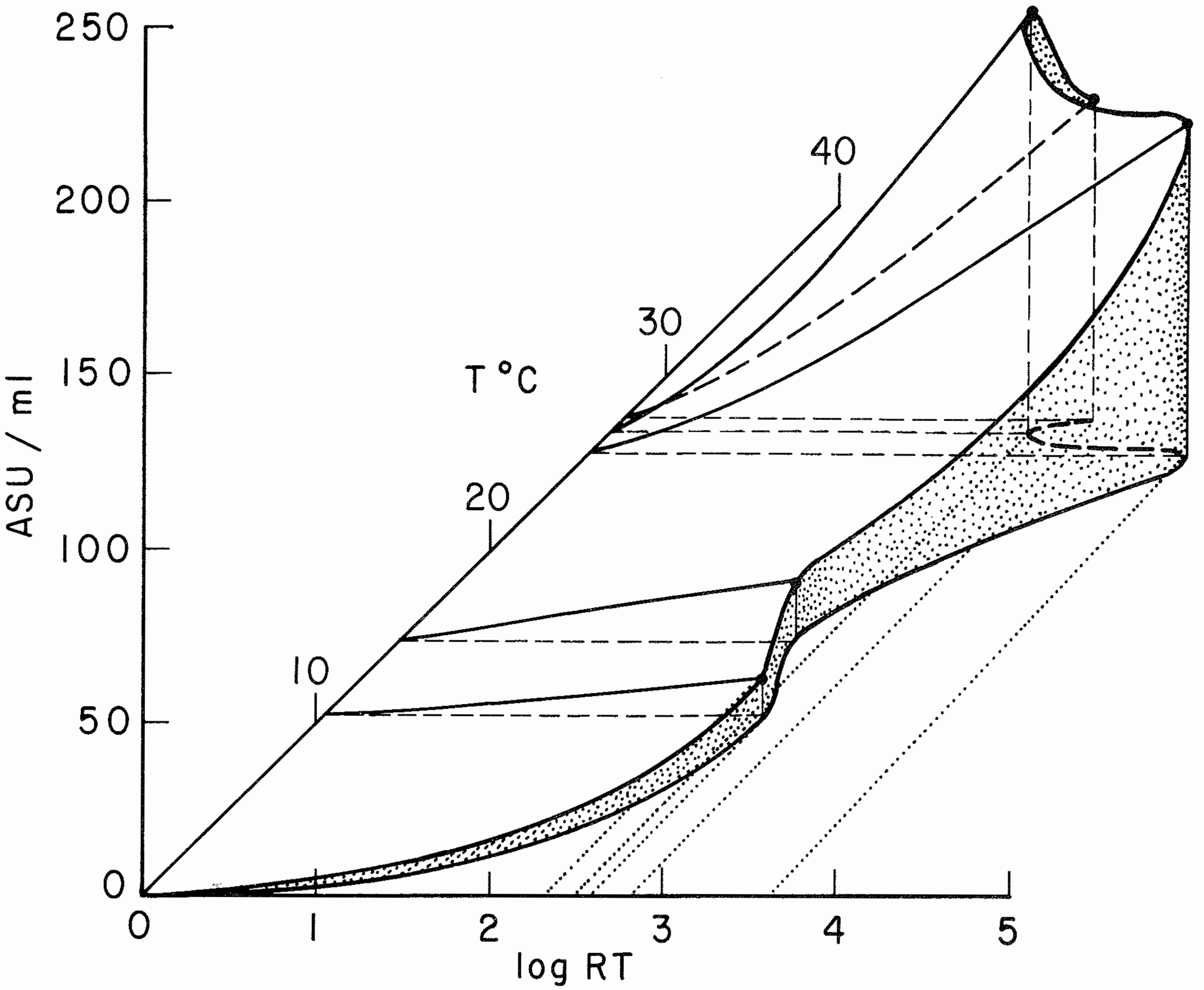


FIG. 16. ALGAL PRODUCTION RELATED TO TEMPERATURE AND RETENTION TIME: BUCHANAN

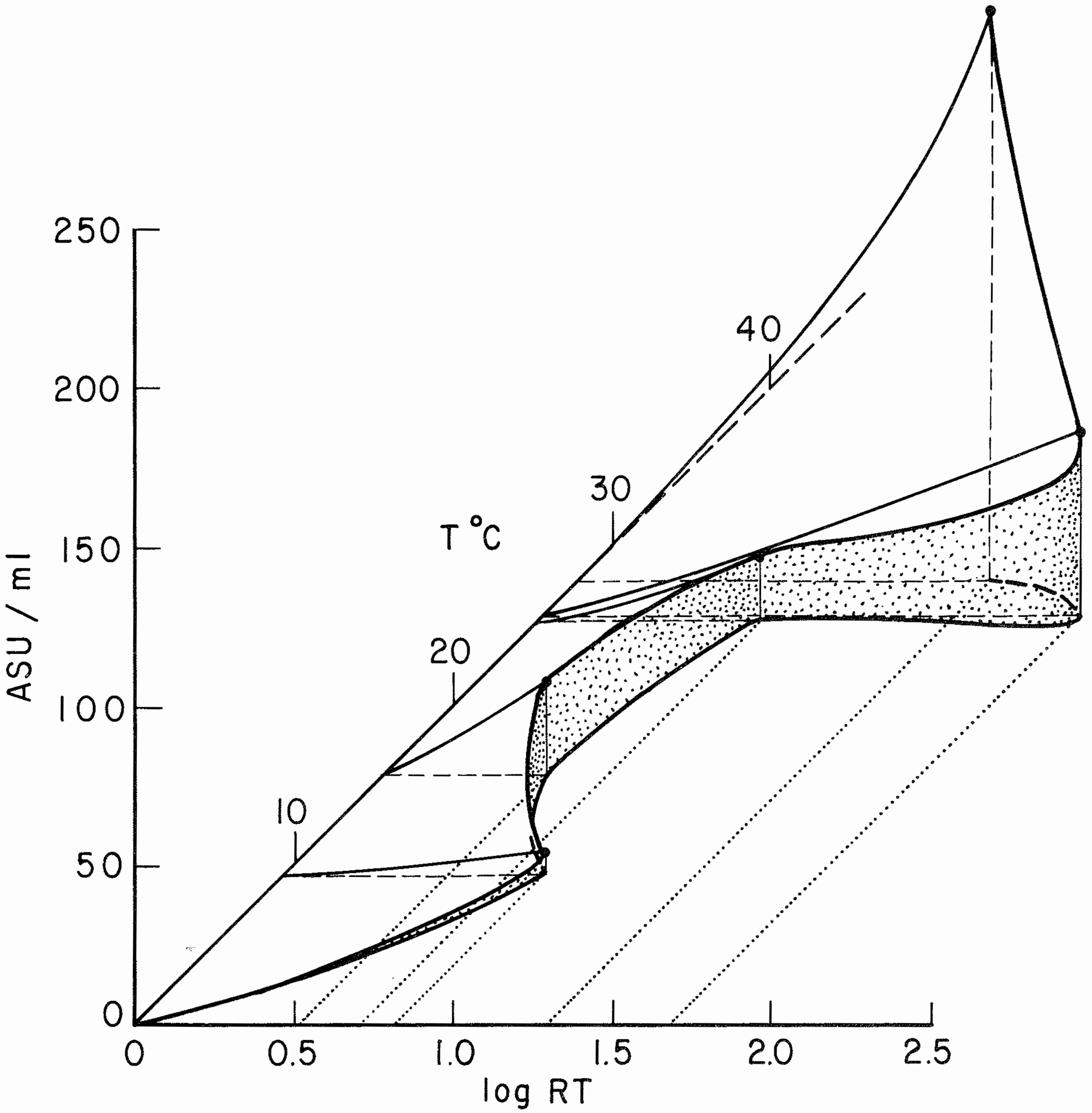


FIG. 17. ALGAL PRODUCTION RELATED TO TEMPERATURE AND RETENTION TIME: INKS

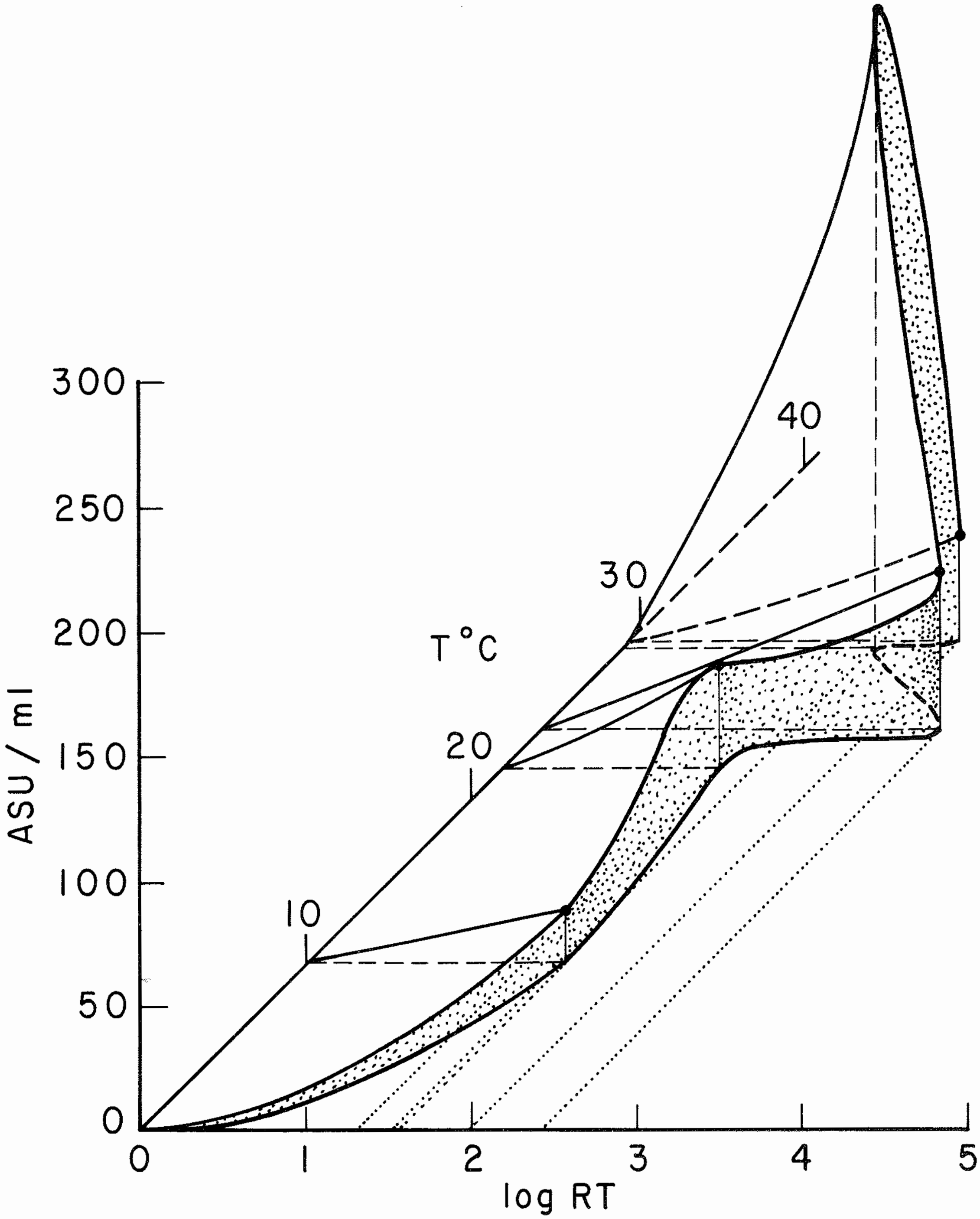


FIG. 18. ALGAL PRODUCTION RELATED TO TEMPERATURE AND RETENTION TIME: JOHNSON

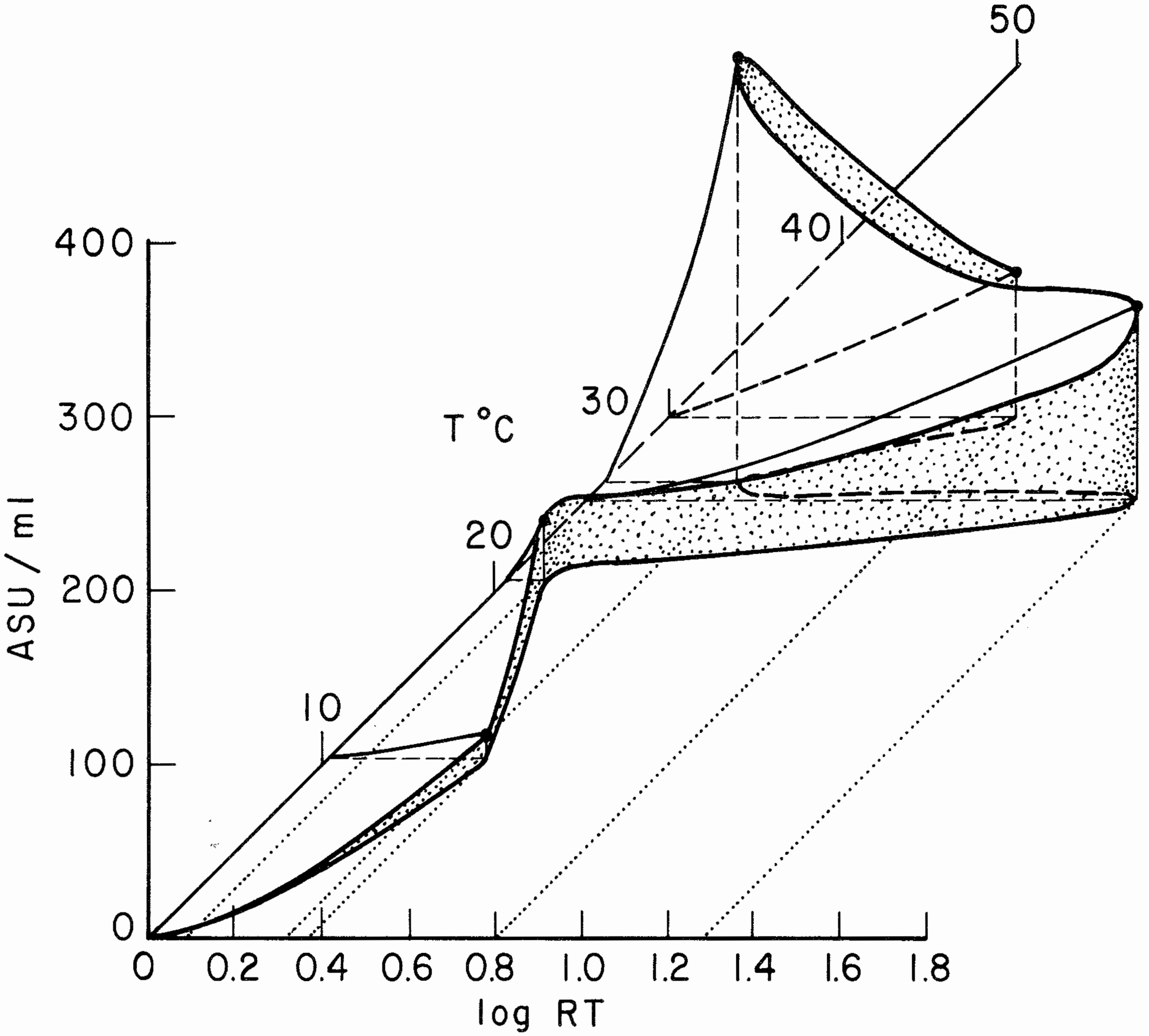


FIG. 19. ALGAL PRODUCTION RELATED TO TEMPERATURE AND RETENTION TIME: MARBLE FALLS

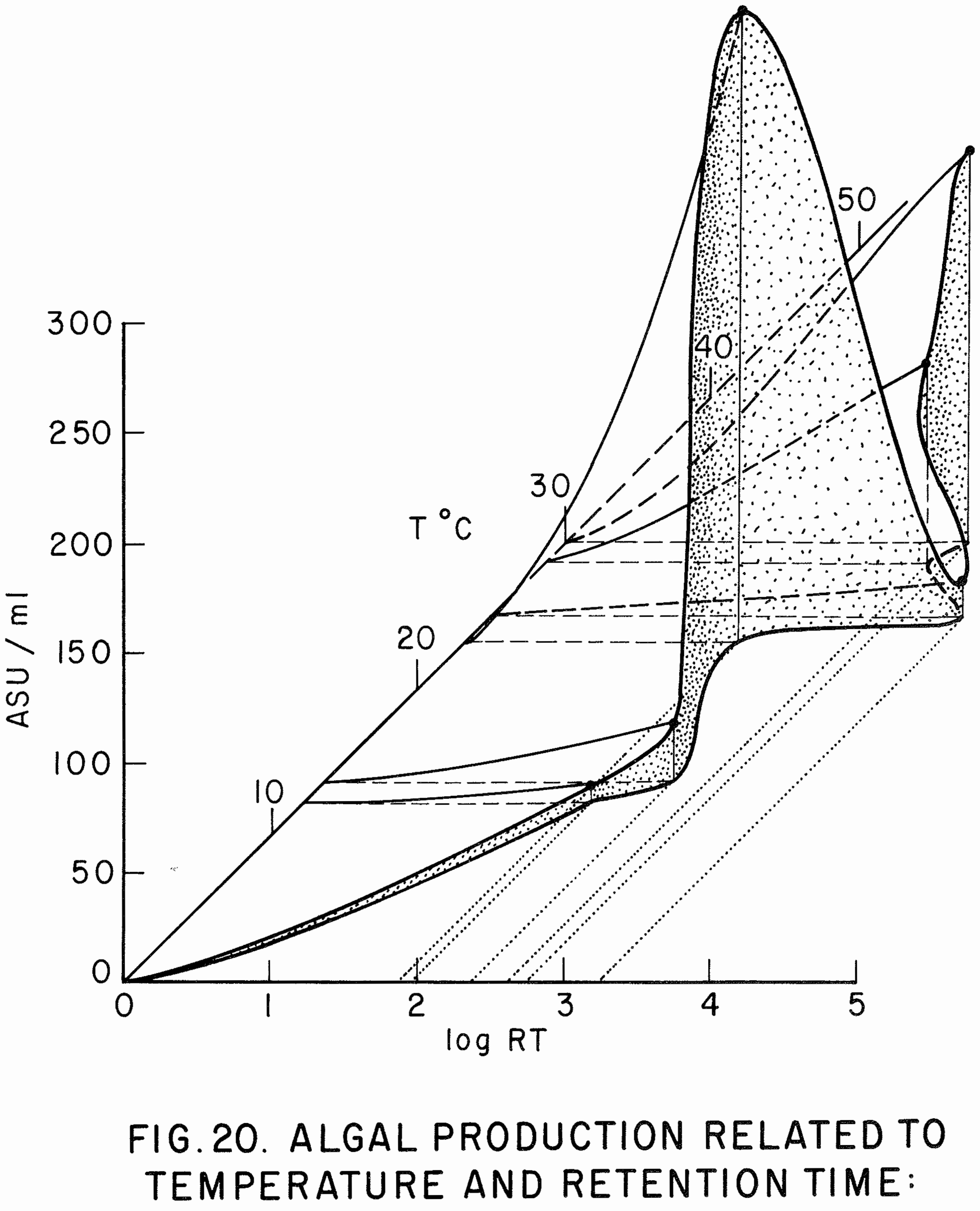


FIG. 20. ALGAL PRODUCTION RELATED TO TEMPERATURE AND RETENTION TIME: TRAVIS

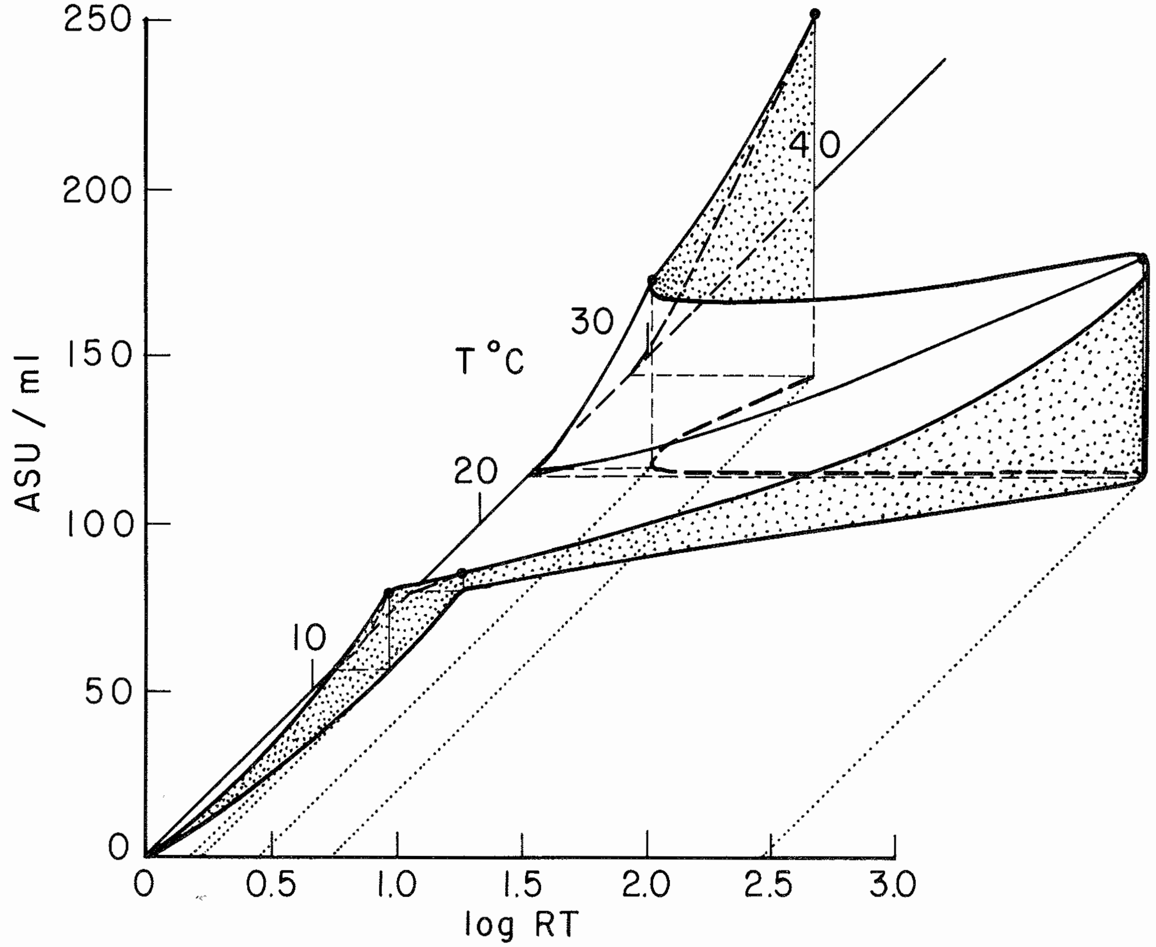


FIG. 21. ALGAL PRODUCTION RELATED TO TEMPERATURE AND RETENTION TIME: AUSTIN

phytoplankton productivity and the respective retention times and temperatures:

Lake	ASU	Temperature °C	Log RT, days
Buchanan	123	27	2.5
Inks	183	27.9	1.31
Johnson	246	26.8	0.32
Marble Falls	263	29.1	1.53
Travis	292	23.2	1.90
Austin	108	28.6	0.75

These algae counts are not meant to imply that the maximum areal standard units of algae are those represented here. Higher counts were found in all the lakes at different times. These data reflect the optimization of the three variables only . . Retention times weren't available for Town Lake because of its low water dam-spill structure.

Figure 22 relates the recorded Langelys correlated with temperature and ASU. Theoretically the maximum algal production should have occurred at higher temperatures and solar radiation. Exactly the opposite occurred for two points as is shown in Figure 22. The trend, however, appears to be toward higher productivity with increased solar radiation if one considers the higher values only.

Dissolved Oxygen

In the epilimnion of storage reservoirs such as Lakes Buchanan and Travis, during thermal stratification, dissolved oxygen is supplied by atmospheric aeration and photosynthesis. Since energy is required

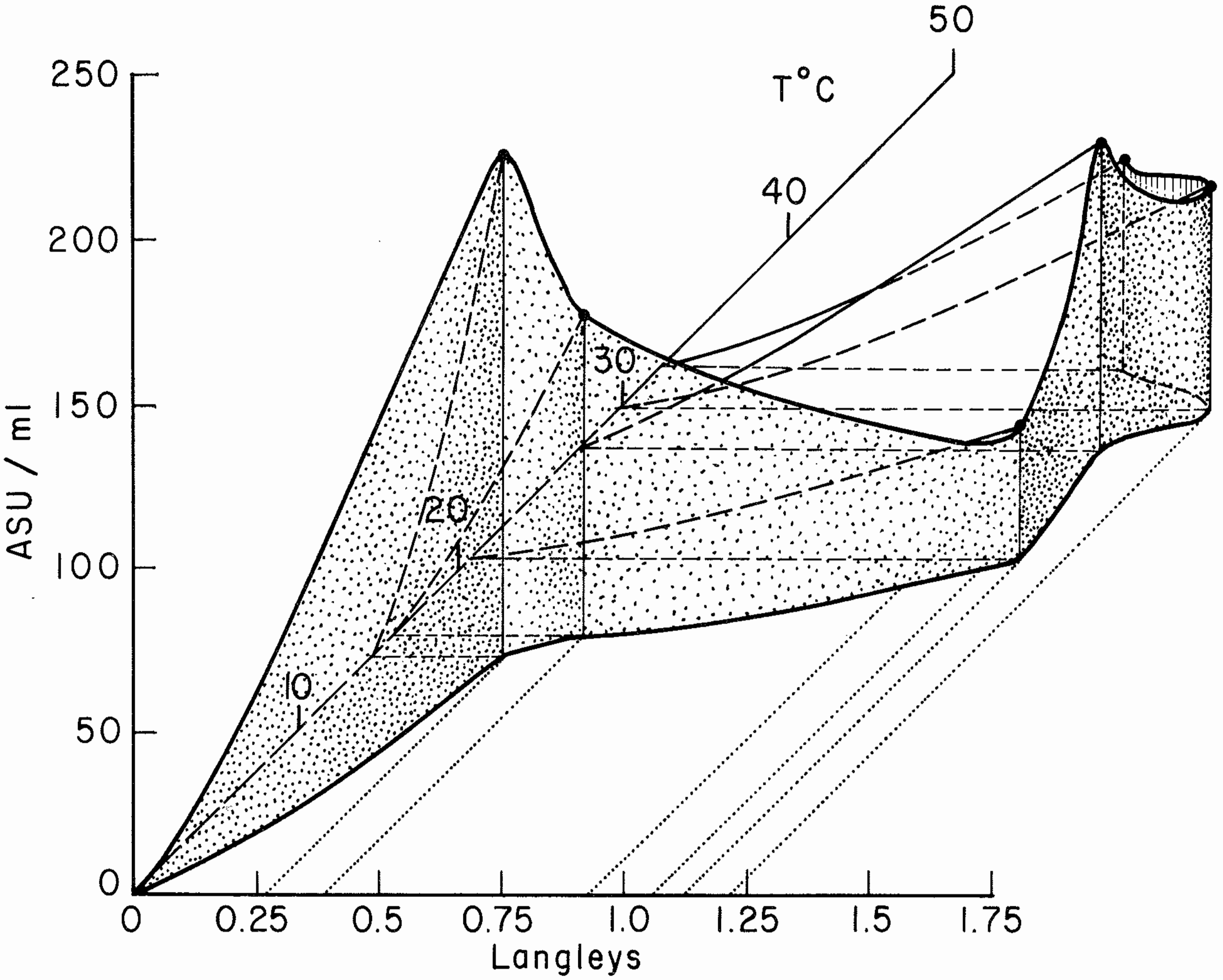


FIG. 22. ALGAL PRODUCTION RELATED TO TEMPERATURE AND SOLAR RADIATION: TOWN LAKE

in the form of light, photosynthesis is limited to the photic zone where light is sufficient. However, as previously discussed, the productivity of these reservoirs was small and, thus, oxygenation of the epilimnion is primarily caused by wave action. At the thermocline there is a rapid change in dissolved oxygen. The dead organisms from the epilimnion sink and are decomposed in the thermocline, hypolimnion and sediments. The sediments also exert a chemical oxygen demand. If the period of stratification is long or if there is a large quantity of organic matter being decomposed, the dissolved oxygen is depleted in the hypolimnion. Then anaerobic decomposition occurs with the evolution of carbon dioxide, methane and hydrogen sulfide. During the autumn the thermocline sinks mixing hypolimnetic waters with those of the epilimnion thereby lowering the oxygen of the surface waters. During the winter the impoundment is generally completely mixed and the dissolved oxygen is at saturated levels. The above description is exemplified by the Lake Travis data presented in Figure 23.

