# PHYSICAL-CHEMICAL CONDITIONS IN JOHN REDMOND RESERVOIR, JUNE, 1964, TO JUNE, 1965

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by

Carolee Emley Bussjaeger

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# PHYSICAL-CHEMICAL CONDITIONS IN JOHN REDMOND RESERVOIR, JUNE, 1964, TO JUNE, 1965

## INTRODUCTION

During the past decade a number of large federal reservoirs have been built for flood control purposes and for water storage. These reservoirs provide the most prominent and abundant limnological features of the Mid-Continent area of the United States (Carlander, 1963). At the present time there are more than a dozen federal reservoirs either impounding water or being constructed in Kansas. Several more are being planned. The John Redmond Reservoir is the seventh completed in Kansas since 1948 by the United States Army Corps of Engineers.

The number of published limnological studies concerning large artificial impoundments is limited. Most of the research on reservoirs that has been conducted in this region has dealt with fisheries or with limnological conditions associated with practical fisheries problems. In addition, most of these studies were conducted several years after the impoundment was completed. Hence, very little is known about limnological conditions in a newly impounded reservoir or of the changes that occur during the initial stages of impoundment.

Tiemeier (1951) conducted a preliminary study on Kanopolis reservoir in Kansas during the summer of 1950. His study included pH, turbidity, water temperatures, and plankton conditions. However, at the time of his study the reservoir had been impounded for two years. Tenkiller Ferry Reservoir in Oklahoma was the object of a limnological study during the summer and winter months of 1960 (Summers, 1961). This study was conducted primarily for the purpose of predicting the success of walleye stocking proposed for the spring of 1961.

In Colorado, Pennak (1949) conducted a limnological study on seven reservoir lakes. His report included data concerning the yearly cycles of pH, total and organic seston, and species composition of the copepod populations. Harris and Silvey (1940) made a comparative study of the limnology of four Texas reservoirs. They reported on physical and chemical conditions, including pH, alkalinity, soluble phosphates, nitrates, and relative amounts of calcium, sodium, and potassium. Wright (1958) studied the variations in chlorophyll, phytoplankton, zooplankton, and gross productivity in the Canyon Ferry Reservoir in Montana during September and October, 1956.

The present study was conducted as part of a long-range project to determine the effects of impoundment on the limnological characteristics of the Neosho River and to learn what changes, if any, occur in a large body of water during the initial stages of impoundment. Miller (1965) conducted a pre-impoundment study to determine the physical-chemical conditions of the Neosho River during the summer of 1963. Brock (1965), during this same period, made a survey of the benthos and zooplankton in the river. The study of the physical-chemical conditions of the river was continued during the period September, 1963, to March, 1964, by Hall (1964), and Thomas (1964), during the summer of 1964, studied variations in the primary productivity of the reservoir during the initial stages of impoundment. These studies will provide bases for determining changes in limnological conditions that occur in the reservoir after impoundment.

The purpose of the present study was to measure, record, and analyze various physical-chemical conditions in the John Redmond Reservoir during the initial stages of impoundment, June, 1964, to June, 1965. This study includes physical-chemical data recorded at four sample stations on the reservoir. The measurements include air and water temperatures, specific conductance, seston, dissolved oxygen, pH, alkalinity, dissolved chemical concentrations (calcium, sodium, potassium, nitrates, and soluble phosphates) and chlorophyll concentrations.

## DESCRIPTION OF THE AREA

The John Redmond Reservoir, located approximately 2.5 miles northwest of Burlington in Coffey County, Kansas, was constructed as part of a flood control program for the Neosho River Valley. The construction of three upstream reservoirs was also included in this program. The Council Grove Reservoir in Morris County was completed in the spring of 1965. It is presently impounding water and regulating the flow of the Neosho River near its headwaters. Another reservoir is under construction in Marion County and is scheduled for completion during 1966. This reservoir will regulate the flow of the north fork of the Cottonwood River. Still in the planning stages, the third reservoir will be located on the Cottonwood River near Cedar Point in Chase County. When completed, this series of reservoirs will make it possible to regulate the flow of water along the Cottonwood and Neosho rivers in the upper Neosho River Valley.

The Neosho River is one of the major rivers in the Arkansas River Drainage Basin which drains the southern half of Kansas. It is located in the physiographic province known as the Central Lowlands which is a plain of low relief and mature topography. The area is largely agricultural and much of the land is under cultivation (Fenneman, 1931, 1938). With its origin in the Flint Hills of Morris and Wabunsee counties in eastcentral Kansas, the Neosho River drains 6,285 square miles along a 281 mile southeasterly course through Kansas. Of the total drainage, 1,830 square miles are drained by the Cottonwood River, which joins the Neosho approximately 25 miles above the John Redmond Dam; and 505 square miles are drained by the Spring River which joins the Neosho in extreme southeastern Kansas. It has been estimated that 208,000 acres of land are subject to overflow along the Neosho River, and an additional 58,000 acres along the Cottonwood. Since 1844 at least 48 floods have occurred in the Neosho River basin. Nine of these floods were of major importance (Schoewe, 1951).

The John Redmond Dam extends more than four miles across the Neosho River Valley and impounds a conservation pool of approximately 9400 acres with a capacity of 82,700 acre-feet. The reservoir drains an area of 3,015 square miles. At maximum elevation, the flood control pool covers 31,700 acres with a capacity of 608,300 acre-feet. The water is expected to fill the flood control pool an average of once every five years (United States Army Corps of Engineers, 1959).

Although official impoundment did not begin until September 1, 1964, the basin of the reservoir was partially flooded prior to that time. Heavy rains in April, 1964, filled the reservoir to within a few feet of the expected conservation level. However, the reservoir was operated as a detention basin only during this period, and there was a continuous drawdown until official impoundment began in September (Figure 1). Heavy rains in November, 1964, again brought the water to conservation level; and during June, 1965, rains in excess of 14 inches raised the water level to more than 26 feet above conservation level. At conservation level, the reservoir is relatively shallow. Except for old river and creek channels which run through the reservoir, the depth tends to be less than three meters throughout most of the basin.

Beginning in June, 1964, water samples were taken from four stations located in the main part of the conservation pool (Figure 2). Hickory Creek was located near point "A" where the channel of Hickory Creek joined the main channel of the Neosho River. At conservation level the maximum depth at this station was approximately eight meters. Ottumwa was located along the Neosho River channel near point "B" at the upper end of the conservation pool. Maximum depth at this station was approximately ten meters. Redmond Cove was located near the dam just south of the spillway chute. Maximum depth in this area was four meters.

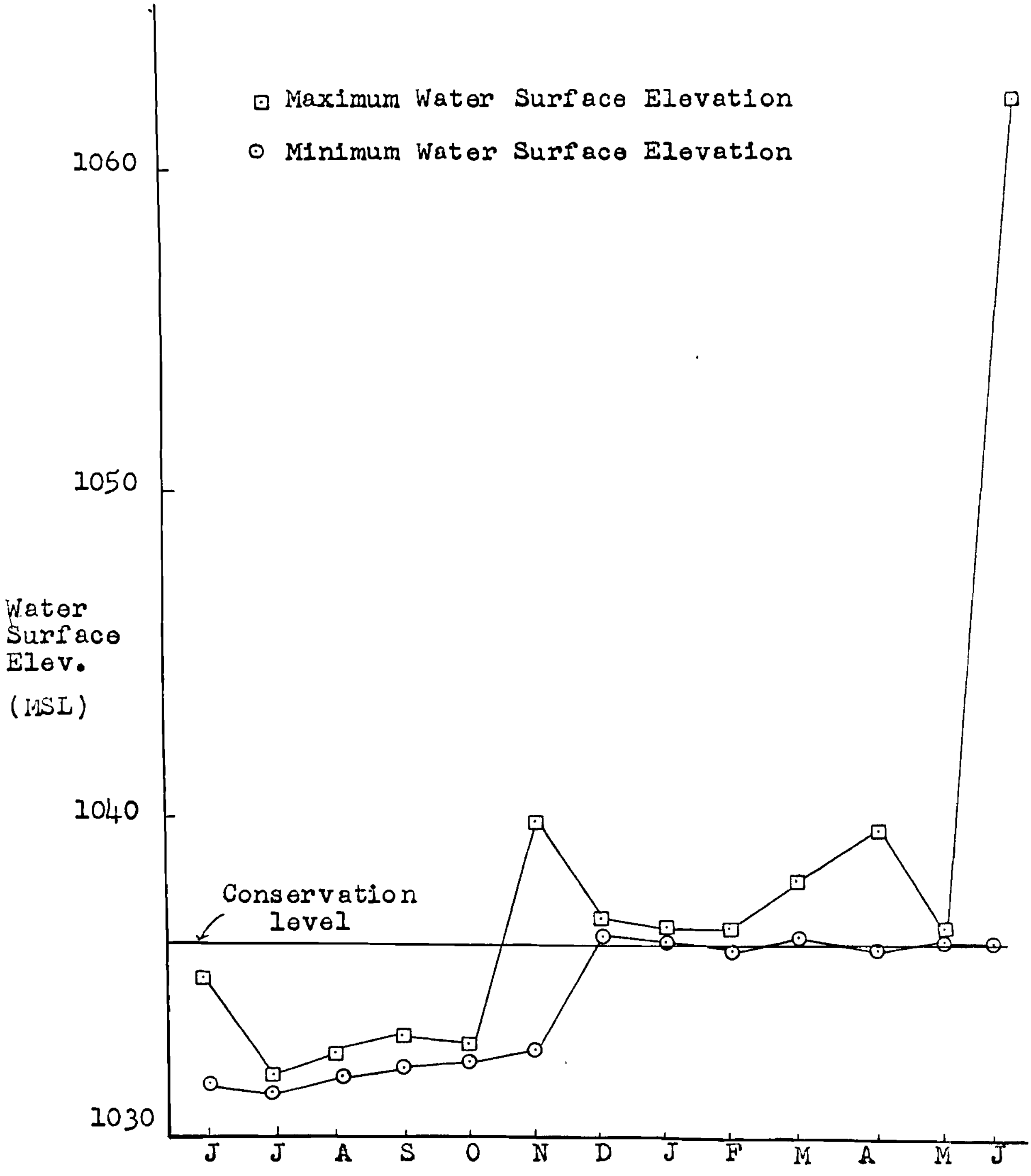


Figure 1. Maximum-minimum water surface elevations in John Redmond Reservoir, June, 1964, to June, 1965.