However, in the main stream reservoirs (as exemplified by the Lake Austin data in Figure 24) there was a gradual decrease in oxygen from water surface to sediments. Since there was no distinct thermocline, an abrupt change in dissolved oxygen would not be expected.

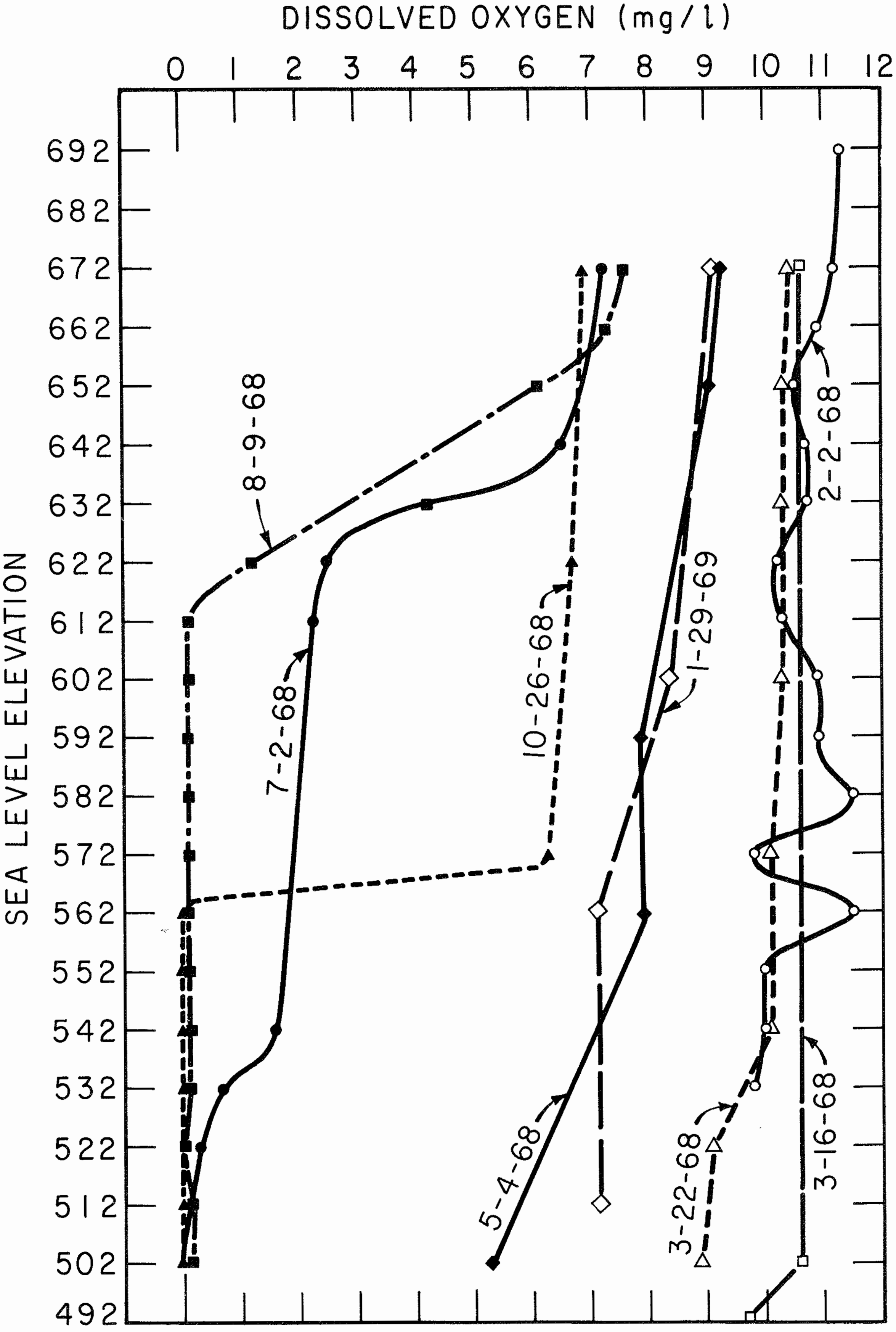


FIG. 23. DISSOLVED OXYGEN FOR LAKE TRAVIS

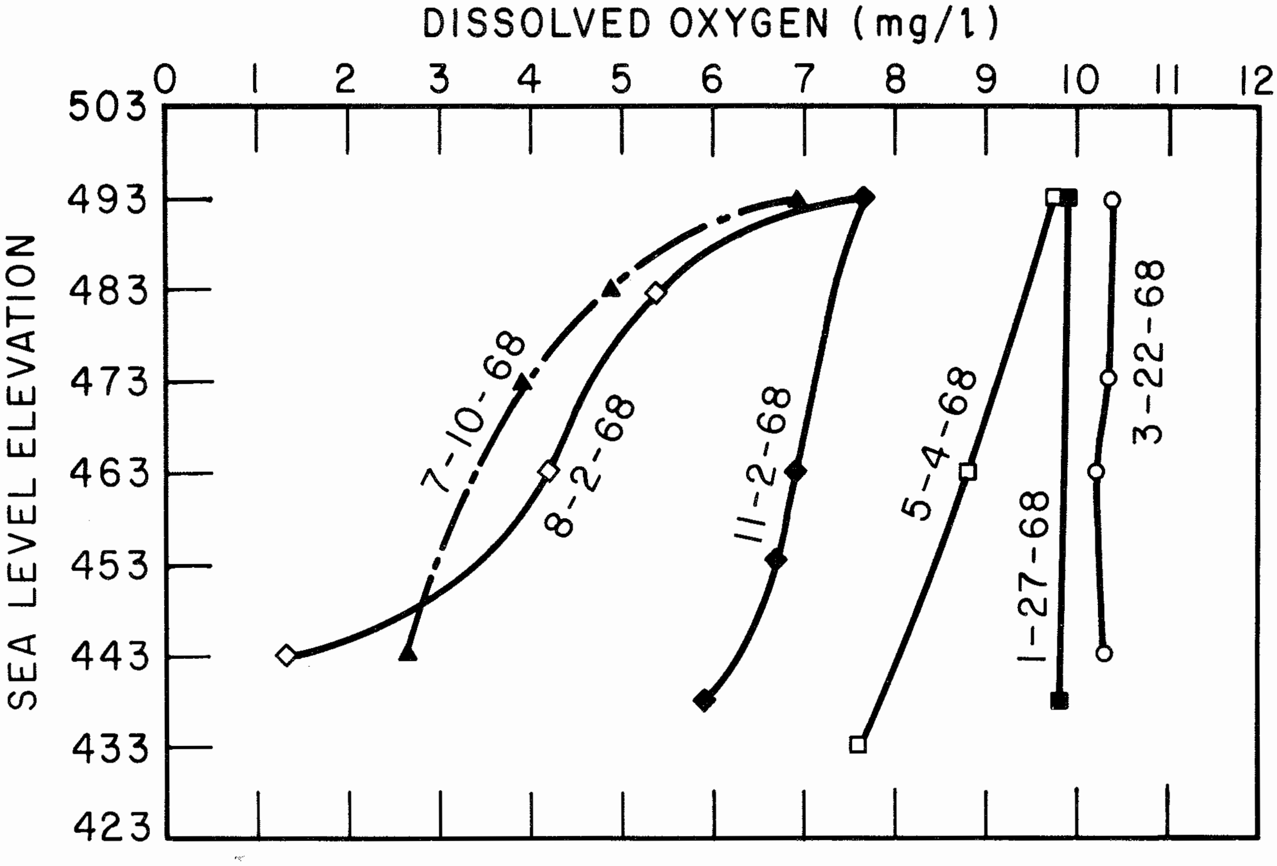


FIG. 24. DISSOLVED OXYGEN FOR LAKE AUSTIN

pH, Alkalinity and Hardness

Photosynthesis by aquatic plants utilizes carbon dioxide. This, of course, only occurs where there is sufficient light present, such as in the epilimnion. If no free CO_2 remains, the plants will remove it from the bicarbonate species present and thereby increase the carbonate concentration as well as raise the pH. Carbonates of calcium and magnesium are but weakly soluble in solution and will thus precipitate. In the hypolimnion, respiration and decomposition of organic matter increases the CO_2, thereby reducing the pH, and , thus, dissolving the precipitating calcium and magnesium.

Such phenomena occurred in the storage reservoirs (as typified by the pH, alkalinity and hardness data presented in Figure 25 for Lake Travis). For each water quality characteristic there is a marked change occurring at the thermocline. In contrast, the main stream reservoirs (as typified by the pH, alkalinity and hardness data in Figure 26 for Lake Inks) showed a pH gradient from water surface to sediments, but because there was no thermocline there was no marked change at any depth. Thus, the alkalinity and hardness were relatively uniform with depth except for a few samples obtained from above the sediments in the summer. Such increases were probably the result of the sediments being disturbed at the time of sampling.

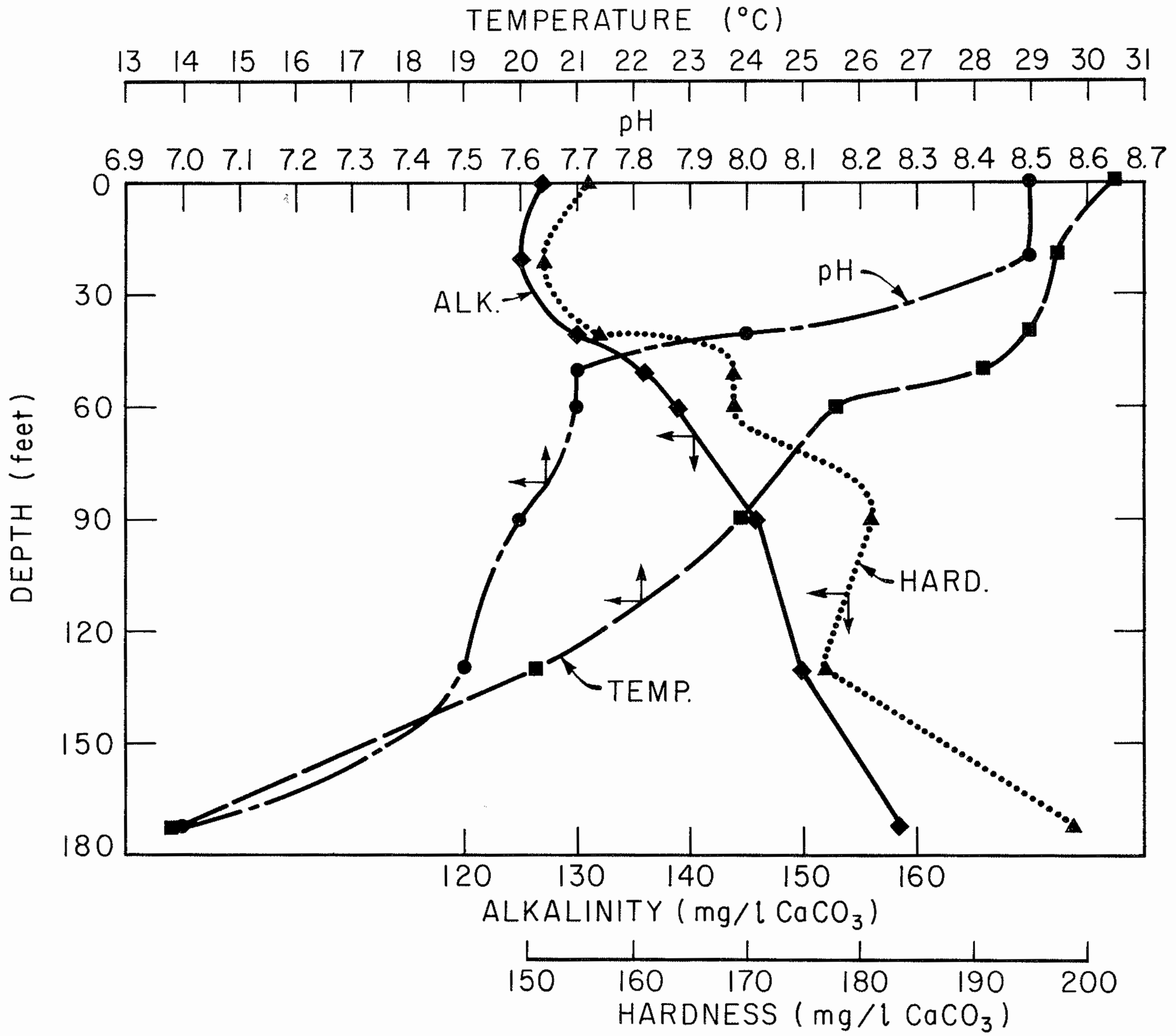


FIG. 25. LAKE TRAVIS (8-9-68) - pH, ALKALINITY, HARDNESS

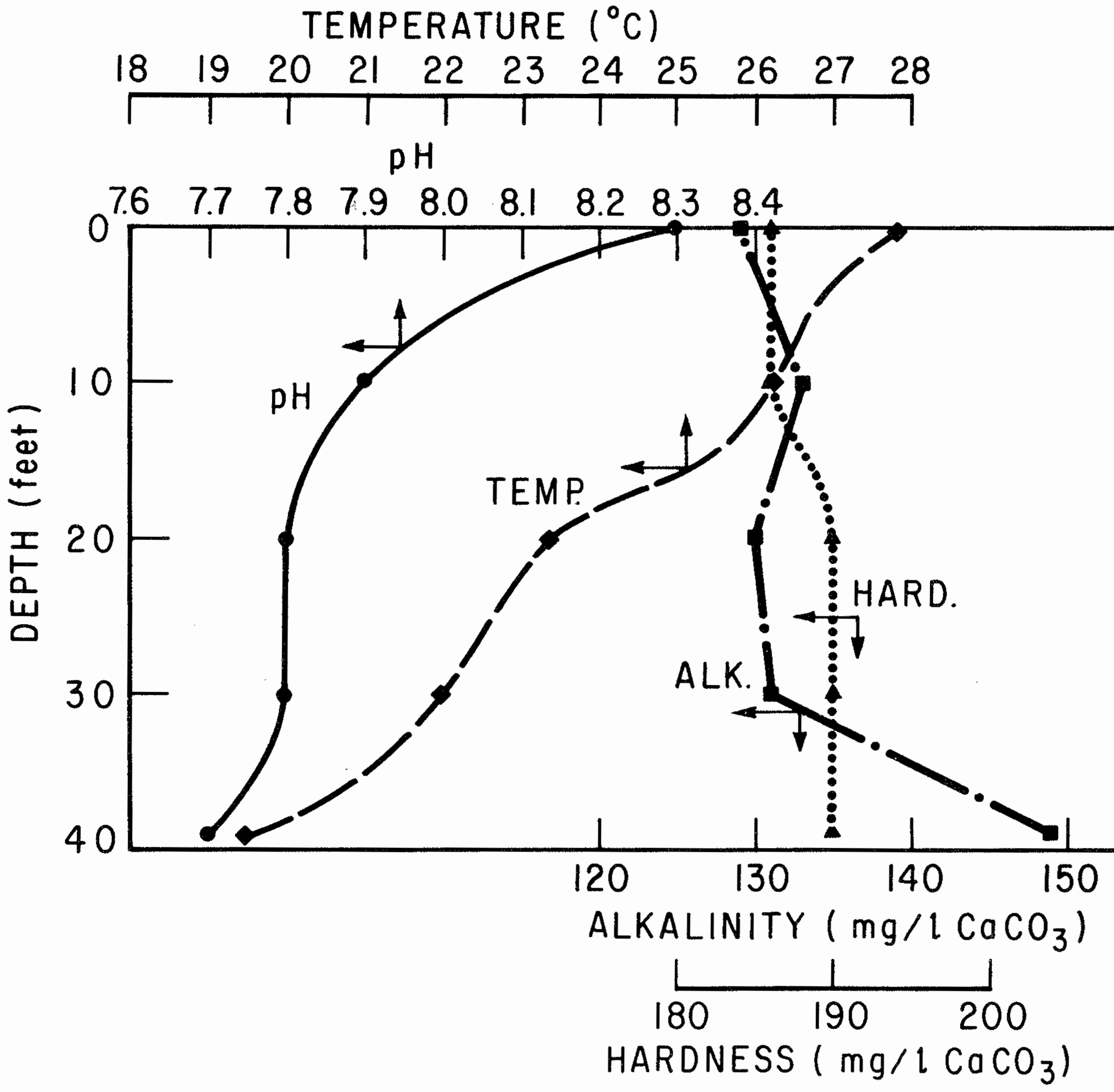


FIG. 26. LAKE INKS (7-12-68) - pH, ALKALINITY, HARDNESS

Nutrients

During phytoplankton growth, the nutrients are removed from the epilimnion and incorporated into the cells. Upon death, the organisms sink to the lower waters. During the decomposition of these organisms in the hypolimnion, nutrients are released to the water. Thus, as shown by the silica and temperature data in Figure 27, the abrupt change in silica concentration occurred at the thermocline. For other nutrients such as nitrate an additional phenomenon occurred. After the oxygen had been depleted in the hypolimnion, the oxidation-reduction potential decreased. Due to this potential change some of the nitrate was reduced. This reduction occurred first above the sediments where the oxidation-reduction potential was the lowest. This phenomenon brought about the nitrate depth profile shown in Figure 27. The increase in ammonia at this time was also due to the products resulting from the anaerobic decomposition processes occurring in the sediments.

The effect of nutrient concentrations in Highland Lake's water on phytoplankton growth will be discussed in detail by another report (Floyd, et al, 1969).

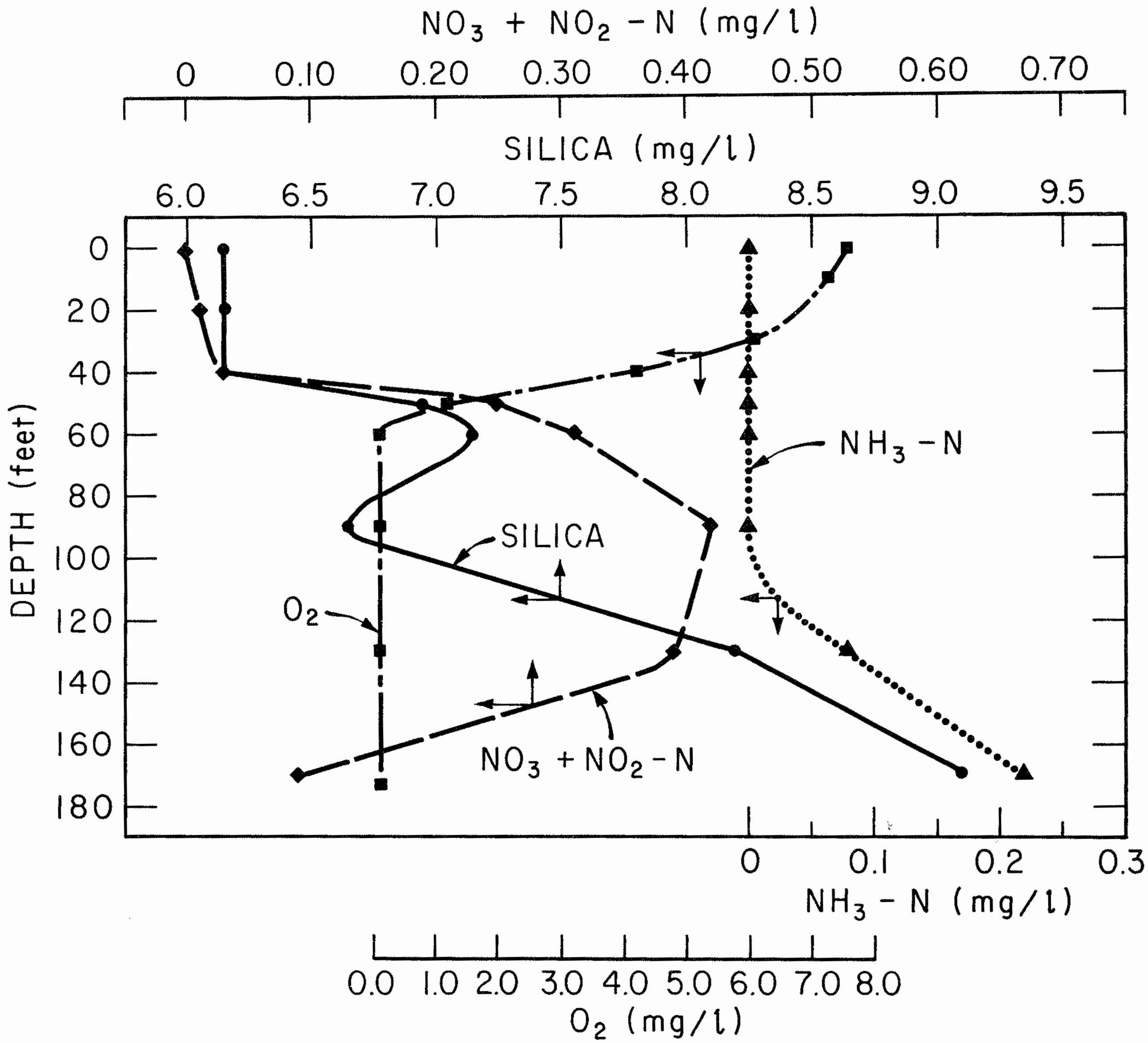


FIG. 27. NUTRIENT BEHAVIOR IN LAKE TRAVIS (8-9-68)

Bacteria

The effects of temperature stratification on total and coliform bacteria will be discussed in depth by another report (Gravel, et al, 1969).

Water Quality of Impoundment Releases

The water quality of the releases from the Highland Lakes will vary with the type of thermal stratification existing in the impoundment and the depth at which the penstock is located.

As previously discussed, only the deep reservoirs such as Lakes Buchanan, Johnson and Travis developed a "typical" thermal stratification which divides the impoundment into epilimnion, thermocline, and hypolimnion. The reports of Debler (1959), Kao (1965) and Koh (1964) are consistent in showing that there is separation of flow into layers toward a dam opening in a typically stratified impoundment. Since the water quality changes from epilimnion to thermocline to hypolimnion, the water quality of the impoundment's release depends in which the depth of the penstock is located. For Lakes Buchanan and Travis, the penstock is located at a depth at which the hypolimnion exists during all but a few months of the year. Thus, water containing low oxygen, higher hardness, alkalinity and conductivity, and higher nutrient concentrations are released downstream. In Lake Johnson, however, the water is released from the top so that released waters contained high oxygen, lower hardness, alkalinity and conductivity, and lower nutrients.

The reports of Debler (1959), Kao (1965) and Koh (1964) do not show agreement as to the critical values of discharge and Froude number at which this phenomenon of layered flow ceases to be present. However, those impoundments that exhibit a thermal gradient from water surface to sediments without a typical thermal stratification do not appear to have a selective withdrawal phenomenon. Thus, the release would be a composite of the water quality in the impoundment pool. Hence, the location of the penstock depth has little effect whether it is located in the bottom section of the dam such as for Lake Inks or the upper section of the dam such as Lakes Marble Falls and Austin.

Chapter 4

WATER QUALITY DATA

The purpose of this section is to present and evaluate the significance of the water quality data obtained from the various sampling stations outlined on Figure 1. The data are presented according to sampling station and are divided into two major sections - chemical data (presented in Appendix D) and biological data (bacteriological presented in Appendix E and algal presented in Appendix C). Because of its importance as a problem in the water supplies obtained from the Highland Lakes, taste and odor measurements are treated separately.

Water Quality of Sampling Stations

Bend, Texas

The first sampling station was located about 20 miles upstream from the headwaters of Lake Buchanan. Because of its four foot depth and rather turbulent mixing conditions, a mid-depth sample was found to be sufficient.

The chemical data varied greatly over the year as to be expected of a freely-flowing river. The river was always turbid. The nutrient influx was rather high in nitrate during the winter, but decreased rapidly through the summer. Ammonia remained less than 0.10 ppm. Phosphorus was quite high compared to downstream conditions varying from 24 to 154 ppb. Silica ranged from 5 to 10 ppm. Total organic carbon concentrations indicated some organic pollution.

Bacteria concentrations varied greatly throughout the sampling period. On one occasion the concentration of coliform bacteria was 288/ml which might be construed as being of questionable water quality since it is more than 20 times the figure of 100/100 ml which has been set as a guide for quality waters. The total bacterial concentration varied even more; from a low of 37/ml to 19,000/ml.

Algae concentrations varied from 3.6 to 136.4 Areal Standard Units per milliliter throughout the sampling period. These figures correspond to 5 and 214 phytoplankton cells per milliliter, far below bloom proportions.

Lake Buchanan Pool

The second sampling station was located at the deepest point of Lake Buchanan Pool approximately 300 yards from the dam and a mile from shore. It was always sampled at dawn.

The data indicate that Lake Buchanan has a temperature stratification cycle typical of a deep subtropical impoundment. Stratification existed in October. The pH changed with depth even in winter. The surface waters remained about pH 8.3 except during the fall when the pH dropped to 7.8 probably because of mixing of some of the hypolimnetic waters with those of the epilimnion. This is because the pH of the hypolimnetic waters changed considerably due to the decomposition process occuring in the sediments. The pH just above the sediments was as low as 6.9 by October. The dissolved oxygen profile substantiates this conclusion. In the course of but approximately two months the oxygen just above the sediments decreased from approximately 9.0 mg/l in April to 0.20 mg/l in June. Through the remainder of the summer and fall oxygen became depleted in the hypolimnion.

As the flow entering the reservoir decreased from winter to summer, there was a corresponding increase in the hardness, alkalinity and conductivity. Stratification of alkalinity, hardness and conductivity as well as some nutrients such as nitrate plus nitrite and silica occurred in conjunction with temperature stratification. Phosphorus, ammonia and total organic carbon were generally too low for accurate measurement except for some samples obtained at the thermocline during the summer.

Of major significance was the decrease in the concentration of these chemicals and nutrients between the sampling stations at Bend and Buchanan Pool. An example is the data obtained in winter presented in Table 34.

Table 34

Chemical Decrease Due to Impoundment

Water Quality Characteristic	Sampling Station	
	Bend	Buchanan Pool
Hardness (mg/l as $CaCO_3$)	230	120
Alkalinity (mg/l as $CaCO_3$)	162	106
Conductivity (mhos/cm)	595	516
Nitrate plus Nitrite (mg/l as N)	1.06	0.15
Silica (mg/l as SiO_2)	7.7	6.2

The decrease in velocity as the Colorado River entered Lake Buchanan probably allowed sedimentation of the silt carried by the turbulent stream. Whether the chemicals removed were sorbed or just entrapped by the settling silt is presently unknown.

Coliform concentrations were consistently low in the pool area of the lake. Predictably, the trend was to higher concentrations with depth. The importance of the higher concentrations in the hypolimnion is that the lower temperature and high nutrient concentrations allowed these organisms to survive for greater periods of time than they normally would in the epilimnetic reaches. No correlation could be found between the total bacterial numbers and coliform numbers, even with depth. Unusually high coliform counts were found at all depths on 10-5-68 and in the release waters from this Lake. The reason for the pollution level counts is unknown at this time.

Phytoplankton counts varied from 11.4/10 (ASU/No.) to 119.9/78 (ASU/No.) per milliliter. This range may have been due to a temperature dependence: the low was for February while the high was found in June. Greater depths did show small numbers of phytoplankters throughout the year. In all probability their presence at those bottom levels (up to 150 feet) was due to a settling phenomenon and not active metabolic productive capabilities.

Lake Buchanan Release

During the winter the waters of the release appeared to be similar to a composite sample of the water in the reservoir behind the dam. During the summer the water quality of the release was quite similar to the water quality in the hypolimnion at elevation of the penstock outlet (except for one pH reading which is considered doubtful because of instrument difficulties that particular day). The November sample was obtained when there was no release and reflects the effect of a large quantity of rooted plants on the water quality of the headwaters of Lake Inks.

The coliform and total bacterial appeared to follow the same pattern in the release as in the pool above.

Lake Inks Pool

The data on temperature variation with depth indicate the fact that Lake Inks is a main stream reservoir. Sometimes there were thermoclines a few feet felow the surface due to the large releases from Lake Buchanan into the comparatively smaller volume of Lake Inks. Because of the lack of a distinct thermocline there is a rather uniform decrease in pH and dissolved oxygen from water surface to sediments. This was greatly affectedby the water quality of the hypolimnetic release from Lake Buchanan. Exceptionally low dissolved oxygen concentrations were found in the surface waters in the fall. The concentration of alkalinity, hardness, conductivity, total organic carbon and nutrient was quite similar to that of Lake Buchanan.

Both coliform and total bacteria counts were higher in the bottom waters than in surface waters. The water above the sediments contained concentrations which exceeded the 100/100 ml set at a break point for these discussions, more at the rule than the exception. Presumably, the same conclusion can be drawn because of the colder waters, longer dieoff duration, and higher nutrient quality of the waters immediately above the sediments.

The greater numbers of phytoplankton genera found in Lake Inks Pool were those of the green algae. Again, the concentrations found throughout the year in the surface waters were widely separated: 5.0/3 (ASU/No.) to 183.1/57 (ASU/No.) per milliliter. Similarly, a temperature dependence was noted. The low count was obtained in February and the high in July.

Lake Inks Release

The release from Lake Inks was obtained during every sampling period. In general, the water quality of the release was a composite of the water quality in the pool behind Lake Inks Dam. Evidently, the lack of a thermocline or rapid change in density in the pool eliminated the possibility of a selective withdrawal of water such as occurred from the hypolimnion of Lake Buchanan. Occasional high coliform counts were observed which did not correlate to any erratic changes in temperature or any other water quality parameter. Turbulence and resulting disturbed bottom sediments appeared to be at least a partial answer to their spontaneous increase. Algal counts were similar to those found in the pool.

Llano River

Lake Johnson is formed by the confluence of the Colorado River (release from Lake Inks) and the Llano River. Comparison between the two shows considerable difference, not unexpected because the two rivers travel through two different geological areas. The temperature and pH of the Llano River was generally higher than that of the Lake Inks release. Although the hardness was similar in the two systems, the Llano River had a much lower conductivity and a somewhat higher alkalinity. The nutrients were also significantly different. While the silica content of the Lake Inks release remained approximately 6.0 - 6.5 mg/l throughout the year, the silica in the Llano River rose from 8.0 in winter to 13.0 mg/l in summer. While the nitrate plus nitrite concentration in the Lake Inks release rose throughout the year, the nitrate plus nitrite concentration in the Llano River decreased from 0.35 mg/l in the winter to 0.01 mg/l in summer. Small quantities of ammonia were found throughout the spring and summer in the Llano River indicating some biological degradation. However, some organic pollution was indicated by total organic carbon measurements.

The contribution made by this stream, carrying runoff nutrients and microorganisms, is obvious from the bacteriological data (Table E-1, appendix). In almost all cases the concentrations of coliform bacteria exceeded the 100/100 ml figure.

Significant phytoplankton concentrations were found in these waters. Concentrations of up to 74.7/90 (ASU/No.) per milliliter were recorded. The numbers were not near bloom proportions. However, many genera of blue-green algae were observed.

Junction of the Colorado and Llano Rivers

The purpose of this sampling station was to obtain the water quality of the headwaters of Lake Johnson. However, the water at this junction was deep enough (35 feet) to stratify so that well mixed conditions for a composite sample of the two rivers could not be attained. The sampling was continued, however, to determine if there was a significant difference between the water quality of the headwaters and that of the pool behind the dam.

During the summer there was distinct temperature, pH and dissolved oxygen decrease with water depth. Even in the fall with less than a ^{o}C difference between the water surface and sediments, there was a marked difference for pH and dissolved oxygen between the water surface and sediments. During the summer there was some increase in alkalinity, hardness and conductivity with depth.

Based on the temperature of the Lake Inks release it is possible during the summer that this cold water did not become much warmer during its travel to the Lake Johnson headwaters and slid under the warmer Llano River waters enhancing the apparent temperature, chemical and nutrient stratification which occurred at this sampling station. This is apparently verified by the silica data for the two summer sampling periods. There was apparently an inverse silica stratification caused by the high silica in the Llano River flowing over the low silica

Lake Inks release. Furthermore, this could be the cause for the low nitrate plus nitrite concentrations in the surface waters and the higher nitrogen concentration in the lower waters. Similar profiles were found about a mile downstream at a sampling station used for another study (Pittman, et al, 1969).

Concentrations of bacteria in these waters were similar to those found in both the Llano River and the Lake Inks release, indicating that the detention period required for effective dieoff was probably greater than that which was evidenced during the sampling period.

Temperature may have been an important factor in the production of up to 239.4/273 (ASU/No.) phytoplankton per milliliter in July, 1968. Throughout the year, blue-green and green algae were found in approximately equal numbers of genera. Significant numbers of genera of Euglenophyta were also present throughout most of the year, a factor which should not be overlooked when considering indicator organisms and possible pollutional environs.

Lake Johnson Pool

Lake Johnson is a cross between a storage reservoir and a main stream reservoir. Its water level is kept at a constant level, yet it is only 80 feet deep behind the dam. Thus, the temperature stratification is typical of a storage reservoir although the thermocline is located at a shallow depth. The dissolved oxygen profile does not show the marked change at the thermocline as is typical of a storage reservoir but shows the gradation from water surface to sediments typical of a main stream reservoir. Lake Johnson was the reservoir which first had oxygen depleted above the sediments. This occurred by the end of April. Oxygen was depleted from 35 feet down by June and the oxygen 15 feet below the surface was at only half the saturation concentration. Even in October the bottom 20 feet of water was depleted of oxygen. The pH profile was similar to that of the oxygen.

The conductivity profile was a mirror image to that of the pH and dissolved oxygen from the spring through the fall. Silica in contrast to nitrogen showed no stratification. Nitrate plus nitrite was 0.20 mg/l at the surface and 0.42 mg/l above the sediments in April. By June this element had decreased to 0.01 mg/l in the surface waters and increased with depth until 50 feet. Then, however, the reduced conditions above the sediments probably caused a change in nitrogen from nitrate to ammonia. By July, most of the nitrogen present in the bottom waters was in the form of ammonia. The ammonia did decrease in the bottom waters through the summer.

Consistently throughout the sampling period the coliforms were in concentrations of less than ten per milliliter. By comparison, the total bacteria went to concentrations as high as 6.3 million counts per 100 milliliters. Contaminated runoff, high nutrients which prolonged dieoff rates, lower temperatures, and other factors undoubtedly caused these numbers to persist.

Similar patterns of phytoplankton development were observed in this pool. In February, 1968, the surface waters contained only 18.8/13 (ASU/No.) per milliliter whereas in June the figure reached 261.5/113 (ASU/No.) per milliliter. Green algae genera were dominant throughout most of the year. No pattern was observed in phytoplankton development in the lower waters.

Lake Johnson Release

Unfortunately during all the sampling periods, the Lower Colorado River Authority was not releasing from Wirtz Dam on the days that samples were obtained. Thus, the data obtained more appropriately describes the water quality of the headwaters of Lake Marble Falls.

Lake Marble Falls Pool

The temperature data for this sampling station never showed a temperature variation of over 3°C from water surface to sediments. No distinct thermocline was ever found during the days when samples were obtained. Thus, the limnological characteristics were typical of a main stream reservoir.

The pH decreased gradually with depth during the summer months, having the largest variation of 8.3 at the surface and 7.4 above the sediments at the end of July. The dissolved oxygen showed a similar profile becoming as low as 0.20 mg/l above the sediments at the end of July.

Even though there was no typical thermal stratification, there was some evidence of an increase in alkalinity, hardness and conductivity concentrations with depth in the July data. These data were similar in concentration to the Lake Johnson pool. Nitrate plus nitrite also showed such stratification during the June sampling period. The nitrate plus nitrite concentration decreased from winter through summer as it did in the Lake Johnson pool. The July sample showed a maximum nitrate plus nitrite concentration about mid-depth, while ammonia appeared for the first time with a maximum above the sediments probably due to the reduced conditions prevalent at that time. No stratification of silica occurred.

Consideration should be given to the decrease in pH with depth. As the figure of 7.4 is approached from 8.3, the aquatic environment becomes more amenable to the survival of bacteria, pH 7.0 - 7.5 being optimum for most species. As in most instances in the reaches of the Highland Lakes, the coliform content was comparatively low but the total bacteria varied from 55/ml to greater than 5,000/ml.

Phytoplankton concentrations exhibited the same pattern as in the upper reservoirs in the chain. The counts varied from 8.2/7 to 245.8/148 (ASU/No.) per milliliter for February and June respectively.

Lake Marble Falls Release

During the summer and fall, the Lower Colorado River Authority was not releasing waters from Starke Dam on the days that samples were collected. Thus, the data obtained at those times are more indicative of the water quality of the headwaters of Lake Travis. However, the chemical data are quite similar to a composite of the water quality found in Lake Marble Falls Pool.

Pedernales River

This sampling station was located about twenty miles upstream from where the Pedernales River joins the Texas Colorado River release from Lake Marble Falls. The depth of the Pedernales River at this sampling station was only 2 feet deep. Since the stream was always quite turbulent,one sample from mid-depth was considered representative of the water quality of the Pedernales River.

The temperature warmed quickly in the spring and cooled quickly in the fall as is typical of a stream. The pH was always approximately 8.3. The dissolved oxygen was always near saturation level.

In general, the hardness and particularly the alkalinity concentrations were higher than those found in the Lake Marble Falls release. Conductivity was only occasionally slightly greater in the Pedernales River. During the winter some measurable phosphorus was found in the Pedernales River. Nitrate plus nitrite concentrations were approximately 1.0 mg/l during the winter in the Pedernales River and then dropped significantly through the summer. Silica concentrations in the Pedernales River averaged approximately 10 mg/l compared to 7 mg/l in the Marble Falls release.

Comparatively low algal counts and algal genera numbers were observed in these waters. Counts as low as 5/2 (ASU/No.) per milliliter were recorded.

Junction of the Colorado and Pedernales River

This sampling station was located approximately 1 mile downstream from the actual confluence of the Pedernales River with the Colorado River coming from Lake Marble Falls. However, the depth of the water at the sampling station was approximately 90 feet, which indicates that thermal stratification would occur so that no composite sample of the two rivers could be obtained. The sampling was continued, however, so that a comparison could be made between the water quality variation with depth at this station located at the headwaters of Lake Travis and the station located in the pool behind Mansfield Dam.

The temperature variation with depth throughout the year indicates that at the headwaters Lake Travis is functioning as a storage reservoir. A thermocline was apparent as early as the end of April. Even in winter there was a decrease in pH and oxygen with depth. The pH of 6.5 found in March was checked. By the end of April the oxygen above the sediments was as low as 4.1 mg/l and was depleted by the end of June. Throughout the summer very low concentrations were found below 35 feet. During the summer, stratification of hardness, alkalinity and conductivity as well as the nutrients such as nitrate plus nitrite and silica was found. Nearly all the nitrate plus nitrite was extracted from the water by the summer months. Ammonia concentrations were significant during the reduced conditions prevalent in the hypolimnion during the summer.

From a water quality viewpoint the concentrations of both coliform and total bacteria were not excessively high. Variations in the total count did occur, as in the surface samples which varied from

65/ml to 2,800/ml. However, the significant trend was one of general increase with depth. The coliform concentrations were consistently <1/ml or <10/ml.

Green algae were the predominant group of phytoplankton found during the year.

Lake Travis Pool

The temperature data for this sampling station indicate that the pool functions as a storage reservoir. Because of this, as well as being the deepest reservoir, Lake Travis was more frequently sampled than any other impoundment. The pH and dissolved oxygen profiles showed only a slight decrease with depth in March. However, by early May the pH varied from 8.7 in the surface waters to 7.8 above the sediments, while the dissolved oxygen varied from 9.2 in the epilimnion to 5.3 above the sediments. By early July the dissolved oxygen was depleted above the sediments and only 2.50 mg/l was present at 55 feet below the water surface. By early August, the dissolved oxygen was depleted in the entire hypolimnion and this condition persisted through the end of October even though the thermocline had dropped to a depth of approximately 100 feet.

The chemical and nutrient data at this pool sampling station were quite similar to the water quality data obtained at the stratified sampling station located at the headwaters of Lake Travis where the Lake Marble Falls release and the Pedernales River join. It is particularly important to note the decrease in total inorganic nitrogen available to the algae in the epilimnion as well as the extremely low concentrations of total phosphorus still being found even this far down in the chain of reservoirs.

Apparently, because of the stabilization characteristics of this impoundment due to increased retention times of the waters, and because of the relatively long reach above the pool area, there is a significant decrease in total bacteria numbers. Ordinary trends to increase with depth did not occur and large fluctuations in coliform numbers were in evidence.

Similar concentrations of phytoplankton were found over the sampling period encompassed by this report as in the afore-discussed waters. The range extended from 6.6/8 to 178.1/242 (ASU/No.) per milliliter on January 9, 1969 and August 9, 1968 respectively. The predominant algal division represented through the year was the green algae division, Chlorophyta.

Lake Travis Release

During the summer months, the sampling dates coincided with releases by the Lower Colorado River Authority from the stratified Lake Travis pool. The sampling station was located at a bridge approximately one-quarter mile below the turbulent tail race. For this reason, the oxygen concentration was somewhat higher than that found at the pool depth from which the release was made. However, the pH, temperature, hardness, alkalinity, conductivity, nitrate plus nitrite and silica concentrations are quite similar. This indicates that because of the density difference with depth in the pool, selective withdrawal of hypolimnetic water was occurring during peaking power operations.

Lake Austin Pool

Based on the yearly temperature data, Lake Austin functions as a main stream reservoir. During early August a thermocline was formed, but it was probably due to the cold density current from the Lake Travis release traveling down along the Lake Austin bottom. Because of the cold release from Lake Travis, even the surface waters during the summer were not as warm as the upstream Lake Travis Pool.

During early May there was a small decrease in pH and dissolved oxygen with depth. As typical of a main stream reservoir the dissolved oxygen and pH change from water surface to sediments was gradual. By early August the pH and dissolved oxygen just above the sediments was 7.6 and 1.35 mg/l, respectively. Although "overturn" occurred by early November, there was still a difference between the oxygen of the surface waters as compared to that just above the sediments.

No chemical or nutrient stratification was evident. The chemical, nutrient and total organic carbon concentrations were quite similar to the Lake Travis release.

Due to the main stream characteristic of this impoundment and because of the comparatively short retention times, the bacterial concentrations throughout the sampling period were erratic. Patterns of increases with depth did not present themselves as in the other impoundments in the Colorado River reach. The coliform concentrations were surprisingly low considering the extent of urbanization along Lake Austin.

The phytoplankton counts which were made on Lake Austin during 1968 were not indicative of the productivity potential for that reach of the Colorado River. A low count of 9.2/5 (ASU/No.) was recorded in the surface waters on May 4, 1968 and a high of 107.5/219 (ASU/No.) per milliliter was recorded for August 8, 1968.

Counts of over 200 ASU have not been unusual. Seasonal predictions of the standing crop of algae are difficult because of the annual lowering process which essentially returns the lake bed to the river channel.

Lake Austin Release

The sampling point at this station was located approximately 100 feet below the release. On all sampling dates except November, releases were occurring. The data for temperature, pH, dissolved oxygen, chemicals, nutrients and total organic carbon appeared to be a composite of the water column in Lake Austin behind Tom Miller Dam.

Town Lake Pool

The temperature and depth data for this sampling station definitely show that Town Lake is a main stream reservoir. There is a temperature gradient at all times of the year including as late as the November sample because of the hot water releases into this reservoir from the City of Austin steam plant.

There was no pH change with depth and less than 1 mg/l decrease in dissolved oxygen with depth. However, there was a significant depletion of oxygen during the summer. The dissolved oxygen concentration was 5.50 mg/l in July and approximately 5.70 mg/l in August. However, the concentration of total organic carbon remained as low as that found in the upstream reservoirs. Thus, no consistent organic pollution could be detected on the six days of the year when samples were obtained. The oxygen depletion could well be due to the biochemical and chemical oxygen demand of the bottom sediments.

The chemical and nutrient (excepting phosphorus) concentrations at this sampling station were quite similar to the Lake Austin release except in the fall. This might be due to the effect of little or no release during this period of the year from Lake Austin allowing the tributaries, particularly Barton Creek, to exert a greater influence. The phosphorus concentration was exceptionally high during the fall in comparison to the upstream reservoirs.

A reversal of the classical increase in bacterial numbers with increase in depth occurred in this impoundment. Runoff and other discharges into this impoundment undoubtedly contribute to its accelerated eutrophication. Although the pool of this main stream impoundment exhibited the bacterial concentration reversal as stated above, various coves and creek discharge points consistently contain high numbers of coliform organisms. The obvious answer to the comparatively lower counts in the pool, or mainstream reaches, is that definite bactericidal capabilities on the part of other microorganisms is occurring. Also, during discharges from Lake Austin immediately above, the bacteria are swept downriver simply by volume replacement hydraulics.

The overall potential of this shallow impoundment to generate both numbers and different genera of phytoplankton is not indicated by the numbers reported herein. A low of 13.9/8 (ASU/No.) per milliliter was reported for May 4, 1968 while 152/75 (ASU/No.) were present on March 16, 1968. On several occasions, bottom waters contained higher counts than did surface waters. Green algae and diatoms were usually the predominant types.

Town Lake Release

This sampling station was located immediately below Longhorn Dam. Unfortunately, the City of Austin was not releasing the water from Town Lake on the days when samples were obtained. Except for oxygen and pH the sample obtained at this station had the same water quality characteristics as the samples obtained from the Town Lake Pool.

Decker Lake

This sampling station was at first located at the pump in the Colorado River which transferred water to the now filling Decker Lake. Samples were not obtained in the summer or fall because the owner of the private roadway leading to the pump refused permission to cross his land. In winter, 1969, the sampling station was then transferred to Decker Lake itself.

As compared to the Town Lake release there was a considerable increase in the phosphorus. This undoubtedly was due to the entrance into the Colorado River of the effluent from the City of Austin's Govalle Wastewater Treatment Plant between Town Lake and the pumping station. Surprisingly, there was no increase found in the total organic carbon concentration or coliform.

Decker Lake may have the potential to cause severe algal nuisance problems in the future due to the cooling water recycling. To date the surface counts have not been uncommonly high and no unusual groups of algae have been predominant.

Tastes and Odors

Most of the Highland Lakes are free of the changes in water quality encompassing serious tastes and odors imparted to the waters by microorganisms. Occasionally, surface waters in the pool areas of Buchanan, Inks, Johnson, Marble Falls, and Travis will have a slight grassy odor with a threshold value of approximately 2 to 3. No progression to more serious tastes and odors has been noted. Waters from immediately above the sediments occasionally exhibited a slightly septic to medicinal property during periods of marked stratification and corresponding oxygen depletion in the thermocline. Fortunately, these did not persist through a season and were primarily due to the near septic conditions of the waters. Reaeration of the waters having the septic-medicinal odors eliminated this problem.

Lake Austin and Town Lake were quite different from the five other impoundments. High concentrations of Potamogeton and Myriophyllum are present in all areas of the impoundments throughout most of the year. These higher plants allow untold numbers of microscopic organisms to grow on the surface of the leaves and stems. Decomposition of the higher plants results in organic materials being placed in solution and suspension. These organics furnish nutrients for the growth and proliferation of undesirable odor producing phytoplanktons and other microscopic organisms such as the actinomycetes. The blue-green algae, also present in peak periods, contribute both directly and indirectly to the taste and odor problem in these waters. Upon decomposition, microbes such as the actinomycetes thrive on their protoplasmic constituents.

Figure 28 shows the threshold odor values in Lakes Austin and Town. At the present time the City of Austin takes its water from these impoundments. The predominant odor which occurred in Lake Austin and Town Lake during 1968 was the classic earthy odor. This is typically difficult to eradicate by conventional treatment methods. Permanganate and activated carbon are used routinely for reduction of the compounds causing the odor. The subject of problems concerning tastes and odors in water supplies is not limited to this region alone but is certainly a universal one.

A partial answer to the question of why the threshold odors did not peak significantly in both impoundments in the summer of 1967 may be the relatively low rainfall in June for that year. (Table A-2). Runoff normally caries nutrients in much higher quantities than ordinarily found in the impoundments, and soil microorganisms carried in the runoff also deteriorate later in the impounded waters giving rise to tastes and odors. Periods of reduced rainfall also promote higher rates of evaporation. Table A-3 lists monthly evaporation rates (in acre-feet) for six of the seven lakes studied. Note the evaporation data for Lake Austin. Twelve hundred acre-feet of water were lost. Theoretically, the more concentrated taste and odor compounds should result in higher threshold odor values. Apparently though, the microorganisms which are capable of degrading the odor

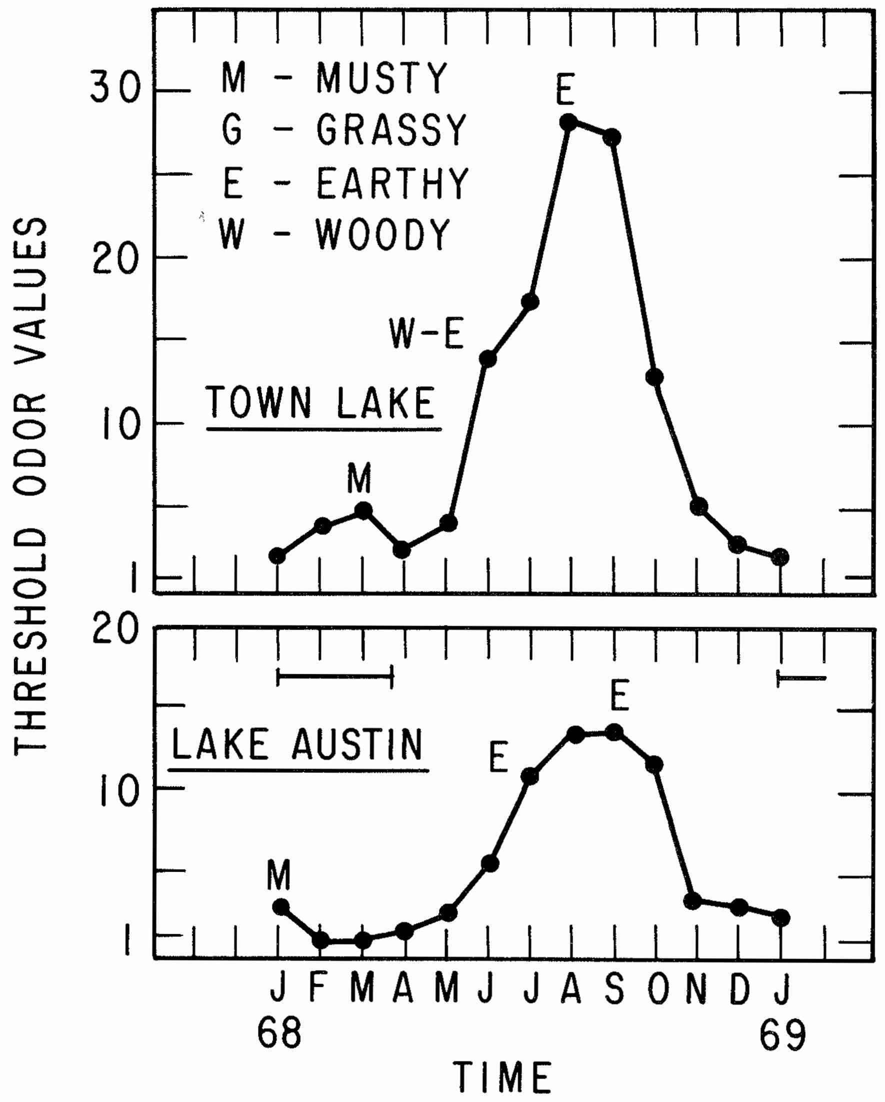


FIG. 28. THRESHOLDODOR CONCENTRATIONS LAKES AUSTIN AND TOWN

compounds have a better opportunity to do so when said compounds are more concentrated. Evaporation in the southwestern part of the United States is certainly an important feature to be considered and has been the subject of many attempts at control measures. Considering Lake Austin alone, more than 1/20 of the entire volume of that impoundment was lost by evaporation. Slightly less than half its volume was lost over the entire year, making evaporation alone a costly physical factor.