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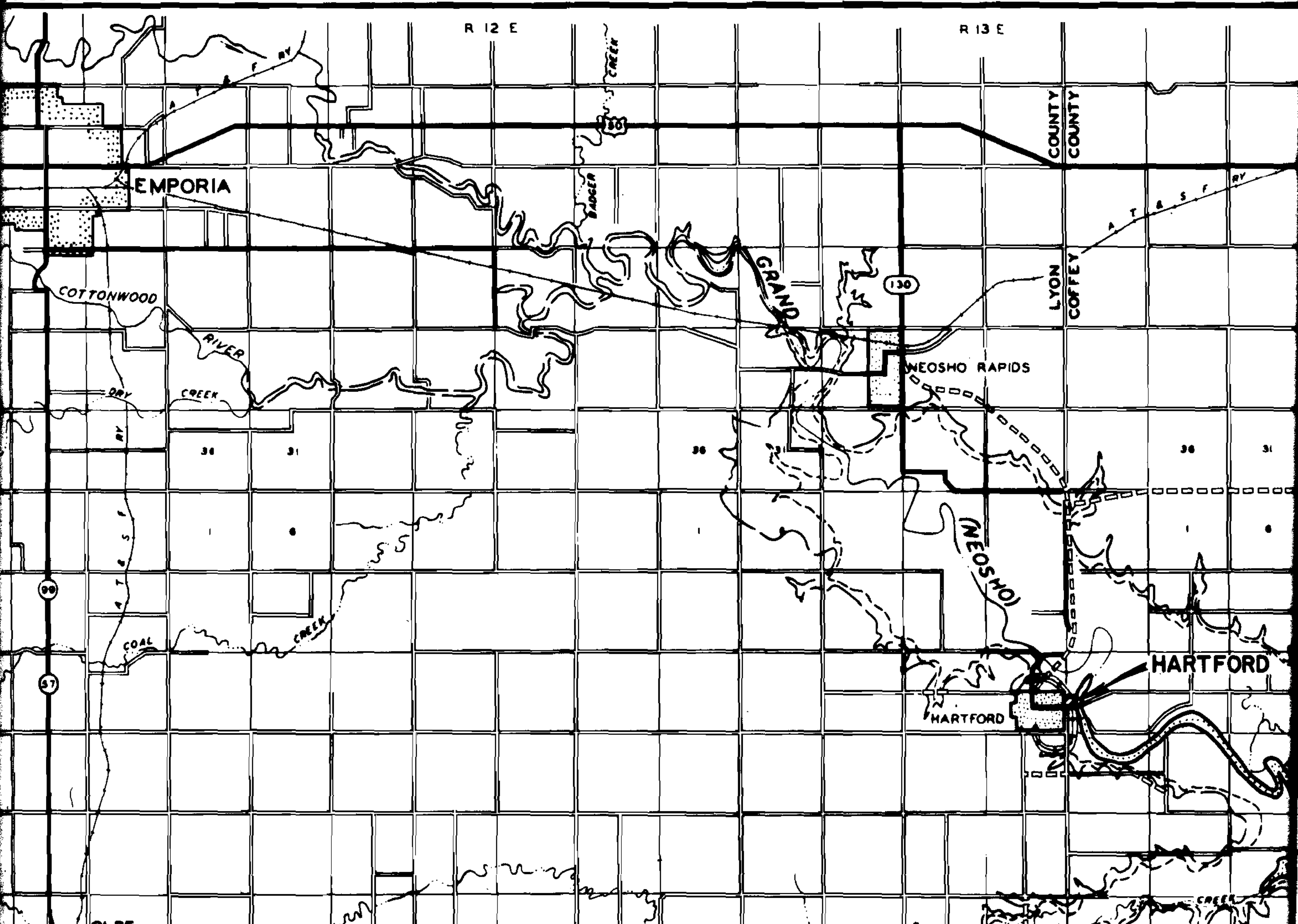
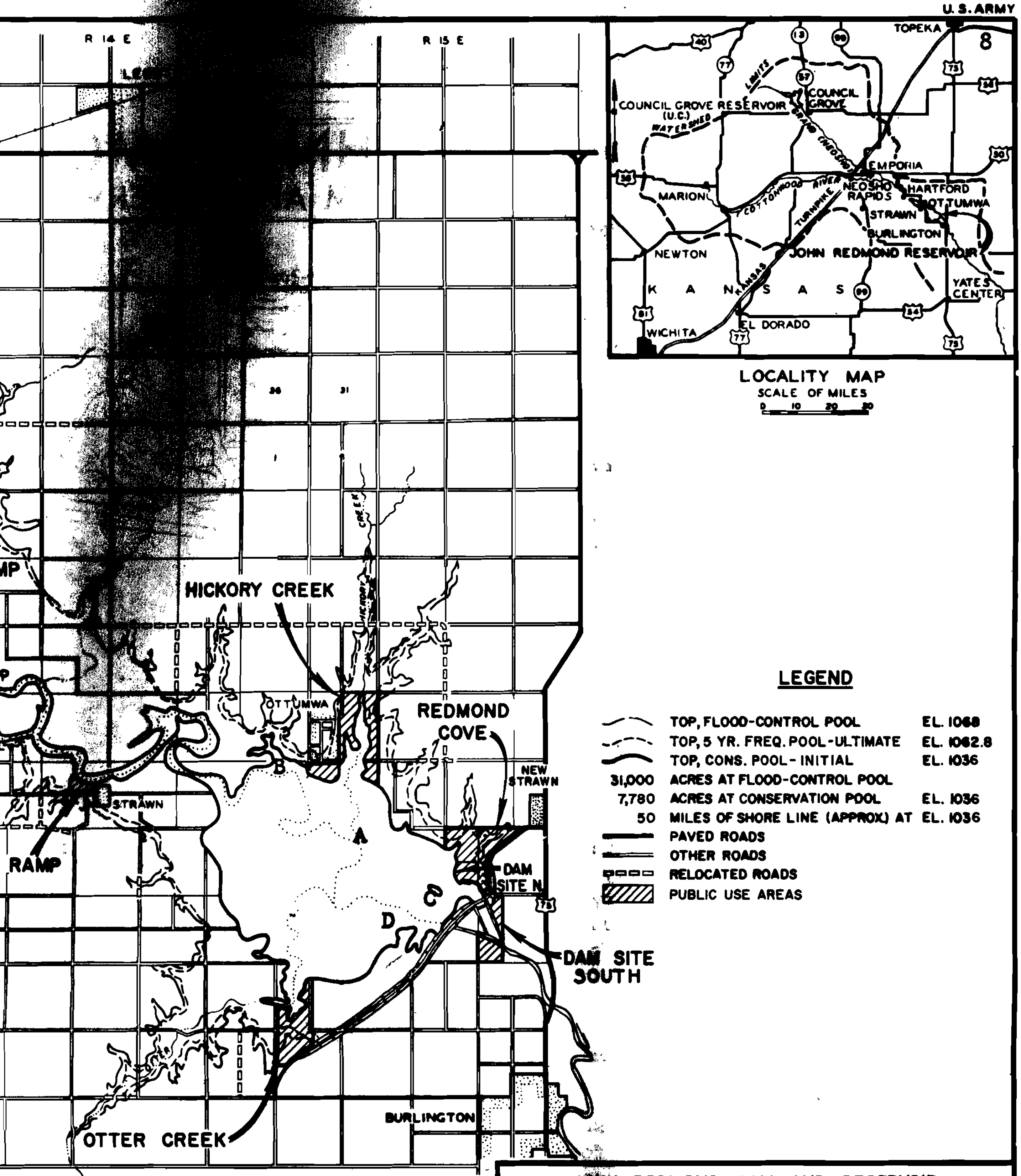





ure 2. John Redmond Dam and Reservoir showing the approximate location of sample stations.
A = Hickory Creek; B = Ottumwa
C = Redmond Cove; D = East Point.

## ULTIMATE RESERVOIR PLANS

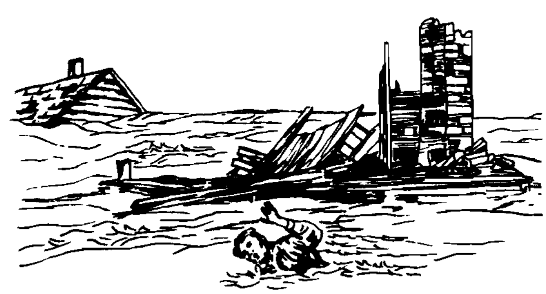
| Storage Item | Elevation | Acre-Feet | Surface Acres |
|---|---|---|---|
| Water Supply Storage | | ( 34,900) | |
| Water Quality Control | 1039.0 | ( 27,600) | 9,400 |
| Sedimentation | | ( 20,200) | |
| Flood Control | 1068.0 | 562,100 | 31,700 |
| TOTAL | | 644,800 | |

## NAME CHANGE

Originally called the Strawn Dam, the project was renamed for the Burlington Daily Republican's publisher, John Redmond. He actively promoted flood control for the Neosho Valley after viewing a flood control project in Ohio in the early 1920's. John Redmond died in 1953 at the age of 80.

## FLOODS OF RECORD

The whole story of the John Redmond project is not complete until the flood record is reviewed. T valley had been under flood waters 57 times in 34 y Farming the bottom lands was a gamble. The maximum flood of record occu in June-July 1951, one year after the project was authorized. The flood volume was equivalent to more than 12½ inches of runoff over the entire 3,000 miles of drainage area.



## TWO TOWNSITES DIRECTLY AFFECTED

Two townsites were directly affected by the reservoir. The Corps of Engineers constructed a protective dike three-fourths around the town site of Hartford to keep out reservoir waters. Strawn was relocated six miles eastward above the designed flood pool.

## INVESTMENT AND RETURNS

John Redmond Reservoir, a Federal investment of nearly $30 million, with Council Grove, Marion and Cedar Point reservoirs, will hold back damaging floods to a minimum in the upper Neosho (Grand) River Basin. Annual returns from this four-reservoir system in flood protection, wate supply, recreation and other benefits is expected to near the $5 million mark.

U.S. ARMY ENGINEER DISTRICT, TULSA

CORPS OF ENGINEERS

Tulsa, Oklahoma

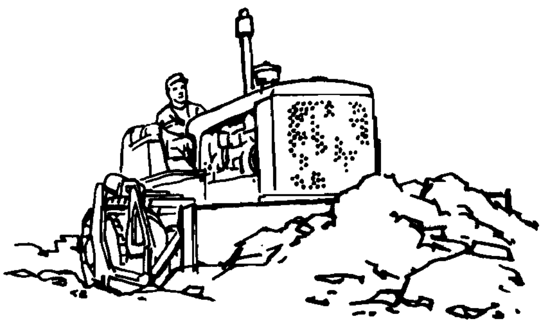
# JOHN REDMOND
## DAM AND RESERVOIR

## AUTHORIZATION

John Redmond Dam and Reservoir was authorized by Congress on 17 May 1950. The Corps of Engineers designed the project and began its construction in 1959.

## CONSTRUCTION

The dam is 84 feet above the streambed and about 4 miles long. The 680-foot long concrete spillway has fourteen 40x35-foot gates to control spillway discharges. During dry periods two 30-inch gated pipes will control low-flow discharges. One 30-inch water supply pipe will be used by communities which have contracted for the water supply storage.



## LAKE AND LAND USE

The lake and Government-owned lands surrounding it are developed and managed for public use. Desirable areas were selected to install such facilities as picnic tables, fireplaces, campsites, water, parking areas, boat-launching ramps and roads.

East Point was located near the dam at point "D" just south of the old channel of the Neosho River. Maximum depth in this area was three meters.

## METHODS AND MATERIALS

At each of the four sample stations (Figure 2), water samples were collected with a Kemmerer water sampler from the top, middle, and bottom meters of water, the exact depth of each sample depending upon the maximum water depth at the respective stations. These samples were used for the determination of dissolved oxygen, pH, alkalinity, and specific conductance. In addition, a composite sample was prepared of water collected from the euphotic zone and was used for the determination of chlorophyll, seston, soluble phosphates, nitrates, calcium, sodium, and potassium.

Measurements were recorded once a week during the winter months, and at least twice a week during the summer months. Water temperatures were recorded at meter intervals from the surface to the bottom, using a Whitney underwater thermistor thermometer. Light penetration was determined with a six-inch Secchi disk, and a Whitney underwater photometer. The euphotic zone was considered to be the depth to which one per cent of surface illumination penetrated. The electrical resistances of the water samples were measured with an Industrial Instruments RC 12 conductivity bridge and converted to specific conductance in micromhos per $cm^3$ at 25°C.

All chemical analyses were conducted according to procedures outlined in Standard Methods (APHA, 1960). The dissolved oxygen concentration was determined by the Rideal-Stewart modification of the Winkler method during the early stages of the study, but the Alsterburg modification was used later. Hydrogen-ion concentrations were measured with a Beckman Zeromatic Model 96 pH meter. Phenolphthalein and methyl orange alkalinities were determined by titration with N/50 sulfuric acid to end-points of pH 8.3 and pH 4.6, respectively; and then converted to carbonate and bicarbonate concentrations in mg/l. Soluble phosphates were determined by the stannous chloride method. A Model 21 Coleman Flame Photometer was used to measure relative amounts of calcium, sodium, and potassium. Nitrogen determinations were made according to the methods recommended by the Hach Chemical Company (1964).

Seston was determined by centrifuging a 500 ml water sample in a Foerst plankton centrifuge at approximately 20,000 rpm. The centrifugate was then placed in a preweighed porcelain crucible, dried in an electric oven at 50°C, and cooled in a desiccator. The weight of the total seston was calculated by subtracting the crucible weight from the combined weight of the crucible and the dried centrifugate. Suspended organic solids were determined by measuring the loss on ignition of the centrifugate.

Chlorophyll determinations were made from composite water samples collected from the euphotic zone. These samples were returned to the laboratory and a 100 ml portion was filtered through a Type AA millipore filter. The filter and residue were then placed in 5 ml of 90% acetone and refrigerated. After 18 to 24 hours the samples were returned to room temperature and the chlorophyll extract decanted. A Beckman Model B spectrophotometer was used to determine the absorbance values of the extract at 665, 645, and 630 mu. The resulting values were used to calculate the concentration of chlorophyll according to the procedures of Richards and Thompson (1952).

## RESULTS AND DISCUSSION

In general, very little variation was observed from one sample station to another on any one sample date for the conditions measured. Any observed variation was usually attributed to differences in sampling time. Hence, trends which appeared to be characteristic throughout the reservoir are illustrated by the data collected at Hickory Creek.

Temperature. The monthly mean surface water temperature ranged from a maximum of 28°C in July to a minimum of 1°C in December. Surface water temperatures varied little from station to station on any given sampling date and were generally similar to air temperatures (Figure 3). Throughout most of the year, the water temperatures were relatively uniform from the surface to the bottom. However, there was a tendency for the reservoir to become weakly stratified during June and July. During this period a thermocline was frequently evident even in areas of the reservoir where the water depth did not exceed three meters.

Temperature profiles such as those recorded at Hickory Creek between June 22 and July 10, 1964 (Figure 4) indicated that thermal stratification was of short duration. On June 22, the water column was homothermous, and the dissolved oxygen concentration in the bottom meter was

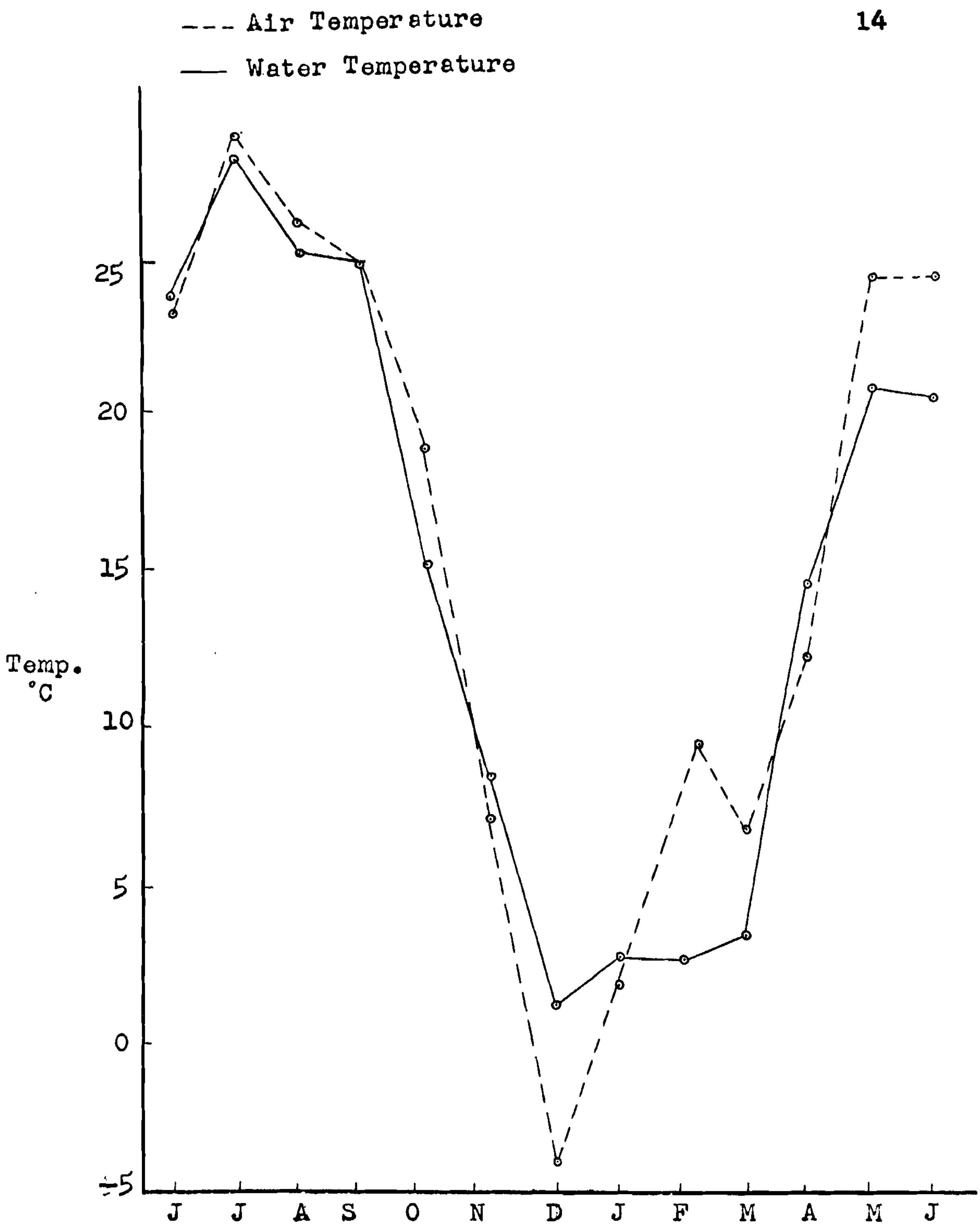



Figure 3. Monthly mean air and surface water temperatures at Hickory Creek, John Redmond Reservoir, June, 1964, to June, 1965.