Chapter 5

DISCUSSION AND CONCLUSIONS

The need for more and better water quality data on Texas impoundments has grown not only because of the large proposed increase in the number of impoundments, but also because of their ever-expanding uses. Today, Texas impoundments are used not only for conservation, flood control, hydroelectric power, and water supply for municipal, industrial, and agricultural needs; but also for fish management, recreation, industrial cooling, water pollution control by stream flow regulation, and control of freshwater quantity and quality inputs to Texas Bays. Thus, the type of water management desired and needed in Texas requires that the quality of water stored in and released from such impoundments be under investigation to determine if the quality is suitable for the various intended uses.

This study has clearly shown that the water quality in the Highland Lakes Reservoirs is greatly affected by its morphology and purpose in the reservoir series. The large storage reservoirs have a sufficient volume to detain the water for a long period and sufficient depth so that a stable temperature stratification (similar to that in natural lakes) does develop over a long period of the year. In contrast, the smaller main stream reservoirs do not have the morphology to develop a stable temperature stratification, although there is a temperature gradient from water surface to sediments. Sometimes thermoclines do develop, but are quickly broken by the quick passage of large volumes of water through these reservoirs.

One rapid means to assess the water quality of these reservoirs from a biological viewpoint has been the bacteriological analysis for coliform organisms and examination of the standing crop of phytoplankton. Throughout the year the numbers of coliform bacteria most often found in surface waters was less than ten per milliliter. These numbers were not indicative of a pollutional quality. Total bacterial counts indicated that the waters could sustain the gram positive forms to some appreciable extent although the total organic carbon measurements did not demonstrate levels of organic carbon at which the gram positive forms could multiply. Occasionally pollutional level numbers of coliform bacteria were found in the bottom waters. Apparently many of these bacteria originated in the bottom sediments where organic materials exist in sufficient supply to maintain their growth and reproduction.

Phytoplankton populations did not reach "bloom" proportions in any of the impoundments during the year. There exists a definite trend to higher phytoplankton concentrations in Lake Austin and Town Lake. This may be indicative of subtle changes in water quality with distance of the Colorado River reach or, more likely, intensified urbanization around those two impoundments. Tastes and odors and their related problems which are directly or indirectly related to algae in Town Lake and Lake Austin are a continual concern. Intense earthy odors were evident at concentrations approaching T.O. values of 30 in these two reservoirs during the year.

From chemical measurements of the waters, it appears that the exceptionally low concentrations of phosphorus and iron throughout the year might limit plant growth. Only in Town Lake and Decker Lake do phosphorus concentrations appear which can be accurately measured. Although nitrogen concentrations are significant through the winter, there is a steady depletion of nitrogen through the warmer months of the year in the epilimnion of most of the impoundments and in this season nitrogen could become limiting. However, fairly high concentrations of ammonia did develop during these months in the hypolimnion of the large storage reservoirs and are naturally available to the phytoplankton and/or bacterial species in the winter when these reservoirs become mixed. Silica was obviously not limiting at any time of the year.

The most important chemical water quality problem was dissolved oxygen. In all the impoundments (except Town Lake which is essentially a mixed river) the dissolved oxygen was severely decreased in the lower waters whether the impoundment was a storage or main stream reservoir. In all reservoirs, there was a low total organic carbon concentration and low methylene blue extraction (during the only sampling period in which this measurement was made) indicating little organic pollution. Furthermore, the oxygen depletion occurred first above the sediments indicating that the oxygen depletion was primarily caused by the biochemical and chemical oxygen demand of the sediments rather than by the decomposition of the relatively small phytoplankton population which settle after death to the hypolimnion from the epilimnion. The effect of such low oxygen concentrations upon the ecology of these impoundments is obvious.

There appeared to be a significant decrease in the chemical content of the Colorado River as it entered the headwaters of Lake Buchanan. Decreases in bacteria and phytoplankton also might have occurred. The mechanism of removal is not known at this time.

The chemical concentration of the impoundment increased as sampling proceeded downstream. Also, the chemical concentration increased from winter to summer due to less flow and higher evaporation in the summer months. Chemical stratification occurred only in those impoundments that had a stable temperature stratification.

The water quality of the peaking power releases from the impoundment was directly related to whether a stable temperature stratification existed in the impoundment. Only three impoundments, Lakes Buchanan, Johnson and Travis, fulfilled these conditions. For such conditions, the process of selective withdrawal probably occurred during peaking power releases from these impoundments. Because the penstocks of Lakes Buchanan and Travis are located at a great depth, water was withdrawn from the hypolimnion which contained little dissolved oxygen. From Lake Johnson a gate near the top of the dam fed water to the penstock and thus water with a high dissolved oxygen concentration was released downstream.

Chapter 6

RESEARCH

This investigation of the Highland Lakes demonstrated that many voids exist in our knowledge of and ability to predict the water quality changes which occur by impounding a river. The following are areas in which research is being conducted or hopefully will be started during the second year of the project.

I. Studies during various seasons of the year to determine why there appears to be a decrease in chemicals, bacteria and phytoplankton as the Colorado River enters Lake Buchanan.

II. An investigation to determine the causes of oxygen depletion in the lower waters of all these impoundments.

   A. Development of dissolved oxygen and pH probes capable of accurate in situ measurement in deep reservoirs.

   B. Detailed studies on the rate of oxygen decrease in the hypolimnion.

   C. In situ determination of the biochemical and chemical oxygen demand of the sediments.

   D. Development of a waste assimilative capacity model for reservoirs.

E. Determination of the distribution and kinds of bottom fauna relative to the dissolved oxygen concentration and season in lower depths of selected lakes.

III. Development of a model to determine the coliform dieoff rate in stratified impoundments.

A. Laboratory studies controlling those variables which are radically different in the hypolimnion and epilimnion.

B. Field measurements using coliform bacteria placed in dialysis bags located at different depths.

C. Determination of the concentrations of fecal coliform and fecal streptococci in impoundments under investigation for establishment of ratios pursuant to human vs non-human concentrations.

IV. Studies on the phytoplankton cycles.

A. Relationship between the phytoplankton concentrations and the light penetration of different wavelengths.

B. Determination of the limiting nutrient.

1. Laboratory studies on the effect of addition of nutrients to filtered waters from the Colorado River entering and leaving the chain using unialgal cultures.

2. Laboratory studies on the addition of nutrients to the mixed population of various lake waters during different seasons.
3. Field studies using carbon 14 to determine at what concentration the limiting nutrient controls growth.
4. Field studies to determine the rate of nitrogen fixation by the phytoplankton.

V. Investigation of the water quality released from impoundments during peaking power operations.

A. Determination of the extent of selective withdrawal from an impoundment.

B. Determination of the factors affecting reoxygenation of the low oxygen waters released during peaking power operations.

C. Development of a model to determine the optimum peaking power releases if the hydroelectric agency is penalized for release of poor quality water.

VI. Continuation of seasonal sampling in Lakes Travis, Austin, Town and Decker so that with these data, the data reported in this study, and data obtained in previous studies in 1966 and 1967 the significance of different water quality characteristics can be evaluated over a long term.

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APPENDIX

Table A-1

Rainfall Data for Austin for Periods During Which Phytoplankton Counts were Conducted. Values are in Inches.

Month	1966	1967	1968	10 yr. Aug.
January	1.58	0.25	7.94	2.03
February	3.23	1.52	1.64	2.59
March	0.50	1.09	2.09	1.06
April	3.74	4.44	1.87	2.56
May	3.13	3.35	8.75	3.30
June	1.53	trace	3.10	4.24
July	0.47	1.15	3.11	2.15
August	6.21	3.71	0.74	3.15
September	3.22	5.71	3.42	3.59
October	0.60	4.55	0.60	3.68
November	0.11	4.36	4.91	2.36
December	0.87	3.41	0.55	2.20
TOTAL	25.19	33.54	38.72	32.90

Table A-2

Calculated Detention Times in the Highland Lakes for the Months of 1968. Quotations are in Days.

Month	Buchanan	Inks	Johnson	Marble Falls	Travis	Austin
January	78	3	10	<1	68	<1
February	410	7	36	2	222	<1
March	148	3	13	<1	99	2
April	204	3	19	1	132	2
May	99	2	10	<1	79	1
June	358	5	34	2	182	2
July	675	20	100	7	492	3
August	218	12	87	<1	630	6
September	173	41	190	15	975	10
October	4500	48	300	19	1795	46
November	2110	80	417	30	1940	294
December	1768	42	310	16	1295	233

Table A-3

Evaporation Measurements of the Highland Lakes
Values are in Acre-feet.

	Lake Buchanan			Lake Inks		
Month	1966	1967	1968	1966	1967	1968
Jan.	4,043	4,962	2,139	145	169	68
Feb.	3,837	5,720	4,497	137	210	156
Mar.	5,728	8,700	5,515	202	324	192
Apr.	5,766	9,689	7,245	204	361	< 52
May	10,435	12,478	8,340	364	458	290
June	14,870	15,867	9,229	525	583	314
July	18,155	17,991	17,441	649	679	580
Aug.	15,593	15,336	16,121	570	604	584
Sept.	9,783	9,003	9,564	345	360	351
Oct.	9,358	8,997	8,762	335	352	322
Nov.	7,368	5,187	6,740	267	201	248
Dec.	6,316	4,653	5,538	229	181	203
TOTAL	111,252	118,313	101,131	3,972	4,482	3,560

	Lake Johnson			Lake Marble Falls		
Month	1966	1967	1968	1966	1967	1968
Jan.	1,142	1,328	675	127	146	75
Feb.	1,201	1,547	1,174	127	181	131
Mar.	1,843	2,441	1,578	195	181	176
Apr.	1,949	2,901	1,875	217	323	209
May	2,485	3,538	2,385	276	394	266
June	3,966	4,667	2,710	442	520	302
July	4,890	5,419	4,305	545	383	482
Aug.	4,239	4,818	4,686	472	537	522
Sept.	2,784	2,906	2,794	310	324	311
Oct.	2,614	2,710	2,460	291	302	274
Nov.	2,125	1,514	1,939	237	169	216
Dec.	1,695	1,347	1,472	189	150	164
TOTAL	30,933	35,136	28,053	3,428	3,610	3,128

Table A-3
(cont'd)

Evaporation Measurements of the Highland Lakes

Values are in Acre-feet.

	Lake Travis			Lake Austin		
Month	1966	1967	1968	1966	1967	1968
Jan.	3,386	3,669	1,978	179	334	112
Feb.	3,543	5,403	3,683	263	501	173
Mar.	5,809	7,326	5,184	486	400	417
Apr.	6,974	7,993	5,610	584	783	446
May	6,461	8,721	8,115	533	875	628
June	10,852	11,172	9,637	963	1,200	746
July	12,575	12,426	12,016	1,178	1,389	1,033
Aug.	10,408	10,603	13,055	1,002	1,217	1,207
Sept.	7,483	6,157	7,632	720	726	715
Oct.	7,287	6,165	6,359	655	670	604
Nov.	5,852	3,334	5,119	534	363	484
Dec.	4,337	2,989	3,663	401	321	354
TOTAL	84,967	85,958	82,051	7,498	8,779	6,919

Table A-4

Seasonal Change and Daily Variation in Solar Radiation During 1968. Values Reported are in Langleys *

Date	L	Date	L	Date	L	Date	L
Jan. 1	.35	Feb. 17	.19	April 4	1.37	May 21	1.28
2	.45	18	.54	5	1.40	22	.98
3	.10	19	.46	6	1.31	23	.98
4	.13	20	1.16	7	1.07	24	
5	.15	21	.35	8	.98	25	
6	.35	22	.13	9	.99	26	
7	.72	23	.58	10	1.10	27	1.17
8	.15	24	1.19	11	.36	28	1.28
9	.15	25	1.15	12	1.37	29	1.29
10	.25	26	1.16	13	1.28	30	1.30
11	.35	27	1.08	14	.68	31	1.18
12	.80	28	.26	15	1.27	June 1	.97
13	.95	29	1.35	16	.87	2	1.17
14	.95	Mar. 1	1.15	17	.48	3	1.15
15	.70	2	1.16	18	.47	4	1.19
16	.95	3	1.26	19	.68	5	1.07
17	.65	4	.75	20	1.07	6	.97
18	.15	5	.35	21	.97	7	
19	.75	6	.95	22	.97	8	
20		7	1.26	23	.47	9	
21		8	.26	24	1.38	10	1.30
22	.25	9	1.27	25	1.37	11	1.30
23	.36	10	1.17	26	1.36	12	1.20
24	.96	11	.25	27	1.27	13	
25	.97	12	1.24	28	1.06	14	
26	.42	13	1.35	29	1.36	15	
27	.12	14	1.15	30	1.32	16	
28	.12	15	.56	May 1	1.32	17	1.15
29	.40	16	1.26	2	1.07	18	1.27
30	.28	17	.86	3	1.06	19	.97
31	.72	18	.46	4	1.17	20	.97
Feb. 1	.81	19	.26	5	1.19	21	1.06
2	.95	20	.95	6	.98	22	1.16
3	1.16	21	.74	7	.47	23	
4	.98	22	1.35	8	.98	24	1.35
5	1.0	23	1.35	9	.97	25	1.05
6	.96	24	1.40	10	.66	26	1.23
7	1.10	25	1.35	11	.27	27	1.28
8	1.05	26	1.47	12	.36	28	1.32
9	.90	27	.47	13	1.16	29	1.22
10	.25	28	.57	14	.67	30	1.33
11	1.05	29	.66	15	.98	July 1	1.25
12	1.05	30	.96	16	1.08	2	1.23
13	.40	31	1.06	17	.57	3	1.03
14	.09	April 1	.45	18	1.37	4	1.13
15	.84	2	.77	19	1.32	5	1.26
16	.34	3	1.18	20	1.33	6	

* (Mean maxima for 24 hour period)

Table A-4 (cont'd)

Seasonal Change and Daily Variation in Solar Radiation During 1968.

Values Reported are in Langleys *

Date	L	Date	L	Date	L	Date	L
July 7		Aug. 23	1.22	Oct. 9	.90	Nov. 25	.90
8		24	1.01	10	1.15	26	.40
9		25		11	.80	27	.20
10	1.15	26	1.16	12	.90	28	.90
11	1.13	27	1.16	13	1.05	29	.29
12	1.20	28	1.25	14	1.11	30	.10
13	1.23	29	1.22	15	1.02	Dec. 1	.90
14	1.14	30	1.12	16	.85	2	.40
15	1.24	31	.61	17	1.10	3	1.00
16	1.14	Sept. 1	1.22	18	1.00	4	1.00
17		2		19	1.00	5	.90
18		3	1.19	20	1.00	6	.90
19		4	.83	21	.91	7	1.00
20		5		22	.81	8	.90
21		6		23	.91	9	.30
22	1.30	7		24	1.05	10	.30
23	1.33	8		25	1.00	11	.70
24	1.30	9	1.14	26	1.00	12	.90
25	1.32	10	1.03	27	.90	13	.98
26	1.27	11	1.23	28	1.01	14	.90
27	1.33	12	1.22	29	1.01	15	
28	1.35	13	.45	30	.90	16	.50
29	1.25	14	.15	31	.80	17	.71
30	1.25	15	1.17	Nov. 1	.92	18	.81
31	1.34	16	1.17	2	.92	19	.15
Aug. 1	1.23	17	1.27	3	.90	20	.10
2	1.23	18	1.21	4	1.00	21	.80
3	1.23	19	1.25	5	.80	22	.90
4	1.22	20	1.15	6	.90	23	.95
5	1.25	21	1.10	7	.89	24	.95
6	1.36	22	1.00	8	.15	25	.70
7	1.26	23	1.11	9	.90	26	.40
8	1.25	24	1.11	10	.99	27	.70
9	1.20	25	1.20	11	1.00	28	.80
10	1.25	26	1.20	12		29	.70
11	1.18	27	1.21	13		30	.40
12	1.25	28	.90	14		31	.50
13	1.34	29	1.15	15	.90		
14	1.29	30	1.10	16	.80		
15	1.23	Oct. 1	1.11	17	.90		
16	1.23	2	1.20	18	.92		
17	1.33	3	.90	19	.93		
18	1.23	4	.40	20	.92		
19	1.15	5	.80	21	.91		
20	.84	6	1.15	22	.40		
21	.74	7	.90	23	.91		
22	1.23	8	.90	24	.91		

* (Mean maxima for 24 hour period)

Table B-1

Temperature - Lake Buchanan

Sea Level Elevation	Date 2/10/68	4/6/68	6/12/68	7/12/68	10/5/68	1/30/69
1019	10.5	14.7	26.8	27.3	25.8	11.1
1009		14.7	26.3	27.3	25.4	
				27.3		
999	10.5	14.5	25.8	27.3		
					25.4	
989	10.5	14.5	25.3	27.3		
979		14.5	24.8	26.8	25.4	10.6
	10.0		23.4	25.8	25.4	
969		14.5	22.9	24.4		
	10.0		20.5	23.9	25.4	
959		14.4	20.0			
	9.0	13.6	18.0	22.0	25.4	9.8
949		12.9	17.6	20.5	24.2	
	8.5			20.0	23.4	
939		12.7	16.1	16.6		
	8.5				20.1	
929		12.4	14.2	15.7	18.3	
	8.0	12.0				
919		11.8	14.2			
	8.0	11.8	13.7	15.2	16.8	9.4
909						

Table B-2

Temperature - Lake Inks

Sea Level Elevation	Date 2/23/68	 4/6/68	 6/12/68	 7/12/68	 10/5/68	
887	9.0	15.8	25.4	27.8	25.4	
877		15.6	22.5	26.3	25.0	14.5
	9.0	14.9				
867		14.7	20.5	23.4	25.0	
	8.6					
857		14.5	20.0	22.5	24.6	
	8.6					
847		13.7	20.0	22.0	24.6	12.0
	8.6					
837		13.3	20.0	21.0	24.6	
		12.9				
827			18.5	19.5	23.8	11.0

Table B-3

Temperature - Lake LBJ

	Date					
Sea Level Elevation	2/24/68	4/27/68	6/19/68	7/20/68	10/19/68	
825	10.2	22.0	29.1	29.2	24.2	
						13.0
815	9.8	21.4		27.8	24.2	
		20.5	24.8			
805	9.3	20.5	24.0	27.8	23.7	
		19.0	23.5			
795	9.3	17.5		26.8	23.7	
			22.5	25.4		12.5
785	9.3	16.5		22.9	23.7	
			22.0			
775	9.3	15.5	21.0	21.5	23.7	
765	9.3	15.3	20.5	20.0	23.7	
		14.7			21.0	12.0
755	9.3	14.0	20.0	19.0	20.5	
			18.0			
745		11.7	17.5	17.6	19.5	
			17.0	17.1	19.0	11.5
735						

Table B-4

Temperature - Lake Marble Falls

Sea Level Elevation	Date					
	2/25/68	4/27/68	6/26/68	7/27/68	10/19/68	2/1/69
738	10.2	21.4	26.8	30.0	25.2	14.0
728	9.8	20.8	26.3	30.0	25.2	
	9.4					
718	9.8	20.6	25.8	29.5	24.7	
		20.5				
708	9.4	19.7	25.8	29.1	24.7	13.5
698	9.0	19.4	25.8	27.8	24.7	
	8.6	19.2				
688	8.6	19.0	25.3	27.8	24.7	13.0
			25.3	27.3		
678	8.6	18.5				
668						

Table B-5

Temperature - Lake Travis

Date

Sea Level Elevation	2/2/68	3/16/68	3/22/68	5/4/68	7/2/68	8/9/68	10/26/68	
692	13.6							
682					29.2			
				23.2		30.5		
	13.0	12.5	12.2					13.8
							24.7	
672					28.3			
				23.2		30.0		
	13.1	11.6	12.2					
					27.8		24.7	
662								
				22.5		29.5		
	13.0	11.6	12.2					
					27.3		24.7	
				22.0				
652								
						29.5		
	12.3	11.2	12.2	22.0				
							24.7	
642					27.3			
				19.5		29.0		
	12.3	11.2	13.2					
632					25.3		24.7	
				18.0		28.2		
	12.1	11.2	11.8		24.4			
622								
					23.0		24.2	
	12.0	11.2	11.8	17.5		25.6		
612								
					22.5		24.2	
	10.9	10.9	11.8	15.7		25.2		
602								13.4
							24.2	
					22.0			
	10.9	10.9	11.8	14.2				
592								
						23.9		
					22.0			
	9.9	10.9	11.8	13.7			24.2	
582						23.9		
					21.0			
							24.2	
	9.8	10.4	11.6	13.6				
572						22.5		
					20.0			
	9.8	10.4	11.6	13.2			24.2	
562						22.1		
					19.5			13.0
	9.2	10.4	11.6	12.2			22.3	
552								
						21.2		
					18.5			
	9.2	10.4	11.6	12.0			21.8	
542								
			11.5			20.3		
					17.5		20.5	
532	9.7	10.4	10.8	11.5				
						18.6		
					14.2			
							18.3	
522		10.4	10.8	11.5		15.1		
					12.2		15.6	
512		10.4	10.4	11.4		14.2		
								12.5
					11.7		14.7	
502		10.4	10.4	11.4		13.8		
							14.7	
					11.7			
492			10.4				14.7	
482							14.2	

Table B-6

Temperature - Lake Austin

Sea Level Elevation	Date					
	3/22/68	5/10/68	7/10/68	8/2/68	11/2/68	1/27/69
493	11.5	11.2	23.4	28.7	22.8	18.0
	11.5			28.3		
483	11.5	16.2	22.5	25.2	22.8	
	10.8					
473		15.8	21.5	24.7	22.8	
	10.8					
				24.3		
	10.8					
463		15.5	21.5	24.3	22.8	
	10.8					
	10.8					
453		14.8	21.5	23.8	22.3	
	10.8					
	10.8					
443		14.2	21.5	23.4	22.3	
	10.8					16.0
					22.3	
		14.2				
433						

TABLE C-1

Phytoplankton Distribution in the Highland Lakes by Division, Genus, Areal Standard Units Per Milliliter and Numbers Per Milliliter

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Colorado River at Bend, Surface 2/9/68 Total ASU/No: 3.6/5				
Aphanizomenon 0.4/1		Diatom lsp 1.0/2		Gymnodinium 1/1
		Navicula 1.2/1		
Colorado River at Bend, Surface 4/6/68 Total ASU/No: 80.2/66				
Aphanizomenon 2/1	Pediastrum 2/1	Cyclotella 55.2/46		
	Closterium 6/2	Tabellaria 8/11		
Colorado River at Bend, Surface 6/13/68 Total ASU/No: 53.6/60				
	Scenedesmus 15.8/11	Diatoms 2.7/2	Euglena 12.4/17	
	Closterium 8/7	Navicula 4.9/9	Phacus 2.8/2	
	Polytoma 2/10	Gyrosigma 5/2		
Colorado River at Bend, Surface 7/11/68 Total ASU/No: 136.4/214				
Chroococcus 0.4/1	Scenedesmus(3) 73.6/126	Diatom(4) 11.0/37	Euglena 3.2/3	
Merismopedia 0.6/1	Pediastrum 32/11			
	Closterium 2.3/4			
	Ankistrodesmus 11.7/28			
	Coelastrum 1.6/3			
Colorado River at Bend, Surface 10/4/68 Total ASU/No: 61.1/136				
Spirulina 3.0/18	Scenedesmus 18.2/47	Diatom(2) 12.1/40	Phacus 3/3	
Phormidium 0.4/2	Pediastrum 10.6/8		Euglena 8.4/8	
Merismopedia 0.7/2	Coelastrum 3.8/6			
	Closterium .5/1			
	Ankistrodesmus .4/1			

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Buchanan Pool, Surface	2/9/68 Total ASU/No:	11.4/10		
Microcystis 2/1	Chlorococcum 2/4 Cosmarium 3/1	Diatom 1sp 3/3 Cyclotella 1.4/1		
Buchanan Pool, 55 Feet	2/9/68 Total ASU/No:	13.9/17		
Aphanizomenon 0.5/1	Cosmarium 5.4/5 Chlorococcum 4/8 Desmid (1) 2/1	Tabellaria 2/2		
Buchanan Pool, 105 Feet	2/9/68 Total ASU/No:	5/2		
	Cosmarium 2/1 Pediastrum 3/1			
Buchanan Pool, Surface	4/6/68 Total ASU/No:	16/49		
Aphanizomenon 7/40	Closterium 3/1 Eudorina 4/7		Euglena 2/1	
Buchanan Pool, 30 Feet	4/6/68 Total ASU/No:	10/10		
	Closterium 3/1 Arthrodesmus 2/1 Polytoma 0.2/1	Anthrospira 0.8/1 Navicula 1.5/4 Cymbella 1/1 Tabellaria 1.5/1		
Buchanan Pool, 80 Feet	4/6/68 No Count			
Buchanan Pool, 103 Feet	4/6/68 Total ASU/No:	8/3		
	Closterium 4/1	Nitzschia 4/2		

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Buchanan Pool, Surface	6/13/68 Total ASU/No:	119.9/78		
Microcystis 23/20	Cosmarium 3.4/2 Pleodorina 8.5/8 Pediastrum 28/2 Pyrobotrys 23/22 Staurastrum 17/5 Closterium 11/3 Chlorella 6/16			
Buchanan Pool, 50 Feet	6/13/68 Total ASU/No:	20.7/13		
	Pleodorina 9.7/6 Closterium 6/2 Pyrobotrys 5/5			
Buchanan Pool, 105 Feet	6/13/68 No Count			
Buchanan Pool, Surface	7/12/68 Total ASU/No:	94.3/51		
Microcystis 46/7 Oscillatoria 1.3/2 Nodularia 4/2 Anabaena 2/4	Coelastrum 2.5/1 Staurastrum 11.6/9 Oocystis 8.6/15 Pediastrum 13/2 Actinastrum 1.2/1 Ankistrodesmus 3.2/7	Cyclotella 0.9/1		
Buchanan Pool, 45 Feet	7/12/68 Total ASU/No:	11.4/5		
Microcystis 7.5/2	Closterium 1.1/1 Staurastrum 1.6/1		Trachelomonas 1.2/1	
Buchanan Pool, Bottom	7/12/68 Total ASU/No:	10.9/5		
Phormidium 0.4/3 Microcystis 4.5/1	Pediastrum 6/1			

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Buchanan Pool, Surface	10/5/68 Total ASU/No: 94.9/39			
	Coelastrum 5/3 Staurastrum 9.1/5 Ankistrodesmus 9.7/11 Pediastrum 66/5 Scenedesmus .7/2	Diatom 2.8/11	Euglena 1/1 Phacus .6/1	
Buchanan Pool, 65 Feet	10/5/68 Total ASU/No: 67.3/38			
Phormidium .3/2 Chroococcum .6/2	Pediastrum 51/7 Coelastrum 5.1/5 Ankistrodesmus 2.2/5 Staurastrum 4.0/3 Scenedesmus .3/1	Diatoms 3.8/13		
Buchanan Pool, 100 Feet (Bottom)	10/5/68 Total ASU/No: 28.1/16			
Phormidium .2/2	Scenedesmus 0.8/2 Coelastrum 0.8/1 Pediastrum (colorless) 23/1	Diatom 3.3/10		
Buchanan Pool, Surface	1/8/69 Total ASU/No: 35.2/46			
Phormidium 0.2/1	Staurastrum 10.4/5 Coelastrum 1.3/2 Ankistrodesmus 2.6/3	Diatoms 3spp 20.7/35		
Buchanan Release, Surface	4/6/68 Total ASU/No: 46.8/109			
Aphanizomenon 18/96	Closterium 10/4 Pyrobotrys 2/1 Pediastrum 3.8/1	Tabellaria 10/5 Diatoma 2/1 Diatom 1sp 1/1		
Inks Pool, Surface	2/9/68 Total ASU/No: 5.0/3			
	Pyrobotrys 2/1	Fragilaria 2/1 Diatom 1sp 1/1		