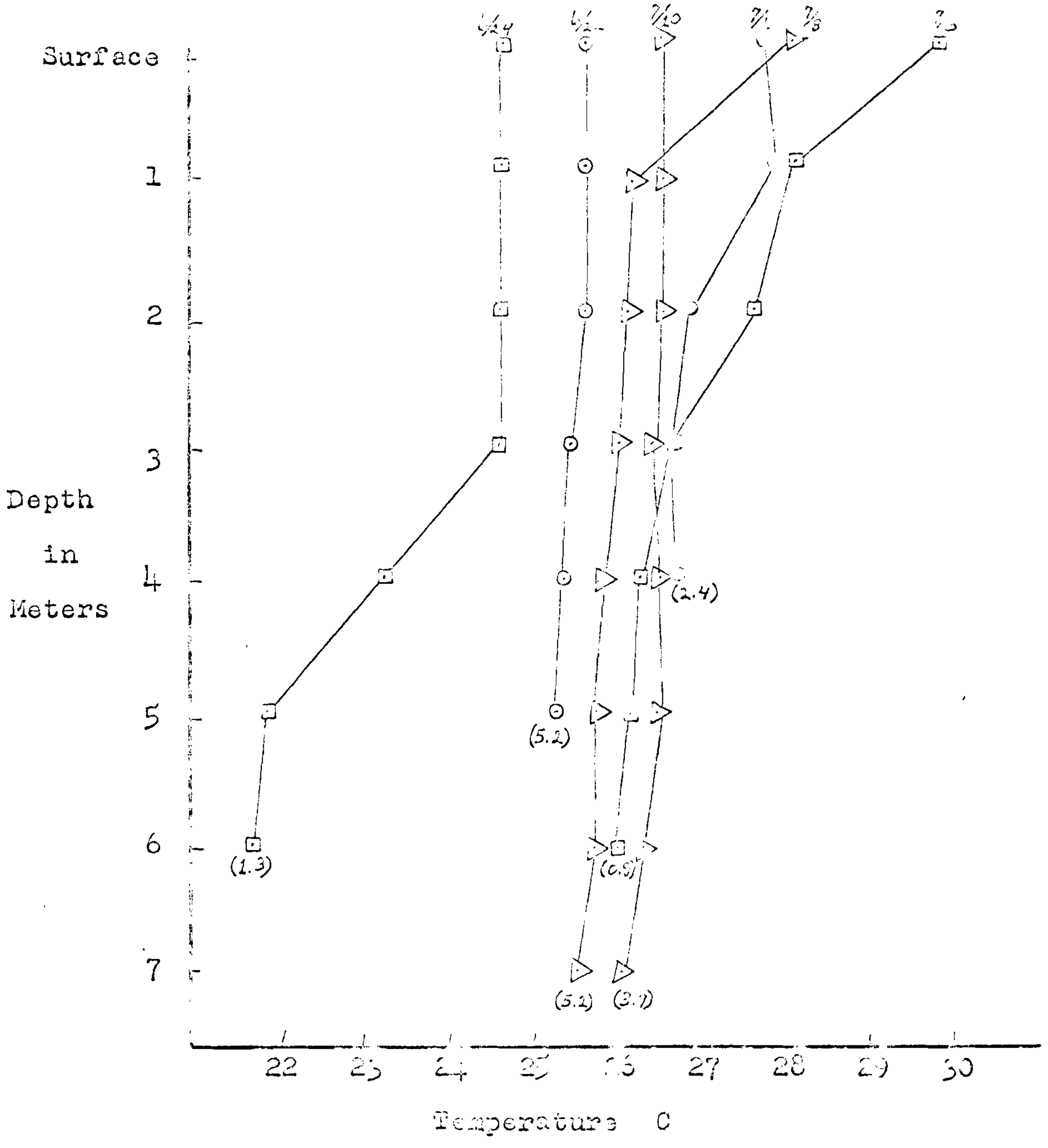



Figure 4. Temperature profiles recorded at Hickory Creek, John Redmond Reservoir, for each sampling date, June 22 to July 10, 1964, inclusive. Dissolved oxygen in bottom meter, mg/l ( ).

about 5 mg/l. Two days later, surface temperatures were slightly lower, and a thermocline was evident between three and five meters. At this time dissolved oxygen in the bottom meter was reduced to 1.3 mg/l. Winds, which were calm on June 22, were blowing from the northwest with a velocity of five to ten miles per hour on June 24. Apparently, this initial stratification was broken up during the next few days, for water temperatures at all depths were several degrees warmer by July 1. On this date a weak thermocline was detected between one and two meters. Dissolved oxygen in the bottom meter was still quite low, being 2.4 mg/l. On July 3 and 8 the thermocline occurred in the top meter. A secondary thermocline may have been present between two and three meters on July 3. Only 0.8 mg/l of dissolved oxygen was present in the bottom meter on July 3, but by July 8, this had increased to 5.2 mg/l. This increased oxygen concentration probably indicates that the reservoir had undergone mixing sometime between July 3 and 8, and may have been in the initial stages of stratifying again on July 8. On July 10, the reservoir was again essentially homothermous. Thus, variation in the depths of the thermocline and the variation in the amounts of dissolved oxygen in the bottom meter would indicate that the reservoir became thermally stratified at least two and possibly three times, during the period June 22 to July 10.

Evidence of thermal stratification was observed at Hickory Creek at other times during the summer, but never on two consecutive sampling dates. Similar conditions existed at the other three stations throughout the summer. Conditions during stratification generally included a considerable difference between surface and bottom temperatures and a decrease in dissolved oxygen in the bottom meter. At times, the dissolved oxygen was less than one mg/l in the bottom meter of water, and frequently, the maximum temperature change occurred in the top meter of water.

Thermal stratification during the summer months is apparently common for many large impoundments in Kansas. Andrews and Breukelman (1952) reported that five of the 19 state lakes which they studied exhibited thermal stratification. Lyon County State Lake stratified when the maximum depth was only four meters (Prophet, 1965). Thermal stratification occurred in the reservoir only when air temperatures were quite warm and the winds were calm so there was little or no mixing of the water.

Dissolved Oxygen. Dissolved oxygen levels in the top meter of water showed an inverse relationship to surface water temperatures (Figure 5). The lowest averages for

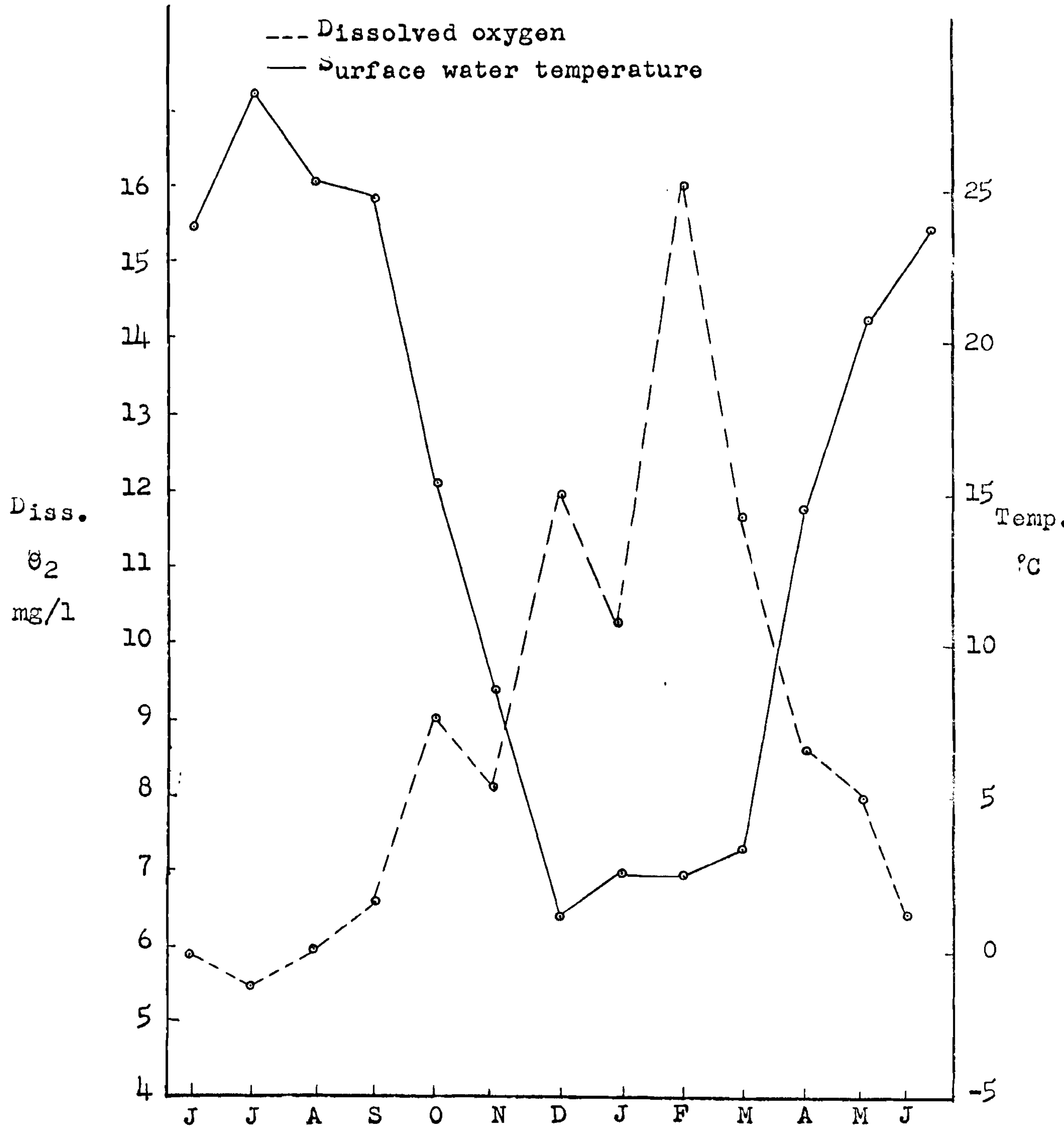



Figure 5. Monthly averages of dissolved oxygen and surface water temperatures at Hickory Creek, John Redmond Reservoir, June, 1964, to June, 1965.

dissolved oxygen were recorded during July when the surface water temperatures were highest. The highest monthly average for dissolved oxygen was recorded during February when the temperatures were relatively low. In general, the top and bottom dissolved oxygen levels varied little from one station to another on any one sampling date. The monthly average dissolved oxygen in the top meter of water in the reservoir varied from 5.5 mg/l at Hickory Creek in July to 16.1 mg/l at Hickory Creek in February. The average dissolved oxygen in the bottom meter of water varied from 2.4 mg/l at Ottumwa in July to 16.3 mg/l at Hickory Creek in February.

Although it would appear from the monthly averages that dissolved oxygen in the bottom meter of water never reached critical levels, there were days when the bottom oxygen supply was nearly depleted. As mentioned before, this condition occurred when there was a tendency for the reservoir to be thermally stratified. As can be seen in Figure 6, dissolved oxygen concentrations in the bottom meter fluctuated greatly during June and July. Dissolved oxygen in the bottom meter of water at Hickory Creek was less than 2 mg/l on June 24 and July 1, 3, and 22. Similar conditions existed at the other stations. The rapid reduction of dissolved oxygen at the bottom during the short intervals of thermal stratification was probably caused by

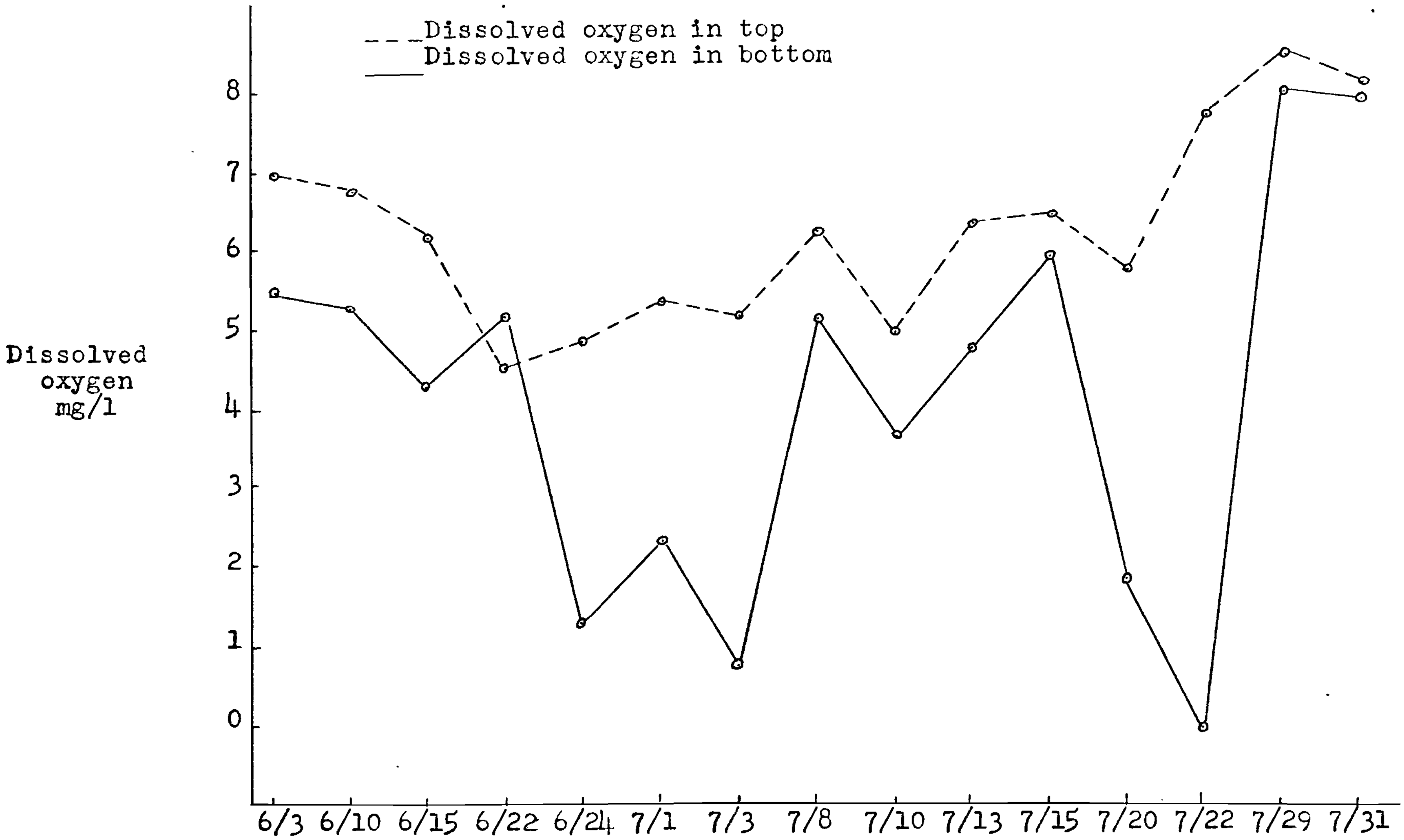



Figure 6. Dissolved oxygen in the top and bottom meters of water at Hickory Creek, for each sample during June and July, 1964.

the decomposition of the large quantities of recently submerged vegetation.

Little difference was observed between the monthly average dissolved oxygen values of the top and the bottom meters of water at Hickory Creek (Figure 7). This condition was exhibited at all stations and was probably the result of the heavy wave action to which the reservoir was subjected much of the time. The maximum difference between the top and bottom monthly average dissolved oxygen levels at Hickory Creek (2.5 mg/l) occurred during July. It was during this period that temporary stratification occurred and the dissolved oxygen was greatly reduced in the bottom meter of water. During February, March, and May, the average bottom oxygen levels at Hickory Creek were approximately 0.1 mg/l higher than surface values.

Miller (1965) reported oxygen concentrations between 3.2 and 11.2 mg/l in the Neosho River during the 1963 summer, and Hall (1964) reported oxygen concentrations between 3.6 and 19.0 mg/l in the Neosho River during the winter of 1963-1964. In both cases the oxygen content in the river exhibited greater fluctuation than the oxygen content in the reservoir. This is not unexpected since the river water is more highly saturated during periods of low flow, and it is more likely to be depleted of oxygen during

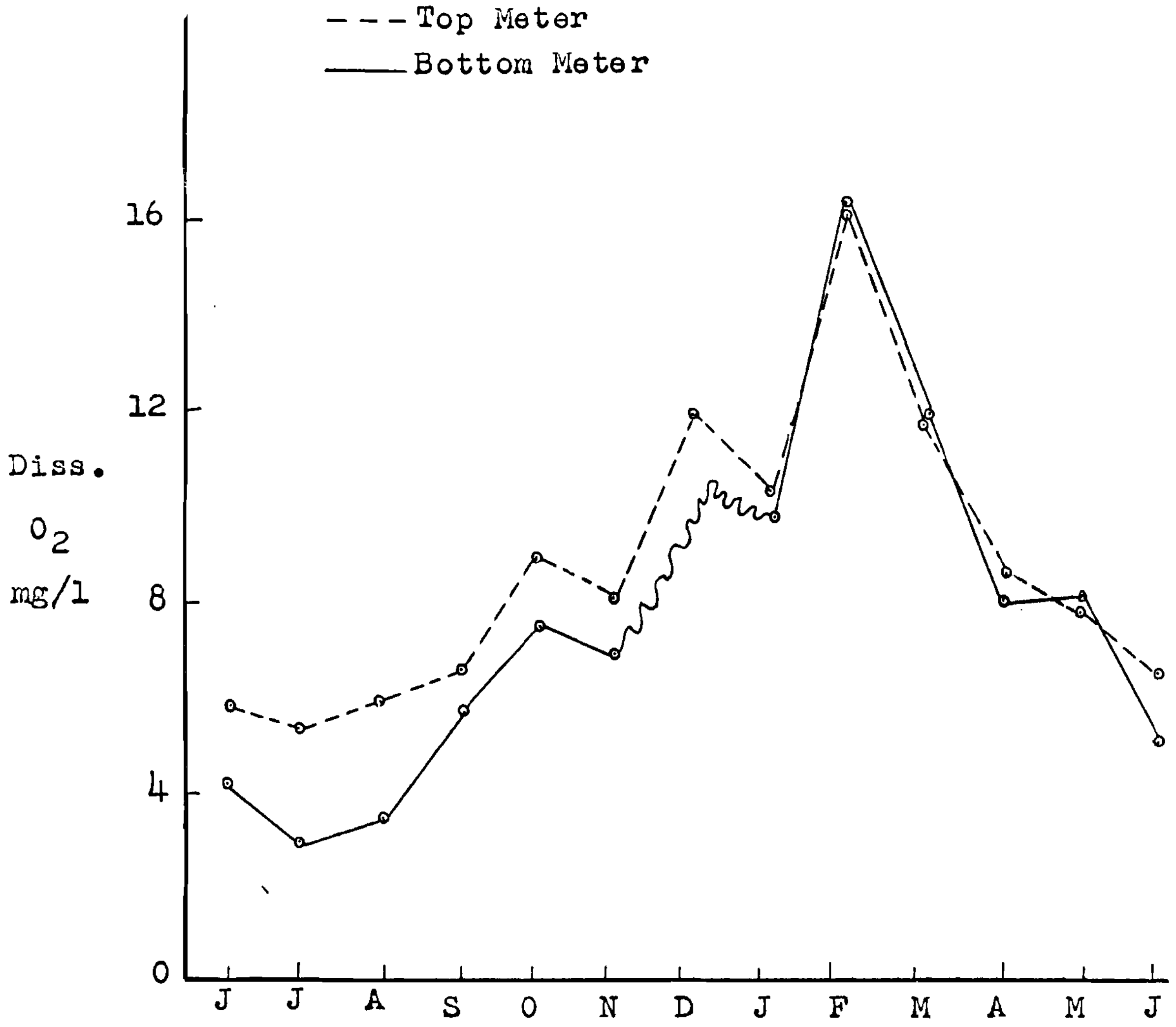



Figure 7. Monthly averages of dissolved oxygen in the top and bottom meters of water at Hickory Creek, John Redmond Reservoir, June, 1964, to June, 1965.

No bottom sample taken in December.

periods of high flow due to increased volume and silt and organic load.

Hydrogen-ion concentration. There was usually little variation in the pH from station to station on any given date, although the yearly pH range did vary from one station to another. The pH was usually between 7.8 and 8.2, with lower extremes occurring during periods of high discharge. Extreme highs of pH 9.7 (top) and pH 9.6 (bottom) were recorded for Hickory Creek on February 27. Samples were not taken at the other stations on this date because a heavy ice layer covered the reservoir.

The alkaline condition of the reservoir water was expected since most of the drainage of the upper Neosho River System is from soils derived from limestone. Neel (1951) reported pH values ranging from 7.3 to 8.7 in a Kentucky stream with limestone headwaters. Prior to its impoundment, the pH of the Neosho River in Lyon and Coffey counties ranged from 7.7 to 9.1 (Miller, 1965, and Hall, 1964).

Bicarbonate Alkalinity. Monthly average bicarbonate alkalinity in the top and bottom meters of water at each sample station are reported in Table 1. Carbonates were rarely present; when present they ranged from 2 to 35 mg/l, but were usually less than 10 mg/l. Hence, the total alkalinity was primarily due to the presence of bicarbonates,

Table 1. MONTHLY AVERAGES OF $HCO_3$ (mg/1) IN THE TOP AND BOTTOM METERS OF WATER AT JOHN REDMOND RESERVOIR, JUNE 1964 TO JUNE 1965.

| | Hickory Creek | | Ottumwa | | Redmond Cove | | East Point | |
|---|---|---|---|---|---|---|---|---|
| | Top | Bottom | Top | Bottom | Top | Bottom | Top | Bottom |
| June | 148 | 120 | 131 | 122 | 139 | 127 | 110 | 130 |
| July | 136 | 146 | 148 | 142 | 128 | 129 | 129 | 129 |
| August | 156 | 160 | 159 | 163 | 155 | 151 | 152 | 154 |
| September | 165 | 164 | 167 | 171 | 164 | 160 | 161 | 167 |
| October | 163 | 165 | 162 | 159 | 160 | 170 | 168 | 167 |
| November | 129 | 129 | 131 | 130 | 128 | 130 | 129 | 128 |
| December | 123 | --- | 124 | --- | 100 | --- | --- | --- |
| January | 161 | 157 | 178 | 169 | 153 | 144 | 145 | 141 |
| February | 150 | 152 | 158 | 165 | --- | --- | --- | --- |
| March | 155 | 155 | 144 | 146 | 146 | 145 | 137 | 141 |
| April | 171 | 172 | 172 | 179 | 157 | 155 | 155 | 156 |
| May | 191 | 191 | 194 | 190 | 193 | 194 | 189 | 187 |
| June | 125 | 123 | 112 | 117 | 131 | 132 | 131 | 131 |

---No sample taken.

and bicarbonate alkalinity usually equaled the total alkalinity.