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Inks Pool, 25 Feet 2/24/68 Total ASU/No: 31.2/18				
Anabaena 3/1	Phytoconis 1.2/1 Pediastrum 4/1	Nitzschia 2/2 Fragilaria 15/9 Diatom 2spp 2/2 Synedra 4/2		
Inks Pool, 45 Feet 2/24/68 Total ASU/No: 10.0/10				
Anabaena 0.5/1		Synedra 4/2 Diatoma 5.5/7		
Inks Pool, Surface 4/6/68 Total ASU/No: 26.7/17				
	Chlorococcum 0.5/1 Closterium 4/1 Scenedesmus 2.9/2	Navicula 3/1 Tabellaria 4.2/3 Cyclotella 1/1 Diatom 2spp 3.9/6	Phacus 6/1	
Inks Pool, 30 Feet, 4/6/68 Total ASU/No: 21/17				
	Polytoma 0.5/2 Closterium 3/1	Navicula 4.5/3 Cyclotella 5/7 Tabellaria 8/4		
Inks Pool, 53 Feet 4/6/68 Total ASU/No: 24.4/8				
	Ankistrodesmus 0.4/1 Pediastrum 10/1	Navicula 4/2 Nitzschia 10/4		
Inks Pool, Surface 6/13/68 Total ASU/No: 22.8/20				
	Pediastrum 15/2 Stephanoptera 7.2/13 Polytomella 0.6/5			
Inks Pool, 30 Feet 6/13/68 Total ASU/No: 26.8/36				
	Pyrobotrys 9/3 Pediastrum 3/1 Polytomella 2.1/26 Scenedesmus 6/1	Diatoma 2.1/2	Euglena 1.1/1	Ceratium 3.5/2

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Inks Pool, 58 Feet 6/13/68 Total ASU/No: 3.4/3				
	Closterium 2/1 Scenedesmus .5/1		Lepocinclis .9/1	
Inks Pool, Surface 7/12/68 Total ASU/No: 183.1/57				
Anabaena 2/1	Coelastrum 0.8/1 Pediastrum 74/6 Staurastrum 1.5/1 Scenedesmus 1.0/3 Mougeotia 3/1 Eudorina 5/1	Dinobryon 23/29 Diatom 1.0/4 Uroglenopsis 4/1	Euglena 1/1	Ceratium 10/2 Peridinium 6.8/6
Inks Pool, 20 Feet 7/12/68 Total ASU/No: 73.4/32				
	Pediastrum 58/7 Closterium 1.5/3 Staurastrum 2/1 Coelastrum 1.4/2 Scenedesmus 0.4/1	Diatom (2) 7.1/16 Dinobryon 2/2		Peridinium 1/1
Inks Pool, Bottom 58 Feet 7/12/68 Total ASU/No: 45.8/7				
	Pediastrum 43/2 Scenedesmus 0.3/1	Diatom 0.5/2 Dinobryon 1/1	Euglena 1/1	
Inks Pool, Surface 10/5/68 Total ASU/No: 59.8/55				
Phormidium 1.8/15 Spirulina 0.4/3 Merismopedia 0.5/1	Pediastrum 37/5 Scenedesmus 1.0/3 Staurastrum 4.7/4 Ankistrodesmus 0.5/2	Diatom 4.5/18	Trachelomonas 0.8/1	Ceratium 7.6/2 Peridinium 1/1

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Inks Pool, 30 Feet 10/5/68 Total ASU/No: 106.8/104				
Phormidium 1.7/14 Merismopedia 1.8/3 Spirulina 0.4/4 Anabaena 0.7/1	Scenedesmus 2.8/11 Cosmarium 0.9/1 Pediastrum 67/8 Ankistrodesmus 1.2/5 Staurastrum 3.5/3	Diatoms(4) 14.8/46	Phacus 2/2 Euglena 9.0/5	Peridinium 1/1
Inks Pool, Bottom 57 Feet 10/5/68 Total ASU/No: 52.4/64				
Merismopedia 2.1/5 Phormidium 0.1/1	Scenedesmus 5.7/15 Pediastrum 30/4 Staurastrum 1.3/1	Diatoms (5) 12.2/37	Euglena 1/1	
Inks Pool, Surface 1/8/69 Total ASU/No: 65.4/36				
	Pediastrum 50/4 Ankistrodesmus 3.4/4 Scenedesmus 1.2/4	Diatoms 2spp 10.8/24		
Inks Release, Surface 2/24/68 Total ASU/No: 14.5/17				
	Cosmarium 3/1	Diatom 4spp 4/6 Fragilaria 5.5/9 Synedra 2/1		
Llano, Surface 2/24/68 Total ASU/No: 74.7/90				
	Pleodorina 2/1	Nitzschia 1.2/2 Fragilaria 65/76 Diatom 2spp 2.5/8 Navicula 2/2	Trachelomonas 2/1	
Llano, Surface 4/6/68 Total ASU/No: 11.4/12				
	Ankistrodesmus 3.5/6	Diatom 1sp 4.9/5	Euglena 3/1	

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Llano, 10 Feet 4/6/68	Total ASU/No: 28.6/26			
	Closterium 1/1	Fragilaria 1.8/1	Phacus 5/2	
	Scenedesmus 2/2	Diatoma 2/4	Euglena 1/1	
	Ankistrodesmus 0.5/2	Cymbella 1.8/2		
	Pediastrum 3/1	Navicula 1.8/2		
	Pyrobotrys 2/1	Diatom 3spp 8/8		
Llano, Surface 6/19/68	Total ASU/No: 38.2/40			
	Carteria 1.2/1	Diatom (5spp) 15.5/28	Euglena (3) 9/4	
	Scenecesmus(3) 5.5/5			
	Pandorina 4/1			
	Pyrobotrys 3/1			
Llano, Surface 7/20/68	Total ASU/No: 40.5/98			
Spirulina 1.9/11	Ankistrodesmus 4.6/22	Navicula 0.2/1	Euglena 8/5	Peridinium 7.5/8
Chroococcum 1.5/1	Pyrobotrys 0.9/1	Diatom 2spp 0.2/2		
Phormidium 3.2/20	Pandorina 1.5/1			
Agmenellum 0.7/1	Micractinium 3.9/2			
Oscillatoria 0.5/3	Chlorella 1.9/19			
	Pediastrum 4/1			
Llano, Surface 10/12/68	Total ASU/No: 58.2/83			
Phormidium 2.9/27	Coelastrum 2.2/2	Diatom (3) 9.8/27	Euglena 12.2/9	Ceratium 22.4/7
Merismopedia 0.4/1	Scenedesmus 1.1/3		Trachelomonas 0.8/1	
Spirulina 0.4/3	Pediastrum 3/1			
	Pandorina 2/1			
Llano, Bottom 10 Feet 10/12/68	Total ASU/No: 40.7/89			
Phormidium 4.4/44	Scenedesmus 1.4/5	Diatoms (4) 9.5/26	Phacus 1.6/1	Ceratium 15.0/4
Spirulina 0.1/1	Pediastrum 2/1		Euglena 4.5/4	Peridinium .9/1
Anabaena 0.5/1			Trachelomonas 0.8/1	

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Llano & Colorado, Surface 2/24/68 Total ASU/No:		59.5/36		
Anabaena 3/2	Pediastrum 5.5/1	Diatom (3) 9/6	Trachelomonas 2/1	
	Ankistrodesmus 10/15	Diatom (2) 13/7		
		Nitzschia 3/2		
		Tabellaria 14/2		
Llano & Colorado, 33 Feet 2/24/68 Total ASU/No:		78.5/105		
	Scenedesmus 1/1	Diatom 3spp 5.5/5		
	Pediastrum 4/1	Fragilaria 52/91		
		Cymbella 2/1		
		Diatom 2/1		
		Navicula 2/1		
		Tabellaria 10/4		
Llano & Colorado, Surface 4/6/68 Total ASU/No:		16.9/17		
	Desmid 2spp 1.2/1	Cyclotella 4/3		
	Closterium 3/4	Diatom 3spp 6/6		
	Scenedesmus 0.7/1			
	Pediastrum 2/1			
Llano & Colorado, 15 Feet 4/6/68 Total ASU/No:		44/45		
	Closterium 6/3	Diatom 4spp 14/20	Phacus 2/1	
	Pyrobotrys 1/1	Navicula 2/3	Euglena 4/1	
	Scenedesmus 1/1	Diatom 3spp 13/14		
		Cyclotella 1/1		
Llano & Colorado, 22 Feet 4/6/68 Total ASU/No:		31.6/23		
	Pediastrum 5/1	Diatom 4spp 11/9		
	Scenedesmus 1/1	Nitzschia 1.2/1		
	Chlorococcum 1.2/3	Navicula 0.7/1		
		Tabellaria 1.5/1		
		Diatom 2spp 10/6		

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Llano & Colorado, Surface 6/19/68 Total ASU/No: 77.7/39				
Anabaena 12/7 Aphanizomenon 0.9/2 Polycystis 6/2	Coelastrum 2/1 Pediastrum 27.5/6 Scenedesmus 2.5/3 Staurastrum 3/2 Gonium 1/2 Mougeotia 14/6	Diatom 7/6	Phacus 1.8/2	
Llano & Colorado, 15 Feet 6/19/68 Total ASU/No: 66.4/21				
Anabaena 2/1 Oscillatoria 5/3 Microcystis 27/5 Aphanizomenon .9/1 Nodularia 6/1	Pediastrum(2) 21/5 Gonium 3/2	Navicula (2) .8/2 Fragilaria .7/1		
Llano & Colorado, Bottom 6/19/68 Total ASU/No: 16.5/5				
Nodularia 7/1	Closterium 3/1 Scenedesmus 2/1 Gonium 2/1 Pyrobotrys 2.5/1			
Llano & Colorado, Surface 7/20/68 Total ASU/No: 133.3/292				
Spirulina 4.6/42 Phormidium 5.7/53 Anabaena 2.9/3 Merismopedia .9/4 Chroococcum 1.3/6	Actinastrum 3.9/4 Pandorina 32.7/31 Ankistrodesmus 13.6/69 Scenedesmus .8/3 Pediastrum 14/4 Staurastrum 4.3/6 Cosmarium 1.2/3	Diatom (2) 8/32	Trachelomonas 8/14 Euglena 11.4/10 Phacus 1/1	Ceratium 14.6/3 Peridinium 4.4/4
Llano & Colorado, 25 Feet 7/20/68 Total ASU/No: 140.2/156				
Phormidium 3.0/24 Spirulina 1.1/11 Anabaena .8/1	Pediastrum 67/10 Ankistrodesmus 8.2/41 Scenedesmus 3.4/10 Pandorina 28.3/28	Diatom (2) 6.4/13	Trachelomonas 4.1/7 Euglena (3) 12.9/10	Ceratium 5/1

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Llano & Coloradc, 33 Feet Bottom 7/20/68 Total ASU/No: 239.4/273				
Phormidium 1.8/13	Pandorina 88.8/82	Diatom 11.5/61	Euglena (3) 37.6/35	Peridinium 12.2/11
Spirulina 1.6/14	Scenedesmus 6.0/16		Trachelomonas 12/21	
	Pediastrum 58/10		Phacus 1.5/2	
Llano & Colorado, Surface 10/12/68 Total ASU/No: 76.8/132				
Merismopedia 2.0/4	Pandorina 4/2	Diatoms 12.4/39	Phacus 1.8/1	Ceratium 14.9/4
Phormidium 5.4/44	Pediastrum 23.2/5		Trachelomonas 2/2	
Spirulina 1.4/14	Scenedesmus 3.5/12		Euglena 3.9/3	
Anabaena .8/1	Coelastrum 1.5/1			
Llano & Colorado, 20 Feet 10/12/68 Total ASU/No: 99.7/169				
Phormidium 6.2/61	Pediastrum 16.3/4	Diatom (4) 14.6/61	Trachelomonas 1.5/2	Peridinium 3/3
Merismopedia 5.4/6	Scenedesmus 2.0/7		Euglena 16.4/12	Ceratium 28.7/7
Anabaena 0.6/1	Staurastrum 0.6/1		Phacus 4.1/3	
Llano & Colorado, Bottom 32 Feet 10/12/68 Total ASU/No: 49.2/107				
Phormidium 3.4/34	Pediastrum 24/5	Diatoms (4) 12.9/53	Euglena 2.7/2	
Merismopedia 1.3/3	Scenedesmus 1.3/4		Trachelomonas 1.8/2	
Spirulina 3/3	Pandorina 1.5/1			
LBJ Pool, Surface 2/24/68 Total ASU/No: 18.8/13				
	Chlorococcum .5/1	Diatom 1 .5/1		
	Ankistrodesmus .8/2	Synedra 4/1		
	Staurastrum 1/1	Fragilaria 3/6		
	Pediastrum 9/1			
LBJ Pool, 30 Feet 2/24/68 Total ASU/No: 9.9/4				
	Pediastrum 5/1	Diatom 1sp 1/1		
		Fragilaria .9/1		
		Synedra 3/1		

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
LBJ Pool, 75 Feet 2/24/68 Total ASU/No: 9/3				
	Oedogonium 5/1	Nitzschia 4/2		
LBJ Pool, Surface 4/27/68 Total ASU/No: 41/63				
Anabaena 23/58	Closterium 2/1		Euglena 5/1	Ceratium 9/2
Chroococcus 2/1				
LBJ Pool, 50 Feet 4/27/68 Total ASU/No: 3.4/3				
	Scenedesmus .4/1	Fragilaria 2/1		
	Closterium 1/1			
LBJ Pool, 80 Feet 4/27/68 Total ASU/No: 2.3/2				
Sacconema .8/1			Trachelomonas 1.5/1	
LBJ Pool, Surface 6/19/68 Total ASU/No: 261.5/113				
Anabaena 8.5/16	Chlorella 11.9/35	Diatoma 3/1		Gonyaulax 2.1/4
Microcystis 195/23	Closterium 2/4	Diatom 2spp 1.4/5		
Aphanizomenon 1.8/3	Crucigenia 7/13			
	Pediastrum 19/4			
	Staurastrum 8/2			
	Scenedesmus 1.8/3			
LBJ Pool, 20 Feet 6/19/68 Total ASU/No: 212.7/63				
Anabaena 8.2/6	Pediastrum(2) 136/15	Diatom 1.7/3	Euglena 9/3	
Polycystis 8/3	Coelastrum 24.5/25		Phacus .9/1	
	Scenedesmus 2/2			
	Mougeotia 2/1			
	Staurastrum 4.4/2			
	Desmidium 6/1			
	Eudorina 10/1			
LBJ Pool, Bottom 83 Feet 6/19/68 Total ASU/No: 5.5/5				
	Polytoma .6/3		Trachelomonas 4/1	
	Closterium .9/1			

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
LBJ Pool, Surface 7/20/68 Total ASU/No: 44/112				
Spirulina 3.2/8	Ankistrodesmus 18/69	Navicula 3.4/8		Peridinium 1.5/1
Phormidium 7.5/17	Staurastrum 1.5/1			
Anabaena 5.2/4	Micrastinium 3/1			
	Closterium .5/1			
	Chlorella .2/2			
LBJ Pool, 10 Feet 7/20/68 Total ASU/No: 50.7/77				
Phormidium 3.1/18	Scenedesmus 1.8/7	Diatoms (3) 7.7/40	Euglena 2.6/3	
	Coelastrum 1.5/2		Trachelomonas .7/1	
	Pandorina 2.3/2			
	Pediastrum 31/4			
LBJ Pool, Bottom 83 Feet 7/20/68 Total ASU/No: 41.6/24				
Phormidium .9/7	Pediastrum 36/3	Diatom (2) .8/3	Trachelomonas .8/1	
	Scenedesmus 2.5/9			
	Actinastrum .6/1			
LBJ Pool, Surface 10/19/68 Total ASU/No: 62.8/26				
Phormidium .2/2	Pediastrum 46/8	Diatom 1.7/5	Phacus 2.5/2	Ceratium 7.7/2
	Coelastrum 1/1		Euglena 1.8/1	
	Cosmarium .4/1			
	Scenedesmus 1.1/3			
	Ankistrodesmus .4/1			
LBJ Pool, 65 Feet 10/19/68 Total ASU/No: 49.5/21				
Merismopedia .7/1	Pediastrum 39/5	Diatoms .7/2	Euglena 6.9/4	
Phormidium .4/4	Ankistrodesmus .4/1			
	Scenedesmus 1.4/4			
LBJ Pool, Bottom 80 Feet 10/19/68 Total ASU/No: 10.0/18				
	Pediastrum 1/1	Diatoms 5.1/13	Euglena 3.2/2	
	Scenedesmus .7/2			

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
LBJ Pool, Surface 1/8/69 Total ASU/No: 53.2/14				
Phormidium .2/2	Pediastrum 48/6	Diatoms 1sp 2.2/4	Euglena 2.8/2	
LBJ Release, Surface 2/24/68 Total ASU/No: 26/10				
	Oedogonium 16/1 Micractinium 2/1 Closterium 3/1	Diatom 3sp 5/7		
LBJ Release, Surface 4/27/68 Total ASU/No: 10/10				
Anabaena 2/7	Pyrobotrys 4/2 Closterium 4/1			
Marble Falls Pool, Surface 2/24/68 Total ASU/No: 8.2/7				
	Scenedesmus 1/1	Tabellaria 1/1 Diatom 1 1.7/2 Amphipleura 2/1 Cymbella 1.5/1 Diatoma 1/1		
Marble Falls Pool, 30 Feet 2/24/68 Total ASU/No: 22.7/12				
Aphanizomenon 1.2/1	Ankistrodesmus 4/2 Pediastrum 4/1 Staurastrum 2/1	Navicula .8/1 Diatoma 1.8/1 Diatom 1 3/2 Synura .9/1 Cymbella 1/1	Euglena 4/1	
Marble Falls Pool, 58 Feet 2/24/68 Total ASU/No: 17.5/16				
	Scenedesmus .5/1 Chlorococcum .5/2	Diatom 3spp 12.5/11 Cymbella 2/1	Euglena 2/1	
Marble Falls Pool, Surface 4/27/68 Total ASU/No: 30.5/26				
Anabaena 13.5/10	Closterium 4/2 Pyrobotrys 6/6	Fragilaria 1/1 Tabellaria 2/1 Diatom 3spp 4/6		

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Marble Falls Pool, 25 Feet 4/27/68 Total ASU/No: 26.2/20				
Anabaena 3/2 Chroococcus 2/2	Pyrobotrys 12/5	Nitzschia 7.7/10 Navicula 1.5/1		
Marble Falls Pool, 57 Feet 4/27/68 Total ASU/No: 22/21				
	Closterium 2/1 Pyrobotrys 2/1	Navicula 6/4 Tabellaria 5/2 Cyclotella 1/1 Fragilaria 6/12		
Marble Falls Pool, Surface 6/26/68 Total ASU/No: 245.8/148				
Phormidium 6.8/18 Anabaena 4.7/4	Staurastrum 9.3/4 Pediastrum 123.8/21 Pandorina 12/5 Coelastrum 4.4/6 Chlamydomonas 1.8/8 Scenedesmus 3.0/6 Mougeotia 2.4/4 Eudorina 7.5/3 Closterium 1.8/2 Cosmarium 1.2/1 Pleodorina 17/1	Dinobryon 17.3/23 Diatom (3) 13.5/31	Euglena(2) 12/6 Trachelomonas 4/4	Ceratium 3/1
Marble Falls Pool, 20 Feet 6/26/68 Total ASU/No: 125.7/101				
Anabaena 4.4/5 Phormidium 2.9/6 Chroococcus .6/2	Pediastrum 57.4/10 Scenedesmus 3.2/6 Eudorina 2/1 Closterium 6.2/6 Chlamydomonas .4/2 Ankistrodesmus 2/3 Coelastrum 4.5/5 Mougeotia 1/1 Desmidium 3/1	Diatom (3) 24.3/42 Dinobryon 2.8/4	Phacus 1/1 Euglena(2) 10/6	

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Marble Falls Pool, Bottom 52 Feet 6/26/68 Total ASU/No: 189.2/103				
Anabaena 2/1	Pandorina 2/1	Dinobryon 5.5/3	Euglena (2) 13/7	Ceratium 3/1
Phormidium 1.9/3	Coelastrum 3.6/5	Diatom (3) 42.2/52	Phacus 2/1	
Chroococcus .2/1	Staurastrum 9.1/5			
	Scenedesmus 2.7/7			
	Pediastrum 84.5/11			
	Crucigenia 3.5/2			
	Desmidium 5/2			
	Eudorina 9/1			
Marble Falls Pool, Surface 7/27/68 Total ASU/No: 80.9/174				
Phormidium 8/55	Pediastrum 28/5	Diatom (2) 12.2/57	Trachelomonas 3/6	
Spirulina 1.7/13	Staurastrum 10.1/10		Phacus 1.2/2	
Merismopedia 3.2/6	Coelastrum .6/1			
Anabaena .9/1	Scenedesmus 2.2/10			
Chroococcus .3/1	Cosmarium .5/1			
	Pandorina 9/6			
Marble Falls Pool, 30 Feet 7/27/68 Total ASU/No: 82.2/154				
Spirulina 1.6/10	Pediastrum 41/5	Diatom (3) 15.2/64	Euglena 4/4	
Phormidium 7.5/50	Actinastrum 1.2/1			
Merismopedia .6/1	Staurastrum 6.1/5			
	Scenedesmus 2.9/12			
	Pandorina 1.5/1			
	Coelastrum .6/1			
Marble Falls Pool, 53 Feet 7/27/68 Total ASU/No: 96.5/116				
Phormidium 2.7/21	Pediastrum 72/9	Diatom (3) 7.3/33	Euglena 2/2	
Spirulina .1/1	Scenedesmus 9.9/46			
	Staurastrum 1.7/3			
	Coelastrum .8/1			

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Marble F lls Pool, Surface 10/19/68 Total ASU/No: 106.5/51				
Phormidium .5/5	Pediastrum 86/11	Diatom 2.5/8	Euglena 4.6/2	
Spirulina .1/1	Scenedesmus 2.8/9			
	Staurastrum 4.3/5			
	Cosmarium 1.8/5			
	Coelastrum 2.3/2			
	Ankistrodesmus 1.6/3			
Marble Falls Pool, 30 Feet 10/19/68 Total ASU/No: 97.4/31				
Phormidium .1/1	Ankistrodesmus .4/1	Diatoms 4.9/11	Euglena 4.1/3	Ceratium 7.5/2
	Pediastrum 78/8			
	Staurastrum 1.6/2			
	Scenedesmus .8/3			
Marble Falls Pool, Bottom 51 Feet 10/19/68 Total ASU/No: 76.4/42				
Phormidium .1/1	Pediastrum 52.8/9	Diatoms 9.6/17	Euglena 6/2	
Spirulina .1/1	Coelastrum 2.7/3		Phacus 1.8/1	
	Ankistrodesmus .3/1			
	Scenedesmus 1.7/6			
	Staurastrum 1.3/1			
Marble Falls Pool, Surface 1/8/69 Total ASU/No: 48.8/26				
	Ankistrodesmus 1.6/2	Diatoms 3spp 12.6/20	Euglena 2.6/2	
	Pediastrum 32/2			
Marble Falls Release, Surface 2/24/68 Total ASU/No: 9.8/5				
	Cosmarium 3/1	Fragilaria 4/1		
		Diatom 1sp 1/1		
		Navicula 1/1		
		Synedra .8/1		
Marble Falls Release, Surface 4/27/68 Total ASU/No: 14.2/12				
	Pandorina 4/1	Navicula 2.2/4		
	Pyrobotrys 6/6	Tabellaria 2/1		

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Marble Falls Release, Surface 6/26/68 Total ASU/No: 14/3				
	Closterium 8/2	Fragilaria 6/1		
Pedernales River, Surface 3/2/68 Total ASU/No: 8.2/4				
	Pleodorina 4/1	Navicula 3/2	Euglena 1.2/1	
Pedernales River, 30 Feet 3/2/68 Total ASU/No: 18.5/7				
	Pleodorina 11/3 Polytoma 1.5/3		Trachelomonas 6/1	
Pedernales River, 60 Feet 3/2/68 Total ASU/No: 5/2				
	Pleodorina 5/2			
Pedernales River, Surface 3/16/68 Total ASU/No: 28/18				
		Diatom 4spp 15/8 Diatom 6spp 13/10		
Pedernales River, Surface 4/27/68 Total ASU/No: 38.9/27				
	Chlorococcum 3.2/7	Diatom 8spp 35.7/20		
Pedernales River, Surface 6/26/68 Total ASU/No: 18.5/21				
	Scenedesmus 4.4/4 Closterium 3/1 Eudorina 3/2	Diatom (3) 7.3/13	Euglena 8/1	
Pedernales River, Surface 7/27/68 Total ASU/No: 57.8/68				
Polycystis 17.4/13	Scenedesmus 3.1/10 Pediastrum 15/5 Coelastrum .6/1 Ankistrodesmus 1/2	Diatom (3) 11.9/26	Euglena 5.8/8 Phacus 3/3	

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Pedernales River, Surface 10/26/68 Total ASU/No: 34.1/47				
Phormidium .4/3	Pediastrum 16/3 Scenedesmus 1.1/3 Coelastrum 1.3/1	Diatom (4) 14.1/36	Euglena 1.2/1	
Colorado & Pedernales, Surface 3/16/68 Total ASU/No: 8/4				
		Tabellaria 8/4		
Colorado & Pedernales, 40 Feet 3/16/68 Total ASU/No: 11.7/4				
	Ankistrodesmus 4/1 Scenedesmus .7/1	Diatom 1sp 1/1	Trachelomonas 6/1	
Colorado & Pedernales, 95 Feet 3/16/68 Total ASU/No: 19/7				
	Closterium 7/3 Pandorina 2/1 Chlorococcum 2/2			Ceratium 8/1
Colorado & Pedernales, Surface 4/27/68 Total ASU/No: 36.7/36				
Chroococcus 5/3	Pyrobotrys 26.7/23 Polytomella 1/4 Polytoma 2/5		Euglena 2/1	
Colorado & Pedernales, 40 Feet 4/27/68 Total ASU/No: 18.8/12				
	Pyrobotrys 1.4/1	Navicula 2/2 Cyclotella 4.2/3 Tabellaria 2.7/2 Diatom 1sp 4/2 Pleurosigma 4.5/2		
Colorado & Pedernales, 90 Feet 4/27/68 Total ASU/No: 3.5/4				
		Tabellaria 1/1 Diatom 3spp 2.5/3		

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Colorado & Pedernales, Surface 6/26/68 Total ASU/No: 106.7/830				
Anabaena 7.1/8	Oocystis .4/1 Mougeotia 3.5/3 Eudorina 3.4/2 Staurastrum 1/1 Scenedesmus .7/2 Pediastrum 9/1	Diatom 39.3/781	Trachelomonas 4/4 Phacus 3/3 Euglena(2) 5.5/2	Ceratium 11/3 Peridinium 19/19
Colorado & Pedernales, 35 Feet 6/26/68 Total ASU/No: 101.1/61				
	Coelastrum 3.5/3 Pediastrum 59/7 Scenedesmus .8/2 Staurastrum 3/1 Eudorina 3.4/2 Pandorina 2/1 Mougeotia 4/1	Diatom (2) 17.9/40 Dinobryon 1.5/1	Phacus 2/1	Ceratium 3/1 Peridinium 1/1
Colorado & Pedernales, Bottom 89 Feet 6/26/68 Total ASU/No: 94.3/57				
Anabaena .9/1 Phormidium 1/1	Pediastrum 62/5 Coelastrum 2.5/2 Scenedesmus 2.4/5 Ankistrodesmus 3.2/7	Diatom (2) 22.3/36		
Colorado & Pedernales, Surface 7/27/68 Total ASU/No: 29.5/23				
Microcystis 7.8/3 Anabaena 2/2	Staurastrum 5/2 Ankistrodesmus .9/2 Actinastrum 1/1 Pandorina 4/1	Fragilaria 5.8/6 Navicula 2.2/5		Peridinium .8/1

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Colorado & Pedernales, 30 Feet 7/27/68 Total ASU/No: 50.3/58				
Oscillatoria 1.2/2	Ankistrodesmus 4.1/11	Fragilaria 12.4/20	Trachelomonas 2/1	
Microcystis 17/7	Micractinium 3.2/2	Navicula .5/1		
	Pyrobotrys 2.3/2			
	Oocystis 3.4/2			
	Chlorella 1.2/6			
	Polytomella .2/3			
	Staurastrum 2.8/1			
Colorado & Pedernales, 80 Feet 7/27/68 Total ASU/No: 24/8				
Agmenellum 2/1		Fragilaria 4/3		
Microcystis 18/4				
Colorado & Pedernales, Surface 10/26/68 Total ASU/No: 132.8/38				
Phormidium 1/6	Coelastrum 3.3/3	Diatoms 3/8	Euglena 3/2	Ceratium 22.4/5
	Pediastrum 92/7			
	Staurastrum 6.8/4			
	Ankistrodesmus 1.3/3			
Colorado & Pedernales, 30 Feet 10/26/68 Total ASU/No: 67.5/33				
Phormidium .8/7	Pediastrum 38/5	Diatom 2.4/7	Euglena 1/1	Ceratium 21.5/5
	Scenedesmus 1/3			
	Ankistrodesmus 1.6/4			
	Eudorina 1.2/1			
Colorado & Pedernales, Bottom 85 Feet 10/26/68 Total ASU/No: 69.1/72				
Phormidium 1.4/11	Coelastrum 4/4	Diatoms (4) 16.7/42		
	Scenedesmus 1.7/6			
	Pediastrum 40/4			
	Staurastrum 4.5/3			
	Ankistrodesmus .8/2			

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Travis Pool, Surface 2/2/68 Total ASU/No: 24.8/23				
	Pyrobotrys 13/14 Dactylococcus 4/1 Chlorosarcina 5.1/6 Zygnema 2/1	Amphipleura .7/1		
Travis Pool, 95 Feet 2/2/68 Total ASU/No: 23.5/12				
	Staurastrum 4/1 Zygnema 4/1 Polybotrys 11.2/6 Closterium 1/1 Eudorina 2/1	Amphipleura .7/1 Diatoma .6/1		
Travis Pool, 155 Feet 2/2/68 Total ASU/No: 245/122				
	Polybotrys 2/1 Zygnema 3/1 Mycanthococcus 240/120			
Travis Pool, Surface 3/16/68 Total ASU/No: 13/6				
	Ulothrix 3/1 Polybotrys 8/4	Tabellaria 2/1		
Travis Pool, 80 Feet (out of 185 feet) 3/16/68 Total ASU/No: 8/4				
	Pyrobotrys 8/4			
Travis Pool, Surface 3/22/68 Total ASU/No: 10.2/5				
	Pyrobotrys 7/3 Pandorina 2/1	Synedra 1.2/1		
Travis Pool, 100 Feet 3/22/68 Total ASU/No: 28.3/13				
	Pyrobotrys 24.1/10 Desmid 1sp 4/2 Polytoma .2/1			

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Travis Pool, 175 Feet 3/22/68 Total ASU/No: 20.4/9				
	Pyrobotrys 12/5	Cyclotella 1.4/2 Fragilaria 7/2		
Travis Pool, Surface 5/4/68 Total ASU/No: 292/215				
	Staurastrum 27/7 Pyrobotrys 253/205 Scenedesmus 9/2			Ceratium 3/1
Travis Pool, 80 Feet 5/4/68 Total ASU/No: 3/7				
	Pyrobotrys 3/7			
Travis Pool, 170 Feet 5/4/68 Total ASU/No: 7.4/3				
	Staurastrum 4/1	Navicula 1.4/1		Ceratium 2/1
Travis Pool, Surface 7/2/68 Total ASU/No: 91.7/212				
Chroococcus .9/2	Staurastrum 5.4/3 Mougeotia 2.9/3 Pleodorina 29/3 Closterium 1/1 Scenedesmus .8/2 Coelastrum 3.2/4	Diatom (2) 39.2/189 Dinobryon 2.3/3		Ceratium 7/2
Travis Pool, 55 Feet 7/2/68 Total ASU/No: 61.9/31				
Chroococcum .8/2	Coelastrum 13.7/9 Pediastrum 41/3 Ankistrodesmus .6/1 Closterium 1.7/2	Diatom (2) 3.1/13		Peridinium 1/1
Travis Pool, 150 Feet 7/2/68 Total ASU/No: 8.6/6				
	Staurastrum 2/1 Scenedesmus .4/1 Pediastrum 5/1	Diatom 1.2/3		

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Travis Pool, Bottom 180 Feet 7/2/68 Total ASU/No: 5.8/20				
	Scenedesmus 2.2/7 Coelastrum 1/1	Diatom (2) 2.6/12		
Travis Pool, Surface 8/9/68 Total ASU/No: 178.1/242				
Microcystis 21/3 Phormidium 13/2 Oscillatoria 3spp 6/14 Anabaena 1.2/1	Ankistrodesmus 45/107 Pleodorina 2/1 Staurastrum 18/20 Oocystis 7/15 Pandorina 1.8/1 Polytoma .6/3 Scenedesmus 2.1/3	Fragilaria 55/66 Navicula 3.6/5	Trachelomonas 1.8/1	
Travis Pool, 50 Feet 8/9/68 Total ASU/No: 29.1/66				
Oscillatoria .8/2 Anabaena 1.7/3	Ankistrodesmus 17/39 Chlorella 1.2/12 Staurastrum .6/1 Pyrobotrys 1.2/1 Closterium 1.2/1	Navicula 3.1/5 Fragilaria 2.3/2		
Travis Pool, 90 Feet 8/9/68 Total ASU/No: 12.6/12				
	Ankistrodesmus 4.8/8	Caloneis 6/2 Fragilaria 1.8/2		
Travis Pool, 173 Feet 8/9/68 Total ASU/No: 29.7/26				
Oscillatoria 1.7/2	Pyrobotrys 5/2 Ankistrodesmus 1.4/4 Polytoma 2.4/7 Pandorina 3/1 Staurastrum 2/1	Caloneis 13/4 Navicula 1.2/5		

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Travis Pool, Surface 10/26/68 Total ASU/No: 12.8/16				
Phormidium 1.2/6	Staurastrum 1.8/1 Coelastrum 4.1/4 Scenedesmus .6/2	Diatom .8/2		Ceratium 4.3/1
Travis Pool, 110 Feet 10/26/68 Total ASU/No: 3.7/11				
Phormidium 1.1/5	Scenedesmus .3/1	Diatom 1.4/4	Euglena .9/1	
Travis Pool, 190 Feet 10/26/68 Total ASU/No: 11.6/34				
Phormidium 1/7	Eudorina 1.6/1 Scenedesmus .6/2 Coelastrum 1/1	Diatoms 3spp 7.4/23		
Travis Pool, Surface 1/9/69 Total ASU/No: 6.6/8				
	Staurastrum 4.6/2 Scenedesmus .6/2	Diatoms 3spp 1.4/2		
Lake Travis Release, Surface 3/22/68 Total ASU/No: 9/3				
	Pandorina 3/1 Desmid 1sp 6/2			
Austin Pool, Surface 3/22/68 Total ASU/No: 24.1/15				
	Polybotrys 11.3/7	Cyclotella 1/1 Navicula 3.2/3 Tabellaria 8.6/5		
Austin Pool, 25 Feet 3/22/68 Total ASU/No: 44.4/21				
	Pyrobotrys 15.7/7 Pediastrum 6/1 Synura 2/1 Closterium 1.5/1	Tabellaria 17.4/9 Synedra 1/1 Cyclotella .8/1		

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Austin Pool, 48 Feet	3/22/68 Total ASU/No:	93.7/46		
	Pyrobotrys 32.5/13 Scenedesmus .8/1 Closterium 2.7/2 Eudorina 3/1 Euastrum 1/1	Navicula 17/10 Synedra 2.7/2 Tabellaria 29/14 Fragilaria 5/2		
Austin Pool, Surface	5/4/68 Total ASU/No:	9.2/5		
	Pyrobotrys 1/1	Tabellaria 2.2/1 Nitzschia 2/1		Ceratium 4/2
Austin Pool, Surface	5/4/68 Total ASU/No:	33.8/32		
	Polytoma .2/4 Pediastrum 10/2 Pyrobotrys 6.6/2	Diatom 6spp 11/10 Diatom 2spp 6/14		
Austin Pool, 30 Feet	5/4/68 Total ASU/No:	26.5/15		
	Pyrobotrys 7/3	Actinella 2/4 Gyrosigma 3/1 Tabellaria 2/3 Cyclotella 1.5/1 Fragilaria 8/2		Ceratium 3/1
Austin Pool, 51 Feet	5/4/68 Total ASU/No:	14.3/6		
	Pyrobotrys 8/3	Cyclotella 1.3/1 Navicula 2/1 Nitzschia 3/1		
Austin Pool, Surface	7/10/68 Total ASU/No:	57.6/149		
	Coelastrum 8/8 Ankistrodesmus 18.6/121 Pandorina 2.1/2 Chlorella .9/13 Pediastrum 24/4		Euglena 1sp 4/1	

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Austin Pool, 20 Feet 7/10/68 Total ASU/No: 40.4/58				
	Ulothrix 6/1 Pediastrum 8/2 Scenedesmus 3.1/10 Staurastrum 6/3 Coelastrum 4.6/7 Closterium .5/1	Diatom (2) 8.7/30	Phacus 2/2 Euglena 1.5/2	
Austin Pool, Bottom 49 Feet 7/10/68 Total ASU/No: 40.1/55				
Phormidium .3/1	Scenedesmus 1.8/5 Pediastrum 12/2 Closterium 1/2 Coelastrum .8/2 Staurastrum 3/2	Diatom (2) 8/31	Phacus 5/4 Euglena 7/4 Trachelomonas 1.2/2	
Austin Pool, Surface 8/2/68 Total ASU/No: 107.5/219				
Phormidium .2/2	Scenedesmus 3.3/10 Coelastrum 1.3/2 Staurastrum 4.1/3 Actinastrum 1.8/1 Eudorina 2/1 Pediastrum 36/4	Diatom (3) 35.9/177 Dinobryon 10.1/6	Phacus 12/12 Euglena .8/1	
Austin Pool, 10 Feet 8/2/68 Total ASU/No: 34.7/33				
	Staurastrum .9/1 Mougeotia 4/1 Pediastrum 10/2 Scenedesmus 1.2/4 Coelastrum .7/1	Diatom 15.9/23 Dinobryon 2/1		
Austin Pool, 50 Feet 8/2/68 Total ASU/No: 51.6/28				
	Mougeotia 15/1 Coelastrum 1.6/2 Scenedesmus .3/1 Actinastrum .9/1	Diatom 27.9/17	Phacus 3.2/4 Euglena 2.7/2	

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Austin Pool, Surface 11/2/68 Total ASU/No: 65.9/26				
Phormidium .3/2 Anabaena .5/1	Scenedesmus 2.2/8 Pediastrum 47/4 Staurastrum 3.6/3	Diatom 2.8/6		Ceratium 9.5/2
Austin Pool, 30 Feet 11/2/68 Total ASU/No: 59.3/25				
Phormidium .2/2	Pediastrum 41/3 Scenedesmus .8/3 Ankistrodesmus .8/2 Staurastrum 3.2/3 Coelastrum 1/1	Diatom 2.3/7	Phacus 2/2 Euglena 3.2/1	Ceratium 4.8/1
Austin Pool, Bottom 52 Feet 11/2/68 Total ASU/No: 66.7/38				
Phormidium .8/5	Pediastrum 48/5 Staurastrum 1.3/1	Diatoms (3) 8.7/23	Euglena 3.6/3	Ceratium 4.3/1
Austin Pool, Surface 1/8/69 Total ASU/No: 69/18				
Nodularia 10/2	Pediastrum 4/2 Ankistrodesmus 1.8/2	Diatoms 4spp 13.2/10 Tabellaria 40/2		
Austin Release, Surface 3/22/68 Total ASU/No: 82.6/52				
	Pyrobotrys 23.8/11 Chlorococcum 6/7 Scenedesmus .5/1 Closterium 1.2/1	Tabellaria 26/13 Cyclotella 3.5/5 Synedra 7.2/5 Diatoma 10.7/6 Navicula 2.7/2		Glenodinium 1/1
Town Lake, Surface 3/16/68 Total ASU/No: 152/75				
	Pyrobotrys 15/7 Closterium 4/1	Tabellaria 102/51 Navicula 6/3 Diatom 3spp 19/10 Gomphonema 6/3		

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Town Lake, 15 Feet 3/16/68 Total ASU/No: 154/86				
	Chlorococcum 7/13	Gomphonema 10/5		Ceratium 16/2
	Zygnema 12/1	Tabellaria 90/51		
	Pleodorina 2/1	Nitzschia 2/1		
		Navicula 5/3		
		Diatom 2spp 10/9		
Town Lake, Surface 5/4/68 Total ASU/No: 37.8/28				
	Polytoma .1/1	Diatoma 1/1		Ceratium 2/1
	Pyrobotrys 8.2/5	Cymbella 1.5/1		
		Tabellaria 5/3		
		Diatom 3spp 6/6		
		Diatom 2spp 7/7		
		Nitzschia 7/3		
Town Lake, Surface 5/4/68 Total ASU/No: 13.9/8				
	Pyrobotrys 3.8/3	Tabellaria 1.4/1	Euglena .7/1	
	Pleodorina 4/1	Diatoma 1/1		
		Cymbella 3/1		
Town Lake, 10 Feet 5/4/68 Total ASU/No: 45.5/20				
	Pyrobotrys 16.5/5	Fragilaria 3/1		
	Pleodorina 3/1	Cocconeis 1/2		
		Actinella 2/1		
		Cymbella 20/10		
Town Lake, 15 Feet 5/4/68 Total ASU/No: 21.3/12				
	Pyrobotrys 11/6	Fragilaria 4/1		Ceratium 3/1
		Diatoma 1.3/1		
		Diatom 3spp 2/3		

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Town Lake, Surface 7/10/68 Total ASU/No: 92.7/107				
Anabaena 1/1 Phormidium .3/1	Mougeotia 40/1 Scenedesmus(2) 5.4/12 Staurastrum 4/2 Coelastrum 4.1/7 Pediastrum 13/3 Pandorina 6/3 Closterium .6/1 Pyrobotrys .7/1	Diatom (3) 16.7/74	Trachelomonas .9/2	
Town Lake, Bottom 15 Feet 7/10/68 Total ASU/No: 55/109				
Anabaena .6/1	Coelastrum 4.9/6 Pediastrum 16/3 Scenedesmus (2) 2/5 Staurastrum 4/2 Closterium 2.2/4 Pandorina 3/3 Mougeotia 4/1	Diatom (3) 17.9/83	Euglena .4/1	
Town Lake, Surface 11/1/68 Total ASU/No: 67.6/55				
Phormidium .4/3 Merismopedia .8/1	Coelastrum 4.2/3 Scenedesmus .3/1 Pediastrum 28/5 Ankistrodesmus .7/2 Staurastrum 1.4/1	Diatoms 28.2/35	Phacus 1.3/1 Trachelomonas 1.5/2	Peridinium .8/1
Town Lake, Bottom 15 Feet 11/1/68 Total ASU/No: 184.8/165				
Phormidium .2/2	Pediastrum 37/7 Staurastrum 2.7/2 Scenedesmus .9/3 Cosmarium 2/3 Ankistrodesmus .8/2 Coelastrum 1.2/1 Chlorella .8/1 Pandorina 4.4/2	Diatoms (4) 130.4/139	Euglena 4.4/3	

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Town Lake, Surface 8/2/68 Total ASU/No: 71.1/98				
Merismopedia .5/1 Phormidium .8/5	Scenedesmus 3.9/12 Eudorina 4/1 Pediastrum 35/4 Staurastrum 1.7/1	Diatom (2) 14.7/69 Large Diatom 8.8/3	Phacus .7/1 Euglena 1/1	
Town Lake, 18 Feet 8/2/68 Total ASU/No: 49.9/63				
Phormidium .3/2	Scenedesmus 1.1/3 Coelastrum 2.6/4 Staurastrum .9/1	Diatom (2) 9/41 Large Diatom 36/12		
Town Lake, Surface 1/8/69 Total ASU/No: 95.2/22				
	Ankistrodesmus 4/4 Pediastrum 16/2	Diatoms 3spp 8.4/10 Tabellaria 60/4		Ceratium 6.8/2
Town Lake Release, Surface 5/8/68 Total ASU/No: 24.6/13				
	Pyrobotrys 2/1 Eudorina 4/1 Polytoma .1/6 Pediastrum 6/1	Navicula 4/3 Tabellaria 8/4 Nitzschia 4/1		Ceratium .5/1
Decker, Surface 3/16/68 Total ASU/No: 182/80				
	Pyrobotrys 11/4	Tabellaria 133/61 Fragilaria 18/7 Synedra 9/5 Gyrosigma 11/3		
Decker, Surface 5/8/68 Total ASU/No: 38.8/17				
	Pyrobotrys 16/5	Diatom 4spp 4.8/6 Tabellaria 9/4 Gyrosigma 6/1		Ceratium 3/1

Table of Phytoplankton Distribution in the Highland Lakes - Continued

CYANOPHYTA	CHLOROPHYTA	CHRYSOPHYTA	EUGLENOPHYTA	PYRROPHYTA
Decker, Surface 7/10/68 Total ASU/No: 85.6/105				
Anabaena 2.6/1	Eudorina 1/1	Diatom (4) 18.1/67	Phacus 2/2	
Oscillatoria 5.5/1	Pediastrum 35/6			
Phormidium .3/1	Coelastrum 8.6/13			
	Scenedesmus 2.6/7			
	Staurastrum 2/1			
	Pandorina 5.8/3			
	Pyrobotrys 2/2			

Table C-2

Genera of Phytoplankton Which Have Been Reported in Lakes Travis, Austin, and Town with Frequency and Grouped by Division. *

Cyanophyta

Anabaena, C
Chroococcus, O
Merismopedia, O
Spirulina, O
Arthrospira, R
Oscillatoria, C
Phormidium, C
Lyngbya, R
Aphanizomenon, R
Nodularia, O
Microcystis, O

Chlorophyta

Platymonas,O
Polytoma, R
Gonium, R
Pandorina, R
Eudorina, R
Platydorina, R
Pleodorina, R
Volvox, R
Pyrobotrys, O

Chlorophyta (cont'd)

Palmella, R
Stigeoclonium, R
Cladophora, R
Chlorococcum, O
Pediastrum, C
Chlorella, R
Oocystis, R
Ankistrodesmus, C
Scenedesmus, C
Actinastrum, R
Mougeotia, R
Cosmarium, O
Arthrodesmus, O
Closterium, O
Micrasterias, O
Staurastrum, O

Euglenophyta

Euglena, O
Lepocinclis, R
Phacus, O
Trachelomonas, O

Chrysophyta

Cyclotella, O
Melosira, O
Tabellaria, C
Diatomella, O
Diatoma, C
Fragilaria, C
Opephora, O
Synedra, O
Asterionella, O
Actinella, R
Navicula, C
Pinnularia, C
Amphipleura, R
Gyrosigma, R
Gomphonema, O
Cymbella, C
Nitzxchia, C

Pyrrophyta

Ceratium, C
Glenodinium, R
Gymnodinium, C
Peridinium, O

* O = Occasional
R = Rare
C = Common

Table D-1

Physical - Chemical Data

Code for Descriptive Conditions

Brz:	Breeze
Cl:	Cool
Cldy:	Cloudy
Clm:	Calm
Clr:	Clear
Dz:	Drizzling
F.D.:	Floating Debris
Mld:	Mild
M.W.:	Muddy Water
nBrz:	No Breeze
nW:	No Wind
nR:	Not Releasing (Generating Electricity)
O:	Overcast
pCldy:	Partly Cloudy
Ra:	Rainy
R:	Releasing (Generating Electricity)
S:	Sunny
Spill:	Water Coming over Spillway
SW:	Swift Water
T:	Turbid Water
W:	Windy
Wrm:	Warm
X:	Dead Plant life present
Cld:	Cold

Table D-1

Sampling Station	Date	Description of conditions			Depth (ft.)	Temperature (°C)	Dissolved Oxygen (mg/1)	TOC (mg/1 C)	MBE (mg/1)	pH	Hardness (mg/1 $CaCO_3$)	Alkalinity (mg/1 $CaCO_3$)	Conductivity (μMHO/CM)	Phosphorus (mg/1 P)	Silica (mg/1)	$NO_2 + NO_3$ (mg/1 N)	NH_3 (mg/1 N)	Iron (mg/1)
			Light Penetration	Light Intensity														
Bend, Texas	2-9-68				M.D.	10.5	10.4	6			230	162	595	0.06	7.7	0.94	0.00	-
	4-5-68	Brt, S, sBrz		4,400	M.D.	19.0	10.6	1		8.3	270	195	844	0.05	5.2	0.53	0.10	-
	6-11-68	Clm, Dusk		700	M.D.	28.8	7.0	14			219	162	633	0.15	8.8	0.43	0.05	-
	7-11-68	Clm, clr, sBrz		1,000	M.D.	29.0	8.8	4.5		8.3	236	179	730	0.02	9.1	0.06	0.01	0.016
	10-4-68	Cldy, Dz, nBrz		100	M.D.	22.0	7.6	5.0	0.04	8.2		205	677	0.04	12.6	0.10	0.15	0.008
	1-30-69	Cld, W			Surf.	11.0	8.9	4.0		8.4	384	220	115	0.03	4.6	0.11	<0.05	0.075
Lake Buchanan Pool	2-10-68	Cldy, Clm	5'		Surf.	10.5	10.7	6		8.3	116	99	475	0.00	6.2	0.19	0.01	<0.003
					25'	10.5	10.0	10		8.4	96	102	490	0.00	6.2	0.22	0.00	0.003
					55'	10.0	10.2	4		8.3	100	102	514	0.00	6.0	0.18	0.00	<0.010
					75'	8.5	9.9	4		8.3	163	107	559	0.09	5.9	0.16	0.00	0.004
					105'	8.0	8.5	4		8.0	124	118	551	0.02	6.3	0.17	0.00	<0.003
	4-6-68	S, Brz	5'	3,800	Surf.	14.7	10.2	6		8.3	152	120	479	0.01	5.9	0.36	0.00	<0.010
					30'	14.5	9.5	5		8.2	143	124	477	0.00	5.9	0.35	0,00	<0.010
					65'	13.6	9.5	5		8.1	141	124	477	0.05	6.3	0.36	0.00	0.011
					80'	12.7	9.5	-		8.2	126	129	492		6.5	0.35	0.00	<0.010
					103'	11.8	8.9	5		8.0	132	124	477	0.02	6.2	0.39	0.00	<0.010
	6-12-68	S, Brz	5'	5,600	Surf.	26.8	8.5	8		8.2	182	129	596	0.00	5.1	0.31	0.00	<0.010
					20'	25.8	6.5	6		8.0	184	132	594	0.00	5.0	0.34	0.00	-
					40'	24.8	6.4	13		8.3	186	134	606	0.02	5.8	0.38	0.00	-
					50'	22.9	4.2	7		7.7	190	134	606	0.33	5.5	0.40	0.00	<0.010
					60'	20.0	3.4	8		7.6	186	134	600	0.00	6.7	0.40	0.00	<0.010
					80'	16.1	2.3	6		7.6	186	134	574	0.01	7.6	0.44	0.00	-
					105'	13.7	0.2	8		7.4	186	141	573	0.05	8.4	0.33	0.09	0.070

Sampling Station	Date	Description of Conditions			Depth (ft.)	Temperature (°C)	Dissolved Oxygen (mg/1)	TOC (mg/1 C)	MBE (mg/1)	pH	Hardness (mg/1 $CaCO_3$)	Alkalinity (mg/1 $CaCO_3$)	Conductivity (μMHO/CM)	Phosphorus (mg/1 P)	Silica (mg/1)	$NO_2 + NO_3$ (mg/1 N)	NH_3 (mg/1 N)	Iron (mg/1)
			Light Penetration	Light Intensity														
Lake Buchanan Pool (Cont'd)	7-12-68	pCldy, Brz	4'	4,000	Surf	27.3	7.10	3.3		8.4	178	124	604	0.000	5.5	0.28	0.00	-
					15'	27.3	7.05	3.3		8.3	178	129	604	0.000	5.1	0.26	0.00	-
					35'	26.8	5.35	4.5		8.0	182	129	604	0.005	4.9	0.38	0.48	-
					45'	24.4	2.00	8.5		7.5	186	129	616	0.001	4.9	0.22	0.14	-
					60'	22.0	0.80	2.6		7.5	186	133	616	0.000	5.1	0.49	0.00	0.05
					80'	16.6	0.60	3.3		7.4	194	138	600	0.003	6.4	0.49	0.00	<0.01
					102'	15.2	0.15	3.9		7.3	194	142	591	0.000	7.5	0.44	0.00	-
	10-5-68	Cldy, Dz, Brz	2.5'	1,500	Surf.	25.8	6.75	3.0	0.05	7.8	182	115	595	0.000	2.9	0.04	0.00	<0.01
					60'	25.4	5.90	2.0		7.6	190	116	598	0.000	5.8	0.07	<0.05	0.01
					65'	24.2	5.40	3.0		7.5	178		595	0.000	5.7	0.08	<0.05	0.01
					80'	20.1	0.00	6.5		7.1	182	145	595	0.000	9.2	0.02	0.64	0.01
					100'	16.8	0.00	4.0		6.9	198	166	602	0.140	12.3	0.00	1.20	0.02
	1-30-69	Cld, W, Cld	3.0'	1,000	Surf.	11.1	10.25	4.0		8.0	186	149	586	0.000	5.0	0.07	0.00	0.02
					30'	10.6	9.95	2.0		8.4	190	132	583	0.000	5.0	0.07	0.00	0.03
					60'	9.8	9.65	2.0		8.3	194	112	586	0.000	4.9	0.09	<0.05	0.03
					100'	9.4	8.35	2.0		8.1	196	132	586	0.015	5.0	0.08	0.05	0.05
Lake Buchanan Release	2-10-68	Cldy, Clm, nR				9.0	10.20	4.0			92	108	518	0.010	6.1	0.18	0.01	0.01
	4-6-68			12		14.0	9.70	6.0		8.2	113	124	493	0.020	6.3	0.37	0.00	<0.01
	6-12-68	R, mixed		7,200		20.0	4.05	6.0		6.8	186	129	587	0.004	6.1	0.42	0.00	-
	7-12-68	Clm, Cldy, nR		2,600		24.0	2.10	2.6		7.7	186	133	604	0.000	6.1	0.44	0.02	-
	10-5-68	X, nR, still		100		22.0	6.80	2.0	0.03	8.2	198	138	595		8.4	0.00	0.52	<0.01
	1-30-69	nR					12.20	3.0		8.0	190	132	573	0.015	4.9	0.07	<0.05	0.03