There was generally little variation between surface and bottom bicarbonate levels. Surface bicarbonate concentrations ranged from 78 mg/l at East Point on June 21, 1965, to 205 mg/l at East Point on June 4, 1965. Monthly average bicarbonates in the top meter ranged from 100 mg/l at Redmond Cove in December to 194 mg/l at Ottumwa in May. In most cases, bicarbonates tended to be greater than 150 mg/l. There was some variation between bicarbonate levels from station to station in both the top and bottom meters of water. Bicarbonate values tended to be highest at Ottumwa, lowest at East Point and Redmond Cove, and intermediate at Hickory Creek. Thus, alkalinity tended to exhibit a gradient within the reservoir. The lower bicarbonate concentration at the lower end of the reservoir was probably due to the photosynthetic activity of the phytoplankters and rooted aquatic plants in the reservoir. Primary producer utilization of carbon dioxide as the water mass moved through the basin could have resulted in the observed decrease.

Any seasonal changes in bicarbonate alkalinity were somewhat obscured by the fluctuations of the water level in the reservoir. The gradual increase in bicarbonates during the summer months of 1964 was probably related to the low flow of the Neosho River above its confluence with the Cottonwood River (Figure 2). Most of the water flowing into the reservoir during this period was from the Cottonwood River (U.S. Dept. of Interior, Geological Survey, 1964). These two rivers show distinctly different physical-chemical characteristics. Bicarbonate content in the Neosho River ranged from 94 to 174 mg/l during the period of June to November, 1964. For the same period, bicarbonates ranged from 124 to 255 mg/l in the Cottonwood River (Purkeypile, 1965). The sharp drop in bicarbonate alkalinity in November was probably due to the introduction of a large volume of water into the reservoir from heavy rains upstream along the Neosho. This tended to dilute the impounded water, resulting in lower bicarbonate alkalinity.

During the winter months an increase in alkalinity is apparently common in most lakes and rivers. This is probably due to the combined effect of the accumulation of free carbon dioxide and a decrease in photosynthetic activity during the cooler months (Hutchinson, 1957). Bicarbonate alkalinity in the reservoir showed a marked increase between December and January. The rapid decline in bicarbonates during June, 1965, was again probably due to the influx of large amounts of water from upstream flooding.

Table 2. MONTHLY AVERAGE SPECIFIC CONDUCTANCE (umhos/cm$^3$) AT 25 C OF THE TOP AND BOTTOM METERS AT JOHN REDMOND RESERVOIR, JUNE, 1964 TO JUNE, 1965.

| | Hickory Creek | | Ottumwa | | Redmond Cove | | East Point | |
|---|---|---|---|---|---|---|---|---|
| | Top | Bottom | Top | Bottom | Top | Bottom | Top | Bottom |
| June | 455 | 405 | 451 | 428 | 473 | 486 | 452 | 442 |
| July | 469 | 489 | 517 | 528 | 453 | 463 | 462 | 466 |
| August | 494 | 512 | 506 | 517 | 491 | 502 | 501 | 502 |
| September | 550 | 509 | 533 | 549 | 535 | 524 | 524 | 521 |
| October | 373 | 362 | 365 | 365 | 377 | 354 | 358 | 357 |
| November | 274 | 239 | 259 | 288 | 265 | 259 | 246 | 258 |
| December | 316 | --- | 111 | --- | 125 | --- | --- | --- |
| January | --- | --- | --- | --- | --- | --- | --- | --- |
| February | 288 | 283 | --- | --- | --- | --- | --- | --- |
| March | 219 | 219 | 204 | 206 | 232 | 222 | 202 | 208 |
| April | 367 | 383 | 347 | 362 | 343 | 334 | 324 | 320 |
| May | 536 | 538 | 565 | 428 | 515 | 516 | 513 | 485 |
| June | 360 | 354 | 333 | 339 | 372 | 392 | 570 | 270 |

---Conductivity bridge out of order

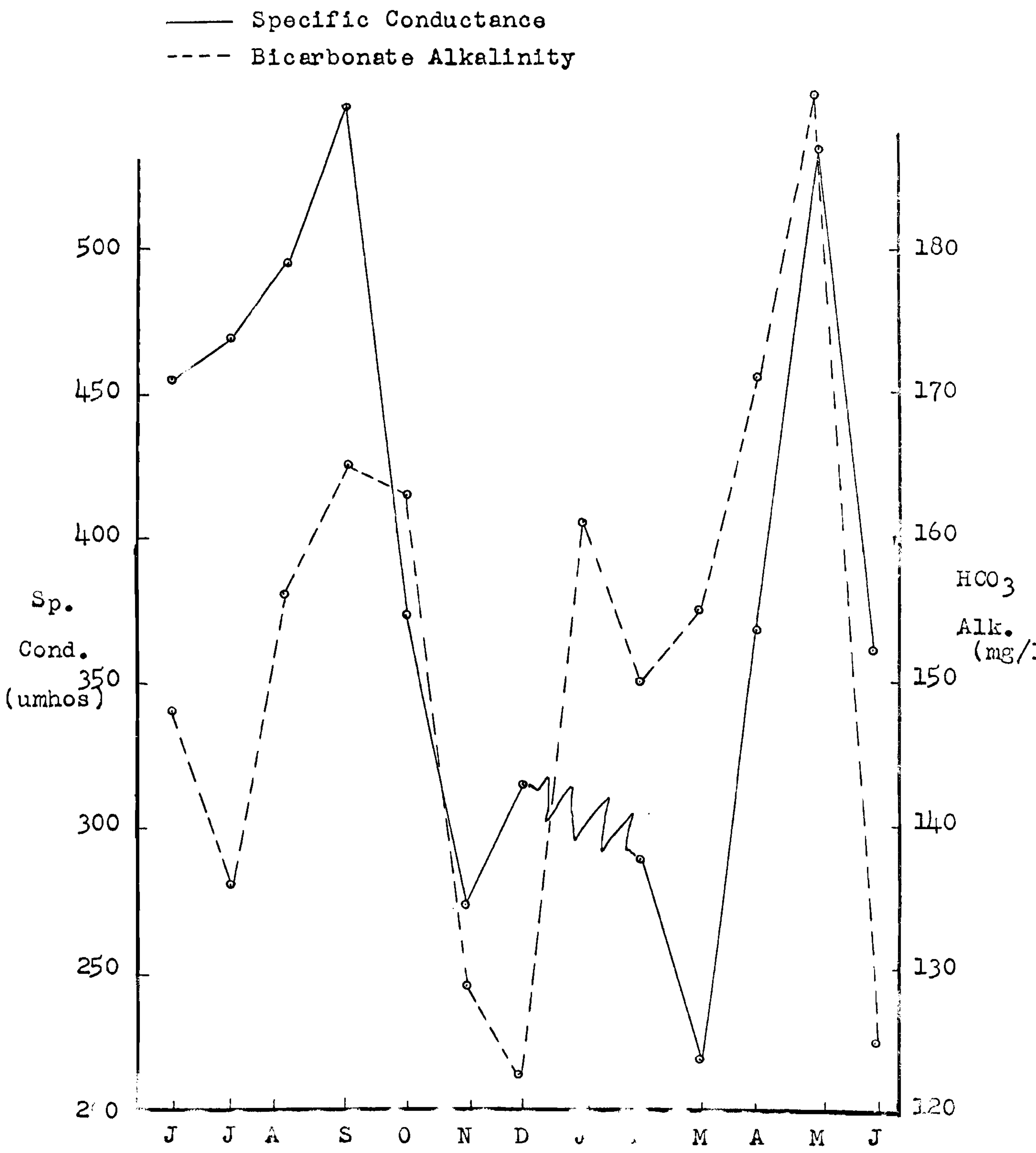



Figure 8. Monthly average specific conductance and bicarbonate alkalinity at Hickory Creek, John Redmond Reservoir, June, 1964, to June, 1965.

(Conductivity Bridge out of order December to February).

Specific Conductance. The monthly average specific conductance ranged from 111 umhos/cm$^3$ at Ottumwa in December to 565 umhos/cm$^3$ at Ottumwa in May (Table 2). There appeared to be a direct relationship between specific conductance and bicarbonate alkalinity (Figure 8). Both measurements followed the same trend at all stations, being highest in the summer months and lowest in the winter. The relationship between specific conductance and bicarbonate alkalinity is to be expected since bicarbonates represent the major source of inorganic ions in freshwater (Hutchinson, 1957).