Sampling Station	Date	Description of Conditions			Depth (ft.)	Temperature (°C)	Dissolved Oxygen (mg/1)	TOC (mg/1 C)	MBE (mg/1)	pH	Hardness (mg/1 CaCO$_3$)	Alkalinity (mg/1 CaCO$_3$)	Conductivity (μMHO/CM)	Phosphorus (mg/1 P)	Silica (mg/1)	NO$_2$ + NO$_3$ (mg/1 N)	NH$_3$ (mg/1 N)	Iron (mg/1)
			Light Penetration	Light Intensity														
Lake Inks Pool	2-23-68	pCldy		3,400	Surf.	9.0	10.3	4.0		7.9	98	102	496	0.01	6.2	0.21	0.00	<0.01
					25'	8.6	10.3	0.0		8.0	107	106	498	0.01	5.8	0.20	0.00	<0.01
					45'	8.6	9.9	6.0		7.9	116	102	507	0.01	5.9	0.23	0.00	-
	4-6-68	S, Brz	5'	7,800	Surf.	15.6	10.6	6.0		8.3	174	124	468	0.01	5.9	0.27	0.01	<0.01
					15'	14.9	10.4	6.0		8.1	137	124	477	0.01	6.2	0.30	0.00	<0.01
					30'	14.5	10.1	6.0		8.1	152	124	475	0.01	5.8	0.34	0.00	0.01
					53'	12.9	9.2				130	124	478	0.01	5.9	0.35	0.00	<0.01
	6-12-68	S, Clm	5'	6,200	Surf.	25.4	9.1	14.0		7.8	178	132	570	0.00	6.4	0.24	0.11	-
					10'	22.5	5.9	9.0		8.2	182	134	581	0.02	6.2	0.35	0.03	<0.01
					20'	20.5	4.7	7.0		8.6				0.00	6.2	0.41	0.00	?
					30'	20.0	3.9	9.0		7.4	186	129	575	0.08	6.0	0.39	0.00	<0.01
					58'	18.5	1.6	8.0		7.2	186	134	574	0.00	7.5	0.37	0.01	0.02
	7-12-68	S, sW	4'	7,000	Surf.	27.8	7.7	4.5		8.3	186	129	588	0.00	6.4	0.19	0.03	-
					10'	26.3	4.1	2.6		7.9	186	133	600	0.00	6.7	0.29	0.03	-
					20'	23.4	1.8	3.3		7.8	190	130	604	0.00	6.1	0.38	0.01	-
					40'	22.0	1.6	5.3		7.8	190	131	600	0.00	6.5	0.45	0.00	0.01
					58'	19.5	0.0	2.6		7.7	190	149	616	0.00	8.3	0.23	0.24	-
	10-5-68	Cldy, sBrz	2.5'	3,200	Surf.	25.4	4.9	3.0	0.03	7.5	190	125	595	0.00				-
					30'	24.6	4.1	4.0		7.3	190	125	595	0.00	5.8	0.02	0.29	<0.01
					40'	24.6	0.6	7.0		7.2	186	125	595					-
					57'	23.8	0.0	4.0		7.1	206		619	0.08	12.8	0.02	1.05	0.15
	1-31-69	Ra, 45°F	5'	800	Surf.	14.5	7.4	4.0		8.4	218	132	632	0.00	6.3	0.02	0.00	0.02
					30'	12.0	7.3	0.0		8.1	218	134	639	0.00	6.8	0.03	<0.05	0.03
					50'	11.0	4.3	0.0		8.0	218	136	646	0.02	8.1	0.04	0.28	0.06

Sampling Station	Date	Description of Conditions			Depth (ft.)	Temperature (°C)	Dissolved Oxygen (mg/l)	TOC (mg/l C)	MBE (mg/l)	pH	Hardness (mg/l $CaCO_3$)	Alkalinity (mg/l $CaCO_3$)	Conductivity (µMHO/CM)	Phosphorus (mg/l P)	Silica (mg/l)	NO_2 + NO_3 (mg/l N)	NH_3 (mg/l N)	Iron (mg/l)
			Light Penetration	Light Intensity														
Lake Inks Release	2-23-68	pCldy			Surf.	9.5	11.2	2.0		7.8	139	103	496	0.00	6.2	0.200	0.00	<0.01
	4-5-68	S, Clr., SW		380	Surf.	14.5	10.4	6.0		8.1	154	124	485	0.00	6.0	0.310	0.00	<0.01
	6-12-68	S, Clm, R		7,600	Surf.	22.0	5.8	8.0		8.0	186	132	574	0.21	6.2	0.400	0.00	<0.01
	7-12-68	S, Clm, R, SW		7,000	Surf.	25.0	4.5	3.9		7.8	186	133	600	0.003	6.5	0.360	0.04	-
	10-5-68	Cldy, R			Surf.	24.0	4.0	3.0		7.2	198	123	592	0.000	5.8	0.040	0.40	<0.01
	1-31-69	Ra, nR, 45°F					8.9	0.0		8.2	218	112	636	0.000	6.2	0.050	<0.05	0.02
Llano River	2-24-68	S, Clr	5'	34	Surf.	7.2	11.4	7.0		8.1	146	144	405	0.000	8.5	0.325	0.00	<0.01
					15'	6.3	12.0	0.0		8.1	132	144	393	0.010	8.7	0.385	0.00	-
	4-6-68	S, Brz	3'	3,000	Surf.	20.9	9.5	7.0		8.8	161	182	447	0.020	8.4	0.150	0.03	<0.01
					5'	20.5	9.5	5.0		8.8	182	177	456	0.020	8.5	0.150	0.05	-
					10'	16.6	7.2	4.0		8.8	126	137	485	trace	6.9	0.320	0.02	<0.01
	6-19-68	- *	1'	2,800	Surf.	30.6	6.9	9.5		8.6	174	141	445	0.027	13.2	0.010	0.04	-
					12'	29.6	5.8	5.3		8.3	174	144	459	-	13.2	0.030	0.09	-
	7-20-68	Clr, Clm	2'	3,400	Surf.	31.0	6.8	5.3		8.3	182	154	444	0.005	12.1	0.030	0.00	-
					12'	30.1	4.7	9.0		8.2	186	154	440	0.034	11.5	0.040	0.02	-
	10-12-68	S, W		1,200	Surf.	25.9	8.3	3.0	0.05	8.5			474	0.010	12.3	0.000	0.16	<0.02
					15'	25.1	6.1	3.0		8.3			462	0.030	12.3	0.000	0.10	<0.02
	1-31-69	Ra, Cld, 45°F	3'		Surf.	14.0	9.4	0.0		8.4	208	172	471	0.000	5.8	0.030	<0.05	0.03
					10'	13.0	9.0	0.0		8.3	258	169	492	0.000	6.4	0.030	<0.05	0.03
Junction of Llano & Colorado Rivers	2-24-68	S, Clr	5'	460	Surf.	8.6	10.9	6.0		8.2	98	116	471	0.000	6.7	0.255	0.00	<0.01
					33'	6.9	10.5	7.0		8.3	132	129	433	0.000	7.7	0.670	0.00	-
	4-6-68	S, Brz	5'	6,400	Surf.	17.4	10.0	7.0		8.4	132	124	475	0.020	6.9	0.240	0.00	<0.01
					15'	16.4	9.8	6.0		8.3	174	137	475	0.000	6.3	0.280	0.00	<0.01
					22'	14.9	9.5	6.0		8.4	124	133	492	0.020	6.3	0.310	0.00	<0.01

Sampling Station	Date	Description of Conditions			Depth (ft.)	Temperature (°C)	Dissolved Oxygen (mg/1)	TOC (mg/1 C)	MBE (mg/1)	pH	Hardness (mg/1 $CaCO_3$)	Alkalinity (mg/1 $CaCO_3$)	Conductivity (µMHO/CM)	Phosphorus (mg/1 P)	Silica (mg/1)	$NO_2 + NO_3$ (mg/1 N)	NH_3 (mg/1 N)	Iron (mg/1)
			Light Penetration	Light Intensity														
Junction of Llano & Colorado Rivers (cont'd)	6-19-68	-*	4'	6,800	Surf.	30.6	8.3	9.2		8.6	176	139	481	0.005	10.0	0.01	0.00	-
					10'	29.6	5.9	8.5		8.2	176	141	481	0.003	-	0.05	0.03	-
					15'	26.8	4.4	1.3		7.8	178	141	483	0.015	-	0.15	0.03	-
					20'	24.0	4.1	4.5		7.7	183	141	470	0.003	6.4	0.33	0.00	-
					34'	22.5	3.9	6.0		7.6	183	148	505	0.009	-	0.33	0.02	-
	7-20-68	C, Clm	3'	2,000	Surf.	30.1	7.9	5.8		8.4	186	145	460	0.000	9.1	0.04	0.00	-
					20'	29.6	5.7	4.5		8.2	186	142	482	0.000	9.3	0.03	<0.01	-
					25'	27.3	3.1	5.3		7.7	190	145	528	0.000	7.5	0.17	0.02	-
					33'	26.8	2.1	7.3		7.6	198	149	531	0.015	7.4	0.16	0.05	-
	10-12-68	W, S		5,200	Surf.	25.5	7.1	9.0	0.04	8.3			500	0.000	10.6	0.00	0.10	<0.01
					20'	25.1	5.7	5.0		8.0			500	0.000	10.6	0.00	0.13	<0.01
					32'	24.7	4.8	4.0		7.6			495	0.020	10.5	0.00	0.13	0.01
	1-31-69	Ra, Cld, 45°F	3'		Surf.	15.0	9.3	0.0		8.3	266	125	518	0.000	7.2	0.05	<0.05	0.02
					20'	14.5	8.7	2.0		8.3	206	157	516	0.000	7.7	0.06	<0.05	0.03
					33'	14.5	6.5	0.3		8.0	218	158	556	0.015	7.7	0.05	<0.05	0.07
L.B.J. Pool	2-24-68	S, nW, FD	3'	5,600	Surf.	10.2	9.5	5.0		8.0	132	120	496	0.000	7.3	0.25	0.00	<0.01
					30'	9.3	10.2	3.0		8.0	122	120	494	0.000	7.2	0.26	0.00	<0.01
					60'	9.3	9.8	1.0		8.1	135	130	518	0.010	7.2	0.27	0.00	<0.01
					75'	9.3	10.1	4.0		6.8	122	118	516	0.010	7.2	0.24	0.05	-
	4-27-68	Brz, pCldy, Mld	5'	3,400	Surf.	22.0	8.0	3.0		8.5	163	143	465	0.000	7.3	0.20	0.00	<0.01
					15'	20.5	7.3	6.0		8.3	167	140	459	0.000	7.3	0.22	0.00	0.01
					25'	19.0	6.5	3.0		8.1	159	138	469	0.000	7.4	0.29	0.00	<0.01
					50'	15.5	5.8	3.0		8.0	167	134	500	0.000	7.7	0.35	0.00	<0.01
					65'	14.7	4.9			7.9	167	129	513	0.020	6.6	0.38	0.00	<0.01
					80'	11.7	0.4	8.0		8.0	167	124	500	trace	7.6	0.42	0.03	-

Sampling Station	Date	Description of Conditions			Depth (ft.)	Temperature (°C)	Dissolved Oxygen (mg/1)	TOC (mg/1 C)	MBE (mg/1)	pH	Hardness (mg/1 $CaCO_3$)	Alkalinity (mg/1 $CaCO_3$)	Conductivity (μMHO/CM)	Phosphorus (mg/1 P)	Silica (mg/1)	$NO_2 + NO_3$ (mg/1 N)	NH_3 (mg/1 N)	Iron (mg/1)
			Light Penetration	Light Intensity														
L.B.J. Pool (cont'd)	6-19-68	pCldy, Brz	3'	3,600	Surf.	29.1	8.45	5.3		8.5	183	141	463	0.000		0.01	0.00	-
					15'	27.8	4.55	4.5		8.0	183	141	463	0.003	7.6	0.12	0.00	-
					20'	24.0	1.35	5.3		7.6	183	141	463	0.003	7.5	0.30	0.00	-
					25'	23.5	1.25	6.5		7.6	181	144	480	0.000	6.8	0.36	0.00	-
					50'	21.0	0.40	6.0		7.6	183	141	469	0.003		0.41	0.00	-
					75'	18.0	0.00	6.5		7.6	188	144	469	-		0.20	0.16	-
					83'	17.0	0.00	8.5		7.4	191	146	481	-		0.01	0.48	-
	7-20-68	Clm, Clr	4'	6,000	Surf.	29.2	8.35	7.3		8.3	186	136	472	0.000	7.4	0.04	0.04	-
					30'	26.8	4.50	4.5		7.9	186	136	485	0.000	7.2	0.04	0.04	-
					35'	25.4	1.35	5.3		7.6	190	140	504	0.003	7.4	0.04	0.05	-
					40'	22.9	0.90	3.3		7.5				0.000	7.3	0.04	0.16	-
					50'	21.5	0.20	3.3		7.5	190	147	552	0.000	7.1	0.10	0.22	-
					70'	19.0	0.00	7.3		7.5	193	151	555	0.009	7.6	0.05	0.34	<0.01
					83'	17.1	0.00	7.8		7.5				0.038	10.9	0.02	0.11	-
	10-19-68	Clm, S, Cl		7,000	Surf.	24.2	6.35	5.0	0.04	7.8	174	138	555	0.000	9.5	0.04	<0.05	<0.01
					30'	23.7	5.90	7.0		7.7	182	134	562	0.000	9.6	0.04	<0.05	<0.01
					60'	23.7	4.50	5.0		7.5	178	138	559	0.000	9.5	0.04	0.14	<0.01
					65'	21.0	0.00	5.0		7.2	190	165	612	0.010	10.5	0.02	1.30	<0.01
					70'	20.5	0.00	5.0		7.1	190	169	595	0.020	10.6	0.00	1.10	0.09
					83'	19.0	0.00	9.0		7.0	208	191	612	0.400	13.1	0.00	1.90	0.20
	2-1-69	Cldy, Dz, nBrz	3'	380	Surf.	13.0	9.50	2.0		-	210	143	539	0.000	8.3	0.07	<0.05	0.02
					30'	12.5	8.70	2.0		-	198	147	516	0.000	8.6	0.07	<0.05	0.03
					60'	12.0	7.40	0.0		-	202	150	518	0.000	8.9	0.08	0.10	>0.10

Sampling Station	Date	Description of Conditions			Depth (ft.)	Temperature (°C)	Dissolved Oxygen (mg/l)	TOC (mg/l C)	MBE (mg/l)	pH	Hardness (mg/l $CaCO_3$)	Alkalinity (mg/l $CaCO_3$)	Conductivity (μMHO/CM)	Phosphorus (mg/l P)	Silica (mg/l)	$NO_2 + NO_3$ (mg/l N)	NH_3 (mg/l N)	Iron (mg/l)
			Light Penetration	Light Intensity														
L. B. J. (cont'd)	2-1-69				80'	11.5	6.05	0.0		-	202	147	528	0.000	8.6	0.07	0.18	<0.01
L.B.J Release	2-24-68	S, nW, FD	2'			9.5	10.60	1.0		8.0	124	121	494	0.000	7.0	0.24	0.00	<0.01
	4-27-68	Brz, pCldy, Mld		6,800		19.8	8.40	3.0		8.6	167	136	479	trace	6.7	0.27	0.02	<0.01
	6-19-68	pCldy, Brz, nR		3,000		28.0	10.10	7.8		7.9	183	144	469	0.000	7.4	0.21	0.00	-
	7-20-68	Clr, Clm, nR		2,400		29.0	8.35	6.5		8.2	182	136	500	0.005	7.2	0.03		-
	10-19-68	S, Clm, Cl, nR		7,000		24.0	9.15	5.0		8.0	174	136	567	0.000	9.5	0.07	<0.05	<0.01
	2-1-69	Cldy, Dz, nW, nR					10.00	0.0		-	206	152	533	0.010	8.9	0.07	<0.05	0.02
Lake Marble Falls Pool	2-25-68	S, Clr, 50°F	5'	5,800	Surf.	10.2	11.2	5.0		8.3	138	119	490	0.000	7.3	0.30	0.00	-
					15'	9.4	11.2	1.0		8.3	126	111	494	0.000	7.3	0.30	0.00	-
					30'	9.4	10.6	4.0		8.1	126	116	499	0.000	7.2	0.26	0.00	-
					45'	8.6	10.4	5.0		8.3	142	108	505	0.000	7.2	0.30	0.00	-
					63'	8.6	10.6	0.0		8.0	157	114	516	0.000	7.4	0.27	0.00	-
	4-27-68	Brz, S, FD	5'	7,800	Surf.	21.4	9.3	3.0		8.7	167	138	477	trace	6.6	0.24	0.01	<0.01
					25'	20.5	8.9	6.0		8.6	172	134	494	0.000	6.9	0.24	0.00	<0.01
					45'	19.2	8.1	3.0		8.3	167	138	478	0.000	6.5	0.26	0.00	<0.01
					57'	18.5	6.6	6.0		8.4	176	138	497	0.020	7.3	0.30	0.00	<0.01
	6-26-68	Brz, O, 80°F	6'	3,000	Surf.	26.8	7.2	4.5		8.2	187	139	505	0.000	8.0	0.18	0.00	<0.01
					10'	26.3	7.0	4.5		8.1	183	141	521	0.000	8.0	0.18	0.00	<0.01
					20'	25.8	5.7	6.5		7.9	183	141	528	0.000	7.4	0.21	0.00	<0.01
					52'	25.3	5.0	5.3		7.8	187	141	539	0.000	7.9	0.34	0.00	<0.01
	7-27-68	pCldy, Brz	5'	5,800	Surf.	30.0	7.0	6.0		8.3				0.000	7.7	0.03	0.00	<0.01
					20'	29.5	6.7	6.0		8.1	179	125	501	0.000	7.7	0.04	0.02	<0.01

Sampling Station	Date	Description of Conditions			Depth (ft.)	Temperature (°C)	Dissolved Oxygen (mg/1)	TOC (mg/1 C)	MBE (mg/1)	pH	Hardness (mg/1 CaCO$_3$)	Alkalinity (mg/1 CaCO$_3$)	Conductivity (μMHO/CM)	Phosphorus (mg/1 P)	Silica (mg/1)	NO$_2$ + NO$_3$ (mg/1 N)	NH$_3$ (mg/1 N)	Iron (mg/1)
			Light Penetration	Light Intensity														
Lake Marble Falls (cont'd)	7-27-68				30'	29.1	4.1	6.0		7.8				0.000	7.5	0.02	<0.01	<0.01
					40'	27.8	2.0	6.0		7.5				0.004	7.1	0.07	0.01	-
					53'	27.3	0.2	6.0		7.4	187	150	550	0.004	8.4	0.01	0.30	0.02
	10-19-68	S, Clm, Cl		7,200	Surf.	25.2	6.9	5.0	0.04	8.0	178	136	564	0.000	9.1	0.02	<0.05	<0.01
					30'	24.7	6.5	5.0		7.9	178	141	555	0.000	9.5	0.03	<0.05	<0.01
					50'	24.7	6.7	5.0		7.9	182	141	555	0.000	9.1	0.02	<0.05	0.01
	2-1-69	Cldy, Dz, Cld 45°F	3'	380	Surf.	14.0	10.1	0.0		-	198	145	539	0.000	8.1	0.08	<0.05	0.02
					30'	13.5	9.4	0.0		-	198	145	541	0.000	8.1	0.07	<0.05	<0.02
					49'	12.5	8.2	0.0		-	198	147	539	0.010	8.4	0.08	0.08	0.04
Lake Marble Falls Release	2-24-68	-*	2'			9.5	12.0	2.0		-	112	118	491	0.000	7.3	0.23	0.02	-
	3-16-68						9.9	5.0		-	117	116	461	0.025	6.4	0.25	0.00	0.01
	4-27-68	Brz, S, 85°F		5,400		22.0	9.1	6.0		8.3	167	161	494	0.000	6.8	0.24	0.00	<0.01
	6-26-68	O, nR, Spill		7,200		27.0	10.0	3.9		8.2	178	139	505	0.000	7.5	0.17	0.00	-
	7-27-68	pCldy, nR, Spill		7,600		30.5	8.6	6.0		8.3	175	139	523	0.000	7.5	0.03	0.02	<0.01
	10-19-68	nR		8,000	Surf.	24.0	9.1	10.0	0.02	8.0	182	132	555	0.010	9.2	0.02	<0.05	<0.01
	2-1-69	Cld, Dz, X, nR				11.0	14.5	0.0		-	202	139	536	0.000	7.7	0.06	0.14	0.02
Pedernales River	3-3-68	S, W, MW			Surf.													<0.02
					30'													0.01
					60'													<0.01
	3-16-68	-*					9.8	5.0			194	194	463	0.045	9.3	0.95	0.00	-
	4-27-68	Clm, Dusk		100		26.0	7.9	3.0		8.4	249	221	561	0.020	6.3	0.55	0.00	<0.01
	6-26-68	S, Brz		7,000		28.0	7.1	2.6		8.3	228	199	463	0.000	10.6	0.40	0.00	
	7-27-68	Cldy, low flow		3,200		31.0	7.3	6.0		8.3		202	506	0.008	11.0	0.18	0.02	0.20

Sampling Station	Date	Description of Conditions			Depth (ft.)	Temperature (°C)	Dissolved Oxygen (mg/l)	TOC (mg/l C)	MBE (mg/l)	pH	Hardness (mg/l CaCO$_3$)	Alkalinity (mg/l CaCO$_3$)	Conductivity (µMHO/CM)	Phosphorus (mg/l P)	Silica (mg/l)	NO$_2$ + NO$_3$ (mg/l N)	NH$_3$ (mg/l N)	Iron (mg/l)
			Light Penetration	Light Intensity														
Pedernales River (cont'd)	10-19-68	S, SW		4,000		18.5	8.8	15.0	0.03	8.2	198	197	594	0.000	9.7	0.14	<0.05	<0.01
	1-29-69	W, Cl	5'	2,400	Surf.	18.0	9.2	0.0		8.3	266	233	650	0.015	4.6	0.28	<0.05	0.02
Colorado & Pedernales Junction	3-16-68	S, Clr, Clm, nW	3'	3,800	Surf.	13.8	9.5	5.0		8.1	128	132	469	trace	7.3	0.48	0.00	0.01
					20'	12.0	10.5	5.0		8.0	132	134	463	0.000	7.3	0.47	0.00	<0.01
					40'	12.0	9.4	5.0		8.0		128	473	0.010	7.3	0.42	0.00	0.01
					60'	11.6	9.5	5.0		7.8	138	125	465	trace	7.3	0.39	0.00	<0.01
					75'	11.2	9.4	5.0		7.5	132	120	475	0.000	7.4	0.36	0.00	-
					93'	10.9	8.4	4.0		6.5	104	118	465	0.040	7.5	0.36	0.00	0.01
	4-27-68	Brz, O, 85°F		3,300	Surf.	22.6	8.2	3.0		8.3	180	111	479	0.000	6.5	0.34	0.00	<0.01
					15'	21.0	8.0	3.0		8.1	176	143	489	trace	6.4	0.27	0.04	<0.01
					40'	18.5	5.8	3.0		7.8	167	138	477	0.010	6.6	0.30	0.00	<0.01
					70'	13.3	5.2	4.0		7.8	176	145	477	0.016	7.2	0.40	0.00	<0.01
					90'	11.7	4.1	2.0		7.9	176	145	479	trace	7.3	0.41	0.00	<0.01
	6-26-68	O, Brz, 80°F	5'	3,000	Surf.	28.3	6.9	3.3		8.4	174	141	459	0.000	-	0.09		<0.01
					30'	27.8	6.6	3.3		8.2	174	141	445	0.003	6.7	0.09		<0.01
					35'	26.3	2.1	3.3		7.5	187	144	505	0.003	7.7	0.29		<0.01
					40'	25.3	1.4	2.6		7.4	191	157	505	0.003	7.8	0.29		<0.01
					60'	23.4	0.9	3.3		7.4	183	148	482	0.003	7.8	0.37		<0.01
					89'	21.0	0.0	2.6		7.3	183	148	470	0.003	8.7	0.27		<0.01
	7-27-68	Cldy, Clm	6'	1,000	Surf.	29.2	8.4	6.0		8.3		125	436	0.000	5.6	0.04	0.00	-
					20'	27.8		4.0			155	127	441	0.000	5.5	0.05		-
					30'	26.8	4.5	6.0		7.9		91	316	0.001	5.9	0.03		-
					40'	22.9	0.9	6.0		7.5	179	146	496	0.000	6.5	0.01		-

Sampling Station	Date	Description of Conditions			Depth (ft.)	Temperature (°C)	Dissolved Oxygen (mg/l)	TOC (mg/l C)	MBE (mg/l)	pH	Hardness (mg/l $CaCO_3$)	Alkalinity (mg/l $CaCO_3$)	Conductivity (µMHO/CM)	Phosphorus (mg/lP)	Silica (mg/l)	$NO_2 + NO_3$ (mg/l N)	NH_3 (mg/l N)	Iron (mg/l)
			Light Penetration	Light Intensity														
Colorado & Pedernales Junction (cont'd)	7-27-68				70'	19.0	0.0	5.0		7.5	159	155	501	0.001	7.5	0.15		-
					86'	17.1	0.0	4.0		7.5	183	155	456	0.016	9.3	0.04		<0.02
	10-26-68	Clr, Clm, Cl, S		1,200	Surf.	24.6	5.7	6.0	0.03	7.8	182	143	512	0.000	7.3	0.09	0.00	0.01
					30'	24.6	5.5	19.0		7.7	178	139	505	0.000	7.3	0.10	0.00	<0.01
					60'	24.6	5.4	2.0		7.6	178	136	512	0.000	7.4	0.11	0.05	<0.01
					85'	24.6	4.2	3.0		7.5	182	153	503	0.060	7.3	0.11	0.13	<0.03
	1-29-69	W, Cl	5'	2,400	Surf.	14.0	9.7	3.0		8.4	171	145	507	0.010	6.9	0.09	0.00	0.02
					30'	13.5	9.7	0.0		8.3	175	145	504	0.000	7.4	0.10	0.00	<0.02
					65'	3.0	9.1	0.0		8.0	171	149	526	0.000	6.8	0.09	<0.05	<0.03
					80'	12.5	7.4	0.0		8.0	183	158	547	0.044	7.1	0.11	0.08	>0.10
Lake Travis Pool	2-2-68	S			Surf.	13.6	11.3											
					15'	13.0	11.2											
					25'	13.1	10.9											
					35'	13.0	10.5											
					45'	12.3	10.7											
					55'	12.3	10.7											
					65'	12.1	10.2											
					75'	12.0	10.3											
					85'	10.9	10.9											
					95'	10.9	10.9											
					105'	9.9	11.5											
					115'	9.8	9.8											
					125'	9.8	11.5											
					135'	9.2	10.0											

Sampling Station	Date	Description of Conditions			Depth (ft.)	Temperature (°C)	Dissolved Oxygen (mg/1)	TOC (mg/1 C)	MBE (mg/1)	pH	Hardness (mg/1 $CaCO_3$)	Alkalinity (mg/1 $CaCO_3$)	Conductivity (µMHO/CM)	Phosphorus (mg/1 P)	Silica (mg/1)	$NO_2 + NO_3$ (mg/1 N)	NH_3 (mg/1 N)	Iron (mg/1)
			Light Penetration	Light Intensity														
Lake Travis (cont'd)	2-2-68				145'	9.2	10.0											
					155'	9.7	9.8											
	3-16-68	S	10'	5,600	Surf.	12.5	10.6	1.0		8.1	122	120	424	0.000	7.1	0.24	0.00	<0.01
					180'	10.4	9.7	1.0		8.2	124	121	407	0.000	7.2	0.23	0.00	<0.01
	3-22-68	pCldy	8'	7,800	Surf.	12.2	10.4	1.0		8.1	136	122	427	0.000	7.3	0.23	0.00	<0.01
					20'	12.2	10.3	1.0		8.1	135	122	420	0.000	7.0	0.25	0.00	-
					40'	12.2	10.3	1.0		8.0	158	115	420	0.000	7.2	0.23	0.00	<0.01
					70'	11.8	10.3	2.0		8.0	145	123	424	0.000	7.1	0.24	0.00	<0.01
					100'	11.6	10.1	1.0		8.0	155	120	420	trace	6.9	0.22	0.00	<0.01
					130'	11.6	10.1	1.0		7.9	161	115	438	trace	7.0	0.22	0.00	<0.01
					150'	10.8	9.1	1.0		7.9	136	121	427	0.000	6.5	0.23	0.00	<0.01
					175'	10.4	9.0	1.0		7.9	132	120	435	0.015	7.4	0.23	0.00	<0.01
	5-4-68	Brz, S, Cl	6'	5,000	Surf.	23.2	9.3	5.0		8.6	172	144	460	trace	7.3	0.27	0.00	
					25'	22.2	9.1	14.0		8.8	159	142	460	0.017	7.0	0.25	0.05	
					80'	14.2	7.9	3.0		8.3	166	142	450	0.000	7.9	0.37	0.00	
					110'	13.2	7.9	3.0		8.5	166	138	450	0.010	7.5	0.42	0.00	
					170'	11.4	5.3	5.0		7.8	161	135	443	0.055	7.9	0.49	0.00	
	7-2-68	pCldy, Clm	8'	8,200	Surf.	29.2	7.3	2.6		8.3	167	130	424	0.001	6.7	0.10	0.00	
					40'	27.3	6.5	2.0		8.1	162	135	424	0.000	6.9	0.13	0.00	
					55'	24.4	2.5	2.0		7.6	183	142	445	0.003	7.0	0.26	0.00	
					70'	22.5	2.3	2.6		7.5	175	147	448	0.003		0.30	0.01	
					140'	17.5	1.6	1.3		7.3	183	151	466	0.001		0.38	0.00	
					150'	14.2	0.7	1.3		7.3	187	151	475	0.001	7.5	0.39	0.00	
					160'	12.2	0.3	1.3		7.3	191	158	475	0.000	7.7	0.37	0.03	
					180'	11.7	0.0	1.3		7.3	187	160	473	0.003	8.3	0.30	0.18	

Sampling Station	Date	Description of Conditions			Depth (ft.)	Temperature (°C)	Dissolved Oxygen (mg/1)	TOC (mg/1 C)	MBE (mg/1)	pH	Hardness (mg/1 $CaCO_3$)	Alkalinity (mg/1 $CaCO_3$)	Conductivity (µMHO/CM)	Phosphorus (mg/1 P)	Silica (mg/1)	NO_2 + NO_3 (mg/1 N)	NH_3 (mg/1 N)	Iron (mg/1)
			Light Penetration	Light Intensity														
Lake Travis Pool (cont'd)	8-9-68	pCldy, Brz	8'	8,000	Surf.	30.5	7.6	5.0		8.5	156	127	420	0.003	6.3	0.00	0.00	<0.01
					20'	29.5		13.0		8.5	152	125	427	0.010	6.3	0.01	0.00	<0.01
					40'	29.0	4.2	5.0		8.0	156	130	427	0.010	6.3	0.03	0.00	-
					50'	28.2	1.2	7.0		7.7	169	136	444	0.000	6.9	0.25	0.00	-
					60'	25.6	0.1	6.0		7.7	169	139	444	0.035	7.3	0.31	0.00	-
					90'	23.9	0.1	5.0		7.6	181	146	469	0.003	6.8	0.42	0.08	<0.01
					130'	20.3	0.1	5.0		7.5	177	150	463	0.000	8.4	0.39	0.00	-
					173'	13.8	0.1	7.0		7.0	198	159	472	0.035	9.2	0.09	0.22	-
Lake Travis Pool	10-26-68	Clr, S, Brz, Wrm		4,800	Surf.	24.7	6.9	14.0	0.030	8.1	158	124	462	0.000	7.3	<0.01	0.00	<0.01
					50'	24.2	6.7	24.0		8.0	162	124	516	0.000	7.3	0.01	0.00	<0.01
					100'	24.2	6.3	6.0		7.9	162	126	478	0.000	7.3	<0.01	0.05	<0.01
					110'	22.3	0.0	11.0		7.2	162	138	500	0.010	9.2	0.00	0.10	<0.05
					130'	20.5	0.0	7.0		7.2	178	141	498	0.000	9.7	0.00	0.22	0.08
					140'	18.3	0.0	4.0		7.2	178	147	512	0.010	9.8	0.00	0.19	0.05
					150'	15.6	0.0	4.0		7.2	178	149	505	0.000	9.9	0.00	0.29	<0.05
					190'	14.2	0.0	4.0		7.0	186	172	550	0.190	12.7	0.00	1.04	0.05
	1-29-69	W, Cl	5'	2,000	Surf.	13.8	9.1	0.0		8.2	208	141	494	0.000	7.0	0.09	0.00	<0.02
					70'	13.4	8.4	2.0		8.1	175	138	503	0.000	7.0	0.11	0.00	<0.03
					110'	12.5	7.1	0.0		7.9	179	152	523	0.000	6.9	0.17	<0.05	<0.05
					160'	11.5	7.2	0.0		7.9	192	149	526	0.022	6.9	0.15	<0.05	<0.05

Sampling Station	Date	Description of Conditions			Depth (ft.)	Temperature (°C)	Dissolved Oxygen (mg/1)	TOC (mg/1 C)	MBE (mg/1)	pH	Hardness (mg/1 $CaCO_3$)	Alkalinity (mg/1 $CaCO_3$)	Conductivity (μMHO/CM)	Phosphorus (mg/1 P)	Silica (mg/1)	$NO_2 + NO_3$ (mg/1 N)	NH_3 (mg/1 N)	Iron (mg/1)
			Light Penetration	Light Intensity														
Lake Travis Release	3-21-68	Cldy, W, mixed				12.5	10.2	1.0		8.0	127	121	408	0.000	6.9	0.24	0.00	<0.01
	5-4-68	Brz, S, Cl		5,500		14.5	7.6	5.0		8.7	170	142	443	0.010	8.0	0.50	0.00	-
	7-2-68	Cld, Cldy		1,800			3.3	1.3		7.4	179	147	456	0.000	7.1	0.35	<0.05	<0.01
	8-9-68	pCldy, Brz, R		5,600	Surf.	21.0	3.2	4.0		7.4	177	146	463	0.000	7.8	0.41	0.00	-
	10-26-68	Clr, S, nR		3,800	Surf.	24.5	8.0	4.0	0.026	7.8	182	141		0.000	9.0	0.04	0.12	0.01
	1-29-69	W, Cl, nR				14.0	10.9	3.0		7.9	147	154	545	0.000	6.6	0.26	<0.05	0.04
Lake Austin Pool	3-22-68	S, Clr, 49°F	4'	4,200	Surf.	11.5	10.4	2.0		8.0	155	123	436	0.000	6.8	0.23	0.00	<0.01
					15'	10.8	10.4	1.0		8.1	128	124	438	trace	6.9	0.24	0.00	-
					30'	10.8	10.2	1.0		7.8	120	125	428	0.000	7.1	0.21	0.00	<0.01
					48'	10.8	10.3	0.0		8.0	116	126	438	0.000	6.9	0.24	0.00	<0.01
	5-4-68	Brz, S, 75°F, FD	3'	8,000	Surf.	17.2	9.8	3.0		8.4	166	139	456	trace	7.1	0.39	0.00	-
					30'	15.5	8.8	10.0		8.2	159	138	443	trace	7.7	0.39	0.00	-
					51'	14.1	7.6	5.0		8.1	157	139	450	0.016	7.1	0.40	0.00	-
	7-10-68	Clr, Clm	3'	2,400	Surf.	23.4	6.9	3.3		8.0	174	145	479	0.000	7.2	0.32	0.00	-
					10'	22.5	4.9	3.3		7.7	174	142	483	0.003	7.5	0.35	0.00	-
					20'	21.5	3.9	3.9		7.6	178	147	483	0.000	7.6	0.37	0.00	-
					49'	21.5	2.7	3.3		7.7	182	149	483	0.003	8.2	0.33	0.01	0.04
	8-2-68	Cldy, Brz	4'	1,200	Surf.	28.7	7.7	4.0		8.3	178	152	480	0.003	8.5	0.31	<0.05	<0.01
					10'	25.2	5.4	4.0		8.0	178	152	480	0.000	8.4	0.38	0.00	<0.01
					25'	24.3	4.2	5.0		7.8	182	157	480	0.000	8.5	0.40	<0.05	-
					50'	23.4	1.4	5.0		7.6	178	152	480	0.000	9.2	0.44	0.00	0.01
	11-2-68	Cld		1,400	Surf.	22.8	7.7	4.0	0.024	8.4	176	149	496	0.000	9.9	0.06	<0.05	<0.01
					30'	22.8	6.9	6.0		8.2	180	150	500	0.000	10.1	0.05	0.09	<0.01
					40'	22.3	6.7	8.0		8.2	180	152	489	0.020	10.0	0.05	<0.05	<0.01
					52'	22.3	6.0	6.0		8.2	220	154	496	0.030	10.1	0.05	0.07	0.01

Sampling Station	Date	Description of Conditions	Light Penetration	Light Intensity	Depth (ft.)	Temperature (°C)	Dissolved Oxygen (mg/1)	TOC (mg/1 C)	MBE (mg/1)	pH	Hardness (mg/1 $CaCO_3$)	Alkalinity (mg/1 $CaCO_3$)	Conductivity (μMHO/CM)	Phosphorus (mg/1 P)	Silica (mg/1)	$NO_2 + NO_3$ (mg/1 N)	NH_3 (mg/1 N)	Iron (mg/1)
Lake Austin Pool (cont'd)	1-27-69	Cldy, Dz, Cl			Surf.	18.0	9.8	3.0		7.9	198	172	550	0.030	9.4	0.23	<0.05	0.04
						16.0	9.8	7.0		7.7	202	178	562	0.015	9.4	0.25	<0.05	<0.03
Lake Austin Release	3-21-68	Cldy, W, mixed				12.4	10.4	3.0		8.0	150	126	442	0.020	6.7	0.24	0.00	<0.01
	5-4-68	Brz, S, FD		6,500		14.5	8.9	5.0		8.4	168	138	450	0.010	7.9	0.42	0.00	-
	7-10-68	Clr, Clm		4,000		24.0	5.7	3.9		7.7	174	145	479	0.000	7.4	0.33	<0.03	-
	8-2-68	Cldy, SW, R		900		26.5	6.0	5.0		8.0	178	155	480	0.003	8.3	0.37	<0.05	<0.01
	11-2-68	Cld.		1,400	Surf.	22.0	6.0	7.0	0.025	8.2	184	154	496	0.000	9.8	0.04	<0.05	<0.01
	1-27-69	Cldy, Dz, Cl,nR				14.0	11.3	4.0		7.7	194	185	530	0.000	9.2	0.13	0.00	<0.03
Town Lake Pool	3-15-68	Cldy, W, 60°F	3'	2,400	Surf.	14.8	10.7	5.0		8.0	122	129	438	0.000	6.3	0.25	0.00	<0.01
					15'	13.0	10.8	4.0		7.0	122	129	438	trace	5.9	0.24	0.00	<0.01
	5-3-68	pCldy, Wrm	3'	5,400	Surf.	20.5	10.0	4.0		8.5	174	144	454	0.020	7.4	0.40	0.00	-
					10'	18.0	9.5	4.0		9.0	166	142	443	0.031	7.0	0.40	0.00	-
					15'	17.2	9.3	4.0		9.1	159	138	450	0.040	7.4	0.42	0.00	-
	7-10-68	pCldy, Clm, Wrm	0.5'	6,800	Surf.	27.8	5.5	3.3		7.7	169	136	457	0.016	7.2	0.38	<0.05	0.02
					16'	23.5	5.5	2.6		7.7	178	149	460	0.009	7.5	0.43	0.00	-
	8-2-68	S, 95°F, W	1'	7,300	Surf.	31.8	6.1	4.0		7.7	178	161	482	0.003	8.8	0.45	0.00	0.01
					18'	27.4	5.5	4.0		7.9	194	164	510	0.003	8.8	0.46	<0.05	-
	11-1-68	S, Wrm, Brz		7,200	Surf.	32.5	7.5	2.0	0.026	8.0	220	193	555	0.000	9.8	0.30	0.06	<0.01
					15'	27.0	6.9	2.0		7.9	220	200	553	0.000	9.9	0.31	0.05	<0.01
	1-27-69	Cldy, Dz, Cl			Surf.	26.3	8.1	0.0		7.8	218	198	580	0.058	8.7	0.29	<0.05	0.05
					15'	19.2	8.9	4.0		7.7	226	200	600	0.070	8.9	0.31	<0.05	<0.03

Sampling Station	Date	Description of Conditions			Depth (ft.)	Temperature (°C)	Dissolved Oxygen (mg/1)	TOC (mg/1 C)	MBE (mg/1)	pH	Hardness (mg/1 $CaCO_3$)	Alkalinity (mg/1 $CaCO_3$)	Conductivity (μMHO/CM)	Phosphorus (mg/1 P)	Silica (mg/1)	$NO_2 + NO_3$ (mg/1 N)	NH_3 (mg/1 N)	Iron (mg/1)
			Light Penetration	Light Intensity														
Town Lake Release	5-7-68	-*				17.5	9.2	5.0		7.8				0.028				
	7-10-68	pCldy		6,000		25.5	8.0	5.3		7.8	169	147	473	0.003	7.3	0.41	0.06	<0.18
	8-2-68	S, W, 95°F, R		6,600		29.5	8.1	7.0		8.0	178	155	481	0.003	8.6	0.47	0.10	<0.01
	11-1-68	S, Wrm, Brz,nR		1,200		31.0	7.5	4.0	0.031	8.1	224	198	555	0.000	9.8	0.35	0.13	<0.01
	1-27-69	Cldy, Dz, Cl,nR				22.5	7.9	4.0		7.6	222	202	580	0.058	8.7	0.37	<0.05	<0.03
Decker Lake Pump in Colorado River	3-15-68	Cldy, O, Brz		500		14.0	11.2	4.0		7.7	129	131	454	0.054	6.9	0.37	0.00	-
	5-7-68	-				17.5	9.9	1.0		7.8				0.054				
	7-10-68					26.0	7.6	5.8		7.8	210	147	453	0.081	7.2	0.44		-
	1-27-69	Cldy, Dz				20.0	11.8	5.0		7.8	191	150	548	0.260	2.7	0.32	<0.05	0.01

Table E-1

Bacteriological Contents of Highland Lakes Waters
for Period of 2-9-68 through 2-1-69

Sampling Station	Date	Location	Coliform No./ml	Total No./ml
Colorado River at Bend	2-9-68	Surface	<10	19,000
	4-5-68	Surface	<10	37
	6-12-68	Surface	< 1	8,200
	7-11-68	Surface	7	>10,000
	10-4-68	Surface	288	1,400
	1-30-69	Surface	0.1	510
Lake Buchanan Pool	2-10-68	Surface	<10	26,000
		25'	<10	4,000
		55'	<10	8,000
		75'	<10	10,000
		105'	<10	80,000
	4-5-68	Surface	<10	50
		30'	<10	50
		65'	<10	55
		80'	<10	21
		103'	<10	7,250
	6-12-68	Surface	< 1	10,400
		20'	< 1	8,400
		40'	< 1	1,700
		50'	< 1	2,400
		60'	< 1	300
		80'	< 1	11,100
		105'	< 1	18,900
	7-12-68	Surface	1	2,200
		15'	< 1	1,800
		35'	3	7,300
		45'	< 1	100
		60'	< 1	3,100
		80'	< 1	2,300
		102'	37	1,900
	10-5-68	Surface	24	2,800
		60'	27	2,000
		65'	25	3,300
		80'	25	1,300
		100'	27	2,200
	1-30-69	Surface	0.02	30
		30'	0.02	20
		60'	0.02	130
		100'	0.02	100
Lake Buchanan Release	2-10-68		<10	21,000
	4-5-68		<10	35
	6-12-68		< 1	1,200
	7-12-68		9	
	10-5-68		192	1,000
	1-30-69		0.08	400
Lake Inks	2-23-68	Surface	1	8,000
		25'	1	1,000
		45'	< 1	4,000

Sampling Station	Date	Location	Coliform No./ml	Total No./ml
Lake Inks (cont'd)	4-6-68	Surface	<10	32
		15'	<10	24
		30'	<10	22
		55'	<10	23
	6-12-68	Surface	< 1	7,900
		10'	< 1	6,000
		20'	< 1	3,700
		30'	< 1	5,900
		58'	< 1	20,300
	7-12-68	Surface	7	3,800
		10'	7	10,100
		20'	7	12,500
		40'	< 1	1,800
		58'	126	34,300
	10-5-68	Surface	< 1	1,000
		30'	1	1,500
		40'	1	600
		57'	25	1,100
	1-31-69	Surface	0.01	150
		30'	0.02	30
		50'	0.01	100
Lake Inks Release	2-24-68		< 1	2,000
	4-5-68		<10	9
	6-12-68		< 1	10,700
	7-12-68		24	5,000
	10-5-68		4	>10,000
	1-31-69		0.11	70
Llano River	2-24-68	Surface	1	3,000
		15'	15	1,000
	4-6-68	Surface	<10	13
		5'	<10	7,250
		10'	<10	15
	6-19-68	Surface	<10	>10,000
		12'	<10	4,000
	7-20-68	Surface	< 1	3,500
		12'	< 1	6,200
	10-12-68	Surface	1.8	1,500
		15'	0.8	1,200
	1-31-69	Surface	0.06	80
Colorado & Llano (upper LBJ)	2-24-68	Surface	1	9,000
		33'	8	3,000
	4-6-68	Surface	<10	19
		15'	<10	10
		22'	<10	152
	6-19-68	Surface	<10	2,000
		10'	<10	508,000
		15'	<10	1,000
		20'	<10	>10,000
		34'	<10	>10,000
	7-20-68	Surface	< 1	3,000
		20'	< 1	5,600
		25'	< 1	7,000
		33'	< 1	3,500

Sampling Station	Date	Location	Coliform No./ml	Total No./ml
Colorado & Llano (continued)	10-12-68	Surface	0.04	1,500
		20'	0.2	1,800
		32'	0.2	1,900
	1-31-69	Surface	0.17	70
		20'	0.19	90
		30'	0.09	180
Lake LBJ	2-24-68	Surface	< 3	3,000
		12'		
		30'	1	2,000
		60'	8	3,000
		75'	< 3	6,000
	4-27-68	Surface	<10	124
		15'	<10	220
		25'	<10	135
		50'	<10	66
		65'	<10	178
		80'	<10	224
	6-19-68	Surface	10	TNC
		15'	10	TNC
		20'	10	1,000
		25'	10	10,000
		50'	10	7,000
		75'	10	5,000
		83'	10	1,000
	7-20-68	Surface	< 1	
		30'	< 1	5,000
		35'	< 1	
		40'	< 1	7,200
		50'	< 1	3,000
		70'	< 1	
		83'	< 1	
	10-20-68	Surface	0.1	390
		30'	0.1	200
		60'	21.1	290
		65'	< 0.02	430
		70'	< 0.02	170
		83'	< 0.02	440
	2-1-69	Surface	0.03	40
		30'	0.02	10
		60'	0.55	120
		80'	0.02	230
Lake LBJ Release	2-24-68		5	1,000
	4-27-68		<10	75
	7-20-68		< 1	10,800
	10-20-68		1	340
	2-1-69		0.13	50
Lake Marble Falls	2-24-68	Surface	< 3	2,000
		15'	1	<1,000
		30'	3	2,000
		50'	3	<1,000
		63'	< 1	2,000

Sampling Station	Date	Location	Coliform	Total No./ml
Lake Marble Falls (Continued)	4-27-68	Surface	<10	55
		25'	<10	57
		45'	<10	323
		57'	<10	71
	6-26-68	Surface	<10	1,000
		10'	<10	3,000
		20'	<10	2,000
		52'	<10	<1,000
	7-27-68	Surface	1	3,000
		20'	< 1	1,600
		30'		200
		40'	1	2,000
		53'	1	>10,000
	10-20-68	Surface	0.6	430
		30'	0.6	580
		50'	1.7	700
	2-1-69	Surface	0.10	80
		30'	0.13	140
		49'	0.23	150
Lake Marble Falls Release	2-16-68		1	2,500
	2-24-68		3	5,000
	4-27-68		10	50
	6-26-68		10	4,000
	7-27-68		1	1,100
	10-20-68		1.6	360
	2-1-69		0.91	170
Pedernales River	2-16-68	Surface	< 1	500
	3-3-68	Surface	<10	10,000
		30'	<10	81,000
		60'	<10	1,900
	4-27-68	Surface	<10	123
	6-26-68	Surface	<10	10,000
	7-27-68	Surface	< 1	2,500
	10-26-68	Surface	0.78	254
	1-29-69	Surface	0.03	110
Colorado & Pedernales	2-16-68	Surface	1	1,500
		20'	< 1	100
		40'	< 1	300
		60'	< 1	
		70'	< 1	700
		93'	< 1	900
	4-27-68	Surface	<10	65
		15'	<10	71
		15'	<10	34
		70'	<10	149
		90'	<10	186
	6-26-68	Surface	<10	1,000
		30'	<10	1,000
		35'	<10	2,000
		40'	<10	4,000
		60'	<10	5,000
		89'	<10	7,000
	7-27-68	Surface	< 1	2,800
		20'	< 1	2,600
		30'	< 1	3,600
		40'	< 1	700
		60'	< 1	
		80'	< 1	2,100

Sampling Station	Date	Location	Coliform No./ml	Total No./ml
Colorado & Pedernales (continued)	10-26-68	Surface	0.06	495
		30'	0.06	363
		60'	0.08	545
		85'		775
	1-29-69	Surface	0.03	10
		30'	0.03	50
		65'	0.08	80
		80'	Too much growth	80
Lake Travis	2-16-68	Surface	< 1	<100
		180'	< 1	800
	3-22-68	Surface	< 1	<100
		20'	< 1	900
		40'	< 1	800
		70'	< 1	500
		100'	< 1	800
		130'	< 1	1,000
		150'	< 1	1,400
		175'	< 1	100
	5-4-68	Surface	<10	80
		25'	<10	30
		80'	<10	260
		110'	<10	80
		170'	<10	600
	7-2-68	Surface	<10	2,000
		40'	<10	1,000
		55'	<10	2,000
		70'	<10	1,000
		140'	<10	5,000
		150'	<10	4,000
		160'	<10	8,000
		180'	<10	2,000
	8-8-68	Surface	0.192	300
		20'	0.043	1,500
		40'	0.557	1,100
		50'	1.150	3,500
		60'	0.768	3,000
		90'	0.168	500
		130'	0.384	1,000
		173'	0.720	3,700
	10-26-68	Surface	0.04	339
		50'	< 0.02	617
		100'	0.04	472
		110'	0.02	157
		130'	0.02	182
		140'	< 0.02	109
		150'	0.02	350
		190'	0.02	1,620
	1-29-69	Surface	0.05	200
		70'	0.02	270
		110'	Too much growth	300
		160'	0.42	150

Sampling Station	Date	Location	Coliform No./ml	Total No./ml
Lake Travis Release	3-21-68		1	300
Lake Austin	3-22-68	Surface	< 1	900
		15'	< 1	700
		30'	< 1	800
		48'	< 1	1,500
	5-4-68	Surface	<10	2,030
		30'	<10	1,760
		51'	<10	280
	7-10-68	Surface	< 1	200
		10'	< 1	300
		20'	2	100
		49'	< 1	600
	8-1-68	Surface	< 1	1,000
		10'	1	1,100
		25'	< 1	1,100
		50'	1	1,400
	11-2-68	Surface	0.06	370
		30'	1.1	1,160
		40'	0.04	660
		52'	0.1	440
	1-27-69	Surface	Too much growth	500
		Bottom	0.71	530
Lake Austin Release	5-4-68		10	60
	7-10-68		1	400
	8-1-68		1	500
	11-2-68		14.8	2,100
	1-28-69		0.36	400
Town Lake	3-15-68	Surface	< 1	<100
	5-3-68	Surface	<10	2,660
		10'	<10	1,410
		15'	<10	520
	5-7-68	Surface	<10	330
	7-10-68	Surface	50	12,400
		10'	46	10,000
	8-1-68	Surface	42	6,100
		18'	20	3,200
	11-1-68	Surface	2.6	1,130
		15'	0.2	600
	1-28-69	Surface	2.6	2,700
		15' (bottom)	0.1	1,600
Town Lake Release	7-10-68		20	12,800
	8-1-68		10	3,800
	11-1-68		0.5	840
	1-28-69		11	1,500
Decker Lake	3-15-68	Surface	< 1	1,200
	5-7-68	Surface	<10	470
	7-10-68	Surface	60	19,400
	1-27-69	Surface	0.10	50