Chlorophyll and Organic Seston. Table 3 shows the monthly averages for chlorophyll and the average percentage of organic seston in the euphotic zone at each station. Chlorophyll levels varied from 3.2 ug/l at Ottumwa in December to 30.6 ug/l at Hickory Creek in September. Although there was considerable variation in chlorophyll levels from station to station, all stations exhibited relatively high chlorophyll levels during the late summer and fall months and low values during the winter months. Chlorophyll levels tended to follow a cyclic pattern during July and August, 1964, with peaks occurring at approximately two-week intervals. At Hickory Creek, for example, peaks of 13.1, 39.8, 28.8, and 15.1 ug/l occurred on July 6, 20, 31, and August 12, respectively (Figure 9). Although values

Table 3. MONTHLY AVERAGE CHLOROPHYLL (ug/l) AND % ORGANIC SESTON IN THE EUPHOTIC ZONE AT JOHN REDMOND RESERVOIR, JUNE, 1964, TO JUNE, 1965

| | Hickory Creek | | Ottumwa | | Redmond Cove | | East Point | |
|---|---|---|---|---|---|---|---|---|
| | Chloro. | Seston | Chloro. | Seston | Chloro. | Seston | Chloro. | Seston |
| June | 6.73 | 21 | 14.0 | 17 | 4.3 | 17 | 8.49 | 22 |
| July | 21.0 | 26 | 19.4 | 23 | 12.0 | 29 | 14.6 | 34 |
| August | 15.2 | 25 | 14.6 | 30 | 13.5 | 28 | 14.9 | 21 |
| September | 30.6 | 16 | 21.7 | 15 | 25.8 | 21 | 23.7 | 15 |
| October | 24.7 | 27 | 27.1 | 23 | 21.4 | 21 | 19.9 | 19 |
| November | 29.4 | 44 | 12.7 | 69 | 15.2 | 78 | 21.0 | 67 |
| December | 5.0 | 31 | 3.2 | 32 | 6.2 | 8 | -- | -- |
| January | 5.5 | 42 | 6.6 | 73 | 3.8 | 40 | 5.9 | 32 |
| February | 12.8 | 44 | 11.9 | 48 | -- | -- | -- | -- |
| March | 15.6 | 17 | 9.9 | 25 | 13.6 | 14 | 13.1 | 15 |
| April | 11.0 | 14 | 14.2 | 11 | 14.0 | 11 | 15.5 | 29 |
| May | 23.5 | 34 | 18.6 | 26 | 17.3 | 24 | 20.5 | 18 |
| June | 21.2 | 22 | 10.9 | 17 | 9.3 | 22 | 8.6 | 17 |

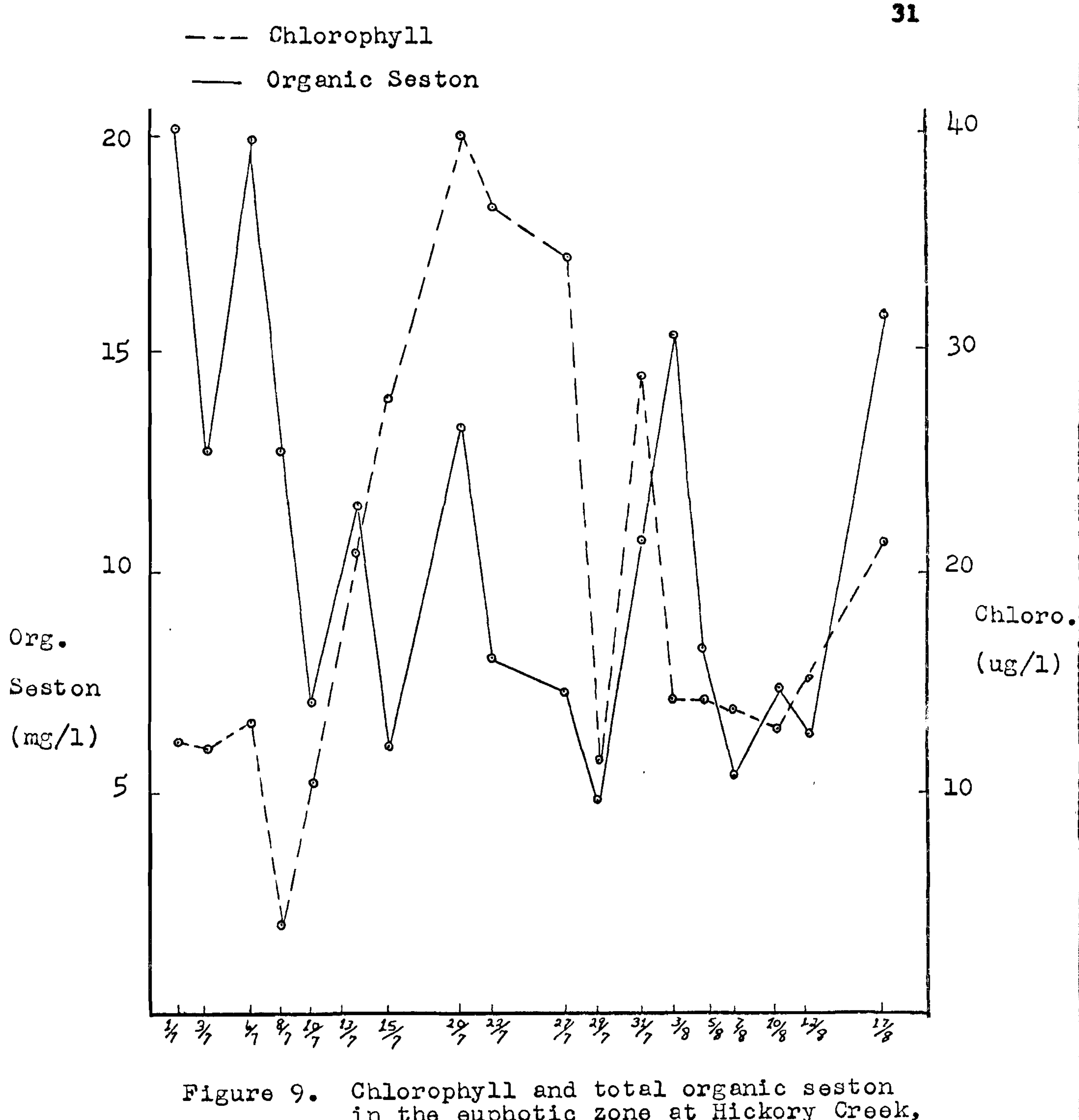



Figure 9. Chlorophyll and total organic seston in the euphotic zone at Hickory Creek, John Redmond Reservoir, for each sample date during July and August, 1964.

fluctuated from date to date, the general trend was for the amount of chlorophyll in the euphotic zone to increase throughout the summer months.

Throughout the study period there was an overall tendency towards an increase in chlorophyll in the euphotic zone. Chlorophyll levels in the reservoir were considerably higher than those reported by Hall (1964) for the Neosho River prior to impoundment. He reported chlorophyll averaged from 1.2 ug/l in January to 10.6 ug/l in March. Chlorophyll levels in the reservoir were also higher than the average of 0.2 to 3.6 ug/l which Prophet (1965) reported for the partially reflooded Lyon County State Lake, Kansas.

The average percentage of organic seston varied from 78% at Redmond Cove in November to 8% at Redmond Cove in December. However, the percentage of organic seston tended to be high during the winter months and relatively low throughout the rest of the year. The total amount of organic seston followed a cyclic pattern and appeared to be related to the amount of chlorophyll present, although the organic seston showed a much shorter cycle with peaks occurring at about four-day intervals.

Soluble Phosphates and Nitrates. Soluble phosphate levels were relatively high in the reservoir throughout the study (Table 4). Monthly averages ranged from 0.10 mg/l at East Point in September to 0.77 mg/l at Hickory Creek in

Table 4. MONTHLY AVERAGES OF $PO_4$ AND $NO_3$ (mg/l) IN THE EUPHOTIC ZONE AT JOHN REDMOND RESERVOIR, JUNE 1964, TO JUNE 1965.

| | Hickory Creek | | Ottumwa | | Redmond Cove | | East Point | |
|---|---|---|---|---|---|---|---|---|
| | $PO_4$ | $NO_3$ | $PO_4$ | $NO_3$ | $PO_4$ | $NO_3$ | $PO_4$ | $NO_3$ |
| June | .37 | --- | .52 | --- | .37 | --- | .31 | --- |
| July | .19 | .32 | .22 | .33 | .23 | .34 | .23 | .35 |
| August | .16 | .41 | .17 | .47 | .26 | .22 | .20 | .27 |
| September | .15 | .22 | .13 | .37 | .16 | .36 | .10 | .19 |
| October | .11 | .20 | .12 | .28 | .14 | .10 | .10 | .21 |
| November | .34 | .55 | .34 | .60 | .22 | .50 | .23 | .05 |
| December | .33 | .25 | .58 | .44 | .36 | .19 | --- | --- |
| January | .42 | .17 | .51 | .30 | .44 | .36 | .49 | .44 |
| February | .77 | .60 | .28 | .59 | --- | --- | --- | --- |
| March | .23 | .82 | .28 | .94 | .22 | .89 | .35 | 1.29 |
| April | .42 | 1.20 | .21 | 1.00 | .33 | .60 | .42 | 1.40 |
| May | .34 | .56 | .38 | .14 | .33 | .04 | .34 | .59 |
| June | .47 | .27 | .50 | .51 | .54 | .43 | .51 | .42 |

---No sample taken

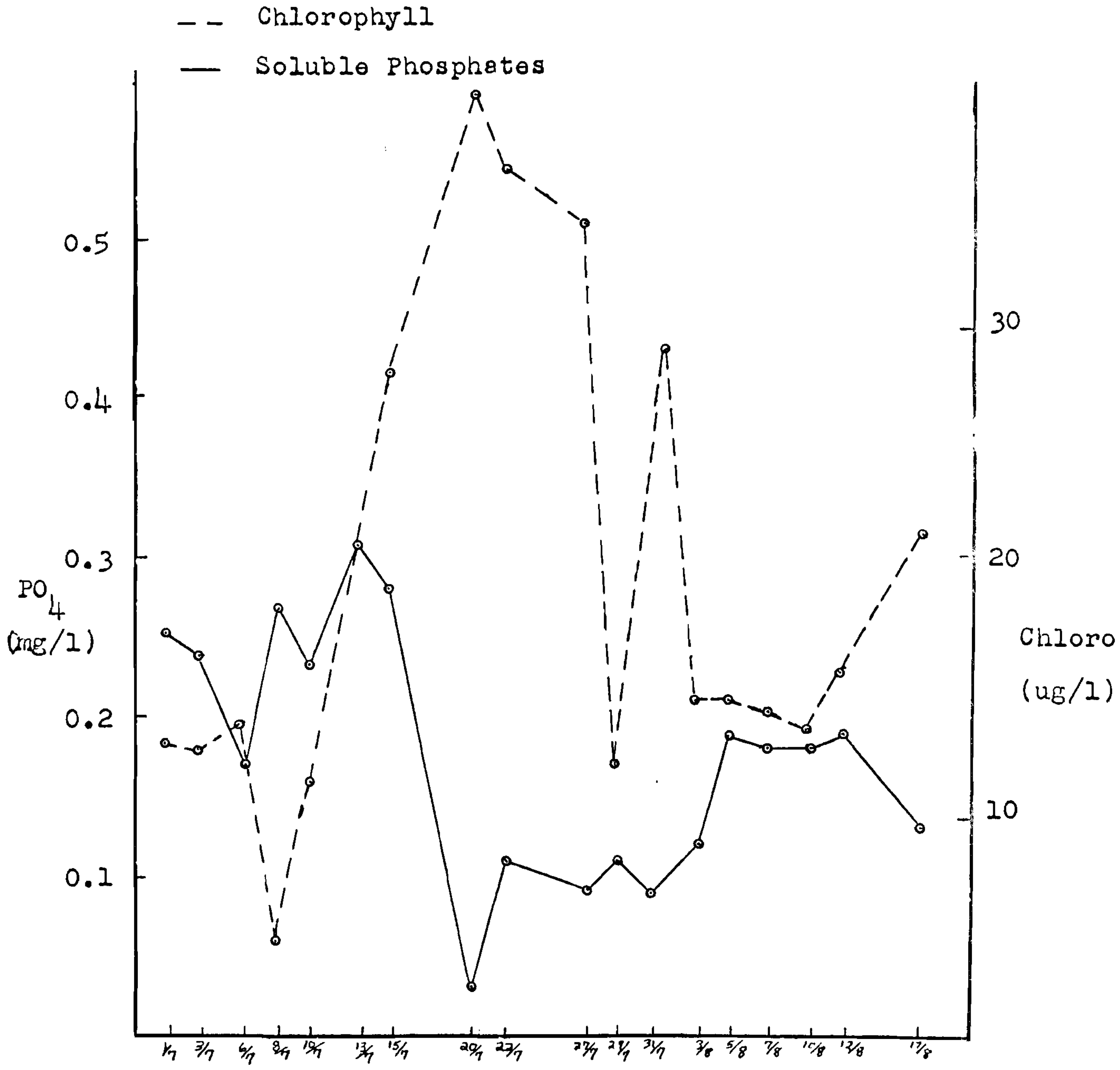



Figure 10. Chlorophyll and soluble phosphates in the euphotic zone at Hickory Creek, John Redmond Reservoir, for each sample date during July and August, 1964.

February. A marked increase occurred in November, and throughout the rest of the study soluble phosphates continued at a much higher level. There appeared to be an inverse relationship between soluble phosphates and chlorophyll levels during July and August (Figure 10). For each peak in the chlorophyll curve there was a corresponding valley in the phosphate curve. Phosphate measurements during this period ranged from 0.03 mg/l on July 20, to 0.30 mg/l on July 13. After the increase in phosphate levels in November there was no apparent relationship between the phosphate and chlorophyll levels. No doubt during this time phosphate levels exceeded the needs of the producers and did not become limiting. There was little variation in phosphate levels from station to station on any given sampling date.

The high level of soluble phosphates in the reservoir may have influenced the chlorophyll levels. According to Welch (1952) phosphorus is regarded as of great importance in determining the biological productivity of a body of water. Soluble phosphates showed an inverse relationship to chlorophyll during the summer months of 1964. The lack of such a relationship after the increase in phosphate levels during November may mean that the amount of phosphate tied up in organic matter after that time was negligible. Tarzwell (1950) reported that the minimum amount of soluble phosphate essential for extensive phytoplankton growth was about 0.02 mg/l.

The monthly average soluble phosphates in the reservoir during the study was lower than the range of 0.20 to 1.84 mg/l reported by Hall (1964) for the Neosho River, but higher than the phosphate values reported for several other lakes and reservoirs. Prophet (1965) reported phosphate values ranging from 0.02 to 0.16 mg/l for Lyon County State Lake, and Harris and Silvey (1940) reported phosphates ranged from 0.16 to 0.6 mg/l during their study of Texas reservoir lakes. Heron (1961) found that phosphate levels in lakes may be increased by a temporary enrichment brought about by heavy rainfall in the drainage basin. This would account for the sharp increase observed in phosphate levels during November and at other times when there was an increased inflow of water into the reservoir. The soluble phosphates in the reservoir area are probably influenced by the introduction of organic matter from slaughter houses, feed lots and sewage disposal plants upstream.

Individual nitrate measurements were usually greater than 0.25 mg/l. Monthly averages ranged from 0.05 mg/l at East Point in November to 1.4 mg/l at East Point in April. The highest nitrate concentrations were recorded in April at all stations. There was no apparent relationship between nitrate fluctuations and any of the other conditions

Table 5. MONTHLY AVERAGE Ca, Na, AND K (mg/l) IN THE EUPHOTIC ZONE AT JOHN REDMOND RESERVOIR, JUNE, 1964, TO JUNE, 1965.

| | Hickory Creek | | | Ottumwa | | | Redmond Cove | | | East Point | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ca | Na | K | Ca | Na | K | Ca | Na | K | Ca | Na | K |
| June | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| July | 44 | 11 | 2.9 | 46 | 12 | 3.3 | 42 | 11 | 1.8 | 39 | 11 | 1.9 |
| August | 41 | 8 | 5.0 | 41 | 9 | 5.1 | 38 | 7 | 4.6 | 38 | 8 | 4.7 |
| September | 40 | 10 | 6.1 | 40 | 10 | 6.2 | 40 | 9 | 6.8 | 39 | 9 | 6.0 |
| October | 33 | 7 | 3.7 | 37 | 7 | 3.6 | 35 | 4 | 3.3 | 33 | 4 | 3.4 |
| November | 30 | 2 | 3.5 | 30 | tr | 3.3 | 31 | tr | 3.2 | 30 | tr | 2.8 |
| December | 42 | 9 | 8.8 | 44 | 9 | 9.6 | 28 | 7 | 8.9 | -- | -- | -- |
| January | 50 | 12 | 9.0 | 64 | 14 | 8.1 | 55 | 12 | 9.1 | 48 | 12 | 12.3 |
| February | 73 | 21 | 6.3 | 80 | 25 | 5.8 | -- | -- | -- | -- | -- | -- |
| March | 46 | 5 | 1.6 | 29 | 3 | 1.5 | 39 | 4 | 1.7 | 37 | 3 | 1.5 |
| April | 60 | 12 | 2.8 | 61 | 12 | 2.8 | 53 | 11 | 2.8 | 54 | 11 | 2.8 |
| May | 39 | 9 | 3.2 | 46 | 11 | 3.0 | 42 | 9 | 3.0 | 40 | 9 | 3.5 |
| June | 21 | 8 | 4.2 | 20 | 7 | 4.7 | 24 | 9 | 4.0 | 24 | 9 | 4.0 |

--No sample taken

measured. In Texas, Harris and Silvey (1940) reported comparable nitrate variations of 0.01 to 1.35 mg/l with the greatest concentrations occurring in midsummer and midwinter. Heron (1961) had no explanation for the erratic nitrate variations which occurred in his study of waters of the English Lake District.

Calcium, Sodium, and Potassium. Calcium, sodium, and potassium levels in the reservoir showed a general tendency for a composition of Ca>Na>K (Table 5), which Hutchinson (1957) suggests is characteristic of all fresh waters moving through rivers and lakes. Calcium ranged from 20 to 80 mg/l, but was usually about 44 mg/l. This is comparable to the range of 34 to 48 mg/l of calcium reported by Harris and Silvey (1940). Sodium ranged from only a trace to 25 mg/l, but was usually about 10 mg/l. This is somewhat higher than the range of 2.6 to 4.6 mg/l reported by Harris and Silvey. Potassium ranged from 1.5 to 9.6 mg/l and was usually about 4 mg/l. This, too, is higher than the range of 0.8 to 1.6 mg/l reported by Harris and Silvey.

# CONCLUSIONS

Surface water temperatures were similar to air temperatures throughout the study period, and there was generally very little difference between the surface and bottom temperatures. Thermal stratification, when it does occur in the reservoir, will probably always be of short duration, for several reasons. The relatively shallow nature of the reservoir and the fact that it is subjected to high winds much of the time keeps the water well mixed. This, along with the constant turnover of water in the reservoir from inflow and drawdown, leaves little chance for stratification to become well developed.

Oxygen is not expected to become a major limiting factor in the reservoir. The critical limit of oxygen for most aquatic organisms is usually considered to be approximately 5 mg/l (Andrews, 1958). The times during the past year when dissolved oxygen in the bottom meter was less than 5 mg/l were few and of short duration. On the occasions when dissolved oxygen in the bottom meter was nearly depleted, there was evidence of thermal stratification. However, there were times when the reservoir tended to be weakly stratified, yet the dissolved oxygen in the bottom meter was greater than 5 mg/l. It appears more probable that the depletion of dissolved oxygen in the bottom during the 1964 summer was due to the decomposition of the large amount of recently inundated vegetation. On warm calm days there was little or no mixing of the water, and decomposition rapidly depleted the oxygen on the bottom. The lack of mixing may have resulted from the calm condition as much as from thermal differences. Once the bulk of this organic matter decomposes, oxygen may never become critical in the bottom meter of water.

With soluble phosphates and other nutrients being present in such apparent excess, it is anticipated that the reservoir will prove to be a highly productive body of water. Frequent algal blooms should support a large biomass of zooplankton and fish. The main limiting factor to productivity may prove to be light penetration, since much of the time the euphotic zone did not exceed a depth of one meter.

The chemical nature of the water in the reservoir may be subject to frequent and considerable change, depending upon whether most of the water entering the reservoir comes from the headwaters of the Neosho River or from the Cottonwood River. However, once the reservoirs at Marion and Cedar Point are completed and it is possible to regulate the flow of water in both rivers, the chemical conditions in the reservoir may become more stable.

## SUMMARY

Four sample stations were established within the conservation pool of the John Redmond Reservoir. Various physical-chemical conditions were recorded at each station from June, 1964, through June, 1965. Measurements included in the study were: air and water temperatures, specific conductance, seston, dissolved oxygen, pH alkalinity, calcium, sodium, potassium, nitrates, phosphates, and chlorophyll concentrations.

During the study pH was generally between 7.8 and 8.2 and bicarbonates were usually greater than 150 mg/l. Dissolved oxygen varied with the water temperatures, but was usually greater than 5.5 mg/l in the top meter of water. Soluble phosphates were comparatively high, usually above 0.3 mg/l. Calcium, sodium, and potassium levels varied from time to time, but usually followed the pattern of Ca>Na>K. Specific conductance varied from 111 to 565 umhos/cm$^3$ and showed a direct relationship to alkalinity. Organic seston ranged from 8% to 75% of the total seston. Nitrates ranged from 0.05 to 1.4 mg/l, but did not seem to follow any particular pattern. Chlorophyll levels ranged from 3.2 to 30.6 ug/l, and tended to increase throughout the study.

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